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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT INCIDENT REPORT

**EASTERN AIRLINES, INC.,
BOEING 727-25 N8139
ATLANTA HARTSFIELD INTERNATIONAL AIRPORT,
ATLANTA, GEORGIA**

AUGUST 22, 1979

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16. Abstract

On August 22, 1979, Eastern Airlines, Inc., Flight 693, a Boeing 727-25, encountered a small but intense rainshower with associated wind shears on the final approach to the William B. Hartsfield Atlanta International Airport, Atlanta, Georgia. The aircraft, with 71 passengers and 6 crewmembers on board, came within 375 ft of crashing before it exited the shower and a missed approach was completed.

The National Transportation Safety Board determined that the probable cause of this incident was the unavailability to the flightcrew of timely information concerning a rapidly changing weather environment along the instrument landing system final approach course. The unavailability of this data resulted in an inadvertent encounter with a localized but heavy rainshower with associated wind shears which contained changes in the horizontal and vertical wind velocities which required the flightcrew to use extreme recovery procedures to avoid an accident. Contributing to this incident was the lack of equipment for the airport terminal area that could have detected, monitored, and provided quantitative measurements of wind shear both above and outside the airport's boundaries.

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Adopted: May 28, 1980

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SYNOPSIS

On August 22, 1979, Eastern Airlines, Inc., Flight 693, a Boeing 727-25, encountered a localized but heavy rainshower with associated wind shears on the final approach to the William B. Hartsfield Atlanta International Airport, Atlanta, Georgia. The aircraft, with 71 passengers and 6 crewmembers on board, came within 375 ft of crashing before it exited the shower and a missed approach was completed.

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FACTUAL INFORMATION

History of the Flight

About 1512, 1/ on August 22, 1979, Eastern Airlines Inc., Flight 693, a Boeing 727-25, encountered a localized but heavy rainshower with associated wind shears on the final approach to landing on runway 27L at the William B. Hartsfield Atlanta International Airport, Atlanta, Georgia.

Flight 693, a regularly scheduled passenger flight, was en route to Atlanta from Indianapolis, Indiana, with 71 passengers and 6 crewmembers on board. According to the flightcrew, the en route portion of the trip was routine, and as the flight approached Atlanta, it was cleared to descend and vectored into position for an instrument landing system (ILS) approach to runway 27L. The first officer was flying the aircraft.

1/ All times herein are eastern daylight time, based on the 24-hour clock.

According to the flightcrew, they had received Automatic Terminal Information Service (ATIS) information MIKE which stated in part, "Atlanta weather, three thousand five hundred scattered, estimated ceiling one three thousand broken, three zero thousand broken, visibility eight (miles), temperature eight-nine, wind two three zero degrees at seven (knots), altimeter three zero zero zero. ILS approaches runway 26. ILS approaches runway 27L. Simultaneous ILS approaches in progress . . . . Advise on initial contact you have information MIKE." The flightcrew did not inform the controller that they had received ATIS information MIKE.

As Flight 693 approached the Atlanta area, the flightcrew said that they observed thunderstorms in the vicinity of the airport both visually and on the aircraft weather radar, and they monitored the storms during the descent. According to the pilots, the storms were "scattered" and were located to the north and to the south of the approach course to runway 27L. The captain said that there was one cell south of the approach course and three cells, aligned on a north-south axis, to the north of the approach course. The southernmost cell of the three northern cells appeared to be located on the approach course to runway 26, which is 5,500 ft north of runway 27L.

The captain said that he placed his radar set in the contour mode to examine the cells while the flight was inbound to the outer marker (OM) of the ILS approach to runway 27L. However, he could not recall what he saw in great detail. He said that he was not concerned with the three "little cells" to the north which resembled "three little bubbles....about the size of eraser heads"; he was more concerned about the cell to the south.

Atlanta approach control continued to vector Flight 693 toward the ILS approach course. At 1508:09, the controller cleared the flight to cross Anval--an intersection located 3.5 nmi east of the OM and 8.5 nmi east of the the threshold of runway 27L--at 3,500 ft, 2/ to maintain 170 kns indicated airspeed (KIAS) to the OM, and to contact the tower. At 1510, Flight 693 reported over Anval. The local controller cleared the flight to land on runway 27L and added, "the winds are calm and keep your speed up as long as feasible on final, sir. You'll break out of that rainshower in about 3 miles, and there is rain down the middle of runway 27 left right now." Flight 693 acknowledged receipt of the transmission. The local controller said that the rainfall was of moderate intensity.

According to the captain, he monitored the communications between the local controller and the two flights which were ahead of his aircraft on the approach—Delta Airline's Flight 1154, a Lockheed 1011, and Delta Flight 452, a Boeing 727. At 1509:24, the local controller cleared Flight 452 to follow Flight 1154 for landing and informed the flight that there was a shower on the "approach end of runway two seven left." At 1509:54, Flight 1154 told the local controller that it was "clearing" the runway "in that shower that's (unintelligible) end of the runway now."

Flight 693 intercepted the glide slope outside of the OM at 3,500 ft. The first officer said that he used his fuel flow meters to establish the desired thrust settings for the descent, and accordingly, established a fuel flow of about 3,500 to 3,800 pounds per hour (pph) on each engine. Except for minor adjustments

2/ All altitudes herein are mean sea level unless otherwise specified.

to keep the aircraft on the desired descent path, he said he maintained those thrust settings until the aircraft encountered the intense rainshower. According to the engine manufacturer 3,500 pph fuel flow would produce 4,650 lbs thrust at 2,000 ft and 4,580 lbs thrust at 1,000 ft.

The aircraft was placed in the landing configuration at the OM and the final landing checklist was completed before the heavy rainshower and wind shear were encountered. The landing flap setting was 30°; and the computed missed approach or go-around engine pressure ratio (EPR) setting was 1.93. The reference speed for the final approach was 120 KIAS; however, the first officer said that he attempted to hold 135 KIAS after passing the OM. He also said that he kept about a 2° to 3° noseup pitch attitude to stay on the ILS glide slope, and that after leaving the OM, the rate of descent was about 500 to 700 fpm.

The flightcrew said that the ground was in sight as the aircraft overflew the OM. The aircraft was flying in light rain, light turbulence, and experiencing "a little bit of airspeed fluctuation." At 1,000 ft above ground level (a.g.l.), the rain and turbulence increased. The crew said that the turbulence became "moderate" and remained at that level until the aircraft flew out of the precipitation. The rain became "heavy" and, according to the flight engineer, it was heavy enough to increase the noise level within the cockpit. Ground visibility was lost and was not regained until after the aircraft flew out of the area of precipitation. The flight engineer said that the aircraft reentered a cloud layer as the rain and turbulence increased; however, the pilots were unable to confirm this, because of the amount of rain on the windscreens.

About 1,000 ft a.g.l. and simultaneous with the increased levels of rain and turbulence, the indicated airspeed began to fluctuate. The first officer said it decreased from about 135 KIAS to about 120 KIAS, increased to about 140 KIAS, and then, a few seconds later, decreased to between 108 and 110 KIAS. When the airspeed began to decrease, the first officer noted that the rate of descent had increased to 1,000 fpm. At 800 ft a.g.l., he rotated the aircraft to a 10° noseup pitch attitude, advanced the thrust levers, and called for takeoff power. The captain then refined the thrust setting to the missed approach or takeoff power setting.

According to the first officer, the pitch correction and added thrust had no effect. The descent rate increased to 1,500 fpm and then to 2,000 fpm. The first officer then rotated the aircraft to a 15° noseup pitch attitude and advanced the thrust levers to their forward stops to obtain whatever thrust that was "available at that time." The captain again insured that the thrust levers were against their forward stops.

At 500 to 600 ft a.g.l., and at an airspeed of between 105 KIAS and 110 KIAS the stall warning system's stickshaker activated. Almost simultaneous with stickshaker activation, the ground proximity warning system (GPWS) activated; the below glidepath light illuminated; and the audio "pull-up" and whooper warnings began. The captain said that the stickshaker and GPWS warnings continued to operate until the descent rate was arrested and recovery began. He estimated that the stall warning system operated for about 10 to 20 sec.

When the stickshaker activated, the first officer said that he reduced the aircraft's noseup pitch angle from 15° to about 12° noseup and that the stickshaker stopped shortly thereafter. However, the captain said that he believed the first officer "overreacted" to the stickshaker when he lowered the nose. He told the first officer to pull the nose up when the pitch angle reached "about ten to twelve degrees." The first officer estimated that the stall warning operated about 5 to 10 sec. At this point, the flight engineer said that the instantaneous vertical velocity indicator (IVSI) depicted a 2,100 to 2,200 fpm rate of descent.

According to the flightcrew, the aircraft flew out of the precipitation at 375 ft a.g.l. in a right wingdown attitude and began to accelerate. The descent was arrested and a climbout was begun. The landing gear and flaps were raised during the climb, and the aircraft accelerated to 200 KIAS.

The flight engineer said that the thrust levers were against their forward stops for about 30 to 35 sec. The N_1 compressor rpms and exhaust gas temperatures (EGT) of all three engines had exceeded their limits and were operating within the red bands on their respective gages. The highest readings were noted on the No. 3 engine. However, the engines operated satisfactorily during the 30- to 35-sec overboost period and for the remaining 50 min of flight.

At 1512:44, the local controller told the flight that the tower had received a "low altitude alert, check your altitude," and then asked if the crew had the airport in sight. At 1512:52, the captain answered, "...No sir, we kinda missed out here." At this time, the aircraft was climbing and was accelerating away from the stall regime. The captain then told the local controller "There's quite a bit of rain . . . a wind shear out there. I don't see how anybody could make an approach to the left one," (runway 27L).

At the captain's request, approach control then vectored Flight 693 to a clear area south of the airport to hold until the weather cleared. At 1542, landing traffic at the airport was switched to the east, an approach clearance to runway 9R was offered and accepted, and the aircraft was landed on runway 9R without further incident.

Aircraft Information

The aircraft, a Boeing 727-25, N8139, was powered by three Pratt and Whitney JT8D-7B engines. The engines are rated at 14,000 lbs of takeoff thrust up to 84° F. Since all three engines had been subjected to overtemperature and excess N_1 rpm, they were removed from the aircraft and shipped to the Eastern Airlines' maintenance facility at Miami, Florida, where they were disassembled and inspected. Two of the engines showed no evidence of heat distress. The examination of the No. 3 engine disclosed that the blades of all stages of the turbine and the inlet guide vanes were discolored. However, it was not possible to ascertain if the discoloration resulted from one instantaneous overtemperature or from normal engine usage.

The aircraft was equipped with a Bendix X-band weather radar. The equipment's gain control had a fixed gain position which, according to the company's flight manual, provides optimum viewing for normal conditions; however, the gain can be adjusted by rotating the gain control knob. The equipment did not have an antenna stabilization switch. The captain said that he could not recall the tilt angle of the radar antenna, and that he believed that the gain control was in "fixed gain position."

A flight data recorder (FDR) and cockpit voice recorder (CVR) were on board the aircraft and were operational. The FDR recording foil was removed and a 4-min readout was made. Since only the last 30 min of cockpit communications and conversations are retained on the CVR tape, this tape was not read out.

Meteorological Information

At the time of the incident, numerous thunderstorms in the Atlanta area were producing heavy rainshowers and gusty surface winds. Except within the showers, where the ceiling was probably less than 1,000 ft and the visibility was probably less than 3 mi, the prevailing ceiling was above 3,000 ft and surface visibility was generally greater than 3 mi. The area and terminal forecasts also predicted thunderstorm activity over the southeastern United States and in the Atlanta area and the flightcrew had been given these forecasts before they departed Indianapolis.

The investigation showed that the thunderstorm activity began to build in the airport area after 1400. By 1500, there were numerous thunderstorms, some of which produced heavy rainshowers and gusty winds; the 1445 and 1454 surface observations reported winds from 260° at 16 kns and from 360° at 4 kns, respectively, with a peak gust of 32 kns during the period.

The surface weather observations at Hartsfield are taken at the National Weather Service's (NWS) facility which is located about 1.5 nmi north of the airport. The first pertinent mention of thunderstorm activity in the airport area was at 1454, at which time the following surface observation for the Hartsfield-Atlanta Airport was issued.

> <u>1454, record special</u>, estimated ceiling 3,000 ft overcast, visibility--4 statute miles, thunderstorm, light rainshowers, temperature--79° F, wind--360° at 04 kns gusting to 32 kns, altimeter setting--30.01 inHg, thunderstorm began 1450 overhead moving northeast, rain began 1433, lightning cloud to ground northwest.

This observation was transmitted by telewriter to the Atlanta approach control and tower. At 1500:04, ATIS information ALPHA containing this weather was issued; however the wind gust conditions were omitted inadvertently from the text.

During the period between 1153 and 1454, the surface weather observations at the Atlanta airport showed that the temperature at the airport rose from 84° to 89° F. At 1454, about 18 min before the incident, the temperature dropped to 78° F and remained there for the next 2 hrs.

The NWS's WSR-57 S-band radar located at Athens, Georgia--57 nmi east of the airport--also displayed numerous radar echoes of varying intensity levels in the Atlanta area. The intensity of radar weather echoes is expressed in the following six levels as set forth in the "Pilot/Controller Glossary" contained in Appendix 4, Air Traffic Control Handbook 7110.65A and the Airman's Information Manual (AIM):

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

A properly functioning X-band aircraft weather radar has the capability to contour level 3 cells.

At 1508, the weather radar photographs from the NWS's weather radar located at Athens showed that a level 2 cell was located about 7 nmi west of the aircraft; a level 4 cell was located about 9 nmi northwest of the aircraft; and another level 4 cell was located about 2.5 nmi northwest of the threshold of runway 27L. These photographs also showed a comma-shaped echo over the ILS course to runway 27L. At 1508, this echo had a horizontal east-west dimension of about 3.75 nmi; at 1518, photographs showed that this dimension had decreased to about 1.4 nmi.

A further description of the weather situation was given by Eastern Flight 209. Flight 209, a DC-9, was making a parallel ILS approach to runway 26 and was slightly behind Flight 693 on its approach to runway 27L. According to Flight 209's captain, there were three storm cells off his right wing (north), and "another big cell" south of the approach course to 27L. When he went to contour mode on his radar all the cells contoured. However, he did not describe any cells directly west of his aircraft or Flight 693.

The WSR-57 S-band weather radar at Athens only measures energy reflected from the precipitation contained in weather targets. It does not have the design capability to measure the motion of the air within the cell. During test projects conducted from 1976 to 1978, Doppler type of weather radar has demonstrated the capability to detect, in real time, air motion and wind shear. 3/ This type radar is being tested and evaluated at the FAA's Technical Center, Atlantic City, New Jersey.

The weather returns shown on the color weather radar displays in the Atlanta ATC Center and Approach Control are relayed from the WSR-57 S-band radars at Athens, Bristol, Tennessee, and Centreville, Alabama. These color displays were subject to the same limitations as the originating radar systems as regards detecting air motion within the storm cells. The color radar displays in the center and approach control had been scheduled to undergo evaluations; however, the tests had been delayed because of the "fuzzy" quality of the presentations.

3/ NOAA Technical Memorandum ERL NSSL-86, Final Report on the Joint Doppler Operational Project (JDOP), March 1979.

During interviews of ATC personnel, several supervisors and a controller commented on the usefulness of these displays. The comments indicated that these displays were of little value for furnishing information to a pilot about the storm's intensity or its distance and direction from an aircraft. This shortcoming was attributed to the size of the display and the fact that it was a separate unit which was not intergrated into the ATC video display. The video displays used to control traffic in the approach control facility delineated precipitation areas by a solid line around the circumference of the area of precipitation; however, no relationship has been established between the six NWS radar echo intensity levels and the intensity level of the precipitation displayed within the demarcation line.

At the time of the incident, a Low Level Wind Shear Alert System (LLWSAS) was in service at the Hartsfield-Atlanta Airport. The system uses six vector-vane type wind sensors which are positioned on the airport. A centerfield wind sensor is positioned north of and at about the midpoint of runway 9R/27L; the other five sensors are positioned circumferentially about the centerfield sensor and near the boundary of the airport. The data retrieved from the sensors are inserted into and processed by a computer where vector differencing, centerfield averages and gust calculations are made; processing time is 1 sec. If preset thresholds are exceeded —a 15-kn vector difference, a 9-kn gust factor — these data are transmitted to the displays in the tower cab. Vector difference alarms are indicated by two audible alarms and flashing digits on the displays. The local controller on duty in the tower at the time of the incident did not recall hearing or observing a system audio or visual alarm either before or after the incident occurred. While the system has the capability of detecting surface level wind shears within the boundary of the airport, it has little or no capability to detect a wind shear aloft or wind shears outside the airport's boundaries.

Aircraft Performance

The aircraft performance was calculated by integrating and comparing data from the FDR, the Automated Radar Terminal Service ARTS-III printout, ATC transcripts, and the flightcrew's statements concerning the manner in which they flew the aircraft. Further verification of these data was sought by analyzing the FDR readouts from the aircraft preceding and the two aircraft following Flight 693 on the appoach to runway 27L.

Flight 693's FDR foil was undamaged and a readout of the 2 min before and the 2 min after the indicated low point of the altitude trace was made. (See appendix C.) The OM, which is 5 nmi from the threshold of runway 27L, was passed about 58 sec on the readout's time baseline; the lowest altitude--1,400 ft (about 375 ft a.g.l.)—occured at 2 min 9 sec.

Twenty seconds after the start of the readout, the pilot began to descend from 3,500 ft. Between 20 sec and 98 sec, the aircraft descended at an average rate of 923 fpm to 2,300 ft. Between 98 sec and 113 sec, the aircraft descended at an average 1,500 fpm to 1,925 ft, and between 113 sec and 129 sec, it descended at an average 1,969 fpm to 1,400 ft. Thereafter, the aircraft began to climb and achieved a rate of climb of about 2,004 fpm.

During the first 27 sec of the readout, the airspeed was stabilized at 162 KIAS. About 30 sec before crossing the OM, the airspeed began to increase, reaching 184 KIAS within 8 sec and then restabilizing about 162 KIAS as the OM was crossed. Between 70 sec and 100 sec, while the aircraft was descending at 923 fpm to 2,300 ft, the airspeed decreased to 128 KIAS. Over the next 5 sec, the airspeed increased to 144 KIAS and then decreased. The lowest airspeed--110 KIAS--was recorded 9 sec before the lowest altitude was recorded. Beginning at 120 sec, the airspeed began to increase and reached 209 KIAS at 170 sec. The most erratic movements and maximum variations of the airspeed trace occurred between 102 sec and 130 sec. These coincided with the maximum descent rates noted on the altitude trace and the largest excursions noted on the vertical acceleration trace.

During the first 30 sec of the readout, the aircraft's heading was fairly stable on the ILS localizer course heading of 270°. Thereafter, it deviated either side of the localizer course; to 278° at 64 sec; to 262° at 80 sec; and then back to 270° at 90 sec, where it stablized until 115 sec. Over the next 14 sec and during the latter part of the aircraft's descent, the heading increased to 290° and then returned to 270°. Flight 693's ground track, which was computed from ARTS-III bearing and range data, showed that it was aligned on the localizer centerline until it was within 2 nmi of the end of the runway. At 2 nmi, the aircraft began to drift to the right, and at 1 nmi from the runway end, it was 1,500 ft to the right of the localizer centerline.

The ARTS-III printout also provided aircraft groundspeed, altitude, and time. These data were plotted and correlated with the FDR data. The ARTS-III altitude and groundspeed data were compared with the FDR altitude and airspeed plots. The altitude plots were essentially the same. The FDR airspeed plot was corrected to true airspeed 4/ and compared with the groundspeed data. This comparison disclosed several large headwind fluctuations during the approach. The headwind plot disclosed the following: during the first 20 sec the headwind component was about 5 kns; at 38 sec it was 24 kns; at 50 sec it was 3 kns; at 60 sec it was 10 kns and, except for momentary excursions, between 75 sec and 105 sec it was between 11 to 14 kns. The headwind then decreased and reached zero at 120 sec. Between 120 sec and 135 sec, the headwind component again increased and reached its maximum value of 39 kns, and, thereafter, within 10 sec it decreased to a 4-kn tailwind. (See appendix A.) Correlation of the FDR and ARTS-III data also showed that the lateral winds acting on the aircraft were negligible.

Correlation of the groundspeed and altitude trace with the ILS glidepath showed that the aircraft began its initial descent about 340 ft above the glidepath, and then began a descent correction to intercept it. At the OM, the aircraft was 200 ft above the glidepath. At about 4.25 nmi from the end of the runway, the glidepath was intercepted; however, the aircraft rose above the glidepath again and the descent continued to about 375 ft a.g.l. About 3.4 nmi from the end of the runway, the aircraft intercepted the glidepath, descended through it, and descend to about 375 ft a.g.l. About 2.3 nmi from the end of the runway, the aircraft began to climb out. (See appendix B.)

4/ True airspeed is indicated airspeed corrected for altitude and temperature.

The vertical wind component after the first officer rotated the aircraft and applied takeoff thrust to begin the missed approach was calculated by subtracting the rate of climb capability of the aircraft from the known descent rates. Climb capability essentially depends on pitch angle, thrust application, airspeed, gross weight, density altitude, and aircraft configuration. Pitch angle, thrust application, and aircraft configuration were not available on any recorded data. Therefore, flightcrew statements were used for these inputs, and a computer program utilized to perform the calculations.

A computer program based on the relationship between the forces acting on the aircraft was conducted by the NASA Ames Research Center. The program's objectives were to calculate the vertical wind component and to further evaluate the data obtained from the FDR, ARTS-III, and the flightcrew's statements. The FDR foil time of 117 sec was selected because of the high descent rate recorded at that time, and three computer runs were made for this point. The assumptions for the first two runs included takeoff thrust and 10° and 15° noseup pitch angles based on the flightcrew's statements. These runs did not include radar data. The third run included radar data, the calculated maximum thrust, and a noseup pitch angle of 12.7°. The calculated vertical wind components for the three pitch angles were as follows: 10° noseup pitch -- 49 fps (29.0 kns); 12.7° noseup pitch — 59 fps (34.9 kns); and 15° noseup pitch — 68 fps (40.3 kns).

A no-wind condition performance program disclosed that at idle thrust, landing gear down, and flaps 30°, the aircraft could not have followed the same flightpath shown by the obtained data. Under a no-wind condition, the speed brakes would have had to have been deployed in order to duplicate the aircraft's actual approach profile.

At the Safety Board's request, the Boeing Commercial Airplane Company conducted performance analyses of the incident. Their analyses were based on data derived from the FDR and the flightcrew's description of thrust settings and aircraft pitch angles used during the descent and missed approach. Calculations were made at several points along the FDR trace.

The analyses substantiated the likelihood of downdraft and wind shear activity during the approach and go-around maneuver; however, the actual magnitudes of the horizontal and vertical wind components could not be determined from the available data.

Comparison of the FDR data to the predicted performance capability of the aircraft indicated that at 28-sec FDR foil time the aircraft encountered either an increasing headwind or a decreasing tailwind; about 104-sec FDR foil time, the aircraft encountered a combined change in horizontal wind velocity and a downdraft that ranged in magnitude from 2,000 fpm to about 3,000 fpm; and between 120 sec to 128 sec the aircraft's erratic acceleration and deceleration were probably caused by a sudden headwind shear. However, by 130 sec, the aircraft's performance was consistent with predicted capability.

The analyses indicated that between 20 sec and 83 sec the aircraft maintained an approximate 3° glide slope descent and the thrust fluctuated between 3° glide slope thrust (about 12,839 lbs) and flight idle thrust (about 921 lbs). Between 61 and 82 sec, the aircraft decelerated at 1 kn/sec and the sink rate increased from about 900 fpm to about 1,400 fpm. These changes were within the aircraft's predicted performance capability and, therefore, were either the result of flightcrew action or a downdraft and wind shear encounter.

In order to corroborate further the conditions on the ILS approach to runway 27L, the FDR's recordings of three other aircraft were read out. Delta Airlines Flight 452, a Boeing 727, was about 2 min ahead of Flight 693. Its FDR recording disclosed that the approach was flown at 160 KIAS and at a descent rate between 800 to 900 fpm. Except for a sharp increase of 18 KIAS for about 10 sec just outside the OM, the flight's descent path to landing was smooth with little variation. The 18-KIAS airspeed excursion took place about the same place where Flight 693 experienced a sharp 25-KIAS increase--shortly after intercepting the glidepath at 3,400 ft.

Delta Airlines Flight 128, a Boeing 727, was about 1 min behind Flight 693. It's FDR recording showed that between 3,200 and 2,900 ft its rate of descent exceeded 1,300 fpm for 9 sec. The descent rate then was reduced and a 900 fpm descent rate was maintained to landing. About the same position where Flights 693 and 452 experienced the airspeed increases, Flight 128 experienced a 10-KIAS increase which lasted 10 sec.

Delta Airlines Flight 1742, a McDonnell Douglas DC-9, was the second aircraft to follow Flight 693, and it was about 3 min behind Flight 693. About the same position where the other three aircraft encountered airspeed increases, Flight 1742 experienced a 20-KIAS increase which lasted about 25 sec, and the aircraft's descent rate increased to about 1,300 fpm. At the point inside the OM where Flight 693 had experienced the greatest rate of descent, Flight 1742's descent increased to 1,600 fpm for about 11 sec. After landing, Flight 1742's pilot informed the Atlanta tower, ". . . you got a nice shear there inside the marker."

Air Traffic Control Procedures

FAA Air Traffic Control Handbook 7110.65A (Handbook) contains the procedures which govern the handling of arriving air traffic, and the procedures to be followed by controllers for relaying pilot weather reports.

Paragraphs 394 and 1010 of the Handbook contain the procedures governing the information a controller should provide an arriving aircraft. Pursuant to paragraph 394, the controller should provide current approach information to an arriving aircraft on first radio contact or as soon as possible thereafter. However, "Approach information contained in the ATIS broadcast may be omitted if the pilot states the appropriate ATIS code." If the arriving pilot does not state that he has received the appropriate ATIS broadcast, the controller either can request the pilot to obtain the ATIS information or provide the following data: the approach clearance or type of approach to be expected; the runway, if different from that to which the instrument approach is to be made; surface wind; ceiling and visibility if the ceiling is reported to be below 1,000 ft or below the highest circling minimum, whichever is higher, or the visibility is less than 3 mi; and the altimeter setting.

Paragraph 394b states that the controller should issue "any known changes classified as special weather observations as soon as possible"; however, these need not be issued after they are included in an ATIS broadcast and "the pilot states the appropriate code."

Paragraph 1010 contains the landing information that should be provided to an aircraft. The paragraph essentially reiterates data contained in paragraph 394 and relieves the controller from the requirement to provide data contained in the ATIS broadcast if the pilot states that he has received the broadcast.

Air traffic controllers are required to furnish numerous services, and the Handbook establishes an order of priority for these services. Paragraph 22 requires that the controller "give first priority to separation of aircraft as required in this handbook and to the issuance of safety advisories. Give second priority to other services that are required but do not involve separation of aircraft." Safety advisories are defined as those relating solely to the alerting of aircraft to potential conflicts with the terrain, obstructions, or other aircraft.

Paragraph 981 of the Handbook contains guidance for transmitting low level wind shear advisories; however, the procedures contained therein only apply to locations equipped with a Low Level Wind Shear Alert System, and methods to disseminate data derived from that system.

During the period 15 min before and after the incident, the ATC transcripts disclosed that the tower controllers issued numerous advisories on the weather situation.

At 1454:12, Delta Flight 208 reported to the Atlanta tower that "there's a pretty good wind shear about three hundred ft from left to right." At 1454:19, the tower controller relayed this pilot report to the next aircraft, stating in part, "a three hundred ft wind shear from left to right." At 1454:31, Eastern Flight 82 advised the tower that it had encountered a wind shear at "about a hundred ft there was a little one when we landed." At 1455:08, the tower controller passed these pilot reports to all aircraft on his frequency, "Okay all aircraft. . . wind shear report three hundred ft from left to right and a small one at a hundred ft, and a heavy rainshower off the approach end of the runway (27L)." At 1456:38, the local controller issued the same advisory to Delta Flight 1120. Thereafter, there were no further pilot reports concerning wind shear. At 1500:21, the controller asked Delta Flight 1132, which had just landed, for a report on wind shear conditions. Flight 1132 reported that they had encountered "a little wavy. . . stuff there at a thousand ft but down next to the ground didn't seem too bad." Thereafter the tower controllers ceased the wind shear advisory.

At 1513:00, Flight 693 reported a wind shear encounter to the Atlanta tower, stating, "There's quite a bit of rain. . . a wind shear out there. I don't see how anybody can make an approach to the left one." At 1513:11, while the local controller was engaged in assisting Flight 693 during its missed approach procedure, the tower monitor controller, who has the capability of overriding the local controller on the radio, advised Delta Flight 128, the next aircraft on the approach, "caution wind shear about a mile and a half ahead." At 1517:08, Delta Flight 1742 reported after landing that there was "a nice shear there inside the marker." During the time of these encounters none of the controllers recalled noting an alarm by the Low Level Wind Shear Alert System.

Between 1455 and 1515, only two conversations relating to wind shear or wind shifts were recorded at the local control position for traffic using runway 26. At 1459:31, Eastern Flight 291 reported a "pretty good wind shift to the left at about two hundred ft." This pilot report was passed to the next aircraft. At 1513:24, the monitor position asked the local control controller for runway 26 if he had "any wind sheer on your runway?" The controller answered that he had received one pilot report concerning wind shear "and that was it."

__Wind Shear Training__

On January 23, 1979, the FAA issued Advisory Circular, AC 00-50A, entitled "Low Level Wind Shear." The Circular, which canceled an earlier circular on the same subject, included descriptions of the low level wind activity to be expected around thunderstorms, the outflow from a "downburst cell," and the effects the flow could have on an aircraft on an ILS approach, and recommended methods for reporting a wind shear encounter.

According to the Advisory Circular, there is a strong downdraft in the center of the thunderstorm cell and there is often heavy rain in the vertical flow of air. As the vertical flow nears the ground, it turns 90° and becomes a strong horizontal wind, flowing outward radially from the center. An aircraft traversing this type of activity on an ILS approach would fly through a headwind, a downdraft, and a tailwind. The effects of these wind components would be as follows: as the aircraft enters the headwind component, its airspeed and lift increase and it balloons above the glidepath; as the aircraft leaves the headwind and enters the downdraft its airspeed and lift decrease and the aircraft begins to sink. The downward flow of the air further complicates the situation since it decreases the aircraft's angle of attack and increases the sink rate. As the aircraft leaves the downdraft, it encounters an increasing tailwind, which further decreases its airspeed and lift and increases the sink rate. According to the Circular, the "moment of truth" for this situation occurs as the aircraft encounters the headwind and rises above the glidepath. If, at that point, the pilot "does not fully appreciate the situation" and attempts to regain the glide slope by reducing thrust and pushing the nose over, the aircraft will enter the downdraft and subsequent tailwind areas with a reduced angle of attack and in a thrust-deficient configuration. Depending upon the wind velocities of the downburst activity, the failure of a flightcrew to institute a missed approach at the "moment of truth" or shortly thereafter could produce an accident.

Both the Circular and the AIM urge that pilots report wind shear encounters to ATC. Both publications recommend that the report contain the loss or gain of airspeed and the altitudes at which it was encountered. The AIM contains the following example. "Tulsa Tower, American 721 encountered wind shear on final, gained 25 kns between 600 and 400 ft followed by loss of 40 kns between 400 ft and surface." The Circular contains a similar example.

The Advisory Circular also includes operational procedures designed to help a pilot caught in a low level wind shear. The Circular notes that in this situation a pilot may pull the noseup and trade speed for altitude; i.e., trade kinetic energy for potential energy. However, if at or below V_{ref} or V_2 — minimum takeoff safety speed — the trade should be attempted only in extreme circumstances. The Circular states, "Wind shear simulations have shown, however, that in many cases trading airspeed for altitude (down to stickshaker activation speed) prevented an accident, whereas maintaining V_{ref} resulted in ground impact." Similar data were contained in a performance study published by the Boeing Commercial Airplane Company. The study contained an analysis of the performance available between V_{ref} and stickshaker speed, and noted, in part, that if inadvertently caught in a severe tail wind shear and, or, intense downdraft:

> "Simultaneously with commanding go-around power, pitch the aircraft up to the go-around attitude or higher to check the rate of descent. Do not worry too much about loss of airspeed until approaching stick shaker speeds. . . . " 5/

The procedures contained in the Circular and the Boeing study are reflected in the wind shear training programs conducted by the carriers in simulators. The simulator training procedures recommend that go-around or takeoff thrust be applied when the shear is encountered, and that the aircraft be rotated to the go-around attitude or higher if necessary. If the stickshaker activates the pilot should reduce his pitch attitude until it ceases and then retain that attitude.

These procedures are reflected in a "note" contained in the Eastern Airlines' Missed Approach Procedure. After requiring in part that the pilot simultaneously apply takeoff thrust and back pressure on the yoke to stop the descent, raise the flaps to 25°, raise the landing gear after obtaining a positive climb rate, and maintain V_2 to V_2 + 10 KIAS, the procedure contains the following note:

> "Under adverse conditions, such as a high rate of descent near the ground, the body angle required to establish maximum lift may exceed 15°. In extreme conditions, even the Flight Director V-bars WILL NOT program sufficient body angle to stop descent and establish a climb attitude. 'STOP DESCENT' REQUIRES THE AIRCRAFT TO BE ROTATED UNTIL A RATE OF CLIMB IS ESTABLISHED. MAXIMUM LIFT WILL OCCUR BETWEEN 10 TO 15 KNOTS BELOW V_{ref} AT 1.15 TO 1.2 V_s (stall speed). THIS WILL APPROACH STICK SHAKER ACTIVATION WHICH WILL PROVIDE A WARNING OF OVER-ROTATION AND SPEED REDUCTION AT APPROXIMATELY 1.1 V_s."

During the last few years, all air carriers have programed their flight simulators with wind shear models based upon those discovered during the U.S. and foreign accident investigations. Flightcrews are required to fly the simulator through these wind shear models in order to recognize the shear and its effect on the aircraft, and to familiarize themselves with the flight procedures which have been established to counteract the effects of wind shear. Both the captain and

5/ Boeing Airliner Magazine, pg. 19, January 1977.

first officer stated that they had received this training. The first officer said he had never flown the simulator through one of these wind shear models. He had received training in the first officer's seat and had been trained to perform the tasks required to assist the captain during the maneuver.

Both pilots stated that the shear encountered on the approach was more violent than any they had experienced during their simulator training; however, both pilots praised the training they had received. The captain stated that the wind shear training "saved us" and that if they had not applied that training, "we would not have been able to stay in the air long enough to fly out of it." The first officer said that "the simulator was quite accurate in what you would encounter and what the airplane might do." He then added, "I think the simulator gives you a little more courage than you might have had to try the maneuver."

ANALYSIS

The examination of the evidence disclosed that Flight 693, while on the ILS approach, encountered a localized but heavy rainshower with associated wind shears which included changes of velocities in both the horizontal and vertical wind components and that the weather conditions which existed near the airport at the time of the incident contained the potential to produce the wind shear activity which the flight encountered. The investigation also revealed deficiencies in the ATC procedures employed during the time of the incident, however, these deficiencies did not produce or contribute to the incident.

The intense rainshower and associated wind shear activity during Flight 693's descent was confirmed by the aircraft performance analyses, the wind analyses, and the computer analyses performed at NASA. The correlation of these analyses identified the types of wind motion, the approximate velocities, and the time the aircraft encountered them. At 28 sec FDR foil time, the aircraft transitioned from a small decreasing tailwind into an increasing headwind. The headwind component increased about 20 kns within 7 sec. About 104 sec, the aircraft again encountered an increasing headwind; however, this horizontal shear was accompanied by a downward vertical velocity of about 2,000 to 3,000 fpm. This calculated downdraft velocity correlated closely with the vertical values derived from the NASA computer run made at a 10° noseup pitch attitude, and the run made at a 12.7° noseup pitch attitude.

According to the first officer and the captain, as the aircraft descended below the glidepath and the rate of sink increased, the first officer raised the nose of the aircraft, advanced the thrust levers, and called for takeoff or missed-approach thrust. When this failed to arrest the descent rate, the thrust levers were placed full forward to obtain all available thrust, and the aircraft was rotated to a 15° noseup attitude. At this point, the stickshaker activated and the first officer lowered the nose, and attempted to accelerate the aircraft from the stickshaker regime. He believed the stickshaker stopped when the pitch attitude was reduced to about 12° noseup. Despite the 12° noseup pitch attitude and the thrust overboost, the aircraft continued to lose airspeed and to descend. Performance calculations indicated that the combination of the airspeed loss and the downdraft exceeded the climb capability of the aircraft.

While the FDR readout confirmed the flightcrew's recollection of altitudes and airspeeds during the weather encounter, it did not confirm the manner in which the first officer maneuvered the aircraft through it. Because of its design limitations, the FDR could not provide data which showed (1) the thrust settings used to maintain the aircraft's descent rate before it encountered the wind shear, (2) the exact time the thrust levers were advanced to apply takeoff thrust, or (3) when total available thrust was applied. The recorder could not provide the precise time the aircraft was rotated to 10°, 15°, and 12° noseup attitudes, or whether these precise pitch attitudes, in fact, were attained. The results of the computer no-wind performance program provided positive evidence of the existence of a wind shear inside the OM, and this was corroborated by the performance of the aircraft which preceded and followed Flight 693 on the final approach. However, the computations which provided the velocities of the horizontal and vertical winds within the shower were based on the assumption that Flight 693 was flown to the precise values of thrust and noseup pitch attitudes described by the flightcrew. Therefore, if the aircraft was not flown at those parameters it did not perform to its predicted climb capability for those configurations, its performance was derogated, and, consequently, the winds affecting it may have been less than those computed.

Between the OM and the onset of the weather encounter, about 104 sec FDR foil time, Flight 693 decelerated at about 1 kn/sec and its rate of descent varied between 1,400 and 900 fpm. The performance study showed that these values were within the performance capability of the aircraft, and that the required thrust settings to produce this descent ranged from 3° glide slope thrust to flight idle thrust. During this time period, the evidence also showed that the aircraft had descended from 200 ft above the ILS glidepath and had intercepted it and that the first officer was trying to slow to 135 KIAS. While the descent and deceleration could be attributed to the effect of a decreasing tail wind, it also could reflect an attempt by the first officer to intercept and maintain the glidepath and to decelerate to his desired target airspeed of 135 KIAS. The weight of the evidence indicated that the thrust settings were below those recalled by the first officer, and the wind shear and downdraft may have been encountered at thrust settings which were below 3° glidepath thrust and may have approached flight idle thrust.

The first officer said that his initial response to the effects of the wind shear was to rotate the aircraft to a 10° noseup pitch attitude and apply takeoff thrust. The aircraft would have achieved the 10° noseup pitch attitude almost immediately; however, the engine's response would have been subject to the inherent delays of the engine's acceleration schedule. While the engines were accelerating to the point where they could deliver the requested thrust, the increased angle of attack without additional thrust would have also increased the aircraft's rate of deceleration and decreased its energy level. If the aircraft entered the rainshower at lower energy levels than those assumed in the peformance studies, then the wind velocities computed in that study may have been less than those stated earlier in this report and the aircraft may have possessed the climb capability to overcome the effects of the downdraft and wind shear. Although the precise values of the wind velocity changes could not be determined conclusively, the downdraft and wind shear did cause the aircraft to descend below the desired flightpath and required the flightcrew to use extreme flight techniques to recover from the effects.

The evidence suggests that either the present flight instruments need to be modified or that additional instruments may be required to enable a pilot to fly at or just above the stickshaker activation speed. Since stall must be avoided, the pilot must take positive action to stop the aircraft's deceleration when the stickshaker activates. Without a precise target angle at which to aim, the correction angle must be estimated, and thus the pitch angle must be decreased until the stickshaker stops. If the pilot fails to reduce the pitch angle sufficiently, the aircraft may stall. Conversely if the desired angle is overshot valuable climb performance may be lost. In an actual encounter of this type, the pilot's reaction to the stimulus provided by the stickshaker could be abrupt and a considerable amount of overshoot could result. There was persuasive evidence indicating that this type of overshoot occurred momentarily during this incident. Between 120 and 129 sec FDR foil time, the FDR altitude trace showed that the aircraft descended 300 ft while its airspeed increased 26 KIAS. While part of this airspeed increase was attributable to the abrupt increase in the headwind component, part of the acceleration and the descent also may have been attributable to the fact that the nose was lowered in response to the stickshaker. Although neither pilot could recall seeing any pitch attitudes below 10° noseup, the captain stated that the first officer did "overreact" to the point where he requested him to raise the nose of the aircraft. Therefore, the Safety Board believes that the pitch angle was reduced momentarily to values that were not only lower than those noted by the flightcrew but may have approached 0° pitch. In addition, at the time of the correction the aircraft was, due to the wind shear activity, turning to the right and the resultant bank angle would have further reduced the angle of attack, and the aircraft's climb capability. Therefore, for the small amount of time the aircraft's nose was dropping and until the nose was raised and the 12° to 15° noseup pitch attitude was restored, climb performance was sacrificed. In this case, because of the aircraft's altitude above the ground, the loss of climb performance did not result in an accident.

The performance data disclosed that two factors combined to prevent the wind shear encounter from creating an accident. The first was the variation of the downdraft pattern from the classic configuration normally present in this type of phenomenon. Between the OM and the establishment of the missed approach climb, the winds which influenced the aircraft were, sequentially, as follows: headwind, a combination headwind downdraft, downdraft, and headwind. Instead of encountering the downwind portion of the outflow pattern after the downdraft was traversed, Flight 693 encountered a substantial headwind. This, in effect, immediately increased the aircraft's climb capability, and therefore, increased its ability to attain a positive vertical speed and execute the missed approach.

The second factor which enabled the flight to traverse the wind shear was the fact that, except for the momentary overcorrection in response to the stall warning, the first officer attempted to maneuver his aircraft in accordance with the procedures that he had seen demonstrated during wind shear training in the flight simulator. When he recognized the onset of this particular shear, he did not try to reestablish the landing approach; takeoff thrust was applied, the aircraft was rotated to a pitch angle which activated the stickshaker, then the nose was lowered until the stickshaker stopped, and the aircraft's nose was raised again. Finally, the pilots applied the total thrust available even though it meant exceeding engine limitations. Although the performance calculations indicated that recovery did not take place until the head wind component was entered, the flightcrew's tactics delayed the aircraft's descent and helped keep it airborne until the downburst area had been traversed. Had the first officer lowered the aircraft's nose and attempted to retain V_{ref} speed, the aircraft either would have crashed or the recovery would have been made at a lower altitude.

Since wind shear activity of varying intensities was located on the approach course to runway 27L for several minutes before and after Flight 693's encounter, the weather conditions in the vicinity of the airport were examined to determine the cause of this type of activity.

At 1508, when Flight 693 was about 12 nmi east of the end of runway 27L, there were three cells located within 15 nmi of the airport: a level 2 cell was located about 7 nmi west of the aircraft, a level 4 cell was situated 9 nmi to the northwest of the aircraft; and a level 4 cell was located in the vicinity of the airport. There also was an east-west comma shaped echo over the runway 27L ILS course.

The statements of Flight 693's pilots corroborated the ground weather radar photographs. According to the crew, there was a storm cell to the south of and three cells just north of the approach course, and the captain stated that the northern three cells "looked like they were touching each other." Except for the level 2 cell to the west of the aircraft, the pattern described by the pilots was similar to that of the radar photo analysis; the differences could be attributed either to the characteristics and capabilities of the radar sets involved, the differences in distance and location of the radar antennas from the observed cells, the manner in which the captain of Flight 693 adjusted his weather radar controls, or a combination of any of these factors. The weather situation also was corroborated by the captain of Eastern Flight 209; his aircraft was making a parallel ILS approach to runway 26 and was slightly behind Flight 693 on its approach to runway 27L. According to Flight 209's captain, his weather radar portrayed thunderstorm cell echoes in about the same location as those described by the captain of Flight 693.

As Flight 693 approached the OM, the level 2 cell to the west of its position probably decreased in area. Although analysis of the Athens radar photographs indicated that the echo from this cell was of level 2 intensity at 1508 and had decreased to level 1 intensity at 1518, the cell probably intensified shortly before the incident and then decreased to level 2 again shortly after the incident. This conclusion is based on the flightcrew's report that they encountered an area of heavy rain almost simultaneous with the aircraft's entry into the wind shear. During the intensification of this cell, a contour should have been portrayed on the aircraft's weather radarscope if it was functioning properly. The captain said that he did not attempt to contour the cells after they were inbound from the OM. However, even if the radar had been in the contour mode after the flight departed the OM the crew probably would not have had time to detect and avoid the cell because of its small area and rapid evolution.

The Athens radar photographs of the airport area also indicated that Flight 693 probably encountered the comma-shaped echo at the time of the wind shear event. A comma-shaped weather echo can indicate severe weather containing strong vertical velocities and the performance data showed that Flight

693 was exposed to strong downdrafts. Since downdrafts are located most often within the rain shaft of a cell, the fact that the aircraft encountered the downdraft and heavy rain at the same time and the fact the aircraft simultaneously exited the heavy rain and wind shear offer further confirmation that a downdraft was associated with the echo. Recent studies of such downdrafts, downbursts, and microbursts have shown that, as the vertical winds embedded in these meteorological events approach the ground, they become horizontal in direction and in their early stages these horizontal outflows tend to be symmetrical in shape.

Interpolation of the Athens radar pictures for the time of the incident showed that the comma-shaped echo had a horizontal east-west dimension of about 2 nmi and was moving east at about 20 kns. Flight 693's flightpath began to balloon above the glidepath about 4.25 miles from the end of the runway and the climb from the flight's lowest altitude began 2.4 nmi from the end of the runway. Therefore, the wind shear encounter was encompassed within a horizontal east-west distance of about 1.85 nmi; a distance which closely approximates the east-west horizontal dimension of the comma-shaped echo.

Flight 693 encountered the rainshower about 3.5 nmi from the end of runway 27L. At this time, Delta 128 was outside the OM for runway 27L; Eastern Flight 209 was about 1 mi north on a parallel approach to runway 26; and other aircraft were operating south of the airport before turning on final approach to runway 27L. A Low Level Wind Shear Alert System wind sensor was located 1/4 mi east of runway 27R. The fact that the system did not alarm and that Flights 128 and 209 and those south of the airport did not report any significant shears indicated that the meteorological event encountered by Flight 693 was probably contained within the area defined by the traffic south of the airport, the positions of Flights 209, 128, and the system sensor. The horizontal distance from the wind sensor to Flight 128 was 5 nmi and from Flight 209 to the traffic south of the airport was 6 nmi. Therefore, the area encompassing the event was about 5 nmi by 6 nmi. Since the evidence suggests that the low level wind field associated with significant convective activity tends toward symmetry, the meteorological event encountered by Flight 693 would have had a horizontal dimension of 1 to 2 nmi. At the time of the incident, Delta Flight 128 was about 1 nmi behind Flight 693 and did not encounter any significant wind shear during its landing approach. This could indicate that the lifespan of the meteorological event was only minutes.

About 2.4 nmi from the end of runway 27L and after the downdraft was traversed, Flight 693 encountered an increasing headwind. At this time, a cell was in the vicinity of the airport and about 4 nmi northwest of the aircraft. Air flow from the cell could have produced the headwind. Between 1430 and 1500, the temperature dropped almost 10° F and probably produced an inversion at the airport which extended from the surface to about 400 ft a.g.l. An inversion of this nature might have prevented the strong winds associated with the storm cell west of the aircraft from reaching the surface, and this could explain the absence of strong horizontal wind speeds in the area and the lack of a Low Level Wind Shear Alert System Alarm at the time of Flight 693's encounter.

Therefore, the meteorological event which Flight 693 encountered was contained within a small geographical area, had a short lifespan, and was not detected by the weather sensing and recording equipment. The only evidence of its existence were the reports forwarded to air traffic control by the pilots who had encountered wind shear activity on their approaches. The localized and short-lived wind shear occurred outside the airport boundaries and, therefore, no wind sensors were located adjacent to its point of peak severity. Had a wind sensor been located along the final approach course and had the downdraft affected the surface wind sufficiently to activate the alarm system, the Low Level Wind Shear Alert System might have provided some warning of this wind shear. The probability that this warning might be given indicates that some consideration should be given to placing wind sensors outside the airport boundary and along the final approach courses to an airport's primary runway.

Even with sensors mounted along the final approach course and integrated into the Low Level Wind Shear Alert System, the system would still be limited to the detection of those aberrations that manifest themselves close enough to the surface to affect the sensors, such as a gust front. Thus, any wind shear that does not occur in close proximity to the surface will not produce any alarm. Therefore, other equipment such as the microwave Doppler weather radar which would scan both the airport and its surrounding area and the air space above the airport must be developed and installed to solve the wind disturbance detection problem.

Since the only evidence of the existence of the wind shear was the pilot reports to the air traffic controllers, the burden of either preventing or lessening the encounter was placed upon the air traffic control system. Except for communications which involved the handling and preparation of ATIS data, the ATC procedures were in accordance with those contained in the Handbook. The pilot reports of the wind shear encounters were relayed to other traffic expeditiously.

Two ATIS broadcasts were pertinent to this incident--MIKE and ALPHA. Information MIKE was broadcast at 1430 and was in effect when Flight 693 established radio contact with approach control. At 1453:14, Flight 693 contacted approach control and stated that they were descending to 14,000 ft. Although the flightcrew stated in their interview that they had received information MIKE, they did not, as directed by the ATIS broadcast, advise the controller that they had received the message. The controller did not question them regarding the omission, nor did he provide them with the data listed in paragraph 394. During the ensuing transmissions, the controller informed the flight of the landing runway and the type of approach that was to be flown. Since the existing ceiling and visibility were above the requirements of paragraph 394a(4), the only data the approach controller was charged to provide and failed to provide were the surface wind conditions and altimeter setting. Neither of these items would have assisted the flightcrew to either avoid the wind shear encounter or to change the manner in which they handled their aircraft during the encounter, since the surface winds existing at the airport at the time of the transmission were not indicative of the strength of the conditions later encountered on the approach course. Therefore, these deviations from prescribed communications procedures by the flightcrew and the controller were not considered contributory to this incident.

At 1500:04, ATIS information ALPHA was broadcast. ALPHA reflected the 1454 "record special" surface weather observation, the contents of which were transmitted by telewriter to the Atlanta tower and approach control facility. The weather contained in ALPHA differed from that in MIKE particularly since it contained the first reference to thunderstorm activity at the airport. At the time of its initial transmission, Flight 693 and several other air carrier aircraft were on either approach or local control radio frequencies and would not have received or known of ALPHA unless they were monitoring the ATIS frequency on their backup radio or overheard other arriving flightcrews report to the controller with information ALPHA.

Examination of the ATC transcripts at and after 1500 disclosed that neither the tower nor approach control advised the aircraft on their frequency, as required by paragraph 394b of the ATC Handbook, of the contents of the special weather observation. Neither facility made a "blind" transmission to alert aircraft on their frequency that a new ATIS information was now current. Although many facilities have adopted this method to alert aircraft of new ATIS data, the procedure is not required by the handbook. However, the Safety Board could not establish that either of these omissions contributed to the incident. The evidence indicates that the pilots of Flight 693 and other pilots in the airport area were aware that thunderstorm and rainshower activity existed in close proximity to the airport.

Any evaluation of the services provided by controller personnel and the timeliness of the preferred services must be measured against the order of priorities placed upon the controller. Paragraph 22 of the ATC Handbook requires that the controller "give first priority to separation of aircraft as required in this handbook and to the issuance of safety advisories. Give second priority to other services that are required but do not involve separation of aircraft." The ATC Handbook, paragraph 33 defines safety advisories as those relating solely to alerting aircraft to potential conflicts with terrain, obstructions, or other aircraft.

During the 10- to 15-minute periods before and after the issuance of the 1454 "record special" weather observation, the ATC transcripts of the Atlanta facilities disclosed numerous instances which indicated controller involvement with traffic separation. The transcripts disclosed that holding, vectoring, and airspeed management procedures were being used to separate the arriving flights. At the time the special weather observation and information ALPHA were issued, the Atlanta ATC facilities were engaged in handling a high volume of traffic and that the weather in the airport area added to the traffic control problems.

The ATC transcripts disclosed that, despite the traffic load, the tower controllers issued numerous advisories on the weather situation and the location and intensity of shower activity. Flight 693 was advised that there was shower activity on the runway, and between the OM and the runway, and that they would "break out of that rainshower in about 3 miles." The transcripts showed that this type of advisory was transmitted to several Delta flights, a Braniff flight, and an Eastern flight.

The tower controllers issued timely advisories of wind shear encounters to the aircraft that followed behind the reporting aircraft. The advisories contained the quantitative data regarding the shear as it was reported to them. Advisory Circular AC 00-50-A, Low Level Wind Shear, recommends that pilots report any wind shear encounter to ATC and that this report "should be in specific terms and include the loss/gain of airspeed due to the shear and the altitude(s) at which it was encountered." Except for Flight 693's report, the pilot reports all indicated the altitude of the encounter, some located the encounter geographically, and one indicated that it was a horizontal shear. However, none provided any descriptions of the energy or strength of the shear or the effect of the shear on their aircraft. Flight 693's report merely stated that the aircraft encountered a wind shear and that the captain did not see how any aircraft could complete an approach to runway 27L.

The Safety Board, in conclusion, could not find any evidence that the flightcrew had failed to comply with any directives, guidelines, or regulations. The decision to execute the approach was a matter of judgment based upon the pilot's assessment of the existing weather situation. The captain indicated that he was aware of contour-producing cells in the area; however, none of these were evident directly along his intended approach course. Showers were being reported both by the local controller and by the pilots of preceding flights traversing the final ILS approach course. The captain knew these aircraft were landing at the airport without reported difficulties. The rainshower which contained the strong downdraft that was later encountered may have been visible to the flightcrew as their aircraft approached it. However, because of the limited forward visibility conditions, the Safety Board believes the flightcrew could not be expected to assess the intensity of this shower or the need for course deviation. Under these circumstances, the Safety Board could not conclude that the captain's decision to land was unreasonable.

The evidence appeared to indicate that the major criterion upon which the flightcrews at Atlanta based their decisions to approach and land in the presence of the thunderstorm activity was the fact that there were no contour-producing cells above the approach courses. The Safety Board is compelled to note that this criterion may still expose an aircraft to hazardous weather conditions. Even a level 1 or level 2 cell may have the potential to generate conditions which could endanger an aircraft flying beneath it on a landing approach, especially if the cell is in its generation stage. The Safety Board believes that any echo-producing storm cell located astride the landing approach course should be avoided regardless of whether or not it can be contoured by the aircraft's radar.

CONCLUSIONS

Findings

1. Flight 693 encountered a localized but heavy rainshower with associated wind shear during its approach to the Atlanta airport. The shower contained changes of horizontal and vertical wind velocities.

2. The meteorological event was contained within a small geographical area and had a lifespan of minutes.

3. The Low Level Wind Shear Alert System's wind sensors were positioned on the airport. There were no wind sensors located outside the airport's boundaries.

4. The Low Level Wind Shear Alert System's wind sensors on the airport did not detect the wind shear condition. The remote weather radar displays at Atlanta and the WSR-57 radar at Athens did not have the capability to measure the motion of the air within the cells. Therefore, the wind shear condition was not detected until Flight 693 traversed the area.

5. The pilot reports concerning wind shear encounters at the airport did not contain any descriptions of airspeed and altitude losses.

6. There were several deviations from standard ATC communications practices and procedures by the controller and the pilots before the incident; however, these deviations did not produce or contribute to the incident.

7. The wind shear contained changes in the horizontal and vertical wind velocities which caused the aircraft to descend below the desired landing approach path.

8. The flightcrew was unable to assess the intensity of the rainshower and its associated wind shear before they entered it.

9. The flightcrew maneuvered the aircraft in accordance with the procedures contained in the company's wind shear training program.

10. The wind shear training program conducted by the company, in accordance with the FAA training requirements, contributed to the ability of the flightcrew to maneuver their aircraft through the shear area successfully.

<u>Probable Cause</u>

The National Transportation Safety Board determined that the probable cause of this incident was the unavailability to the flightcrew of timely information concerning a rapidly changing weather environment along the instrument landing system final approach course. The unavailability of this data resulted in an inadvertent encounter with a localized but heavy rainshower with associated wind shears which contained changes in the horizontal and vertical wind velocities which required the flightcrew to use extreme recovery procedures to avoid an accident. Contributing to this incident was the lack of equipment for the airport terminal area that could have detected, monitored, and provided quantitative measurements of wind shear both above and outside the airport's boundaries.

SAFETY RECOMMENDATIONS

Since November 1974, the Safety Board has initiated 22 recommendations concerning wind shear and associated areas. These recommendations were originated during the Safety Board's investigations of wind shear related accidents and special studies on the subject. They addressed areas concerning weather reporting, pilot reporting, storm classification, wind shear detection equipment, inflight procedures, and flightcrew training. As a result of FAA and industry response to the problem identified in these investigations and the Board's recommendations, progress has been made toward minimizing the hazards contained in wind shears.

A classification system which identifies the intensity of thunderstorm radar echoes was developed. This system was disseminated to the aviation community in the AIM, and to the air traffic controllers in their manual and is in use.

AC00-50A established recommended procedures for flightcrews to use in reporting an encounter with a wind shear to controllers. The Circular contains flight procedures to cope with the effects of a low level wind shear in the event one of these phenomona is entered inadvertently. It also addresses the problem of educating flight personnel to the characteristics of various types of wind shear and the aerodynamic effects these characteristics produce on their aircraft's performance.

As a result of the efforts of the FAA and industry air carrier flightcrews receive training in these areas, and, in particular, they are required to fly through various wind shear models in their required simulator training programs.

A Low Level Wind Shear Alert System was developed and placed in operation at several major airports. The system represented a step forward; however, as shown by the circumstances of this incident, the system contains several shortcomings. An area of prime concern remains the inability of the ground detection systems to detect a wind shear above and in the vicinity of an airport and then to furnish up to date quantitative measurements of the motion of air within that wind shear.

Another area of concern is the lack of an airborne system or systems which can (1) provide a warning to a pilot of the existence of wind shear, and (2) provide accurate flight guidance to a pilot for the required corrective maneuvers in the event his aircraft has penetrated a wind shear.

On May 3, 1979, the FAA issued ANPRM No. 79-11, Docket No. 19110. which addressed the wind shear problem. The Notice discussed the problem, the FAA's research and development programs bearing on it, and requested comments and recommendations that would assist the FAA "in determining what, if any regulatory proposals should be developed."

The FAA programs took a twofold approach to the wind shear problem. One approach explored the feasibility of placing detection equipment on the ground and transmitting the data to the pilot; the other tried to determine whether equipment could be installed in the aircraft that would provide the pilot with wind shear information in "real time." The Notice summarized the results of, and the present status of their programs and then requested comments that would assist them to answer four specific questions. On July 23, 1979, the Safety Board replied to the ANPRM, and commented to the four questions as follows:

"The Safety Board has watched with great interest the work of the FAA Wind Shear Program since its inception, and commends all those individuals of both industry and government for their efforts in the development of ground and airborne systems. We anticipate that, whatever systems are chosen, the hazards of low-level wind shear encounters will be minimized. Therefore, the Safety Board strongly supports the proposed rule and offers the following comments on the questions:

1. <u>Is there a valid need to amend Part 121 and require wind shear detection equipment?</u>

The Board believes that there is a need for this requirement. We base this conclusion on the findings of our investigations of several accidents involving wind shear. In these accidents, we found that the lack of recognition, surprise, the absence of recommended piloting techniques, and the combined effects of degraded aircraft performance were all contributing factors. These findings prompted the Safety Board to issue several safety recommendations. Recommendation A-76-42 recommended that research be expedited to develop equipment and procedures which would permit a pilot to transition from instrument to visual references without degradation of vertical guidance during the final segment of an instrument approach. Recommendation A-76-43 recommended expediting the research to develop an airborne detection device which will alert a pilot to the need for rapid corrective measures as an airplane encounters a wind shear condition. We believe that the airborne equipment developed thus far, with refinements, fulfills the intent of our recommendation and should be standard equipment on all air carrier type aircraft.

2. <u>Which of the various systems is best suited to Part 121 operations, would be cost effective, and would provide a flightcrew with adequate and timely information to avoid wind shear hazards?</u>

The Board believes that the Modified Flight Director would be the least expensive because a flight director is already installed and with the modifications would be used in all flight environments as well as in wind shear encounters. However, the Board is impressed with the Airspeed/Groundspeed Comparison and Acceleration Margin Systems and would like to see these systems incorporated into one integrated package along with the Modified Flight Director. We believe that the Airspeed/Groundspeed and Acceleration Margin Systems should be used as "raw data instruments." For example, the flight director receives most of the pilot's attention during an approach, but the prudent pilot never ignores the "raw data" instruments such as the altimeter, glideslope indicator, or localizer. He uses these instruments as another source of information with which to make operational decisions. The "raw data" instruments also provide the redundancy that is necessary for safe flight.

3. <u>Have all practical solutions to the wind shear problem been explored, or are there other simpler and less costly solutions available?</u>

The Board believes that the forecasting and detection of low-level wind shear development should be given equal consideration with the development testing and operational use of the Acoustic Doppler Wind Measuring System (A-74-82), we concede to your findings that the system is expensive and is inoperable in heavy precipitation, and we encourage you to continue working for the further development of a pulsed doppler laser technique.

4. <u>How reliable would the various systems be in providing wind shear information and what operating and maintenance costs would each of them be likely to impose on aircraft operators?</u>

In general, all the systems are only as good as the actual winds fed into them. Winds, in conditions conducive to wind shear, are almost constantly changing in speed and direction and may bear little relationship to the wind input of the cockpit ground speed indices. The Board, therefore, believes that a means must be developed that quickly updates the threshold winds and transmits the updated winds to the airborne equipment.

Specifically, the Modified Flight Director does not directly provide wind shear information, but it does provide the flightcrew with speed control and attitude guidance when wind shear is encountered. The guesswork is taken out of corrective procedures and technique.

The Airspeed/Groundspeed Comparison and the Acceleration Margin Systems alert the flightcrew of wind shear and provide them with the magnitude (if the threshold wind has not changed) of that shear, as well as providing the airplane's acceleration potential under the circumstances. As stated in a previous answer, the Board would like to see an integrated system which consolidates these three systems, provides the flightcrew with prior knowledge of the wind shear, and provides them with flight guidance to penetrate it.

In summary, the Board believes that a system that may be acceptable to the airlines should be able to predict unacceptable low-altitude wind shear values and warn the pilot to abandon the approach. The unacceptable values could then be restrictive much the same as visibility currently restricts the initiation and continuation of an approach. In order to accomplish this in "real time," constant updating of low-level winds must be transmitted to the airborne equipment. However, regardless of the absence of these refinements, the Safety Board is satisfied that the equipment developed so far will be of inestimable value in wind shear encounters and should be required under Part 121."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

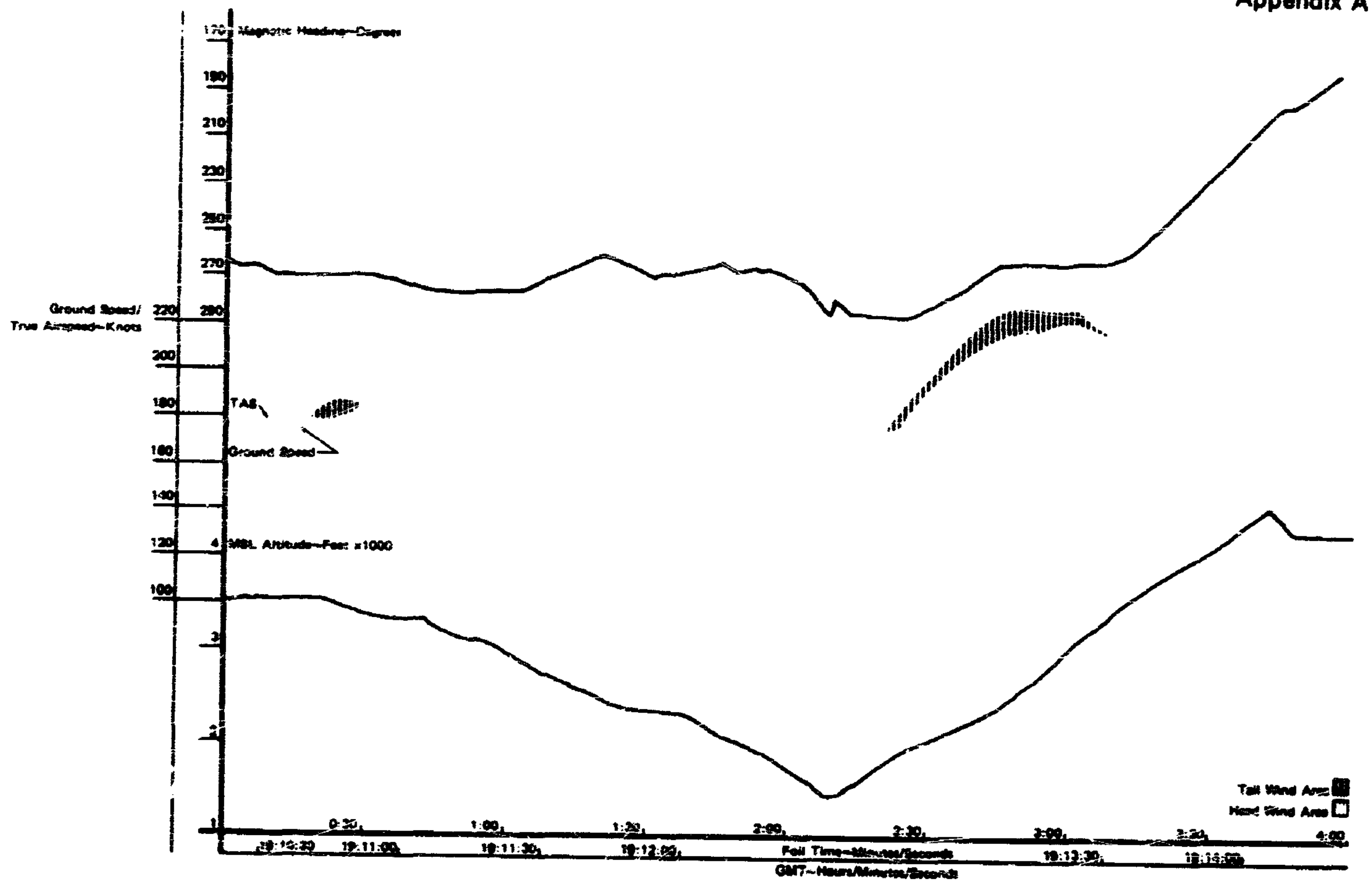
/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

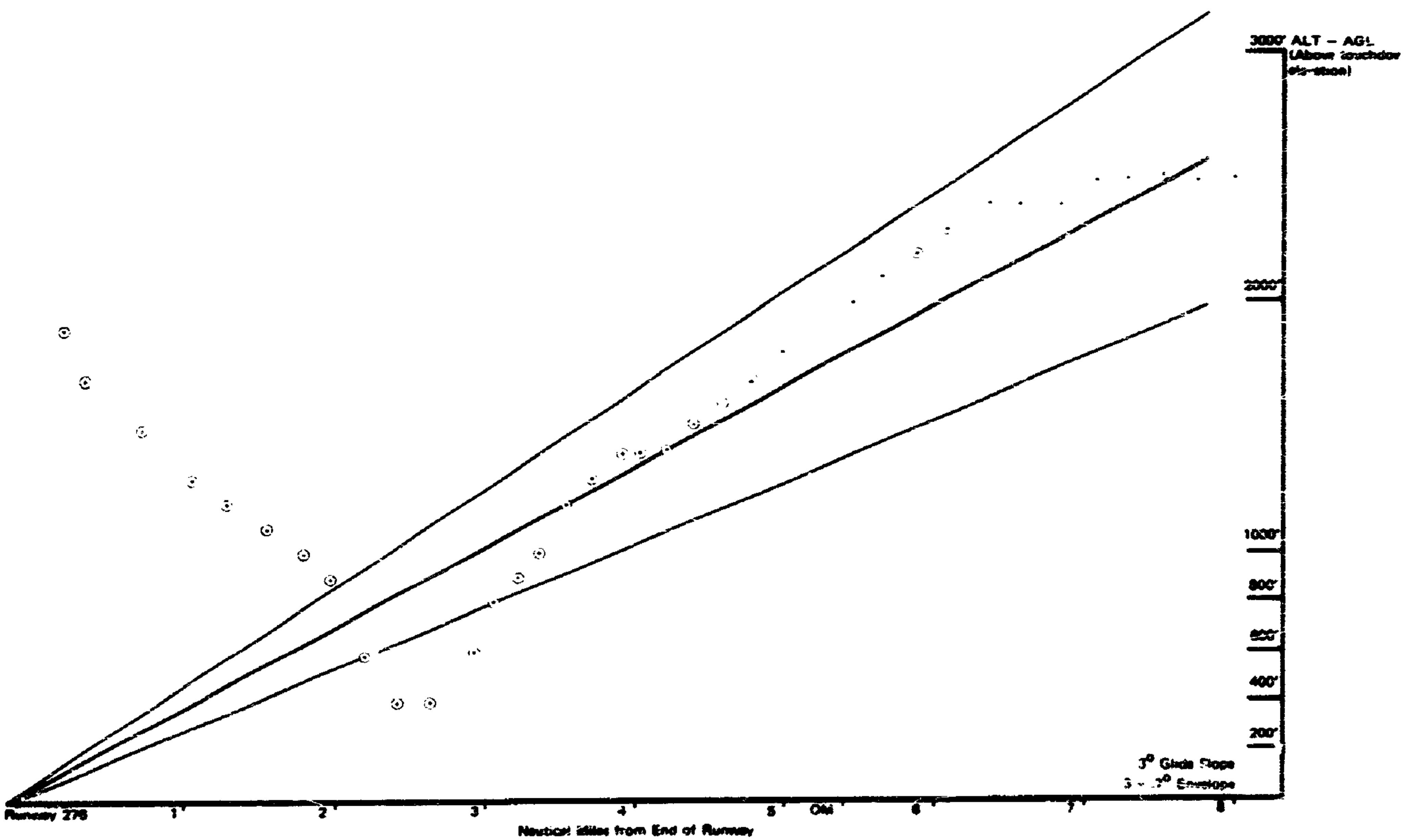
May 28, 1980

Appendix A

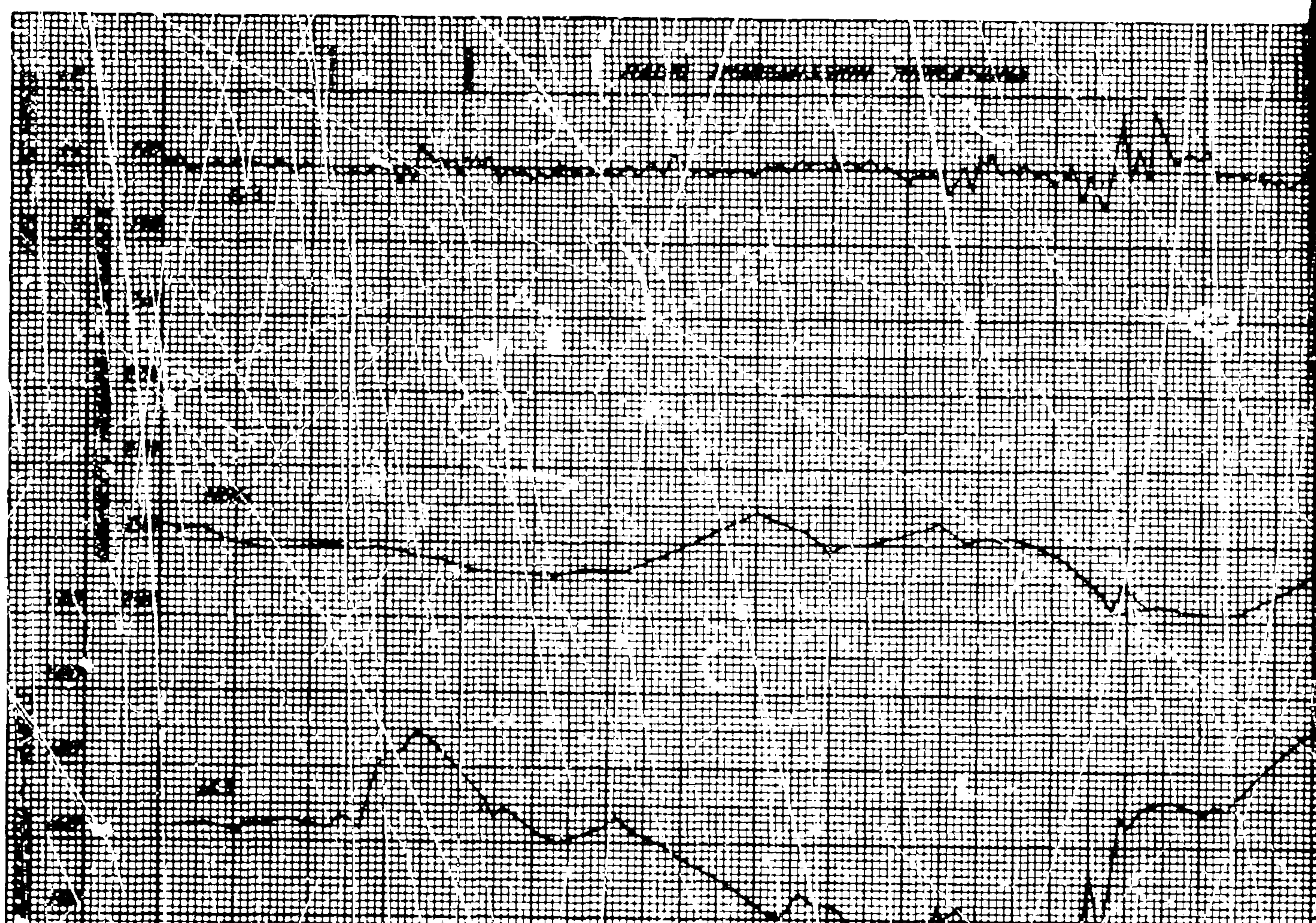


NTSB Washington, D.C. FDR Heading & Altitude True Airspeed & ARTS III Groundspeed
EAL, Boeing B-727, N8139 FLT 693, Atlanta, Georgia
August 22, 1979

Appendix B



NTSB Washington, D.C. ARTS III Glideslope
EAL, Boeing B-727, N8138 FLT 693, Atlanta, Georgia
August 22, 1979



Appendix C