CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A–043/2013

Accident involving a BOEING 767-332 ER aircraft, registration N-182DN, operated by DELTA AIR LINES, at the Madrid-Barajas Airport (Madrid, Spain) on 5 December 2013

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Foreword

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 5.5 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 1.4 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.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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[1] Foreign Object Debris

Abbreviations

00:00	Hours and minutes (period of time)
00.00:00	Hours, minutes and seconds (chronological time)
00°	Geometric degrees / Magnetic heading
00°00’00”	Degrees, minutes and seconds (geographic coordinates)
00 ° C	Degrees Centigrade
A/P	Autopilot
ACC	Area Control Center
ACS	Area control surveillance rating on air traffic controller license
AD (DA)	Airworthiness Directive
ADI	Aerodrome control instrument rating
AENA	Spain’s Airport Operator and Air Navigation Services Provider
AIP	Aeronautical Information Publication
AIR	Air control endorsement on air traffic controller license
Al	Aluminum
AMC	Airport Management Center
APP	Approach Control Station
APPR	Approach flight panel mode
APS	Approach control surveillance rating on air traffic controller license
ASDA	Accelerate-stop distance available. Runway length available for takeoff run plus stopping area
ATC	Air Traffic Control
ATIS	Automatic Terminal Information
ATPL(A)	Airline Transport Pilot License (Airplane)
C/L	Check List
CATCL	Community Air Traffic Controller License
CAVOK	Weather conditions with visibility of 10 km or more, no clouds below the reference altitude and no cumulonimbus clouds, and no significant weather events.
cm	Centimeter
CRM	Cockpit Resource Management
Cu	Copper
CVR	Cockpit Voice Recorder
dd/mm/yyyy	Day, month, year (date)
DFDR	Digital Flight Data Recorder
DGAC	Spain’s Civil Aviation General Directorate
E	East
EASA	European Aviation Safety Agency
EICAS	Engine indicating and crew-alerting system
EOBT	Estimated off-Block Time
ESASA:	European Aviation Safety Agency
FA	Flight attendant
FAA	Federal Aviation Administration
FOD	Foreign Object Debris
Ft	feet
g	g
G	Acceleration due to gravity
GMC	Ground movement control endorsement on air traffic controller license
GMS	Ground movement surveillance endorsement on air traffic controller license
hPa	Hectopascal
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument landing system
IR(ME)	Instructor rating for multi-engine airplane
ITT	Interstage turbine temperature
JAA	Joint Aviation Authorities
Kg	Kilogram
Km	Kilometer

Kt	Knot
L	Left (used to designate runways).
LCL	Local controller
LDA	Landing distance available.
Lb	Pound
m.	Meter
MAC	Mean aerodynamic chord
MAOT	Maneuvering Area Operations Technician
METAR	Aerodrome meteorological report
Mg	Magnesium
MHz	Megahertz
Mn	Manganese
MTOW	Maximum takeoff weight
N	North
NDB	Non-directional beacon
NM	Nautical mile
NTSB	National Transport Safety Board
P/N	Part number
PF	Pilot flying
PM	Pilot monitoring
PNF	Pilot not flying
Psi	Pounds per square inch
PT	Power turbine
QNH	Local Q-code altimeter setting (Query Newlyn Harbour).
R	Right (used to designate runways).
RADAR	Radar endorsement on air traffic controller license
RAT	Ram air turbine
RESA	Runway End Safety Area
RFFS	Rescue and Firefighting Service
S	South
S/N	Serial number
SAR	Search and rescue
SB (BS)	Service Bulletin
SDP	Apron Control Service
TAF	Aerodrome forecast
TCL	Terminal control endorsement on air traffic controller license
TMA	Terminal Maneuvering Area
TODA	Take-off distance available.
TORA	Take-off run available.
TWR	Control tower
UTC	Universal Coordinated Time
VFR	Visual flight rules
VHF	Very high frequency
VOR	VHF omnidirectional radio range
W	West

Synopsis

Owner and Operator:	DELTA AIR LINES
Aircraft:	BOEING 767 – 332 ER
Date and time of accident:	5 December 2013 at 12:05 local time[2]
Site of accident:	Madrid Barajas Airport
Persons onboard:	203
Type of flight:	Commercial Air Transport - Scheduled - International - Passenger
Phase of flight:	Takeoff - Initial climb
Date of approval:	31 May 2016

Summary of the incident

The Boeing 767-300 ER aircraft operated by Delta Air Lines, registration N182DN and call sign DAL415, took off at 11:41 from runway 36L at the Madrid-Barajas Airport en route to JFK Airport in New York. Onboard were 192 passengers, 3 pilots and 8 flight attendants.

During the takeoff run the aft right wheel on the right main landing gear broke and the debris from the tire detached and struck the lower wing, forming a hole and also rupturing important components in the hydraulic system, which in turn detached and struck the upper surface of the wing, causing one of the outer panels to detach.

The damage to the hydraulic system made it impossible to retract the landing gear. The crew detected this immediately during the climb and declared an emergency, returning to the airport as instructed by ATC and landing on runway 32L at 12:05.

At the end of the landing run the aircraft left the runway via the last rapid-exit taxiway on the left side (L3), coming to a stop outside said taxiway in a grassy area located halfway between the end of runway 32L and terminal T4, located further south.

There was no fire during the landing. The airport firefighters, however, who were already on alert, as they had been the first to detect the rupture of the wheel when they heard a loud noise as the airplane passed in front of the firefighting station on the north side of the airport, escorted the aircraft during its landing run and, once the airplane came to a stop, doused the landing gear.

[2] Unless otherwise specified, all times in this report are local. To obtain UTC, subtract one hour from local time.

There were no injuries and the passengers were disembarked normally via the right front door using a ladder.

The investigation has concluded that the accident was caused by one of the main gear tires breaking, which in turn resulted from a metal piece being left inside the tire during the retreading process.

Five safety recommendations are issued, one of them to DELTA AIRLINES, one to ENAIRE, two to BOEING and one to GOOD YEAR.

1. FACTUAL INFORMATION

1.1. History of the flight

A Boeing 767-332 ER aircraft, operated by Delta Air Lines, registration N182DN and call-sign DAL415, took off at 11:41 from runway 36L at the Madrid-Barajas Airport en route to JFK Airport in New York with 192 passengers, 3 pilots and 8 flight attendants (FA) onboard.

During the takeoff run, the right rear tire on the right main landing gear burst, with the detached parts of the tire striking the underside of the wing, puncturing it and also fracturing important hydraulic system components. When these components detached, they struck the top side of the wing, causing the loss of a panel there.

Figure 1. Photographs of the holes in the upper and lower wing

The damage to the hydraulic system made it impossible to retract the landing gear. The crew detected this immediately during the climb and declared an emergency, returning to the airport as per ATC's instructions, landing on runway 32L at 12:05.

At the end of the landing run, the aircraft exited the runway via the last rapid exit taxiway on the left side (LA), via the paved area in the vicinity of LA and LB (holding points for 14R threshold), without the crew having any directional control, and headed toward taxiway J3, coming to a stop in a grassy area located halfway between the end of runway 32L and zone A of terminal T4, which is the one located further south.

Figure 2. Photograph of the aircraft just after exiting the runway

There was no fire during the landing, though the firefighters, who were the first to detect the explosion of the tire upon hearing a loud noise as the airplane passed in front of the station situated on the north side of the airport, had already been alerted. They accompanied the aircraft during its landing run and cooled off the landing gear once the airplane came to a stop.

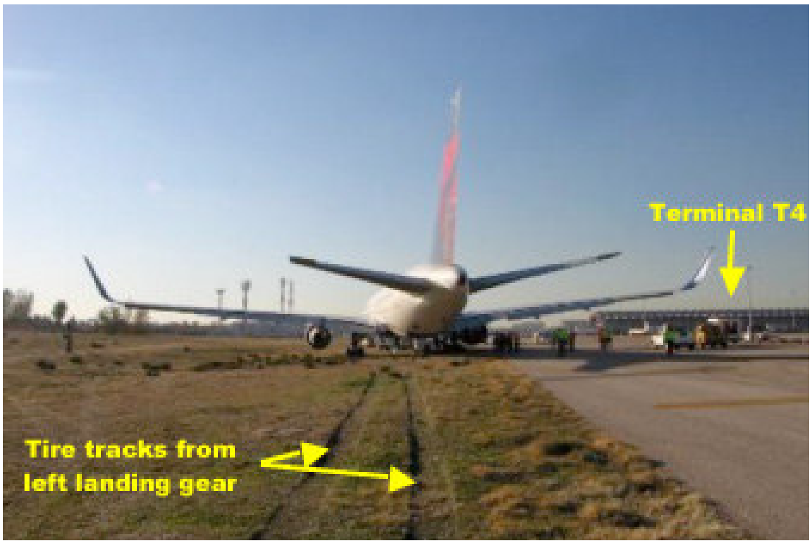

Figure 3. Photograph of the aircraft shortly after stopping

A timeline of the most relevant events is provided below:

11:38 h The tower cleared the crew to enter runway 36L and take off, informing the crew that winds were calm.

11:41 h The airplane took off.

11:42 h The aircraft informed the Control Center on 131.175 MHz that they had a problem and were considering declaring an emergency, but that first they had to evaluate exactly what had happened. They were at 3,500 ft climbing to 13,000 ft. The Control Center instructed them to hold that altitude when they reached it.

11:43 h The Rescue and Firefighting Service (RFFS) informed the airport tower of an explosion they had heard while an airplane was taking off from runway 36L. The tower reported they were unaware of any problems but that they would contact the Control Service to which they had transferred the airplane to see if they had been notified of anything and that departing traffic would be stopped so the runway could be checked.

11:44 h The aircraft with callsign IBE04VQ was lined up to start its takeoff run but was not cleared for takeoff. Just then the tower asked the Control Center if the aircraft was under their control and if they knew what had happened. The Control Center confirmed it was under their control and that they had not called the crew so as not to bother them.

11:46 h The crew once more contacted the Control Center and confirmed they would be returning and asked for vectors. They were instructed to turn left to heading 220º.

The tower informed the RFFS that airplane DAL415 was still climbing as planned and that the crew was recommending a check of the runway.

11:47 h The Control Center asked the crew to confirm their desire to return to the airport. The crew responded in the affirmative and stated their intention to declare an emergency. The Center asked if they needed help and the crew replied they were still trying to determine exactly what was happening.

The tower informed the RFFS that airplane DAL415 was returning to the airfield without knowing the exact problem, that it was not on approach yet and that they would be told the landing runway when they knew for sure.

11:48 h A local alarm[3] (ALA2) was declared by airport authorities and the siren at the Airport Management Center (CGA) was activated.

The crew of the airplane awaiting takeoff at the threshold reported to the Control Center that they had seen smoke coming out of the right engine when the Delta Air Lines airplane took off. The Control Center immediately relayed this to the aircraft's crew, which replied they had a hydraulic system failure.

11:49 h The Control Center asked the crew if they were going to need assistance, to which they replied in the affirmative, and which runway they preferred to land on, 32L or 32R, replying 32L.

11:50 h The airplane declared an emergency and the Control Center asked the tower to close runway 36L.

11:51 h The aircraft was transferred to the approach frequency (128.7 MHz).

11:52 h The crew contacted approach, which instructed them to maintain heading 180º and to contact when they were 10 NM out. The tower informed them that runway 36L was being checked and that some objects had been found on it. It also confirmed that the aircraft was expected to land on runway 32L in ten minutes. Traffic waiting to take off from the affected runway was also

[3] The local alarm is activated when an incident occurs that due to its nature and scope, can be handled by groups within the airport through the preventive and limited mobilization of resources.

notified that the runway was not in use and that they would be redirected to runway 36L.

11:57 h The crew was transferred from Control to the tower frequency, 127.1 MHz, for the final approach. The crew contacted the tower and were instructed to maintain heading for runway 32L.

The tower informed the Control Center that debris from the tire and the fuselage had been found on the takeoff runway.

11:58 h The Control Center informed the crew that parts of the tire and fuselage had been found on the takeoff runway, which the crew acknowledged.

12:00 h They were cleared to land on runway 32L.

12:02 h The crew were transferred to ground control on frequency 118.15MHz.

12:03 h The tower reminded the Control Center that runway 32R does not have the same rapid exit taxiways as 32L and that it is faster to leave that runway.

12:05 h The airplane landed on runway 32L and left via exit LA. A general alarm[4] (AG2) was declared at 12:06. Runway 32L remained inoperative while it was checked.

12:07 h The pilot informed the tower that they had lost the brakes during landing, asked if there was smoke in the airplane and asked to speak to the firefighters.

12:08 h The tower informed the Control Center of the landing, with some difficulties and that they had almost departed from the runway. It also reported that runway 32L was being closed.

12:09 h The RFFS reported that one of the tires on the right main landing gear was blown out and that the airplane was stopped off the runway on J3 and the potential fire was under control. The tower informed the pilot that there was no fire and the RFFS was cooling off the gear.

12:10 h The AMC asked the tower to request information from the crew on the situation inside the airplane.

12:11 h The captain reported no injuries and that the situation was normal. Vehicles (shuttle buses) were then sent to evacuate the passengers. The general alarm (AG2) was deactivated.

[4] A general alarm is activated when an incident occurs that due to its nature and scope can be handled by groups within the airport, though resources external to the airport may be required to some extent.

12:27 h Airport Medical Services (AMS) arrived at the aircraft.

12:31 h The vehicles to evacuate the passengers arrived at the aircraft.

12:40 h The boarding ladder arrived at the airplane and at 12:45 the disembarkation began.

12:50 h The AMS confirmed that all the passengers were well and calm and left the scene.

13:27 h The airline reported that the passengers were being taken to a hotel.

13:30 h The local alarm was canceled.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor				N/A
None	11	192		N/A
TOTAL	11	192		

1.3. Damage to aircraft

The airport sustained significant damage.

1.4. Other damage

After leaving runway 32L vial exit taxiway LA, the aircraft struck a sign, pulling it out of the ground. It also damaged three taxiway lights near the taxiway leading to the 14R threshold (LA), a runway centerline light, an edge light on runway 14R-32L, several small signs, four reflectors on the edge of exit taxiway J3 and two inspection chambers.

1.5. Personnel information

1.5.1. Crew

The captain, 57, had an airline transport pilot license (ATPL(A)), class ratings for the Boeing 757, Boeing 767, Lockheed 382 and Douglas DC-9 models. He also had instrument (IR) and multi-engine (ME) ratings. He had 16,739 flight hours, of which 6,623 had been on the type and 412 as the copilot. In the previous 90 days he had flown 152 hours, and the last type check had been on 22 April 2013.

His license, which had been issued by the FAA, was valid until 20 April 2014 and his medical certificate until 20 December 2013.

The copilot, 51, had an airline transport pilot license (ATPL(A)), class ratings for the Boeing 757, Boeing 767, Douglas DC-9 and Cessna Citation CE-500 models. He also had instrument (IR) and multi-engine (ME) ratings. He had 12,000 flight hours, of which 10,880 had been for Delta Air Lines. He had 4,685 hours on the type. In the previous 90 days he had flown 168 hours, and the last type check had been on 30 July 2013.

His license, which had been issued by the FAA, was valid until 30 July 2014 and his medical certificate until 19 December 2013.

The pilot who was in the observer's seat, 50, had an airline transport pilot license (ATPL(A)), class ratings for the Boeing 757, Boeing 767, and Beechcraft 1900 models. He also had instrument (IR) and multi-engine (ME) ratings. He had 13,000 flight hours, of which 9,900 had been at the airline. He had 5,304 hours on the type. In the previous 90 days he had flown 135 hours, and the last type check had been on 12 November 2013

His license, which had been issued by the FAA, was valid until 12 November 2014 and his medical certificate until 10 January 2014.

1.5.2. Controllers

Four controllers on duty were in contact with the aircraft. They all had EU air traffic controller licenses issued by AESA and had aerodrome control instrument (ADI) ratings, and the following endorsements: control tower (TWR), ground movement control (GMC), ground movement surveillance (GMS) and radar (RAD). They also had approach control surveillance (APS) ratings with radar (RAD) and terminal control (TCL) endorsements. Finally, they had air control surveillance (ACS) ratings with radar (RAD) and terminal control (TCL) endorsements.

The local controller who cleared the takeoff on runway 36L was 41 and the language entry in her license showed a level 6 for Spanish and 5 for English. She had 12 years of experience, nine of them at the Madrid-Barajas Airport tower. Her license and ratings were valid until 2 November 2014 and her medical certificate until 17 November 2014.

The controller who was in contact with the crew during the landing on runway 32L was 42 and had an On-the-Job Training Instructor (OJTI) endorsement. The language entry showed a level 6 of Spanish and 4 of English. He had 12 years of experience, of which nine had been at the Madrid-Barajas Airport tower. His license and ratings were valid until 3 February 2015 and his medical certificate until 11 September 2014.

The supervisor, 48, had a language rating of 6 for Spanish and 5 for English. She had 22 years of experience and had been stationed at that tower for 15 years, 7 of them as supervisor. Her license and ratings were valid until 9 October 2014 and the medical certificate until 11 February 2015.

The supervisor, 47, also had an On-the-Job Instructor endorsement and a level 6 in Spanish and 5 in English. He had 12 years of experience, all at the Madrid-Barajas tower, and had previously worked for AENA as an aeronautical engineer. His license and ratings were valid until 28 August 2014 and the medical certificate until 2 July 2014.

1.6. Aircraft information

1.6.1. General information

The Boeing B-767-332 ER aircraft, registration N182DN, had been delivered on 5 November 1992 with serial number 25987. It had 95,491 hours of operation.

It had a wingspan of 47.574 m, a length of 48.514 m, a total height of 16.104 m and was configured to carry 211 passengers.

According to the flight manual, its maximum takeoff weight was 185,065 kg (408,000 lb) and maximum landing weight 145,149 kg (320,000 lb). Its zero fuel weight (ZFW) was 133,809 kg (295,000 lb)[5] and its maximum taxi weight was 185,519 kg (409,000 lb).

It was equipped with two PRATT & WHITNEY PT6A-67D 4060 turbofan engines.

[5] A plate in the cockpit, however, said 298,300 lb.

The left (no. 1) engine had serial number 727744 and was delivered on 30 September 1997. It had a total of 67,754 hours of operation (9,625 cycles) and the time since its last overhaul was 48,801 hours (6,649 cycles).

The right (no. 2) engine had serial number 724751 and was delivered on 18 June 1996. It had a total of 69,140 hours of operation (12,811 cycles). The time since its last inspection was 1,505 hours (202 cycles) and the time since its last overhaul was 18,479 hours (2,672 cycles).

The main landing gear had eight wheels, four on each main gear leg. The tire that burst was the right rear tire on the right main landing gear, designated as tire no. 8. The serial number of this rim was DL1726. The part number of the tires was 020-807-0 and their serial number was 1277R00294. They had been retreaded by Good Year at its Kingman (Arizona) plant in July 2013. The tires were mounted on the rims on 21 August 2013 and the wheels were installed on the airplane on 3 September 2013. They had undergone 145 cycles since then.

The maintenance checks were conducted by the operator[6], were in order and in keeping with the approved maintenance program.

1.6.2. Wing structure

The main wing structures, that is, the front and rear spars, stringers, ribs, the shell panels and the reinforcement panels, are made of aluminum. The central wing box is inside the fuselage and all of the connecting elements are also made of aluminum.

The wing houses the fuel tanks and the landing gear, which is supported by a beam and the aft spar.

The secondary structures on the wing support the fairing, control mechanisms and control surfaces, which are made from composite materials.

[6] Its certificates include the following: USA: FAA - 121 Certified Air Carrier No. DALA026A, USA: FAA - 145 Certified Aviation Repair Station No. DALR026A y EU: EASA - 145 Certified Aviation Repair Station No. EASA.145.4380

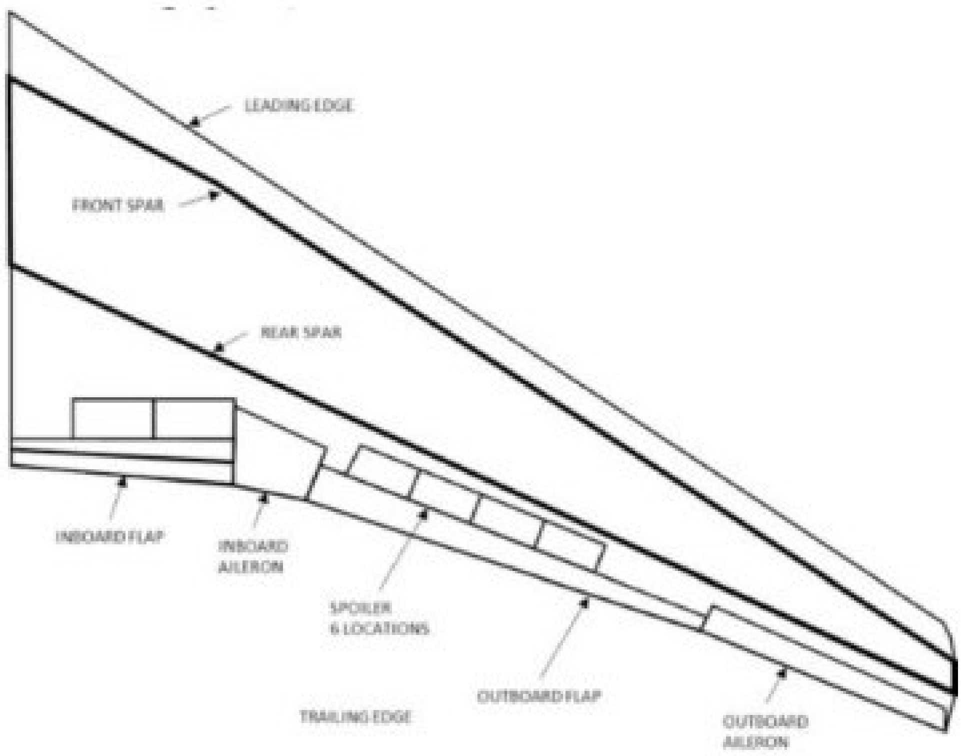

Figure 4. Wing structure

1.6.3. Hydraulic System

The hydraulic system consists of three independent sub-systems that supply fluid at a maximum pressure of 3,000 psi to operate various systems on the airplane. They are identified as left, (L), right (R) and center (C).

Several independent pumps can supply pressure to each system. The flight control surfaces, such as the ailerons, elevators and rudder are actuated by one or more of the hydraulic systems in a configuration that minimizes the effects of losing one or two hydraulic systems.

The critical high-pressure supply and low-pressure return lines are made of titanium. Non-critical return lines are made of aluminum and the tubing is made of stainless steel.

The tubing is colored to identify it, with the left system tubing colored red, the right system tubing colored green and the center system tubing colored blue.

The typical pressure found in hydraulic lines is 3000 psi in pressure lines, 600 psi in return lines and 65 psi in the supply lines.

There are accumulator tanks that supply pressure if there is a fault in the left or center systems. The pilots have a cockpit indication on the status of each hydraulic system. Figure 5 shows a diagram of the system and the components that are actuated in each sub-system.

The following considerations apply to the main hydraulic system:

— The center hydraulic system components are located both in the right main landing gear well and in the front part of the left wing, next to the fuselage fairing. The primary pressure sources for this system are two AC pumps. The pump that handles the demand of the center system is an air-driven pump. The two AC pumps are on continuously when the switches are on and electricity is available. The air-driven pump is powered by air obtained from the engine bleed and it can be in the ON or AUTO position. In the former, the pump is on continuously.
— The left and right system components are located in their respective engines, in the fairing. The main source of pressure for each is the engine-driven pump, which is on constantly when the engine is running. A depressurization valve, controlled by the pump switch, stops the flow of fluid from the electric pump, which can be in ON or AUTO.

When ON, the pump runs continuously. In AUTO, the pump is off until the demand on the system exceeds the supply being output by the engine-driven pump. The electric pump is on continuously in AUTO mode when the flaps are actuated while on the ground. Also when on the ground, the left electric pump is inhibited when either engine is started to reduce the electrical load on the auxiliary power unit (APU) generator.

— Each hydraulic system has a fluid tank that is pressurized with air from the pneumatic system. It also has two modules that filter the clean fluid that drains from the pump to return it to the system. Heat exchangers in the fuel tanks cool the excess fluid from the pump before it returns to the tank.
— Ground connections are located on the engine pylon, on the main landing gear beam, between the wheel housing and the fairing. These connections allow hooking up an external source of hydraulic pressure.

As for the components in the secondary hydraulic system:

— The ram air turbine (RAT) provides a source of back-up pressure for the center system. It is located at the front right of the fuselage. It lowers automatically if engine shaft RPMs (N2) fall below 50% in both engines. It can also be actuated manually from the cockpit. When it deploys, it supplies pressure to the center system to power the flight controls.

— The pitch trim system automatically provides hydraulic power to the stabilizer control system if the left and center hydraulic systems fail. It uses the right system to pressurize an isolated part of the left hydraulic system without transferring fluid between the two systems. The isolated part of the left hydraulic system contains a stabilizer setting module that acts to trim the stabilizer. This system's components are located in the stabilizer compartment at the rear of the aircraft.

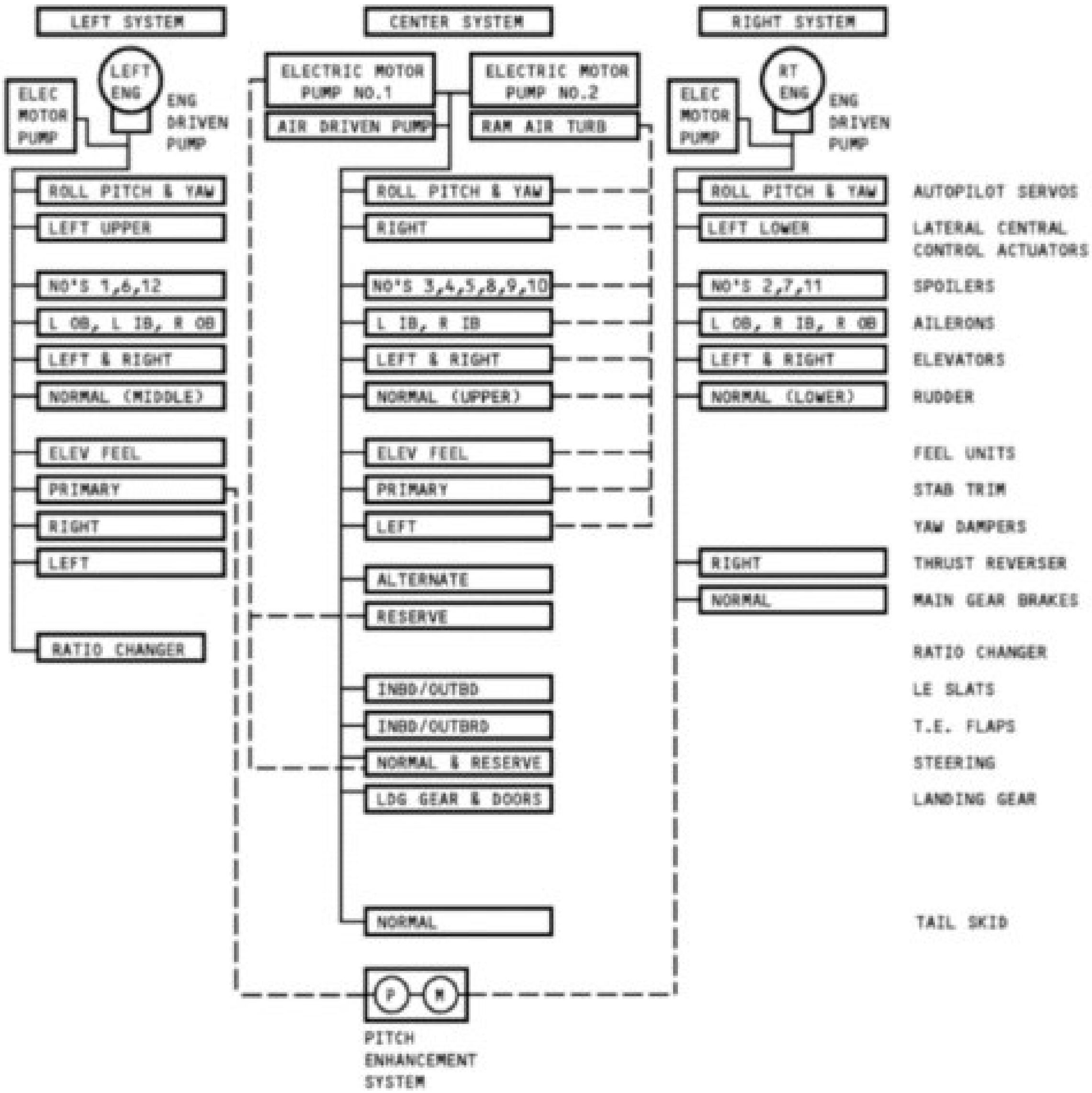

Figure 5. Hydraulic system operational diagram

1.6.4. Brake system

The hydraulic brake system features multiple rotor and stator discs in each main gear wheel. The brakes are actuated by the captain's and first officer's brake pedals, or automatically via valves in the autobrake system. There is also an anti-lock system to keep the brakes from locking during braking operations.

The brake system is normally supplied by the right hydraulic system, though if pressure is lost in the right hydraulic system, the central system is automatically selected by the alternate brake selection valve to supply pressure and actuate the brakes. If pressure is lost in the center and right systems, the pilots can select the stand-by system to operate the brakes. This system features an electric motor powered by the pump in the center system that is dedicated to provide braking and to steer the front wheel.

If the stand-by system is not working, a hydraulic accumulator in the brake system will provide limited braking capabilities.

The effectiveness of emergency braking operations is limited either by the friction between the tire and the surface of the runway (limited friction) or by the maximum pressure available when the pedals are depressed (limited torque). Hydraulic fluid in the accumulator tank is drained in three phases during braking: the initial fill of the tank, the demand for hydraulic fluid flow during braking and the flow of said fluid past the valve. During the first two phases the amount of fluid in the accumulator will depend on the pressure exerted on the brakes and on how it is exerted, such that constant, gradual braking pressure will result in slower draining of the fluid than if the brake pedals are pumped more than once.

1.6.5. Landing gear

The landing gear system consists of two main gear bogies and the front gear, a system for lowering and raising the gear, wheels and brakes, a steering system, and a system to give readings in the cockpit on the status of the gear and their associated doors.

The main landing gear absorbs the primary loads during landing and supports most of the airplane's weight when on the ground. The doors open and close as the bogies move.

The front gear is used to steer the airplane when taxiing on the ground. It also absorbs part of the loads produced during landing. Its doors also open and close with the motion of the bogie.

The raising and lowering of both the main and front landing gear, and the opening and closing of their respective doors, is powered by the hydraulic system, complemented by mechanically actuated components.

The gear can be lowered mechanically in an emergency if the hydraulic system fails. The system provides readings in the cockpit on the condition of the gear.

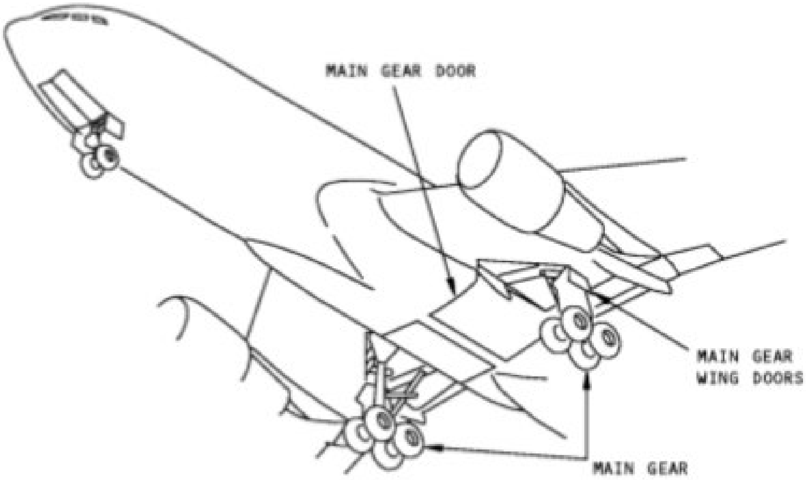

Figure 6. Position and components of the landing gear

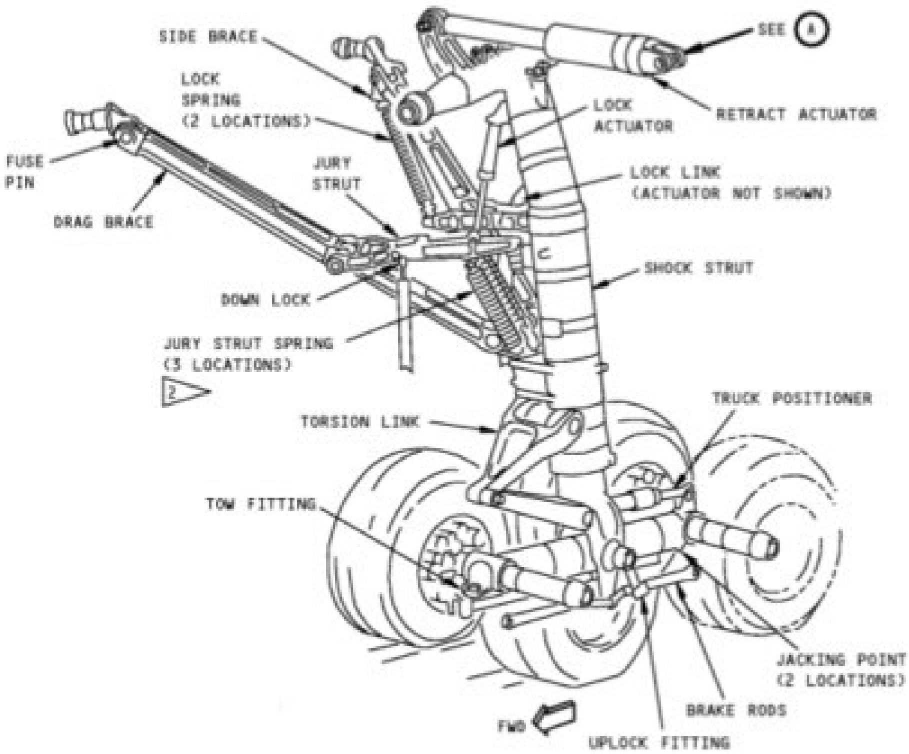

Figure 7. Main gear components

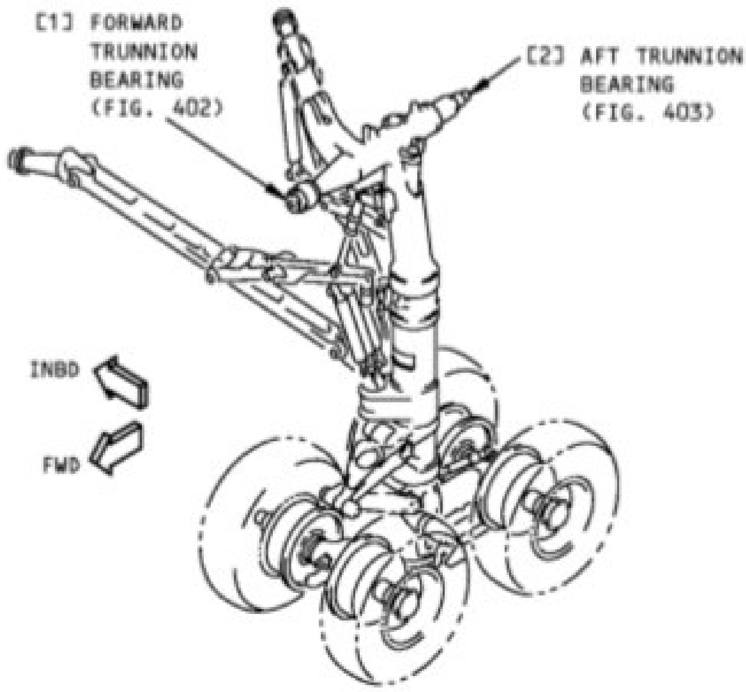

Figure 8. Front gear components

1.6.6. Engine reverse thrust system

The reverse thrust system is part of the thrust control system, which features two levers to supply power to the engines, a brake and an automatic accelerator.

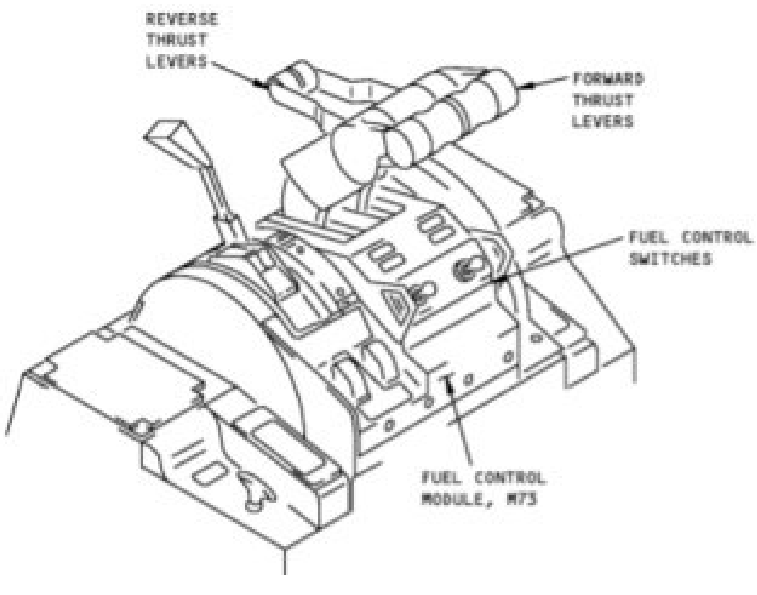

Figure 9. Thrust levers

This system is used to supply fuel to the engine in a controlled manner.

The thrust levers are moved forward and back and are directly connected to the brake and automatic accelerator via a control link. The levers can travel forward 56º. There is a mechanical stop within the lever that keeps it from moving backward unless a latch is operated.

The range of travel of the reverse thrust levers is 88.5%. There is a mechanical interlock that impedes moving the levers forward from the idle position when the reversers are armed.

1.6.7. Fuel system

The fuel system has three tanks: a central tank located low in the fuselage that can be loaded with a maximum of 80,490 lb (38,324 kg) of fuel, and one in each wing that can hold 42,671 lb (19,355 kg) of fuel each.

Fuel from the center tank is used first. When it is empty, fuel is taken from the wing tanks. Each wing tank supplies the same-side engine, though either one can supply the engine on the other side by means of a transfer valve.

The system has a fuel jettison mechanism, activated from the upper panel in the cockpit, which allows fuel in the center tank to be jettisoned if an emergency forces the crew to reduce the weight of the airplane to adjust its performance during landing. The jettison flow rate is 80,400 lb per hour, meaning it would take one hour to completely empty the center fuel tank.

At takeoff, the airplane was carrying 101,000 l of fuel, and according to its load sheet, its weight was 373,950 lb (169,619 kg).

1.6.8. Information in the Quick Reference Handbook (QRH)

The Quick Reference Handbook (QRH), located in the cockpit, contains stopping distances for the airplane that include the distance from the time the airplane is at an altitude of 1,000 ft, depending on its configuration. With the flight conditions present (gross weight, pressure altitude, temperature and runway condition), the tables state that in the event of a loss of the center and right hydraulic systems, the required landing distance would be approximately 7,500 ft. In this case the airplane traveled some 13,000 ft (including the distance in the air), which is 5,500 ft more than specified in the QRH.

This is because the braking distance contained in the QRH is not calculated based on a specific braking model using fluid from the accumulator, but rather using the active braking source at a reduced efficiency. This model does not take into account the finite nature of the accumulator as a source of pressure.

Also studied was whether the crew's reaction time in applying the brakes was consistent with the information in the QRH. It was concluded that the runway length seemed sufficient at first, meaning there was no urgency to step on the brakes. A more detailed analysis concluded that in this specific case, delaying the braking action a little would result in a shorter total stopping distance. Though this finding may seem counterintuitive, it stems from the fact that the accumulator has a specific amount of hydraulic fluid, which is exhausted after the brakes are depressed. At high speeds, the accumulator empties sooner because there is more fluid flowing through the lines in the brake system, since the frictional pressure is lower. Studying the effect of the pressure applied to the brakes revealed that delaying the braking action shortened the part of the landing run where friction is higher, which is the time during which the hydraulic fluid is used at a faster rate.

1.6.9. Retread certification process

Based on the information provided by the airplane manufacturer, the process for certifying the retread of the tire is in keeping with the regulation laid out by the Aviation Authority in the United States (Federal Aviation Administration – FAA), which is 14 CFR 25.729 (f).

The certification test consisted of launching a projectile from an air cannon. The projectile was a solid rubber cylinder 2 inches (5.08 cm) thick, weighing 2.4 lb (1.088 kg) and with a 6-inch (15.24 cm) diameter with a hardness equivalent to that of a tread with typical use. The projectile was launched from an area spanning 10° from the tire's outer rotational plane outward and 7° from the tire's inner rotational plane inward.

The only components associated with an essential function on the wing's lower surface, identified during the certification process, were the cable pulleys for central lateral control actuators on both wings, which were designed to withstand an impact from the tire tread without experiencing an unacceptable deviation to the lateral control cables. The test makes no mention of the hydraulic systems located in the area where the projectile was launched, meaning said systems were not regarded as essential since only two hydraulic systems (the right and center) were located in the wings, exposed to being struck by an ejected tire tread. The third hydraulic system (left) is located next to the wing fuel tank, where the wing's main structure affords it more protection.

During the investigation, the manufacturer also noted that it was studying a way to mitigate the consequences associated with the damage to certain areas that could be caused by tire fragments, as happened in this event.

It also reported that since the 767-200 and 767-300 models were certified, new certification methodologies and approaches had been developed, as a result of which both the European Aviation Safety Agency (EASA) and the aforementioned FAA are reviewing their certification standards to deal with the threat of tire blow-outs.

1.7. Meteorological information

The 11:30 and 12:00 METARs, from shortly before the airplane took off, were as follows:

- METAR LEMD 051030Z VRB01KT CAVOK 07/00 Q1029 NOSIG
- METAR LEMD 051100Z 22001KT CAVOK 09/M00 Q1029 NOSIG

1.8. Aids to navigation

This information is not applicable to this investigation.

1.9. Communications

The table below provides a literal transcription of the most relevant conversations between the crew and ATC.

TIME	STATION	TEXT
11:42:44	DAL415	Departure, DAL415 35 hundreds for one three thousands, we've had a problem, I think We'll have to declare an emergency and request vectors … We'll have to take a look at… the problem first
11:42:58	LECM	DAL415 roger, then maintain one three thousand when reaching.
11:46:03	DAL415	Yes sir, we are climbing now for 9.000 ft on our way up for 13.000 ft… we'd like to not get too much further away from the airport, can you give us vectors back towards the airport?
11:46:13	LECM	Affirm… DAL415 turn left heading two two zero
11:46:25	DAL415	…Left turn, do we make a right turn… it's pretty much …to our left
11:46:40	LECM	DAL415, to your right there's traffic coming out of the 33R, can you climb a little higher and then turn left?
11:46:49	DAL415	That's affirm… DAL415, we'll continue climbing 13.000 and then we'll make to the left turn, to what heading?
11:46:59	LECM	You can turn left to heading two zero zero at your discretion when you are high enough
11:47:04	DAL415	Ok, two zero zero when able, DAL415
11:47:22	LECM	DAL415, confirm you want to return to the airport?
11:47:26	DAL415	That's affirmative sir, we have declared an emergency, we are coming back in
11:47:30	LECM	Roger, do you need any help with the…
11:47:33	DAL415	…Not sure at this…, we are sill trying to figure out what exactly is wrong
11:48:34	DAL415	DAL415, go ahead sir, we are in the last turn to heading two zero zero
11:48:38	LECM	Roger, you can continue turning left to heading one eight zero and… the traffic that was behind you in the runway has told me that he saw some kind of smoke coming out of your right engine… number two, number two engine
11:48:52	DAL415	Ok, DAL415 understand smoke coming out, we think we have a hydraulic failiure
11:49:29	LECM	DAL415, do you know you are gonna need assistance by the… at the runway
11:49:38	DAL415	DAL415, that's affirmative sir, if you can have …*ininteligible*… appreciate it
11:49:54	LECM	DAL415, I believe I blocked you, do you need 32R or is 32L ok?
11:50:02	DAL415	32L will be find, sir
11:51:43	LECM	DAL415 contact Madrid on 128.7, bye bye
11:51:48	DAL415	128.7 for DAL415, thank you
11:52:00	DAL415	Madrid, DAL415 is with you, emergency aircraft

TIME	STATION	TEXT
11:52:05	LECM	DAL415 good morning, radar contact, maintain heading One eight zero, It's initial vector and I'll call you back within one zero miles, sir
11:52:16	DAL415	DAL415 roger
11:53:54	LECM	DAL415 turn left heading one five zero degrees, heading one five zero, descend altitude 8.000ft, QNH 1029
11:54:07	DAL415	DAL415 is left turn to one five zero, descending 8.000ft on altimeter 1029
11:54:15	LECM	DAL415 that's charlie charlie sir, if you need any speed or any vector let me know whenever you want
11:54:26	DAL415	Ok, DAL415, thank you, we are going to… as we descend We'll just probably take vectors for the final for the ILS 32L
11:54:35	LECM	415 …*uninteligible*… expect final vector on next frequency In about… sixteen, seventeen miles
11:54:44	DAL415	DAL415
11:56:55	LECM	DAL415 descend altitude 5.000ft and report heading on 127.1, bye now
11:57:02	DAL415	…Descending to 5.000ft and we'll report the heading on 127.1, was it?
11:57:09	LECM	…415 that's charlie charlie sir, bye bye
11:57:18	DAL415	…5.000… *interference*… requesting vectors for ILS 32L
11:57:23	LECM	Delta one… correction, DAL415 buenos días, identified, maintain heading, expect 32L
11:58:43	DAL415	DAL415, go ahead madam
11:58:45	LECM	DAL415, you may descend altitude 4.000ft, QNH1029 and for your information debris of fuselage and tyre have been found on the runway
11:58:59	DAL415	Ok, understand for DAL415 you found the… a tyre and other debris?
11:59:07	LECM	Affirm sir, fuselage debris, but did you find a tyre?
11:59:09	DAL415	Debris, debris of tyre
11:59:38	LECM	DAL415 roger Sir, turn left heading zero three zero degrees
11:59:42	DAL415	Turning left zero three zero degrees, DAL415
12:00:11	LECM	DAL415 continue turning left heading three six zero degrees, cleared ILS approach 32L
12:00:19	DAL415	DAL415 is continuing to turn three six zero… and cleared to the ILS 32L approach
12:01:07	DAL415	Now, DAL415, be advised we are gonna have to stop short ahead on the runway
12:01:16	LECM	415 that's copied, and confirm continue approach
12:02:29	LECM	DAL415 call now tower on 118.15 and good day… good. Luck, Sir
12:02:35	DAL415	118.15, DAL415

Below is a summary of the most important telephone communications between controllers in the Tower (LEMD) and the supervisor in the Madrid TMA (LECM).

TIME	MESSAGE
11:44:15	LEMD asks LECM if they have DELTA 415 on the frequency, which LECM confirms. They also ask if they know of any problems, since the RFFS at the airport reported hearing a loud noise. They reply that the crew has informed of a problem and they are waiting for more information and for a potential emergency declaration.
11:46:10	LECM reports that the crew has asked that the runway be checked. LEMD replies they are doing it and will report any findings.
11:47:35	LECM confirms that the crew have declared an emergency and they are returning to the airport.
11:49:35	LEMD reports that the airplane that was waiting to take off behind saw smoke.
11:55:24	LEMD confirms the landing will be on runway 32L and that a check of runway 36L turned up several rubber fragments and other debris identified as belonging to the fuselage.
12:08:41	LEMD informs LECM of the landing on runway 32L but with problems, since the crew exited the runway as best they could and that both 36L and 32L will remain closed until further notice.

Finally, other conversations of significance to the incident are provided below.

TIME	MESSAGE
11:43:15	The RFFS at the north station inform ATC that they heard an explosion as DAL415 was taking off and that they could have a problem.
11:43:21	ATC informs IBE04VQ, which was going to take off immediately after DAL415, that an aircraft has entered the clearance area and that they cannot clear IBE04VQ to take off.
11:45:15	The control tower asks one of the vehicles in the Maneuvering Area Operations Service, call sign PAPA 14, to please check runway 36L.
11:46:44	ATC informs the RFFS that DAL415 confirms they have a problem and they recommend checking the runway, but they do not know the exact nature of the problem.
11:47:14	PAPA 14 starts its check of the runway with authorization from the control tower.
11:48:06	Airplane IBE04VQ informs ATC they saw a large amount of smoke coming out of the number two engine.

TIME	MESSAGE
11:49:14	PAPA 14 informs the tower they found debris and recommend sending in several more vehicles[7].
11:51:38	The Tower clears vehicle PAPA 20 to enter runway 36L.
11:51:57	The Tower clears vehicle PAPA 3 to enter runway 36L.
11:54:10	Vehicle PAPA 20 informs the tower there are various fragments (rubber, panels) and that it will take time to pick up them all up. The vehicle also requests cleaning services.
11:54:11	The RFFS tell the Tower that the Airport Management Center (AMC) had told them that the airplane would land on runway 32L, and ask for confirmation. The tower confirms 32L as the runway on which the airplane will land.
11:55:38	The Tower clears the RFFS to follow the aircraft on runway 32L after it lands.
12:02:54	Vehicle PAPA 20 informs the tower that it found tire debris and that when it detached, it must have caused panel fragments to detach as well.
12:03:33	Vehicle PAPA 3 informs the tower that the last third of the runway has been checked and cleared of debris.
12:05:19	The RFFS report entering the runway, which the Tower acknowledges.
12:07:52	The tower clears vehicle PAPA 7 to enter runway 32L to check it.
12:09:37	The tower clears vehicle PAPA 21 to enter runway 32L to check it.
12:10:34	Vehicle PAPA 20 informs the tower that runway 36L was thoroughly checked and cleared of debris by the five service vehicles involved. It also confirmed that the cleaning services were not required. The tower instructs them to check runway 32L.
12:12:33	The RFFS confirm the external damage and that there is no fire.
12:15:00	The RFFS report they are cooling off the landing gear and that they have requested buses to evacuate the passengers.
12:17:08	The tower clears the Lighting Service to check the area where the airplane left the runway.
12:15:33	The tower clears vehicle PAPA 10 to enter runway 32L to check it over and to see if there is any damage along its sides.
12:29:48	The RFFS inform that the ladder to offload the passengers and the buses are alongside the airplane. They also ask the tower to inform the pilot that they are moving the ladder alongside the airplane door.
12:42:53	The RFFS report that the ladder is at the airplane door and ask ATC to inform the pilot that medical services are also there in case anyone needs medical attention.

[7] The communications imply that vehicles PAPA 8 and PAPA 9 also entered the runway, but there is no record in the audio files of when they were cleared to enter the runway. The audio files do, however, record the moment when they were cleared to leave the runway after taking part in the inspection and clearing of the runway.

1.10. Aerodrome information

1.10.1. General information

The Madrid-Barajas Airport is located 13 km northeast of the city. It is a category 4E[8] airport as per the ICAO code. Its reference point is at an elevation of 609 m (1998 ft) and it has two sets of parallel runways, 18R/36L, 18L/36R, 14R/32L and 14L/32R.

When the airport is operating in the north configuration, the 36 runways are used for takeoffs and the 32 runways for landings. When it is in a south configuration, the 14 runways are used for takeoffs and the 18 runways for landings.

1.10.2. Runway 36 L

Runway 36L measures 4,179 m x 60 m, and its threshold (THR) is at an elevation of 605 m (1985 ft).

Based on the information in the AENA AIP (Aeronautical Information Publication), the stated distances and lengths are as follows:

- The stated takeoff run available (TORA) distance is 3,720 m.
- The takeoff distance available (TODA), including the clearway, is 4,150 m.
- The accelerate-stop distance available (ASDA) is 3,720 m.
- The landing distance available (LDA) is not published.

The clearway[9] (CWY) measures 430 m x 150 m, the runway strip[10] measures 4,299 m x 300 m and the runway end safety area[11] (RESA) measures 240 m x 150 m. No stopway[12] (SWY) area is defined.

[8] The number 4 indicates an airplane reference field length of 1,800 m and the letter E that the airplanes that operate there must have a wingspan between 52 m and 65 m and an outer main gear wheel span between 9m and 14m.

[9] The CWY is an area beyond the paved runway that is free from obstacles and under the control of airport authorities.

[10] The strip is an area that includes the runway and stopping zone to reduce the risk of an accident in the event of an aborted takeoff and to protect the aircraft during takeoff and landing.

[11] The RESA is a symmetrical area about the runway centerline located beyond the strip that serves to reduce the risk of impact in the event of a runway departure. The RESA must extend a distance of 90 m and it must be at least twice the width of the runway.

[12] The entire area beyond the stated TORA distance that can be used to brake the airplane in the event of an aborted takeoff. It must be at least as wide as the runway.

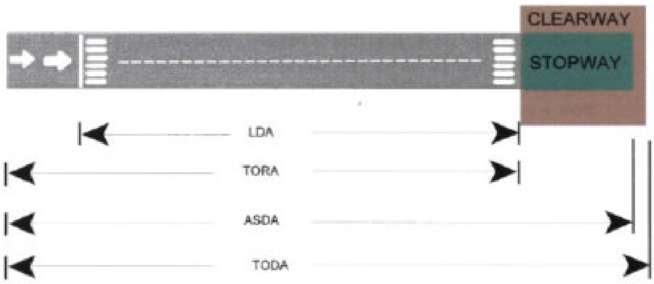

Figure 10. Stated runway distances and lenghts

Figure 11 shows the profile of runway 36L/18R.

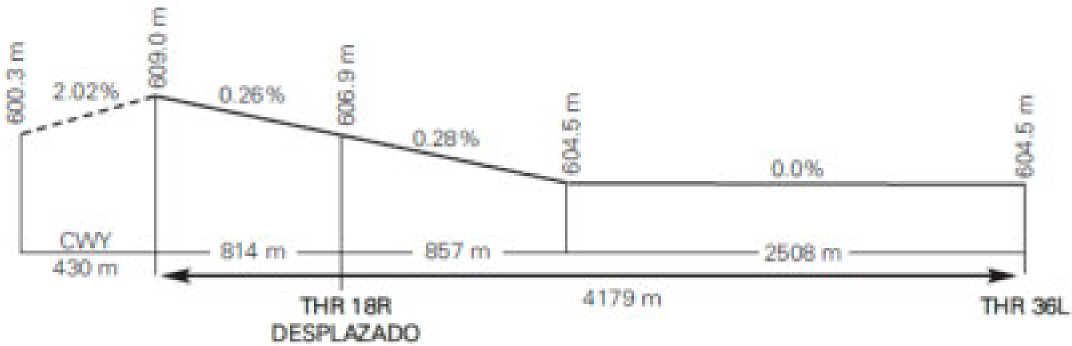

Figure 11. Profile of runway 36L / 18R

1.10.3. Runway 32 L

Runway 32L measures 3,988 m x 60 m and its threshold, which is at an elevation of 589.1 m (1933 ft), is displaced 928 m.

The touchdown zone (TDZ) is at an elevation of 594.2 m (1949 ft).

Based on the information in the AENA AIP, this runway only has one LDA listed measuring 3,600 m.

The lengths of the CWY and SWY areas are not described. The runway strip measures 4,108 m x 300 m, and the RESA measures 240 m x 150 m.

Figure 12 shows the profile of runway 32L/14R.

Both this runway and 32R feature an area with an Engineered Material Arresting System (EMAS), which is designed to stop an aircraft that has overrun the runway.

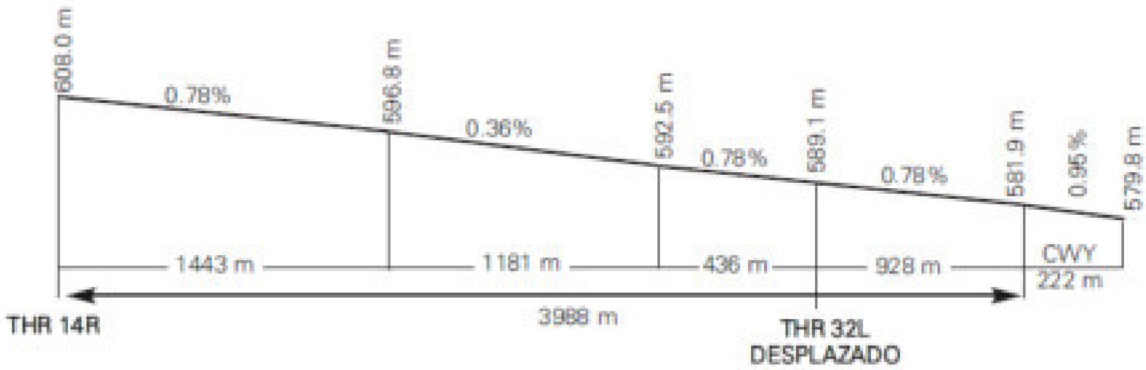

Figure 12. Profile of runway 32L / 14R

The EMAS consists of a material made of porous concrete blocks placed along the runway extension at the threshold. This material collapses under the weight of an airplane that travels beyond the runway threshold. The resistance offered by the crushed material decelerates the airplane and stops it safely within the limits of the RESA.

These areas measure 69.2 m (227 ft) wide by 63.1 m (207 ft) long, and they are located 78 m in front of the localizer antennas for the 32L and 32R runways, that is, 3,318 m away from the 32L threshold and 3,300 m away from the 32R threshold.

The AIP states that if used by an aircraft, the EMAS must be restored so as to ensure compliance with braking specifications in future events.

Therefore, the company operating the aircraft that suffers the runway overrun must have the insurance coverage necessary to cover any damage, including the cost of restoring the EMAS.

In addition to the restrictions for the RESA where this system is installed, and due to the characteristics of said system, any kind of foot or vehicular traffic in this area is strictly prohibited.

This runway is set up to conduct CAT II/III precision ILS (Instrument Landing System) approaches. It has a PAPI visual aid configured for a 3° glideslope. The threshold has green lights with wing bars and the touchdown zone has white lights over a 900 m distance.

The runway centerline has lights over 3,060 m: white over 2,160 m, red and white over 600 m and red over the last 300 m. The distance between the lights is 15 m.

At the edge of the runway there are lights over 3,988 m, white over 2,460 m and yellow over 600 m. The lights are spaced 60 m apart.

At the end of the runway there are red lights. There are no lights in the stopway, but there are indicating lights on rapid exit taxiways L2, L3, L4, L5 and L7.

1.10.4. Emergency procedures at the airport

Madrid-Barajas is a category 9 airport in terms of the services and protection that must be provided by the Rescue and Firefighting Service (RFFS) as required by its ICAO category. This means that for aircraft that routinely operate at the airport, the sum of movements of aircraft with a maximum length of 61 m to 76 m and a maximum with fuselage of 7 m during the three months with the most movements is equal to or greater than 24[13].

The RFFS has a staff of 144, between brigade chiefs and firefighters, divided into four different stations. The central station is located at the halfway point of runways 14L-32R and 14R-32L; the north station is west of runway 18R-36L, halfway down the runway; the satellite station is at the halfway point of runways 18R-36L and 18L-36R; and the south station in the area of Terminal 3.

1.10.5. Airport's emergency response plan

The airport has an Emergency Response Plan that details the situations requiring its activation. These are:

- Aircraft accidents at the airport (zone A).
- Aircraft accidents outside the airport (zone E).
- Incidents on in-flight aircraft (in-flight emergency).
- Incidents on aircraft on the ground.
- Incidents involving aircraft and/or vehicles in the Movement Area.
- Incidents during refueling operations (spills, fires, etc.) in the Movement Area.

Once activated, there are three levels, one each for local alarm, general alarm and emergency phases.

A local alarm refers to an incident that due to its nature and scope, can be handled by resources within the airport through their preventive and limited mobilization.

[13] Regulated by the AESA technical instruction on the Rescue and Firefighting Service, PAUT-13-INS-016-1.0 of 7 February 2013.

A general alarm refers to an incident that due to its nature and scope, can be handled by resources within the airport, though external resources may be required to some extent.

An emergency is an incident that due to its nature and scope requires generalized assistance from external resources.

The plan explains the course of action for each case.

1.10.6. Procedure 10-36-GEOPS-01. Operating instruction for handling FOD[14] found on a runway

There is a procedure for picking up foreign objects from the runway. The first two steps to take if FOD is found during a check of the runway that is suspected to have come from an aircraft are shown below:

1) The FOD is to be picked up and the exact point where it was found will be marked or its appropriate position memorized (basic data: first, second or last third of the runway, location between taxiways, distance from edge (at the centerline, left or right half, distance to centerline, etc.)) so it can be marked on a map at the conclusion of the runway inspection.
2) At the end of the inspection and with the runway clear, the MAOT[15] will photograph the FOD found alongside a calibrated ruler as reference. The photos will be immediately sent to the AMC, along with a description of the area where each FOD was found and any information contained on it (registration or reference number, etc.) not discernible in the photographs. The time of the runway inspection immediately preceding the latest inspection will also be indicated.

1.11. Flight recorders

1.11.1. Digital Flight Data Recorder

The airplane had a Lockheed 209 F digital flight data recorder (DFDR), serial number (S/N 00899), which was recovered in perfect conditions on the day of the event. Its data were recovered, the most significant of which are summarized below:

[14] Foreing Object Debris.
[15] Maneuvering Area Operations Technician

— The airplane was properly configured during takeoff, with the flaps at 5°. The takeoff run was normal.
— Three seconds prior to rotation there was a low-pressure reading in the center hydraulic system and there were several spikes in the readings from the three accelerometers, indicating a possible blowout of a tire. The crew continued with the rotation and the airplane took off 3 s later.
— Just as the aircraft became airborne, the right inboard aileron stopped moving as it was no longer receiving a signal from the control wheel inputs. This indicates that the right and center hydraulic systems were not providing adequate pressure. The next pressure reading from these two systems was received 22 seconds later, by which time the pressure was zero.
— The DFDR data also show that there was no problem with the flight controls during the flight following the loss of the two hydraulic systems.

For the landing the flaps were extended 20°.

— The landing was conducted at a speed of 172 kt. The touchdown point was 1,100 ft beyond the threshold, meaning there were 8,939 ft available for the landing run.
— Due to the loss of the center and right hydraulic systems, and of the reserve for nose wheel steering, the airplane could only be steered and braked using the rudder, the left engine reverser, three of the 12 spoilers and the accumulator steering braking system on the left wheel.
— Once the speed fell below 80 kt, the rudder was no longer enough to keep the airplane centered in the runway, and it started to veer left due to the moment induced by the activation of the reverser on the left engine.
— Shortly after the airplane exited via the taxiway (40 s later), the fluid in the braking system accumulator was fully depleted, meaning it was no longer possible to stop the wheels by depressing the brakes.

Additional relevant data associated with each of the phases of the incident are provided below:

Takeoff

After the tire blowout that rendered the center and right hydraulic systems inoperative, the right system pressure did not drop immediately, unlike the pressure in the center system. The reading was not recorded until the airplane reached a pressure altitude of 3000 ft. It is very likely that this reading was anomalous, and that the valid reading should have been one of low pressure throughout.

Approach and landing

The airplane was configured for a manual landing on runway 32L with the flaps extended 20°. The airplane's gross weight was approximately 368,000 pounds, which was 48,000 lbs above the maximum landing weight (MLW). The recommended landing speed (VREF) for this configuration was 183 kt, that is, 20 kt higher than VRE30 + 20. The airplane descended with the auto throttle on. The wind was from the north-northeast at an average speed of 5 kt.

Shortly after descending below a radio altimeter altitude of 1,000 feet, the auto throttle was disengaged and the airplane started to fall below the glideslope, where it remained until the landing. The flare was initiated at an approximate radio altitude of 100 ft, and the pitch attitude at the instant of touchdown was 5.5°, at which time the auto throttle was set to idle.

The landing took place at an indicated speed of 169 kt and a ground speed of 172 kt.

The aerodynamic brakes (spoilers) were deployed manually some 6 s after landing (the automatic system was inoperative due to the loss of the hydraulic system).

The auto throttle was put in the reverse position 7.5 s after touchdown, and 2 s later the left engine reverser deployed. The right engine reverser did not deploy because the right hydraulic system was inoperative.

The brake pedals were applied 11.5 s after touchdown.

Since the center and right hydraulic systems were inoperative, both the normal and standby pressure systems for the brakes were unavailable, with only the fluid in the accumulator available. This tank sends its signal to the recorder via the normal system, but as it was unavailable, the pressure at which the brakes were applied was not recorded.

After the left reverser was deployed, the crew made inputs to move the rudder to the right to keep the airplane centered on the runway centerline.

Approximately 15 s after touchdown, the reverse thrust on the left engine was selected to nearly its maximum power. This required further input to the rudder to stay on the runway centerline, until the indicated speed fell below 80 kt, at which point the rudder was unable to maintain the airplane centered on the runway.

The airplane started to veer left despite the rudder being displaced completely to the right.

Some 40 s after the initial application of the brakes, the longitudinal deceleration fell to zero, indicating that the hydraulic fluid in the accumulators had been exhausted. The airplane continued veering left on magnetic heading 280° (44° left of the runway centerline) at a speed of 32 kt.

Runway trajectory

The airplane touched down 1,100 ft past the threshold, meaning there were still 8,939 ft available. The aerodynamic brakes were fully deployed 3,000 ft after the threshold, and 750 ft later the reverser was also deployed. The brake pedals were fully depressed 4,500 ft after the threshold, by which point there were 5,539 ft of runway left.

The reverser reached peak effectiveness with 3,500 ft left. Once the indicated speed fell below 80 kt, the airplane started to veer left, 8,500 ft past the threshold. It exited the runway via the last exit taxiway, with 450 ft of runway left. At that point its indicated speed was 40 kt. During the landing run, the left main landing gear departed the paved area of the runway at a point 9,800 ft past the threshold. The airplane left the runway via exit J3 and the tarmac between the end of runway 32L and terminal T4.

The brakes became unavailable with the airplane 10,100 ft beyond the threshold and after veering 300 ft from the runway centerline. The airplane finally came to a stop in a grassy area 10,500 ft past the threshold, 600 ft away from the runway centerline.

1.11.2. Cockpit Voice Recorder

The airplane was equipped with a Fairchild FA 2100 CVR, serial number 4095, which was recovered in good condition on the day of the event and from which the sound recorded on four tracks was extracted. One of them was for the captain's microphone, another for the copilot's microphone, the third had conversations between the two and the flight attendants and a fourth recorded sounds from the area microphone.

The CVR recorded a loud noise at 11:41:55, which could have been the noise heard when the tire blew out. About 2 s later, a second, louder noise is heard that could indicate the moment when a part of the tire impacted the wing. The table below summarizes the most relevant conversations between the crew members (the captain and copilot), which were recorded on the CVR.

HOUR	CAPTAIN	COPILOT (pilot flying)
11:40:46	Ok, can you have the aircraft?	
11:40:47		got it!
11:41:53	V1	
11:41:55	Rotate	
11:42:01		Look a tyre there!
11:42:04	Positive rate!	
11:42:09		* gear up!
11:42:13	* hydraulic	
11:42:37	Look at..., look at ahead , come back around	
11:43:05	Maintain 13 thousand, Delta 415	
11:43:07	Ok, Climb power?	
11:43:17		You wanna get climb power?
11:44:27	Ladies and gentlemen, this is the * crew in the deck here a loud thing after take off, we have an hydraulic issue, the pilots are well aware of the situation we are fully trained for that we´ll back quick information in just a few moments. We do ask you please stay seated	
11:44:28		hydraulics system pressure right and center
11:45:12		..Right hydraulic system pressure, center hydraulic system pressure…
11:45:45		Right and center system pressure light extinguish
11:49:11		Madrid operations from Delta 415, be advised. We have hydraulic issues on the right and center hydraulics ** returning for landing and we´ll be there in about 15 min.

HOUR	CAPTAIN	COPILOT (pilot flying)
11:49:36		..center system hydraulic power to stabilizer trim inop
11:51:10		Yes, we are declaring emergency and we are returning for landing, we have the right and center hydraulic systems are out
..check list is completed except for the deferred items		
we need to do a descent… approach		
11:51:32	I´m wondering if we don´t have some kind of…	
11:51:36	Ladies and gentlemen, from your cockpit… we have experienced an issue with our hydraulic systems… everything is ok but we have to return for landing.. So we have our systems checked out… we are not allowed to continue at this point.. So we will be returning to Madrid to land here in approximately 15 to 20 minutes *stay seated with your seat belt fastened.	
11:52:27	you got your ILS in there?	
11:52:29		yeah, I put it in there
11:52:39	32 left	
11:52:43	so you can * * 167 for flap 20	
11:52:52	that´s not working	
11:52:57	.. Flap 5 is .. you can slow to 180 or whatever you.. 180 is fairly good speed right?	
11:53:07		two or four, should be 184, right? yeah, I got 185
11:53:39	..the autobrake in the trash..	
11:53:47	descent check list: altimeters?	
11:53:50	ten twenty nine	
11:53:51	cross check	ten twenty nine

HOUR	CAPTAIN	COPILOT (pilot flying)
11:53:52	minimums?	
11:53:55	twenty two fourteen	
11:54:01	landing data, flap 20	
11:54:02	Vref 30 plus 20	
11:54:55	This is gonna be an overweight landing too	
11:54:58	Ah.. Is this bug Vref 30 + 20 so that we **	
11:55:28	Ok, approach briefing?	
11:55:31		ahh, yeah…. yeah yeah
11:55:35	anti ice, not required, autobrake are off, seat belt signs on,	
11:55:42	Fuel cross feed.. It doesn´t matter.. pressurization panel set	
11:55:47	recall? We know all that already	
11:55:52		but we have any brakes?
11:55:54	Manual	
11:55:55		but we have, but we have
11:55:57	Yes!	
11:55:59	reserve brakes, reserve brakes source to the alternate brakes is available	
11:56:13		what about flying?
11:56:28	I´m going to put the gear handle down	
11:56:30		yeah, I agree
11:56:45	..the disagree light *** ok, descent check list is completed, approach checklist?	
12:00:07	* fly over the tower?	
12:00:10	I don´t know she´s land	
12:00:17	we got a land	
12:00:19		got a land, right, but we
12:00:49	reserve brakes and steering switch is on	

HOUR	CAPTAIN	COPILOT (pilot flying)
12:01:11	..Only accumulator brake pressure is available for brakes	
12:01:14	Apply steady, increasing brake. Do not taxi	
12:01:18		Now, DAL415, be advised we are gonna have to stop short ahead on the runway
12:01:34		down
12:01:48	speedbrake	
12:01:49		down
12:03:09	glide slope alive	
12:03:43	I´m sure we have brake pressure	
12:04:32	one thousand, clear to land	
12:04:42		autopilot
12:04:59	oki doki in approach	
12:05:27	four, two, cero	
12:05:31		speedbrakes
12:05:32	Let put the nose down	
12:05:33		right!
12:05:38	brakes!	
12:05:49	hundred to twenty! 100 kts, 90, 80 oh we got	
12:06:28		we shut it down

1.12. Wreckage and impact information

1.12.1. Damage to the aircraft

After the tire blew out during takeoff, the pieces that detached were ejected, causing damage to various parts of the aircraft affecting the wing, the center and left hydraulic systems, the landing gear, the fuselage and the tail, requiring several components in the affected parts to be replaced.

The components that detached were found on runway 36L, but they did not cause damage to any airport component or system.

In contrast, during the landing run on runway 32L and the subsequent uncontrolled departure from the runway, the airplane did break various signaling and lighting components.

Damage was detected in both wings, with the damage being more severe in the right wing. Thirteen lines in the center and right hydraulic systems were broken, and important structural components in the right wing were also damaged. There was damage to the underside of the wing and on the left engine pylon.

Both the top and bottom sides of the no. 7 spoiler on this wing were damaged, as were the drag panels, though the spoiler was operative.

The antiskid pump was separated from its housing and was on the top surface of the right wing, held only by an electrical cable. The hydraulic lines that supplied it were broken. Both the antiskid pump accumulator and its related hydraulic lines were broken (Figure 14).

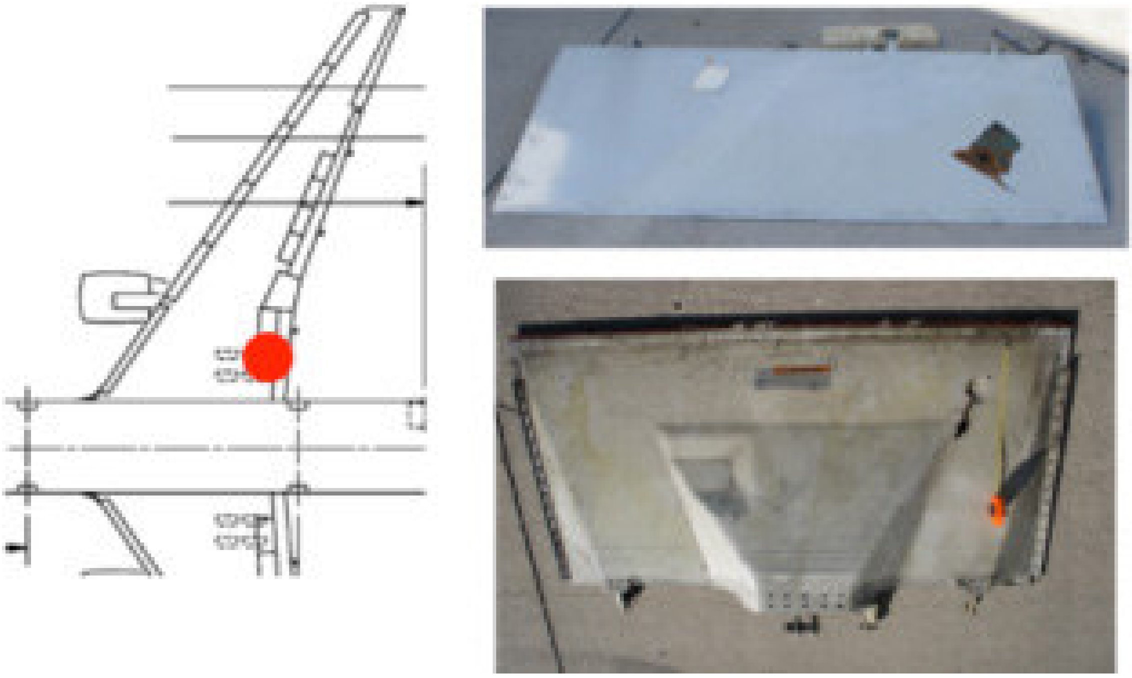

Figure 13. Spoiler no. 7

A rib on the trailing edge had a significant fracture (Figure 15), and the upper xxx was noticeably bent. The damage noted in the hydraulic system affected the nos. 1, 6 and 12 spoilers, which were rendered inoperative.

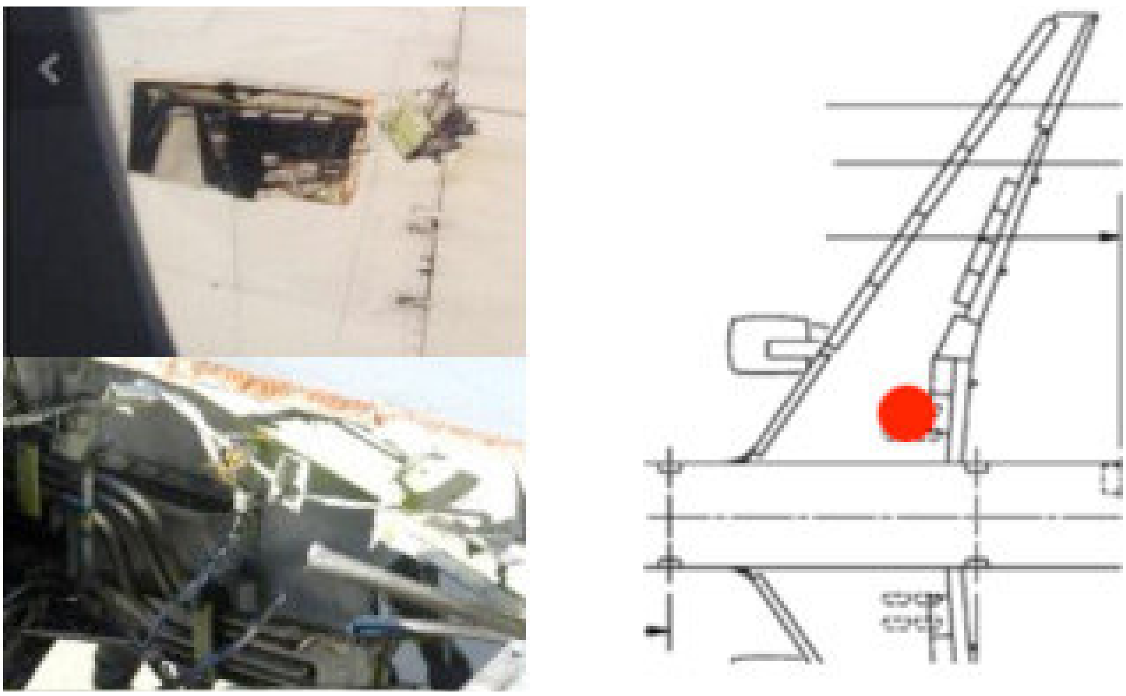

Figure 14. Panel perforated by the antiskid pump

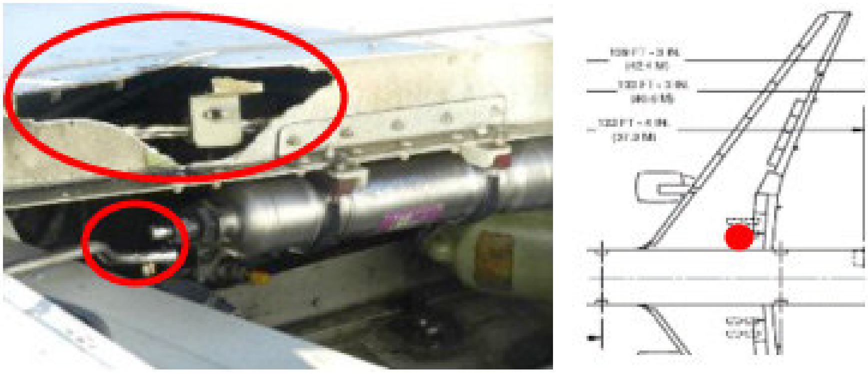

Figure 15. Aft spar and accumulator

Figure 16. Damage to right wing flaps

The left wing also exhibited various impact marks.

The most apparent damage was to the top surface on the leading edge of the slat. There were also some yellow paint marks in that area.

There were bits of gravel in the flap.

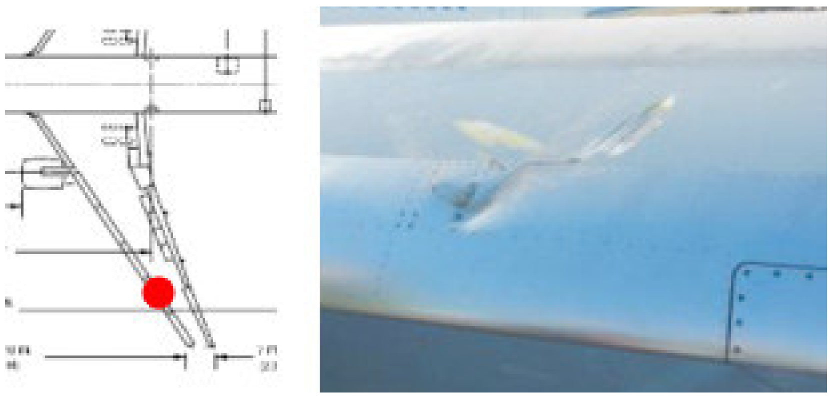

Figure 17. Damage to the slat

All along the fuselage and the tail there were various marks on the right side at the points marked in Figure 19; specifically, over one of the windows, at the aft door and on the vertical stabilizer front fairing. As for the landing gear, the right front tire exhibited two puncture marks on the tread, as well as scuff marks.

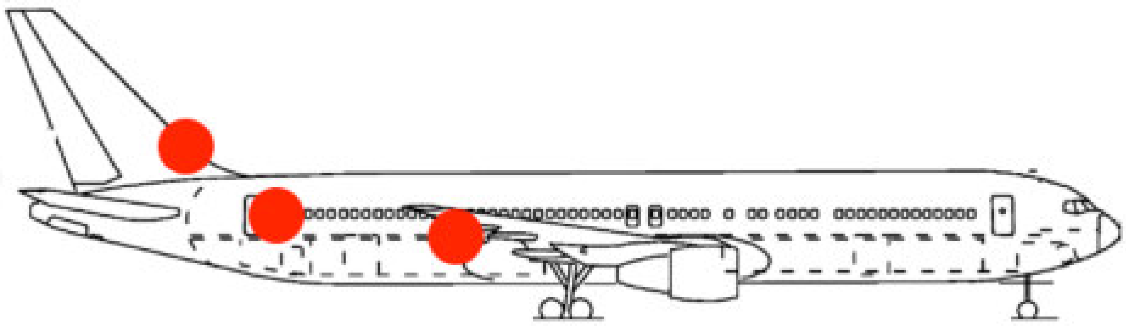

Figure 18. Damage to fuselage

The main gear was completely covered in mud (tires, wheels, brakes and the gear doors).

The right rear tire on the right main landing gear (wheel no. 8), which had blown out, had lost more than half of its tread, which tore along 180°, detaching in pieces of various sizes that were found on both the takeoff and landing runways.

Figure 19. Wheel No. 8

All of the tires were damaged to some extent and had to be replaced.

As for the engines, multiple pit marks were found on the compressor blades in the left and right engines. The right engine also had debris along the area of the reverser and the exhaust nozzle, as well as some holes in the first stage of the turbine.

In the cockpit the actuator for the flaps was in the 5º position and the flaps indicator read 20º. The alternate selector also indicated 20º.

The standby brakes and the steering system for the front gear were engaged.

The landing gear handle was activated.

The amounts shown on the Engine Indicating and Crew Alerting System (EICAS) for the hydraulic system were 1.07 for the left, 0.00 for the center and 0.08 for the right. The messages displayed on the EICAS were as follows:

— ALTN ANTISKID
— R REV ISLN VAL
— R HYD SYS MAINT

In the passenger compartment, the panels on seven seats were disconnected and one oxygen mask had dropped.

1.12.2. Damage to the airport

Three taxiway edge lights, one runway centerline light and one runway edge light were damaged, as were several signs, four edge reflectors on exit taxiway J3 and two electrical transformer panels.

1.12.3. Debris found on the runways

An inspection of the runway from which the aircraft took off turned up parts of the tire from wheel no. 8, hydraulic system tubing, parts of the panels that were damaged and a metallic piece shaped like a small strip, measuring 87 mm long, 5 mm wide and 1 mm thick. It was slightly bent at the center, forming an angle of approximately 160º. This piece was the same shape as a slot located below the tread on the tire that exploded, into which it fit perfectly. See photographs in Figure 23.

Figure 20. Some of the debris found on runway 36 L

Figure 21. Metal part found on runway 36L, and placed in slot in tire

On runway 32L only a few bits of tire were found, as shown in Figure 24.

Figure 22. Debris found on runway 32 L

1.13. Medical and pathological information

Not applicable.

1.14. Fire

There was no fire, but the airport's Rescue and Firefighting Services cooled off the landing gear to avoid a possible fire due to the high temperatures reached by the brakes during the landing run.

1.15. Survival aspects

The airport has a TECHNICAL INSTRUCTION. RESCUE AND FIREFIGHTING SERVICE. ICAO-FFS CATEGORY AND FS LEVEL OF PROTECTION, which specifies the actions needed to determine the ICAO-FFS category of a public-use aerodrome and the level of FFS protection that must be provided during the aerodrome's hours of operation, its publication by the Aeronautical Information Services (AIS), as well as the resources needed (extinguishing agents and water, number of vehicles and personnel) for each of the levels of protection defined to provide the Rescue and Firefighting Service (RFFS). It also lays out the possibility of providing varying levels of protection based on user demand.

1.16. Tests and research

1.16.1. Analysis of the piece found on runway 36L

The piece found on runway 36L was a small strip and measured 87 mm long, 5 mm wide and 1 mm thick. It was slightly bent at the center, forming an angle of approximately 160°. A simple observation with the unaided eye of the two sides of the piece revealed signs on its surface that it had been crushed and dragged.

It was examined in a laboratory using non-destructive eddy current testing. This revealed a high level of ferromagnetism and indicated that its composition corresponded to that of an austenitic stainless steel.

A study of its microstructure showed the presence of elongated grains that were longer in the longitudinal direction of the piece than in its transversal direction. This granular morphology could have originated during the manufacturing process of the piece from which the fragment detached, via lamination in the longitudinal direction. But it could also have been produced later if the piece was on the ground a long time and subject to continuous crushing forces.

The study also revealed that although austenitic stainless steel is not ferromagnetic, plastic deformation at low temperatures can cause part of the austenite to transform into martensite, which is ferromagnetic. This would explain some of the ferromagnetism detected in the piece.

Figure 23. Piece found on runway 36L

Both sides of the piece had different areas covered in a layer of oxidized aluminum alloy. Along with the aluminum, also found in these areas were copper (Cu), magnesium (Mg) and manganese (Mn), which would explain the presence on the surface of some alloy of these materials with aluminum (Al), all of which are widely used in the aviation industry.

1.16.2. Visual inspection of the tear on the tire by the manufacturer

The tear on the tire was visually inspected by the manufacturer, which concluded that the tear started underneath the tread, specifically in the area that contained the piece of debris that was found on runway 36L. From there, the tear progressed along the inside of the tire following the layout of the fibers, and ripped the tread until part of it detached.

1.16.3. Study of the rear on the tire

Based on information provided by the National Transportation Safety Board (NTSB), a study of the tear on the tire was conducted at the facilities that the company that had retreaded the tire has in Atlanta (USA). Present during this study were representatives from the operator, the aircraft manufacturer and the company that retreaded the tire.

An NTSB investigator was present on behalf of Spain's Civil Aviation Accident and Incident Investigation Committee (CIAIAC).

A representative of the tire manufacturer was on hand when the tire was received to check its condition, though he later recused himself due to questions involving intellectual property protection.

Before examining the tire, the parties involved toured the facilities at the retreading plant to learn about the process used to retread tires.[16]

The records of the shearography[17] done before and after the retread were then examined, as well as the data in the plant's tire retread tracking system.

According to the report issued, the images clearly showed that there was no FOD in the area where the metal piece that was found on runway 36L was suspected of having been located.

The data in the tire retread tracking system also provided considerable details on the retreading process, including the time at each station in the process, the operator in charge, the machine identification and details on the material used.

The inspection revealed the following findings:

- The tire exhibited an X-type break, indicative of a high-energy tear in which parts of the tread were ejected in opposite directions, resulting in the underside of the tread tearing in a "V" shape.
- When the area where the metal piece was suspected to have been lodged was examined, they checked the transversal section of the tread. This area houses the top layer of the tread, the bottom layer of the tread and the plies or fabric of the tire. During the retreading process, the tire is ground to the area between the lower layer of the tread and the top layer of the casing. This area is called the protective strip. Assuming that the metal piece was introduced during the retreading process, the findings indicate that this is the only place where the metal piece could have been located, and that there are no penetration marks directly above or below this area. The suspected area is covered by an intact piece of tread. A bottom view of the part of the tread shows the pattern of the piece of the tread, separated from the top layer of the tread. No impression of the metal piece was found.
- The tears in the layers of the tire go toward the suspect area instead of away from it.
- An analysis of the material in this area, which exhibited grooves from the tearing but without being smooth, revealed that the metal piece was in that position during the retreading process.

[16] Goodyear did not supply this information during the investigation, alleging that such information cannot be put in writing for legal concerns related to the protection of intellectual property, pursuant to American law. For this same reason it was also not possible to obtain information on the tire retread tracking system

[17] Shearography is a non-destructive testing method that yields information about the interior of inspected materials through the use of optical methods based on laser technology. This method can detect detached areas, delamination, wrinkled areas, porosity, foreign objects, impact damage and other internal characteristics as long as they affect the movement of the surface under loading.

— The orientation of the top and bottom layers of the tread reveals that the bottom layer was precisely aligned with the "cut" on the top layer. This would indicate that it is not a cut, but a tear along the line of threads on the bottom layer.
— The metal piece was examined under a microscope. No rubber debris was found attached to the piece. If the piece had been inside during the retreading process, bits of rubber should have adhered to it. The piece exhibited a high degree of meteorization, i.e. scratches and corrosion. This indicates that it could have been on the runway for a considerable length of time.
— One end of the piece was sharp, and could have resulted in a puncture by means of a high-speed impact, having been lifted off the ground by the forward tire and projected toward the rear tire.

The conclusions of the study were as follows:

— There are no signs of any problems during the tire retreading process.
— There is no evidence of foreign objects in the shearography images or of errors in the quality control process.
— The retreaded area was properly adhered to adjacent areas.
— The tread separated in multiple layers of the tire.
— It is likely that the tire tore as the result of a high-energy impact in the area with the X-type break.

1.17. Organizational and management information

1.17.1. Information provided by the crew

The crew was interviewed on the evening of the day of the incident. First the observer was interviewed, then the copilot and finally the captain.

The captain, who was in the LH seat, reported that he had not noticed anything unusual until the takeoff, and that they lined up behind an Iberia A320.

The operating speeds were V_1=157 kt and V_r=161 kt.

They were cleared to take off and during the rotation, he felt a strong vibration that lasted throughout the flight. When they moved the lever to retract the landing gear, the gear did not go up.

On the EICAS screen certain messages, such as those concerning hydraulic fluid amounts and low pressures are inhibited immediately after takeoff until the airplane reaches a radioaltitude of 400 ft.

When they were at about 1,000 ft they received a "C&R Hyd low" indication. They continued with their approved instrument departure, which was ZMR 1 AL, on initial climb to a pressure altitude of 13,000 ft.

Along with the observer, they combatted the emergency using the Quick Reference Handbook. The observer then handled the relevant communications with both the flight attendants and the passengers.

He also noted that despite having the gear down, their climb performance was not significantly affected.

Once on the return approach, they lowered the gear lever and prepared for an ILS approach to runway 32L, setting the flaps from 5º to 20º, as indicated in the procedures.

The same procedure also stated that in APPR mode, they would only have one A/P, but that that was enough to conduct an ILS approach without any problems.

They calculated V_{ref}, which yielded a value of 181 kt, a speed they maintained during the approach. Just before landing they reduced their speed to 169 kt.

They did not know what was limiting during a tire blowout. By following the abnormal procedure in the QRH for R+C HYD SYS PRESS, they were able to determine that the reserve brakes and the steering system were inoperative, and that only the fluid in the accumulator was available to stop the airplane.

They initially intended to stop the aircraft on the runway, but by the end of the landing run they had lost the ability to brake with either pedal, so they had to use reverse thrust, which made them depart the runway to the left.

The airplane had almost stopped by the time they veered off the taxiway. Before doing so, they stopped both engines, slowly coming to a halt on a grassy area.

He underscored that the behavior of the passengers and crew was poper, with no signs of panic.

As for the copilot, he reported in his statement that he was the pilot flying for the duration of the flight.

According to his version, there was nothing out of the ordinary from boarding until takeoff. They held a normal takeoff briefing as per company procedures, and taxied uneventfully to the R5 holding point on runway 36L. They lined up on the runway, noting nothing unusual. He emphasized the length of the runway and the great visibility.

During the rotation he did not recall hearing a noise, but he did feel a significant vibration. His first impression was that the problem was coming from a wheel on the nose gear.

After receiving the positive rate report, he requested the gear up, but it did not retract.

After selecting climb thrust, they decided to return to the airfield, which is why he maintained the 5° flap configuration and engaged the A/P.

As per company procedures, he handled the communications while his colleagues dealt with the emergency. He stated that he declared an emergency (Mayday).

ATC initially instructed them to turn to heading 220°. When he saw the mountains come into view, he requested a turn to the right, but this was not authorized due to traffic.

After clearing the mountains at 12,000 ft, and keeping them in sight, he started the turn as instructed and remained at 13,000 ft. He was then cleared to hold heading 180°.

When they were on the downwind leg of the traffic pattern, he prepared the cockpit for the approach, modifying the values selected in the Flight Management System.

His colleagues told him that according to the list for "Right & Center Hyd low", he would only have the left reverser and the brake accumulators to stop the airplane.

He delayed in selecting the APPR (approach) function on the Flight Control Panel since he knew this would engage the three A/P, and with two of them out of service due to the loss of the hydraulic systems, he was unsure how the airplane would react. After selecting it he noticed that only one A/P was working, which was enough to conduct a category I approach.

With the A/P engaged, he noticed that the yoke was tilted to the left significantly, between 15° and 20°, and when he disengaged the A/P he had to apply the same correction manually. He checked the trims and they all seemed normal.

To make full use of the available runway, he made the approach a little below the glide slope, making what he thought to be a good landing.

Despite not knowing if they would work, he deployed the spoilers manually on landing and stepped hard on the brakes initially.

The observer stated that he was seated in the rear (jump) seat.

He stated that it was he who did the walk-around check, during which he found absolutely nothing unusual. He recalled having paid particular attention to the tires, and that one of the airline mechanics checked their pressure.

During the boarding, start-up and push-back from parking stand 71, he did not notice anything unusual and all of the normal procedures were carried out.

The taxi route to the runway 36L threshold was long, and it was during this process that he briefed the flight attendants.

They entered the runway behind an Iberia A319/320 and were cleared to take off.

The operating speeds they calculated were V1 157 kt and Vrotation 161 kt. They took off with the flaps set to 5°.

As soon as they started to rotate, they felt a strong vibration. He did not recall hearing an explosion but he underscored the intensity of the vibration.

When they were at about 400 ft, the Master Caution turned on, practically simultaneous with the "R&C Hyd Low" fault indication.

They tried to retract the landing gear but were unable to do so and the gear doors remained open.

They declared an emergency (Mayday) and the pilot flying handled the flying duties and communications, while he and the captain reviewed the Quick Reference Handbook.

They also read the checklist for a hydraulic system failure (Hyd Fail Right & Center), and he noted that there is a specific list for a simultaneous failure of these two systems.

After reading the list and assessing the situation, he spoke with the flight attendants to update them on the situation, telling them they would return to the airport in about 20 minutes and make a normal landing. He also spoke with the airline's ground operations service and informed the passengers of their plan.

They were initially on the ZMA1AL departure and climbed to 13,000 ft.

A flight attendant then took a picture of the wing that showed a panel missing on the right wing and a fluid leaking out.

They decided it was hydraulic fluid and that they were not losing fuel, hence the normal fuel readings they had in the cockpit.

They told the flight attendants to ready the emergency equipment in case they had to use it, but that they would make a normal landing.

They carried out the landing checklist and lowered the flaps to 20° using the alternate deployment procedure, that is, using the electrical system.

They also calculated the reference speed (VR), which turned out to be 181 kt, using the formula contained in the C/L of Vref30 + 20 kt.

The list explained that they would only have the hydraulic fluid in the accumulators available for braking; as a result, a smoother braking action was recommended.

Throughout the flight the copilot had to tilt the yoke 5° to the left to keep the wings level. He reasoned that this was because the hole in the right wing caused a loss of lift.

They thought it very important to try to make a very soft landing, as they were concerned about the little clearance between the ground and the open wheel bay doors, which they knew could also affect them during the taxi.

They knew the right engine reverser was inoperative and that they could only rely on the left engine reverser to slow the airplane.

Once on the ground, the plane decelerated at a normal rate, reaching 80 kt as they approached the end and 60 kt when they exited the runway.

They realized they had lost the ability to brake and before running onto the grassy area where they would come to a stop, they secured the engines, stopping them and securing the reverser as well.

They did not have nose-wheel steering, and as a result they were only able to steer the airplane using differential braking.

They ended up with no control of the airplane and he thought that maybe the use of the reverser (on the left side only) had made then veer off the runway.

When they stopped they made another announcement to inform the passengers of the situation. He rated their reaction very favorably.

The brakes were hot and they smelled smoke in the cockpit from the brakes, but the firefighters cooled them off quickly.

After establishing radio contact with the Tower and the firefighters, they decided to engage the Auxiliary Power Unit so as to have AC to power the remaining radio and to cool the passenger cabin.

He also stated that in the airline's Flight Operations Manual there is a guide on what steps to take in the event of an incident, which they followed.

He seemed to recall opening the CVR circuit breakers some 10 minutes after coming to a stop.

The buses to offload the passengers took a long time to arrive (about 35 min.), and when they did the passengers were disembarked via the 1R door, which was the only one where ground crews had placed a ladder.

He seemed to recall that the landing weight had been 368,500 lb and that the weight at the parking stand had been 376,000 lb.

They did not consider dumping fuel since the center tank only had 17,000 lb and, as this is the only tank from which fuel can be dumped, they did not consider the drawbacks to be worth it in light of the advantages they would gain.

They checked the Operation Data Manual for the landing distance they needed with a failure of two hydraulic systems (left and center). This contains a list that takes everything into account for that fault and requires no additional considerations. The resulting distance was 6,340 ft, so they knew they had more than enough distance available on the runway to land.

He reiterated that the intention of the pilot flying was to remain on the runway all along, and that in his opinion it was the combination of the left reverser to brake along with the loss of effectiveness of the brake accumulators that caused them to run off the left side of the runway.

1.17.2. Statement from the controllers on duty

There were four controllers on duty in the airport control tower who were in contact with the aircraft. The controller at the departures desk, who cleared the crew to take off, the controller who assisted them with the landing, and two supervisors who were in the tower.

These last three were interviewed. They stated that the firefighters had been the first to report a loud noise (like an explosion) as the aircraft passed in front of the station located in the north part of the airport, west of runway 36L.

When ATC received this information they stopped takeoffs, leaving an airplane at the runway threshold that was about to start its takeoff run and whose crew had not reported anything as they were unaware of an explosion and had not seen anything strange or worth mentioning.

They then notified the approach controllers and the inspection of runway 36L was started.

The crew themselves were aware of this explosion and suggested a check of the runway, during which multiple pieces of the tire that had exploded, debris from detached components and a metal piece were found.

The crew then reported that they were returning and confirmed that they had not dumped any fuel.

During the incident the approach controllers were in contact with the crew and firefighters, relaying information about the aircraft and the actions required by the crew.

The access ways to runway 32L were cleared in preparation for the landing. No other aircraft were allowed near this runway, since the area where the airplane came to a stop is the busiest in the airport in terms of traffic. That is why it was decided to clear the area well in advance of the landing, as ATC anticipated a complicated landing, possibly leading to a serious accident.

During the landing, controllers thought there was smoke coming out of an engine. They did not initially think the airplane would remain on the runway blocking it, but that it would exit the runway.

The crew did not state their intentions or request permission to land forward of the threshold to gain distance. They also did not ask why the threshold was displaced[18].

They noted that the manual on emergencies and special situations mentions that with a hydraulic failure, it is possible for the airplane to have a long landing run, leading to a runway overrun.

They confirmed that the crew were not informed about the presence of an emergency stopping system (EMAS) on this runway because, as they noted, this information is not contained in the emergency manual.

[18] The supervisor explained that ATC requested a while ago that the threshold no longer be displaced. It was displaced originally to free the runway crossing as quickly as possible back when the existing runways intersected, thus providing more operational freedom when moving aircraft on the ground. He stated that it no longer makes sense now that the airport has four runways. He admitted, however, that he did not know if it was possible to displace the threshold again, as this could affect issues such as the sound footprint or aspects related to obstacles.

The supervisor, however, said that during the landing run he felt the airplane was going very quickly and that it would not be able to stop within the runway and that they would have to use the EMAS as it was going faster than usual. This made him think that the airplane was under control, but on seeing it going so fast he was not sure. Upon seeing it exit the runway he realized the crew were not in control.

During the landing they saw smoke and dust from two different sources (it may have been the landing gear doors, though as he stated, they do not reach the ground when open).

After the landing the crew did not make any radio contact until the airplane stopped, after which the first report they made was that they were without brakes.

They asked for the frequency of the firefighters, and they were told it was 118.15 MHz, since during the event the firefighters had been on another frequency and all two-way communications with the crew were being relayed through the Tower.

They also reported that the departure controller has to watch the clearance area on the runway, and thus does not always visually monitor the maneuver.

The separation between arrivals is 4 NM on runways with a clearance area, and 3 NM on those without.

They also noted that when runway 32L was rendered inoperative and only runway 32R was available, this increased the workload.

Operations continued with only the two right runways, 36R and 32R, in use.

Se quedaron operando únicamente con las dos pistas derechas, 36 R y 32 R.

The supervisor also stated that the emergency frequency, 122.97 MHz, is used by several stations, as well as by the firefighters. That is why whenever there is an event involving more than one department, there is usually interference in the communications. In fact, he reported that in June of that year, when an airplane of the same airline was taking off, several tires blew out during the takeoff run and that the controller who was on the line was saturated by the number of people talking to him all at once, in addition to having to attend to the conversations with the pilot on one frequency and with the tower on another.

In the event at hand, the supervisor took over the emergency frequency, thus reducing the workload, but the ground operator was also on that frequency and giving instructions that could have confused the firefighters.

The supervisor stated that in general, communications problems are possible whenever there is an event that involves apron control services and maneuvering area technicians. He also noted that he had already informed the Tower Chief in writing of the problems that had occurred during the incident in June.

As for the controllers relaying information between the crew and firefighters, he was of the opinion that having crews and firefighters communicate directly could also lead to problems, so he saw nothing unusual in having the controller relay messages between them. He also stated that in his opinion, the most important thing in these cases is to have communications with the crew and with emergency personnel on different frequencies.

As a final note, he stated that landings on runway 32L are hard to see from the tower, and that there is also a blind spot for the surface radar.

1.17.3. Information provided by ATS

At 11:42, the Boeing 767-332, DAL415 registration N182N, appeared to take off normally from runway 36L en route to JFK airport via standard departure (SID) ZMR1AL.

The aircraft had initially been parked at stand no. 71 of terminal T1. Its EBOT was scheduled for 11:25 and it had been cleared by the tower for start-up at 10:20. The entire taxi phase was executed normally.

From the tower nothing seemed out of the ordinary about the takeoff run, and once airborne, it was transferred by the local controller (LCL) for runway 36L (118.975 MHz) to sector DEPW of the TMA (131.175 MHz), a transfer that the pilot acknowledged normally and without reporting any incident during the takeoff maneuver.

Once DAL415 started its takeoff run, the flight with callsign IBE04VQ was instructed to enter and hold on runway36L and await takeoff clearance.

This flight would have had to wait two minutes due to the turbulent wake of the preceding aircraft. It would then be affected (as per the "clearance area" procedure involving runways 32R and 36L) by BERS32R, which was at the end of runway 32R. The pilot of IBE04VQ, which was lined up on the runway before DAL415 finished its takeoff run, also did not report anything unusual in the takeoff of the preceding aircraft.

With DAL415 on the initial phase of its flight on the Madrid TMA frequency, the firefighters in the station next to the takeoff runway, 36L, reported to the tower on a dedicated frequency (122.975 MHz) that they had heard what sounded like an explosion, and that it could have come from the aircraft that had just taken off on runway 36L (DAL415). Upon receiving this information, and as a preventive measure, the tower requested an inspection of the runway and flight IBE04VQ, which was waiting on the runway, was not cleared to take off. At the same time the ACC supervisor was conveyed the information received from the firefighters so the ACC could contact DAL415 and ask the pilots if they had noticed any problems during the takeoff.

The ACC reported back that the crew had noticed something unusual and recommended a check of the runway. A few seconds later they informed that DAL415 was declaring an emergency and would be returning to the airport due to hydraulic problems (this same information was relayed on the hotline between the TMA controller for sector DEPW, who was on the frequency with DAL415, and the LCL controller for runway 36L at Barajas).

The emergency protocol was immediately activated at the tower. The airport's Air Management Center was notified and the emergency siren was sounded to alert the RFFS. On the emergency frequency (122.975 MHz), the firefighters were updated on everything that had happened until then.

The tower authorized the Maneuvering Area Operations service to enter the runway and do the inspection.

Upon doing this, the service reported finding debris of what appeared to be fuselage, bits of rubber and other solid objects (small metal plates). As a result the ACC was notified so they could relay to the crew of DAL415 what had been found on the runway after their takeoff. At that moment it was also decided to leave runway 36L inoperative.

The aircraft that were at the holding point for that runway were redirected to runway 36R. The airport's departure ATIS informed that only runway 36R was available, and from that moment on the ATC clearances for every airplane at the airport that had originally planned to take off from runway 36L were modified.

At 11:53 the notification from the airport declaring a local aviation alarm was received.

The TMA controllers directed the airplane toward runway 32L for landing, estimating a landing time of about 12:05.

The airplane flew the initial phase of the ZMRAL SID and climbed to over 10,000 ft. It was subsequently directed by TMA controllers toward the west of the airfield to join the approach to runway 32L.

After learning of the runway to be used for landing, the emergency teams were coordinated and informed of the runway on which the landing would be made so they could take their positions.

Before the landing, and aware of the problems with the airplane's hydraulic systems and that it was considerably overweight due to not having time to dump fuel, taxiing traffic in the airport's maneuvering area was arranged to as to keep it completely clear of the areas near the runway, especially those closest to the final third of the runway.

The airplane with callsign AEA1028, which had landed on runway 32R and was initially taxiing on taxiway A toward terminal T123, and given its location in the area that was most likely to be affected, was quickly rerouted to taxiway M (opposite the normal taxi direction) so that it could subsequently enter via gate 6 and be as far away as possible from the final third of the runway on which DAL415 was going to land (it was informed of the situation and instructed to expedite the maneuver). All other taxiing traffic was stopped sufficiently far away from the affected area.

At 12:05, that is, 23 minutes after having taken off, it landed on runway 32L.

During the landing, the speed at which it touched down was apparently high (170 kt according to the radar display), but there were no indications of the problems the pilot would have stopping the airplane within the physical limits of the runway.

ATS coordinated with the RFFS, which was cleared to follow the airplane on the runway and given complete freedom to intervene.

In the end the airplane could not be stopped before the end of the runway. The pilot took advantage of the paved area between zones LA and LB (holding points at 14R threshold) to exit the runway to the left (as seen from the tower control room).

When it turned, the aircraft seemed to be moving at a high speed compared to a normal taxi speed.

After exiting the runway, the airplane taxied on J3 toward Terminal T4 before finally stopping outside the limits of the taxiway paved area, in a grassy area.

The RFFS vehicles remained behind the airplane at all times, following it throughout its entire landing and taxi run until it stopped.

As the airplane decelerated on runway 32L after landing, on several occasions there seemed to be smoke issuing from the landing gear (especially as the airplane approached the end of the runway).

Once the airplane stopped, the pilot informed the tower that he had lost the brakes during the landing maneuver.

The firefighters reported that the airplane's right landing gear was damaged and that there was a hole in the right wing, but that there was no fire.

The tower coordinated all of the actions needed to relay messages between the crew and the RFFS until the situation was verified to be under control and no longer posed any danger.

Finally, ATS also coordinated efforts between the RFFS, the captain of the aircraft and the Airport Management Center (CGA in Spanish) to send and position a ladder so that the passengers could be offloaded to waiting buses and transported to the terminal.

The RFFS informed that the airplane’s position hampered placing the ladder on the left side.

The AMC was kept apprised at all times of the activity taking place in the airport’s maneuvering area.

From the time the airplane landed, it was decided to leave runway 32L inoperative in case the airplane had caused damage to its surface or left debris that could have potentially endangered subsequent landing operations.

ATS coordinated with the Madrid ACC and TMA supervisors to divert arriving aircraft to runway 32R.

The ACC informed that the number of arrivals was expected to be high and that successive landings would be separated by 3 NM.

Logically, and due to the operational effect that landings on 32R have on takeoffs from 36R (due to the “clearance area”), this measure would affect the number of takeoffs that could be processed via runway 36R.

Between 12:07 and 12:12 the airport was in a state of “General Alarm”, as this was the most critical period of the emergency.

In the meantime, runway 36L was being checked and at 12:15 the airport reported that it was operational and suitable for use, and that all of the foreign objects found on it had been removed.

The ATIS was used to inform pilots that runway 36L was in operation, and ATC started issuing departure clearances for this runway. The actions of the LCL controllers involving runways 36L and 36R had to be coordinated since when the first airplanes arrived at runway 36L for takeoff, there were still airplanes on 36R taking off with non-preferred SIDs (toward the west) that were incompatible with simultaneous takeoffs from runway 36L.

At 13:00 the TMA supervisor called to inform that takeoffs were not being accepted from runway 36L. Only an Airbus A340 that was lined up on the runway was cleared to take off. The remaining airplanes at the 36L holding point were rerouted to runway 36R.

The Airport Management Center (CGA) was informed of this and the airport's ATIS information was again changed to let pilots know that only runway 36R was available for takeoffs.

The CGA called at 13:30 to request information on the 10 airplanes that took off from runway 36L before DAL415, since debris had been found on the runway that may not have belonged to DAL415 (this was a miscommunication and it was later determined that all of the debris found on the runway had indeed come from DAL415).

At 13:33 the airport finally reported that the local alarm was being deactivated.

Another check of runway 36L was made between 13:13 and 13:36, and the airport then reported that this runway was in use, specifically at 13:41.

In any event and since the ACC was still not allowing takeoffs from this runway, 36L remained inoperative and airplanes continued to take off only from runway 36R.

Runway 32L had been affected by the landing of the incident aircraft, and airport personnel had to remove debris left by the aircraft on the runway (rubber and some fairing components), as well as gravel and dirt that had been left on the runway (especially on the last third).

Also removed were some broken covers from the area where the airplane had veered off the runway. By rapid exit taxiway L1, crews found hydraulic system fluid that was cleaned up by the firefighting service.

In all, runway 32L was out of service until 14:00 (coinciding with the turnover between the morning and afternoon shifts in the tower). Also at this time, a report was received from the ACC that takeoffs from 36L were being permitted, as a result of which operations at the airport returned to normal (with four active runways). Taxiway 13 (where DAL415 was located) remained closed to taxiing traffic.

Despite the event, the control tower did not need to implement traffic regulation measures. Even with only two runways in use, the control tower attempted to keep airport operations as normal as possible. Except in the critical minutes of the emergency (when DAL415 was landing and the rescue service vehicles were following it in the maneuvering area), when taxiing traffic was stopped and the start-up rate was reduced, the rest of the time, takeoff clearances were issued as requested by pilots.

The LCL controller on runway 32L (arrivals) was charged with directly coordinating with the crew of DAL415 from its landing until the local alarm was deactivated at the airport.

The controllers directly involved in the emergency (LCL 36L and LCL 32L) were relieved of their stations half an hour before the local alarm was deactivated at the airport (at 13:00). After being relieved, and since up to three control stations at the tower were closed due to having two of the airport's runways inoperative, the supervisors did not consider it necessary to keep these two controllers assigned to a frequency, and the control service at the tower was provided by the other available controllers.

1.17.4. *Information provided by the airport*

At 11:27, one of the four daily inspections scheduled for runway 36L had been made. No foreign objects were found.

The airport's Emergency Plan was activated, with a local alarm being declared first and then a general alarm.

The Madrid-Barajas Airport has a dedicated radio frequency that separates emergency management from all other stations and ensures fluid operations throughout the airfield without frequency changes by the RFFS.

Figure 24. Section of runway 36L where debris was found

Figure 27 shows the 150-m long segment of runway 36L where the main components of the tire that blew out, as well as other debris from the aircraft, were found.

As a result of how this emergency was handled, airport officials identified the following areas where improvements could be made:

— Review Operating Instruction 10-36-GEOPS-01 on handling FOD found on a runway in those cases where numerous objects gathered can reliably be proven to have come from an aircraft, to reference, number, measure and catalog each object, including general and specific photographs of the objects on the runway such that they can be used to analyze the origins of an incident or possible accident. An area should also be defined to which the objects should be taken and kept under lock until they are handed over to the CIAIAC.

— Have the Air Navigation Service evaluate the need to write a procedure or guidelines on clearing taxiways that may be affected by an aircraft arriving with brake problems and that could require a runway length that exceeds the normal length. This procedure should include clearing the area of aircraft and vehicles. The need for a procedure to coordinate with SDP should also be evaluated.
— Analyze the procedure for communications between the tower and Apron Control Services and the RFFS so as improve their efficiency and maximize coordination. The following aspects should be improved:
  – Distinguish between the Barajas Tower and Barajas Apron in all communications, whether made by the RFFS or in response to them.
  – The need to properly identify the RFFS when making a call, specifying the vehicle and the situation.

In addition, the Aviation Safety Department, after analyzing the actions of the airport's various services, made a total of 18 internal recommendations to improve the efficiency of the Emergency Plan.

1.18. Additional information

1.18.1. Manufacturer of the landing gear tires

The tire has to withstand loads under a wide range of operating conditions, many of them extreme. The high demands placed on these tires require that they be made from a compound of several products, including rubber, fabric and steel. Each component serves a very specific function in the performance of the tire.

The tire manufacturer offers two tire designs, bias and radial, corresponding to two different ways of describing the angular orientation of the layers that make up the casing, which is the tire's structural component. Only bias-type tires are certified for use on the Boeing 767-300 aircraft.

Above the casing is the tread, which is the part of the tire that is in contact with the ground. This manufacturer's tires have molded circumferential grooves in the area that contacts the ground for improved grip.

During the retreading process, the tread is replaced, and the layer of rubber between the tread and the casing is designed to be thick enough to act as an intermediate layer between the tread and the casing.

Underneath is a rubber layer, the body of the casing, consisting of numerous intertwined layers of nylon plies, which is specially designed to improve the bond between the body of the casing and the tread.

For bias (diagonal) tires, the plies in the casing are placed at angles of 30° to 60° with respect to the centerline, or the wheel's direction of rotation. Successive plies are applied at opposing angles to provide higher strength.

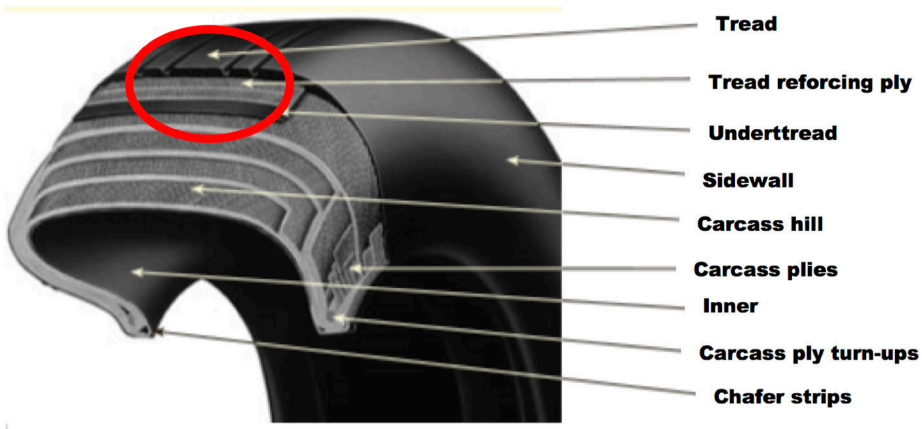

Figure 25. Cut-away view of a bias tire

The tires outfitted on the airplane were of the bias type.

The bead, made of wires, provides an anchor for mounting the tire to the wheel. It is made of overlaid steel wires covered in rubber to form a single edge. Generally, bias tires have one to three beads per side, while radial tires have one per side, regardless of the tire size.

Finally, there are protective cloth or rubber strips placed between the outer casing plies in the area of the bead. The purpose of these strips is to protect the casing plies from potential damage when mounting or removing the tire.

1.18.2. Retreading tires

The process of retreading tires involves the following steps: initial inspection, shearography, complete grain-by-grain inspection, air injection test, drying, smoothing, hardening, application of the various tread layers, balancing, curing, recutting, post-production shearography, inspection of the retread, air injection and final certification.

In the case of the tire that blew out, whose specific characteristics are listed below, these steps were carried out on the following dates:

CHARACTERISTICS	RETREAD PROCESS
Manufacturer: Michelin Part number: 020-807-0 Retreaded by: Goodyear (Kingman, AZ) Retread date: July 2013 Retread type and level: R-1 (Radial)	Initial inspection: 27-06-2013 First shearography: 27-06-2013 Complete inspection, air injection test and drying: 28-06-2013 Smoothing, hardening, application of tread layers and balancing: 30-06-2013 Curing: 01-07-2013 Recutting, post-production shearography, inspection, air injection and final certification: 02-07-2013

During the investigation, both the NTSB and Goodyear were asked for information on the quality control of the tire retreading process at least three times, as well as for the shearography that was conducted on the tire.

Goodyear did not send the information, alleging intellectual property rights. Instead, the company offered the possibility of visiting a factory in the United States or the Netherlands to see first-hand how tires were retreaded and to see the results of the shearography on the display of the machine used in this process.

The NTSB reported that pursuant to American law, it was not possible to require Goodyear to provide that information.

This all led to a formal protest letter being sent by the CIAIAC to the NTSB sent in January 2015, but even then the information requested could not be obtained.

In response to said letter, the NTSB replied that Goodyear had attempted to comply with the CIAIAC's requests as follows:

- Show the CIAIAC the available shearography data and let an expert interpret it, after signing a confidentiality agreement.
- Show the quality process used by the company.
- Show the quality control documents, without providing a copy.

As for the request for the passenger manifest made to Delta Air Lines, it reported that the airline did not have it as it had not kept a copy of this list.

Finally, as concerns the misplacement of the tire by Delta Air Lines, they apologized and noted that the tire was in the custody of the airline and that the NTSB was not in possession of it.

1.19. Useful or effective investigation techniques

The investigation into this event relied heavily on attempting to analyze the interaction between the various parties involved in the emergency, that is, the crew, ATC and airport services, focusing the analysis based on the parameters that comprise the well-known SHELL (software, hardware, liveware, environmental) method, which relates how people relate with their physical (machine), organizational (procedures), personal (relationships) and environmental surroundings. In this case, the model seemed to offer the best chance to gain a perspective into the reactions and behaviors exhibited throughout the timeline of the event.

2. ANALYSIS

An analysis of the factors involved in this event inevitably poses a series of questions that the investigation attempted to answer, one by one.

The first four have to do with the general aspects of the operation and the unfolding of the entire emergency management process, while the last two involve the design of the aircraft.

2.1. General aspects of the emergency and its progression

The first consideration to note in the analysis is how given that one of the main gear tires clearly blew out during the rotation, whether it can be stated unequivocally that the blowout was caused by a metal piece that was found on the takeoff runway.

To this end, and after the analyses that were carried out on both the piece and the tire, there can be no doubt that the tire broke and tore gradually as a crack opened up inside the tire caused by the damage resulting from said metal piece. The damage originated in an area below the tread that exhibited the exact same shape and dimensions as this piece.

A more important question to answer is whether the piece was on the runway during takeoff and was propelled into the tire when one of the front tires ran over it, with sufficient force to penetrate the rear tire, or whether the metal piece was already inside the tire, presumably inserted during one of the retreading stages, gradually slicing into the rubber until it caused it to tear completely, this event happening precisely at a time when the tire is subject to some of the highest loading, which is during takeoff.

Though it seems difficult for a piece to be introduced into the tire during the retread process, due to the inspections that are conducted, mainly the shearography (which is done twice), and due to the quality controls presumably in place, investigators were unable to ascertain, for various reasons, what exactly this quality control process entails.

On the other hand, it is unlikely for a dull piece of metal, with a very thin profile and of moderate ductility, to penetrate the tread and the internal layers without bending or being ejected. It seems much more logical to think that in any case, it would have dug into the tire, and not lodged itself in an internal volume tangent to the direction of rotation, i.e. normal to the radius of the tire. It must also be noted that even if it had been propelled by one of the front gear tires at great speed, the distance between the two bogies does not seem to be sufficient to achieve the acceleration needed for the piece to penetrate the tire.

Finally, it must be noted that as soon as the incident took place and the runway was inspected, the piece was found immediately; in other words, the people who usually inspect the runway found it easily, as they did the remaining debris that detached after the blowout. Also of note is the fact that the runway had been checked by the same people fifteen minutes before the event and nothing had been found.

After careful consideration of the two possibilities, this investigation concluded that the piece was inside the tire as the result of having been inserted there during the retreading process. A safety recommendation is issued to Goodyear that it review its quality system to avoid a similar occurrence in the future, in which a foreign object is inserted into a tire during the retreading process.

The second question is how the crew learned of the problem and how ATC was informed and whether the event was handled as expected or if any aspects need to be improved.

The crew detected the problem because the airplane systems designed to notify them worked properly and they reported it immediately (24 s after the hydraulic system failure warning). They then took a reasonable amount of time to ascertain what was happening and decide if they had to declare an emergency. The conversations in the cockpit and between the crew and ATC clearly indicate that they resolved the situation ably, methodically and in keeping with procedures.

It should be noted that at the time of the tire blowout, the Rescue and Firefighting Service crew that was on duty in the north station heard the noise and immediately reported it to emergency services (21 s after the crew reported it). This action is a good example of the kind of practice that should be encouraged.

From then on they were on the alert, which allowed them to have enough time to get into position and wait for the airplane to land and to reach the place where it came to a stop in a very short time.

The third question posed is whether ATC acted diligently and in keeping with what is expected of this service. In this regard, it should be noted that the controllers who were involved in the emergency were highly experienced (none with fewer than 12 years on the job) and followed the procedures at all times, using standard phraseology, and they guided the aircraft in an orderly fashion while not burdening the crew with unnecessary interruptions.

Any time there is an emergency as significant as the one considered herein, the crew need to focus all their attention, and it would be undesirable for ATC, in their desire to offer their support, to be constantly interrupting the work of the pilots. In this regard, it should be noted that ATC only communicated with the crew as strictly necessary, allowing them to remain focused on combatting the emergency.

During the investigation a question was raised concerning if it would have been better to direct the crew to land on runway 32R to move them further away from the more populated area, but that would have required them to spend more time in the air and diverting other aircraft that were on approach, introducing an element of greater risk. Besides, the crew had the basic elements needed to make the approach to runway 32L and land.

Over the course of the event, the only element missing, both by the crew and by ATC, is the fact that no mention was made of the emergency stopping area (EMAS) at the end of runway 32L.

The pilots confirmed they were unaware of its existence, even though, as expected, the presence of this area is specified in the Aeronautical Information Publication.

The controllers did not take the initiative to inform the crew about the existence of the EMAS, since as they noted, this aspect is not included in the Emergency Manual.

It seems reasonable to issue recommendations to both the aircraft operator, DELTA AIRLINES, and to the company that manages the ATC contract, ENAIRE, that they include in their procedures the need to take into account the existence of this emergency stopping area so as to at least have the option to consider whether to use it or not.

Analyzing the communications between internal ATC stations with the RFFS and airport services indicates that their actions were properly coordinated at all times.

Another question that arose during the investigation is the suitability of having the RFFS interact directly with the crew in the final moments, once the airplane was on the ground and taxiing to its eventual stopping point. In this regard, it was concluded that it was easier, and offered less room for error, to have ATC relay the messages between them, as was done. Furthermore, any delay introduced by using this method was of little consequence.

Once the airplane stopped and the door was opened, which is when the RFFS first had direct contact with the crew, it would be desirable for any communications to be confident and unequivocal, to which end it would be logical to consider whether the RFFS members, or at least the person directing them on the scene, should have an acceptable level of English. A recommendation is not issued in this regard, but airport services should reflect on this subject.

The <u>fourth question</u> that arises from a purely operational standpoint is whether the crew should have reduced the airplane's weight by dumping fuel.

To answer this question, we must keep in mind that the center tank is the first to be used up. Only when it is empty is the fuel taken from the wing tanks. It takes at least one hour to completely empty the center tank.

The runway on which they were going to land was long enough for the airplane to land with the weight it had, as indicated in the Quick Reference Handbook. It seems, then, that the crew's decision in this regard was the correct one. In addition, there is no place set up in the vicinity of the airport over which fuel can be dumped, and the area they were flying over did not allow them to dump fuel.

2.2. Aspects involving the design of the aircraft's systems

A fifth, and important, question that arises, this time involving the design of the aircraft, is if it is reasonable for a tire blowout to affect such critical systems on the airplane and why said systems are not better protected.

It must be noted that eight hydraulic system lines on the trailing edge were damaged, rendering the right and center systems inoperable, affecting the nose wheel steering system and the brakes, and leaving only the brake accumulator to stop the airplane. Also left inoperable were nine out of twelve air brakes and the right reverser. In addition to this, there was also significant structural damage, such as a fractured spar in the right wing.

The aircraft manufacturer shares this concern and is working to see how best to reinforce the protection for all the systems housed in the wings to avoid a reoccurrence of this event. Understandably, the time period needed to draw satisfactory conclusions will be lengthy, but a safety recommendation is still being issued to the manufacturer to prevent a similar situation from happening in the future. Although these actions are already underway and both the FAA and EASA are reviewing the certification rules, meaning the results of all this work must be known before a determination can be made on improving the safety and protection of these and other systems located in the wing, issuing a recommendation offers a suitable means of tracking all this work.

Finally, there is a sixth and final question stemming from this event, namely, why the aircraft did not stop on the runway if the distance specified in the QRH was below that available for landing and the airplane touched down very close to the threshold.

Boeing's QRH has a section with tables for calculating landing distances. These tables are calculated to include the distance from the time the airplane is at an altitude of 1,000 ft until it is over the runway threshold plus the actual distances on the ground.

Taking into account the loss of the center and right hydraulic systems, and for the weight, pressure altitude, temperature and runway conditions present, the landing distance should be about 7,500 ft. This figure does not include the effect of a blowout, which is not considered among those configurations for which a landing distance in published.

The difference between the figures in the table and the actual distance traveled is that the braking distance expressed in the QRH is not calculated using a specific braking model that uses all the liquid in the accumulator; instead, it is calculated using a model that assumes that the hydraulic system is fully active for braking and the efficiency of the accumulators is overestimated in comparison to that of the system as a whole.

This is obviously not the correct way to do the calculation, as it does not take into account the finite nature of the accumulator as a source of pressure. In reality, the pressure on the brakes is supplied by the accumulators as the fluid in them, fluid that cannot be replenished, is exhausted.

To address this, the manufacturer is working to ensure that the QRH considers every case, including the scenario specific to this event. However, due to the importance of having this information available as soon as possible, a safety recommendation is being issued to the manufacturer to make the necessary changes to the QRH such that it reflect the actual landing distance required.

It would also be appropriate for the manufacturer to inform other operators using similar airplanes in their fleets of any progress made in these areas.

3. CONCLUSIONS

3.1. Findings

- During takeoff, just as the airplane was rotating, the right rear wheel on the main landing gear blew out, ejecting pieces that struck the underside of the right wing, perforating it.
- Two of the eight tires had been manufactured by Michelin and retreaded by Goodyear.
- Several hydraulic system lines broke, rendering unusable the airplane's center and right hydraulic systems.
- Important components in the secondary structure of the right wing were damaged.
- The crew detected it immediately and notified emergency services.
- The airport's RFFS also heard the noise and notified ATC.
- ATC stopped takeoffs from that runway until it was inspected by ground services personnel.
- The airplane was guided by ATC until it landed on runway 32L.
- The aircraft touched down 1,100 ft past the threshold.
- During the landing run, only the hydraulic system accumulators were available for braking, and they were depleted after the first braking maneuver, before coming to a stop.
- The reverser on the right engine was also rendered inoperative.
- The aircraft left the runway via the last exit taxiway on the left, with no steering or braking control.
- Upon leaving the runway, it struck a signpost and several lights.
- The firefighters were in place before the landing, waiting for the aircraft, and followed it during its landing run.
- During the landing, all of the airplanes that were taxiing in areas near runway 32L were stopped.
- The airplane stopped in a grassy area located between the end of runway 32L and zone A of terminal T4.
- At the end of runway 32L there is a RESA containing an EMAS zone that was not used.
- The crew reported they were unaware of the existence of the EMAS zone.
- A fire was not declared but the RFFS cooled off the landing gear to lower its temperature.
- There was no emergency evacuation; instead, the passengers exited the airplane using a ladder placed at the front door and were then transported to the terminal in buses.
- An inspection of the runway revealed a piece of metal on the one used by the airplane to take off. This piece was confirmed to have caused the tire to blow out.
- The stopping distance for the aircraft listed in the QRH for the conditions in effect indicated that the airplane should have stopped on the runway, meaning it was not calculated properly.

- The airplane manufacturer is working to modify the QRH and to reinforce the area of the wing where key hydraulic system lines are located.

3.2. Causes/Contributing factors

The incident was caused by the blowout of one of the main gear tires, caused by a metallic piece that had remained inside the tire during the retreading process.

The rubber that detached from the tire struck and perforated the underside of the right wing, damaging several hydraulic lines and rendering the airplane's center and right hydraulic systems inoperative. A part from the hydraulic system then struck the top surface of the wing, perforating it as well.

4. SAFETY RECOMMENDATIONS

REC. 10/16. It is recommended that DELTA AIRLINES ensure that its crews have proper knowledge of the information provided in the AIP for the Madrid-Barajas Airport.

REC: 11/16. It is recommended that ENAIRE include in the Emergency Manual the need to notify crews that are conducting an emergency landing of the existence of an EMAS stopping area on those runways that have one.

REC. 12/16. It is recommended that BOEING conduct a risk analysis to determine the need to develop mitigating measures to minimize damage to those areas that may be affected by a tire blowout so as to avoid rendering inoperative those systems that are essential to control the aircraft.

REC. 13/16. It is recommended that BOEING make the necessary changes to its QRH such that it reflect the actual landing distance for the situation applicable to this event.

REC. 14/16. It is recommended that GOODYEAR review its quality system such that a repeat occurrence of a foreign object being introduced into the tire during the retreading process is avoided.

5. APPENDIX

ANNEX 1. NTSB Comments on CIAIAC's Draft Final Report

ANNEX 2. Delta Air Lines Comments on CIAIAC's Draft Final Report

ANNEX 3. Good Year Comments on CIAIAC's Draft Final Report

ANNEX 1

NTSB Comments on CIAIAC's Draft Final Report

Below are NTSB staff comments on the CIAIAC Draft Final report regarding N182DN, a Boeing 767-332ER, operated by Delta Air Lines as flight 415.

Comments on the Causes/Contributing Factors

Page 60, Section 3.2. The U.S. Team disagrees with the second part of the first sentence that states, "…caused by a metallic piece that had remained inside the tire during the retread process. " The factual information gathered during the investigation and stated in Section 1.16.3. does not support this statement. As stated in Section 1.16.3, the findings and conclusions of the U.S investigators from the examination of the tire and metal piece that was found on the runway included; there were no signs of any problems during the tire retreading process; the shearography images that were taken during the retread process showed there was no evidence of foreign objects in the tire or of errors in the quality control process; the retreaded area was properly adhered to adjacent areas; the tread separated in multiple layers of the tire and that it is likely that the tire burst as the result of a high-energy impact in the area with the X-type break; and the metal piece had no rubber debris attached to it but exhibited a high degree of meteorization (i.e. scratches and corrosion) that is consistent with being on the runway for a considerable time.

Therefore, the US Team believes that the Causes/Contributing Factors should be:

The incident was caused by the blowout of one of the main gear tires resulting from high-speed impact with a foreign object during takeoff.

The rubber that detached from the tire struck and perforated the underside of the right wing, damaging several hydraulic lines and rendering the airplane's center and right hydraulic systems inoperative. A part from the hydraulic system then struck the top surface of the wing, perforating it as well.

Specific comments:

Throughout the report the event flight is referred to as both flight 145 and flight 415. The correct flight number is 415.

Page 9, Synopsis, 2nd last paragraph: "…caused by a metallic object that remained lodged inside during the retreading process." See discussion above.

Page 13, Section 1.3: Suggest this information be included in Section 1.4 since this section is for airplane damage.

Page 13, Section 1.4 Other Damage, 1st line; Replace "vial" with via.

Page 28, Figures 11 and 12: Replace "desplazado" with displaced.

Page 32, line 1, should say "recorder" instead of recorded. 2 Page 37, Paragraph 1.12.3: The paragraph states that an inspection of the runway "turned up parts…", and it later included "a metallic piece…" Was there a diagram produced of the runway as to where the parts were found on the runway?

Page 38, Figure 23: The right photograph should state that the metal piece was not found in the tire and that this photograph was taken after placing the metal piece, which was found on the runway, into the tire tread.

Page 39, Section 1.16.1, 3rd paragraph, last two sentences. "This granular morphology could have originated during the manufacturing process of the piece from which the fragment detached, via lamination in the longitudinal direction. But it could also have been produced later if the piece was on the ground a long time and subject to continuous crushing forces." These two sentences are analysis and should be in Section 2. The second sentence is a conclusion from the examination of the piece and is more likely. If this piece was imbedded in the tire, one would expect to have less meteorization and no/less corrosion.

Page 39, Section 1.6.2. "The tear on the tire was visually inspected by the manufacturer, which concluded that the tear started underneath the tread, specifically in the area that contained the piece of debris that was found on runway 36L. From there, the tear progressed along the inside of the tire following the layout of the fibers, and ripped the tread until part of it detached." This paragraph should be deleted since it incorrectly characterizes the findings from the examination of the tire that are described in Section 1.16.3. .

Page 39, Section 1:16.3, "Study of tear on the tire": The more accurate title of this section would be "Study of the Burst Tire Pieces" since the examination was of the entire tire and not just one tear.

Page 39, section 1.16.3, Paragraph 1: "A study of the tear on the tire was conducted at the facilities that the company that had retreaded the tire has in Atlanta (USA). Suggest deleting the first part of the sentence since the examination was not conducted because of information provided by NTSB.

Page 40, Section 1.16.2, 2nd paragraph, suggest the following, "The NTSB invited a representative of tire manufacturer, Michelin, who was initially part of the examination group when the tire was received to check its condition, though he later recused himself…"

Page 40, Section 1.16.3, 5th paragraph on page 40: The paragraph states, "According to the report issued, the images clearly showed that there was no FOD in the area where the metal piece that was found on runway 36L was suspected of having been located." It would be important to add that "According to Goodyear, shearography can detect

FOD pieces which are 8 mm or larger. The piece of metal found on the runway was approximately 87 mm". The US Team believes this information is evidence that the piece was not embedded in the tire because it would have been apparent in the shearography that was conducted immediately after the retread procedure.

Page 40, Section 1.16.3, 6th paragraph, 1st bullet: Suggest the bullet be reworded to say, "The tire exhibited an X-type break, indicative of a high-energy burst at that location in which parts of the tread were ejected in opposite directions, resulting in the underside of the tread tearing in a "V" shape.

When an area where the metal piece could possibly have been lodged was examined, the investigators checked the transversal section of the tread. This area houses the top layer of the tread, the bottom 3 layer of the tread and the plies or fabric of the tire. During the retreading process, the tire is ground to the area between the lower layer of the tread and the top layer of the casing. This area is called the protective strip. If the metal piece was introduced here during the retreading process, this is the only place where the metal piece could have been located. The findings indicate that there were no penetration marks directly above or below this area. The suspected area is covered by an intact piece of tread. A bottom view of the part of the tread shows the pattern of the piece of the tread, separated from the top layer of the tread. No impression of the metal piece, or any other FOD, was found."

Page 40, 4th bullet: Suggest this bullet be deleted, "Analyzing the material in this area, which exhibited grooves from the tearing but without being smooth indicates that the metal piece was on the position of the rethreading. " This is an inaccurate statement. There is no data supporting the metal piece was in the tread. See above comments in the Cause/Contribution Factors section.

Page 55, Section 2.1

The US Team does not agree with the analysis in the first seven paragraphs. The Team believes that this analysis is not supported from the findings from the examination of the tire pieces, the metal piece found on the runway, and the shearography. These examinations concluded that there were no signs of any problems during the tire retreading process; the shearography images that were taken during the retread process showed there was no evidence of foreign objects in the tire or of errors in the quality control process; the retreaded area was properly adhered to adjacent areas; the tread separated in multiple layers of the tire and that it is likely that the tire tore as the result of a high-energy impact in the area with the X-type break; and the metal piece had no rubber debris attached to it but exhibited a high degree of meteorization (i.e. scratches and corrosion) that is consistent with being on the runway for a considerable time. As stated in the Team's findings of the examination of the tire, the evidence suggests that the tire burst as a result of a high-speed impact by an object in the area with the X-type break on the tire.

Page 55, Section 2.1: 2nd paragraph states "…there can be no doubt that the tire broke and tore gradually as a crack opened up inside the tire caused by the damage resulting from said metal piece. The damage originated in an area below the tread that exhibited the exact same shape and dimensions as this piece." The findings from the tire examination do not support that the tire burst resulted from internal damage but rather that the tire failed from a high-energy impact from a foreign object.

Page 55, Section 2.1: 4th paragraph: The end of the paragraph states, "…investigators were unable to ascertain, for various reasons, what exactly this quality control process entails." This is inaccurate representation of the work conducted by the team of U.S. investigators. All shearography data supports that there were no FOD in the retread after completion of the retreading process.

Page 55, Section 2.1, paragraph 5: "…It seems much more logical to think that in any case, it would have dug into the tire, and not lodged itself in an internal volume tangent to the direction of rotation, i.e. normal to the radius of the tire. It must also be noted that even if it had been propelled by one of the front gear tires at great speed, the distance between the two bogies does not seem to be sufficient to achieve the acceleration needed for the piece to penetrate the tire." These statements are not supported by any engineering analysis or testing. The US Team believes that it is likely that a piece of FOD penetrated the event tire during the takeoff roll.

Page 55, Section 2.1, paragraph 6: "Finally, it must be noted that as soon as the incident took place and the runway was inspected, the piece was found immediately; in other words, the people who usually inspect the runway found it easily, as they did the remaining debris that detached after the blowout. Also of note is the fact that the runway had been checked by the same people fifteen minutes before the event and nothing had been found." Has human factors issues related to inspection of runways been researched or examined? The US Team does not challenge that an inspection of the runway was conducted prior to the event, however, there is no information available to the investigation as to how this pre-event inspection was conducted. Was the entire length of the runway inspected from vehicles or from workers walking along the runway? How many personnel and vehicles were used? How long did it take to inspect the entire length of the runway? It cannot be assumed that a normal inspection of a runway will find all possible FOD. In addition, inspection of a runway after an event, especially in an area where pieces of the tire were laying was conducted by workers on foot and specifically looking for small objects. A lot of human factors research has been completed regarding inspection/monitoring of instruments, etc. which would be similar to understanding the difference in inspecting runways before and after an incident/accident. The US Team is able to assist with this research and analysis if necessary.

Page 55, Section 2.1, paragraph 7: "After careful consideration of the two possibilities, this investigation concluded that the piece was inside the tire as the result of having been inserted there during the retreading process. A safety recommendation is issued to Goodyear that it review its quality system to avoid a similar occurrence in the future, in which a foreign object is inserted into a tire during the retreading process." As discussed above, the US Team does not agree with this conclusion.

Page 59, Section 3.1, Conclusions:

"- An inspection of the runway revealed a piece of metal on the one used by the airplane to take off. This piece was confirmed to have caused the tire to blow out." As stated above, the US Team believes that the tire to burst as a result of a high-energy impact with a foreign object during the takeoff roll. The Team does not agree that the data supports that the metal piece was introduced to the tire during the retreading process.

Page 59, Section 3.1: There are no findings addressing the tire examination and its observations. Recommend including the findings and conclusions detailed in Section 1.16.3.

Page 61, Section 4.- SAFETY RECOMMENDATIONS:

REC. XXX/15. It is recommended that GOODYEAR review its quality system such that a repeat occurrence of a foreign object being introduced into the tire during the retreading process is avoided. Recommend this be deleted. As stated above, the US Team believes the investigative findings do not support that the metal piece was introduced to the tire during the retreading process. This recommendation implies that there were deficiencies found in the Goodyear quality control process

ANNEX 2

Delta Air Lines Comments on CIAIAC's Draft Final Report

1. Update company name from “Delta Air Lines” to “Delta Air Lines, Inc.” or “Delta Air Lines” on the following pages: 1, 9 (three locations), 10, 12, 14, 53 (two locations), 56, and 61 (two locations).

2. The event flight was 415 and was erroneously stated as 145 on pages: 9, 10, 11, 12, 24, 25 (three locations), 46, 47 (eight locations), 48, 49 (three locations), and 50 (three locations).

3. Page 3-5, TOC: Review accuracy of section titles and associated page numbers.

4. Page 13, Section 1.3: Is this damage to aircraft or airport?

    a. If this is aircraft, replace “airport” with “aircraft”.

    b. Consider using the word the ICAO defined term “substantial damage.”

5. Page 13, Section 1.5.1 Crew:

    a. The first copilot total time, 12,000 hours, cannot be verified. Based on Delta Air Lines records, we can only verify his time at Delta Air Lines, which is 10,880 hours.

    b. The second copilot total time, 13,000 hours, cannot be verified. Based on Delta Air Lines records, we can only verify his time at Delta Air Lines, which is 9,990 hours.

6. Page 21, Section 1.6.7:

    a. This section references the “Quick Reference Handbook (QRH)” for the flight crew to access performance information. However, at Delta Air Lines this information is contained in the Operational Data Manual (ODM). i. The QRH is referenced on pages 13, 8, 21 (three locations), 22 (two locations), 42, 57 (two locations), 58 (four locations), 59, and 61.

    b. The sentence “The Quick Reference Handbook (QRH), located in the cockpit, contains stopping distances for the airplane that include the distance from the time the airplane is at an altitude of 1,000 ft, depending on its configuration” is inaccurate. The landing performance charts include an assumption that the aircraft touches down 1,000 feet from the threshold.

7. Page 22, Section 1.6.8 Retread Certification Process:

    a. Last three paragraphs are not relevant to tire retread processes. Consider creating a section about aircraft certification to withstand damage from debris.

8. Page 32, Section 1.11.2 Cockpit Voice Recorder (CVR), paragraph 2: Table summarizing CVR recorded conversation is not included.

9. Page 38, Section 1.16.2: Unable to locate source of this statement. Please consider including a reference if this statement was not included in the NTSB field notes.

10. Page 39-40, Section 1.16.3 Study of the tear on the tire: Consider revision based on the NTSB field notes.

11. Page 43, paragraph 17: Consider replacing "Fas" with flight attendants.

12. Page 44, last paragraph: correct "Operation Data Manual" to "Operational Data Manual".

13. Page 55, Section 2.1 Analysis: a. Paragraphs 2 and 7: Consider revision analysis to reflect findings from the NTSB field notes.

14. Page 57, paragraph 1: Consider adding information about ICAO Resolution A38/8 regarding English language proficiency. Consider recommending that RFFS personnel be required to maintain similar proficiency.

15. Page 58, paragraph 2: Consider rewording the statement that the calculation was "obviously not correct" since the Boeing calculations did not take into account the multiple failures that had occurred.

16. Page 59, Section 3.1 Findings:

    a. Finding 2: Correct the statement to reflect that only two of the eight main tires were manufactured by Michelin and retread by Goodyear. The remaining six tires were manufactured and retread by Goodyear.

    b. Finding 18: This finding is not documented in the crew statement section (1.17.1), only in the air traffic controller statement.

    c. Finding 22: Consider rewording the finding that the landing distance calculation was not calculated properly. The flight crew was unable to properly calculate the landing distance because the Boeing calculations did not take into account the multiple failures that had occurred.

17. Page 60, Section 3.2 Causes/Contributing Factors, paragraph 1: Consider revising based on NTSB field notes.

18. Page 61, Recommendation 1: Consider being more specific in the findings about the flight crews lack of awareness of AIP information.

a. If this is specifically related to the recognition of the EMAS, consider revising the recommendation that air carriers emphasize EMAS recognition in training.

b. Additionally, consider recommending that chart developers include EMAS in the Additional Runway Information section, similarly to “Grooved” and lighting information.

c. Additionally, the knowledge of the location of EMAS would not have changed the outcome of the event. Due to the lack of symmetrical braking and thrust reverser usage, the aircraft naturally tracked off the runway. There is no analytical data in the report to support that the flight crew could have maintained runway centerline and align with the EMAS.

ANNEX 3

Good Year Comments on CIAIAC's Draft Final Report

General Data Inconsistencies or Missing Information in CIAIAC Draft Report IN- 043/2013:

In general, the report fails to account for the available information on the appearance of the incident tire. Careful examination of the #7 main tire reveals the following:

o The rupture shows clear evidence of initiating in the area of the tire at approximately 6:30 (in relation to the tire serial number).

- The fabric structure of the tire shows evidence of tearing outwards from this area, towards the area of the tire identified by the CIAIAC as having possibly contained the metallic piece.

o The general appearance of the tire in the serial side outermost groove area at 10:30, the area stated as having the metallic piece, has the following available information:

- There are no working separations in this area, as would most likely be apparent with 89 taxi/takeoff/landing cycles on this retreaded tire leading up to this event.

- The area shows visible tearing associated with an abrupt, quick event.

- There are no curing marks in the surrounding rubber material, as would most likely be visible from a foreign object cured into the retread package.

- There is no evidence of rubber bonding to the metallic piece, as would be expected if it was to be cured in a tire.

- A foreign object like this cured into a tire would be expected to have one of the following characteristics:

o If the metallic piece did not bond to the surrounding rubber, there would be evidence of a working separation in the immediate area due to repeated use in service for 89 cycles.

§ There is no evidence of a working separation caused by repeated flexing of an object in the tire while the tire travels in and out of the runway surface footprint.

o If the metallic piece bonded to the surrounding rubber, there would be expected to be some evidence of the following:

§ An unmistakable impression, from curing, in the surrounding rubber.

· There is no sign of cure marks significantly matching the metallic piece.

§ At least one of the following:

· Evidence of cured rubber on the metallic piece.

o There is no evidence of cured rubber on the metallic piece.

· Evidence of a working separation in the immediate area.

o There is no evidence of a working separation in the immediate areas.

- State of the art non-destructive inspection, shearography, was performed twice, upon receipt of the tire: before retreading, and after the tire was fully built and cured.

- A foreign object, such as this metallic piece, would be easily visible use shearography.

o The archived images clearly show no foreign material was in the tire.

- Goodyear aircraft tires are manufactured according to strict manufacturing guidelines, FAA approved process specifications, and superior associate training. This tire received multiple visual and processing inspections, from multiple retreading associates, during the processing of the tire to the R-1 retread level.

o There were no anomalies found during the processing of this tire to the R-1 retread level.

The following are areas which were found to be in need of review/revision:

o 1.6.8. Retread Certification Process (page 22)

- This section does not address a retread certification process. This section should most likely be retitled Retraction Mechanism Certification.

o 1.12.3 Debris found on runways (page 37)

- Current verbiage describes the metallic piece fit into the suspect área as being a “perfect fit”. This area shows no curing impression from an object, which would be expected for a perfect fit.

o 1.16.2 Visual Inspection of the tear on the tire by the manufacturer.

- The manufacturer of the retread is Goodyear. The manufacturer of the casing/carcass is Michelin. This section does not clearly state which manufacturer has made the claim of tearing initiation from the metallic piece area. Goodyear Aviation representatives have made no such claim. Michelin Aviation representatives present during the first day of review activities at the Delta Wheel shop were not on record as stating this claim.

o 1.16.3 Study of the tear on the tire (page 39, 40, 41)

- In paragraph 3 is it not clearly stated that "tire manufacturer" is the casing manufacturer, Michelin.

- In the area of "The inspection revealed the following findings:" at the 5th bullet item which states "Analyzing the material in this area, which exhibited grooves from the tearing but without being smooth, indicates that the metal piece was in that position during the retreading." Should state that this is an indication that the metal piece was "not" in that position during the retreading.

o 1.18.2 Retreading tires (page 53)

- Under "CHARACTERISTIC" table:

- Retread type and level should state it is an R-1 (Bias) not "radial".

- Under 'RETREAD PROCESS" table:

- The drying process was "initiated" on 28-06-2013, not "completed".

- Under the 3rd paragraph, and subsequent paragraphs, concerning release of Goodyear company records, the following should be made clear:

- Goodyear invited the CIAIAC to visit both the Atlanta, Georgia (USA) and Tilburg, Netherlands retread facilities.

o Goodyear records and documents related to the quality process are open for review in each facility.

§ Due to the technical mature of the documents, onsite review is required, as each section can be further reviewed in the production areas with demonstrations and by communication with the actual staffing associates involved in the retreading process.

o Release of such documents outside of Goodyear may diminish our hard earned technical superiority and provide intellectual support for our competitors.

- Goodyear agreed to release the shearography documents to the CIAIAC as long as the CIAIAC would agree:

o To sign a secrecy agreement protecting the proprietary nature of this document within the CIAIAC.

o To have a recognized expert help inspect the shearography documents.

§ There is significant training required to properly understand and interpret shearography information.

o 3.1.- Findings

- In 2nd bullet, the statement "All the tires had been manufactured by Michelin and retreaded by Goodyear" is not clear in stating exactly which tires are being referenced. Since there are a total of four tires on each side of the aircraft, all four tires on the right side of the aircraft would have to be confirmed to meet this statement condition.