DATA SUMMARY

LOCATION

Date and time	**Friday, 31 August 2007; 21:05 h UTC**
Site	**Mariscal Sucre International Airport in Quito (Ecuador)**

AIRCRAFT

Registration	**EC-JFX**
Type and model	**AIRBUS A-340-600**
Operator	**Iberia, L.A.E.**

Engines

Type and model	**ROLLS ROYCE RB211-Trent 556-61**
Number	**4**

CREW

	Pilot in command	Copilot
Age	**54 years old**	**38 years old**
Licence	**Airline Transport Pilot**	**Airline Transport Pilot**
Total flight hours	**14,529 h**	**6,597 h**
Flight hours on the type	**3,160 h**	**5,392 h**

INJURIES

	Fatal	Serious	Minor/None
Crew			**16**
Passengers			**304**
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**Commercial air transport – Scheduled international passenger flight**
Phase of flight	**Landing – Touchdown**

REPORT

Date of approval	**21 February 2011**

0. SYNOPSIS

The incident was reported on the following day by the Accident Investigation Commission (Junta Investigadora de Accidentes, JIA) of the Republic of Ecuador to the Civil Aviation Accident and Incident Investigation Commission (CIAIAC), which appointed an accredited representative pursuant to Annex 13 of the ICAO. The JIA later delegated the investigation to the CIAIAC. The BEA in France was notified of this fact.

1. FACTUAL INFORMATION

1.1. History of the flight

1.1.1. *Cruise and approach phases*

The aircraft had taken off from Madrid Barajas at 10:50 and, after a normal flight, entered into Ecuadorian airspace. The crew of the transatlantic flight consisted of the pilot in command, a relief captain and two copilots.

The runway in use at Mariscal Sucre Airport in Quito was 17. The 20:30 METAR for the airport indicated 9 kt winds from 120° gusting up to 19 kt with variability ranging from 060° to 180°. The temperature was 17°, the dew point 5°, QNH 1,026 hPa, visibility in excess of 10 km, and the cloud cover was 5 to 7 octas at 1,200 m and 3 to 4 octas at 3,000 m. The aeronautical information publication (AIP Ecuador) lists runway 17 threshold with an altitude of 9,217 ft.

Air Traffic Control (ATC) cleared the aircraft to descend to 17,000 ft and to enter left base runway 17.

The crew of EC-JFX did not assent to this maneuver, requesting instead an ILS approach to runway 35 with circling to 17, which was authorized by ATC.

At about 20:54, there was a warning in the cockpit of a fault in the blue hydraulic pump for number 2 engine (B ENG2 PMP), and another of a low blue reservoir hydraulic fluid (B HYD RSVR). The blue system does not pressurize the aircraft braking system.

At around 21:00:55 (FDR time), the crew notified they were on final 35 on visual approach to 17 with left tailwind leg. The control tower cleared them to the 17 visual circling and requested to be informed of entering left base leg.

The crew had armed the autobrakes to position 2, to activate after landing. At 21:01:08, with the aircraft at an altitude of 11600 ft, the two auto pilots were disconnected. Auto thrust control was kept engaged throughout the maneuver until the landing.

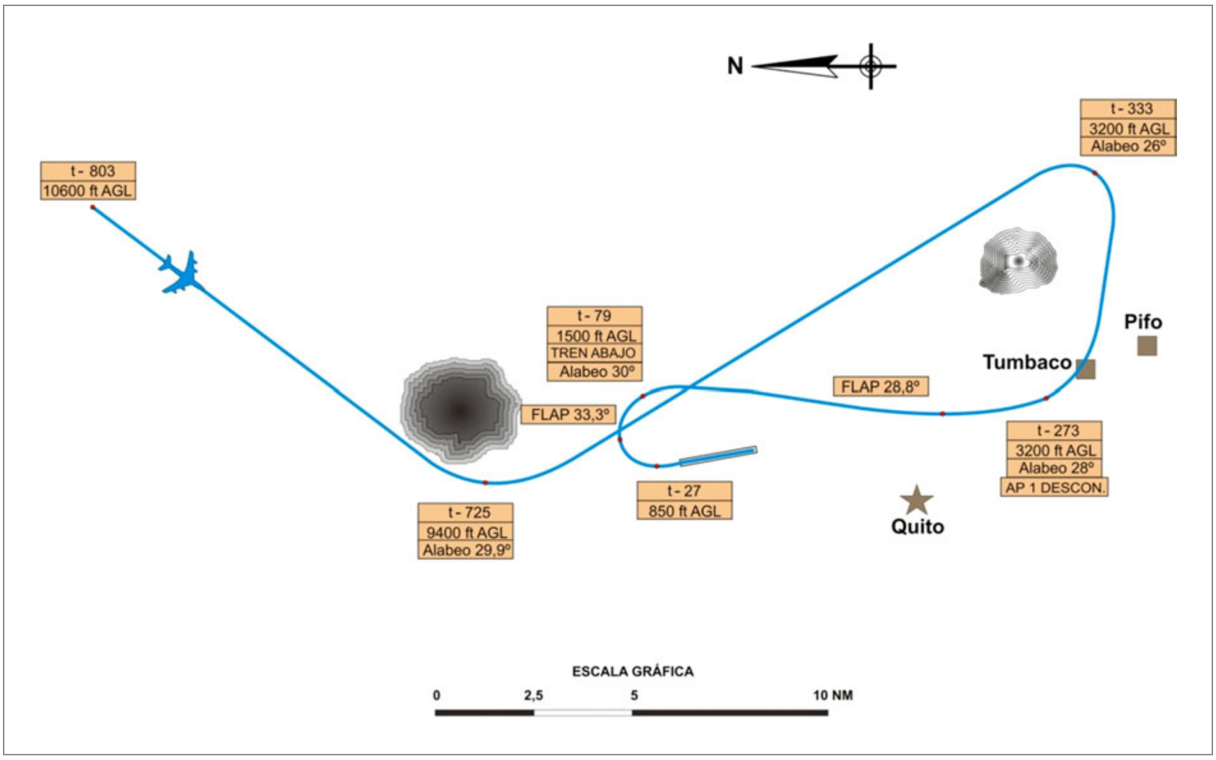

Figure 1. General diagram of the path taken by the aircraft according to the FDR

On the 17 downwind leg, the aircraft descended to 1500 ft AGL. The landing gear was lowered as they abeam the runway threshold (at 21:04:00). Seventeen seconds later, they notified the tower they were "turning left base." At 21:04:25, they informed ATC that they were on final for 17, and 23 seconds later they were cleared to land with winds from 140° at 8 kt.

According to the wind data recorded in the DFDR, corrected by the estimated drift and ground effect, the aircraft, aligned on final, encountered winds varying from approximately 18 kt to 0 kt from variable directions, but which was generally a pure crosswind with respect to the runway heading (172° magnetic according to the DFDR). The crosswind correction was generally carried out with the wings almost level (with small roll corrections) while keeping a drift correction angle (crab method).

1.1.2. *Final approach and landing*

On final approach, at 140 ft AGL, as indicated in the operator procedure for visual approaches, the auto thrust (A/THR) was engaged in speed mode (SPD); the flight directors (FD) were not engaged (thus the A/THR was managing the speed); auto brakes were selected in position two (low); the slats and flaps were in FULL (24°/34°) configuration and the center of gravity was approximately 33% of the mean aerodynamic chord.

During the final approach phase, the aircraft had a right 3° drift with respect to the runway, and at that time its heading was practically the same as that of the runway. The drift correction angle was later increased such that at touchdown, the wings were level, the fuselage was aligned some 7° left with respect to the runway centerline and the drift or path of the aircraft's center of gravity with respect to the ground formed a 3° angle to the right of the runway centerline.

The first contact indication on the microswitches of the main landing gear legs was recorded at 21:05:06. Calibrated airspeed was about 146 kt. The weight of the aircraft upon landing was 240.3 tons (the maximum landing weight is 259 tons). Since certain vertical acceleration and descent speed values were exceeded, a "load report 15" was generated, according to which the following limit values were recorded for various parameters from one second before to one second after touchdown:

	Maximum	Minimum
Vertical acceleration	2.080 g	1.018 g
Lateral acceleration	–0.050 g	–0.561 g
Roll angle	2.5°	–0.4°
Pitch angle	5.7°	3.7°
Descent rate according to radio altimeter	–16,0 ft/sec	6.7 ft/sec

The aircraft contacted the runway surface some 160 m in with a groundspeed of 175 kt. Pieces of tire were found from the contact point forward for the length of the landing run, during which the aircraft was more or less aligned with the runway centerline until coming to a stop 2720 m away from the touchdown point.

After landing, and as a consequence of the CLG M2 wires loom being damaged (see point 1.3.3), the following warnings were received: "L/G LGCIU 2 FAULT" ("landing gear control and interface unit"), "BRAKES AUTO BRK FAULT," "WHEEL TIRE LO PR" and "BRAKES RELEASED." These last two appeared in the ECAM immediately after the touchdown. The first two didn't appear as their display is inhibited since the touchdown until the speed is below 80 kt. On the other hand, the spoilers deployed and the reversers worked properly.

1.1.3. *Landing run and aircraft evacuation*

During the landing run, the control tower notified the crew of aircraft EC-JFX of disintegrating tires, which the crew acknowledged at 21:06:22. They were also told to maintain their position, and the crew asked about the presence of firefighters at 21:06:48. The tower confirmed that the firefighters were already stationed behind them. The crew asked about the presence of smoke or anything out of the ordinary.

The crew informed the cabin attendants of the possibility of an emergency evacuation. Firefighters later confirmed to the tower that the aircraft could not taxi in its current condition, as was confirmed by maintenance personnel who reported to the scene.

Tires 10, 4 and 8 had burst. Tire 12 had deflated, while tires 3 and 7 had endured a high brake temperature.

At 21:13:38, the aircraft crew asked if the passengers could be disembarked in situ, since the tires would have to be replaced on the runway, which would require approximately one and a half hours. The control tower authorized the operation and the passengers deplaned via stairs situated at the front left exit (the one furthest away from the burst tires) and were transported to the terminal in shuttle buses.

1.1.4. *Subsequent actions*

Once the burst and deflated tires were replaced, the aircraft was taken to the stand. Tires 3, 7, 9 and 11 were later replaced as well due to an overload condition.

In his report following the incident, the pilot in command (PIC) did not note any technical problems during the approach or landing. In his opinion, the approach had been completely stable and he had not foreseen the possibility of such a hard landing.

An inspection of the runway following the incident revealed numerous tire debris scattered from the touchdown point on and a tread some 600 m away from the threshold. No foreign object debris was reported on the runway surface which could have damaged the tires.

1.2. Personnel information

1.2.1. *Pilot in command (CM-1), seated in the LH seat*

Gender, age:	Male, 54
Nationality:	Spanish
Type rating:	A-340
Previous type ratings:	B-767, B-757, DC-9, B-747
Total flight hours:	14,529 h
Flight hours on the type:	3,160 h (all as captain)
Hours in last 30 days:	26:15 h
Hours in last 7 days:	0 h

Hours in last 72 h:	0 h
Last simulator:	27-3-2007
Start of current duty period:	09:15 on 31-8-07
Previous rest period:	fifteen days

The CM-1 had 21 years of experience with the company. He had been flying the A-340-600 since June 2001, and later alternated with the A-340-600. He had flown to Quito on 12 previous occasions (on the -300 and -600), and had landed on runway 17 only a few times (with the -300 and -600). It was not possible to determine the exact number of landings he had made on that runway.

The high number of crewmembers used by the operator meant that, due to the schedule rotations, each captain only landed in Quito a few times per year.

According to an analysis of FDR data by the operator in the previous year, approximately 15% of all flights had landed on runway 17, especially from June to August due to the prevailing winds.

The operator's training syllabus for the second quarter of 2006 focused on Quito, meaning approaches to both runways were practiced on the -300 simulator (the operator did not have a -600 simulator at the time of the incident).

1.2.2. *Copilot (CM-2), seated in RH seat*

Gender, age:	Male, 38
Nationality:	Spanish
Type rating:	A-340
Previous type ratings:	MD-87
Total flight hours:	6,597 h
Flight hours on the type:	5,391 h (all as copilot)
Hours in last 30 days:	33:55 h
Hours in last 7 days:	0 h
Hours in last 72 h:	0 h
Last simulator:	15-7-2007
Start of current duty period:	09:15 UTC on 31-8-2007
Previous rest period:	Fifteen days

The CM-2 had been with the company since 1 December 1997 and had flown to Quito on 18 occasions. He had landed just a few times on runway 17, though it was impossible to establish an exact number.

1.3. Technical information on the aircraft

1.3.1. *General*

The A-340-600 had been used by the operator to fly to Quito airport since December 2005. The aircraft carries 352 passengers in a typical configuration of two classes (compared to 266 passengers in a typical A-340-313 configuration). The maximum landing weight of aircraft EC-JFX (serial number MSN 672) is 259 tons.

The main landing gear on the Airbus A-340-600 has three legs with four wheels each, numbered as shown in Figure 2 below. All twelve wheels have brakes. The radial tires are Michelin Near Zero Growth (NZG), size 1400 × 530R23/40/235, P/N M16004. These tires comply with technical standard order (TSO) 62D of the Federal Aviation Administration (FAA). The tire speed limit is 235 mph (204 kt or 378 km/h).

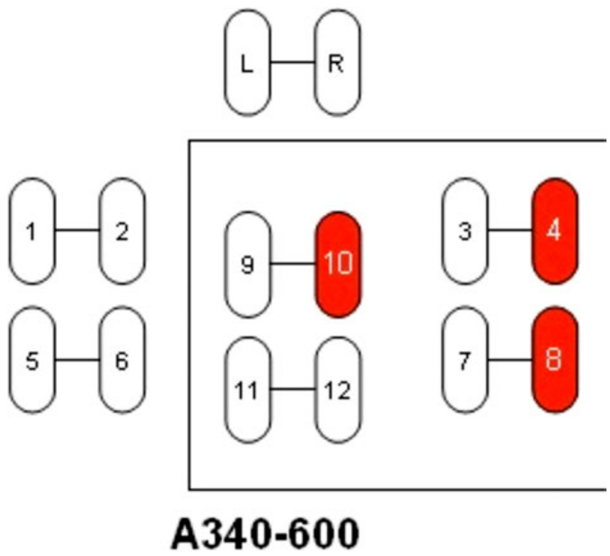

Figure 2. Wheel numbers according to diagram published by the tire manufacturer (Michelin)

The pitch angles which result in a tail strike are 12° (shock absorbers fully extended) and 8.5° (shock absorbers fully compressed). These values should be compared with 14.2° and 10.1°, respectively, for the A-340-300.

The aircraft's Flight Manual, Section 4.03.00 P 07A, 17-4-2003, provides the following table on the loss of altitude resulting from an automatic go around maneuver as a function of the initiation height:

Altitude loss after automatic go around initiation

Initiation height (ft)	Height loss (ft)
Above 75	32
50	22
40	18
30	14
20	10

After the landing of the incident flight, the following tasks were performed on the brake system:

ALTERNATE BRAKE SYSTEM BLEED AMM 32-43-00-870-801

NORMAL BRAKE SYSTEM BLEED AMM 32-42-00-870-801

There were no reports of any brake problems in the aircraft's recent maintenance history which may have contributed to this incident.

The following service bulletins, issued by Airbus, had been incorporated into the aircraft:

- Flight Control Law - improvement in lateral behaviour, incorporated on 3 Feb 2006. New standard for the flight warning computer, SB31-5024, incorporated on 17 Feb 2007.
- SB31-5029 to activate the 70-60 ft callouts, incorporated on 17 Feb 2007.

Tires 3, 4, 7, 8, 9, 10, 11 and 12 from the aircraft (see Figure 2) were sent to Michelin's facilities in France for a detailed inspection. The most relevant results from that inspection (Michelin RG report number 307-122) were as follows:

- No abnormalities were found in the tires' manufacturing records.
- Tires 4, 8 and 10 had withstood high landing loads due to the considerable stresses, deformation and drift.

The following conditions caused the blown out tires to deform:

- Severe impact on landing to the outer edge of the crown (serial number side).
- Flexion of the sidewall, contact with the ground, friction and total abrasion of the sidewall causing a rapid deflation and burst.
- Dislocation of the tire during the realignment of the aircraft with the runway centerline while running flat, breaking of the casing plies on the rim flanges and shoulders; friction, scuffing and perforation of the crown and total breaking of the crown block.

The loads and stresses withstood by those three tires during the crab landing led to the rapid burst after touchdown and dislocation of the components during the subsequent run, once they had completely deflated.

No anomalies were detected on the 5 other tires except for transversal scratches on the shoulders and longitudinal scratches at a 10° angle to the tread, confirming the existence of a landing with drift.

1.3.2. *Tire load limits*

Airbus reported that its tire specifications included an explicit requirement to cover landings with side slip, which called for the tire to withstand a landing with a combined descent rate and drift angle as shown in Figure 3 below.

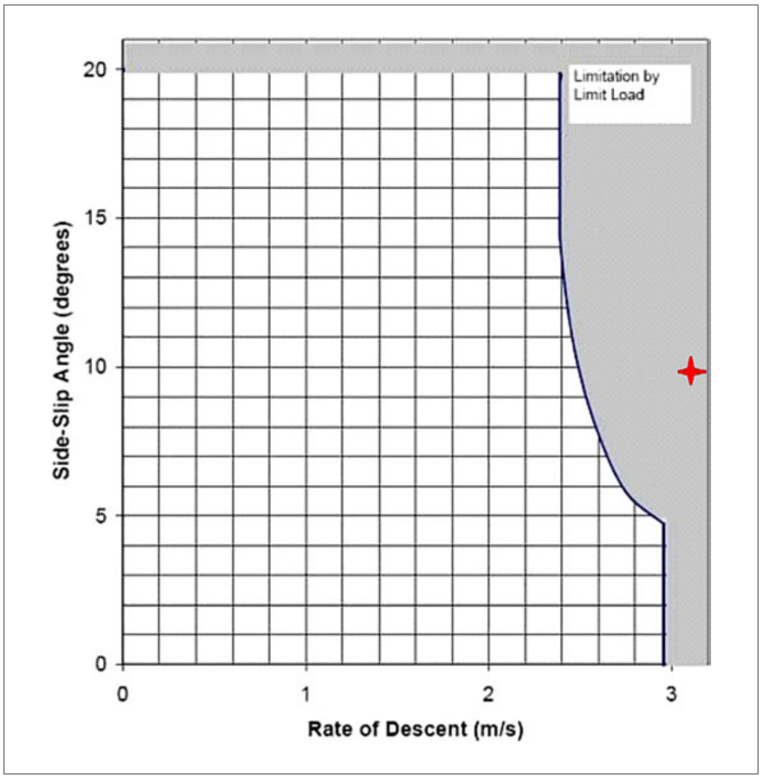

Figure 3. Operational envelope for the A-340-600 tires, indicating the landing conditions for the EC-JFX landing in this incident, with approximately 3.3 m/s y 10° of side slip

The Airbus specification also detailed the applicable speed/time curve for demonstrating the tire's strength using a test which consisted in simulating a landing with drift on a dynamometer, in which the speed is constantly decreased as the vertical load changes. In the test, a vertical load peak of some 24,000 daN (see Figure 4) was reached.

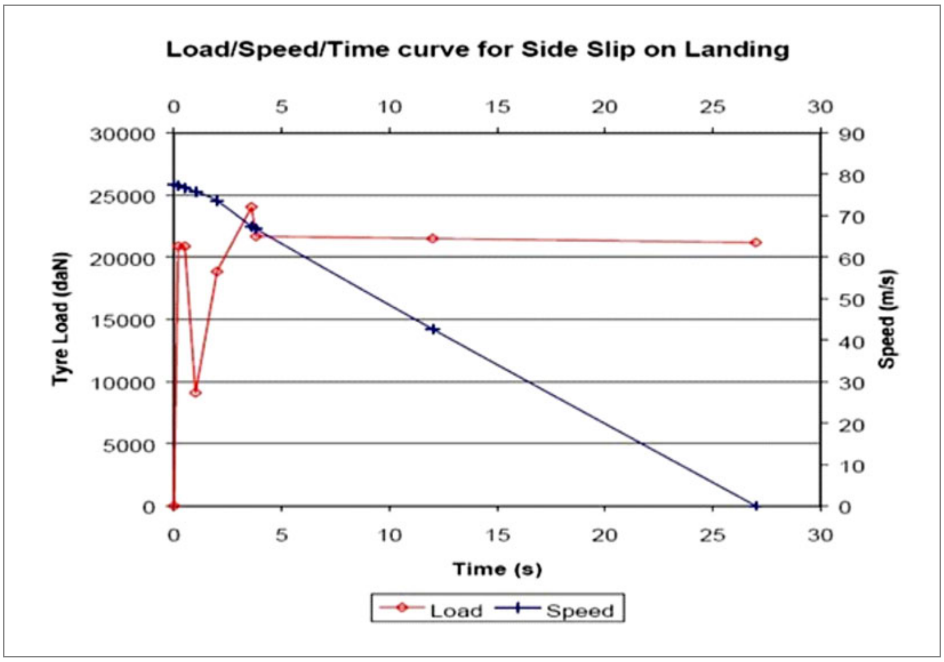

Figure 4. Combination of speed and vertical load used to certify the tires used on the EC-JFX for a landing with side slip

For the type of tires in the incident, Airbus stated that Michelin had shown compliance with this requirement by performing a dynamometer test which simulated a landing with over 20° side slip angle and a descent rate of 2.4 m/s (7.9 ft/s) without any tire damage.

Airbus reported that its calculations indicated that each tire on EC-JFX had been subjected to at least 36,000 daN during the incident landing (conservatively assuming a uniform load distribution among the 12 wheels), thus exceeding the maximum value of 24,000 daN tested for during the tire certification.

A dynamometer test is also required under technical standard order C62D of the FAA.

Additionally, Airbus indicated that in over 160,000 cycles accumulated by the A-340-500 and -600 fleet that use the same gear and tires, there had been no reports of tires failing within their operational envelope. The experience with hard landings with excessive residual drift is limited to two events (see Section 1.8).

1.3.3. *Other damage*

It must be noted that in the CLG the M2 wires loom and its link to the bogie were damaged; this loom goes along the front part of such CLG. The bogie position signals and the wheels spins to the no. 2 LGCIU (Landing Gear Control and Interface Unit) are transmitted through it. The absence of damage in the bogie indicates that probably the damage was as result of the impact of wheel detached pieces.

1.4. Meteorological information

The METARs for Quito airport applicable to the approach and landing were as follows:

	21:00 h	Special 21:07 h	21:30 h
Wind	110° 9 kt, with gusts of 19 kt, varying in direction from 040° to 150°	100° 7 kt	110° 8 kt
Cloud cover	5 to 7 octas at 1,200 m; 3 to 4 octas at 3,000 m	5 to 7 octas at 1,200 m; 3 to 4 octas at 3,000 m	5 to 7 octas at 1,200 m; 3 to 4 octas at 3,000 m
Temperature	16°	16°	16°
Dew point	4°	4°	4°

In all three cases horizontal visibility was in excess of 10 km and the QNH was 1,026 hPa, with no significant changes forecast.

1.5. Aerodrome information

Quito airport has one runway in a 35/17 orientation, measuring 3,120 × 46 m, on magnetic headings 352° and 172°, respectively. The runway strip is 3,240 × 160 m. Runway 35 has a runway end safety area (RESA) measuring 280 × 90m.

Runway 35 has a Category I ILS, while 17 does not have an ILS. Runway 35 has a precision approach path indicator (PAPI) located to the left which provides a 3.12°-glide slope. Runway 17 also has a PAPI to the left with a glide slope of 3°.

Figure 5(a) shows the runway longitudinal profile. It can be observed that runway 17 starts with an upward slope of approx. 1%.

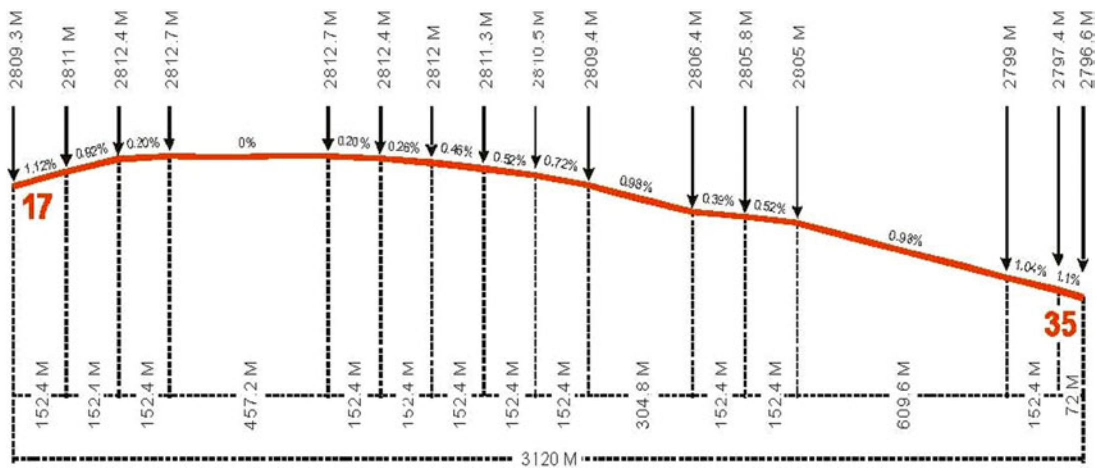

Figure 5(a). Runway longitudinal profile

Figure 5(b) shows the chart concerning the instrumental approach performed by the crew to runway 35, previous to their “circling” for visual approach to runway 17.

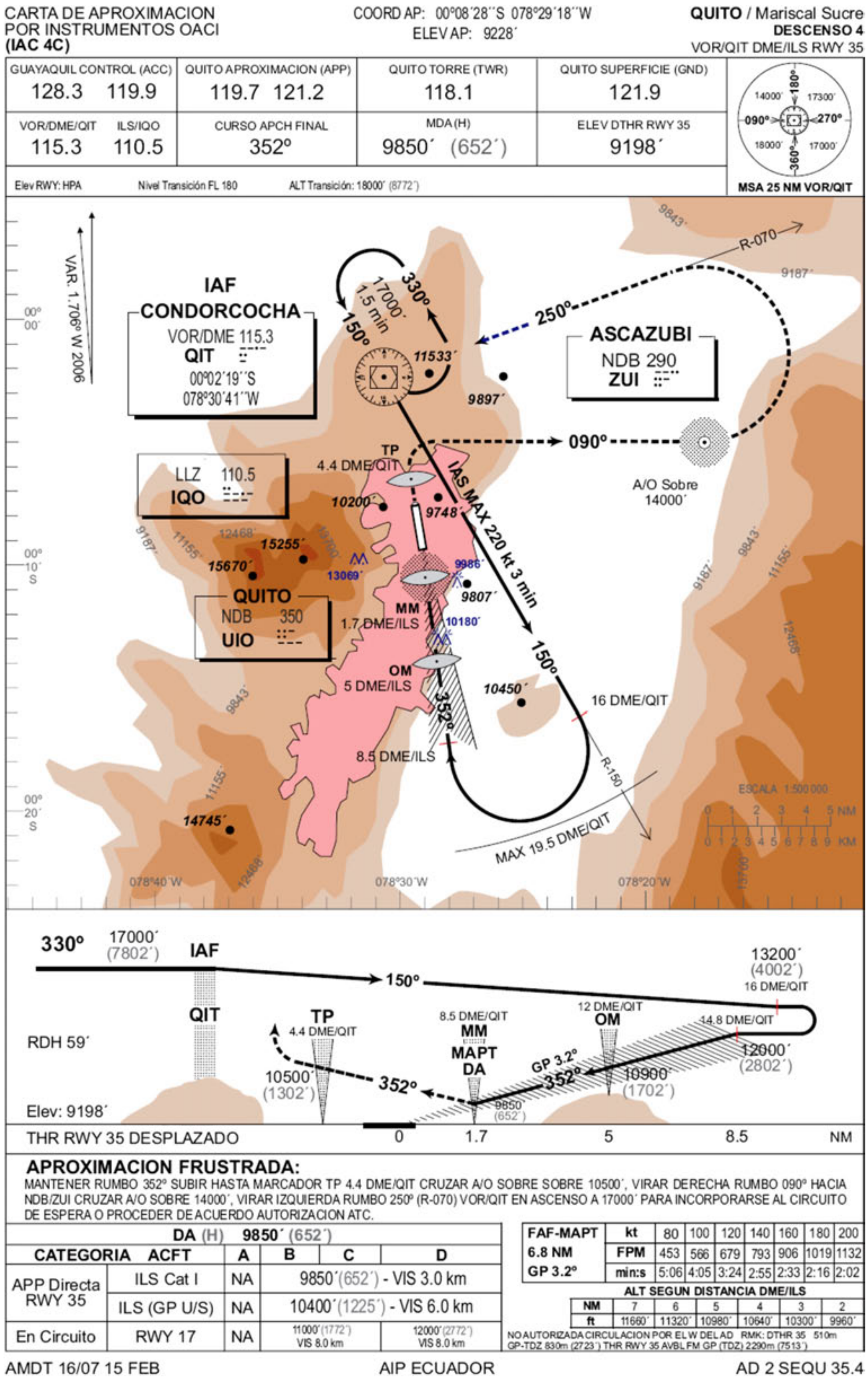

Figure 5(b). “Descent 4” approach on AIP Ecuador

1.6. Flight recorders

1.6.1. *Cockpit voice recorder*

The aircraft was equipped with a solid state Honeywell CVR, P/N 980-6022-001. This recorder tapes the last thirty minutes of sounds on the flight deck on four tracks, corresponding to the CM-1, CM-2 and CM-3 microphones, and the area microphone. There are two other tracks which record two hours from the area microphone and the other three channels mixed into one.

The relevant sound files were obtained once the information was downloaded from the recorder. It was determined, however, that the aircraft had probably remained energized with the CVR recording for a prolonged period after the incident, since only the sound of aircraft landing and taking off could be heard on the area microphone channel, followed by the voices of people in the cockpit with Ecuadorian accents, presumably maintenance personnel from the operator, talking among themselves and actuating different switches until the recording ends. The CVR, therefore, did not provide any useful information to the investigation.

At this point it must be noted that the aircraft operator had established, as from May 24, 2006, procedures[1] for the maintenance personnel to disconnect the CVR after an incident. This is included in the MK-NT01 QR25 Norm, paragraph 5.4 in the following terms:

> "5.4. Evidences protection
>
> The Maintenance Base or Department must preserve every accident or serious incident evidences, since the first very moment and until the Authorities, or the Procedures and Safety Unit in case there are no explicit instructions from the Authorities, determine.
>
> The evidences protection includes:
>
> - CVR, FDR, DAR/QAR/, PCMCIA registers preservation. The recording of new data or parameters will be prevented in order to avoid the previous registers by over-writing. On that purpose, as soon as the TMA personnel enter in the aircraft, they must disconnect the electrical power of the units, according to the AMM instructions. In the absence of Authorities instructions and if the aircraft is not guarded, the registers must be disassembled and take them to a safe and guarded place until their delivery to the Authorities or for their sending to the STAR Department of the Reliability Unit, as appropriate.
> - .../..."

[1] This procedure is derived from the CIAIAC investigation carried out in 2005, in an incident in which the same circumstance was present (CVR recording).

1.6.2. *Flight data recorder*

The aircraft was equipped with a Honeywell solid state FDR, PN 980-4700-042. Once downloaded, its information proved useful to the investigation.

The data most relevant to the investigation are shown in the following graphs. The descent rate shown is the value recorded in the FDR (parameter IVV). The indicated airspeed and groundspeed differ significantly due to the altitude at which the airport is located.

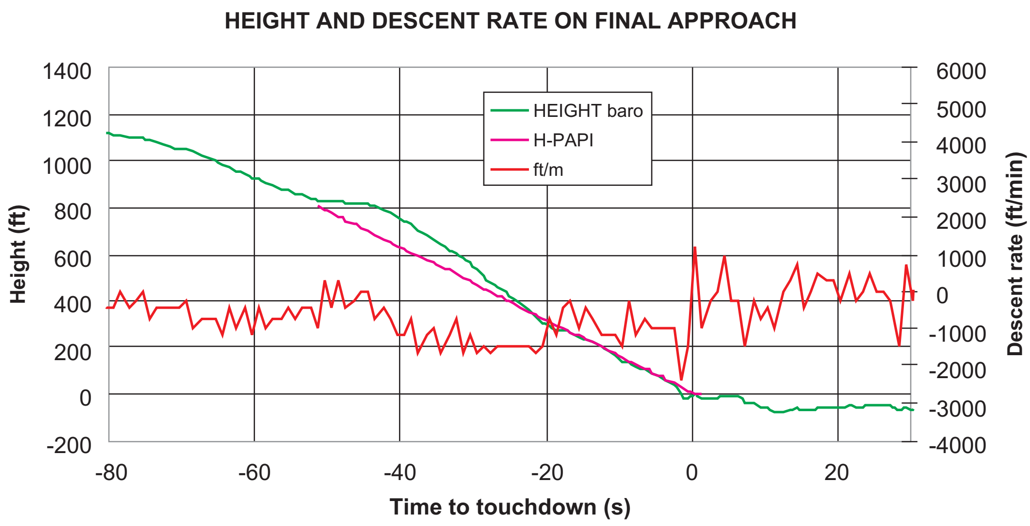

Figure 6. Descent rate and glide slope

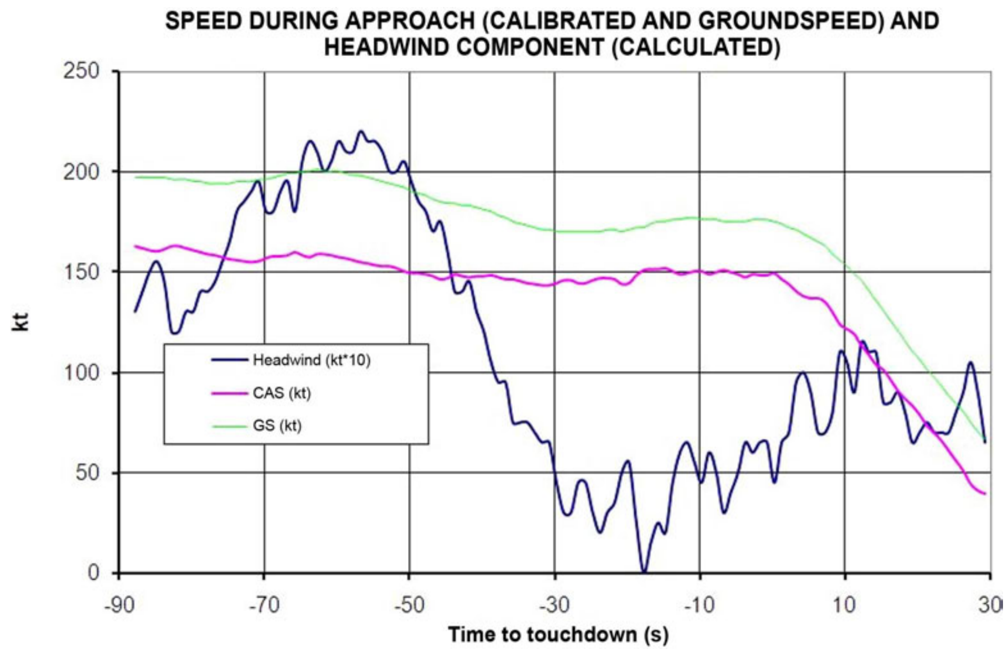

Figure 7. Aircraft speed on approach

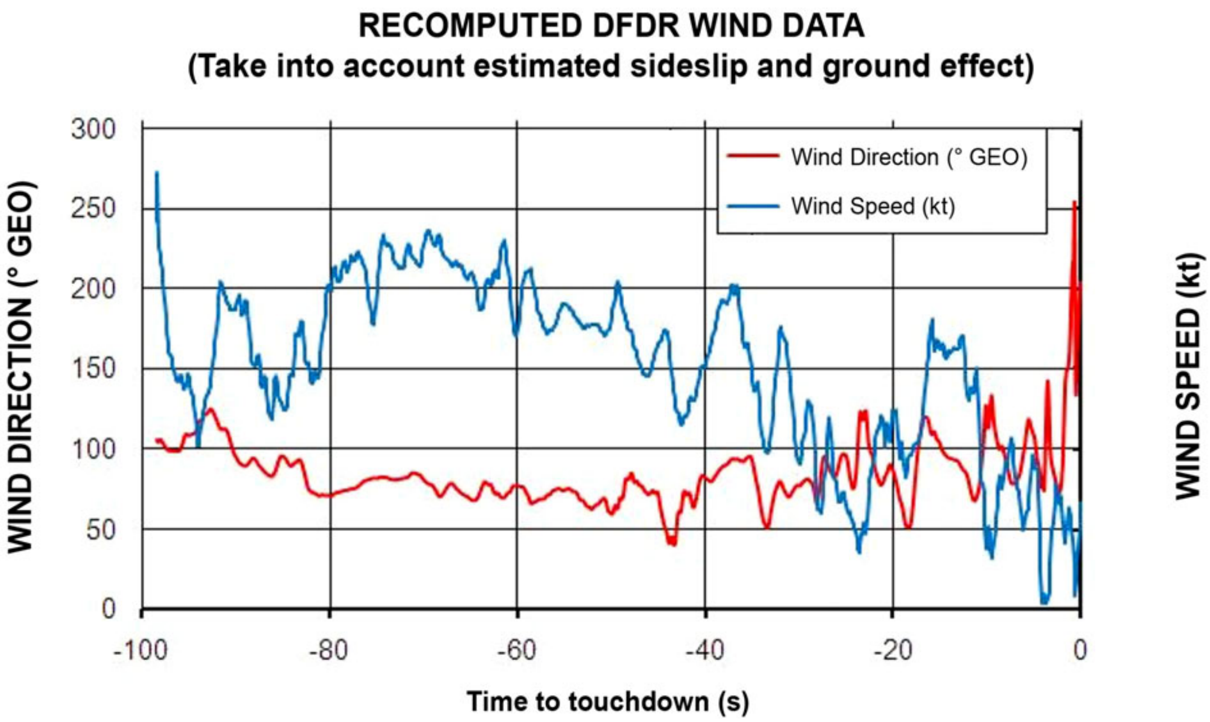

Figure 8. Wind direction and speed during approach

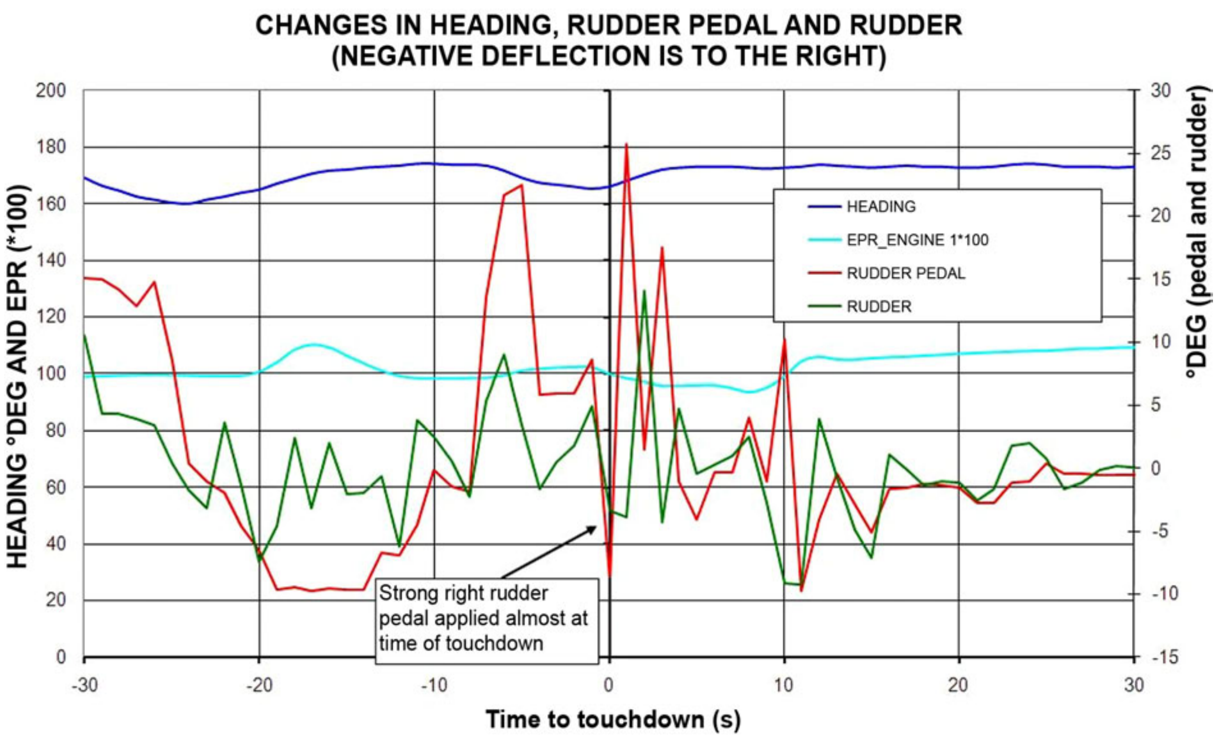

Figure 9. Direction and use of rudder pedal

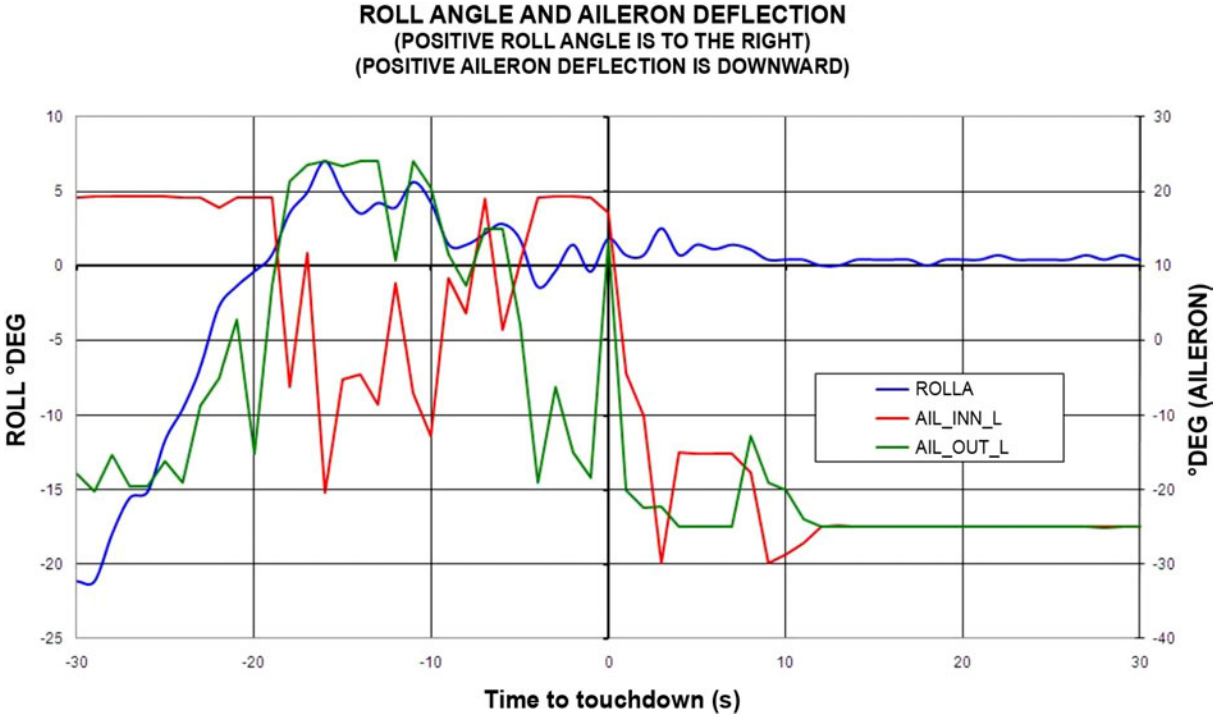

Figure 10. Roll angle and use of ailerons

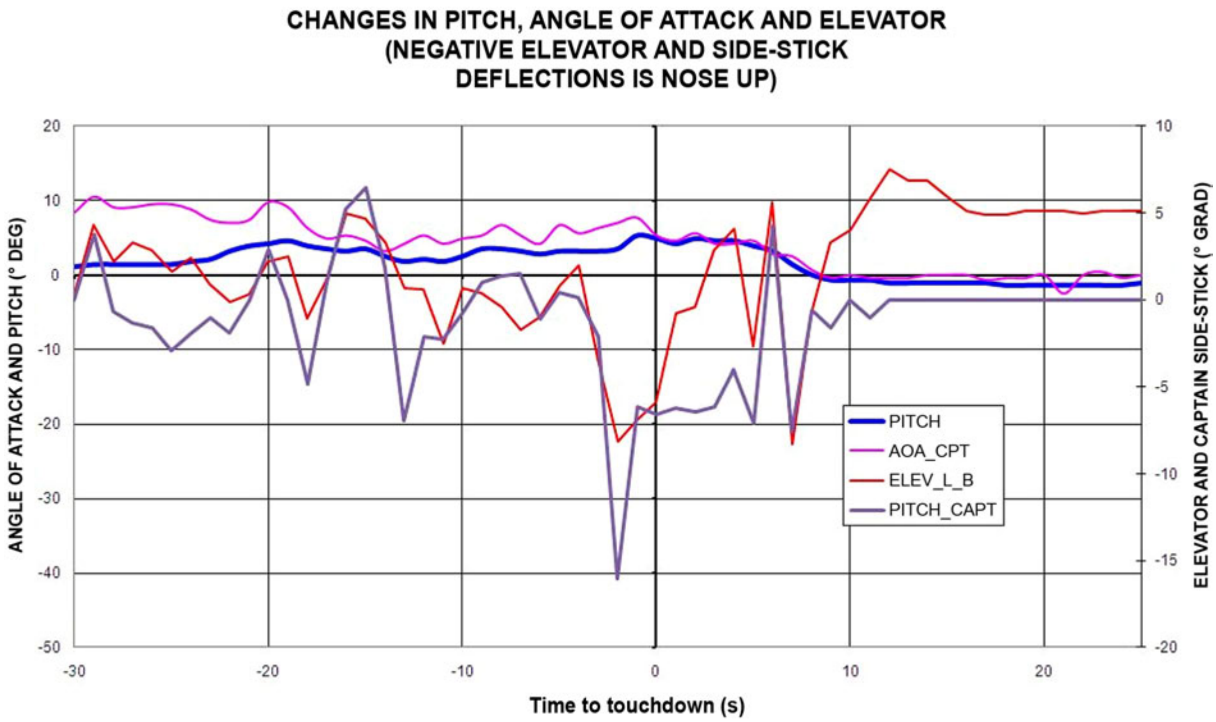

Figure 11. Pitch and use of elevator

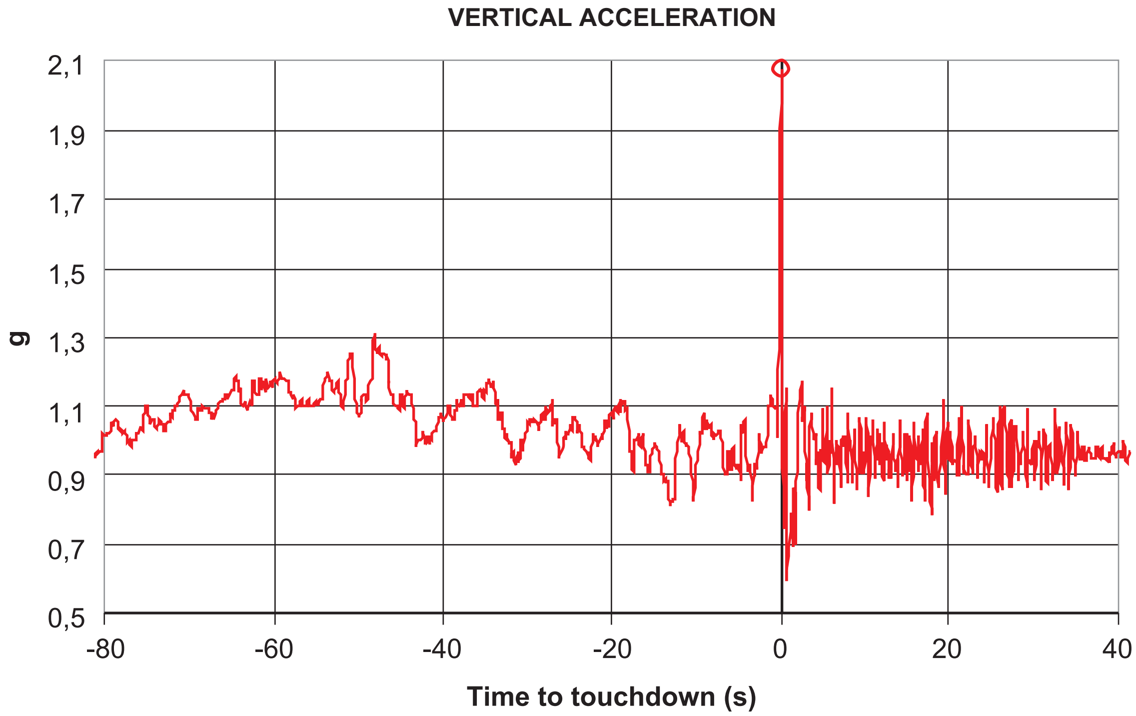

Figure 12. Vertical acceleration (maximum during touchdown: 2.08 g)

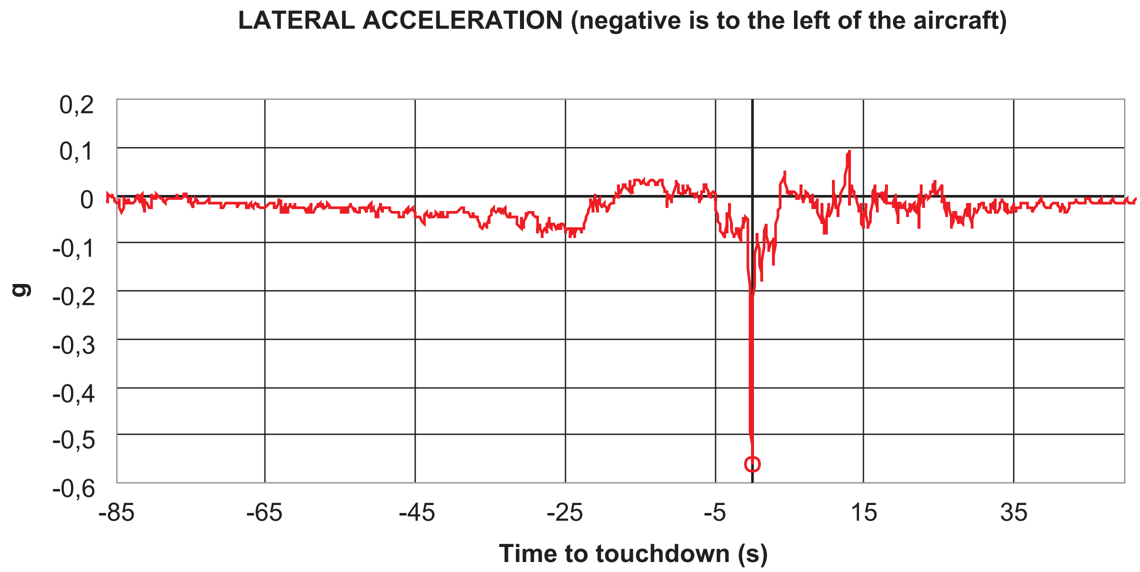

Figure 13. Lateral acceleration (maximum during touchdown: –0.561 to the left)

Auto thrust was engaged the entire time.

Large left roll angles are present until second -25, as the turn from base to final is completed. After the turn, the aircraft's heading varied from 160-165°. The graph of lateral acceleration shows the aircraft deviating right (producing acceleration to the left).

Figure 14. Final part of the aircraft's path obtained from FDR coordinate data adjusted to the point on the runway where the aircraft came to a stop. Photo property of Google Earth

Of significant importance to the event were the consecutive changes in the crosswind directions during the last 20 seconds before touchdown.

The aircraft's descent rate was high (due to the high groundspeed, not because the approach was unstable in that regard), and could not be canceled out by the last second flare maneuver.

Moreover, shortly before touchdown, though the right rudder pedal was momentarily applied, it had no effect as there was insufficient time to correct the crab angle.

The touchdown data are:

- Aircraft attitude or pitch angle: around 5° (maximum angle for a tail strike with shock absorbers fully compressed is 8.5°).
- Elevator: some 6° in the nose up direction.
- Heading: between 165° and 166°.
- Pedal: 9° right.

1.7. Operational procedures

The operator provided information and established procedures for Quito airport in its Operations Manual, part C (24-11-2005), which listed the following relevant aspects to the incident described herein:

- Given the mountainous terrain, published maximum maneuvering speeds must be strictly observed.
- The main approach is the 35 ILS-VOR, with a permissible tailwind of 10 kt.
- Only a circling approach to the E (east) of runway 17/35 is possible for runway 17.
- The low visibility circling maneuver is described in the Flight Crew Operating Manual (FCOM) issued by the aircraft manufacturer, Section 3.03.19 (see Figure 15), which states the need to be stable at an altitude of 400 ft at the conclusion of the base leg. The standard pattern visual approach is performed at 1,500 ft AGL (see Figure 16).

Given the conditions at Quito airport, the operator required that the pilot flying (PF) during landings always be the Captain of the aircraft, who had to have at least one year of experience in the A-340 fleet. To maintain his rating on the airport, he was required to have landed there at least once in the previous year, or undergo simulator training on that airport or fly there as an observer on a regularly scheduled flight.

There is no record of the operator, either by itself or with the manufacturer's support, having performed an in-depth study of the landing conditions on runway 17 when operations to Quito airport were initiated.

The operator did not have an A-340-600 flight simulator at its disposal, though it did have an A-340-300 simulator.

The manufacturer provided information on crosswind landings for the A-340-600 in the FCOM applicable to the operator, which states:

> "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."

Other operational information from the manufacturer (FCOM Bulletin No 814/1 dated June 2004) indicated:

> "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."

The Airbus Flight Crew Training Manual, in Section 02.160, states that in case of strong winds, the aircraft may land with a maximum residual drift of 5° to avoid excessive roll (5°). Though the FCOM did not include any limits in this regard, there was an operational bulletin (FCOM Bulletin 819/1, December-06, "Avoiding hard landing") which listed this limit, in addition to many other recommendations applicable during crosswind landings.

The operator had general crosswind procedures (for all types of aircraft) in its Operations Manual, Part B 2.05.50. Although no values were listed, it was customary to eliminate the crab angle by applying the pedal once below 20 ft.

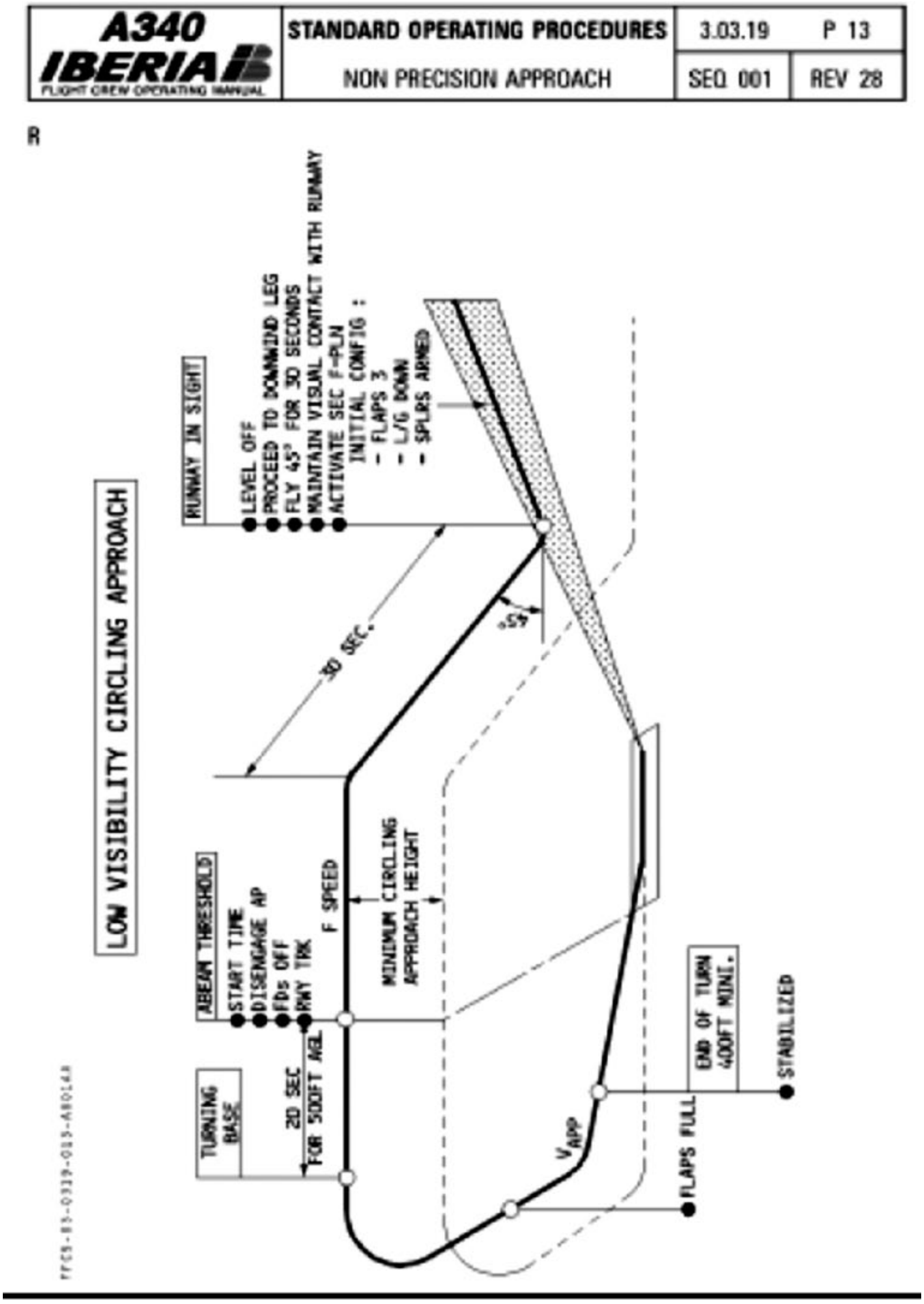

Figure 15. Low visibility pattern approach maneuver taken from Iberia FCOM

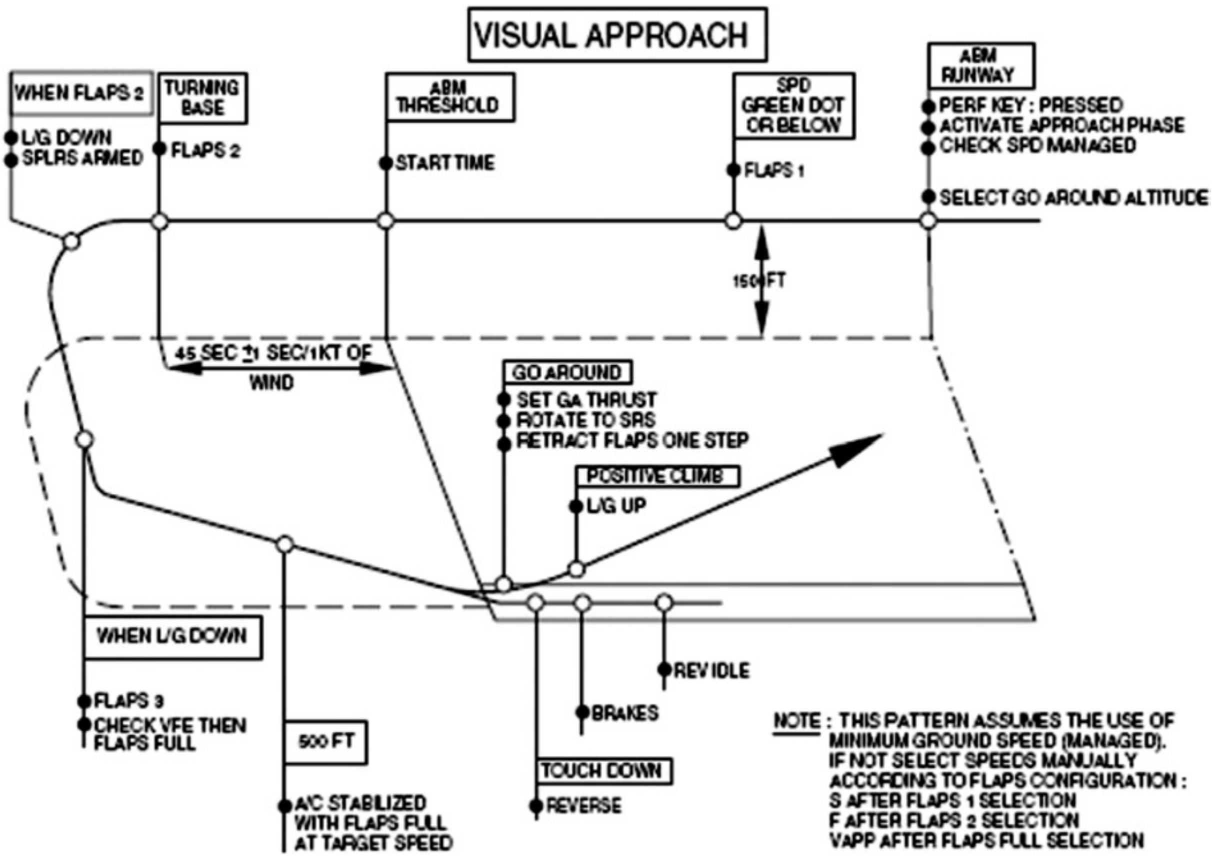

Figure 16. Standard visual pattern, taken from Airbus FCOM

The course on the differences between the A-340-600 and A-340-300 consisted of one day of classroom sessions and at least two landings on the -600. In addition to other differences, the course highlighted those involving the geometry and the possibility of a tail strike.

The operator had no instructions in its Operations Manual requiring that the CVR be disconnected following a reportable event. There were instructions for maintenance personnel to disconnect the CVR after such an event.

1.8. Previous similar events

Reports were found documenting two other events involving an A-340-600 in a crosswind landing and resulting in tire bursts during touchdown:

- Landing at Heathrow Airport on 25 Feb 2006. The final report on the event[2] states that when the pilot disengaged the autopilot at 275 ft, he found it increasingly more

[2] Report EW/C2006/02/04 of the AAIB of the United Kingdom.

difficult to maintain the aircraft aligned with the runway centerline extension given existing wind conditions. To remain on the runway, the drift angle had to be increased to over 10°, resulting in the bursting of two tires and minor damage to the gear and flaps.

- Landing at Melbourne Airport on 26 Oct 2005. The final report on the event[3] states that the aircraft landed with a right 15° drift angle and with a right 5° downward roll, which caused the number 1 tire to burst. A dual input situation arose when both pilots commanded movements simultaneously on their control columns.

1.9. Lateral forces produced by tires contacting runway during landing

The following analysis is relevant insofar as given the misalignment of the aircraft's trajectory with respect to the runway, a large lateral force to the left was required on touchdown to correct the path and thus prevent the aircraft from departing the runway after touchdown.

Had the aircraft not touched down with a certain crab angle, the resulting lateral acceleration of –0.561g may not have been generated (thus avoiding the burst), though the lateral force may then have been insufficient to change its trajectory.

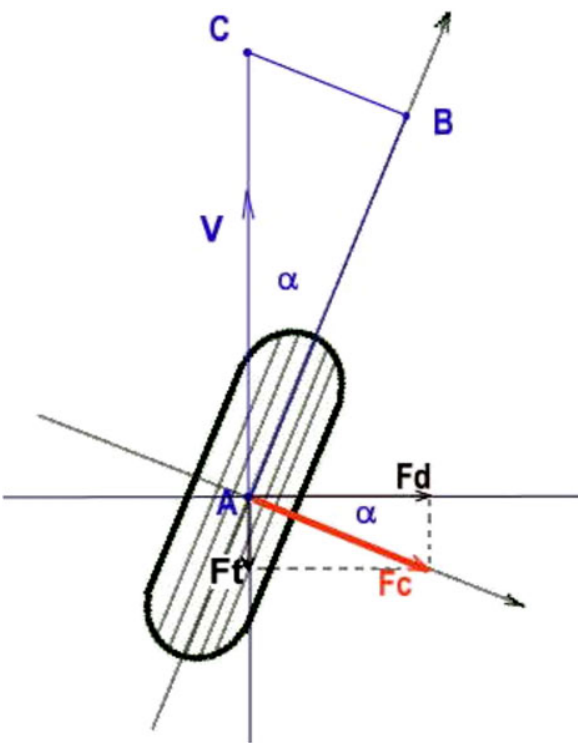

Figure 17. Force diagram

During a touchdown with crab angle α, the motion of the wheel from A to C (see Figure 17) can be separated into rotation from A to B and displacement or slip from B to C perpendicular to the wheel's plane of rotation.

The friction in that displacement from B to C results in a force that is perpendicular to the plane of the wheel that resists the displacement. This force is sometimes called "cornering," though in certain Airbus documents[4] cornering refers to component Fd in the drawing, while component Ft is called braking force.

Displacement AC is greater than rolling distance AB. In this case there is also

[3] Aviation Occurrence Report 200505311 of the ATSB of Australia.
[4] Flight Operations Briefing Notes. Landing Techniques. Crosswind Landings (Ref. FLT_OPS–LAND–SEQ 05– REV 02–APR. 2006).

slippage, with the slip rate being defined at the ratio (AC-AB) / AC which, as is apparent, equals (1 – cos (α)).

The cornering effect is maximum for slip rate values on the order of 0.15. Then, cos (α) = 0.85, resulting in an α of about 30°.

The cornering effect generates driving forces (components perpendicular to the displacement of the wheel) and a braking force Ft that opposes the direction of motion.

To maximize the driving force, Fd = Fc · cos (α), of the cornering effect, the angle of the wheel that maximizes the product Fc · cos (α) must be found using trial and error. For increasing values from 0° to 30°, Fc also increases, while the cosine decreases with increasing α. The maximum value of Fd is obtained experimentally by considering the characteristics specific to each case.

So, while the 10° drift angle during the incident was enough to impart a lateral acceleration of –0.561 on the aircraft and modify its trajectory, it also subjected the tires to increased lateral loading.

1.10. Preventive actions

1.10.1. *Operator*

The operator suspended operations for A-340-600 at Quito airport in November 2007 following an accident involving another aircraft at that airport. Once defined the approaches maneuvers to both runways, guaranteeing that the aircrafts are adequately stabilized with time enough previously the touchdown, the operator adopted a new procedure for precision approach to runway 35 and opted for proceeding to the alternative airport in case runway 17 being in service.

Given the size of the operator's fleet, its pilots would fly to Quito infrequently. Consequently, the operator has organized a group of captains to fly there on a more regular basis.

The operator has contracted the use of an A-340-600 flight simulator to train its crews.

1.10.2. *Aircraft manufacturer*

At the time of the incident, various documents and publications from the manufacturer were in circulation concerning the subject of hard and crosswind landings on the A-340-600. More hard landings were occurring on the -600 (with 11 landing gears disassembled as a result) than on the -300, given the former's greater length and weight. According to Airbus, the most relevant safety information had been incorporated in the Flight Crew Training Manual in April 2007.

Following the incident, in September 2007, the manufacturer held a workshop with the operator to refresh several aspects intended to prevent such situations. The presentation included an analysis of actual landing data provided by several operators of A-340-300 and A-340-600 fleets. Some of the points raised were:

- The higher proportion of hard landings in the A-340-600 than in the A-340-300.
- Somewhat higher rate of hard landings at Quito and San Jose airports (due to their intrinsic difficulty arising from local factors).
- Confirmation of the ample margin to tail strike on most flares maneuvers involving the A-340-600.
- Suggestions for improving training.
- Review of their usual recommendations:

  — Avoid destabilizing the trajectory below 200 ft.
  — The descent rate must be controlled before the flare (in other words, a slope of around 3° and a non-increasing descent rate).
  — Initiate the flare by exerting firm back pressure on the stick and maintaining it as required.
  — Avoid moving the stick forward once the flare is initiated (releasing some of the back pressure on the stick is acceptable).

In October 2007, Airbus issued another document for circulation to present the results of hard landings in the A-340 fleet (as stated above, 11 landing gears replaced in the -600 series versus 16 in the -300 series, the latter fleet having had 27 times more landings than the former).

In addition to the operational and training recommendations, the measures being instituted to mitigate the situation as much as possible included the introduction of a new callout at 70-60 ft on approach, already incorporated by many operators (it had been implemented on EC-JFX, see Section 1.3), an improvement of the logic in "load report 15" issued by the data management unit (DMU) and the modification of the lower articulation link on the main landing gear, all of which had already been implemented by most carriers.

2. ANALYSIS

2.1. General

An analysis of all available information indicates that the flight proceeded normally until a few seconds before touchdown.

It is believed that the “B ENG2 PMP” and “B HYD RSVR” warnings received on approach had no technical bearing on the event. The brakes and the thrust reversers functioned correctly.

The crew did not report any malfunctions in any of the aircraft’s systems.

The fact that runway 17 was in use (and not 35 as called for in the operator’s instructions for the VOR-ILS approach) forced the crew to make a circling approach.

The performance of this maneuver is subject to certain restrictions due to the relief of the area where the airport is located. The existence of a mountain in the extension of the downwind leg (see Figure 1) prevents prolonging this leg excessively. There is no indication that the operator had planned this maneuver in any detail.

In this case, the downwind leg was performed with a little separation from the runway and a constant turn was made from the downwind leg until final, without defining the base leg, which left the aircraft fairly well aligned with the runway at a radio altimeter reading of 500 ft. From the point the turn was started, however, only 27 s (approximately 1 NM, see Appendix A) remained until touchdown. Whether the downwind leg could have been prolonged without compromising safety given the rising mountain terrain is debatable.

The crew had selected the auto brakes to Mode 2 (LOW), which meant there was a 20% margin in the length of runway available with respect to that required. Had Modes 3 or 4 been selected, which is more common for airports at that altitude, there would have been a greater runway margin (between 30% and 42%, respectively) and the pressure on the crew to touch down a close as possible to the threshold would probably have been less.

Despite the short amount of time before touchdown, the aircraft made a reasonably stable approach with regard to the glide path and speed (around 150 kt calibrated airspeed) with an adequate correction for crosswind, which was from the left at 10 kt.

The descent rate was high due to the high groundspeed (GS). When the aircraft was at 400 ft high above the runway, the calculated descent rate was about 1500 ft/min, above the 1,200 ft/min established by the operator. When the flare was initiated the height was about 1,000 ft/min.

The headwind component was high at first and very small upon landing. The 10-kt crosswind component present at the start of the approach had also practically disappeared by the time the aircraft neared the ground.

The crew, therefore, faced consecutive changes in the crosswind component during the last 20 seconds before touchdown. Under those conditions, it was difficult to align correctly with the runway, especially considering the length of runway available, the elevated groundspeed and other factors which complicate operations at Quito. The Airbus FCTM guidance not to exceed 5° roll or yaw when correcting for crosswind while landing is difficult to adhere to in practice, since the pilot has no references by which to measure those angles with any precision, much less at a time of increased workload.

These wind changes at very low altitude probably contributed to the fact that they crew couldn't manage to stabilize the aircraft's descent rate and pitch angle, and also prevented the horizontal trajectory from being adequately corrected so the aircraft would be aligned with the runway centerline. Although the 21:00 METAR for the airport forecast 19-kt gusts, ATC only reported 8-kt winds from 140° without gusts at 21:04. Section 1.4 details how a special METAR was issued at 21:07 with 7-kt winds from 100°, so it is possible that during the final approach, prevailing wind conditions were changing considerably.

It would have been necessary to apply left aileron well in advance of the landing which, at a low height, could entail other risks. The aircraft heading was already deflected to the left, though its center of gravity was moving right. Under those conditions, applying right rudder to align the fuselage with the runway centerline with the aircraft too far off the ground could have increased the risk of the aircraft departing the runway to the right. The final rudder application was not enough to right the fuselage in time and the tires were subjected to a high lateral load which was transmitted through the shock absorbers to the rest of the structure.

The fact that the aircraft was not stabilized during approach and furthermore with an excessive descent rate, being necessary strong yaw and bank corrections to keep the required horizontal course, probably led to high vertical loads during the landing as well. The flare was normal compared to data from other flare maneuvers provided by Airbus, though the perception is that great care must be taken on the A-340-600 to avoid tail strikes, resulting in less pronounced flares than those used with the A-340-300.

The safest option would have been to execute a go around while on final approach, which could be performed even at very low heights without touching the runway surface (see loss of altitude table in Section 1.3.1, though this table assumes automatic control).

Despite everything, the crew was able to maintain directional control during the landing run even after the tires burst and stop the aircraft on the runway, thus minimizing the resulting damage. After verifying the condition of the aircraft with help from the control tower and the firefighters who rapidly reported to the scene, the correct decision was made to disembark the passengers using stairs.

The crew did not report any abnormalities during the approach. Since the cockpit voice recorder was taped over, neither the cockpit resource management nor the possible standard callouts made to help the PF could be evaluated. Although the operator had established procedures requiring the CVR be disconnected after an incident (MK-NT01 QR25 Norm, dated May 24 2006, paragraph 5.4), the appropriate measures as described in ICAO Annex 6 (6.3.11.2) were not taken in this case.

2.2. Strength of the tires

The high lateral loads on the tires during the landing occurred simultaneously with the vertical loads resulting from a landing that was harder than usual, and with strong inertial and centrifugal loading due to the high groundspeed caused by the high altitude of Quito airport, although the tire speed limit of 204 kt was not violated.

The combination of both lateral and vertical loads, though within the approved aircraft envelope, exceeded the strength limits of the tires, which led to a burst of tires 8, 10 and 4 on touchdown and during the initial moments of the landing run.

There is a precedent in two similar events in London and Melbourne which resulted in tires bursting with load combinations below those encountered by EC-JFX, as shown below:

	Lateral	Vertical
Quito	–0.56 g	2.08 g
Heathrow	–0.37 g	1.75 g
Melbourne	0.4 g	1.7 g

Information was requested from the aircraft manufacturer concerning tire strength under a combination of lateral and vertical loads. The reply was that the landing conditions at Quito exceeded the specifications tested during the tire certification process (see Figure 3).

According to certification data, the tires may have withstood the touchdown despite the 10° drift had the descent rate been lower.

No sufficient basis could be established, therefore, to issue a safety recommendation involving the strength of the tire.

2.3. Preventive actions

2.3.1. *Operator*

Section 1.10.1 explains the actions taken by the operator concerning the A-340-600 operations at Quito airport, the selection of captains for said operations and the availability of an A-340-600 flight simulator for the crew training. They are considered as adequate and therefore, the issuance of relevant safety recommendations is not deemed necessary.

2.3.2. *Aircraft manufacturer*

The manufacturer had issued various publications concerning hard landings in general, and with crosswinds in particular, before the occurrence of this incident. The propagation of this information in various aircraft training or operations documents, however, diminished its effectiveness, in the operator’s opinion. Specifically, the 5° maximum drift angle for landing was in the Flight Crew Training Manual (FCTM) and not in the Operations Manual.

A check of the manuals for other aircraft revealed that this information is not included in the limits section of the Operations Manual.

3. CONCLUSION

No evidence was found of any existing defects in the aircraft tires or of malfunctions in any of its systems, nor of the presence of foreign object debris on the runway surface.

The probable cause of the event is considered to be the performance of a landing with a high drift angle of the main gear relative to the runway centerline, combined with a high descent rate. This is consequence of a non stabilized approach, with excessive descent speed, which forced the crew to perform strong yaw and bank corrections in order to maintain the required horizontal course.

The downwind leg of the visual approach circuit was performed with a little separation from the runway and a continuous turn was made since the downwind leg until the final, which gave little margin to the crew to stabilize the aircraft before touchdown.

The consecutive changes in the crosswind component when the aircraft was close to the ground contributed to the crew not being able to stabilize it during final approach.

APPENDIX A
Detail of the final approach