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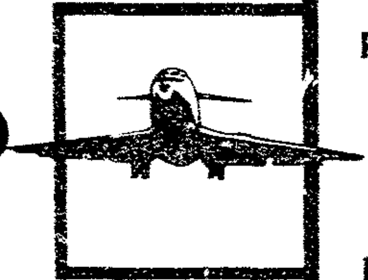

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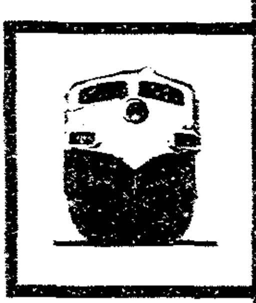

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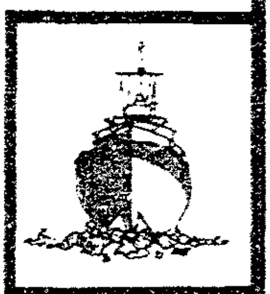
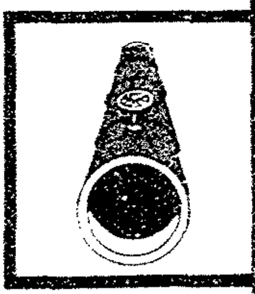


AIRCRAFT ACCIDENT REPORT

AIR CANADA FLIGHT 965,
LOCKHEED L-1011, C-FTNJ,
NEAR CHARLESTON, SOUTH CAROLINA
NOVEMBER 24, 1983



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16. Abstract At 1926, on November 24, 1983. Air Canada Flight 965, a Lockheed L-1011, C-FTNJ, with 145 passengers and 15 crewmembers on board, encountered severe turbulence about 105 miles off the coast of Charleston, South Carolina, while en route to Toronto. Canada. from Port of Spain. Trinidad. At 1916:02, the flight had been cleared to climb and maintain flight level (FL) 370 from FL 350. About 2 minutes later, the ground controller asked the flight to start a turn to the north because of other traffic. The captain stated that he may have to detour around some thunderstorm and also replied that he was in the turn. About 8 minutes later, the flight encountered severe turbulence which lasted several seconds.

One flight attendant and three passengers were seriously injured during the encounter, and two physicians aboard the flight provided immediate medical attention. The flight continued to its destination and landed without further incident about 1 1/2 hours after the accident. Medical assistance was available at the gate to provide treatment when the flight arrived.

The National Transportation Safety Board determines that the probable cause of the accident was an encounter with severe clear air turbulence produced by the intrusion of thunderstorm cells into strong winds aloft.

17. Key Words Clear air turbulence, thunderstorms, jet stream winds, jet upset, flight planning, weather briefing, inflight weather advisories air traffic control, hazardous in-flight weather advisory service (HIWAS), passenger service carts, restraint of cabin equipment.		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: October 16, 1984

AIR CANADA FLIGHT 965 LOCKHEED L-1011, C-FTNJ NEAR CHARLESTON, SOUTH CAROLINA NOVEMBER 24,1933

SYNOPSIS

At 1926, on November 24, 1983, Air Canada Flight 965, a Lockheed L-1011, C-FTNJ, with 145 passengers and 15 crewmembers on board, encountered severe turbulence about 105 miles off the coast of Charleston, South Carolina, while en route to Toronto, Canada, from Port of Spain, Trinidad. At 1916:02. the flight had been cleared to climb and maintain flight level (FL) 370 from FL 350. About 2 minutes later, the ground controller asked the Flight to start a turn to the north beceuse of other traffic. The captain stated that, he may have to detour around some thunderstorms and also replied that he was in the turn. About 8 minutes later, the flight encountered severe turbulence which lasted several seconds.

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1. PACTCAL INFORMATION

1.1 History of the Flight

Air Canada Flight 965 was a regularly scheduled international passenger flight from Port of Spain, Trinidad, to Toronto, Canada. There were 145 passengers on board an2 a crew of 15. One passenger was assigned to the first-class section and 144 to the economy section, including a 2-year-old boy. The flightcrew consisted of the captain and first and second officers. The cabin crew consisted of the flight service director and 11 fight attendants.

Since Air Canada does not have a dispatcher assigned et Port of Spain, the flightcrew performed a routine self-briefing in preparation io: the scheduled 1540 e.s.t. 1/ flight to Toronto. on November 24, 1933. Air Canada provides their briefing office with surface weather analysis and prognostic upper air charts. TV weather station charts, and significant weather prognosis charts. Also, through the use of a computet, forecasts and actual weather were available for most routes, terminals, and alternates. in

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

addition, the fligh' lan made available to the flightcrew included valid terminal and alternate forecasts, ⁻0 millibar (35,000 feet) constant press–re chart, TV weather station charts, and a significant weather prognosis for the intended route of flight.

The flight plan essentially required a direct flight northeast over Puerto Rico to OLDEY Intersection via airways A220, B14, and AR4. The flight was to turn north et OLDEY onto AR3 and make landfall at Carolina Beach, North Carolina, then onto AR1 to Wilmington, North Carolina, from OLDEY. Also, OLDEY is 116 nmi east of Charleston, South Carolina. At Wilmington, the flight was to proceed north on jet route 109 (J109) to Buffalo, New York, and then to Tcronto. The planned cruising altitude for that day's flight was flight level (FL) 350.

The scheduled minimum fuel load was 105,200 pounds. However, an additional 1,700 pounds of fuel was added. The actual gross takeoff weight was calculated to be 386,975 pounds.

The weather along the initial legs of the flight was forecast to be essentially clear, with only a chance of encountering a few thunderstorms shortly after departure. Thereafter, the weather would be clear until approaching the southeast coast of the United States. A frontal system was oriented on a north–northeast to southsouthwest line, over the northern portion of Florida and northward along the Atlantic Coast. There were a few thunderstorms forecast to be associated with the frontal system with tops to 34,000 feet mean sea level (m.s.l.). The fligh? was also expected to encounter increasing jet stream winds from the southwest from the coast to its destination. From southern Pennsylvania to Toronto, it could expect to encounter moderate clear air turbulence (CAT) from FL 250 to FL 310.

At 1557, Flight 965 departed Port of Spain on an instrument flight rules (IFR) flight plan to Toronto. The night was cleared as filed and operated without difficulty through San Juan, Puerto Rico, Air Route Traffic Control Center (ARTCC) airspace. Thereafter, radio communications were transferred to a high frequency Aeronautical Radio, Incorporated (ARINC) frequency for overwater control purposes. At 1915:34, Flight 965 contacted the Jacksonville ARTCC, METTA sector controller and reported. ". ..we're at flight level three five zero we're just by SMELT at zero one four and we're estimating OLDEY at two zero Carolina Beach next." The controller advised the flight that it was in radar contact, 15 miles west of SMELT (32 nmi southeast of OLDEY) and cleared the flight to proceed direct to Buffalo. At 1916:02, the controller informed Flight 365 that in just a little while he would have to change the flight's altitude assignment and asked whether FL 330 or FL 370 would be desirable. The flight requested FL 370, and it was assigned at 1916:19.

At 1917:58, the controller transmitted, "and Air Canada nine sixty five could you start your turn for Wilmington sir about a let's see we'll need a good heading out of you at least of about (unintelligible!." At 1918:09 Flight 965 responded, "we just got it tuned in now and . . . Buffalo and its about a sixty degree turn to the right." The controller acknowledged their transmission, and at 1918:17, Flight 965 stated, "and a little later on we may . . . may have to do a little . . . detour, we show a thunderstorm up ahead.'; At 1918:22, the controller replied, "alright, sir, I need to start a turn to the north at least I gotta thirty seven (a being 727), I gotta (unintelligible)." The flight acknowledged, "Okay we're in the turn now," at 1918:27.

At 1923:24, Flight 965 reported level at FL 370 and "in moderate chop to light turbulence (unintelligible) buildup uh showers.-: According to the captain, about this time in the vicinity of OLDEY, he noted a flash of lightning to the north, and the flight began to encounter light to moderate "chop." He stated that he switched on the fasten seatbelt sign and announced on the public address system (PA), "We are encountering unexpected light turbulence, please remain seated and fasten your seatbelt as a precautionary measure." He said thet the airplane was in "upper cloud" and that there was some static discharge on the windscreen and reflections from the strobe lights. During this time, he noted a corth-south line of light weather radar returns on his scope which was tilted downward 2°. He noted a second return about 20 nmi to the right of his course. The first officer stater' that the radar showed a light broken line of clouds extending northeast from OLDEY. The second officer stated that Saint Elmo's fire 2/ preceded the light to moderate "chop:'

Meanwhile, the flight attendants had completed a beverage and meal service. There were two flight attendants in first class, one at the aft end of the coach cabin and six in the aft section of the economy class compartment. The flight service director and the purser were in the lower galley (located about the mid-section of the airplane) counting money from the beverage service and another attendant was working in the galley. Tie flight attendants in the passenger compartments were about to prepare another cold beverage service when the flight began to encounter some light turbulence. The fasten seatbelt sign illuminated and the captain announced in both English and French, the predominant languages on board, that they were expecting to encounter some turbulence. He had instructed everyone to remain seated with seathelts fastened. Passengers en route to seats from the aft washrooms were advised by flight attendants to take the nearest available seat.

According to flight attendent reports, within about a 5-minute period following the firs: sign of moderate turbulence, the airplane "...suddenly shook and dropped twice." One attendant stated that she felt a tremor in the airplane before the airplane "plunged," and another stared she heard a loud bang before it dropped. They stated that loose articles flew about the cabin and that ?he pessenger service carts were hurled up to the ceiling of the cabin. Several passengers screamed and most were frightened by the severe encounter.

The flight service director and the purser also heard the announcement but remained counting money in the lower galley, and were tossed lo the ceiling during the encounter. The flight service director immediately proceeded to the cabin to assess the injuries and damage and inform the captain. His exit from the galley elevator was temporarily blocked by two overturned passenger service carts.

Minutes after the captain of Flight 965 informed the controller of the severe turbulence encounter, the flight service director told the captain tha? tnere were 5 injured flight attendants end 19 injured passengers. The second officer radioed Toronto and advised them of the severe turbulence encounter end of the number of injured on board, and told them that the maintenance department would have to make a severe turbulence check of the airplane.

Two doctors on board The flight assisted the flight attendants with the injured. The medical kit on board the airplane was not needed in treating the injured. Following consultations between the captain and ?he doctors, it was decided that the fight would

2/ A phenomenon of static electrical discharge which forms at prominent points on an airplane.

continue to Toronto where appropriate medical treatment would be administered. Of the total injured on board, three passengers and one flight attendant were seriously injured. The flight proceeded to Toronto without further incident and landed at 2050. The flight was met immediately by company and medical personnel who assisted and treated the passengers.

At 1925:59, Flight 965 stated, "and center from Air Canada 965, we just went through severe turbulence . . . one big heavy bang." The first officer was flying the airplane, and he changed the autoflight system from the altitude-hold mode to the turbulence-hold mode immediately after the severe encounter. He stated that it was one severe jolt. The second officer reported that it felt as if the nose of the airplane had been pushed downward very hard and that he was lifted out of his seat and tossed somewhat against his seatbelt and shoulder harness. The altimeter showed a 500-foot loss and then an immediate gain in altitude at the time of the encounter. Loose navigational charts and logbooks were tossed all over the cockpit floor. The flightcrew reported there was about a 2-minute period of moderate turbulence after the severe jolt.

At 1927:41, in response to the controller's query about whether the flight had broken out of the severe weather, Flight 965 transmitted," yeah 965 smoothing out now we . . . had . . . severe turbulence, . . . for a minute or two, we have several people injured . . . (unintelligible) tell people to avoid that area if possible, we . . . had a few showers on . . . a radar but we're well clear of. . . according to us." The controller acknowledged the flight's report and instructed another flight to turn 15° to stay clear of the area transited by Flight 965.

There were other airplanes in the area which also experienced turbulence. Two airplanes closest to Flight 965 were People Express Flight 545, a B-727 and Delta Flight 845, another L-1011. People Express 545 was located at FL 370, 15 miles southwest of Flight 965 on AR7, which crosses AR4 at OLDEY, and Delta 845 was located at FL 430 about 57 miles southsouthwest of Flight 965. At 1922:42, Peoples Express 545 transmitted, "Jax People five forty-five just for your information . . . we're getting some . . . moderate to almost severe out there at . . . three seven zero." Immediately following the transmission, there were five other airplanes which either requested more information about the activity or deviations to the east of the thunderstorms. Peoples Express 545 was in weather conditions similar to those encountered by Flight 965. Delta 845 was south of the heaviest thunderstorm activity. Also, one flight reported making a 30° turn to the east on its own initiative and another flight which was ahead of Flight 965 requested its position. This flight was at FL 390 and reported smooth conditions and that ". . .it looks like we're flying right down between uh two lines, however." Nineteen seconds later, still another flight reported that it was at FL 410 and 10 to 15 miles from the METTA Intersection (32 miles west of OLDEY). The crew thought they went through the tops or something and encountered severe turbulence which lasted about 30 seconds. At 1927:20, Peoples Express 545 stated, "Center People five forty-five, i think we just went through the area that whoever was talking about seventy miles south of Wilmington . . . went through the tops we got . . . some pretty good jolts and oh some lightning flashes static discharges and everything it was not very pleasant."

The accident occurred in darkness at 1926 off the coast of Charleston, South Carolina, at 33° 12' north latitude, 77° 50' west longitude.

1.2 Injuries to Persons

Injuries	Crew	Passenger	Others
Fatal	0	0	0
Serious	1	3	0
Minor	4	16	0
None	10	126	0
Total	15	145	0

1.3 Damage to the Airplane

The airplane sustained relatively minor damage to the interior of the cabin; damage was limited to seats, ceiling, movie screen, passenger service carts, and galley areas.

1.4 *Other Damage*

None.

1.5 Personnel Information

The flightcrew and flight attendants were qualified in accordance with current Canadian regulations. The air traffic controller was qualified in accordance with Federal Aviation Administration (FAA) regulations. ***(See*** appendix B.)

1.6 Aircraft Information

The airplane, registration C-FTNJ, a Lockheed **L-1011-385-1-15,** serial No. 193E1067, was manufactured by Lockheed-California Company in **1974** and leased by Air Canada. The airplane was equipped with three Rolls Royce **RB** 211-22B engines. It was exported to Canada in **1982.** Its airworthiness had been maintained in accordance with a continuous maintenance and inspection program approved by the Canadian Department of Transport. (See Appendix C.)

A postturbulence inspection of the airplane by Air Canada maintenance personnel revealed a 5/8-inch crack in the top skin of both horizontal stabilizers at fuselage station (FS) 1875 and leading edge station (LES) **154.38.** The cracks were repaired in accordance with Lockheed's structural repair manual. Lockheed reported that these cracks are similar to cracks reported by several other **L-1011** operators. Lockheed attributes these cracks to relatively low amplitude, cyclic loads due to design (Chem-Mill radius in the skin) and not loadings associated with the turbulence encounter. **The** damage to the interior of the cabin was also repaired, and the airplane was released for flight on November **26, 1983.**

At the time of the accident, the operating weight of the airplane was about 325,500 pounds, and the center of gravity was at the **27** percent mean aerodynamic chord (MAC). The maximum permissible takeoff *gross* weight is **466,000** lbs. The boundary for the onset of the high speed buffet for this operating weight at FL **370 is** beyond the maximum operating speed for the airplane; however, buffet would have occurred at a computed acceleration of 1.? G. The onset of the low speed buffet would occur at Mach 0.585 or 187 KIAS at 1.0 G. 3/

The airplane was equipped with a Lockheed automatic flight control system and an BCA X-band weather radar system. There were no reported discrepancies with this equipment.

1.7 Meteorological Information

The overall surface weather pattern along the East Coast of the United Stares at 1600 was a trough of low pressure extending from northern New York to the south through the western part of Florida with a cold frontal system along the Appalachian Mountains. There was also a weak low pressure area along the front centered over Virginia and North Carolina with a north-south line of instability through eastern North Carolina. The weather conditions east of the front over the Carolinas and Virginia were characterized by overcast to occasionally broken clouds with southerly winds and rainshowers. The 1900 surface weather chart showed essentially the same conditions except thet the line of instability had moved east, just off the coast of North Carolina.

The 200 millibar (about 39,000 feet) chart showed a low over western Ontario with a trough extending south along the Mississippi Valley. The Atlantic Coastal States were under a southsouthwesterly flow with the maximum jet stream winds located over eastern Tennessee, eastern Kentucky, West Virginia, and Pennsylvania with winds up to 150 knots. The winds along the North Carolina and South Carolina coastlines were south–southwest at 70 to 80 knots. There was cold temperature advection with the flow over Georgia and Alabama.

It was noted on the copy of the significant weather prognosis provided by Air Canada that, for the frontal system in the vicinity of the East Coast of the United States, the cumulonimbus tops were forecast to be at FL 340. On the copy of the same map provided by the National Weather Service (NWS), the cumulonimbus tops were forecast to be at FL 390. Otherwise the charts were identical.

The following is a list of excerpts of detailed weather information pertinent to Flight 965:

1. Area Forecasts

issued November 24, at 1240 and valid until 0100 on November 25--Flight precautions North Carolina and South Carolina - icing, IFR, turbulence, and thunderstorms. 4/ Turbulence forecast for Florida and coastal waters. Isolated embedded thunderstorms with light rainshowers. Cumulonimbus tops to 40,000 feet.

3/ A speed in excess of a specified mach number or G limit will result in airframe buffet because of shock wave induced airflow separations from the airplane's airfoils in high altitude flight. Low speed buffet will occur at low speed when the stall angle of attack is approached causing airflow separation.

4/ Thunderstorms imply severe or greater turbulence, severe icing, and low level wind shear. This comment is included in every area forecast.

Issued November 24, at 1840 and valid until 0700 on November 25--Flight precautions North and South Carolina - IFR, thunderstorms. No significant turbulence outside of convective activity. Scattered thunderstorms with moderate rainshowers. Cumulonimbus tops to 30,000 feet.

2. Convective SIGMET's 5/

SIGMET 34E, issued November 24 at 1755--forecast valid until 1955-- Virginia, North Carolina and coastal waters, from 30 miles southeest of Richmond, Virginia, to 20 miles southwest of Rocky Mount, North Carolina, to 60 miles south of Wilmington, North Carolina - Line of thunderstorms 25 miles wide moving from 280° at 15 knots. Tops to 40,000 feet. Line will move east - southeastward at 15 knots through 1955.

SIGMET 36E, issued November 24 at 1855--forecast valid until 2055--Virginia, North Carolina and coastal waters, from 40 miles west of Norfolk, Virginia, to 40 miles northeast of Wilmington, North Carolina, to 90 miles east of Charleston, South Carolina - tine of thunderstorms 25 miles wide moving from 280° at 20 knots. Tops to 45,000 feet. Line will move eastward at 20 knots through 2055.

3. Radar

The 1930 overlay from tine National Weather Service radar at Charleston, South Carolina, showed the location of the turbulence encounter of Air Canada Flight 965 to be in an area reported on the log to be 1/10 moderate rainshowers and 2/10 light rain. The maximum top was 19,000 feet.

The 1930 overlay from the National Weather Service radar at Wilmington showed Flight 965 to be on the edge of the precipitation in an area interpreted to be light rainshowers (level 1) and about 12 miles east-southeast of a line of thunderstorms with heavy (level 4) reinshowers and 24 miles north-northeast of another area of level 4 thunderstorms. The radar log reported most tops below 35,000 feet.

4. Satellite Photographs

The 1930 Geostationary Operational Environmental Satellite (GOES) infrared photograph showed an area of apparent convective activity end associated cirrus clouds in the vicinity of the turbulence encounter. Based upon the temperature profile, the maximum tops of the clouds were about 48,000 feet (pressure altitude).

5/ Significant Meteorological Information.

5. Soundings

The 1802 sounding at Charleston, South Carolina, showed a shallow moist layer at 31,400 feet with strong temperature layering (inversions) from 41,500 feet (pressure altitude) to the tropopause at 55,700 feet. The winds aloft report was not available from 31,276 feet to 61,763 feet. The wind at 31,276 feet was from 223° at 85 knots.

The 1800 sounding at Cape Hatteras was only tracked to 27,700 feet and offered no data at the altitude of the turbulence encounter. The winds aloft terminated with the sounding at 27,700 feet. The wind report at 27,678 feet was from 231° at 64 knots. No reports were available for higher altitudes.

1.8 Aids to Navigation

There were no known difficulties with navigational equipment.

1.9 Communications

There were no known difficulties with communications.

1.10 Aerodrome Information

Not Applicable.

1.11 Flight Recorders

The airplane was equipped with a Fairchild A-100 cockpit voice recorder (CVR). The record of communications recorded by the CVR was overwritten following the occurrence, and therefore, of no use to the investigation.

The airplane was also equipped with a Lockheed 209E digital fight data recorder (DFDR) serial No. 1030. The recorder was retrieved from the airplane immediately after its arrival in Toronto and subsequently read out for the Safety Board by Canadian authorities.

A review of the SFDR data made available to the Safety Board disclosed that, at 1926:08:77, the airplane experienced a peak vertical acceleration of -1.042 G's. Comparison of the pressure altitude and airspeed parameters associated with this "G" excursion revealed an altitude increase of 250 feet in the 2 seconds prior to the maximum "G" and about a 10-knot loss in airspeed. In the next 2 seconds, the airplane lost 100 feet of altitude and 15 knots of airspeed. The airplane's pitch attitude decreased from approximately 3° to 0.87° in the 14 seconds prior to encountering the maximum "G" and iccreased by over 3" in the next second. Following the peak G excursion, the airplane dropped about 1,000 feet in 1 minute before level flight at FL 370 was reestablished.

The recorded horizontal stabilizer parameter showed that at the time of the encounter the stabilizer deflected initially about 1.5° upward in 3 seconds. Then, 1 second later, it moved downward 2°. This change in deflection coincided with the point of maximum negative G loading.

The DFDR data also showed that the airplane had been flown in the command/control wheel steering mode cntegory of autopilot **A** at the time of the accident. According to the flightcrew, this category was the altitude-hold mode. The climb from FL **350** to FL **370** was flown with the autoflight system engaged using the vertical speed mode. The throttles were controlled manually to maintain a fairly constant Mach number from **0.82** to **0.83.** Cruise thrust was set on leveloff at FL **370** to maintain Mach **0.83** or about **270** knots indicated airspeed (KIAS). Then, the altitude-hold mode was engaged to maintain FL **370.** The DFDR records airspeed and altitude, which is derived from the captain's central air data computer; the computer displays these data on his instruments. There were no reported discrepancies between the first officer's and captain's altimeter and airspeed indicators.

The **NWS** provides criteria for the reporting of turbulence. (See appendix D.) This criteria is based on variations in airplane altitude and/or attitude. For example, turbulence which causes only slight momentary changes in altitude and/or attitude is classified as "light." Review of the DFDR altitude and airspeed traces recorded up to about 10 seconds before the severe jolt confirmed that the airplane was in light to moderate turbulence before the severe turbulence encounter.

1.12 Wreckage and Impact Information

The interior of the airplane was damaged only slightly during the turbulence encounter. All fasten seatbelt signs and the PA equipment were in working order,

Some of the damage to the cabin occurred as a result of the unrestrained passenger service carts. The flight attendant seated in seat **38F** had noticed that one of the passenger service carts had moved away from its anchored position. She had moved and reiocked the cart immediately after the captain made his announcement about turbulence. She was injured by the same cart during the turbulence encounter.

The anchor-type devices in the floor of the L-1011 consist of a standard flush-mounted plate with a retractable anchor pin. To anchor the passenger service cart, the pin is pulled upward and also rotated slightly to lock into position. (See figure 1.) There is also a locking mechanism mounted on the underside of the passenger service cart itself. The mechanism consists of a locking pin and lever assembly, a channel bracket (guide), a spring steel stop, and a brake for the rear wheels. (Figure **2** shows the underside of a typical passenger service cart used in **Air** Canada's **L-1011.)** The cart is designed in accordance with Air Canada's specification **No. 25-30-030.** The locking pin and wheel brake are both attached tc the toe-operated lever. In order to anchor the cart to the floor, it is positioned over the floor-mounted pin so that the anchor pin is within the guide bracket and up against the steel spring stop. The toe-operated lever is then moved to the left to its locked position. This action brakes the rear wheels and slides the locking pin horizontally through the guide bracket. **If** the cart is properly positioned, its locking pin will slide through the hole in the anchor pin without difficulty, thus securing the cart to the cabin floor.

As shown in figure **2,** the steel spring stop is displaced out of the guide bracket, making it difficult to place the passenger service cart in the exact position to capture the floor-mounted pin with the toe-operated, lever locking device. Flight attendants who were interviewed by Canadian investigators stated that these passenger service carts are difficult to position and lock in place particularly in turbulent conditions. They said that occasionally they have difficulty unlocking the wheels and cannot easily reposition the carts.

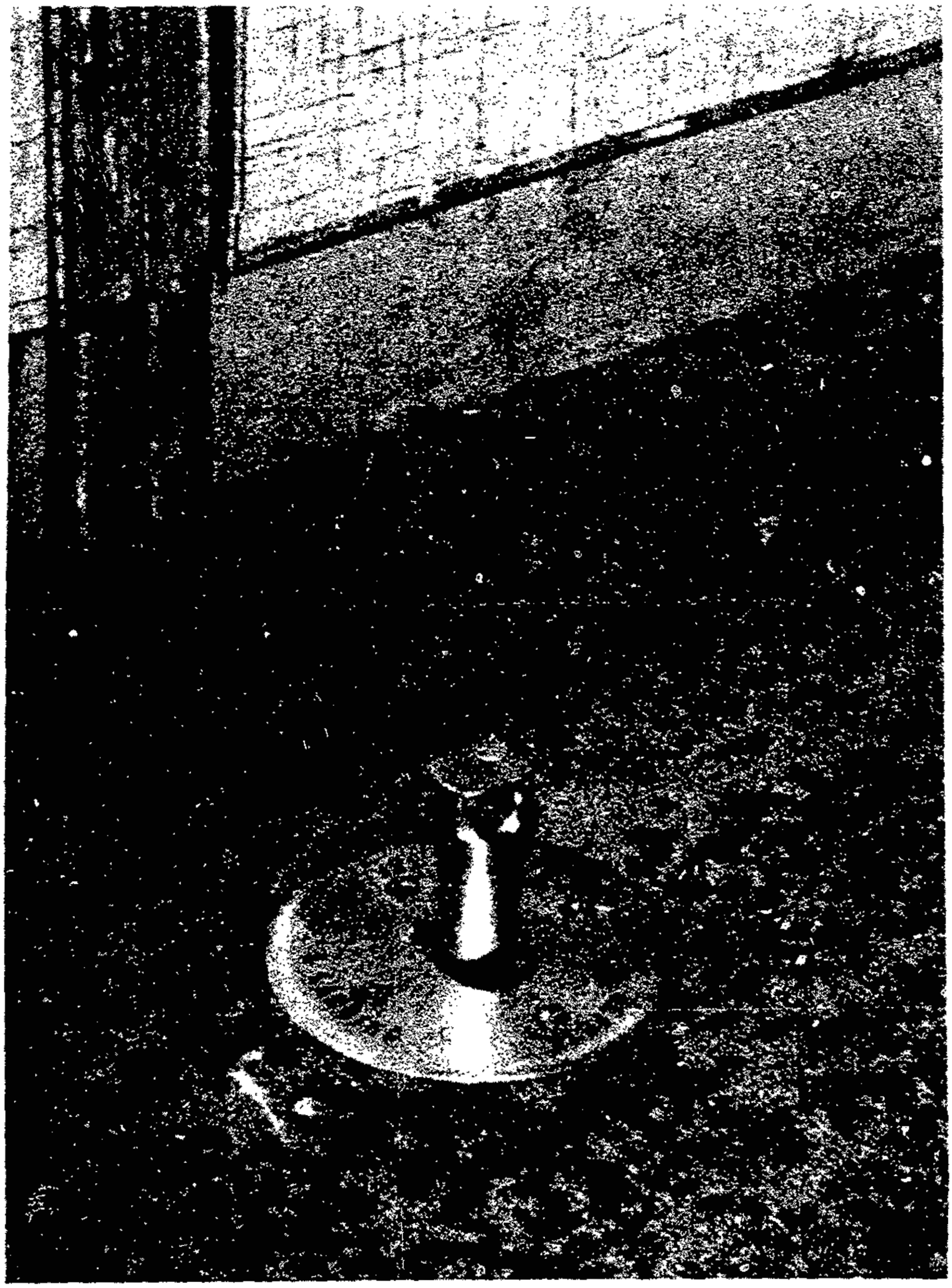

Figure **1.—Floor-mounted,** retractable anchor pin.

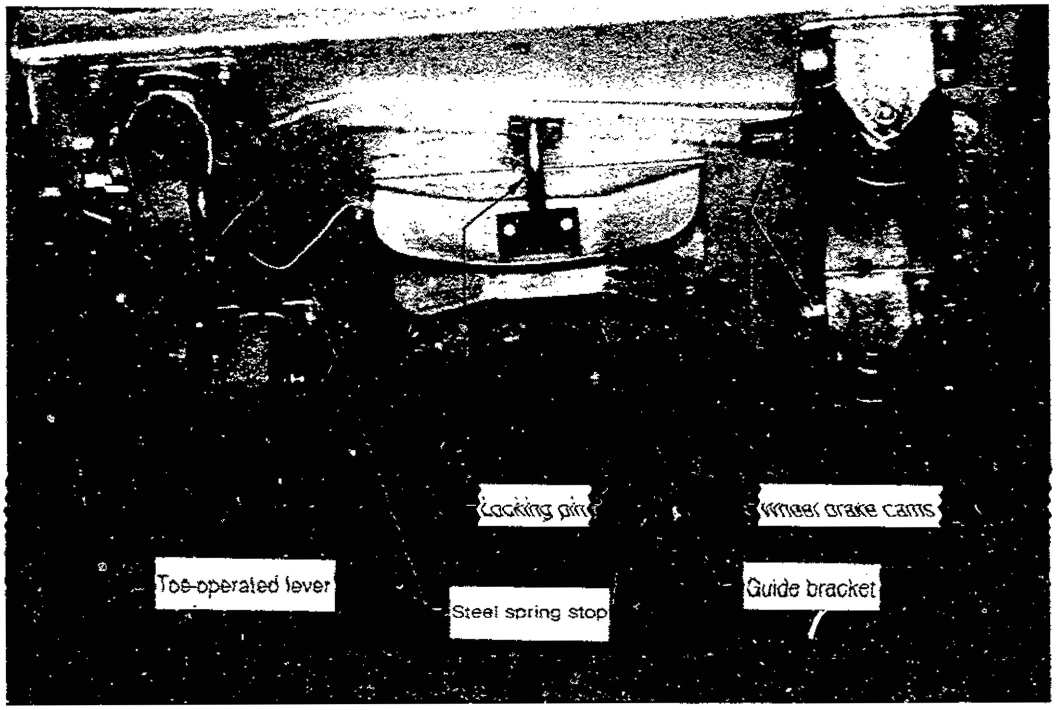

Figure 2.—Underside view of a typical passenger service cart used by Air Canada on the Lockheed L-1011.

1.13 Medical and Pathological information

In addition to the two physicians on board, the flight was met by six other physicians with assistants and medical equipment. Since most of the injuries were sustained by passengers seated in the economy cabin, or the aft section of the airplane, all uninjured passengers in the forward sections of the cabin were allowed to disembark first. This decision did not interfere with efforts to assist the injured. The injured were evaluated and an injury priority determined. Those passengers complaining of back, hip, or neck injuries were immobilized with either half or full backboards before being treated. The three seriously injured passengers were removed first. The evacuation was carried out in an organized and controlled manner by moving the injured persons through the rear cabin door exit L4 and onto a food lift truck to waiting ambulances. The flight attendant in the lower galley was treated by a physician separately. She was stabilized and removed from the airplane through the lower galley service door.

Twenty-four persons, including both crew and passengers, were taken to nearby hospitals for further examination and treatment. One flight attendant and three passengers received serious injuries in the encounter. The flight attendant was in the lower galley preparing to strap into one of the two available crew seats (left-hand seat) when the airplane suddenly dropped. She came to rest on the floor and injured her back seriously. The three seriously injured passengers sustained back, hip, and neck injuries. Four flight attendants and 16 passengers received minor injuries. The flight service director received a minor chest injury when he landed on a passenger service cart and the purser received a minor head injury. Both were in the lower galley at the time of the occurrence. Three passenger service carts hit the ceiling and turned over when they struck the floor in front of seat rows 38C, D, E, and F. A flight attendant in seat 35F received a minor injury when she was struck by one of the carts. The minor passenger injuries were primarily caused by flying articles.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The accident was survivable.

1.16 Tests and Research

1.16.1 Autoflight System

Use of the altitude-hold mode of the autoflight system during severe turbulence is contrary to recommended procedures by the airplane manufacturer and the company. In this mode, the autoflight system will attempt to maintain the pressure altitude selected for a particular flight level. In a turbulence encounter, severe pitch maneuvers can result, which may exceed design structural limits of the airplane. Since the altitude-hold mode of the autoflight system was in use when Flight 965 encountered the severe turbulence, the Safety Board requested Lockheed to determine, if possible, the degree to which the autoflight system may have aggravated the effects of the encounter.

Lockheed examined DFDR, weather, aerodynamics, and engineering data as it applied to the autoflight system. Lockheed determined that the severe jolt occurred so rapidly that the rate of stabilizer movement caused by the autoflight system was relatively slow by comparison. They stated that this is not unreasonable for most wide body airplanes, since the extremely high pitching moments of inertia, relative to the available pitch control forces, reduce the autoflight system's ability to change the pitch angle to relieve gust loads. Therefore, the altitude-hold mode did not contribute to the severity of the gust load encounter.

1.16.2 Air Carrier Turbulence Accident History

Safety Board records indicate that during the 7-year-period from 1975 to 1981, 44 air carrier (14 CFR 121) accidents were attributed to turbulence. These accidents resulted in only minor damage to the airplanes, but 70 persons sustained serious injuries, while another 80 received minor injuries. Twenty-nine of the 44 accidents were caused by convective-type turbulence associated with thunderstorms, and 15 were caused by clear air turbuience. About 66 percent of the accidents associated with convective activity occurred during normal cruise flight. About 47 percent of the clear air turbulence type accidents also occurred in normal cruise flight. Turbulence-type accidents represented the most prevalent type of air carrier accident from 1975 to 1981.

1.16.3 NASA Clear Air Turbulence Research

For several years, the National Aeronautics and Space Administration (NASA) has, in cooperation with the Safety Board, been developing and epplying methods for determining airplane motion and related winds by using data recorded in flight by flight data recorders and data recorded by ATC radar. These methods are being used to assist in analyzing and understanding the circumstances associated with accidents and incidents involving turbulence encounters. Recently, NASA has been able to define the cause of two severe turbulence encounters each involving wide body airplanes. 6/

In the first case, a DC-10 encountered severe turbulence while cruising in an easterly direction at FL 370. 7/ The severe turbulance was encountered minutes after the airplane passed over a developing line of thunderstorms with cloud tops at 30,000 feet. The severity of the encounter was evident by the large fluctuations in the "G" trace from +1.7 to -1.0 G's. In the second case, a DC-10 encountered severe turbulence while cruising in a westerly direction at FL 390. 8/ The airplane encountered the turbulence as it was heading into the prevailing wind while approaching the Wind River Mountain Range. The "G" trace showed a fluctuation of from +1.6 to -0.6 Gs. NASA analytically reconstructed a vortex model of the turbulence by matching vortex arrays with wind components derived from the flight recorder data. NASA reported that previous studies indicated that most severe clear air turbulence is likely caused by vortices generated when stable stratified shear layers become unstable in what is known as a Kelvin-Helmholtz instability. Additionally, previous data recorded during airline operations showed several instances where vertical wind *gusts* have reached values of 50 to 80 feet per second. Analysis of these two encounters showed that the **airplanes** encountered "...vortex arrays which were generated by destabilized wind shear layers near the tropopause." In these two cases, "...the maximum value of vortex-induced velocities were of the same order of magnitude.': NASA concluded that the two cases were similar in that the "...destabilization of shear layers and the generation of vortices appeared to have been caused by tilting, in one case by cloud buildup in the lower atmosphere, and in the other by mountain lee waves." Further, NASA reported that "vortex models appear to be promising aids in achieving a better understanding of the periodic, deterministic nature of the severe turbulence. The results obtained using vortex modeling also appear consistent with previous ideas about severe CAT [clear air turbulence1 that were based on theory and observations."

1.17 Additional Information

1.17.1 Air Traffic Control

The FAA's Jacksonville Air Route Traffic Control Center (ARTCC) is a Level III (high density traffic) en route facility located at Hilliard, Florida. The facility provides en route radar services in an area encompassing northern Florida, portions of Georgia, North Carolina, and South Carolina and adjacent coastal waters within the South Atlantic Control Area.

There is a Center Weather Service Unit (CWSU) located in the ARTCC staffed with a meteorologist. The purpose of the CWSU, in part, is to alert facility ATC personnel of existing or anticipated adverse weather conditions within the facility's operating airspace. The CWSU was staffed and operational at the time of the accident. Facility records indicate that two CONVECTIVE SIGMETS were in effect within the facility's airspace at the time of the accident. Prior to the accident, all facility equipment was reported to be operating satisfactorily.

6/ "Identification of Vortex Induced Clear Air Turbulence Using Airline Flight Records." E. K. Parks, University of Arizona, Tucson, Arizona, and R. C. Wingrove, R. E. Bach, Jr., and R. S. Mehta, NASA Ames Research Center, Moffett Field, California, AIAA Paper No. 84-270, presented at the AIAA, 22nd Aerospace Sciences Meeting, January 9-12, 1984, Reno, Nevada.
7/ Aircraft Accident--United Airlines, Douglas DC-10, Hannibal, Mo., April 3, 1981.
8/ Aircraft Accident—United Airlines, Douglas DC-10, Morton, Wy., July 16, 1982.

The controller working Flight 965 stated that the first pilot report (PIREP) of any turbulence was received 5 minutes after Flight 965 first contacted him. He said %he PIREP was "chop" in an area on the west side of weather depicted on his radarscope. He stated that Flight 965 was traveling east of the weather. He further stated that other airplanes had passed within 10 miles of the location where Flight 965 encountered turbulence, but that he had not received any turbulence reports from these airplanes when they passed through that area. When questioned on whether he was able to distinguish weather patterns or cells on his scope from the computer generated "H" symbols thar denote heavy weather areas, he responded that he was not. He also stated that the "H" symbols depicting heavy weather areas vary greatly depending on whether the radar system covering the area is in linear polarization (LP) or circular polarization (CP). 9/ He stated that when the radar was in CP, the weather area depicted would be smaller in area than if the radar system was in LP. Therefore, the radar would no; present an accurate picture of the weather in the actual area. The controller stated that he was aware of FAA's new Hazardous In-Flight Weather Advisory Service and that he was not aware of any SIGMETs affecting the Jacksonville ARTCC ere2 at the time of the eccident. Facility procedures call for distribution of SIGMET information to controllers for reference a their work stations. The Safety Board was not able to determine why the controller did not have this information.

1.17.2 Hazardous In-Flight Weather Advisory Service (HIWAS)

On July 14, 1981, the FAA issued Notice N 7110.658 establishing a Hazardous In-flight Weather Advisory Service (HIWAS) designed to use selected navigationai aid frequencies (VOR's) for broadcasting continuous vital weather information in order to reduce controller workload. The Notice directed ther an in-service program evaluation be conducted in the Jacksonville and Miami ARTCC areas for the dissemination of aviation in-flight weather advisories. Although this was a test program, the FAA intended it to be mandatory.

In the Notice, the FAA's Air Traffic Service stated that broadcasts of aviation inflight weather advisories over control frequencies and VOR's were frequently delayed or not accomplished because controllers had higher priority duties. When such broadcasts are needed, often a controller's task of separating aircraft is also most demanding, and Flight Service Station (FSS) specialists are often busy providing services to airborne aircraft during adverse weather periods. Application of the Notice was limited to ARTCC sectors, terminal facilities, and FSS's within the Miami and Jacksonville ARTCC areas. The Notice suspended the specifications of Handbook 7110.65B directing terminal and en route facilities to broadcast SIGMET alerts, and suspended the specifications of Handbook 7110.65F directing FSS facilities to broadcast weather advisories. The Notice stated that the test program would be advertised in a Class II 10/ Notice to Airman (NOTAM), and that facilities would further disseminate information about the program in their contact with pilots. Additionally, all FSS's in the FAA's Southern Region were to assure that pilots became aware of the HIWAS in-service evaluation during pilot weather briefings. User (pilot) comments were to be solicited, and feedback was to be forwarded to FAA Headquarters (AAT-350) through the Southern Regional Air Traffic Division. The provisions of the Notice were tentatively scheduled to become effective on August 1, 1981, for a 90-day period, but stated that the actual date would be announced by a

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9/ Linear/circular polarization is a seiective function of the radar. LP function is utilized in normal weather periods. The CP function is utilized during periods of weather in order to reduce the intensity and area of weather echoes on the controller's scope.

10/ Class II NOTAMs are printed in a biweekly publication and distributed through the mail; Class I NOTAM's are distributed via telecommunications.

General Notice (GENOT). The appropriate NOTAM had been published as a Class II NOTAM on July 14,1981.

On September 5, 1981, the FAA's Air Traffic Director issued a GENOT stating that the HIWAS inservice evaluation would be implemented at 1000, September 9, 1981, and directed that FSS's in the Southern Region notify Fixed Base Operators, Military Base Operations, air carriers, and other users.

On July 14, 1983, the FAA issued Order 7110.92 implementing the HIWAS program on a systemwide basis. The Order stated that the HIWAS programs at the Miami and Jacksonville ARTCC areas were commissioned effective OR the date of the order, and that additional HIWAS programs would be implemented on a center-by-center basis by GENOT.

On November 14, 1983, the FAA issued Air Traffic Control Document Change Proposal AAT-365-83-2 notifying concerned user groups of proposed changes to HIWAS Order 7110.92. The proposal requested that comments on the changes be forwarded to the FAA (AAT-360) by January 16, 1984.

On December 6, 1983, the FAA's Deputy Associate Administrator for Engineering testified before the U.S. House Committee on Public Works and Transportation, Subcommittee on Investigations and Oversight, concerning the FAA's Aviation Weather Program. He stated, "The Hazardous In-Flight Weather Service (HIWAS) was successfully demonstrated in Florida and is now an established program in the Miami and Jacksonville Center areas. Visual Omni Range (VOR) frequencies are now .being identified to expand this service nationally by 1985. Based upon user comments, procedures are being amended so that controllers will advise pilots when a HIWAS update has occurred. In addition, center weather advisories will be included in the broadcast information-"

L17.3 User Group Interviews Regarding HIWAS

During its investigation, Safety Board investigators questioned 130 personnel employed by air carriers or assigned to military units who operated in and out of the Jacksonville and Miami ARTCC's with regard to the HIWAS program since its implementation in September 1981. These users were air carrier pilots, chief pilots, military and FAA pilots, and flight and station managers. Nine air carrier pilots interviewed were operating within the METTA Sector at the time of the accident. Except for one air carrier pilot, all stated that they were not familiar with the HIWAS program. The one exception, a being 757 captain, stated that he was not aware of the program before November 29, 1983, but that he had recently read a notice on the subject.

Additionally, Safety Board investigators questioned the 130 individuals on how they would normally expect to receive hazardous weather reports such as SIGMETs once their flight was airborne. All stated that they expected the controller to provide them with the information. About one-half of those questioned -- those who were employed by Part 121 air carriers -- stated that, in addition to ATC notifying them, their respective companies had programs to provide them with the information through the use of a company radio.

In addition to the users interviewed, Safety Board investigators contacted other groups regarding the HIWAS program. The Air Line Pilots Association stated, in part, in a letter to the FAA of October 18, 1983, that, "To the best of our knowledge, the

HIWAS program, as implemented in the Miami and Jacksonville areas, is not acceptabie to any of the major user organizations." The Air Transport Association stated, in part, in its letter to the FAA of November 21, 1983, that, "While FAA Draft Order 7110.92A is far superior to its predecessor, it still does not satisfy primary airline objectives." One ATA member airline reported, "It is a service that would not appear to be compatible with our desires or needs, even on an interim basis."

1.17.4 Air Canada Turbulence Penetration Procedures

Excerpts of specific company procedures for severe turbulent air penetration pertaining to the L-1011-1-15 airplane are as follows:

1. Flight through severe turbulence should be avoided if possible. When flying at 30,000 feet or higher, it is not advisable to avoid a turbulent area by climbing over it unless it is obvious that it can be overflown well in the clear. For turbulence of the same intensity, greater buffet margins are achieved by flying at the recommended speeds at reduced altitudes.

2. If airspeed is greater than 300 KIAS, reduce to 300 KIAS regardless of Mach number. If airspeed is below 255 KLAS, do not further reduce speed if Mach is within target range. If both Mach and airspeed are less than minimum target values, increase speed until the first target is attained. These speeds are applicable for severe turbulence such as that encountered in a thunderstorm and provide fully adequate structural margins and airplane control. Note that an airspeed reduction is not normally required at high alitudes. At medium altitudes the required airspeed can be attained by smoothly retarding the throttles.

4. The target speed increases linearly to 300 knots at 30,300 feet. Above 30,000 feet, maintain Mach 0.80–0.84.

5. Before entering areas of known turbulence:

   o Use the weather radar to determine the best penetration heading when the turbulence is associated with thunderstorm activity.

   o Determine best penetration altitude, preferably below the cruise chart optimum value of altitude vs. weight.

   o Select a heading which will clear storm cells by 5 miles when OAT [outside air temperature1 is above freezing, and by 10 miles when OAT is below freezing. When at or above 20,000 feet, clear the cells by 20 miles.

   o Engage autopilot in any mode except Altitude Hold.

   o Use of the autopilot turbulence penetration mode is recommended for autopilot operation in severe turbulence. In this mode the attitude rate gains are reduced. (Additionally, the yaw damper operating with the autopilot TURB mode will aid in maintaining stable control and in reducing structural loads.) Do not use altitude hold mode.

- Continuous Ignition should be ON. If throttle movements are required they should be made smoothly and **slowly** from stabilized thrust settings. If non-recoverable engine surge occurs (rapidly rising EGT), complete the Engine Shutdown checklist. If engine limitations have not been exceeded, restart the engine using the In Flight Relight procedure.

- Severe turbulence **will** cause large, and often rapid, variations in indicated airspeed. DO NOT CHASE THE AIRSPEED.

- Make thrust changes only if necessary to maintain target airspeed.

- The recommended procedures for manually controlled flight in severe turbulence are:

  a. Attitude - Meintain wings level and the desired pitch attitude. **Use** the attitude indicator as the primary instrument. In extreme drafts, large attitude changes may occur. DO NOT USE SUDDEN LARGE CONTROL INPUTS. After establishing the trim setting for penetration speed. DO NOT CHANGE STABILIZER TRIM.

  b. Altitude - Allow altitude to vary. Large altitude variations are possible in order to maintain the desired attitude and approximate airspeed. DO NOT CHASE ALTITUDE.

- If autopilot is engaged, select turbulence mode.

En Route Weather and Hazardous In-Flight Weather Advisories, **U.S.A.**

The following is excerpted from Air Canada's Route Manual, Chapter 4, page 2, dated September 6, 1983:

Hazardous Inflight Weather Advisory Service **(HIWAS)**

The FAA through FSS's will broadcast hazardous weather advisory service to be transcribed and continuously broadcast over designated VOR's. **HIWAS** will be implemented on a centie by centre basis. Miami an? Jacksonville are the first centres to have HIWAS.

The HIWAS broadcast shall include a summary of SIGMETS, AIRMETS [Airman's Meteorological Informetion] and urgent PIREPS pertaining to the ARTCC area in which the broadcast facility is located. During periods when there are no pertinent weather advisories, an appropriate statement shall be issued.

Designated VORs on which **HIWAS** is Broadcast

Jacksonville ARTCC	-	Florence, Savannah, Tallahassee, Jacksonville
Miami ARTCC	-	Orlando, St. Petersburg, Miami, Fort Myers, Key West.

1.18 New Investigative Techniques

None.

2. ANALYSIS

2.1 General

The flightcrew was certificated and qualified for the Eight. They had received the training and off-duty time prescribed by Canadian Department of Transport regulations. There was no evidence of any pre-existing psychological or physiological condition thet might have affected the flightcrew's performance.

The airplane was certificated and equipped in accordance with Canadian Department of Transport regulations and approved procedures, and the Department had approved the maintenance program under which the airplane was maintained. The airplane had been maintained in accordance with these approved procedures. There was no evidence of a failure or malfunction of any airplane component.

The METTA Sector radar controller at the Jacksonville ARTCC was properly certificated and medically qualified for his prescribed duties.

2.2 The Flight

The weather data available to the flightcrew during the self-briefing showed the general surface weather pattern and the upper ai; pattern. In addition to the synoptic and forecast upper wind and temperature charts, the flightcrew also had a significant weather prognostic chart available. This chart had forecast that, at 1900, e frontal system with associated cumulonimbus activity would be about parallel to the southern United States coastline in the vicinity of Virginia and the Carolinas. Few cumulomimbus were expected to have tops at FL 340. Except for a possible copying error. the Safety Board could not determine why the company's copy of the same chart issued by the National Weather Service showed the tops to be ai FL 340 instead of at FL 390.

Based on the recorded weather information and pilot reports, Flight 965 was in an area of thunderstorms and on the eastern edge of a jet stream oriented south-southwest to north-northeast, with the core over and to the west of the Appalachian Mountains. The winds in the vicinity of tne turbulence encounter were west-southwesterly at 70 to 80 knots based upon the 1900 200 millibar chart. The Safety Board attempted to determine the potentia1 for Turbuience at FL 370 based on atmospheric stability and wind shear. Upper air soundings were used from Charleston, South Carolina, and Cape Hatteras, North Carolina. The sounding from Charleston, South Carolina, showed no significant changes in stability (layering) in the vertical structure of the atmosphere in the vicinity of FL 370, but significant changes in stability from about 43,000 feet to the tropopause at about 56,050 feet. Wind shear information is an important element in determining potential clear ai? turbulence. The lack of winds aloft data above about 28,000 feet, however, precluded tne Safety Board from determining whether or not wind shear existed at FL 370. The Charleston sounding showed a relatively homogeneous column of sir in the vicinity of Flight 9654 encounter. This column of air would be considered conducive to wave development in the atmosphere and conducive to the question of turbulence. Although specific winds aloft data was not available, the Board believes that wind shears did exist because of the strong winds aloft along with the intrusion of thunderstorms.

At 1918:17, about 2 minutes after the flight had been cleared from FL 350 to FL 370, and 19 seconds after it had been asked to start a right turn for Wilmington, North Carolina, Flight 965 reported to the controller that it may have to detour in a little while because they had a thunderstorm up ahead. The flightcrew was expecting to proceed along Atlantic Route AR4, past the SMELT interse-tion to OLDEY, where they were planning to turn north onto AR3. The controller had turned the flight north slightly before it reached OLDEY. The turn from about 295° to about 355° was not enough to divert it east of the frontal activity. So it was headed directly toward another line of intense thunderstorm cells.

The first pilot report of turbulence came at 1922:42 from Peoples Express 545, when it was southwest of Flight 965, but closer to another area of thunderstorm activity, and another flight immediately asked the controller where Peoples Express 545 was located. Forty-two seconds later, Flight 965 reported level at FL 370 and ". . . we're in a moderate chop to light turbulence (unintelligible) buildup and showers." At this point, the captain had noticed a flash of lightning to the north, switched on the fasten seatbelt sign, and made the PA announcement about turbulence. Since it was nighttime, the crew had determined that they were in upper cloud based on the reflection of strobe lights, and had also observed some static discharges on the windscreen. Although several flights in the next several minutes either changed course or requested more information. Flight 965 did not, and it continued on the northerly heading. At 1925:59, 2 minutes 35 seconds later, Flight 965 reported that it had encountered the severe jolt, just north of the PANAL intersection (the encounter actually took place south of the PANAL intersection.)

Reconstruction of Flight 965's flightpath using the 1930 overlay from the NWS radar at Wilmington showed that Flight 965 had been about 12 miles eastsoutheast of a line of thunderstorms with very heavy, level 4, rainshowers, and 24 miles north-northeast of another area of heavy, level 4, rainshowers. The radar showed that precipitation tops were mostly below 35,000 feet. Also, the radar data confirmed that Flight 965 was in an area of fighter rainshowers at the time of the encounter.

After making the northbound turn at OLDEY, the ceptain had observed fading, light weather returns on his radar, 40 to 50 miles ahead with 2° of downward tilt of the antenna. This observation indicated that the flight was overflying shower activity at heights of about 22,000 to 27,000 feet. The NWS radar overlay, however, showed that the flight was not directly over any significant shcwer activity during its flight, but that it had proceeded northbound to within about 12 miles of an area of intense shower activity before the severe turbulence was encountered. Ccmpany procedures request that flightcrews remain 20-miles away from thunderstorms above 20,000 feet. The Board concludes that the thunderstorm activity directly ahead of Flight 965 should have been visible on the captain's radarscope, but that the tops of the precipitation probably would have been shown as below 35,000 feet in this area. Therefore, the selected altitude of FL 370 would have allowed the airplane to overfly the thunderstorm activity. The flightcrew's report of flying in upper clouds along with the presence of static discharges indicates the flight encountered cirrus or ice crystal clouds. These types of clouds could have been the "anvil" of cumulonimbus clouds which occurs downwind of cumulonimbus activity. The captain would not have been able to detect this anvil cloud with his radar. The 1930 GOES .satellite photograph confirmed the existence of this type of weather condition.

Furthermore, the captain was not aware of the convective SIGMET's which had reported the maximum tops to be from 40,000 to 45,000 feet; these were issued after the flight departed Trinidad. The 1930 NWS radar overlay showed the maximum precipitation top at 19,000 feet. This cell was located about 65 miles north-northeast of Flight 965 when the severe jolt was encountered. The captain's second radar return, about 20 miles to the right of his course, was not verified by ground radar, but it should not have been a factor in the encounter because of the direction of the prevailing winds.

The Board consulted with NASA about this accident and learned that it was their view that Plight 965 encountered the same type of clear air turbulence that existed in the 1981 Hannibal, Missouri, encounter. (See footnote 7.) A review of FAA Advisory Circular 00-6, "Aviation Weather," dated 1965, states that, "...thunderstorms commonly penetrate the upper troposphere and sometimes the stratosphere. They should be given a wide berth horizontally and vertically because they are capable of producing extreme turbulence. ..." It further states, "Turbulence, in particular, may be encountered in clear air for a considerable distance horizontally and vertically from grcwing thunderstorms" U.S. Air Force Manual 51-12, "Weather For Aircrews." dated August 1, 1974, alerts military pilots of this phenomenon by stating that, 'Severe tubulence can be encountered in the anvil 15 to 30 miles downwind. ..The most Severe turbulence outside the storm occurs in the clear air downwind." The Safety Board believes that the evidence shows that Flight 965 encountered turbulence developed as a result of the level 4 thunderstorm activity 24 miles south-southwest of the flight which had protruded into the high, southwesterly winds aloft. This formation would have produced the wave of clear air turbulence which disturbed the airplane.

There was no specific forecast of clear air turbulence for the area in which Flight 965 was transiting. Based upon the information in the World Meteorological Organizations Technical Note No. 155, 11/ clear air turbulence would not have been anticipated. The two convective SIGMETs which were issued implied moderate to severe turbulence associated with thunderstorms. Consequently, in view of the current criteria used by NWS, the Safety Board considers the forecasts issued to have been substantially correct with regard to thunderstorm activity and they implied the potential for severe turbulence. Nevertheless, since the airplane encountered a form of clear air turbulence, 12/ the Safety Board believes that, in view of recent research and investigation experience, the criteria used by NWS is not entirely adequate. The Board believes that in cases such as this, the forecasts could be improved by considering the interaction between jet stream velocity winds and thunderstorms which have the potential to produce clear air turbulence downstream of cumulonimbus clouds. .Adoption of this criteria in this regard by the NWS could prevent similar occurrences by alerting flightcrews about this phenomenon so that they can select proper routes and best courses of action to deviate around thunderstorms. Since the flightcrew believed the: it could overfly the thunderstorm activity, it continued its flight within 20 miles of other cumulonimbus activity, thereby placing the airplane in a position where it encountered severe turbulence from a source which the flightcrew did not expect.

2.3 Air Traffic Control

The METTA Sector controller was not aware of any turbulence in his area until Peoples Express 545 made his report. He had no: been informed of the convective SIGMETs that had been issued. In addition, he had Seen using the circular polarization

11/ A publication normally used by the National Weather Service as e guide for "Forecasting Techniques of Clear Air Turbulence, Including That Associated With Mountain Waves."
12/ The term ciear air turbulence describes turbulence encountered in clear air and it is generally used to describe high level turbulence occuring outside of convective clouds. Also, it is frequently used to describe turbulence encountered in cirrus clouds.

(CP) feature of his radarscope and, therefore, had not been viewing the more detailed picture of the weather pattern. He probably was using the CP feature because he was more concerned about separating aircraft, his primary responsibility. However, after becoming aware of the PIREP on turbulence, the controller assisted the other flights by providing advisories and modified routings. Although it appeared that he had an opportunity to recommend that Flight 965 turn farther east to avoid flying close to the thunderstorms, he became preoccupied at that time in providing required separation between Flight 965 and People Express 545 as they converged in the area of OLDEY at the same flight level. As a result, he turned Flight 965 north only to provide sufficient separation between the two aircraft before Flight 965 arrived at OLDEY.

The FAA implemented the HIWAS program to alleviate the burden on the controller of providing weather advisories. In the Safety Board's opinion, the basic concept has merit. Its use could be to the en route controller what automatic terminal information service (ATIS) has become to the terminal airspace controller. However, the Board is concerned that numerous active pilots interviewed during this investigation said that they were not aware of the HIWAS program. It is evident that an educational and communication problem exists which must be corrected. The FAA announced the program in the form of a Class II NOTAM, which is disseminated only to about 13,004 recipients. Although the use of a Class II NOTAM was an appropriate method of disseminating this information, the Board believes that this action was obviously not sufficient in view of the survey. Also, the details of the program were not disseminated directly to foreign carriers. Information about the HIWAS program was available to foreign carriers through publication in the U.S. Aeronautical Information Publication (AIP) if the carrier subscribed to the publication through the U.S. Government Printing Office. It is the Board's view that effective publication of the program could have Seen achieved by closer coordination between domestic end foreign offices within the FAA and additional measures should be taken to ensure widespread distribution. This could be accomplished by making use of the Airman's Information Manual (AIM), Advisory Circulars, Inspector Operations Bulletins. and pubic announcements.

Transport Caneda had received the NOTAM but FAA Class II NOTAMs do not receive widespread distribution in Canada. Air Canada pilots rece[illegible] it in the form of an insert to their operations manuals. Although the Safety Board cannot overemphasize the need for flightcrews to thoroughly review and insure they understand supplemental information issued for inclusion into company operating manuals, the HIWAS Information in the insert bore little resemblance to the information prcvided originally by the FAA. In fact, the differences gave the impression that the HIWAS was an optional program rather than one which required participation. The Board believes that Air Canada and all other airlines *must* insure that the information contained in Class II NOTAMs is thoroughly reviewed and disseminated so that it is clearly understood by their pilots and other appropriate personnel. It is understandable, therefore, why so many pilots were not aware of the program. All of rhe 130 personnel interviewed stated that they expected the ATC controller to provide any SIGMET or additional weather advisories that were issued after an airplane's takeoff. Since the majority of the pilots interviewed flew for air carriers, they also expected their companies to provide such information via company radio or **AIRINC.** However, there is no requirement for AIRINC to provide this information.

In the opinion of **F.4.4** supervisory personnel in the Air Traffic Procedures Division responsible for the program, they had distributed the HIWAS program information in a routine and standard manner, thereby fulfilling their responsibilities. The Safety Board understands the FAA's position, but believes that more effort is needed to advertise the program in order to insure that flightcrews receive this vital weather information.

In addition, the Board believes that the criteria for selecting certain VOR stations to broadcast HIWAS information needs further review by the **FAA.** The nearest HIWAS VOR station to Flight 965 was at Florence, South Caroline, *a* location several miles inland. Since Flight 965 was entering U.S. airspace from a deep ocean environment, they may not have been able to receive the Florence VOR information. The Board believes that the FAA did not adequately consider maximum reception altitudes, the location of heavily traveled preferential jet routes, and trans-Atlantic and trens-Pacific traffic entering **U.S.** domestic airspace when it developed its program. Furthermore, the Safety Board is concerned about the potential problems inherent in changing navigational frequencies in order to receive an off-route HIWAS VOR with the sophisticated navigational computer equipment on board such airplenes as the Boeing 757 ana 767. This *equipment is programmed to automatically select and identifjj VOR/VORTAC stations* required for a particular route of flight. The Safety Board related io the Boeing Company *its* concern about the compatibility of **HIWAS** with the use of the new generation airplanes. Boeing reported that **with** dual *navigational* **receivers** installed as standard equipment on all Boeing airplanes, selecting an unprogrammed frequency of an off-route VOR station would not compromise the **flight** management system's (FMS) ability ***to*** provide accurate ana current flight guidance from *a* single receive?. However, they expressed concern about the impact HIWAS monitoring might have on crew workload, particularly if monitoring is necessary while in terminal airspace environment for an extended period of time. They believed that the HIWAS program reduces the effectiveness of their design -- to minimize the tuning of navigational radios. Although there is presently a limited number of VHF communication frequencies available, Boeing suggested that the FAX consider using communication frequencies. This would be consistent with other advisory services such *as* ATIS **and** Flignt Watch (FSS Weather Advisory Service). The Safety Board is aware that the FAA plans to implement the current **HIWAS** program/procedures on *a* nationwide oasis at all domestic ARTCC facilities at an early date. However, the Board believes that implementation of the current **HIWAS** program at additional ARTCC facilities should be postponed until the existing program is modified to correct the problems identified In the Safety Board's investigation of this accident and a program is instituted to insure adequate dissemination of information concerning **HIWAS** to the aviation community.

2.5 Survival Aspects

This was a survivable accident. The severe encounter resulted in e peak vertical acceleration of - 1.042 G's. This meant that the airplane was subjected to a **-2.04** G excursion. The total period of time in which the associated altitude end airspeed deviations occurred was within about 1 minute. The fact that the autoflight system was in the altitude-hold mode did not add to the severity of the encounter and its use by the flightcrew prior to the encounter was not contrary to company procedures. However, the sudden noseup and nosedown maneuver resulted in loose articles, including the heavy passenger service carts, flying around the cabin. Since the airplane pitches about its lateral axis or within the area of the wing, the passengers and carts in the aft section of the airplane experienced the greatest vertical displacement in the pitch maneuver. Therefore, the most damage and injuries occurred in this section of the cabin. The fasten seatbelt signs and PA equipment were in working order. flight attendant statements and medical information indicated that the seriously injured occupants with hip and brick injuries were not securely restrained in their seats at the time of the severe turbulence encounter. Review of **Air** Canada's procedures indicated that flight attendant's are required to ensure that passengers are seared with their seatbelts fastened when the fasten seatbelt **sign** is illuminated. **Also,** if the captain advises that turbulence is expected, flight attendants are to ensure that all loose cabin equipment is properly stowed and secured, in addition to securing themselves et their inflight stations immediately thereafter. **All** indications were that the fligh attendants were attempting to follow their procedures at the time of the severe turbulence encounter. Nevertheless, passengers received injuries that could have been prevented. Because of the unsuspecting nature of clear air turbulence, the Safety Board cannot over emphasize the need for flight attendants to exercise diligence when checking to see if passengers are heeding the fasten seatbelt sign and must forcefully instruct passengers to not delay in securing themselves in :heir seats. Additionally, passengers must coorperate with flight attendents under these circumstances by ensuring that personal belongings are secured.

Although the passenger service car's are equipped with locking mechanisms which connect with standard anchoring devices in the floor of the L-1011, the Safety Board is concerned that the carts were not secured during the turbulence encounter. One of the problems with the passenger service cart locking mechanism is the difficulty a flight attendant experiences in determining when the cart is properly positioned over the floor anchor pin. Proper positioning over the floor anchor pin becomes extremely difficult to accomplish when the spring steel stop. which is an intregal per; of the locking mechanism, is bent out of shape or is displaced, as shown in figure 2. Another problem is that the sane toe-operated lever used to secure the cart to the floor anchor pin also brakes the rear wheels. Since the toe—perat lever also applies the brakes, a flight attendant could be mislead under these circumstances into thinking that the cart is secured to the floor anchor pin after operation of the toe lever when, in fact, it is not. The Safety Board believes that without a mechanical indicator to readily show whether the cart is anchored, extra effort is required to anchor the cart with this type of locking mechanism Preventive maintenance also is needed to ascertain whether the locking mechanisms are working properly. The manufacturer should consider providing additional, or different, means of anchoring the carts.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was qualified for the scheduled flight and there were no psychological or physiological factors which would have adversely effected their performance.

2. There was nn evidence of a failure or malfunction of any component which would have caused the accident.

3. The radar controiier was qualified to perform his prescribed duties, and :here was no known evidence of medical factors which would have adversely affected his performance.

4. The flightcrew was furnished with sppropriete weather information prior to dispatch, enabling them to make sound decisiors concerning the type of weather conditions they could expect to encounter during the course of the flight.

5. The weather forecasts issued by NWS were prepared using current criteria and were substantially correct by tha? measure.

6. The National Weather Service criteria for forecasting clear ai? turbulence are inadequate.

7. The flightcrew believed that it could overfly the thunderstorm activity.

8. The flight was downwind and within 20 miles of e line of thunderstorms in an area of light rainshowers at the time of the severe turbulence encounter.

9. The Mght encountered severe clear air turbulence generated as a result of thunderstorms protruding into the lave! of high. southwester!? winds aloft.

10. The captain appropriate;? instructed flight attendants and passengers to be seated and fasten their seatbelts at the first sign of turbulence.

11. The fasten seatbel: signs and public address equipment were in working order.

12. The occupants were injured because some were not securely rest-ained in their seats and because sone were hit by loose articles in the cabin.

13. The flight attendants and passengers had sufficien? time to secure themselves in their seats before the severe turbulence encounter.

14. The means for insuring restraint of the passenger service carts et the serving stations in passenger aisles needs improvement.

15. Neither the flightcrew nor the controller was aware of the convective SIGMET's that had been issued after Flight 965 left Trinidad.

16. The controller provided adequate information and instructions to other Sights in the area once he became aware of the PIREP on turbulence.

17. The manner in which the FAA distributed information regarding implementation of the HIWAS program was inadequate.

18. The current HIWAS program is not adequate beceuse the FAA did not consider maximum reception altitudes, the location of traveled preferential jet routes, and trans-Atlantic and trans-Pacific traffic.

19. The ability to use sophisticated on-board navigational computers successfully with the HIWAS program needs to be established.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was an encounter with severe clear air turbulence produced by the intrusion of thunderstorm cells into strong winds aloft.

4. RECOMMENDATIONS

As a result of the accident, the National Transportation Safety Board recommended that the National Oceanic and Atmospheric Administration:

> Advise its weather forecasters to be alert for situations where there is a jet stream or strong upper level winds in association with lines of developing or developed thunderstorms which may produce an area of

severe ciear air turbulence, and to issue appropriate warnings of this potential turbulence to pilots through area forecasts, SIGMETs or other appropriate means of communication. (Class II, Priority Action) **(A-84-106)**

--that the Federal Aviation Administration:

Postpone nationwide implementation of the Hazardous Inflight Weather Advisory Service Progaram a? Air Traffic Control Centers until the broadcasting procedures are impros-ed **and** program information **is** disseminated widely. (Class 11, Priority Action) (A-84-111)

Designate communication frequencies within the 118-135 MHz ***band*** for each Air Route Traffic Control Center to broadcast Hazardous Inflight Weather Advisory Service informstion. (Class II, Priority Action) **i.4-84-112)**

Develop procedures similar to those currently used in terminal areas for Automatic Termina! hformation Service, for flightcrews to monitor an individual facility3 Hazardous Inflight Weather Advisory Service frequency **and** to inform the controller/facility on initial contact that the night has the current HIWAS infornation. (Class II, Priority Action) (A-84-113)

During a transition period following the inplementation of Hazardous Inflight Weather Advisory Service, require Air Traffic Controllers to advise flightcrews when critical safety information is being made available through HIWAS. For example, ARTCC, controllers **should be** required to advise flights upon initial contact "significant weather information available on HIWAS." (Class II, Priority Action) **(A-84-114)**

Institute a program to ensure that changes to ATC operations and communications procedures, means to disseminate aviation weather information, etc., are published in a manner to directly reach all users of the National .airspace System. (Class II. Priority Action) (A-84-115)

Also as a result of its investigation. the National Transportation Safety Board suggested that the Canadian Aviation Safety Board reconmend to the Canadian Air Transportation Administration thet it:

Require Air Canada to initiate a daily irspection program to assure that each pessenger service cart (PSC) locking mechanism is undamaged **and** can be properly aligned with the floor-mounted anchor pin until a positive lock indicator is installed or a more reliable means of positioning and anchoring *the* PSC is designed ***and*** installed.

Require Air Canada to develop a *positive* lock indicator for passenger service carts (PSCs) on the Lockheed L-1011 ai-plane, or alternatively that all Air Canada L-1011 airplanes, and PSCs be changed over to the "mushroom" type restraint devices.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

October 16, 1984

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident about 2000, e.s.t., on November 24, 1983. An investigator-in-charge was assigned from the Washington Headquarters Office along with specialists in the areas of air traffic control, weather, survival factors, and airplane performance. The investigation was conducted in conjunction with Canadian authorities who supplied the Safety Board with most of the information about the operation, crew interviews, injury, and airplane information-

Parties to the investigation included the Federal Aviation Administration, the Canadian Aviation Safety Board, Air Canada, Lockheed California Company, and the National Aeronautical and Space Administration.

2. Public Heering Information

No public hearing or deposition proceeding was conducted as a result of this inquiry.

APPENDIX B

PERSONNEL INFORMATION

Captain Robert J. Fox

Captain Robert J. Fox, age 50, held a Canadian Airiine Transport Pilot Licence, No. YZA-836, with a single and multiengine land rating and type ratings in the DC-3, DC-8, DC-9, VC-8, VC-9, and L-1011. He became a captain on the L-1011 on March 17, 1982. He held a Category 1 medical certificate issued June 1983. He had 22,900 hours of total flight time, 2,733 hours of which were flown in the L-1011. In the previous 7 days, he had flown 18.4 hours in the L-1011. He had been off duty for about 18 hours before the accident flight.

First Officer Ronald J. D. Frerichs

First Officer Ronald J. D. Frerichs, age 46, held a Canadian Airline Transport Pilot Licence No. QMA-787 with a single and multiengine land rating and type ratings in the B 727, DC-3, DC-8, DC-9, and L-1011. He became a first officer on the L-1011 on February 21, 1979. He held a Category 1 medical certificate issued September 1983. He had 12,480 hours of total flight time, 5,081 hours of which were flown in the L-1011. In the previous 7 days, he had flown 4.8 hours in the L-1011. He had been off duty for 20.5 hours before the accident flight.

Second Officer Gary I. Dell

Second Officer Gary I. Dell, age 27, held a Canadian Senior Commercial Pilot Licence No. YZS-158764 with a single and multiengine land rating. He became a second officer on the L-1011 on January 19, 1979. He held a Category 1 medical certificate issued July 1983. He had 4,470 hours of total flight time, 3,400 hours of which were flown in the L-1011. In the previous 7 days, he had flown 2.3 hours in the L-1011. He had been off duty for 18.5 hours before ?he accident flight.

Controller Carl W. Davidson

Controller Carl W. Davidson was employed as an Air Traffic Control Specialist by tine FAA for about 8 years. He had been qualified in his area of operation at the Jacksonville, ARTCC for about 4 years. He had been on duty for about 3.5 hours before the accident. During his assignment shift, he had been assigned to the METTA radar controller position for ebout 1.4 hours before the accident. He held a FAA medica? Certificate issued or. June 29, 1983, with no limitations.

APPENDIX C

AIRPLANE INFORMATION

Lockheed L-1011, C-FTNJ

The airplane, manufacturer serial No. 193E-1067, was manufactured by Lockheed California Company in 1974 and was leased by Air Canade until 1982 when it was exported to Canada. The airplane was maintained in an airworthy condition under a continuous maintenance and inspection program approved by the Canadian Department of Transport.

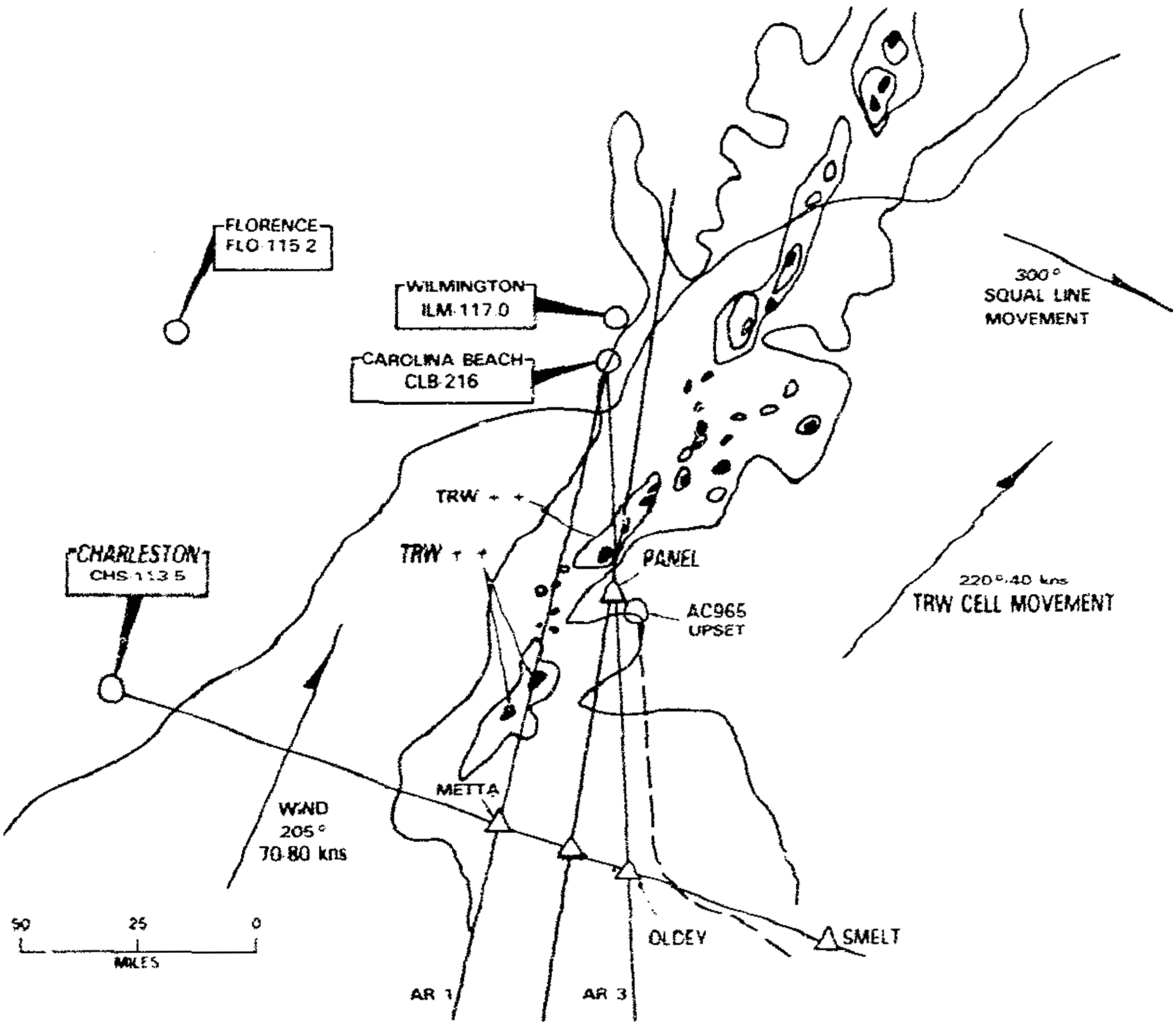
The airplane had made a total of 8,542 landings and accumulated a total of 26,544 hours of operation.

The airplane was powered by three Rolls Royce Model RB-21-22B engines. Specific data follows:

Engine	No. 1	No. 2	No. 3
Serial No.	10213	10171	10151
Time since new (hours)	15,906	17,756	18,527
Time since overhaul (hours)	650	438	3,243

APPENDIX D

ROUTE OF FLIGHT AND WEATHER OVERLAY



APPENDIX E

NWS TURBULENCE REPORTING CRITERIA TABLE

TURBULENCE REPORTING CRITERIA TABLE

INTENSITY	AIRCRAFT REACTION	REACTION INSIDE AIRCRAFT	REPORTING TERM-DEFINITION
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as **Light Turbulence**.* or Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as **Light Chop**.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.	Occasional – Less than 1/3 of the time. Intermittent – 1/3 to 2/3 Continuous – More than 2/3.
Moderate	Turbulence that is similar to Light Turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as **Moderate Turbulence**;* or Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as **Moderate Chop**.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.	**NOTE** 1. Pilots should report location(s), time (GMT), intensity, whether in or near clouds, altitude, type of aircraft and, when applicable, duration of turbulence. 2. Duration may be based on time between two locations or over a single location. All locations should be readily identifiable.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as **Severe Turbulence**.*	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.	EXAMPLES. a. Over Omaha, 1232Z, Moderate Turbulence, in cloud, Flight Level 310, B707.
Extreme	*Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage.* Report as **Extreme Turbulence**.*		b. From 50 miles south of Albuquerque to 30 miles north of Phoenix, 1210Z to 1250Z, occasional Moderate Chop, Flight Level 330, DC8.

* High-level turbulence (normally above 15,000 feet ASL) not associated with cumuliform cloudiness, including thunderstorms, should be reported as CAT (clear air turbulence) preceded by the appropriate intensity, or light or moderate chop.

SC/AMS Meeting 7/? ?

APPENDIX F

USEE GROUP INTERVIEW COMMENTS

The Station Manager of a 14 CFR Part 121 air carrier at the Jacksonville airport stated he was not aware of the HIWAS program and had not received any information on the subject.

Seventy-two (72) pilots of a major Part 121 air carrier were questioned, in person, on the subject of HIWAS on November 29, 1983, in their flight operations section at the Atlanta Hartsfield Airport. Those questioned included flightcrews and flight managers. The equipment they operated included DC-9, B-727, A-300, L-1011, and E-757 airplanes. Of the 72 questioned, 71 were not familiar with the HIWAS program. One B-757 captain stated he was familiar with the program and that he bad just read a notice on it that morning. He stated that he was not aware of the program prior to November 29, 1983.

Nine flightcrew members who were operating in the METTA sector at the time of the accident were questioned and all stated that they were not aware of the HIWAS program. Those interviewed represented seven United States Part 121 air carriers, one from the U.S. Air Force Military Airlift Command (MAC), and one represented a foreign *flag* carrier.

Additionally, the flight manager of a Part 121 air carrier based at Newark, New Jersey, interviewed by phone, stated that he was not aware of the HWAS program.

The flight manager of a Part 121 air carrier based at LaGuardia Airport stated that he was not familiar with the HIWAS program.

The Flying Safety Office, Military Airlift Command (MAC), was asked if they were familiar with the HIWAS program. Seven (7) MAC pilots qualified in the full range of aircraft operated by that command stated that they were not familiar with the *HIWAS* program.

Five pilots assigned to the Accident hvestigation Branch, U.S. Naval Safety Center, stated that they were not familiar with the HIWAS program.

Four (4) pilots employed by 14 CFR Part 135 operators were question and all stated they were not aware of the HIWAS program.

The Chief Pilot of a Part 121 air carrier with a crew base at the Miami International Airport stated that he was aware of the HIWAS program but believed it was designed for the general aviation community and not the air carrier community. Three days after investigators concluded their interview with this individual, he contacted them and stated that he bad interviewed about 20 of his assigned flightcrew members and found that none was aware of the HIWAS program.

Fourteen pilots were interviewed at Dulles International Airport. Of the 14, 7 were Part 91 operators of light aircraft and 7 were operators of corporate aircraft. All 14 stated that they were not aware of the HIWAS program.

Two pilots assigned to the FAA's Atlanta Flight Inspection Field Offices were interviewed by phone, and they stated that they were not aware of the HIWAS program.

Two pilots assigned to the FAA's Hangar 6 flight operations at Washington National Airport stated that they were not familiar with the HIWAS program.

Seven U.S. Coast Guard pilots who operate, generally, within the Miami and Jacksonville ARTCC areas stated that they were not aware of the HIWAS program.

The crew of Flight 965 was not aware of the HIWAS program.

The CALPA member assigned to the Board's ATC Group for the investigation stated that he was not aware of the HIWAS program. He further stated that it is the policy of Air Canada that the flightcrew secure the airplane when they are aware that they will be operating in either forecast or known areas of turbulence.