SERIOUS INCIDENT

Aircraft Type and Registration:	Gulfstream G200, EC-KRN	
No & Type of Engines:	2 Pratt & Whitney PW306A turbofan engines	
Year of Manufacture:	2008 (Serial no: 188)	
Date & Time (UTC):	14 January 2015 at 2127 hrs	
Location:	London Luton Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 3	Passengers - 3
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to four mainwheels and tyres	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	3,169 hours (of which 2,010 were on type) Last 90 days - 65 hours Last 28 days - 33 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

Synopsis

Within a second of touchdown, a tyre, probably the right outboard, burst. The flight crew were aware of the burst tyre and perceived that a second tyre had also burst on the right side. They experienced directional control and braking difficulties which resulted in them selecting the emergency braking system. The crew brought the aircraft to a stop on the runway, after which it was found that all four mainwheel tyres had burst.

History of the flight

The aircraft had departed from Dakhla Airport, Morocco, and was on approach to London Luton airport. The commander was the pilot flying (PF) and the co-pilot was not flying (PNF). The aircraft's Digital Flight Data Recorder (DFDR) did not record the incident flight, so the following series of events was established from the Cockpit Voice Recorder (CVR).

The descent was normal with the aircraft vectored onto the ILS approach for Runway 26. The ATIS, which the crew listened to during the descent, reported turbulence with the wind from 180° at 17 kt gusting 31 kt, variable from between 140° and 210° and the runway reported as "wet-wet-wet". Having established the aircraft on the final approach, the crew commented about the strong crosswind from the left. The aircraft was fully configured for landing and, having transferred to the tower frequency, was cleared to land, with the controller advising the wind was from 190° at 18 kt gusting 28 kt. Earlier the crew had verbalised the before-descent and approach checklist items.

The crew disconnected the autopilot at approximately 1,800 ft, following which the PNF managed the thrust levers, at the request of the PF, due to the turbulent conditions, with the approach speed set at V_{REF} +10 kt; V_{REF} was 129 kt based on a landing weight of 25,400 lb. As the aircraft approached the ILS minima, the airspeed was reduced to V_{REF} +5 kt and at about 50 ft the thrust levers were retarded towards the idle position. Within a second of touchdown, a loud bang was recorded on the CVR; from the automatic height callouts the rate of descent at touchdown did not appear to be excessive. This was immediately followed by the PF advising of braking difficulties and the PNF saying "WE HAVE A BURST TYRE". The PNF encouraged the PF to continue to apply the brakes, but the PF again queried their effectiveness at slowing the aircraft. In response, the PNF called for emergency braking to be selected (this was about 16 seconds after touchdown)[1]. Two seconds later the emergency brake position was set and two seconds after that a 'grinding' sound of varying intensity started; it is likely that this sound was generated by a wheel rim coming into contact with the runway surface. Eight seconds after the emergency brake had been set, a loud short duration sound was recorded, followed by two further similar sounds, two and seven seconds later. These sounds were probably the three remaining tyres bursting. The grinding sound then ceased as the aircraft came to a stop on the runway, 38 seconds after it had initially touched down. The fire service attended the scene but were not needed.

Commander's report of the incident

The commander believed that after touchdown the aircraft suffered a burst of both right mainwheel tyres, with a couple of seconds delay between them; he thought both tyres had burst because he felt the aircraft lean to the right followed by a more pronounced inclination to the right. Maximum reverse thrust was selected. He stated that his ANTI SKID OFF light illuminated while the crew were regaining directional control and it was only after the aircraft came to a rest that he realised that all four mainwheel tyres had burst.

Description of the aircraft

The Gulfstream G200, formerly known as the IAI Galaxy, is a twin-engine business jet (Figure 1). It is operated by two crew and has a typical seating arrangement of 8 to 10 seats with a maximum of 19 passenger seats.

Figure 1

Photograph of EC-KRN (copyright Yan David)

Footnote

[1] Several, almost equally spaced short duration sound pulses were recorded at about this time. These sounds may have been caused by the nosewheels travelling over the runway centre line lights, which would indicate that the ground speed of the aircraft would have been approximately 88 kt at the time.

Brake system description

The aircraft is equipped with a normal and emergency hydraulic wheel brake system. Brake pedals actuate brake units on each of the four main landing gear wheels. Under normal operation, when the brake pedals are pressed, pressure from the right hydraulic system is metered by a Power Brake Valve (PBV) to two anti-skid control valves, then via fuse and shuttle valves to each of the four brake units.

The emergency braking system is selected by placing the 'PARK/EMERG' handle in the emergency position. Under emergency operation, when the brake pedals are pressed, pressure from the left hydraulic system is metered by the PBV via shuttle valves to each of the four brake units. The anti-skid control valves are bypassed under emergency operation so there is no anti-skid protection under emergency braking.

In normal mode the PBV supplies a braking pressure of 1600 ±50 psi and, in emergency mode, a lower pressure with a reduced pedal sensitivity to minimise the probability of tyre skid. However, the aircraft manufacturer has stated that without anti-skid:

> *'it takes very little brake pedal application to provide sufficient pressure to the brakes to cause them to skid and eventually blow the tires.'*

Parking brake system description

The parking brake is selected by placing the PARK/EMERG handle in the park position. A PARKING BRAKE ON caution message appears on the EICAS[2] whenever the parking brake is engaged. A T/O UNSAFE PARKING warning message appears on the EICAS with an aural warning if the parking brake is engaged with the aircraft on the ground and the thrust lever set beyond the 'cruise' range.

Anti-skid system description

The anti-skid system prevents wheel skidding by limiting the metered brake pressure to the brakes. Maximum braking efficiency is obtained when all wheels are at a maximum rate of deceleration, short of a skidding wheel. Wheel speed sensors in each wheel transmit signals to an anti-skid Electronic Control Unit (ECU) which sends corresponding signals to the anti-skid control valves to vary brake pressure as required.

Prior to and after touchdown the anti-skid system prevents brake pressure being applied ('anti-skid touchdown protection') until the wheels have spun up to above 35 kt, or 2.5 to 3.5 seconds have elapsed since transition of one weight-on-wheel switch, whichever occurs first.

The anti-skid pushbutton is located on the left side of the glareshield and serves as the on/off button and also illuminates ANTI SKID OFF when a failure is detected; a further ANTI SKID OFF light is located on the right side of the glareshield. There is no associated aural warning with an anti-skid failure and no EICAS message.

Footnote

[2] EICAS is the Engine Indication and Crew Alert System, located centrally on the instrument panel.

The anti-skid system provides for 'locked wheel protection' which will remove brake pressure on both paired wheels whenever the wheel speed on one or both of the wheels drops below 30% of groundspeed. The Gulfstream G200 Airplane Flight Manual (AFM)[3] states:

> *'After a tire burst at speeds higher than 30 knots a locked wheel condition is detected when the burst wheel speed decreases under 30% of the aircraft groundspeed and braking is lost on both wheels (anti skid off light comes on). The anti-skid system is to be switched off and braking continues.'*

The aircraft manufacturer has clarified that, if a tyre bursts at a speed above 30 kt, the burst tyre's wheel speed can drop below 30% of the aircraft groundspeed. If this occurs, and the wheel speed remains below 35% groundspeed for at least 1 second, then a 'locked wheel' condition will be detected and the ANTI SKID OFF light will illuminate. This will result in all brake pressure being removed from the wheel with the burst tyre and from its adjacent wheel. It will not be possible to apply any brake pressure to either wheel (even if the speed goes back above 35% groundspeed) until either the anti-skid button is pressed or emergency braking is selected. Even though the ANTI SKID OFF light is illuminated, anti-skid is still operational on the opposite landing gear leg. Pressing the anti-skid button in this situation will completely deactivate anti-skid and will permit normal brake pressure to reach all wheels. Selecting emergency braking in this situation will also result in brake pressure being restored to all wheels, but at a lower pressure, with reduced pedal sensitivity.

Quick Reference Handbook procedure for ANTI SKID OFF illumination

The Gulfstream G200 Quick Reference Handbook (QRH)[4] section for 'Anti-Skid System Failure' includes the following:

> **'ANTI-SKID OFF light illuminates during landing roll for more than one second:**
>
> 1. Wheel Brakes……..RELEASE
>
> **If light goes out:**
>
> 2. Wheel Brakes….....APPLY (AS REQUIRED)
>
> **If light remains illuminated:**
>
> 3. ANTI-SKID Pushbutton……..PRESS OFF
>
> **CAUTION: WHEN ONE OF THE ANTI-SKID OFF LIGHTS ILLUMINATE, ANTI-SKID SHOULD BE TURNED OFF TO PREVENT POSSIBLE ASYMMETRIC BRAKING.**
>
> 4. Wheel Brakes…….APPLY CAUTIOUSLY
>
> (Consider runway distance and condition.)

Footnote

[3] Gulfstream G200 Airplane Flight Manual Revision 19, 9 February 2014.
[4] Gulfstream G200 Quick Reference Handbook Revision 19, 9 February 2014.

Aircraft manufacturers typically highlight certain emergency QRH procedures as 'memory items', procedures to be performed without reference to the QRH. The aircraft manufacturer of the G200 has stated that none of their QRH procedures were 'memory items' and that, once a pilot had been trained to fly a G200, they would have been exposed to all types of abnormal and emergency procedures where they would have handled the initial situations without reference to 'memory items' in a checklist; examples include a hot engine start, engine failure during takeoff, engine fire, dual generator failure, and a blown tyre during takeoff or landing. It further stated that:

> *'pilot actions in such situations are performed in a reflex manner without reference to a check list and can be considered basic airmanship being common to most airplanes'*

and that:

> *'In the case of an anti-skid failure, all pilots know that heavy braking will cause blown tires. First instinct is get off the brakes if braking is in progress and reapply brakes with less force. If braking is totally lost, the next reflex action is to use the emergency brake to stop the airplane. If directional control is an issue, use of rudder and nose wheel steering is the first reaction to stay on the runway. A G200 pilot familiar with the specific check list may also include the anti-skid off action.'*

Commander's explanation of actions following tyre burst

The commander confirmed that the ANTI SKID OFF light QRH procedure is not a 'memory item' and commented that it is impractical to search for this QRH procedure during a landing roll. He said that, in this instance, he had focussed on maintaining directional control of the aircraft, which he achieved, and stopping the aircraft in the runway distance remaining, which he also achieved. He did not consider turning the anti-skid off and he selected emergency braking because he felt that the normal braking system was not responding properly as they were nearing the end of the runway.

Aircraft examination

The aircraft was not examined by the AAIB but photographs taken by the operator revealed that all four tyres had flat spots which had worn through the tyre and carcass (Figure 2). The damage to the left tyres and the right inboard tyre appeared to be similar, while the damage to the right outboard tyre covered a more elongated area. All four wheels had suffered rim damage, but the most substantial rim damage was to the right outboard wheel (Figure 3).

Functional tests were carried out on the aircraft which did not reveal any faults with the brakes, anti-skid system, or the parking brake system. The checks included functional tests of the 'anti-skid system locked wheel protection', the 'anti-skid touchdown protection' and the wiring from the anti-skid transducers to the anti-skid ECU were inspected with no faults found. The DFDR was also tested and operated correctly. The parking brake valve and

anti-skid ECU were removed from the aircraft and underwent functional tests, which they passed. The aircraft was released back to service with no further reports of brake problems or DFDR recording problems.

Figure 2
Damage to tyres

Figure 3
Right outboard wheel rim damage

Recorded data

The aircraft was equipped with a 120-minute duration CVR and a 25-hour duration DFDR. The CVR contained a complete record of the incident, with the recording commencing 90 minutes before landing. The communications between the flight crew were in Spanish so the Comisión de Investigación de Accidentes e Incidentes de Aviación Civil (CIAIAC) of Spain provided assistance to the AAIB in translating the CVR. Details from the CVR are included in the '*History of the flight'* section of this report.

DFDR operation

When the DFDR was downloaded, it was found that the entire incident flight, from Dakhla Airport to Luton Airport, had not been recorded. The record of the in-bound flight to Dakhla had ended normally. This was followed by a series of six recording periods lasting a total of about 10 minutes. These are all believed to have occurred the following day, when the aircraft was on the ground being prepared for the flight to Luton Airport. These were the last recordings on the DFDR.

The flight recording system in EC-KRN is a 'two-box' design, with a Flight Data Acquisition Unit (FDAU) providing encoded data to a DFDR. Under normal operation, the FDAU remains electrically powered and the position of the park brake controls the electrical power to the DFDR. When the park brake is OFF the DFDR records and when the brake is in the PARK position, the DFDR recording ceases. When the DFDR is not recording, or if a fault is detected, an FDR FAIL message is displayed on the EICAS display. The flight crew stated that they had not observed an FDR FAIL message during the incident flight.

Both the DFDR and FDAU are equipped with a comprehensive Built In Test (BIT) function that monitors for internal faults and asserts a status output in the event of a fault being detected. The BIT data from the DFDR was analysed by the manufacturer to determine whether there was evidence of a defect that would have prevented recording. None was found.

Shortly after the incident, a test of the park brake was made, which confirmed the FDAU and DFDR fault status was working correctly when the park brake was cycled between PARK and OFF positions. The FDAU BIT was also checked and seven previous flights recorded on the DFDR, and a download made after the aircraft's subsequent flight from Luton Airport, were analysed for inconsistencies. No evidence of a fault was found. The operator stated there was no record of a previous fault with the DFDR system and no faults were observed after the aircraft returned to service.

Analysis

Flight data recorder analysis

The evidence indicates that electrical power to the DFDR was most likely lost at some point during the preparation of the aircraft for its flight to Luton. However, no fault could be found that explained why the DFDR stopped recording, or why an FDR failure message would not have been displayed on the EICAS.

Analysis of tyre bursts

Within a second of touchdown there was a loud bang which was most likely one of the tyres bursting. The right outboard tyre and wheel had suffered the most damage so it was probably this tyre that burst first. The commander perceived that a second tyre burst on the right side a couple of seconds later but there was no associated sound on the CVR for this. The first tyre burst probably caused its wheel speed to drop below 30% of the aircraft's groundspeed so the 'locked wheel' condition was detected, which explains the triggering of the ANTI SKID OFF light. This would have resulted in a loss of brake pressure not only to the wheel with the burst tyre but also to its adjacent wheel. The remaining brake effectiveness would therefore have been 50% of normal braking effectiveness. This loss of braking, combined with the wet runway surface, was probably the reason why the flight crew were reporting braking difficulties on the CVR and it is what prompted them to select the emergency braking system[5]. Eight seconds after the emergency brake system was selected there were three loud short-duration sounds, within about seven seconds of each other. These were probably the sounds of the three remaining tyres bursting as a result of flat spots incurred during skidding. Without the protection of anti-skid very little brake pedal application is required to skid a tyre. These three tyres suffered less damage and made less noise when they burst than when the first tyre burst, probably because the aircraft had decelerated by this time and therefore there was less energy in the tyres.

It was considered whether the first tyre burst could have been caused by a failure of the 'anti-skid touchdown protection', but this system was tested after the incident with no faults found. The anti-skid ECU was also tested, with no faults. It is therefore possible that the first tyre burst as a result of foreign object damage (FOD). The commander perceived that the right inboard tyre burst a couple of seconds later due to an additional lean to the right, and it is possible that this tyre also burst due to FOD. However, the lack of a second loud bang indicated that it more likely burst later, with the two left tyres, after the emergency braking system was selected.

The QRH procedure for an ANTI SKID OFF light illumination calls for the anti-skid pushbutton to be pressed off. This is in order to restore brake pressure to any tyres that have not burst and thus prevent asymmetric braking. If the flight crew had pressed this button they would have had normal brake pressure to all four wheels, but without anti-skid the remaining tyres might still have burst as a result of excessive brake pedal application.

The more significant factor that contributed to the long landing ground roll was the approximately 16 second period between the first tyre bursting and the emergency braking system being selected. During this 16 second period only the left two brakes were operational.

Footnote

[5] Note: selecting the emergency brake system causes the loss of anti-skid but it does not cause the ANTI SKID OFF light to illuminate.

'Memory items' and the QRH

The aircraft manufacturer expected flight crew to be able to perform the 'ANTI SKID OFF' QRH procedure as a result of training rather than as a result of memorising it. However, highlighting important 'memory items' in the QRH can serve as reminders to flight crew and operators as to which procedures need to be rehearsed in recurring training.

Safety actions

Aircraft manufacturer

As a result of this serious incident the aircraft manufacturer has stated that it is reviewing the anti-skid QRH procedure to emphasise the operation of the anti-skid during initial and recurring training.

The AFM system description for the case of a tyre burst was not clear. The text: '*braking is lost on both wheels (ANTI SKID OFF light comes on)'* could be interpreted to mean that anti-skid braking is lost, when it is intended to mean that complete braking is lost. It is also not clear whether '*both wheels*' means adjacent wheels or opposite paired wheels. The fact that brake pressure is lost to both adjacent wheels means that asymmetric braking will occur, but this consequence is not stated in the system description – it only appears in the QRH.

The aircraft manufacturer has stated that it is considering an AFM revision to clarify the procedure in case of a tyre burst.

Aircraft operator

The aircraft operator has stated that it has initiated a process of internal research with the participation of their most experienced G200 pilots to establish suitable mitigation measures to prevent a repeat incident.