ACCIDENT

Aircraft Type and Registration:	Airbus A340-642, G-VSHY
No & Type of Engines:	4 Rolls-Royce Trent 556-61 turbofan engines
Year of Manufacture:	2002
Date & Time (UTC):	25 February 2006 at 1254 hrs
Location:	Runway 09R, London Heathrow Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 18 Passengers - 268
Injuries:	Crew - None Passengers - None
Nature of Damage:	Serious damage to two tyres and wheels; minor damage to flaps and right main landing gear
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	10,000 hours (of which 7,000 were on type) Last 90 days - 240 hours Last 28 days - 80 hours
Information Source:	AAIB Field Investigation

Synopsis

Towards the end of the final approach to Runway 09R at London Heathrow Airport, in strong gusting crosswind conditions, the aircraft began to drift to the right of the runway extended centreline. At the moment of touchdown, the aircraft was drifting to the right, its heading was some 10º to the left of its track and its roll attitude was approximately 3.5º right wing low. These factors resulted in the tyres of the two outer wheels of the right main landing gear making firm contact with the right edge line of the designated runway surface. The aircraft remained on the paved surface but both tyres deformed and burst, causing minor damage to the aircraft. Following the touchdown, the aircraft tracked to the left and regained the runway centreline. The flight crew slowed the aircraft and turned off the runway on to a taxiway, where it was brought to a stop. Here, the passengers disembarked and were taken to the terminal by bus. After an inspection, the aircraft was towed to a nearby stand.

History of the flight

The crew reported for duty at 0055 hrs for their flight from Los Angeles to London. The flight crew comprised a commander and two co-pilots, with the commander acting as the Pilot Flying (PF). The aircraft took off at 0209 hrs and, prior to the landing, had an uneventful flight. Before starting the descent, the flight crew briefed for an expected landing on Runway 09L at Heathrow.

The commander was to remain the PF for the approach and landing, with one co-pilot occupying the right seat and the other occupying the flight deck jump seat.

Heathrow was experiencing delays and, during the descent, the flight crew were instructed by ATC to hold. Whilst in the hold, they were advised that they would be landing on Runway 09R, so the crew re-briefed for an approach to this runway. Due to reports of windshear on short final approach to Runway 09L, it was decided to land with Flap 3 selected[1] and fly 5 kt faster than the calculated approach speed, giving a final approach speed of 161 kt. After about twenty minutes in the hold, ATC passed radar vectors to the crew to enable the aircraft to intercept the ILS for Runway 09R. The commander elected to keep the autopilot engaged and stated that, once established on the ILS, the aircraft remained in line with the runway centreline. The commander disengaged the autopilot on passing the Decision Altitude of 275 ft and, at 50 ft radio altitude (RA), commenced the landing flare. All three pilots reported that the aircraft then began moving rapidly to the right. The commander was aware the aircraft was quickly approaching the edge of the runway and reduced the flare in an effort to expedite the touchdown. He did not attempt to kick off the drift with rudder just prior to touching down as he considered to do so might have brought the nose of the aircraft over the edge of the runway. Consequently, the aircraft touched down on the right edge of the delineated runway, with about a 10º drift angle to the left and whilst tracking slightly to the right of the runway heading. As a result, the two outboard tyres of the right main landing gear burst.

The commander brought the aircraft back towards the centreline and, as he was doing so, he became aware that the EFIS[2] display indicated the tyre pressures of the two right outer main wheels were at zero. He therefore decided to use full reverse thrust in helping to slow the aircraft. As the speed reduced through 80 kt, a master caution also alerted the crew to the loss of these tyre pressures. ATC informed the crew that they believed some tyres had burst and that the emergency services had been alerted.

The aircraft vacated the runway at exit point N5E, where it was brought to a halt on the taxiway. As there were no other adverse indications on the flight deck, the flight crew kept the engines running whilst awaiting the arrival of the emergency services. The crew made use of the aircraft's tail-mounted camera to try and assess the level of damage but, whilst they could see the wheels, the picture definition was not adequate to see them in sufficient detail.

The emergency services were quickly in attendance and were able to advise the crew on a discreet radio frequency that the two outer tyres on the right main gear were badly damaged and completely deflated. The crew consulted the aircraft manuals to see whether it was possible to taxi the aircraft in this condition but decided to remain in their current position. Also, the airfield duty manager was on the scene and was sufficiently concerned about the state of the affected landing gear to request that the passengers be disembarked and taken to the terminal by bus. Once the passengers had left the aircraft, an engineering inspection was carried out, following which the aircraft was judged safe to be towed to a nearby stand.

When later asked if he had considered going around, the commander stated that the event had happened

Footnote

1 Normal landing is made with Full Flap.

Footnote

2 Electronic Flight Indication System.

very quickly and, at such a late stage in the approach, he thought to do so might have resulted in the aircraft departing the runway.

Weather

The Heathrow ATIS valid at 1220 hrs reported the following weather:

> Wind 060º at 21 kt, visibility 10 km or more, clouds FEW at 2,500 feet, temperature +6º, dew point -4º and QNH 1018 hPa.

It also advised that there was moderate turbulence on the approach and that windshear had been reported on short final approach to Runway 09L with a loss or gain of 10 kt. The wind direction was such that that the touchdown zone for Runway 09R was generally downwind of the airport's central area, Figure 1. The turbulence downwind of the buildings/structures may have contributed to the overall turbulent conditions experienced during the landing, although LHR does not appear to be any different from most major airports in the UK in this regard.

Crosswind landing limits

The operator's aircraft manual for the A340-600 states that the maximum demonstrated crosswind for a manual landing, including gusts, is 37 kt.

Standard operating procedures

The operator's Flight Crew Operating Manual (FCOM), revision 06/01 June 2005, for the A340-600 contains the following information relating to landing in crosswinds:

> ***'Crosswind landings***
>
> *The preferred technique is to use rudder to align the aircraft with the runway heading during the flare while using lateral control to maintain the aircraft on the runway centerline.*

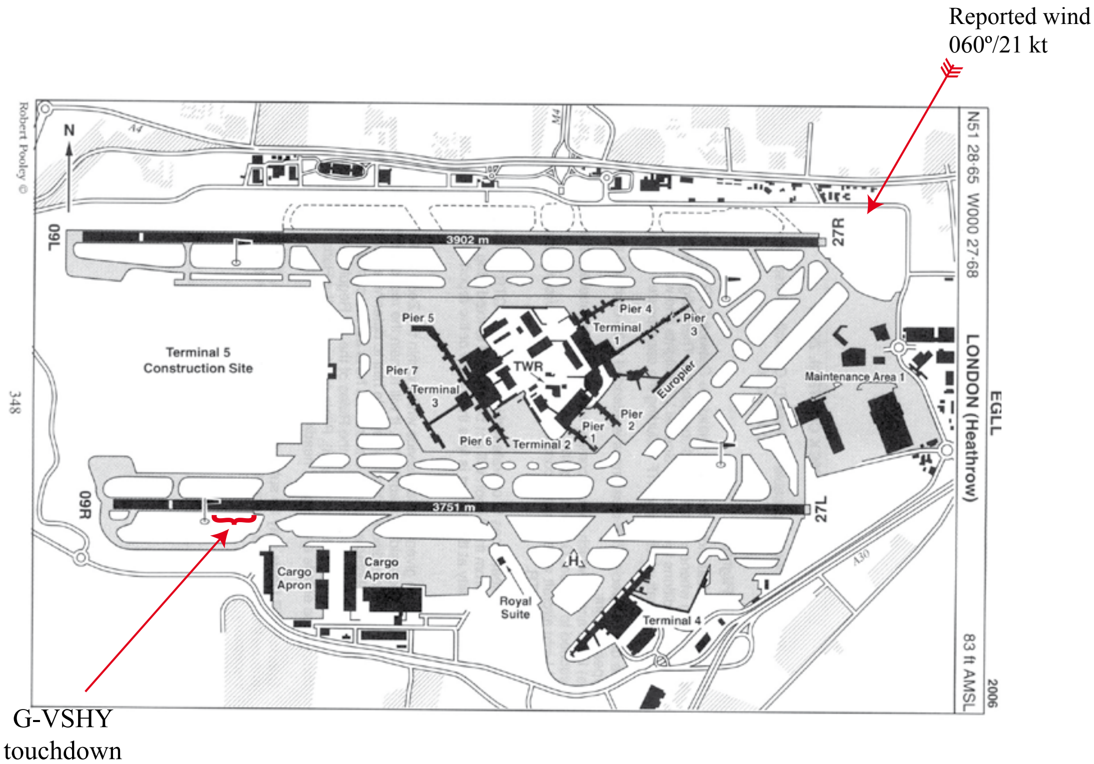


Figure 1

Routine use of into wind aileron is not recommended, because sidestick deflection commands roll rate until touchdown.

In strong crosswind conditions, small amounts of lateral control may be used to maintain wing level. The lateral stick input must be reduced to zero at the first main gear touchdown.'

An FCOM Bulletin issued by the aircraft manufacturer, No 814/1 dated Jun 04, also contains information relevant to landing the A340 in crosswinds. Extracts from this document, obtained from the operating company, are presented below:

'SUBJECT:** **AIRCRAFT HANDLING IN FINAL APPROACH'

'Approach Stabilization Criteria...........Aircraft Handling on the Lateral Axis

Generally speaking, lateral handling of fly-by-wire aircraft is conventional. But, in very gusty conditions, it is necessary to recall the principle of the flight control law in roll. With the sidestick, the pilot can order a roll rate up to a maximum of 15 degrees/second. However, the aerodynamic capacity of the roll surfaces, when fully deflected, is much higher: That is, up to about 40 degrees/second. This means that, if the aircraft is flying through turbulence that produces a roll rate of 25 degrees/second to the right, the aircraft still has the capacity to roll to the left at a rate of 15 degrees/second, with full sidestick command. This is more than what is necessary in the worst conditions.

The sidestick's ergonomical design is such that the stop at full deflection is easily reached. This may give the pilot the impression that the aircraft is limited in roll authority, because there is a time delay before the pilot feels the result of his/her action. On conventional aircraft, due to the control wheel inertia, the pilot needs considerably more time to reach the flight control stop.

The flight control system of Airbus fly-by-wire aircraft partially counteracts roll movements induced by the effects of gust, even with the sidestick in the neutral position. The PF must ensure that the overall corrective orders maintain the desired aircraft lateral axis. He/she will minimize lateral inputs and will resist applying sidestick order from one stop to the other. Every sidestick input is a roll rate demand, superimposed on the roll corrections already initiated by the fly-by-wire system. The pilot should only apply "longer term" corrections as needed.

Before flare height, heading corrections should only be made with roll. As small bank angles are possible and acceptable close to the ground, only small heading changes can be envisaged. Otherwise, a go-around should be initiated.

Use of rudder, combined with roll inputs, should be avoided, since this may significantly increase the pilot's lateral handling tasks. Rudder use should be limited to the "de-crab" manoeuvre in case of crosswind, whilst maintaining wings level with the sidestick in the roll axis.'

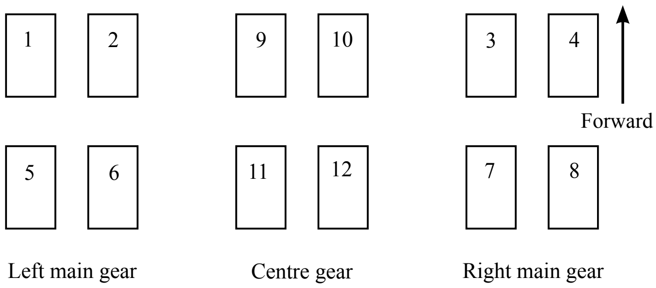
Extracts from FCOM Bulletin No 814/1, dated Jun 04

Description of landing gear and tyres

Landing gear

The aircraft is equipped with two main landing gear legs, left and right, and a centreline gear, each one being equipped with four wheels. The nose gear is fitted with two wheels. The eight wheels on the main landing gear, and the four on the centre gear, are fitted with carbon disc brakes, operated normally through anti-skid units. When airborne, with the landing gear extended, the centre gear bogey tilts forward and the main gear bogies tilt backwards. The oleo extension of the main and centre legs is such that the wheels on the centre gear always make contact with the runway after those on the main gears, irrespective of the pitch attitude of the aircraft.

The main and centre landing gear wheels are numbered as follows:



Tyres

A tyre consists of a bead, sidewall, shoulder, crown and tread, and multiple plies embedded in the rubber, Figure 2. The specific tyre type fitted to G-VSHY was the Michelin Near Zero Growth (NZG) radial tyre, Pt No M16004, size 1400 x 530R23/40/235. Tyre No 4 had undergone 133 landings and 61% of the allowable tread had worn away. Tyre No 8 had also undergone 133 landings, with 58% of the allowable tread worn away.

The stated advantages of NZG tyres over conventional tyres are that they are lighter, sustain less wear at touchdown, have an increased resistance to tears and cuts and an improved resistance to abrasion.

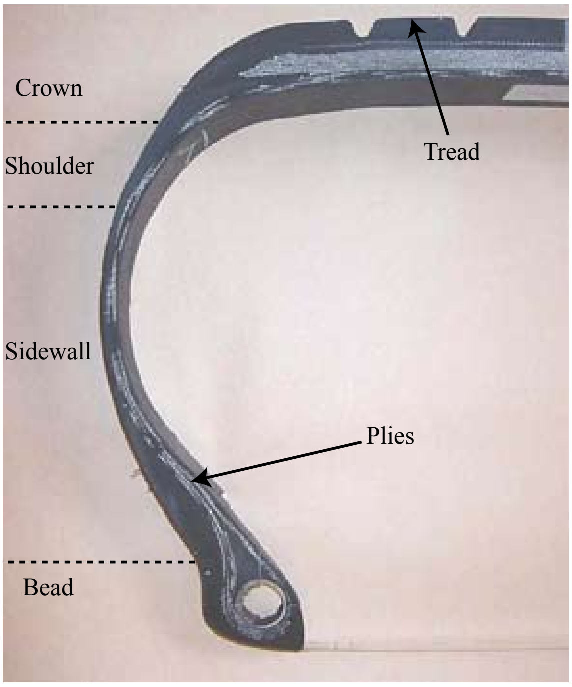


Figure 2

Runway marks

Clear tyre marks were made by all the main landing gear tyres on the runway during the landing, Figure 3. These indicated that the aircraft had touched down on a track of approximately 093º, adjacent to the aiming markers. Wheel No 7 and No 8 touched down first, followed approximately 10 m further on by wheel No 5 and No 6. Some 20 m after the inital touchdown point, wheel Nos 3, 4, 9 and 10 all made contact with the runway. Wheel No 4 and No 8 had touched down on the white line delineating the right edge of the runway. It was not possible to determine from the tyre marks where the nose wheels touched down. It was also apparent from the tyre marks that tyre Nos 4 and 8 had burst at about the same time that wheel Nos 3, 4, 9 and 10 made contact with the runway.

A gouge was present in the runway surface in the area where the two tyres had burst, most likely caused by the No 4 outer wheel rim contacting the ground. Whilst the fore and aft wheels on each bogey are in-line with the longitudinal axis of the aircraft, the marks on the runway made by the No 3 and 7 main gear tyres were consistent with the aircraft's heading being to the left of its track, ie, skidding to the right. Approximately 40 m after the start of the right main gear wheel tracks, wheel Nos 4 and 8 crossed over the runway right edge on to the hard shoulder for a short distance, after which the tyre tracks from all the main gear wheels indicated that the aircraft had tracked towards the runway centreline.

Aircraft damage

Tyres No 4 and 8 burst on landing, Figure 4. The resultant flaying rubber dislodged and broke a number of brackets on the bogey and caused several small dents on the inboard flap and flap track canoe fairing.

Damage had also occurred to the No 4 wheel, normal brake hydraulic line coupling (Part Number 201589204), sufficient to cause a slight seep of hydraulic fluid. Whilst wheel Nos 4 and 8 had remained intact, the outboard rim of the No 4 wheel had been ground flat over an arc of approximately 40º around its circumference.

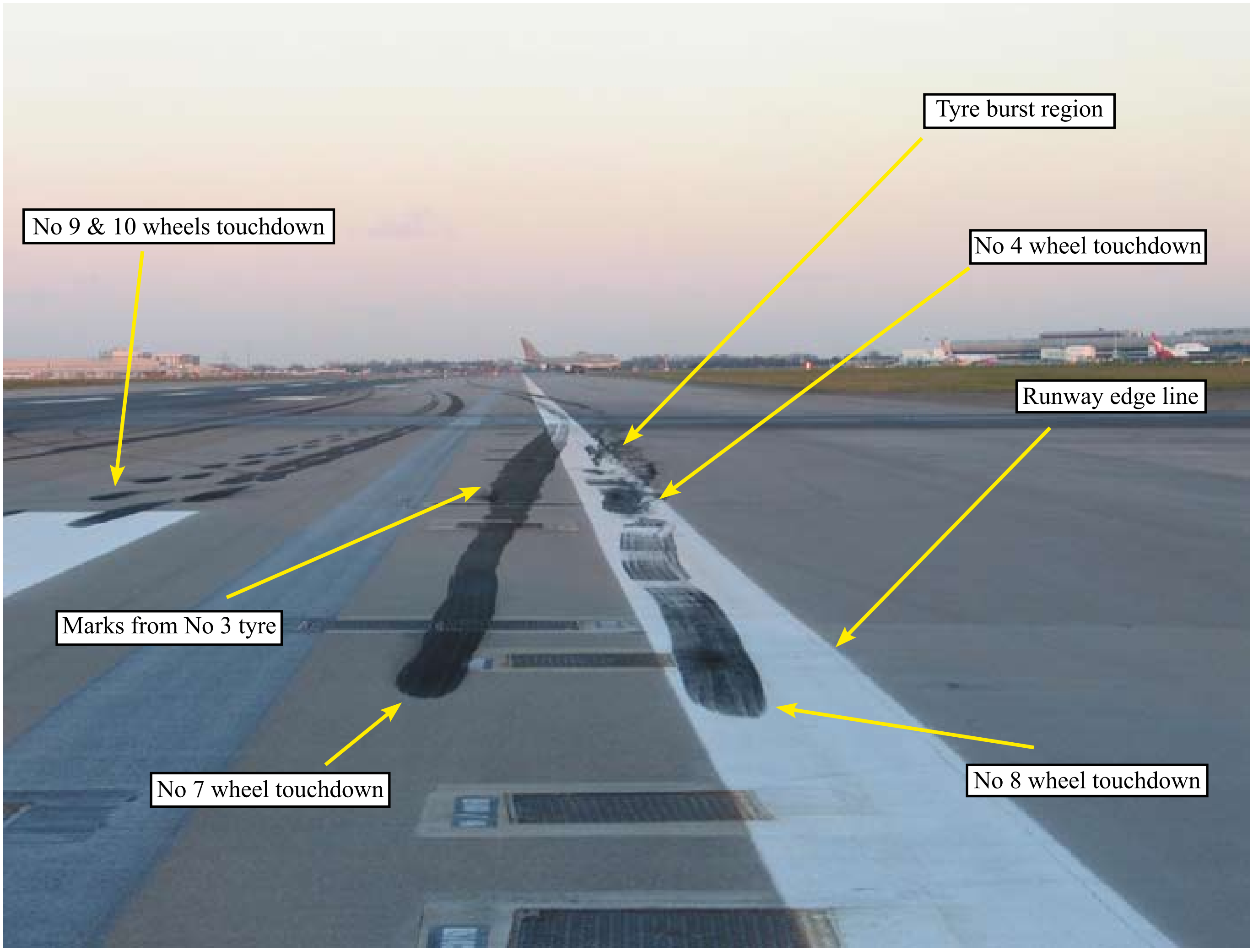


Figure 3

Marks made by the tyres from the right and centre main landing gear

Figure 4

Damage to the No 4 and No 8 tyres

Engineering investigation

On-aircraft

The No 3, 4, 7 and 8 wheel assemblies were removed from the aircraft for further investigation by the AAIB. In addition, the operator's engineers carried out the following two inspections, as detailed in the Aircraft Maintenance Manual:

> *'AMM 05-51-15 - Inspection after a tire burst or tread throw or wheel failure,*
>
> *AMM 05-51-11 - Inspection after hard or over weight landing.'*

During these inspections, the operator discovered evidence of delamination of a stator plate in the No 8 wheel brake unit (Part Number 2-1663-3) and noted that the 'temperature indication' paint on its axle had changed colour to an 'off-white'. This indicated that the axle had possibly been subjected to overheating. A hardness check was subsequently undertaken by the landing gear manufacturer, which established that the axle had not in fact overheated. Given the lack of damage to the wheel hub and the fact that there had been no overheat warnings or messages on the aircraft's Post Flight Report system, the operator's engineers assessed that the damage to the brake unit had not occurred during this flight or as a result of the landing.

Wheel examination

The fuse plugs in the No 4 and 8 wheels were intact and there was no evidence that the heat shields or wheel material had been subjected to excessive heat. In addition to the outboard rim of the No 4 wheel being ground flat over an arc of approximately 40º, the outer rim of the No 8 wheel exhibited light scratch marks that were assessed as being caused by contact with the runway. The chin ring and a section of the heat shield in both the No 4 and 8 wheels had been dented by flaying rubber. Rubber marks were also found on the inner and outer rims of both wheels, which was consistent with them running on deflated tyres. Wheel hub Nos 3 and 7 were assessed as serviceable. Examination of the remaining wheels and tyres by maintenance personnel failed to reveal any abnormalities.

No 8 wheel brake unit examination

The brake manufacturer examined the No 8 brake unit and identified that there was light oxidation on the No 3 stator to a depth of approximately 3 mm from the rim. This was consistent with the stator having been overheated at some point. However, this brake unit had been fitted to the aircraft from new and it was not possible to determine when this may have occurred. The remainder of the brake unit was assessed as being in good condition with approximately 40% of its life remaining.

Tyres examination

Tyre Nos 3, 4, 7 and 8 were returned to the manufacturer's Research & Development establishment for inspection by their quality department.

The shoulders of tyre Nos 3 and 7 both displayed signs of moderate scrubbing and the manufacturer believed that the majority of this damage probably occurred prior to the incident. Such damage often results from the shoulders making contact with the ground whenever an aircraft is manoeuvred in a confined area. However, it is possible that some of this damage was caused following the failure of the No 4 and 8 tyres.

The No 4 tyre was extensively damaged, with approximately 70% of the tyre detached from its two beads. Damage to the outboard sidewall indicated that the tyre had distorted sufficiently for the sidewall to rub along the runway, causing the plies to be ground away. This resulted in a hole in the sidewall and the sudden deflation of the tyre, which then appeared to have allowed the outboard rim of the wheel to make a brief contact with the ground. As the wheel continued to rotate, the rims cut through the tyre sidewalls, allowing most of the tyre to detach from its beads. The damage to the No 8 tyre was similar, with approximately 50% of the tyre detached from the beads. There was, however, only light scoring to the wheel flange, which probably occurred when the aircraft was taxiing off the runway.

Tyre Nos 4 and 8 both displayed evidence of overheating on their treads and sidewalls. The treads were also extensively scratched. However, given the distortion of the tyres following the loss of pressure, it was not possible to determine if this damage occurred before or after the tyres burst and such damage did not necessarily indicate the drift of the aircraft at touchdown. The manufacturer assessed that all the tyres were serviceable prior to the incident with no evidence that any had been incorrectly inflated.

Tyre performance

The performance of a tyre is not only dependent on the load applied, but also the manner in which it is applied, ie, the vertical and lateral accelerations experienced by the tyre at touchdown. Whilst the acceleration and the order and timing of the wheels touching down is known, it was not possible to determine accurately the load on the No 4 and 8 tyres, as the aircraft manufacturer was unable to provide information on the amount of lift the wing was producing when the tyres burst. However, a review of the aircraft manufacturer's test data indicated that the vertical and lateral acceleration recorded on the Flight Data Recorder for this landing placed the tyres on the edge of their performance envelope at maximum rated load.

Flight Recorders

The two solid-state flight recorders (DFDR and QAR) were removed from the aircraft and replayed, and both had retained data covering the events leading up to and during the landing. Pertinent parameters recorded during the approach and landing are shown in Figures 5 and 6.

Wind data

Strong winds were evident throughout the approach, and the wind parameters recorded on the FDR were calculated by the aircraft's inertial reference system. The aircraft manufacturer has indicated that the calculation process introduces a small delay before data is available on the aircraft databases, but were unable to quantify the time period involved. In addition, the manufacturer stated that the accuracy of recorded wind information for wind speeds in excess of 50 kt was within 10º54 and 10 kt, whilst the values for winds less than 50 kt should be used as an indication only. Wind data recorded during the approach and landing is tabled below (Table 1).

Approach Phase

By 2,500 ft agl, the aircraft had been configured for the landing; Flap 3 had been selected and the landing gear lowered. The aircraft was established on the localiser, both autopilots and the auto-thrust system were engaged and autobrake Mode 3 had been armed.

Manual speed selection was used down to 2,000 ft agl, from which point 'selected speed' was used. The approach target speed was recorded as being predominantly 161 kt, although temporary increases up to 169 kt were observed between 2,000 ft and touchdown. Recorded airspeeds during this same period ranged from 156 kt to 173 kt and the associated auto-thrust system responses resulted in variations in the N_1 speed from all four engines ranging from 25% (flight idle) to 54%. Aircraft pitch attitude varied by ±3º about an average of 1º nose up, with roll attitude values varying by ±2º about a mean of 0º. The aircraft was tracking the localiser and, with the wind from the left, adopted a drift angle of 5.6º ±1.6º.

From 430 ft agl to 225 ft agl, recorded wind speed values remained essentially constant at an average of 27 kt, but the wind direction backed by approximately 10º, resulting in a slightly higher crosswind component.

Height above ground (feet)	*Wind Direction (º) and Speed (kt)*	*Wind speed fluctuation (kt)*
5,000 – 4,500	070 / 40	±5
4,500 – 4,000	070 / 40	±8
4,000– 3,500	060 / 36	±8
3,500 – 3,000	057 / 35	±11
3,000 – 2,500	055 / 26	±6
2,500 – 2,000	055 / 25	±11
2,000 – 1,500	050 / 30	±11
1,500 – 1,000	043 / 21	±11
1,000 – 500	048 / 25	±9
500 - Touchdown	039 / 26	±12

Table 1

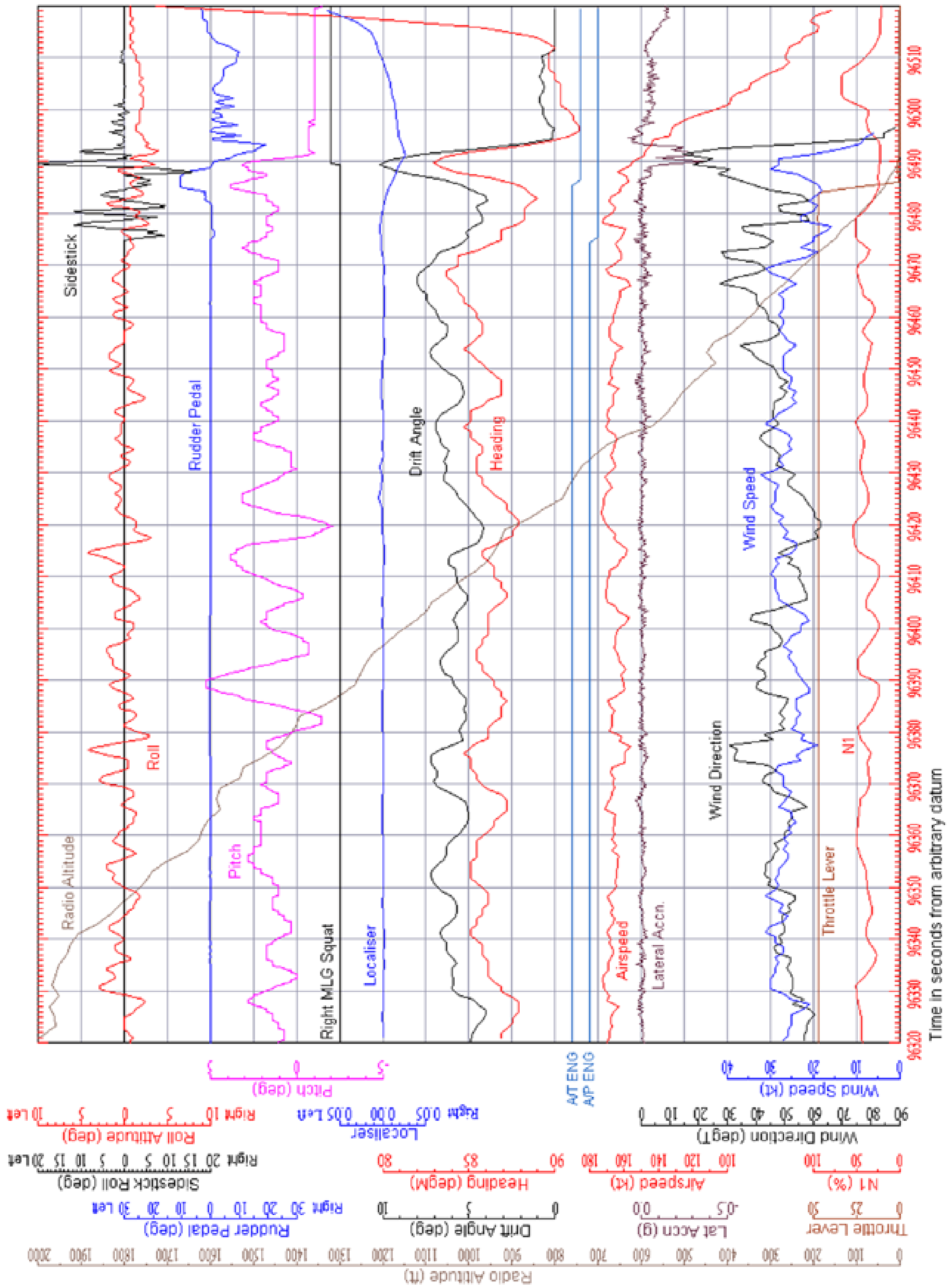

Sidestick
Radio Altitude
Roll
Rudder Pedal
Pitch
Right MLG Squat
Localiser
Drift Angle
Heading
Airspeed
Lateral Accn.
Wind Speed
Wind Direction
Throttle Lever
N1
A/T ENG
A/P ENG
Time in seconds from arbitrary datum

Figure 5

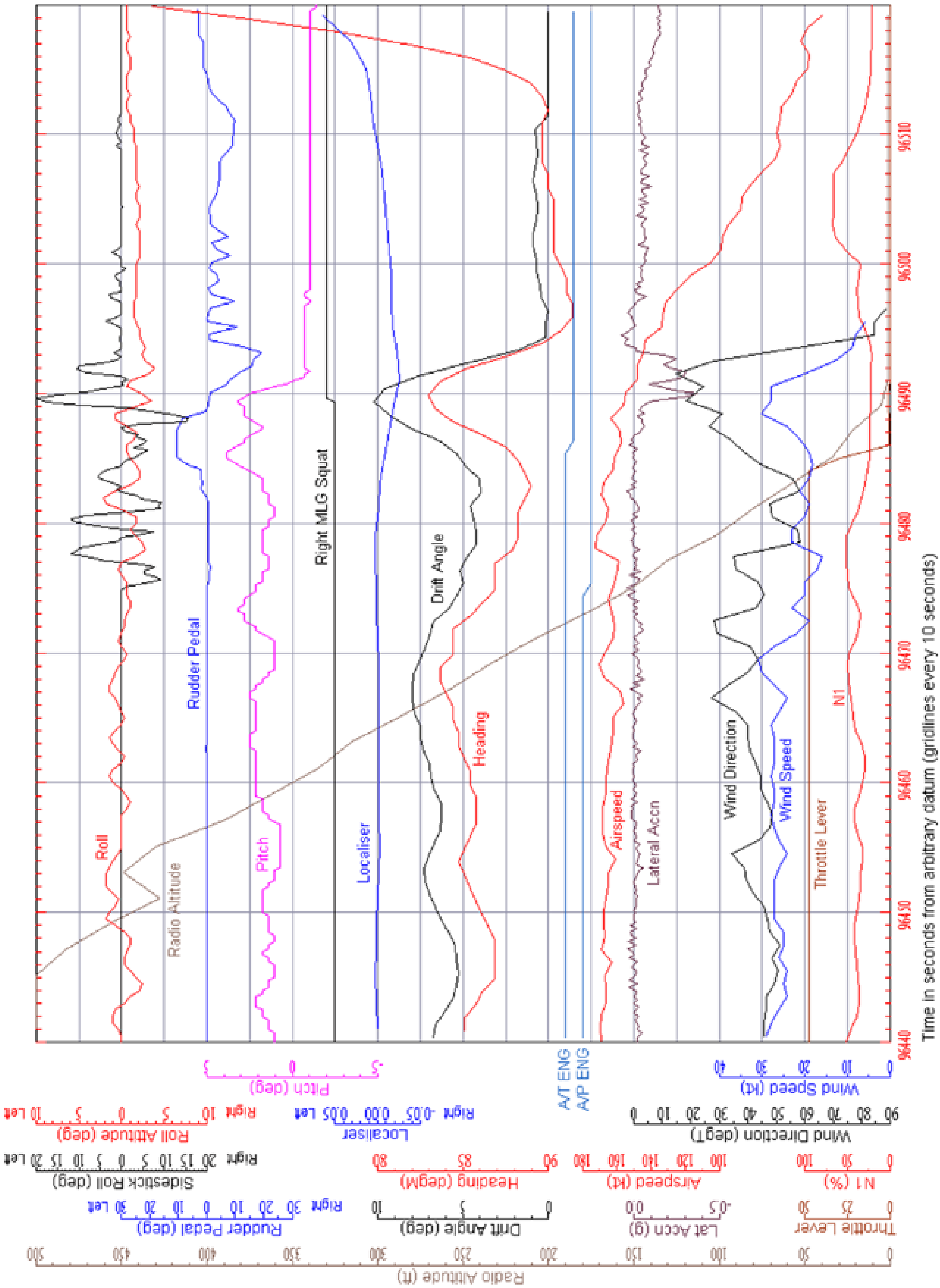

Roll
Radio Altitude
Rudder Pedal
Pitch
Right MLG Squat
Localiser
Drift Angle
Heading
A/T ENG
A/P ENG
Airspeed
Lateral Accn
Wind Direction
Wind Speed
Throttle Lever
N1
Time in seconds from arbitrary datum (gridlines every 10 seconds)

Figure 6

The aircraft began to track very slightly to the right of the extended centreline[3], its heading reduced and the drift angle increased to 8º. By 150 ft agl, the drift angle was reducing through 5º as the extended centreline was regained. The autopilots were disengaged at this point and movements of only the left sidestick indicated that the aircraft was being flown manually by the commander.

Landing Phase

Over the first two seconds after autopilot disconnection, a slight manual control input of right rudder pedal and a sidestick displacement of between 5º and 9º to the right were made. A maximum rudder surface deflection of 6.9º (trailing edge to the right) was also recorded and the aircraft began to roll to the right. Over the next four seconds, two consecutive sidestick deflections to the left of, approximately, half full scale deflection were applied to correct the roll attitude, which reached a maximum of 2.8º right wing down. At the same time, with wind speed remaining essentially constant at 21 kt, the wind direction veered 13º, which resulted in a reduction of the crosswind component and an increase in the headwind component. Airspeed then increased to 172 kt and thrust reduced, with all four engine N_1 values falling to flight idle (25%).

By 69 ft agl, the drift angle had reduced to a minimum of 4º and recorded localiser values showed that the aircraft was drifting to the right of the extended centreline. A small amount (2º) of left rudder pedal was applied followed, two seconds later, at 46 ft agl and the start of the flare, by a much larger (10º) left pedal input. At the start of the larger rudder pedal input, with the aircraft between 46 ft and 34 ft agl, the thrust levers were retarded and the auto-thrust system disengaged. N_1 values for all four engines indicated that they were at flight idle at that point. During this initial flare, pitch attitude had increased to 3.9º (nose up) by the time the aircraft had descended to 34 ft agl.

Between 34 ft agl and touchdown, the recorded wind direction backed by 30º and its speed increased by 10 kt[4]. Drift angle began to increase as the aircraft yawed left and, by 22 ft agl, aircraft pitch attitude had reduced to 1.8º nose up. The aircraft continued to deviate further right of the extended centreline whilst yawing to the left. During the two seconds before touchdown, two further deflections of the left sidestick of 15º right and full scale left (20º) were recorded. Pitch attitude was increased to 3.2º during this period and, one second before touchdown, the rudder pedals were centralised by the right pedal being depressed.

The aircraft landed at a speed of 156 kt, to the right of the centreline on a heading of 083ºM and with a drift angle of 10.2º, Figure 7.

Roll attitude at touchdown was 3.5º right wing down. The right main landing gear contacted the ground first, followed almost immediately by the centre and left main landing gears. The aircraft's rate of descent at touchdown was calculated to have been approximately 500 ft/min; a normal acceleration of 1.75g and a lateral acceleration of -0.37g were recorded. Wheel speeds were recorded by the FDR and, with the exception of wheel Nos 4 and 8, all showed normal indications during and after spin-up. Speeds recorded from wheel No 4 remained at zero, whilst that from wheel No 8 peaked at only 38 kt.

Footnote

3 Localiser deviations indicated a displacement to the right of a maximum of 0.002 Difference in Depth of Modulation (DDM).

Footnote

4 For reference, over the seven seconds prior to touchdown, the computed wind speed had increased from 21 kt to 30 kt and its direction had backed from 062º to 019º.

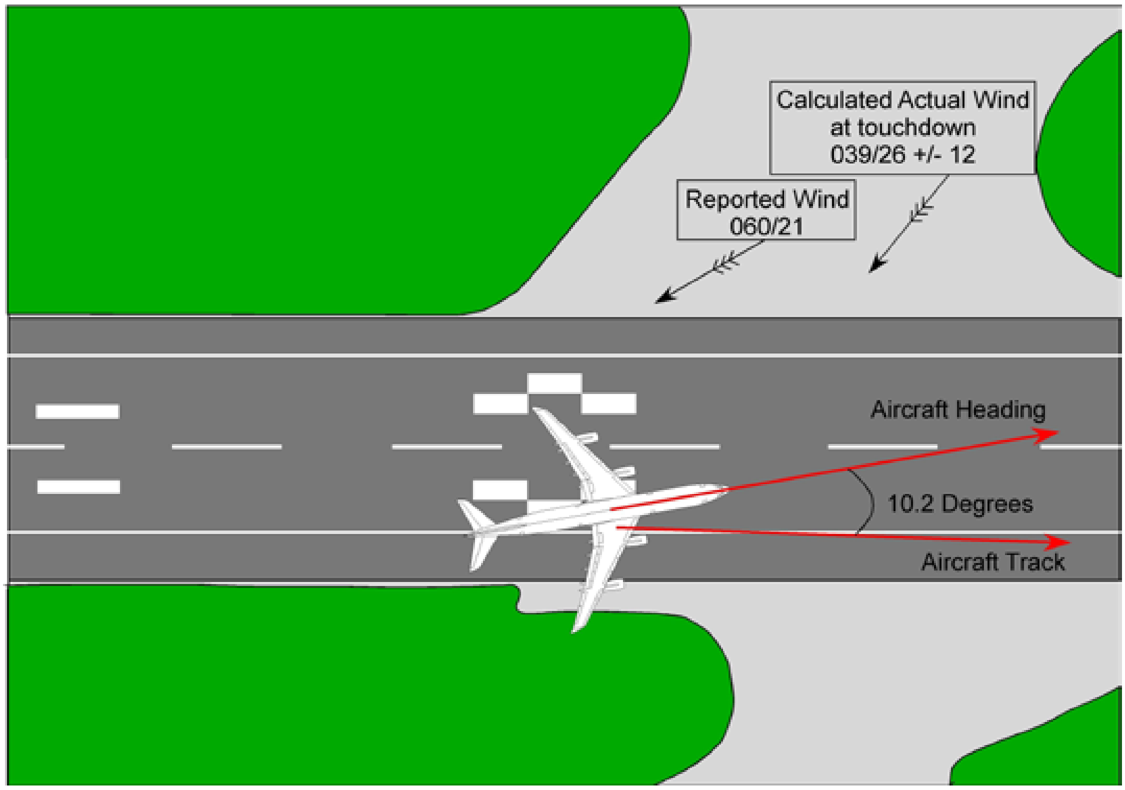


Figure 7

After Landing

Following touchdown on the main landing gear, the aircraft was de-rotated to lower the nose gear onto the runway and ground spoilers deployed. Longitudinal acceleration values between -0.28g and -0.3g were recorded which were consistent with autobrake operation. Consistent brake pressures were recorded from all main gear brake units, with the exception of Nos 4 and 8, which remained near zero. A progressively increasing application of right rudder pedal was made, culminating in 20º deflection after four seconds. The aircraft began to yaw to the right as it regained the centreline of the runway. Significant values of lateral acceleration ranging between -0.29g and -0.17g were recorded during this turn[5]. Towards the end of the turn, airspeed had reduced to 133 kt and reverse thrust was selected. Whilst slowing through 98 kt, symmetrical manual braking was applied which disengaged the autobrake system. Right rudder pedal inputs were made at various stages during the rollout and a master caution indication was recorded as the aircraft slowed through 80 kt. Idle reverse was selected at approximately 60 kt. Nosewheel steering and differential braking were used to vacate the runway to the left, following which the aircraft was brought to a halt.

At no stage during the approach and landing were any control inputs recorded on the FDR from the right sidestick. Also, no windshear or other warnings were recorded.

Footnote

[5] It should be noted that the sense of this lateral acceleration was opposite to that which may be expected during a normal turn to the right and hence may be indicative of the tyres skidding on the runway surface.

Analysis

Operational issues

The aircraft had been correctly configured to land under the prevailing weather conditions, and an appropriate approach speed had been selected. Whilst the initial approach was somewhat turbulent, the aircraft performed as expected with the autopilot accurately tracking the ILS. A drift to the right of the runway extended centreline commenced when the aircraft was at about 100 ft agl, shortly after the autopilot had been disengaged; the aircraft remaining to the right of the runway centreline until about a second after touchdown.

Despite a lag of unknown duration in recording the wind speed and direction, and an element of inaccuracy in the figures themselves, it is known that the aircraft was subjected throughout the approach to a crosswind from the left. The FDR data showed a small (no more than 2º), but predominant, roll attitude to the right when the aircraft was below about 200 ft agl and it was the combination of this crosswind and roll attitude that maintained the aircraft's drift to the right.

Whilst the exact time and extent are not known, the wind speed increased and backed significantly during the very final stage of the approach. From the crew's recollection this seems to have occurred whilst the aircraft was in the flare. The FDR data indicates that no major rudder input was made until the aircraft was at about 60 ft agl, when about 10º of left pedal was applied. Over the next five seconds, the aircraft's drift angle increased from about 5º to 10º. This coincided with the commander making various roll inputs, to compensate for the roll effect of the rudder inputs attempting to keep the wings level. These were, again, predominantly to the right, whilst the aircraft continued to deviate to the right, away from the centreline.

Just before G-VSHY touched down, the right rudder pedal was pressed sufficiently to centralise the rudder pedals, but not to have any significant de-crabbing effect on the aircraft. This supports the commander's statement that he was concerned that to de-crab the aircraft at touchdown might result in a further move to the right, possibly taking the aircraft off the runway. The effect was that the aircraft touched down with a drift angle of 10.2º and a resultant (large) lateral acceleration of -0.37g. A roll attitude at touchdown of 3.5º to the right ensured that the right main landing gear contacted the ground first and, despite the centre and left landing gear touching down immediately after, meant that the forces associated with large lateral acceleration were experienced, initially, by the two outer tyres on the right main gear.

When manually landing an aircraft in a strong crosswind, a significant drift angle may be necessary for the aircraft to track the runway centreline using the 'crabbing' technique, as well as when used in conjunction with the 'wing down' technique. In such circumstances, it is generally the practice that the aircraft should be flown so that the main landing gear tracks the runway centreline, or even slightly to its upwind side. With a long bodied aircraft such as the A340-600, before touchdown, this may require the nose of the aircraft to be aligned approximately with the upwind edge of the runway. By doing so, even with the instantaneous wind changing rapidly, it is likely that the drift may be 'kicked off' and the aircraft landed, before the aircraft drifts too far towards the downwind edge of the runway.

Safety action

Although landing in a crosswind should be within the capabilities of a qualified line crew, it is probable that an approach and a manual landing in a strong and turbulent crosswind is not experienced that often, either in reality or in the simulator. To emphasise the appropriate techniques to be used when landing in crosswinds, the operator has included the following information in a recently issued general notice to flight crews:

- *'In crosswind conditions, a crabbed approach should be flown. Aim to put the centre gear on the centerline. During the flare, rudder should be applied as required to align the aircraft with the runway heading. Any tendency to drift downwind should be counteracted by an appropriate input on the sidestick. In the case of a very strong crosswind, the aircraft may be landed with a residual drift [maximum 5º] to prevent an excessive bank [maximum 5º]. Consequently, a combination of partial de-crab and wing down technique may be required. The pilot should disconnect the autopilot early enough to resume manual control of the a/c and to evaluate the drift before flare.*
- *When disconnecting the AP for a manual landing, the pilot should avoid the temptation to make large inputs on the sidestick. The pilot should avoid any tendency to drift downwind.'*

Engineering issues

The tyre marks on the runway were consistent with data on the Flight Data Recorder, in that when the aircraft touched down, it started to skid to the right. At this point, the load placed upon tyre Nos 4 and 8, generating the aircraft vertical and lateral accelerations, distorted both tyres sufficiently to allow their sidewalls to scrape along the runway. As they were worn through, both tyres would have suddenly deflated, allowing the wheel rims to cut through the sidewalls and largely separate the tyres from the beads. Flaying rubber then caused minor damage to components in the immediate area. As the aircraft decelerated, the amount of sideways skidding reduced and the aircraft track aligned with its heading, which directed the aircraft towards the runway centreline.

Information was sought from the manufacturer throughout the investigation concerning the landing parameter limits for this aircraft/tyre combination, in respect of drift angle, landing gear and applied tyre loading. Having analysed the available data their response is summarised as follows:

- There were no anomalies seen with the performance of the aircraft systems
- The landing loads applied to the landing gears were within the design envelope
- The general aircraft parameters for the landing were within any defined limits; the event is not classified as a hard landing
- The roll and pitch angles at touchdown were acceptable
- There is no absolute crosswind limit for landing, but a 'maximum demonstrated crosswind' is demonstrated during certification tests
- Analysis of the data indicates that the aircraft landed within the demonstrated crosswind limit
- This was an extreme landing case and, as a consequence, resulted in the failure of two tyres. However, in such an event, tyre failure is an acceptable situation, as the aircraft demonstrated that it remained satisfactorily controllable.

Although there was evidence that one of the stator plates in the No 8 wheel brake unit had overheated, all other indicators suggested that this had not occurred on the subject flight and, therefore, was unlikely to have been associated with the failure of the No 8 tyre.

Conclusions

The aircraft commander had committed to making the approach in reported wind conditions that were within the maximum demonstrated crosswind limits, including gusts, for the aircraft. For most of the approach, the autopilot had maintained the aircraft on the glideslope and localiser but, when disconnected at a height of 275 ft, the pilot found it increasingly difficult to maintain the aircraft on the runway extended centreline in the demanding wind conditions.

Although the computed wind parameters immediately before touchdown were within the aircraft's limits, the crosswind component and wind speed both increased significantly during the flare. As the aircraft commenced the flare, with the aircraft already downwind of the runway centreline, the pilots' recollections and the recorded data both indicated that sudden severe turbulence was encountered at this critical stage of flight. At this point, in order to remain over the runway, the aircraft's drift angle increased to over 10º. Advice to pilots from the operator, issued after this incident, states that in very strong crosswinds, the aircraft may be landed with a maximum residual drift of only 5º, to prevent the bank angle exceeding 5º. This advice also notes that when disconnecting the autopilot for a manual landing, the pilot should do so early enough to resume manual control of the aircraft and to evaluate the drift before flare.

Whilst, according to the manufacturer, a firm landing with drift of this magnitude will not damage the aircraft, it was demonstrably outside the limits for the tyres. In the absence of any apparent pre-existing defects being identified during their detailed examination, it was concluded that the tyres had been serviceable prior to touchdown.

Although the commander momentarily considered going around, his decision to expedite the landing probably prevented the aircraft from departing the runway. Given the relatively long time required, in such circumstances, for the engines to spool-up to go-around power, the aircraft would probably have touched down in any case, with the distinct possibility that it may have departed the paved surface and become airborne having sustained more serious damage than two burst tyres.