ACCIDENT

Aircraft Type and Registration:	Boeing 747-41R, G-VROC
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines
Year of Manufacture:	2003
Date & Time (UTC):	28 October 2009 at 1956 hrs
Location:	Johannesburg International Airport, South Africa
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 18 Passengers - 228
Injuries:	Crew - None Passengers - None
Nature of Damage:	No 14 tyre burst, part of a landing gear door detached, impact damage to flap and flap fairing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	16,073 hours (of which 8,630 were on type) Last 90 days - 182 hours Last 28 days - 53 hours
Information Source:	AAIB Field Investigation

Synopsis

During the takeoff roll, after passing V_1 decision speed, the flight crew heard a "large thud", which was followed by moderate lateral vibrations and vibrations felt through the control column and rudder pedals. The flight crew continued the takeoff and landed safely at their destination. An investigation revealed that the No 14 tyre had burst during the takeoff ground roll at approximately 160 kt. The evidence indicated that the tyre probably burst when it ran over a foreign object. However, no foreign object was found and due to some missing tyre material, the nature of this object could not be determined.

History of the flight

The aircraft was operating a scheduled passenger service from Johannesburg International Airport (JNB) to London Heathrow Airport. Prestwick was selected as the primary alternate for operational reasons and fuel uplifted accordingly. The resulting takeoff weight was approximately 351,000 kg. The cockpit crew comprised the commander, the co-pilot, who was the pilot flying for takeoff, and a third pilot who would assist the operation at other times during the flight.

The departure and takeoff from Runway 03L was uneventful until shortly after the aircraft passed V_1[1]

Footnote

[1] V_1 is the takeoff/abort decision speed.

speed, when a "large thud" was heard. This was followed by moderate lateral vibrations and accompanied by vibrations felt through the control column and rudder pedals. Upon the commander's call "rotate", the co-pilot pitched the aircraft nose-up and, when a positive rate of climb had been established, called for the landing gear to be retracted. The landing gear was selected up and retracted normally, at which point all unusual airframe vibrations stopped.

The three pilots discussed the thud and vibrations and initially concluded that the nosewheel had hit a runway centreline light, which on previous occasions had caused some vibration. However, on this occasion the vibration was of greater amplitude, and the crew considered the possibility that a tyre had burst during the takeoff. The co-pilot asked the commander to inspect the EICAS[2] 'GEAR' page, which presented no abnormal indications, although tyre pressures were not monitored. He then continued to hand fly the aircraft and judged that it "flew very well" with "no abnormal vibrations or buffeting". The flaps were retracted normally, the autopilot was engaged and the remainder of the departure was flown without incident.

The commander contacted the JNB Tower controller to advise that the aircraft may have suffered a tyre failure and requested a runway inspection. Later, when in contact with a subsequent ATC agency, the commander was advised that a piece of rubber, some honeycomb material and a piece of metal had been found.

Most of the cabin crew reported feeling a thud and vibrations during the takeoff. One stated that at the time of the thud she was nudged sideways in her seat and that the noise came from the left side of the aircraft. The third pilot went into the cabin to speak to a company pilot travelling as a passenger who he judged might be able to offer an informed opinion. The positioning pilot indicated he had felt the thud and vibrations but was not aware of any abnormalities after retraction of the nosewheel, close to which he was seated.

Later in the flight the pilots contacted the operator's engineering support organisation (known as Maintrol), who suggested that, in the absence of buffeting or abnormal tyre pressure, there was no undue cause for concern. However, this aircraft was not equipped with tyre pressure sensors. The pilots also contacted the company engineer in JNB to request that he attempt to identify the debris.

In a further attempt to identify the debris found at JNB the co-pilot broadcast to the crews of aircraft that had departed JNB earlier, asking if they had received any abnormal indications. None reported that they had. In a subsequent transmission, Maintrol informed the pilots that the rubber debris was a piece of tyre of a type used on the B747-400.

After a discussion involving cockpit and cabin crew, considering the continued normal behaviour of the aircraft in flight and having consulted the *Flight Crew Training Manual* (FCTM) produced by the aircraft manufacturer, the pilots decided to continue to London.

Maintrol said it would advise London Heathrow of a possible landing gear problem and engineering support would be available upon landing. After a period of in-flight crew rest, the commander assumed the duties of pilot flying. The pilots reviewed the landing procedure from the FCTM and elected to use the lowest autobrake setting, reverse thrust, as required to assist deceleration

Footnote

[2] Engine Indication and Crew Alerting System.

and to extend the landing gear early to provide an opportunity to identify and address any subsequent abnormalities. The commander commented in his announcement to the passengers that, with reference to the vibrations on departure, the aircraft would be stopping after landing in order that engineers could inspect the aircraft prior to taxiing to its parking stand.

On first contact with the Heathrow Radar controller the co-pilot discovered that this ATC unit was not aware of any problems. The co-pilot therefore explained the situation briefly, suggesting that aircraft following G-VROC on approach be accorded greater separation. ATC coordinated the following aircraft to approach 10 nm behind G-VROC and commented later that the lack of forewarning had no other operational impact. When transferred to the Heathrow Tower frequency the co-pilot was informed that the aerodrome fire and rescue service (AFRS) would be in attendance and that a runway inspection would be carried out after the landing. On-board G-VROC there were no abnormal vibrations, EICAS annunciations, or other indications when the landing gear was extended. The landing itself appeared normal but the crew subsequently noted that the aircraft was leaning slightly to the right.

The co-pilot contacted the AFRS after the aircraft vacated the runway, to request an inspection of the landing gear. This revealed damage to the outboard front tyre on the right wing landing gear (WLG). Accordingly, the aircraft stayed on the parallel taxiway until after discussion with the operator's attending engineers, who confirmed damage to the tyre. The engines were then shut down and the aircraft was towed to a stand chosen to minimise the distance that it would have to be moved.

Aircraft examination

Examination of the aircraft revealed that the tyre on the No 14 wheel had burst. The Boeing 747 main landing gear consists of four four-wheeled main landing gear legs, and the No 14 wheel is the outboard front wheel on the right WLG. A large chunk of tyre carcass of almost half the tyre's circumference was missing (Figure 1). Part of the right WLG shock strut inboard door had separated and was found near taxiway A9 adjacent to Heathrow's Runway 27R. This door sits directly above the No 14 wheel and there were black tyre marks on its underside (Figure 2). The aircraft had also suffered impact damage to its right wing inboard flap fairing and to the leading edge and underside of the right inboard aft flap. A wishbone-shaped support bracket (p/n 65B13644-6) which forms part of the connection between the right WLG shock strut and the right WLG outboard door had failed at its lower forward lug. A rod (p/n 65B12747-1) connected to the forward hinge of the right WLG door had also failed. There was also some damage to clamps on the shock strut and drag strut of the right WLG.

Figure 1

Damaged No 14 tyre on G-VROC after landing at Heathrow

Figure 2

Separated section of the right WLG shock strut inboard door
(left: held in position against the rest of the door; right: black tyre marks visible on its underside)

Aircraft parts recovered from Johannesburg Airport

During a runway inspection after the aircraft's departure from Johannesburg, two large sections of tyre, one about 0.8 m long and one about 0.3 m long, were found, as well as a number of smaller fragments of tyre, some pieces of aluminium honeycomb material, and a metal part. These parts were found on Runway 03L-21R between Taxiway H and Taxiway N, but the relative locations of the parts was not documented. The metal part was later determined to be part of one of the failed lugs on the wishbone-shaped support bracket (p/n 65B13644-6). The small pieces of honeycomb material could not be positively identified, but were probably from the WLG shock strut inboard door. When the No 14 tyre was reconstructed with the recovered tyre parts from Johannesburg, it revealed that a section of tyre carcass approximately 0.7 m long was still missing. An additional inspection of the runway environment was carried out by the Johannesburg Airport authority on 10 January 2010, but no further tyre parts were found.

Flight recorder data

In accordance with regulatory requirements, the aircraft was equipped with a 25 hour duration Flight Data Recorder (FDR) and a 120 minute Cockpit Voice Recorder (CVR). The aircraft was also equipped with a Quick Access Recorder (QAR). These were all successfully replayed. The CVR record of the takeoff had been overwritten due to the flight duration between Johannesburg and Heathrow. The FDR and QAR contained records of the entire flight.

Of significance during the takeoff was the record of the lateral, longitudinal and normal acceleration. FDR and QAR acceleration information was provided by a triaxial accelerometer attached to the inboard side of the right outboard landing gear bay.

The takeoff appeared normal until shortly after passing $V_{1,}$ which was 149 kt (Figure 3). As the aircraft accelerated through 160 kt (177 kt groundspeed), there was a series of rapid fluctuations in lateral, longitudinal

and normal acceleration. For a period of one eighth of a second, a normal acceleration change from 1 g to -2.9 g occurred, coincident with a deceleration of 0.3 g and a lateral acceleration of 0.75 g. This rapid excitation of the accelerometer is believed to have been the result of either tyre debris or a shockwave striking the accelerometer as the tyre failed. The longitudinal acceleration returned to its previously normal indication, but the aircraft then commenced a series of four cyclic lateral oscillations, which was accompanied by an increase in normal axis vibration. Rotation occurred approximately two seconds later, at 165 kt. As the aircraft took off, the lateral oscillations and normal axis vibration stopped. The maximum recorded groundspeed with the main gear in contact with the runway surface was 189 kt. The aircraft climbed without further incident.

Examination of recorded data for tyre speed and landing gear exceedences

Under certain circumstances, rated tyre speeds may be inadvertently exceeded during takeoff. The risk of such an exceedence is increased at airports that experience warm temperatures and are at high elevations above mean sea level, such as Johannesburg in South Africa and Las Vegas in the USA. In addition to monitoring of speeds by the flight crew, the operator used its Flight Data Monitoring (FDM) system to verify maximum groundspeeds during each takeoff. For G-VROC, the rated tyre speed was 204.2 kt, with the FDM system providing an automatic notification at 202 kt.

G-VROC had flown 57 times since the No 14 tyre was fitted on 18 September 2009. FDM records were available for 46 of these flights, from which the maximum takeoff groundspeed was found to have occurred during the incident flight, which was 189 kt, some 15.2 kt below the rated tyre speed. Of the records that were not available, none of the flights were from airports considered to pose a risk of nearing rated tyre speeds and no flight crew reports of an exceedence were made.

The operator's FDM records for G-VROC were also checked for airspeed exceedences of the landing gear and reports of hard landings during the duration of the tyre fitment. None was found.

History of the No 14 tyre

The No 14 tyre was a Michelin bias-ply H49x19.0-22[3] tyre, rated to 204 kt. It was installed as new (no retreads) on G-VROC on 18 September 2009, and had completed 57 flight cycles at the time of the failure. The tyre pressures were required to be checked during every Daily Check, but there was no requirement to record the tyre pressures unless they were below limits. There were no aircraft technical log entries for the No 14 tyre pressure having been below limits or having required reinflation since its installation. The operator noted that it was possible that small 'top-ups' were not being recorded and that they would reiterate to their staff the requirement to record any reinflations in the aircraft technical log. The last Daily Check had been performed on the aircraft at Johannesburg sometime between its arrival at 0455 UTC and its departure at 1942 UTC. The tyre pressure of the adjacent tyre (No 13) was measured at 210 psi after the aircraft landed at Heathrow following the incident; this was within the limits of 194 psi to 213 psi (for maximum takeoff weight).

Footnote

[3] The designation 'H49x19.0-22' denotes 49 inch outside diameter, 19 inch width and 22 inch inside diameter.

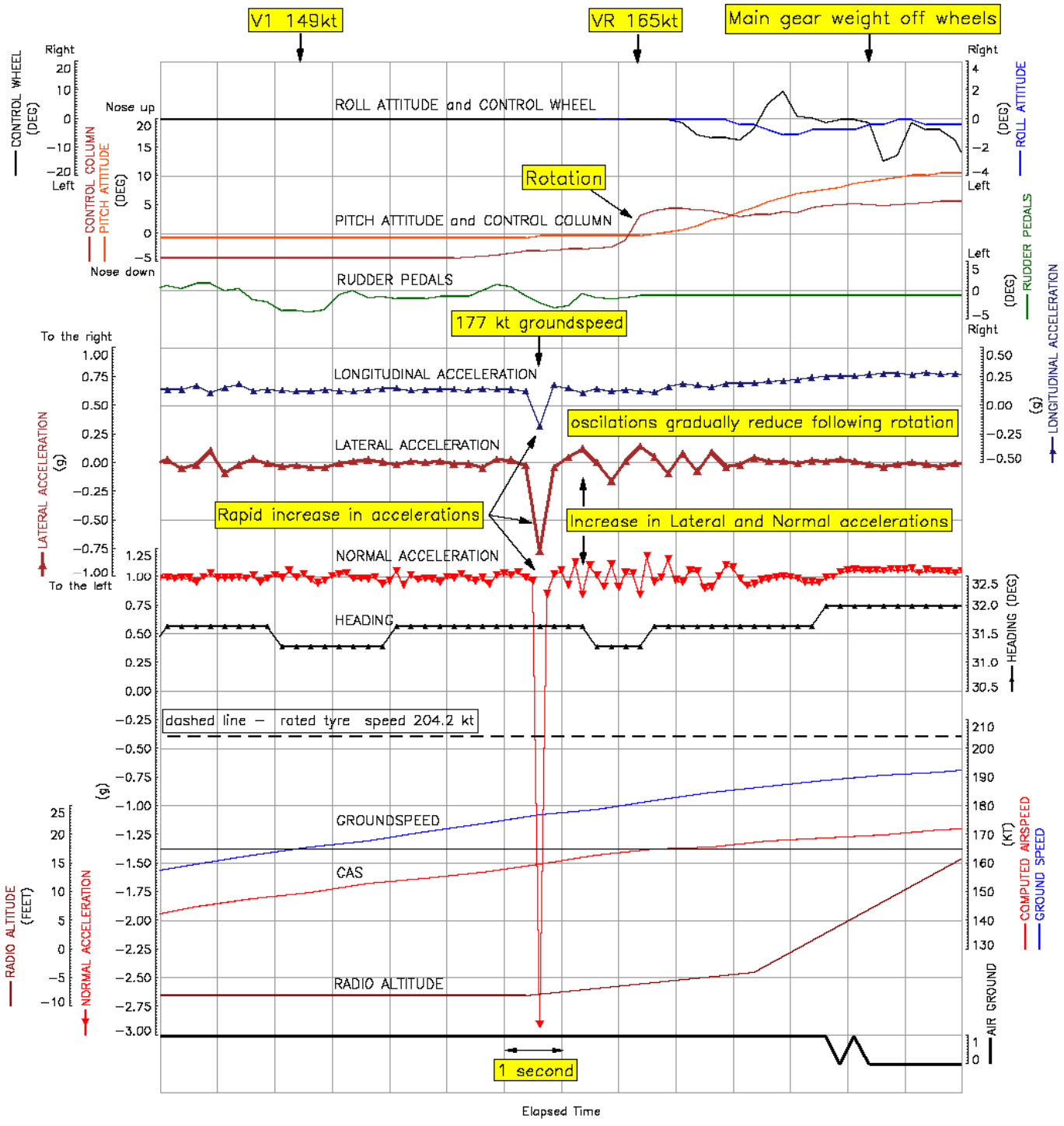

Figure 3

G-VROC – Recorded data for takeoff from Johannesburg Airport

Detailed examination of the No 14 tyre

The failed tyre was removed from the No 14 wheel at the overhaul facility used by the operator. The wheel was leak checked with a new tyre; no leaks were found. An initial examination of the tyre was carried out onsite and it was then sent to the tyre manufacturer's production facility for a more detailed examination. When the tyre was reconstructed with the two separated pieces from Johannesburg, a classic X-type burst pattern was revealed (Figure 4). An X-type rupture indicates a high pressure blowout, and therefore the tyre had not burst in a low pressure 'run-flat' condition. On one of the separated sections there was an area in the centre of the crown where there was a straight break between almost all the casing plies (Figure 5), as if they had been cut. The area surrounding this straight 'cut' exhibited plies that had the appearance of having failed in tensile overload.

Figure 4

No 14 tyre reconstructed with the two large sections found on runway at Johannesburg.
Right: classic X-type burst pattern and 'cut' in upper section

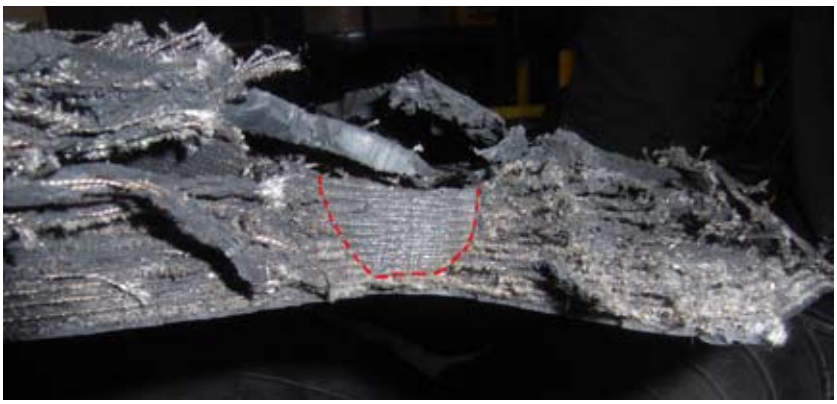

Figure 5

Close-up of 'cut' area highlighted in top right section of Figure 4

The manufacturer determined that there were no defects in the construction of the tyre and there was no evidence of internal heat or inner liner wrinkling. Because there were missing pieces in the area of the X-type rupture, the manufacturer could not determine a definitive cause, but they considered that impact from a foreign object was the most probable cause of the tyre burst. They considered that the section of tyre with the straight 'cut' was probably caused by a sharp object, but because the 'cut' was not located near the centre of the X, it is probable that this cut occurred after the initial tyre burst.

Metallurgical examination of failed lug and rod

The failed lug on the wishbone-shaped support bracket (p/n 65B13644-6) and the failed rod (p/n 65B12747-1) were examined by a metallurgist. The fracture surfaces were examined under both optical and scanning-electron microscopes. The examinations revealed that both the support bracket and the rod had failed as a result of static tensile overload. There was no evidence of any progressive crack growth on any of the fracture surfaces.

Runway inspections at Johannesburg Airport

Three runway inspections are carried out each day at Johannesburg Airport[4]. On the day of the incident, 28 October 2009, the 'dawn' runway inspection was carried out at 0348 hrs on Runway 03L and 0425 hrs on Runway 03R. The 'day' runway inspection was carried out at 1307 hrs on Runway 03R and 1316 hours on Runway 03L. The 'dusk' runway inspection was completed on Runway 03R at 1953 hrs, and Runway 03L was about to be inspected when the G-VROC incident occurred on that runway.

Footnote

[4] Annex 14 to the Convention on International Civil Aviation, volume 1 – *'Aerodrome design and operations'*, published by ICAO, recommends a minimum of two such inspections daily.

Guidance in the Flight Crew Training Manual (FCTM)

The version of the FCTM consulted by the pilots during the flight contained the following advice:

> *'If the crew suspects a tire failure during takeoff, the Air Traffic Service facility serving the departing airport should be advised of the potential for tire pieces remaining on the runway. The crew should consider continuing to the destination unless there is an indication that other damage has occurred (non-normal engine indications, engine vibrations, hydraulic system failures or leaks, etc.).*
>
> *Continuing to the destination will allow the airplane weight to be reduced normally, and provide the crew an opportunity to plan and coordinate their arrival and landing when the workload is low.'*

Analysis

The No 14 tyre burst during the takeoff ground roll at approximately 160 kt, which was well below the 204 kt rated tyre speed. The X-type burst pattern of the tyre indicated that it had ruptured at high pressure. Such ruptures can occur during a heavy landing, but this event occurred during the takeoff roll and the FDM data revealed no exceedences during the previous 57 landings. The adjacent tyre to the No 14 tyre was in satisfactory condition and its pressure was within limits, which meant that the No 14 tyre would not have been carrying excessive load. There was no evidence of a manufacturing defect in the tyre or overheat within the liner, and therefore the most probable cause of the tyre burst was penetration by a foreign object. The missing tyre material in the vicinity of the X made it impossible to determine what type or shape of object caused the

rupture. The cut in one of the separated tyre sections was probably caused after rupture, as it was not located in the centre of the X. Despite a repeat inspection of the runway area environment by the airport authority, no foreign objects or the missing tyre sections were found.

The possibility that the small piece of failed lug caused the tyre to burst was considered, but this lug had failed in overload with no evidence of progressive cracking; it was therefore more likely that the lug had failed when ruptured sections of tyre carcass struck the WLG outboard door.

The decision of the flight crew to continue to the original planned destination was in accordance with the guidance provided in the FCTM.

Conclusion

The No 14 tyre burst during the takeoff ground roll at approximately 160 kt. The evidence indicated that the tyre probably burst when it ran over a foreign object. Due to the missing tyre material, the nature of this object could not be determined.