Nacelle collision with ground, Boeing 747-41R, G-VWOW

Micro-summary: **While landing in a stiff crosswind, this Boeing 747's #1 engine nacelle touched the ground.**

Event Date: **2005-11-03 at 1714 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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INCIDENT

Aircraft Type and Registration:	Boeing 747-41R, G-VWOW
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	3 November 2005 at 0714 hrs
Location:	Runway 27R London (Heathrow) Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 20 Passengers - 348
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to lower side of engine pod
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	9,470 hours (of which 2,740 were on type) Last 90 days - 221 hours Last 28 days - 81 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft flew an approach to Runway 27R at London (Heathrow) Airport, whilst subjected to a crosswind component of approximately 30 kt from the left. A roll to the left immediately after touchdown was not detected by the handling pilot who was concentrating on selecting reverse thrust on the engines. This roll resulted in the left hand (No 1) engine striking the ground. It subsequently transpired that the crosswind component had reduced from 32 kt to 8 kt in the last 25 ft of descent prior to touchdown.

History of flight

The aircraft was flying a scheduled public transport flight from New York's John F Kennedy Airport to London (Heathrow) Airport (LHR). Prior to departure the flight crew had studied the weather forecast information, and in particular the landing conditions at LHR. The forecast indicated that LHR would be subject to a strong southerly wind with a high probability of heavy rain showers. During the cruise the flight crew updated themselves on the LHR forecast and actual weather utilising the ARINC Communication Addressing and Reporting System (ACARS). When preparing for their approach, the crew received the LHR ATIS which advised that the nominated landing runway was Runway 27L, the surface wind was 200°/12 kt and that windshear and severe turbulence could be expected on the approach. The commander, who was the handling pilot, briefed the first officer (FO) on the approach and mentioned that they

could be landing on either 27L or 27R as both runways were commonly used for landing at their estimated time of arrival of 0710 hrs. He also commented that they were likely to encounter a significant crosswind on landing.

Whilst in the hold at the Ockham VOR, the Heathrow Director advised the flight crew that they would be landing on Runway 27R. During the subsequent ILS approach the FO appraised the commander of the crosswind and headwind components, read directly from the Flight Management Computer. ATC cleared the aircraft to land when it was at 1,400 ft and gave a surface wind of 210° at 18 kt; this was the wind automatically averaged over a 2 minute period. The autopilot and autothrust were disengaged at 1,350 ft, at which time the crosswind component was 28 kt from the left. The crew experienced windshear at this point, with a variation in IAS of ±25 kt. The touchdown appeared normal to the flight crew and the speedbrakes deployed automatically, followed by the commander's selection of reverse thrust on all engines. The commander reported that he found operation of the thrust levers slightly awkward as he was relatively inexperienced in operating from the left hand seat. Neither of the pilots was aware of any engine to ground contact.

As the aircraft landed, the flight crew of another aircraft on the ground observed the landing aircraft's left side outer engine contact the runway, and reported this to the ATC ground controller. When the aircraft had decelerated to approximately 60 kt during the landing roll, the ATC tower controller transmitted "WHEN YOU LANDED YOU IMPACTED YOUR LEFT HAND I THINK IT'S THE NUMBER ONE ENGINE COWLING ON THE RUNWAY". The aircraft was then inspected by the AFRS before taxiing to a remote stand where the passengers disembarked without further incident.

Aircraft examination

Examination of the aircraft showed an area of scraping on the underside of the No 1 engine nacelle. The nacelle is made up of a fixed inlet cowl at the front and a fixed C-Duct cowl at the rear, with twin fan cowl doors in between. A sump for waste fluids from the engine, located in the bottom of the nacelle at the aft end of the fan cowl doors, has an overboard drain mast that protrudes below the doors. The damage consisted of longitudinal scraping of the aft part of the inlet cowl, the lower edges of the fan cowl doors and the forward part of the C-Duct cowl, together with slight local deformation of a bulkhead at the aft end of the inlet cowl. In addition, the drain mast on the bottom of the sump had been partly abraded away, and the sump, together with some of the associated pipelines, had suffered local deformation. The engine was not damaged and no fluid release occurred. Inspections to identify runway scrape marks were necessarily brief, as it was not considered appropriate to impose major delays on runway operations; no marks were located.

Tyre pressures and landing gear shock strut pressures and extensions were checked and the deployment sequence of speedbrakes, with and without roll control inputs present, was checked using video of the sequence with the aircraft stationary on the ground. No anomalies were found.

At the time of the examination, with the aircraft lightly loaded (no payload, 18,100 kg of fuel) and supported on its landing gear, the ground clearance of the outboard nacelles averaged 75 inches (1.9 m). Information from the 747-400 Flight Crew Training Manual indicated that, with the engine type fitted to G-VWOW, nacelle ground contact would occur with the combination of aircraft pitch and roll angles shown in Figure 1. The graph

related to a situation with relevant main landing gears in ground contact, with shock struts compressed, and the aircraft pitched about the body gear and rolled about a wing gear. It applied to a 'Normal Landing' situation and it was clear that changes in wing bending due to factors such as inertial loading and lift reduction on spoiler deployment could lead to significant variation in the roll angle at which nacelle ground contact would occur. The nacelle profile differs somewhat for the two other engine types that can be fitted to the B747-400 and it was noted that with one of these types the roll angle required for outboard nacelle ground contact at a given pitch angle can be up to 1° lower than shown in Figure 1.

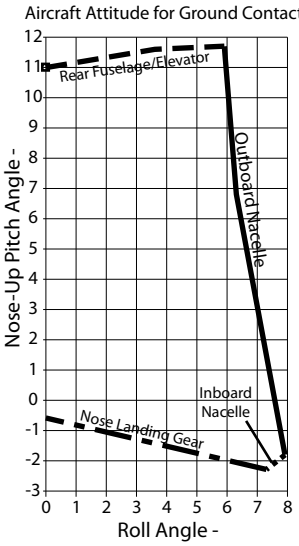

Figure 1

Meteorology

An aftercast from the Meteorological Office stated that a low pressure system centred over Ireland was feeding a fresh to strong unstable south-westerly flow over south-east England. This was reflected in the LHR 0001 hrs TAF which forecast that the surface wind between 0600 hrs and 0900 hrs would become 190° at 22 kt gusting to 35 kt, with the possibility of heavy rain showers and cumulo-nimbus clouds. A meteorological report taken at LHR 6 minutes after the incident measured the surface wind as 210° at 23 kt gusting to 36 kt.

During the final approach, the first officer was reading out wind data derived from the aircraft's inertial system which indicated a rapid reduction in crosswind component as the aircraft entered the flare. Data from the aircraft's Quick Access Recorder indicated a 32 kt crosswind component at a height of 24 ft agl reducing rapidly to an 8 kt crosswind component at mainwheel touchdown.

Air Traffic Control

In order to minimise disturbance to local communities, LHR operates a system of alternating the landing runways on a daily basis as laid down in the Manual of Air Traffic Services (MATS) part 2. Following the normal sequence of alternation, the landing runway in use on the morning of this incident was Runway 27R. It is widely accepted however, that significantly more turbulence is experienced, on the final approach to Runway 27R (with a southerly wind) than on Runway 27L. The UK Aeronautical Information Publication (AIP) contains the following warning for LHR:

> *Pilots are warned, when landing on Runway 27R in strong southerly/south westerly winds, of the possibility of building-induced turbulence and large windshear effects.*

At 0602 hrs, in response to several requests from landing aircraft, the Operations Duty Manager at LHR approved the use of Runway 27L as the landing runway. Arrival aircraft crews listening out on the LHR Director frequencies after this time would not have been aware of the reasons behind the runway selection, and this was the case for the incident aircraft crew.

At 0529 hrs, the LHR Visual Control Room supervisor had approved Tactically Enhanced Arrival Measures (TEAM) operations. These measures can be implemented during periods of significant airborne delays and involve landing aircraft on the departure runway in addition to the nominated landing runway in order to reduce these delays. The aircraft involved in this incident landed on Runway 27R (which had become the departure runway after the change in the nominated landing runway) under TEAM operations.

Flight Data Recording

Data from the Flight Data Recorder (FDR) and Quick Access Recorder (QAR) were successfully recovered. A time history of relevant FDR parameters for the final approach and landing roll is shown in Figure 2. It can be seen that, up to about 6 seconds before touchdown, the recorded wind direction was generally from the south (actual direction about 200°), with a windspeed that varied from about 15 to 30 kt. Right rudder pedal was applied about 6 seconds before touchdown. The recorded QAR windspeed reduced to about 8 kt just before touchdown. These wind parameters were derived from inertial navigation system data. The aircraft appears to have touched down with a small amount of left bank (about 2°) at about 147 kt. After touchdown, there was a rocking motion in roll with a period of about 4 seconds. The bank angle was generally about 2° to the left with an amplitude of about ±2°. After touchdown, left (into wind) control wheel was applied. About 5 seconds after touchdown, the bank angle reached a value of about 5.6° to the left. This coincided with the selection of the thrust reversers. It can also be seen that the control wheel was reduced to the neutral position when this bank angle was achieved, and that the bank angle returned to about zero. Thereafter, into wind (left) control wheel was applied for the remainder of the landing roll.

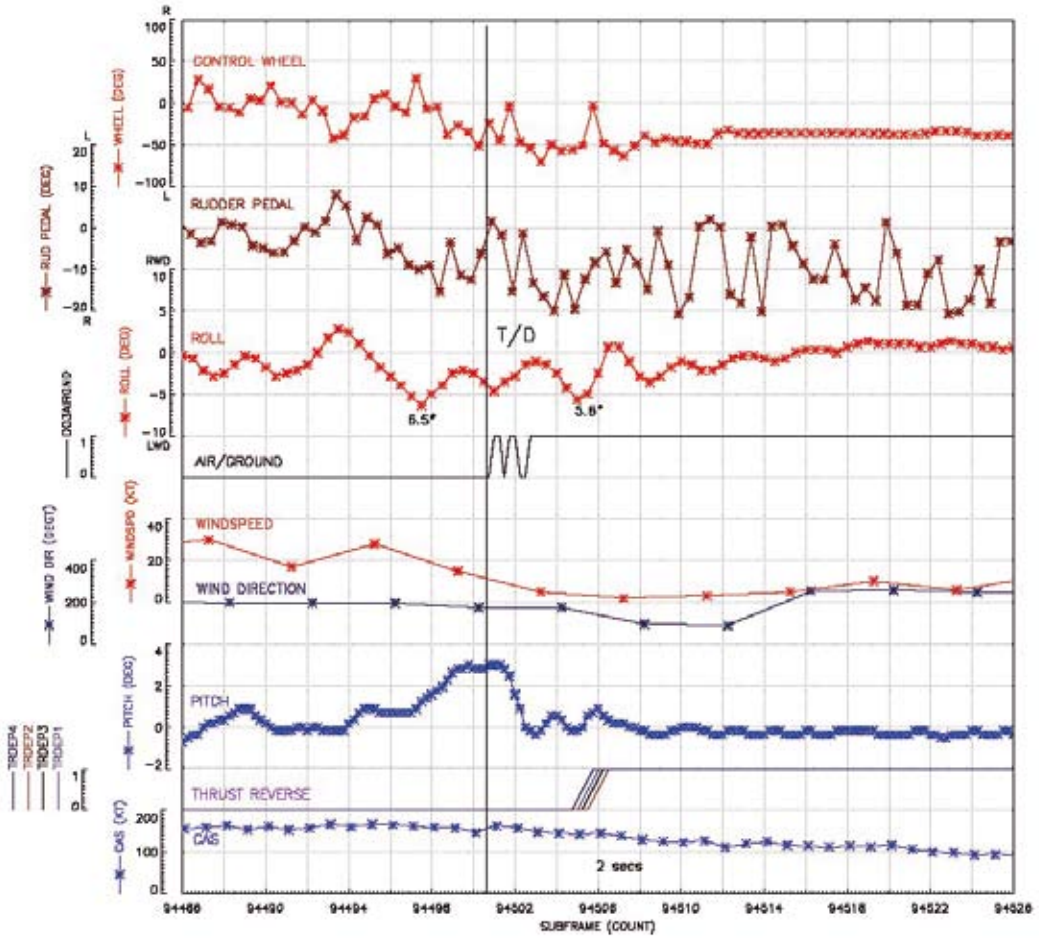

Figure 2

Relevant Flight Data Parameters

Crosswind landing technique

The Boeing 747-400 Flight Crew Training Manual presents three different crosswind landing techniques one of which is the 'de-crab during flare'. This technique is taught on this operator's conversion and command courses and is described in the Flight Crew Training Manual as follows:

> *The objective of this technique is to maintain wings level throughout the approach, flare and touchdown. On final approach, a crab angle is established with wings level to maintain the desired track. Just prior to touchdown while flaring the airplane, downwind rudder is applied to eliminate the crab and align the airplane with the runway centreline.*
>
> *As rudder is applied, the upwind wing sweeps forward developing roll. Hold wings level with simultaneous application of aileron control into wind. The touchdown is made with cross controls and both gear touching down simultaneously. Throughout the touchdown phase upwind aileron application is utilised to keep the wings level.*

This was the technique that the commander was seeking to employ during this incident. The operator uses the manufacturer's maximum crosswind guideline of 32 kt in wet conditions but impose a 20 kt crosswind limit under any conditions when the first officer is the handling pilot. The commander had flown 176 hours in command of this type of aircraft and had not landed with a crosswind greater than 20 kt. During the operator's command course, it is a requirement for the commander under training to show proficiency in crosswind takeoff and landing. The command course simulator syllabus also notes that:

> *'a combination of left and right hand circuits in day and night and including strong crosswinds should be flown'.*

After touchdown the speedbrakes, which are normally pre-armed, deploy to reduce the lift on the wings and thereby improve braking effectiveness. The Flight Crew Training Manual states:

> *'after touchdown, with the thrust levers at idle, rapidly raise the reverse thrust levers up and aft to the interlock position, then apply reverse thrust as required'.*

Discussion

Having received the weather forecast and airfield ATIS, the flight crew were expecting a significant crosswind component from the left during the approach and landing at LHR. The FO's readouts of the crosswind during the approach confirmed what the commander was expecting and experiencing. However, approximately six seconds prior to touchdown, as the commander commenced the 'de-crab during flare' procedure, the crosswind component reduced significantly. This occurred rapidly during a high workload period and is unlikely to have been fully assimilated by the commander. His initial input of left control wheel, in order to keep the wings level during the de-crab manoeuvre, led to a bank angle of approximately 6° to the left, possibly as a result of overcompensating for the expected crosswind. Although this was corrected prior to mainwheel touchdown, the bank angle was not stabilised and the aircraft continued to oscillate in roll, predominantly to the left, after the mainwheels had touched down. Left control wheel input was applied through the touchdown phase as would be expected with a crosswind from the left, and as recommended in the manufacturer's flight crew training manual. A

small additional left control wheel input, coincident with speedbrake deployment, preceded a further roll excursion to the left. The pitch/roll angle combination recorded by the FDR did not reach the predicted attitude limits for nacelle ground contact but these would be affected by changes in wing bending. It was likely that this further roll excursion led to the engine pod contacting the ground. The commander commented that he did not detect this roll developing as he was concentrating on attempting to raise the thrust levers rapidly, as per the flight crew training manual, and he found some difficulty in doing so. It was also relatively dark outside and, together with rain on the windshield, this may have masked his perception of the changing attitude. He was also relatively inexperienced in the left hand seat on this aircraft, and the view over the reverse slope of the flightdeck coaming, compared to that from the right hand seat, may have hampered early recognition of an abnormal bank angle.

The investigation also considered the decision by ATC to direct this aircraft to land on Runway 27R. Earlier that morning a decision had been taken to change the landing runway from 27R to 27L in response to requests by aircraft commanders. Whilst a change of landing runway from 27R to 27L would be unlikely to have any effect on reducing the crosswind component, such a change would significantly reduce flight crew workload during a critical stage of the approach because it would reduce the turbulence encountered. Aircraft on the LHR Director frequencies at the time of this change were asked which landing runway they would prefer and most stated 27L. By the time that the incident flight crew were established with LHR Director, aircraft were no longer being given the option of which runway to use for landing; both 27L and 27R were being used for the landing runway as directed by ATC. This would appear to be inconsistent, since if a choice of landing runway is offered at the time of the decision to change the primary landing runway, then this option should be maintained until there is a significant change in circumstances.

Follow up action

The Operator

In response to this incident, the aircraft operator issued Notice to Aircrew 88/05. This notice re-confirmed the manufacturer's crosswind landing technique described earlier and also added:

> *'Reverse thrust should only be selected when the aircraft is firmly on the ground. Aileron control must not be compromised during reverse selection.'*

The aircraft operator has also included discussion, training and practice of crosswind landing techniques during the next recurrent simulator checks of all its Boeing 747-400 pilots.

Air Traffic Control

London Heathrow ATC Operations issued a Supplementary Instruction (SI 007/06) to MATS part 2 on 17 February 2006 which became effective immediately. This SI restricts the use of Tactically Enhanced Arrival Measures (TEAM) when wind conditions are likely to cause turbulence during final approach to Runway 27R except when there is an urgent operational requirement.