ACCIDENT

Aircraft Type and Registration:	Boeing 757-225, TF-ARD
No & Type of Engines:	2 Rolls Royce RB211-535E4 turbofan engines
Year of Manufacture:	1985
Date & Time (UTC):	20 August 2005 at 1210 hrs
Location:	Palma, Majorca
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 9 Passengers - 229
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the radome, landing lights and co-pilot's windscreen
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	8,000 hours (of which 4,000 were on type) Last 90 days - 130 hours Last 28 days - 60 hours
Information Source:	AAIB Field Investigation

Synopsis

Shortly after departure from Palma Airport, the aircraft entered a small but intense area of hail associated with a cumulo-nimbus cloud which was not identified on the aircraft's weather radar. Although the encounter caused damage to the aircraft's radome, landing lights and co-pilot's windscreen, the flight continued to its destination, London Gatwick, without incident.

History of the flight

The aircraft had departed London Gatwick airport at 0834 hrs that morning for a scheduled flight to Palma Airport, Majorca before returning to Gatwick. The flight was uneventful and the aircraft landed at Palma in good weather at 1020 hrs.

Following the turnaround, the co-pilot was to be the Pilot Flying (PF) for the return trip. Whilst the aircraft was on the ground, the weather deteriorated and a thunderstorm with heavy rain drifted over the airport. Departures were delayed and the Standard Instrument Departure (SID) for Runway 06R, the departure runway, had been cancelled with aircraft now being cleared to maintain runway heading to assigned altitudes to avoid the worst of the weather. TF-ARD was 'pushed back' at 1150 hrs, followed by an extended time to taxi to the holding point for Runway 06R because other aircraft departures were being delayed due to the thunderstorm. By the time the aircraft received its departure clearance, which was to maintain runway heading to 3,000 ft, the rain had stopped and other aircraft were departing with normal timed spacing. When the aircraft was lined up on Runway 06R, the checklist was completed and the weather radar was selected to ON. In accordance with Standard Operating Procedures (SOPs), the commander, as the Pilot Not Flying (PNF), had his Navigation Display (ND) set to Weather with a range of 20 nm selected and the radar beam tilted 5° up. The co-pilot had Terrain selected on his ND. The only weather returns displayed on the screen were green with no active cells showing.

The aircraft which departed ahead of TF-ARD was an A321, with the same departure clearance. The commander of that aircraft was the PF and also had his weather radar selected ON and set to 20 nm range. He recalled that, shortly after takeoff, there was an isolated, small, weather return at about 5 nm which he made a 10° turn to the right to avoid. He did not consider it very active but, in view of the recent weather, thought it prudent to take the avoiding action. When abeam that cell, another much larger and active cell was displayed at about 15 nm ahead, and he made a 50° avoiding left turn. This aircraft did not encounter any heavy rain, hail or severe turbulence during the departure or the climb to cruising level.

Having received take-off clearance, the co-pilot of TF-ARD carried out the takeoff and climbed on runway heading, in accordance with the departure clearance. The aircraft was in Instrument Meteorological Conditions (IMC) with no significant weather being displayed on the weather radar and, initially, no rain or turbulence was encountered. From the crew's recollection, at about 3,000 ft the aircraft encountered heavy hail which, although very short in duration, produced an extremely loud sound on the flight deck. The autopilot remained engaged and the PF continued the departure. The weather radar failed and the aircraft continued the climb in IMC without encountering further precipitation. The crew were aware that the aircraft had been damaged, as the co-pilot's windscreen was cracked but, on feeling the inside surface of the screen, the co-pilot confirmed that only the outer layer had suffered damage. With no weather radar and the windscreen damage not preventing further climb, the crew elected to continue to their destination rather than returning to Palma and risk encountering further severe weather.

During the flight to Gatwick the commander asked the cabin crew to inspect the engine nacelles and wing leading edges for evidence of damage, but none was apparent. Also, the flight crew could not hear any unusual noises on the flight deck that might have suggested severe damage to the radome, and there appeared to be no increase in the rate of fuel consumption. The aircraft made a normal landing at Gatwick, with the co-pilot as the PF, as he had adequate visibility through his damaged windscreen. The aircraft was taxied to a remote stand where the passengers were disembarked.

Weather

The synoptic situation at 1200 hrs showed an active cold front over Majorca, lying from Northern Italy to the Eastern Spanish coast, moving slowly southeast. Satellite pictures indicated a line of thick frontal cloud over Majorca which extended north-eastwards to the southern coast of France. A cumulo-nimbus cell was situated over the southwest of the island of Majorca in the vicinity of Palma Airport.

The Palma Airport Terminal Area Forecast (TAF) and Meteorological Actual Reports (METARs) covering the period of the flight were:

TAF

LEPA 200800Z 201019 33010KT 9999 FEW015 BKN050 TEMPO 1019 05008KT TEMPO 1019 5000 TSRA SCT020CB PROB30 TEMPO 1019 3000 TSGR

METAR

LEPA 201200Z 33008KT 1400 R24/P1500 TSRA FEW009 SCT020CB BKN035 20/18 Q1019 NOSIG

LEPA 201230Z 01006KT 320V060 6000 RA FEW008 FEW020CB BKN040 21/19 BECMG NSW

Aircraft Damage

Inspection of the aircraft confirmed that the outer layer of the co-pilot's windscreen had been cracked, both of the wing root landing light lenses had been shattered and that the radome had been severely damaged, with several large areas of material missing from its most forward region, Figure 1. Due to the length of flight, it could not be determined if the tears in the radome had been caused directly as a result of the hail encounter, or as a result of the aerodynamic loads imposed as the aircraft continued to Gatwick.

The radome is a fibreglass honeycomb structure, comprised of inner and outer skins, bonded to a honeycomb material between the skins, which provides structural rigidity. The outer skin had disbonded from the honeycomb layer over a circular area of some 60 cm radius, and aerodynamic loads had caused it to be deformed inward, which had prevented movement of the weather radar antennae. The antennae itself appeared to have been undamaged. The radome hinges, latches and fuselage location points were undamaged and the radome itself remained securely located.

The Boeing 757 windscreens are built up from several layers of toughened glass, interspersed with layers of a softer material intended to prevent complete shattering of the screen. The glass outer layer is non-structural and hence, if cracked or crazed due to, for example, impact damage, the overall strength of the screen is not compromised. The other glass layers provide the structural element of the windscreen. The outer pane of the first officer's windscreen was crazed; examination showed evidence of eight crack initiation points and in excess of 32 further impact points. Damage was limited to the outer ply and hence did not cause a reduction in the structural integrity of the windscreen. The commander's windscreen was not cracked and showed no evidence of impact points.

Three cabin window outer panes, adjacent to seats 19A, 23F and 24F were damaged. These windows consist of three panes, an inner non structural 'scratch' panel and a middle and outer structural pane. The outer pane is designed to be capable of carrying the maximum design fuselage pressure differential and the middle pane is designed to be capable of carrying 1.5 times

Figure 1

Damage to radome

the same pressure. This ensures that, in the event of either the middle or outer pane failing, the cabin would remain fully pressurised. The damage was restricted to the outer panes and consisted of a single gouge on windows 19A and 23F and two gouges on window 24F, all approximately four and five centimetres in length and two millimetres in depth. There was no evidence that the panes had cracked. The appearance of the gouges indicated that they had been caused by sharp edged objects, rather than by hail impact, and it is highly likely that these windows were struck by pieces of the shattered landing light lenses.

A further detailed examination of the airframe and engines revealed several small impact points on the fuselage, immediately aft of the radome, and on the leading edges of both wings and the horizontal and vertical stabilisers. All of the damage was within the limits specified in the aircraft's Maintenance Manual and did not require rectification action. The weather radar was functioned and found to be serviceable.

The radome, landing lights, passenger windows and the co-pilot's windscreen were replaced and the aircraft returned to service.

Flight Recorders

The aircraft was fitted with a 25 hour Flight Data Recorder (FDR)[1] and a Cockpit Voice Recorder (CVR)[2] of 30 minutes duration. The CVR recordings made at the time of the incident were overwritten with more recent information when the aircraft was on the ground after landing.

Examination of the data from the FDR for the flight showed nothing abnormal during the departure from Palma. The recorded vertical and longitudinal accelerations showed no change from their nominal values during the period of the incident. However, it was noted that the four samples per second sample rate for normal acceleration was only half that specified by JAR Ops Requirements. This matter is being investigated by the Icelandic AAIB.

Analysis

Given the weather conditions for the departure, the crew ensured that the weather radar was being used in accordance with the Standard Operating Procedures (SOPs). The FDR data did not show clearly where the hail encounter had occurred but the A321 commander and the B757 crew's recollection was that they both encountered the hail at an altitude of about 3,000 ft. This suggests that the small weather radar return observed by the A321 commander may have been the area of hail encountered by the B757. It is considered that the B757 probably did not fly through the larger, active storm cell, which the A321 commander turned to avoid. It is also possible that the hail was falling from the anvil of a cumulo-nimbus cloud, separated by some distance from the main cell. However, whilst the damage was relatively severe, the aircraft remained in a safe condition and was able to return to Gatwick. As noted by the cabin crew, there was no observable damage to the engine intakes or flying surfaces that could be seen in flight, and only the outer, non-structural, layer of the co-pilot's windscreen was cracked.

A major limitation of the aircraft weather radar systems is that ice crystals or hail may only produce small, or no, returns. This was a feature in a previous event reported by the AAIB (G-MIDJ, AAIB Bulletin 6/2004). Only rain or soft hail is detected and the intensity is displayed

Footnotes

[1] Honeywell Universal Flight Data Recorder UFDR: *Part Number 980-4100-DXUN, Serial Number 9763*.

[2] L-3 A100A CVR: *Part Number 93-A100-80, Serial Number 62388.*

as colours ranging from green (low intensity) to red (high intensity).

The UK Civil Aviation Authority have published an Aeronautical Information Circular (AIC) 81/2004 (Pink 66), entitled '*THE EFFECT OF THUNDERSTORMS AND ASSOCIATED TURBULENCE ON AIRCRAFT OPERATIONS',* which sets out the limitations of, and recommended practices to be adopted when using, weather radar. Of relevance to this incident are the following paragraphs:

> *'Para 2.4.1*
>
> *Stability in the upper atmosphere results in the characteristic anvil shape of the spreading out of the top of the Cumulo-nimbus cloud and strong upper winds will often cause hail to fall from the overhang. Flight beneath the overhang should be avoided'.*

> *'Para 2.10.3 (b)*
>
> *Although wet precipitation is the most reflective of radar signals, other water products will reflect lesser amounts of incident radar energy. In descending order (ie from most to least reflective) these are: wet hail, rain, hail, ice crystals, wet snow, dry hail and dry snow.'*

Conclusions

The aircraft encountered a small but intense area of hail whilst in IMC during its departure from Palma. The weather radar was in use at the time in accordance with the Operator's SOPs but this did not detect the hail. Whilst the hail encounter resulted in severe damage to the radome and other aircraft components, the flight was safely continued to its destination.