CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A-010/2013

Accident involving a Boeing 767-200 aircraft, registration XA-TOJ, operated by Aeromexico, during takeoff from the Madrid-Barajas airport (LEMD, Spain) on 16 April 2013

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COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

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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.

Table of contents

Abbreviations

ACS	Area Control Surveillance
ADI	Aerodrome Control Instrument
AIP	Aeronautical Information Publication
AIR	Air control endorsement
AP	Autopilot
APU	Auxiliary Power Unit
APS	Approach Control Surveillance
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATOT	Actual Takeoff Time
ATPL (A)	Airline Transport Pilot License (airplane)
CAS	Computed Airspeed
CIAIAC	Spanish Civil Aviation Accidents and Incidents Investigation Commission
CPC	Cabin Pressure Controllers
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DMAN	Departure Management
ECAM	Electronic Centralized Aircraft Monitor
EFB-	Electronic Flight Bag
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ESB	Executive on Board Service
EW	Empty Weight
FA	Flight Attendant
FAA	Federal Aviation Administration
FCOM	Flight Crew Operations Manual
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FFS	Full Flight Simulator
FL	Flight Level
FMC	Flight Management Computer
FOD	Foreign Object Debris
Ft	Feet
IFR	Instrument Flight Rules
GMC	Ground Movement Control
GMS	Ground Movement Surveillance
GOM	General Operations Manual
Hr	Hour(s)
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IRS	Inertial Reference System
kg	Kilograms
km	Kilometers
Kt	Knots
LEMD	ICAO code for Madrid airport (Spain)
LVP	Low Visibility Procedures
m	Meters
MAD	IATA code for Madrid airport (Spain)
MCG	Minimum Control Speed on the Ground
METAR	Airfield weather routine report
MHz	Megahertzs
MLW	Maximum Landing Weight
MMMX	ICAO code for México airport (México)
MTOW	Maximum Take Off Weight
N1	Low-pressure compressor speed in a turbine engine

N/A	Not applicable
NM	Nautical Miles
NOTAM	Notice to Air-Men
OPT	On-Board Performance Tool
PA	Passenger Address
PEDs	Portable Electronic Devices
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
PM	Pilot Monitoring
PSU	Passengers Service Units
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RAD	Radar control
RTOW	Regulated Take Off Weight
RWY	Runway
S/N	Serial Number
SDP	Apron control service
SOP	Standard Operational Procedures
TCL	Terminal Control
TOW	Takeoff Weight
TUC	Time of Useful Consciousness
TWR	Tower
UTC	Coordinated Universal Time
ZFW	Zero Fuel Weight

Synopsis

Owner and Operator:	Aeromexico
Aircraft:	Boeing 767-200, registration XA-TOJ
Date and time of accident:	Tuesday, 16 April 2013 at 12:58[1]
Site of accident:	Madrid-Barajas airport (LEMD, Spain)
Persons onboard:	3 flight crew, 6 flight attendants (FA) and 154 passengers
Type of flight:	Commercial air transport – Scheduled – International – Passenger
Date of approval:	24 June 2015

Summary of the accident

The aircraft, callsign AMX002, was cleared to take off from runway 36L at the Madrid-Barajas airport (LEMD) at 12:57:44. The wind was from 270° at 3 kt. According to the statement from the three FAs who were seated in the rear of the aircraft, there was a strange noise during the takeoff run. By the time they reported it to the cockpit, the flight crew had already detected pressurization problems and, upon reaching a cabin pressure altitude of 14000 ft, the passenger oxygen masks were released. As a result, the crew decided to return to the airport of departure. At 13:20, the aircraft's flight crew informed the control center that they were returning to the airport due to pressurization problems.

An Air Europa A330-200 aircraft with callsign AEA071, which had been the eight aircraft after AMX002 to take off, at 13:29, informed the tower after taking off that they thought that debris on the runway had struck their nose wheel and damaged the left tire, which had depressurized. The airline decided to have the aircraft return, and in preparation, the aircraft circled above Lisbon to burn fuel and subsequently returned to the Madrid-Barajas airport. The control tower requested an inspection of runway 36L, during which metal fragments were found. The crew of another aircraft (AEA051), which took off before AEA071, also reported seeing debris on the runway.

Aircraft AMX002 landed without further incident on runway 18L at Madrid-Barajas at 14:08. Except for the two FAs who were seated at the rear of the airplane, and who complained of neck pain, there were no injuries. There was damage to the bottom of the tail and almost all of the APU[2] compartment doors had been lost. The runway was

[1] All times in this report are in UTC, unless specified otherwise. To obtain local time, add 2 hours to UTC time.

[2] APU- Auxiliary Power Unit

inspected again in case the aircraft had lost additional components during the landing. Two metallic parts were found.

Aircraft AEA071 eventually landed at 17:39 after declaring an urgency (PAN PAN). The airport had activated a local alarm. None of the aircraft's occupants was injured.

The investigation looked in detail into the timeline of the takeoff as well as into the handling of the emergency and the crew's response to the depressurization.

The investigation concluded that the accident occurred because the aircraft rotated at a speed that was well below that needed for takeoff. The takeoff speeds provided to the crew had been calculated based on the zero fuel weight (ZFW), instead of the takeoff weight (TOW).

1. FACTUAL INFORMATION

1.1. History of the flight

The aircraft had flown from Mexico City to Madrid (MMMX-LEMD) on 13 April. On 16 April, the crew were picked up at the hotel and arrived at the aircraft one and a half hours before the departure time. In the cockpit there were three pilots, the captain and two copilots. The second copilot stated that he did the walkaround check of the aircraft prior to the flight, noticing nothing out of the ordinary. In the cockpit, the captain and the first copilot did the checks, entered data into the FMC[3] and did the taxi and runway in use briefing, as well as a special checklist for transoceanic flights. They entered into the backup FMC the data on the route to take in the event of an engine failure on takeoff, and coordinated as usual with the flight attendants. Five minutes before leaving, they received the OPT (Onboard Performance Tool) data calculated by their dispatch personnel. These data included the weight and balance information for the aircraft, as well as the takeoff speeds calculated for their regulated takeoff weight (RTOW[4]), which was limited by the conditions specific to the runway or by other considerations. The crew just had to enter these data into the navigation system for display in the PFD[5]. This system had been recently implemented since six months before the accident these aircraft performance calculations were carried out by dispatchers in Mexico and verified by the second copilot using the manufacturer's takeoff tables contained in the Flight Crew Operations Manual (FCOM). On the date of the accident there was no dispatch office in Madrid and the calculations were done by a dispatcher in Mexico[6] and emailed to the airline's base in Madrid. In the case of the accident flight, the data calculated and entered were not sent in the format output directly by the program; rather, the main data were extracted and added to the body of the email, along with the results of the calculation. As per company procedures, the crew entered these data into the system. The speeds entered were as follows:

- V_1 118 kt
- V_r 118 kt
- V_2 126 kt

After contacting the tower to request clearance, the crew taxied to holding point R4, where they adjusted the inertial navigation system and received clearance to take off at 12:57:44. During the takeoff run, the crew made the usual speed callouts (80, V_1 and V_r),

[3] FMC- Flight Management Computer

[4] RTOW Regulated Takeoff Weight- takeoff weight that takes into account specific runway conditions, obstacles and the type of climb for a given density altitude.

[5] PFD- Primary Flight Display

[6] Takeoff speeds for stations outside Mexico are calculated by the International Dispatch Office in Mexico City.

but the aircraft was unable to become airborne at the rotation speed. The captain eased the control inputs to accelerate the aircraft. The crew then felt the aircraft bounce before finally managing to take off. Surprised by what had happened, the crew checked the takeoff configuration (flaps and speed), but noticed nothing unusual.

One of the FAs, who had been seated at the back of the airplane and who, along with her colleague, felt something during the takeoff run, after the captain informed them that they were at 10000 ft (end of sterile cockpit), went to the forward section to inform the purser, and then the flight crew. A few seconds after reporting it, the passengers' oxygen masks were deployed. According to the crew's statement, during the climb the Cabin Altitude Warning light came on. The crew donned their oxygen masks, silenced the alarms and carried out the low pressure procedure[7]. They did not do an emergency descent, but they did stop climbing. They later asked ATC to descend, and were cleared to descend to 11000 ft, at which point the crew removed their oxygen masks.

The crew decided to return to the Madrid-Barajas Airport. They informed ATC and the company of the pressurization problem they were having. The company authorized them to do an overweight landing without jettisoning fuel. At 14:02:00, they were cleared to land on runway 18L. The landing was normal but very heavy due to the excess weight from the high fuel load. While taxiing to parking, the tower controller informed the crew that there was debris from their aircraft on the runway. The crew stated that this was the first time they became aware of damage to the aircraft's structure, damage that they confirmed after they exited the aircraft and saw the tail area. Due to the temperature reached by the brakes while landing and then taxiing to parking, the main gear thermal fuses were activated and, once the airplane came to a stop, released the pressure in the main gear tires. The firefighting service installed fans at both landing gear legs to lower the brake temperature and reduce the risk of fire. Company personnel verified that the contents of the two cargo holds had not shifted.

No passengers were injured. The FAs reported their neck pain once the aircraft was on the ground.

[7] The crew later clarified that they were referring to the CABIN AUTO INOP procedure.

Figure 1. View of the aircraft after it reached its parking stand

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	2	-	2	N/A
None	3+4	154	161	N/A
TOTAL	9	154	163	-

1.3. Damage to aircraft

The aircraft sustained structural damage to its tail assembly, to the APU housing, and to the trim on the aft door of the service hatch, with scraping and loss of material from station 1480 to 1950. The main gear tires were also deflated by the thermal fuse plugs due to the brake overheating caused by the overweight landing.

1.4. Other damage

During the takeoff run, the aircraft damaged the runway pavement and several runway centerline lights with its tail (see Figure 5). Debris from the tail left on the runway then damaged the nose gear on an Air Europa A330-200, callsign AEA071, the eighth airplane to take off after the Aeromexico AMX002.

1.5. Personel information

1.5.1. Flight crew

The flight crew consisted of three pilots: a captain and two copilots. It was their first time flying together as a crew, and the accident flight was the second leg (Madrid-Mexico City).

Captain

The captain, who was the pilot flying (PF) at the time of the accident, was a 54-year old Mexican national. He had valid and in force an unrestricted airline transport pilot (ATP) certificate, and had obtained his captain's rating for the Boeing B767-200 and B767-300 in October 2012. He also had valid instrument flight (IFR), multi-engine, instructor simulator and B-737 NG[8] check pilot ratings. He also had a valid group-1 psychophysical air transport aptitude certificate. On the date of the accident, he had a total of 20,066 flight hours, of which 149 had been on the aircraft accident type.

According to information from the airline, it was his first time flying to the Madrid-Barajas Airport with that aircraft, though he had flown numerous times to Madrid ten years earlier on other aircraft. On 3 April he had flown from Mexico City to Charles de Gaulle (France) on a B767-300, returning to Mexico City on 7 April on a B767-200. He then had five consecutive rest days before the flight to Madrid on 13 April.

Copilot-First officer

The copilot (first officer), who was the pilot monitoring (PNF/PM)[9] at the time of the accident, was a 41-year old Mexican national. He had valid and in force an unrestricted

[8] NG- Next Generation Boeing family. Includes the B737-600/-700/-800/-900ER (Extended Range) models.

[9] PNF/PM- Pilot Not Flying/ Pilot Monitoring-

airline transport pilot (ATP) certificate with a copilot's rating for the Boeing B737-NG, B767-200 and B767-300, the latter obtained in December 2012. He also had instrument flight (IFR) and multi-engine ratings. He likewise had a valid group-1 psychophysical air transport aptitude certificate. On the date of the accident, he had a total of 11,696 flight hours, of which 147 had been on the aircraft accident type.

According to information from the airline, it was his second time flying to the Madrid-Barajas Airport with that aircraft. The first time had been on 6 April, returning to Mexico City on 9 April. He then had three consecutive rest days before the flight to Madrid on 13 April.

Copilot-Second Officer (or relief pilot)

The copilot (second officer) was a 49-year old Mexican national. He had valid and in force an unrestricted airline transport pilot (ATP) certificate with a captain's rating for the Boeing B737-NG, and copilot's rating for the B767-200 and B767-300, the latter obtained in December 2012. He also had category II, instrument flight (IFR) and multi-engine ratings. He likewise had a valid group-1 psychophysical air transport aptitude certificate. On the date of the accident, he had a total of 13,428 flight hours, of which 278 had been on the aircraft accident type.

According to information from the airline, it was his first time flying to the Madrid-Barajas Airport with that aircraft. His previous flight had been on 8 April to Santiago de Chile, returning to Mexico City on 11 April. He then had one rest day before the flight to Madrid on 13 April.

1.5.2. Flight attendants (FAs)

The cabin crew consisted of six flight attendants: a purser (ESB[10]) and five flight attendants[11], all of them Mexican nationals.

- The purser and two FAs located at the front of the cabin had 24, 15 and almost 2 years of experience at the company, respectively.

The FA located at the right rear of the cabin had 21 years of experience, and the two FAs at the left rear of the cabin had 15 and almost 2 years of experience at the airline. It was these two who reported neck pain after the accident. They all had in force licenses and had successfully completed the last refresher training course for FAs.

[10] In Mexico, the titles of the various FAs are not the same as in Spain. The purser or cabin chief is referred to as an ESB – Executive of Onboard Service.

[11] In Mexico, the titles of the various FAs are not the same as in Spain. The FAs are referred to as pursers.

1.5.3. *Operations officer / Dispatch personnel*

The dispatcher, a 21-year old Mexican national, had an operations officer license that was in force at the time of the accident. It had been issued in 2011. She had a valid group-3 psychophysical air transport aptitude certificate. According to the airline, she had taken the B767-200/300 course and had been with the dispatch department for 3 months.

1.5.4. *Local aerodrome controller 36L*

The controller who cleared the accident aircraft for takeoff, a 36-year old Spanish national, had a valid community air controller's license with an LEMD unit endorsement and the following ratings and rating endorsements:

LEMD- ADI[12]/TWR[13]/RAD[14]

LEMD- ADI/GMC[15]/GMS[16]

LEMD- ADI/AIR[17]/RAD

He also had an APS[18] rating (with RAD and TCL[19] endorsements) and an ACS[20] rating (with RAD and TCL endorsements), all of them valid and in force.

The controller had a valid and in force class-3 medical certificate. His first rating, according to station records, dated from 15 February 2008. In 2012 he had taken the refresher training for SDP (apron control service), DMAN (departures management) and LVP (low-visibility procedures) simulation, and from 2013 until the date of the accident he had taken one refresher course.

1.6. Aircraft information

1.6.1. *General information*

The aircraft, a Boeing 767-283ER, registration XA-TOJ and serial number 24727, was manufactured in 1990. It was equipped with two Pratt & Whitney PW-4060 engines and

[12] ADI- aerodrome control instrument rating
[13] TWR- control tower endorsement
[14] RAD- aerodrome radar control endorsement
[15] GMC- ground movement control endorsement
[16] GMS- ground movement surveillance endorsement
[17] AIR- air control endorsement
[18] APS- approach control surveillance rating
[19] TCL- terminal control endorsement
[20] ACS- area control surveillance rating

had a maximum takeoff weight (MTOW) of 179,168 kg, and an empty weight (EW) of 83,834.9 kg.

The B767 is part of the dual-engine family of aircraft designed for medium- and long-range flights. The B767-200 can carry up to 216 passengers on routes over 3900 NM long. The B767-200ER, with center fuel tanks, can also carry 216 passengers on routes over 5200 NM long. Both models have the same dimensions, though the seating arrangements can vary by airline.

The aircraft had a Registration Certificate, Certificate of Airworthiness, Aircraft Station license, Aircraft Noise Certificate and an Insurance Certificate, all of them valid and in force. It had a total of 99,771 flight hours, and its last maintenance inspection (a 100-hr check) had been performed on 13 April 2013. Its next inspection (300-hr) was scheduled for 24 April 2013.

Figure 2. Photograph of the aircraft[21]

Some B767 models have a tail bumper designed to absorb a tail strike, should the tail impact the ground during takeoff rotation, for example. This specific aircraft model (B767-200), as per the manufacturer's design, did not have this protective component.

1.6.2. Information on speeds

An aircraft's takeoff speeds are based on the minimum control speed, the stall speed and the tail clearance margins. The speeds for aircraft with a short fuselage are normally based

[21] Image taken from airliners.net

on the stall margin, whereas for aircraft with a long fuselage, they are limited by the tail clearance margin.

The main speeds used during the takeoff sequence are as follows:

V_1 decision speed- maximum speed at which the crew can decide to abort the takeoff and still stop the aircraft within the runway limits.

V_r rotation speed- speed at which the aircraft's nose starts to lift and increase the angle of attack to climb at a proper rate, even though at that instant, the main gear is still on the ground.

V_2 takeoff climb speed- minimum speed that must be reached at a given safety altitude.

Both the Flight Crew Operations Manual (FCOM) and the Dispatch Manual indicate that the regulation prohibits taking off with a V_1 lower than the minimum control speed on the ground (MCG), which is shown in the performance tables. Appendix A contains this table which shows rough speed values for given weights and other factors. This table also shows that V_1 (MCG), for the temperature and pressure altitude conditions, could be interpolated[22] to 118 kts, the same as the value shown for V_1.

1.7. Meteorological information

The weather conditions at the time the accident aircraft took off were as shown in the following METARs:

METAR LEMD 161230Z 21006G17KT 160V280 CAVOK 24/10 Q1022 NOSIG[23]

METAR LEMD 161300Z 21006G18KT CAVOK 25/12 Q1022 NOSIG[24]

METAR LEMD 161330Z 19006KT 130V290 CAVOK 25/12 Q1021 NOSIG [25]

At the time the accident aircraft took off, there was a slight tailwind, gusting to 18 kt. Visibility was in excess of 10 km, the sky was clear and the temperature was 25°.

Based on the information gathered, the average 2-minute wind at the 36L threshold at 12:50:00 was at 2 kts from 220°, and at 13:00:00 (takeoff run of AMX002), it was at 01

[22] Shown in the graph for 20° instead of 25°
[23] Information available to the crew before takeoff
[24] Information during the takeoff of AMX002 at 12:59
[25] Information during the takeoffs of AEA051 and AEA07 at 13:27 and 13:29

kt from 201°. At 12:57, before takeoff, the controller informed the crew, "AMX002, wind 270/03[26], cleared for takeoff, 36L"[27].

1.8. Aids to navigation

Not applicable to this event.

1.9. Communications

According to the control tower log, a summary of the sequence of events is as follows. At 13:01, runway 18R was inspected following a notification from AEA071. The runway remained occupied for the duration of this inspection. At 13:58, the runway configuration was changed due to a shift in the wind. At 14:04, an entry indicated that the Aeromexico aircraft, callsign AMX002, was returning to the airport due to a depressurization problem, landing on runway 18L without incident. Runways 18L, 14R and 14L were then checked. At 16:53, the local alarm was activated due to the arrival of AEA071, which had a blown-out front tire. It landed without incident and stopped at point R1, where the passengers deplaned and assistance was rendered to the aircraft. This was followed by a new check of runway 18R.

The most relevant communications concerning the takeoffs of the aircraft involved, as well as the return to Madrid-Barajas of two of them, can be found in Appendix B.

1.10. Aerodrome information

The Madrid-Barajas Airport (IATA:MAD, ICAO:LEMD) is 13 km northeast of the city of Madrid, at an elevation of 609 m/1998 ft. The airport has four asphalt runways: 14R/32L, 14L/32R, 36R/18L and 36L/18R. Runway 36L/18R is 4,179 m long and 60 m wide.

At the time of the accident, the runways in use for takeoffs were 36L and 36R (North configuration). Runway 18R/36L remained inoperative from 13:30 until 14:05, after which time normal operations resumed in a South configuration with runway 18R in use.

[26] Instantaneous wind information shown on the wind gauge at the controller's console.
[27] These communications were held in Spanish

1.11. Flight recorders

1.11.1. General information

The aircraft had a Honeywell flight data recorder (FDR), serial number 1044, and a Honeywell cockpit voice recorder (CVR), serial number 62952. On the day of the accident the CIAIAC requested that these recorders be preserved. They were subsequently read out. The CIAIAC also had access to the cabin pressure computers (CPC) and the quick access recorder (QAR).

The FDR does not record information pertaining to the aircraft's calculated performance data during takeoff (thrust, calculated speeds entered into the system, etc.). Of the information contained on the FDR, there was only information involving the activation of the Cabin altitude warning above a cabin pressure of 10,000 ft. In an effort to obtain more information, CPC1 and CPC2 were removed from the airplane, but the manufacturer reported that the only information contained on the non-volatile memories of those units had to do with faults due to low air flow. There was no way to ascertain the cabin pressure or the time when the fault occurred.

The CVR recording lasted 2 hours 1 minute. The flight crew did not open the CVR breaker and the aircraft remained energized for a long time after landing. This resulted in the flight information being recorded over, meaning there was no information of use to the investigation available on the CVR. In this regard, the regulation pertaining to preserving recorder data is discussed later (see Section 1.17.10 Information on preserving recorder data).

1.11.2. Information on the data read out from the DFDR

The DFDR data were synchronized with the ATC time by using the time of the aircraft's takeoff clearance (12:57:49) as the reference. Appendix C contains graphs of the parameters of most relevance to the takeoff and to the cabin's depressurization. The flaps setting used by the crew was 15°. Below is a brief timeline with the most relevant events, from takeoff until landing:

UTC TIME	Remarks
TAKEOFF	
12:57:44	The aircraft is cleared to take off from runway 36L. The wind is from 270° at 3 knots.
12:58:10	The autothrust system is engaged.
12:58:41	Rotation initiated. CAS[28] 124 kt[29]. Pitch 0.4°. Control column 3.3°[30].
12:58:46	Pitch angle 8,8°, CAS 134 kt
12:58:47	Main gear tires in the air. Radioaltitude 4 ft. Pitch 12 °. CAS 137 kt. Control column 6.9°.
12:58:48	Radioaltitude 6 ft. Pitch 13°. CAS 138 kt. Control column 7.2°. Roll 0°.
12:58:49	Radioaltitude 5 ft. Pitch 13,7°. CAS 138 kt. Control column 7.4°.
12:58:50	Radioaltitude 4 ft. Pitch 14.1. CAS 138 kt. Control column 8.6. Roll 1.4°. Control wheel 8.6°.
12:58:51	Main gear on the ground. Pitch 13°. Control column 11.2°. Roll -0.7°. CAS 136 kt. Radioaltitude 1 ft. Left throttle lever moved forward from 70° to 77°, right lever from 70° to 75°.
12:58:52	Main gear on the ground. CAS 138 kt. Pitch 10.9°. Control column 8.2°. Roll 0°. Radioaltitude 3 ft.
12:58:53	Main gear in the air. CAS 141. Pitch 13°. Control column 6.2°. Roll -1.1°. Radioaltitude 4 ft.
12:58:54	CAS 142 kt. Stick shaker activated. Pitch 15.1° Control column 7.2°. Roll -2.1. Radioaltitude 11 ft.
12:58:55	CAS 148 kt. Stick shaker[31] activated. Pitch 16.2°. Control column 8.4°. Roll -2.1. Control wheel -5°.
12:58:56	CAS 148 kt. Pitch 15.1°, control column 7.7°. Roll 1.1°. Stick shaker deactivated.
12:58:57	CAS 148 kt. Pitch 15.8° and control column 7.6. Roll 7.7°. Stick shaker activated once more.
12:58:58	CAS 150 kt. Pitch 19° and control column 3,3°. Roll 8.4°, control wheel -29°. Stick shaker activated.
12:59:01	CAS 156 kt. Radioaltitude 90 ft. Gear lever up.
12:59:03	CAS 157 kt. Pitch 13.7°. Control column 2.5°. Roll -5.3°.

28 CAS-Computed Airspeed- speed used by the flight data computer, equivalent to the calibrated airspeed and displayed to the crew on their instruments.
29 Their rotation speed was 118 kt. The correct rotation speed was 156 kt.
30 The increase in the control column angle is directly related to the increase in the pitch angle.
31 Stall warning device that causes the control column to vibrate and generates a sound in the cockpit.

UTC TIME	Remarks
CLIMB	
12:59:28	Control tower instructs them to contact frequency 13.175 MHz.
12:59:53	ATC clears them to climb to FL 160.
13:05:32	ATC authorizes FL240
13:07:00	MASTER WARNING activated (This warning features both an aural alert and the MASTER WARNING light. It remains activated for 22 s.)
13:07:03	CABIN ALTITUDE[32] warning activated. Outside altitude is 16832 ft. When this warning activates, a panel in the overhead panel turns on, there is an aural alert and there is a message on the EICAS[33].
13:07:39	MASTER CAUTION activated.
13:08:31	Crew report they will remain at FL170, as they have a small problem.
13:09:29	Crew report they can leave FL170 and continue to climb. CABIN ALTITUDE remains active.
13:11:22	FL190 reached. Crew ask to remain at this level, as they have a problem[34].
13:12:56	Crew report pressurization problem and request to descend.
DESCENT	
13:13:17	ATC clears them to descend to FL130. Aircraft at 18896 ft.
13:14:00	ATC clears them to FL110, the minimum for that airway.
13:14:55	MASTER CAUTION clears. Altitude 13648 ft.
13:16:10	Aircraft reaches 11076 ft and stabilizes at FL110.
13:16:57	ATC asks crew if they plan to return to Madrid.
13:17:02	Crew inform ATC that the pressure regulators are not working and that they are returning, but they have to check the landing weight.
13:37:03	ATC informs crew that the runway configuration at the airport has changed.
13:55:30	ATC clears crew to descend to 8500 ft.
13:56:11	CABIN ALTITUDE clears. Aircraft altitude is 10136 ft.
14:02:00	ATC clears them to land on runway 18L.
14:04:06	Aircraft on ground (GROUND signal active).

[32] This warning comes on when the cabin altitude exceeds 10000 ft.

[33] Engine Indication and Crew Alerting System.

[34] Probably shortly before the passenger oxygen masks deployed, meaning that the cabin altitude was 14,000 ft.

1.12. Wreckage and impact information

After landing, the aircraft was directed under its own power to the parking stand, where it remained until the subsequent inspection. The damage was as described in Section 1.3 (see Figure 1). The debris found by the marshallers was removed and placed in storage (see Figures 3 and 4).

Figure 3. Pieces picked up by runway personnel in the last third of runway 36L

Figure 4. Pieces picked up by runway personnel in the runway 18L landing area

The runway used for takeoff (36L) showed damage along the entire section where the aircraft impacted it during rotation (see Appendix D). There were marks on the runway from light 107 (in the direction of takeoff, 360°) to 137. In all, the area affected was 525.4 meters long (see Figure 5).

Figure 5. Marks on the runway

1.13. Medical and pathological information

Investigators were unable to access the medical report for the FAs who complained of neck pain after landing at the Madrid-Barajas Airport. According to their statements, they were treated by the airport medical service and then taken to a hospital for further tests, where the neck collars placed on them at the airport were replaced.

1.14. Fire

There was no fire after the impact.

1.15. Survival aspects

Not applicable to this event.

1.16. Tests and research

During the investigation the visibility of an aircraft in a similar position, both at the runway threshold and at the point of rotation (see Figure 6), was checked from the position of the 36 local takeoff controller’s position in the tower so as to determine whether the controller could have seen the aircraft scraping the runway.

Figure 6. View from the controller's post of an aircraft similar to the Aeromexico B767 at the threshold and while rotating

1.17. Organizational and management information

1.17.1. Information on the OPT

The Onboard Performance Tool (OPT) is Boeing software approved by the FAA that is used to calculate takeoff and landing performance, including takeoff speeds and EPR[35] or N1[36] settings with normal thrust and an equivalent temperature. This tool is used by the personnel in charge of doing the weight and balance calculations (dispatcher or operations officer). The use, formats and output data of the tool are described in the Dispatch Manual for each model. The OPT allows flight dispatchers to calculate aircraft performance independently from the calculations done by the crew, thus expediting the dispatch process.

On 18 September 2012, the Mexico Aviation Department approved an amendment to the B767-200 Dispatch Manual, which included the OPT procedures and updated the takeoff weight tables for those stations that did not have this software (the Paris-Charles de Gaulle and the Madrid-Barajas airports) [37].

On 4 October 2012, Aeromexico issued two operational alerts for pilots of 737,767 and 777 aircraft (FOA-16/12R2) and for operations officers (OA-05/12R2), informing them of

[35] EPR - Engine Pressure Ratio,

[36] N1 – Low-pressure compressor speed in a turbine engine

[37] The takeoff speeds for stations outside Mexico were calculated in the International Dispatch Office, located in Mexico City.

the implementation of the OPT starting on 1 October to calculate takeoff speeds and thrust settings (N1 or EPR) for the 737, 767 and 777 fleets. During the initial implementation phase (from 1 to 15 October), all takeoff weight tables and the associated thrust setting tables had to be available and shown to the Captain if he required it. From 16 October, which was regarded as the date of the final implementation phase, the OPT would be the only method for determining speeds and thrust settings. As a result, the alerts noted that all of the takeoff weights published on the Aeromexico intranet and the dispatch manuals would be eliminated and replaced by the OPT. The alerts also informed that only in those stations where the file could not be received in OPT format would the data be sent as part of the weight and balance manifest.

The format of the OPT file is as shown below:

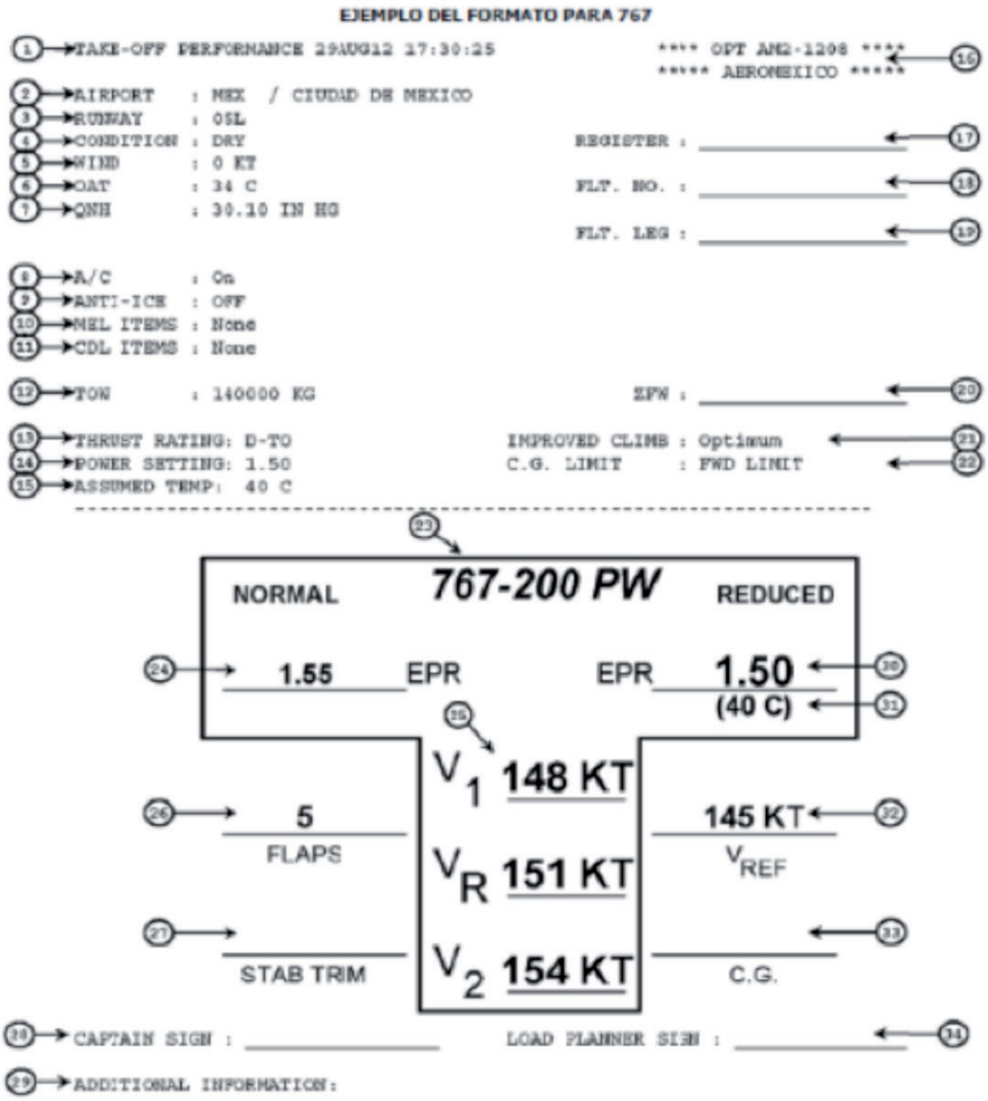

Figure 7. Sample performance data output by the OPT

On 9 January 2013, Aeromexico issued an operational alert[38] for operations officers (OA-06/12R2) reminding personnel to comply with the policies specified in the dispatch manual for correctly selecting certain parameters for calculating speeds.

At the time of the accident, Aeromexico offered an alternative means for pilots to check this information on portable electronic devices (PEDs), but there was no associated procedure, since the most accurate data were those calculated by the OPT.

On the day of the accident, there was no station in Madrid with the OPT software installed. The information received by the crew a few minutes before the flight began had been sent by e-mail from Mexico, and is shown below:

Jefe turno

De:
Enviado el: martes, 16 de abril de 2013 12:18
Para:
Asunto: Sistema de mensajería

```
ZCZC 969 161213 APR 13
QU MADJTCR
.MEXOPAM 161218/8046B5581
TAKEOFF PREFORMANCE ****OPT AM2-1301****
 ****AEROMEXICO*****
AIRPORT   MAD   REGISTER  XA)T)O)J
RUNWAY    36L   FLT NO.   002
CONDITION DRY   FLT LEG   MEX/MAD
WIND      CALM  SUP. RWY  ----
OAT       23C   ANTI-ICE  E/W AUTO
QNH       1023  MEL ITEMS NONE
A/C       ON    CDL ITEMS NONE
TOW  171687.KGS   ZFW  105087.KGS
THRUST RATING D-PW4060   IMPROVED CLIMB NONE OR FIXED
POWER SETTING 1.38   C.G. LIMIT FWD2 LIMIT
ASSUMED TEMP  55C
-------------------------------
  NORMAL  B767-200PW  REDUCED
  1.58 EPR        EPR 1.38
               *55 C*
   15    V1 118 KTS  125                Mcc  1/9
  FLAPS  VR 118 KTS  VREF
         V2 126 KTS
   5.7          20.9
  STAB TRIM         C.G.
CAPT SIGN --------  LOAD PLANNER SIGN----------
SENT-TO MEXOPAM MADJTCR
```

Figure 8. Data received by the crew on the day of the accident

The information included weight data and speeds presumably calculated from those weight data.

[38] This alert canceled and replaced one issued earlier (OA-06/12R1) on 31 December 2012

The information in the OPT format with the results of the calculation using both the TOW and the erroneous (ZFW) data are shown in Appendix E.

After the accident, on the same date, Aeromexico issued two operational alerts[39] for 737, 767 and 777 pilots (FOA-03/13R1) and operations officers (OA-03/13) that complemented the information in the Dispatch Manuals and the operational alerts issued previously, reminding them that the "OPT format is the only official document authorized for delivery to a flight crew. The information generated by the OPT cannot be sent in a document/format different than that provided by the program". If it was delivered in a format different than that specified, the Captain was required to request the information in OPT format. The alerts similarly asked all pilots to verify and ensure that the data contained in the official OPT format reflected the actual operating conditions and the airplane/engine configuration.

On the day of the accident, a circular was also sent to all pilots that asked them to do a cross-check of the OPT data.

The airline also reported its intention of supplying the Madrid station with the equipment needed to print out an official OPT.

In June 2013, a new alert was issued to operations officers (replacing one from May), OA-04/13/R1, on OPT use and its omission, and reminding of the application of the policies in place for calculating takeoff speeds, thrust and flaps settings, and which noted that the ZFW was to be written down by the Captain of the flight only, and not by operations officers, who would not use this information, as it might lead to mistakes since this information was not actually entered into the system. This way, one of the members of the crew would also be directly involved in the data checking process. This last requirement was distributed to the crews by way of circular MEXOJ-097/13.

At the request of the CIAIAC, the airline reported that the OPT system features warnings informing of mistakes when structural weight or minimum weight limits are exceeded. However, due to the wide range of values for some data, the system allows calculations for both very low weights and for weights close to the MTOW. The manufacturer of the software (Boeing) was asked about the possibility of modifying the program so that it would not allow faulty or inconsistent data to be entered, or to have it alert the user to any inconsistencies. Boeing reported that it would consider the Commission's proposal in future updates, though it would require changing both software and equipment.

1.17.2. Crew experience

According to the airline, no pilot flew two or more types of aircraft, regardless of whether they were able to fly other models in the past. Some pilots flew the B-737, others the B-767 and others the B-777.

[39] These alerts canceled and replaced two issued earlier (FOA-16/12R2 and OA-05/12R2) on 4 October 2012

Before the accident, a B-767 or B-777 crew could not include two or more pilots who had 100 hours or less on that aircraft model (B100 pilot[40]). As a result of the accident, and so as to ensure that the crews had more experience on the aircraft model, the minimum amount of experience needed by the crew was changed in June 2013, with a requirement that a crew could not have two or more pilots with fewer than 28 flights on an aircraft model (B28). This applied to actual, not simulated, flights.

1.17.3. Simulator training programs

The company reported that during the initial B-767 simulator training sessions, scenarios were generated that used low weights, thus allowing crews to do takeoffs and landings without interrupting the exercises and maximizing instruction time by avoiding system resets (for example, takeoffs and landings considering MLW[41] limitations). The weights and speeds provided by the airline are shown below:

➢ Para las sesiones 201, 202, 203, 204, 241, 301, 302, 303, 304, 341, 401, 403, 404 aplican:

Peso	Velocidades
G.W. 120,200 kgs.	V1 122 kts
Z.F.W. 100,700 kgs.	VR 128 kts
FUEL 19,500 kgs.	V2 134 kts

Figure 9. Weights and speeds used in the simulator

These reference speeds used during initial training are not very different from those calculated by the OPT and used by the crew on the day of the accident.

1.17.4. Previous events

According to the company, there had been two tailstrikes during takeoff maneuvers, both involving a B737:

- On 10 February 2010, a B737-800 experienced a tailstrike resulting from an early rotation due to apparent mistakes in calculating speeds using tables, combined with a high rate of rotation during the takeoff.
- On 24 January 2013, a B737-800 experienced a tailstrike during takeoff because, as the company explained, the aircraft's rotation was started 2 knots before the calculated V_r, combined with a maximum recorded rate of rotation of 5.63° per second (FDR), with the maximum allowed rate being 3° per second.

---

[40] A pilot is B100 when FFS hours (Full Flight Simulator . level C or D mobile simulator) plus flight hours add to 100 hours or less. In the case of the accident crew, none of its pilots was B100.

[41] MLW - Maximum Landing Weight

Another case, not reported by the company, involved not a tailstrike as such, but two mistakes observed in the dispatch information delivered to crews. In these cases, which occurred in early 2013, it was noted that the weight used had been the ZFW or the MTOW instead of the TOW. Fortunately, the crews realized the mistake and the faulty speed values were corrected.

The airline also issued a circular intended to remind all Aeromexico crews of the rotation and pitch angle values for each airplane in its fleet, as given in the manufacturer's manuals and which were included in the FCTM, for example. This circular is shown below.

JEFATURA DE PILOTOS
CIRCULAR No. MEXOJ-091/13

México, D.F. a 14 de Mayo de 2013.

A: **TODOS LOS PILOTOS**

ASUNTO: **"EVENTOS DE TAIL STRIKE":**

Estimados Compañeros:

Derivado de los recientes acontecimientos (cuatro eventos "TAIL STRIKE" en nuestros equipos, 2 de estos en los últimos 5 meses), nos permitimos solicitar a ustedes de su apoyo para apegarse a los procedimientos establecidos en la técnica de despegue tal como se indica en el FCTM correspondiente:

- No rotar anticipadamente el avión hasta alcanzar la Vr.
- Respetar el régimen de rotación.
- Respetar el ángulo máximo establecido para cada equipo.

REGIMEN DE ROTACIÓN	
B-737	DE 2° A 3° / SEG
B-767	DE 2° A 2.5° / SEG
B-777	DE 2° A 2.5° / SEG
B-787	DE 2° A 2.5° / SEG

ÁNGULO DE IMPACTO TAIL STRIKE	
B-737-700	14.3°
B-737-800	11°
B-767-200	13.1°
B-767-300	9.6°
B-777 LR	12.1°
B-787	11.2°

Figure 10. Maximum rotation angles

After this circular was issued, a tailstrike event took place on 25 May 2013 involving a B-737, which resulted in a revision to the airline's standard operating procedures (SOP) to have crews include in their takeoff briefings a reminder of the rotation rate and the maximum pitch angle for the aircraft model in question (see Figure 11).

El Capitán coordinara:

- La salida de plataforma y el rodaje a la pista en uso.

EL PF coordinara el TAKE OFF BRIEFING.

- **Durante este briefing, se deberá hacer mención del régimen de rotación para cada equipo, así como el ángulo máximo.**
- La falla de motor antes y después de V1 (sí existiese un procedimiento especial de ascenso se ***mencionará***).
- ***Procedimiento de abatimiento de ruido (si aplica)***
- El ascenso IFR publicado o ascenso visual en ruta. ***(Mencionar si las condiciones orográficas son factor durante el ascenso que requiera coordinarse).***
- En el primer vuelo y/o con cambio de tripulación del día efectuar la coordinación de ***Cabin Alt Warning.***

Figure 11. Revised SOP that includes a reminder of the maximum rotation angle

The company also considered including the OPT software in the PEDs of the flight crew to allow them to check results or do special calculations.

1.17.5. Tailstrikes

Appendix F shows the QRH[42] procedure for a tailstrike. The most important point notes not to pressurize the aircraft due to the possibility of structural damage. The crew are required to select manual pressurization mode and fly at the lowest safe altitude possible. The last point mentions that the CABIN AUTOMATIC INOPERATIVE procedure should <u>not</u> be carried out.

1.17.6. Recovering from a stall or near stall

A stall condition can occur at any altitude and can be recognized by the stick shaker, which makes the control column vibrate, accompanied by one or more of the following conditions:

- Buffeting, which can be strong at times
- No pitch and bank control
- Inability to stop the descent rate

The QRH (see Appendix F) lists the immediate actions to take following the first stall indication (buffeting or stick shaker activation). The main actions include disengaging the autopilot and autothrust, followed by gently pitching the aircraft down until the stall

[42] QRH- Quick Reference Handbook

indications subside. In the second phase, the QRH mentions increasing engine thrust. The FCTM, however, states that in certain circumstances where a high thrust configuration already exists, such as during takeoffs or "go-around maneuvers", it may be necessary to reduce thrust to keep the angle of attack from increasing.

1.17.7. *Sterile cockpit*

The sterile cockpit phase is one during which pilots must not be interrupted while in the cockpit, except in the event of an emergency or unlawful interference.

According to the General Operations Manual, the sterile cockpit is in effect:

- Before takeoff and during the climb until indicated in the checklist or at 10000 ft AGL.
- During the descent as indicated in the checklist or at 10000 ft AGL, ending when the aircraft exits the runway after landing.

For B737, B767 and B777 aircraft, the cabin crew are informed of the end (during the climb) or start (during the descent) of the sterile cockpit by means of the message "Cabin crew crossing 10000 ft".

During the sterile cockpit period, pilots must only engage in activities related to the safe conduct of the flight, avoiding actions that distract them, such as filling out forms, eating and non-essential communications between pilots and/or cabin crew. If communicating with the cabin crew is required, it will be carried out via the intercom or the PA (passenger address) system.

The Flight Attendant Manual, however, states that while the sterile cockpit is in effect, all communications with the cockpit shall be via the headset/intercom. The sterile cockpit may be interrupted if a FA has to report information involving abnormal situations in the passenger cabin that could lead to an emergency situation. The FA duties listed in the General Operations Manual include that of immediately informing the purser of any unusual situation in the passenger cabin. The purser must then coordinate with the captain and with the other FAs to respond to emergencies and abnormal situations.

When a safety or security situation arises in the passenger cabin, the FAs must coordinate the response to the abnormal or emergency situation with the flight crew by placing an emergency call (three chimes in the case of the B767) and then verbally describing the type of emergency. The same method will be used by the flight crew if they need to inform the cabin crew of a serious or emergency condition.

1.17.8. Pressurization system

The cabin pressurization is controlled by adjusting the conditioned air in the cabin by means of the outflow valve. The positive pressure relief valves and the negative pressure relief doors protect the fuselage against excessive differential pressure. The pressurization system features both automatic and manual modes of operation.

The pressurization system is in automatic mode when the cabin altitude switch is selected to AUTO1 or AUTO2 (see Figure 7). If the selected auto mode fails, control is automatically switched to the other auto mode.

Figure 12. Cabin altitude control panel

In automatic mode, the pressurization system uses ambient pressure data from the air data system in conjunction with the selected cabin auto rate, the takeoff altitude and the indicated landing altitude, to calculate the cabin pressurization schedule.

If the cabin altitude exceeds 10000 ft, the CABIN ALT (center forward panel) and CABIN ALTITUDE (overhead panel) lights illuminate, an acoustic warning is activated and a CABIN

ALTITUDE warning appears on the EICAS. The lights turn off and the EICAS message clears when the cabin altitude falls below 8500 ft.

When the auto pressure control fails, or if the cabin altitude control mode is selected to manual (MAN), the AUTO INOP light turns on, an acoustic alarm sounds and a CABIN AUTO INOP caution appears on the EICAS. When this happens, the pressurization control system has to be operated in manual. To do this, once the system is selected to manual, the switch is placed in CLIMB to open the outflow valve and allow the cabin altitude to rise, or placed in DESCEND to close the outflow valve and allow the cabin altitude to drop. There is an indicator that shows the open/closed (OP/CL) status of the outflow valve.

Appendix F shows the QRH procedure for a CABIN ALTITUDE or CABIN AUTO INOPERATIVE indication in the cockpit. The former condition, which involves a warning and the inability to control the cabin altitude, requires the crew to descend without delay to the lowest safe altitude possible or to 10000 ft. The crew followed the second procedure.

1.17.9. Emergency declaration

According to the airline's General Operations Manual, and as per the requirements in Annex 2 and 10 on emergency declarations:

When in an emergency situation, the pilot in command must, as soon as circumstances allow, establish contact with ATC and declare the emergency.

Some examples of an emergency include:

- In-flight engine failure or fire
- Cabin depressurization
- Smoke or fire in the passenger cabin and/or cockpit
- Uncontrollable stabilizer
- Loss of control of the airplane
- Pilot incapacitation
- Fuel below emergency fuel [...]
- Any other situation that in the Captain's opinion jeopardizes the safety of the airplane, passengers or crew.

A cabin depressurization is categorized in the airline's General Operations Manual as an

Alert 2 situation out of three possibilities, meaning a situation that poses a threat to people, aircraft, facilities or operations.

Depending on the circumstances, the mayday and urgency declarations must be made.

MAYDAY declarations, used together or separately, indicate the presence of a grave and imminent threat and are used to request immediate aid.

According to the manual, these calls can only be made by order of the aircraft's Captain.

Urgency declarations (PAN PAN), used together or separately, indicate that a crew wishes to inform of a problem that requires landing but not immediate assistance.

The crew did not make a MAYDAY declaration, and simply reported having a pressurization problem.

1.17.10. Preserving recorder data

The airline's General Operations Manual, in keeping with the stipulations of section 6.3.4 of ICAO Annex 6, specifies the following:

> **Flight data and voice recorders (GOM)**
>
> The flight data and voice recorders must not be disabled or de-energized intentionally for any reason during a flight, unless required by an abnormal or emergency procedure.
>
> In order to preserve the contents of the flight recorders, they must be disconnected after the flight following an accident or incident, and not be connected again until their data have been read out.

The General Operations Manual does not expressly state who is responsible for disconnecting the units to preserve the recordings, or how to disconnect them, though it does specify that it should be done once the flight is complete. The applicable regulation in Spain (EU OPS, OPS 1.085) assigns this task to the captain. ICAO Annex 6, Part 1 states in Chapter 6 that the operator must ensure that its crews know the laws, regulations and procedures of those States in which they operate. Chapter 10 of the General Operations Manual, International Operations, does make a generic reference to the need to observe European regulation requirements.

1.17.11. Clearance and pushback procedure at the Madrid-Barajas Airport

According to Section of the AIP, Engine/turbine start-up:

> A - Aircraft must be fully ready for start-up before calling on the associated frequency.
>
> […]
>
> D - When a current or future start-up clearance is issued, BARAJAS-CLEARANCE DELIVERY will give the aircraft the ATC clearance. When an aircraft requests pushback or taxi, BARAJAS-CLEARANCE DELIVERY will instruct the aircraft to call the Apron Control Service [SDP in Spanish] on the associated frequency. SDP will issue the pushback and/or taxi instructions and approval.

The airline reported that the procedure published in the Jeppesen charts (consistent with that published in the AIP) to start pushback at the Barajas Airport stated that to request flight clearance, the pushback checklist had to be complete. Crews, after receiving start-up clearance, would normally have time to check the data entered into the FMC, coordinate as necessary for takeoff and the instrument departure, and review the procedure to use in the event of an aborted takeoff or an engine failure during the initial climb. After this they would receive the weight and balance information and the OPT data, and once completed, they would focus on the pushback, start-up and taxi process. The company reported that the airplane normally used for the Madrid route was the B-777, and that the B-767 was not usually assigned to this route. B-777 crews, based on their experience at this airport, suggested that ATC be asked ahead of time if any changes were expected involving the flight plan as filed, so as to make the necessary arrangements and not have to carry out several tasks in a short time, thus improving situational awareness while observing the processes suggested in the manuals.

1.17.12. Alarm activation at the airport and runway inspection process

The list of aircraft (callsigns) that took off after the accident aircraft is shown below:

LIST OF TAKEOFFS RWY36L

	ATOT (UTC)[44]	AIRPLANE TYPE
AMX-002	12:59	B762
AEA-1173	13:05	E95
IBE-3172	13:12	A321

[43] ATOT- Actual Takeoff Time

	ATOT (UTC)[44]	AIRPLANE TYPE
AEA-1093	13:13	B738
AEA-1015	13:14	B738
AEA-9048	13:16	A332
AEA-9164	13:18	A332
AEA-051	13:28	A332
AEA-071	13:29	A332

The local alarm was activated at 16:53 h as a result of the PAN PAN call made by AEA071, which was returning to the airport due to a fault in the nose gear. This alarm was cleared at 18:29 h.

According to information provided by the airport, runway inspections are scheduled four times a day, though as many inspections as are needed may be conducted if there is a possibility of FOD[44] on the runway.

These standard inspections must be conducted within the following time frames:

HORAS	REV 1	3:00	9:00
	REV 2	9:00	15:00
	REV 3	15:00	21:00
	REV 4	21:00	3:00

On the day of the accident, the following inspections were carried out:

- 04:18 h - Scheduled inspection
- 10:42 h - Scheduled inspection
- 13:28 h - Inspection and cleaning of RWY 18R/36L due to FOD reported on it by the crews of AEA071 and AEA051. Metallic pieces removed.
- 14:50 h - Inspection of RWY 18L/36R after the debris from AMX002[45], which had landed on it, was reported. Metallic pieces removed.

[44] FOD- Foreign Object Debris

[45] There was significant damage to the aircraft's tailcone. Three right main landing gear tires had blown out, as had one tire on the left main landing gear.

- 15:18 h-15:26 h - Inspection of the other two runways.
- 17:44 h - Inspection of RWY 18R/36L after landing of AEA071. Nothing is found.
- 20:32 h - Inspection of RWY 14L/34R at request of TWR due to bird strike. Remains removed.
- 22:49 h - Inspection of RWY 18L/36R due to reported bird strike. Nothing found.
- 22:51 h-23:19 h - Inspection of the other three runways..

After the accident the airport conducted an internal review of its handling of the situation, which it provided to the CIAIAC. This analysis concluded that the correct actions had been taken, as specified in the airport's procedures. Areas of improvement were identified, however, and a new procedure was created with two associated instructions to complement the runway inspection process:

- Operating instruction for visual inspections on returns and diversions
- Operating instruction for handling FOD found on a runway

1.18. Additional information

1.18.1. Tailstrikes and related pressurization problems

Tailstrikes can cause significant damage to the firewall. This failure during a flight can result in the tail collapsing if the flight continues with the aircraft pressurized.

There are several published studies and reports on tailstrikes (Boeing[46] and Airbus[47]). According to information published on its website, Boeing is working to reduce tailstrikes by designing and installing new devices on the models more prone to tailstrikes, or by modifying takeoff procedures as a result of exhaustive testing conducted during takeoffs.

In the case of takeoffs, various factors increase the likelihood of a tailstrike:

- Improperly trimmed stabilizer
- Bad rotation technique
- Improper use of the flight director

[46] http://www.boeing.com/commercial/aeromagazine/articles/qtr_1_07/article_02_1.html
[47] http://www.skybrary.aero/bookshelf/books/195.pdf

- Thrust to weight ratio
- Flaps/slats configuration
- Rotating before V_r
  - Early rotation: very aggressive, misreading
  - Early rotation: incorrect takeoff speeds
  - Early rotation: especially when a significant difference exists between V_1 and V_r
- Excessive pitch attitude at the start
- Strong gusts and/or crosswind can cause the loss of aerodynamic speed and/or the need to modify the lateral flight control, which could deploy some of the flight spoilers and thus reduce the amount of lift the aircraft has
- Oil level in the landing gear struts

These factors can be mitigated by using proper takeoff techniques (contained in the Operations Manual for the specific models), including:

- Visually checking for asymmetries between landing gears and for possible hydraulic leaks before the flight
- Careful crosscheck of takeoff data among crew members
- Selecting the right flaps configuration
- Normal rotation technique on takeoff
- Rotating at the right time. Rotating early means less lift and less distance between the tail and the ground
- Rotating at the right rate - not rotating at an excessive rate or with an excessive pitch angle
- Using the right takeoff speeds
- Considering the use of a higher flaps setting to provide additional tail clearance in some models

- Using the right amount of aileron to keep the wings level during the takeoff run

The crew may not always be aware that a tailstrike has occurred if the impact was not felt. An analysis of these events indicates that in some cases, the tail scrapes so slightly that the crew do not feel it. In these cases, the crew are usually alerted to the strike by the passengers, flight attendants, crews of other aircraft near the runway, ATC or ground personnel.

As a result, the crew will be made aware that the fuselage may have been damaged, meaning that the cabin may not be pressurized. The cabin altitude may then be the same as the aircraft altitude, which must be limited to ensure the comfort of the passengers. The crew must thus avoid flying at an altitude that requires the cabin to be pressurized and divert to a suitable airport where the damage can be evaluated.

1.18.2. Information from Eurocontrol on preventing runway excursions[48]

As part of Eurocontrol's European Action Plan to prevent runway excursions, a specific mention is made with a recommendation involving the crew's process for handling the dispatch data.

Recommendation 3.4.13: The aircraft operator should ensure their standard operating procedure (SOP) requires the flight crew to perform independent determination of takeoff data and perform the crosscheck of the results with the data received. The aircraft operator should ensure their Standard Operating Procedures include flight crew cross-checking the 'weight and balance sheet' and 'performance' data input into the Flight Management Computer (FMC).

Traditionally the dispatcher will provide the Flight crew with the weight and balance sheet or loading form containing all the loading information. In some instances, the flight crew will have to complete the weight and balance sheet 'manually'. In this case the company should provide procedures for the pilots to independently crosscheck the data before it is being used for performance calculations. The next step will be to use the data either to be entered into the EFB[49] or to do the performance calculations on paper. The calculation should be done prior to receiving the final weight and balance sheet when the actual load can be ascertained with reasonable accuracy to avoid errors due to time pressure and hurry up syndrome.

[48] http://www.skybrary.aero/bookshelf/books/2053.pdf

[49] EFB- Electronic Flight Bag. Integrated, semi-integrated or portable system from Boeing and Jeppesen to do performance and other calculations. Similar in this case to the OPT system installed on the flight crew's PEDs.

1.18.3. The importance of cabin decompression and hypoxia[50]

The main risk in a pressurized cabin is the possibility of a cabin decompression. This can be due to improper operation of the pressurization system or to damage to the aircraft resulting in a crack in the fuselage that allows the air in the cabin to exit the aircraft (loss of a window, crack in the fuselage from an explosion, etc.). The rate of depressurization can be slow (in the event of a small air leak), while an explosive or rapid decompression occurs rapidly, normally in a few seconds.

The consequences of a decompression, and its effect on the cabin's occupants, depend on a number of factors, including:

- The size of the cabin; the larger the cabin, the slower the decompression
- The damage to the aircraft structure; the larger the opening, the faster the decompression
- The differential pressure; the higher the differential pressure between the cabin and the outside, the more energetic the decompression.

When the cabin pressure drops, the cabin occupants are no longer protected against the dangers of high altitudes, leading to an increased risk of hypoxia, decompression, severe discomfort and hypothermia. It is thus imperative that the flight crew recognize the different types of decompression and take effective actions to deal with the problems arising from the loss of cabin pressure.

A slow or unexpected decompression leads to a very gradual drop in cabin pressure. This can result from a faulty door seal, a malfunctioning pressurization system or a cracked window.

A slow decompression may not always be obvious. The crew may not notice the changes in the cabin until the oxygen masks drop from the Passenger Service Units (PSU). Therefore, the crew must be cognizant of the signs that could indicate a slow decompression. In some cases, an unusual noise like a whistling or hissing sound around a door could indicate a slow decompression, and must be reported to the crew immediately.

One of the first physiological indications of a slow decompression might be ear discomfort, or joint or stomach pain, caused by expanding gases. But the greatest threat during a decompression, whether sudden or gradual, is hypoxia.

Hypoxia is a shortage of oxygen at the cellular level that alters the functions of various organs. The nervous system (brain) is the most sensitive to this oxygen deficiency. In an average individual, this deficiency becomes apparent starting at an altitude of 10000

[50] http://www.airbus.com/fileadmin/media_gallery/files/safety_library_items/AirbusSafetyLib_-FLT_OPS-CAB_OPS-SEQ09.pdf

ft, even though the oxygen content remains at 21% from sea level up to an altitude of approximately 115 km.

As the air expands with altitude, the number of molecules drops, lowering the partial pressure of the gases that make up the atmosphere, even though the relative percentages are the same. This is what makes the 10000 ft level critical to maintaining the oxygen content in arterial blood above 87%, the level required for the body's biological functions.

As the hypoxia worsens, the individual's judgment, reasoning, memory, intelligence and alertness will all become impaired. The individual will become indifferent and may have a false sense of well-being. He may feel a headache, nausea or euphoria, and over time, or as the altitude increases, these symptoms will reach a critical level, eventually leading to loss of consciousness. That is why aircraft crews and passengers must always have available to them an oxygen system while in flight, so as to avoid hypoxia, whether or not the cabin is pressurized.

When a pilot flies in a cabin at a pressure of 15000 ft without an oxygen mask on, his vision becomes blurry, his field of vision will narrow, leading to "tunnel vision", which is similar to looking through a tube, his nails, lips and ears will turn purple and his time of useful consciousness (TUC) will decrease as the altitude increases. At 18000 ft, the TUC is 20 to 30 minutes, at 20000 ft it drops to 8 to 15 minutes, and if oxygen is not administered, loss of consciousness will follow.

The effects of hypoxia are usually very difficult to recognize when they appear gradually. If the relevant actions required to correct the shortage of oxygen (pressurization system) and to descend the aircraft to the safe altitude of 10000 ft are not taken, the consequences could be fatal[51].

1.18.4. Eyewitness statements

1.18.4.1. Flight crew

The crew had arrived in Madrid on Sunday morning. On the day of the accident, Tuesday, the pilots were picked up at the hotel and arrived at the aircraft one and a half hours before the departure time.

There were three pilots in the cockpit, each with his own flight duties. The first copilot was helping the captain (pilot flying) enter the flight plan into the FMS, with the taxi route and runway in use briefing, and entering the position to align the inertial reference system[52]. Transoceanic flights required a special checklist. The crew had listened to the ATIS and

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[51] See, for example, the accident involving a Helios Airways airplane near Athens on 14 August 2005: http://www.aaiasb.gr/imagies/stories/documents/11_2006_EN.pdf

[52] This aircraft is equipped with three IRS units. Before takeoff, their positions must be updated at the holding point to minimize alignment errors.

requested ATC clearance. They then did a check, along with the captain, with help from the flight plan and oceanic charts. They entered the data for an engine failure on takeoff into the backup FMS. The captain did the briefing with the purser on safety and dealing with unruly passengers. The second copilot checked the log book, did the walkaround check of the aircraft, handled the entry of positions into the IRS and coordinated with the FAs. During the walkaround he did not notice anything unusual and although the APU was inaccessible, he recalled that the APU doors were closed.

The handling company gave them three flight plans, one of them the Master. They received both NOTAM types (I Navigation and II Airport). The OPT system had been recently implemented. Six months earlier they had to check the figures using RTOW tables, but for this flight the weight and balance sheet data were provided from Mexico, as were the takeoff speeds, along with the runway analysis. The personnel who delivered the information were not licensed flight dispatchers, meaning they could not do the calculation or account for the information sent from Mexico. These data were received five minutes before their departure time. They did not check them, though one crew member noted that checking the speeds against the tables would not have taken two minutes to complete, since it was not part of the procedure. They reviewed the information they received and entered the speeds on the takeoff page of the FMS and the Vbugs[53] on the airspeed indicator.

Their takeoff weight was normal, and as such did not draw their attention. The speeds were not discussed in the cockpit either. Once at the holding point, they updated the position of the IRS.

During the takeoff run they called out 80 knots, V_1 and V_r, but the aircraft did not become airborne at Vr. The captain, who was the pilot flying at the time, loosened the tension on the controls a bit to accelerate the airplane. For an instant, they felt something like a bump, as if they had bounced on the landing gear. Once airborne they checked their takeoff configuration (flaps, speeds), finding nothing out of the ordinary. The cabin crew did not report anything.

After the takeoff they noticed that the cabin pressurization system was not working properly, but they did not know why. During the climb the Cabin Altitude Warning was received, so they donned their oxygen masks, silenced the alarms and performed the low pressure (AUTO INOPERATIVE) checklist. According to their statement, the AUTO INOP light turned on in the pressurization panel and a CABIN AUTO INOP message appeared on the EICAS. The crew did not make an emergency descent, though they stopped climbing and asked ATC to descend. They were cleared to descend to 11000 ft. By this time the passenger oxygen masks had dropped, which they realized because the Pax Oxy switch was lit. Given the circumstances, they decided they had no choice but to return. When they

[53] The Vbugs are physical markers placed on the airspeed indicator to remind the crew of the calculated takeoff speeds.

informed the cabin crew that they were returning to Madrid-Barajas, they FAs informed them that they had heard a noise during the takeoff.

They contacted the airline via satellite phone and they were cleared to do an overweight landing without jettisoning fuel. At 11000 ft they removed their oxygen masks. The landing was normal but very energetic due to the excess weight, which resulted in the landing gear tires overheating during the landing. The crew did not declare an emergency, and only reported that they had a pressurization problem, which they regarded as a contingency, and not an emergency. While taxiing to parking, the tower controller informed them there was aircraft debris on the runway.

The crew did not receive any complaints from the passengers. Once on the ground, the affected FAs reported their neck pain.

1.18.4.2. Cabin crew

FA_1 was seated in the left rear facing forward. Opposite her was FA_2, and a third FA was on the right side.

On takeoff, the two FAs seated on the left felt a strange upward motion, accompanied by a loud sound that alerted them that something unusual was happening. According to FA_2, this sound was continuous but it did not last long. FA_1 stated that the sound, which did not surprise her too much, lasted around 15 seconds. It reminded her of a dragging sound. They thought that a tire rim had made contact with the ground or that there was a problem with a strut. They informed FA_3 of this, who confirmed feeling the same thing.

According to FA_2, the airplane shook a little on takeoff, and she felt whiplash in her neck. FA_1 also started to feel neck pain. During the flight the passengers did not make any comments, though as they were leaving some said they had felt the impact.

They did not report it to the cockpit, nor did they stand up until the captain signaled 10000 ft, indicating the end of the sterile cockpit. FA_2 stood when she heard the 10000 ft signal and went forward to report the sound to the purser. When she got to the front, she felt dizzy, as if the cabin were depressurizing. She told the purser, who relayed it to the flight crew, informing them that the FAs had felt a hard impact and heard a noise during takeoff.

A five-year old passenger started complaining of an ear ache. FA_1 went for a glass of water to give to the child, and noted that her ears were starting to feel strange too. At that moment, just as FA_2 was exiting the cockpit, the oxygen masks dropped. FA_2 went throughout the cabin with a portable O_2 bottle, ensuring that the passengers had donned their masks. No one required first aid.

From then on they worked to prepare the passenger cabin, assigning tasks in the event that an evacuation was necessary. The cockpit notified them of the landing ten minutes in advance.

Once at the airport, these two FAs were treated by the airport's medical staff, which placed a neck collar on them. They were then taken to a hospital in Madrid, where they were x-rayed and the neck collar placed on them at the airport was replaced.

1.18.4.3. Captain of flight AEA051

During takeoff, they saw something green that was the size of a newspaper. They were in the final third of the runway (last 3000 ft) and were unable to make out what it was, since they were just then rotating the aircraft. They were then transferred to approach control and they did the after-takeoff checklist. After establishing the aircraft's configuration, they reported that they had seen something on the runway. They then immediately heard flight AEA071 reporting a blowout and that it was returning. Although they did not notice anything strange upon arriving at their destination (Havana), they decided to conduct a thorough inspection to look for possible impact debris, but found nothing unusual.

1.18.4.4. Captain of flight AEA071

The captain stated that they began their takeoff run on runway 36L at 13:29 h. Their destination was Caracas. The copilot was the pilot flying. Once airborne, the copilot said that he thought he saw large debris in front of them, just prior to the rotation. They immediately received an ECAM warning, "WHEEL TIRE LOW PR". The pressure indicator for the left front wheel changed from green to amber, eventually falling to zero after approximately ten minutes.

They reported the situation to the tower controller, adding that they thought that FOD had impacted their nose wheel during the takeoff run. The airline decided to have the crew return to Madrid to evaluate the damage, and the captain took over the PF duties. They decided to burn fuel over the Atlantic to avoid an overweight landing and were cleared by Lisbon ATC to enter a holding pattern at 10000 ft. At 16:28 h, with 20000 kg of fuel, the crew asked Lisbon to return to Madrid. Fearing that the only remaining nose wheel was also damaged and would blow out during the landing, and facing a possible evacuation of the aircraft, the crew declared an urgency (PAN PAN) to ensure that the firefighters and medical services were alerted and standing by.

At 17:39 h, the aircraft landed gently, using only the reversers to brake, first at full to a speed of 70 kt, and then at idle until just before exiting the runway. The aircraft remained in place and the passengers were disembarked. Maintenance personnel replaced the two nose tires and the aircraft was then taxied to parking.

1.18.4.5. Operations officer/Flight dispatcher

When she reported to work, she received the information on flight AMX002 from a colleague already “balanced” [54]. She updated passenger information, baggage weights and researched the conditions in which the flight would take place. She started to open the various programs needed to process the different flights assigned to her.

After updating the flight, she proceeded to calculate the speeds. In her statement, the dispatcher admitted that the mistake had been using the ZFW instead of the TOW. After sending the speed information, she realized it was incorrect, but after receiving a call from Madrid and under time pressure, she corrected the data, forgetting to correct and re-send the takeoff speeds. She also added that she had done that flight only a few times with the B767 and that the Madrid station had a procedure that was unique to that station, and was thus handled completely differently.

1.18.4.6. Local controller runway 36L

The controller stated that he was surprised by the B767-200, since it was not normal for Aeromexico to fly that model. He looked at it and watched the entire takeoff run. He remembered seeing the rotation. It took two seconds for the airplane to become airborne, but it eventually rose normally. He transferred it off the frequency and the crew signed off without saying anything. The takeoff of AEA051 was normal. The next airplane, AEA071, noted before being transferred that they had seen metallic debris on the final third. This information resulted in takeoffs being halted and he requested that the signalmen inspect the runway. AEA051 called later to report the presence of objects on the runway. The signalman then informed that there were several metal pieces. It was then decided to change runway configurations, which kept these runways closed for 10-15 minutes. The next aircraft departed from runway 15R.

1.18.4.7. Passenger

In an interview given to Mexican media on the day of the accident, a passenger on the flight, then back at the Madrid-Barajas Airport, stated that the aircraft sustained a very hard impact during takeoff that surprised everyone, but the airplane continued with the takeoff. After the pilot reported that they were above 10000 ft, the oxygen masks dropped and the pilot instructed everyone to don their masks. This passenger remarked that the FAs were quite nervous, and that after ten or fifteen minutes, the pilot informed them that they were returning to the Madrid-Barajas Airport. When they saw the aircraft after deplaning, they were surprised by the extent of the damage. The passenger stated that no one had been injured[55].

[54] With the list and trim calculations already started.

[55] The injured FAs only reported their neck pain after the passengers had disembarked.

1.19. Useful or effective investigation techniques

Not applicable

2. ANALYSIS

2.1. Analysis of the flight preparation - Calculation of takeoff speeds

The airplane was scheduled to make the return flight from Madrid to Mexico City (LEMD-MMMX) on 16 April. The previous flight had been on 13 April (MMMX-LEMD). In the cockpit were three pilots: the captain and two copilots. The second copilot did the walkaround check of the aircraft, finding nothing unusual. Five minutes before the departure time (about 12:25), they were e-mailed the OPT (Onboard Performance Tool) data from the dispatch office in Mexico City. ATC authorized them to push back immediately afterwards. According to the procedure in the Jeppesen charts for the Madrid airport (which matched the one in the AIP), the crew had to be fully ready for pushback before contacting ATC. The company reported that this was unusual and that normally crews, after receiving pushback clearance, had sufficient time to do the necessary checks (compare the data entered into the FMC, coordinate and brief abnormal takeoff procedures). They would then receive the weight and balance form and the OPT data, and after checking all of it, the crew would focus on the pushback, start-up and taxi phases. The Mexico-Madrid route was usually covered by the B-777. The B-767 was not normally assigned this route. The accident crew were not sufficiently familiar with these procedures, which could have added to the pressure and to the lack of time to finish all these tasks. The B-777 crews, based on their experience at this airport, suggested that ATC be asked ahead of time if any changes were expected involving the flight plan so as to make the necessary arrangements and not have to carry out several tasks in a short time, thus improving situational awareness while complying with the processes suggested in the manuals. Though no safety recommendation will be recommended in this case, this type of best practice can be extrapolated and shared with crews of other fleets, especially those that may, on occasion, fly these same routes.

The members of the flight crew had valid licenses and medical certificates, and they had considerable flight experience, though not on this aircraft model. It was their first time flying together as a crew. They had arrived on 13 April on the Mexico City-Madrid flight. The accident leg (Madrid-Mexico City) was their second flight together. Before the accident, the airline did not assemble a B-767 or B-777 crew if two or more pilots on said crew had fewer than 100 hours on the aircraft model (B100 pilots). After the accident, this requirement was modified to ensure more experienced crews were used by specifying that a crew could not have two or more pilots with fewer than 28 flights on that aircraft model (B28 pilots). This only took into account actual, and not simulated, flights.

The OPT data include weight and balance information on the aircraft, as well as the takeoff speeds calculated for the takeoff weight and limited by certain conditions. According to the procedure put in place by the airline six months earlier, the crew only had to enter the data into the navigation system, which would then be displayed on the PFD. Before it was the second copilot who would first perform these calculations using the manufacturer's takeoff tables, which were kept onboard the aircraft. At that time there was no dispatch station in Madrid, and as a result the calculations were carried out by a dispatcher in Mexico[56] and e-mailed to the base in Madrid. Neither the data entered nor calculated were sent in the format output by the program directly; instead, the key figures were extracted and added to the body of the e-mail along with the results of the calculation. In light of the results output by the OPT and the e-mail that was sent (see Section 1.17.1 Information on the OPT), the calculations were made by inputting the zero fuel weight (ZFW) into the system instead of the takeoff weight (TOW), which is why the resulting speeds were below those actually needed for the aircraft to take off.

V entered (ZFW)	Actual V (TOW)
• V_1 118 kt	• V_1 152 kt
• V_r 118 kt	• V_r 156 kt
• V_2 126 kt	• V_2 161 kt

The body of the message, however, stated that the data used for the calculation were correct, and thus during their check of the data, the crew did not detect any mistakes. They then, as per company procedure, entered these data directly into the system.

As a result of the initial analysis into the causes of the accident, and of lessons learned from previous events, the airline immediately prohibited the sending of information in a format that was not the OPT format until the OPT was implemented in stations at airports where it was not installed (the company's intention was to install the equipment needed to print out the OPT results at its Madrid station).

Similarly, the procedure for checking the data used in the calculations was changed to involve more members of the crew and to require dispatchers to only use the takeoff weight (TOW) figure that was going to be used for the performance calculation to avoid errors. Several circulars were issued to spread this information among dispatch staff and crews. The maker of the software was asked about the possibility of introducing alerts into the program when mutually inconsistent data are entered. The maker reported that it would consider this CIAIAC proposal in future revisions, though as of the publication date of this report, no such changes have been made.

None of the crew members noticed the low values for the takeoff speeds. It was later learned during the airline's simulator sessions, that weights lower than usual were used to allow crews to practice takeoffs and landings without having to interrupt the exercises. Specifically, the speeds used by the crew during these sessions were as follows:

[56] Takeoff speeds for stations outside Mexico are calculated by the International Dispatch Office in Mexico City.

Simulator V

- V_1 122 kt
- V_r 128 kt
- V_2 134 kt

These speeds were not very different from those erroneously calculated on the day of the accident. This could account for why none of the crew members caught the mistake, and instead accepted the speed values as correct. However, regulations prohibit taking off with a V_1 lower than the minimum control speed on the ground (MCG). In this accident, this V_{MCG} was 119 kt, meaning that both the V_1 and V_r given to the crew were lower than the V_{MCG}. As a result, the airline was informed during the investigation of the added value of continuing to have crews check the speeds in the tables even if the calculations were done by dispatch personnel. The airline reported that they were working to introduce the OPT software into the PEDs of crew members so they could check the results or do special calculations, in keeping with the practices recommended by Eurocontrol. As a result, no safety recommendation is issued in this regard.

2.2. Analysis of the takeoff maneuver

The weather information showed that visibility was good and the temperature was 25°. No large differences were noticed between the wind information at the moment of takeoff and that provided by the controller shortly before. There wind was weak from the northwest, and this factor is not thought to have influenced the aircraft's performance during the takeoff maneuver.

Once cleared for takeoff, during the takeoff run the crew engaged the autothrust system and made the usual speed callouts (80, V_1 and V_r), but the aircraft was unable to become airborne at the rotation speed. According to information from the DFDR, the rotation was started at a speed of 124 kt by raising the pitch angle to 0.4°. The rotation speed that had been given to the crew was 118 kt, when the actual speed based on TOW was 156 kt. The pitch angle was increased to 8.8° within five seconds after starting the rotation, by which point the recorded speed was 134 kt, still insufficient for the aircraft to go airborne. One second later, the main gear was in the air and a radioaltitude of 4 ft was recorded. The crew continued to raise the pitch angle to 14.1°. The speed was 138 kt. One second after reaching this pitch angle, the main gear again contacted the runway, although the aircraft's pitch remained at 13° and the bank angle was slightly to the left. An angle of 13.1° is the tailstrike angle for a B767-200, a limit that the crew should have been aware of. According to the DFDR information, the crew at that moment moved the engine levers forward to provide more thrust to the aircraft. In the two seconds following the return of the main gear to the ground, the gear lifted off (at 138 kt) and touched the runway (at 141 kt) again. The crew eased off the controls slightly before raising the pitch angle to 13° again. Upon reaching a pitch angle of 15.1°, at a speed of 142 kt and with a slight left bank angle, the stick shaker was activated for two seconds, and then again for another two seconds. The recorded data indicate that the pitch angle continued to increase to a maximum of 19°, while the speed went from 148 kt to 150 kt. The altitude at that point was 47 ft. The crew then eased the pressure on the controls. The QRH procedure requires disengaging the autopilot and the autothrust and lowering the nose of the aircraft to reduce the angle of attack and thus deactivate the stick shaker.

The crew rotated at a speed that was 32 kt below that required, which resulted in the aircraft not having sufficient lift to climb. Based on the information analyzed, the autothrust system was not disengaged nor did the crew lower the aircraft's pitch angle. They increased thrust by pushing the thrust levers forward, even though the FCTM warns not to apply more thrust on takeoff to keep the pitch angle from increasing even more. In light of this information, it may be concluded that the crew were unable to identify the stall during takeoff, applying more thrust and vaguely backing off the controls, only to increase the pitch angle later to 19° (even as the stick shaker was active) when the maximum angle to avoid a tailstrike is 13.1°. A safety recommendation is thus issued on the need to train crews to recognize stalls and to recover from them, as detailed in Section 4.

According to various studies, including some from Boeing and Airbus, tailstrikes are preventable. The most effective prevention measures involve training programs that reinforce the use of proper takeoff and landing procedures. Although the creation of technological barriers to aid the crew is also encouraged, training is regarded as essential to preventing these events. The airline reported that after the accident, a circular was issued to remind crews of the maximum pitch angles and rotation rates for each aircraft model used at the airline. Later, following another tailstrike event, the operating procedures were revised to require this reminder explicitly as one of the points in the takeoff briefing. Appendix F shows the QRH procedure for a tailstrike. Although this issue will be analyzed later in more detail, it is worth noting that the most important point in this procedure involves not pressurizing the cabin due to the possibility of structural damage. The crew is instructed to select manual pressurization mode and fly at the lowest safe altitude possible. The final point specified is not to perform the Cabin Automatic Inoperative procedure, which was carried out by the crew in this case. If the crew had been aware of the tailstrike, they would not have pressurized the aircraft and would have returned to the airport of departure to avoid further risks, hence the need to identify the factors in a possible tailstrike. In light of this information, and though the airline did take steps intended to remind crews of certain takeoff information and practices aimed at avoiding tailstrikes, a safety recommendation is issued in this regard.

2.3. Analysis of the coordination between the flight and cabin crews

The aircraft model involved in the accident (B767-200) did not have a tail bumper to absorb the impact or provide a cockpit indication of a tailstrike. Given the nature of the damage it probably would not have prevented the impact, although it would have alerted the crew to the certain tailstrike that occurred during takeoff. According to their statements, none of the crew members was aware of the tailstrike or of the structural damage to the aircraft until they exited the airplane after landing. There is no record of any passenger reporting the tailstrike, and the only occupants who felt anything resembling the tail striking and dragging along the runway were the FAs who were seated at the rear of the aircraft, and who also did not identify the event as a tailstrike, despite describing it as a strong and lengthy occurrence. The FAs repeated during the interviews that it did not occur to them to alert the crew until the sterile cockpit period was over.

According to the General Operations Manual, during the sterile cockpit period pilots must only engage in activities directly related to the safe operation of the flight, avoiding activities that distract them, such as non-essential communications with the FAs. If it is necessary, however, such a communication may be made using the intercom or the PA, and according to the Flight Assistant's Manual, the sterile cockpit can also be interrupted so that FAs may report information involving unusual situations that take place in the passenger cabin that could lead to an emergency situation, this being expressly listed among their tasks. The purser has to coordinate the handling of emergencies and unusual conditions with the captain and with the other FAs.

As a result, and since the only people onboard the aircraft who felt the hard and continuous tailstrike, despite not identifying it as such, were flight attendants, they should have informed the purser and she in turn should have reported this abnormal situation to the cockpit, despite the sterile cockpit being in effect. As a result, a safety recommendation is issued in this regard, as detailed later on.

2.4. Analysis of the handling of the depressurization

The crew stated that after the takeoff they started noticing problems with the pressurization. During the climb, they received a Cabin Altitude Warning. They donned their oxygen masks and silenced the alarms. The Auto Inop light then turned on in the pressurization panel and a Cabin Auto Inop message appeared on EICAS, as a result of which they performed the low-pressure (Cabin Automatic Inoperative) procedure. During the investigation, the crew reported that they did not do an emergency descent, though they did stop the climb.

Based on DFDR data, the Master Warning horn and light were activated at 13:07:00, followed 3 seconds later by the Cabin Altitude Warning, which is triggered when the cabin altitude exceeds 10000 ft. The Master Caution[57] was activated at 13:07:39. This caution comes on when the automatic pressure control fails, or if the cabin altitude mode goes to manual. This would have happened if the system had been unable to pressurize the cabin in automatic, or if the crew selected manual control mode. Despite any steps that the crew might have taken initially to analyze this abnormal situation, they remained at FL170 and then decided to continue climbing to FL190. Since they were unable to solve the cabin pressurization problem, they asked ATC to remain at this flight level, and five minutes after the first warning, they asked to descend. Two minutes later the Master Caution cleared. It was during this time that the passenger oxygen masks were released. The crew stated that they became aware of this due to the lit Pax Oxy switch, and decided to return to the Madrid-Barajas Airport. During this time the crew were unaware of the possible reasons for the constant warnings, and therefore unaware of the risks inherent to a gradual depressurization, which is why they did not execute an immediate emergency descent. As a result, a safety recommendation is issued in this regard, as detailed later on.

2.5. Runway inspections

Based on the available information, the crew were unaware of the tailstrike and of other possible structural damage, and therefore of a potential runway contamination. The controller reported that he watched the takeoff run and saw nothing unusual. It was later confirmed that the distance between the tailstrike event and the controller's post made it difficult to detect the tailstrike. As a result, it was not possible to anticipate the presence of FOD on the runway until other aircraft with long takeoff runs encountered the debris. The airport's and ATC's actions regarding scheduled runway inspections, and those carried out as requested later, were determined to have been correct. The airport analyzed the accident and identified areas of improvement, creating a new procedure and two associated instructions to complement the runway inspection process. However, if a similar event were to occur in which both the crew and ATC personnel were unaware that an event with the potential to leave debris on the runway had occurred, it would probably have been handled in the same way.

2.6. Analysis of how the emergency was managed

According to the General Operations Manual, and in keeping with ICAO rules, when in an emergency situation, the pilot in command must, as soon as circumstances allow, contact ATC and declare an emergency. One example of an emergency that is specifically included is a cabin depressurization. Based on this, the crew should have made a MAYDAY call or, failing this and after descending below a safe altitude of 10000 ft, made an urgency (PAN PAN) call. A MAYDAY declaration can only be made on the captain's orders. The crew

[57] Due to the Cabin Auto Inop alert displayed on the EICAS.

stated that they did not declare an emergency because they regarded it as a contingency and not as an emergency. This requires the issuance of a safety recommendation on crew training and refresher training involving the handling of emergency situations.

The investigation also noted that the cockpit voice recorder was not preserved after the accident, which made it impossible for the investigation to have this valuable record of the cockpit crew's management of the accident. The analysis found that the General Operations Manual does not explicitly assign responsibility for preserving the information in the recorders following an accident or incident. This is in violation of the applicable European regulation. The airline has already noted that, by virtue of operating in the United Kingdom, Spain and France, the applicable law is Regulation 859/2008 (EU OPS 1). According to ICAO Annex 6[58], the requirement to preserve the recorders is specified, but without specifically assigning this task to anyone. As a result, a safety recommendation is issued in this regard.

[58] Annex 6- >Section 6.3.4.2.2 To preserve flight recorder records, flight recorders shall be de-activated upon completion of flight time following an accident or incident. The flight recorders shall not be re-activated before their disposition as determined in accordance with Annex 13.

3. CONCLUSIONS

3.1. Findings

An analysis of all the information available revealed the following findings:

- The aircraft's documentation was valid and in force.
- The crew members had valid and in force licenses, ratings and medical certificates.
- The captain had been rated on the type since October 2012, and the copilots since December 2012.
- The pilots had flying experience, but not many hours on the aircraft type.
- The flight from Mexico had been their first flight together as a crew.
- It was the captain's and second officer's first time flying into Madrid, and the second time for the first officer.
- The crew received the takeoff performance data five minutes before closing the doors.
- The system for calculating B767 takeoff speeds (OPT) had only been implemented at the airline six months earlier.
- The Madrid station did not have dispatchers or the OPT software installed.
- The information was delivered in a different format from that output by the OPT, with the data copied and pasted into an e-mail that was sent to the base in Madrid.
- The crew entered the speed data after checking the weights, but did not calculate the speeds, in keeping with company procedure.
- The speeds delivered to the crew had been calculated based on the zero fuel weight (ZFW).
- The speeds delivered to the crew were lower than the takeoff speeds applicable based on their takeoff weight (TOW).
- The unusually low values were not noticed by the crew.
- During simulator sessions (conducted not much earlier), the crew had used takeoff speeds similar to those used in the accident.

- The mistakes in the cargo manifest and in the aircraft's weight and balance data were not detected.

- Upon the aircraft's return, the cargo and baggage distribution was verified to match the information contained in the cargo distribution list.

- The operations officer who calculated the takeoff speeds in the OPT had a valid and in force license, had taken the B767-200/300 course and had little experience doing that job at the airline.

- Visibility was good and there was almost no wind.

- The rotation speed provided to the crew was 118 kt, when the actual speed, based on their takeoff weight, was 156 kt.

- According to DFDR information, the rotation was commenced at a speed of 124 kt, 32 kt below the actual speed required to takeoff based on their TOW.

- The aircraft lifted off momentarily as the landing gear lifted off the ground, only to impact again a few seconds later.

- The crew continued to raise the pitch angle, exceeding the limits recommended by the manufacturer to avoid a tailstrike.

- The crew were unable to recognize the aircraft's stall. The stick shaker was activated for a few seconds and the crew did not apply the full stall procedure for a takeoff (disengage autothrust and do not apply more thrust)

- The aircraft model involved in this accident (B767-200) was not designed with a tail bumper to absorb the strike or with a system to warn of a tailstrike, unlike other Boeing models.

- The crew did not realize they exceeded the tailstrike angle and were unaware that the aircraft's structure may have been damaged.

- As a result, the crew did not apply the tailstrike procedure, which requires leveling the aircraft at the lowest safe level and not performing the Cabin Automatic Inoperative procedure.

- Only the cabin crew seated at the rear of the aircraft felt the hard, continuous impact in that area.

- The affected FAs did not inform the purser until the sterile cockpit phase was terminated at 10000 ft.

- The crew continued to climb, unaware that the aircraft has sustained damage.
- The Master Warning- Cabin Altitude Warning- Master Caution were activated in that sequence, as per DFDR data.
- The crew performed the Cabin Automatic Inoperative procedure, instead of the Cabin Altitude procedure.
- The crew did not immediately conduct an emergency descent of the aircraft.
- The passenger oxygen masks were released when the cabin altitude exceeded 14000 ft.
- The crew were unaware of the possible reasons for the constant alerts, and therefore unaware of the risks inherent to a gradual depressurization.
- The crew did not declare an emergency despite a cabin depressurization being explicitly listed in the General Operations Manual.
- From his position, the controller was too far away to see the tailstrike.
- The controller was not advised of the damage to the runway or of the FOD on it until the takeoff of the eighth aircraft after the accident aircraft, which ran over debris that damaged its nose wheel.
- The crew of the previous aircraft of the same company (AEA051) did not identify as FOD what they thought they saw during the rotation until AEA071 reported its damage.
- The aircraft's tail impacted the runway over a distance of 525 meters.
- The inspections of the runways where the aircraft took off and then landed were carried out as per the inspection plan and in response to the incidents reported.
- The airline took actions to ensure a crew composition with more experience by modifying the requirements for assigning crews to aircraft.
- The airline took actions to avoid sending performance information in a format different from the OPT until this software is installed at all its stations.
- The airline took actions to raise the awareness of operations officers on the need to verify the data entered.

- The airline took actions to have crews verify the data they receive against actual operational data, in keeping with Eurocontrol proposals.

- The airline took actions to remind crews of the maximum rotation values for each aircraft type.

- The airline define the instances in which the sterile cockpit can be interrupted, such as when abnormal situations occur in the passenger cabin.

3.2. Causes

The accident occurred because the aircraft started to rotate at a speed that was well below the required rotation speed, which had been incorrectly calculated by the dispatcher using the aircraft's zero fuel weight (ZFW) instead of its takeoff weight (TOW). This error was not detected subsequently by the crew while entering the data into the FMS.

The following factors also contributed to the accident:

- The system for calculating performace data (OPT) had been recently implemented at the airline;

- Both the dispatch officer and the crew members had little experience in this area;

- The airline did not have a station in Madrid with the OPT software installed, meaning there was no procedure in place for sending the information.

4. SAFETY RECOMMENDATIONS

The crew were unable to recognize the aircraft's stall during the takeoff, and as a result they did not properly execute the stall recovery procedure (immediately reduce the pitch angle and do not increase thrust during the takeoff attempt). Since this stall occurred at the most critical moment in the operation, with little time to react, crews should be trained not only on stalls in cruise situations, but particularly in high thrust situations like takeoffs and go around maneuvers.

> REC 28/15 It is recommended that Aeromexico incorporate stall maneuvers in high thrust situations into its flight crew training program so as to ensure that crews are able to recognize these situations and immediately execute the appropriate procedure.

The three FAs located at the rear of the passenger cabin were the only ones who felt the tailstrike, describing it as a hard and continuous impact. Though the procedures contained in the General Operations Manual and in the Flight Attendant's Manual state that the sterile cockpit can be broken when a FA reports information involving abnormal situations in the passenger cabin that could lead to an emergency situation, the FAs waited until the end of the sterile cockpit period before informing the purser. This prolonged the amount of time that the flight crew were unaware of the possibility of structural damage.

> REC 29/15 It is recommended that Aeromexico take the measures required to ensure that proper communications and coordination are established between the flight and cabin crews when presented with any in-flight anomaly, especially during the sterile cockpit phase.

The crew did not declare an emergency even though a cabin depressurization is described as such in the General Operations Manual. Reporting an emergency, whether a MAYDAY or urgency, prepares control and airport personnel for the possible assistance and special services that may be required. In this case, the accident aircraft made an uneventful approach and subsequent landing that did not require any special actions to be taken by any other groups, but crews need to be aware of the advantages of declaring an emergency.

> REC 30/15 It is recommended that Aeromexico take measures to train its crews and make them aware of the different emergency declarations and of the benefit of having specialized personnel standing by during potentially dangerous operations.

Lastly, the cockpit voice recorder was not preserved after the accident, which made it impossible to have information that would have been of great value to the investigation. The General Operations Manual did not explicitly assign responsibility to a crewmember to preserve the information in the recorders following an accident or incident. This violates the applicable European law, which directs the captain to preserve the information on that recorder. The company has already noted that, by virtue of operating in the United Kingdom, Spain and France, the applicable law is Regulation 859/2008 (EU OPS 1).

REC 31/15 It is recommended that Aeromexico take the measures required to inform those crews that fly to Europe of the specific European regulation, especially that pertaining to the preservation of recorders after an accident or serious incident.

5. APPENDICES

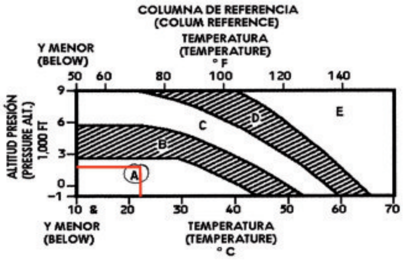
APPENDIX A

TAKEOFF PERFORMANCE TABLES

RENDIMIENTOS
PERFORMANCE

MANUAL DE DESPACHO 767-200
DISPATCH MANUAL

VELOCIDADES DE DESPEGUE
TAKEOFF SPEEDS
FLAPS 15



AJUSTES A LA V1 POR PENDIENTE Y VENTO (SLOPE/WIND V1 ADJUSTMENT)										
PESO (WEIGHT) 1,000 Kg	PENDIENTE (SLOPE) % ABAJO DN			ARRIBA UP		VIENTO (WIND) KTS COLA TAIL			FRENTE HEAD	
	-2	-1	0	1	2	-10	0	10	20	30
180	-2	-1	0	3	5	-1	0	0	1	1
160	-2	-1	0	2	4	-1	0	0	1	1
140	-2	-1	0	2	3	-1	0	0	1	1
120	-1	-1	0	1	2	-2	0	0	1	1
100	-1	-1	0	1	2	-3	0	0	1	1

P&W 4060

FLAPS	PESO (WEIGHT) 1,000 Kg	A			B			C			D			E		
		V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2	V_1	V_R	V_2
	180	155	160	165	158	162	165									
	178	154	159	164	157	161	164									
	176	152	158	163	155	160	163									
	174	151	156	162	154	158	162									
	172	149	155	161	152	157	161									
	170	148	154	160	151	156	160	154	158	160						
	168	147	153	159	150	155	159	153	157	159						
	166	146	151	158	149	154	158	152	156	158						
	164	145	150	157	147	152	157	150	154	157						
	162	144	148	156	146	151	156	149	153	156						
	160	143	147	155	145	150	155	148	152	155						
	158	142	146	154	144	149	154	147	151	154						
	156	141	145	153	142	147	153	145	149	153						
	154	139	144	152	141	146	151	144	148	151						
	152	138	143	151	139	144	150	142	146	150						
	150	137	142	150	138	143	149	141	145	149	145	148	149			
	148	136	141	149	137	142	148	140	144	148	144	147	148			
	146	134	140	148	136	141	147	139	143	147	142	145	147			
	144	133	138	148	135	139	147	137	141	146	141	144	146			
	142	131	137	147	134	138	146	136	140	145	139	142	145			
15	140	130	136	146	133	137	145	135	139	144	138	141	144	142	143	144
	138	129	135	145	132	136	144	134	138	143	137	140	143	140	142	143
	136	128	133	144	131	135	143	133	137	142	136	139	142	139	141	142
	134	126	132	143	129	133	142	131	135	141	134	137	140	137	139	140
	132	125	130	142	128	132	141	130	134	140	133	136	139	136	138	139
	130	124	129	141	127	131	140	129	133	139	132	135	138	134	137	138
	128	123	128	140	126	130	139	128	132	138	131	134	137	132	136	137
	126	122	127	139	124	129	138	126	131	137	129	132	136	129	134	136
	124	120	125	138	123	127	137	125	129	136	128	131	135	127	133	134
	122	119	124	137	121	126	136	123	128	135	126	129	134	124	131	133
	120	118	123	136	120	125	135	122	127	134	125	128	133	122	130	132
	118	116	122	135	119	124	134	121	126	133	124	127	132	122	129	131
	116	115	120	134	117	122	133	119	124	132	122	125	131	122	128	130
	114	113	119	133	116	121	132	118	123	131	121	124	130	122	126	129
	112	112	117	132	114	119	131	116	121	130	119	122	129	122	125	128
	110	110	116	131	113	118	130	115	120	129	118	121	128	122	124	127
	108	109	115	130	111	117	129	114	119	128	117	120	127	120	123	126
	106	107	113	129	110	115	128	112	117	127	115	119	126	119	121	125
	104	106	112	128	108	114	127	111	116	126	114	117	125	117	120	124
	102	104	110	127	107	112	126	109	114	125	112	116	124	116	118	123
	100	103	109	126	105	111	125	108	113	124	111	115	123	114	117	122

Si V1 cae en el área sombreada comprobar contra $V_{1(MCG)}$
(CHECK $V_{1(MCG)}$ IN SHADED AREA)

$V1_{MCG}$

TEMPERATURA (ACTUAL OAT)		ALTITUD PRESIÓN PIES (PRESS ALT FT)				
°C	°F	0	2,000	4,000	6,000	8,000
50	122	112	108			
40	104	119	114	110	105	101
30	86	121	117	112	108	103
20	68	122	119	115	111	106
10	50	122	119	115	112	108
0 Y MENOR & BELOW	32 Y MENOR & BELOW	123	120	116	112	109

VREF

PESO (WEIGHT) 1,000 Kg	FLAPS 30	25	20
180	173	170	177
170	166	165	171
160	158	160	166
150	150	155	160
140	145	149	154
130	139	144	148
120	134	138	142
110	128	132	136
100	122	126	129

AJUSTE DEL ESTABILIZADOR (STAB TRIM)

PESO (WEIGHT) 1,000 Kg	C.G. % CAM (MAC)						
	12	16	20	24	28	32	36
	UNIDADES DE AJUSTE (TRIM UNITS)						
180	7	7	6	5	4 1/2	3 1/2	2 1/2
170	7	7	6	5	4	3	2
160	7	6 1/2	5 1/2	4 1/2	3 1/2	2 1/2	2
150	6 1/2	5 1/2	4 1/2	4	3	2	1
140	6	5	4	3 1/2	2 1/2	1 1/2	1/2
130	5 1/2	4 1/2	4	3	2	1	1/2
120	5	4 1/2	3 1/2	2 1/2	2	1	1/2
110	5	4	3	2 1/2	1 1/2	1/2	1/2
100	4	3 1/2	2 1/2	2	1	1/2	1/2

3-3-36
01-JAN-11

AEROMEXICO

REV 01/11

APPENDIX B

COMMUNICATIONS BETWEEN AIRCRAFT AND ATC[59]

[59] Held in Spanish language

TAKEOFF

12:55:48	TWR	AMX002?
12:55:51	AMX002	Go ahead.
12:55:53	TWR	AMX002, good afternoon. Are you ready?
12:55:55	AMX002	Can we have 30 seconds to initiate... for the IRS, please?
12:56:01	TWR	Yes, of course. Call back when ready. Thanks.
12:56:04	AMX002	Will do, thanks.
12:56:33	AMX002	AMX002, ready now for takeoff.
12:56:37	TWR	AMX002, line up and wait 36L.
12:56:42	AMX002	Line up and wait 36L, AMX002.
12:57:44	TWR	AMX002, wind 270/03. Cleared for takeoff 36L.
12:57:49	AMX002	Cleared for takeoff 36L, AMX002.
12:59:28	TWR	AMX002, 31 175.
12:59:31	AMX002	31 175, thanks.
Other communications		
13:25:58	TWR	051, wind 150/05. Cleared for takeoff 36L.
13:26:02	AEA051	Cleared for takeoff 36L, AEA051.
Other communications		
13:28:26	TWR	AEA071, wind 150/03. Cleared for takeoff 36L
13:28:31	AEA071	Cleared for takeoff 36L, AEA071.
13:30:00	TWR	AEA071, 3117. Good bye.
13:30:02	AEA071	31 17. We thought we saw a piece of rubber on... on the runway, just before rotating. Uh, uh, uh... it's pretty big, in the center of the runway.
13:30:10	TWR	Roger, thank you.
13:30:43	TWR	Barajas, PAPA7
13:30:45	PAPA7	PAPA7, yes, the traffic that just took off from 36L reported seeing a large piece of rubber on the runway. Can you go there and check it out?
Other communications		
13:32:19	AEA051	Madrid tower, AEA051.
13:32:21	TWR	Go ahead.
13:32:26	TWR	AEA051?
13:32:27	AEA051	Yes, hello. AEA051. We took off 5 minutes ago and we think we saw a piece of metal or... in the last quarter of the runway, when we were rotating. In about the final 3000 ft of the runway. Something green.
13:32:46	TWR	Yes, the traffic behind you also reported it. We're doing an inspection now. Thank you.
Communications concerning FOD found on runway 36L		

CLIMB- DESCENT

Communications with aircraft		
13:08.26	AMX002	… CONTROL AMX002
13:08.29	LECM	GO AHEAD
13:08.32	AMX002	… WE'RE GOING TO REMAIN AT ONE SEVEN THOUSAND, WE HAVE A SLIGHT PROBLEM HERE, GIVE US ABOUT THREE MINUTES
13:08.40	LECM	VERY WELL, NO PROBLEM. THANK YOU
Coordination between sectors		
13.08.49	SCTR/WNN	FROM THE WEST NORTH
13.08.53	SCTR/ZML	HELLO, GO AHEAD
13.08.54	SCTR/WNN	YES, HELLO, THE AEROMEXICO EN ROUTE TO ZAMORA TOLD ME THEY'RE GOING TO HOLD ABOUT THREE MINUTES AT ONE SEVEN ZERO, THEY HAVE A PROBLEM. I'LL KEEP IT FOR NOW UNLESS YOU WANT IT.
13:09.02	SCTR/ZML	PERFECT, GREAT, THANK YOU.
Communications with aircraft		
13:09.29	AMX002	… WE CAN LEAVE ONE SEVEN THOUSAND FEET NOW, ... 002
13:09.34	LECM	ROGER, THANKS
Coordination between sectors		
13:10:34	SCTR/WNN	WITH YOU NOW.
Communications with aircraft		
13:11.05	AMX002	MADRID, AMX002, GOOD AFTERNOON AT ONE NINE THOUSAND SEVEN HUNDRED.
13:11.12	LECM	AMX002 GOOD AFTERNOON, RADAR CONTACT, CONTINUE CLIMBING TO FL290.
13:11.23	AMX002	TWO NINE ZERO, UH… CAN WE HOLD AT ONE NINE ZERO FOR NOW? WE HAVE A PROBLEM IN THE COCKPIT.
13:11.29	LECM	YES, AFFIRMATIVE, YOU CAN HOLD AT ONE NINE ZERO, NO PROBLEM.
13:11.33	AMX002	ONE NINE ZERO, AMX002.
Coordination between sectors		
Communications with aircraft		
13:12:51	AMX002	MADRID, AMX002.
13:12:54	LECM	AMX002 GO AHEAD.
13:12:56	AMX002	(GARBLED) ZERO THOUSAND FEET WE HAVE A PRESSURIZATION PROBLEM. WILL HOLD AT THIS POSITION.
13:13:05	LECM	AMX002 ROGER, I UNDERSTAND YOU ARE HOLDING AT LEVEL ONE NINE ZERO, CORRECT?
13:13:12	AMX002	REQUEST TO DESCEND TO ONE ZERO THOUSAND, AMX002.
13:13:17	LECM	ROGER, ONE SECOND... DESCEND TO FL130.
13:13.22	AMX002	ONE THREE ZERO, AMX002

13:14:00	LECM	AMX002 DESCEND TO FL110, THAT'S THE MINIMUM FOR THE AIRWAY.
13:14:06	AMX002	ONE ONE ZERO, MINIMUM FOR THE AIRWAY, AMX002. WE'RE IN A HOLDING PATTERN RIGHT NOW, IS THAT OK?
13:14:16	LECM	AMX002 AFFIRMATIVE. TO WHICH SIDE, TO THE LEFT?
13:14:21	AMX002	TO THE RIGHT.
13:14:25	LECM	VERY WELL, ROGER, THANKS, AT YOUR DISCRETION.
13:14:32	AMX002	COPY, TO THE RIGHT.
13:14:34	LECM	TO THE RIGHT AT FL110, THANK YOU.
Coordination between sectors		
Communications with aircraft		
13:16:55	LECM	AMX002, MADRID? DO YOU ANTICIPATE RETURNING TO MADRID?
13:17:02	AMX002	UH… YES, LOOK, WE'RE GOING TO... WE HAVE A PROBLEM WITH THE CABIN PRESSURE CONTROLLERS, NEITHER OF THEM IS WORKING. (GARBLED) THE MASKS AND WE HAVE TO RETURN TO, TO LAND. NOTHING MORE. GIVE US A LITTLE TIME TO CHECK THE LANDING WEIGHT TO RETURN TO MADRID.
13:17:21	LECM	CORRECT, VERY WELL. NO PROBLEM. CONFIRM WHEN YOU CAN SO I CAN GIVE YOU INSTRUCTIONS.
13:17:26	AMX002	…ECT WE'RE HOLDING HERE.
Coordination between sectors to transfer communications from the ZML sector to the West Northwest (WNN) sector		
13:19:12	LECM	AMX002, MADRID?
13:19:14	AMX002	GO AHEAD PLEASE.
13:19:17	LECM	PLEASE CALL MADRID RADAR ON ONE ONE EIGHT DECIMAL FOUR. THEY KNOW YOU'RE RETURNING TO MADRID AND THAT YOU WANT TO HOLD FOR NOW TO BURN FUEL. REPORT WHEN READY AND THEY'LL GIVE YOU INSTRUCTIONS TO LAND AGAIN IN MADRID. GOOD BYE.
13:19:35	AMX002	THANK YOU, HAVE A GOOD DAY AND THANK YOU VERY MUCH.
13:19:37	LECM	THANK YOU, HOPE EVERYTHING GOES WELL.
Problems establishing communications on the frequency provided. Actions to establish contact.		
13:31:07 Communications with aircraft (crew are given information on runway in use, 32L, and approach instructions)		
13:36:58 Communications with aircraft (crew are given information on change to runway in use, 18R, and approach instructions)		
Communications with various sectors to coordinate the holding pattern and fuel burn of l AEA071		
13:42:05	AMX002	MADRID AMX002
13:42:10	LECM	AMX002 CALLING?
13:42:12	AMX002	YES, CORRECT, ONE ONE THOUSAND, REQUEST TO START DESCENT
13:42:15	LECM	AMX002 AT THIS TIME WE ARE CHANGING TO THE SOUTH CONFIGURATION, EXPECT RUNWAY 18… R

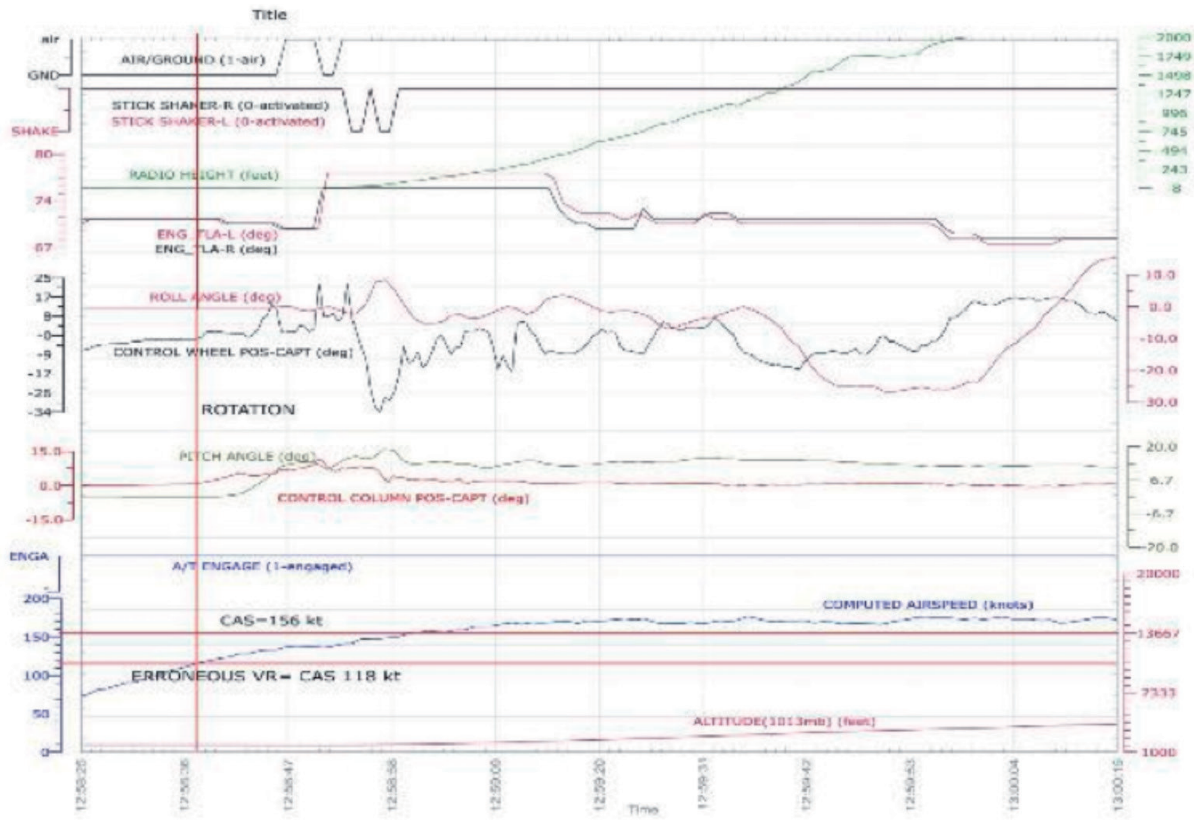
13:42:29	AMX002	… 18R AND CAN WE START OUR DESCENT?
13:42:10	LECM	NO, HOLD ELEVEN THOUSAND UNTIL TAKEOFFS COMPLETE. HOLD OVER EREMA… 002
13:42:36	AMX002	HOLDING PATTERN OVER EREMA, WE'RE ALREADY PAST EREMA. SHOULD WE GO BACK FROM OUR CURRENT POSITION?
13:42:42	LECM	NO, YOU CAN HOLD OVER YOUR POSITION, YOU CAN HOLD OVER YOUR POSITION, START A THREE SIX ZERO TO YOUR LEF... TO YOUR RIGHT, AND YOU CAN... IT'LL BE ONE OR TWO THREE SIX ZEROS BEFORE YOU CAN PROCEED.... WITH THE APPROACH
13:42:55	AMX002	OK, RIGHT-HAND HOLDING PATTERN AND CURRENT POSITION AMX002
13:48:50	LECM	AMX002 EXPECT RUNWAY 18L DUE TO PROBLEMS ON 18R
13:48:57	AMX002	18L AMX002
Remaining messages contain no new instructions involving the clearance to descend and make ILS approach.		

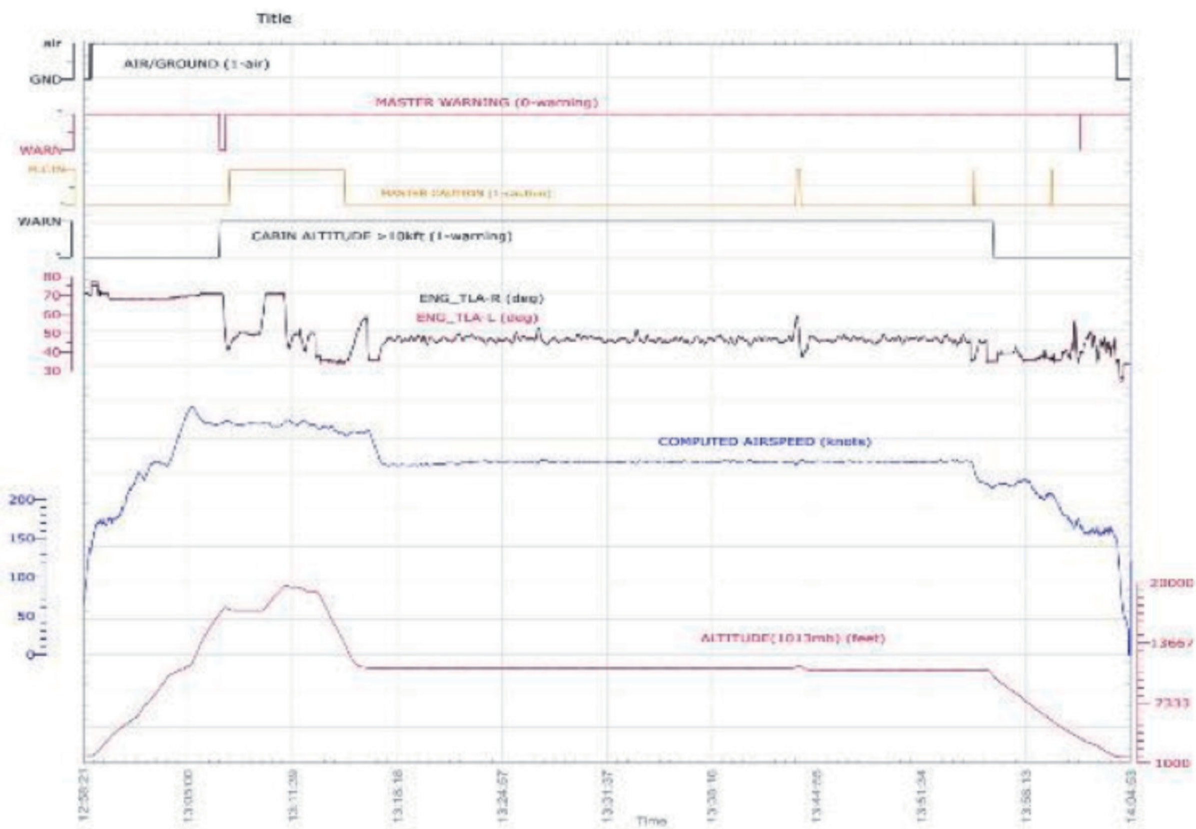
LANDING

14:01:55	AMX002	Barajas tower. AMX002, final 18L
14:02:00	TWR	AMX002, good afternoon. Verify gear down and locked. Winds calm. Cleared to land 18L.
14:02:08	AMX002	Cleared to land 18L, AMX002
Remaining messages irrelevant, aircraft en route to parking, crew informed of damage to fuselage.		

APPENDIX C

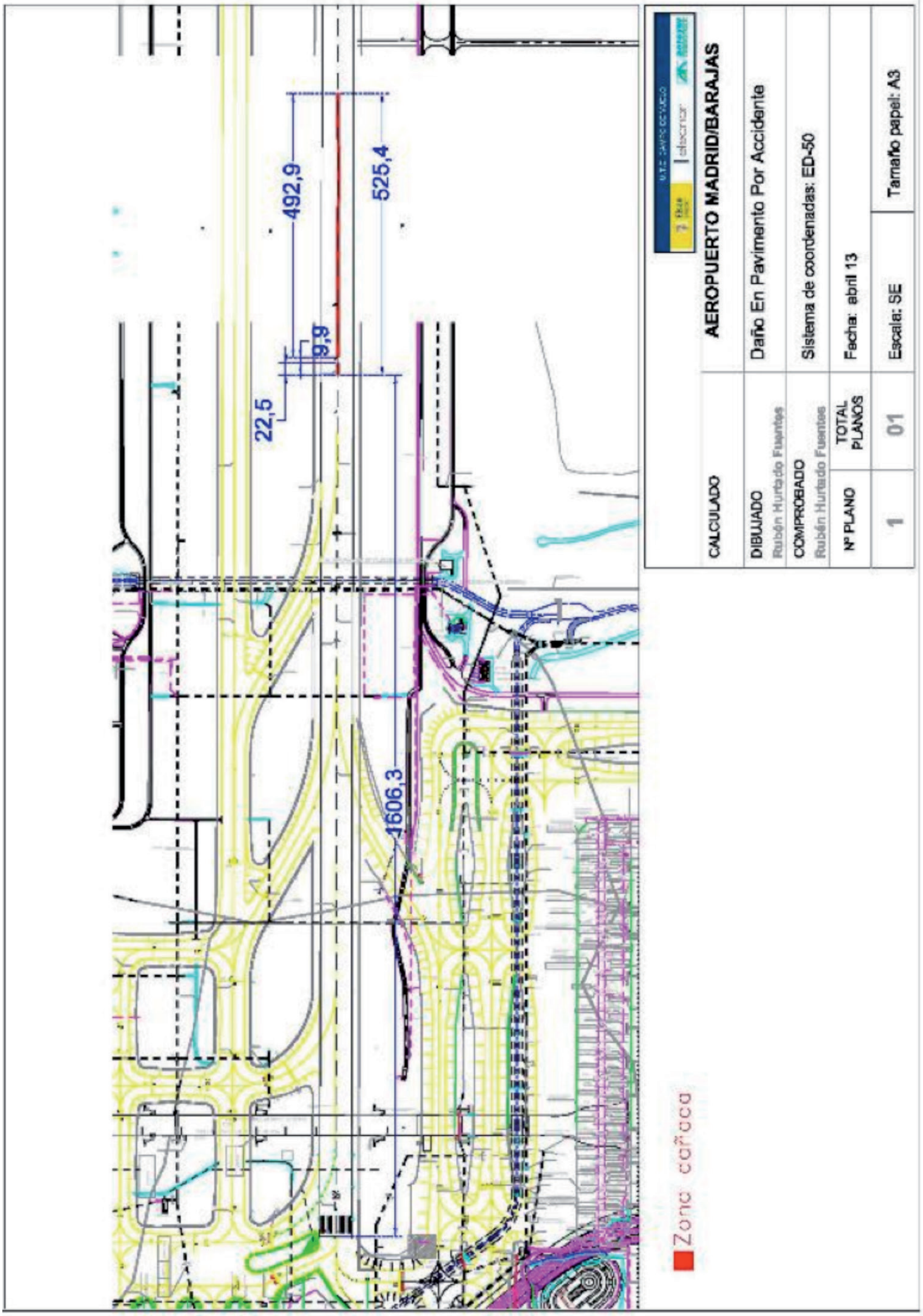
GRAPHS OF DFDR PARAMETERS


Title
AIR/GROUND (1-air)
STICK SHAKER-R (0-activated)
STICK SHAKER-L (0-activated)
RADIO HEIGHT (feet)
ENG_TLA-L (deg)
ENG_TLA-R (deg)
ROLL ANGLE (deg)
CONTROL WHEEL POS-CAPT (deg)
ROTATION
PITCH ANGLE (deg)
CONTROL COLUMN POS-CAPT (deg)
A/T ENGAGE (1-engaged)
COMPUTED AIRSPEED (knots)
CAS=156 kt
ERRONEOUS VR= CAS 118 kt
ALTITUDE(1013mb) (feet)
Time


Title
AIR/GROUND (1-air)
MASTER WARNING (0-warning)
CABIN ALTITUDE >10kft (1-warning)
ENG_TLA-R (deg)
ENG_TLA-L (deg)
COMPUTED AIRSPEED (knots)
ALTITUDE(1013mb) (feet)
Time

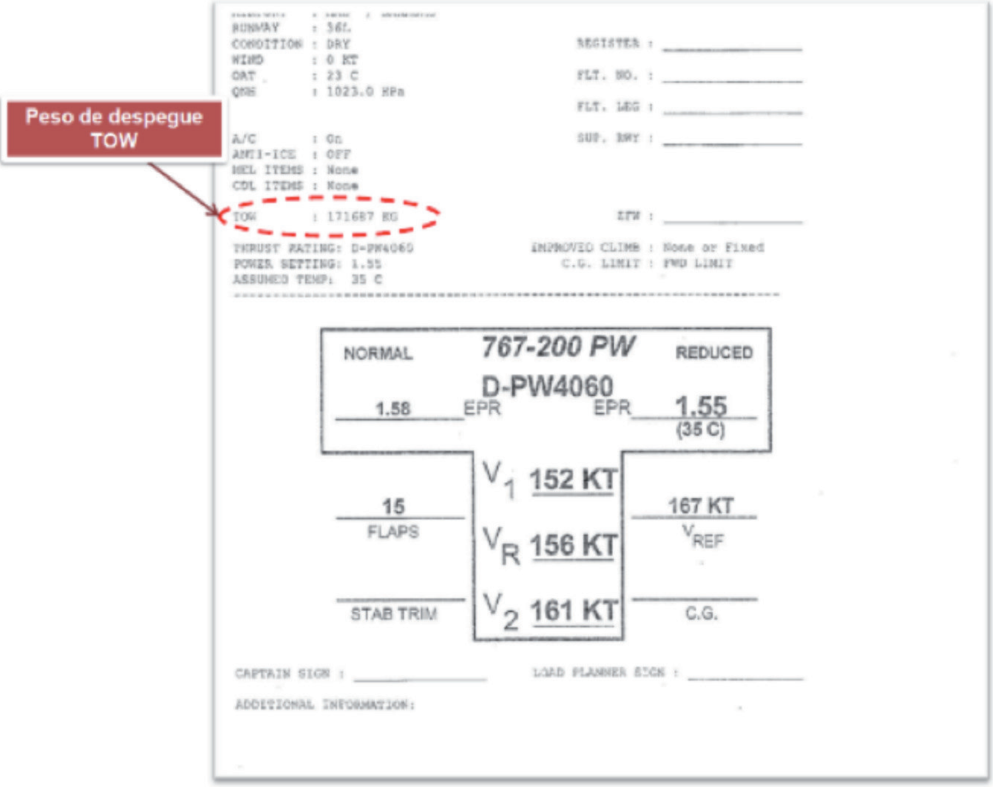
APPENDIX D

AREA OF RUNWAY DAMAGED DURING TAILSTRIKE EVENT


492,9
525,4
9,9
22,5
1606,3
Zona dañada
AEROPUERTO MADRID/BARAJAS
CALCULADO
DIBUJADO
Rubén Hurtado Fuentes
COMPROBADO
Rubén Hurtado Fuentes
Nº PLANO
1
TOTAL PLANOS
01
Daño En Pavimento Por Accidente
Sistema de coordenadas: ED-50
Fecha: abril 13
Escala: SE
Tamaño papel: A3

APPENDIX E

T-FORMAT OPT CALCULATIONS FOR TOW AND ZFW



RUNWAY : 36L
CONDITION : DRY
WIND : 0 KT
OAT : 23 C
QNH : 1023.0 HPa

REGISTER : ___
FLT. NO. : ___
FLT. LEG : ___
SUP. RWY : ___

A/C : On
ANTI-ICE : OFF
MEL ITEMS : None
CDL ITEMS : None

TOW : 171687 KG

ZFW : ___

THRUST RATING: D-PW4060
POWER SETTING: 1.55
ASSUMED TEMP: 35 C

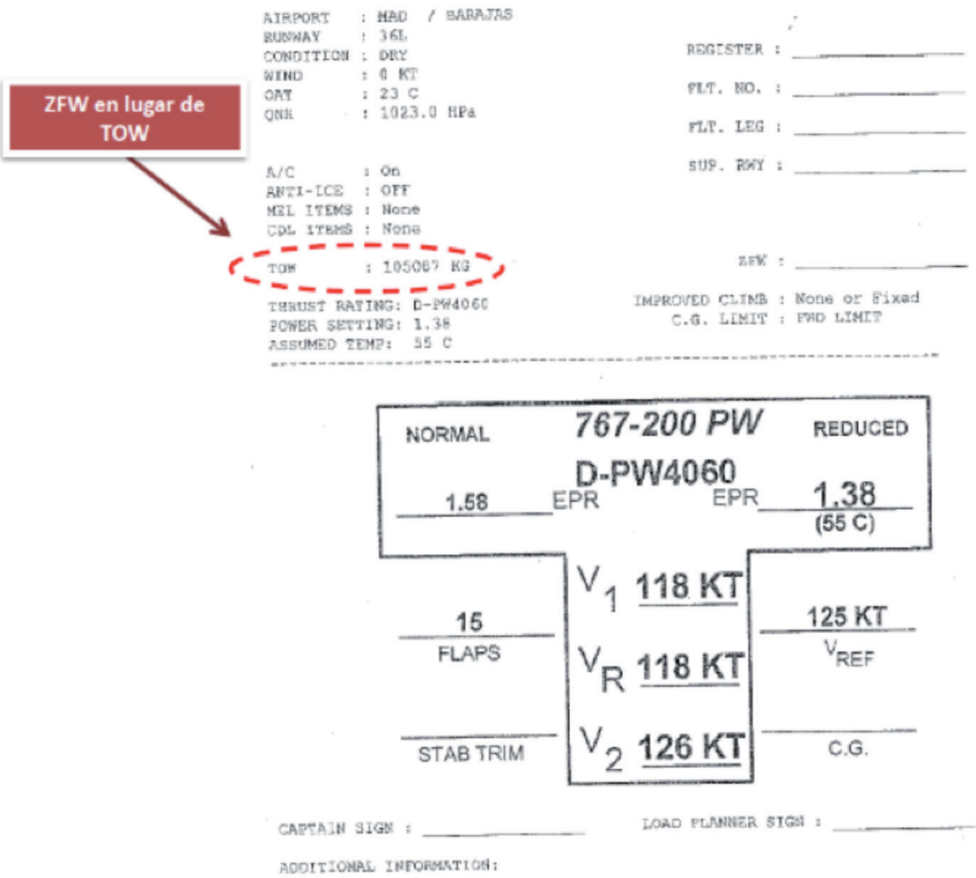
IMPROVED CLIMB : None or Fixed
C.G. LIMIT : FWD LIMIT

767-200 PW
D-PW4060

NORMAL		REDUCED
1.58 EPR		EPR 1.55 (35 C)
15 FLAPS	V_1 152 KT	167 KT V_{REF}
	V_R 156 KT	
STAB TRIM	V_2 161 KT	C.G.

CAPTAIN SIGN : ___
LOAD PLANNER SIGN : ___

ADDITIONAL INFORMATION:



AIRPORT : MAD / BARAJAS
RUNWAY : 36L
CONDITION : DRY
WIND : 0 KT
OAT : 23 C
QNH : 1023.0 HPa

REGISTER : ___
FLT. NO. : ___
FLT. LEG : ___
SUP. RWY : ___

A/C : On
ANTI-ICE : OFF
MEL ITEMS : None
CDL ITEMS : None

TOW : 105087 KG

ZFW : ___

THRUST RATING: D-PW4060
POWER SETTING: 1.38
ASSUMED TEMP: 55 C

IMPROVED CLIMB : None or Fixed
C.G. LIMIT : FWD LIMIT

767-200 PW
D-PW4060

NORMAL		REDUCED
1.58 EPR		EPR 1.38 (55 C)
15 FLAPS	V_1 118 KT	125 KT V_{REF}
	V_R 118 KT	
STAB TRIM	V_2 126 KT	C.G.

CAPTAIN SIGN : ___
LOAD PLANNER SIGN : ___

ADDITIONAL INFORMATION:

APPENDIX F

QRH PROCEDURES

Non-Normal Checklist

767 Air Systems

Quick Reference Handbook

CABIN ALT

CABIN ALTITUDE or Rapid Depressurization

CABIN ALTITUDE

Messages: CABIN ALTITUDE

Condition: A cabin altitude exceedance occurs.

1 Don the oxygen masks.

2 Establish crew communications.

3 Check the cabin altitude and rate.

4 **If** the cabin altitude is uncontrollable:

PASS OXYGEN switch .... Push and hold for 1 second

Without delay, descend to the lowest safe altitude or 10,000 feet, whichever is higher.

To descend:

Move the thrust levers to idle

Extend the speedbrakes

If structural integrity is in doubt, limit airspeed and avoid high maneuvering loads.

Descend at VMO/MMO

XA-APB, XA-MAT

Caution! Speedbrakes may automatically retract to the "50%" position when airspeed exceeds 320 KIAS. If this occurs, do not extend speedbrake lever beyond the "50%" position until airspeed is less than 315 KIAS.

■ ■ ■ ■

REV 01/12 AEROMEXICO 2-1 01-APR-12

Non-Normal Checklist

767 Air Systems

Quick Reference Handbook

AUTO INOP

CABIN AUTOMATIC INOPERATIVE

Messages: CABIN AUTO INOP

Condition: One of these occurs:

- The automatic pressurization control is failed.
- The cabin altitude mode selector is on manual.

1 CABIN ALTITUDE MODE SELECT....................................MAN

2 CABIN ALTITUDE
MANUAL control....................Move to CLIMB or DESCEND as needed to control cabin rate and altitude

Note: Recommended cabin rate is approximately 500 FPM for climbs and descents.

Recommended cabin altitude in cruise is:

FLIGHT LEVEL	CABIN ALTITUDE
Up to 230	Land File Elevation
260	2000
300	4000
350	6000
400 and above	8000

3 **Checklist Complete Except Deferred Items**

Continued on the next page

Non-Normal Checklist

767 Air Systems

Quick Reference Handbook

▼ CABIN AUTOMATIC INOPERATIVE continued ▼

Deferred Items

Descent Checklist

Pressurization .... LDG ALT ___

Recall...Checked

Autobrake ....___

Landing data .... VREF ___, Minimums ___

Approach briefing ....Completed

Approach Checklist

Altimeters ....___

When at pattern altitude

CABIN ALTITUDE
MANUAL control.............................Hold in CLIMB until the outflow valve indication shows fully open to depressurize the airplane

Landing Checklist

Speedbrake.. ARMED

Landing gear...Down

Flaps...____

■ ■ ■ ■

▼ **Tail Strike continued** ▼

6 Do **not** accomplish the following checklist:

CABIN AUTOMATIC INOPERATIVE

■ ■ ■ ■

Non-Normal Checklist

767 **Miscellaneous**

Quick Reference Handbook

Tail Strike

Condition: The tail hits the runway.

Caution! Do not pressurize the airplane due to possible structural damage.

1 Cabin altitude MODE SELECT....................................MAN

2 CABIN ALTITUDE
MANUAL control............................Hold in CLIMB until the outflow valve indication shows fully open to depressurize the airplane

3 Level off at the lowest safe altitude.

4 Plan to land at the nearest suitable airport.

XA-JBC, XA-MAT, XA-TOJ

5 Choose one:

◆ Climb above 11,000 feet is **not needed**:

▸▸ **Go to step 6**

◆ Climb above 11,000 feet is **needed**:

PACK control selectors (both)............................OFF

This ensures cabin will remain depressurized when outflow valve closes automatically at 11,000 feet.

Do **not** accomplish the following checklist:

PACK OFF

▸▸ **Go to step 6**

▾ **Continued on the next page** ▾

Approach to Stall or Stall Recovery

All recoveries from approach to stall should be done as if an actual stall has occurred.

Immediately do the following at the first indication of stall (buffet or stick shaker).

Note: *Do not use flight director commands during the recovery.*

PILOT FLYING	PILOT MONITORING
Initiate the recovery: ♦Hold the control column firmly. ♦Disconnect autopilot and autothrottle. ♦Smoothly apply nose down elevator to reduce the angle of attack until buffet or stick shaker stops. Nose down stabilizer trim may be needed.*	♦Monitor altitude and airspeed. ♦Verify all required actions have been done and call out any omissions. ♦Call out any trend toward terrain contact.
Continue the recovery: ♦Roll in the shortest direction to wings level if needed.** ♦Advance thrust levers as needed. ♦Retract the speedbrakes. ♦Do not change gear or flap configuration, except ♦During liftoff, if flaps are up, call for flaps 1.	♦Monitor altitude and airspeed. ♦Verify all required actions have been done and call out any omissions. ♦Call out any trend toward terrain contact. ♦Set the FLAP lever as directed.
Complete the recovery: ♦Check airspeed and adjust thrust as needed. ♦Establish pitch attitude. ♦Return to the desired flight path. ♦Re-engage the autopilot and autothrottle if desired.	♦Monitor altitude and airspeed. ♦Verify all required actions have been done and call out any omissions. ♦Call out any trend toward terrain contact.

The Approach to Stall or Stall Recovery maneuver calls for the crew to advance the thrust levers as needed. Under certain conditions, where high thrust settings are already applied such as during takeoff or go-around, it may be necessary to reduce thrust in order to prevent the angle of attack from continuing to increase. This is because airplanes with underwing-mounted engines have a nose-up pitch moment relative to increased thrust.

APPENDIX G

REGULATIONS ON FLIGHT RECORDERS

Section 6.3.4 of Annex 6, Flight Recorders - General, specifies the following:

> 6.3.4.2 Operation
>
> 6.3.4.2.1 Flight recorders shall not be switched off during flight time.
>
> 6.3.4.2.2 To preserve flight recorder records, flight recorders shall be de-activated upon completion of flight time following an accident or incident. The flight recorders shall not be re-activated before their disposition as determined in accordance with Annex 13.

According to European regulation EU-OPS (EU-OPS 1.085):

> f) The commander shall:
>
> 10. not permit:
>
> (i) a flight data recorder to be disabled, switched off or erased during flight nor permit recorded data to be erased after flight in the event of an accident or an incident subject to mandatory reporting.
>
> (ii) a cockpit voice recorder to be disabled or switched off during flight unless he/she believes that the recorded data, which otherwise would be erased automatically, should be preserved for incident or accident investigation nor permit recorded data to be manually erased during or after flight in the event of an accident or an incident subject to mandatory reporting.

According to the applicable regulation in Spain, EU OPS, OPS 1.085, Crew responsibilities, the commander:

> 10) shall not permit:
>
> i) any flight data recorder to be disabled or switched off, or permit the data recorded on it during or after the flight to be erased, in the event of an accident or incident subject to mandatory reporting.
>
> ii) a cockpit voice recorder to be disabled or switched off during flight unless he/she believes that the recorded data, which otherwise would be erased automatically, should be preserved for incident or accident investigation, nor permit recorded data to be manually erased during or after flight in the event of an accident or an incident subject to mandatory reporting.

Part 1 of ICAO Annex 6 states in Chapter 3 that:

> 3.1 Compliance with laws, regulations and procedures
>
> 3.1.1 An operator shall ensure that all employees when abroad know that they must comply with the laws, regulations and procedures of those States in which operations are conducted.
>
> 3.1.2 An operator shall ensure that all pilots are familiar with the laws, regulations and procedures, pertinent to the performance of their duties, prescribed for the areas to be traversed, the aerodromes to be used and the air navigation facilities relating thereto. The operator shall ensure that other members of the flight crew are familiar with such of these laws, regulations and procedures as are pertinent to the performance of their respective duties in the operation of the aeroplane.

The information in Chapter 10 of the General Operations Manual, International Operations, states the following:

> European law currently has no regulations equivalent to FAR 129 for foreign operators, nor do the countries in which Aeromexico operates issue operating specifications.
>
> Operating in European airspace requires observing:
>
> - ICAO Annex 6
> - The operating requirements and procedures published in this manual and in the Jeppesen manual, by way of special revisions, for operations applicable to European airspace, such as: European RVSM, communications with 8.33 kHz spacing, B-RNAV, Category II/III, ACAS II, communications failure, and others.
> - The noise requirements at the Madrid and Charles de Gaulle airports when executing SID procedures, which must be meticulously observed to avoid flying over noise-sensitive areas and the associated fines for the Company.
> - Any other requirement that may be specified by the European aviation authority.