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Flight Crew of DC-10 Encounters Microburst During Unstabilized Approach, Ending in Runway Accident

The approach controller did not warn the crew of the possibility of wind shear, but the official Portuguese accident report noted that such an experienced crew should have been aware that wind shear was a possibility.

FSF Editorial Staff

There were numerous thunderstorms and rain showers in the vicinity of the airport as the crew of the McDonnell Douglas DC-10-30F began its final approach to the Faro (Portugal) Airport. As the aircraft descended through 229 meters (750 feet) radio altitude (RA), it encountered a downburst. The approach became unstable, with a rate of descent that varied from 30.5 meters per minute (100 feet per minute) to 396 meters per minute (1,300 feet per minute). [A downburst is a strong, concentrated downdraft that creates an outward burst of damaging winds at the surface and is usually associated with convective showers and thunderstorms.]

The crew continued the approach, and as the aircraft crossed the threshold of Runway 11, they encountered a crosswind component of 40 knots (74 kilometers per hour) and a tailwind component of 10 knots (19 kilometers per hour). The aircraft touched down on the left side of the runway. The right-main landing gear collapsed, and the aircraft slid down the runway. As it slid, the aircraft broke apart … . It came to rest off the runway, exploded and burned. Two cabin crew members and 54 passengers were killed, and two crew members and 104 passengers were seriously injured in the Dec. 21, 1992, accident.

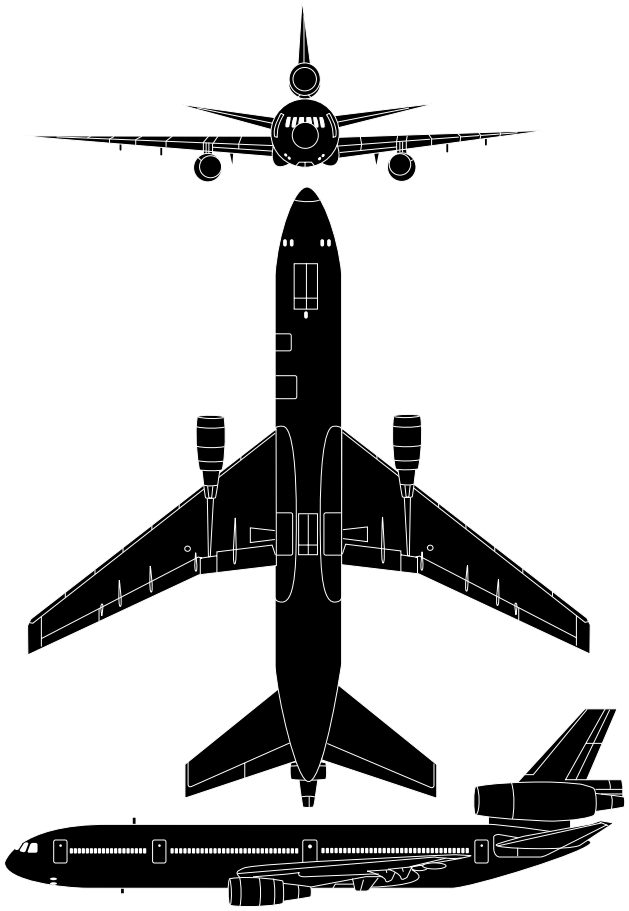
The accident aircraft was owned by the Royal Dutch Air Force and was operated by Martinair Holland N.V., said the final report of the Portuguese Director-General of Civil Aviation (DGAC). The accident flight was a nonscheduled public transport flight from Amsterdam, Netherlands, to Faro.

Before the flight, "the captain examined satellite pictures, which showed a low-pressure area over the Atlantic, near the south coast of Portugal," the report said. "The forecast indicated isolated thunderstorms and rain showers."

The accident flight's departure from Amsterdam was delayed approximately 40 minutes because of a problem with the thrust reverser on the No. 2 engine. The flight departed at 0552 hours local time with three flight crew members, 10 cabin crew members and 327 passengers. "After takeoff, the flight proceeded normally according to flight plan, without incident," the report said. The cruising altitude for the flight was flight level (FL) 370 (37,000 feet [11,285 meters]).

The first officer was the pilot flying. At about 0755, he conducted the crew briefing for the approach. Because it was raining at the airport, the captain recommended that the first officer make a landing that was "not too soft … you have to make it a positive touchdown, then," the report said.

At 0801, the captain and first officer reviewed the procedures and facilities for the approach at Faro. They noted that the



McDonnell Douglas DC-10

The McDonnell Douglas DC-10 first flew in 1970. It was designed as an all-purpose commercial transport able to carry 270 mixed-class passengers and 380 passengers in an all-economy configuration. The DC-10-30 series has a maximum takeoff weight of 263,085 kilograms (580,000 pounds), a maximum cruising speed of 490 knots (908 kilometers per hour) and a service ceiling of 10,180 meters (33,400 feet). The DC-10-30 has a range of 4,000 nautical miles (7,413 kilometers) with maximum payload at maximum zero-fuel weight.

Source: *Jane's All the World's Aircraft*

runway at Faro did not have an approach-light system and that the very high frequency omnidirectional radio range (VOR) approach was not aligned with the runway. The captain told the first officer that they needed at least 2,000 meters (6,562 feet) visibility for the VOR approach.

At 0803:42, the crew contacted Lisbon Control Center (which was controlling the flight) and requested a descent. The flight was cleared down to FL 230 (23,000 feet [7,015 meters]). After obtaining the weather report for Faro, the captain told the first officer that if they could not land at Faro, they would proceed to Lisbon.

The first officer reviewed the aircraft's airborne weather radar and told the captain that he did not see anything on the display, the report said. Then, the captain and the first officer discussed the possibility of radar returns from the right at a distance of 10 kilometers (6.2 miles).

At 0809:36, the flight was cleared to descend to FL 70 (7,000 feet [2,135 meters]), and the crew was told to contact Faro Approach Control, which the crew acknowledged. The crew then contacted Faro Approach Control and reported descending to FL 70. Faro Approach Control provided landing instructions and the current weather conditions to the accident crew.

The weather provided to the accident crew was as follows: Winds from 150 degrees at 18 knots (30 kilometers per hour), visibility 8,203 feet (2,500 meters), thunderstorms with 3/8 clouds at 500 feet (152 meters), 7/8 clouds at 2,300 feet (701 meters), 1/8 cumulonimbus clouds at 2,500 feet (762 meters), temperature 61 degrees F (16 degrees C).

The first officer commented that the weather was extremely bad. A cabin crew member asked the flight crew about the weather at Faro, and the captain replied that the weather was extremely bad, the report said.

The first officer flew the instrument approach into Faro. At 0820:10, the accident flight was cleared to descend to 1,220 meters (4,000 feet), which the crew acknowledged.

The first officer asked the captain for "slats takeoff," which was followed 27 seconds later by a request for "flaps 15," the report said. The captain confirmed both requests.

At 0824:34, the flight was cleared down to 915 meters (3,000 feet), the report said. Moments later, Faro Approach Control cleared another flight for landing and told the crew of that flight that the wind was from 150 degrees at 20 knots (37 kilometers per hour) and that the runway was flooded.

At approximately 0826, the accident crew reported overhead and leaving 1,220 meters (4,000 feet) for 915 meters (3,000 feet), the report said. Faro Approach Control then cleared the accident flight to descend to 610 meters (2,000 feet). "According to crew statements, the aircraft was flying in clear sky at [1,220 meters (4,000 feet)] when passing overhead Faro with the airport and [another aircraft that was landing] visible," the report said.

At approximately 0829, Faro Approach Control instructed the accident crew to report at minimums or the runway in sight and informed the flight crew that the runway was flooded, the report said.

When the accident flight was about seven nautical miles (NM) (13 kilometers) distance measuring equipment (DME) from Faro VOR, "the landing gear was selected down," the report said. The first officer then asked the captain for "flaps 35."

At 0830:18, "the autopilot was changed from altitude hold to vertical speed," the report said. The first officer then asked for "flaps 50," which was confirmed by the captain, "and then the aircraft was configured for landing."

The captain gave the other flight crew members wind information from the aircraft's inertial navigation system (INS): "Wind is coming from the right, 30 knots [56 kilometers per hour], drift 12 degrees … ," the report said.

At 0831, the accident flight was 3.5 nautical miles (6.4 kilometers) out at 366 meters (1,200 feet). At this point, the captain said the runway was clearly visible. Sixteen seconds later, the first officer announced, "Spoilers," and six seconds later the spoilers were armed.

Approach Became Unstable

When the accident aircraft was at an altitude of 995 feet (303 meters) and at a speed of 140 knots (259 kilometers per hour), "an oscillation [began] with values of vertical G between +0.75 G and +1.25 G," the report said. "With the aircraft at 249 meters [815 feet], a fluctuation [began] in the flight parameters."

At 0832:11, Faro Approach Control asked the accident crew if they had the runway lights in sight. The crew reported the lights in sight. Faro Approach Control then cleared the flight for Runway 11 and told the crew that the wind was from 150 degrees, gusting to 20 knots (37 kilometers per hour).

"About three to four seconds before contacting the runway, the captain took action … ."

At 0832:15, "The start of synchronized oscillations of N_1 [compressor speed], between 55 [percent] and 105 percent [were recorded on the accident aircraft's digital flight data recorder (DFDR)]," the report said. Eight seconds later, when the accident aircraft was at a radar altitude of approximately 177 meters (580 feet), the first officer switched the autopilot from CMD (command mode) to CWS (control-wheel steering).

Faro Approach Control then asked the accident crew if the runway lights were too bright. The crew responded that the lights were acceptable at the present level.

At 0832:50, the captain warned the first officer, "Speed is a bit low, speed is low," the report said. Four seconds later, the captain said, "Speed is okay." The first officer then asked for "windshield anti-ice. I don't see anything," the report said.

At 0833:05, the captain warned the first officer, "A bit low, bit low, bit low," which was acknowledged by the first officer, the report said. Two seconds later, the autothrottle increased power to 102 percent and "the aircraft leveled off and the airspeed stabilized."

The captain warned that the wind was from 190 degrees at 20 knots [37 kilometers per hour], the report said. The autopilot was then switched from CWS to manual.

At 0833:12, the airspeed began decreasing and fell below the approach reference speed. "The throttles were reduced to approximately 40 percent, the aircraft pitch attitude was maintained. A rudder deflection [to the left] was registered, reaching a maximum deflection of -22.5 degrees. The rotation along the longitudinal axis (roll) [reached] 1.76 degrees (left wing–down)," the report said.

"About three to four seconds before contacting the runway, the captain took action, pulling the elevator to pitch up, almost at the same time when there was an increase in the engine power by the captain's initiative," the report added. "Three seconds later, spoilers No. 3 [and No.] 5 extended and the aircraft had a bank of +25.318 degrees (left wing–up)."

The radio altimeter audio alerted that the aircraft was descending through 15 meters (50 feet). One second later, "the captain warns 'throttle,' and the sound of the throttle levers advancing follows," the report said.

At 0833:20, the aircraft contacted the runway, and "two seconds later, the aural warning for landing gear not down and locked [sounded]," the report said. [Investigators determined that the gear was down and locked.] "The first contact with the runway was made by the right-main landing gear, on the left-hand side of Runway 11," the report said.

The DFDR captured several parameters when the aircraft contacted the runway: 126 knots (176 kilometers per hour) indicated airspeed (IAS); 116.72 degrees magnetic heading; + 8.79 degrees pitch up (maximum elevator detection occurred on contact, and maximum pitch-up of +9.4 degrees occurred one second after contact with the runway); 5.62 degrees roll, left-wing up; 1.9533 G vertical acceleration; and +275 meters per minute (900 feet per minute) vertical descent. The investigators determined that the descent rate should have been 965 meters per minute (600 feet per minute) and that the actual descent rate exceeded the operational limits of the aircraft.

At 0833:28, "roll angle reached +96.33 degrees, with a pitch of -6.39 degrees, nose down, [and] heading was 172.62 degrees," the report said.

The right landing gear collapsed, and "the right engine and right wing tip contacted the runway," the report said. "The right wing suffered total rupture between the fuselage and the right engine. The aircraft slid along the runway for about 30 meters [98 feet] and gradually moved to the right, supported by the center landing gear.

"After the rupture of the right wing, fire developed and enveloped the fuselage from the right to the left. The right wing followed a trajectory next to the aircraft up to the area [where] it came to rest. The aircraft [departed] the runway at the right-hand side, with a track of about 120 degrees, in an inverted position.

"When leaving the runway and entering the runway edge, with soft and flooded ground [caused by] the torrential rain that [had fallen] on Faro Airport, the aircraft rolled left and the left-wing bottom side dug into the ground [and] disintegrated partially, and the fuselage broke into ... sections. It came to rest with the rear section in a normal position and the front section on the left side with the windows and doors [contacting] the ground. The fuel flowing from the tanks caused explosions followed by fire, causing the destruction of the rear fuselage up to the rear pressure bulkhead."

The aircraft came to a stop approximately 1,100 meters (3,609 feet) from the threshold of Runway 11 and 100 meters (328 feet) right of the runway centerline. "The accident occurred inside the airport perimeter," the report said.

The accident "was witnessed simultaneously by the firemen who crewed the vehicles [on the airport] and by the controllers on duty," the report said.

Fire Fighters Provided Key Rescue Assistance Despite Muddy Conditions

An airport fire-truck crew were in their truck with the engine running, next to the fire brigade building, when they observed the crash and explosion. At 0834:45, the fire-truck crew drove to the crash site, positioned themselves close to the left side of the aircraft tail and began fighting the fire. A second fire truck arrived 30 seconds later and took a position close to the tail section.

Shortly thereafter, the rescue services chief arrived at the right side of the wreckage. As the flames diminished in intensity, the chief "saw figures coming out of the aft section of the aircraft and [started the] rescue operation," the report said. As survivors exited the aft section, they also were covered with watery foam that contained aqueous film-forming foam solution (AFFF) particles. [AFFF is a highly efficient fire-extinguishing agent, a primary resource in aircraft rescue, fire fighting and counteracting oil spills.] The evacuation continued for about three and a half minutes, made possible by the fire fighters' actions, which kept escape routes open, until an explosion reignited the fire.

Another fire-truck trying to reach the accident site became stuck in the muddy ground off the runway.

At 0837:09, the fire appeared to be under control, but it was re-ignited by a violent explosion that was located, according to reports of some witnesses, "in the middle of the wreckage" and according to others came "from under the No. 2 engine," the report said. "Together with the explosion, an intense flame spread horizontally up to the middle of the fuselage."

As the explosion took place, panic spread among the survivors, who began "running in the direction of the terminal," the report said. "The team chief and a [person] from the airport operation service picked up some wounded victims … and drove them to the arrival lounge." Airline ground personnel, customs officials and border police "took the wounded to the rescue post in the terminal," the report said. "The nurse on duty had not been warned of the accident."

Moments later, the first fire-truck to arrive at the accident site emptied its water tank, and the driver drove to a well to refill its tank. Forty-five seconds later, the fire-truck that was stuck in the mud emptied its water tank. "The cannon operator [on the truck] [integrated] himself in the rescue operation, and the driver proceeded to [the other truck that had emptied its water tank] in order to help with the refilling," the report said.

The fire appeared to be under control, but it was re-ignited by a violent explosion.

Another fire-truck emptied its water tank at 0838:45. "The cannon operator [joined] the rescue operation, and the driver [received] instructions to go back to the building in the command vehicle and pick up the Mercedes [fire-fighting] vehicle equipped with [fire-extinguishing] chemical powder," the report said.

At 0841:29, "the rescue chief [requested], by radio, transport vehicles and ambulances to evacuate the victims," the report said. Thirty seconds later, another fire-truck ran out of water and departed to refill its tank.

The Mercedes vehicle arrived at the crash site with 1,500 kilograms (3,307 pounds) of fire-extinguishing chemical powder at 0845, the report said. The driver attempted to maneuver the vehicle next to the wreckage, but this was not possible because there were crash victims in the muddy area.

At 0846:40, "the rescue services chief [asked] again for vehicles to transport the victims," the report said. The first ambulance arrived at the accident site at 0851:11, followed five minutes and 46 seconds later by three more ambulances.

A fire-truck that returned from refilling its water tank became stuck in the mud when the driver attempted to obtain a wind-favorable position on the right side of the aircraft.

The Faro municipal fire fighters arrived at 0900:39. Moments later, another ambulance arrived. The driver of another fire-truck

that had refilled its water tanks was returning to the accident site when the truck had a flat tire caused by the wreckage. This truck blocked another fire-truck that was returning on the road to the accident site.

After repeated demands from a fire department team chief, a bus arrived at the accident site to transport survivors who had been in the forward section of the aircraft, the report said. At the rescue station set in the airport terminal, a doctor who had been passing by the airport stopped and assisted a Red Cross nurse in treating the injured persons. The most seriously injured were transported by ambulance to a local hospital.

At 1003:03, "fire re-ignited in the aft cargo compartment [of the accident aircraft]," the report said. "This fire was extinguished [by] the municipal firemen and other brigades."

The airport rescue chief "expressed concern about the large number of people around the accident site, [who were] hampering the rescue operation," the report said. The search for and the gathering of dead bodies continued and 40 to 50 stretchers were requested. At 1107, a Portuguese Air Force aircraft arrived with 60 stretchers, and several Portuguese Air Force helicopters flew survivors to the hospital.

By 1500, "the operation for search and gathering of dead bodies was finished, although later one body was reported missing," the report said. "This body, which was half-buried underneath the wreckage, was only located and removed 47 hours later with the help of a specialized member of the Dutch Police." Military vehicles transported the dead to the morgue at Faro hospital at 1700. The airport reopened at 1900.

Eighty Percent of Those Killed Died in Postcrash Fire

Of the 340 occupants on board the accident flight, 56 (two cabin crew members and 54 passengers) were killed. Of the fatalities, 45 died as a result of the postcrash fire, nine died from head trauma, one died from either trauma or fire and one died from asphyxiation. Two crew members and 104 passengers were seriously injured, while nine crew members and 169 passengers received minor or no injuries. The aircraft was destroyed by the impact and postimpact fire.

All crew members were tested for alcohol only, with negative results. Medical examination and review of the medical histories of the three cockpit crew members revealed no abnormalities that would have contributed to the accident.

When investigators reviewed the wreckage pattern of the accident aircraft, they found that it had touched down "on the left-hand side of Runway 11, with a crab angle of seven degrees to the right and a roll angle of 5.62 degrees, left wing–up," the report said. "The aircraft wreckage was spread over the runway and on [both sides] in an area of around 184,800 square meters [1,989,187 square feet]."

In the touchdown zone of the runway, "traces of continuous sliding could be seen, with an increase in the width of the marks of the tires of the right-main gear and lighter slide marks of the tires of the main-center gear … ," the report said. "After the tire marks on the runway, a parabolic [curved] impact zone could be seen, approximately 15 meters [49 feet] wide, due to the impact and sliding of engine No. 3 on the runway."

The inboard right-wing flap was found on the left side of the runway, at the intersection of a taxiway. A few meters beyond the flap, "a wide and deep cut could be seen, [which had been] produced by the rim of the center-main gear No. 2 wheel," the report said. "This cut could be seen along the runway, turning progressively to the right-hand side and stopping close to the centerline."

The fuselage was found broken into two main parts. "The forward part, not consumed by fire … showed substantial damage on the right-hand side and a cut on the left-hand side … ," the report said. "This fuselage part was oriented 274 degrees west, and the distance between the radome and the runway centerline was 115 meters [377 feet]. The aft part of the fuselage … was consumed by fire, which started after the aircraft came to a stop. This part was oriented at 230 degrees west at [a] distance between the tailcone and the runway centerline of 82 meters [269 feet]."

"The aft part of the fuselage … was consumed by fire, which started after the aircraft came to a stop."

The cockpit was found substantially damaged "on the right-hand side with multiple fractures and skin deformation," which caused the right-lateral window to open, the report said. "Signs of sliding ... on the runway surface could also be seen, and also runway-edge mud, confirmed by the presence inside the cockpit of a [large] quantity of mud, water and vegetation. Inside the cockpit, the instrument panels and systems show[ed] fractures at the attachment points and were partially covered with mud."

When the tail section was examined, investigators found "the horizontal tailplane and right elevator were broken from the fuselage into parts ... ," the report said. "The fractures show that the break-off was caused by bending upwards in a vertical direction towards the vertical stabilizer. These parts were consumed by fire."

The report continued: "The vertical fin and rudder were broken from the fuselage … and fractured in several pieces. The fracture close to the separation zone show[ed] that the break-off was caused by bending forces to the left of the aircraft."

The right wing was found "separated from the fuselage and some meters away from the attachment point, partially consumed by fire," the report said. "Slats No. 1 and [No.] 3, spoiler No. 1 and the inboard aileron were destroyed by fire. Engine No. 3 was connected to the wing by the pylon and showed important deformation caused by sliding on the ground."

The left wing was found "connected to the fuselage, showing several fractures caused by stress and explosion," the report said. "The wing-tip top skin showed marks of sliding on the ground. The inboard flap, vane, spoiler No. 1 and aileron were attached to the wing structure. The inboard flap was extended and at the end of its travel at 50 degrees."

When investigators examined the aircraft cabin, they found that the forward cabin (which, because of favorable wind conditions, was not touched by fire), showed "massive deformation consistent with the sliding on the right-hand side and ceiling, in the soft soil of the runway edge, and mud, sand and light vegetation entered this area," the report said.

The fuselage walls were deformed inward and "caused the general release of ceiling panels and the attachment points, air conditioning ducts and cables, with the isolating materials being exposed, [and] on the right-hand side, the lateral supports failed as well as window frames, PSUs [passenger service units] and luggage bins," the report said.

The left side of the fuselage sustained "less destruction, and it could be verified that panels, bins and PSUs, although deformed, remained in place," the report said. "In spite of the extensive damage sustained by the fuselage, there was no major structural deformation of the cabin floor, including the rails which fix the seats to the bulkheads. The after-impact state of the remaining cabin interior as passenger seats, jump seats, galleys, lockers and bulkheads, was very much affected by the rescue services [that evacuated] wounded passengers and trapped passengers."

The central and aft fuselage from row 17 "was destroyed by impact or by the explosions and subsequent fire, [and] it was not possible to examine the wreckage to assess the postimpact state of its equipment," the report said.

Investigators recovered seat groups from rows 16 and 22, and groups H, G and K from row 26, the report said. "These seats, many of which were destroyed by fire, showed great structural deformation, but it was not possible in the majority of the cases to separate the result of impact from the action of the mechanical means used to remove the wreckage," the report said. "The seats of rows 23 to 41, as well as the remaining cabin equipment of this section, were consumed by fire, which destroyed this part of the fuselage."

The passenger and cargo doors and escape slides were examined. On the left side of the aircraft, the crew and forward passenger door "showed evidence of being forced by the rescue teams," the report said. "The escape slide had a cut." The intermediate passenger door was closed and deformed, with the escape slide intact.

The central passenger door "was ejected from the aircraft and showed cuts in the structure," the report said. "It was found [about] five meters [16.4 feet] from engine No. 3. The girtbar was buried in the ground. The escape slide was not found." The aft passenger door "was destroyed, still connected to the rail, but in an inverted position," the report said. "The escape slide was released, not inflated and [was] destroyed. The upper cargo compartment door "showed indication of being sawed with [a] mechanical saw by the rescue team."

When the right-side doors and escape slides were examined, the crew and forward passenger door "was deformed but intact," the report said. "The escape slide was intact." The intermediate passenger door "was separate[d] from the aircraft and deformed," the report said. "The escape slide was intact." The aft passenger door "was not found and [was] presumed [to have been] destroyed in the fire that started after the aircraft came to rest," the report said. "The escape slide was destroyed."

All three engines were operating "at high RPM and were delivering power at impact."

No Signs of Precrash Fire or Mechanical Malfunction Found

The aircraft's engines were examined and showed no evidence of an internal fire, the report said. All three engines were operating "at high RPM [revolutions per minute] and were delivering power at impact," the report said.

The No. 1 engine was found "separated from the wing by fracture of the pylon thrust fittings and pylon aft bulkhead, and was located … on the right-hand side of the fuselage and close to the zone of separation of the two fuselage sections," the report said. The No. 2 engine was found "in its normal position on the aircraft, in the tailcone," the report said.

The No. 3 engine "was connected to the wing by the pylon," the report said. "The pylon was deformed with the engine leaning to the left. The cowling was touching the ground in the area between 7 [o'clock] and 10 o'clock (seen from [the rear])."

All landing gear were located and examined. The right-main gear "components were found attached to the right wing or in its vicinity, except the truck beam, which separated from the gear assembly and was found at approximately 10 meters (33 feet) to the left [of the wreckage]," the report said.

The left-main gear "was intact and in the position down and locked," the report said. "It was verified that the tires were damaged by fire." The main-center gear "was in the position down and locked, but totally destroyed by fire," the report said. The right-hand wheel showed damage to the right rim, resulting from scraping through the runway, which made the tire separate, [and it] was found close to the runway centerline." The nose gear showed no damage "and it was down and locked," the report said.

The history and maintenance records of the accident aircraft were reviewed. The aircraft was manufactured in 1975, at which time it was purchased by the Royal Dutch Air Force. At the time of the accident, all applicable airworthiness directives (ADs) were up to date.

The aircraft technical log was recovered from the crash site, the report said. A review of the log, plus additional information supplied by the operator, showed no pending items that affected the airworthiness of the aircraft. Nevertheless, the aircraft was dispatched from Amsterdam with the No. 2 engine thrust reverser unserviceable. This was in violation of the aircraft operations manual (AOM) dispatch deficiency guide, "which made landings in Amsterdam mandatory with three operating reversers," the report said.

The weight-and-balance for the accident flight was computed by investigators and found to be within the limits prescribed in the accident aircraft's AOM.

Final Flight Phase Reconstructed Using On-board Recorders

The accident aircraft was equipped with a cockpit voice recorder (CVR) and a DFDR. "The CVR and [DFDR] were found in the aircraft wreckage in the tail right side, with the covers showing signs of [exposure] to fire," the report said. When the CVR was opened, investigators found that approximately 10 centimeters (four inches) of the tape had been destroyed. "The recording [ended] when the aircraft landed at Faro," the report said.

When the CVR tape was reviewed, "the legibility of the recording was [poor because of] a strong background noise, which severely affected the reading; therefore, it was necessary to request the help of [the] NTSB [U.S. National Transportation Safety Board], which used a digital filtering technique to remove noises," the report said.

The DFDR was sent to the NTSB for readout. The DFDR tape "showed discoloration and contamination, mainly in the [section that registered during] the last minute before the accident," the report said, but investigators were able to successfully read the tape.

The aircraft was dispatched from Amsterdam with the No. 2 engine thrust reverser unserviceable.

The accident aircraft was also equipped with an airborne integrated data system (AIDS), the report said. "It was possible to reconstruct the development of the last flight phase, using the recordings of [the] DFDR, AIDS and [air traffic control] radar," the report said.

The background and qualifications of the flight crew were reviewed. The captain, 56, held an airline transport pilot (ATP) certificate that was valid until February 1993. He had logged a total of 14,441 flying hours, with 1,240 hours as captain in the DC-10. In 1992, the captain made five flights to Faro Airport.

The captain had been employed by Martinair since 1968. Since joining Martinair, he had been a training captain on the Convair CV-640; first officer on the McDonnell Douglas DC-8; captain and instructor on the McDonnell Douglas DC-9; captain, instructor and deputy chief pilot on the Airbus A310; and first officer, captain and instructor on the DC-10.

The captain had been involved in two incidents during his flying career, the report said, but the nature of the incidents was not revealed.

The first officer, 31, held a commercial pilot certificate and an instrument rating. He had logged a total of 2,288 hours, with 1,787 hours as first officer in the DC-10. The first officer had made no flights to Faro Airport in 1992, but he had made one flight to Faro in 1990.

The first officer obtained his private pilot license in 1983 and his commercial certificate and instrument rating in 1988. He was then employed as a business aviation pilot flying the Cessna 172 and Cessna 182. He was also employed as a first officer on a CE-550 (Cessna Citation) for six months, until being hired by Martinair Holland in 1989. He entered initial training as a first officer on the DC-10. The first officer did not have any reports of previous accidents or incidents.

The flight engineer, 29, held a flight engineer certificate that was valid until May 1993, and he was an instrument-rated commercial pilot. He had logged a total of 7,540 flying hours, with 1,348 hours as flight engineer on the DC-10. He began his flying career as a pilot for oil and charter companies.

The flight engineer had obtained his commercial certificate and instrument rating in Canada. He began his flying career as a pilot for oil and charter companies. He was employed as a second officer for Canadian Airlines in 1988, a flight engineer for Swissair from 1989 to 1991 and a second officer for Canadian Airlines in 1991, and he was hired by Martinair as flight engineer on the DC-10 in 1992, the report said. The report said that the flight engineer had been involved in some previous accidents as a pilot, but it gave no details.

The flight crew all had valid medical certificates, with no restrictions.

Investigators reviewed the activities of the flight crew during the 72 hours preceding the accident and did not find "any significant abnormalities of behavior or evidence of overwork or jet lag," the report said. "However, it was not possible to find in detail the private activities of the crew in this period, i.e., rest hours before reporting for duty."

The weather encountered by the accident flight was reviewed. "The sky was very cloudy or overcast, with a predominance of vertical cumulonimbus clouds associated with bands of convergence, causing rain [and] heavy showers, at times with thunderstorms," the report said. Between 0827 and 0837 (the period during which the accident occurred), "the average rainfall intensity reached values of around 60 [millimeters] to 65 millimeters (2.3 inches to 2.5 inches) per hour, which means that a violent storm arose," the report said.

Wind sensors in the vicinity of the Runway 11 threshold showed that at 0832:30 (about a minute before touchdown), "a rotation in wind started (20 degrees + 20 degrees + 10 degrees in a period of one minute) and an increase of average intensity (from 20 [knots] to 27 knots [37 kilometers per hour to 50 kilometers per hour] in a period of two minutes) and then between [0832:30 and 0833:00], a gust of 35 knots [65 kilometers per hour] with a magnetic direction of 220 degrees occurred," the report said.

A special weather observation at Faro Airport, taken approximately six minutes after the accident, reported the following conditions: Wind from 170 degrees at 23 knots (43 kilometers per hour) gusting to 34 knots (63 kilometers per hour), visibility 3.1 miles (five kilometers), light or moderate thunderstorm without hail but with rain, 3/8 stratus at 300 feet (91 meters), 7/8 stratocumulus at 2,300 feet (702 meters) 2/8 cumulonimbus at 2,000 feet (610 meters), temperature 55 degrees F (13 degrees C), dew point 54 degrees F (12 degrees C).

The Netherlands National Aerospace Laboratory (NLR) investigated the wind-shear conditions in the vicinity of Faro Airport during the accident flight's approach, the report said. The study revealed that the accident aircraft "crossed a downburst during the final-approach phase, from which it emerged at [214 meters (700 feet)] without negative effects, except the beginning of the oscillations in the flight parameters."

The report continued: "At around one kilometer [0.6 mile] from the runway threshold, the aircraft crossed two more [small microbursts]. The last microburst created variations in headwind and tailwind in an intensity that could have triggered the wind-shear warning system if the aircraft had been equipped with such a device." [A microburst is a downburst that has a maximum horizontal extent of four kilometers (2.5 miles)].

At times during the final approach wind-shear values could have exceeded the accident aircraft's performance limits, the report said.

Investigators reviewed the actions of the accident flight crew during the approach. "As a whole," the report said, " ... the crew coordination procedures were performed in a satisfactory way."

"The longitudinal instability [that] was registered during the final phase of the approach may have induced the pilot to manually reduce the power, in order to bring the aircraft back to the glidepath or with the objective of stopping the sequence of oscillation which probably resulted from an interaction between the operation of the automatic systems, namely the ATS [automatic throttle system] and the operation of the controls by the pilot," the report said.

The instability may have resulted when the aircraft encountered an updraft while the autopilot was engaged in the command mode, the report said. The oscillations were aggravated when the autopilot was switched to CWS.

Between 0827 and 0837 (the period during which the accident occurred), "a violent storm arose."

The approach became unstable "when the aircraft was at a radar altitude of [229 meters (750 feet)] and continued during the remainder of the approach," the report said. "The [Martinair] company operations manual … strongly recommends that in cases when an approach is not stabilized at [153 meters (500 feet)] (height above touchdown) or below that level, the approach should be abandoned … ."

The report said that the captain should have "considered the approach as unstable when the rate-of-descent below 500 feet suffered variations between [+31 meters per minute and 397 meters per minute (100 feet per minute and 1,300 feet per minute)] … ."

The report said that the high sink-rate resulted from "the fact that the throttles were reduced to idle at a radar altitude of about [46 meters (150 feet)], when under normal circumstances the autothrottle should only initiate the retard mode at a radar altitude of [15 meters (50 feet)] ."

The power was prematurely reduced to idle, probably as a result of the crew's concern about the landing distance available and to prevent excessive airspeed, the report said.

As the aircraft crossed the runway threshold, it "encountered a crosswind component of 40 knots [74 kilometers per hour], and a tailwind component of 10 knots [19 kilometers per hour] … ," the report said.

"The switching from CWS mode to normal flight just before landing [at RA 25 meters (80 feet)] must have contributed [to] the abrupt flare followed by the hard landing due to the fact that the landing technique with CWS on is significantly different from manual landing," the report said. "The switching from CWS to manual was provoked by the [captain's] command of right wing–up, which was counteracted by the [first officer]."

The Faro approach controller did not warn the accident flight of the possibility of wind shear during its approach, nor did the crew of the aircraft that landed before the accident flight report a wind-shear encounter, the report said. However, "it's thought that the captain [of the accident flight], as an experienced professional, could be aware of the possibility of [an] occurrence of this type of phenomen[on] in the meteorological conditions present in the Faro Airport area," the report said.

The report noted: "The crosswind component resulting from the wind provided by the approach controller was 14 knots [26 kilometers per hour] and the one resulting from the [aircraft's INS] was 20 knots [37 kilometers per hour] … . According to the AOM procedures, the crosswind component should not exceed 15 knots [28 kilometers per hour] under braking conditions 'medium' and five knots [nine kilometers per hour] under braking conditions 'poor.' The use of flaps selection 35 degrees, as recommended in company procedures for … wind-shear conditions, instead of the 50-degrees selection [that] was used, would have [increased] the landing distance."

Using the 35-degree flap setting would have increased the accident flight's landing distance by 300 meters (984 feet), which would have exceeded the landing distance available on Runway 11 by 255 meters (837 feet). "The crew did not use operational procedures which took into account the occurrence of wind shear," the report said.

Investigators reviewed Faro Airport's facilities and navigational aids (NAVAIDs). The airport's only runway (11/29) is 2,490 meters (8,170 feet) long and 45 meters (148 feet) wide. The runway lighting consists of edge, touchdown-zone and centerline lights. The approach ends of both runways are equipped with precision approach path indicator lights. "Lighting of Runway 11 was in perfect working condition at the time of the accident," the report said.

The available NAVAIDs consisted of a VOR/DME and a nondirectional beacon (NDB).

Information on surface winds at Faro Airport was gathered by sensors installed near the thresholds of Runways 11 and 29, and the information was displayed in the airport control tower "at the Airport Control and Approach Control [positions]," the report said. The displays in the airport control tower "show the wind for Runway 11 or 29, according to the selection made," the report said.

The report noted that the wind-display selector "is a rotating switch, which rotates 30 degrees between the reference marks for Runways 11 and 29," the report said. "The displays do not show any other information that clearly could determine which runway was selected."

Investigators determined that the wind information provided to the accident flight by Faro Approach Control was for Runway 29. As a result, the approach controller who provided wind information to the accident flight said he was not aware of any wind gusts while the accident aircraft was on short final to Runway 11.

Based on its investigation, the DGAC Investigation Commission presented the following conclusions:

- "The aircraft was in an airworthy condition and was properly certified for the flight;
- "The weight-and-balance was within the approved limits;
- "There were no indications of faults on the aircraft or its systems that could either have contributed to the degradation of safety, nor could have increased the workload on the crew during the last phase of the flight;
- "The inoperative items at departure from Amsterdam did not affect the aircraft operation;
- "The crew [were] properly ... qualified and certified for the operation of the aircraft;
- "The air traffic controllers were properly licensed and qualified;
- "The aircraft in the final phase of the approach crossed a turbulence area associated with microburst and downburst phenomena that initiated a longitudinal instability of the aircraft;
- "The use of the automatic flight control systems (ATS [and] CWS) could have degraded the crew's perception of the turbulence and the instability of the approach;
- "The aircraft was informed by [Faro] Approach Control that the runway was flooded. The crew did not associate the term flooded with bad braking conditions (Poor), due to a lack of update of the ICAO [International Civil Aviation Organization] phraseology in the [AOM] and Crew Training Manual;
- "Faro Approach Control did not transmit to the aircraft the [information that winds] on Runway 11 … reached 220 degrees with 35 knots [65 kilometers per hour] between [0832:40 and 0833:30];

- "The captain's intervention during the whole approach seems to have been too passive, and concerning the last power increase, it came too late;
- "The accident was generally survivable; [nevertheless, the survival rate was reduced] by the fire [that] broke out and [spread] after the impact;
- "The action of the fire-fighting personnel [made] a significant contribution to the [survival] of the passengers of the aft section [by] keeping open the escape routes;
- "The emergency plan was activated correctly, but its further development was affected by insufficient coordinating instructions; [and,]
- "The medical equipment at Faro Airport at the time of the accident was inadequate in certain respects."

Weather and Multiple Human-error Factors Contributed to Accident

The DGAC determined that the probable causes of the accident were "the high rate of descent in the final phase of the approach and the landing made on the right landing gear, which exceeded the structural limitations of the aircraft, [and] the crosswind, which exceeded the aircraft limits and which occurred in the final phase of the approach and during landing."

The report said that the following factors contributed to the accident:

- "The instability of the approach;
- "The premature power reduction and the sustaining of this condition, probably due to crew action;
- "The incorrect wind information delivered by [Faro] Approach Control;
- "The absence of an approach-light system;
- "The incorrect evaluation by the crew of the runway conditions;
- "CWS mode being switched off at approximately [24 meters (80 feet)] RA, causing the aircraft to be in manual control in a critical phase of the landing;
- "The delayed action by the crew in increasing power; [and,]
- "The degradation of the lift coefficient due to the heavy [rain] showers."

Based on its investigation, the DGAC Investigation Commission developed a number of recommendations. Some of the significant recommendations made to Martinair were:

- Review procedures for takeoffs and landings and specify when the first officer should be allowed control of the aircraft during adverse weather and/or during marginal operating conditions;
- Review procedures for operation of the aircraft with the No. 2 engine thrust reverser inoperative; and,
- "Reassess the training of crews concerning wind shear, especially concerning the recognition … of this phenomenon."

Some of the significant recommendations regarding the operation of Faro Airport were:

"The high rate of descent in the final phase of the approach and the landing made on the right landing gear … exceeded the structural limitations of the aircraft … ."

- Install a runway approach-light system;
- Install wind displays in the control tower that conform to international standards;
- Install wind sensors on Runway 11 that conform to international standards;
- Improve emergency access routes from the fire brigade building to the runway and create [an] alternative access [route], and improve terrain drainage ;
- Improve the water refill system for fire fighting vehicles; and,
- Review and change airport emergency plans to conform with ICAO standards.

The Netherlands Aviation Safety Board (NASB) commented in the final accident report: "The [NASB] is of the opinion that the Portuguese report, in general, correctly reflects the course of events leading up to the accident. The [NASB] agrees with the factual information and generally agrees with the analysis and the conclusions drawn from it."

But the report added: "The [NASB believes] that the analysis of several aspects in the course of events should be expanded, in order to accurately determine the probable causes of the accident and the contributing factors, for the purpose of learning the lessons and taking accident prevention measures."

The NASB noted that "the crew of the [accident flight] [had] been fully aware [of] the prevailing weather at the Faro Airport, with the exception of the extreme conditions at the time of the accident," the report said. "From the forecast and the prevailing weather, the crew … did not expect the ... wind-shear phenomena. … Consequently, according to AOM procedures, the crew briefing incorporated a standard 50-degree flap landing, anticipating a wet runway."

The NASB said that "the Actual Landing Distance as calculated by the crew according to company regulations, was within the Available Landing Distance. With the reported wind [of] 150 degrees, [15 knots to 20 knots (28 kilometers per hour to 37 kilometers per hour)], the crosswind component was within the limit of 30 knots [56 kilometers per hour] for braking action 'Good' and also within the limit of 15 knots [28 kilometers per hour] for braking action 'Medium.'"

Knowing the runway was wet, the captain "instructed the [first officer] to make a positive touchdown, which is standard operating procedure to avoid aquaplaning," the report said. "The reported weather at Faro was not of exceptional concern to the crew, since, with the precautions they had taken in view of the wet runway, all conditions were within the operational limits of the aircraft."

Nonstandard Terminology Led to Crew Misunderstanding

The NASB commented on the Faro approach controller's report to the accident flight that "the runway conditions are flooded," the report said. In ICAO terminology, the word "flooded" indicates that "extensive standing water is visible," the report said. "This word should, if possible, be accompanied by a figure indicating water depth. The word 'Flooded,' however, did not trigger the crew's mind, and its significance was not realized by the crew."

The captain understood the term "flooded" to mean that the runway was wet, the report said. "In the AOM, no reference is given to the word 'Flooded,'" the report said. "The AOM states that braking action is 'Medium' with 'Moderate to heavy rain on a clear runway' and 'Poor' with 'standing water.' If the crew had understood the meaning of the word 'Flooded,' they would have considered the braking action as 'Poor.' In view of the prevailing weather, with heavy rain at times, they applied the AOM tables for braking action 'Medium.'"

The NTSB also commented on the DGAC's final report. The NTSB said that in accordance with Martinair's AOM approach precautions for wind-shear procedures, "it appears from the report that the following procedures were not followed:

- "Achieve a stabilized approach no later than [305 meters (1,000 feet)] AGL [above ground level];
- "Avoid large thrust reductions or trim changes in response to sudden airspeed increases, as these may be followed by airspeed decreases;
- "Consider using the recommended flap setting. (Recommended flap setting is minimum flap setting authorized for normal landing configuration.); [and,]
- "Use the autopilot and autothrottles for the approach to provide more monitoring and recognition time. If using the autothrottles, manually back up the throttles to prevent excessive power reduction during an increasing performance shear."

The NTSB concluded: "During the approach, use of flaps 50, the low airspeed and throttle movement to idle minimized the flight crew's options for recovery and increased the recovery time required. Once the autopilot was disengaged, CWS with ATS remained, functions which were inappropriately used by the flight crew."♦

Editorial note: This article was adapted from *McDonnell Douglas Corporation DC-10-30F, Martinair Holland NV, Final Report on the Accident Occurring at Faro Airport — Portugal, on 21 December 1992*, Report no. 22/Accid/GD1/92, prepared by the Director-General of Civil Aviation (DGAC) of Portugal. The 150-page report was unofficially translated from Portuguese into English by the Netherlands Aviation Safety Board, and in the event of conflicting text, the Portuguese report is the valid document.

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