CIAIC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report IN-022/2019

Accident involving a CESSNA 560XL-XLS+, registration D-CGAA, at Alicante-Elche Airport (Spain), on 30 May 2019

GOBIERNO DE ESPAÑA

MINISTERIO DE TRANSPORTES, MOVILIDAD Y AGENDA URBANA

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Notice

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.6 of Regulation (UE) nº 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

Contents

Abbreviations

° ′ ″	Sexagesimal degree(s), minute(s) and second(s)
ºC	Degree(s) Celsius
AMM	Aircraft maintenance manual
AEMET	Spain's State Meteorological Agency
AFM	Aircraft flight manual
AOC	Air Operator Certificate
APU	Auxiliary Power Unit
ARC	Authorised Release Certificate
ATC	Air traffic control
ATPL	Airline Transport Pilot License
B.I.T.E.	Built-in-test equipment
CAA	Civil Aviation Authority or Administration
CAMO	Continuing airworthiness management organisations
CAS	Crew Alerting System
CAT	Airport category
CB(s)	Circuit Breaker(s)
CEOPS	Control centre
CPL	Commercial Pilot License
CPL(A)	Commercial Aircraft Pilot License
CVR	Cockpit Voice Recorder
DC	Direct current
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EHAM	ICAO code for Amsterdam Airport- Schipol, Netherlands
EDP	Engine-driven pump
ELT	Emergency Location Transmitter
FDR	Flight Data Recorder
gal/min	Gallons/minute
GS	Ground Speed
h	Hour(s)
hPa	Hectopascal
IFR	Instrumental Flight Rules
ILS	Instrument Landing System
IR(A)	Instrument Rating
kg	Kilograms
KCAS	Calibrated airspeed in knots
KIAS	Knots-indicated airspeed
km	Kilometre(s)
Kt(s)	Knot(s)
LAPL	Light Aircraft Pilot License
lbs	Pounds
LEAL	ICAO code for Alicante-Elche Airport, Spain
LEPA	ICAO code for Palma de Mallorca Airport, Spain
LFLM	ICAO code for Charnay-lès-Mâcon Airport, France

LH	Left hand
L/R	Left and right hand
m	Metre(s)
m^2	Metre(s) squared
METAR	Aviation routine weather report
MHz	Megahertz
MLG	Main Landing Gear
MTOW	Maximum take-off weight
NDT	Non-destructive testing
nm	Nautical mile
NOTAM	Notice distributed by means of telecommunications that contains information related to the establishment, condition or modification of any aeronautical facility, service, procedure or danger whose timely knowledge is essential for personnel in charge of flight operations.
p/n	Part number
s/n	Series number
NLG	Nose landing gear
PAPI	Precision Approach Path Indicator
PIC	Pilot-in-command
psi	Pressure per square inch
RH	Right hand
rpm	Revolutions per minute
SB	Service bulletin
SEI	Fire Extinguishing Service
SEP	Single-piston engine aircraft
SL	Service letter
TAF	Terminal aerodrome forecast
TCDS	Type Certificate Data Sheet
TM	Metric tonne
TRI	Type Rating Instructor
TTR	Target Tracking Radar
TWR	Control tower
UTC	Universal Time Coordinated
VMC	Flight Visual Meteorological Conditions
V_{MCL}	Minimum control speed (landing)
V_{MCG}	Minimum control speed (ground)
V_{ref}	Reference speed for landing
VOR	VHF Omnidirectional Range

Synopsis

Operator:	Air Hamburg Luftverkehrsgesellschaft mbH
Owner:	NSOW AG
Aircraft:	CESSNA 560XL-XLS+, registration D-CGAA, s/n: 560-6173
Date and time of accident:	Thursday 30 May 2019, 11:55 UTC
Site of accident:	Alicante-Elche Airport - LEAL (Alicante – Spain)
Persons on board:	Two crew members and two passengers, unharmed
Type of flight:	Commercial air transport - Passengers
Phase of flight:	Landing - Landing roll-out
Flight rules:	IFR
Date of approval:	30 September 2020

Summary of accident

On Thursday 30 May 2019, at 11:55 UTC, the aircraft CESSNA 560XL-XLS+, registration D-CGAA, departed from Amsterdam-Schiphol Airport-EHAM (Netherlands), during landing roll-out on runway 10 of at Alicante-Elche airport-LEAL (Spain), on section R2 at gate B, the main landing gear brakes locked causing a runway excursion.

Both the crew and passengers were unharmed.

The aircraft incurred significant damage to the main landing gear.

The investigation of the incident has revealed as a possible cause of the aircraft runway excursion during the landing roll-out, the loss of directional control due to the locking of the main landing gear wheel brakes.

The report contains two recommendations addressed to the operator in order to ensure the continuous training of its crew in operating procedures and to ensure that the FDRs of its aircraft are configured to record all available parameters.

1. FACTUAL INFORMATION

1.1. History of the flight

On Thursday 30 May 2019, the CESSNA 560XL-XLS+ aircraft, registration D-CGAA, departing from Amsterdam-Schiphol airport - EHAM (Netherlands), was heading to Alicante-Elche airport - LEAL (Spain), carrying out a commercial transport flight with two passengers on board.

The pre-flight inspection at EHAM was carried out normally as well as the flight that passed without incident throughout, with no CAS warnings of any kind being to the crew.

At 11:55 UTC, the aircraft was ready to land on runway 10 at LEAL without having identified any failure in the systems, when the pilot-in-command, after starting the landing roll-out, pushed the brake pedals and the aircraft began to deviate to the right side, and he observed that the aircraft's speed was not decreasing as expected.

The pilot stated that he could not keep the aircraft aligned with the runway.

He lifted his feet off the brake pedals and began to brake with the emergency brake, but it was not providing the necessary effect either, so he pushed the rudder to the left to try to compensate for the drift but was unable to keep the aircraft on the runway. He applied the emergency brake again, noting the sensation of a tyre having burst.

Photograph 1: Aircraft at the accident site

The aircraft veered to the right leaving the runway in section R2, at gate B, stopping on the unpaved area on the right strip of the runway.

The main landing gear wheels sunk into the ground, with no tyre on the left wheel, and a burst but still attached tyre on the right one.

None of the occupants of the aircraft were injured and they were able to exit the aircraft unassisted.

The aircraft incurred significant damage to the main landing gear.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor				
None	2	2	4	
Total	2	2	4	

1.3. Damage to the aircraft

The aircraft suffered significant damage to the main landing gear, in particular, the wheel and brake assemblies, which were damaged after the incident.

1.4. Other damage

Runway 10 remained closed from 12:00 UTC on the day of the incident until 17:56 UTC on the same day, due to operations to remove the aircraft and clean the runway.

Rate 0 was declared at the airport and a total of 27 flights were diverted to other airports.

No other additional damages to third parties were identified.

1.5. Personnel information

1.5.1. Pilot-in-command

The 54-year-old German captain had an airline transport pilot license for aircraft, ATPL(A), issued by the German Civil Aviation aeronautical authority on 08/01/2014 with the following ratings:

- Instrumental flight rating, IR(A)
- SEP (Land) 31/12/19, PIC (Pilot in command)
- Type rating for the C560XL/XLS aircraft, TRI (type rating instructor) and PIC valid until 31/12/2019.

He had a total of 9766 hours of flying time, of which 7714 hours were in the type of aircraft involved in the incident.

He also had experience of flying other aircraft such as the Beechcraft King Air. 200/B300 and the Cessna 550.

At the time of the incident, he had been working for the operator for four years and five months.

His recent activity was as follows:

- in the last ninety days he had flown: 70 h
- in the last 24 h: 0 h
- and his pre-flight rest was 18 h.

His Language Proficiency Level was level 4, valid until 11/05//2021.

He had class 1 and 2 medical certificates valid until 12/10/2019 and for LAPL until 12/10/2020.

1.5.2. Co-pilot

According to the operator, the German co-pilot had a CPL(A) commercial pilot license for aircraft issued by the German Civil Aviation aeronautical authority on 06/02/2015 with a valid type rating for the C560XL/XLS.

He had a total of 5500 hours of flying time, of which 68 hours were in the type of aircraft involved in the incident.

His recent activity was as follows:

- in the last 24 h, seven flying hours
- and his pre-flight rest was 18 h.

He had valid class 1 and 2 medical certificates.

1.6. Aircraft information

1.6.1. General information

The Cessna 560XL-XLS+ aircraft manufactured by the Cessna Aircraft Company (USA), is a medium-sized, low-wing, conventional-tail executive jet. It has retractable tricycle landing gear. Its pressurised cabin can accommodate, in addition to the two-person crew, up to 12 passengers, although the standard is 9. It's certified according to TCDS EASA IM.A.207. Its basic dimensions are:

- Wingspan: 16.97 m
- Length: 16.07 m
- Height: 5.23 m
- Wing area: 34.4 m^2
- MTOW: 9163 kg
- Maximum landing weight: 8482 kg

According to its TCDS, the aircraft's minimum control speed (VMCL) for landing is 92 KCAS (92 KIAS), its minimum ground control speed (VMCG) is 98 KCAS (98 KIAS), and the maximum speed supported by the wheels and tyres on the ground is 165 kts.

The powerplant consists of two turbojet-type Pratt & Whitney Canada engines, model PW545C and TCDS EASA IM.E.013, with serial numbers DF0352 and DF0353, RH and LH respectively.

The APU mounted in the tail is a Honeywell, model RE100 (XL) with s/n: P-972/3800722-1.

The wing-integrated fuel tanks have a maximum usable capacity of 3057 kg. The fuel system is fully automated so that each engine receives fuel from its respective wing tank. However, it also has a crossfeed system which, when selected, allows both engines to receive fuel from a single tank.

The wing's control surfaces include an external aileron with a trim tab on the left side, two flap sections per wing (inboard and outboard), and upper and lower aerodynamic brakes on each wing called speedbrakes.

1.6.2. Maintenance information

The aircraft involved in the incident was built in 2014. Its series number is: 560-6173. Maintenance was carried out by a maintenance centre approved by the German authority as a Continuing Airworthiness Management Organisation (CAMO) and two other organisations with EASA Part-145 approval. The organisation responsible for maintenance was authorised to carry out line and base maintenance checks for CESSNA 560XL aircraft and Pratt & Whitney Canada PW545C engines, as well as for other aircraft.

Having studied the record of maintenance checks involving aspects of the landing gear carried out in recent months, we have assessed the main actions taken at each one:

- A base maintenance check was carried out on 17/05/2019 when the aircraft had 4434:03 flight hours and 3182 cycles. In addition, the crew had reported that the R/H speedbrake switch was not working. The malfunction was confirmed due to there was a broken cable that was replaced. During the inspection, both the CVR and the FDR were read and verified with correct results.

- On 15/04/2019, corrective maintenance was carried out when the aircraft had 4335:54 flight hours and 3118 cycles, as a result of the pilot reporting problems with the main landing gear. The inspection confirmed the need to replace the tyres on both the main and nose landing gear. When replacing the nose gear tyres, the bearings were found to be corroded. The wheels were balanced and the main landing gear RH and LH shock absorbers were serviced because they showed signs of oil leakage. After checking the ARC's for the wheels, it was confirmed that the replacement tyres were indeed new.

- On 08/04/2019, corrective maintenance was carried out when the aircraft had 4318:31 flight hours and 3107 cycles, as a result of the pilot reporting loose static cables in the NLG. The bonding jumper in the NLG was replaced.

- On 20/03/2019 scheduled maintenance was carried out when the aircraft had 4273:54 flight hours and 3072 cycles. Various actions were performed although none related to the landing gear and, therefore, maintenance checks previous to this date have not been further evaluated.

At the time of the accident, the aircraft had a cumulative flight time record of 4473:30 hours and 3212 cycles.

The maintenance programme in force and approved by the German authorities was the AHH-326-C560xls edition 2, revision 1.1, dated on 19/03/2019.

This maintenance programme is based on the consideration that the aircraft performs at least 1000 flight hours and 700 cycles annually.

According to the aircraft logbook, the flight of the incident corresponded to record no.1,535. Its origin and destination were EHAM-LEAL, with take-off occurring at 09:32 and landing at 11:55 UTC. The total flight duration was 2:23 hours, and two passengers were on board. Upon arrival at its destination, the aircraft had 2000 lbs of fuel, with 4475:53 total flight hours and 3213 cycles recorded. The incident was recorded as a loss of brake pressure which led to the emergency brakes being used, bursting both tyres (LH and RH) on the main landing gear.

The day before the event, on 29/05/2019, the aircraft made two flights with origin and destination LEPA-LFLM and LFLM-EHAM. These flights, which had a duration of 00:54 flight hours and 01:45 flight hours respectively, were recorded in the flight logbook as entry no. 1534 and passed without any recorded incident.

The aircraft had 4470:51 hours of flight time and 3210 cycles. The next scheduled overhaul was due after another 125 hours of flight time, so at the time of the incident, it had just been inspected.

The most recent available weight and balance sheet for the aircraft is dated 10/09/2018.

1.6.2.1. Maintenance manual: tasks relating to the landing gear

According to the aircraft's AMM, the tasks relating to the landing gear which should have been performed during the checks listed in the previous section were those related to the following actions:

- Protection of all main landing gear surfaces against corrosion, particularly the rims, as improper maintenance involving nicks, handling scratches, etc., can lead to fatigue cracks and wheel failure. The rims must be handled with care, protecting the painted areas and the finishes. Unprotected areas of aluminium alloy in contact with air corrode easily.

- When fitting a main landing gear wheel, it's important to remove excess grease from the axle, bearing housings and wheels. A visual inspection should also be carried out to ensure the absence of damage to any of the components: the joints, the tyre, the brakes, and the outer surfaces of the carbon discs to identify the possible presence of brown or orange stains that would indicate the beginning of possible catalytic oxidation.

- With regard to main landing gear wheel maintenance, installation and removal procedures, it's important to ensure the required inflation of the tyres and apply the proper torques to the mounts. No impacts or wrenches should be used to remove over-tightened bolts.

- Special care must be taken when handling bearings as they can be easily damaged by impacts and by contact with dirt, dust, humidity and other contaminants.

- Maintenance of the main landing gear wheel brakes includes the removal and installation of the brakes and connections, operational testing and brake adjustment. When carrying out maintenance, special care must be taken to prevent hydraulic fluid from contaminating the system through open connections. The hydraulic and pneumatic hoses must be sealed with plugs, and precautions must be taken not to damage the shaft and shaft thread.

- When the brakes are disassembled, the surface finish of the axle should be visually inspected for signs of damage and/or corrosion. Sometimes the brake assemblies are interchanged, in which case the hydraulic system shuttle valves must be rotated 180°, and the bleed settings and bleed plugs must also be interchanged. Each mating surface of the brake assembly and inner bushing must be lubricated.

- The wiring between the brakes and the pedals should also be checked because it can get tangled or catch, making it difficult to apply the brakes.

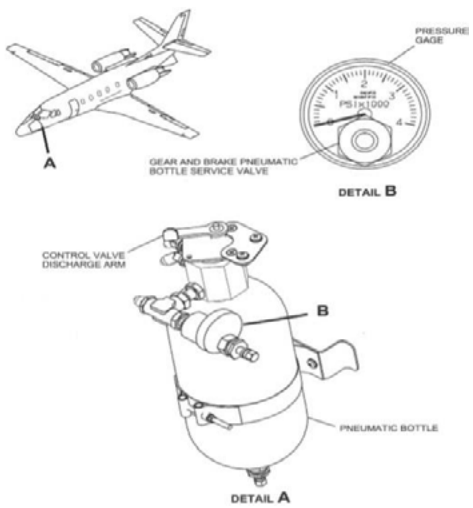


Figure 1: Brake system accumulator

- Basic maintenance of the pneumatic brake system or emergency system, and landing-gear brake systems includes ensuring that the pressure in the pneumatic bottle or accumulator, located in the left side of the nose of the aircraft, is maintained at 2000 psi.

- Checking and adjusting the anti-skid system and the electronic and hydraulic components of the system, inspecting the brake fluid reservoir, the fit of the pipes, the bleed valves and their couplings, to ensure that everything is installed correctly and that there are no signs of damage, corrosion, or fluid leakage, and that the fluid level is correct.

The anti-skid system must be free of air to work properly. You must ensure that it is adequately purged after the installation of any component. Make sure there are no white flags on the B.I.T.E. fault indication system (Built-In Test Equipment).

1.6.3. Airworthiness status

The aircraft with serial number 560-6173 and registration D-CGAA had a registration certificate issued by the German Civil Aviation Authority (Luftfahrt Dundesamt) on 02/10/2014, with registration number 40137. The registration certificate lists a Swiss-based company as the owner.

The aircraft had Airworthiness Certificate No. 40137 issued by the German CAA on 02/10/2014, which classified it as a “Large category aircraft”. It also had an airworthiness review certificate issued by the same authority valid until 15/09/2019.

The aircraft also had the following available authorisations:

- Aircraft station license issued on 04/09/2014 including various pieces of equipment, among them two communications and navigation units, VHF, DME, TTR, ALT and ELT.

- EASA Form 45 noise certificate, no. 24411, issued on 02/10/2014.

The aircraft had a valid accident insurance policy.

1.6.4. Operator information

The operator had a valid air operator certificate ref: D-326 AOC, issued by the German CAA on 10/12/2015, authorising it for commercial air operations.

1.7. Meteorological information

1.7.1. General situation

At low levels, there was an anticyclone centred on eastern Cantabrian Sea, which extended towards the Azores, North Africa and the North of Europe. Low pressures in the southwest of the peninsula and western Morocco. Strong pressure gradient with very strong gusts in the Strait of Gibraltar and the Gulf of Lion. Developing cloudiness in the interior of Mallorca due to a convergence of breezes but no precipitation. Trade winds in the Canaries.

1.7.2. Conditions at the accident site

According to reports from the Alicante-Elche aerodrome, the meteorological conditions at the time of the incident were as follows:

METAR LEAL 301130Z 12007KT 070V200 9999 FEW040 23/10 Q1025 NOSIG=

METAR LEAL 301200Z 12007KT 050V220 9999 FEW040 23/10 Q1025 NOSIG=

(*Transcription: Alicante-Elche airport, conditions described by the METAR at 11:30 and 12:00 h UTC were 7 kt wind, direction 120º, temperature 23ºC, predicted visibility: greater than 10 km, scant cloud cover with bases at 4000 feet, 10ºC dew point, and QNH of 1025 hPa*.)

And the forecast applicable to the aerodrome at the time was:

TAF LEAL 301100Z 3012/3112 10010KT 9999 FEW030 TX24/3012Z TN14/3106Z BECMG 3018/3020 VRB04KT=

(*Transcription: Alicante-Elche airport, conditions described by the TAF on day 30, at 11:00 h UTC, forecast valid from day 30 at 12:00 h UTC until day 31 at 12:00 h UTC; wind direction 100º at 10 kt, predicted visibility: greater than 10 km, scant cloud cover with bases at 3000 feet, maximum temperature on day 30 at 12:00 UTC of 24ºC, and minimum temperature on day 31 at 06:00 UTC of 14ºC; change of conditions between 18:00 and 20:00 UTC on day 30, variable wind direction with speed less than 4 kt*)

The remote sensing images (electric discharges, satellite and radar) confirmed there was little cloud cover, no convective activity and, as per the previous reports, the wind was light and the visibility good.

In conclusion, there are no meteorological phenomena to consider in the investigation of the incident.

1.8. Aids to navigation

The flight was operating under instrumental flight rules (IFR).
All the aids for the Alicante-Elche airport approach were operational when the incident under investigation occurred.

1.9. Communications

According to the ATC communications transcripts, at 11:52:54[1] the tower cleared the flight involved in the incident for landing, indicating that runway 10 was clear, with wind at 110° and 9 kts.

At 11:54:10, another aircraft called TWR on reaching the holding point on runway 10, indicating that it was ready for departure.

At 11:56:13, the flight involved in the incident called TWR reporting that it had stopped on the runway. From 11:56:34 to 11:56:57, TWR communicated with the pilot in an attempt to clarify whether his aircraft had inadvertently veered off the runway or experienced some other type of emergency.

At 11:57:22, the firefighters called the top deck of the control tower while the controller was managing the other traffic ready to take off on runway 10.

At 11:58:38, TWR called the aircraft involved in the incident again. The crew replied that they were fine and that they would call back because something had happened to the brake system. The firefighters were contacted and asked to attend and report back on the incident.

At 11:59:55, airport marshals contacted TWR to provide an account of what had happened. They confirmed that the traffic was off the runway, to one side; that a runway edge light was broken and that the aircraft had a collapsed wheel. They were waiting for the fire service to arrive.

At 12:00:30, TWR cleared the fire service to enter the runway.

[1] All times indicated in this report are UTC hours unless expressly stated otherwise.

At 12:01:45, TWR called the aircraft involved to ask if it required any kind of assistance. The pilot asked them to give him five minutes to check if there was a fire or any indication of the condition of the brakes. TWR eventually informed the pilot that it was proceeding to organise the aircraft's removal from the runway because it had a blown tyre.

At 12:02:08, TWR called the fire service to request they check the temperature of the aircraft's brakes.

1.10. Aerodrome information

Alicante-Elche Airport (LEAL) is located 8 km southwest of the city. Its reference point has the coordinates 38° 16 '56" N - 000° 33 '29" W and an elevation of 43 m.

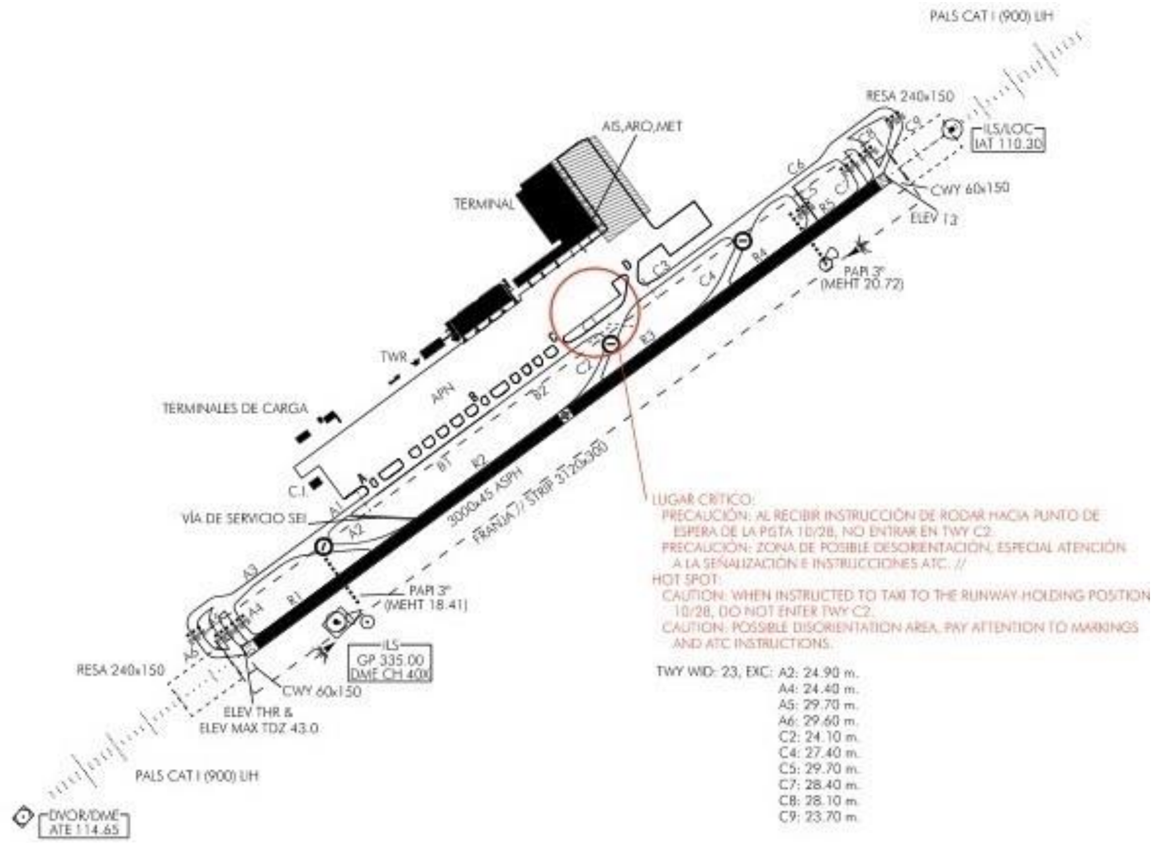


Figure 2: Map of LEAL Airport

It has a 3000 m long and 45 m wide 10-28-oriented runway, with a lateral strip of vegetation-covered land measuring 3120 m long and 300 m wide.

The airport is operational 24 hours per day and has a meteorological service. It has PAPI facilities at both runway thresholds, a rescue and firefighting service, apron lighting and taxi guidance systems and signals, instrumental assistance for CAT I precision landing (900 m), VOR/DME on both runways and ILS on runway 10.

1.11. Flight recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR).

The operator preserved the recorders after the event and provided the information required to download the logs. The CIAIAC recorder laboratory carried out the data analysis.

1.11.1. Flight Data Recorder

The FDR fitted in the aircraft was model L3 FA2100, series number: L3 - 2100-2043-00.

Photograph 2: FDR

The data obtained from the parameters relative to the hydraulic, braking and landing gear system was analysed for the final section of the flight only, which is when the incident occurred. The following information was obtained:

- The aircraft touched down at 11:56:00 at a speed of 107.2 KCAS. None of the hydraulic systems were operating at that point.

- According to the BRAKE PRESS LOW recorder parameter, the low brake pressure message was displayed momentarily for the first time at 11:52:43 and then continuously, from 11:56:19 to the end of the FDR recording. At all other times, it showed normal values. When the warning reactivated at 11:56:19, the aircraft's heading was 107°, and the KCAS speed was 43.8 kts.

- The aircraft came to a stop at 11:56:30.

- The four parameters called BRAKE PEDAL 11, 12, 21 and 22, correspond respectively to the pilot's pedals 11 (left) and 12 (right) and the co-pilot's 21 (left) and 22 (right). No values were recorded during the flight for any of them, possibly, according to the CIAIAC laboratory, because the recorder was not configured to log them.

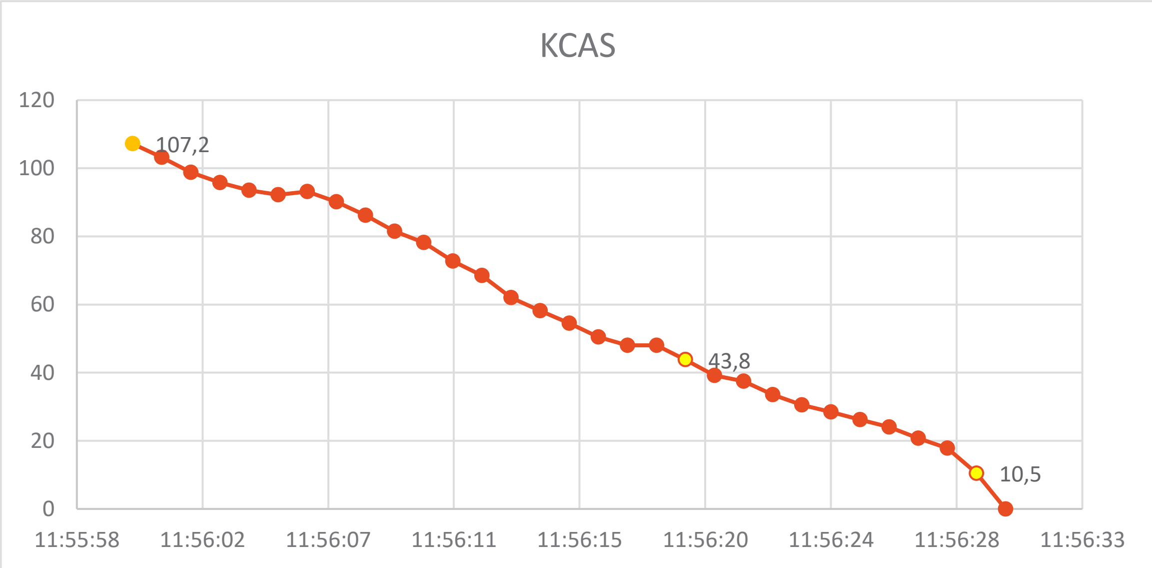


Figure 3: Speed of the aircraft during landing roll-out

- The HYD PRESS parameter (corresponding to the CAS message, HYDRAULIC PRESSURE) in ON or OFF, shows that the hydraulic system is pressurised in the ON position giving service to any of the users of the system, such as the flaps, landing gear, speedbrakes and thrust reversers. When it's in the OFF position, no hydraulic pressure is being provided to any component of the aircraft. The recorders show that it was ON during the extension and retraction of the flaps and the deployment of the landing gear. For the rest of the flight it remained in the OFF position.

- At 11:57:19, when the aircraft was already at a standstill, the CAS HYDRAULIC FLOW L/R warning was issued indicating low hydraulic flow rate on both hydraulic pumps and showing the parameters HYD FLOW 1 and 2. The alert remained in effect until the end of data recording.

- The speed of the aircraft decreased continuously and proportionally from the moment it touched the runway until the moment at which the low brake pressure warning appeared and remained until the end of the recording. However, deceleration in this last section was slower.

- No emergency notification or warning was recorded except for the MASTER CAUTION in second 20.

The following table summarises the relevant time milestones extracted from the data recorded by the FDR:

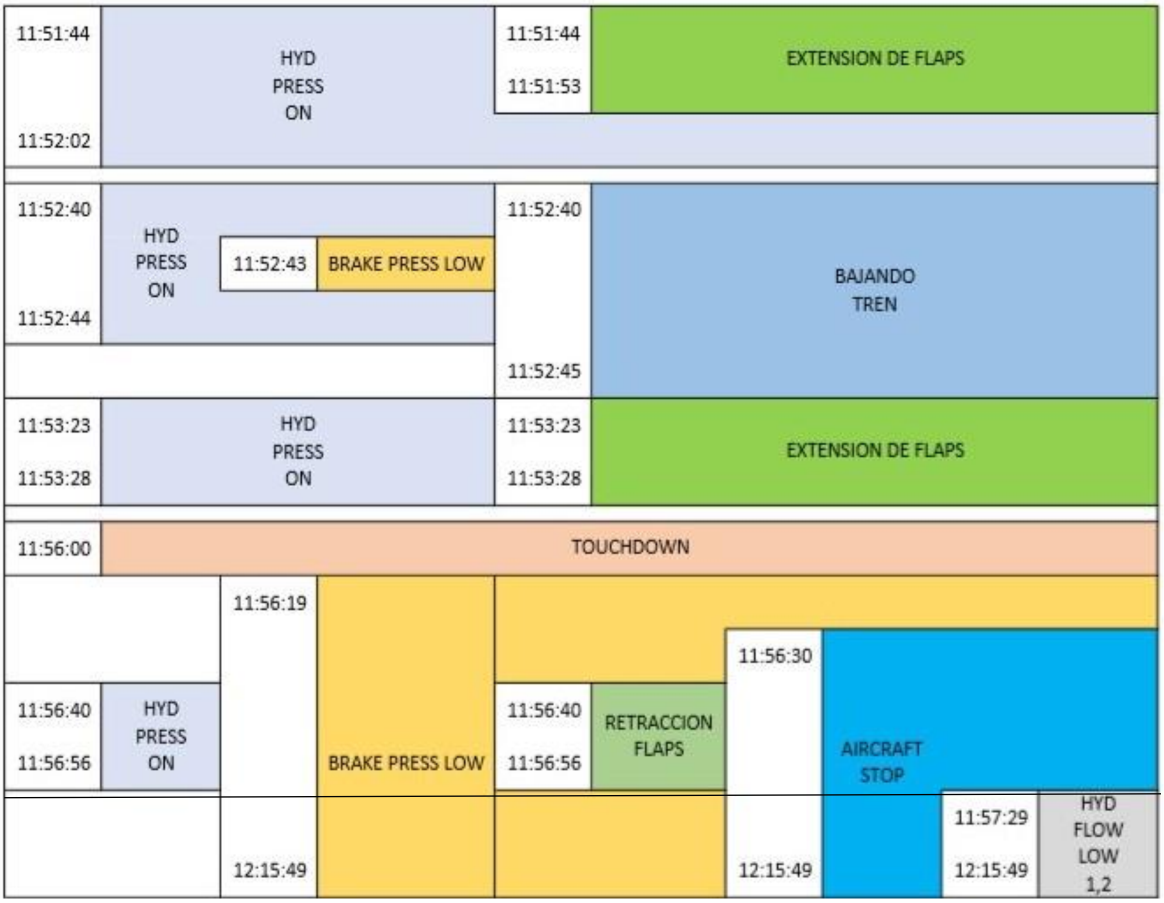


Figure 4: Table summarising the timings of FDR parameters related to the brake and hydraulic system.

The FDR graphs corresponding to the previous conclusions are shown below:

- Graph showing the main parameters as a function of time and attitude.
- Graph showing the brake and hydraulic system parameters (not including the PARKING BRAKE parameter).
- Graph showing the brake and hydraulic system parameters in the final moments only, before landing and during the landing roll-out.

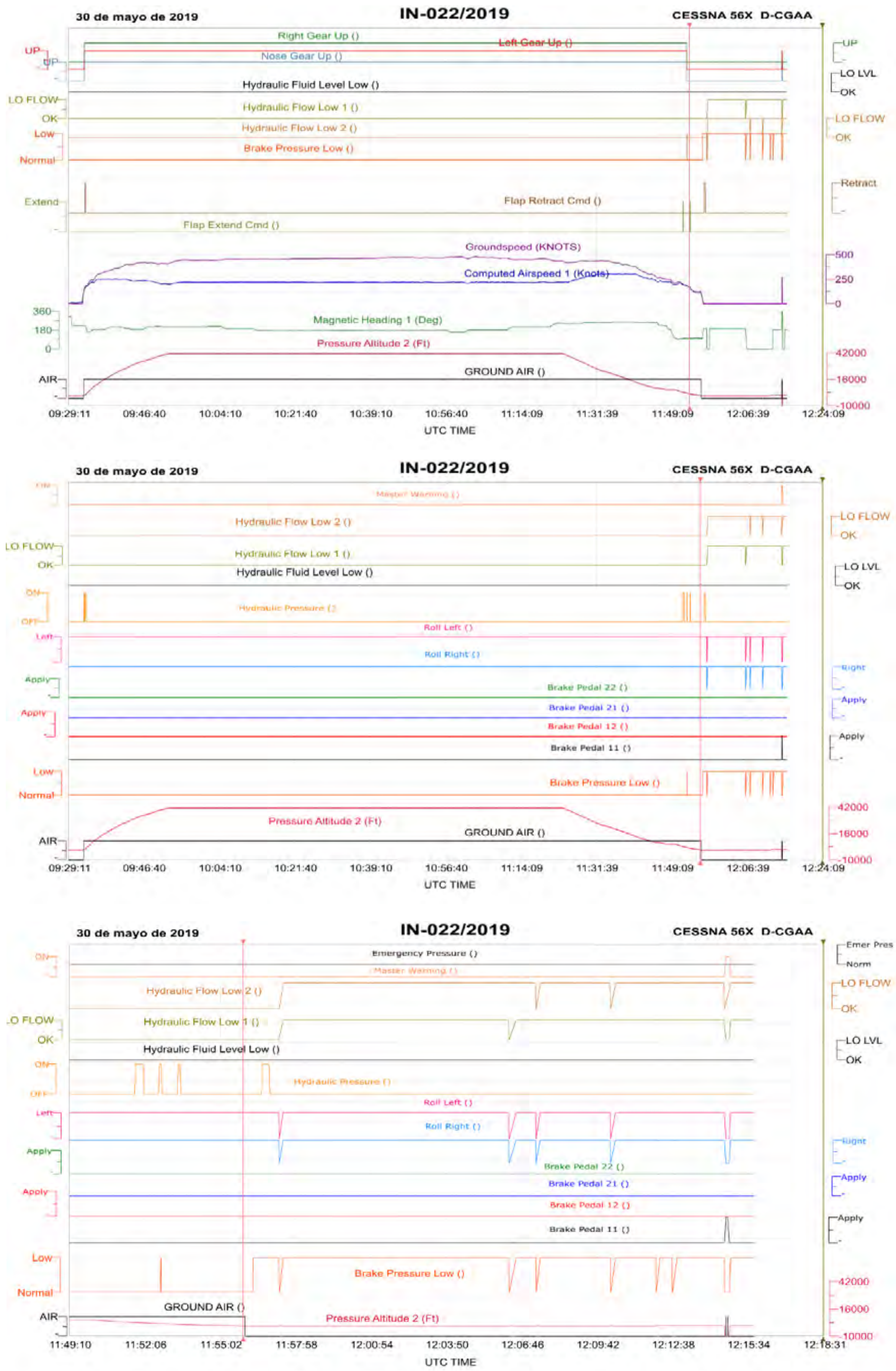


Figure 5: FDR data

1.11.2. Cockpit voice recorder

Photograph 3: CVR

The cockpit voice recorder equipment was manufactured by L3 model FA2100, p/n: 2100-1025-22 and n/s: 000915978.

The following information of interest to the investigation was obtained by listening to and transcribing the conversations recorded by the CVR:

- After completing the checklist for landing, with landing gear down, flaps 35, and autopilot engaged, the aircraft touched down.
- From second 15 after touchdown, the ambient noise in the cabin changed, registering a sound that could correspond to the tyre bursting. The pilots then comment that the wheels are locked, (the word "locked" is heard in the cockpit), at which point TWR asks the pilot if they have a problem, questioning whether the aircraft had veered off the runway. The pilot doesn't answer initially, but the sounds of crew switching off the engines can be heard.

1.12. Wreckage and impact information

Specialised maintenance technicians from Cessna Spanish Citation Service Center, collaborated with the CIAIAC during the inspection of the aircraft.

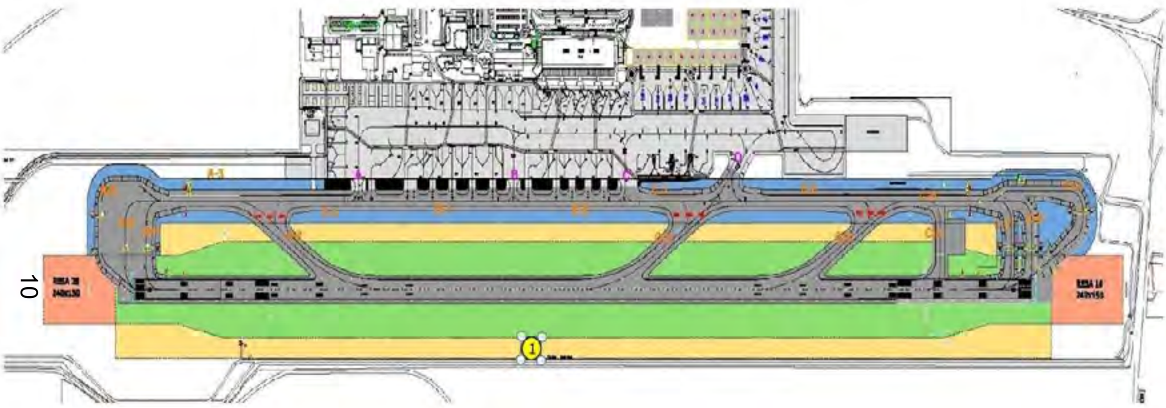


Figure 6: Location of the aircraft after the incident

The yellow circle (1) in figure 6 shows the aircraft's final position on the runway's unpaved side strip.

The main landing gear had lost its left tyre, and the right was partially detached. The rims of both wheels, which were damaged and deformed, had sunk into the ground and parts were missing.

Photograph 4: MLG RH

Photograph 5: MLG LH

Photograph 6: MLG RH, wheel assembly

Photograph 7: Emergency brake hose

Photograph 8 right: MLG LH, wheel assembly

Photograph 9: MLG LH, rim, detail of the brake housing surfaces

The inspection of the aircraft identified the damage listed below but did not find any previous malfunction that could have contributed to the accident:

- The rims and brake disc housings were severely deformed, and the brake cylinder was damaged. The possible presence of corrosion on the painted surfaces was also noted.
- No hydraulic fluid spills were observed on the surfaces around the fluid lines, and the joint fittings appeared to be in good condition.

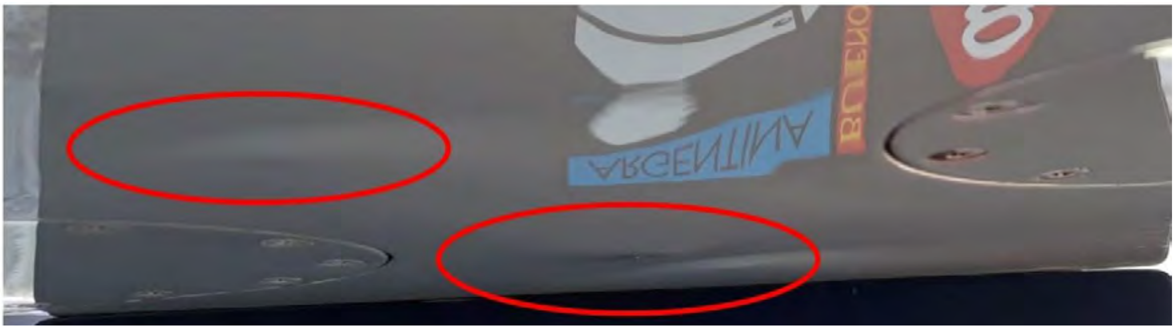
Photograph 10: hydraulic fluid lines

- Right main landing gear (MLG RH): the tyre was blown and partially dislodged from its rim, the brake discs and brake hose were badly damaged. The emergency brake hose was also badly damaged. The references for the damaged parts are: RH Wheel assy p/n: 6641650-15, RH Brake assy p/n: 2-1601-1T3 y RH emergency brake hose p/n: 6627100-80.
- Left main landing gear (MLG LH): no tyre, wheel and brake damaged. References for the damaged parts: LH Wheel assy p/n: 6641650-15, LH Brake assy p/n: 2-1601-1T3.

Photograph 11: LH Damage to inboard flap, top side

- The left inboard flap had damage to the upper surface, apparently caused by the detachment of the different layers of the tyre. There was no damage to the right wing. Three 2 to 3" diameter holes and surface cracks were observed on the underside of the left-wing inboard flap. Wave-shaped roughness was also observed on the underside of the left wing, between the FWD and AFT main spar, in this case with no evidence of apparent cracks. The reference for the damaged part was: flap inboard assy p/n: 6525130-37.

Photograph 12 and 13: LH Damage to inboard flap, underside and detail of puncture hole



Photograph 14: LH Deformation on underside of wing

Left Photograph 15: Brake system accumulator

Right Photograph 16: Pneumatic brake accumulator pressure gauge (emergency brake)

- The remaining control surfaces were in good condition. It should be noted that the rudder was deflected to the left.
- Normal brake system: The hydraulic brake system reservoir was empty, the pressure indicated on the system gauge was 600 psi.
- Emergency Brake System: the pneumatic system brake accumulator pressure was 1600 psi (normal pressure is between 1800 and 2050 psi).

Photograph 17: B.I.T.E. indicator.

- B.I.T.E. Indicator for the anti-skid brake system: The white flags visible in the equipment circles show failures of the anti-skid system's control valve and control unit.

- Inside the cockpit on the control and indication panel:
  - The messages LOW BRAKE PRESSURE and ANTISKID FAIL were displayed on the CAS screen after the incident.

Photograph 18: CAS messages

Photograph 19: Emergency brake lever

  - Emergency brake lever activated.
  - Position of left panel circuit breakers (CB): the only one popped is the FLT HR Meter (flight hour meter).
  - Position of right panel circuit breakers (CB): two popped breakers found, RADAR and MASTER APU.

Photograph 20: LH CB panel

Photograph 21: RH CB panel

Photograph 22: Runway edge light remains

Photograph 23: Main landing gear tyres (to the right, LH wheel, to the left, RH wheel)

Photograph 24: Aircraft at a standstill at the accident site

Photograph 25: Skid marks on the runway

- Tyre and wheel wreckage found on the runway: remains of the two wheels, the brake discs, lines, rims and tyres. The marks on the runway contained tyre debris stuck to the asphalt in parallel tracks corresponding to the distance between the main landing gear wheels. The mark left by the right wheel transferred a large amount of rubber from the tyre to the asphalt. The mark made by the left wheel was predominantly caused by surface erosion/abrasion.

1.13. Medical and pathological information

Not applicable.

1.14. Fire

Not applicable.

1.15. Survival aspects

Not applicable.

1.16. Tests and research

1.16.1. Crew information

1.16.1.1. Information provided by the pilot-in-command

According to the pilot's statement, he carried out the pre-flight inspection at EHAM together with the co-pilot. No abnormality was found in the aircraft. They closed the doors, instructing their passengers on emergency procedures.
They obtained clearance to start the engines and after completing the checklists, headed to runway 22.
They tested the brakes in both positions, checking that the brake performance was normal. All parameters were correct, no CAS warning was displayed, and no errors were observed on the aircraft.
The flight was uneventful.
After receiving clearance for descent close to their destination in LEAL, they positioned the aircraft in the ILS. At 10 nm, they extended the flaps to 15°, at 7 nm they deployed the landing gear, and at 5 nm the flaps were set to 35°.
There was no CAS notification of possible errors in the aircraft.

On landing and making contact with runway 10 at LEAL, when the brakes were applied the plane began to veer to the right.
The aircraft veered further and further towards the right. The pilot felt he was unable to keep it in the centre of the runway. The aircraft's speed decreased very slowly, despite applying maximum braking pressure.

He took his feet off the brake and began to brake with the emergency brakes.Even so, the emergency braking did not supply the necessary braking effect.
In an effort to keep the aircraft on the runway, he turned the rudder to the left as far as possible and pulled the emergency brake again. He suspected the left tyre had burst.
According to his testimony, he couldn't keep the aircraft on the runway. It veered to the right and stopped in the unpaved area on the right-hand runway side strip with the main landing gear sunk into the ground.

None of the occupants were injured, and all were able to exit the aircraft unassisted.
According to the pilot's statement, he concluded that the brakes had locked on both sides, failing to produce the required braking effect.

He insisted all operational procedures had been properly followed.

1.16.1.2. Information provided by the co-pilot

The co-pilot's statement coincides exactly with the statement provided by the pilot-in-command. It was, therefore, deemed unnecessary to include it in this section.

1.16.2. Related reports/communications

1.16.2.1. Information provided by the network executive

The network executive's report indicated at 12:46 h that, having punctured a wheel, an aircraft had veered off the runway and was blocking it. The occupants were unharmed. Rate 0 was declared until 15:30 h, diverting flights to Valencia, Murcia, and Barcelona. At 14:17 h, work to remove the aircraft was ongoing. Rate 0 was extended until 17:30 h.

At 17:56 h, the aircraft had been removed, and the runway was operational. The runway closure NOTAM was cancelled and replaced by another with obstacle information. In total, there were 27 traffic diversions to other airports.

1.16.2.2. Report from the airport Guardia Civil

The Alicante-Elche airport security detachment reported that at 13:55 local time, the airport declared a local alert status as a result of a private flight from Amsterdam having veered off the runway on landing.

The runway excursion occurred when the main landing gear wheels burst during landing. Both crew and passengers were evacuated without injury. The landing runway was declared inoperative, and flights were diverted to Valencia Airport.

At 18:29 h, additional information was provided indicating that by 18:00 h, the aircraft had been removed from the runway and all operations and air traffic were restored.

1.16.2.3. Notification report from the Controller

Written at 11:30 h on 31/05/2019, the controller's report says that conditions on the day of the event were VMC and that he contacted the pilot of the aircraft involved in the incident on communication frequency 118.155 MHz. The controller stated that the traffic landed on runway 10. It then veered off to the south side of the runway in section R2, on a level with gate B. The controller also noted that the pilot had reported the event could have been caused by brake failure.

1.16.2.4. Airfield Maintenance report

At 13:50 h the runway maintenance team reported that they had removed the remains of the tyres, aircraft sheet metal and broken pieces of the runway edge light (n26) from the runway. It confirmed that the aircraft had stopped on the R2 runway side strip facing south. They had checked that all the centreline lights were secured, especially those that had come into contact with the metal part of the main landing gear (centreline light n81 and two RETILs)[2]. They proceeded to sweep the area, and at 17:40 h, CEOPS announced the End of the Local Alert.

1.16.2.5. Report form the Duty Manager and the Operations Control Centre

At 12:00 h, the airport Duty Manager was informed by the operations coordinator that an aircraft had veered off runway 10 on landing due to its main landing gear tyres having burst. The aircraft had exited the runway about halfway along, in the direction of the runway side strip.

At 12:12 h, the Duty Manager coordinated with TWR to declare the runway as Rate zero.

Network management was informed that the aircraft's maximum weight was 10 MT.

At 12:15 h, the towing service was called. The aircraft's captain reported that they had 1,885 pounds of fuel remaining on the aircraft and were not carrying dangerous goods.

At 12:28 h, CIAIAC was notified. The agency requested photos, as well as custody and preservation of the flight recorders.

At 13:31 h, the crane arrived, although it wasn't required in the end.

The aircraft was situated to the south of the runway. It had lost its tyres, and the main landing gear was embedded in the ground around one meter from lighting trenches. To move the aircraft, operators had to place a skate on one of the main landing gear wheels. The other wheel had to be raised with a large forklift (provided by another operator) and a lifting cushion.
With help from the fire service, the aircraft was removed from the levelled strip, clearing the runway at 15:25 h.

At 15:40 h, following a runway inspection and the evacuation of all the parties involved in the aircraft's removal, the runway was definitively cleared.
On the instructions of CIAIAC, a guard was left to supervise the aircraft.

[2] RETIL: Rapid Exit Taxiway Indicator Light.

1.16.2.6. SEI personnel intervention report

At 13:55 h, TWR alerted SEI (the airport fire extinguishing service) to inspect an aircraft which had come to a halt on the runway following brake problems. All the fire extinguishing vehicles deployed, and when they reached the aircraft they observed that it had left the runway and was now stationary on the runway side strip. Additionally, the main landing gear wheels had been stripped of their tyres and were embedded in the ground. The aircraft was on a level with R2 and close to C2.

There was a broken edge light on the southern edge of the runway. Two passengers and the pilot were outside the aircraft. The co-pilot was inside the aircraft. All were unharmed. They contacted TWR and the Main Command Post to inform them of the situation and, on the request of the pilot, send a vehicle to transport the passengers.

The pilot mentioned that his brakes hadn't worked and that he had to pull the emergency brake which caused the aircraft to spin on him.

Approximately five minutes later, an ambulance arrived on the scene accompanied by marshals and airport officials. With help from a hoist supplied by another operator, the fire service towed the aircraft to the south of the runway outside of the strip.

At 17:40 h local time, the local alert was terminated, and this was communicated to the Main Command Post.

1.16.3. Tests/Inspections

Taking into account the actions declared by the crew, as well as the reports provided by airport personnel, controllers, firefighters, the operator, the reviews from the maintenance personnel at the organisation responsible, the inspection carried out by the aircraft manufacturer and the damages identified, the following aspects were considered worthy of further investigation:

- The records and trajectory of the landing roll-out.
- Information on the landings of the three flights prior to the incident.
- The influence of the wind direction during landing roll-out.
- The tyre breakage.
- The service bulletins of the aircraft's manufacturer.
- The service bulletins of the manufacturer of the main landing gear wheel/brake assembly.
- And the operating procedures, which are included as an annexe at the end of the report.

1.16.3.1. The records and trajectory of the landing roll-out

By analysing the data recorded by the FDR, we have been able to plot the aircraft's trajectory during the landing roll-out. This trajectory can be seen in figure 7.

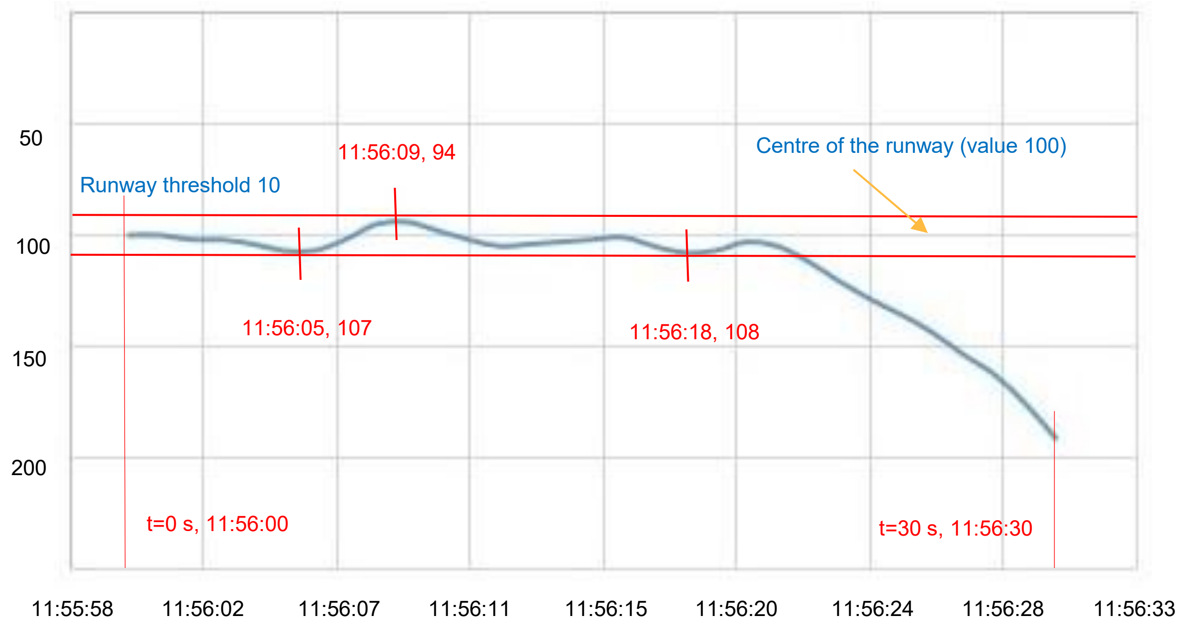


Figure 7: Trajectory of the aircraft during landing roll-out

The duration of the landing roll-out was thirty seconds. Touchdown occurred at 11:56:00 UTC, and the aircraft stopped at 11:56:30 UTC.

After landing and during the landing roll-out, neither the extension of the speedbrakes or thrust reversers were recorded.

At 11:56:00 UTC (t = 0) the plane landed in the centre of the runway, aligned (with heading 099). The wind was 095/8 (head-on to the runway), and the rudder was slightly inclined to the left. The aircraft's speed was 107.2 KCAS.

During the first part of the landing roll-out (the first fifteen seconds), the wind direction changed three times (t = 2s, t = 8s and t = 11s). The aircraft heading changes and rudder deflections in this period are consistent with these wind variations and with the corrections made to keep the aircraft in the centre of the runway.

At 4 seconds after landing, t = 4s, increasing decelerations were recorded, reaching a maximum value in second 15 (t = 15s). In the two subsequent seconds (t = 16s and t = 17s) they decreased, registering a significant rudder deflection to the left and the aircraft heading deviating to the right again (heading 105), coinciding with the full left foot application of the brakes to keep the aircraft in the centre of the runway. In the following three seconds the deceleration increases again and in the subsequent second (t = 21s) there is a significant rudder deflection to the left.

In second 19 the warning LOW BRAKE PRESSURE was recorded, followed by MASTER CAUTION in second 20.

In seconds 23 and 24, a new significant rudder deflection to the left was recorded, this time accompanied by lateral accelerations. The ANTISKID FAIL warning was displayed in second 24.

The aircraft began to deviate sharply to the right with low decelerations and slight rudder deflections to the left (from t = 25s onwards). Travelling with a heading of 192, it came to a halt off the runway (in second t = 30s), with a higher left rudder deflection value again.

1.16.3.2. Information on the flights prior to the incident

The three landings prior to the incident were analysed to evaluate the following parameters:

- Landing speed: taking into account that the weight and wind conditions differed for the three previous flights, the GS values were 106, 92 and 102 kts[3]. The GS of the flight involved in the incident was 107.2 kts.

- Duration of the landing roll-out: in addition to the duration of the landing roll-out, the time taken to reach 33 kts of GS has also been considered in order to arrive at a fixed value comparison for all flights. In the flights prior to the incident, landing roll-out duration values of 25, 31 and 21 seconds were found. With regard to reaching 33 kts of GS, the values were 17, 27 and 15 seconds. On the day of the incident, the duration of the landing roll-out for the affected aircraft was 30 seconds, and it took 19 seconds to reach 33 kts of GS.

- Aircraft braking devices: an extension of the speedbrakes and the deployment of the thrust reversers were detected in the three flights prior to the incident. They were not detected in the flight involved in the incident.

- None of the preceding flights received any kind of failure alert. The flight involved in the incident, however, recorded the ANTISKID FAIL, LOW BRAKE PRESSURE and the MASTER CAUTION alerts.

- The rudder deflections in the preceding flights were between 0 and 5°. For the flight involved in the incident, they were between 0 and 16°.

[3] The first figure provided corresponds to the flight immediately previous to the flight involved in the incident, the second figure to the flight two flights before, and the third to the flight three flights before the incident.

- The longitudinal decelerations experienced by the aircraft were between -0.1g and -0.3g in the flights prior to the incident. For the flight under investigation, they were between -0.1g and -0.37 g.

1.16.3.3. Influence of the wind direction during landing roll-out

The following data recorded by the FDR has been analysed in relation to the parameters corresponding to the landing roll-out, which are detailed below:

- time: counted from touchdown, identified as t = 1 corresponding to 11:56:00 UTC, to t = 30 corresponding to the moment at which the aircraft stopped at 11:56:30 UTC.
- wind direction
- wind intensity measured in kts
- aircraft heading, and
- rudder deflection: deflection values with a negative sign indicate deflection to the left.

t (seconds)	Wind direction	Wind intensity	Aircraft heading	Rudder deflection
0	95.6	8	99.76	-4.13
1	99.1	5	99.67	-2.72
2	142.0	5	102.39	-3.25
3	161.7	6	102.48	0.35
4	167.3	6	103.54	-3.52
5	171.6	9	107.14	-4.31
6	156.8	13	107.14	-4.31
7	120.2	9	101.78	2.72
8	64.7	11	95.45	3.34
9	52.7	11	94.48	2.11
10	77.3	8	97.82	0
11	124.5	7	102.39	-2.46
12	146.2	7	104.85	-2.46
13	154.0	8	104.41	-1.32
14	142.0	6	103.10	-0.26
15	128.0	5	101.69	4.22
16	113.2	5	101.07	-11.78
17	125.2	6	105.12	-15.03
18	130.8	9	108.46	-13.54
19	120.2	11	106.88	-9.23
20	102.7	10	103.18	-11.87
21	104.1	11	105.21	-15.82
22	117.4	11	111.97	-11.43
23	104.1	7	120.94	-14.77
24	151.9	5	129.29	-16
25	104.1	11	136.14	3.69
26	150.5	3	143.96	-1.58
27	104.1	2	154.07	-3.16
28	152.6	0	163.39	-2.99
29	104.1	11	175.69	-2.55
30	169.5	6	191.87	-9.84

According to these values, the wind direction varied in direction and intensity on several occasions during the landing roll-out, influencing the aircraft's heading, which was rectified continuously by the pilot through the deflection of the rudder.

The following are the most significant values (shaded in blue in the table):

- t = 0, the plane landed in the centre of the runway, aligned (with heading 099). The wind was 095/8 (head-on to the runway), and the rudder was slightly inclined to the left.
- t = 2, the wind begins to roll to the right with light intensity (6 knots), changing to between 171/9 and 156/13 in periods t = 5 and t = 6, that is, between 71 and 56 degrees of component crosswind from the right, with intensities of 8.5 and 10.8 knots respectively. This change in wind conditions is consistent with the aircraft's nose veering to the right as indicated by its 107-degree heading. Rudder deflections are to the left.
- t = 8, the wind conditions change again between 052/11 and 077/8. In other words, the wind was now coming from the left (48 and 23 degrees crossed respectively). The heading changes between 94 and 97 degrees due to the aircraft's tendency to turn into the wind. Rudder deflections are to the right.
- t = 11, the wind changes again, once more coming from the right. The nose of the aircraft then veers right (heading 104), and the rudder deflects to the left to keep it in the centre of the runway.
- t = 17, the aircraft's heading deviates to the right again (heading 105) and a high left rudder deflection value is recorded.
- t = 21, from here the heading begins to deviate more and more sharply to the right, with high rudder deflections.
- t = 25 onwards, the rudder position values decrease until the moment the aircraft stops, when a higher value is registered towards the left.

1.16.3.4. Tyre breakage

Photograph 26 corresponds to the main landing gear left wheel tyre. The rupture visible in the section of material is perpendicular to the tyre, which indicates an explosion due to overpressure. This type of direct breakage occurs when the rupture originates in a place where there is enough energy to be able to break all the layers at the same time. This area could correspond to the one marked in the photograph with a yellow arrow, similar to a linear cut in the tyre.

This tyre was ejected during the landing roll-out, which probably coincided with the moment when the pilot-in-command noted the sensation of the left tyre having burst.

Photo 27 shows the tyre on the right wheel of the main landing gear, which remained attached to its rim until the aircraft stopped. In the photograph, the top yellow arrow indicates a whitish area which is typical of wear caused by friction between an immobilised tyre, fixed to its rim, and the asphalt on the runway. The bottom arrow points to what's known as conical breakage, whereby, starting at the initial point of rupture, the tyre's interior gas travels to the outside, gradually decreasing the tyre's pressure, so that the gas that remains inside is no longer capable of breaking the layers of material simultaneously but produces a breakage in a gradual and staggered way.

Photograph 26: Left wheel tyre

Photograph 27: Right wheel tyre

1.17. Additional information

Not applicable.

1.18. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1. Analysis of the meteorological conditions

The meteorological conditions at Alicante-Elche Airport around the time of the event (11:55 UTC) were suitable for the flight, and no unexpected adverse conditions that could have contributed to the accident were recorded.

The possible effect of the wind was taken into consideration during the investigation. Its direction and speed were between 100º and 10 kts according to the TAF, and 120º and 7 kts according to the METAR. Taking into account the fact that the aircraft landed on runway 10 and using the METAR data as a reference because it's more precise at the time of the incident, the crosswind component that could have caused the aircraft to deviate to the right was approximately 2.4 kts andthe tailwind component was 6.6 kts.

With regard to the wind direction and intensity during the landing roll-out, the data recorded by the FDR shows the aircraft touched down aligned with the centre of the runway. However, after a few seconds, the change of wind direction to the right, which reached an intensity of 13 variable kts, produced a crosswind component from the right with intensities between 8.5 and 10.8 kts. This change in wind conditions is consistent with the aircraft's nose veering to the right as indicated by its 107-degree heading.

From that moment, during the first half of the landing roll-out, which corresponds to the first 15 seconds after landing, the successive changes of wind direction and intensity forced the pilot to constantly adjust the rudder to try to keep the aircraft aligned with the runway.

Furthermore, the pilot had to manage the brake lock that had occurred as a result of the overpressure of the pedals, as he had not extended the speedbrakes or deployed the thrust reversers, so greater braking was required with normal brakes.

Consequently, it's considered that changes in wind direction and intensity during the landing roll-out could have contributed to the pilot's difficulty in controlling the aircraft and keeping it in the centre of the runway, requiring him to constantly adjust of the rudder while at the same time he was dealing with the locked brakes.

2.2. Operational analysis

Until the moment of landing, the flight operation was adequate, and the crew acted according to the operating procedures without observing any incident.

With the checklist before landing, the CAS had to be checked, so if there had been a failure in any system it would have been shown at that time, but everything was correct.

Having touched down on the runway and given that, according to the crew testimonies and the flight data records, there was no type of warning or CAS alert issued, in principle, there was nothing to suggest that the braking system or any other, would not work adequately.

Upon landing, the moment when the pilot put his feet on the pedals to brake the aircraft, in his words "stepping on them fully", was the moment when he realised that the brakes had locked and the aircraft was not decelerating as expected.

Furthermore, the aircraft began to drift to the right, preventing him from keeping it aligned with the centre of the runway.

There is no evidence that the rest of the landing procedure was applied in addition to the normal brakes. In fact, according to FDR records, the speedbrakes were never extended nor were the thrust reversers engaged. The procedure was only followed up to the moment when, after the touchdown, the normal brakes were used and when realising that they were locked, the emergency brake was used.

The pilot's perception of the speed decreasing very slowly despite applying maximum brake pressure is consistent with the fact that, unlike the previous flights which followed the landing procedures, on this flight, neither the speedbrakes nor the thrust reversers were used.

After landing, the wind changed from a headwind to a right-hand crosswind. Consequently, the nose of the aircraft began to veer towards the wind side (to the right). After a few seconds, the crosswind component from the right increased, and the aircraft again turned right, into the wind. The rudder deflections recorded during this period are consistent with actions to correct for wind variations.

However, the decelerations observed (according to the FDR) show that the aircraft began to brake as soon as its weight had transferred to the wheels. The landing roll-out lasted for thirty seconds, similar to the roll-out duration of the previous flights, but without activating the speedbrakes or thrust reversers.

For this aircraft, the minimum control speed on landing is 92 KCAS, and its speed at the moment of the touchdown was 107.2 KCAS. The speed was, therefore, adequate for the manoeuvre and similar to the landing speed of the preceding flights, although slightly higher.

The deceleration analysis obtained from the FDR records shows that the aircraft began to brake as soon as its weight rested on the wheels and confirms the two applications of the emergency brakes that the pilot made according to his testimony, so the records are consistent.

The first braking interval occurred between seconds 4 and 15 of the landing roll-out. From second fifteen, according to the CVR recording, the ambient noise in the cockpit changed, registering a sound that may be consistent with the tyre bursting given that the pilots go on to comment that the wheels were locked.

During this first part of the landing roll-out, the wind direction changed on three occasions, changing from a headwind to a right-hand crosswind, then a left-hand crosswind and finally returning to blow from the right (t = 2s, t = 8s and t = 11s). The aircraft heading changes and rudder deflections in this period are consistent with these wind variations.

Between seconds eighteen and twenty, the new decelerations show the second application of the emergency brakes when the pilot declared that he thought a tyre had burst. Possibly, what actually happened at that moment was the tyre detaching from the rim.

19s after toughdown, the low brake pressure CAS warning appeared, at which point the aircraft's speed was 43.8 KCAS.

The braking attempt made with the pedals pressed to the maximum after the take-off was what caused the brakes to lock and generated overpressure in the tires causing the left tire to burst and detach, allowing the loss of brake pressure while the tire was eroding on the pavement during the movement of the aircraft.

The attempt to slow the aircraft by applying maximum pressure to the pedals after touchdown caused the brakes to seize and generated overpressure in the tyres. This, in turn, caused the left tyre to burst and detach, leading to a loss of brake pressure while the rim was eroding on the pavement during the aircraft's displacement.

Considering that the aircraft was not decelerating enough, with the information of low brake pressure, the pilot lifted his feet from the pedals and activated the emergency brake, in addition to deflecting the rudder to the left to compensate for the drift. This decision was in line with operating procedures and was, therefore, correct.

From that moment, the asymmetric braking favored the loss of directional control of the aircraft and after the second application of the emergency brake, the second tire exploded, which had gradually lost pressure and transferred rubber to the pavement until the moment of stopping the aircraft off the runway.

When moving at low speeds on the ground, in the case of this incident at 43.8 KCAS and lower, directional control through the rudder is somewhat inefficient. This would have made it difficult to align the aircraft with the runway as indicated by the pilot.

The type of breakage identified in the MLG LH wheel tyre corresponds to the type of damage that occurs as a result of overpressure, which it must have acquired during the landing roll-out with the brakes locked. The fact that the breakage is located in a specific area on both tyres, implying that the wheels were fixed and not turning as they travelled down the runway, corroborates this theory.

The type of breakage produced in the MLG RH tyre and the fact that it was partially detached, confirms that it burst from a progressive loss of pressure, wearing down as a result of friction with the runway and transferring the tyre rubber to the asphalt until the aircraft came to a standstill.

As the pilot was unable to control the direction of the aircraft, it left the runway heading towards the right-hand unpaved strip, where it came to a standstill with the main landing gear embedded in the ground.
The deviation to the right was possibly due to the asymmetric braking favored throughout the landing roll-out by the detachment of the left tyre and the braking effect of the emergency brake that was already only acting on the right wheel.

When the LOW BRAKE PRESSURE message appeared, implying a normal brake failure, the ANTISKID FAIL message also lit up. According to the crew, they followed the applicable operating procedures, which involved checking the PWR BRKS CB. Possibly this was done, and it must have been connected because.
Then, the WHEEL BRAKE FAILURE emergency procedure was carried out, which indicates that two memory actions are applied by the pilot, consisting of removing their feet from the brake pedals and applying the emergency brake, as he did according to his statement.

The anti-skid system was no longer operational, in any case, not even after the use of the emergency brake, since when it is applied, it does not work by design, not facilitating the directional control of the aircraft, and may cause an excess of force in the applying the emergency brake lever and keeping the wheel brakes locked.

According to the position of the CBs in which they were found after the incident, the PWR BRKS was connected, so the possibility that the brakes were inoperative due to disconnection of this switch is ruled out.

Although what cannot be ruled out is a random failure of this circuit breaker since the manufacturer warned in its SL560XL-32-06 of 08/08/2000 that the use of this CB as a switch to disconnect the brake system (usual practice between pilots), when not in use, can cause random, undetectable faults.

In general, it can be concluded that the excessive application of pressure on the normal brake system pedals at a speed higher than usual, without the assistance of speedbrakes or thrust reversers, could have caused the brakes to lock and the consequent blow-out and detach of the left tyre, rolling the rim assembly and couplings on the runway, breaking various components that caused the loss of pressure in the brake system.

From that moment on, the emergency brake helped the aircraft to stop but, at the same time, generated asymmetry in the braking. The right tyre began to lose pressure until it also exploded, making directional control of the aircraft even more difficult.

The rudder deflection values are similar to those recorded during the three previous landings, so it can be deduced that the heading changes experienced by the aircraft and the rudder deflections are consistent with the changes in wind and the aircraft's tendency to turn into it.

Neither the extension of the speedbrakes nor the action of the thrust reversers were recorded during landing, which influenced the deceleration rate to be lower than in the previous landings. Neither pilot announced that both deceleration devices were not being used.

The crew partially followed the procedures, probably because they considered the normal brakes would be enough to stop the aircraft on the runway, but after touchdown and realising the aircraft was veering to the right as a result of changes in wind direction and intensity on the runway, the pilot pressed the pedals excessively, causing the brakes to lock.

For unconfirmed reasons that left the anti-skid system inoperative, the braking didn't provide the deceleration the pilot was expecting, and he hadn't engaged either the speedbrakes or the thrust reversers.

All of this contributed to the bursting of the tyres and the asymmetric braking that aggravated the directional control of the aircraft, for which, in addition, considering that the pilot had never experienced a similar situation, resulted in a runway excursion of the aircraft.

2.3. Analysis of the aircraft wreckage

An inspection of the aircraft's landing gear after the incident showed that the two tyres on the main landing gear wheels had burst, the left one disengaging from its wheel completely, and the right one shedding rubber down to the rim, which was transferred to the runway as the aircraft moved along it.

The uneven marks of the wheels on the runway pavement suggest that greater pressure was applied to the right brake, which favoured the aircraft's deviation to the right.

It seems probable that asymmetrical braking occurred when the normal braking system was used, so that, when any of the hydraulic cylinders of the wheels were broken, it affected the emergency braking system since they use the same actuating elements.

The breakages in the tyres were located in specific areas that imply the wheels were not moving, therefore, they were braked, corroborating that the brakes were locked, preventing them from turning.

When the pilot pressed the brake pedals to maximum, the pressure and overheating in the tyres caused by the friction with the runway was sufficient to make the tyres burst. Firstly, the left tyre, in which we observed a breakage compatible with overpressure, causing it to detach from the rim abruptly during the roll-out, and then secondly, the right, in which the breakage was indicative of a gradual loss of pressure, resulting in it not detaching from the wheel until the aircraft had come to a stop.

The simultaneous locking of the two wheels suggests to the search for a common cause. The braking and anti-skid systems on each wheel operate independently, so it is dismissed that the reason is found in the specific elements of any of them.

Furthermore, during the repair and inspection of the aircraft, no malfunction of any element that was not damaged during the incident was observed, since these broken or deteriorated elements were replaced before without the possibility of verifying their operability.

One common element of the normal brake system is the anti-skid control unit. An issue with this unit had been flagged by the B.I.T.E. and could have impeded its performance. On the other hand, the emergency brake system also acts on both wheels at the same time, but according to the findings, this system worked when its operation was demanded, although also during the roll out some of the parts were broken, the left wheel couplings, as well as the corresponding brake cylinder.

No failures were found in the brake systems or in the hoses, which were not apparently attributable to damage caused by the incident itself.

The damage seen on the upper surface of the left inboard flap was apparently caused by the various layers of rubber detaching from the tyre. This is consistent with the left tyre completely separating from its rim and, because of its position, hitting the inboard flap in the wake of the blow-out. The small holes and undulations on the underside would have been produced by the impact of other parts of the left wheel assembly when they detached as the aircraft moved along the runway.

No similar damage was observed on the right wing, which is consistent with the fact that the right tyre didn't detach completely but gradually lost pressure and material until the aircraft came to a stop.

The friction and abrasion caused by the rims being in direct contact with the ground deteriorated and damaged the brake assemblies as far as the cylinders and the hydraulic lines. The consequent loss of hydraulic fluid through these parts is coherent with the FDR records that showed low hydraulic pressure detected when the aircraft had already stopped. Therefore, the spillage that emptied the hydraulic reservoir occurred as a result of damage to the main landing gear wheel assembly after the wheels rolled across the asphalt in a locked position and sank into the ground after the runway excursion.

The systems for the flaps, spoilers, nose-wheel steering, rudder, landing-gear extension, etc., all functioned normally, proving there was no shortage of hydraulic fluid in any of the systems until the aircraft was at a standstill.

Consequently, the damage observed in the aircraft corroborates that the landing roll-out took place with the brakes locked, causing the explosion of both tyres of the main landing gear.

2.4. Analysis of the aircraft's maintenance

After analysing the tasks carried out in the last scheduled preventive and corrective maintenance checks, no element was identified that could have directly and unequivocally contributed to the incident.

The directives, SBs and SLs of the manufacturers that it has been possible to verify were implemented by the operator through the different authorised maintenance organisations involved in the airworthiness of the aircraft.

What was observed was the general condition of the rims and brake discs which showed signs of corrosion, although this probably didn't contribute to the incident. In any case, this was not verifiable given the significant deterioration and damage incurred by the main landing-gear wheel assembly as a consequence of the runway excursion.

According to several SBs issued by the manufacturer of the wheel assembly, there are various influencing elements, with an unpredictable nature on the brake performance, such as tyre cleaners, greases, disinfectants, mounting lubricants, and contamination of these substances on the brake-assemblies during disassembly and installation, whichhas been impossible to assess accurately given the deteriorated condition of the wheel assemblies after their breakage during taxiing and subsequent collapse on the strip of land where the aircraft stopped.

On the other hand, the improvements implemented by the manufacturer through various SBs to the main landing-gear wheel-assemblies in relation to increasing the fatigue life of the tyres and the thermal relief plugs that could cause tyres to deflate, it has been verified with the operator and the aircraft manufacturer that they were updated and implemented, installing the new improved p/n.

The tyres had been replaced with new ones a month and a half before the incident, both on the main landing gear and the nose. The replacement was correctly documented, and together with the satisfactory result of the pre-flight inspection, this suggests to presume the tyres were in good condition and did not contribute to the incident, although their starting pressure could not be verified.

The severe damage to the LH wheel assembly, in particular, has made impossible to check elements like the bearing cones installed in the wheel, which according to one of the manufacturer's SBs can, in some cases, be subject to assembly errors and cause a malfunction.

As indicated in previous sections, the aircraft manufacturer issued an SL (number 32-06 of 2000) referring to crews' standard practice of disconnecting the CB corresponding to PWR BRKS to deactivate the normal brakes and prevent the engine from having to run them when they are not needed. The SL was issued after the manufacturer found that continually using the CB to disengage the brakes could result in an undetectable fault within the CB itself. If this CB fails randomly, even though it was in the connected position, it would result in the normal pedal-activated brakes being inoperative and they would be perceived as hard brakes, which also do not brake the plane.

This perception of the brakes being fully pressed without braking efficiency coincides with that expressed by the crew, but which could not be confirmed with objective data.

According to the position of the CBs after the incident, in the left panel the only one that was deactivated was the FLT HR Meter, and in the right panel those of RADAR and MASTER APU.

In principle, none of these would affect the operation of the landing gear, brake system or the hydraulic system involved in locking the brakes. Consequently, we must assume that the CB corresponding to PWR BRKS was connected, although a random failure cannot be ruled out as discussed above.

According to the operating procedures, when the ANTISKID FAIL message is displayed, it may be because the anti-skid system itself has failed, or it could be related to the LOW BRAKE PRESSURE alert as a result of a malfunction in the normal braking system.

It is confirmed that the CAS messages simultaneously displayed after landing were ANTISKID FAIL and LOW BRAKE PRESSURE. As previously indicated, both messages are displayed together when the normal brake system fails. When this happens, the only brake system available is the emergency system, and consequently, the anti-skid system is not operational.

Furthermore, the LOW BRAKE PRESSURE message is displayed if the hydraulic pressure in the power system drops below 900 psi. After the incident, the hydraulic pressure indicated on the system pressure gauge was 600 psi. The low hydraulic pressure in the brake system, therefore, confirms that its effectiveness would have been severely reduced when it was activated by the pedals. This was most likely caused by a loss of hydraulic fluid through the brake actuator systems which sustained damage as the left rim rolled along the runway without a tyre.

The fact that the brake system's hydraulic reservoir was empty, was caused by the fluid spilling at the time of the aircraft stopped, when various components of the system broke after the wheels collapsed on the strip of land.

In fact, this is corroborated by the hydraulic pressure FDR data, which shows the pressure was correct at all times up to the moment the aircraft stopped.

The B.I.T.E. identified failures in the control valve and system control unit of the anti-skid system. The tests carried out by the aircraft's manufacturer after the incident did not show any failure in the control valve or the control unit and they did not require replacement. These warnings were, therefore, presumably triggered during the emergency as a result of the pilot having to use the emergency brake when the normal brakes failed, thereby deactivating the anti-skid system, as well as losing hydraulic pressure after stopping the aircraft.

The use of the emergency brake system was verified by the fact that, after the incident, the accumulator had a pressure of 1600 psi instead of 2000 psi as it should be, and as was available when the pre-flight inspection was carried out.

On the other hand, if there had been any interruption in the operation of the DC generator, this could have caused the normal brakes to be inoperative along with the anti-skid system and with the rudder control, since all three systems are powered by this generator.

Since no warning notice was displayed, any interruption in its operation could only be due to disconnection rather than malfunction. The corresponding CB was checked after the incident and found to be connected, but it has not been possible to verify that it could have been disconnected occasionally and reconnected, so it cannot be assumed that this CB could be the reason for the failure of the systems.

In conclusion, the general maintenance of the aircraft was adequate, not identifying any element that could contribute to the incident.

It has only been found that there was a loss of pressure in the brakes during the landing roll-out that left the normal and anti-skid braking system inoperative after locking the brakes due to excessive pressure in the pedals, which led to the burst of the tyres and the brake system emergency was used.

2.5. Analysis of the FDR logs

The data extracted from the FDR records and the CVR information, are consistent with the statements of the crew and the information inferred from the investigation.

The aircraft touched down at 11:56:00 at a speed of 107.2 KCAS. No hydraulic system was operating at that moment, but in accordance with operating procedures, the flaps had been extended on successive occasions without incident, and the landing gear deployed, therefore, the hydraulic system had adequate pressure to operate these elements until landing.

The FDR parameter for low brake pressure, BRAKE PRESS LOW, was first logged at 11:52:43. It lasted one second and was not reported by the crew, as it coincided with the moment the landing gear was deployed and which is not considered important, taking into account that from that moment on it remained at normal values until 19" after touchdown.

According to the records, by 19" the aircraft had decelerated from 107.2 KCAS at the time of touchdown to 43.8 KCAS, at which point the continual and proportional low brake pressure was registered. From that moment, it decelerated more slowly but nonetheless continuously, until the main gear collapse on the off-runway terrain, stopping the aircraft at 11:56:30. All of this took place with the normal brakes being locked and the emergency brake being activated twice.

From 11:56:19 until the end of the FDR recording, the BRAKE PRESS LOW parameter was registered, and the aircraft's heading was 107°, in line with its deviation to the right and the runway excursion. The aircraft's speed was 43.8 KCAS and, therefore, sufficient to activate the anti-skid system, which can be activated from 12 kts.

Records for the HYD PRESS (ON/OFF) parameter showed consistent values while the hydraulic system was pressurised in the ON position servicing the flaps and the landing gear, since the speedbrakes and thrust reversers were not used.

The low hydraulic flow warning for both hydraulic pumps registered through FDR parameters HYD FLOW 1 and 2 was not produced until 11:57:19 when the aircraft had already stopped. It remained at this value until the end of the recording data, being consistent, therefore, with the hydraulic spill that emptied the reservoir after several elements of the hydraulic system sustained damaged.

The hydraulic pressure was correct throughout the landing roll-out, confirming that the hydraulic pumps were working correctly as the subsequent inspection corroborated it. Moreover, being a closed system, the accumulator would have maintained the pressure in the system even if the pumps were not working. All of these considerations rule out a malfunction in the hydraulic pumps.

According to the information from the analysis of the FDR records, the anti-skid system was operational in terms of the need for the aircraft's speed to be at least 12 kts, since it landed at 107.2 KCAS, and only reached a speed of fewer than 12 kts just 2" before coming to a halt off the runway.

No value was recorded for BRAKE PEDAL parameters 11, 12, 21 and 22, which correspond to the movement of the pilot and co-pilot pedals throughout the flight, so as per the CIAIAC laboratory analysis, it is possible that the recorder may not have been configured to record them.

Consequently, it has been impossible to contrast the information provided by the crew regarding the exact moment of braking and the moment in which the brakes were locked.

The severe damage to the components of the main landing gear wheel and brake assemblies made it impossible to assess the presence of hydraulic system leakages, although it seems unlikely that no liquid residue would be seen on adjacent surfaces if it had occurred.

The fact that the LOW BRAKE PRESSURE message was displayed from the moment the normal brakes were used and the left tyre burst, suggests that the hydraulic fluid level was previously adequate. Furthermore, elements that require hydraulic pressure, such as the flaps and landing gear, had worked when required. Bearing in mind that the pressure did not decrease due to a failure of the hydraulic pumps, as detailed above, it must have been due to a malfunction in the anti-skid system control unit, rendering the system inoperative so that when excessive pressure was applied to the pedals, the brakes locked.

If the landing gear is extended and the pressure drops below 900 psi, a pressure switch installed in the pump manifold illuminates the CAS messages LOW BRAKE PRESSURE and ANTISKID FAIL. As the hydraulic pressure reading after the incident was 600 psi, these messages were duly displayed.

The fact that the FDR records do not show any type of emergency notification or warning appears to support the hypothesis that the system was fully operational at the time of landing.

In conclusion, based on the flight records analysed, we have found that a loss of brake pressure occurred during the activation of the normal brakes, when they locked, rendering both the brake system and the anti-skid system inoperative and causing the tyres to burst. The hydraulic system was pressurised and operating correctly at all times until the moment the aircraft came to a standstill and the fluid reservoir emptied. According to the records, the speedbrakes and thrust reversers were not activated, and the aircraft gradually decelerated until it exited the runway.

3. CONCLUSIONS

3.1. Findings

- The pilot-in-command had a valid ATPL(A) Airline Transport Pilot License for aircraft issued by the German Civil Aviation Authority with IR(A), SEP (Land) and PIC type-ratings for the C560XL/XLS, TRI and PIC.
  - He had a total of 9766 hours of flying time, of which 7714 hours were in the type of aircraft involved in the incident.
  - He had been with the company for more than four years and five months and his recent activity was compliant with the requirements outlined in the operator's OM.
  - It was the first time he had encountered this type of incident.
  - He had valid class 1 and 2 medical certificates.
- The co-pilot had a CPL(A) commercial pilot license for aircraft issued by the German Civil Aviation Authority with a valid type rating for the C560XL/XLS.
  - He had a total of 5500 hours of flying time, of which 68 h were in the type of aircraft involved in the incident.
  - His recent activity was compliant with the requirements outlined in the operator's OM.
  - He had valid class 1 and 2 medical certificates.
- The operator had a valid air operator certificate issued by the authority authorised to issue commercial air operations permits.
- The aircraft was built in 2014 with series number: 560-6173 and had a cumulative flight time record of 4473:30 hours and 3212 cycles.
- Maintenance was carried out by a maintenance centre approved by the German authority as a Continuing Airworthiness Management Organisation (CAMO) and two other organisations with EASA Part-145 approval.
- The last scheduled base maintenance overhaul had been performed thirteen days before the incident, and the next scheduled inspection was scheduled after 125 more flight hours.
- The aircraft had a valid airworthiness certificate to carry out the flight.
- The meteorological conditions were suitable for the flight, and no unexpected adverse conditions that could have contributed to the accident were recorded.
- The wind changed in direction and intensity on successive occasions during the landing roll-out, contributing to the tendency of the aircraft to veer to the right.
- The flight proceeded normally until the moment of landing without any prior failure alerts or warnings being displayed in the cockpit.
- After the incident, the B.I.T.E. showed a failure in the control unit and the control valve of the anti-skid system. This was not corroborated by the inspection, which found all the components were working properly.
- The anti-skid system was inoperative.
- The pilot confirmed he applied maximum pressure to the brake pedals.
- The FDR and CVR records were preserved by the operator and showed information

consistent with the findings of the investigation.

- According to these records, the brake system lost pressure 19" after touchdown.
- The FDR was not configured to provide data for the BRAKE PEDAL parameter.
- During the landing, the procedure was not completed by deploying the speedbrakes or actuating the thrust reversers, according to FDR records.
- During the landing roll-out, neither pilot stated that the speedbrakes and the thrust reversers were not being used to stop the aircraft. so only the normal brakes were used.
- During the landing roll-out, the CAS screen showed the messages LOW BRAKE PRESSURE and ANTISKID FAIL after the MLG LH tyre burst and the emergency brake was applied for the first time.
- Given the ineffectiveness of the normal brakes, the pilot applied the emergency brake twice in a row during the landing roll-out.
- The pilot pushed the rudder to the left to compensate for the drift to the right but was unable to control the aircraft. No element has been identified that determined the inoperability of the rudder except that its effectiveness is diminished at low speeds on the ground.
- The hydraulic system functioned correctly during the flight, maintaining the correct pressure and flow values delivered by the hydraulic pumps until the moment the aircraft came to a standstill when it showed low levels of hydraulic fluid.
- Following the incident, the brake hydraulic reservoir was empty, and the system pressure was 600 psi instead of the required minimum allowable value of 900 psi.
- After the incident, the brake system accumulator had a pressure of 1600 psi instead of 2000 psi required.
- The analysis of the aircraft wreckage revealed that the brakes on both wheels of the main landing gear had locked causing both tyres to burst, first, the left one, which detached from its rim, and second the right one, which remained attached although damaged until the aircraft came to a stop.
- An analysis of the type of breakage produced in the tyres revealed that the left tyre burst due to overpressure. The right tyre suffered a progressive loss of pressure and transferred material (rubber) onto the asphalt of the runway. This resulted in asymmetrical braking that caused the aircraft to veer to the right.
- During the inspection of the aircraft by the manufacturer, all the affected elements were disassembled. Despite this, the assessment found nothing that would explain the loss of brake pressure, although, the remains of the wheel assemblies were badly damaged after the incident.
- The pilot was unable to control the direction of the aircraft when braking, veering onto the unpaved area to the right of the runway.
- The damage to the aircraft is consistent with the crew's testimonies and the findings of the accident investigation.

3.2. Causes/contributing factors

The investigation of the incident has revealed as a possible cause of the aircraft runway excursion during the landing roll-out, the loss of directional control due to the locking of the main landing gear wheel brakes.

4. OPERATIONAL SAFETY RECOMMENDATIONS

REC 33/20: It is recommended that the operator, Air Hamburg Luftverkehrsgesellschaft mbH, should establish appropriate procedures to ensure, that the maintenance organisations responsible for their aircraft configure the FDRs to record all the parameters enabled on the devices, and in doing so, guarantee that future investigations into air accidents or incidents have access to as much flight information as possible.

REC 34/20: It is recommended that the operator, Air Hamburg Luftverkehrsgesellschaft mbH, should establish appropriate procedures to ensure its crews receive adequate ongoing training, thereby ensuring compliance with the organisation's operating procedures and reducing the risk of their incomplete or inappropriate application in abnormal operating situations.

5. ANNEXES

5.1. Aircraft systems relevant to the incident

5.1.1. The aircraft's hydraulic system

The hydraulic system operates the elevator, landing gear, flaps, speedbrakes, and thrust reversers. All hydraulic control valves are connected via a main multi-way manifold and two control manifolds for the thrust reverser. The braking system has an additional independent anti-skid system for the main landing gear wheels.

The fundamental hydraulic pressure of the aircraft is provided by two positive displacement pumps, driven by the engines (EDPs). Either pump can supply enough flow to operate the system on its own.

Each pump sends the hydraulic fluid through a filter, a non-return valve with a flow sensor and a relief valve to control the correct pressure and the amount of flow pumped. When activated, the aircraft's basic system pressurises to 1500 psi.

In the case of the main landing gear wheel brakes, a hydraulic pump driven by an electric motor charges an accumulator that feeds this independent system.

The hydraulic unit indication system allows to identify if the system pressure is not adequate by displaying the message HYDRAULIC PRESSURE on the CAS panel.

Similarly, if the liquid in the reservoir falls below the minimum amount required for operation, it displays the message HYDRAULIC FLUID LEVEL LOW. If the flow supplied by each of the hydraulic pumps is less than that required for normal operation, the messages HYDRAULIC FLOW LOW LH and RH will appear for the left and right hydraulic pump respectively. Finally, the HYDRAULIC PRESSURE message shows that the system is adequately pressurised and that, while illuminated on the CAS screen, it is actively operating the hydraulics-reliant component of the selected system.

When a hydraulics-reliant component has completed its action, a bypass valve takes over through the return line, keeping the system pressurised at 1500 psi and controlling the pressure through the corresponding relief valve.

The hydraulic fluids approved for this system are Skydrol and Hyjet. The accessories used in the hydraulic fluid distribution system are compression unions (flare-type fittings), aluminium tubes and flexible hoses.

5.1.2. Landing gear

Both the main landing gear (MLG) and nose gear (NLG) have only one wheel per assembly. The NLG tyre is designed to be able to dislodge water, mud, etc. The tyre used for the main landing gear is the drag type. The landing gear retraction system is electrically controlled and hydraulically powered.

The main landing gear retracts into the wing so that when folded, the main gear leg is covered by a door or aerodynamic fairing mounted on the wing itself. The nose gear retracts forward into the nose cone section of the fuselage and, when folded, is enclosed by three doors. If the landing gear is extended, all three doors remain open. The actuators incorporate an internal locking system to keep the gear in the extended, gear-down position. It also has a mechanical gear-up locking system that is used to keep the gear in the retracted position.

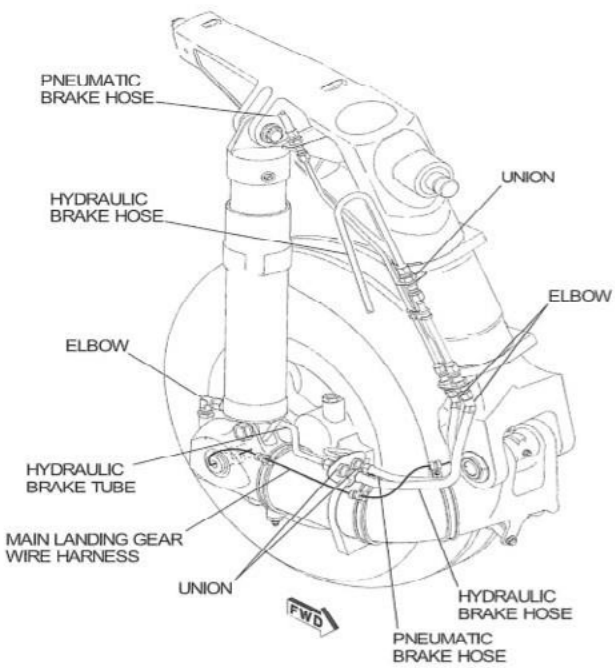


Figure 8: Components of the MLG leg

The aircraft also has an emergency manually operated landing gear extension system that releases the landing gear through free fall. In the event of a manual release failure, a pneumatic system releases the gear-up locking devices and extends and locks the gear in the gear-down position.

The nose gear controls the direction of the aircraft and is mechanically actuated by the rudder pedals which can be moved by up to 20° to each side. When the aircraft is moving on the ground, the maximum deflection of the front wheel is 90° to each side.

5.1.2.1. Landing gear brake system

The carbon multi-disc-type braking system is installed on the main gear wheels and operated via the pedals in either of the two cockpit crew positions. The system works by applying hydraulic pressure to the cylinders integrated into the assembly, trapping the discs that rotate with the wheels between a pressure plate and a torsion plate. The hydraulic pressure reaches the cylinders via two different paths or brake systems; the normal system or the parking/emergency system.

Should the hydraulic pressure fail, the assembly contains a hydraulic shuttle valve which will provide pressure for the emergency operation of the brakes.

The normal brake system applies pressure when the pedals are depressed, the right pedal to the MLG RH wheel and the left pedal to the MLG LH wheel. The parking/emergency brake system is operated by a lever on the cockpit instrument panel and sends pressure to the brake assemblies on both wheels at the same time.

The cylinders are common to both systems and can be operated by either of the two systems.

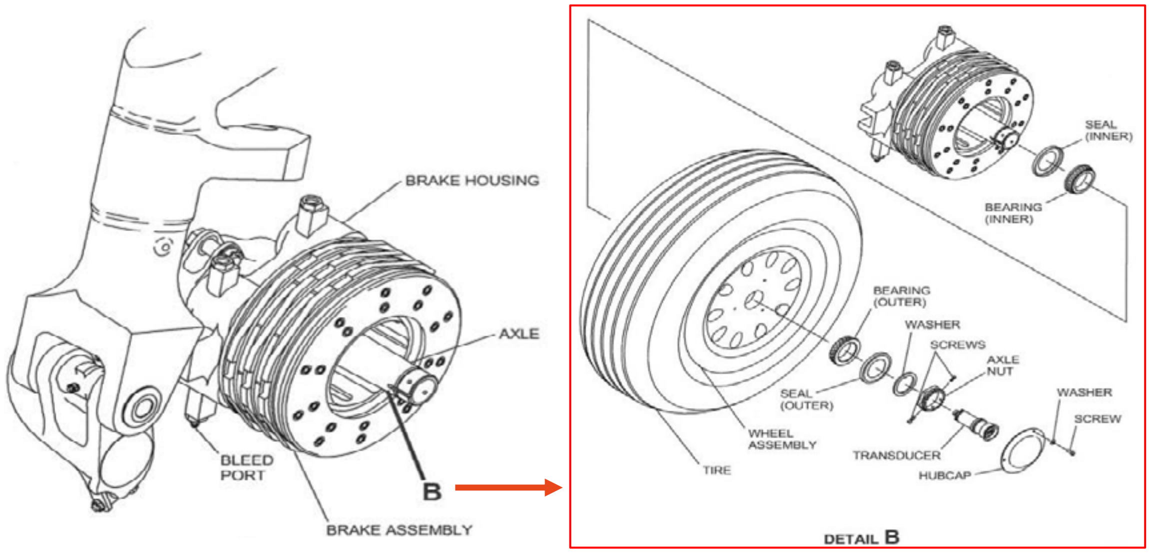


Figure 9: Components of the normal brake system

In the emergency system, the braking force can be modulated by the movement of the lever. When the lever in the rearward position, it is in the parking brake position. If the lever is in the forward position, the parking/emergency brake is not engaged.

Should the normal hydraulic braking system fail, an alternate emergency pneumatic system is available. The pneumatic pressure is contained in an emergency air bottle that is controlled by a lever with a red handle located to the left of the auxiliary gear control T-lever (AUX GEAR CONTROL). Pulling the lever will apply the same pressure to both sets of main landing gear brakes. This is accomplished by releasing back pressure on the lever and allowing it to move forward, relieving the pressure.

Air pressure to the brakes can be modulated to provide any desired braking ratio, but differential and anti-skid braking are not available when using this system.

The emergency air accumulator, when fully charged, contains enough pressure for 6 or more full braking applications. To obtain the most efficient braking with this system, sufficient air pressure must be applied to the brakes to be able to achieve the desired deceleration ratio and maintain the pressure until the aircraft stops.

The parking brake is a part of the normal braking system and employs non-return valves that prevent fluid return after applying the brakes. The parking brake is engaged by pressing the pedals and pulling out the black parking brake lever located under the lower left side of the instrument panel. The parking brake should not be applied if the brakes are very hot. This could cause the thermal relief valves to open due to insufficient time for proper cooling, or the thermal relief plugs in the wheel to melt, in both cases causing the tires to deflate.

Electrically, the brake system is powered by two switches on the left CB panel in the cockpit. The 5 A SKID CONTROL switch supplies power to the anti-skid system, and the 15 A PWR BRKS switch supplies power to the normal brake motor/pump.

If the PWR BRKS CB is pulled, the hydraulic brake system pumps are disconnected, the normal braking system becomes inoperative, and the action of the pedals on the rudder is disabled. This means braking can only be provided by the emergency braking system.

5.1.2.2. Landing gear anti-skid system

The braking system has an anti-skid protection system. While the conventional braking system operation is available at all speeds, skid protection is only available at speeds of between 12 and 175 kts. The anti-skid protection is designed to operate with maximum brake pressure applied by the pilot.

The braking system is hydraulically operated, although it has another, independent pneumatic emergency system and braking can be activated by either of the two systems.

The aircraft is slowed through the direct application of the normal braking system and the anti-skid system, modulating the brake force by adjusting the displacement of each of the pedals.

Two-speed transducers on each wheel detect the beginning of the skid and transmit this information to the digital anti-skid control unit, allowing it to act.

The speed transducer on the wheel is attached between the main landing gear shaft and the drive shaft. Thus, when the wheel rotates, the transducer generates a signal for each turn of the wheel. That signal is then sent to the anti-skid control unit as a variable frequency. The control unit accepts the data output from the left and right-wheel speed transducers independently and converts these signals to a continuous current voltage directly proportional to the wheel speed. Any significant variation in wheel speed voltage produces an error signal that activates the anti-skid valve, which, in turn, controls the amount of brake pressure being applied to each wheel.

The system incorporates a feature called "touchdown protection" (or "squat" switches), which inhibits the braking pressure before touchdown.

Touchdown protection is inactive when the wheel speed is above 40 kts and until five seconds after landing. If an excessive deceleration of the wheel occurs, the transducer voltage drops suddenly. An error signal is generated that energises the anti-skid valve, which will modulate the brake pressure as required to prevent the aircraft from skidding. When the aircraft speed drops below 12 kts, the anti-skid function is deactivated.

The anti-skid braking system is designed to be independent of the main hydraulic system. Braking can be achieved by either of the two independent systems: the hydraulic system and the support or emergency pneumatic system. As indicated above, normal braking can be applied by either pilot; however, the emergency brake control is installed only under the left side of the instrument panel.

The specific system components mentioned above (the power supply, the accumulator and the reservoir) are located on the left side of the fuselage, ahead of the battery compartment.

The brake system power package includes, in addition to the hydraulic pump, an electric motor, a filter and associated piping. The motor is a fixed displacement motor that delivers approximately 0.3 gal/min at 7000 rpm. The engine only runs when the landing gear lever is in the down position, and the pressure switch mounted on the accumulator outlet is closed. The switch contacts are normally closed and open when the pressure increases to 1500 psi; they close when the pressure drops at least 170 psi above 1230 psi.

If the landing gear is extended and the pressure drops below 900 psi, a pressure switch installed on the pump manifold will illuminate the CAS, LOW BRAKE PRESSURE, and ANTISKID FAIL messages.

Pressure relief is produced by a valve mounted in the pump housing calibrated to trip at 1700 psi.

The accumulator is pre-charged with compressed nitrogen gas and located inside the access door panel to the brake compartment. The reservoir contains a visual indicator to indicate the fill level.

A switch on the instrument panel allows the pilot to select anti-skid ON or OFF. When the switch is in the ON position, the anti-skid function is operational. With the switch in the OFF position, the message CAS, ANTISKID FAIL will be displayed, and the pilot will have brake power but no anti-skid function.

If the system fails, braking will only be available through the emergency system. The anti-skid control module incorporates a test circuit that continuously monitors the anti-skid system. If a fault is detected, the message CAS, ANTISKID FAIL will be displayed. Certain faults in the system are displayed by the B.I.T.E. indicator (Built-In Test Equipment) or fault display unit, through white flags visible in circular fault indicators. This is located on the left side of the nose compartment.

The B.I.T.E. continuously tests the system and can show the following faults:

- Left transducer failure indicated as LEFT XDCR on the B.I.T.E.
- Right transducer fault indicated as RIGHT XDCR.
- Non-agreement of values between the right and left squat switch indicated as SQUAT DISAGREE.
- Control valve failure indicated as VALVE.
- Control unit failure indicated as CONTROL.

If the hydraulic pressure in the normal brake system drops below 900 psi, the CAS message LOW BRAKE PRESSURE will appear, and the available braking will be that of the emergency system through the air support brake system.

5.2. Operational procedures

Pre-flight inspections carried out by the crew must be in accordance with the procedures established in the aircraft manufacturer's flight manual (AFM) and include, among other tasks, a visual inspection to verify the condition of the tyres, the brakes, the level of hydraulic fluid, and to check that the extension of the landing gear shock absorbers is correct. The general condition of the landing gear should also be checked.

The following list details some of the operating procedures included in this manual and part B of the operator's operating manual that are directly related to the systems identified as possible contributors to the incident.

5.2.1. Pre-landing procedures

The pre-landing procedure included in the AFM contains the following actions:

1. Landing Gear ……..……….. DOWN (3 green)
2. Flaps ……..…………………..35º
3. Speedbrakes ……..……….... retracted
4. Speed ……..…………………...V_{ref}
5. Autopilot and yaw damper ...OFF

Part B, section 2.5.17 of the operator's operating manual, explains the checks on the pre-landing checklist. The following is an excerpt:

> *When the aircraft is fully configured, stabilised and having received clearance to land, the pilot-in-command (PF) will request the pre-landing list.*

BEFORE LANDING / FINAL CHECK 1000	
Landing Gear	DOWN, 3 GREEN [M]
Flaps	(35°) SET [M]
CAS MSG	CHK [B]
Landing Clearance	RECEIVED [B]
Landing Lights	ON [M]
Autopilot& Yaw Damper	OFF [F]

6. The third step of the checklist consists of checking the CAS in case of unexpected messages.

5.2.2. Landing procedures

The landing procedure included in the AFM contains the following actions:

1. Power control ....idle
2. Brakes ....apply after the nose wheel makes contact with the runway.
   If the normal brake pedals do not brake the aircraft, the emergency brake should be applied, correcting the system before the next flight.
   The anti-skid system will not be operational so excessive pressure on the emergency brake lever may cause the wheel brakes to lock and the tyres to burst.
3. Control the nose wheel ....apply forward pressure
   You must ensure that the nose wheel has made contact with the runway before deploying the speedbrakes and thrust reverser.
4. Speedbrakes .... extend
5. Thrust reverser .... deploy
6. Thrust reverser indicator lights ....check DEPLOY indication
7. Reverse thrust ....as required
8. Thrust reverser ....lever to idle position at 60 KIAS.

The aircraft operating manual indicates that after making contact with the runway, the speedbrakes should be extended and the throttle should be in the idle position to activate the thrust reversers. The brakes will be applied to the extent required to stop the aircraft, and when the use of the thrust reversers is no longer necessary, they will retract.

5.2.3. Anti-skid system failure procedure (ANTISKID FAIL)

The "ANTISKID FAIL" CAS message is displayed in amber. It indicates a failure of the anti-skid braking system.

- If the LOW BRAKE PRESSURE message appears:
  1. Refer to the procedure for the amber CAS message LOW BRAKE PRESSURE.

- If the LOW BRAKE PRESSURE message does not appear:
  1. SKID CONTROL CB .... connected
  2. ANTI-SKID switch ....OFF then ON, if message remains
  3. ANTI-SKID switch ....OFF
  4. Landing distance...multiply by 1.6
  5. Speedbrakes ....extend (after runway contact)
  6. Thrust reversers ....maximum .(after nose wheel contact)

Caution:

- Differential power braking or normal brakes are available. However, as the anti-skid brake is not working, excessive force on the brake pedals can cause the wheel brakes to lock and rupture the tyres.
- If the hydraulic anti-skid pump fails after the accumulator pressure exceeds 850 psi, the amber LOW BRAKE PRESSURE message may not appear until normal brakes are used.
  7. Wheel brakes .... apply gently
  8. Prepare to use the emergency brake system

5.2.4. Low brake pressure procedure (LOW BRAKE PRESSURE)

The “LOW BRAKE PRESSURE” CAS message is displayed in amber. It indicates a failure of the normal brake system. The message “ANTISKID FAIL” will also appear.

1. PWR BRKS CB.. connected

If the message remains:

2. Consider that you will have to use the emergency braking system
3. Landing distance .... multiply by 1.4

Caution:

The anti-skid system does not work during emergency braking. Excessive pressure on the emergency brake lever can cause both wheel brakes to lock, causing both tyres to burst.

4. Brake pedals ....remove your feet
5. Emergency brake lever...pull as required
6. Thrust reverser..apply to maximum

5.2.5. Wheel brake failure procedure (WHEEL BRAKE FAILURE)

The “WHEEL BRAKE FAILURE” CAS message is displayed in amber.

The anti-skid system does not work during emergency braking. Excessive force on the emergency brake lever may cause the wheel brakes to lock and rupture the tyres. After landing, clear the runway and stop. Do not try to taxi to the stand with emergency brakes.

Repeated application and release of the emergency brake lever can cause premature loss of tyre pressure.

1. Brake pedals ……………………………………….remove your feet
2. Emergency brake lever ……………….................pull
3. Speedbrakes (after landing) ....extend
4. Thrust reversers…………………………………....maximum
5. Landing distance……………………..................multiply by 1.4
6. Directional control………………………....……..maintain with the nose wheel

If the DC generator is disconnected, the normal braking system and the anti-skid system are inoperative, which means the only available braking system is the emergency brake system. In this situation, the rudder effect is inefficient.

5.2.6. Disconnection of the DC generator (DC GENERATOR OFF L/R)

Should either of the two DC generators fail (DC GENERATOR OFF L/R) or be disconnected (OFF), both the anti-skid and normal brake systems will be inoperative. The only available braking system will be the emergency brake system. Differential rudder control will also be unavailable. In addition, other systems will be inoperative, such as anti-ice, engine fire detection, speedbrake, etc., and cabin depressurisation will have to be carried out manually.

5.3. Service Bulletins

5.3.1. Service Bulletins from the aircraft's manufacturer

Below, is a list of the SLs[4] (Service Letters) issued by the aircraft manufacturer (CESSNA) in relation to the aircraft involved in the incident s/n: 6173:

- SL560XL-32-06 of the 08/08/2000: relating to the operation of the brake system. For information only. All CBs must be connected before applying power to the aircraft. CBs should not be used as a switch to disconnect the normal brake pump in order to prevent the engine from cycling. CBs are not to be used as switches because they can weaken and fail without warning. If the PWR BRKS CB is disconnected, the normal brake system is disabled, and there is no normal braking through the pedals. The crew will notice that the pedal brakes are ineffective.

  In this case, the aircraft can only be slowed using the pneumatic system. The normal brake system and anti-skid system installations are close but independent, and each has its own components, accumulator and reservoir. These systems supply pressurised hydraulic fluid to the normal and anti-skid brake system valve actuator, which regulates a maximum of 1000 psi ± 20 psi to the brakes. This pressure will vary according to the pressure exerted by the pilots through the brake cylinders and the electrical commands sent from

[4] SL: Service Letter - Document issued by a manufacturer of aircraft or aeronautical components to communicate information, advice and recommendations relating to the operation and service of an aircraft to the operators in general - owners, flight operations and engineers.

the anti-skid system control unit.
Both pilots and maintenance personnel must understand that when operating the aircraft if the PWR BRKS CB is pulled out, the normal braking system is inoperative, and the emergency brake must be used. Continually pulling this CB to deactivate the normal braking system can cause it to malfunction.
- SL560XL-32-08 of the 30/10/2000 communicating Goodrich SL no.1866[5]: warns against the use of non-Goodrich approved cleaners for the main landing gear and nose-gear aluminium wheel assemblies. SL560XL-32-09 of the 08/05/2001 communicating Goodrich SL no. 1878: warns against the use of disinfectants not approved by Goodrich in some countries.
- SL560XL-32-29 of the 22/12/16: This service letter provides instructions for inspecting of the locking tab that prevents the main landing gear rod end and the piston rod from rotating independently. It is recommended that this inspection be included in the inspection schedule.

5.3.2. Service Bulletins from the manufacturer of the main landing gear wheel/brake assemblies

Below, is a list of the SBs and SLs applicable to the aircraft involved in the incident s/n: 6173, issued by the manufacturer of the landing gear wheel and brake assemblies (Goodrich):

- SB 831 (3-1571-32-1) 19/10/00: affects the wheel assembly of C560 aircraft using p/n: 3-1571-1, indicating that to increase the fatigue life of the Michelin tyre operators should install p/n: 3-1571-2 (new number for improved part), which increases the section to absorb the increase in loads. The change affects the base of the wheel; it should be implemented the next time any of the parts are changed.
- SB1006 (3-1571-32-3) 18/02/08 rev. 2: further improves the wheel assembly for aircraft using p/n: 3-1571-1 and p/n: 3-1571-2, for the new assemblies p/n: 3-1571-3 and 4. Implementation is advised within the next 3 tyre changes.
- SB1026 (3-1571-32-4) 15/06/07: applicable to the main wheel assembly, is issued to introduce a new and improved thermal relief plug assembly, as some operators had submitted reports having detected low tyre pressure caused by a leaking thermal relief plug.
- SB1088 (3-1571-32-6) rev.1 24/05/10: applicable to the wheel fastening nuts and bolts, recommending further inspections as several operators reported that these inserts had come loose.
- SB1097 (3-1571-32-7) 25/02/11: Improvements to the wheel assembly, specifically, the fastening nuts and bolts as several operators have reported the loss or damage of these elements. Replacement at the next screw change is recommended.

[5] Goodrich: wheel and brake assembly manufacturer.

- SB1114 (3-1571-32-8) 31/01/12: To introduce a new seal between the base of the wheel and the heat shield assembly, giving the wheel tube extra protection from abrasion.
- SB1194 (3-1571-32-9) 23/02/18: Improve the wheel assembly with a new seal so that the new groove in which the seal is housed is deeper than the old one. Substitution with the new seal is recommended when replacement is required.
- SL1889 15/06/01: Procedure for applying an adhesive sealant.
- SL1914 03/02/06 rev.1: recommending that unapproved parts should not be used in wheel and brake assemblies.
- SL1977 30/07/07 rev.1: establishing procedures for the use of chemical substances in the maintenance of landing gear wheel assemblies and their brakes, and hubcaps with a cadmium coating or containing beryllium, ceramic fibres, or asbestos.
- SL1987 26/10/05 rev.1: in relation to the main landing gear wheels. Provides instructions on how to calculate the number of tyre changes that may make NDT inspections necessary. An unworn tyre removed due to obvious damage can lead to undesirable NDT inspections. A tyre removed with fewer than 100 landings counts as ½ a change. A tyre removed after more than 100 landings counts as 1 tyre change.
- SL2000 01/11/04: establishes a series of precautions to observe during the installation of bearing cones in the main and nose landing gear wheels. Given that the p/n and sizes are very similar, the purpose is to ensure that the correct bearing cones are installed in the wheel rims. Some operator maintenance personnel have inadvertently installed the incorrect cones, which can result in damage to the landing gear.
- SL2022 11/01/06: in relation to the main landing gear wheels, establishing procedures for balancing the wheels and tyres.
- SL2048 11/16/06: issued for the introduction of a new primer. The new chrome-free primer reduces environmental impact.
- SL2054 05/07/07: in relation to the main and nose gear wheels, operators have the option of using Mobil Aviation Grease SHC 100 (product code 530063) on wheel assembly bearings. Operators must ensure that Mobilith SHC 100 is not used. Mobilith SHC 100 is not for aviation use and is not approved.
- SL2056 04/04/07 rev.1: the purpose of this service letter is to provide instructions to make sure the transmission insert bolts have the correct torque value. This should be checked at the next tyre change as multiple operators reported finding loose screws or inserts during overhaul.
- SL2074 03/01/08: to indicate the required valve core tightening.
- SL2076 28/02/08: in relation to the main and nose landing gear assemblies, recommending that the grease used in the bearings be changed.

- SL2078 29/02/08: in relation to the main and nose landing gear assemblies. We have received reports of maintenance personnel suffering serious injuries due to tyres bursting during inflation. We, therefore, recommend they be inflated from a source equipped with a nitrogen pressure regulator. In other words, please ensure a pressure regulator system is used during inflation.