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Thirteen passengers were injured slightly; two passengers and one flight attendant were injured seriously during evacuation. The aircraft was substantially damaged.

The National Transportation Safety Board determines that the probable cause of this accident was that the captain did not recognize, and may have been unable to recognize, an increased rate of descent in time to arrest it before the aircraft struck the approach light piers. The increased rate of descent was induced by an encounter with a low-altitude wind shear at a critical point in the landing approach where he was transitioning from automatic flight control under instrument flight conditions to manual flight control with visual references. The captain's ability to detect and arrest the increased rate of descent was adversely affected by a lack of information as to the existence of the wind shear and the marginal visual cues available. The minimal DC-10 wheel clearance above the approach lights and the runway threshold afforded by the ILS glide slope made the response time critical and, under the circumstances, produced a situation wherein a pilot's ability to make a safe landing was greatly diminished.

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AIRCRAFT ACCIDENT REPORT

IBERIA LINEAS AEREAS DE ESPANA
(IBERIAN AIRLINES)
McDONNELL DOUGLAS DC-10-30, EC CBN
LOGAN INTERNATIONAL AIRPORT
BOSTON, MASSACHUSETTS
DECEMBER 17, 1973

ADOPTED: NOVEMBER 8, 1974

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C. 20591
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SYNOPSIS

About 1543 e.s.t. on December 17, 1973, Iberia Lineas Aereas de Espana Flight 933, a DC-10-30, crashed while making an instrument landing system approach to runway 33L at Logan International Airport, Boston, Massachusetts.

Thirteen passengers were injured slightly; two passengers and one flight attendant were injured seriously during evacuation. The aircraft was substantially damaged.

The aircraft first struck approach light piers about 500 feet short of the threshold of the runway. The aircraft then struck an embankment and sheared its right main landing gear. The aircraft skidded to a stop on the airport about 3,000 feet beyond the threshold and 280 feet north of runway 33L.

At the time of the accident, low ceilings with obscurations and a visibility of 3/4 mile in rain and fog prevailed at Logan Airport.

The National Transportation Safety Board determines that the probable cause of this accident was that the captain did not recognize, and may have been unable to recognize, an increased rate of descent in time to arrest it before the aircraft struck the approach light piers. The increased rate of descent was induced by an encounter with a low-altitude wind shear at a critical point in the landing approach where he was transitioning from automatic flight control under instrument flight conditions to manual flight control with visual references. The captain's ability to detect and arrest the increased rate of descent was adversely affected by a lack of information as to the existence of the wind shear and the marginal visual cues available. The minimal DC-10 wheel clearance above the approach lights and the runway threshold afforded by the ILS glide slope made the response time critical and, under the circumstances, produced a situation wherein a pilot's ability to make a safe landing was greatly diminished.

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

1. INVESTIGATION

1.1 History of Flight

Iberia Lineas Aereas de Espana Flight 933, a DC-10-30 with Spanish registration EC CBN, was a scheduled international passenger flight between Madrid, Spain, and Boston, Massachusetts. It departed Madrid at 903 1/ (1403 Greenwich mean time) on December 17, 1973, with 153 passengers and 14 crewmembers aboard. The flight into the Boston area was routine, and no problems were reported with the aircraft or its systems.

At 1524, Flight 933 contacted Boston Approach Control. The approach controller cleared the flight to descend to 3,000 feet and provided radar vectors to intercept the instrument landing system (ILS) localizer course for runway 33L at Logan International Airport.

At 1538, the approach controller informed the flightcrew that they were 9 miles from the outer marker (OM) and cleared the flight for the ILS approach to runway 33L. Two minutes later, the controller cleared the flight to contact the Boston control tower.

Flight 933 contacted the Boston tower local controller who at 1540:30, advised ". . . runway . . . visual range is out of service, the visibility is three quarters, the wind is three one zero at ten, report the lights in sight." Flight 933 responded, "Roger."

The captain of Flight 933 flew the ILS approach with the No. 1 autopilot coupled and both autothrottle systems (speed mode) engaged. All prelanding checks were completed at the appropriate times, and the aircraft was properly configured for landing. The indicated airspeed over the runway threshold was to be 140 kn., and the automatic speed control was set at 145 kn.

At 1541:44, the local controller cleared Flight 933 to land and informed the flightcrew that the braking action was reported to be fair to poor.

According to the flightcrew, the aircraft was on the ILS glide slope until the captain disconnected the autopilot. When the flight engineer called, "300 feet," the first officer saw the approach lights to his right, "about the 1 to 2 o'clock position." He reported, "Lights to the right," and the captain responded, "Ok, lights in sight." The captain then disconnected the autopilot and banked the aircraft to the right to align it with the runway. He did not disengage the autothrottle system.

According to the captain, the aircraft was aligned with the runway when the flight engineer called, "minimum decision height." The

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

captain knew that the aircraft was low, but he thought there was no problem. He then overrode the autothrottle system to advance the throttles and simultaneously increased slightly the back pressure on the control column. He recalled that after the first officer and flight engineer told him that the aircraft was still low, he advanced the throttles farther, but felt that the aircraft was continuing to descend. The flight engineer then rapidly called out, "50, 40, 30, 20, 10," and the aircraft struck the approach light pier.

Members of the flightcrew stated that when the "lights in sight" call was made, only the approach lights were visible. According to the first officer and the radio operator-navigator, 1/4 to 1/3 of the runway could be seen when the flight engineer called "minimum decision height."

At 1542:22, the radio operator-navigator on Flight 933 reported to the tower, " . . . runway in sight." Nine and one-half seconds later, while the local controller's transmitter was activated, the sound of the approach lighting system audio alarm was recorded in the tower. The tower local controller stated that as he reached toward the monitor panel to silence the alarm, he heard the transmission: "Iberia nine three three, we have an accident." The ground controller also heard the alarm, which was followed by an explosive noise. He saw a trail of fire along runway 33L and notified the airport fire department that an accident had occurred.

The captain and first officer of an Air Canada flight, which was parked on the taxiway adjacent to the threshold of runway 33L, saw Flight 933 when it emerged from the fog, less than a mile from their position. They stated that Flight 933 was low-- "too low to recover" and "desperately low." They saw the aircraft strike the approach light piers and then the embankment between Boston Harbor and the airport. After losing its right main landing gear, the aircraft bounced into the air, settled back to the runway, and skidded to a stop off the right side of the runway. A fire erupted on the left side of the aircraft as it skidded along the runway.

Following impact with the embankment, the captain's seat slid to its aft limit of travel, and he could not see the runway. He pushed forward on the control column, and the aircraft struck the runway--hard. The aircraft then slid down the runway and off to the right. The captain declared an emergency and ordered the evacuation of the aircraft.

The accident occurred at 1542:31.5, on December 17, 1973, and during daylight hours. The sky was obscured by fog and moderate rain. The geographic coordinates of the accident site are 42° 21' 48" N. latitude and 71° 00' 18" W. longitude.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Nonfatal	1	15	0
None	13	138	

1.3 Damage to Aircraft

The aircraft was substantially damaged.

1.4 Other Damage

Two approach light piers were destroyed and two others were heavily damaged. In addition, ALS lights, threshhold lights, runway lights, and about 175 feet of walkway were destroyed.

1.5 Crew Information

The captain, first officer and flight engineer were trained and qualified in the DC-10 aircraft at the McDonnell Douglas facility in Long Beach, California. They were certificated for their respective duties according to the laws and regulations of the Spanish Government. Before the flight, the flight crewmembers received rest periods required by the Spanish Government.

1.6 Aircraft Information

The aircraft was a DC-10-30, manufactured by the McDonnell Douglas Corporation. The aircraft had been maintained according to company procedures and government requirements.

The takeoff gross weight of EC CBN was 490,910 lbs. (233,141 kg.) with about 182,000 lbs. (162,341 kg.) of fuel on board. The landing weight and center of gravity were within prescribed limits. (See Appendix C.)

1.7 Meteorological Information

Special surface weather observations taken at Logan International Airport at the times indicated showed that the following conditions exitted:

1541 - Indefinite ceiling at 300 feet, sky obscured, visibility-3/4 mile in moderate rain and fog, wind-200° at 9 knots, altimeter setting-29.25 inches, runway 4R visual range-3,500 feet variable to 4,500 feet.

1545 - Similar conditions existed except the surface winds were from 300° at 7 knots. The temperature and dew point were 41° F. and 38° F., respectively.

Moderate rain began at 1529 and continued until after the accident.

The 1900 winds aloft observations at the following locations and altitudes were as follows:

Chatham, Massachusetts

(60 miles southeast of Logan)

Altitude (feet) 2/	Direction (true)	Speed (Kn.)
1,000	220°	39
2,000	220°	43
3,000	220°	43

Portland, Maine

(83 miles north of Logan)

1,000	185°	30
2,000	185°	35
3,000	185°	37

Earlier observations (0700) at these locations and altitudes were similar except the winds were from southeasterly and easterly directions.

A radar weather observation taken at Chatham at 1533 showed a precipitation area 250 miles in diameter centered 25 miles east of Chatham. The area was moving east-northeastward at 50 knots.

There was no meteorological equipment for measuring winds aloft at the Logan Airport. Also, no meteorological or pilot reports were available regarding the existence of adverse wind conditions on the final approach path to runway 33L.

Before departing Madrid, the flightcrew received a folder of international meteorological data, including terminal forecasts for the Boston area. The data, however, did not include either existing or forecast winds aloft reports for the Boston area.

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

1.8 Aids to Navigation

Logan International Airport is equipped with approach surveillance radar and ILS. There were no reported difficulties with either the radar or ILS.

At the time of the accident, the No. 1 localizer transmitter and the No. 2 glide slope transmitter were in operation on runway 33L. These components were flight tested the following day, and they operated within prescribed tolerances.

The ILS glide slope angle for runway 33L is 3°. The lowest decision height (DH) is 216 feet, and the glide slope is unusable below 200 feet. The threshold crossing height (TCH) of the glide slope beam is 34.3 feet. Neither the Iberian approach chart nor the official U. S. approach chart displayed the TCH; they did, however, contain a notation that the glide slope was unusable below 200 feet. The height of the glide slope beam is 51.1 feet above the approach light pier first struck by the aircraft. The approach light pier is 25 feet above the mean water level of Boston Harbor. It is located 492 feet from the threshold of runway 33L.

Runway 33L was not equipped with a visual approach slope indicator (VASI).

The captain's restrictions for the ILS approach (all components operating) to runway 33L were: DH 216 feet and visibility minimums of 1/2 mile or a runway visual range of 2,400 feet.

1.9 Communications

Air-to-ground communications were normal.

1.10 Aerodrome and Ground Facilities

The Logan International Airport is located on a peninsula that extends eastward into the Boston Harbor. Two sets of parallel runways and a single runway are available. The airport elevation is 19 feet, and the elevation of the touchdown zone for runway 33L is 16 feet.

Runway 33L is 10,080 feet long and 150 feet wide, and surfaced with bituminous concrete. It is equipped with high-intensity runway lights and a standard configuration "A", high-intensity approach light system with sequenced flashing lights. The runway threshold is about 200 feet from the shore of Boston Harbor. The approach light system is mounted on wooden piers set into the waters of the harbor.

According to Boston tower personnel, the runway lights were set for maximum intensity. They could not recall the intensity of the approach lights, but stated that the existing weather conditions would have dictated a maximum setting.

1.11 Flight Recorders

EC CBN was not equipped with a cockpit voice recorder, and none was required.

EC CBN was equipped with a Sunstrand Data Control digital flight data recorder (DFDR), serial No. 2201. The recorder uses tape as a recording medium, which requires electronic processing to retrieve the parameters of flight information. The recorder case was slightly damaged, but the tape was intact. Printouts of all 96 parameters were made from a computer tape, which was generated from the DFDR tape.

At 1543:41, the No. 1 radar altimeter read 20 feet. The approach light audio alarm sounded at 1542:31.5, indicating a difference of about 1 minute 10 seconds between the DFDR time and the recorded air traffic control time.

The processed data from the DFDR were examined for abnormalities in the aircraft's approach profile and flight characteristics. These data indicated that as the aircraft neared the OM, it was configured for landing with the gear down and flaps extended to 50°. The aircraft was established on the glide slope and localizer centerlines when it passed the OM. The radio and pressure altimeter altitudes corresponded to the published glide slope crossing altitude of 1,457 feet. The aircraft's magnetic heading was 318°, or 11° left of the published localizer heading. The computed (indicated) airspeed was 148 kn.

After passing the OM, the aircraft remained on the localizer and glide slope centerlines for 62 seconds while descending to 500 feet. During this period of time, the average values recorded for pitch attitude, airspeed, thrust, and heading were 1.3° aircraft noseup (a.n.u.) 148.9 kn., 72.8 percent N_1 3/, and 321.5°, respectively. The rate of descent averaged 911 feet per minute (fpm). Calculated values for a similarly configured DC-10 of the same weight, on a 3° descent profile with no wind conditions, were 4.2° a.n.u., 145 kn., 76.2 percent N_1, and 770 fpm.

As the descent continued below 500 feet, the aircraft began a gradually increasing deviation to the left of the localizer centerline. At the same time, the aircraft rose slightly above the glide slope, the airspeed increased 4 to 6 kn., and both the pitch attitude and thrust decreased. The recorded values for longitudinal acceleration were negative.

3/ A measurement of thrust expressed in terms of the percentage of N_1 (low pressure) compressor rotational speed.

The aircraft passed the middle marker (MM) left of the localizer course about 110 feet, and was about 3 feet below the glide slope. The pitch attitude, airspeed, and heading were 0.5° a.n.u., 133 kn., and 329°, respectively. The thrust settings were about 56 percent N_1.

The autopilot command mode was disengaged within 3 seconds after the aircraft passed the MM. Thrust settings at that time were about 54 percent N_1 on engines Nos. 1 and 3 and 48.5 percent on engine No. 2. The aircraft's pitch attitude was 0°. Within 3 seconds after the autopilot was disengaged, an aircraft noseup pitch change began; 3 seconds later thrust began to increase.

Nine seconds after the autopilot was disengaged, the pitch attitude was 5.4° a.n.u., and the thrust was increasing through 77 percent N_1. Steep increases in both the vertical and longitudinal acceleration were recorded. During that 9 seconds, the aircraft's rate of descent averaged 1,060 fpm. The signal which indicates that the landing gear are extended was interrupted 12 seconds after the autopilot was disconnected.

The DFDR data were also used to derive winds aloft along the aircraft's final approach path. This was accomplished by comparing a no-wind plot of the aircraft's position with a plot of its known position throughout the approach profile. The no-wind plot was established from the heading, airspeed, and altitude data. The plot of the aircraft's known position was established from altitude, glide slope, and localizer deviation data.

The winds derived are as follows:

Altitude (Feet)	Direction (Magnetic)	Speed (Kn.)
1,000	191°	35
900	191°	32
800	193°	31
700	195°	30
600	197°	28
500	200°	24
400	205°	20
300	225°	15
200	260°	12
100	210°	8
Surface	315°	8

1.12 Wreckage

The aircraft struck light piers and then the embankment along the edge of the harbor. The right main gear was sheared. The aircraft then became airborne for about 1,200 feet, landed on runway 33L, veered off the runway to the right, and skidded to a stop about 3,000 feet from the threshold and 280 feet north of the runway. (See Appendix E.)

The aircraft stopped in an upright position. The fuselage aft section had partially separated near station 1811. The aft section was twisted to the right and was resting on the tail cone with the right horizontal stabilizer touching the ground.

The leading edge slats and trailing edge flaps on both wings were fully extended. The right inboard flap had separated from the wing and was found near the runway threshold.

The inboard and outboard ailerons on both wings were intact. The left stabilizer contained numerous perforations, and the right stabilizer was damaged extensively.

The left main gear had separated from the aircraft, and it was located along the wreckage path about 150 feet from the aircraft. The nose gear assembly failed rearward and was embedded in the fuselage at station 735. The drag support for the centerline gear failed; the gear rotated aft about its upper pivot and was embedded in the fuselage.

The No. 1 engine pylon separated from the left wing. The engine and pylon assembly rotated outboard about 45°, but remained under the wing.

The No. 2 engine remained intact and in place on the fuselage pylon. The No. 3 engine pylon separated from the right wing. The engine and pylon assembly rotated inboard about 90°. The assembly remained under the right wing.

Examination of the aircraft's structure, engines, flight controls, and instruments revealed no evidence of preimpact failures or malfunctions.

Examination of the captain's seat disclosed that the rack drive pinion and needle bearing, which was mounted on the pedestal above the dual electric actuator and clutch assembly, disengaged from the gear sector and gear rack support, which was mounted within the seat bottom support pan. This allowed the seat to move freely in the horizontal plane.

1.13 Medical and Pathological Information

Thirteen passengers were treated for minor cuts, abrasions, and bruises. They were not hospitalized.

A female flight attendant and two female passengers were hospitalized. The flight attendant, who jumped to the ground from the top of the fuselage, sustained pelvic fractures. One of the passengers fractured her right ankle. The other passenger, who slid off the top of the fuselage, fractured her left ankle and suffered compression fracture of the second lumbar vertebra.

1.14 Fire

The aircraft caught fire while it skidded along and off the runway. The Massachusetts Port Authority Fire Department located on the Logan Airport, responded immediately and arrived within 3 minutes of the crash alarm that was activated by the Boston Tower ground controller. The City of Boston Fire Department was also notified. Department firemen responded and assisted in the rescue operations.

According to the firemen, fire was burning under the left wing, around the left engine, and along the left side of the fuselage when they arrived at the aircraft. Fuel from a ruptured left wing fuel tank was feeding the fire. The firemen extinguished the fire and spread a protective foam cover on the leaking fuel.

1.15 Survival Aspects

This was a survivable accident.

The aircraft was equipped with eight floor-level escape exits, four on each side of the fuselage. All exits were equipped with automatic escape slides. The exit doors could be opened electrically, pneumatically, or manually.

The flight attendants reported that they could not open the right forward (R-1), right aft (R-4), and left aft (L-4) doors. They did not attempt to open the left No. 3 (L-3) door because of fire near that exit.

The R-1 door could not be opened in the pneumatic, or emergency mode, because a backstop, which holds the striker assembly against the valve arm of the air bottle, was bent. The bent backstop prevented activation of the air bottle valve. When the system was properly rigged, the door operated pneumatically.

Inspection of the L-3, L-4, and R-4 doors revealed that the actuating mechanisms operated freely and were properly rigged.

The floor failed in the aft cabin area between fuselage stations 1530 and 1850. The floor was displaced upward about 3 feet, causing many failures of seat tracks and seat restraint components. None of the seats, however, completely detached. The floor and seat displacement obstructed both aisles in the cabin.

Five persons were trapped in the aft fuselage, because the aisles were blocked and they could not open the L-4 and R-4 exits. Four of these persons escaped through a break in the top of the fuselage. They slid or jumped to the ground. The fifth person was later rescued by the flightcrew.

The remaining 162 persons escaped through the four open exits. The R-2 exit slide did not inflate automatically, but it was successfully inflated manually. The evacuation was completed in about 2 minutes.

According to the flight attendants, the cabin lights went off after the first impact. No one could recall having seen the emergency lights illuminate; however, several firemen reported that some of the emergency exit lights were on. The battery packs which power the cabin emergency lights were tested; they were depleted.

1.16 Tests and Research

Tests were conducted in a McDonnell Douglas DC-10 simulator equipped with a Redifon Electronics, Inc., Visualator System. The simulator was programmed to reproduce the aircraft's characteristics and the approach and environmental conditions that existed at the time of the accident. The objectives of the simulator tests were to: (1) Further evaluate the DFDR data obtained from the accident aircraft, (2) observe the performance of the DC-10-30 autopilot/approach coupler, and (3) examine the flight conditions that confronted the flightcrew of Flight 933 during the transition from automatic to manual flight.

Five pilots who were qualified in the DC-10-30 aircraft participated in the tests. Forty-eight approaches were flown using the autopilot/approach coupler and autothrottle systems to an altitude of 200 feet or below. All of the approaches began when the aircraft was established on the localizer and glide slope centerlines, outside the OM, and at an altitude of 1,500 feet. The automatic speed control was set at 145 kn.

The winds aloft, which were derived from the DFDR data, were programmed into the simulator for the initial tests. Variations in pitch attitude, airspeed, and thrust induced by these winds were evident throughout the approaches flown. The most noticeable variations were the reductions in thrust and pitch attitude that occurred when the aircraft descended through 200 feet.

The average rate of descent from the OM to an altitude of 400 feet was 840 fpm. The rate of descent decreased to 780 fpm as the aircraft neared 200 feet. When the autopilot was disengaged at 200 feet, the pitch attitude and thrust conditions caused the rate of descent to increase to 1,170 fpm within 7 seconds. If a substantial pitch attitude increase was not initiated within 6 seconds after disengagement, the aircraft descended to runway elevation, before reaching the runway threshold, in about 9 seconds. The pilots were unable to recover from the high descent rate by adding thrust alone. When the autopilot was left engaged, it made pitch and thrust corrections that resulted, without flare, in wheel contact on the runway, 130 feet beyond the threshold.

Simulator data recorded for the initial tests differed only slightly from that recorded on the DFDR. Through trial and error, the programmed wind data were changed to produce traces more consistent with those from the DFDR. The wind values which produced the most consistent traces are:

Altitude (Feet)	Direction (Magnetic)	Speed (Kn.)
1,000	191°	35
900	192°	34
800	191°	34
700	191°	33
600	192°	32
500	194°	29
400	199°	21
300	211°	13.5
200	278°	5
100	310°	6
Surface	308°	5

After resolution into longitudinal and lateral components, these winds are as follows:

Altitude (Feet)	Longitudinal (Kn.)	Lateral (Kn.)
1,000	23.0 tailwind	26.0 left crosswind
900	22.6 "	25.7 "
800	22.15 "	25.4 "
700	21.7 "	25.1 "
600	20.4 "	24.3 "
500	18.0 "	23.0 "
400	11.8 "	17.3 "
300	5.8 "	12.1 "
200	3.3 headwind	4.1 "
100	6.0 "	2.0 "
Surface	4.0 "	2.0 "

These winds were used for all subsequent tests. The tests demonstrated that immediately following autopilot disengagement, the pilot had to increase the pitch attitude significantly to prevent a touchdown short of the runway threshold. The autopilot, when left engaged, increased the pitch attitude; however, the no-flare wheel contact on the runway occurred only [illegible] feet from the threshold.

Each pilot flew at least two approaches that required a transition from automatic flight control with instrument references to manual flight control with visual references. The transition was made between 180 and 160 feet above the runway elevation. All of the pilots successfully landed on the runway. However, on several approaches, the wheel clearance above an imaginary approach light 250 feet from the threshold was 10 feet or less. On most of the approaches, the pilots applied elevator control inputs within 4 seconds after the autopilot was disengaged to increase the aircraft's pitch attitude to about 6° a.n.u. within 10 seconds. All of the pilots had observed the first tests and were aware of the action required to prevent a high rate of descent from developing after the autopilot was disengaged.

The deviation to the left of the localizer course that began as Flight 933 neared 500 feet could not be reproduced in the simulator. Consequently, a lateral offset was produced by offsetting the localizer course 125 feet to the left of the Visulator runway centerline. None of the pilots had difficulty realigning the aircraft with the runway after the autopilot was disengaged.

The pilots agreed that the runway picture they saw from 200 feet was not alarming enough to cause them to initiate a missed approach. Several pilots commented on the subtle increase in the rate of descent that followed autopilot disengagement. They also commented that it was difficult to judge the pitch attitude and descent profile from the visual cues available because of the programmed, 4,000-foot runway visual range.

1.17 Other Information

Iberian operational procedures specify that the captain may, at his discretion, keep the autothrottle system engaged during landing.

In November 1973, the Douglas Aircraft Company issued all operators letter (AOL) No. 10-515, which stated that one DC-10 operator had reported a bent backstop bracket on the air bottle striker arm assembly. The bent bracket prevented emergency operation of the exit door. Douglas noted that the bracket deformation may have occurred during the incorporation of the provisions of Service Bulletin 52-26. However, since the Service Bulletin had been complied with on EC CBN during production, the Douglas AOL did not identify the aircraft as one which might have been affected.

The glide slope antenna in the DC-10-30 is mounted in the nose section of the aircraft. Under mid-range c.g. conditions, the vertical distance between the path of the antenna and the path of the bottoms of the aft landing gear wheels is 26.5 feet when the aircraft is flying a 3° glide slope at recommended final approach speeds. Excluding allowances for installation tolerances, beam irregularities, and tracking errors, the nominal clearance of the aft wheels of EC CBN would have been 24.6 feet above the approach light stanchion and 7.8 feet over the threshold of runway 33L, had the aircraft remained on the 3° glide slope.

In 1968, the Convention on International Civil Aviation 4/ recommended that the TCH for ILS facilities be established at 50 feet ± 10 for category I facilities and 50 feet, + 10, -3 feet, for Category II facilities. These values were based on an assumed maximum vertical distance of 19 feet between the path of the aircraft's glide slope antenna and the path of the lowest part of the wheels. This combination would provide a nominal wheel clearance of about 30 feet at the runway threshold.

In 1970, the Aerospace Industries Association of America, Inc., conducted a study to evaluate minimum wheel clearances at the threshold and to assess the effects of increasing the vertical distance to 29 feet between the paths of the glide slope antenna and the wheels on typical wide-bodied aircraft. The study concluded that a nominal wheel clearance of 20 feet would prevail, with a clearance of at least 10 feet when a reasonably probable combination of adverse tolerances was applied to a glide slope having a TCH of 47 feet. This study led to the FAA's approval of glide slope antenna installations that exceeded the 19-foot criteria.

On February 24, 1972, the FAA issued Order 8260.24 establishing standards for the relocation of Category I glide slope facilities and the installation of new facilities. The maximum and minimum TCH's for those facilities authorized for category D 5/ aircraft were specified as 60 feet and 47 feet, respectively. The minimum TCH was based on a nominal wheel clearance of 20 feet above the threshold. This height was considered sufficient to account safely for deviations from the glide slope because of system and flight technical errors. The runway 33L glide slope facility at Logan International Airport had not been relocated to comply with this order because of a lack of funds.

4/ Annex 10, Second Edition, Volume 1, April 1968, International Standards and Recommended Practices Aeronautical Telecommunications.

5/ An approach category of aircraft--the approach speed is 141 kn. or more, but less than 166 kn., and the maximum landing weight is more than 150,001 pounds.

On April 10, 1973, the Douglas Aircraft Company issued the following information on ILS approaches in a letter to all DC-10 operators:

"ILS Approach

If ILS is available, it should be used whenever possible regardless of the weather conditions, because it affords the most accurate flight path control. Glide slope angles for the ILS vary from 2.5° to 3°. The ILS generally establishes a safe touch-down point down the runway beyond the threshold; however, it does not always provide margins as large as we would like. The minimum glide slope beam height above the threshold for a Category II ILS is 47 feet. For this minimum Category II case the wheel height over the threshold will be at least 20 feet (no flare) . . . . By FAA recommended standards, a Category I beam can have a minimum height over the threshold as low as 40 feet. The no flare wheel height over the threshold will be down to 13 feet when the airplane is on a 2.5° glide-slope that crosses the threshold at 40 feet, however; a normal flare will raise this clearance by several feet. Touchdown distance (no flare) in this case would be 200 feet from the threshold.

"Some Category I beams have a glide slope height over the threshold that is below the FAA recommended minimum height of 40 feet which could result in even lower wheel heights over the threshold and shorter touchdown distances.

"The above ILS approach examples are predicated on the fact that the airplane is on the glide path at a stabilized pitch attitude with no windshear. Momentary increase in pitch attitude, the effect of windshear and ILS beam bends and tolerances are all adverse items that can result in wheel heights over the threshold that are lower than those stated above.

"Under no circumstances should a 'duck under' maneuver be executed. The tendency to 'duck under' the glide slope in the latter stages of the approach can be obviously dangerous. One of the reasons for locating the glide-slope antenna in the nose of the DC-10 was to position the airplane on the glide slope such that the pilot would feel comfortable with the airplane in the proper slot as determined by visual cues (pilot's sight picture of the approach lighting, threshold, and runway lighting, visual aim point, etc.) when the pilot transitions from instruments to visual. Nothing but trouble in the form of a short landing can result from a 'duck under' maneuver in the DC-10 or any other large jet aircraft.

"It can be seen that the airplane must not be flown below the glide slope when approaching the threshold on an ILS approach. This is especially true on some Category I beams that have glide slope heights over the threshold that are below the FAA recommended minimum height of 40 feet. Autopilot coupled approaches on these runways must not be continued below 100 feet, because it will be necessary to fly above the glide slope when approaching the threshold to ensure adequate wheel height clearance. It is imperative that operators survey their route structure and inform their pilots about the runways having low glide slope heights over threshold." (Emphasis supplied.)

Iberia provided each pilot with a copy of the above letter, shortly after receipt, and incorporated the information into its training program. Also, the captain of Flight 933 received similar information during his DC-10 transition training.

Before the accident, Iberia had not conducted a survey of the airports on its routes to determine which of them had ILS runways with low TCH's.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

The crewmembers were trained, qualified, and certificated for their respective duties according with the laws and regulations of the Spanish Government. There was no evidence that medical factors or fatigue affected the flightcrews' performance.

The aircraft was certificated, equipped, and maintained according to regulations and approved procedures. The gross weight and c.g. were within prescribed limits during the approach. With the exception of the bent backstop bracket on the air bottle sticker arm assembly, there was no evidence of preimpact failure or malfunction of the aircraft's structure, powerplants, or systems.

The National Transportation Safety Board, therefore, directed its attention to the meteorological and operational factors that could have caused the aircraft to develop a high rate of descent which led to impact short of the runway.

The Wind Shear Phenomenon

The weather conditions that existed in the Boston area at the time of the accident suggested that a low altitude wind shear was present.

The problems associated with wind shear have been examined in several theoretical analyses and analog simulations. However, most studies have been confined to the effect of the shear on the aircraft's touchdown point, assuming no control or thrust changes. Apparently, little research has been done to consider the effect of the pilot's performance on the aircraft's flight profile during and subsequent to the aircraft's passage through a wind shear. This more complex subject, however, has been discussed hypothetically. 6/

When encountering a wind shear on final approach, the pilot or autopilot must make coordinated pitch attitude, thrust, and heading changes to minimize deviations from the optimum flightpath and airspeed. The direction and extent of the deviations will depend on the characteristics of the shear and the response of the flight control system servo loops.

During a precision instrument approach through a wind shear characterized by a diminishing tailwind, the higher-than-normal ground speed produced by the initially stable tailwind necessitates a higher-than-normal rate of descent for the aircraft to remain on the glide slope. Under these conditions a lower pitch attitude and less thrust are required than would be required during the more common no-wind or headwind approach. As the descent continues, the effect of the shear induced by a rapid decrease in the tailwind component is a rapid increase in the velocity of the aircraft relative to the air mass in which it is moving. The increased velocity causes the indicated airspeed to rise, and the resultant increase in lift causes the aircraft to rise above the glide slope. Both pitch attitude and thrust must be decreased further to limit deviations from the glide slope and the target airspeed. As the aircraft intercepts the glide slope again, the pitch attitude and thrust must be increased to reestablish the desired rate of descent and airspeed. As the tailwind continues to diminish, or becomes an increasing headwind, readjustments of pitch attitude and thrust must be made continuously. Ideally, the attitude and thrust, at any instant, should be that required to decelerate the aircraft at a rate equal to the rate of change of the longitudinal wind component, while establishing a rate of descent compatible with the instantaneous ground speed and the glide slope angle. After passing through the wind shear and into wind with a constant longitudinal component, the aircraft will descend below the glide slope, because of the continuous deceleration and resultant loss of lift. Prompt pitch control changes and throttle

6/ W. W. Melvin, "Wind Shear on the Approach," Flight Safety Facts and Analysis, Vol. 5, No. 3 (March 1974).

corrections are required to prevent an increase in the rate of descent. In addition to attitude and thrust changes, heading corrections are required to minimize deviations from the localizer course that are caused by the diminishing speed of the crosswind component.

The hazard presented by a diminishing tailwind-type shear on final approach is the continuous need for pitch attitude changes and additions to thrust. If the shear persists to a low altitude, the aircraft can be placed in a high rate of descent, thrust-deficient condition close to the ground. Under these conditions, the response of the control servo loops can be critical.

How Wind Shear Affected Flight 933

At 1341, the surface wind at Logan was from 290° at 9 kn. Since surface winds are usually representative of the winds within the earth's friction layer, which extends from the surface to elevations of 200 to 300 feet, these winds probably extended to approximately those elevations.

At 1900, however, the winds aloft from 1,000 to 3,000 feet at Chatham and Portland were from a southerly direction at about 40 kn. Also, the 0700 observations at these locations and elevations showed winds of a similar speed from a southeasterly direction. Consequently, the wind velocity in the Boston area at altitudes as low as 1,000 feet was near 40 kn. from a southerly direction at the time of the accident. These winds would have produced a tailwind component of about 30 kn., at these altitudes, for an aircraft flying the runway 33L localizer course.

The examination of DFDR data, including the data reproduced in the DC-10 flight simulator, provided more positive evidence of the wind conditions along Flight 933's final approach profile. The Safety Board believes that the wind conditions derived from the simulator tests are the most representative of those affecting the aircraft.

The DFDR data show that the flight descended from 500 feet to 200 feet in 20 seconds. During the 20-second period, the longitudinal wind component changed from an 18-kn. tailwind to a 3.3-kn. headwind, and the left crosswind decreased from 23 to 4 kns. Between these altitudes, therefore, the longitudinal wind shear was about 7.1 kn. per 100 feet, and the lateral wind shear was about 6.3 kn. per 100 feet.

DFDR data clearly indicate the effects of the wind shear on Flight 933. During the initial portion of the higher-than-normal rate of descent, the lower-than-normal pitch attitudes and thrust setting were consistent with a fairly constant tailwind. An 8° to 10° difference between aircraft heading and localizer course was established to correct for the left crosswind. These flight conditions were essentially stable, and the localizer and glide slope deviations were minimal until the aircraft reached about 500 feet. Thereafter, a rapid increase in indicated airspeed, a rise above the glide slope, and a deviation left of the localizer course occurred. To compensate for these deviations, the aircraft pitched down about 1°, the thrust was reduced, and a heading correction to the right was begun.

The aircraft returned to the glide slope and pitched up slightly as it descended through 260 feet. The effect of the thrust reduction was evident by a negative longitudinal acceleration. However, the indicated airspeed remained essentially constant, indicating that the aircraft's deceleration approximated the rate of change of the longitudinal wind component.

The pilot, upon passing through 200 feet, was required to discontinue the coupled approach because the glide slope was not usable below that altitude. At 300 feet, he saw the approach lights, and he disengaged the autopilot about 7 seconds later at an altitude of 184 feet. At that time, the aircraft was at a low pitch attitude, a low thrust condition, and slightly left of the localizer course. Also, the autopilot was disengaged about the same time that the aircraft descended below the altitude of the wind shear band.

The Safety Board believes that the wind shear condition alone was not severe enough to create an unmanageable problem for the captain of Flight 933. However, when combined with the need to change from automatic flight control to manual flight control, the poor visual cues and the low wheel clearance afforded by the combination of airborne and ground ILS equipment serious difficulties were created.

As demonstrated in the flight simulator tests, the concurrent transition from automatic to manual flight control and the emergence of the aircraft from the wind shear produced a serious problem. The simulated aircraft quickly and subtly developed a high rate of descent, which required significant increases in pitch attitude and thrust to arrest. Had the captain of Flight 933 been able to retain autopilot coupling, these corrections might have been made. However, because he had to disengage the autopilot, he became the control element in the control servo loop; therefore, he required a sensory signal to alert him to the need for control changes.

Although the captain had the runway threshold in sight, he could not see enough of the runway to derive an accurate perception of his attitude. Moreover, because the aircraft was established on the glide slope when the captain began his transition to visual flight, and because his first visual observation was not alarming, he probably was not anticipating the need for an immediate pitch or thrust correction. Finally, the subtle increase in the rate of descent and the more obvious need for a lateral correction undoubtedly prolonged his recognition and reaction time.

The captain applied back pressure to the control column and overrode the autothrottle system to increase the thrust 4 to 5 sec. after he had disengaged the autopilot. However, the pitch attitude and thrust changes were not sufficient to reduce the rate of descent adequately. During the simulator tests, judgment of pitch attitude was difficult because of the limited visual cues available. Furthermore, because of the low pitch attitude, the change required was greater than changes associated with normal approach corrections. The captain of Flight 933 undoubtedly felt he had made sufficient correction. However, by the time he received oral warnings and recognized and reacted to the continuing descent, impact short of the runway was inevitable.

Another factor in this accident was the low wheel clearance afforded DC-10 aircraft by the TCH of the runway 33L glide slope beam. Had Flight 933 been able to remain on the glide slope, the main landing gear wheels would have passed only 24.6 feet above the light pier, which they struck, and 7.8 feet above the runway threshold. The Safety Board believes that these clearances are too low for the existing ILS weather minima. Moreover, the TCH was not published in official U. S. instrument approach procedures and was unknown to the captain of Flight 933. (See Appendix F.)

The Safety Board recognizes the difficulties associated with locating the glide slope receiver antenna in wide-bodied aircraft. However, primary emphasis has been placed on optimizing the antenna location for automatic approaches conducted on Category II facilities, where the specifications require a minimum TCH of 47 feet, a usable glide slope to a DH of 100 feet, and a glide slope interception point on the runway of not less than 950 feet from the threshold. Under these conditions, a glide slope which provides a nominal wheel clearance of 20 feet above the threshold, or 10 feet with a reasonably probable combination of adverse tolerances, may afford an adequate margin of safety.

Approaches on Category I facilities, however, are a different matter, and although the FAA and the aircraft industry have recognized the hazards of approaches on these facilities, the Safety Board believes that the hazards should be eliminated. A combination of airborne and ground equipment which, when used properly, can lead a pilot into a precarious situation is inherently unsafe. Also, since the merits of a stabilized approach are too well known for dispute, a practice that requires the pilot to change his flight profile near DH, and actually fly the aircraft above the glide slope to the point of flare in order to prevent a short landing, does not provide a safe solution.

If ILS glide slope transmitters are relocated in accordance with FAA Order 8260.24, a greater margin of safety will be provided to the pilots of wide-bodied aircraft using Category I facilities. Where it is impractical to relocate the transmitters, the Safety Board believes that decision heights and visibility minimums should be raised substantially for Category D aircraft. Additionally, the TCH's for all ILS facilities should be published in the official U. S. instrument approach charts.

As confirmed by the simulator tests, one of the most serious problems during transition from instrument to visual references near DH is the availability of adequate visual cues to provide vertical guidance. These cues should provide the pilot with instant recognition of his position relative to the safe approach slope. A VASI system is capable of providing this information and should be installed with all ILS facilities used by air carrier aircraft. (See Appendix F.)

Currently, operational equipment that is capable of accurately and frequently measuring and reporting winds aloft over or near an airport is not available. Likewise, operational equipment capable of measuring and reporting wind shear is not available, although an acoustic doppler system for measuring wind shear has been developed and tested with favorable results. Consequently, the Safety Board believes that the development of systems capable of accurately measuring and reporting winds aloft, including wind shear, should be emphasized. (See Appendix F.)

Survivability Aspects

The aircraft and passengers seat restraint mechanisms remained intact throughout the crash sequence. These factors, in conjunction with relatively low deceleration forces, permitted the occupants to survive the crash with only minor injuries. The low injury rate, in turn, proved significant in enabling the occupants to evacuate the aircraft quickly. The quick and efficient evacuation, the relatively slow propagation of the fire, and the rapid response of the fire department reduced the post-crash fire hazard substantially.

The Safety Board could not determine positively why the captain's seat came loose after the aircraft struck the embankment. However, the impact forces probably distorted the gear rack support sufficiently to disengage the rack drive pinion and needle bearing from the seat support mechanism. After the impact, the high noseup attitude and positive acceleration of the aircraft would have forced the seat to its aft limits of travel.

Three major factors combined to reduce the severity of the fire: (1) Type A kerosene fuel with a high flashpoint, (2) fuel did not collect in puddles because of the slope of the terrain, and (3) the low temperature of the fuel caused by the long flight at high altitude.

The right forward exit door failed to function because of the deformed backstop bracket. The manufacturers had issued a letter to bring the problem to the attention of all DC-10 operators. However, the letter did not apply to EC CBN since the Service Bulletin changes had been accomplished during production. Consequently, it is likely that the backstop was deformed before delivery of EC CBN to Iberia Air Lines. The FAA has since issued an airworthiness directive requiring replacement of the bracket with one made of stronger material.

The reason the two aft exit doors failed to open could not be determined. Both doors were properly rigged, and they operated pneumatically when tested later. It is possible that, under the stress of the situation, the flight attendant did not apply sufficient force (35 pounds) to the door control handle to actuate the emergency system.

2.2 Conclusions

(a) Findings

1. There was no evidence of a malfunction or damage to the aircraft's structure, flight instruments, flight controls, or powerplants before impact with the approach light [illegible]ors.

2. [illegible] 933 approached Logan International Airport, [illegible] conditions were: Indefinite ceiling at 300 [illegible] cured, and visibility-3/4 mile in moderate [illegible].

3. [illegible] as conducting a coupled ILS approach to run- [illegible] he autothrottle system was engaged.

4. [illegible] encountered a mean longitudinal wind shear of [illegible] kn. per 100 feet and a mean lateral shear of [illegible] n. per 100 feet between 500 and 200 feet.

5. The [illegible] of the wind shear on the aircraft were most pronounced at a [illegible] when the captain had to transition from automatic fl[illegible]t with instrument references to manual flight with visual references.

6. The poor visual cues available because of the low ceiling and visibility made the visual detection of the aircraft's pitch attitude and rate of descent difficult; runway 33L was not equipped with a visual approach slope indicator.

7. Flight simulator tests showed that, under the existing flight conditions, a significant pitch attitude increase and thrust addition were required within 6 seconds after the autopilot was disengaged to arrest the high rate of descent induced by the wind shear.

8. The captain of Flight 933 made significant pitch attitude and thrust corrections within 9 seconds after he had disengaged the autopilot. These corrections were made too late to avoid collision with the approach light piers.

9. The runway 33L glide slope was unusable below 200 feet.

10. With a DC-10-30 aircraft on the glide slope, the low TCH of the runway 33L glide slope beam (34.3 feet) provided only 7.8 feet of aircraft wheel clearance over the runway threshold and only 24.6 feet of clearance over the approach lights which were struck first.

11. The runway 33L glide slope transmitter had not been relocated in accordance with FAA Order 6260.24.

(b) Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was that the captain did not recognize, and may have been unable to recognize, an increased rate of descent in time to arrest it before the aircraft struck the approach light piers. The increased rate of descent was induced by an encounter with a low-altitude wind shear at a critical point in the landing approach where he was transitioning from automatic flight control under instrument flight conditions to manual flight control with visual references. The captain's ability to detect and arrest the increased rate of descent was adversely affected by a lack of information as to the existence of the wind shear and the marginal visual cues available. The minimal DC-10 wheel clearance above the approach lights and the runway threshold afforded by the ILS glide slope made the response time critical and, under the circumstances, produced a situation wherein a pilot's ability to make a safe landing was greatly diminished.

3. RECOMMENDATIONS

The Safety Board made a recommendation (SR A-74-55) to the FAA on July 10, 1974, to continue to install VASI's on all ILS runways used by air carrier aircraft with first priority to Category I approaches.

On October 3, 1974, the Safety Board made seven recommendations to the FAA (SR A-74-77 through 83.) These recommendations involved the relocation of ILS glide slope transmitters, changes to ILS approach procedure charts and ILS weather minima, modification of pilot training and information programs to include wind shear phenomenon, and the development of equipment and systems to measure and report wind shear. (See Appendix F.)

On April 4, 1974, the FAA issued an airworthiness directive to correct deficiencies in the backstop bracket that prevented emergency operation of the exit door. The airworthiness directive required periodic inspection of the bracket until it is replaced with one made of stronger material.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

November 8, 1974

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident at 1605 on December 17, 1973. The Safety Board immediately dispatched an investigative team to Boston. The team established investigative groups for operations, air traffic control, witnesses, weather, human factors, structures, powerplants, systems, and flight data recorder.

Parties to the investigation were: The Federal Aviation Administration, Iberia Airlines, International Federation of Airline Pilots Association, McDonnell Douglas Corporation, and General Electric Company.

2. Hearing

No public hearing was held.

 APPENDIX B

CREW INFORMATION

Captain Jesus Calderon Gaztelu

Captain Jesus Calderon Gaztelu, 53, was employed by Iberian Airlines on April 29, 1953. He holds Piloto Transporto License No. 172, which had been renewed on July 17, 1973. He passed a medical examination before his license was renewed. License renewal must be accomplished each 6 months.

Captain Calderon had accumulated 21,705 flight-hours, including 426 hours in the DC-10. In the 90, 30-, and 1-day periods before the accident, he flew 148, 78, and 7 hours, respectively. He had completed refresher training on October 19, 1973.

First Officer Alfredo Perez Vega

First Officer Alfredo Perez Vega, 54, was employed by Iberian Airlines on November 18, 1946. He holds Piloto Transporto License No. 408, and he had passed a medical examination to renew his license on December 15, 1973.

First Officer Perez accumulated 34,189 flight hours, including 403 hours in the DC-10. In the 90-, 30-, and 1-day periods before the accident, he flew 165, 68, and 7 hours, respectively. He had completed refresher training on October 9, 1973.

Flight Engineer Celedonio Martin Santos

Flight Engineer Celedonio Martin Santos, 42, was employed by Iberian Airlines on December 13, 1952. He holds Mecanico License No. 175; it must be renewed annually, which was last accomplished on May 14, 1973. He passed the prerequisite medical examination.

Flight Engineer Martin had 15,317 flight-hours, including 263 in the DC-10. During the 90-, 30-, and 1-day periods before the accident, he flew 164, 74, and 7 hours, respectively.

Radio Operator-Navigator Candido Garcia Bueno

Radio Operator-Navigator Candido Garcia Bueno, 51, was employed by Iberian Airlines on December 9, 1941. He holds Radio Operator License No. 204, which had been renewed September 2, 1973. He passed the medical examination for renewal of his license.

Radio Operator-Navigator Garcia had accumulated 14,562 flight-hours, including 384 hours in the DC-10. During the 90-, 30-, and 1-day periods, before the accident, he flew 164, 74, and 7 hours, respectively.

APPENDIX B

Flight Attendants

The 10 flight attendants were qualified for their duties according to Iberian Airline procedures and the laws and regulations of the Spanish Government.

APPENDIX C

AIRCRAFT INFORMATION

EC CBN was owned and operated by Iberian Airlines. Its date of manufacture and manufacturer's serial no. were March 20, 1973, and 1,073, respectively. The aircraft had accumulated 2,016:29 hours time in service including 568:26 hours since the last major inspection.

EC CBN was powered by three CF6-50 turbofan jet engines manufactured by the General Electric Company.

The engine serial nos. and times in service were as follows:

Engine No.	Serial No.	Time
1	455,255	1,028:15
2	455,142	912:45
3	455,313	406:35