CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A-032/2008

Accident involving a McDonnell Douglas DC-9-82 (MD-82) aircraft, registration EC-HFP, operated by Spanair, at Madrid-Barajas Airport, on 20 August 2008

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MINISTERIO DE FOMENTO

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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) n° 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1, 4 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

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

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

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Abbreviations

00°	Sexagesimal degrees
00 °C	Degrees centigrade
AAIB	Air Accidents Investigation Branch (United Kingdom)
AC	Advisory Circular
ACAS	Airborne Collision Alerting System
ACC	Area Control Center
ACOB	Air Carriers Operations Bulletin
AD	Airworthiness Directive
ADF	Automatic Direction Finder
AENA	Aeropuertos Españoles y Navegación Aérea
AEP	Aviation Emergency Plan
AESA	Spain’s Aviation Safety Agency
AFM	Aircraft Flight Manual
AFMC	Advanced Flight Management Computer
AIP	Airport Improvement Program
AMC	Acceptable Means of Compliance
AMM	Aircraft Maintenance Manual
AMT	Aviation Maintenance Technician
AOA	Angle Of Attack
AOC	Air Operator Certificate
AOG	Aircraft On Ground
AOL	All Operators Letter
AOO	Airport Operations Office
AP	Autopilot
APU	Auxiliary Power Unit
AQS	Aviation Quality Sources
ARR	Arrivals
ART	Automatic Reserve Thrust
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATLB	Aircraft Technical Log Book
ATOS	Air Transportation Oversight System
ATOW	Actual Takeoff Weight
ATPL (A)	Air Transport Pilot License (Airplane)
ATS	Auto-Throttle System
BITE	Built-In Test Equipment
CAA	Civil Aviation Authority (United Kingdom)
CAME	Continuing Airworthiness Management Exposition
CAMO	Continuing Airworthiness Management Organization
CAS	Calibrated Air Speed
CAST	Commercial Aviation Safety Team
CAWS	Central Aural Warning System
CDL	Configuration Deviation List
CDU	Control Display Unit
CECOP	Madrid Fire Department’s Operational Control Center for Emergencies
CG	Center of Gravity
CIAIAC	Civil Aviation Accident and Incident Investigation Commission
CLD	Clearance. ATC Service at Madrid-Barajas. Frequency for Clearances
CPL (A)	Commercial Pilot License (Airplane)
CPS	Central Processing Station
CRM	Crew Resources Management
CRS	Certificate Release to Service
CTIP	Control Tower Integrated Position
CV	Control Vehicle

Abbreviations

CVR	Cockpit Voice Recorder
CWY	Clearway
DADC	Digital Air Data Computer
DEP	Departures. ATC Service at Madrid-Barajas. Frequency for Takeoff Control
DFDR	Digital Flight Data Recorder
DFGC	Digital Flight Guidance Computer
DFGS	Digital Flight Guidance System
DME	Distance Measuring Equipment
DOW	Dry Operation Weight
DGAC	Spain’s Civil Aviation General Directorate
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitoring
EDG	Engine Driven Generator
EFIS	Electronic Flight Instrument System
EGPWS	Enhanced Ground Proximity Warning System
EICAS	Engine Indicating and Crew Alerting System
EO	Engineering Order
EOAP	Electronic Overhead Annunciator Panel
EPR	Engine Pressure Ratio
FA	Flight Attendant
FAA	Federal Aviation Administration
FC	Flight Cycle
FCOM	Flight Crew Operation Manual
FDAU	Flight Data Adquisition Unit
FDM	Flight Data Monitoring
FH	Flight Hours
FI	Flight Instructor
FIM	Fault Isolation Manual
FIV	Fast Intervention Vehicle
FOEB	Flight Operations Evaluation Board
FOQA	Flight Operations Quality Assurance
FOR	Flight Operation Report
FSC	Flight Safety Committee
FSQB	Flight Safety Quality Board
FTSD	Fault Tolerant System Design
GND	Ground. ATC Service at Madrid-Barajas. Frequency for taxiing.
GPWS	Ground Proximity Warning System
h	Hour(s)
HIL	Hold Item List
Hz	Hertz
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IESA	Iniciatives Empresarials Aeronautiques
IFR	Instrument Flight Rating
ILS	Instrumental Landing System
INTA	Instituto Nacional de Técnica Aerospacial (National Institute for Aerospace Technology)
IOSA	IATA Operator Safety Audit
IRU	Inertial Reference Unit
JAA	Joint Aviation Authorities
JAR-OPS	Joint Aviation Regulations
kt	Knot(s)
LCD	Liquid Crystal Display
LEMD	ICAO code for Madrid-Barajas airport
LH	Left Hand
LIR	Load Instruction Report

Abbreviations

LOAS	Line Operations Assessment System
LOSA	Line Operations Safety Audit
m	Meter(s)
MAC	Mean Aerodynamic Chord
MAD	IATA (International Air Transport Association) code for Madrid-Barajas Airport
MCC	Maintenance Control Center
MEL	Minimum Equipment List
METAR	Aviation routine weather report
MICU	Mobile Intensive Care Units
MIN	Maintenance Information Notice
MLG	Main Landing Gear
MMEL	Master Minimum Equipment List
MOE	Maintenance Organization Exposition
MRBR	Maintenance Review Board Report
MTOW	Maximum Takeoff Weight
NASA	National Aeronautics & Space Administration
N/A	Not available /Not applicable
NTSB	National Transportation Safety Board
NTSC	National Transportation Safety Committee
O	Operations
OAC	Observation and Alarm Center
OM	Operations Manual
OPS	Operations
P	Both pilots
PCU	Power Control Unit
PF	Pilot flying
PNF	Pilot Not Flying
POI	Principal Operation Inspector
PPL (A)	Private Pilot License (Airplane)
PSPS	PostStall Pusher System
PTR	Practice Training Recurrence
PSEU	Proximity Switch Electronic Unit
P/N	Part Number
QAR	Quick Access Recorder
QNH	Atmospheric Pressure (Q) at Nautical Height
RAM	Random Access Memory
RAT	Ram Air Temperature
RESA	Runway Extreme Safety Area
RFFS	Rescue and Firefighting Services
RH	Right Hand
RNP	Required Navigation Performance
RSA	Release to Service Authorization
SAFA	Safety Assessment for Foreign Aircraft
SAFO	Safety Alert for Operators
SAMUR	Madrid's Municipal Assistance Emergency and Rescue Services
SANA	Safety Assessment for National Aircraft
SAS	Scandinavian Airlines
SB	Service Bulletin
SDP	System Display Panel
SENASA	Servicios y Estudios para la Navegación Aérea y la Seguridad Aeronáutica
SEP	Surveillance & Evaluation Program
SFE	Synthetic Flight Examiner
SIB	Service Information Bulletin
SIF	Stall Indicator Failure
SMS	Safety Management System

Abbreviations

SOP	Standard Operating Procedures
SSA	System Safety Assessments
SUMMA	Madrid's Emergency Medical Services
TAT	Total Air Temperature
TCAS	Traffic Collision Avoidance System
TEM	Threat and Error Management
TLB	Technical Log Book
TOWS	Takeoff Warning System
TRE	Type Rating Examiner
TRI	Thrust Rating Indicator
TRP	Thrust Rating Panel
TRIM	Elevator trim
TRS	Thrust Rating System
TRTO	Type Rating Training Organization
TSM	Troubleshooting Manual
TWR	Control Tower
T/O	Take-Off
USOAP	Universal Safety Oversight Audit Program
UTC	Universal Time Coordinated
V	Volt
WDM	Wiring Diagram Manual
VHF	Very High Frequency
VIA	Versatile Integrated Avionics
VOR	VHF Omnidirectional Range
WDM	Wiring Diagram Manual
WO	Working Order
WOW	Weight On Wheels

Synopsis

Operator:	Spanair
Aircraft:	McDonnell Douglas DC-9-82 (MD-82); registration EC-HFP
Date and time of accident:	20 August 2008; at 14:24 h[1]
Accident site:	Madrid-Barajas Airport (Spain)
Persons onboard and injuries:	172 (6 crew & 166 passengers); 154 fatal (6 crew & 148 passengers) & 18 seriously injured
Type of flight:	Commercial Air Transport – Regular – Domestic – Passengers
Phase of flight:	Takeoff – Takeoff run
Date of approval:	26 July 2011

Summary of accident

The Civil Aviation Accident and Incident Investigation Commission was notified of the accident at 14:43 on 20 August 2008 by means of a telephone call placed from the Airport Operations Office (AOO) at Barajas Airport. A team consisting of six investigators, as well as the President of the Commission, immediately proceeded to Barajas.

In keeping with international regulations, the NTSB of the United States of America was notified as the representative of the State of design and manufacture of the aircraft. Also informed were national civil aviation authorities, the European Aviation Safety Agency (EASA) and the International Civil Aviation Organization (ICAO). The NTSB appointed an accredited representative to participate in the investigation, assisted by experts from the NTSB, the FAA, Boeing, as successor of the rights and obligations of the original aircraft manufacturer, and from Pratt & Whitney, the engine manufacturer. Spanair, the operator of the aircraft, participated in and cooperated with the investigation, providing experts on operations, airworthiness and maintenance. Spain's DGAC and the Aviation Safety Agency[2], as well as the European Aviation Safety Agency, also collaborated in supplying information and were kept apprised of the more important aspects of the investigation.

[1] Unless otherwise specified, all times in this report are local times in the Spanish mainland. To obtain UTC, subtract two hours from local time. The local time in the Canary Islands is one hour less than in the mainland.

[2] Spain's civil aviation authority is comprised jointly by the Civil Aviation General Directorate (DGAC) and Spain's National Aviation Safety Agency (AESA).

The investigation has determined that the accident occurred because:

The crew lost control of the airplane as a consequence of entering a stall immediately after takeoff due to an improper airplane configuration involving the non-deployment of the slats/flaps following a series of mistakes and omissions, along with the absence of the improper takeoff configuration warning.

The crew did not identify the stall warnings and did not correct said situation after takeoff. They momentarily retarded the engine throttles, increased the pitch angle and did not correct the bank angle, leading to a deterioration of the stall condition.

The crew did not detect the configuration error because they did not properly use the checklists, which contain items to select and verify the position of the flaps/slats when preparing the flight. Specifically:

- They did not carry out the action to select the flaps/slats with the associated control lever (in the "After Start" checklist);
- They did not cross check the position of the lever or the status of the flaps and slats indicating lights when executing the "After Start" checklist;
- They omitted the check of the flaps/slats when doing the "Takeoff Briefing" in the "Taxi" checklist;
- During the visual check performed as part of the "Final Items" in the "Takeoff Imminent" checklist, the actual position of the flaps/slats as shown on the cockpit instruments was not verified.

The CIAIAC has identified the following contributing factors:

- The absence of a takeoff configuration warning resulting from the failure of the TOWS to operate, which thus did not warn the crew that the airplane's takeoff configuration was not appropriate. The reason for the failure of the TOWS to function could not be reliably established.
- Improper crew resource management (CRM), which did not prevent the deviation from procedures in the presence of unscheduled interruptions to flight preparations.

As a result of the investigation, 33 recommendations on operational safety have been issued to the International Civil Aviation Organization (ICAO), the Federal Aviation Administration (FAA) of the United States, the European Aviation Safety Agency (EASA), Spain's Aviation Safety Agency (AESA), the provider of airport and air navigation services in Spain, AENA (Spanish Airports and Air Navigation), and to the operator, Spanair, as appropriate.

1. FACTUAL INFORMATION

1.1. History of the flight

On 20 August 2008, in the flight preceding the accident flight, the aircraft, a McDonnell Douglas DC-9-82 (MD-82), registration EC-HFP, departed Barcelona early in the morning en route to Madrid in what was the first leg scheduled for that day. The accident flight crew had arrived at the operator's offices in Barcelona Airport at around 08:00 and, along with the cabin crew, held the pre-flight briefing. The airplane took off from Barcelona at 08:55, arriving in Madrid at 10:13. The flight was uneventful and no abnormalities were reported in the Aircraft Technical Logbook (ATLB).

Upon arriving in Madrid, the flight crew exited the airplane. The aircraft was then scheduled at 13:00 as estimated departure time with the same crew that had flown the previous leg. It was the scheduled flight JKK5022, a passenger transport flight from Madrid-Barajas airport to Gran Canaria airport, located on the island of the same name.

At 13:06:18 the aircraft contacted Control via the frequency for Clearance Departures East (CLD-E), requesting permission for start-up. Once authorized to start its engines, the crew contacted South-North Ground Control (GND South-North) at 13:10:18 to start taxiing. The DFDR started to record data at 13:13:57[3].

The aircraft left stand T21 at the Barajas T2 Terminal and taxied via taxiway MIKE. At 13:19:47, the aircraft switched to the frequency for Central-South Ground (GND C-South) so as to continue taxiing to point ROMEO1 (R1).

At 13:24:45, the aircraft contacted Control on the 36L Departure (DEP) frequency, reporting that they were approaching point ROMEO1. At 13:24:57, once they were ready for takeoff, Control (DEP) stated: *SPANAIR 5022, WIND 150 06, CLEARED FOR TAKEOFF RUNWAY 36 LEFT*.

At 13:25:03, the aircraft acknowledged the ATC clearance, only to call back at 13:26:27 to report: *MADRID SPANAIR 5022, LOOK, WE HAVE A SLIGHT PROBLEM, WE HAVE TO EXIT THE RUNWAY AGAIN*. ATC (DEP) authorized them to exit the runway and asked if they intended to return to parking. The crew reported that they would contact ATC again once off the runway as soon as they received word from the company's technical services. The crew had detected an abnormally high Ram Air Temperature (RAT) probe reading. The DFDR data indicated that when the recording started as the aircraft started to taxi[4], the RAT probe temperature was 56 °C, and it kept rising until it reached

[3] One of the design conditions specified for the installation of the DFDR on this airplane is that it start recording as soon as the parking brake is released and that it stop when it is engaged.
[4] At 13:13:57, as already indicated.

104 °C. It is known that the captain established contact via cell phone[5] with the operator's Maintenance Control Center (MCC), located at its headquarters in Palma de Mallorca, to request guidance and information regarding the problem. According to testimony given by MCC personnel, they gave the captain instructions to reset breaker Z-29 several times, which the captain replied he had already done. MCC then advised the crew to obtain assistance from maintenance in Barajas.The conversation between the aircraft and the MCC lasted about two minutes, as estimated by MCC personnel. After this, MCC contacted the maintenance shift manager at Barajas to inform him that the airplane was returning to the stand due to an overheating RAT probe. Simultaneously, the crew communicated via radio on the operations frequency with Spanair's ground assistance agent to request maintenance services. The agent received the crew's request and contacted the operations department at the company's headquarters in Palma de Mallorca, which authorized replacing the aircraft, since another was available, in case it was necessary to declare the aircraft they were using AOG (Aircraft on Ground)[6]. The agent then informed the crew that the replacement of the aircraft had been authorized, but the crew decided to wait until maintenance reported on the scope of the malfunction.

At 13:29:00, the DFDR recording was interrupted once more, probably when the crew engaged the airplane's parking brake. At that time, the aircraft was on taxiway ZW1. At 13:33:12, the crew contacted ATC (DEP) again to report that they had to return to parking. The DFDR recording resumed at 13:33:47. The aircraft taxied back, establishing contact on the various ground frequencies until it reached its assigned stand, R11, a remote parking position in the T2 apron, at which it arrived at approximately 13:42.

The DFDR recording was interrupted again at 13:42:50. The flap deflection parameter remained at 11° throughout the DFDR recording periods, from the start of the taxi sequence until the return to the stand. The RAT probe temperature reading during the taxi back to the apron was 104 °C.

Two maintenance technicians (AMT) reported to the airplane. After being informed of the problem by the crew, the maintenance technicians proceeded to make an entry in the ATLB. The captain asked them if they had received any calls from the Maintenance Control Center (MCC) in Palma de Mallorca, to which they replied no, since they did not have a mobile phone, only radios.

A visual check of the probe by the maintenance technicians did not reveal any abnormalities. One of the maintenance technicians then used the ice protection meter

[5] Among the cockpit's equipment, Spanair included a cellular phone. According to information provided by the company, many pilots used their own cellular phones to contact maintenance services. It was not possible to determine which phone the captain used to talk to the MCC department.

[6] AOG: Aircraft On Ground.Expression used when an airplane is grounded for technical or other reasons.

selector and heat switch[7] to ensure that the RAT probe heating circuit was energized, which confirmed the malfunction.

CVR information became available starting at 13:51:22. The conversation being held in the cockpit at that time involved the use of dry ice to lower the temperature of the probe. The CVR recorded the voices of the crew, the maintenance technicians and other people who were entering and leaving the cockpit, such as the purser and another Spanair captain who was traveling onboard.

At 13:51:48, the captain remarked on their significant delay and noted that they had to log everything that had occurred. At 13:53:21, he asked the purser if it was hot in the passenger cabin, which she confirmed.

The maintenance technician checked Chapter 30.8 of the Minimum Equipment List (MEL) and saw that the airplane could be dispatched with the probe heating inoperative as long as icing conditions were not forecast for the flight. At 13:54:02, the maintenance technician called his shift supervisor on the handheld radio to request his concurrence. The shift supervisor also consulted the MEL. The maintenance technician finally proposed to the captain that the airplane be dispatched with breaker Z-29 pulled so as to disconnect the electrical supply to the RAT probe heater. The captain agreed.

Once this breaker was pulled, an "inoperative" label was placed on the RAT display. Once the maintenance technicians checked to make sure no current was being drawn, the appropriate entries were made in the ATLB to indicate that the maintenance was deferred as a category C[8] in accordance with item 30.8 of the MEL. The pre-flight maintenance inspection was completed and the airplane was declared "release for service"[9].

At 13:54:34, the CVR recorded a comment by the first officer regarding how they could not do a flex takeoff[10].

At 13:57:47, the first officer initiated a private telephone conversation on his cellular telephone in which he reported to the other person that they were still in Madrid, that they will have a delay and that as a result they would have to change their plans.

[7] The ice protection meter selector and heat switch for measuring current and supplying heat to the static tubes, the captain's and first officer's pitot tubes, the temperature probe, the rudder pitot tube and the angle of attack transducers are located in the overhead panel. It is a rotary switch that supplies current to all of the heating elements when in any position except OFF. The anti-ice heaters anenometer is located adjacent to the selector switch and provides an indication of the current in each heating circuit as selected.

[8] Royal Decree 1762/2007 of 28 December, which defines the usage requirements for the MMEL/MEL in Spain, establishes four categories for determining the maximum amount of time that an inoperative item can go unrepaired. Category C items must be corrected within 10 calendar days, excluding the day the item is found.

[9] An airplane is certified release for service on the CRS maintenance certificate.

[10] A flex (flexible) takeoff is one of the modes that can be selected on the automatic Thrust Rating System (TRS). This mode is used to reduce engine wear on takeoffs when permitted by conditions.

At 13:59:29, a third person, who was a Spanair flight attendant traveling in the jump seat to Las Palmas, was heard asking the crew about the malfunction, specifically, whether "*the relay had been replaced*", to which the first officer replied that it had been pulled, this surprised this person. They then talked again about using dry ice to cool the probe. The third cockpit occupant then remarked that the probe temperature would climb again, to which the first officer replied in the negative since they had pulled "*the push button*" [11].

At 14:02:36, after requesting that an announcement be made to the passengers, the captain exited the airplane to personally oversee the refueling operation.

At 14:07:02, the first officer requested permission from ATC to start the engines. The transmission was made on the GND frequency instead of the clearance delivery (CLD) frequency. After tuning in to the proper frequency, the aircraft received the appropriate clearance from ATC at 14:08:08.

At 14:08:43, the crew started the "Prestart" and "Before Start" checklists. One of the crew was heard saying "BELOW THE LINE"[12]. The captain anticipated some of the items on the "Before Start" checklist before they were read by the first officer[13]. At 14:09:01 the engine start sequence was commenced, during which the crew discussed whether or not to conduct a manual takeoff. At 14:12:08, once the engines were started, the "After Start" checklist was performed. The item to check the flaps/slats was omitted because coincident with that point, the captain asked the first officer to request permission from ATC to start taxiing to runway 36L. While they waited for said clearance, they calculated the thrust (EPR) required. A value of 1.95 was heard on the CVR. They once again discussed the option of doing the takeoff with manual or automatic thrust.

At 14:14:23, the captain contacted ATC (GND) once more to request taxi to the runway, asking if they could obtain an estimate in the delay before they could start taxiing. They were told there was no delay and given instructions to taxi to the runway 36L holding point. At 14:14:33, the parking brake was released in preparation for taxi, at which point the DFDR started recording again. From the start of the taxi sequence until the end of the recording, the flaps deflection reading indicated 0°.

At 14:15:56, the crew read the "Taxi" checklist. The captain's reply to the first officer's reading of the last item on the checklist (Takeoff briefing) could not be heard on the CVR. During the taxi, conversations were held in the cockpit among the pilots and the third person who was traveling in the jumpseat.

[11] The first officer is believed to have used the term "push button" to refer to the Z-29 circuit breaker.
[12] See Section 1.17.1.3.2. Before Takeoff Checklists for MD80 series airplanes, for an explanation of this expression.
[13] According to the airline's operating procedures, on the ground the checklists are read by the first officer and performed by the captain. The items anticipated by the captain were: seat belts, doors, anticollision and cabin report.

At 14:18:14, the first officer once more noted that autothrottle would not work.

At 14:19:08, the aircraft once more contacted ATC (DEP) on the 36L departure frequency to report that they were near point ROMEO5. ATC informed them they were in line and that they would call back right away.

At 14:21:05, ATC (DEP) radioed: "SPANAIR 5022 NEXT IN LINE BEHIND AIRLINE MD80, TAXI INTO POSITION AND HOLD RUNWAY 36L". The aircraft acknowledged the communication. ATC cleared the aircraft for takeoff immediately afterwards.

At 14:22:06 two chimes were heard on the CVR, used by the purser to indicate to the pilots that the passenger cabin is ready for takeoff. The first officer performed the "Takeoff Imminent" checklist, reading all of the items on the checklist, which the captain verified. On the CVR recording the first officer can be heard reading the final items on the checklist, saying: "FINAL ITEMS, WE HAVE, SORRY, EIGHT, ELEVEN, ALIGNED, ELEVEN, STOWED...". He then discussed again the possibility of engaging the autopilot immediately after takeoff.

At 14:23:09, following the takeoff of the aircraft directly ahead of them, ATC (DEP) informed: "SPANAIR 5022, WIND 210 05, CLEARED FOR TAKEOFF, RUNWAY 36 LEFT". The crew acknowledged at 14:23:14, saying: "CLEARED 36 LEFT SPANAIR UHHHH 5022".

At 14:23:10, the engine throttles were advanced followed by the release of the brakes at 14:23:19.

At 14:23:29, an EPR value of 1.4 was reached. At 14:23:31, the crew commented that the autothrottle system was not working and that they had to do a manual takeoff. Nine seconds later EPR was at 1.95.

During the takeoff run, the SIXTY, ONE HUNDRED, V1, POWER CHECK and ROTATE[14] callouts were heard. At the time of the V1 callout, the speed[15] recorded on the DFDR was 154 KCAS. At ROTATE it was 157 KCAS.

At 14:24:10, the DFDR recorded the change from ground mode to air mode in the ground sensing system on the nose wheel. The approximate length of the takeoff run was 1950 m.

Throughout the takeoff run and until the end of the CVR recording, no sounds were recorded emanating from the Takeoff Warning System (TOWS).

At 14:24:14, the stall warning stick shaker activated, as well as the horn and synthetic voice warning of an aerodynamic stall. The first officer said "ENGINE FAILURE" in a

[14] Voice in English that identifies the rotation speed on takeoff.
[15] Unless otherwise specified, the speed values shown are calibrated airspeed (CAS).

questioning voice and a second later, at 14:24:15, the captain asked in a very loud voice how to turn off the warning voice. At that time the speed was 168 KCAS and they were at a radio altitude of 25 ft, a pitch angle of 15.5° and a right bank angle of 4.4°.

The right bank angle increased to a maximum of 20°, at which time there was a change in the position of the throttle levers of about 4° in the left and 32° in the right in the direction of reduced thrust that lasted one second. As a result, the EPR dropped two seconds later to a value of around 1.65 in both engines. A corresponding change in engine parameters was also observed. The throttles were immediately moved to their maximum thrust positions, resulting in EPR values of around 2.20. These values remained constant until the end of the recording.

From that moment on the "bank angle" warning was heard coming from the Enhanced Ground Proximity Warning System (EGPWS), as was the alternating horn and voice stall warning in the cockpit: "[horn] stall, [horn] stall, [horn] stall", which sometimes sounded over the EGPWS warning. The stall warning stick shaker remained active until the first impact with the ground.

At 14:24:19, the maximum pitch angle (18.3°) and radio altitude (40 ft) values were reached.

At 14:24:24, the initial impact with the ground was heard, resulting in a vertical acceleration of 3.17 g's. At that instant the aircraft's recorded attitude was a pitch of 10.4° and a right bank of 5.3°. The speed was 154 KCAS.

At 14:24:30 the DFDR flight data recording finished.

At 14:24:36, an aircraft reported to ATC GND C-South tower frequency that there had just been an accident.

The aircraft was destroyed as a result of the impact with the ground and of the ensuing fire.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal	6	148	154	
Serious	1	18	18	
Minor				Not applicable
None				Not applicable
TOTAL	**6**	**166**	**172**	

Among the deceased, 135 were Spanish nationals and 19 were citizens of other countries. As for the survivors, 16 were from Spain and 2 were of other nationalities.

1.3. Damage to aircraft

The aircraft was destroyed as a result of the impact and subsequent fire.

1.4. Other damage

The main damage was from the fire that broke out after the aircraft's impact with the ground and which was limited to surrounding grass, trees and shrubs. A total area of some 45 Ha was burned.

1.5. Personnel information

1.5.1. *Cockpit crew*

1.5.1.1. Captain

1.5.1.1.1. *General information*

The captain, 39 years of age, had an airline transport pilot license (ATPL(A)) that was issued on 26 September 2000, and a Class 1 medical certificate valid until 30 August 2009.

He had obtained his private pilot license (PPL(A)) on 24 April 1995 and his commercial captain license (CPL(A)) on 4 May 1998. He held DC-9/MD-80/90 and IFR ratings, valid until 27 October 2008.

He had served in Spain's Air Force, having been assigned to the Air Force's 801st rescue squadron in April 1991, where, as a Captain, he was a flight instructor and test captain of CASA 212 aircraft.

He joined Spanair on 10 June 1999. He did his theoretical and simulator training portions for the MD-aircraft type rating at the Delta Airlines training center in Atlanta (United States). The base training and line training phases were done at Spanair. He obtained his first MD-80 rating on 14 September 1999, after which he flew as a first officer in the MD-80 fleet starting on 2 December 1999.

He became an MD-80 theory instructor on 27 February 2001. On 3 October 2005, he started his captain's training, which he finished on 7 February 2006. The reports of his tests, simulator sessions and line training indicate he was an above-average pilot. After the captain's course, during the simulator training he did in October 2006 to renew his rating, some notes were written down about the necessity of improving his CRM skills, specifically demanding him more coordination and rapport with the other pilot. Notes made during a subsequent training session indicated an improvement in this area, acknowledging his proper application of CRM concepts.

Throughout 2006 and until February 2007 he flew as a first officer even though he was rated at both piloting positions. His first flight as a captain was delayed for reasons of seniority within the company until 24 February 2007.

1.5.1.1.2. *Flight, duty and rest hours*

The captain had a total of 8476 flight hours, of which approximately 2700 had been while he was in the Air Force. He had a total experience of 5776 h on the MD.

He had flown 3118 h as a captain, of which 1996 had been in the Air Force and 1122 as a captain in Spanair MD aircraft.

The captain's flight and duty hours[16] over the last year, as well as the rest hours prior to the accident flight, were as follows:

Period	Flight time (hours:minutes)	Duty time (hours:minutes)
Last 12 months	659:00	N/A
Last 90 days	182:45	N/A
Last 30 days	56:37	102:27
Last 7 days	21:14	24:15
Last 24 hours	1:18	2:13

Start of duty time on 20 August 2008: 08:00.

Rest prior to start of duty: 32:30 h.

On 20 August 2008, the captain was scheduled to fly Barcelona-Madrid-Las Palmas-Madrid, going on duty at 08:00 and finishing at 19:20[17].

[16] The definitions of flight, duty and rest times are in the operational regulations for commercial air transportation, OPS 1, Subpart Q, Flight and Duty Time Limitations and Rest Requirements of Commission Regulation (EC) No. 8/2008 of December 2007, which went into effect on 16 July 2008.

[17] As per EU-OPS 1, Subpart Q of Commission REGULATION (EC) No. 8/2008 of 11 December 2007, the maximum duty period is 13 hours, which may be extended by 1 hour.

1.5.1.1.3. *Last recurrent training completed*

The captain's training records show that the most recent training he completed had been as follows:

- Operator's proficiency check[18]: 11 August 2008.
- Ground training: 07 July 2008
- Winter and low visibility operations recurrent: 20 September 2007
- Crew resource management (CRM): 03 October 2007
- Emergency procedures: 10 April 2008
- Practice Training Recurrent (PTR): 10 April 2008
- Dangerous goods: 10 September 2007
- Security procedures: 16 September 2005

1.5.1.1.4. *Additional information*

The captain was married and had three daughters. He had been based out of Barcelona since his promotion to captain, though his normal residence was in Palma de Mallorca. This situation had worried him for some time until he received benefits[19] from the company that guaranteed him that after each rotation, the company would provide him housing in Barcelona or pay for his travel expenses to his residence in Palma de Mallorca.

Crewmembers who knew the captain describe him as being disciplined, precise and meticulous in his job, someone who adhered to procedures rigorously.

Another first officer stated that he took his job very seriously and preferred to stay in Barcelona to sleep instead of returning to Palma if he had to fly the next day.

His colleagues reported during interviews that "he was the kind of pilot who asked for flaps", meaning he specifically commanded the first officer to select the suitable flaps deflection on the control handle once the area around the airplane was clear during pre-flight operations.

1.5.1.1.5. *Seventy-two hours before the flight*

On 16 August 2008, the captain flew the Palma de Mallorca-Belfast-Reus rotation. The next day, 17 August 2008, he flew the Barcelona-Jerez-Bilbao routes. The first officers

[18] The operator's proficiency check is a type of periodic check whose purpose is to demonstrate the competence of flight crew personnel in carrying out normal, abnormal and emergency procedures (Commission REGULATION (EC) No. 8/2008 of 11 December 2007, Appendix III, Paragraph OPS 1.965).
[19] This type of work benefit is known in airline slang as "commuting".

who flew with him on those days did not report anything out of the ordinary on the flights.

On 18 August, he flew the Bilbao-Athens-Barcelona route with the first officer from the accident flight. On 19 August he rested and slept in Barcelona. He was seen having breakfast in the hotel on the morning of the day of the accident before he left for the airport.

On 20 August, he was taken to the airport in a transport service provided by the company. During the drive to the airport he was talking to another pilot he knew about that day's schedule. That captain did not notice anything out of the ordinary.

He arrived at the company's airport office at 08:00 and met with the rest of the crew. They held the dispatch briefing in the office and then proceeded to the airplane.

After the Barcelona-Madrid leg, the captain, first officer and the rest of the crew left the airplane and went to the company's office in Terminal 2 at Barajas. The captain talked with several colleagues. They reported that he was in good spirits and that he did not mention any problems with the airplane.

1.5.1.2. First officer

1.5.1.2.1. *General information*

The first officer, 31 years of age, had a commercial pilot license (CPL(A) that was issued on 16 July 2001, and a Class 1 Medical Certificate valid until 11 July 2009, which noted that he had to wear corrective lenses for distance vision. He held DC-9-MD-80/90 and IFR ratings, both valid until 25 March 2009.

He had received his commercial pilot training at SENASA[20], completing it in 2001. He then took a flight instructor course which resulted in his obtaining an FI rating, which he had not maintained. For a while, he gave classes to FA's at the SENASA school in Salamanca.

When he finished his pilot training he tried to find a job in various companies, but to no avail. Job offers for pilots were scarce at the time. He was finally hired by Spanair in February 2007. His previous flight experience was 220 h.

[20] SENASA (Servicios y Estudios para la Navegación Aérea y la Seguridad Aeronáutica, S.A.) is a public company attached to the Ministry of Development that provides, among other services, aviation training for air traffic controllers, pilots, air navigation maintenance and engineering technicians, communications technicians and air navigations operations technicians.

After joining the company he took the MD fleet rating course at the Flight Academy of Scandinavian Airlines (SAS) from 5 February to 25 March 2007. He obtained his type rating on 29 March 2007. He then took the operator's conversion course before starting his unsupervised line flights. His initial line training was scheduled to last 150 h. After completing 185 h, his instructor proposed that it be expanded by 30%[21], which the company approved.

According to his instructors, his progression in the MD type rating course and line training, including the expanded line training hours, were considered normal for someone with his previous flight experience.

He had his first line check in August 2007, the result of which was unsatisfactory. The evaluator's report noted that he had deviated from the capture altitude and from the selected approach speed while flying with the autopilot disengaged and thrust in manual. He completed additional line training and passed the line check on 2 September 2007. The results of the refresher training conducted later at the company were within Spanair standards.

1.5.1.2.2. *Flight, duty and rest hours*

The first officer had a total of 1276 flight hours, of which 1054 had been on the MD.

The first officer's flight and duty hours over the last year, as well as the rest hours prior to the accident flight, were as follows:

Period	Flight time (hours:minutes)	Duty time (hours:minutes)
Last 12 months	838:14	N/A
Last 90 days	255:32	N/A
Last 30 days	99:01	158:25
Last 7 days	26:39	37:39
Last 24 hours	1:18	2:13

Start of duty time on 20 August 2008: 08:00.

Rest prior to start of duty: 32:30 h.

On 20 August 2008, the first officer was scheduled to fly Barcelona-Madrid-Las Palmas-Madrid, going on duty at 08:00 and finishing at 19:20.

[21] Spanair guidelines specify that whenever the flight time initially specified for completing a given training phase is exceeded by 30%, the instructors must request an extension.

1.5.1.2.3. *Last recurrent training completed*

The first officer's training records show that the most recent training he completed had been as follows:

- Operator's proficiency check: 17 July 2008
- Ground training: 15 January 2008
- Winter and low visibility operations recurrent: 20 April 2008
- Crew resource management (CRM): 05 March 2008
- Emergency procedures: 12 February 2008
- Practice Training Recurrent (PTR): 12 February 2008
- Dangerous goods: 11 June 2007
- Security procedures: 13 April 2007

1.5.1.2.4. *Additional information*

The first officer was single and his girlfriend lived in Salamanca. He operated out of Barcelona, where he shared an apartment with co-workers from Spanair, though he was from Palma de Mallorca, where his parents resided. In his free time he normally went to Salamanca to be with his girlfriend.

At the time of the accident the company was laying off personnel, which the first officer knew would affect him. He planned to find another job and keep flying.

He was interested in obtaining his airline transport pilot license before leaving the company, which is why he was flying as much as possible. In the last month he had flown 99 hours.

Pilots who had flown with him describe him as a serious and disciplined pilot who was polite and who made an effort to collaborate. They specifically noted how much he loved to fly and how happy he was to have the chance to do so.

1.5.1.2.5. *Seventy-two hours before the flight*

On 16 August 2008, the first officer flew the Reus-Belfast-Palma de Mallorca rotation. The next day, 17 August 2008, he flew the Bilbao-Barcelona-Alicante-Barcelona-Bilbao routes. The pilots who flew with him on those days did not report anything out of the ordinary on the flights.

On 18 August, he flew the Bilbao-Athens-Barcelona route with the captain from the accident flight. On 19 August he rested. He was in Barcelona the entire day and had dinner at his home. He went to bed at around 22:00.

On 20 August he drove to the airport in his car. He met the rest of the crew in the company's office at Barcelona Airport. When they arrived in Madrid after the first flight of the day, he went with the rest of the crew to the company's office, where he talked with the office manager. They talked about the company's situation and about possible alternatives when he was laid off.

At the end of the August 20 rotation, the first officer had planned to vacation with his girlfriend in Palma de Mallorca for a few days. When the aircraft returned to the stand following the first taxi sequence, he telephoned her from the cockpit to inform her of their delay. At that moment she was traveling from Salamanca to Madrid.

1.5.2. *Flight attendants*

There were four flight attendants (FA) onboard the airplane (1 purser and three assistants). They all had valid licenses and ratings for the aircraft type as well as valid medical certificates.

All four FAs had received periodic training within the time frames established by the company. This training included a theory and a practical part. The theory part involved knowledge of emergency equipment and procedures, pilot incapacitation, evacuation procedures, crowd control techniques, security procedures, crew resource management, health and medicine. The practical training consisted of doing emergency drills.

1.5.3. *Maintenance technicians*

1.5.3.1. AMT 1 (Aviation Maintenance Technician - Madrid)

Male, 46 years of age.

He held a Part 66 B1.1 license (Mechanical, turbine airplanes), valid until 26 July 2011, applicable to the following aircraft types: Airbus A319/A320/A321 (V2500 engines) and McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines).

He joined Spanair on 2 November 1999 and had aircraft maintenance experience since March 1999.

Over the course of his career he had taken a total of 37 aircraft maintenance courses, seven of which included human factors as they relate to aircraft maintenance.

When he joined Spanair, the company provided him with training on "Logbook Procedures" and on the "Organization and Maintenance Procedures Manual".

He had taken an annual course on "Organization Procedures and Maintenance Quality System" since December 2006.

1.5.3.2. AMT 2 (Aviation Maintenance Technician - Barcelona)

Male, 25 years of age.

He held a Part 66 B1.1 license (Mechanical, turbine airplanes), valid until 24 January 2013, applicable to the following aircraft type: McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines).

He joined Spanair on 19 April 2004, at which time he had no previous aviation maintenance experience.

Over the course of his career he had taken a total of two courses on the DC-9-80, neither of which included training in human factors as they relate to aviation maintenance. He also received no training in the company's maintenance procedures.

1.5.3.3. AMT 3 (Aviation Maintenance Technician - Madrid)

Male, 41 years of age.

He held a Part 66 B1.1 license (Mechanical, turbine airplanes) and B.2. (Avionics), valid until 13 January 2011, applicable to the following aircraft types: Airbus A319/A320/A321 (V2500 engines) and McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines).

He joined Spanair on 6 April 1999 and had aircraft maintenance experience since January 1988.

Over the course of his career he had taken a total of 37 aircraft maintenance courses, eight of which included human factors as they relate to aircraft maintenance.

When he joined Spanair, the company provided him with training on "Logbook Procedures" and on the "Organization and Maintenance Procedures Manual".

From March 2002 until October 2007 he had taken a total of seven courses on the procedures in the operator's Maintenance Management and Organization Manual and the Maintenance Quality System.

He was on duty on 20 August. His shift had started at 06:30 and it ended at 14:30.

1.5.3.4. AMT 4 (Aviation Maintenance Technician - Madrid)

Male, 26 years of age.

He had a valid Part 66 Category B1 (Mechanical) and B1.1 (Mechanical, turbine airplanes) license, which included the McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines) aircraft. It was valid until 29 August 2012.

Within the company he attained the category of AMT certifier in September 2007 for the DC-9-80 and A319/A320/A321 aircraft models.

He joined Spanair on 21 June 2004, at which time he had no previous aviation maintenance experience.

Over the course of his career he had taken a total of five aircraft maintenance courses, one of which included human factors as they relate to aircraft maintenance.

When he joined Spanair, the company did not provide him with any training on "Logbook Procedures" or on the "Organization and Maintenance Procedures Manual". He also received no training on operator procedures involving the Maintenance Management and Organization Manual and the Maintenance Quality System.

1.5.3.5. AMT 5 (Aviation Maintenance Technician - Madrid)

Male, 26 years of age.

He held a Part 66 B1.1 license (Mechanical, turbine airplanes), valid until 21 May 2012, applicable to the following aircraft types: Airbus A319/A320/A321 (V2500 and CFM56 engines) and McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines).

He joined Spanair on 8 January 2007 and had aircraft maintenance experience since October 2002.

Over the course of his career he had taken a total of six aircraft maintenance courses, none of which included human factors as they relate to aircraft maintenance.

Between the time he joined Spanair and 20 August 2008, the company did not provide him with any training on "Logbook Procedures" or on the "Organization and Maintenance Procedures Manual". He also received no training on operator procedures involving the Maintenance Management and Organization Manual and the Maintenance Quality System.

1.5.3.6. AMT 6 (Aviation Maintenance Technician - Madrid)

Male, 45 years of age. AMT Team Leader.

He held a Part 66 B1.1 license (Mechanical, turbine airplanes) and a B.2 license (Avionics), valid until 28 June 2011, applicable to the following aircraft types: Airbus A319/A320/A321 (V2500 engines) and McDonnell Douglas DC-9-80 (Pratt & Whitney JT8D engines).

He joined Spanair on 4 March 1988 and had aircraft maintenance experience since March 1987.

Over the course of his career he had taken a total of 42 aircraft maintenance courses, seven of which included human factors as they relate to aircraft maintenance.

From the time he joined Spanair until 20 August 2008, he took a total of eight courses on operator procedures involving the Maintenance Management and Organization Manual and the Maintenance Quality System.

1.6. Aircraft information

1.6.1. *General*

The McDonnell Douglas DC-9-82 (MD-82) aircraft was type certified on 29 July 1981 under revision 26 of FAA Type Certificate no. A6WE. The initial version of this certificate was approved by the FAA on 23 November 1965, its original holder being the Douglas Aircraft Company. On 25 August 1967, this company merged with McDonnell Aircraft to form McDonnell Douglas. In 1997, McDonnell Douglas was taken over by Boeing, which obtained ownership of Type Certificate A6WE from the FAA on 30 January 1998.

The accident aircraft was built in 1993 with serial number 53148 and fuselage number 2072. It was delivered to Korean Air on 19 November 1993 and registered in South Korea initially as HL-7204 until 18 June 1998, and then as HL-7548 until 23 July 1999. Since 24 July 1999 the airplane had been operated by Spanair with Spanish registration EC-HFP.

The aircraft had an Airworthiness Certificate, No. 4516, issued on 4 February 2005 and valid until 22 July 2008. The request to renew the certificate was presented shortly before its expiration date. In keeping with DGAC procedures, the certificate was due for a full renewal that year (documentation, physical and in-flight), and it was not possible to conduct the inspection, scheduled for 22 August 2008, before the certificate's validity expired. As a result, the certificate was extended until said date, pursuant to DGAC Circular 11-19B.

According to technical records, the aircraft had accumulated a total of 31963 flight hours and 28133 total cycles as of 20 August 2008.

The airplane was equipped with two Pratt & Whitney JT8D-219 engines in a 217C configuration. The No. 1 engine (left) had serial number P728154 and a total of 22872 flight hours and 15547 total cycles. The No. 2 engine (right) had serial number P725716 and a total of 43990 flight hours and 28766 total cycles.

The reverse of engine n° 2 (right engine) had been deactivated. On the handle of that engine reverse thrust lever there was a label with the word "DEACT" hand written on it and that handle was safety-wired to the throttle lever. Those actions were registered in the ATLB and it was indicated that the malfunction was transferred to the Hold Item List (HIL).

The aircraft was configured with 167 passenger seats, two seats for the flight crew, one jumpseat in the cockpit, two folding seats next to the left forward access door and another two next to the rear access door. These four seats were for the flight attendants.

1.6.2. *Systems description*

1.6.2.1. High-lift devices

The MD82 is designed with high-lift devices on the wing trailing edges (flaps) and leading edges (slats).

Each half-wing has two (2) flaps sections: inboard and outboard. Each section is moved by means of two (2) hydraulic actuators. All the sections are mechanically linked together so that the extension and retraction movements are synchronized.

There are six (6) slats on the leading edge of each wing, numbered zero (0) to five (5) from inboard to outboard. They are operated as a unit. Each slat is supported by tracks that move along rollers situated on the leading edge of the wing. There are 15 tracks on each wing, of which 7 are drive tracks and 8 are idle tracks. The extension and retraction motions for the entire assembly are controlled by two hydraulic actuators that turn a stepped pulley or drum. The slat drive cable drum contains twelve grooves from which six closed cable loops are routed to the left wing slats and six to the right wing slats.

1.6.2.1.1. *Operation/actuation (see Figure 1)*

The flaps and slats are operated jointly in the flight deck with a single flap/slat control level, situated on the front right of the cockpit's central pedestal.

The motion of this lever is transmitted by cables to the flap/slat sequencing mechanism, which is connected by cables and linkages to both the flap and slat actuation systems.

The cables corresponding to the flap system are routed to the flap control valve located in the left wheel well, which displaces the control valve pushrod so as to port hydraulic pressure to the actuating cylinders to either extend or retract the flaps, depending on the position commanded by the flap/slat control lever.

As they move, the flaps operate the flap follow-up cable system, which moves the flap control valve pushrod in the opposite direction to that of the cables connecting it to the flap/slat control lever, such that the valve closes when the flaps reach the commanded position.

The slats operate in conjunction with the flaps and have three positions: retracted, intermediate and fully extended, depending on the flap/slat control lever position. Thus, when the flaps/slats selection flap/slat control lever in the cockpit is in the UP/RET position, the slats are retracted (RET); with the flaps flap/slat control lever in the cockpit below flaps 14°, the slats extend to their intermediate position (MID); and with flap/slat control lever positions above flaps 14°, the slats are fully extended (EXT).

The cables corresponding to the slat system operate the slat control valve through linkages within the flap/slat sequencing mechanism. There are two electromechanical actuators within the flap/slat sequencing mechanism that also operate the slat control valve through mechanical linkage.

When the flap/slat control lever is moved from the UP/RET position to any other position, the slats start to extend, and the lever position microswitch (S1-467) is activated, inside of which there are five contacts, with two providing a 28V DC signal to the two stall warning computers. The first time that the flap/slat control lever is moved in the extend direction with the aircraft on the ground, activation of the microswitch triggers BITE automatic test on the number 1 and 2 stall warning computers, which signal the electromechanical actuators to move the slats to their maximum extension and, depending on whether the flap/slat control lever is positioned above or below flaps 14°, either maintains the slats fully extended if above flaps 14°, or retracts them to the intermediate position otherwise.

The slats are controlled mechanically for flap positions between 0° and 13°, inclusive, corresponding to an intermediate slats position, and electromechanically between 15° and 40°, corresponding to full extension of the slats.

For flap/slat control lever positions between 0° and 13° inclusive (slat extension to the intermediate position), the flap/slat control lever actuates the slats control valve directly. Slat extension from the intermediate position to the full extend position is accomplished by means of the two electromechanical actuators that receive signals from the stall warning computers and actuate the slat control valve through mechanical linkage. If, during takeoff, the airplane approaches a stall condition, the stall warning computers detect this and automatically send a signal to the electromechanical actuators to fully extend the slats if they are in the intermediate position (Autoslat). Once the condition clears, the stall warning computers send a signal to the electromechanical actuators to return the slats to their previous position. If the slats are retracted (flap/slat lever in the UP position), the autoslat function is not in effect since the lever position microswitch S1-467 is not activated, meaning the stall warning computers do not receive the 28V DC signal from the microswitch.

When the control valve is actuated, either mechanically or electromechanically, the valve admits hydraulic pressure to two hydraulic actuators that turn the slat drive cable drum and corresponding six closed cables loops routed to the left wing slats and six to the right wing slats that actuate the sliding slat tracks directly.

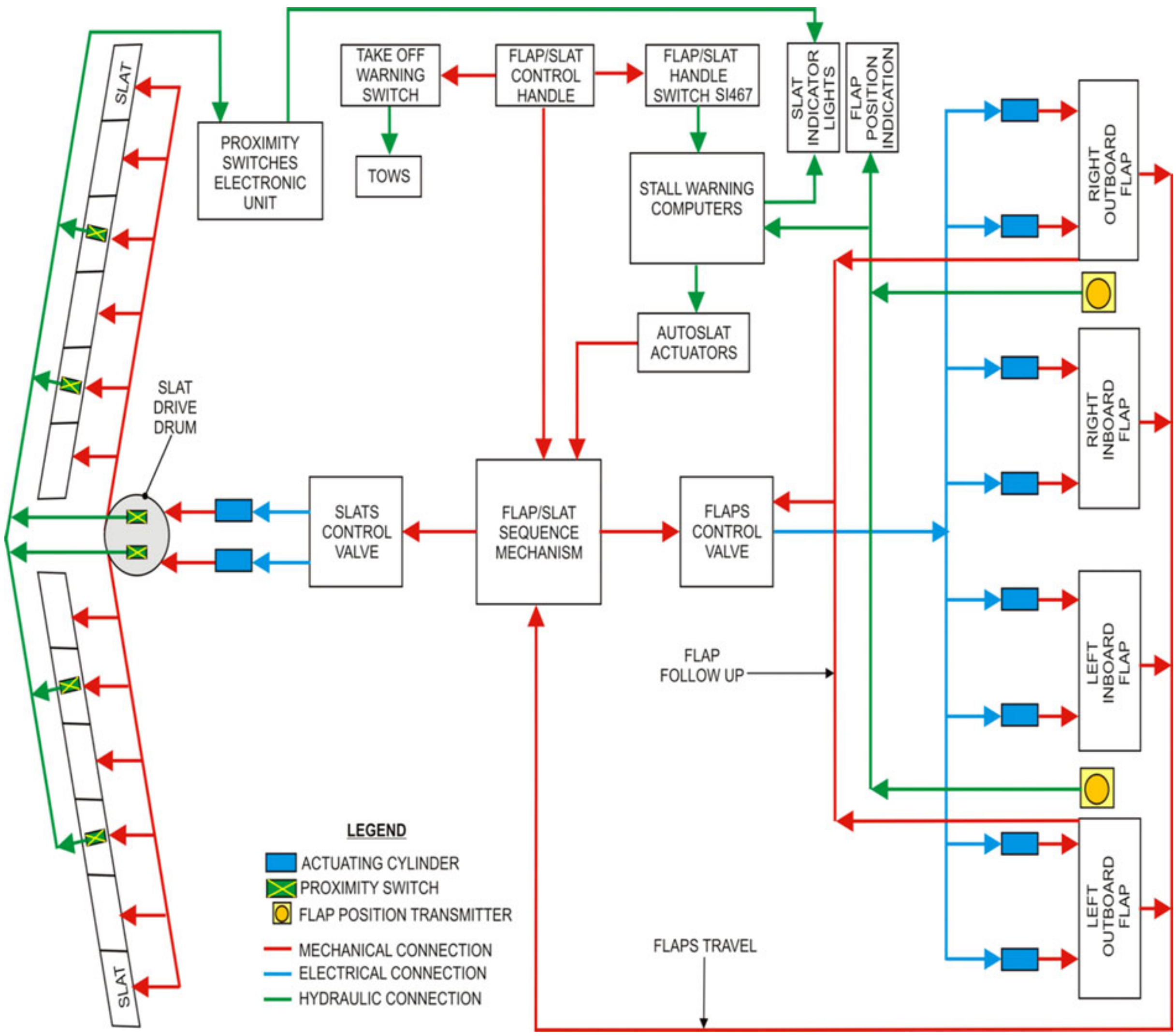


Figure 1. General diagram of flaps/slats system

1.6.2.1.2. *Flaps/slats cockpit controls*

1.6.2.1.2.1. Flap/slat control lever (see Figure 2)

The flap/slat control lever is situated at the right front part of the pedestal. It moves through a slot with two graduated scales labeled on the pedestal cover, one on each side of the slot. Both scales have markings to indicate the UP/RET, 0, 11, 15, 28 and 40 degree positions. Two additional areas are labeled on the right scale, one indicating T.O. EXT shown around the 0° to 24° range, which corresponds to takeoff values, and another indicating LAND EXT shown around the 28° to 40° range, which corresponds to landing values.

The flap/slat control lever has two triggers, one on each side of the lever. When lifted against against spring pressure, the triggers move two stubs, or detent pins, one located on each side of the lever at the bottom. These are located inside the pedestal, each one housed in a sliding track, both also located inside the pedestal.

The left track is fixed, and provides conventional notches, or detents, for each of the markings labeled on the left side of the pedestal cover (UP, 0, 11, 15, 28 and 40 degrees). The detent pin operated by the left trigger engages the selected conventional fixed detent on the left side.

The right track is variable and has a single notch, or detent, that can be adjusted for takeoff to any position from 0° to 24° by means of a flap takeoff selection thumb wheel, with its associated indicator window, situated on the right side of the pedestal. This allows for selection of an exact takeoff flaps position to be selected that differs and is independent from the limited available fixed positions in the takeoff range. The detent pin operated by the right trigger may be set into the selected variable detent on the right side.

When the flaps/slats flap/slat control lever is moved to the selected position, the right stub lodges in that notch appropriate detent pin engages the selected detent, which prevents the lever from being moved unless the right appropriate trigger is lifted.

Takeoff condition – CG/flaps selection/indication panel and longitudinal trim indicator (see Figure 2).

The TAKE-OFF CONDTN LONG TRIM indicator is located on the aft left part of the central pedestal in the cockpit.

It has a wheel that is used to input the position of the aircraft's center of gravity for that flight in a display window. It features another wheel, also with an associated window, that is used to input the value of the flaps angle selected by the crew for takeoff.

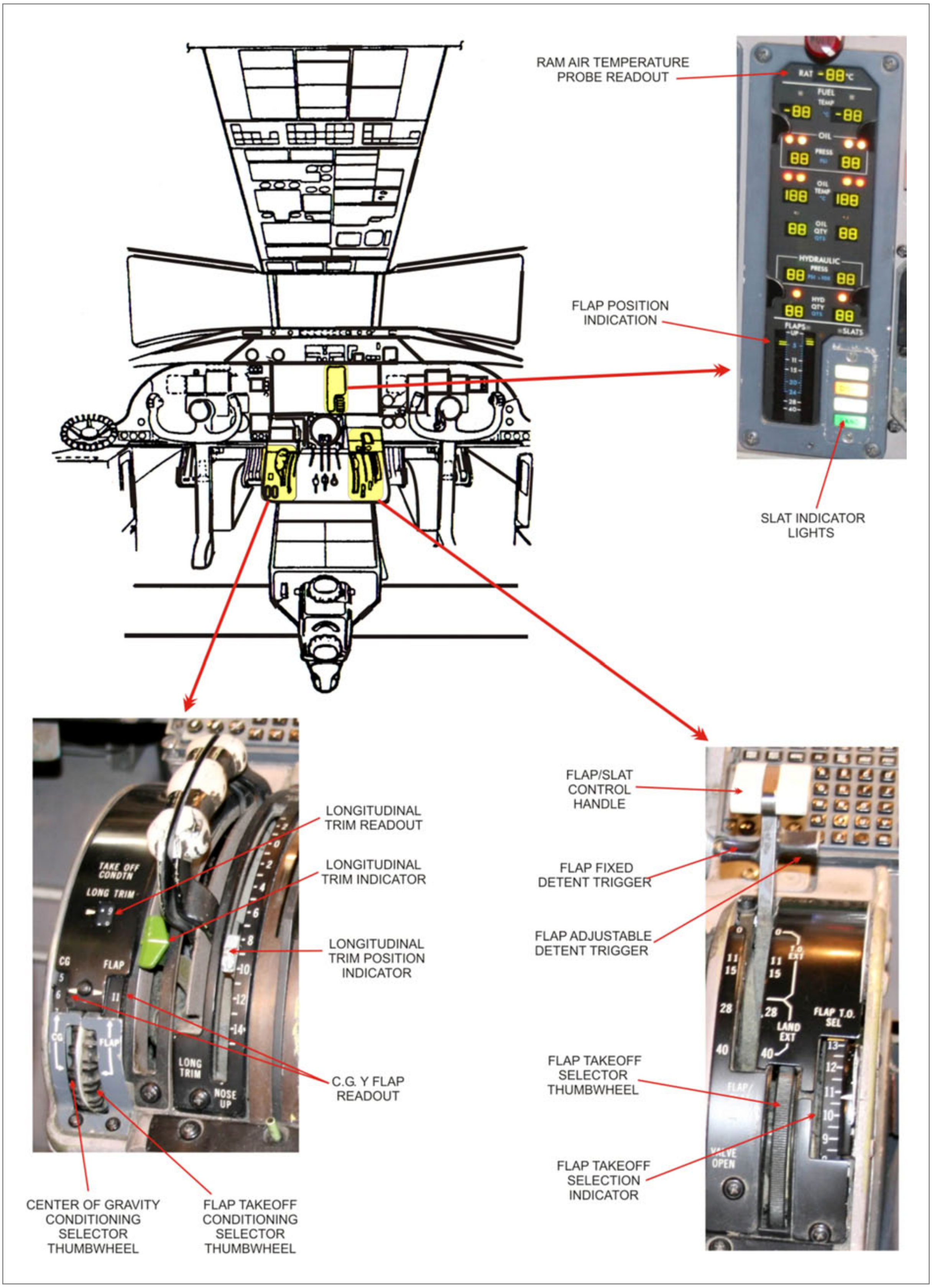


Figure 2. Flaps/slats controls and indicators

A mechanical calculator combines both values and, by means of an index and a window, indicates the value of stabilizer trim that the crew should use for takeoff.

Inputting the value for the flaps angle as indicated above also moves an axle that reaches across the pedestal to its right side, where it actuates a hinge that positions a flaps warning microswitch for takeoff. When the position selected on the flap/slat control lever matches the value input with the wheel on the takeoff condition panel, a cam presses on the flaps warning microswitch, which then sends a signal to the takeoff warning system (TOWS), indicating that the flaps selection is correct, so that the TOWS flaps warning is not activated.

The TOWS also provides an aural warning if the stabilizer is not correctly positioned for takeoff. The mechanical computer calculates the proper stabilizer setting and positions a switch. A cam driven by the stabilizer position indicating cable actuates this switch to suppress the warning when the stabilizer is in the proper position.

1.6.2.1.3. *Flaps and slats position sensors and indicating systems*

There are two flaps position transmitters, one on the left wing and another on the right. They are located in the inboard hinge of each outboard flap and they send their data to the flaps position indicator, to the stall warning computers and to the digital flight guidance computers (DFGC).

The flaps and slats indicators are located in the right bottom side of the central instrument panel (see Figure 2).

The flaps indicator consists of a vertical linear scale, graduated from UP/RET to 40°, with independent indicators for the LH and RH flaps. The indication is provided by means of two horizontal rows of LCDs (liquid crystal display) on each side. These lights change color from red to green to indicate on the scale the position of the flaps.

The slats indicator has four lights, T/O, DISAG, AUTO and LAND, colored blue, amber, blue and green, respectively. When lit, these lights indicate the following:

- T/O: flap/slat lever positioned within takeoff range – (1) Slats in MID, flaps less than 26° and flap/slat control lever positioned in MID, or (2) Slat in EXT, flaps less than 26° and flap/slat control lever positioned in EXT.
- DISAG: the position of the LH and RH slats do not agree with each other or are not in the position commanded by the flap/slat lever, or the flap/slat lever is not in agreement with the landing flaps setting.
- AUTO: the slats have been automatically extended to their maximum EXT position by the stall warning system.
- LAND: the flaps are extended within the landing range (greater than 26°), the slats are fully extended and the flap/slat control lever is positioned in EXT.

The signal for the T/O, DISAG and LAND lights comes from the Proximity Switch Electronic Unit (PSEU), which receives data on the position of the flap/slat control lever from the position microswitch (S1-467). The AUTO light signal is provided directly by the stall warning computers.

The positions of the slats are provided by eight proximity sensors, four on the right side and four on the left. Of the four sensors on each half-wing, two are located in the slat drive cable drum assembly and two are next to the sliding tracks for the 1 and 3 slat.

1.6.2.2. TOWS, takeoff warning system

Airplanes in the MD-80 series feature a central aural warning system (CAWS) in the cockpit that provides various audible warnings to the crew when certain potentially unsafe conditions arise or when improper configurations or problems with the operation of certain systems exist.

The TOWS is part of CAWS. The TOWS provides alert warnings for the following components involved in the configuration of the aircraft for takeoff:

- Flaps
- Slats
- Spoilers
- Stabilizer
- Parking brake
- Auto brake
- Auto spoilers

The aural warnings consist of an alternating sequence of tones complemented by a synthetic voice to indicate the reason for the warning. Should one or more of these components be improperly configured, the system is designed to sound the alarm followed by the synthetic voice announcement.

The TOWS will issue an aural warning (in parentheses, the synthetic voice) as long as the following conditions exist:

- Airplane on the ground,
- Both throttle levers forward and
- One or more of the following exist:

  — Flaps not in agreement with the takeoff position selected on flaps position adjusting wheel on the elevator trim position calculator (FLAP).
  — Slats retracted (“SLAT”).
  — Spoilers lever in not retracted position (SPOILERS).

- Position of horizontal stabilizer disagrees by more than 1.5° with the position set by the takeoff calculator (STABILIZER).
- Parking brake not released (BRAKE).
- The auto brake is not set to the takeoff position with the spoilers armed for takeoff (AUTO BRAKE).
- Spoilers not armed for takeoff with the auto brake selector in the takeoff position (AUTO SPOILER).

The TOWS is only active on the ground and is inhibited in with the airplane in flight.

Of the three CAWS power supplies, the CAWS system components that carry out the TOWS functions receive 28V DC from the number two power supply through a breaker labeled P-38, which is located in the bottom panel behind the LH seat in the cockpit. This panel is labeled "CAWS, SSRS-1, LDG GR, T/O, A/P, SP BK, CAB ALT".

1.6.2.3. Ground sensing system. The R2-5 relay

The aircraft has systems that should function only while in flight, only on the ground, or differently whether in flight or on the ground. The systems that so require it receive the information that the aircraft is on the ground or in the air through the ground sensing system.

The system consists of three switches located in the nose landing gear that detect whether the aircraft is on the ground or in the air, twenty relays located in the avionics compartment and two circuit breakers located in the cockpit through which the system is supplied with 115V AC power (see Figure 3).

In the nose landing gear there is a switch that closes if the gear is down and locked and opens otherwise, and two switches, situated on either side of the gear, that close if the strut is compressed, which happens when the airplane is on the ground, and open when the strut is extended, that is, when the airplane is in flight.

The gear down and locked switch is connected in series with that on the left strut. When the airplane is on the ground, both switches complete a circuit that supplies eleven (11) relays, and which makes up the left group of the system. A circuit breaker is present in this circuit, identified as K-33[22] in the top panel situated behind the LH seat in the cockpit and labeled as "Left Ground Control Relay".

When the airplane is on the ground, the right strut switch closes to complete a circuit that powers nine (9) relays. This makes up the right side of the system. There is a circuit

[22] This breaker denomination may vary from one airplane to the next.

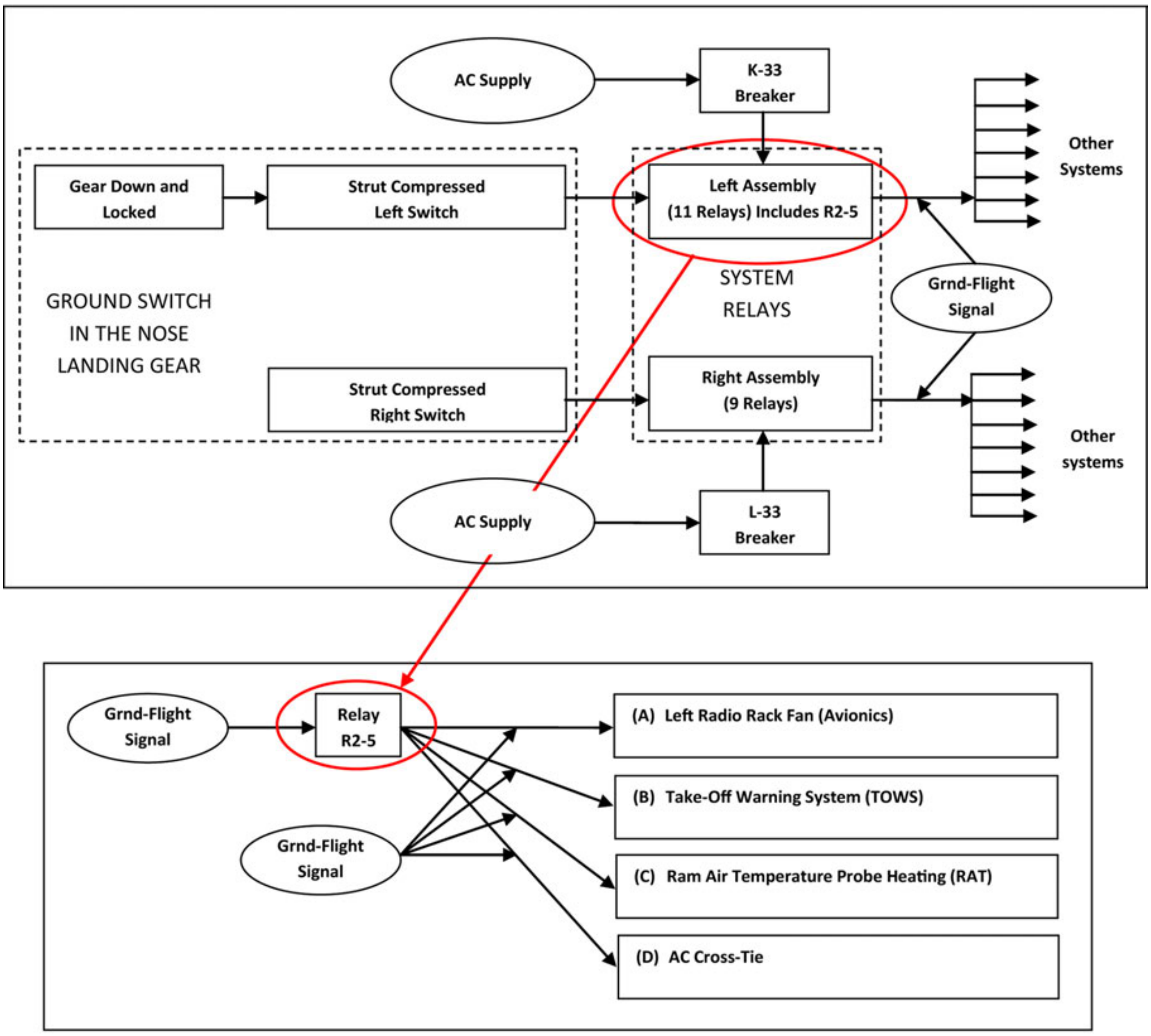


Figure 3. General diagram of the ground sensing system. Relay R2-5

breaker identified as L-33 on the same panel behind the LH seat in the cockpit and labeled as "Right Ground Control Relay".

When the airplane is in flight, the nose gear switch and both side strut switches, left and right, are open and therefore so are the electrical circuits that power the relays.

All the system relays have their coils on one side connected to the power supply via their respective circuit breakers, and on the other to ground through the respective switches on the nose gear.

Each system relay also has four sections, identified as "A", "B", "C" and "D", with three contacts each, in each of which the circuit between contact numbers 2 and 3 is closed while in a flight condition and between 2 and 1 while in a ground condition. The contacts are in a hermetically sealed enclosure at the top of which are the terminals to which the wires from those aircraft electrical circuits that use the coils and the relay sections are connected.

The left group of relays includes the so-called R2-5 relay, which is an electromechanical component manufactured by the Leach Corporation, part number (P/N) 9274-3642. The R2-5 relay is fed directly through the K-33 breaker. From the R2-5 relay, the power is distributed, among others, to the R2-58 relay, which provides information on the airplane's ground-flight condition to the stall warning system, and to the R2-308 relay, which is part of the approach idle system. The R2-5 relay transmits the ground-flight condition to the following four systems:

- Section "A": Indication for the radio rack ventilation system in the avionics compartment. Has two fans, left and right, both of which should be running on the ground and only one in flight.
  The operation of the fans on the ground and in flight is controlled by section A of the R2-4 relay. Relays R2-5 and R2-6, the latter of which is part of the ground sensing system on the right side, are involved in the indication of the "Radio Fan Off" message shown in the overhead annunciator panel (EOAP).
  Section A of relay R2-5 is supplied with 12V DC.

- Section "B": Take-off warning system (TOWS), which sounds an aural warning in the cockpit when the aircraft is about to take off in an incorrect configuration.
  When the airplane is on the ground with the nose gear strut compressed, both the number 1 and 2 contacts in this section of the relay close to activate the TOWS. When the airplane is in flight, contacts 1 and 2 open and the TOWS is deactivated.
  Section B of relay R2-5 is supplied with 17.3V DC.

- Section "C": Static ports and probe heaters, consisting of a series of heaters.
  The operation of each of these heaters is controlled by various relays. In particular, the Ram Air Temperature probe heater is controlled through relay R2-5 and must be on when the aircraft is in flight and off when it is on the ground.
  Section C of relay R2-5 is supplied with 115V AC.

- Section "D": AC cross-tie system, which distributes AC power to the left and right busses from different sources. With the aircraft on the ground, the bus cross-tie is enabled when the electricity is supplied by the engine-driven generators (EDG) and inhibited when it is supplied by the auxiliary power unit (APU) or an external source.
  The control of the system is affected by three relays from the ground sensing system: relay R2-309, from the RH relay group and which enables the automatic mode of operation of the system on the ground, and relays R2-5 and R2-8, the latter of which belongs to the RH ground sensing system. Relay R2-5 inhibits cross-tie operation of the left bus on the ground when the electricity is supplied by the APU or an external source.
  Section D of relay R2-5 is supplied with 28V DC.

As for its mechanical characteristics, the R2-5 relay consists of a pivoting armature that actuates eight pairs of contacts, two for each section.

A spring makes the armature rotate in one direction, while a coil makes the armature rotate in the opposite direction when current flows through it (coil energized). The spool is energized when the airplane is on the ground, and is in its rest state when the airplane is in flight.

As for its nominal specifications, the relay is designed for the coil to operate using 115V/400Hz AC while drawing a maximum current of 0.1 A at 25 °C, and so that 115V/400Hz AC or 28V DC and a maximum of 10 A of current can flow through its contacts. It has a minimum service life of 100000 cycles. In terms of environmental conditions, it is designed to operate properly between –60 and +71 °C, up to an altitude of 80000 ft and to withstand 25g impacts lasting a maximum on nine milliseconds.

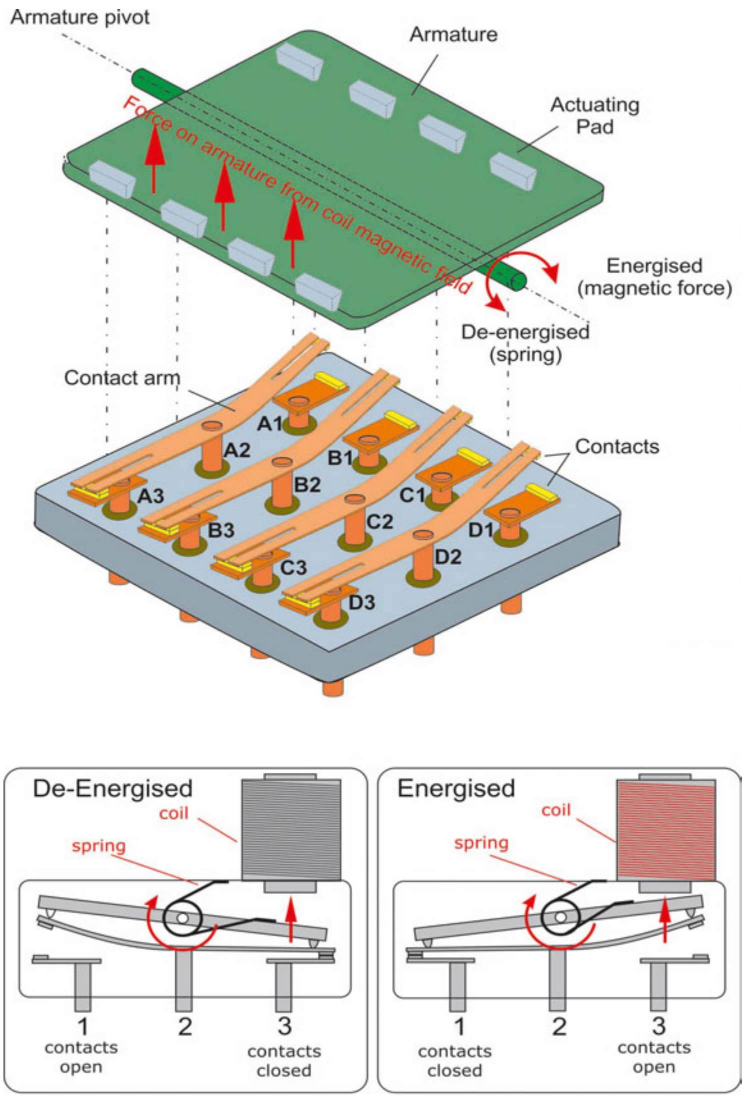


Figure 4. Interior of R2-5 relay

1.6.2.4. Ram Air Temperature probe heater circuit

The aircraft has a series of systems that rely on the value of the outside air temperature to ensure they are operating under adequate conditions. This is done by measuring the ram air temperature (RAT) through a probe (RAT probe) that is located on the lower right front side of the fuselage.

So as to keep ice from forming and blocking the probe, the probe includes a heater that must be in operation when the aircraft is in flight and disconnected when on the ground.

When the pilot supplies the air data sensors with electricity through the rotary switch meter selector and heat, located in the Ice and Rain Protection section of the overhead instrument panel and labeled "Meter Sel & Heat", the heater receives AC power from a circuit which includes a circuit breaker that is found in position Z-29 in the lower panel located behind the LH seat in the cockpit, and labeled as "Ram Air Temp & Probe Heater". This circuit receives power through the "C" section contacts of relay R2-5 in the left assembly of the ground sensing system, which interrupts the current when the aircraft is on the ground. The rotary switch also allows for the operation of the heaters for all the air data sensors to be checked on the ground.

The probe temperature reading is displayed on the central flight instrument panel, in the top part of the system display panel (SDP). If the system is not working properly and the heater is on with the aircraft on the ground, the probe will measure abnormally high temperatures while on the ground, far above ambient.

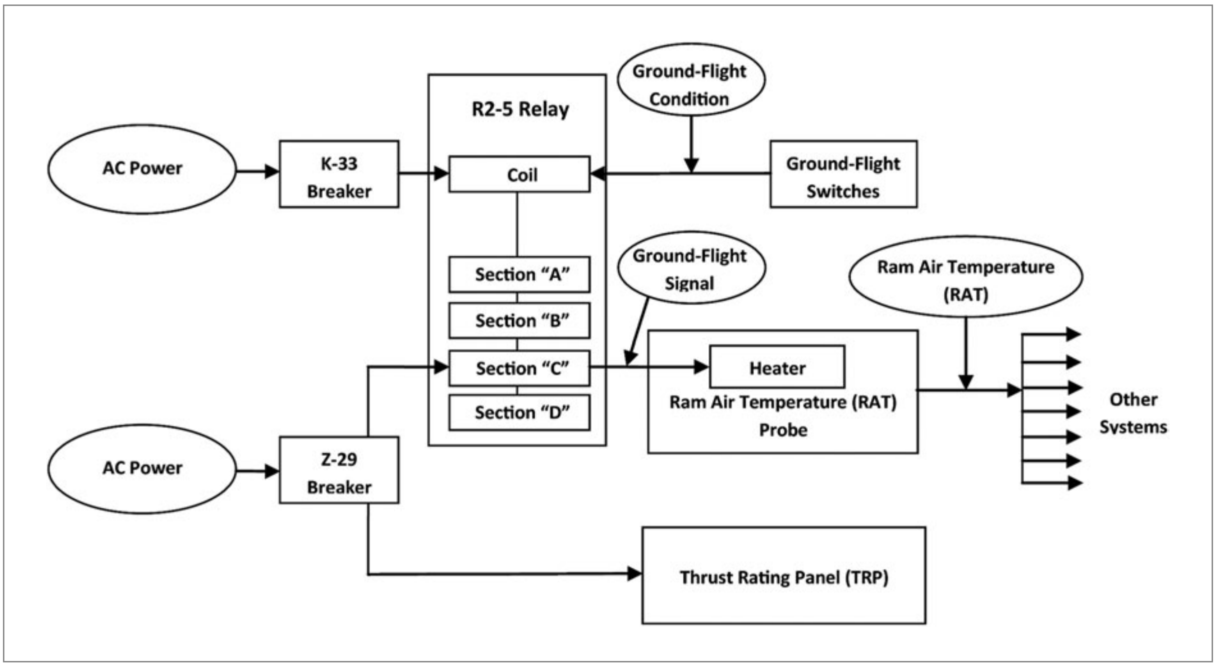


Figure 5. Diagram of RAT probe heater

AC Power to the Thrust Rating Panel (TRP), which is part of the Thrust Rating System (TRS), is also fed through the same Z-29 circuit breaker. This panel will not function if it does not receive power, as a consequence of which the auto-throttle system will not have the information supplied by the TRP, such that the desired EPR must be input manually.

1.6.2.5. Stall protection system

The MD82 is equipped with a system to detect and protect against stalls. The system uses two computers (SWC1 and SWC2), each of which can detect approach to stall conditions independently and activate the system. Each computer monitors the aircraft's angle of attack (AOA), its rate of change and the aircraft's configuration (position of flaps/slats and deflection of the horizontal stabilizer) so as to provide the pilots with various warnings. The system is powered when the main gear struts are fully extended, with the extension of the left main gear strut enabling the no. 1 computer (SWC1) and the extension of the right main gear strut enabling the no. 2 computer (SWC2). The system also performs a check of the angle of attack when the airplane starts its rotation on takeoff, with SWC1 doing the check when it receives a flight signal from the left ground sensing system through section D of relay R2-58, and SWC2 doing the check upon receiving the signal from the right ground sensing system through section D of relay R2-6. An analysis of the DFDR revealed that the extension of the main gear struts takes place approximately four seconds after the extension of the nose gear strut following rotation.

When either computer detects approach to stall conditions, indications will be provided to warn the pilots of this condition by means of vibrators installed in the control columns (stick shaker). When either computer detects a stall condition, it will provide a signal to the autoslats system that will extend them fully if they are in an intermediate position while at the same time activating the corresponding visual (STALL lights on either side of the glareshield) and acoustic (various tones and the *stall* synthetic voice) warnings.

If both computers simultaneously detect stall conditions above pre-set values (six-second duration or a 3° increase in the angle of attack) and the slats are fully extended, the Post Stall Pusher System (PSPS) is activated that will in turn push both control columns forward by means of a mechanical pusher (stick pusher), forcing the nose of the aircraft downward. At the same time the STICK PUSHER PUSH TO INHIBIT lights located to the left of the stall indications will turn on.

The approach to stall indications and the stall warnings and indications are produced as far in advance as is necessary so as to allow for a faster system response if said approach to stall indications are coincident with higher rates of variation in the angle of attack.

Lastly, when the slats are retracted (flap/slat control lever in the UP/RET position), the autoslat and the Post Stall Pusher System are disabled.

The visual and acoustic warnings are activated via the central aural warning system (CAWS) whenever either or both of the stall warning computers (SWC1 or SWC2) detect a stall condition.

If either computer detects a fault, or if there is a disagreement between them, a STALL IND FAILURE warning is issued on the electronic overhead annunciator panel (EOAP).

There are two modules (SSRS1 and SSRS2) in the CAWS that activate simultaneously when a signal from either stall warning computer SWC1 or SWC2 is received. Of the three CAWS power supplies, the SSRS1 is powered from the number 2 supply. SSRS1 sends a tone and a synthetic "stall" voice to the speaker located in the captain's console and illuminates the captain's side warning. SSRS2, which is powered from the number 3 power supply, has the same effect on the first officer's side. Even if both modules are activated simultaneously, the announcement of the word "stall" is out of phase, such that an echo effect is created when the word "stall" is heard over the two speakers.

1.6.2.6. Autothrottle

The autothrottle can be set from takeoff to landing. This automatic control moves the throttle levers to maintain speed or thrust, depending on the mode selected and on the airplane's configuration. Autothrottle can be set for the following maneuvers: takeoff, climb, cruise, hold, approach, flare and go-around.

The autothrottle function is engaged by moving the switch located in the flight guidance control panel (FGCP) from the OFF to the AUTO THROT position.

The switch is kept in that position by way of a solenoid as long as all the requirements for engaging it are satisfied. With the Flight Director in takeoff mode, however, the solenoid that maintains the autothrottle switch in the AUTO THROT position cannot be energized unless the takeoff (TO) or flex takeoff (TO FLEX) mode is selected on the thrust rating panel (TRP).

The sequence for activating the autothrottle begins by selecting TO or TO FLEX on the TRP, pressing the TO/GA button on the throttle levers and engaging the autothrottle switch on the FGCP. To engage takeoff mode, the flaps must be in a takeoff position (flaps lever in a position other than UP/RET) and the aircraft must have been on the ground more than 20 s.

When the autothrottle is engaged as described above, if the normal takeoff (TO) mode is selected on the TRP, the autothrottle will advance the throttle levers until the EPR limit is reached, with the reference needle on the EPR display going automatically to that value. When the airplane reaches 60 KIAS, clamp mode activates, which locks out the throttle levers.

1.6.2.7. Automatic Reserve Thrust system

The Automatic Reserve Thrust system (ART) is designed to supply additional thrust in the event of an engine failure on takeoff. The ART receives information on the high pressure seciton rotation speed (N1) in the engines and compares them. If a difference in excess of 30% is detected, it increases the thrust on the engine with the higher N1 value by operating a solenoid valve in its fuel control unit to increase the fuel flow to that engine.

The system is self-test. When the crew places the associated actuator in the AUTO position and the slats are extended in the MID or EXT position, the "READY" light turns green on the central instrument panel. When an engine failure on takeoff causes the system to activate, the amber-colored "ART" light is on.

The system automatically disengages when the slats are retracted.

The ART system has not to be used when the flexible take-off mode (or with reduced take-off thrust) (TO FLEX) is selected in the Thrust Rating Panel (TRP).

1.6.2.8. Approach idle control system

The MD82 is equipped with an approach idle control system that is designed to adapt the idle setting on the engines to that corresponding for the aircraft on the air or ground, depending on the aircraft's condition.

For each engine, the system recognizes the airplane's ground or flight condition through the nose gear down switch in the nose landing gear and the ground sensing system. In the circuit for the left engine, there is a switch located on the left side of the nose landing gear that detects the gear's extension status. This switch is connected in series with section A of the R2-308 relay, which belongs to the left set of relays in the left ground sensing system. Similarly, the circuit for the right engine has a switch located on the right side of the nose landing gear, and which also detects the nose gear's extension status, that is connected in series with section B of the R2-8 relay, which is part of the right set of relays in the right ground sensing system

When airplane on the ground conditions exist for a given engine, a solenoid in that engine's fuel control system is activated after a five-second delay such that with the throttle lever in the idle position, the fuel flow is regulated so that the engine enters ground idle mode. When the airplane is in approach mode and the throttle is in idle, the solenoid is deenergized and the fuel flow is that associated with approach idle (high).

The circuits in both engines are connected such that if one detects a flight condition and the other a ground condition, a light is on in the electronics equipment bay labeled "APPROACH IDLE INOP", which will remain on until the reset switch is closed.

Based on the data recorded on the DFDR, when the aircraft was on the ground before the accident, both engines maintained similar idle rates. When the throttles were retarded, both engines exhibited N1 and N2 rpm values consistent with ground idle.

1.6.2.9. Flight data recording system

The flight data recording system gathers and stores information from before and during the flight itself.

The recording system includes a digital flight data recorder (DFDR), a flight data acquisition unit (FDAU), an accelerometer and a quick access recorder (QAR) that allows for fast access to the flight information recorded. The system architecture is as follows:

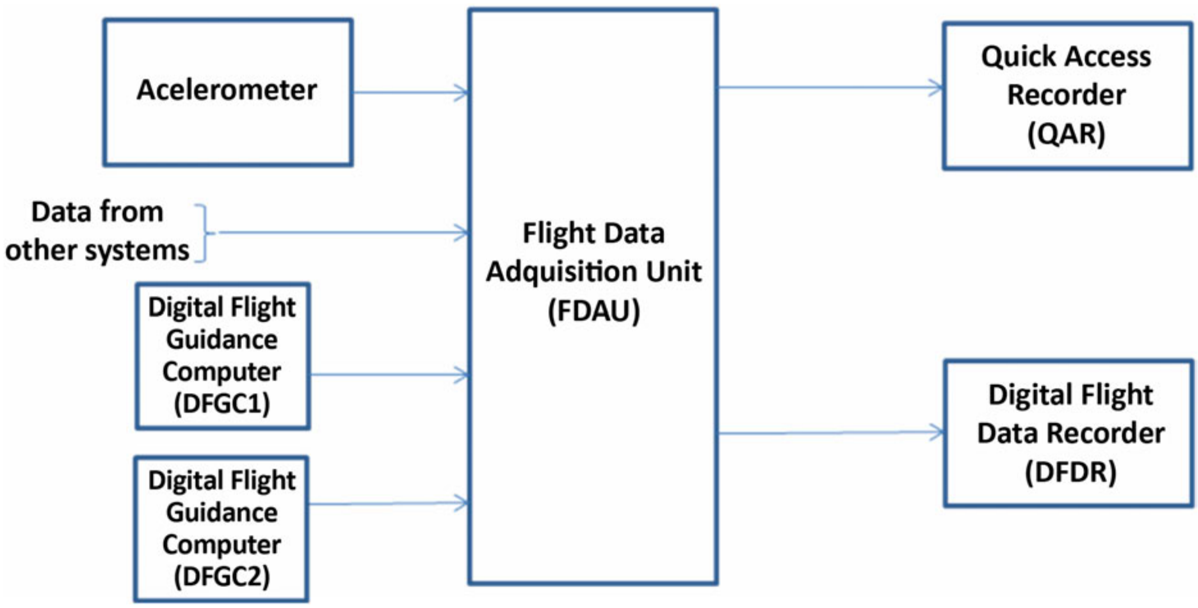


Figure 6. Architecture of flight data recording system

The FDAU obtains and processes the data gathered from the various sensors, computers and systems and sends them to the DFDR and QAR for recording.

One of the systems that provides information to the FDAU is the digital flight guidance computer (DFGC). This is a redundant system, meaning there is a DFGC1 and a DFGC2. Both are always in operation, but the information is sent from DFGC1 if the autopilot (AP) 1 is selected, and DFGC2 if AP2 is selected. Each DFGC communicates with the FDAU independently through a dedicated bus.

1.6.3. *Maintenance information*

1.6.3.1. Maintenance program

Aircraft EC-HFP was maintained in accordance with the MPDM80SP maintenance program, approved on 3 April 2008 by Spain's DGAC in its periodic review TR 05-002.

The MPDM80SP maintenance program is based on the MRBR of the manufacturer, Boeing, Revision 2, issued in November 2003.

The inspection periods and frequencies under this program are:

No.	Inspection Type	Inspection Interval
1	Pre-flight	Before each flight
2	Daily	Every calendar day
3	W	14 calendar days
4	A	120 days
5	C	16 months or 4,500 FH, whichever comes first
6	IV	5 years or 15,500 FH, whichever comes first
7	D	10 years, 30,000 FH or 25,000 FC, whichever comes first

The airplane had a total of 31963 flight hours and 28133 cycles. It was delivered to Spanair on 24 July 1999 with 9821 total hours and 10,986 total cycles since manufacture. Since that date a total of 33 of the major inspections (A, C, IV and D) had been conducted in accordance with the approved maintenance program. The last of these inspections (a type A) had been performed on 22 and 23 May 2008, with 31282 h and 27645 cycles on the airplane.

1.6.3.2. Faulty operation of the RAT probe heater

1.6.3.2.1. *Excessive RAT probe temperature indications on the ground in aircraft EC-HFP*

Between 18 and 20 August 2008, the DFDR recorded six instances in which the RAT temperature probe indicated excessively high temperatures in EC-HFP.

The tables below list the movements of the airplane on 18, 19 and 20 August 2008 in chronological order, the times when the DFDR recorded a high RAT temperature reading, the entries made by the flight crews in the airplane's ATLB and the replies provided by company maintenance personnel. Out of all the events, only three were noted in the ATLB, all three by different crews. Except for the last high temperature event detected before the takeoff of the accident flight, in every other previous case the airplane had taken off with a high RAT temperature indication.

A detailed description of each event, as well as a graphical representation of various parameters obtained from the DFDR, is shown later in this report in Section "1.16.5 Behavior patterns of high RAT probe temperature indications in EC-HFP"[23].

18 August 2008

No.	UTC Time	Local Time	Route	Place	Description	Remarks
1	17:10	19:10	LCG-MAD	IN FLIGHT	Duration: 47 minutes. Crew reported: «DURING APPU AUTO SLAT FAIL LIGHT ON WHEN F15° SELECTED»	
2	19:00	21:00	—	Madrid	Maintenance replied: «SYSTEM, CHECKED AND STALL WARNING COMPUTER TEST PERFORMED SATISFACTORY AND P.S.U. TEST PERFORMED OK. PLS INFO IN NEXT FLIGHT»	
3	18:50	20:50	—	Madrid	PFC	
A	**19:15 - 19:23**	**21:15 - 21:23**	**PRIOR TO TAKEOFF**	**Madrid**	**DFDR. High RAT temperature.**	**Event not logged in ATLB by the crew. The airplane took off with a RAT temperature indication in the cockpit of approximately 40 °C.**
4	19:25	21:25	MAD-AGP	IN FLIGHT	Duration: 48 minutes	
5	20:30	22:30	—	Malaga	PFC	
6	21:15	23:15	AGP-MAD		Crew informed Maintenance that the "Auto Slats Fail" light did not energize and that the flight lasted 50 minutes.	

[23] In order to better identify references issued subsequent to this report, the chronological sequence is numbered and the cases in which the DFDR recorded high RAT temperature readings are assigned a letter.

19 August 2008

No.	UTC Time	Local Time	Route	Place	Description	Remarks
7	03:30	05:30	—	Madrid	Maintenance thanks crew for information and performs the DAILY CHECK.	
8	05:00	07:00	—	Madrid	PFC	
9	05:53	07:53	MAD-BCN	IN FLIGHT	Duration: 49 minutes.	
10	07:55	09:55	—	Barcelona	PFC	
B	08:29 - 08:43	10:29 - 10:43	PRIOR TO TAKEOFF	Barcelona	DFDR. RAT temperature high.	Event not logged by crew in ATLB. The airplane took off with a high RAT temperature indication in the cockpit (in excess of 100 °C).
11	08:50	10:50	BCN-GRX	IN FLIGHT	Duration: 1 hour and 10 minutes.	
12	10:10	12:10	—-	Granada	PFC	
C	10:44 - 10:49	12:44 - 12:49	PRIOR TO TAKEOFF	Granada	DFDR. RAT temperature high.	Event not logged by crew in ATLB. The airplane took off with a RAT temperature indication in the cockpit of approximately 50 °C.
13	10:48	12:48	GRX-BCN	IN FLIGHT	Duration: 55 minutes.	
14	12:05	14:05	—	Barcelona	PFC	
D	13:32 - 13:50	15:32 - 15:50	PRIOR TO TAKEOFF	Barcelona	DFDR. RAT temperature high. Crew noted in the ATLB that: «DURING TAXI FOR THREE TIMES THE RAT GOES TO 90° AND THE CORRESPONDING EPR'S BELOW 1.30»	First crew to log a high temperature reading in the ATLB. The entry was made after the airplane had landed at the destination airport, even though the anomaly became apparent during the previous takeoff, which was made with a high RAT temperature reading in the cockpit (in excess of 100 °C).
15	13:50	15:50	BCN-MAD	IN FLIGHT	Duration 1 hour.	
16	15:30	17:30	—	Madrid	Maintenance noted in ATLB: «RESET TESTED; OK PLS INFO IF FAILS AGAIN.»	This ATLB entry was handled in Madrid be the technician referred to as AMT 1.
17	15:35	17:35	—	Madrid	PFC	
E	16:10 - 16:21	18:10 - 18:21	PRIOR TO TAKEOFF	Madrid	DFDR. RAT temperature hight. The crew noted in the ATLB that: «DURING TAXI, RAT GOES TO 90°, EPR'S BELOW 1.30 (SAME AS SEQ 36)»	Second high temperature reading made in ATB by a crew. The entry was made after the airplane had landed at the destination airport, even though the anomaly became apparent during the previous takeoff, which was made with a normal RAT temperature reading in the cockpit.
18	16:22	18:22	MAD-BCN	IN FLIGHT	Duration 52 minutes.	

20 August 2008

No.	UTC Time	Local Time	Route	Place	Description	Remarks
19	01:00	03:00	—	Barcelona	Maintenance notes in ATLB that: «RAT/TRI TEST PERFORMED ACC AMM 34-18-00 RESULTING SATISFACTORY». Other maintenance activities are also performed.	This ATLB entry was made in Barcelona by the technician referred to as AMT 2.
20	05:30	07:30	—	Barcelona	PFC	
21	06:55	08:55	BCN-MAD	IN FLIGHT	Duration 53 minutes.	
22	08:30	10:30	—	Madrid	PFC	
F	11:10 - 11:43	13:10 - 13:43	PRIOR TO TAKEOFF	Madrid	DFDR. RAT temperature high. The crew noted in the ATLB that: «BEFORE TAKE OFF RAT TEMP RISES TO 99 °C AND EPR LIM DOWN TO 1.38 WITH TO SELECTED RAT PROBE HEATER ACTIVE ON GND»	Third high temperature entry made in ATLB by a crew. The crew decided to return to parking to request assistance from Maintenance.
23	11:00 (estimated departure time)	13:00 (estimated departure time)	MAD-Las Palmas Crew returns to remote parking at 13:33	Madrid	RETURN TO REMOTE PARKING R-11.	
24	11:55	13:55	—	Madrid	Maintenance notes in ATLB that: «C/B Z-29 PULLED AND PLACARED TX TO HIL SYSTEM MUST BE CHECKED A/C RELEASED ACC MEL»	This ATLB entry was made in Madrid by the technicians referred to as AMT 3, AMT 4 and AMT 5. Their shift supervisor was AMT 6.
25	12:24	14:24	TAKEOFF	Madrid	Accident.	

1.6.3.2.2. *Instructions in manufacturer's manuals*

The DC-9-82 (MD-82) Maintenance Manual (AMM) is structured into chapters and sub-chapters that generally begin with a section dedicated to the description and operation of the system or sub-system in question, a second section that describes troubleshooting procedures for that system, and a third section that describes maintenance practices or instructions to be followed.

In AMM chapter 30-30-00, on anti-ice protection, there is a part in the troubleshooting section called "Pitot and Static – Troubleshooting", which lists the maintenance actions to be carried out in order to detect the origin of a fault in the event of a malfunction in the various devices, including the temperature probe heating. In the case of the RAT probe heater, the maintenance actions for detecting the source of the malfunction are only given for the situation in which heat is not supplied to the probe in flight. No specific indications are provided, however, regarding the course of action to take if the probe is being heated with the airplane on the ground.

There are references to the RAT probe and its heating in other parts of the AMM and in other manuals. In Chapter 30-30-00 of the AMM there is a basic description of the RAT heating system (Chapter 30-30-00, page 1) and electrical circuit block diagrams (Chapter 30-30-00, page 106), that show the circuit and its components, including the relationship between the RAT probe heater and the R2-5 relay. In this chapter, in the section on maintenance practices (Chapter 30-30-00, page 204, "Adjustment/Test Static, Pitot, and Anti-ice Heaters"), there is a procedure for checking the operation of the RAT probe heater (D "Test RAM Air Temperature Probe Heater). The instructions for that test indicate that, in order to avoid damaging it, the RAT probe should not be heated on the ground for longer than two minutes.

In Chapter 30-31-02 of the Wiring Diagram Manual (WDM), the wires and the contact positions on the R2-5 relay are identified.

The "Ram Air Temperature and Thrust Rating System" section in chapter 34-18-00, page 201 of the Maintenance Manual includes instructions for conducting a general test of the RAT temperature probe and thrust rating systems. The AMM also has procedures for checking the RAT probe heater in Section 34-16-02, titled "Ram Air Temperature (RAT) Probe – Maintenance practices".

The manufacturer's Operations Manual (FCOM) contains indications of a general nature for crews concerning the operation of circuit breakers. Specifically, it states that indiscriminately pushing or pulling a circuit breaker can have unforeseen effects due to the interconnections between systems.

In order to incorporate troubleshooting procedures in its aircraft maintenance manuals, Boeing relies on the presence of at least one of the following conditions:

- A specific anomaly does or has existed.
- The descriptive and/or schematic information in the manual is not enough to easily locate the source of a malfunction.
- The malfunction will probably occur frequently during the service life.

1.6.3.2.3. *Operator's Minimum Equipment List (MEL)*

As for the operator's Minimum Equipment List (MEL), it was located in Part B of the company's Operations Manual. This document contained a checklisting of those systems or components that could be inoperative at the start of the flight while still allowing the airplane to be dispatched, as long as the operating and maintenance procedures associated with each were complied with.

Point 2, "Contents of the MEL" of Sub-chapter 2, states that "All items which are related to the airworthiness of the aircraft and not included on the list are automatically required to be operative." The Takeoff Warning System, TOWS, was not included on said list, and therefore should have been operational at the start of the flight. In fact, an item in Spanair's MEL included a check of the proper operation of the TOWS as a prerequisite to dispatching the aircraft with certain elements inoperative[24].

Item 30.8 in the Spanair MEL (see Appendix 1) allowed dispatching the airplane with the RAT probe heater inoperative as long as the flight did not take place in known or forecast icing conditions, and required that the malfunction in said system be corrected within ten calendar days of its discovery.

Additionally, item 34.9 in the Spanair MEL (see Appendix 1) provided relief for dispatching an airplane in the event that the RAT probe and the Thrust Rating Systems were inoperative, noting that in this case, the EPR limit mode would be inoperative and the limits for this engine parameter would have to be calculated and entered into the system manually.

1.6.3.2.4. *Statements from flight crew and maintenance personnel regarding high RAT indications*

The flight crew for the high RAT temperature event that took place on 18 August 2008 in Madrid before taking off for Malaga did not notice it and therefore did not log it in the ATLB. They noted that as part of the "Final Items" on the before takeoff checklist, the engine and RAT temperature parameters are always checked, as are the breakers.

They knew that energizing the RAT probe on the ground limits the value of the EPR, as a result of which maximum engine thrust would be unavailable if the auto throttle were used.

The crew from the flight of 19 August detected the problem with the high RAT temperature reading before their last flight from Barcelona to Madrid. While taxiing, and after completing the taxi checklist, they noted that the RAT temperature was oscillating. They also remember seeing the Autoslat failure light turn on, though it stayed off once the associated breaker was reset. They did not consult the MEL and decided to take off in manual mode. During the climb they managed to successfully engage the auto throttle system (ATS). After landing in Madrid they continued watching the RAT temperature reading, though this time it did not increase. They then logged the malfunction they had detected prior to takeoff in the ATLB.

[24] Item 32.8 in the MMEL, on the "PARKING BRAKES ON Annunciator System", specifies that, following a specific maintenance activity, this system can be inoperative if the Anti-Skid and TOWS systems are working properly.

During the first flight of the day between Madrid and Barcelona they did not recall seeing anything out of the ordinary. They did remember, however, that while waiting at the holding point prior to takeoff, the temperature reading was normal.

The maintenance technician (AMT1) who checked the initial malfunction logged in the ATLB on 19 August 2008 in Madrid consulted the ATLB (sequence 36L) and saw that the RAT probe temperature reading was 34 or 35 °C, which is a fairly normal value in the summer and is not indicative of heat being applied to the RAT probe. He reset the Z-29 breaker, which allows electricity to flow through the resistance that supplies heat to the RAT probe, and noted that the temperature was normal. He then made a visual check of the probe itself, which did not reveal anything abnormal. Finally he touched the probe with his hand, noting that it was not hot then.

After this, he used the rotary switch meter selector and heat to verify that no electricity was being drawn by the RAT probe; that is, that it was functioning normally, since this probe is only supposed to be heated while in flight.

He then simulated flight conditions by opening the breakers for the left (K-33) and right (L-33[25]) ground sensing relays so as to simulate flight mode. He verified that the RAT probe heater was working, as it should under those conditions.

Following this, he proceeded to do the operational test for the TRI (Thrust Rating Indicator) from memory, only resorting to the Maintenance Manual to check one parameter.

Having completed these actions, he was unsuccessful in reproducing the fault described in the ATLB. He finally informed the crew of the next flight that he had not detected the fault logged in sequence 36L, and asked them to inform him if the system failed again.

The crew consulted the ATLB and item 30.8 in the MEL on RAT probe heating, and item 34.9 on the RAT probe itself and the thrust selection systems. When they started to taxi, they twice noted that the RAT temperature reading was high, so they decided to take off in manual. During the flight they did not observe any faults. After landing at Barcelona Airport, the taxi to the gate lasted approximately two minutes, during which time they did not check the value of the RAT temperature.

The night of 19 August 2008, the airplane was in Barcelona. The maintenance technician (AMT2) who investigated the fault went in to work on the night shift. After checking the ATLB, he used the rotary switch meter selector and heat to select RAT heating to verify that the indicator went to zero, which meant that there was no current

[25] See footnote 22 regarding the different nomenclatures that may be used for these devices in other MD-82 airplanes.

flowing through the probe heater, and that therefore the fault described by the crew could not be duplicated. Two other maintenance technicians, both of them shift supervisors, also verified that the temperature probe was not energized on the ground.

After these checks, AMT2 consulted the AMM, specifically Chapter AMM 34-18-00, on the description and operation of the RAT and TRI. He decided to carry out the adjustment test in Section 2 of this chapter, aided by another maintenance technician. All of the checks involved in the test were satisfactory. He finished by making another entry in the ATLB.

On 20 August 2008 in Madrid, two maintenance technicians (AMT3 and AMT4) reported to parking location R11, where the airplane was, after being told by their shift supervisor that the crew had detected a high RAT temperature reading. In addition to the information provided in Section 1.1, History of the flight, AMT3 confirmed that after checking the Minimum Equipment List (MEL) and verifying that the airplane could be dispatched with the RAT heater inoperative, he did not consider checking other airplane documentation, such as the Maintenance Manual, nor did he suspect, by his own admission, that there was a link between the RAT probe and the TOWS.

He stated that the company had never imposed a time limit for fixing any line faults that are discovered, nor had the noticed any hesitation to replace an aircraft with another should such an action be necessary for technical reasons.

On 20 August 2008, the Spanair Maintenance Chief at the Madrid-Barajas Airport, whose functions include the coordination and oversight of the administration, production and organization of the Madrid base, went into work at 06:45. He conducted the turnover between the night and day shift supervisors. He was not informed when the crew of the airplane decided to return to parking due to technical problems and did not intervene during, nor was he informed of, the maintenance action taken to solve the malfunction since, as he stated, his involvement is dependent on the airplane being declared AOG. He was also unaware that the company's Operations Department in Palma de Mallorca had authorized the possible use of another airplane.

With respect to the actions taken to repair this malfunction, he said that after EC-HFP had concluded the flights scheduled for that day, a maintenance technician would have checked the list of outstanding maintenance issues (the Hold Item List - HIL) and would have tried to fix the malfunction once and for all.

In his opinion, it was not necessary to check any other points in addition to 30.8 of the Minimum Equipment List (MEL), such as 34.9, for example, because the MEL establishes no connection between the two.

In reply to the question posed at the judicial inquiry as to why different solutions had been applied to the same malfunction, in reference to the checks in Barcelona the night before and to the technicians' actions the day of the accident, he said that the last action was made in line and the other during the airplane's daily inspection, which is why the AMM was used in Barcelona and not the MEL. He thought it was normal not to consult the Maintenance Manual during the inspection on the parking area at Barajas, since that would have required declaring the airplane out of service, this way being able to check the manuals in the office.

1.6.3.3. Maintenance records

1.6.3.3.1. *Maintenance record requirements*

The Aircraft Technical Logbook (ATLB) is a document used jointly by airplane crews and maintenance personnel. It is used to record any defect found during aircraft operations, along with the maintenance action taken to fix it.

The ATLB is a requirement under Regulation 2042/2003, paragraph M.A. 305 b) "Aircraft continuing airworthiness record system".

Additionally, M.A. 401 "Maintenance Data" in the same regulation specifies the following in item a):

> "*The person or organization maintaining an aircraft shall have access to and use only applicable current maintenance data in the performance of maintenance including modifications and repairs".*

Item b) defines the maintenance data considered applicable for the purposes of the regulation:

> *"Any applicable requirement, procedure, standard or information issued by the competent authority.*
>
> *Any applicable airworthiness directive.*
>
> *Applicable instructions for continuing airworthiness, issued by type certificate holders, supplementary type certificate holders and any other organization that publishes such data in accordance with Part 21.*
>
> *Any applicable data issued in accordance with 145.A.45(d)."* [26]

[26] This point in the regulation states that: "The organization may only modify maintenance instructions in accordance with a procedure specified in the maintenance organization's exposition. With respect to those changes, the organization shall demonstrate that they result is equivalent or improved maintenance standards and shall inform the type-certificate holder of such changes. Maintenance instructions for the purposes of this paragraph means instructions on how to carry out the particular maintenance task: they exclude the engineering design of repairs and modifications".

Lastly, Section c) of M.A. 401 specifies that the person or organization shall establish a work card or worksheet system or make precise reference to the particular maintenance task or tasks contained in such maintenance data.

1.6.3.3.2. *Spanair procedures for making ATLB entries*

Spanair's document titled "Technical Logbook Procedures", issued on 11 April 2008, specifies that the Certificate Release to Service (CRS) must be completed by maintenance personnel and in accordance with EASA PART 145 with exclusive regard to the maintenance action referred. Paragraph 145.A.50 specifies that any maintenance action requested must be performed correctly by the organization using the maintenance data specified in 145.A.45.

This same document indicates that the CRS means, among other things, that all defects have been corrected or processed in accordance with approved maintenance documentation.

1.6.3.3.3. *ATLB maintenance records for EC-HFP*

As part of the investigation, the information contained in the ATLB for the six months before the accident (from 21 February to 20 August 2008) was compiled and analyzed. The study excluded those entries that made reference to daily and pre-flight inspections.

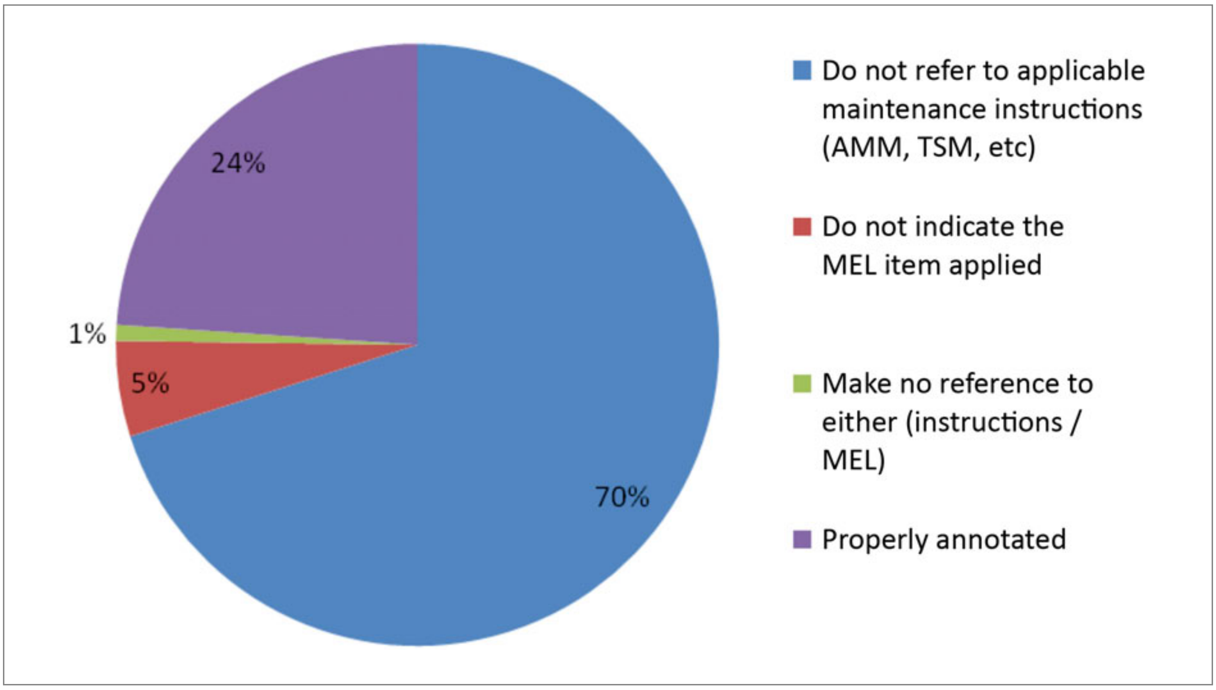


Figure 7. Breakdown of the findings of the logbook study (for period from 21 February – 20 August 2008)

An analysis of the remaining entries contained in the logbook revealed the following:

- Approximately 76% of the entries did not make reference to the applicable maintenance data (AMM, TSM[27], etc.).
- Only 24% of the entries correctly referenced applicable maintenance data.
- Do not refer to applicable maintenance instructions (AMM, TSM, etc.).
- Do not indicate the MEL item applied.
- Make no reference to either (instructions/MEL).
- Properly annotated.

1.6.4. *Weight and balance*

The airplane was refueled in Barajas with 10130 liters (18000 pounds[28]) of JET A-1 fuel and the passengers and cargo were taken on. As noted in the load sheet, the maximum takeoff weight (MTOW) was 147000 pounds. The total payload was 5190 pounds and the passenger weight was 27655 pounds. The load sheet also noted some last-minute changes that increased the weight by 555 pounds. The total number of passengers reflected in the load sheet was 163, which was corrected to 166 following the last-minute modifications.

In total, the aircraft started its initial taxi run to the runway 36L threshold with an actual takeoff weight (ATOW) of 142448 pounds, distributed as follows:

- Dry operating weight (DOW): 84318 pounds
- Passengers: 28210 pounds
- Payload: 5190 pounds
- Fuel: 24730 pounds

The load sheet listed the aircraft's center of mass for takeoff at 8.05% MAC, which was within the approved limits (–0.8% and 26% MAC) specified in Chapter 6, Weight and Balance, of the Operations Manual, Part B.

According to the load sheet, the fuel burned while taxiing was 800 pounds, meaning the aircraft would have weighed a total of 141648 pounds upon reaching the runway threshold.

Once at the threshold, the aircraft returned to parking to fix the malfunction with the abnormal heating of the RAT probe and refueled the amount burned during the taxi run so as to equal the initial 24730 pounds, meaning the second taxi sequence was

[27] TSM: Trouble Shooting Manual.
[28] Assumes an average density of 15 °C, between the minimum and maximum values (0.775-0.84 kg/m^3) listed in ATSM D4052 (American Society for Testing and Materials).

started with the same weight of 142448 pounds. The crew did not prepare a new load sheet since the weights were the same as for the first taxi run.

The takeoff after the second taxi run, then, was made with a total weight of 141648 pounds.

1.7. Meteorological information

The meteorological information shown below is taken from the METAR reports provided by the Madrid-Barajas Airport weather office, from the ATIS information that is broadcast over the radio and from information provided by the controller at the time the airplane was cleared for takeoff.

1.7.1. *METAR information*

The METAR reports provided by the weather office at the Madrid-Barajas Airport for the time interval spanning the accident (corresponding to 14:00, 14:30 and 15:00) are as follows:

METAR LEMD 201200Z 35002KT CAVOK 28/06 Q1019 NOSIG

METAR FOR MADRID BARAJAS AIRPORT FOR THE 20TH AT 12:00 UTC, WIND FROM 350° 2 KT, VISIBILITY CAVOK, TEMPERATURE 28° DEWPOINT 06°, QNH 1019, TREND: NO SIGNIFICANT CHANGES EXPECTED IN THE NEXT 30 MINUTES

METAR LEMD 201230Z 18007KT 090V240 CAVOK 28/02 Q1018 NOSIG

METAR FOR MADRID BARAJAS AIRPORT FOR THE 20TH AT 12:30 UTC, WIND FROM 180° 7 KT VARYING IN DIRECTION FROM 90° TO 240°, VISIBILITY CAVOK, TEMPERATURE 28° DEWPOINT 02°, QNH 1018, TREND: NO SIGNIFICANT CHANGES EXPECTED IN THE NEXT 30 MINUTES

METAR LEMD 201300Z 14004KT CAVOK 29/03 Q1018 NOSIG

METAR FOR MADRID BARAJAS AIRPORT FOR THE 20TH AT 13:00 UTC, WIND FROM 140° 4 KT, VISIBILITY CAVOK, TEMPERATURE 29° DEWPOINT 03°, QNH 1018, TREND: NO SIGNIFICANT CHANGES EXPECTED IN THE NEXT 30 MINUTES

1.7.2. *ATIS information*

The information provided by the ATIS minutes before and shortly after the accident is as follows:

- Information L (LIMA) provided automatically by the ATIS at 14:10:34.

  12:10:34 Automatic ATIS_ DEPARTURE LEMD INFO DEP L TIME 1210 RWY IN USE FOR DEP 36L AND 36R AND FOR ARR 33R AND 33L TRL 140 ACFT MUST BE RDY TO STARTUP BFR CONTACT CLR DELIVERY FREQ 130 075 EB AND FREQ 130 350 WEST AND NB FLOCK OF LARGE BIRDS IN FNA IN DEP WIND 200 DEG 3 KT VIS CAVOK T 28 DP 4 QNH 1018 NOSIG

- Information M (MIKE) provided automatically by the ATIS at 14:20:34.

  12:20:34 Automatic ATIS_DEPARTURE LEMD INFO DEP M TIME 1220 RWY IN USE FOR DEP 36L AND 36R AND FOR ARR 33R AND 33L TRL 140 ACFT MUST BE RDY TO STARTUP BFR CONTACT CLR DELIVERY FREQ 130 075 EB AND FREQ 130 350 WEST AND NB FLOCK OF LARGE BIRDS IN FNA IN DEP WIND 230 DEG 4 KT VIS CAVOK T 28 DP 3 QNH 1018 NOSIG

The crew of JKK5022 probably used the information in one of these two ATIS messages, though no specific mention is made in their conversations with the Tower.

The information entered manually in the tower for the 14:37:15 ATIS informs that only runway 36R was available for takeoffs. The 14:53:39 ATIS informed that the runways in use for takeoffs and landings were 33L and 33R, meaning that runway 36R was closed. The re-opening of runway 36R for takeoffs was reported in the 17:19:13 ATIS.

1.7.3. *Wind data*

At every runway threshold there are two anemometers to measure wind speed and direction, one of them a backup. They are located 300 m away from the threshold (touchdown zone) and 150 m away perpendicularly from the runway centerline.

Every second a value is taken from the direction sensor and the pulses from the speed sensor are integrated. This speed, which is averaged over one second, is in turn averaged with the speed from the previous second, this last value being used to measure instantaneous wind speed. In other words, the instantaneous speed is the average speed over two seconds. The wind direction is the instantaneous direction recorded every second.

The data shown on the wind displays at the control positions in the Tower are obtained from the information extracted from the two anemometers located on each runway. According to the data provided by the airport's weather office, the instantaneous wind data for runway 36L/18R recorded every 10 seconds for the period from the time takeoff clearance was granted until the takeoff (14:23:22 - 14:23:40) were:

Date	Time	VIC36L[29]	DIC36L[30]
20/08/2008	14:23:10	06 kt	208°
20/08/2008	14:23:20	05 kt	180°
20/08/2008	14:23:30	05 kt	264°
20/08/2008	14:23:40	03 kt	270°

Date	Time	VIC18R	DIC18R
20/08/2008	14:23:10	04 kt	270°
20/08/2008	14:23:20	03 kt	264°
20/08/2008	14:23:30	03 kt	264°
20/08/2008	14:23:40	05 kt	264°

The data provided by the anemometers for runway 36L - 18R generally show that the winds, though highly variable in direction, were weak. The information for the time of takeoff (approximately 14:23:40) from the anemmeter at the 36L threshold shows a wind of barely 3 kt from 270, and at the anemometer closest to the 18R threshold a 5-kt wind from 264.

1.7.4. *Control clearance information*

The information provided to the aircraft by the controller immediately before the accident (a minute and 20 seconds earlier) was wind from 250° at 7 kt. The wind information provided by the controller to aircraft JKK5022 in its takeoff clearance was 210° 05 kt[31].

1.8. Aids to navigation

The aids to navigation are not pertinent to this investigation. Nevertheless, they were operating normally both before and after the accident.

1.9. Communications

Aircraft JKK5022 contacted the ATC services at Barajas Airport on various frequencies: Ground (GND), Clearance Delivery (CLD) and Departure (DEP). All of the communications

[29] VIC36L, VIC18R Instantaneous speeds, 36L and 18 R thresholds, respectively.
[30] DIC36L, DIC 18R Instantaneous directions, 36L and 18 R thresholds, respectively.
[31] Both refer to the instantanteous values provided by the anemometer.

proceeded normally and were recorded at the Madrid-Barajas Airport ATC facilities. The recorder tapes have been transcribed.

The aircraft also established radio contact with the company's ground handling agent at Madrid-Barajas. Those communications were not recorded.

1.10. Aerodrome information

1.10.1. *General information and location*

The Madrid-Barajas Airport (IATA: MAD, ICAO: LEMD) is located to the northeast of Madrid (reference point coordinates 402820N 0033339W). It is at an elevation of 610 m (2001 ft) in the district of Barajas, 13 kilometers away from the city center. The terminals are within the Madrid city limits, though the runways are mainly in the city limits of both Madrid and Alcobendas and, to a lesser extent, of San Sebastian de los Reyes and Paracuellos del Jarama. It is run by the public company Aeropuertos Españoles y Navegación Aérea (AENA, Spanish Airports and Air Navigation), which reports to the Ministry of Development.

The airport has four asphalt runways: 15R/33L, 15L/33R, 36R/18L and 36L/18R. The aerodrome reference code based on the requirements in ICAO Annex 14 is 4-E[32].

Runway 36L/18R is 4349 m long and 60 m wide. The runway 36L threshold is at an elevation of 605 m and the threshold of runway 18R is at 606.9 m. The longitudinal gradient of runway 36L does not exceed 1% at any one point or 0.8% between its extremes. The length of the runway strip is 4470 m (which extends 60 m beyond the ends of the runway) and its width is 150 m (75 m to either side of the runway centerline). The dimensions of the runway end safety area (RESA) are 90 × 150 m. The clearway (CWY) measures 260 × 150 m. Runway 36L is only used for takeoffs and 18R is only used for landings.

1.10.2. *Access to crash site*

The crash site was between the 36L-18R and 36R-18L runways. The main wreckage was in an area next to the 18R threshold where the De la Vega stream runs. The elevation of the stream at that location is 590 m, while the elevation of the runway 36L strip is

[32] The reference code consists of a letter and a number assigned based on the critical reference aircraft that can operate at the aerodrome. The number relates to the length of field necessary for that aircraft, while the letter relates to the wingspan and the outer main gearwheel span.

606 m, with a constant gradient from one point to the other, the maximum slope being in the vicinity of the stream.

The airport complex has both an outer and an inner fence. The inner fence at the crash site has a concrete foundation some 0.4 m high supporting a wire fence approximately 2 m high with locked access gates along its perimeter. This fence was the main outer perimeter fence before the last expansion of the airport facilities in 2005, and was not removed since it was thought that keeping it would help to increase security against potential human or wildlife incursions.

The nearest access point to the crash site along the fence, considering the path taken by emergency services, was about 940 m away from the wreckage.

The section on "Emergency access roads" in Chapter 9 of ICAO Annex 14, recommends that "*Emergency access roads should be provided on an aerodrome where terrain conditions permit their construction, so as to facilitate achieving minimum response times. Particular attention should be given to the provision of ready access to approach areas up to 1000 m from the threshold, or at least within the aerodrome boundary. Where a fence is provided, the need for convenient access to outside areas should be taken into account*".

1.10.3. *Information on air traffic control at the airport (TWR)*

The Madrid-Barajas Airport has three control towers (see Figure 8).

- The South Tower (TWR S), located within the T2 terminal and formerly the only Control Tower in use at the airport until the start of operations at the North Tower.
- The West Tower (TWR W), located next to the T4 terminal building and constructed to aid in taxiing in the vicinity of the T4 terminal building.
- And the North Tower (TWR N), located next to the satellite building. It is the airport's main tower.

Under normal operating conditions, TWR S and W handle movements within their respective adjoining areas, which are broken down into sectors. TWR N handles arrival (ARR) and departure (DEP) clearances, ground (GND) movements in adjoining sectors and start-up clearances (CLD).

TWR N is located at the junction of the parallel runways. Its position is aligned with the site where the wreckage of the aircraft came to a stop, parallel to runways 36L and 36R. The distance from the visual control room to the wreckage was 4100 m. The tower is 70 m above the ground elevation (603 m), is octagonal in shape and in a North Configuration, has 10 control positions and one supervisory position. The post associated with 36L takeoff clearances faces that runway (see Figure 9).

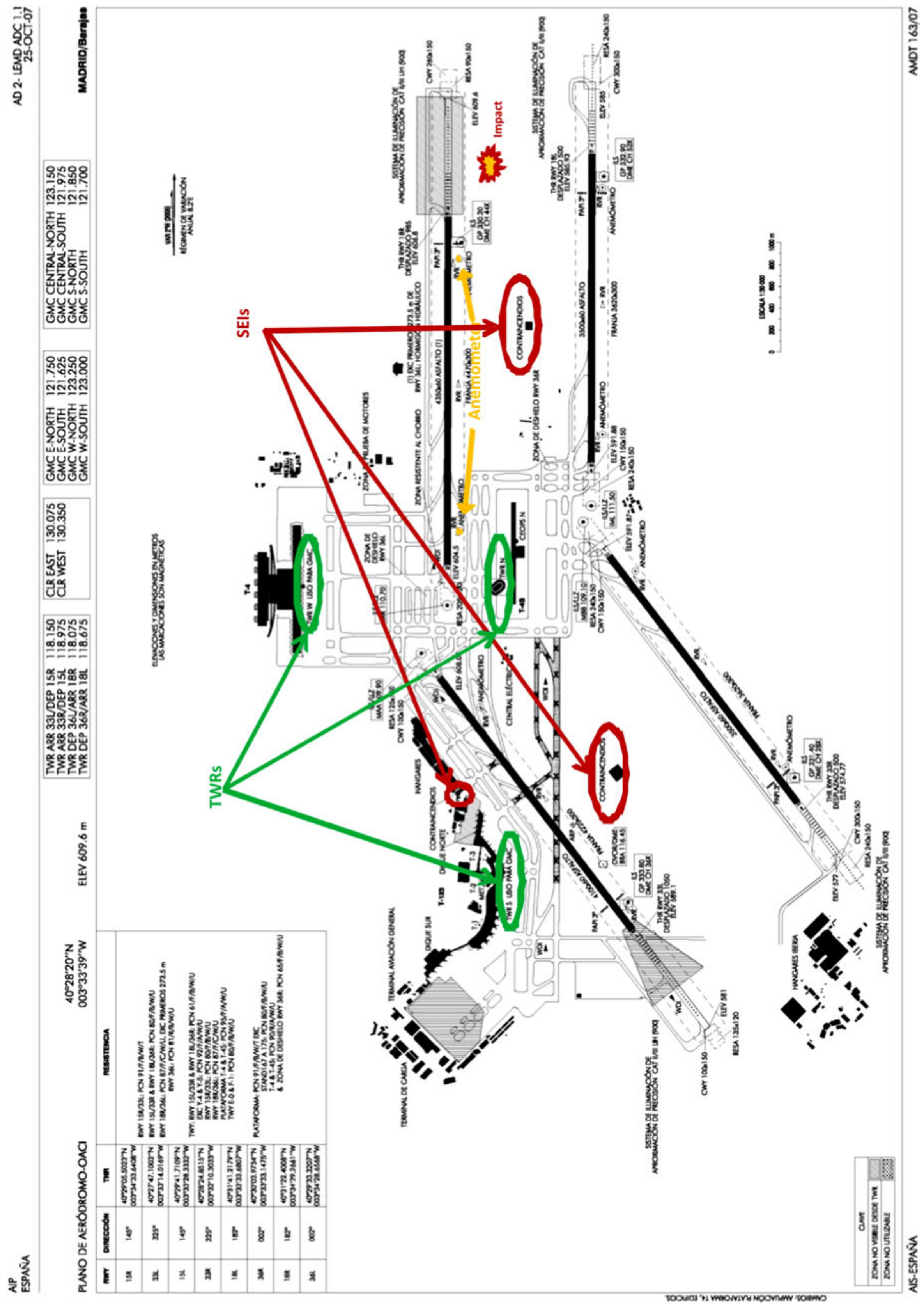


Figure 8. Locations of TWRs and RFFS facilities

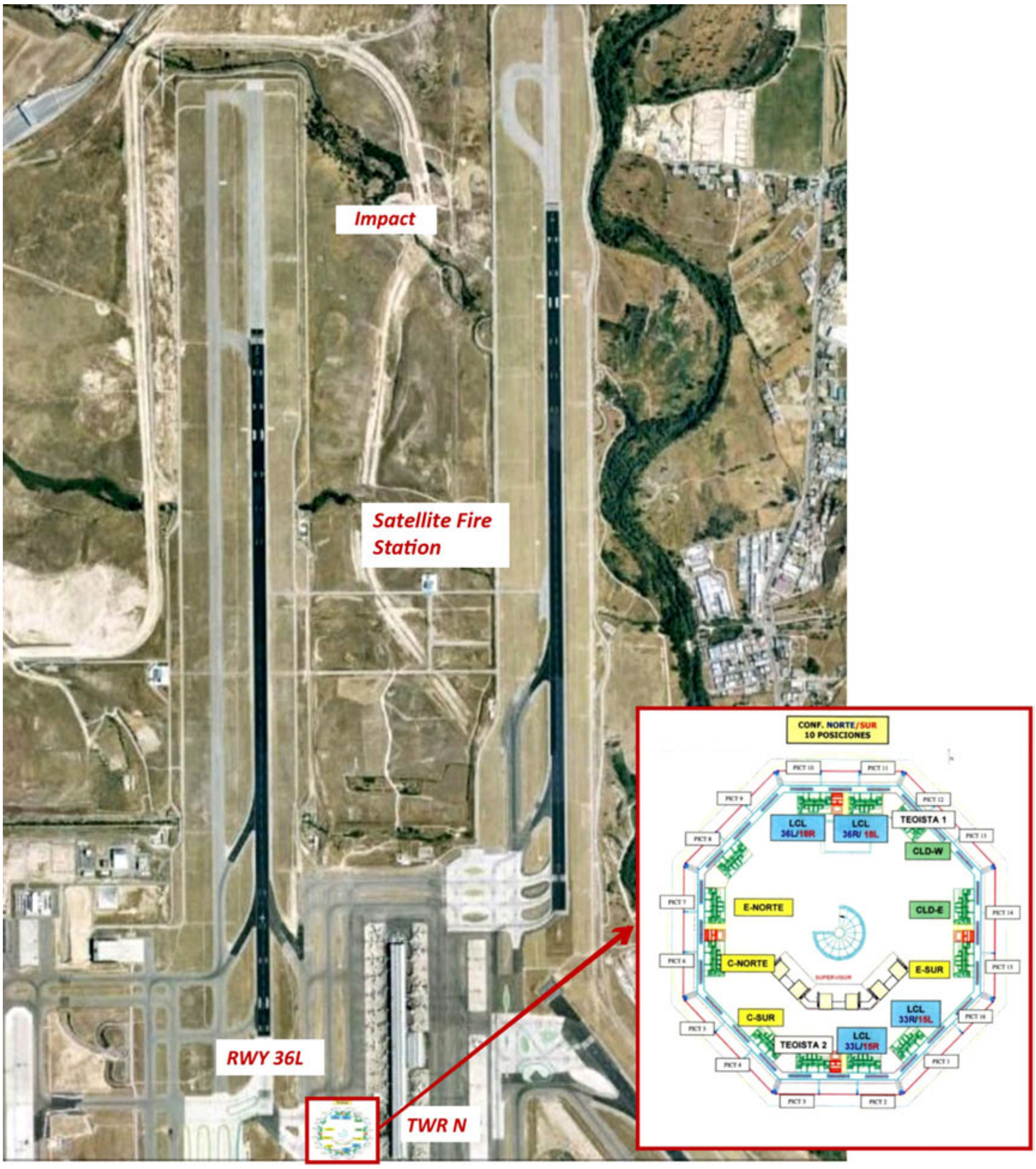


Figure 9. Location of TWR N with respect to the runways and crash site

At the time of the accident, seven control positions were staffed to handle the existing traffic:

- 2 takeoff clearances for runways 36R and 36L
- 2 landing clearances for runways 33R and 33L
- 2 taxi clearances
- 1 start-up clearance.

The supervisor's position was also manned, though the supervisor does not monitor the movement area outside.

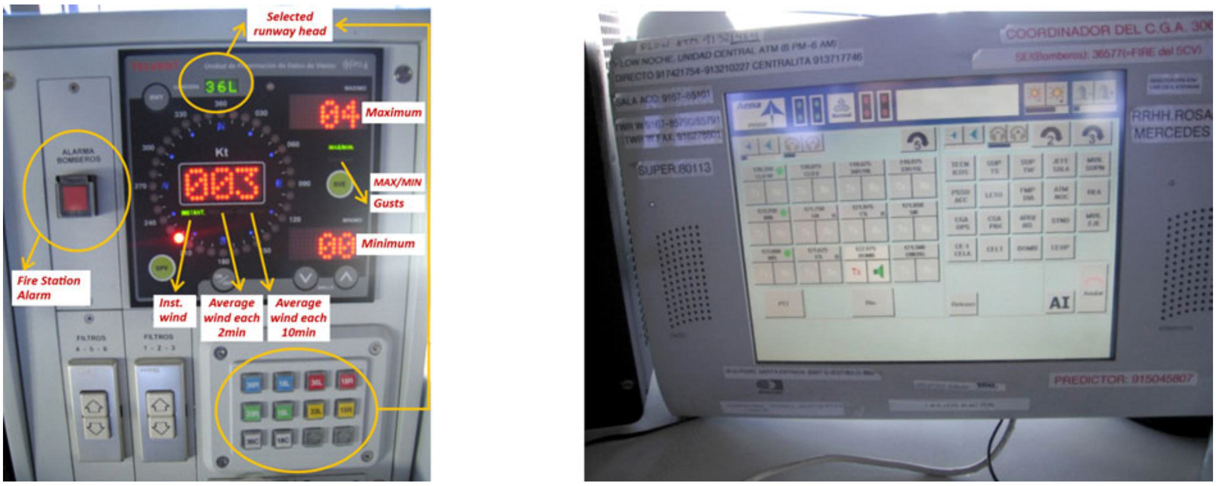


Figure 10. Wind monitor (zephyr) with the RFFS alarm and the scanner (CD30) at the Supervisor's positions

Takeoffs from runway 36L were suspended at 14:37, and from runway 36R at 14:53.

There is a wind monitor or zephyr at every position in the control tower which houses a device that can be used to alert the firefighting service. At the supervisor's post there is a radio scanner, a panel with telephones and another with hotlines for establishing direct contact with the Area Control Center (ACC), the Rescue and Firefighting Service (RFFS) and the Main Control Post at the Airport Operations Office (AOO).

1.10.4. *Rescue and Firefighting Service (RFFS)*

In accordance with ICAO Document 9137-AN/898, Airport Services Manual, Part 1 "Rescue and Firefighting", the Madrid-Barajas Airport's firefighting protection service is rated category 9[33], the maximum being 10. The category 9 protection requirements are summarized in the following table:

Category	Minimum number of vehicles	Reaction time	Extinguisher agent		
			Type	Minimum quantity	Unloading rate
9	3	2 to 3 minutes	Foam efficacy B	24300 liters of water	9000 liters foam solution/min
			Dust chemical product	450 kg	

[33] The level of protection that must be provided at an aerodrome is based on the dimensions of the aircraft that use it, adjusted as required by the frequency of operations (criterion of 700 movements a day in the three most active consecutive months).

The airport has three different RFFS facilities: the Central, Satellite and Apron Firefighting Stations. The latter provides day-to-day coverage for spills, aircraft refuelings with passengers onboard and incidents that occur within the aircraft parking area (apron). It also aids the other two stations with any incidents and activities that may take place in their areas of responsibility.

The Central Firefighting Station is located between runways 15R-33L and 15L-33R. The Satellite Firefighting Station is between the 18R-36L and 18L-36R runways and the Apron Firefighting station is near the T3 terminal building near the taxiways leading to and from runway 15R-33L (Figure 11). Both the Central and Satellite Firefighting Stations have direct access to the runways within their area of responsibility.

In consideration of the airport category, the Aviation Emergency Plan (AEP) specifies the minimum number of firefighting personnel, which is 15 firefighters plus two chiefs. On 20 August 2008, the stations were staffed by 21 firefighters and three chiefs. The personnel were arranged as follows:

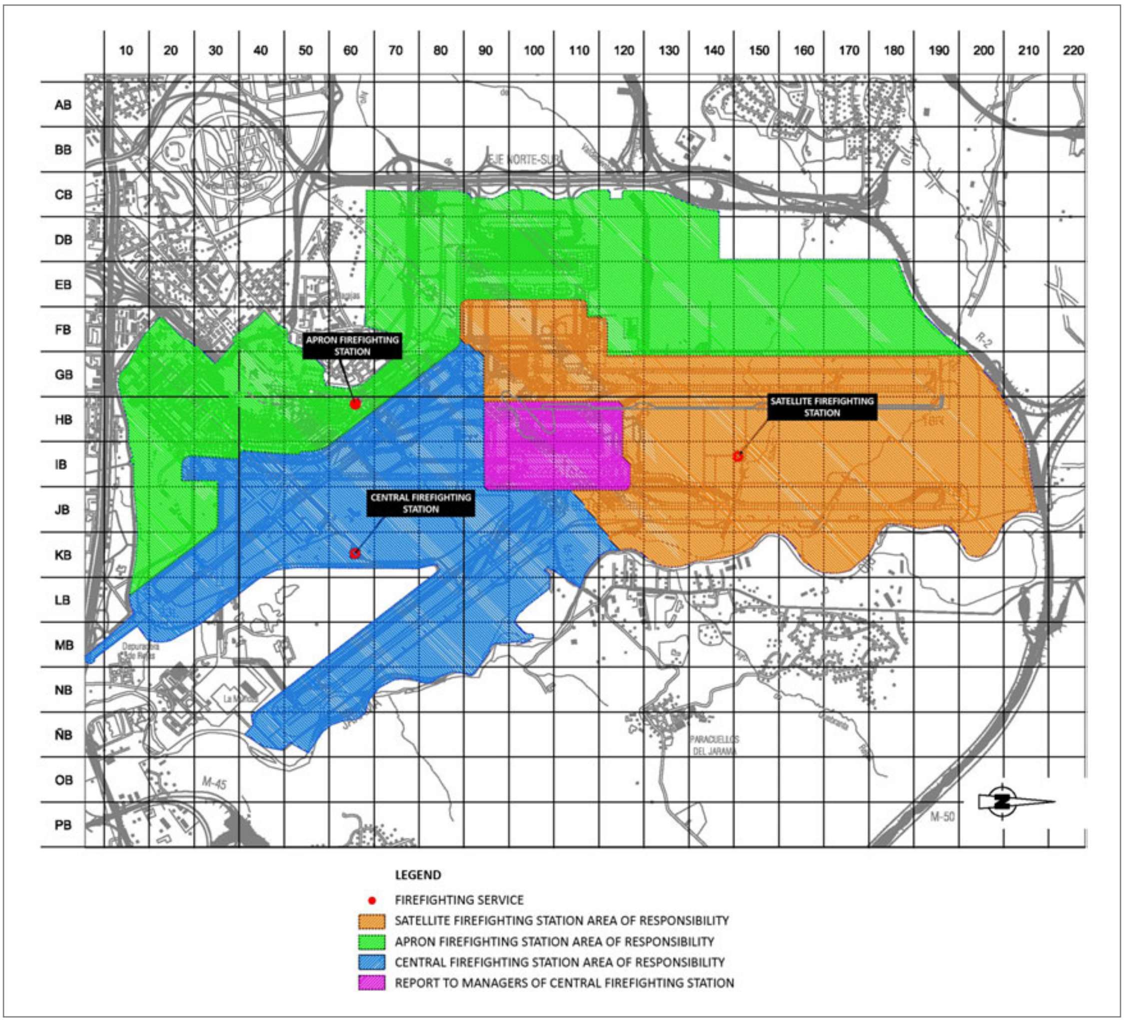


Figure 11. Locations and areas of responsibility of the RFFS stations

- Apron Station:

  — 1 chief
  — 6 firefighters
  — 1 firefighter at the Observation and Alarm Center (OAC), or Watch Room
  — 2 heavy firefighting trucks
  — 1 control vehicle[34]

- Satellite Station:

  — 1 chief
  — 7 firefighters
  — 3 heavy firefighting trucks
  — 1 control vehicle

- Central station:

  — 1 chief
  — 7 firefighters
  — 3 heavy firefighting trucks
  — 1 control vehicle

The function of the firefighter on duty at the Observation and Alarm Center (OAC) is to provide support to the Chiefs by gathering data during emergency situations. This center receives the alarm notification or detects the alert situation through direct observation of the movement area. Once alerted of an emergency situation, the OAC activates the fire station alarms if not previously activated by the TWR.

AENA has defined a training plan for RFFS personnel that is specific for the fire chiefs and firefighter category. The plan includes recommended and mandatory activities, some of which are hands-on while others employ distance (online) learning. In all, the annual program encompasses up to 150 h. Most of the training is hands-on (up to 120 h a year) and consists mainly of live fire drills, training on apron activities, aircraft emergency systems, indoor fires and ventilation, and one 20-hour module dedicated to rescuing victims. Fire chiefs have to take 35 h of training on directing emergency response. The online training focuses on regulatory and basic airport safety issues.

The training records of RFFS personnel from 2003 until 2008 show that the amount of training provided differed from year to year. The fire chiefs devote more time to training,

[34] The control vehicle (CV) is normally a fast intervention vehicle (FIV).

in excess of 70 hours a year in 2008, for example. The trend for firefighters, however, evidenced less time devoted to training and a greater disparity in the number of training hours per year, varying from 36 to 52. With the exception of two fire chiefs, practically all personnel received first aid training only once, as part of a 5-hour training session held in 2008 after the accident, according to the schedule planned in April 2008. Victim rescue training was given on several occasions, the last before the accident having taken place between October and November of 2006 for all firefighters.

Information provided by airport management revealed that the RFFS personnel who responded to the accident had last been involved in a live fire drill in April-May 2007. In November 2008, live fire drills were once again held for all firefighters. This training took into account the familiarization with the airport complex and the use of an airport map divided into grids so as to better locate the emergency. This map is now carried onboard the intervention vehicles.

1.11. Flight recorders

In keeping with operational regulations in effect[35] at the time of the accident, the airplane was equipped with a digital flight data recorder (DFDR) and a cockpit voice recorder (CVR). A quick access recorder (QAR) was also installed on the airplane.

The DFDR and CVR were recovered from the aircraft wreckage the same evening of the accident. They showed signs of impact and fire damage. The information recorded in them was successfully recovered at the AAIB laboratory in the United Kingdom.

The QAR was recovered from the aircraft wreckage in the days following the accident. The optical magnetic disk where the information on the QAR is recorded had been installed on the airplane in early August 2008. The information contained in this disk was downloaded at the facilities of the equipment's manufacturer, Teledyne. The data it held were confirmed to correspond to another of the operator's airplanes and to previous flights. The equipment's recording format and the disk's reading format were verified to be incompatible.

Spanair had started to download QAR data no more than two months earlier. In that time, it had not detected that the information recorded on the disks was faulty.

[35] Commission Regulation (EC) No. 8/2008 of 11 December 2007. Common technical requirements and administrative procedures applicable to commercial transportation by airplane. OPS 1: Commercial Air Transportation - Airplanes, in effect since 16 July 2008 (known as EU OPS regulations).
Subpart K. Paragraphs OPS1.710 and OPS1.725.

1.11.1. *Digital Flight Data Recorder (DFDR)*

The characteristics of the digital flight data recorder were as follows:

Manufacturer: Honeywell
Model: SSFDR
P/N: 980-4700-042
S/N: SSFDR-13470

The DFDR recorded information on 64 parameters over a 100-hour period.

The airplane was equipped with two digital flight guidance computers (DFGC), both of which operate continuously with one computer in use during airplane operations with the other in standby. The no. 2 DFGC was active during the taxi and takeoff phases leading up to the accident. The flight parameters transmitted to the DFDR from the no. 2 DFGC were recorded erroneously, probably due to a problem with the connection between the DFGC and the flight data acquisition unit (FDAU). The parameters in question are the following:

Position of horizontal stabilizer, position of elevator, angle of attack, position of outboard left spoiler, position of inboard right spoiler, position of left aileron, position of rudder, position of slats (LH and RH), autopilot status, LH MLG ground signal and RH MLG ground signal.

The remaining parameters were properly recorded.

The operator did not perform any periodic checks to ensure that the raw data recorded on the DFDR were being properly transformed into engineering units, since existing regulations did not require such checks.

Spanair, in accordance with the stipulations of OPS 1.160.a. (4) (ii), provided the information[36] for transforming the data contained in the recorder into engineering units. This information could not be used to transform the data, as a result of which a document provided by the manufacturer, Boeing, had to be utilized[37].

Since, as previously stated, the company did not conduct periodic checks to ensure the proper transformation of the raw data into engineering units, it also did not check whether the information that was available (transformation algorithms) for decyphering the DFDR recording was correct.

[36] Boeing Document MD-80 DFDR PARAMETER REDUCTION DATA, MSN 53148, Variable 80E010.
[37] MD-80 DFDAU INTERFACE CONTROL DOCUMENT" reference MDC 93K9055 Revision E dated 2 December 2005. Boeing.

Appendix 2 to this report shows the trends for those flight parameters deemed most relevant to the investigation.

1.11.2. *Cockpit Voice Recorder (CVR)*

The characteristics of the cockpit voice recorder were as follows:

Manufacturer:	Sundstrand (Honeywell)
Model:	AV-557-C
P/N:	980-6005-079
S/N:	9228

The CVR had four (4) channels of good audio data, which recorded the 32 minutes prior to the time of the accident. The quality of the sound obtained is good.

1.11.3. *Quick Access Recorder (QAR)*

The characteristics of the quick access recorder were as follows:

Manufacturer:	Teledyne Control
P/N:	2248000-41
S/N:	284

1.11.4. *Regulations regarding operational checks of recorders*

In the EU-OPS regulations, in effect at the time of the accident and at present and currently applicable in Spain, there is no requirement to ensure the proper operation of cockpit voice recorders or of flight data recorders. The purpose of this check is not only to verify that the recorders are actually recording the information, but that the data are of sufficient quality (in terms of range, accuracy, sample period and resolution for FDR parameters, or signal intelligibility for the CVR).

In some European countries, specifically France and the United Kingdom[38], the national authorities did require periodic checks to ensure the flight recorders were functioning

[38] The French regulation that includes the requirement to check the operation of recorders is SFACT letter #98159 of 13 February 1998.
The British regulation that includes the requirement to check the operation of recorders annually is CAP731, Approval, Operational Serviceability and Readout of Flight Data Recorder Systems. 3 July 2006.

properly by means of correlating and validating the information recorded during a sufficiently representative line flight that activates as many parameters as possible.

The EASA is currently working on a plan to modify the regulation (NPA 2009-2b), the consultation period for which ended in February 2011 and which should go into effect in April 2012. The proposed regulation specifies, among other things, the need to verify the proper operation of flight data and cockpit voice recorders periodically.

Moreover, the EASA issued a Safety Information Bulletin, 2009-28, on 9 December 2009 that recommends verifying the proper operation of flight data and cockpit voice recorders in accordance with the stipulations of ICAO Annex 6[39] and EUROCAE ED-112 document.

1.11.5. *Regulations regarding the Flight Data Monitoring (FDM) program*

According to EU-OPS 1.037.a (4), the operator must establish a program to study and analyze flight data. At the time of the accident, Spanair had installed QARs throughout its fleet and had started downloading information from its MD-80 fleet, though the airline lacked the means to analyze these data.

1.11.6. *Synchronization of data recorders*

The CVR and DFDR were synchronized by means of the communications between the aircraft and the control tower at the airport at the time the clearance was issued for the accident aircraft to take off. The synchronization errors were verified to be less than two seconds.

1.12. Wreckage and impact information

1.12.1. *Trajectory taken by aircraft and distribution of debris*

After rotation, the aircraft rose above the runway to a maximum height of 40 ft. It then started to lose altitude while at the same time banking to both sides, as a result of which it deviated to the right. The first part of the airplane to impact the ground was the tail section, followed almost immediately by the right wingtip and the right engine fairings. The tracks left by those impacts were visible to the right of the runway strip as seen from runway 36L, some 60 m away perpendicularly from the runway centerline and 3207.5 m away from the 36L threshold.

[39] Paragraph 6.3.4.3 of Annex 6, Part I, “Continued serviceability” especifies: “Operational checks and evaluations of recordings from the flight recorder systems shall be conducted to ensure the continued serviceability of the recorders.”

The tracks left by the two main landing gear assemblies started 45 m beyond the first impact mark. The track corresponding to the nose gear were 113.5 m away from the first tracks and slightly to the right of the track left by the right main landing gear.

The aircraft continued to travel along the ground for 448 m until it reached the edge of the runway strip. The tracks left by the main legs veered slightly to the right first, then to the left. The nose gear track, which was initially to the right of the right main gear track, remained straight practically throughout its entire length, crossing the MLG right track and almost meeting the left gear track at the end of the run. The path of the aircraft on the ground was at a 16° angle with respect to the runway centerline.

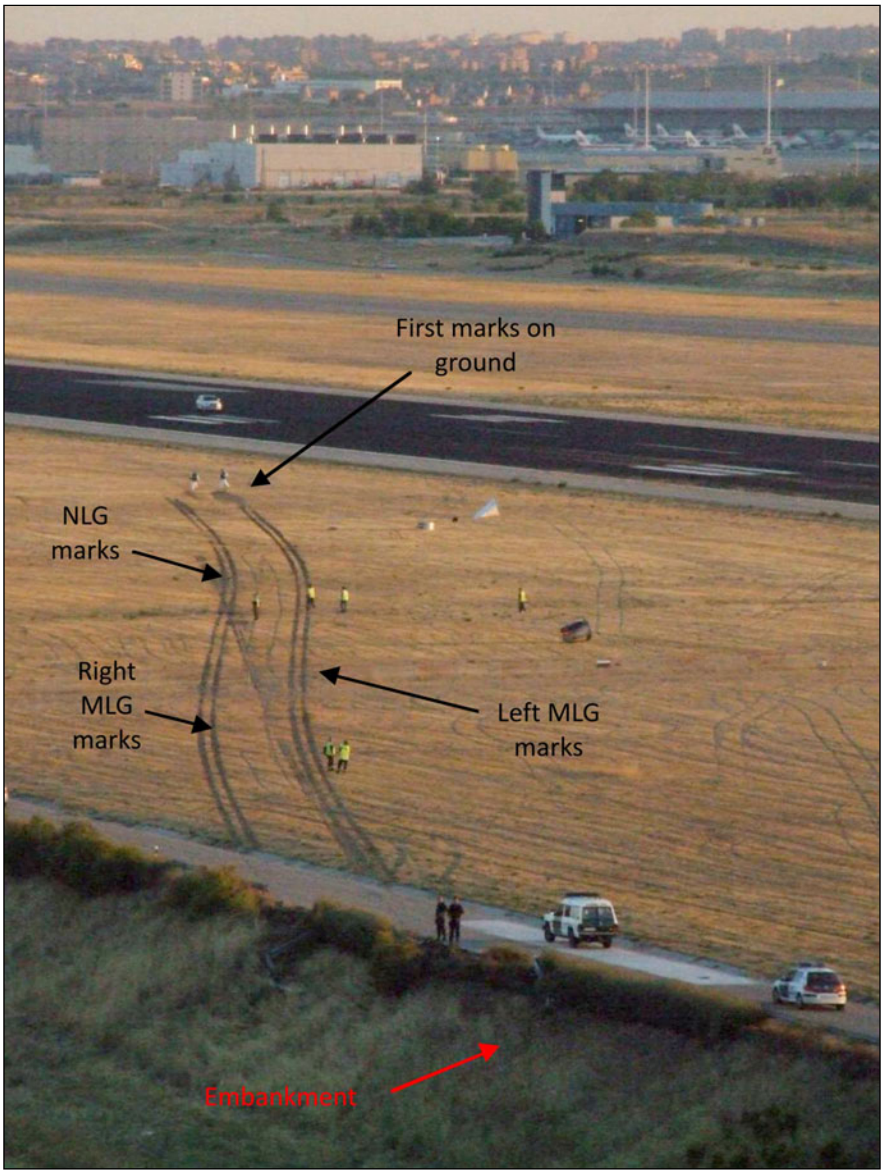


Figure 12. Tracks left by the aircraft as it traveled over the runway strip

Various components detached from the aircraft as it traveled over the ground. The APU drain mast, the tail cone, the no. 2 engine fan exhaust rear duct, the no- 2 engine secondary flow duct and a piece of that engine's fairing were found a few meters beyond and to the left of where the landing gear tracks began. Further forward was a spring from the nose gear torque link and halfway along the trajectory there were several components from the nose gear, the galley drain mast, part of the no. 2 engine lower aft fairing and that engine's reverser.

The aircraft then lost contact with the ground when it reached an embankment located beyond the right side of the runway strip. The tracks on the ground reappeared 150 m away on the airport perimeter road, whose elevation is 5.50 m below that of the runway strip. The aircraft then traveled through a fence that surrounds the road and continued along the ground, which in this area was covered by shrubs and grasses. It jumped over a small stream that ran at an angle to its trajectory and contacted the ground again on the upslope on the other side of the stream. It was during this impact, which was very violent and which left the airplane's outline on the ground, that the aircraft lost its structural integrity. Among the debris found in this area were the keel beam, which is located between the main landing gears, the aft door ramp and the cargo door. This impact may also have broken off the nosegear, causing the strut to detach along with the tires.

The airplane continued moving and a bit further forward the nosegear dug into the ground, which caused the aircraft to rotate first to the right about the gear, and then immediately about its longitudinal axis. During this rotation the aircraft disintegrated.

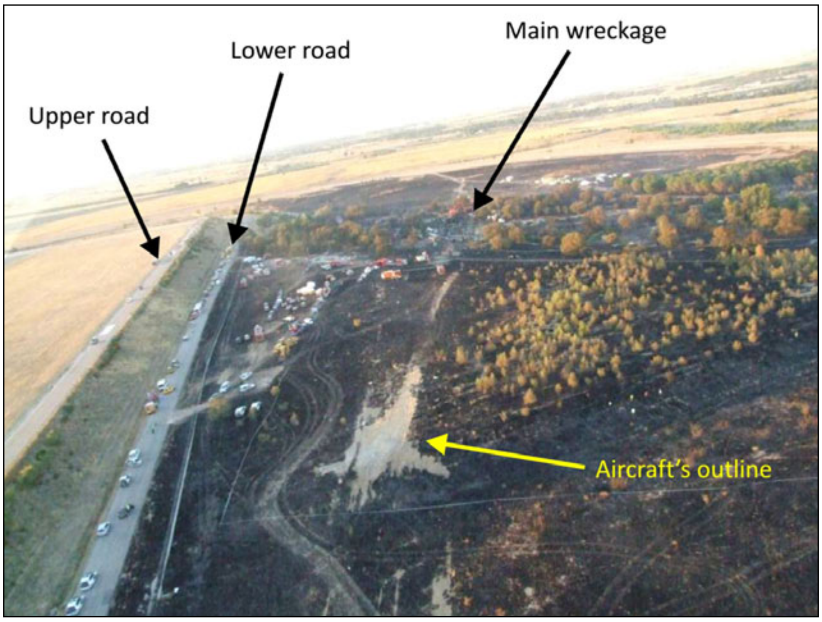


Figure 13. Aerial view of the path taken by the aircraft, showing the outline left by the aircraft on the ground

Both wings broke and both engines, the tail and all three landing gears detached and continued traveling in the forward direction.

The main wreckage then continued traveling along some irregular terrain that sloped downward to the bed of the De la Vega stream, by which time the main structure had mostly disintegrated.

The diagram in Appendix 3 shows the general distribution of the aircraft wreckage.

1.12.2. *Fuselage*

In its final state, the fuselage was highly fragmented and had been affected by the fire. The first third was over the bed of the De la Vega stream and the rest was north of the stream, where the part of the fuselage above the wings was located.

The cockpit had collapsed into the first row of passenger seats and was found on the slope leading up from the left bank of the stream. This part of the wreckage contained the captain's overhead breaker panel, the main breaker panel, the forward left passenger door, a part of this door's frame, part of the forward lavatory and the forward flight attendant's seat.

The forward part of the passenger cabin, corresponding to the first third of the fuselage (up to row 17), was found overturned at the bottom of the stream. Its internal components had been crushed vertically and the rows of seats were upside down. It was the only part of the aircraft that retained its shape.

The aft two-thirds of the passenger cabin back to the rear pressure bulkhead was destroyed by the fire. This part of the wreckage, which included the rear pressure bulkhead itself and part of the aft lavatory and galley, was north of the stream, along with the remains of the center wing box.

The rescue efforts required moving the fuselage and its internal components to the bank of the stream.

Some passenger cabin components, such as the seats, detached from the main wreckage during the final impact. The passengers occupying these seats were still attached to them by the seat belt.

1.12.3. *Primary control surfaces*

Only a segment of the fitting used to attach the left aileron to the left wing was found among the wreckage.

The tail assembly was on the right bank of the stream. The horizontal stabilizer was attached to the vertical stabilizer and the tail assembly had detached from the aircraft when the part of the fuselage to which it is attached broke. It was slightly affected by the fire that broke out after the accident.

The outboard sections of both elevators were broken and had detached from the horizontal stabilizer. The left elevator was, for the most part, attached to the horizontal stabilizer, which still had its control tabs and gears. The outboard section was detached from the stabilizer, as mentioned above, though it was still joined to the inboard section, with the antiflotation tab still attached. The inboard section of the right elevator was joined to the horizontal stabilizer, which still had its control tab attached.

Several access panels were opened to check the status of the internal control components of these surfaces. The right elevator actuator did not appear to be broken or to have suffered any impact damage. The left elevator actuator also showed no apparent damage.

When the left elevator was moved by hand, the associated connections at the bottom of the vertical stabilizer did not move. Disassembling a section of the torsion tube revealed that the cylinder inside the tube was broken.

The rudder remained attached to the vertical stabilizer, though the tabs had detached. The hydraulic rudder actuator and the yaw damper were still connected to the tail assembly.

A visual examination of the rudder's power control unit (PCU), P/N 5918161-5507-001, S/N 04401, did not reveal any damage. The length of the PCU piston, which was actuated, was measured and found to be 8.5 inches, consistent with the full left deflection of the control surface.

There was no visible damage to the yaw damper actuator, Honeywell P/N 2589445-331, S/N 231221.

1.12.4. *Wing control surfaces. Flaps/slats*

Five (5) flaps actuators, three (3) from the right wing and two (2) from the left, were found and identified at the crash site. Since they had lost hydraulic pressure, four (4) of these actuators could be extended and retracted by hand, while the fifth exhibited significant damage from the fire that engulfed it after it detached from the wing structure. Though is was not jammed, it did not move freely and could not be moved by hand.

Figure 14. Part of outboard left flap and central actuator

The two (2) slats control actuators were located and identified, as were the tracks on which ride the three (3) sections. A total of six slats tracks were recovered. They were in the following conditions:

Left wing:

• Idler track for # 0 slat panel	Limited range of motion.
• Drive track for # 0 slat panel	Blocked in fully retracted position.
• Idler track for # 1 slat panel	Limited range of motion.
• Drive track for # 1 slat panel	Blocked in fully retracted position.

Right wing:

• Drive track for # 1 slat panel	Blocked in fully retracted position.
• Idler track for # 1 slat panel	Blocked in indeterminate position.

All of these components had been exposed to the fire and showed signs of having been in a slats retracted condition.

The slats control valve was also found in its position above the right wing root. It had been exposed to an intense fire and it was seized.

1.12.5. *Stabilizers*

The vertical stabilizer was practically intact with the rudder still attached.

Several access panels in the horizontal stabilizer were disassembled in order to examine the horizontal stabilizer spindle, which seemed to be lubricated and did not exhibit any fractures or impact damage. The upper part of the spindle was showing 11 screw threads, while 36 screw threads were visible at the bottom. According to Boeing's calculations, this spindle position corresponds to a 7.9° up angle on the stabilizer.

The left end of the horizontal stabilizer was broken but still attached to the structure. The right end was likewise broken.

1.12.6. *Wings*

Both wings were exposed to the fire that broke out after the accident. In fact, most of the wings had been consumed in the fire, such that only a few fragments were able to be recovered.

The center section of the wing was recovered in two parts:

- The center wing box, which houses the center fuel tank, with the left wing root, which still had the no. 0 slat drive track in place. The entire box exhibited considerable fire damage and most had been consumed in the fire.
- The right wing root with a part of the no. 1 slats panel idler track in its place and the no. 1 slats panel drive track dislodged and attached to the assembly with wires and molten metal.

Left wing:

A part of the outboard section of this wing was found, which was missing its top skin. Missing from this section of wing were the flaps, the slats, the aileron and the fixed trailing edge.

The wing tip surface was found among the wreckage. It was attached to a part of the wing's outer rib, specifically to a fragment that included the area from the leading edge to the aft spar.

Right wing:

Very few components were found from this wing. In addition to the elements listed in Section 1.12.4.1 Flaps/slats, the following parts were found:

- Wing tip, and attached to it the outer rib of this wing
- Refueling panel.

1.12.7. *Engines*

The airplane was powered by two (2) Pratt & Whitney JT8D-219 engines in a 217C configuration. The serial numbers for the left and right engines were P728154 and

P725716, respectively. The engines detached from the aircraft as it was traveling along the ground.

The thrust reverser assembly[40] for the right engine was found some 235 m north from the first marks left by the aircraft on the runway strip, and some 846 m south from the place where the main engine body was found. Its reverse thrust buckets were not deployed. Maintenance records show that the thrust reversers had been deactivated to keep the buckets from opening. The actuating lever in the cockpit had tape on it to alert the crew.

The left engine thrust reverser assembly, which had also detached from the engine body, was found 913 meters north of the first impact mark and 144 meter south of the main engine body. Its reverse thrust buckets were found deployed.

The damage to both reverser assemblies and the position of the left engine buckets, as described above, are consistent with the damage suffered by the aircraft as it moved over the ground. No evidence was found to indicate any anomalous behavior in the reverse thrust assemblies.

The grass covering the terrain under the wreckage was burned, and the destruction evidenced by the trees and shrubs was consistent with that from a brush fire. The no. 1 engine was surrounded by burned grass.

The lower aft section of the no. 1 engine pylon showed damage produced by an intense fire in an area where several hydraulic lines, which had detached from the pump, were jammed between the pylon and the ground. The right part of the pylon came to a rest position on the ground, with the left part on top. The protective sheathing for several hydraulic lines in this area showed signs of fire damage only on the side that was facing the ground.

The damage noted on the pylon, hydraulic lines and cowlings are consistent with the damage a fire on the ground would produce, once the engine reached its final position.

An onsite visual inspection of both engines revealed no evidence of any perforation produced by internal engine components, nor of an in-flight fire, nor of any soft-body impact on the fan blades. The inspection highlighted the existence of hard-body impacts along the leading edge of the fan blades in a counter-rotational direction, which is consistent with the engines striking the ground while turning under power.

The engines' internal components were disassembled and inspected later in the investigation. The findings of this analysis are described in Section 1.16.4.

[40] The thrust reversers on the MD-82 are of the bucket type and have two elements, an upper and a lower, which move backwards and rotate to capture the air current expelled by the engine nozzle and redirect it forward.

1.12.8. *Landing gear*

Parts of the nose gear structure were identified at the accident site and along the path taken by the aircraft as it traveled over the ground.

The nose gear was found detached from its support structure. The lower part of the strut was likewise detached from the cylinder, which was found in a different location.

The left main gear was found with the main wreckage on the banks of the stream. The gear and its attachment fittings were separated from the wing structure. The piston and the axle were separated from the cylinder, which showed evidence of fire damage. The main fitting was intact and attached to part of the wing structure. The cylinder was intact, save for a slight bend at one end.

This gear's piston and axle were found next to the cylinder and exhibited fire damage. The piston was intact and did not appear to have fractured. Attached to it was the bottom part of the torque link. Both tires and wheels were attached to their respective axles, which were burned and fractured.

The right main gear was identified among the main wreckage. It had detached from the wing structure and evidenced intense fire damage. Wrapped around the piston was wire from the metallic mesh of a fence. The piston was connected to the cylinder, neither of which exhibited any fractures. The outboard (no. 4) wheel had detached from the axle. Part of the wing structure was still joined to the attachment fitting. The gear down locking mechanism was broken. The inboard tire was shredded and burned. The brake set for the outboard wheel was found detached from both the gear and the wheel.

The antiskid control unit and the front panel of the control box for the autobrake system were recovered from the site where the main wreckage was found.

The tail skid was found joined to a small section of fuselage. It showed damage and longitudinal scratch marks on its surface.

1.12.9. *Systems*

1.12.9.1. Air conditioning

Both air conditioning packs were found among the aircraft wreckage. Also found were parts of the cabin pressure control system.

1.12.9.2. Auto-flight

The flight guidance control panel was recovered. The switches were found in the following positions:

- Autothrottle – OFF
- AP 1 or 2 DFGC – "2" (right position)
- AP On/Off – OFF (down position)
- Captain's Flight Director – OFF (down position)
- First officer's Flight Director – OFF (down position)

1.12.9.3. Electrical system

The following electrical system components were found and identified. They were later removed from the crash site for analysis.

- Aircraft modular power unit
- DC power supplies (2 units)
- Generator control unit (2)
- External power panel.

The chassis of an electric battery, manufactured by Soft America, P/N 02194000 and S/N 090472, was found with impact damage. The internal components were separated from the casing.

Several electrical system relays were also found and visually inspected. Investigators recorded their as-found conditions.

1.12.9.4. Fuel

The display for the load selector display unit was found among the aircraft wreckage. It had detached from the aircraft and showed appreciable signs of having been exposed to fire. No readings could be obtained from it.

1.12.9.5. Communications

Among the components found and identified in the aircraft wreckage were three VHF radio units, a SELCAL receiver, an announcer reproducer player and a radio transceiver. Also found were two communications panels, though no relevant indications could be obtained from them.

1.12.9.6. Navigation

The following navigation system components were found and identified at the crash site:

- Digital flight guidance computers (2 units)
- Stall warning computers (2 units)
- Enhanced ground proximity warning system (EGPWS) computer
- Central aural warning system unit (front panel only)
- Central Air data computers (2 units)
- Data link transponder (Mode S) (2 units)
- TCAS II computer
- Laser inertial reference units (2 units)
- Navigation VOR-ILS receivers (2 units)
- ADF
- Advanced flight management computer (1 unit)
- Distance measuring equipment (DME) (2 units)

The rudder pitot tube was attached to the vertical stabilizer, though it was bent and broken.

1.12.9.7. Indication system

1.12.9.7.1. *Instrument panels*

The following instrument panels were recovered:

- First officer's main instrument panel
- Center overhead panel
- Navigation control display panel

The indications and positions of the switches were documented and recorded. The most relevant switch positions were as follows:

a) *First officer's main instrument panel*

- Altimeter: 700 ft. QNH 1020 HPa (30.11 inches of mercury).
- The glass on the PFD and NAV CRT was broken and displayed no indications.
- Hydraulic system pump panel:
    - System 1 switch – "High"
    - System 2 switch – "Off"
    - "Trans" switch – "Off"
    - Auxiliary pump switch – Not found

- Brake temperature panel

  - Indicated a 40 °C brake temperature
  - The switch was in the inner right position.

- RMI and clock – Not found.
- Navigation control display – Knobs broken. No information.
- VSI/TCAS – CRT – Screen broken, no display.
- FMA – Screen broken, no display.
- Airspeed indicator:

  - Indicated zero.
  - OFF and red A/S flags visible
  - Barber pole indicated approximately 258 KIAS
  - Bugs

    - Bug 1 - Partially broken, selected to 135 KIAS
    - Bug 2 - Selected to 145 KIAS
    - Bug 3 - Selected to 152 KIAS
    - Bug 4 - Selected to 158 KIAS

b) *Central overhead panel and bottom console panel*

- CADC switch – Normal

  - FLT DIR switch – Both in 2

- CVR indicator – Extreme left position.
- Left and right AC bus subpanel – Missing large part of front panel, switches evidenced severe impact damage.

  - PWR R BUS switch – OFF
  - Left DC load indicator – left scale 0, right scale 0
  - Right DC load indicator – left scale 1, right scale 0

- Electrical panel. The indicators had significant impact damage

  - CVR indicator – Extreme left position.

c) *Navigation display control panel, Honeywell P/N 5961016-17*

- MOD Switch – MAP (of ROSE/ARC/MAP/PLN)
- ADF/OFF Switch – OFF

1.12.9.7.2. *Throttle quadrant*

The throttle quadrant on the center pedestal was found among the main aircraft wreckage. It had significant impact damage and had detached from the structure. Due to the damage present, it was not possible to determine the positions of the throttles or the condition of the internal components.

On the handle for the no. 2 engine reverse thrust lever there was a label with the word "DEACT" hand written on it. This handle was lockwired to the throttle lever for the no. 2 engine.

1.13. Medical and pathological information

Autopsies were conducted on all those who perished in the accident. Of the 154 mortal victims (148 passengers and 6 crew), the forensic analyses revealed that 119 (73%) were directly affected by the fire (to varying degrees). Figure 15 shows the position on board the aircraft of all those who died primarily from burns. Of the 35 (27%) remaining victims, the causes of death were: 32 from traumatic injury, 2 from drowning in water and 1 from smoke inhalation.

The autopsies on the captain and first officer revealed that their bodies absorbed the violence of the impact. In the captain's case, the fundamental cause of death was the destruction of vital organs and chest and abdominal trauma. The immediate cause of death was cardiopulmonary arrest. In the first officer's case, the fundamental cause of death listed in the forensic report was severe head trauma. The immediate cause of death was cardiopulmonary arrest. The toxicology screen was negative for both for all toxic substances analyzed, meaning that drug-induced cognitive limitations were not involved.

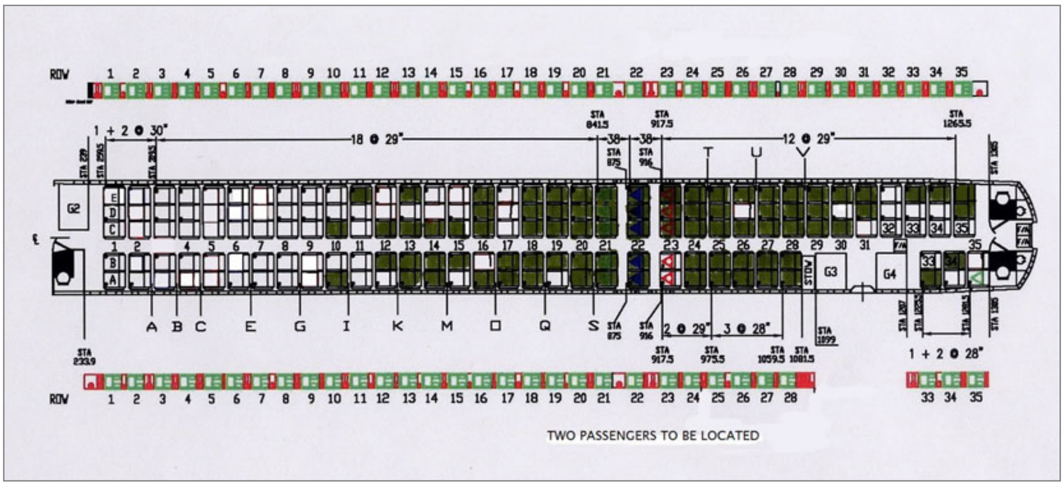


Figure 15. Seating arrangement of burn victims

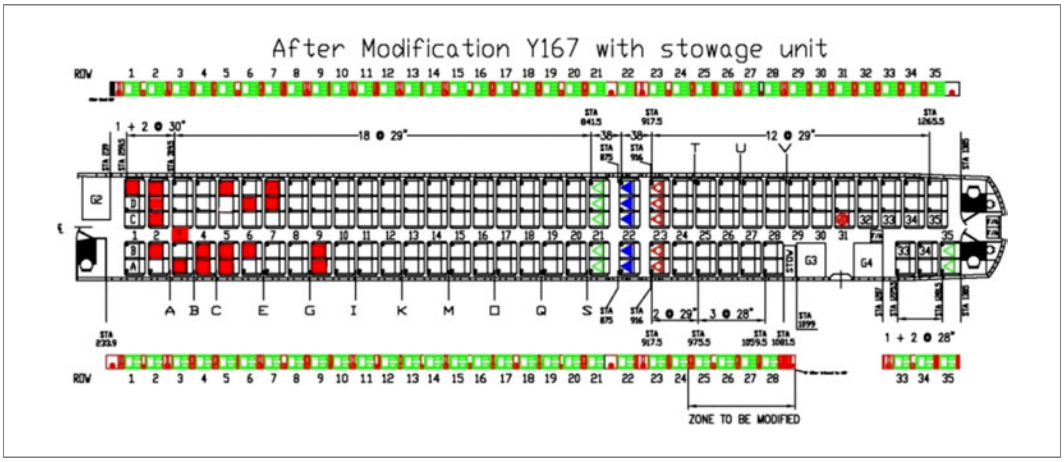


Figure 16. Location of survivors

No injuries to vital organs (heart, main vessels or brain) were identified that would indicate the sudden incapacitation of any crew member from a pre-existing condition. The captain received his last medical examination on 22 July 2008. During this examination, required to keep his license valid, no significant history of medical conditions was noted. The same findings were applicable to the first officer, who had passed his last medical examination on 17 June 2008.

The flight attendants suffered injuries similar to those of the pilots and were consistent with the impact and collapse of the structure. The burns on two of the flight attendants allowed investigators to conclude that they had been at the rear of the airplane at the time of the accident.

A total of eighteen (18) people survived, three (3) of them minors. They were seated between rows 1 and 9 in the passenger cabin (see Figure 16). Their injuries derived from traumas with various complications, depending on the organs affected. Two of them were affected by the fire, one due to smoke inhalation and the other with burns to the arm. The last patients left the hospital on 24 October 2008. One of the patients had to be transferred to the National Hospital for Paraplegics in Toledo, from where she was released on 30 April 2009.

1.14. Fire

The aircraft, after traveling over the runway 36L strip, fell down a 5.5-m hill and after planting the landing gear in the road that ran at the foot of said hill, crashed through a fence, after which it cleared a second slope. Following this, the aircraft impacted the side of an embankment, leaving the outline of its entire surface on the ground.

The violence of this impact resulted in a massive fuel spill and its subsequent ignition. The distance from this point to the final resting place of the main wreckage was 270 m.

The source of the fire stemmed mainly from the area of the aircraft's wings and tail section.

The fire spread, aided by the wind and high temperature, and eventually affected a surface of about 45 Ha (see Figure 17).

The affected terrain held a total of 817 trees scattered over a 26-Ha area. Mixed among the trees were smaller shrubs with woody trunks and grasses. The area was fringed by a network of roads that acted as a fire barrier.

Figure 17. Aerial view of burned area

1.15. Survival aspects

The airplane was configured for 167 passengers. There were two (2) seats in the cockpit for the crew and a jumpseat for an observer. There were also four (4) seats for the flight attendants, two (2) forward and two (2) aft.

The cockpit had collapsed aft into the first row of passenger seats. The cockpit crew suffered the direct impact against the hill of the left bank of the De la Vega stream, the severity of which made survival impossible.

Most of the forward section of the passenger cabin, corresponding to the front third of the fuselage (first 17 rows), was found overturned in the stream. The internal components had been crushed vertically and the seats were upside down. It was the only part of the aircraft that retained its shape (see Figure 18). The aft two-thirds of the aircraft all the way to the pressure bulkhead were destroyed by the fire (see Figure 19). Only the lavatory and aft galley sections were recognizable (see Figure 20).

Figure 18. Top front part of the aircraft

Figure 19. Passengers cabin wreckage

Figure 20. Aft galley

1.15.1. *Emergency response*

1.15.1.1. Information on firefighting and rescue efforts

At 14:24:36[41], the crew of flight IBE6464, situated in the movement area, reported to the airport's control tower that it had seen a possible accident. The taxi controller who received the notification activated the alarm, which sounded at all three of the airport's RFFS stations. The satellite station responded to the alarm activation with its three heavy firefighting vehicles and a fast intervention vehicle, seeing a column of smoke near the runway 18R threshold. At 14:25:25 the Observation and Alarm Center (OAC) at the apron station requested information from the TWR on the nature of the alarm, to which the TWR replied: "GET TO THIRTY SIX LEFT IMMEDIATELY, THERE'S BEEN AN ACCIDENT... HURRY".

At 14:25:55 the TWR alerted the Airport Operations Office[42] (AOO) that there had been an accident on runway 36L.

The fire brigade from the satellite station was the first to arrive near the accident site, though they could not proceed past the internal perimeter fence that surrounds the runway 36L/18R strip. Communications reveal that they reached this point at 14:26:56,

[41] The times for the TWR, the airport's Network Management Center and the Community of Madrid's 112 Emergency Services have been synchronized with the CVR.
The Network Management Center is an AENA unit that oversees all types of incidents and is operational 24-hours a day.

[42] The function of the AOO during emergencies is defined in the AEP. This office monitors the operations at every facility, coordinating the actions that must be carried out when problems occur that affect more than one airport department.

two minutes and twenty seconds after the alarm was sounded[43]. One of the heavy firefighting vehicles cleared the fence without any problem. It is not known exactly how much time elapsed until the rest of the vehicles were able to break through the fence and reach the wreckage on the right bank of the stream. It is known that the fast intervention vehicle did not clear the fence.

The entire brigade from the apron station also responded to the accident site, guided at first by the smoke column. Along the way they joined the fast intervention vehicle from the satellite station, which had doubled back upon reaching the fence. The two brigades reached the wreckage via the left bank of the stream.

Several efforts were made using the radio equipment onboard the RFFS vehicles to contact the tower on the emergency frequency to provide or demand information on the accident, but no reply was received. The tower only became aware of these calls when firefighters from the Central Station contacted it on the taxi frequency (GND S-N).

The third brigade, from the central station, initially proceeded to the T4S terminal in order to ensure the continued operability of the airport, as indicated by procedures in the event of an emergency[44]. Information gleaned from internal communications held among the fire brigades revealed that in light of the event's severity, it too proceeded to the accident site, where it arrived 14:39:31. Under these circumstances, and with all three fire brigades responding to the scene of the accident, the airport was left without RFFS coverage against another contingency for an estimated 20 minutes.

Along with RFFS personnel, firefighters from the Community of Madrid and twelve fire departments from the adjoining towns of Torrejon de Ardoz, Coslada and Alcobendas took part in extinguishing the fire. Aerial support was also provided by three helicopters. The first of these firefighting units arrived on the scene at approximately 14:50.

The first step firefighters had to take was to clear a path through the fire to the wreckage.

Rescuing the victims required moving the fuselage and its internal structure to the bank of the stream so as to facilitate access to the passengers.

The resources were divided into providing assistance to survivors and extinguishing the fire to create safe areas. Two firefighting vehicles, one on each side of the stream, were

[43] The response time is the period between the initial call to the rescue and firefighting service and the time when the first responding vehicle(s) can apply foam at a rate of at least 50% of the discharge rate specified in Table 9.2 of ICAO Annex 14.
Annex 14 specifies that the operational objective of the rescue and firefighting service should be to achieve a response time not to exceed three minutes to any point on each operational runway under optimum visibility and surface conditions.

[44] The airport's PO-08 Procedure (Positioning of RFFS Vehicles in Risk Situations) considers, among other aspects, the distribution of resources such that the airport remains operable when in an emergency or alarm situation.

charged with extinguishing any remaining flames in the aircraft. The rest of the personnel focused on extracting survivors who were trapped in the wreckage and on evacuating the people who were in that part of the fuselage located next to the stream, since beyond that area the victims had either been affected by the fire or by the wave of heat resulting from the combustion.

Efforts to rescue people who had fallen into the stream were hampered by the large fuselage segments in this area that trapped those who had been submerged by the water.

Emergency personnel stated that the main obstacles to the rescue were the fire, due to the smoke it generated and the burn risk, and the water level in the stream, which was higher than normal for that time of year.

1.15.1.2. Medical response

Outside medical personnel (CECOP, SUMMA, SAMUR, and civil protection personnel) were alerted first by calls placed to their centers by civilians who had witnessed the event. As a result, at 14:27, the 112 Emergency Coordination Center activated its services in anticipation of receiving a notification from the AOO, which it did at 14:29:26, after several failed communications attempts.

The first outside emergency medical personnel arrived at the crash site at 14:39 via a SUMMA air ambulance. A second SUMMA helicopter arrived at 14:47. Personnel from both helicopters initiated triage[45] procedures with the wounded.

Airport medical services at the T4 terminal were alerted by the AOO at 14:30 and the services in T4S one minute later. The services located in the T2 terminal were notified at 14:38. They arrived at the crash site, guided by signalmen's vehicles, at approximately 14:50, along with firefighters from offsite fire departments.

Medical attention could only be provided as firefighters cleared the way and set up areas for evacuating survivors. The presence of two doctors among the survivors facilitated the efforts of rescue personnel who were able to direct their efforts to the most seriously injured.

According to information provided by the 112 Emergency Coordination Center in Madrid, eight (8) Mobile Intensive Care Units (MICU), two large capacity ambulances, 20 normal ambulances, four fast intervention vehicles not suited to transporting the

[45] According to the Advanced Trauma Life Support (ATLS) program developed by the American College of Surgeons, triage is a method for selecting and classifying patients based on the treatment they require and the resources available to care for them.

injured and one catastrophe response truck were dispatched to the crash site. In addition to these, there were also three (3) MICUs from the airport's medical services.

The first contingent of ambulances left the meeting point for the accident site at 14:52. Four additional convoys followed until 15:35. Evacuation of the injured concluded at 15:55.

The injured were taken to four Madrid-area hospitals and one in San Sebastian de los Reyes.

1.16. Tests and research

1.16.1. *Analyses of the flap/slat control and indication components*

1.16.1.1. Examination of the flap/slat control lever

The central pedestal was recovered from the aircraft wreckage (see Figure 20). It showed considerable impact damage, especially to its right side, which was partially destroyed. The wheel used to adjust the notch on the right track of the flaps lever was missing, as was its indicating window.

The flap/slat control lever was still in place, attached to the same pedestal axis as the adjustable track and, like the track, could be freely moved about the axis. The left stub, which is normally lodged in the fixed sliding track, had come out of the track and was noticeably bent. The track was in place. A conspicuous mark was noted in the notch corresponding to the UP/RET position.

Both the flap/slat control lever as well as the fixed track were removed from the pedestal and sent to a laboratory at the National Institute for Aerospace Technology (INTA) for analysis.

There were friction marks all along the inner walls of the fixed track, consistent with the normal contact made by the stub with said walls. The track was damaged along the bottom of the housing corresponding to the UP/RET position. This damage consisted basically of the deformation of the material located next to the bottom of the housing, which had an elliptically shaped mark on the track walls and drag marks on the surface of the deformed material. Material had been scraped from the exit of the housing onto the outer surface of the track.

On the inner wall of the track across from the damaged wall mentioned in the preceding paragraph there was another elliptically shaped mark situated halfway along the wall.

There was damage to the various components that comprise the flap/slat control lever. In particular, the stub that marks the fixed positions exhibited significant damage to its flat outer surface and to its cylindrical surface.

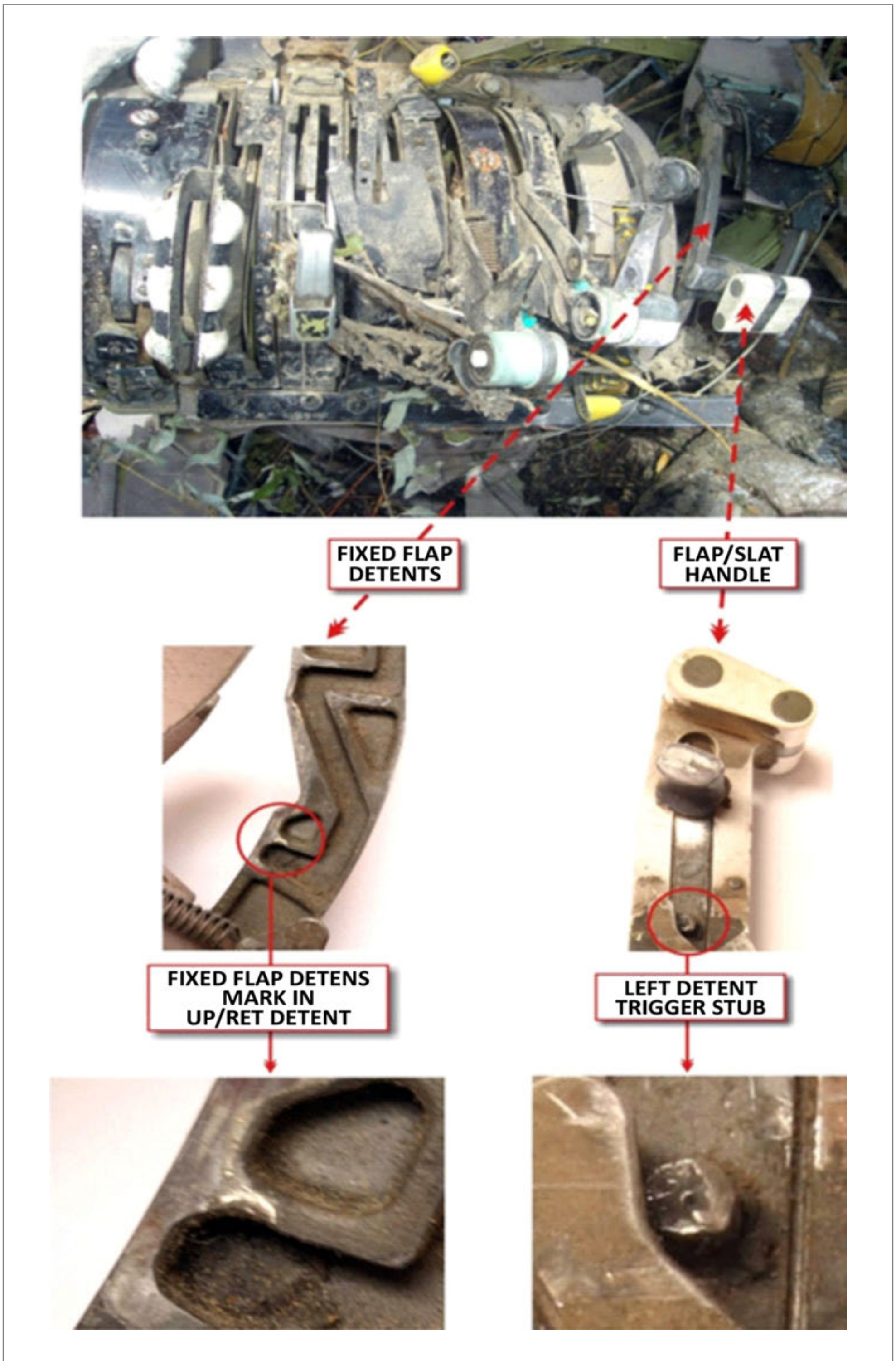


Figure 21. Close-ups of the flap/slat control lever

After both components were studied, it was determined that the mark evident on the track probably resulted from a strong impact of the stub that marks the fixed positions on the flap/slat lever against the track and subsequent relative movement between the stub and the track.

These signs are consistent with the flap control lever being in the UP/RET position at the time of said impact between the stub and the track.

1.16.1.2. Analysis of the slats indicating lights

The lights were recovered from the center instrument panel (see Figure 22), which was heavily damaged by the impact.

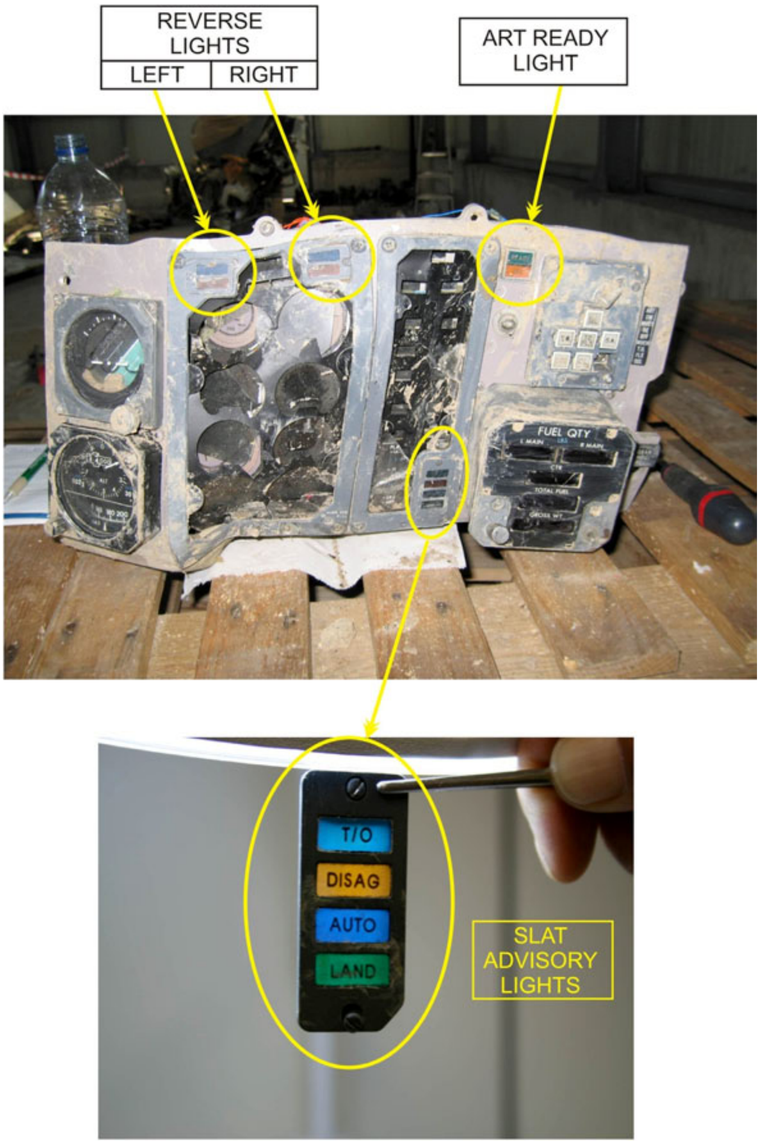


Figure 22. Center instrument panel

So as to allow for a detailed examination, the incandescent bulbs installed in the reverse thrust indicating panels, for the availability of additional automatic thrust in the event of an engine failure (READY/ART) and for the slats were removed from this panel.

These bulbs were sent to the laboratory of the National Institute for Aerospace Technology (INTA) for analysis and to determine the operating conditions that existed during the sequence of impacts of the aircraft with the terrain. In addition, so as to study the characteristics of these types of lamps and compare them with the findings of the analysis, similar lamps from the No Smoking and Fasten Seat Belt signs on the accident aircraft were also sent to INTA. Working and burned out bulbs from another aircraft of the same type, as well as new bulbs, were also sent.

The characteristics of the bulbs from the reverse thrust panels and for the availability of additional automatic thrust in the event of an engine failure were inconclusive in terms of the operation of those systems.

As for the bulbs from the slat panel (two for each indication), the analysis yielded the following results:

- T/O: Both lights were off, meaning that the slats were not in the takeoff position.
- DISAG: The condition of one of the bulbs could not be determined and the other one was off, meaning there was probably no disagreement between the flaps and slats positions.
- AUTO: The two bulbs were off, meaning the autoslat system was not engaged.
- LAND: The condition of one of the bulbs could not be determined and the other one was off, meaning the slats were probably not in the landing position.

These findings are consistent with the indications that would be present if the flaps/slats control handle had been in the UP/RET position during the successive impacts of the aircraft with the ground.

1.16.2. *Analysis of the ground sensing system's R2-5 relay*

Due to the damage suffered by the aircraft, only one of the elements of the TOWS, and of the RAT probe heater, was found: the R2-5 relay from the ground sensing system.

It was also impossible to recover and analyze other components from the left assembly of the ground sensing system and which could have provided information on other possible faults different from those in the relay.

The relay installed in the R2-5 position of the aircraft's ground sensing system had been manufactured by the Leach Corporation, with P/N 9274-3642. The casing was labeled "MFR 58657-9208", indicating the lot number (58567) and the date of manufacture (8^{th} week of 1992).

The relay was hermetically sealed and had four sections with three contacts each, capable of withstanding a 28V DC or 115 V AC (400Hz) 10A current. The specifications call for a service life of 100000 cycles.

It was recovered from the aircraft wreckage, joined to a part of its support plate on which there were a total of eight relays (see Figure 23). There was impact damage on the contacts located on the top side, on the cover, on one of its sides and on the base. In addition, the cover was partially lifted and there were fragments missing from its corners.

The R2-5 relay was inspected to determine if it could have failed. During the initial analysis, it was subjected to a visual inspection, a borescope inspection and a radiographic test. It was also subjected to continuity and functional tests. During a subsequent analysis, involving the CIAIAC and conducted under judicial oversight, the outer casing was opened so that its internal components could be studied in detail. The continuity and functional tests were repeated, before and after the casing was opened, and the internal components were subjected to a visual inspection. The electrical characteristics of these components were also measured. During a third analysis, in which the CIAIAC also took part and also under judicial oversight, continuity and functional tests were carried out in a thermal chamber. The material on contacts C2 and C3, where possible deposits had been observed, was also studied.

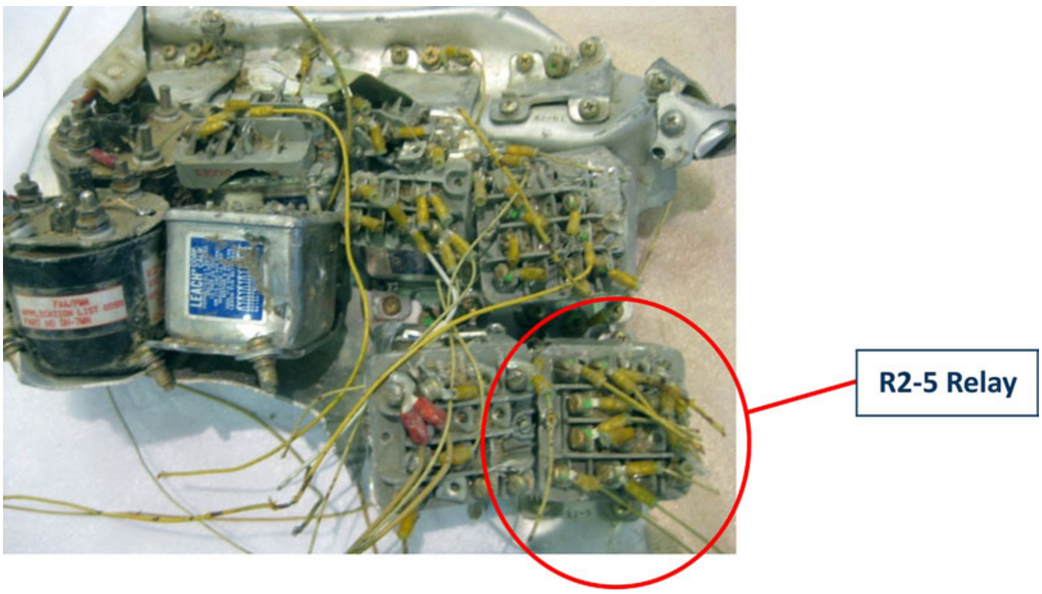


Figure 23. Recovered relay assembly housing R2-5

1.16.2.1. First analysis, conducted in June 2009

As mentioned above, the relay underwent a visual inspection, a borescope inspection and a radiographic test. Continuity and functional tests were also performed.

Copious residue was noted on the outside of the cover, with a large amount of sand between all the contacts. Once the residue was cleaned, it was noted that two contacts had deformed to the point of touching. A borescope was inserted through the holes left by the missing pieces to examine the inside of the cover. Residue deposits were also seen on the inside as far as the borescope could reach. There were no broken connections between the contacts and their respective entry points into the sealed part of the relay.

The radiographic inspection consisted of taking radiographies and a high-resolution computerized tomography scan of the relay. The results revealed no detectable anomalies in the internal components.

The functional test was conducted by referencing the relay specifications. As a preliminary measure, a small Teflon sheet was placed between the contacts that had become joined so as to insulate them electrically. The relay was within specifications for the first test, at ambient temperature and with the coil deenergized. The relay coil was then verified to activate as specified when a voltage was applied and to deactivate when the supply voltage was lowered to within the specified margin. With the relay energized, however, an abnormal behavior was detected when the relay was kept energized at a nominal 115 volts, namely that it reached a temperature of 57 °C (a new relay does not exceed 40 °C), along with a general reduction of the insulation between the contacts. Moreover, contacts 1 and 2 in section C, which should be closed when a nominal voltage is applied, separated as the relay became hot. It was noted, therefore, that

Figure 24. Comparison between the recovered relay and a new one of the same model

during the conduct of this test, the relay installed in the R2-5 position of the aircraft's ground sensing system operated abnormally.

The results did not allow for a determination to be made of any possible link between the defects found with the relay and the abnormal operation of the RAT probe heating and the TOWS over the course of the accident. What is more, it could not be concluded from the tests conducted whether the defective behavior exhibited by the relay was a consequence of the damage suffered in the accident.

1.16.2.2. Second analysis, conducted in October 2010

As indicated above, the relay's outer casing was opened so as to allow for a detailed study of its internal components. The continuity and functional tests were performed again both before and after opening the casing. The internal components were subjected to a visual inspection and their electrical characteristics were measured.

The continuity and functional tests yielded results similar to those obtained during the first analysis, both with the relay unopened and with its outer casing removed. However, when the pieces of wire were removed that had been attached to the relay contacts since it was recovered from the aircraft wreckage (see Figure 24), the general drop in resistance between the relay contacts disappeared. As a result, this drop in resistance was attributed to noise induced by the power supply and by the electromagnetic field of the relay's own coils. When energized to a nominal 115V, all of the contacts behaved normally.

Additional tests were conducted by cycling the relays to simulate various configurations in which "stuck" contacts were held together using pincers: C2-C3, corresponding to the RAT probe heating circuit; B2-B3 and B2-B1, corresponding to the TOWS circuit. The remaining contacts continued functioning normaly in all three configurations.

In terms of the temperature attained, it remained at around 50 °C before the casing was opened.

The visual check of the relay's internal components and the measure of its electrical characteristics did not reveal any anomalies that might have affected its operability.

To summarize the findings of this analysis, the relay installed in the R2-5 position of the aircraft's ground sensing system was found to be operating within specifications.

1.16.2.3. Third analysis, conducted in March 2011

As indicated previously, the relay was subjected to continuity and functional tests in a temperature chamber and the material on contacts C2 and C3, which showed possible signs of sticking, was studied.

During the continuity and functional tests, the relay was subjected to conditions corresponding to its design limit specifications. This was done by placing the relay in a temperature chamber and stabilizing its internal chamber at 5 °C intervals between 40 and 70 °C while measuring its electrical and operating characteristics at every 5° interval. The relay performed properly during these tests, in keeping with its specifications.

The contact block was removed from the relay and contacts C2 and C3 extracted for analysis. Contacts C2 and C3 showed signs of possible deposits. Contact D2 was removed to identify the material on the collar, and contact D3 for analysis for comparison purposes.

First, the material on contacts C2, C3 and D3 was identified. An initial observation was carried out with the naked eye and with a magnifying glass, followed by a more exhaustive observation and a semi-quantitative determination of the chemical composition of the contact material and of the possible deposits on the contacts. This involved the use of a field emission scanning electron microscope (FE-SEM) equipped with a energy-dispersive X-ray (EDX) microanalysis system. The results obtained from this technique were then confirmed by means of a semi-quantitative X-ray fluorescence (XRF) analysis.

The chemical composition of the material on the collars of contacts D2 and D3 was determined using an X-ray fluorescence quantitative chemical analysis and an atomic absorption quantitative chemical analysis.

The results of this analysis of the contacts showed that:

- All of the contacts analyzed consist of a copper alloy collar at the end that acts as a stop, and the contact arm, which has an approximate composition of silver / 10% cadmium oxide (AG/10% OCd).
- All of the areas analyzed exhibited contamination that, in all likelihood, appeared after the accident when, at some point, the relay seal broke, allowing contaminants inside.
- The analyses conducted revealed that contacts C2 and C3, which are opposite each other and in contact during the closing process (corresponding to flight mode), were damaged by melting of their material due to overheating of the surface, which could have fused the two contacts together. The fusing of the two contacts seems to be confirmed by the fact that there were damaged parts in contact C2 that were raised, and which formed a specular image of the damaged area in contact C3, which it touches during the closing process. The surfaces on the two contacts had later separated again.

The preceding implies that at some point, contacts C2 and C3 had fused and subsequently separated. It was not possible to determine whether this process of fusing and separating had been repeated several times. At the time of the analysis, the contacts were apart. It also could not be determined whether the separation took place before, during or after the accident.

1.16.3. *Study of the sounds made by the stall protection system*

The sounds of the horn and synthetic voice (stall) that were activated when the airplane became airborne were recorded on the CVR. The sound of the word "stall" was compared with a sampling of sounds obtained during cockpit tests encompassing three different situations:

- Only the captain's side speaker connected
- Only the first officer's side speaker connected
- Both speakers connected

The word "stall" as recorded during the accident was verified to have an echo sound, which is analogous to that produced when both speakers are operational.

1.16.4. *Disassembly and inspection of engines*

Both of the aircraft's engines were removed and inspected. During the initial stage, they were disassembled at a modular level (low-pressure compressor (LPC), high-pressure compressor (HPC), combustion, high-pressure turbine (HPT) and low-pressure turbine (LPT)). Subsequently some of these modules, specifically the combustion modules on both engines and the low-pressure compressor (LPC) on the no. 2 engine, were disassembled to the component level.

The damage found on both engines was consistent with that resulting from impacting the ground while rotating at high speed, probably after detaching from the aircraft. It may be concluded, then, that they were operating normally until the impact with the ground.

1.16.5. *Behavior patterns in high RAT probe temperature indications in aircraft EC-HFP*

As part of the investigation, a correlation was made between the RAT probe temperatures and other parameters, such as barometric altitude, airplane speed, ground/air signal and time so as to identify possible patterns in the appearance of anomalies.

As already noted in Section 1.6.4.2.1, "Excessive RAT probe temperature indications", between 18 and 20 August 2008, six instances of high RAT probe temperature indications were recorded on the DFDR with the airplane on the ground. In the remainder of the DFDR recording, corresponding to days prior to 18 August, no high temperature readings were recorded. These six cases have been identified with the letters A through F, both in the table showing the chronological analysis in the section "Excessive RAT probe temperature indications" and in the figures shown below. The time used in the graph is UTC.

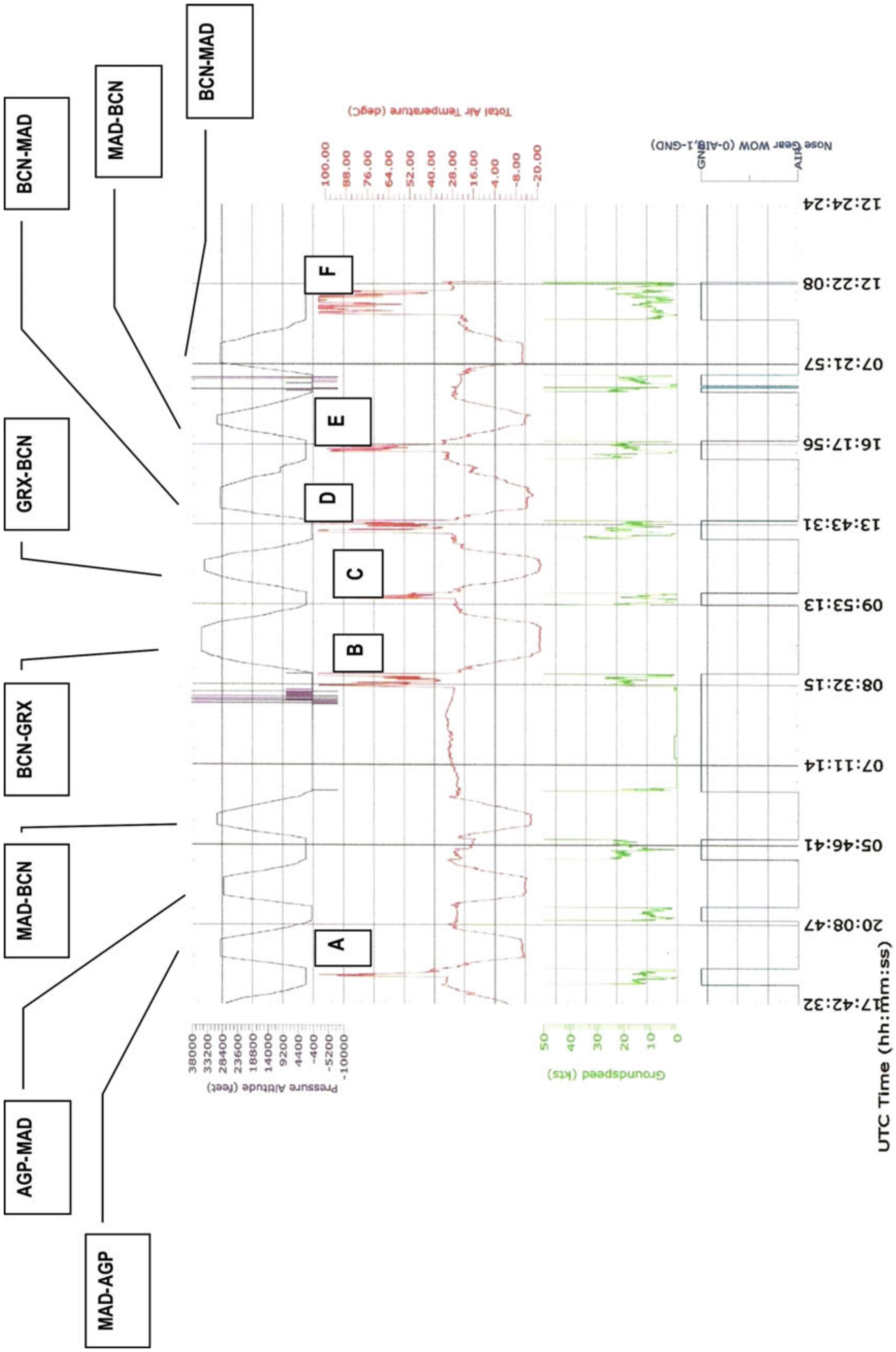
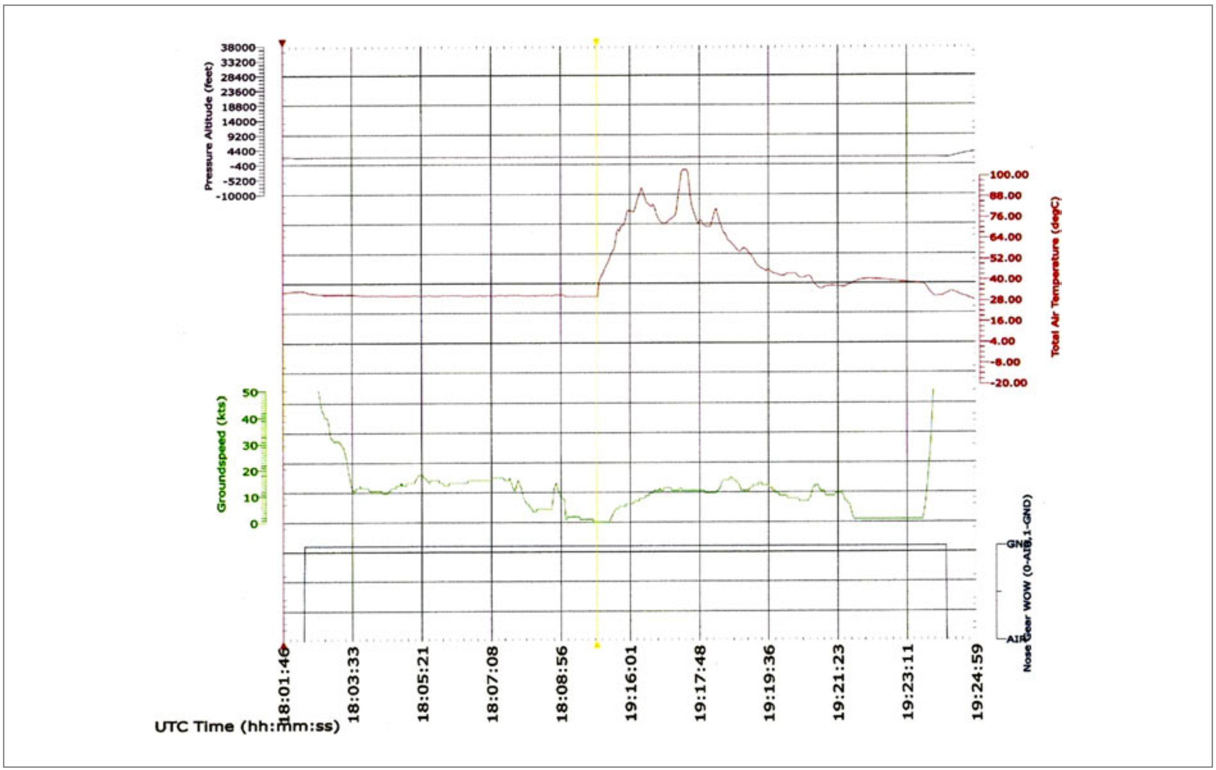


Figure 25. High RAT probe temperature events recorded on the DFDR

CASE A (18.08.08 Madrid)



CASE B (19.08.08 Barcelona)

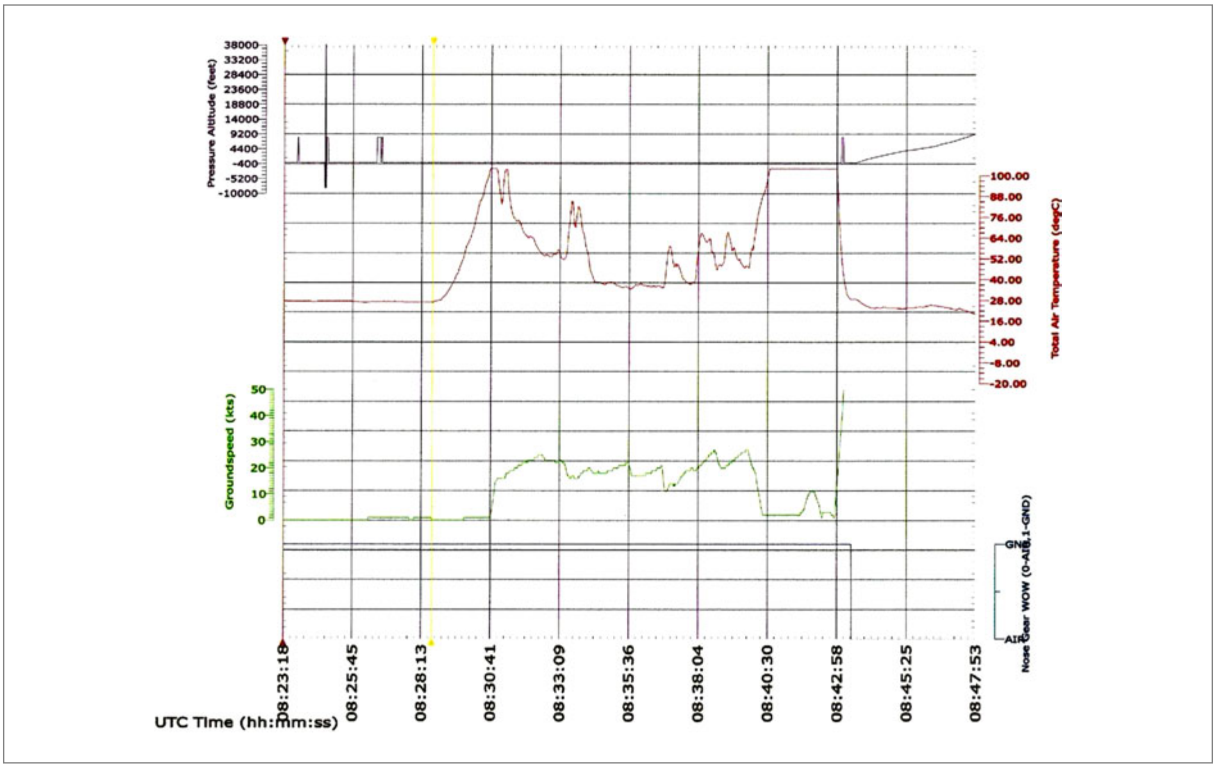
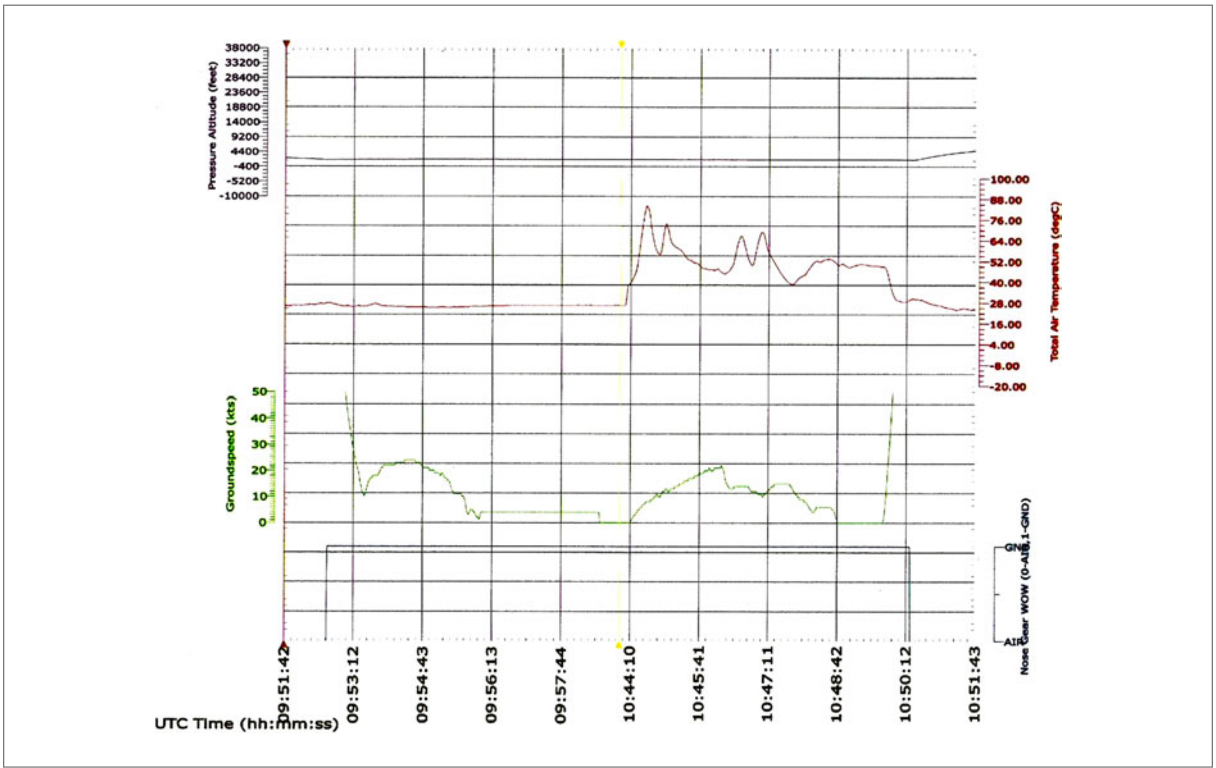


Figure 25. High RAT probe temperature events recorded on the DFDR *(cont.)*

CASE C (19.08.08 Granada)



CASE D (19.08.08 Barcelona)

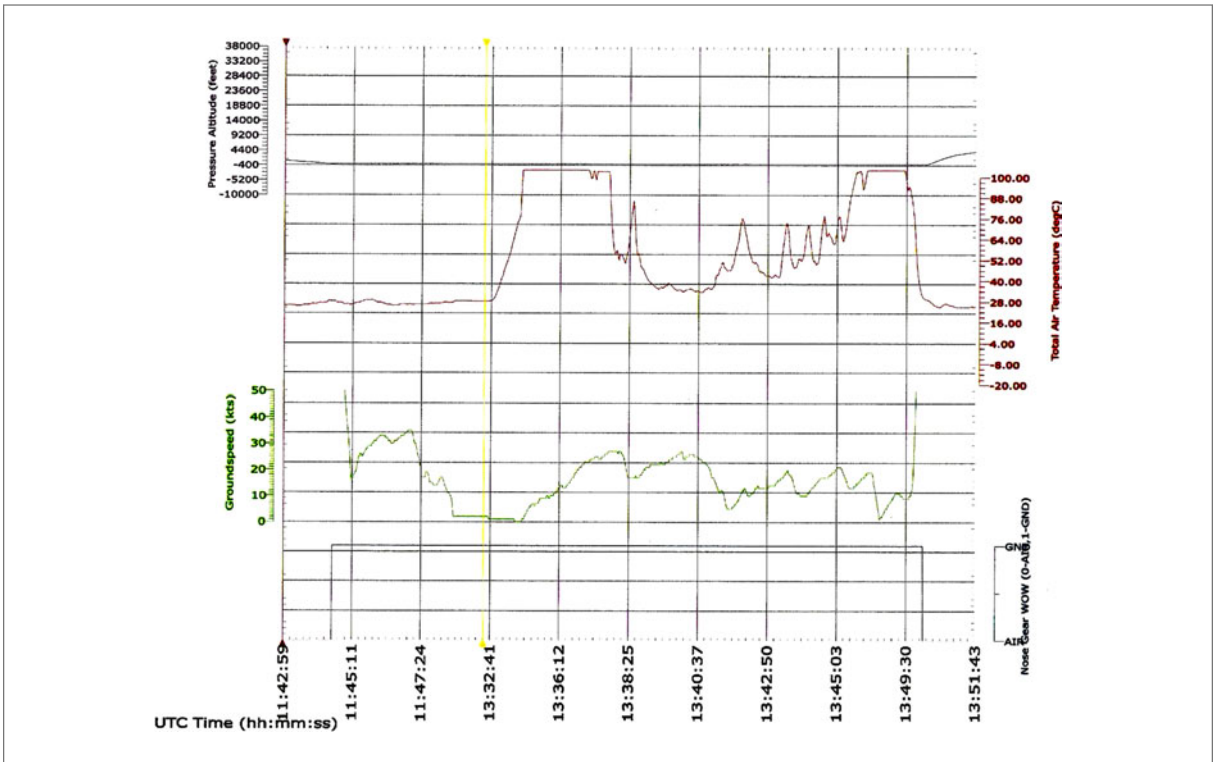
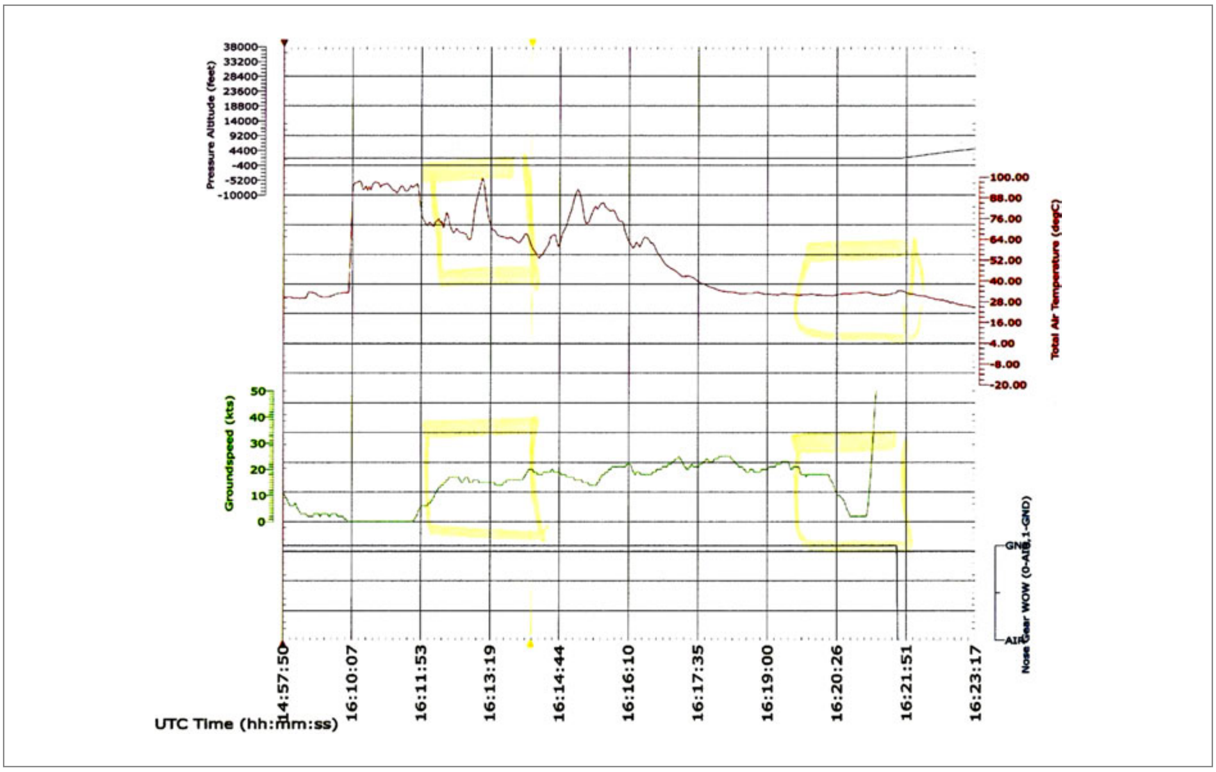


Figure 25. High RAT probe temperature events recorded on the DFDR *(cont.)*

CASE E (19.08.08 Madrid)



CASE F (20.08.08 Madrid)

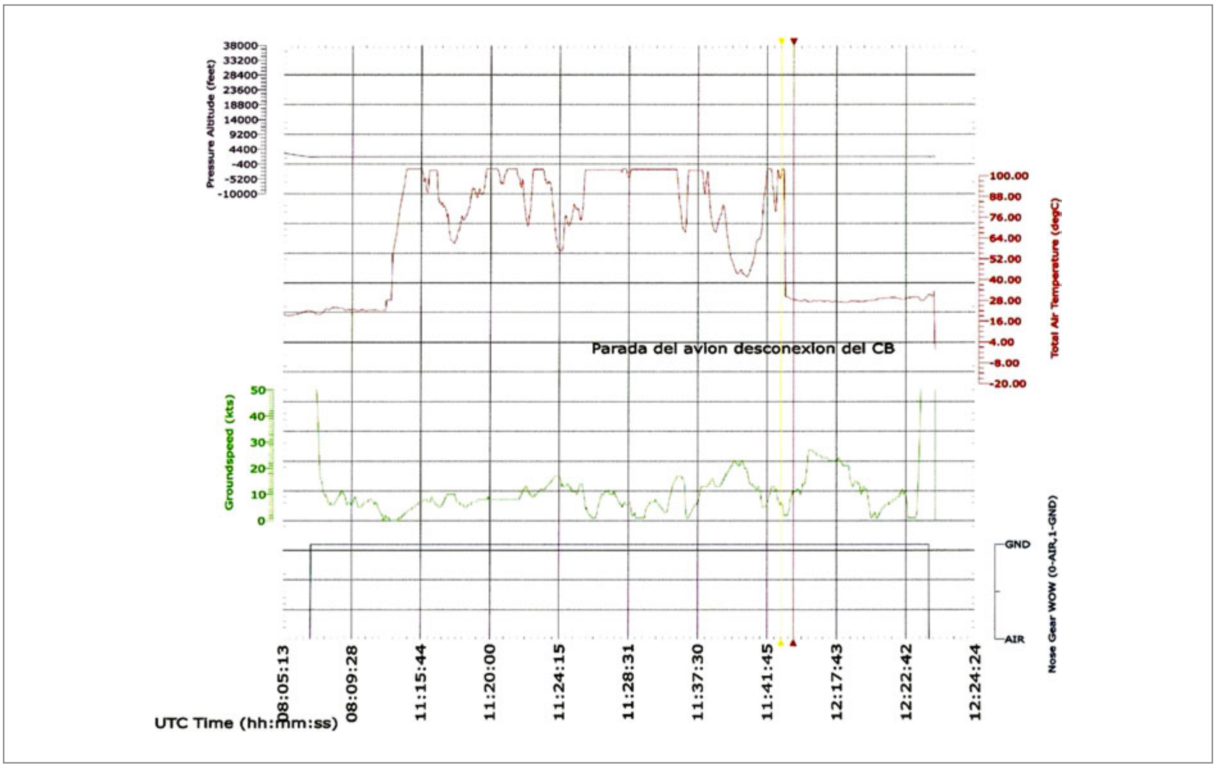


Figure 25. High RAT probe temperature events recorded on the DFDR *(cont.)*

The crews only logged three of the six high temperature indications in the airplane's ATLB. Each of these entries was made by different crews. The first two were made on 19 August and the last on 20 August 2008.

An analysis of the DFDR data reveals the following information:

- The full sequence from the first high temperature case recorded on the DFDR includes nine flights. It spans three days with two extended intermediate overnight stays on 18-19 and 19-20 August.
- The RAT probe heater was energized on the ground on six occasions. The average duration of the events was 14 minutes and 50 seconds, though with a large standard deviation (maximum: 33 minutes, minimum: 5 minutes).
- The high RAT temperature events on a day-by-day basis took place on the 6th flight of the first day, the 2nd, 3rd, 4th and 5th flights of the second day and on the 2nd flight of the third day, the last event taking place immediately prior to the accident.
- In none of the three days was the high RAT temperature recorded on the first flight of the day.
- There seems to be an inverse relationship between airplane speed and the temperature indicated by the RAT, possibly due to the fact that the ram air striking the airplane as it taxies serves to cool the probe, resulting in a drop in its temperature.
- After the takeoffs, the temperature reading showed normal values, possibly resulting from the cooling effect of the ram air despite the heater remaining energized.
- No cases of probe heating were recorded after landing, since the crew de-energized the heater using its associated rotary switch.

1.16.6. *Analysis of performances*

The aircraft's performance was analyzed given the known operating conditions, with a takeoff weight of 142000 lb, a center of gravity of 8.05% MAC (see 1.6.4), and with the following environmental conditions, as discussed in Section 1.7: elevation 2000 ft; outside air temperature 29 °C; light wind. So as to compare with the real flight parameters attained by the accident aircraft, the data from the DFDR and CVR were used, synchronized to within two seconds, as noted in 1.11.6.

The dispatch of the flight took into account the certified performance, in keeping with the operations manual, and which considers a possible fault of the engine during the takeoff run after reaching V1[46], and was planned with an 11°/MID configuration, that is, with the slats in an intermediate position and the flaps extended 11°. These conditions yield, according to normal dispatch procedures, speeds of V1 = 141 KIAS,

[46] V1, or takeoff decision speed, is the maximum speed at which the captain must start to take action if the airplane is to be stopped before the end of the runway.

V_r[47] = 145 KIAS and V_2[48] = 151 kt. The thrust setting on takeoff based on these procedures is EPR = 1.95. Under these conditions, the airplane performance calculations indicate that the airplane should become airborne at $V_{liftoff}$[49] = 148 KIAS, which it should reach after a 40 s takeoff run and a distance of 2000 m. After takeoff the aircraft, even with an engine failure, should be capable of climbing at a 2.7% gradient, approximately 490 ft/min.

For an MD-82 weighing 142,000 lb, the configuration-dependent stall speeds are: 160 KIAS in a 0°/RET configuration, that is, slats and flaps retracted; 130 KIAS in a 0°/MID configuration, that is, slats in intermediate position and flaps retracted; 123 KIAS in an 11°/MID configuration. For the weight in question, a transition speed of 196 KIAS is specified before starting to retract the slats.

Upon initiating the takeoff on the accident flight, the crew correctly selected an EPR of 1.95 on both engines. The DFDR and CVR data show that the aircraft accelerated normally to the call out speeds of V1 = 154 KIAS and Vr = 157 KIAS, which are some twelve knots higher that those calculated following the dispatch procedures used above, and after a 1950-m run. It rotated at an angular speed of 5°/sec to a pitch angle of over 14° as it became airborne. A second after takeoff the stall warning alarms (stick shaker, horn and synthetic "stall" voice) activated. In the ten seconds that the flight lasted, the aircraft climbed to a radioaltimeter altitude of 40 ft. The speed oscillated between 155 KIAS and 175 KIAS. The pitch angle reached 18.3°. the right wing dropped twice, first 20° and then 32°. Over a short interval of about one second, the throttle decreased, with both engines being reduced to an EPR of 1.65, after which maximum throttle was selected as the throttle levers were pushed to their mechanical stops to yield an EPR of 2.20, above the maximum certified takeoff EPR. The aircraft did not climb, however, and did not accelerate. It started desdending slowly as it drifted right. The descent rate reached 15 ft/sec just before the initial impact took place.

To better determine the airplane's ability to fly under circumstances similar to those of the accident, computer simulations were conducted during the investigation using calculation algorithms that reproduce the airplane's flight dynamics in different configurations, the control inputs for normal flying, the time intervals for the mechanisms to respond and the control delays, as well as the environmental factors outlined earlier. The simulations were repeated using different flap and slat configurations: 11°/MID, 0°/MID and 0°/RET. In every flight simulated, with the gear down and the engine thrust set to takeoff power, the airplane was accelerated to the rotation speed specified in the manuals for the normal 11°/MID configuration. Various scenarios were simulated after takeoff to check the airplane's behavior:

[47] Vr is the rotation speed at which the rotation of the airplane about its main gear is initiated so as to reach V2 at an altitude of 35 ft.

[48] V2, or takeoff safety speed, is a referenced airspeed obtained after liftoff at which the required one-engine climb performance can be achieved.

[49] $V_{liftoff}$, ot takeoff speed, is the speed at which following rotation, the airplane's wheels lift off the ground.

- Maintaining a climb speed of V2 + 10, corresponding to the aforementioned configuration, or
- Maintaining a constant pitch rate, repeated for various pitch angles, or
- Extending the high-lift surfaces (flaps/slats), or
- Decreasing the pitch angle three seconds after the activation of the stall warnings (stick shaker and horn).

In the simulations with the airplane in a 0°/RET configuration, if the V2 + 10 speed calculated for the 11°/MID configuration is maintained, the airplane does not climb or stay airborne. The simulation in which the aircraft, in a 0°/RET configuration, attempts to maintain a pitch angle of 14° or above does not succeed either.

In every simulation conducted in a 0°/MID configuration, the airplane remains airborne, either at $V = V2_{(11°/MID)} + 10$, or with pitch angles between 12° and 20°.

With a simulated 0°/RET configuration, the airplane remains airborne and climbs at a maximum pitch angle of 12° or 13°. Also successful are those simulations in which, after rotation and takeoff in a 0°/RET configuration at $V = V2_{(11°/MID)} + 10$, actions are taken to recover from the stall three seconds after the stall warnings. The actions include going to a 15°/EXT configuration, that is, slats extended and flaps down 15°, and adjusting thrust to an EPR of 2.0. The airplane also remained airborne in these simulations when, three seconds following the stall warnings, the nose is lowered and the airplane flown at an attitude just below the stick shaker activation.

The effect of momentarily reducing thrust after takeoff was also analyzed. Three different conditions were reproduced while maintaining a constant 13° pitch angle:

1. Considering constant EPR takeoff thrust of 1.95 in both engines, corresponding to the calculated dispatch value for an 11°/MID configuration.
2. Starting with a constant EPR takeoff thrust of 1.95, then reducing thrust momentarily to EPR 1.65 and increasing it again to the initial EPR value of 1.95 in both engines (Figure 26).
3. Considering the real EPR values recorded on the DFDR, which include a momentary drop in EPR from 1.95 to 1.65 and then an increase to an EPR of 2.20 in both engines (Figure 27).

The simulations showed that the effect of lowering thrust and increasing it immediately as happened in the accident (case 3) was slightly beneficial to the airplane's performance in comparison to maintaining a constant takeoff thrust setting for 11°/MID (case 1). The airplane's speed and rate of climb in the accident scenario were greater than those that would have resulted had the throttles not been moved.

The effect of momentarily reducing thrust is more noticeable if cases 1 and 2 are compared. Retarding the throttles hampers the airplane's performance versus maintaining power constant, but only barely, acting to lower speed and the rate of climb (see Figure 26).

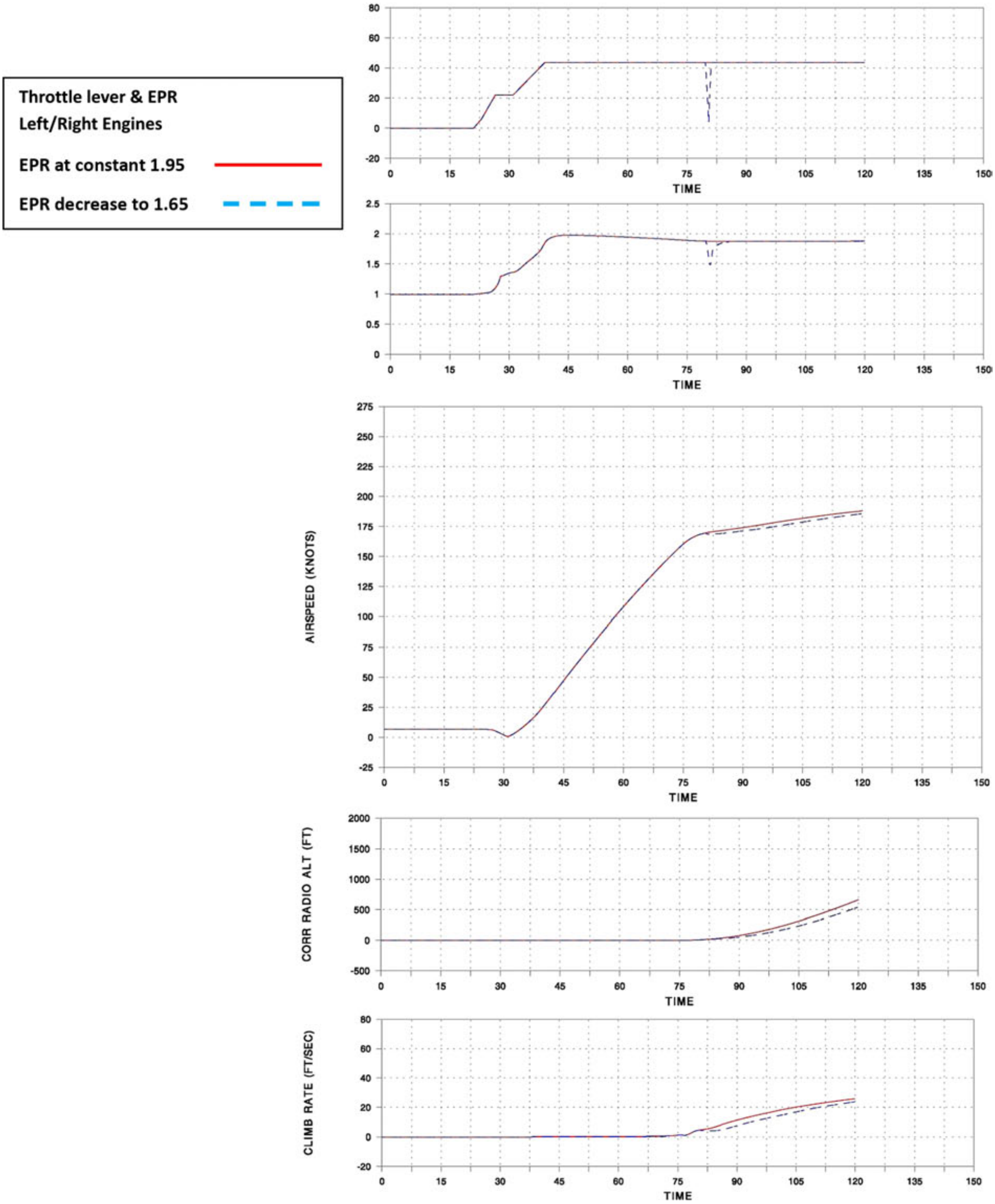


Figure 26. Effect of momentary reduction in EPR from a constant 1.95

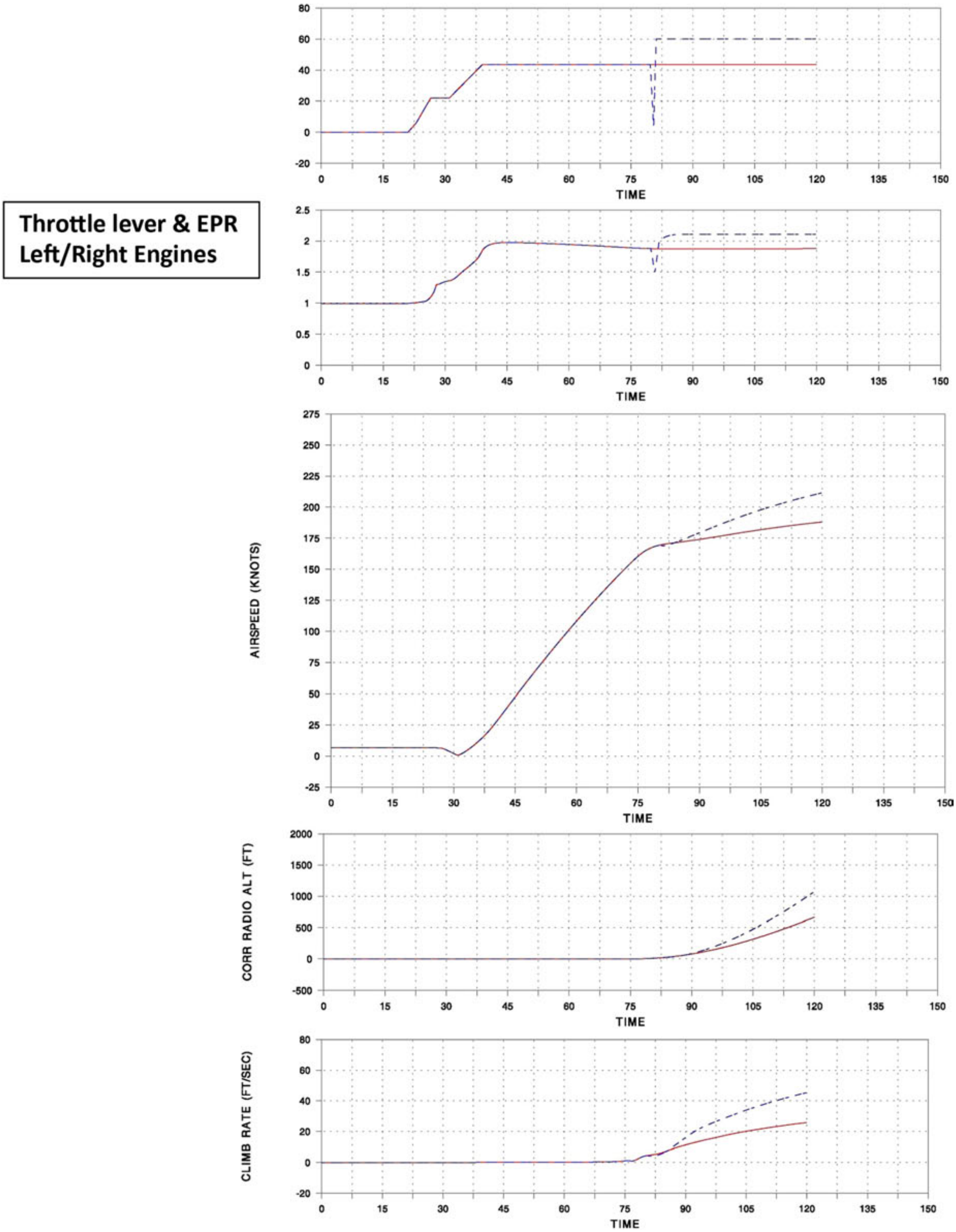


Figure 27. Effect of momentary power reduction to EPR of 1.65 and then increase to EPR of 2.20

In all three cases flight was possible with the airplane in a 0°/RET configuration if the pitch angle was maintained below 13°.

A simulation was also run specifically to assess the forces of the elevator controls. To do this, with the airplane in a slats/flaps retracted configuration (0°/RET), the airplane was trimmed for the configuration corresponding to 11°/MID. It was verified that the untrimmed airplane required slightly lower forces to pitch up.

It should be noted that all of the flight conditions recorded on the DFDR could not be duplicated exactly in the simulations due to the lack or absence of certain parameter recordings. The most important differentiating factor between the theoretical analysis and the airplane's actual performance was the large bank angle that existed immediately after takeoff. The most notable effect of the bank was the loss of effective lift, since the lift force moves away from the vertical due to the inclination of the wing and the ensuing increase in stall speed.

A 32° bank, which was the maximum value measured on the DFDR, increases the stall speed in a clean-wing configuration from 160 KIAS, the stall speed with wings level, to 172 KIAS, the stall speed for a stable turn at that angle. The bank excursions experienced by the airplane cannot be duplicated in the simulations due to the lift asymmetries that occur when the aircraft stalls, and also because the deflections experienced by the control surfaces, which were not recorded on the DFDR, are unknown. That is why the results of the simulations are not fully applicable to a real case.

Additionally, the programming of the software may not accurately represent the aerodynamics of the MD-82 with ground effect. However, in contrast to the statement regarding the bank angle, the DFDR data do indicate that the wings stalled at an angle of attack greater than what the software would have predicted for a clean-wing configuration with ground effect, which underestimates the aircraft's true performance. Consequently, the results of the analysis are considered conservative in this regard.

1.16.7. *Operational ground tests on similar airplane*

So as to aid the CIAIAC in its investigation of the accident, the NTSB carried out a ground test on an MD-88 airplane at Washington's Ronald Reagan National Airport in October 2008.

The test attempted to simulate the possible conditions present in the Spanair airplane on the day of the accident, in terms of a possible failure of the R2-5 relay or of the left ground sensing system. While the results need to account for the fact that the systems on the MD-88 are not identical to those on Spanair's MD-82, their system architectures are sufficiently similar for the conclusions to be applicable to the MD-82 insofar as the TOWS is concerned.

The following cases were considered:

- Breaker Z-29 for the RAT probe heater circuit, open.
- Breaker K-33 for the left relay assembly on the ground sensing system, open.
- Simulated failure of relay R2-5 (power supply cable disconnected).
- Simulated failure of R2-5 relay and breaker Z-29 open.
- Breakers K-33 and Z-29, open.

The test yielded the following results:

With the TOWS operating normally and only the breaker for the RAT probe heater (Z-29) open, the TOWS activated when the flaps and slats were not properly configured for takeoff as both throttle levers were advanced.

With breaker K-33 open, the TOWS did not provide any warnings as both throttle levers were advanced when the flaps and slats were not properly configured for takeoff. In addition, the following indications were observed in the cockpit:

- Failure of stall indication system
- Increase in indicated RAT probe temperature
- The rack cooling system (avionics fan) was off
- The N2 rpm indicator for the left engine was 15% higher than that for the right engine, and
- The “No Autoland” indicating light turned on.

With the R2-5 relay disconnected from its power supply, the TAT reading increased considerably since the RAT probe heater was energized. The TOWS did not issue any warnings when the throttle levers were advanced. Under these conditions, there was no indication available to the test participants of the status or condition of either the R2-5 relay or the TOWS.

With the R2-5 relay disconnected from its power supply and breaker Z-29 open, the TAT reading did not increase since the RAT probe heater was deenergized by the opening of the Z-29 breaker. The TOWS did not issue any warnings when the throttle levers were advanced. Under these conditions, there was also no indication available to the test participants of the status or condition of either the R2-5 relay or the TOWS.

With the K-33 and Z-29 breakers open, the same situation occurred as when the K-33 breaker was open, except that the RAT probe temperature reading did not increase.

1.16.8. *Simulations of stall recovery maneuvers on takeoff*

So as to assess the stall recovery procedures in effect on the date of the accident, tests were conducted in an MD-88 flight simulator with various takeoff configurations: different flaps/slats selections and different centers of gravity.

Both the accident airplane and the simulator had an electronic flight instrument system (EFIS). The simulator is designed to reproduce the same aircraft length as the MD-82 and was programmed to simulate the performance of the Pratt & Whitney JT8D-217C engines installed on the accident airplane.

The tests were carried out by a crew consisting of two experienced pilots rated on MD-80 series airplanes.

The following scenarios were simulated:

- Takeoff with flaps 0, slats retracted and 8% MAC center of gravity, using the stall recovery procedure included in Boeing's MD-82 FCOM in effect on the date of the accident.
- Takeoff with flaps 0 and slats retracted, C.G. 8, using the stall recovery procedure that includes verifying and actuating the flap/slat control lever.

The findings were as follows:

- The reaction time is key to recovering from a stall, given the limitations posed by the height above ground level.
- Immediately recognizing the stall situation is key to reducing the reaction time.
- These are the only conditions in which the stall warning and stick shaker activate simultaneously.
- The stall recovery is much faster with the procedure that includes verifying and subsequently extending the flaps/slats.
- The recovery maneuver with the flaps/slats retracted requires more force than usual to lower and then maintain the pitch angle.
- As the crew conducted more drills, the recovery from the stall became more effective.
- Training is as important as a properly defined procedure since it allows crews to quickly identify the situation and to reduce their reaction time, given the slim margin available to recover from the stall.

1.17. Organizational and management information

1.17.1. *The operator, Spanair*

1.17.1.1. Overall situation

Spanair was created in 1986 as a joint venture of Scandinavian Airlines (SAS) and the Teinver Group[50], though it did not commence operations until 1988. Initially it only flew

[50] Teinver is a Spanish company with interests in the travel agency and aviation sectors. It was also the majority shareholder in Spanair's handling company.

charter flights. It was not until 1994 that it started offering regularly scheduled flights. In 1997 it started offering international regular flights to America on its 767-300 airplanes.

In 2001, as a consequence of the crisis that affected airlines that year, Spanair canceled its flights to America and sold its 767s.

In June 2007, SAS announced it was selling its stake in Spanair. The sale process was prolonged until March 2009, with various offers and potential purchasers. Spanair's current majority shareholder is IEASA (Iniciatives Empresarials Aeronàutiques S.A.), a Spanish business group based in Catalonia with no previous ties to the aviation industry. SAS still holds a minority interest in the company.

In August 2008 the airline started laying off workers in an effort to reduce the workforce as part of its austerity measures. This process affected 25% of the employees and included both maintenance personnel and pilots. In total, it meant the loss of 1000 jobs out of a total workforce of 4000. The plan included measures such as a 24% reduction in capacity, lower costs and a plan to reduce expenses by 90 million euros by 2009. The impact on the company's technical resources meant retiring 15 airplanes from service between 15 September and 1 November of that year, equivalent to a 24% reduction in Spanair's operating capacity, as well as the elimination of nine routes and a reduction of the less profitable flights on other routes.

At the time, the aircraft approved for use by its AOC, number E-AOC-003, in effect since 16 July 2008, were the MD-82, MD-83, MD-87, A-320, A-321 and B-717. This AOC included the transport of passengers and cargo. The company's business was 80% scheduled flights and 20% charter flights.

Its main base was in Palma de Mallorca, though it had a total of seven bases (Madrid, Barcelona, Palma de Mallorca, Malaga, Bilbao, Tenerife and Las Palmas). At the time of the accident, the company's policy on bases shifted in line with its restructuring efforts, which saw the elimination of the less important bases to concentrate all its personnel in Madrid and Barcelona.

1.17.1.2. Spanair's organization

The diagram below, taken from Spanair's Operations Manual, Part A, shows the company's organizational structure in terms of its Operations and Maintenance areas.

Reporting to the Accountable Manager were the Operations Director, who was also the Flight Operations Director, the director of the maintenance system, who was the

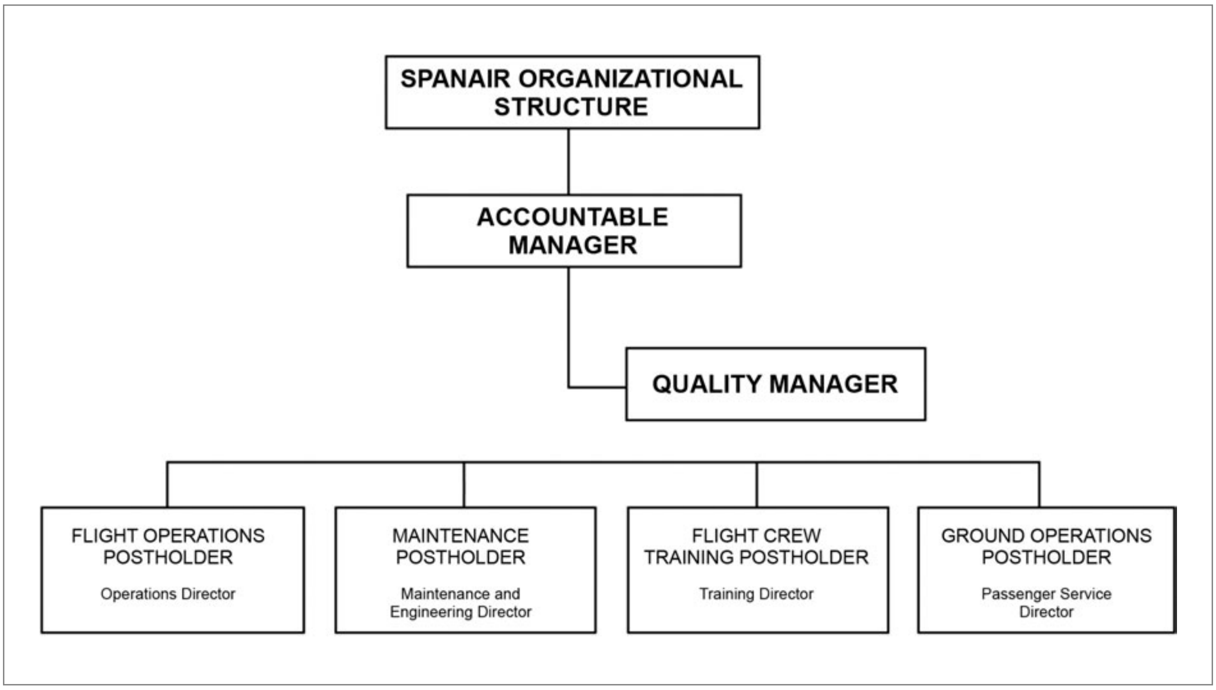


Figure 28. Spanair AOC organizational chart

Maintenance and Engineering Director, the director of crew training, who was the Training Director in the Operations Department, and the director of ground operations, who was the Passenger Service Director. The Quality Manager reported directly to the Accountable Manager.

1.17.1.3. Operational organization

1.17.1.3.1. *Overall structure*

The Operations Department was divided into three sub-departments: Management and Communications; Operations, Supervision and Control of Flight Activities and Training.

The Flight Operations Director informed the Accountable Manager of all issues involving operational safety and was charged with ensuring that operations adhered to the published schedule while minimizing interruptions and delays. The Training Sub-Director was responsible for crew training for both pilots and flight attendants.

The Sub-Director of Operations, Supervision and Control of Flight Activities was responsible for scheduling line checks for pilots and also for the standard operating procedures (SOP). The fleet managers and the head of the technical department report to this sub-director.

1.17.1.3.2. *Operational procedures at Spanair*

1.17.1.3.2.1. General criteria set by Spanair applicable to the checklists

The checklist system established by the operator defined a set of instructions for flight crews on how to perform their duties.

The section of the Operations Manual applicable to the MD80 fleet in effect at the time of the accident specified, when referring to the general criteria for the expanded checklists[51], that the checklists must be read and acknowledged in a clear and loud voice. It explained that the use of the terms "set" or "checked" as replies indicated that the component in question had been adjusted or that the relevant piece of equipment was operating normally. It also explained that the term "as required" should not be used as a reply, instead specifying the position or the indication displayed on the component in question. As for the way in which to complete the checklists, the instructions indicated that at the end of the checklist, the checklist's name must be pronounced followed by the expression "checklist completed".

The "Prestart" checklist had to be completed in its entirety, to include the equipment checks, before the first flight of the day or whenever deemed necessary by the captain. During crew reliefs or stopovers, if both pilots left the cockpit, the full checklist was required, but not the items involving system tests, which only required verifying their switch positions. It was not necessary to perform the shaded items on the checklist if one of the pilots remained onboard.

At Spanair, the method used to perform the normal checklists is the "do-verify" method. On the ground, the PF and PNF had to perform the actions on the checklist, as defined in the expanded checklists. The captain in the RH seat would then read the checklist, and the pilot in the LH seat would answer.

The Spanair Operations Manual did not specifically address interruptions to the flight preparation process arising from malfunctions that require a return to the parking. There was a reference to a situation in which a checklist was not completed, in which case it would be placed in a conspicuous place so as to remind the pilots that the checklist had not been finished.

During the investigation the reference material used by flight crews onboard the aircraft for reading the checklists was reviewed. This material did not specify that the final item for every checklist should be the "checklist completed" statement.

[51] OM-B MD-80. Section 2. Normal Procedures. Chapter 1. Normal Check Checklist. Subchapter 2. Expanded Check Checklist. Rev. 00 (02.05.2007).

1.17.1.3.2.2. Before takeoff checklists for the MD-80 series

According to information gathered from interviews held with the company's operations personnel, the checklists used had originally been the same as those used by SAS when it founded Spanair in 1986, after which time Spanair's checklists evolved separately, though Spanair remained in contact with SAS, which informed Spanair of any modifications to its own checklists.

The checklists to be completed before starting a flight for the MD-80 series included the following number of items (see Appendix 4):

Checklist	No. of items
Prestart	59 (first flight of the day) 26 (if one pilot remains onboard during stopovers)
Before start	8
After start	9
Taxi	8
Take off inminent	6

Each checklist item has associated with it a series of actions. By way of example, item 29 on the Prestart checklist involves the emergency lights and consists of seven actions. In addition to all of the actions and checks to be completed by the pilots during this flight preparation phase, there are those associated with engine start-up.

Prestart checklist

The check of the TOWS was item number 49 on the checklist. It is a shaded item, meaning that its completion was only required prior to the first flight of the day. There was a warning in this item that if the horn did not sound when the system was checked, maintenance action was required prior to takeoff.

Item 31 was "Ice Protection". As with item 49, it was a shaded item that only had to be done prior to the day's first flight. This item includes a total of seven actions to check the ice protection systems. Heating would only be supplied to the sensors (pitot tubes, static pressure ports, angle of attack transducers and RAT probe) if the outside temperature was below 6 °C.

In the Prestart checklist, there is a dotted line after item 56. The expression "Down the line" [52] makes reference to reading the three checklist items on the checklist (57, 58 and 59) that are found below the dotted line.

[52] The expression "Down the line" shown in this checklist corresponds to the "Below the line" heard on the CVR (see Section 1.1).

After start checklist

The last item on this checklist (item 9) was the flaps/slats selection.

According to the expanded Spanair checklists (OM B, Rev. 1, 15 February 2008), the actions required to be taken for item 9 were:

9. FLAPS & SLATS..SET & CHECKED..R/P

When Clear Signal is received:

- Select flaps according Take Off performance calculations.
- Check slats sequence as follows:

FLAP 0-13	15- 24
* Disagree * T/O * Disagree-auto * Disagree * T/O	* Disagree * T/O

- Check flap position indication to agree with selected flap. (Both).
- Check SLAT T/O light to be on and all other SLAT advisory lights off.
- Check for no AUTO SLAT FAIL caution on annunciation panel. (L/P)

The reply to this item was "SET & CHECKED". In the description included in the expanded checklists there was a note that specifically stated to extend the flaps when the all clear signal was received from the ground crew.

The flap/slat selection item is performed by the first officer by selecting the flaps deflection obtained previously in the performance calculations and in which both pilots must confirm that the sequence of slat indicating lights when the handle is activated is correct. Most of the pilots interviewed at the company believed that the performance of this item is contingent on a specific request made by the captain when the ground staff reports all clear, which is when the first officer extends the flaps using the lever, with both pilots verifying the sequence of the slat lights.

Item 4 on this checklist concerns "Ice Protection & Fuel Heat". This item is performed by the captain and involves energizing, among other things, the RAT probe heater by operating the rotary switch for the meter selector and heat. The reply to this item is "SET".

Taxi checklist

Item 5 on the Taxi checklist requires a check of the availability of the additional automatic thrust in the event of an engine failure on takeoff (ART) and the calculated values for takeoff thrust (EPR).

The last item on this checklist (item 8) is the "Takeoff briefing". This item's description specifies that the takeoff speeds, thrust and flaps be checked, among others.

It also expressly states to refer to the conditions specific to the flight, such as adverse weather conditions, the status of the runway, noise abatement procedures, MEL restrictions, etc.

Take off imminent checklist

Last on this checklist (item 6) are the so-called final items. The Operations Manual does not specify how to perform this item. The company pilots interviewed agreed that this item is spoken out loud by the first officer from memory without the captain having to reply. The captain must supervise the first officer, ensuring that the replies, spoken out loud, correspond to the actual condition of the systems and with the setpoints selected. The parameters and settings for takeoff critical components are checked, including the flap and slat indicators.

1.17.1.3.2.3. Stall recovery procedure

The Spanair Operations Manual for the MD-80 series includes the following in its normal stall recovery procedure:

- *Call "Stall-full power"*
- *Apply full power. If ground contact is imminent apply maximum available thrust, i.e. throttles fully forward*
- *Disconnect the autopilot. Be alert to counter-act excessive nose-up trim condition.*
- *Level wings and adjust pitch to minimize altitude loss or to obtain obstacle clearance.*

The guidance then varies depending on whether the aircraft is above or below FL250:

- *Above FL250, accept a loss of altitude while accelerating. Maintain existing configuration.*
- *Below FL250, extend slats if in a clean configuration. Accelerate to the minimum speed for the existing configuration, then adjust configuration as desired.*

1.17.1.3.2.4. The Spanair Operating Manual (SOM) versus Boeing's Flight Crew Operations Manual (FCOM)

The introduction to the normal procedures section in Boeing's MD-82 FCOM applicable on the date of the accident checklists the following guidelines regarding the checklists:

- The pre-flight checklists are to be performed using a scan pattern or scan flow and applying the DO-VERIFY technique (do first, and then verify what was done).
- The checklists must be read in a loud and clear voice and replied to in a similar manner.
- The terms "SET" or "CHECKED" as a reply indicate the selection or operation of equipment, depending on prevailing conditions or on the configuration of the equipment. It also states that the term "AS REQUIRED" should not be used as a reply, the actual switch or control position or actual indication reading should be specified.
- At the end of each checklist the name of the checklist must be stated, followed by the expression "checklist completed".

Before start checklist

The 75 items in this checklist are not numbered. The following note appears at the start of the checklist:

> *NOTES: All system checks and control positions should be done, whenever possible, prior to reading the checklist. Commands preceded by an asterisk (*) are thru-flight items.*

Item 65 corresponds to the TOWS check. It states that if no sound is heard during the TOWS check, maintenance action is required before takeoff. It is an asterisked item.

Item 35 on the checklist involves sensor heating ("Pitot Heat") and requires checking the proper operation and energization of the sensor heaters. It is an asterisked item.

Taxi checklist

This checklist has 12 items. The first is a check of the flaps/slats, stating the selection made. The slat indicating lights must be verified to follow the proper sequence.

The last item on this checklist is the "Takeoff briefing". No guidance is given as to the contents of this briefing.

Stall recovery procedure

Boeing distinguishes among the phases the aircraft is in:

For takeoff, approach, landing or go-around configurations, the actions to take following the first indication of an approach to stall are:

- Apply maximum certified thrust. If ground contact is a factor, apply thrust to the mechanical stop.
- Adjust pitch angle as required while rolling wings level to minimize altitude loss or to provide obstacle clearance.
- Maintain existing flaps/slats and gear configuration.
- Accelerate to the minimum maneuvering speed for existing configuration and then adjust configuration as desired.

If the airplane is in a clean configuration, the actions to take following the first indication of an approach to stall are:

- Apply maximum certified thrust. If ground contact is a factor, apply thrust to the mechanical stop
- Adjust pitch as required to minimize altitude loss
- Extend slats (below IAS/match the slats limit speed)
- Accelerate to clean minimum maneuvering speed
- Adjust configuration as appropriate
- Return to desired altitude and airspeed.

Lastly, the case of an airplane in a clean configuration at altitudes where performance is limited is considered. In this case, the recovery procedure is to:

- Apply máximum certified thrust
- Accept an altitude loss while accelerating to clean minimum maneuvering speed
- Adjust configuration as appropriate
- Return to desired altitude and airspeed.

1.17.1.3.3. *Operator training*

1.17.1.3.3.1. Recurrent training

According to the Spanair Operations Manual, Part D, proficiency checks must be conducted in a simulator every six months. The operator has developed a program that is divided into six sessions and is completed over a total of 36 months. The program covers normal, abnormal and emergency procedures.

Every simulator session for both pilots and first officers includes training on engine failures during takeoff.

The program includes one simulator session on encountering windshear on takeoff and another session on encountering windshear on approach.

1.17.1.3.3.2. CRM Training

CRM training is discussed in Part D of the Operations Manual (OM-D). All Spanair flight crews received an initial CRM training course upon joining the company. After completing the type rating training and joining a fleet department, every crewmember received recurrent training annually. This training covered the entire CRM syllabus over a three-year training cycle.

The initial and recurrent CRM training programs included the following:

- The hurry-up syndrome.
- Stress resulting from "environmental" pressures: operational, psychological or self-induced.
- Mistakes, oversights, errors, deliberate infractions.
- Error chain, incident and accident analysis.
- Communications and coordination.
- Assertiveness and assertive behavior in communications.
- Expectation-bias phenomenon.

In addition to the initial and annual recurrent courses, Spanair also taught the following specific CRM courses:

- Conversion courses (aircraft type and operator conversions). Leadership, promotion to Captain or to Flight crew Supervisor.
- Training of inspectors and instructors.

CRM training was held in classrooms located at CAE (a training organization located in Madrid) and relied on the use of audio-visual equipment. The duration and content of the courses was specified in the Spanair OM-D. The CRM topics normally made use of PowerPoint© presentations that included suitable examples taken from incidents and accidents.

The established practice at Spanair was for all CRM training to be given by CRM instructors trained by the company through an initial CRM trainer's course, and accepted by the civil aviation authority.

The established practice at Spanair's Training Department was to select CRM instructors from a pool of volunteer candidates based solely on professional criteria.

The effectiveness of CRM training on flight crews was evaluated and monitored during flight operations. The operator reported seeing a good overall level of application of CRM techniques.

1.17.1.3.3.3. Line checks conducted by the operator

The investigation included a review of the records for the line checks given by the operator to its pilots. These records contain the forms used during the evaluations. A total of 12 line checks were provided, nine on Airbus airplanes and three on MD airplanes. In all, six had been conducted in 2008 before the accident and the rest had been conducted in 2009. Six were line checks for pilots and six were for first officers, with each check consisting of two flights, one with the examinee as the PF and the other as the PNF.

All of the results were satisfactory. Only in one case was a recommendation made to apply the proper procedure and to review the DFGS before takeoff. In the remaining checks reviewed, the remarks made by the instructor were along the lines that the company's procedures were being followed.

The operator reported that in order to provide its instructors a guide for evaluating the pilots during these checks, starting in 2010 it started to use the "Observation Sheets" taken from the LOAS[53] (Line Operations Assessment System) and published by AIRBUS Flight Operations Support in September 2002.

1.17.1.3.4. *Process for overseeing operational procedures*

According to the Spanair Operations Department's Management Manual, Section 7, Chapter 7.10 Manual Revision Procedure, modifying the Operations Manual Part B requires receipt of a modification proposal from the Fleet Office.

The Fleet Office is responsible for reviewing and proposing the changes and updates to the operating manuals and submitting them to the Technical Department for publication. According to the Management Manual, the reason for revising a manual could come from the manufacturer, public agencies or the company itself, and could stem from audit results, changes to procedures, etc.

As part of the modification process in Part B of the Operations Manual, when a change affects the SOPs, the Procedures Committee is assembled. Section 6 in Chapter 6.8, Fleets, of the Operations Office's Management Manual, describes the make-up and the process for assembling the Procedures Committee. The Procedures Committee consisted of the Fleet Managers and Assistants; the Training Manager for the fleet affected, the head of the CRM Department, the Head of Supervision and Flight Safety Manager,

[53] According to the information included in the "Observation Sheets", the LOAS program uses the methodology of the LOSA (Line Operations Safety Audit) program developed at the University of Texas. The LOSA program is based on data gathered from normal flight operations. It is designed as a tool for use in a non-punitive context for crews under observation. Both the ICAO and IATA support this methodology.

though the presence of every member at the sessions was not always required. The purpose of the Procedures Committee is to analyze and implement those updates and/or modifications born of changes to the documentation affecting the SOP.

Its operating guidelines did not include verifying differences between its SOPs and the manufacturer's or studying previous changes.

According to the company, the changes proposed to the checklists were subject to a risk assessment based on the professional opinions of operations personnel with ample experience in Procedure Committee meetings. The Spanair Operations Manual listed the fleet director as responsible for implementing any changes agreed to. The documents written by the committee were recorded and archived for three years. Investigators were unable to collect any evidence attesting to these facts.

Nor was the investigation able to track the changes made to the flight procedures (expanded checklists) or to the checklists applicable to the MD fleet, nor could it determine the reasons for the changes based on the information considered by the Procedures Committee.

1.17.1.3.5. *Instructions regarding the use of cellular telephones*

In the Spanair's Operations Manual, Part A, Section 8, Operational procedures, Chapter 3, Flight Procedures, item 8.3.15.G, Use of Electronic Equipment Onboard, prohibits the use of portable electronic devices onboard the aircraft.

This prohibition is based on the DGAC Resolution of 9 January 2002, which establishes the operational criteria for the uniform application of the requirement specified in JAR-OPS 1.110 regarding the use of portable electronic devices onboard airplanes.

Said requirement states:

> *"OPS 1.110 Portable electronic devices*
> *An operator shall not permit any person to use, and take all reasonable measures to ensure that no person does use, on board an airplane, a portable electronic device that can adversely affect the performance of the airplane's systems and equipment."*

The aforementiond resolution of 9 January 2002 states that:

> *"2.3.2. Flight and passenger cabin crews should avoid the use of cellular telephones or other transmitting devices during critrical pre-flight procedures, such as, for example, entering route information into the navigation system or when monitoring fueling. Flight crews and other personnel involved in the dispatch of*

an aircraft shall observe the same restrictions that are imposed on passengers with regard to the use of these devices".

At the time of the accident, Spanair had not established operating instructions on the use of cellular telephones by crews in the various phases of flight.

1.17.1.4. Spanair's quality and flight safety organization

1.17.1.4.1. *Quality Department*

The Flight Safety Department reports to the Quality Director, who in turn reports to the Accountable Manager.

The responsibilities of the Quality Director include ensuring that the Quality Assurance Program is properly established, documented, implemented and maintained, to include specifying a framework and a schedule for conducting periodic reviews of the relevant units.

The investigation could not confirm that internal audits were conducted or that Spanair had an annual audit plan.

1.17.1.4.2. *Flight Safety Department*

The department was run by the Flight Safety Manager, under who were an FDM Manager, the Flight Safety Officers for both flight crews (at least one per fleet) and flight attendants and the investigation team. No personnel were assigned exclusively to investigate accidents or incidents, meaning that the Flight Safety Officers also exercised investigative duties in the event of an accident as part of the investigative team under the direction of the Flight Safety Manager.

1.17.1.4.3. *Operational safety program (Safety Culture)*

The priorities that must be followed, as stated in the Flight Safety Manual[54], are, in order:

1. Safety
2. Punctuality
3. All other services

[54] Flight Safety Manual, Rev. 7, 1/07/2007.

In this regard, the On-Time Guarantee that Spanair implemented to improve the services and the quality standards it provided to its customers is a matter of public record. This program offered to compensate the passengers if the airplane doors were closed more than 15 minutes after the scheduled departure time for reasons attributable to the company.

According to the manual, the goal of the company's flight safety program is to identify and monitor possible threats to flight safety. To achieve this, the manual states that operations and the operating environment have to be monitored and analyzed so as to identify adverse trends and so that proper measures can be taken, such as modifying procedures or training or raising awareness of potential risks.

The tools for detecting these trends are:

1. Flight safety forums (FSQB. Flight Safety Quality Board and the FSC, Flight Safety Committee)
2. Safety reports and databases
3. Safety audits
4. Safety trends analysis
5. Company and accident and incident investigations
6. FDM programs
7. Safety information program
8. Coordinating with other departments and with authorities.

According to the Flight Safety Manual, the information distributed was:

- *Flight Safety Magazine* every six months
- *Cabin Crew Magazine* every six months
- *Flight Safety Bulletin*, monthly
- *Flight Safety Notice*, as required

According to information gathered during the investigation, the Flight Safety Department distributed Flight Safety Notices when required and a Flight Safety Bulletin every two months. The bulletins featured information on incidents within the company's different fleets and other news on operational safety.

The Flight Safety managers reported receiving few reports, seven a month at most. There were no reports concerning unsafe takeoff configurations. Spanair communicated 410 events in 2010 to the national event reporting system.

Fifteen Flight Safety Notices were issued in 2008. The one issued on 21 May 2008 emphasized procedural compliance with the company's SOPs following a problem with a pressure control valve switch that was improperly positioned after maintenance. In another notice published on 1 August 2008, the Flight Safety Department warned of the delicate situation the company was in and emphasized the need to be more strict and careful in terms of complying with checklists and standard procedures. Also stressed was the efficient use of all available resources so as to mitigate errors, minimize risks and increase safety.

1.17.1.4.4. *Flight Data Monitoring (FDM) program*

The purpose of the FDM program is to gather and analyze the flight data that is electronically stored by airplane recording systems so that potential operational risks present at air carriers can be identified and corrected.

According to the operational regulations in effect at the time of the accident[55], the FDM program was mandatory for European operators.

At the time of the accident, Spanair was only tracking data for its A320 fleet. QARs had been installed on every aircraft in its MD fleet and the process of downloading the data had begun, though Spanair lacked the resources to analyze said data.

1.17.1.5. Maintenance structure

1.17.1.5.1. *Structure/organization*

Spanair was Part M, Subpart G approved, pursuant to European Commission Regulation 2042/2003, as an organization for managing the continuing airworthiness of the fleets specified in its AOC. It was also PART-145 approved to perform maintenance on aircraft and components to the extent specified in its approval license. According to each approved Maintenance Program, the remaining required maintenance activities were contracted to other approved organizations.

At the time of the accident, Revision 2.1 to the MOE was in effect, dated 18 June 2008, as was Revision 2 to the CAME, dated 11 April 2008. Both were approved by the Seventh DGAC Flight Safety Office on 19 May 2008.

The departments responsible for maintenance and for airworthiness management report to the Technical Director. These departments shared most of their responsibilities and areas.

The main difference between the two structures is that the maintenance organization has the Line Maintenance Department while the CAMO has the Base Maintenance Department.

When Revision 2 to the CAME was issued (11 April 2008), the Spanair staff, as a Continuing Airworthiness Management Organization, had a total of 84 employees distributed as follows:

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[55] Paragraph OPS 1 037. Annex III. (EC) Regulation 8/2008 of 11 December 2007.

Area	Staff
Technical Department	7
Quality Division	11
Technical Control	11
Maintenance and Engineering Subdepartment	3
Engineering Division	11
Materials, Logistics and Auxiliary Workshops Division	1
Base Maintenance Division	1
MCC	7
Engine Division	5
Planning Division	27
TOTAL	**84**

When Revision 2.1 to the MOE was issued (18 June 2008), the Spanair staff, as a maintenance organization, had a total of 411 employees distributed as follows

Area	Staff
Technical Department	7
Quality Division	11
Technical Control	11
Maintenance and Engineering Subdepartment	3
Engineering Division	11
Materials, Logistics and Auxiliary Workshops Division	1
• Logistics and Material • Purchasing • Warehouse • Wheel and Brake Workshop • Electrical, Battery and Calibration Workshop	1 4 45 12 2
Line Maintenance Division	3
• MCC • Structures Workshop • PMI Base • LPA Base • MAD Base • BCN Base • TFS Station • AGP Station • BIO Station	7 6 70 33 65 51 15 12 9
Engine Division	5
Planning Division	27
TOTAL	**411**

Many of the resources of both the maintenance and CAMO organizations were shared.

Item 1.9 a) of the CAME, "Engineering handled by Spanair", mentions that the basic activities of the Spanair Engineering and Engine Divisions included, among others:

- Providing immediate line maintenance assistance as necessary. Those cases not covered by the manuals or beyond the manuals' limitations shall be submitted to Engineering subcontractors and/or to the countries of manufacture of the aircraft or components for further instructions on the actions required.
- Conduct technical research, prepare reports on technical malfunctions or recurring faults experienced in day-to-day operations. The more significant malfunctions, damage or incidents shall be referred to Engineering subcontractors and/or to the countries of manufacture of the aircraft or components.
- Develop corrective actions intended to eliminate or prevent recurring defects and verify the efficiency of said actions.
- Draft troubleshooting instructions as required.

The MOE specifies that line maintenance supervisors must ensure that all of the work that is performed at the various maintenance centers is properly carried out and is in compliance with all regulations relating to the airworthiness and flight safety of aircraft and components. The procedures of the quality system outlined in the MOE must be followed at all times.

Emphasis is placed on ensuring and tracking the proper use and completion of work documents (work cards, work orders, flight parts, etc.). Steps must also be taken to ensure that the proper reference documents and manuals are used and that they are kept up to date.

Base directors are responsible for tracking any incidents involving fleet operations on a daily basis and to report any potential deficiencies and corrective actions taken to the Line Station Director and/or to the Director of the Line Maintenance Division. They are also to interface with the MCC when an airplane is declared AOG, keeping the MCC informed of the problem and of the steps being taken to correct the defects and providing an estimated time for the airplane's return to service.

1.17.1.5.2. *General description of the company's maintenance facilities*

The Maintenance Organization Manual classifies its maintenance facilities as Bases and Stations. At the time of the accident, Spanair had four (4) bases (Palma de Mallorca, Las Palmas de Gran Canaria, Madrid-Barajas and Barcelona) and three (3) stations (Tenerife South, Malaga and Bilbao).

Though the company's manuals do not explicitly describe the factors considered in classifying a facility as a Base or Station, as a general rule the company's bases feature a higher number of both human and material resources than stations.

Distribution of Human Resources at Spanair maintenance facilities

• Base at Palma de Mallorca	70
• Base at Las Palmas de Gran Canaria	33
• Base at Madrid-Barajas	65
• Base at Barcelona	51
• Station at Tenerife South	15
• Station at Málaga	12
• Station at Bilbao	9

Specifically, the base at Palma de Mallorca housed Spanair's maintenance headquarters and featured a computer center that managed a company-wide communications network. The Maintenance Control Center (MCC) was also located at this base.

The base at Madrid-Barajas was the company's second in terms of its staffing. It had offices for the base director, the shift supervisors and the rest of the staff, a communications center, spare parts warehouse, centralized and independent computer resources and a set of all the necessary manuals and documents.

1.17.1.5.3. *Maintenance Control Center (MCC)*

This center was part of the structure of Spanair's Maintenance Organization, reporting to the Line Maintenance Division. It was located at the company's headquarters in Palma de Mallorca.

According to the personnel descriptions for Spanair's departments as a Maintenance Organization, the MCC had a total staff of seven.

This department was responsible for providing 24-hour technical line maintenance support to the entire fleet. It gave real-time support to all of the stations served by Spanair and to flight crews in the event of a malfunction in those airports where Spanair did not have its own or a contracted maintenance service. In those instances where airplanes had technical difficulties resulting in a cancellation, emergency condition and/or possible technical incident, the MCC had to monitor the steps taken to solve the problem.

The MCC reported to the Operations Office on the technical status of airplanes undergoing maintenance or in the event of a malfunction, providing it with estimated times for their return to service.

The MCC also investigated malfunctions and took part in tracking deferred maintenance. It also provided guidance on drafting the MELs for the different fleets and clarification regarding the entries made in the ATLB.

1.17.1.5.4. *Spanair's handling of recurring malfunctions and defects*

Spanair's handling of recurring malfunctions and defects involved both the airworthiness management and the maintenance organizations.

In Section 1 of the CAME, the segment on "Recurring events and defects" indicates that the computer system provides the means for reporting problems as they arise in the airplanes of Spanair's various fleets. The data input process consists of having personnel in the Planning Division enter the information from the ATLB stubs, while the MCC assigns them a four-digit code and handles the analysis of said reports.

Spanair's CAME describes how the computer system considers two criteria for issuing a notice concerning the handling of recurring defects: the seriousness of the malfunction and its recurrence. "*The computer system will issue an event notice based on the seriousness of the malfunction and its recurrence*".

According to the company, the computer system always issued a notice whenever the same ATA code[56] was repeated three (3) times on the same airplane within seven (7) calendar days. This criterion could be adjusted if required by a specific situation it deemed necessary for a particular reason or to track a particular event.

The Maintenance Organization Exposition (MOE) addresses the handling of repetitive malfunctions or faults in Section L2 "Additional Line Maintenance Procedures". These procedures are basically identical to those in the CAME.

Other changes to the MOE originated from internal proposals: in particular, Section 2.7 of the MOE "Procedure for reporting incorrect, incomplete or ambiguous maintenance data to the author of the maintenance data".

1.17.1.5.5. *MEL handling and processing procedures*

The Spanair MEL applicable to aircraft EC-HFP was based on Revision 37 to the MMEL published by the FAA for the DC-9 fleet on 23 March 2007, which was the latest revision to the MMEL on 20 August 2008.

[56] ATA is a method for classifying the different airplane systems by chapter.

The MEL applicable to aircraft EC-HFP was included in Part B of the Spanair Operations Manual and had been approved by the DGAC on 16 April 2008 and corresponded to DGAC Revision 9A of 12 March 2008.

In its approval, the DGAC expressly stated that "*The texts of the Maintenance (M) and Operational (O) procedures to be completed before an aircraft is dispatched with certain items inoperative are not included as a part of this approval*"[57].

Since the MEL is a document that is used jointly by maintenance and flight crews, Spanair referred to it in its Operations Manual as well as in the MOE and CAME.

1.17.1.5.5.1. The MEL in the Continuing Airworthiness Management Organization (CAMO)

Section 1.1.2 of the CAME, "MEL Applicability", in effect at the time of the accident provides an in-depth description of every aspect involved in the application and use of the MEL.

This section defined the MEL approved for each airplane type as an aid to crews and maintenance in their efforts to dispatch the airplane on time from any station. In Point 1.1.2.1, "General", it stated: "*For each airplane type, it specifies the systems or components that must be fully operational, or that may be partially or fully inoperative without compromising flight safety or seriously reducing passenger comfort*".

It also stated that Certifying Personnel had to be familiar with the MEL so as to ensure effective communications with the crew in the event that a maintenance item was deferred.

Point 1.1.2.3 in the CAME, "Application", provided a series of guidelines to be applied by Certifying Personnel for when an airplane could be dispatched based on the MEL:

"...

- *Inform the captain when it is obvious that the equipment/system cannot be repaired before the airplane's departure.*
- *Log the information on the inoperative components/systems in the onboard ATLB.*
- *Label as inoperative the control(s) and/or indicator(s) associated with the inoperative units or components/systems that are accessible to the crew during operations...*"

[57] As per JAR MEL/MMEL.35. Procedures. Operating and maintenance.
(b) The purpose of these procedures shall be identified during the MMEL approval process. However, the procedures themselves shall not be subject to approval.

Point 1.1.2.4 in the CAME, "Crew acceptance", made it clear that the captain had the authority to require a repair even when dispatch was authorized by the MEL.

With regard to the time limits in the MEL, the CAME manual specified that a priority of Certifying Personnel was that an airplane not be dispatched from a Line Base or Station where daily or service inspections were performed with an unresolved MEL item.

The CAME also specified that an item that was deferred or on hold (HIL) would be considered resolved when, once the appropriate action was taken in accordance with the approved data, the required tests specified in said data were satisfactorily completed.

1.17.1.5.5.2. The MEL in the company's Operations Manual

Section 8.6 A, "MEL. Utilization" of Part A of the Spanair Operations Manual stated that: "*When a component is found to be inoperative, an entry shall be made in the technical logbook (TLB). The component shall then be repaired, or deferred in accordance with the MEL*".

Additionally, Part B of the Operations Manual, in Part 4 "Maintenance Action" of Section 09 - MEL, Chapter 01 - Introduction, stated that the captain must be informed by Maintenance as soon as possible if the inoperative component could not be repaired prior to dispatching the aircraft.

1.17.1.5.5.3. The MEL in the maintenance organization

1.17.1.5.5.3.1. On-ramp malfunctions

Section L2, "Additional Line Maintenance Procedures", of the Spanair MOE in effect on the day of the accident contained a flow chart to show how to process ATLB entries made by pilots. Prior to checking the MEL, it required answering the question: "*Can it be corrected prior to dispatching the airplane?*" If it could, it would be corrected and logged in accordance with the company's procedures. If it could not, four possible options were provided as a preliminary step to determining whether the aircraft was in a condition suitable for conducting operations:

- Check the MEL / MEL procedures
- Check limits against manuals
- Check limits with Engineering
- Temporary repair

After completing this step, the answer "*Acceptable for operation?*" had to be answered. If affirmative, the airplane could be dispatched in accordance with company procedures and the MEL; if negative, the airplane would be declared AOG until the fault was corrected.

1.17.1.5.6. *Use of the airplane's Technical Log System*

The Technical Log System is used by the entire organization, its primary purpose being to gather statistical data for the reliability program and to aid in troubleshooting.

The description of the Technical Log System can be found in Point 1.1 of the CAME.

It includes all of the technical records pertaining to engineering and operational details as well as to faults discovered in flight or during airplane inspections, along with the maintenance actions taken. It includes any components that are replaced and the type of inspection performed.

The ATLB is part of the airplane's Technical Log System and consists of:

- A series of sequentially numbered stubs with multiple copies, each of which must be associated with no more than one flight or cycle.
- The cover with the airplane's registration, the Spanair name and an inside pocket with Spanair's address and information on how to contact Spanair MCC if necessary.
- The "Running HIL", which contains the green-colored copies of the ATLB and lists deferred maintenance items.

1.17.2. *Operator audits*

1.17.2.1. Internal operator audits

According to information provided by Spanair, there were two operations audits in 2008. The first, on the entry into force of the EU OPS, started in April 2008 and was completed with the entry into force of the EU OPS on 16 July 2008. This audit was conducted at the request of the aviation authority, which asked operators to analyze deficiencies and provide a plan of action for complying with the new operating guidelines. Said audit detected that the QARs for performing flight data monitoring pursuant to EU OPS 1.037 were not installed throughout the MD fleet.

The second scheduled audit took place in November 2008. Its purpose was to conduct an internal evaluation in preparation for the IOSA audit that was scheduled for February 2009. Six people comprised the audit team.

A total of 95 non-conformities and 12 observations were identified[58].

[58] Observation: The documented statement by the IOSA Auditor based on factual evidence gathered during an Audit that indicates an Operator has not fulfilled an IOSA Recommended Practice.
Finding: The documented statement based on factual evidence that indicates an Operator is not in conformity with an IOSA Standard.

The non-conformities included the following:

- The policy for dealing with intentional and deliberate violations of flight operations procedures by flight personnel was not documented.
- There was no defined policy for establishing and developing procedures and checklists for flight crews. The development of procedures and checklists from the manufacturer's procedures and checklists should be based on operational considerations.
- The documentation did not include the CRM principles and policies.
- The documentation did not include the definition of the company's general policy for the use of checklists or the taskssharing between the PF and PNF during all phases of flight or during automatic flight.
- The documentation did not include a definition of the company's policy on cross-checks or the verification of critical actions.
- The process for selecting instructors, evaluators and line check airmen was not defined.

All of these non-conformities found by the audit were corrected and closed out.

As for maintenance, from 2005 to 2008, neither Spanair's internal quality audits nor the audit intended to do an internal evaluation of the company in preparation for the IOSA audit in 2009 detected any discrepancies involving the absence of applicable reference data in the technical records of the maintenance actions performed.

1.17.2.2. Operator audits by outside entities

1.17.2.2.1. *IATA audits by Aviation Quality Services (AQS)*

The IOSA (IATA Operational Safety Audit) program is an internationally recognized and accepted voluntary evaluation system that is designed to assess an airline's operational management and oversight systems.

The IOSA audits analyze a total of eight areas, including Organization and Management, Flight Operations, Operational Control and Flight Dispatch Procedures, Engineering and Maintenance, Handling Services, Passenger Cabin Operations, Cargo Operations and Security.

Spanair voluntarily underwent an audit and was IOSA certified in 2005. Audits were conducted in 2007 and 2009 to renew that certification.

2007 IOSA audit report

The audit was conducted from 29 January to 2 February 2007. The audit team consisted of a team leader, three auditors and two auditors in training. A total of 21 non-conformities were found, of which three were in the area of organization and management and six in flight operations. There were also five observations in these areas, two in organizations and management and three in flight operations.

One of the observations in the area of organization and management stated that the documentation involving quality was not distributed to operations personnel, a practice that did not promote interest and continuous training. Another reported that the operator should have a program for gathering safety data through cockpit observations.

In the area of flight operations, there were observations regarding how the operator should have a process for selecting instructors, examiners and checkline airmen that included a review of the records for the training department, management recommendations and a review of the training department, as well as an evaluation by more than one person.

2009 IOSA audit report

An IOSA audit of Spanair was conducted from 23 to 27 February. The audit team consisted of a team leader and four auditors. A total of 29 non conformities were identified, two in the area of organization and management and eleven in the area of flight operations. There were also seventeen observations, seven in the area of organization and management and four in the area of flight operations.

The audit report stated that all of the non-conformities detected in Spanair’s last internal audit in 2008 had been corrected and closed out.

Among the observations and non-conformities for the area of operations and management was one regarding the lack of a risk management system at the organization applicable to operations, maintenance and security, and applicable as well to new initiatives that could impact operations, maintenance and security.

Another aspect mentioned is that there was no management and tracking system for storing those records that document compliance with operational requirements that includes, but is not limited to, the qualification and training requirements for operations personnel.

Once again, as in the 2007 audit, an observation was made that there was no flight data monitoring program or a program for analyzing crews’ flight performance during regularly scheduled flights. Spanair claimed that there was no legal requirement to have a program for gathering data or for analyzing flight crew performance during regularly scheduled flights.

In the area of flight operations, a non conformity was identified resulting from the lack of evidence that the training on normal and abnormal procedures and on maneuvers for the MD80 and B717 included the importance of the "aviate, navigate, communicate" principle. As a result, Spanair modified the preface to the emergency procedures in its operations manual, Part B, OM-B.

In the area of maintenance, the 2009 audit also noted that the operator had to ensure that those maintenance organizations that did work for it had to produce documentation that listed basic details of the maintenance performed as well as reference to the approved data used.

Some of these discrepancies resulted in modifications to the Maintenance Organization Exposition (MOE).

Specifically, in revision 2.5 to the MOE, dated 16 March 2009, the following paragraph was added to Section 2.13, "Use and Completion of Maintenance Documentation", which discusses the proper way to fill out the ATLB, among other documents:

> *"In addition, a clear reference will be included to the approved data used, unless a work package (BOW, JSS, etc.), work order (WO), job card, engineering order (EO) or another work sheet is referred to that already includes the appropriate references to the approved data used".*

MOE Section 2.16.1.3, "RSA[59]-certified maintenance activities", of this same revision to the manual, was also modified along the same lines as above to correct a discrepancy detected in this IOSA audit. The modification read as follows:

> *"The RSA will include a clear reference to the approved data used, unless a work package (BOW, JSS, etc.), work order (WO), job card, engineering order (EO) or another work sheet is referred to that already includes the appropriate references to the approved data used".*

Despite the above, the set of MOE forms associated with Revision 3 to this manual, which went into effect on 19 June 2009, included two examples of release to service authorizations by way of ATLB stubs that were filled out without making any reference to the approved maintenance data used to support the associated maintenance task.

The investigation also gathered information that indicates that the company published internal instructions (Maintenance Information Notes (internal distribution only) and Technical Logbook Procedures) with examples explaining how to make maintenance entries in TLBs as a corrective action.

[59] RSA: Release to Service Authorization.

1.17.2.2.2. *SAS audit*

The audit was conducted between 20 and 23 November 2007 by a three-person audit team. The audit identified 34 non conformities and four observations. Two in-flight inspections were conducted.

The audit team's general impression was that the structure of Spanair's safety organization was good, though it did identify some areas for improvement: These included:

- The resources assigned to quality assurance and to the flight safety department were insufficient.
- The company's policy regarding the language to be used in the manuals was unclear.
- The quality assurance organization, with its two quality managers, as described in the manuals, was different from that described in the OM-A.

According to the audit team, the source of the non-conformities probably lay in the documentation, the resources and in the quality assurance activities.

Some non-conformities involved the fact that the company's reporting system did not include maintenance.

1.17.2.2.3. *Boeing Operational visit*

From 5 to 14 November 2007, Boeing conducted an evaluation of Spanair's operations.

The expert observed flight simulator sessions and normal flight operations on both MD and B717 airplanes, as a result of which recommendations were issued.

As regards the simulator, the expert noted the adherence to normal and abnormal procedures. The discipline shown during checklist execution in particular was above average. The performance of the instructors and the preparation for the sessions were described as meticulous and detailed.

The line observations noted good use of CRM and a good knowledge of basic airplane systems and procedures.

During the flight preparation phase it was noted that entries into the CDU[60] (Control Display Unit) were not cross-checked prior to execution. The inspector recommended that a dual verification be performed.

[60] According to Boeing procedures, the data must be input to the CDU by one crew member and verified by the other before it is executed.

The takeoff and approach briefings sounded memorized and were too long. It was recommended that they be revised to focus on the items of interest.

Due to some of the call outs being omitted, it was recommended that special attention be given to this aspect during training. One of the pillars of CRM is that each crew member must be capable of supplementing or backing up the other crew member, and that the proper observance standard call outs is a vital component of a well managed cockpit.

In terms of flight safety management, this same report indicated that Spanair needed to develop a FOQA program for its MD80 and B717 fleets.

1.17.3. *Oversight of the operator by Spain's civil aviation authority. AESA/DGAC*

1.17.3.1. Operational oversight

Until the entry into force of the EU-OPS in July 2008, the DGAC's, or now the AESA's, supervisory activities of air operators such as Spanair included a series of inspections that took place over the course of the year that the Air Operator Certificate (AOC) was valid. These inspections included supervision of en route cockpit and passenger cabin procedures, dispatching, flight planning and supervision, control of air activity, on-ramp inspections (SANA and SAFA programs[61]), and those inspections carried out for the renewal of the certificate itself. Company aircraft, or their instrumentation and equipment, were also inspected as part of the airworthiness certificate renewal process, as required by JAR-OPS 1, subparts K and L.

The AESA reported that in 2008, prior to the date of the accident, Spanair's operational safety had been subjected to 352 inspections of varying scope. The investigation had access to some of this information and to some of the inspection procedures used.

The AESA provided information to the investigation regarding all of the annual renewal inspections carried out from 2003 to 2008. All, except for the last one, lasted one day. The one carried out in 2008, lasted two days, 2 and 3 June of that year, and involved three inspectors.

The annual inspection to renew the AOC consisted of a full inspection of every area. To aid in the conduct of the annual inspections, a checklist was used (AISV-018, July 2003)

[61] The European Union's SAFA program is based on aircraft inspections conducted in non-EU countries. The inspections adhere to the same procedures in every Member State and in other participating States (up to 42 States). Any irregularities that are identified having an immediate impact on operational security can result in the grounding of the aircraft if proper corrective measures are not taken. The concepts and methods invovled in the SANA program are similar to those of SAFA and are applicable to domestic aircraft of the State conducting the inspection.

from 2003 to 2008 inclusive that featured a list of all the aspects to consider, with the relevant regulation, which was the ammended JAR-OPS 1 from 2001[62], and a column for indicating SAT (satisfactory), UNSAT (unsatisfactory) or N/A (not applicable), depending on whether the requirement was satisfied or not or was not applicable. A note on the form explained that any unsatisfactory grade had to be explained in the remarks section.

Form AISV-018 did not contain information on how to evaluate the aspects involving each of the items. AESA officials commented to CIAIAC investigators that they had trouble ascertaining exactly which checks had been made by the inspectors when filling out the sections on the form.

No item was graded as unsatisfactory on any of the renewal inspections. In 2003, 2005 and 2006 no discrepancies were noted. In 2004 two discrepancies were identified on the need to include the required navigation performance (RNP) in the operations manual and to define the corresponding training programs. In 2007 the following observation was made:

"There are mistakes in the filling out of form JAR FCL 1.240 (skill test and proficiency check); namely, the required exercises in the skill test/proficiency check column are not filled out. This situation occurs with some frequency. The Deputy Director for Operations is urged to correct this situation.

- *There are significant differences in criteria between SFEs and TREs when restricting hours/sectors of supervised line flights".*

Spot checks were done during the 2008 inspection in the areas of training, fleet and flight dispatch, which warranted an extension of the inspection. No notable entries were made.

The AESA wrote a new procedure for the approval of the air operator's certificate in 2007 (P-AOC, "Approval of air operator's certificate (AOC)", Rev. 01 dated 2 January 2007), which set up an operator monitoring program that proposed the inspections and audits to be conducted prior to the renewal of the certificate.

One person was designated as being responsible for a company, although the team that did the inspections was not necessarily limited to that company's designee.

As reported by the AESA, this procedure took into account the fact that starting on 16 July 2008, the new EU OPS regulations would go into effect, meaning that air operator certificates would become indefinite. The procedure specified that following the first

[62] JAR OPS 1 was adopted in Spain in the form of Royal Decree 220/2001 of 2 March, which specified the legal requirements for using civilian airplanes to engage in commercial air transport operations.

year since its approval or since its last renovation pursuant to the previous regulation, the AOC would be valid indefinitely and the continuous monitoring program would be extended by two years so that all areas requiring inspection could be covered in that time period.

A total of eight forms were attached to the approval procedure for conducting the inspections. The forms covered different aspects, which included the Operations Manual, the aircraft and its equipment's compliance with the JAR OPS, dangerous goods, station facilities, ramp operations, passenger cabin operations, the company's base and en route operations. Approving or denying an AOC requires the issuance of a report recommending approval or not. Any deficiencies found, and whether or not they have been closed out within the cure period, must also be listed. As part of the P-AOC procedure, one of is forms, identified as form AOC/F/05 (formerly form AISV-018), Evaluation of the Operations Manual, Rev. 01 of 30 November 2006, was used to review parts A, B, C and D of the Operations Manual. At the end of said form there was a note that provided instructions concerning the form itself, stating:

> *INSTRUCTIONS FOR DGAC FORM AOC/F/05 (AISV-018)*
>
> *The letters for the checklist items mean:*
>
> ***S:*** *If the result of that item's inspection is satisfactory.*
> ***I:*** *If the result of that item's inspection is unsatisfactory.*
> ***NA:*** *If the item is not applicable to the inspection.*
>
> ***The definition of the element to be inspected for each checklist item is in bold, followed by the general criteria or guidelines to be used when conducting the inspection.*** *The column on the left lists the regulatory and documentary references that contain more information on the checklist item.*
>
> *The spaces at the bottom of this checklist page must be filled out. Likewise, the company representative must sign in the places provided.*

In June 2008, Spanair's AOC was renewed indefinitely ahead of the entry into effect of the EU OPS.

The investigation also reviewed the information supplied about the en route supervisions of Spanair. The operations inspectors were pilots with considerable flying experience, whose careers in some cases spanned over 50 years, and who had held several type ratings and positions of responsibility at airlines. There was no requirement to be rated on the type of aircraft being inspected. As noted by AESA officials, the inspections were designed to optimize inspection times, meaning that inspectors normally conducted several inspection flights a day on different aircraft and airlines in an effort to meet that inspector's schedule.

These inspections focused on operations in general. To aid the inspectors in their duties, a list-type form was used that contained a list of the items to be observed. These included the proper use of checklists and CRM, among others.

Over the period from 6 August 2007 to 13 August 2008, the AESA engaged in a total of 75 en route inspections involving Spanair, 19 of which detected discrepancies. In general, the discrepancies were very similar and involved items such as flight hours not being logged in the aircraft logbook or a captain not accepting a LIR (Load Instruction Report).

The 2007 training plan for the AESA's operations inspections personnel included the following topics:

- Training for auditors of quality systems in service companies. Five days.
- Airplane Type Rating Training Organizations (TRTO). Two days.
- EU-OPS 1 and related inspection procedures. Four days.
- JAR FCL 1 and 3 pertaining to licensing of pilots of civil airplane and related medical requirements. Two days.
- Commercial aviation insurance. One day.
- Safety management systems. Three days.

It also included one-day workshops on:

En route monitoring, inspection of flight dispatching, analysis of Operating Circular 16B[63] and applicability, SANA/SAFA inspection and certification of examiners/instructors.

According to data provided during the investigation, flight operations inspectors had been given courses on quality systems.

The AESA's training plan for 2011 includes courses on operational safety management systems.

1.17.3.2. Supervision of maintenance

The discrepancies identified during the inspections of Spanair to renew its airworthiness certificate and conducted by the DGAC (now the AESA) in 2007 and 2008, until the date of the accident, were reviewed for this investigation. The number of discrepancies was 139, all of them closed out. There were a total of 34 inspections of the Airbus A320/321 fleet, 49 inspections of the MD80 fleet and 2 of the B717 fleet. This revealed incomplete forms and a lack of references in some maintenance records.

[63] DGAC Circular 16B on flight time limitations, maximum duty time and minimum rest periods for crews constituted the applicable regulation on the topic in Spain before the entry into force of Subpart Q of Commission Regulation 8/2008 of 11 December 2007.

There are other, similar examples, all of which were solved by incorporating the completed entries in the ATLB, including the references to approved maintenance data, as well as by updating the aircraft damage map.

The information provided by the AESA in relation to the Spanair CAMO and Part 145 audits was also reviewed. During the 2009 inspection, as part of the continuous monitoring program, irregularities continued to appear involving the recording of maintenance data in the ATLB entries.

1.17.3.3. Financial oversight

Regulation (ECC) no. 2407/92, in effect on the date of the accident, established the analysis and evaluation of the financial affairs of airlines[64].

Spanair's finances were placed under DGAC supervision starting in March 2007[65]. In that year its results improvement and cost-cutting project was analyzed. In the first half of the year, the company reported a positive result after a years-long streak of losses. In early 2008, the DGAC started to assess the process to sell Spanair, and based on the financial data reported for the first quarter of the year, the DGAC elevated the company's alert level to that of "sustained negative situation"[66] on 1 July 2008. The frequency of SANA inspections was increased. In mid-July, Spanair presented its viability plan.

1.17.4. *Standardization visits by the EASA to Spain's civil aviation authority*

The EASA made standardization visits to the DGAC in 2007 and to the AESA in 2009. The 2007 visit highlighted the need to improve the training of operations inspection personnel. In the area of airworthiness maintenance, the EASA noted that there was no guarantee that the discrepancies detected during inspections of maintenance centers were being closed out.

[64] This subject is currently regulated in the European Union by Regulation no. 1008/2008, which superseded Regulations (ECC) nos. 2407/92, 2408/92 and 2409/92.

[65] In 2007, the DGAC created the so-called Air Operators Safety Committee, among other reasons, as a result of the lessons learned from the crisis that arose following the suspension of operations at the airline Air Madrid. The committee analyzed information concerning the operational safety and the financial oversight of companies. As a result of this analysis, measures were proposed to mitigate risks. These measures could range from increasing the number of inspections to initiating proceedings to suspend or revoke the Air Operator Certificate (AOC).

[66] At the time of the Spanair accident, the DGAC had defined three financial levels of conformity to describe the financial status of airlines: Situation Critical, Sustained Negative Situation and Situation Negative and/or Normal. In the first two cases, the recommended course of action was for exhaustive monitoring and supervision. In January 2009, the classification was changed to a 0-5 scale that combines both objective aspects of the analysis of a company's financial situation, and other significant, secondary aspects derived from the foregoing, such as announcing and implementing layoffs. This case in particular would be classified at the maximum level - 5 - corresponding to the maximum alert level.

1.17.5. *ICAO audit of operational safety monitoring*

As part of the Universal Safety Oversight Audit Program, the ICAO carried out an audit of Spain's civil aviation system from 6 to 16 July 2010.

The audit stated that the AESA had initiated activities in preparation for the implementation of safety management systems by air operator certificate (AOC) holders and by approved maintenance organizations, and had given a basic course on SMS to its operations inspectors. It also stated that the AESA was developing a system for monitoring internal audits and for tracking and closing out the deficiencies identified in continuous airworthiness maintenance organizations and in maintenance organizations, though said system was not yet available.

1.18. Additional information

1.18.1. *Checklists*

1.18.1.1. Guidelines for the design and application of checklists

In the 1980s, two very similar accidents occurred in the United States. On 16 August 1987, a Northwest Airlines DC-9-82 crashed in Detroit when its crew attempted to take off without extending the flaps or slats. The investigation revealed that the taxi checklist had not been performed. Approximately one year later, on 31 August 1988, a Delta Airlines Boeing 727-232 took off without flaps or slats from Dallas following the improper performance of the taxi checklist.

A study conducted by the NTSB[67] highlights the need to pay more attention to the influence human factors have on the design and use of checklists.

In the wake of these two events and of the NTSB study, research was conducted into the use and design of normal checklists. These studies presented the conclusions drawn for improving the design of checklists. Some of the guidelines that emerged from this research[68], and which are applicable to this case, include:

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[67] National Transportation Safety Board, Safety Study; A Review of Flight crew-involved Major Accidents of U.S. Air Carriers, 1978 through 1990. Report No. NTSB/SS-94/01

[68] The authors and research are cited below:
Degani, A., & Weiner, E. L. (1993). Cockpit Checklists: Concepts, Design, and Use. Human Factors 35 (2), pp. 28-43. Research on checklist effectiveness stemming, in part, from an NTSB recommendation resulting from the Detroit Flight 255 accident.
Turner, J. W., Huntley, M. S. Jr. Report N°. DOT/FAA/AM-91/7. April 1991. The Use and design of flight crew checklists and manuals. A special report for the U.S. Federal Aviation Administration.
Human Performance considerations in the use and design of aircraft checklists. January 1995. U.S Department of Transportation. Federal Aviation Administration. Assistant Administrator for System Safety Office of Safety Services. Safety Analysis Division.

"...

- *Checklists should contain as few items as possible.*
- *Include in the replies to the checklist items the values of the parameter selected, instead of replying simply using expressions such as "checked" or "set".*
- *The most critical items on a checklist should be placed at the beginning, thus increasing the possibilities of having those items completed in case of an interruption. It even recommends that those items be included again at the end of the checklist, thus requiring their completion twice.*
- *Critical items such as flaps/slats or trim, which might have to be re-set based on new information, such as a last minute change in runway or wind speed, should be duplicated in those checklists that are used on the ground and confirmed by both pilots.*
- *A last item should be included on the checklists to orally confirm their completion, thus reassuring the crew that the checklist has in fact been completed and that they can proceed to a new task.*

..."

The CAA, for its part, also developed a guide[69] for the design, presentation and use of abnormal and emergency checklists. This guide includes a process for modifying checklists that proposes the use of a tool provided within the document itself so as to assess whether the modification adheres to human factors principles. It also recommends that the procedure be verified to be in accordance with the AFM and that it be verified on a simulator.

1.18.1.2. European Union regulation concerning the design and approval of checklists

Paragraph OPS 1.210 of the regulation that governs commercial civil aviation operations[70] in the European Union states:

"a) *An operator shall establish procedures and instructions, for each airplane type, containing ground staff and crew members' duties for all types of operation on the ground and in flight.*

b) *An operator shall establish a checklist system to be used by crew members for all phases of operation of the airplane under normal, abnormal and emergency conditions as applicable, to ensure that the operating procedures in the Operations Manual are followed.*

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[69] CAP 676. Guidance on the Design, Presentation and Use of Emergency and Abnormal Checklists. CAA, UK (January 2006).

[70] As of this writing, the regulation for operations involving commercial air transport in Spain is defined in COMMISSION REGULATION (EC) No. 859/2008 of 20 August 2008. On the date of the accident, Regulation (EC) no. 8/2008 was applicable. The contents of the paragraphs referenced in this point are the same in both regulations.

c) *An operator shall not require a crew member to perform any activities during critical phases of the flight other than those required for the safe operation of the airplane."*

Appendix 1 to paragraph OPS 1.1045 on the content of Part B of the operations manual, operational aspects related to the airplane type, specifies the required inclusion of:

"*2.1 The normal procedures and duties assigned to the crew, the appropriate checklists, the system for use of the checklists and a statement covering the necessary coordination procedures between flight and cabin crew*".

As for the requirements on the contents of operations manuals, EU-OPS 1.1040 states that:

"*b) An operator shall ensure that the contents of the Operations Manual, including all amendments or revisions, do not contravene the conditions contained in the Air Operator Certificate (AOC) or any applicable regulations and are acceptable to, or, where applicable, approved by, the Authority".*

The European Joint Aviation Authorities (JAA) have published guidelines[71] providing instructions to national authorities in relation to the specific parts of the operations manual that require approval from the Authority. The checklists for each aircraft are not part of the material requiring approval by the Authority. Appendix 7 to these guidelines, page 7-4, lists those parts of the Operations Manual that must be accepted by the Authority. Item 13 states:

«*Operations Manual and other Documents*

JAR-OPS 1.130(a)(3) -	*Authority may accept that the Ops. Manual contains necessary Flight Manual information*
JAR-OPS 1.135(b) -	*Operational documents, if not on printed paper, to be to an acceptable standard of accessibility etc.*
JAR-OPS 1.1040(b) -	*Content of the Operations Manual must be acceptable*
JAR-OPS 1.1045(c) -	*Detailed structure of Operations Manual to be acceptable*
App.1 to JAR-OPS 1.1045 -	*Acceptable Performance data to be included in the Part 'B' 4.1.2 Operations Manual*
App.1 to JAR-OPS 1.1065 -	*Operational documents to be stored in an acceptable form*»

[71] Administrative and Guidance Material. Section Four: Operations Part Two: Procedures.

The AESA confirmed that an operator's checklists as contained in their Operations Manual, Part B, were not approved, only accepted[72]. The AESA emphasized that "*checklists are not required to be approved; checklists are not required to be accepted, only as part of the process of accepting the detailed contents or the structure of the manual*". They reported that the aspects assessed by the authority when accepting checklists are that they:

- Are relevant to the intended operation.
- Do not provide superfluous information.
- Specify how the operator complies with requirements.
- Contain relevant data and limitations applicable to the routes, aircraft or equipment.

As for whether the authority requires the operator to have any procedure for modifying its checklists, the AESA referred to the Spanair Operations Manual, Part A, Chapter 0, Administration and Control of the Operations Manual, 0.2 Amendments and Revisions, 0.2.A Amendments and Revisions. General:

> *"(g) Spanair shall provide the Authority with its proposed amendments and revisions prior to their entry into force. When an amendment affects any part of the Operations Manual that must be approved as per the OPS, this approval shall be obtained prior to the entry into force of the amendment."*

Given that the checklists do not require approval, the Authority would only have to be provided with the proposed amendments and revisions prior to their entry into force.

The EASA reported that even though checklists do not require specific approval, the national authority must review them for acceptance in the same way that it reviews other components of the Operations Manual that do require it, such as the MEL, for example.

1.18.1.3. United States regulations regarding checklist approval

The regulation governing the approval of checklists in the United Stated is FAR 121, specifically FAR 121.315, which requires each airline to publish a checklist approved by the FAA such that the crew is not forced to rely on their memory to perform the procedures in the operations manual.

[72] The involvement of civil aviation authorities in the procedures and checklists of air operators has varying effects depending on the legal terms (approval, acceptance, supervision, etc.) normally used to describe the responsibilities of said authorities. For example, EU OPS regulations define the terms accepted and approved as follows:

"accepted" or "acceptable" means not objected to by the Authority regarding its suitability for the purpose intended;
"approved" (by the Authority) means certified by the Authority as suitable for the purpose intended.

In the United States, the FAA has developed guidelines[73] for its operations inspectors (POI) listing the aforementioned principles on the design of checklists. These guidelines are also a practical reference for operators and manufacturers, who can find in them the very criteria that will be used by the inspector during his assessment. They are also available to the public at large.

1.18.1.4. Methods for performing checklists

There are different ways to perform checklists. The method most widely used by operators for doing normal checklists is "action and verification", also known as "do and verify". This method, as its name indicates, is intended to aid the crew in verifying that the actions have been performed in accordance with a memorized flow of actions; that is, first a number of actions or tasks is completed from memory as assigned to each member, then one of the pilots reads an item from the checklist out loud and the other verifies completion and acknowledges it verbally. At the same time, the pilot who read the item ensures that the reply given by the other pilot corresponds to the real status of that item.

Other checklist types are the "challenge-do-verify", which are normally used for emergency procedures. In these checklists each item is read out loud before it is carried out and is then completed by the pilot to whom it is assigned.

Lastly, there are silent checklists in which the pilot monitoring selects and checks the items silently without involving the pilot flying. These checklists are used when the workload is high, such as after takeoff.

1.18.2. *Regulations and instructions on the sterile cockpit and the use of cellular telephones in the cockpit*

1.18.2.1. Regulations and information issued by the FAA

The sterile cockpit concept was included in FAA regulations in 1981[74]. According to FAR 121 and FAR 135, on commercial air transport operations, those activities that can distract crews from their duties during critical phases of flight are not permitted. These include starting conversations or communications on topics that are irrelevant to operational safety. These rules define the critical phases of flight as all ground opeations, including taxi, takeoff and landing and operations in the air below 10000 feet, except for the cruise phase.

[73] FAA Order 8900.1 Flight Standard Information Management System (FSIMS). Volume 3. General Technical Administration. Chapter 32. Manual, Procedures, and checklist for Part 91K, 121, 125, and 135.

[74] FAR 121.542 y FAR 135.100.

FAA Advisory Circular AC 91-21 clarifies that the use of cellular phones is not permitted on the flight deck once the taxi phase begins, further specifying that phones must be turned off during the flight preparations.

During a checkline inspection of an airline in the United States, an event took place that was categorized as a potential safety hazard.[75] During the takeoff phase, just before reaching V1, a loud "warbling" sound was detected by both crewmembers. It was later determined that the sound came from the first officer's cellular phone, which had been left in the ON position. As a result, the ring tone distracted the crewmembers, which could have led the crew to initiate an unnecessary rejected takeoff.

The crew subsequently reported that there was no mention in the Operations Manual prohibiting the crew from leaving their cellular phones on. A review of the checklists revealed that there was in fact no item requiring crews to turn their cellular phones off. This occurrence highlighted how the sterile cockpit principles included in American regulations (FAR 135.100 and FAR 121.542) would not be satisfied if events of this nature took place during the critical phases of flight.

All of the above resulted in the FAA issuing a safety alert to all operators, SAFO 09003, on 4 February 2009 that recommended operations directors conduct a review of their operations manual to determine whether suitable procedures were in place to remind flight crews of the need to turn off their cellular phones during flight preparations. The recommendation also applied to anyone seated in the cockpit's jumpseat. The SAFO also stressed the need for operators to review the effectiveness of their training programs as regards the sterile cockpit concept.

1.18.2.2. European Union regulations and information

Although the sterile cockpit concept is not explicitly included in the operating rules for commercial air transport, tacit references may be found in paragraph EU-OPS 1.085, Crew Responsibilities, which states:

"f) The commander

9) shall not permit any crew member to perform any activity during takeoff, initial climb, final approach and landing except those duties required for the safe operation of the airplane".

...

11) shall decide whether or not to accept an aeroplane with unserviceabilities allowed by the CDL or MEL".

[75] This event is referenced in the "Background" section of SAFO 09003.

As already mentioned (see Section 1.18.1.2 of this report), EU-OPS 1.210 states that:

"c) *An operator shall not require a crew member to perform any activities during critical phases of the flight other than those required for the safe operation of the airplane".*

1.18.2.3. Operator instructions

The sterile cockpit concept is defined in the Spanair Operations Manual, Part A, Section 8.3.15.B6, Sterile Cockpit, Revision 9 of 14 May 2008, in the following terms:

"The sterile cockpit is defined as including the phases between:

- *The "Fasten Seat Belts" sign being turned on before engine start-up until said sign is turned off during the climb.*
- *The "Fasten Seat Belts" sign is turned on during the descent until said sign is turned off once the airplane has parked and the engines are shut down.*

During this phase, no calls are to be placed to the cockpit, except for emergencies, so as not to interfere with the pilots' duties."

In Section 8.4.3.A.1 of the same manual, *Establishment of procedures*, it states that:

"• *Spanair shall not require any crewmember to perform any activity during critical phases of flight that are not required for the safe operation of the airplane".*
- *The Captain shall not allow any crewmember to perform any activity during critical phases of flight except those functions that are required for the safe operation of the airplane.*

Critical phases of flight in this context are the takeoff run, takeoff and initial climb, final approach and landing, including the landing run, and any other phase of flight at the Captain's discretion".

1.18.3. *FAA Advisory Circular for the certification of takeoff warning systems (TOWS)*

When the MD-80 series of airplanes was certified[76], there was no requirement to install a TOWS. This obligation was imposed in March 1978 with the inclusion of paragraph

[76] The MD-82 was certified under FAR 25, up to amendment 25-40, which went into effect on 2 May 1977.

25.703 in the FAR 25 certification regulation[77]. Although the regulation was not retroactive, the large airplane manufacturers included TOWS in the Boeing 707, 727, 737, 747, McDonnell Douglas DC-8, DC-9, DC-10 and MD-80, Lockheed L1011 and Airbus A300 and A310, which had been certified prior to the appearance of the FAR 25.703 requirement.

FAR paragraph 25.703 requires that the TOWS provide the crew with an aural warning during the initial phase of the takeoff run when the airplane is configured such that a safe takeoff cannot be guaranteed. The criterion used by the FAA to certify these systems after the adoption of FAR 25.703 was to consider them as a back-up for crews, meaning they were classified as non-essential systems when it came to defining their criticality. This category is reserved for those systems whose faults are not considered to result in an unsafe condition in the aircraft, nor reduce its performance nor the crew's ability to handle adverse operating conditions.

In the European Union, the European Aviation Safety Agency adopted specification CS-25 as the certification code for large airplanes in October 2003. This regulation came from the JAR-25 standard, developed within the framework of the JAA[78]. The requirement to install a TOWS is in paragraph CS25.703, in effect since January 1979[79]. In general, the requirements and criteria of the FAA and the European Aviation Safety Agency with regard to the TOWS are the same.

In response to the initial evidence found during the investigation of the accident of the McDonnell Douglas MD-82 in Detroit, the FAA's Aircraft Certification Division created a taskforce on 16 August 1987 for the purpose of conducting a general review of takeoff warning systems, placing special emphasis on the design already in place on MD-80 type aircraft.

This review was intended to consider the possibility of creating new regulatory requirements, as well as to review the operational difficulties encountered during incidents and accidents that had occurred to date involving takeoff warning systems.

The FAA made special mention of the fact that a fault in the TOWS system installed in the majority of airplanes at the time would be unnoticeable to the crew. Also noted was the absence of a requirement or recommendation to conduct a pre-flight check of the system. Save for some exceptions involving individual airplanes, however, the MEL did not allow then, nor does it allow now, for an airplane to be dispatched with the TOWS

[77] This paragraph was added to Part 25 by way of amendment 25-42, with an effective date of 1 March 1978.
[78] The Joint Aviation Authorities (JAA) comprise the civil aviation authorities of most European States and of some outside the EU. Its mission consisted of standardizing civil aviation regulations in Europe and of reconciling them with those of other States. Its responsibilities in this area ceased on 30 June 2009, at which time they were transferred to the European Aviation Safety Agency.
[79] JAR-25, Amendment 5.

inoperative. The report[80] issued by the FAA working group also stated that "...*all of the systems reviewed would meet the current requirements in terms of reliability, provided the manufacturers' recommendations for the system checks were followed in service*".

The transition from analog designs to solid-state circuits resulted in improved self-diagnostic features in systems. Microprocessors and electronic instrumentation systems yielded TOWS systems with redundant circuitry, full monitoring and self-checks and on-screen system message displays[81].

Aircraft manufacturers pointed out that those improvements were not incorporated due to manufacturing requirements, but by operator demands to extend the maintenance intervals and to improve the chances of dispatching airplanes from remote stations that were far from their main maintenance base. The addition of these improvements, however, was regarded as contributing to improved safety margins.

Despite this, latent faults could still appear even in TOWS employing solid-state circuits. The majority of systems included in this study did not require a reliability study as part of the original type certification process.

The FAA concluded with a series of TOWS recommendations that would aid in preventing improper takeoff configurations from causing future accidents:

- The performance of a TOWS check before each flight. Even so, it was acknowledged that a full check of the TOWS before takeoff is practically impossible and its performance would provide no protection against a subsequent fault or deactivation of the system.
- The installation of a warning light to indicate that the TOWS is not energized.
- Improving the reliability of the TOWS by requiring it to be designed to comply with FAR 25.1309 requirements for "essential" equipment, as defined in AC 25-1309. This could be achieved through redundancy, increased monitoring, more frequent maintenance inspections or a combination of all these.
- Eliminating nuisance warnings involving the TOWS during reduced-engine taxi. Two alternatives were offered for solving this problem in keeping with the level of development of designs at the time: the issuance of an FAA airworthiness directive requiring that the TOWS be modified to eliminate these warnings during reduced-engine taxi, or an FAA prohibition on taxi operations that did not use all the engines.

The last of these recommendations drove the FAA to issue Airworthiness Directive AD 90-04-05 on 3 August 1990, applicable to the DC-9 and MD-80, and which required a

[80] The work of the FAA team was detailed in the report titled "Review of takeoff configuration warning systems on large jet transports", NW Mountain Region Aircraft Certification Division, FAA". The quote shown is taken from page 13 of the report.

[81] These improvements were not envisaged in the TOWS design for DC-9-80 aircraft.

modification to the TOWS by way of McDonnell Douglas Service Bulletin SB 31-34 dated 20 December 1989, intended to eliminate nuisance warnings during single-engine taxi operation.

Following the operational safety recommendation[82] issued by the NTSB in its report on the Detroit accident, the FAA published AC 25.703.1 in 1993. The EASA counterpart is AMC 25.703, which establishes the criteria currently accepted by the European Authority for certifying the TOWS design in transport airplanes. According to these criteria, previously designed TOWS could not be regarded as providing an adequate degree of safety when the consequences of a system fault in combination with an improper takeoff configuration could lead to major or catastrophic fault conditions[83]. Therefore, in keeping with these guidelines, the safety level of these systems should be increased so as to classify them as essential, in accordance with FAA AC 25.1309-1A and its EASA counterpart, AMC 25.1309, such that both the FAA's and the EASA's current interpretation is that of considering the inoperability of the TOWS as having severe effects on safety, as recommended in the aforementioned 1988 FAA study.

1.18.4. *Check of the TOWS, flaps selection and energizing sensor heating (including the temperature probe) in various European companies*

After the accident, the procedures used by other five European airlines that operate MD airplanes were studied to check if the TOWS was verified operable on each flight, when the flaps were selected and when the heaters for the probes in the airplane's air data systems were energized.

The investigation found that:

- Three of the five companies studied checked the TOWS before each flight.
- Two companies selected flaps while taxiing, and the other three did it after starting the engines.
- Every company energized sensor heating after start-up.

1.18.5. *Previous incidents involving faults during pre-flight checks of TOWS*

Boeing reported that it was aware of 13 cases that had been communicated by operators from 2000 to 2008 in which the TOWS had failed during the pre-flight checks

[82] NTSB recommendation A-88-66 asked the FAA to develop and disseminate guidelines for the design of CAWS to include a determination of the warning to be provided, the criticality of the warning provided, and the degree of system self-monitoring.

[83] AC 25.1309 defines system criticality based on the severity of the effects a system failure has on safety. Fault conditions are classified as minor, major and catastrophic, depending on the severity of their effects. AMC 25.1309 adds the classifications "no effect on safety", with the least severity, and "hazardous" between major and catastrophic severity.

and which had been solved by replacing the R2-5 relay, and another six cases of combined high RAT temperature readings and failed TOWS tests, of which four were also solved by replacing the R2-5 relay.

1.18.6. *Previous incidents involving high RAT probe temperature indications on the ground*

1.18.6.1. Cases compiled by Boeing

Boeing supplied a list of the notifications received from operators involving cases of elevated RAT probe temperature readings on the ground or which involved the R2-5 relay for the period from 2000 to the end of 2008.

There were a total of 103 faults reported by operators during which an excessively high or different from outside air temperature was detected by the RAT. These cases were handled as follows:

- 71 were solved by replacing the R2-5 relay.
- 18 by replacing the RAT probe.
- 1 by replacing both R2-5 and the RAT probe.
- 2 were deferred in accordance with the MEL.
- 1 by replacing TRI *(Thrust Rating Indicator)*

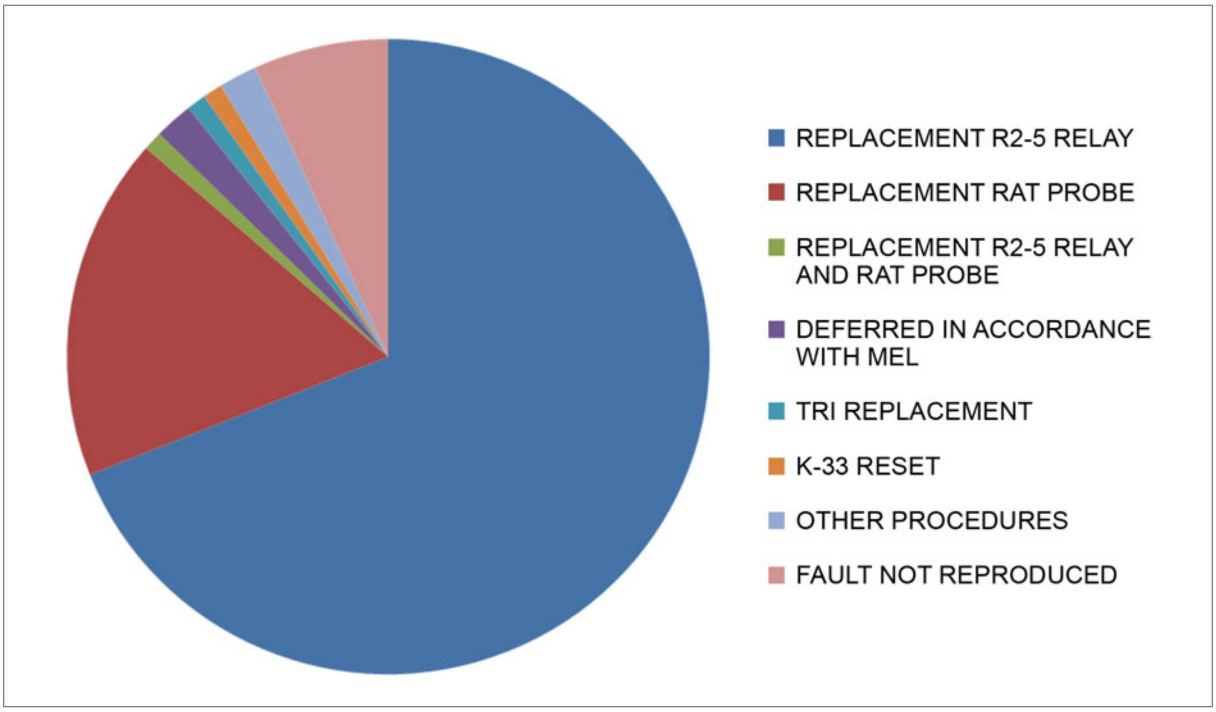

Figure 29. Previous high RAT probe temperatures on the ground. Cases compiled by Boeing (from 2000-2008)

- 1 by resetting the LH Ground Control relay (K-33).
- 2 by way of other maintenance procedures, and
- In the remaining seven cases the fault could not be reproduced.

Of the 71 cases in which the R2-5 relay was replaced, on at least eight of those occasions the relay was found "stuck" in a set position.

Of the 18 cases where the RAT probe was replaced, in at least 13 cases the anomaly did not involve an excessive temperature indication, but rather a difference between indicated and outside temperatures.

Of those 103 cases, in at least six it was reported that the high temperature indication decreased or returned to normal values during the taxi or takeoff phases.

1.18.6.2. Cases reported by Spanair

There are three cases in Spanair's maintenance records of high RAT probe temperatures on the ground involving airplanes in its MD fleet different from the accident airplane. Two occurred prior to the accident and one at a later date.

1.18.6.2.1. *Event of September 2006*

On 1 September 2006 at Barcelona airport, an airplane returned to the stand on three occasions to fix the malfunction. As logged by the crew in the ATLB, in the first instance detected while taxiing, the RAT probe temperature rose to 90 °C. They returned to obtain technical assistance. Maintenance personnel reset the TRI panel and carried out the functional tests for the system, making a note to crews to report on the status of the malfunction during the next few flights. When the airplane started taxiing again, the same condition appeared, prompting the crew to return once more so that maintenance could attempt to fix the problem. This time, maintenance technicians replaced the R2-5 relay, which seemed to solve the problem.

During the next scheduled flight, however, the same fault occurred during taxiing. Maintenance discovered that the reason for the fault was a short between two wires in different systems (taxi lights and RAT heat probe) but in the same wire bundle located in the nose wheel well. The affected wires were supplied with 115 V AC and the short between them when the taxi lights were on was supplying the RAT probe heater.

1.18.6.2.2. *Event of May 2008*

The second instance occurred on an MD-83 on 25 May 2008 in Palma de Mallorca. The crew logged in the ATLB that after engine start-up, the RAT probe temperature indication increased to the point where the warning flag appeared in the indicator. In this case, maintenance reset the K-33 breaker on the left ground sensing system. Following this, several checks were performed during which the RAT probe indicator read correctly, so the airplane was returned to service.

The following day after landing in Barcelona, the pilots noted that the probe heater was on while the airplane was on the ground. On this occasion, maintenance opened the Z-29 breaker, cutting off the flow of electricity to the probe heater and logging the maintenance as deferred as per items 30.8 and 34.9 in the MEL. Before the airplane's next flight, the Spanair Operations Office's Flight Dispatch and Operation Control Department pulled the airplane from the schedule to avoid delays, which gave maintenance the additional time needed to fix the malfunction. The R2-5 relay was replaced, which resulted in the probe and its indicating system working correctly, after which the airplane was returned to service.

1.18.6.2.3. *Event of July 2009*

On 2 July 2009, an MD-87 preparing to depart from Palma de Mallorca to Barcelona received a high RAT remperature indication while taxiing. Specifically, the temperature increased to the limit of the reading (two digits), 99 °C. Upon noticing this situation, and remembering the similarity with the accident airplane, the crew decided to perform the new TOWS functional test, which did not pass. After this, with a still excessive cockpit temperature indication, the crew verified that the aircraft was in a correct takeoff configuration decided and decided to depart for Barcelona after logging the fault in the airplane's ATLB.

Once in Barcelona, the airplane, which was not scheduled to make any more flights that day, was turned over to company maintenance personnel, who were instructed to troubleshoot the system with the aid of a Maintenance Information Notice (MIN 92), which directed troubleshooting the TOWS in accordance with the aircraft's Maintenance Manual and, in the event that no malfunction was found, to replace the R2-5 relay. TOWS tests were conducted and, failing to detect any abnormalities, the R2-5 relay was replaced in accordance with the instructions. Following this maintenance action, there were no further high RAT temperature indications on that aircraft.

1.18.6.3. Cases reported by other operators

Information was obtained concerning possible incidents involving high RAT probe temperatures from the maintenance records of four operators that fly MD series airplanes. In total, the sample studied consists of a fleet of over 100 airplanes and spans a period of 15 years.

The information gathered shows that two of the operators involved had not recorded faults with that component. A third operator detected four cases of high temperature indications provided by the RAT probe during the period from August 2006 to August 2008. After different maintenance activities carried out in an effort to solve the problem, in three of the cases the fault was eventually solved by replacing the R2-5 relay. In one case in particular the R2-5 relay was stuck. In the one case where the R2-5 relay was not replaced, the fault was solved by replacing the RAT temperature probe.

The maintenance records for the fourth operator revealed a total of 22 cases of high temperature RAT probe readings from October 1994 to November 2008. All of these faults were solved by substituting the R2-5 relay. In those records where the model for this component was specified, it matched that installed in the accident airplane.

1.18.7. *Basic aspects of the MMEL and MEL*

1.18.7.1. General overview of the MMEL and MEL

The MMEL is a document containing a list of those aircraft components that may be temporarily inoperative with the aircraft still maintaining the level of safety intended in the corresponding airworthiness certification specifications.

In those EU states that have adopted the JAR-MMEL/MEL regulations into its legislation (which includes Spain), the MMEL is written by the organization responsible for the design of the aircraft type and approved by the State of design. In the United States, the MMEL is written by a Flight Operations Evaluation Board (FOEB), which comprises the FAA, the aircraft manufacturer and operators, and is ultimately approved by the FAA.

The MEL is a document that contains a list of those aircraft components that may be temporarily inoperative at the start of a flight. It is written by the operator for each specific aircraft and approved by the aviation authority. Under no circumstances can it be less restrictive than the MMEL for each aircraft type.The MEL is part of the operator's Operations Manual, though it is used jointly by the flight crew and maintenance personnel.

The MEL is a document that remains applicable until the start of the flight[84]. Some of the items contained in the MMEL/MEL may require specific maintenance actions to be performed first, or certain aircraft operating procedures to be followed or certain limitations to be observed as a prerequisite for dispatching the aircraft with a particular component inoperative.

[84] Royal Decree 1762/2007 defines the start of the flight as "The moment after which an aircraft starts to move under its own power for the purpose of preparing for takeoff".

Every component or system related to airworthiness that is not included in the MMEL/MEL must be operative at the start of the flight[85].

The MEL establishes time limits within which an aircraft can be operated with a certain component inoperative, though said component should be returned to service at the earliest opportunity so as to maintain an acceptable level of safety and reliability.

Regardless, within European Union member States, it is left to the captain's discretion to accept or reject the operation of an aircraft with inoperative components even when doing so is allowed by the MEL[86]. There are no regulations in the European Union that require a diagnosis of the origin of faults or faulty operation before resorting to the MEL to allow an aircraft to be dispatched. On this issue, the EASA is of the opinion that no benefit to operational safety is gained by attempting to find the source of the fault if the MEL is used correctly.

1.18.7.2. Definition of inoperative element, component or system

Commission Regulation (EC) No. 2042/2003 of 20 November 2003[87] establishes that, among other cases, an element shall be considered to be unserviceable when there is evidence of an operational defect or fault.

In Spain, Annex JAR-MMEL/MEL to Royal Decree 1762/2007[88] defines the term inoperative as meaning "*that the equipment does not accomplish its intended purpose or is not functioning within its design operating limits or tolerances. Some equipment has been designed to be fault tolerant and is monitored by computers which transmit fault messages to a centralized computer for the purpose of maintenance. The presence of this category of message does not necessarily mean that the equipment is inoperative*".

ICAO Appendix 6 refers to elements that are inactive or cease functioning without providing a precise definition[89].

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[85] These components are commonly referred to as "NO GO components".

[86] Item f) 11) of Section 1.085 "Crew responsibilities" of ANNEX III to Commission Regulation (EC) No. 859/2008 of 20 August 2008 (published in the OJEU on 20 September 2008), which modifies Council Regulation (EEC) No. 3922/91 regarding the joint technical requirements and administrative procedures applicable to commercial airplane transport. On 20 August 2008, Regulation (EC) No. 8/2008 of 11 December 2007 (published in the OJEU on 12 January 2008), which is identical to the above in this regard, was in effect.

[87] Item a) 4 of Section M.A. 504 "Control of unserviceable components" of Commission Regulation (EC) No. 2042/2003 of 20 November 2003 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organizations and personnel involved in these tasks.

[88] Royal decree 1762/2007 of 28 December, which specifies the requirements for the master minimum equipment list and the minimum equipment list mandated for civilian aircraft intended for commercial air transport and aerial work.

[89] Specifically, Section 6.1.2 of ICAO Annex 6 states: "The operator shall include in the operations manual a minimum equipment list (MEL), approved by the State of the Operator which will enable the pilot-in-command to determine whether a flight may be commenced or continued from any intermediate stop should any instrument, equipment or systems become inoperative".

ANNEX III to Commission Regulation (EC) No. 859/2008 of 20 August 2008[90] does not contain any specific definition for unserviceable elements, components or systems, referring only to elements "with unserviceabilities".

The differences between the FAA's definition of the MMEL contained in the document "DC-9 Dispatch Deviations Guide" and that found in Spanair's MEL for the DC-9-MD-82 aircraft are slight. Both documents indicate that a piece of equipment or system shall be considered inoperative when it does not accomplish its intended purpose and/or it does not function consistently within its design limits or tolerances. The definition contained in the Spanair MEL in effect in August 2008 also includes the same observation that is contained in Royal Decree 1762/2007 regarding certain equipment that has been designed to be fault tolerant and monitored by computers that could transmit fault messages, which would not necessarily imply that said system in unserviceable.

There are informative texts that contain guidance on aspects related to the MEL that also include definitions of what an inoperative element is. Specifically, the Airbus document "*Getting to Grips with MMEL and MEL*", published in August 2005, includes a definition that is more exhaustive than those contained in the texts mentioned earlier. According to this Airbus document, an element should be considered inoperative:

> *"...when it does not satisfactorily fulfill its intended function, regardless of the reason.*
>
> *Therefore, an item is deemed to be inoperative, when:*
>
> - *It does not work at all, or*
> - *It does not perform one or more of the functions for which it was designed, or*
> - *It does not consistently work within its designed operating limits or tolerances, or*
> - *It is requested to be considered inoperative by the dispatch conditions, or*
> - *It is not available due to a primary failure".*

1.18.7.3. Maintenance (M) and operational (O) procedures

Prior to dispatching an aircraft with any of its elements, components or systems inoperative as per the MEL, it may be necessary to perform a maintenance procedure[91], observe specific limitations or conditions or plan and execute operational procedures[92] as appropriate.

[90] Commission Regulation (EC) No. 859/2008 of 20 August 2008 (published in the OJEU on 20 September 2008) amending Council Regulation (EEC) No 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by airplane.

[91] These maintenance procedures are identified with the letter (M) in column 4, "Remarks and Exceptions", of the MEL/MMEL document.

[92] These operational procedures are identified with the letter (O) in column 4, "Remarks and Exceptions", of the MEL/MMEL document.

Point 9 in Attachment G to ICAO Annex 6 specifies that "*For a particular system or item of equipment to be accepted as inoperative, it may be necessary to establish a maintenance procedure, for completion prior to flight, to deactivate or isolate the system or equipment*".

In keeping with the JAR MMEL/MEL.035 requirement of the Annex to RD 1762/2003, the operational (O) and maintenance (M) procedures are necessary in order to satisfy certain elements of the MMEL. These procedures must be prepared and published by the holder of the Type Certificate or by the holder of the Supplemental Type Certificate, as appropriate and referenced in the MMEL. When the MMEL is revised, the procedures must be properly modified.

The purpose of these procedures must be identified during the MMEL approval process. The procedures themselves, however, are not subject to approval by the Authority[93].

1.18.8. *Prior accidents and incidents involving inadequate takeoff configurations*

1.18.8.1. MD-82 Northwest Airlines. Detroit (USA), 1987

On 16 August 1987, a McDonnell Douglas DC-9-82 started its takeoff run on runway 3C the Detroit airport. Following the rotation, the aircraft started to bank and one of the wings impacted a light pole, and then other light poles, before finally hitting the ground. The aircraft was destroyed as a consequence of the impact and ensuing fire. A total of 148 passengers and 8 crew members died. One passenger was seriously injured. In addition, two persons on the ground were killed and four seriously injured.

The NTSB determined the probable cause of the accident to be a failure of the flight crew to use the taxi checklist to ensure the flaps and slats were properly configured for takeoff. A contributing factor was the absence of electrical power to the TOWS, which thus did not warn the crew of the inadequate takeoff configuration. The investigation discovered that the lack of power for the TOWS resulted from a breaker that may have malfunctioned or was intentionally opened by the crew. The reason for that absence of power was not determined.

During the investigation, in September 1987, the Douglas Aircraft Company issued a telex to all DC-9-80 operators, which included SAS, recommending that they modify their checklists to ensure that the TOWS was checked prior to each flight.

The NTSB issued the following recommendation to the FAA:

> *"Issue an Air Carrier Operations Bulletin-Part 121 directing all principal operations inspectors to emphasize in MD-80 initial and recurrent training programs on stall and windshear recovery the airplane's lateral control characteristics, potential loss*

[93] See JAR-MMEL/MEL.035 b).

> *of climb capability, simulator limitations, and flight guidance system limitations when operating near the supplemental stall recognition system activation point (stall angle of atack) (Class U, Priority Action) (A-88-70)".*

In response to this recommendation, the FAA issued circular AC 00-54, Pilot Windshear Guide, which provided clear guidance on recovering the aircraft upon encountering windshear. No additional information was provided regarding stall recovery because that subject was already regarded as being addressed in the Part 121 regulation on training (Appendix E to Part 121) and proficiency checks (Appendix F to Part 121), which require stall training. The recommendation was closed and classified as an acceptable alternative action.

1.18.8.2. B727 Delta Airlines. Dallas-Fort Worth (USA), 1988

On 31 August 1988, Delta Airlines flight 1141 crashed just after taking off from runway 18L at the Dallas-Fort Worth airport, Texas. The aircraft was a Boeing 727-232, with 101 passengers and 7 crew members. The crew stated that the takeoff run was normal, with no luminous or aural warnings issued.

Just after takeoff the aircraft started to bank, as a result of which it hit the antenna for the instrument landing system (ILS) localizer.

The aircraft was destroyed by the impact and the subsequent fire. Of those aboard, 12 passengers and 2 crew members died. Twenty-one passengers and five crew members were seriously injured, with 68 passengers receiving minor injuries.

The NTSB determined the probable cause as:

1. A lack of discipline in the cockpit by the captain and first officer, which resulted in attempting to take off without the flaps and slats properly configured.
2. The failure of the TOWS to alert the crew that the aircraft was improperly configured.

The investigation concluded that the switch that completes the circuit to energize the TOWS was not closed. It was also noted that there was contamination on the internal contacts of said switch. This switch was associated with the operation of the throttle for the number 3 engine.

The NTSB issued the following recommendation to the FAA:

> "*Direct all principal operations inspectors to review the training and operations manuals of their assigned, air carriers and ensure that the verification of flap position during stall recognition and recovery procedures as a part of those procedures. (A-89-122)".*

In reply, the FAA published Air Carrier Operations Bulletin (ACOB) 8-90-5, "Verification of flaps position during stall recognition and recovery", which instructed operations inspectors (POI) to ensure that the operators' manuals included the verification of the flaps lever in their stall recognition and recovery procedure. The recommendation was closed and classified as an acceptable action.

1.18.8.3. B737 Mandala Airlines. Medan (Indonesia), 2005

On 5 September 2005 at 03:15 UTC, a B737-200 operated by Mandala Airlines, registration PK-RIM, crashed during takeoff at Medan Airport, Indonesia.

Of the 117 people onboard, 5 crew members and 95 passengers died, 15 passengers were seriously injured and 2 were unhurt. On the ground 49 people died and 26 were seriously injured. The aircraft was completely destroyed by the impact and ensuing fire.

The investigation revealed that the aircraft was not adequately configured for takeoff. The flaps and slats were not extended.

The Indonesian NTSC determined the following circumstances as the probable cause:

- The aircraft took off in an improper takeoff configuration, with the flaps and slats retracted, which resulted in the aircraft having insufficient lift.
- The inadequate execution of the checklists meant the retracted position of the flaps went unnoticed.
- The TOWS warning horn could not be heard on the channel for the cockpit area microphone on the CVR. It is possible that the TOWS alarm did not sound.

1.18.8.4. MD-83 MAP. Lanzarote (Spain), 2007[94]

On 5 June 2007 at 10:45 local time, an MD-83 aircraft operated by MAP, registration OE-LMM, took off from runway 03 at Lanzarote Airport. Immediately after takeoff, the aircraft started banking violently to both sides. The banking stopped when the aircraft reached a speed in excess of 200 kt. The aircraft then returned to the airport and landed normally.

The CIAIAC's investigation report states that

> "*according to information supplied by Boeing, the stall speed for the aircraft at its takeoff weight and with a 0° flaps and slats retracted configuration was 161 kt.*

[94] Serious incident involving a McDonnell-Douglas MD83, registration OE-LMM, operated by Mapjet, at Lanzarote Airport (Las Palmas, Spain) on 5 June 2007. CIAIAC Report IN-022/2007.

When the aircraft started to bank the speed was 159 kt. The oscillations increased the stall speed up to approximately 202 kt".

The lateral oscillations continued until the speed surpassed 200 kt. Although other factors, such as the center of gravity or spoiler deflection affect the stall speed, these are considered minor in a situation as dynamic as the one that took place. Boeing reported that the response of the aircraft was consistent with the behavior typical of swept-wing passenger turbojets when flying below the stall speed.

The DFDR data included in the report indicate that the aircraft oscillated six (6) times to the right, two (2) of which reached an angle of almost 60°. There were also six (6) banks to the left, whose angles were also on the order of 60° on three (3) occasions. With each banking motion the aircraft lost altitude, the most significant of these leading to a drop in altitude of 140 ft. This situation persisted for the first thirty seconds of the flight, during which the speed did not increase, varying slightly around 190 kt.

The investigation concluded that the crew lost control of the aircraft after rotation as a consequence of the aircraft stalling immediately after takeoff. The stall resulted from the takeoff having been performed in an unapproved configuration with the slats retracted and flaps at 0° as a result of the crew's failure to comply with standard operating procedures, and specifically with the checklists.

There was no TOWS warning during the takeoff run because the K-33 breaker (Left Ground Control Relay), which controls the left ground-air sensing system, was open. Under these circumstances, the information being sent to the TOWS, as well as to the remaining systems on the left ground-air sensing circuit, was that the aircraft was in the air, which is why the TOWS was not activated.

1.18.8.5. Incidents reported to the NASA ASRS system

A check was made of the database for NASA's aviation safety reporting system (ASRS). Fifty-one cases involving TOWS warnings were identified, distributed as follows:

Aircraft models	Number or cases	Takeof attempts with improper configuration
MD-Series	13	4
B737 Series	24	15
B757 Series	5	4
Others	9	4

Of the four takeoff attempts without flaps by MD series airplanes, two resulted from either partially or completely forgetting to perform a checklist.

In every case involving B737 series airplanes, the normal execution of the procedures was interrupted for various reasons.

In one case, also involving a B737, the airplane actually took off without flaps. At an altitude of approximately 100 ft, the stick shaker activated, which made the first officer realize the flaps were retracted, at which point he extended them. The failure of the TOWS to provide the corresponding improper configuration alarm was attributed to a tripped circuit breaker.

Another search was made of NASA's ASRS database to check for events between 1988 and 2009 that had occurred during the takeoff or initial climb phases involving the flight crew and in which the flaps had been a relevant factor. A total of 365 reports were found, of which 88 corresponded to unsafe takeoff warnings stemming from an improper flaps setting.

1.18.9. *Prior events involving modified checklists*

On 21 July 2007, the crew of an A320-232 aircraft, registration VH-VQT, was forced to do a go around at the decision height because they did not have visual references due to fog. The pilot in command did not perform the procedure correctly and the airplane descended to a height of 38 ft AGL before it started to climb.

In the interval that transpired between the decision height and the start of the climb, the crew lost track of the aircraft's flight mode. The operator had changed the standard go-around procedures, as a result of which the crew did not have to confirm the aircraft's flight mode until other items in the procedure had been completed. This led to the airplane not climbing initially and the crew, which was busy with an increased workload, trying to identify unexpected alarms and warnings, failing to check the flight mode of the aircraft.

The operator had not conducted a risk analysis when it changed the procedure.

In the wake of this incident, the operator modified its go-around procedure to mirror the manufacturer's and its Safety Management System (SMS), requiring that a formal risk management assessment be conducted of any proposal to change an aircraft's operating procedure.

1.18.10. *Identification of engine faults in flight*

1.18.10.1. Periodic flight crew training required by European regulations[95]

In paragraph OPS 1.965 of the regulation that governs commercial civil aviation operations in Spain, it states:

[95] See footnote 18.

"b) Operator proficiency check

1) An operator shall ensure that:

i) Each flight crew member undergoes operator proficiency checks to demonstrate his/her competence in carrying out normal, abnormal and emergency procedures; and

..."

Appendix 1 to OPS 1.965 defines the procedures that must be performed in each proficiency check, when applicable. These are:

"1) Operator proficiency checks;

i) Where applicable, operator proficiency checks shall include the following maneuvers:

...

B) Takeoff with engine failure between V1 and V2 or as soon as safety considerations permit;

..."

1.18.10.2. Safety information bulletin issued by the EASA

On 27 April 2009, the EASA published SIB No. 2009-09, which espoused and supported the FAA SAFO No. 09008 of 6 April 2009 concerning the adequate identification and procedures for an in-flight engine failure. The purpose of this SAFO was to remind operators of the importance of properly verifying the indications of a failed engine and of applying the correct procedures.

One of the examples included concerned a crew on approach that, on seeing an "engine ignition" light turn on and without doing any other checks, assumed an engine failure had occurred and continued the approach.

When they attempted to go around on a single engine, the crew lost control of the aircraft and crashed. The investigation revealed that during the training conducted by the crew, the "engine ignition" light had only turned on when there was an engine failure.

Among the actions recommended to avoid erroneous engine failure indications was to include a wide range of engine failure scenarios during initial and periodic training that included faults which could be mistaken for an engine failure.

1.18.11. *Measures adopted after the accident*

1.18.11.1. High-level Conference on Operational Safety (March 2010) and 37th ICAO Assembly

Over the course of the High-Level Conference on Operational Safety held in Montreal from 29 March to 1 April 2010, discussions were held concerning improving the existing practices and procedures related to flight deck and aircraft configuration checklists as integral components of managing operational safety[96].

Along these lines, Spain presented on behalf of the European Union, of the ECAC (European Civil Aviation Conference) countries and of Eurocontrol, working paper HLSC-2010 WP/26, titled: "*The application of safety management principles to the design of flight deck activities*".

According to the conference report[97], the use of standardized operating procedures and of checklists was addressed. In light of increased automation, a review of applicable requirements was deemed necessary that applied the principles of threat and error management (TEM) and of operational safety management.

It was concluded that the ICAO should review existing stipulations and guidelines on flight deck activities in order to evaluate whether additional measures were required. It was also decided that the ICAO should provide the latest information on this topic at the next meeting of the Assembly.

At the 37th Sessions of the ICAO Assembly, held from 28 September to 8 October 2010, a presentation was made of the results of the reviews conducted by the ICAO concerning existing requirements for flight deck activities, checklists and the preparation of standardized operating procedures[98].

These reviews concluded that introducing the concept of critical phases of flight into ICAO stipulations and defining the acceptable activities during these phases would be advisable. The initial review of the proposed amendment is scheduled for 2011.

In terms of checklists and the drafting of standardized operating procedures, a proposal was also made to update those stipulations involving the standardized checklists and operating procedures in Annex 6, Operation of Aircraft, and in the Procedures for Air Navigation Services - Aircraft Operations, Volume I - Flight Procedures, Part III (Doc. 8168, PANS-OPS).

[96] Topic 3.2 on the agenda: Safety initiatives arising from recent accidents.
[97] Doc 9935, HLSC 2010 de OACI.
[98] Working papers A37-WP/73 and A37-WP/74.

In particular, some of aspects being considered are:

The introduction in the PANS-OPS of the concepts "pilot flying" and "pilot monitoring" with respect to the use of checklists, applying industry best practices and human factors considerations. The guidance on the requirements for standard operating procedures (SOPs) for each phase of flight and the use of normal checklists respectively should be expanded to address appropriate activities/checklists for the critical phases of flight. This guidance will be developed taking fully into account safety management principles and in particular hazard identification and analysis. The initial review is scheduled for 2011.

1.18.11.2. Measures taken by the EASA

1.18.11.2.1. *Airworthiness Directive AD 2008-0197*

Based on the initial findings of the investigation provided by the CIAIAC, the European Aviation Safety Agency (EASA) issued Airworthiness Directive AD 2008-0197 on 29 October 2008. The Directive amends the flight manual for DC-9, MD-80, MD-90 and B717 airplanes to include an obligatory check of the TOWS before engine start-up on each flight. It is applicable to all operators of these aircraft in the European Union.

1.18.11.2.2. *Safety Information Bulletin no. 2009-10*

On 14 May 2009, the EASA published SIB no. 2009-10, which recommends that operators rely on ground personnel to check the position of the flaps/slats during operations on the ramp before airplanes taxi for takeoff. It emphasizes the importance of adjusting and selecting the flaps/slats before the aircraft starts to move, which would allow the ground crew to communicate with the flight crew in case an improper configuration was detected from the ground.

Said bulletin also reminds operators that modifying procedures may require approval by the competent authority and additional training for flight crews.

1.18.11.3. Measures taken by the AESA

The AESA has developed guidelines for cockpit checklists. This material includes information on the design and execution of checklists, as well as on the Authority acceptance process.

1.18.11.4. Measures taken by the FAA

1.18.11.4.1. *Safety alert issued on 5 November 2008 (SAFO 08021)*

On 5 November 2008, the FAA issued SAFO 08021, "Importance of Standard Operating Procedures (SOP) as Evidenced by a Take off Configuration Hazard in Boeing DC-9

Series, MD-80 series, MD-90, and B-717 Airplanes” (see Appendix 2). This SAFO made reference to the 1987 McDonnell Douglas telex which recommended that operators check the TOWS before each flight and indicated that the risk of improperly configuring the flaps and slats could be mitigated in two different ways: warning systems and standard operating procedures.

The SAFO recommended that Operations, Maintenance, Safety and Training Directors review their procedures to ensure that the maintenance and operating procedures are effective in ensuring the proper operation of the TOWS. It also urged proper training for maintenance and operations personnel to ensure the approved procedures for the airplane type in question were followed.

The instructions contained in the SAFO are not mandatory.

1.18.11.4.2. *Information for operators regarding checklists issued on 16 March 2010 (InFO 10002)*

On 16 March 2010, the FAA issued an information for operators document that provided a list of references on industry best practices. This document was issued as a result of the Barajas accident of August 2008 and of the findings over the course of the investigation of the need to improve operational safety in air carrier operations.

The goal of this document was to consolidate guidance on industry best practices in operational areas such as checklist design, training, procedures, crew resource management, and error trapping.

To achieve this it provided a webpage available to operators and flight crews containing information on said operational aspects.

Lastly it recommended that directors of safety, directors of operations and training managers familiarize themselves with the documents and references listed on the webpage. In particular, it urged directors of operations and training managers to review their approved programs and operating procedures to determine if any areas of operation needed to be improved based on these best practice documents.

1.18.11.5. Measures taken by the manufacturer

1.18.11.5.1. *Modifications to the FCOM*

After an event that occurred in 2007 in which an MD-80 took off with the flaps and slats retracted, Boeing started to revise its operations manuals (FCOM) for the DC-9, MD-80 and MD-90 models of airplane to include a new item in the Before Takeoff checklist to check the flaps/slats. The changes were incorporated into the FCOMs for the various airplane models in keeping with the timelines in place for normal revisions. Before the accident, the revisions for the DC-9 and MD-90 models were issued. The MD-80 FCOM was issued after the accident, in October 2008. This additional check of the flaps/slats was already included in that checklist in the Spanair Operations Manual (SOM) on the date of the accident.

In March 2009, Boeing published a new version of its MD-80 FCOM that included a definition of the terms "First Flight of the Day" and "Through Flight". According to these definitions, the first flight of the day is the first made by a crew on an aircraft, regardless of whether they have flown together previously that same day. "Through flights" are defined as flights that make up a series of consecutive flights made by the same crew on the same aircraft and to which the following conditions apply:

- There are no changes to the crew during the stopover.
- At least one flight crew member remains onboard the airplane during the stopover.
- All the busses remain energized while on the ground.
- All the items required to be checked on the first flight of the day have been completed.
- Only normal maintenance activities are performed.
- The inertial reference units (IRU) are reset.

1.18.11.5.2. *Procedure for stall recovery on takeoff*

In the revision to the MD-80 FCOM of 15 October 2009, a warning was included in the section in Volume II on the procedure and techniques for recovering from an approach to stall, indicating that on takeoff, the activation of the stick shaker on rotation could indicate an improper configuration of the flaps/slats, in which case the flaps and slats should immediately be verified to be in the proper position.

1.18.11.6. Measures taken by the operator

1.18.11.6.1. *Modification to Operations Manual*

Since the date of the accident, Spanair has revised its Operations Manual[99] three times, in September 2008, March 2009 and June 2009. Specifically, the following changes were made to Part B, Chapter 2, Normal Procedures:

- The preface was modified to specify that the complete "Prestart" checklist be performed, including the systems check, after any maintenance activity.

[99] Spanair OM-B MD-80, Revision 2 of 12/09/2008, Revision 3 of 01/03/2009 and Revision 4 of 10/06/2009.

- The TOWS item in the “Prestart” checklist was modified to have the check performed on every flight.
- An item was added at the end of every checklist to expressly indicate the completion of said checklist.
- The “Taxi” checklist was modified to include a check of the flaps in item number 7.
- Item 6 on the “Take Off Imminent” checklist, concerning the final items, was modified to specify that both pilots must perform them, with each item being read by the pilot in the RH seat and checked and acknowledged by the pilot in the LH seat.
- The definitions of the terms “First Flight of the Day” and “Through Flight” were included, in keeping with the Boeing FCOM edition of March 2009.

According to information provided by the operator, in its next revision to the Operations Manual it plans to include the warning regarding the stall recovery procedure issued by Boeing in its revision of 15 October 2009.

The preface to Section 3, Abnormal and Emergency Procedures, Chapter 1, Emergency Checklist, was changed to include tasksharing between the pilot flying and the pilot not flying.

1.18.11.7. Measures taken by AENA

AENA replaced the Aviation Emergency Plan for Madrid-Barajas Airport that was in effect at the time of the accident with the current one, called the Self-Protection Plan, which addresses new regulatory requirements[100] and has been in effect since October 2009.

The new plan defines accident scenarios, classifying them into two types and situating them in 20 locations within the airport complex. Each location is delimited by a circle on the airport map. This plan states that the center for detecting an emergency situation shall normally be the Control Tower[101] and it details the information to be relayed to the RFFS and AOO when it activates the alarm. This information includes, among other things, the exact location of the emergency referenced to the accident scenario plan, the number of people onboard the affected aircraft, the amount of fuel and the possible presence of dangerous goods.

[100] Royal Decree 393/2007 of 23 March, which approves the Basic Self-Protection Regulation at centers, facilities and offices devoted to activities that could result in emergency situations.
[101] Chapter 6, Emergency Action Plan, Item 6.2.6.1.

2. ANALYSIS

2.1. General

On 20 August 2008 at 14:24, a McDonnell Douglas DC-9-82 (MD-82) aircraft, registration EC-HFP, operated by Spanair, had an accident immediately after attempting to take off from Madrid-Barajas Airport, Madrid (Spain). The aircraft was destroyed as a result of the impact with the ground and the post-impact fire.

The cockpit and passenger cabin crews and the maintenance technicians who were directly involved with the aircraft on the day of the accident were qualified and had valid licenses and ratings, in accordance with applicable civil aviation regulations in Spain and the with the operator's instructionss and procedures.

The air traffic controllers who provided control services to the airplane at Barajas were qualified and had valid licenses, in accordance with applicable regulations in Spain.

The weather conditions present at Madrid-Barajas during the airplane's takeoff maneuver, in terms of temperature, visibility and wind speed and direction, were adequate for the flight.

The airplane was properly certified, had its documentation in order and was equipped pursuant to applicable regulations. Neither its airframe nor its propulsion system had any notable problems before the accident. Only one item had been deferred affecting the engine reversers. This item was noted in the ATLB and had no bearing on the circumstances of the accident. As for its systems, before taking off an abnormally high temperature indication had been detected in the RAT temperature probe, which led to the discovery that the RAT probe heater was being energized while on the ground. This same problem had been noted on previous days, as detailed in this report.

The airplane's load and balance conditions at takeoff were within approved limits.

The investigation data recovered from the Cockpit Voice Recorder (CVR) and from the Digital Flight Data Recorder (DFDR), along with those data obtained from performance tests, from the physical evidence recovered at the accident site and from the laboratory analyses of some of that evidence reveal that the takeoff maneuver was done with the slats and flaps retracted. This constituted an inappropriate configuration that did not ensure safety. The inspections of the slat components recovered from the scene of the accident exhibited signs consistent with the slats being in a retracted condition. The data recorded on the flight data recorder also indicate that the flaps remained retracted during the taxi phase to the runway, during the takeoff run and throughout the accident sequence until the recorder stopped working after the impact. The laboratory tests conducted on the flap actuating lever recovered from the wreckage revealed the existence of marks located in the setting corresponding to the flap/slat retracted position

(UP/RET), possibly produced by the lever itself at the time of impact. Likewise, the results of the laboratory test carried out on the slat indicating lights are consistent with the indications that would be present if the flap/slat control lever had been in the UP/RET position when the aircraft impacted the ground.

The operator had standard procedures and checklists intended to enable the pilots to prepare the airplane for safe operation, and which included the selection and verification of the flap and slat positions. The accident pilots used these procedures as a reference, but did not adhere strictly to their instructions, failing to extend the flaps and slats. As a result, the airplane was not properly configured for takeoff.

The data gathered during the investigation also indicate that the system designed to warn the crew of the improper takeoff configuration (TOWS) did not work. The cockpit voice recorder did not register the sound of the horn or of the synthetic voice that are used to warn the crew when the flaps and slats are not extended. According to the design specifications of this system, the horn should have sounded when the crew advanced the throttle levers for takeoff.

The accident analysis focused on operational, maintenance and human factors aspects in an effort to try to determine the cause of the TOWS failure and its possible connection with the activation of the RAT probe heater on the ground. Also examined were the details of survival aspects and the oversight provided by aviation authorities.

2.2. Position of the flaps and slats

The physical evidence used to ascertain the position of the flaps and slats surfaces at the time of impact with the ground included an inspection of the mechanical components of these surfaces just as they were found after the accident, a check of the components in the flap/slat control lever and an examination of the slats indicating lights.

Of the eight flaps actuators, five (5) were able to be identified in the wreckage: three (3) from the right wing and two (2) from the left. Since there was no hydraulic pressure, four (4) of these actuators could be freely extended and retracted, meaning there is no guarantee that their position remained constant throughout the accident impact sequence. As a result, their positions could not be used to determine the position of the flaps. The fifth actuator exhibited significant damage from the fire that engulfed it after it detached from the wing, and could be moved with some effort. The rupture of the hydraulic pressure lines in both wings must have occurred when the airplane impacted the ground with great force, in the area where the outline of its underside was left marked on the ground after flying off the embankment between the runway strip and the terrain, after which the flaps could have changed position while remaining attached to the rest of the wing. The fifth actuator separated from the wing, which must have occurred after the rupture of the hydraulic lines. As a result it must have been subjected to significant forces or impacts that affected its integrity and modified its geometry, even after detaching. This would cause the cylinder to remain stuck in the position in which it was found. The fire would have affected it later. It is not possible, therefore, to be sure whether the cylinder length present in the fifth actuator when it was found corresponded to that before the pressure lines ruptured. It is reasonable to assume that it became stuck in its final position as a consequence of subsequent impacts. As a result, no conclusive deductions can be obtained from the debris of the wing flaps system.

Two (2) slats control actuators were found and identified, as well as the tracks on which ride the three (3) panels, the left wing root panel and the one immediately next to it, out of a total of six (6) in each half wing, and the equivalent to the preceding description in the right wing. Of the six tracks (one sliding and another for support for each panel) recovered, three were jammed in the slats retracted position. These tracks belonged to panels in both half-wings. This evidence indicates that the slats were not deployed at the moment of impact with the ground.

The slat and flap sensors were not examined because they were not recovered. These sensors send information on the flap/slat position from the wing to the flap/slat indicating system in the cockpit, as well as to the stall computers and to the digital flight guidance computer (DFGC). The flap sensors also send their information directly to the FDAU, from where it is transmitted to the flight data recorder (DFDR). The no. 2 DFGC was in operation during the accident flight. This computer receives the signal from the slat sensors on both wings and sends it to the FDAU, which then transmits it to the DFDR. A transmission problem between the no. 2 DFGC and the FDAU prevented the slat positions from being properly recorded on the DFDR, meaning these data could not be used in the investigation. No abnormal indications were noted in the systems that use the information from the flaps and slats sensors, however, and which could have been adversely affected by the improper operation of the sensors. Based on this, the information recorded in the DFDR involving the flaps correctly reflects the position of these wing surfaces. These DFDR data indicate that throughout the first taxi sequence of airplane EC-HFP in Barajas from stand T21 at the Terminal 2 apron to runway 36L and back to remote stand R11, the flaps remained at 11°. Later, when the DFDR recording resumed once the parking brake was released at stand R11 to once again taxi to runway 36L and until the DFDR ceased operating at the time of the accident, the flaps deflection parameter read 0°.

The only flap/slat control lever position in which the slats are retracted is UP/RET. The CVR data show that during the accident sequence, after takeoff, the stall warning stick shaker was activated, and the stall horn and synthetic stall warning voice both sounded, triggered by the stall computer, which had detected this situation. If the slats had been in an intermediate position, corresponding to an 11° flaps deflection, the stall computer would have automatically sent a signal to the electromechanic actuators to extend the slats fully, in keeping with the design of the Autoslat function. Had this occurred, the DFDR would have recorded a disagree signal between the flaps control lever setting and the slats position as the slats moved from their intermediate to fully extended position. The DFDR data, however, do not show such a disagree signal; hence, it may be concluded that the slats were retracted at takeoff, with the flaps control lever in the UP/RET position.

The flap/slat control lever is situated in the right front part of the pedestal in the flight deck. It was recovered from the aircraft wreckage, severely damaged. Some of its components were not found. A thorough laboratory inspection of the lever and the fixed track revealed dents and a very clear mark that had been left by the stub on the lever on the bottom of the guide housing corresponding to the UP/RET position. The analysis concluded that the damage exhibited by the guide probably resulted from a hard impact of the stub that indicates the fixed position of the flap/slat control lever against the guide, with the lever in the UP/RET position. Such significant damage to the stub and guide would have required the presence of a high instantaneous load being transmitted from the stub to the guide, and could not have been caused by the normal operation of the lever actuating mechanism. These consequences can only be explained as resulting from the impact of the accident in the pedestal of the flight deck. It can be ascertained, then, that at the time the airplane struck the ground, the flap/slat control lever was in the UP/RET position, corresponding to the flaps and slats being retracted.

The incandescent bulbs that indicate the position of the slats were recovered from the center instrument panel, which was also found at the accident site, and sent to a laboratory for analysis. Each indication (T/O, DISAG, AUTO and LAND) uses two lights. Although the condition of one of the DISAG and LAND bulbs could not be determined, the rest were determined to have been off at the time the airplane impacted the ground. The T/O indication turns on when the slats are in one of the pre-set takeoff positions, that is, MID or fully extended, and is off when the slats are retracted. The DISAG light, when off, indicates that there are no discrepancies between the flap and slat positions. This indication turns on momentarily while the slats transition between positions or when the slats on the two wings are in different positions or when the slats position disagrees with that selected on the flap/slat lever. If the light was off at the moment of impact, this means that all of the slat panels were in the same position, which agreed with the position selected on the control lever. Therefore, one possible option is that the control lever was selected to UP/RET. As for the AUTO indication, this energizes when the autoslat function is enabled, in which the slats extend to the maximum position if a stall condition is detected by the computers. As stated earlier, the Autoslat function is only disabled when the slats are retracted, in which case the AUTO light is off. Lastly, the LAND indication turns on when the slats are fully extended and is off in all other cases.

Based on the operating design of the slat indicators, the T/O and AUTO lights can only be off if the flap/slat lever is in the UP/RET position. The DISAG and LAND lights also being off is consistent with that condition. If the airplane had been in a proper configuration, both the T/O and AUTO indications should have been on during takeoff.

Therefore, in light of the laboratory results yielded by the study of the filaments, it may be concluded that the flap/slat lever was in the UP/RET position at the time of the accident.

In summary, the physical evidence detailed herein indicates that the flaps and slats were retracted, consistent with the flap/slat control lever being in the UP/RET position, at the start of the series of impacts that took place during the accident. It can also be confirmed that the crew did not actuate the flap/slat control lever to extend the flaps and slats, and that it therefore did not properly configure the airplane for takeoff.

2.3. Operational aspects

2.3.1. *Events of previous days*

Data extracted from the flight data recorder (DFDR) on airplane EC-HFP indicate that on 18 and 19 August 2008, there were five cases in which the RAT temperature probe overheated on the ground. One of these cases took place on the 18th, with the other four being on the 19th. Only the last two cases occurring on the 19th were logged by the crew in the ATLB. The high RAT probe temperature had been recorded while maneuvering prior to takeoff during the taxi phase. These events involved three different crews.

The crew involved in the August 18 event was unaware of the problem and did not notice the rise in RAT temperature. At the time of takeoff in Madrid, the RAT probe temperature recorded on the DFDR was below 40 °C and autothrottle was selected. When they were interviewed for this investigation, they were surprised to learn of these facts since they had not noticed anything unusual.

The second crew was involved in the first three cases that occurred on the 19th. They did not notice the first two. In the first case, in Barcelona, the RAT probe temperature reached as high as 100 °C, and the takeoff was done by setting the thrust manually, with the pilots operating the throttle levers. In the second case, also unnoticed by the same crew, the RAT probe temperature reached a value of 50 °C at the start of the takeoff run in Granada, though it dropped gradually as the airplane gained in speed, thus raising the EPR limit value. The takeoff in this case was done using autothrottle. The crew noticed the high RAT temperature during the third occurrence while taxiing in Barcelona prior to flying to Madrid. The takeoff was done by setting the thrust manually. They did not record the incident in the ATLB at that time, waiting until they arrived in Madrid to do so. They also did not request maintenance or consult the MEL upon discovering the problem.

The fifth case took place while taxiing in Madrid on the next flight. There had been a change of crew in Madrid, with the outgoing crew briefing the oncoming crew at the company's office during their turnover. This third crew also did not request maintenance services upon noticing the high RAT temperature, though it did consult section 30.8 of the MEL, on RAT probe heating, and section 34.9, which discusses the RAT probe itself and the engine's Thrust Rating System (TRS). This crew followed the indications in the operating procedure (O) listed in item 34.9 of the MEL, and set the EPR manually before taking off without using autothrottle. The crew logged the event in the ATLB upon arriving in Barcelona.

Some conclusions can be drawn from the above sequence of events.

First, the RAT probe heating on the ground is easy for crews to overlook. One crew did not notice it and another only detected it the third time it happened. It is reasonable to think that crews do not constantly monitor the probe temperature parameter while taxiing. This parameter changes the EPR limit value available when taking off using autothrottle, meaning that a high probe temperature value has associated with it equally low EPR limits. The EPR is checked as part of the "Taxi" checklist when the EPR bugs are compared against the EPR limit shown on the thrust rating panel (TRP). If despite this, the high temperature values of the probe or the low EPR values are unnoticed, then in the event of attempting to take off in automatic mode, the throttle levers would retard automatically before reaching a speed of 60 Kt (clamp mode) if manually set to a position above the EPR limit, thus decreasing engine thrust and compromising the takeoff. This should alert crews on takeoff to immediately advance the thrust levers. However, although the takeoffs on the 18th in Madrid and on the 19th in Granada were done in with autothrottle, the above did not happen because the probe temperature decreased gradually, and the EPR limits increased, during the takeoff run, such that as the airplane became airborne the thrust values were normal. The throttles did not retard automatically, meaning there was no throttle position-based indicators to alert the crew. A malfunction of the probe heating system, therefore, can be masked while taxiing as the ram air cools the probe, making both the temperature and EPR values return to normal. In the other case on the 19th that was undetected by the crew, the takeoff was done with the crew setting the thrust manually, meaning that the crew adjusted the thrust during the takeoff run, ruling out the possibility of the throttles retarding automatically. In this case, then, the crew also had no throttle position-based indications that anything was wrong.

Another conclusion that can be drawn is that the two crews that did notice the probe temperature problem handled it in different ways: one did not consult the MEL while the other checked MEL items 30.8 and 34.9. Neither, however, thought it necessary to consult with maintenance. It is not out of the ordinary to resort to the MEL in one case and not the other. The first crew had already formally started the flight when the problem was detected during the taxi phase, and therefore the MEL was not, strictly speaking, applicable, but merely a reference, according to information circular ACJ MMEL/MEL 001 d). The second crew, in contrast, was allowed to check the MEL during the dispatch of the flight. The use of the MEL in this case is considered correct. The maintenance and operations procedures listed in item 34.9 were followed and the crew decided to proceed with the flight by adjusting the thrust manually, since the EPR limit that is set by the autothrottle system in takeoff mode had been invalidated by the improper operation of the RAT probe.

2.3.2. *Crew actions before takeoff*

2.3.2.1. First taxi at Madrid-Barajas

Before starting the Barcelona-Madrid flight on 20 August 2008, the crew had to check the aircraft systems, including the TOWS, as part of the tasks defined in the operator's procedures for preparing for the first flight of the day. At that time the DFDR did not record a high probe temperature, meaning it should have been working properly. The result of the TOWS test should also have been satisfactory since had it not been, the flight would probably not have been initiated since the MEL does not allow for an inoperative TOWS. The flight proceeded without incident and no malfunctions were reported.

When, once at Barajas, the crew returned to the aircraft to prepare for the flight to Las Palmas, it very likely did not perform the operational check of the TOWS, since this was not required by their checklists. The Spanair checklists did not include the recommendation from the manufacturer, McDonnell Douglas, to verify this system prior to each flight.

The information obtained from the DFDR indicates that the probe temperature was 56 °C when the parking brake was released[102], shortly after engine start and after completing the actions listed in the "After Start" checklist, which includes energizing the sensor heaters. This checklist is performed before initiating taxi. At that time, the crew would have been focused on the route to take to reach the runway and on staying alert for other traffic or obstacles in their vicinity. It is thus understandable for the high RAT probe temperature reading to have gone unnoticed at that time.

The DFDR data show that the temperature probe heating was on from the start of the taxi phase. If the RAT probe heater malfunction had been related to a fault of the TOWS through a faulty R2-5 relay, then had the TOWS been checked when executing the checklist, the crew likely would have noticed that is was not operating properly either. Not including this check in the Spanair "Prestart" checklist before each flight resulted in the aircraft starting to taxi without knowledge that the TOWS was not working properly, and unable to warn the crew of an incorrect takeoff configuration.

[102] The DFDR does not record data when the parking brake is set.

The probe temperature reading on the DFDR was descending throughout the taxi phase from the stand to the 36L threshold. This drop coincided with an increase in taxi speed and is explained by the cooling provided to the probe by the air striking it directly as the airplane moved forward. As already mentioned, it is possible that the crew noticed during the checks required by the "Taxi" checklist that the EPR bugs and the EPR limit value provided by the computers did not match, and that the limit was below normal values. There is no CVR data for this time period, making this hypothesis impossible to corroborate. In any case, the aircraft continued taxiing toward the runway 36L threshold.

2.3.2.2. Malfunction of the RAT probe heater

Once the aircraft was cleared for takeoff, the crew reported to Control that there was a problem and decided to leave the runway to ascertain what was happening.

At that time the crew would have been attempting to understand the problem. The crew contacted the Maintenance Control Center (MCC) in Palma by cellular phone, which advised them to reset breaker Z-29 several times. This breaker supplies electrical current to the RAT heating element. The crew had already tried that option and the RAT indication did not decresase or drop. This is to be expected because the outside air temperature on that day was high, and although the action of opening breaker Z-29 disconnects the heater, some time would be needed for the probe to cool down. The crew may not have waited long enough, which is why it may have assumed that opening the breaker had no effect.

As reported by the MCC personnel who spoke with the airplane captain, it is not often that flight crews contact this department from a runway threshold requesting technical instructions on how to deal with an unexpected malfunction. What is more, Madrid-Barajas is a base for the company and has its own maintenance personnel, as well as sufficient human and material resources. It raises the question as to why the captain decided to contact the MCC before resorting to company maintenance personnel at Barajas.

Thanks to the ATLB entries, the crew was no doubt aware of the problems encountered on flights in the previous days. It must have known, therefore, that the problem had not been solved, which could have concerned them somewhat. Resorting directly to the MCC could be indicative of the captain's concern, who might have believed that MCC would provide him with a fast and satisfactory solution. The aircraft's captain was cognizant of the delay involved in returning to the stand and filling out a FOR (Flight Operation Report), as he himself expressed with annoyance in the conversations recorded on the CVR. Eventually, however, he opted to return, a decision that may corresponded with his desire to attempt to solve the malfunction, given the MCC's inability to do so and thinking that it may have been something important.

When the aircraft parked at remote stand 11, maintenance personnel were waiting to enter the aircraft. Since it was a remote stand, there was no air conditioning because there was no external power source like those available at the stands next to the terminals. This meant they only had the power supplied by the APU once the engines were turned off. Under these conditions and an outside air temperature of 30 °C, the inside of the airplane started becoming hot. A reference to the heat is heard on the CVR when the captain asked the purser, who confirmed the elevated temperature in the passenger cabin.

After the maintenance action, the captain, increasingly pressured by the delay and seeing that returning to the stand had not solved the problem with the RAT heating and that he would now have to fill out a report explaining his decision, may have felt a considerable amount of frustration that conditioned his subsequent actions and created in him the need to hurry in an effort to offset the troubles arising from the malfunction.

The CVR reveals how the first officer began to express doubts about the possibility of being able to do a takeoff with autothrottle when he made a reference to a flexible takeoff. A flexible (FLEX) takeoff is one of the takeoff modes that can be selected on the Thrust Rating System (TRS). This topic was revisited by the first officer on five occasions. The last time he made a reference to the operation of the autothrottle system in connection to a flex takeoff was just prior to initiating the takeoff, after completing the "Takeoff Imminent" checklist. Clearly this topic was of concern to the first officer and focus of his attention.

2.3.2.3. Accident flight preparations

Once the maintenance activities were concluded and the crew accepted the dispatch of the airplane, they once again prepared for the flight to Las Palmas. They used the wrong frequency to request start-up, contacting ground control (GND) instead of clearance delivery (CLD), meaning that they had left the last frequency set on the radio without preparing the cockpit for the flight. When the flight crew stopped the engines at stand R11 after returning from the runway threshold, the old flight was considered terminated[103]. From that moment on, they were starting a new flight. Maintenance activities had been performed in the interim and an entry was made in the ATLB that the airplane was being dispatched again. Having to return to parking upset the normal work flow, resulting in the cockpit not being readied for flight since that had already been accomplished during the first taxi phase. On this point it is imperative to note the importance of adhering rigorously to procedures. It is precisely the appearance of abnormal situations that interrupt operations, such as a the RAT probe malfunction in this case, in which the crew's role takes on added significance and adhering to procedures is particularly critical.

[103] Royal Decree 1762/2007 and Commission Regulation 8/2008, which define flight times.

Following ATC's confirmation that nothing had changed with respect to the previous taxi phase, the crew proceeded to start the engines. The final three items from the "Prestart" checklist can be heard on the CVR, after which the captain requested the "Before Start" checklist. During the reading of this checklist, the captain anticipated the first officer and provided replies before the first officer read the item in question, which would lend credence to the hypothesis that the captain felt some amount of time pressure that led him to reduce, or at least not add to, the delay they were already experiencing. Before taxiing, while the aircraft was awaiting ATC's clearance, the captain called to determine whether there was any delay on ATC's part. This was the third time that the captain exhibited his impatience to start up, even going so far as to handle the communications, which was the first officer's task.

After starting the engines, the crew did the "After Start" checklist, as recorded on the CVR. A total of eight items were read, but upon reaching the ninth and final item, Flaps & Slats, the captain interrupted the first officer before he could read it to ask him to request permission from ATC to taxi. Prior to this, there was no mention in the CVR from either pilot that they were starting the sequence of actions and checks involving the adjustment of the flaps/slats. Based on the available information, in practice, the pilots should wait until ground personnel give them the all-clear signal before extending the flaps/slats. It is not clear, as detailed later, whether the action that followed depended on the captain's go-ahead or not. This action included, as described in the expanded checklist, having the first officer configure the flaps/slats by moving the control lever to the corresponding position for the degrees of extension and then completing a protocol that included four (4) checks, two (2) of which involved only the first officer:

- Check that the slat indicator lights followed a specific on/off sequence to confirm that the autoslat function (automatic extension of the slats from MID to EXT) was ready to engage if necessary[104].
- Following the above sequence, check that only the T/O light remained on in the slats indicator.

The captain was responsible for the third check:

- Verify that the AUTOSLAT FAIL light, located on the overhead panel, did not turn on.

A fourth check had to be performed jointly by both pilots:

- Check that the position of the flap/slat control lever was in agreement with the green lights on the LCD display that indicated the degrees of extension of the flaps.

[104] The light sequence takes place when the flaps/slats control lever is moved into place, at which time the airplane does a self-check, extending the slats to the stop (EXT) and then retracting them to the intermediate (MID) position.

At the conclusion of this process, once the Flaps & Slats item on the After Start checklist is read out loud, they should have verified that all of the above had been performed by checking the lights and the lever position. On the CVR, the reply "SET and CHECKED" should have been heard as confirmation, but as noted earlier, the item was not heard and there was no response. The crew thus missed its first opportunity to discover that the airplane's configuration was not correct for takeoff.

The crew would have other chances to correct their omission.

The fifth item on the "Taxi" checklist was a check of the indicating light for the automatic reserve thrust system (ART), which should be on, indicating the possibility of additional automatic thrust in the event of an engine failure on takeoff. The light does not turn on if the slats are not configured for takeoff. The same item on this checklist includes a check of the calculated takeoff EPR. The CVR revealed that while doing this item, the captain told the first officer that they would attempt a takeoff with autothrottle, and that if it did not work, that they would do it in manual. Preparing for takeoff with autothrottle requires selecting either the takeoff (TO) mode on the thrust rating panel (TRP) and placing the ART switch in the automatic (AUTO) position, which should turn on the green READY light in the center instrument panel, indicating that additional thrust is available. If during this process the crew had known that an off READY light means that the slats are not configured for takeoff, it would have gotten their attention, especially given the first officer's concern over the operation of the autothrottle system. Even though the checks made during the investigation of the ART light did not reveal its status at the time of the accident, there is nothing to indicate that it was burned out. And even if it had been, the fact that it did not illluminate should still have drawn the crew's attention.

The last item (number 8) on the "Taxi" checklist is the so-called "Takeoff Briefing". This item's description states that a review be made of takeoff speeds, thrust and flaps, among other things, and that reference be made to any MEL restrictions. The CVR revealed that this item was not done. In addition to reviewing the status of the flaps, the crew's action to open breaker Z-29 to defer the maintenance on the RAT, as annotated in the ATLB, should have been covered in this briefing. The reasons for its omission are unknown, but it is possible that having held this briefing during the first taxi phase and being pressed for time, that the captain did not deem it necessary to repeat the briefing, even though the conditions had changed in that now there were MEL-imposed restrictions.

Lastly, as the airplane was turning to line up with the runway, the CVR reveals that the first officer made a final check prior to takeoff ("Takeoff Imminent" checklist, Final Items) as he reviewed the values of the position of the center of gravity (eight) and flaps (eleven) on the takeoff adjustment panel situated on the pedestal. He then repeated the flaps angle (eleven) that he should have been reading on the LCD screen of the flaps/slats indicator and on the graduated wheel that is positioned with the flap/slat lever. The physical evidence and the flaps reading recorded on the DFDR, however, contradict what the first officer is heard saying on the CVR. Given the operation of the flaps/slats system, it is highly unlikely that the two LCD screens, which receive information directly from the sensors located on the flaps, would have indicated 11° if the flaps had been retracted. This would have required that the sensors on both wings, which are independent, be transmitting erroneous yet matching information for both to have read 11°. It is believed, then, that the check of the final items was not an actual review of the cockpit indications. The captain, for his part, should have been monitoring to ensure that the answers being read aloud by the first officer corresponded to the actual state of the controls, but at the precise moment that the first officer was doing the final items, the captain was lining up the aircraft with the runway, meaning he had to be looking outside and could not verify the answers he was hearing.

Incidents and accidents[105] have resulted from inadvertent omissions of checklist items stemming from situations in which the pilots thought they had properly selected and checked a system that in fact they had not. There are studies[106] on this phenomenon, known as expectation bias. From a human factors standpoint, it is possible for an individual not to notice the presence of a signal when he truly does not expect said signal to exist. There is a natural tendency in man for the brain to see what it is used to seeing (look without seeing). This tendency is associated with normally long activities that are repeated monotonously. In this case, the first officer, accustomed to doing the final checks almost automatically, was highly vulnerable to this type of error, which was possibly exacerbated by the restlessness he displayed throughout the flight preparations involving the availability of autothrottle during takeoff. This phenomenon is often accompanied by unfavorable physical or psychological conditions, such as (time) pressure or a high workload, factors that were undoubtedly present during the preparation for flight JK5022.

The investigation could not determine why the first officer did not set the flaps and slats to their takeoff position. Interviews of company pilots confirmed that the normal routine at Spanair was for the first officer to select the flaps when requested aloud to do so by the captain, after the latter receives the all-clear signal from ground personnel. Not all the interviewees agreed on the description of the procedure, however. One first officer who had flown with the accident captain stated that "[the captain] was the kind of pilot

[105] An example of this phenomenon is the accident of Delta Airlines flight 1141 (see section 1.18.9.2 in this report), in which the crew did not extend the flaps or slats for takeoff. During the checklists, however, the flaps lever was reported to be in the proper position and the flaps and slats extension indicators were also verified correct. Another example is the accident of Helios Airways flight HCY522, in Grammatiko (Greece), on 14 August 2005. In this case the pilots did not place the pressurization system in automatic during the flight preparations nor did they verify the position of the selector knob.

[106] Human Factors of Flight-Deck Checklists: The Normal Checklist. Asaf Degani. San Jose State University Foundation San Jose, CA. Earl L. Wiener University of Mami Coral Gables, FL Prepared for Ames Research Center CONTRACT NCC2-377. May 1990.

who asked for flaps", which indicates that this was not a generalized practice among Spanair pilots. The operations manual is also unclear on this point, as it makes no reference on the procedure to follow. On this occasion, the CVR reveals that the captain did not request the flaps, and the first officer did not configure the airplane by setting the flap/slat control lever since the sequence to which he was accustomed did not take place, and therefore neither did his response. The first officer should have noticed that the flaps had not been requested and informed the captain of this fact; instead, his concern about the operation of the autothrottle system may have prevented him from perceiving this deviation.

In summary, the investigation identified four occasions to properly configure the airplane for takeoff. in all of them, the safety barriers were defeated. First, the action to adjust the flaps and slats extension with the control lever was not carried out; second, neither the position of the lever nor the status of the flap and slat indicators was checked during the performance of the "After Start" checklist; third, the check of the flaps and slats was omitted during the Takeoff Briefing item on the "Taxi" checklist; and fourth, the visual check made during the execution of the final items as part of the "Takeoff Imminent" checklist did not constitute a real confirmation of the position of the flaps and slats as shown on the cockpit instruments.

2.3.3. *Crew actions and airplane performance after takeoff*

According to information obtained from the flight recorders, the takeoff run was normal. When V1 was heard, the speed recorded on the DFDR was 154 kt. The speed recorded at the "ROTATE" event was 157 kt.

Four (4) seconds after rotation, the stall warning system was activated, with the stall warning and horn being heard simultaneously in the cockpit, along with the stick shaker. The signal recorded on the DFDR indicating that the main gear wheels had lost contact with the ground (WOW), and thus that the airplane was completely airborne, is not reliable. This parameter was issued by the no. 2 DFGC, whose link to the FDAU was defective. DFDR data recorded on other flights on which this signal was sent by the no. 1 DFGC to the FDAU, and was thus reliable, indicate that the time elapsed between the loss of contact signal from the nose wheels and the main wheels is approximately four seconds. Therefore, the airplane's takeoff coincided with the activation of the stick shaker and acoustic stall warnings, which were simultaneous. The stick shaker is designed to be active only when the airplane is airborne at 3 to 10 kt above the stall speed. When this speed margin disappears, the acoustic warnings are also activated. In this case, the fact that both sets of warnings were simultaneous means that the airplane was already in a stall condition when they occurred. Moreover, the warnings were received the instant the airplane became airborne after takeoff. At that time the speed was 168 kt, radio altitude was 25 ft, the pitch angle was 15.5° and the bank angle was 4.4° to the right.

The right bank angle increased to a maximum of 32°. The "bank angle" warnings, issued by the Enhanced Ground Proximity Warning System (EGPWS), were heard atop the stall warning and horn. The stall warning stick shaker remained active until the initial impact with the ground.

The pitch angle increased gradually until it reached a maximum value of 18.3° four (4) seconds later (nine (9) seconds after takeoff), at which time the maximum radio altitude of 40 ft was also reached. The speed was 165 kt.

Five (5) seconds later the first impact with the ground was heard. At that instant the airplane had a recorded attitude of 10.4° of pitch and a 5.3° right bank angle. Its speed was 154 kt.

The airplane was airborne for a total of ten (10) seconds, during six (6) of which its climb rate was positive.

The performance analysis conducted during the investigation indicates that with the slats and flaps fully retracted, the airplane's ability to take off is rather limited. Even so, performance calculations and the simulations that were carried out reveal that the aircraft could potentially have flown if the pitch angle had not been so high and the bank angle had been controlled, even with the degradation in performance that resulted from reducing thrust to an EPR value of 1.65 in both engines when the thrust levers were pulled back, as recorded on the DFDR. These results assume ideal conditions with steady and level wings, which was not the case during the accident. Lateral instability is typical stall behavior in transport airplanes with swept wings, like the MD-82. The incident that occurred in Lanzarote in 2007 shows how the bank angle oscillations that the airplane experienced after takeoff led to a reduction in effective lift that translated into drops of up to 100 ft when the airplane tilted laterally. Boeing calculated that in those conditions, the stall speed increased by up to 40 kt with respect to the stall speed for the same clean-wing configuration in level flight. In the accident involving EC-HFP, the airplane's 32° bank angle increased the stall speed by 12 kt (from 160 to 172 kt). The analytical simulations conducted show that with the atmospheric, weight and thrust conditions present during the accident flight, by maintaining a pitch angle below 12°-13°, an airplane with level wings could have flown in a clean-wing configuration. Since the lateral instability effects could not be reproduced, however, it is impossible to know the actual pitch angle below which the airplane could have remained airborne. Since the airplane's lateral control problems seemed to appear once the stall was declared and established, the way to approach said problems would be to try to reverse the situation. With the throttle levers at maximum power, the chances of increasing the airspeed above 172 kt with a 30° bank angle by just lowering the pitch angle seems difficult at best, considering the little time available given their low altitude above the ground. Furthermore, this technique, applied by itself, would have to contend with the pilots' natural opposition to engage in actions that risked not increasing the airplane's distance from the ground. A more effective way to handle a sustained stall would be to change the configuration. This would achieve a beneficial effect more quickly, namely that of reducing the stall speed. On this airplane model with level wings and the weight, temperature and altitude conditions of the accident flight, going from a clean-wing configuration (0°/RET) to one with the slats in the intermediate position (0°/MID) decreases the stall speed by 30 kt (from 160 kt to 130 kt). We must conclude, then, that promptly actuating the flaps would increase the likelihood of surmounting a situation similar to that of the accident.

The possibility that certain crew actions, when correct and taken at the proper time, as shown here, can avoid accidents caused by an incorrect takeoff configuration has been the trend in previous accident investigations. The need to train on takeoff stalls has emerged as a constant from some of the most significant accidents to have occurred due to this cause. As a result, safety recommendations[107] were issued that aimed to redress this deficiency. Such is the case, for example, of the Northwest Airlines accident involving a DC-9-82 aircraft in Detroit in 1987, and the Delta Airlines Boeing 727 accident in Dallas in 1988. In response to these recommendations, the FAA published AC 00-54 and issued bulletin ACOB 8-90-5, which required FAA operations inspectors to ensure that the operators' manuals include a check of the flap lever in the procedure for identifying and recovering from a stall.

There is one known case in which activating the flap/slat lever after taking off without flaps proved effective and allowed the crew to regain control of the aircraft. In May 2005, the crew of a Boeing 737-800 took off from Washington's Reagan National Airport without selecting takeoff flaps. According to the information contained in the NASA ASRS database (ACN: 658970), after rotation and upon reaching 100 ft, the stick shaker activated, at which time the first officer noticed the problem and moved the flaps lever to select 5° flaps. The information from this incident revealed that the takeoff warning system had not worked because a breaker had tripped.

Boeing's FCOM on the date of the accident had procedures for recovering from a stall on takeoff, approach, landing and go-around. These procedures did not include a check of the position of the flap/slat lever, probably based on the assumption that the crew should know the airplane's configuration. After the accident, Boeing modified this aspect of the FCOM. The MD-80 FCOM revision of 15 October 2009 features a warning in the section describing the "RECOVERY FROM APPROACH TO STALL" procedure and techniques in Volume II that if the stick shaker activates on rotation, it could be indicative of an improper flap/slat configuration and recommends immediately verifying that the slats and flaps are properly selected. As specified in Section 1.17.1.3.3, Spanair's training program includes encountering windshear on takeoff. In this training, which is conducted in a flight simulator, the stick shaker is normally activated, which is when the pilot flying takes the measures necessary to recover from the stall before the

[107] The NTSB issued safety recommendations A-88-70 and A-89-122.

stall warning horn or voice are heard. The recovery procedure requires adjusting the attitude and thrust, but not changing the configuration. The Spanair training program does not include stall recoveries in a takeoff configuration, as such training is not mandatory by regulations.

In its Operations Manual, Spanair's stall recovery procedures, while not differentiating between the various phases of flight, are similar to Boeing's. Reference is made to extending the slats below flight level 250 if the aircraft is in a clean configuration.

Based on the above, it would be recommendable for training on takeoff stall recovery to be mandatory and for procedures involving the MD-80 series of aircraft to include a check of the flap and slat lever as part of the stall recovery procedure. The fact that the manufacturer has modified its procedure to include this point specifically is no guarantee that its application will become standard among operators. As a result, the check of the lever should be converted into an instruction and included in the airplane's flight manual, with which airlines' operating manuals must comply.

The time period available to the crew to accurately assess what was happening to the airplane was very brief. As evidenced by the CVR recording, the crew did not recognize the fact that they were in an aerodynamic stall condition. It is possible that the conjunction of the stall warnings, the Enhanced Ground Proximity Warning System (EGPWS) warnings and the high bank angle captured the crew's full attention and prevented them from soundly assessing their situation. Proof of the disorientation suffered by the crew is the loud and annoyed tone with which the captain asked how to turn off the synthetic voice repeating the word "stall", when this warning cannot be silenced, or the first officer's announcement of an engine failure to erroneously account for the airplane's inability to climb normally.

Additional factors were present that hampered the crew's ability to identify and solve the situation and that could have added to their confusion. The fact that the takeoff warning system (TOWS) did not work during the takeoff run could have contributed to the crew's failure to consider a possible airplane configuration problem as the cause of the stall or even, as in fact occurred, to identify the stall itself. Since the TOWS did not sound, the crew would have remained convinced that the flaps were extended 11° and the slats were at MID position. Under these circumstances, there were not many options available to them to explain what was happening to the airplane. A performance analysis indicates that in a trimmed airplane with the flaps extended to 11°, if the same amount of force is exerted on the control column that is normally used to rotate the airplane in that configuration, the airplane will tend to pitch up if the flaps are in fact retracted. This would explain the high pitch angles observed and which served to quickly aggravate the performance of the airplane.

As analyzed up to this point, the checking and setting of the flap/slat lever on takeoff that could have been initiated with the wing in a clean or incorrect configuration is limited primarily by the response time available, and requires first that the situation be identified. All conceivable strategies for reducing that time must be based on training. The more accustomed pilots are to experiencing the feelings associated with a sustained stall situation, the better prepared they will be to identify it and recover from it. In this accident, as in the one in Detroit in 1987, the crew had just a few seconds to correct their mistake once the airplane was airborne. A fast and accurate diagnosis of the situation improves the chances for success, which is why efforts must be made to have crews become much more familiar with situations like those involved in this accident. This can be achieved through specifically designed training. This is corroborated by the simulations conducted during the investigation.

On this point, it is worth noting that capability of simulators to realistically emulate the characteristics of airplanes in sustained stall conditions. Investigations into transport airplane accidents involving stalls have addressed this question[108]. Moreover, studies[109] have been conducted, especially in the United States, and technological advances have been made to improve simulator performance and to better ascertain the behavior of aircraft in conditions that exceed the flight envelope. The NTSB is known for its decades-long efforts to bring this problem to the fore, as are the achievements of American authorities in enacting regulations to define the requirements for certifying flight simulators[110]. Even so, emphasis must be given to the need to train crews in contexts that are increasingly reflective of operational reality and that highlight the risk that exists when reality and the simulated reality differ. As a result, the CIAIAC views safety recommendation A-10-24 from the NTSB to the FAA following the Colgan Air accident[111], asking that requirements be established for simulation models so as to ensure maximum fidelity with actual stall scenarios, as being indicative of the demands that should be made in order to improve aviation safety in this area. Currently, until the Implementing Rules are published effectively transferring responsibility in matters involving flight simulators to the EASA, the initial and periodic certification of these devices in Europe is the purview of national civil aviation authorities, as specified in the JAR-FSTD A (Airplane) or JAR-FSTD H (Helicopter), as applicable. The drafting of similar regulations in Europe and the United States along the lines proposed by recommendation A-10-24 could assist in the rapid definition of these requirements.

[108] In the NTSB report on the Colgan Air accident that took place in Clarence Center, New York, involving a Bombardier DHC-8-400 aircraft on 12 February 2009, includes a summary of this topic in terms of recommendations.

[109] J.V. Foster, K. Cunningham, et al., "Dynamics Modeling and Simulation of Large Transport Airplanes in Upset Conditions," American Institute of Aeronautics and Astronautics, Report No. AIAA-2005-5933, 2005.

[110] FAR 60, which regulates the certification and use of flight simulators in the United States, went into effect on 30 May 2008.

[111] In the Safety Recommendation A-10-24 it is asked to the FAA to define and codify minimum simulator model fidelity requirements to support an expanded set of stall recovery training requirements, including recovery from stalls that are fully developed. These simulator fidelity requirements should address areas such as required angle-of-attack and sideslip angle ranges, motion cueing, proof-of-match with post-stall flight test data, and warnings to indicate when the simulator flight envelope has been exceeded.

In addition to the above, and as already noted, the crew probably confused the stall with the loss of an engine on takeoff, as happened to the first officer, could be explained as associating the low climb performance with a lack of thrust. An engine failure on takeoff is a emergency procedure that is routinely covered in training. It is part of the operator's recurrent training program and of the proficiency checks that are conducted every six months. There was, therefore, a predisposition to find symptoms associated with an engine failure during an emergency situation on takeoff. This situation is not lost on authorities such as the FAA and the EASA. Safety alert SAFO 09008, issued by the FAA on 6 April 2009, and Safety Information Bulletin N 2009-09, issued by the EASA on 27 April 2009, recognize the need to include a wide range of engine failure and other scenarios that might be misinterpreted as an engine failure as part of initial and recurrent training programs.

Apart from this, the most notable aspect of this case is how the first officer's identification of an engine failure led to the momentary pulling back on the throttles, before subsequently being pushed to their mechanical stop. This action is not consistent with the engine failure procedure, which first requires that the affected engine be identified and, if below 400 ft above ground level, not to move the throttles. The reasons why the crew retarded the throttles, then, are difficult to ascertain. Nevertheless, this action could be compatible with the theory that the pilots considered for an instant the possibility of aborting the takeoff even with the airplane already in the air so as to try to stop it on the section of runway remaining. That momentary hesitation could have been followed by the eventual decision to continue with the takeoff and apply maximum thrust.

Simulations have shown that in the accident configuration (0°/RET), a level airplane and a constant 13° pitch angle, pullling back momentarily on the throttles and then increasing to an EPR of 2.20, as happened in the accident, does not hamper the airplane's ability to fly versus the scenario in which the throttles are not retarded from the EPR 1.95 position. The simulations did show, however, that retarding the throttles meant the airplane needed more time to increase its altitude and speed in comparison to the time needed if the throttles are pushed immediately to the mechanical stop.

The simulation data reveal that with a pitch angle in excess of 13°, a takeoff is not possible.

In the accident, with pitch angles above 18° and bank angle oscillations of up to 32°, the time invested in retarding the throttles could have hampered the control of the airplane's attitude.

As detailed later in this report, and in light of the facts, pilots should be given more training to help them deal with highly demanding environments in which errors are more likely to appear.

REC 18/11. It is recommended that the United States Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) require takeoff stall recovery as part of initial and recurring training programs of airline transport pilots.

REC 19/11. It is recommended that the United States Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) study and assess the stall recovery procedure in the Aircraft Flight Manuals (AFM) of large transport airplanes to include a check of the flap/slat lever and its adjustment, if required.

REC 20/11. It is recommended that the European Aviation Safety Agency (EASA) establish requirements for flight simulators so as to allow simulator training to cover sustained takeoff stalls that reproduce situations that could exceed the flight envelope limits.

2.3.4. *The cockpit environment*

The crew held conversations in the cockpit at various stages that were inconsequential to flight activities. The presence of a third person traveling in the jump seat, and who took part in these conversations, contributed to creating an environment that was conducive to distracting the crew from its flight duties.

When the maintenance technicians were onboard during the maintenance activities at remote stand R11, the conversation between the first officer and the third person seated in the cockpit was normal. This third person participated in the conversations being held between the crew and maintenance technicians regarding the measures they were taking to cool the RAT probe with dry ice[112]. Although the crew was not yet immersed in flight preparation tasks at this time, the first officer had already made a reference to the autothrottle system, a topic that, as already noted, concerned him in terms of its operability.

Later, while taxiing to runway 36L, the crew and the third person in the cockpit talked about the malfunction they had encountered and how the temperature had dropped. In the conversation, the first officer was listening to this person, meaning he was not devoting his full attention to looking at the indications and instruments. As a result, his ability to detect, for example, whether or not the flaps were properly selected, was thus diminished. The taxi phase is a particularly critical time, with a high volume of communications and during which interruptions and distractions are more common. In this setting, the crew is more vulnerable to mistakes and omissions.

[112] Dry ice is the common name for solid carbon dioxide, which at ambient pressure is a solid at temperatures below –78 °C.

There were two other times, later, in which the CVR recorded conversations by the crew that were irrelevant to the flight: prior to being cleared for takeoff, and as they were entering the runway, prior to doing the final checklist before takeoff (Takeoff Imminent). In this latter case, they were talking about other events in which they had been involved in recent days.

During this entire time, there was no discomfort noted in the crew for talking about topics that were irrelevant to the flight tasks, meaning they probably did not feel they were doing anything untoward. The events of that day, full of interruptions and unusual events meant that deviations from the operational routine and standard behavior were that much more likely. The conversations that distracted the crew from its tasks centered on these events, which serves to highlight the unique nature of the situation. Obviously, had the RAT not malfunctioned and had the typical operational routine not been altered, there would have been no reason to discuss these subjects on the flight deck, which would have facilitated greater compliance with the rules regarding the sterile cockpit.

The regulations concerning crew obligations during the phases of flight date back to the early 1980s. FAR 121.542 was an attempt at ensuring that pilots focus their attention on operational tasks during critical phases of flight and expressly restricted conversations to relevant operational topics. This regulation involves the concept of critical phase of flight, which includes ground operations such as taxi, landing and takeoff, and air operations below 10000 ft, not including cruise flight. The equivalent regulation in Europe is contained in EU OPS 1.085 and limits activities to those required for the safe operation of the airplane during takeoff, initial climb, final approach and landing. The European regulation does not specify what cannot be done, for example, and does not discuss the type of conversations that can be held. The taxi phase and remaining operations on the ground are not specifically included within the scope of applicability of this rule.

In the case of Spanair, its Operations Manual defines the sterile cockpit period as that time between the turning on and off of the "Fasten Seat Belts" sign. It does not specify what activities are prohibited during this time either.

Accidents have occurred involving distractions that diverted the crews from their tasks and duties. In some of these accidents, conversations during the taxi phase were identified as a contributing factor. Specifically, in the accident involving a Comair Bombardier CL600 on 27 August 2006 in Lexington (Kentucky), the NTSB determined that a non-pertinent conversation by the crew while taxiing contributed to the accident. In this case, essential tasks were omitted, such as the selection and verification of the flaps, which are performed before or during the taxi phase. Therefore, efforts should be made to eliminate or minimize those elements that can distract crews or increase their work load during this phase, in which interruptions are commonplace and communications abound. And yet, European regulations exclude the taxi phase from those periods in which crews are required to limit themselves to only those tasks that ensure safe operations. This should be changed.

As a result of this disparity between the States and existing requirements on activities while piloting, the conclusion was reached at the 37th Assembly of the ICAO, held from 28 September to 8 October 2010, that it would be advisable to introduce the concept of critical phases of flight and to define what activities are acceptable during said phases in the ICAO statutes.

It is often difficult for flight crews to avoid conversations unrelated to operations during periods of low work load, but consideration must be given to the consequences entailed in diverting one's attention at specific instances, even when the attention demanded is seemingly insignificant and the tasks being performed are not complex. Crews must be aware of this fact and be disciplined in their compliance with the sterile cockpit concept so that they can devote their full attention to piloting and thus maximize their chances of detecting an important indication, especially when these indications are not particularly noticeable, as may have been the case in this accident.

It is therefore necessary to highlight during crew training the importance of complying with the sterile cockpit regulations and the consequences that may arise otherwise, using examples from accidents in which a lack of adherence to this rule kept crews from detecting their mistakes.

REC 21/11. It is recommended that the European Aviation Safety Agency (EASA), in keeping with ICAO initiatives, introduce in its regulations the concept of critical phases of flight and define those activities considered acceptable during said phases.

REC 22/11. It is recommended that the European Aviation Safety Agency (EASA) and national civil aviation authorities, when evaluating operator training programs, expressly ensure that:

- the concept of sterile cockpit is stressed,
- the importance of adhering to said concept is stressed, along with the consequences of even minor distractions, and
- examples of accidents are included in which non-compliance with regulations involving the sterile cockpit was a relevant factor.

2.3.5. *Use of personal portable electronic devices*

The CVR data show that while the aircraft was at parking stand R11, the first officer made a personal call on his cellular phone to report that he would be arriving late on the flight returning from Las Palmas to Madrid. At that time, maintenance tasks were being performed involving the malfunction of the RAT probe heater. The data gathered also show that the captain talked by cellular phone with the Maintenance Control Center (MCC) in Palma, seeking advice on the RAT probe heater malfunction before returning to the stand after the initial taxi out in Barajas.

Part A of Spanair's Operations Manual prohibits the use of personal portable electronic devices onboard aircraft. In Spain, a DGAC resolution from the year 2002, which incorporated the requirement set out in JAR-OPS 1.110, referred to avoiding the use of cellular phones during the flight preparation phase, though Spanair's manual made no explicit mention of said use by flight crews during this phase of operation.

Again we must compare the regulation in the United States and mention that FAR 91.21 contains requirements equivalent to those in Europe. Both the regulation and FAA advisory circular AC 91.21-1B, which lists the criteria for the correct interpretation and application of the rule, are implicitly intended to keep personal portable electronic devices carried by passengers onboard the airplane from interfering electromechanically with aircraft equipment.

The captain's use of a cellular phone could be considered in terms of problems with electromagnetic interference, since the purpose of the call he made to the MCC was to obtain information that would aid him in making a decision regarding how to proceed with the operation. The consideration given to the first officer's use of the cellular phone, however, is different in light of its greater potential for distraction. The messages that the flight attendants or the onboard public address systems give to passengers on commercial flights to turn off their cellular phones or portable computers serve to comply with the intent of the regulations, whose aim is to prevent problems with electromagnetic interference. However, in either of the two situations, interference or distractions, flight crews often lack clear instructions, guidelines or references in their procedures and checklists reminding them to turn off their own personal portable electronic devices. Returning to the situation in the United States, in 2009 the FAA published a safety alert for operators (SAFO 09033) in which it warned of the hypothetical dangers associated with leaving cellular phones on due to the distractions they can cause, and recommended to operations directors that they review their operations manuals to ensure that proper procedures were in place to remind crews or anyone traveling in the cockpit to turn off their cellular phones during flight preparations. More recently, in April 2010, the FAA issued additional information to operators (InFO 10003), emphasizing this idea and recognizing the threat posed to safety by the use of personal portable electronic devices in the cockpit.

Although the call made by the first officer while the maintenance activities were ongoing, or that made by the captain to the MCC are not directly associated with the accident, if due consideration is given to the intent of those regulations currently in effect which limit the use of personal portable electronic devices due to the negative effects on the operation of aircraft equipment and systems, as well as to the potential dangers that their use by flight crews entails in terms of the distractions they can cause, this Commission must recommend to authorities that they ensure that operators prohibit their crews from using personal portable electronic devices on the flight deck.

REC 23/11. It is recommended that the European Aviation Safety Agency (EASA) ensure that national authorities require commercial air transport operators to prohibit their crews from using personal portable electronic devices on the flight deck.

2.3.6. *Checklists*

2.3.6.1. Checklist design

Checklists constitute a supremely important element for the safety of aviation transport operations. The checklists are used in all phases of flight. Prior to takeoff, for example, the checklists are intended to prepare the airplane for safe operation.

Properly designed checklists and procedures and adherence thereto are particularly relevant when configuring the airplane for takeoff, since any errors could have fatal consequences in this phase of flight. Therefore, an insistence on improved procedures associated with the use of checklists can reduce the likelihood of a mistake when preparing and configuring the airplane for takeoff.

While the complexity of these checklists should be limited, they are in fact implemented in a wide variety of ways among airplanes from different manufacturers or between airplanes of different types from the same manufacturer. Despite the knowledge, supported by various studies[113], that errors associated with the use of checklists have contributed to a significant number of accidents, and that those errors occur with relative frequency over the course of operations, the design of checklists is a field that was virtually ignored until after the Northwest Airlines accident in Detroit in 1987.

Based on the conclusions drawn from the Northwest Airlines accident in Detroit, the NTSB issued a safety recommendation[114] that has served to develop the field of research

[113] These include, among others: Lautmann, L, & Gallimore, P. (1987). Control of the crew-caused accident:Results of a 12-operator survey. Boeing Airliner. Boeing Commercial Airplane Company (Seattle), Helmreich, R.L., Wilhelm, J.A., Klinect, J.R. & Merritt, A.C. (2001). Culture, error and crew resource management.

[114] In safety recommendation A-88-68, the NTSB asked the FAA to form a research group on human factors that included representatives from NASA (National Aeronautics and Space Administration), the industry and pilots so as to determine methods for presenting checklists which produces better performance on the part of user personnel.

into human factors as it relates to the making of checklists. Some of the norms that emerged from this research[115] were, for example:

- Checklist responses should portray the desired status or the value of the item being considered, not just “checked” or “set”.
- The most critical items on the task-checklist should be listed as close as possible to the beginning of the task-checklist, in order to increase the likelihood of completing the item before interruptions may occur. It is even recommended that those points be revisited at the end of the checklist, so as to doubly ensure their execution.
- Critical checklist items such as flaps/slats, trim, setting, etc… that might need to be reset due to new information, for example a last minute change of runway or variations in wind speed, should be duplicated on the ground phase checklists and be confirmed by both pilots.
- The completion call of a task-checklist should be written as the last item on the checklist, allowing all crew members to move mentally from the checklist to other activities with the assurance that the task-checklist has been completed.

These criteria are generally featured on the checklists prepared by manufacturer and operators, although it cannot be said that they are universally adopted by both. For example, the Spanair checklists in effect at the time of the accident did not include the principle of having the flight crew announces out loud the values selected for the flaps. Moreover, the selection of flaps and slats was the ninth and last item on the After Start checklist. Although the values selected were checked in the last items section of the Takeoff Imminent checklist, these were only reviewed by the first officer and from memory, without a reply from the captain. As for Boeing’s FCOM, it reflected the principle of calling out the numeric value of the flaps extension when selecting them, although other items in different checklists were acknowledged with a “set” or “check”. Also in keeping with the FCOM, the flap/slat lever was the first item checked on the Taxi checklist, though they were not verified at any subsequent point.

After the accident, Spanair and Boeing revised their operating procedures for the MD-80 series of aircraft. The changes made are in keeping with the philosophy presented above. Spanair has included an item at the end of each checklist to expressly indicate its completion. It has also modified the Taxi checklist to add the flaps verification as item 7. Boeing, which had started the process of reviewing its checklists in 2007 after an

[115] Some of the reports and authors are:
Degani, A. & Weiner, E. L. (1993). Cockpit Checklists: Concepts, Design, and Use. Human Factors 35 (2), pp. 28-43. Research on checklist effectiveness followed, in part, from an NTSB recommendation resulting from the Detroit Flight 255 accident.
Turner, J. W., Huntley, M. S. Jr. Report N°. DOT/FAA/AM-91/7. April 1991. The use and design of flight crew checklists and manuals. A special report for the U.S. Federal Aviation Administration.
Human Performance considerations in the use and design of aircraft checklist. January 1995. U.S Department of Transportation. Federal Aviation Administration. Assistant Administrator for System Safety Office of Safety Services Safety Analysis Division.

event involving a takeoff with the flaps and slats retracted, completed for the MD-80 model shortly after the Barajas accident, adding new item, number 3, to its Before Takeoff checklist to check the flaps and slats.

More recently, investigations based on observing operator practices[116] and on pilot notifications of events, or in the analyses of some accidents, the focus has been on omissions that occur while executing procedures, such as those that may result in an erroneous configuration. The phase before takeoff, when the flaps are selected, is filled with interruptions, distractions, bursts of communications and unexpected tasks, all of which can have a negative impact on the execution of checklists even if they are designed using the best of criteria. Oversights normally occur when the execution sequence as practiced during training is interrupted by other tasks that demand the crew's attention. In the Spanair case, such interruptions were unquestionably present. There was a technical problem while preparing for the flight that required the intervention of maintenance personnel. This resulted in a new timeline and forced the pilots to delay the departure and return to the stand.

Strategies have been proposed and tested in actual operational environments in an effort to mitigate the effect of interruptions and excess work load during flight preparation operations. These proposals include crew training on managing these circumstances.

A high work load and the appearance of interruptions are factors that merit special consideration in the case of airplanes of the MD-80 generation. A significant point is that in both the Spanair procedures and in Boeing's FCOM for the MD-80 series, the checklist to be performed prior to engine start (Prestart for Spanair and Before Start in the Boeing FCOM) consists of 59 items (Spanair) and 75 items (Boeing) for the first flight of the day. The TOWS check, for example, is item 49 (Spanair) and 65 (Boeing). Each of these items, in turn, involves the execution of several actions. In a normal operational setting, it is normal for disruptions to appear which prevent the completion of such extensive checklists without interruptions.

Current generation airplanes are equipped with computer-controlled instruments[117] that are effective in helping crews avoid configuration errors. One of their features is an on-screen display of checklists whose items are shown continuously to the crew until the computer confirms that the checklist actions have in fact been executed. These systems are also capable of making configuration checks prior to takeoff by having the computer simulate advancing the throttles and activating the relevant warnings if necessary.

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[116] Loukopoulos,L.D., Dismukes,R.K. & Barshi, I. (2009). The Multi-Tasking Myth: Handling Complexity in Real-World Operations. Aldershot, UK. Ashgate Publishing Limited.

[117] Examples of these systems are the EICAS (Engine Indicating and Crew Alerting System) from Boeing and ECAM (Electronic Centralized Aircraft Monitoring) from Airbus. Both are computer-controlled integrated systems that supply the crew with information on the engines and the instruments, and that also serve as warning systems.

In conjunction with the NTSB, the CIAIAC believes that an in-depth investigation of operational procedures should be conducted so as to avoid configuration errors during takeoff. This Commission also emphasizes the need for continued efforts to progress in this area. Improvements in the design of checklists and in the work methods used in the cockpit, such as defining the sequence of crew actions or applying the do/verify and challenge/response principles when managing the checklists, are the goal of the following recommendation. As a result:

REC 12/09. It is recommended that the International Civil Aviation Organization (ICAO), the Federal Aviation Admministration (FAA) of the United States and European Aviation Safety Agency (EASA) jointly promote the holding of an international conference, to be attended by every civil aviation representative organization, such as authorities, industry, academic and research institutions, professional associations and the like, for the purpose of drafting directives on good industry practices in the area of aviation operations as they apply to checklist design, personnel training and improved procedures and cockpit work methods so as to ensure that crews properly configure aircraft for takeoffs and landings.

Continuing with the checklists, there are very few examples of civil aviation authorities taking the conclusions drawn from studies and work done to date and providing them to those in charge of drafting and applying said checklists, such as aviation manufacturers and operators, or to those responsible for their oversight and approval, such as civil aviation inspectors. In the United States, the FAA has drafted guidelines[118] for its operations inspectors (POI) which include the principles mentioned above on the design of checklists. These guidelines also comprise a practical reference for operators and manufacturers, who find in them the same criteria that will be used by the inspector in his evaluation, and which are also made available to the public at large. In Europe, there is the example of the CAA in the United Kingdom, which published directives[119] in 2006 on the design and use of emergency and abnormal checklists.

Along with the strategic recommendation to undertake a joint and thorough study in this area, it would be useful if an urgent effort were made to compile and disseminate the research and work already done in this area so as to make it as widely available as possible. Therefore:

REC 13/09. It is recommended that the European Aviation Safety Agency (EASA) compile the results of studies and works done, as well as of any

[118] FAA Order 8900.1 Flight Standards Information Management System (FSIMS). Volume 3. General Technical Administration. Chapter 32. Manual, Procedures, and checklist for Part 91K, 121, 125, and 135, derived from studies conducted as a result of the 1987 Northwest Airlines accident in Detroit (1987).

[119] CAP 676. Guidance on the Design, Presentation and Use of Emergency and Abnormal Checklists. CAA, UK (January 2006).

instructions and directives issued by civil aviation authorities to date, concerning the principles and guidelines relative to the:

- design of checklists and
- working methods in the cockpit

so as to allow European operators and manufacturers and national authorities to have clear references on the state of the art in the design and application of checklists.

After the issuance of CIAIAC REC 13/09, the FAA published on March 16, 2010 information for operators (InFO 10002), collecting a list of good practices in the aerial operations industry, such as checklist design, traning and Crew Resources Management (CRM) procedures, the goal being to have operators review their procedures in light of above documents. The CIAIAC considers this measure adopted by FAA as complying fully with the objective of REC 13/09, even though the recommendation was not issued to the FAA. The EASA has acknowledged receipt of this recommendation but has yet to report on what measures it plans to adopt or on its reasons for not taking any action, as the case may be.

2.3.6.2. Operator process for managing checklists and aviation authority oversight in this process

The investigation revealed that, according to the Boeing FCOM, the TOWS should be checked on all "thru flights", a term that was not defined in said manual at the time of the accident. Furthermore, after the Northwest accident in Detroit in 1987, the manufacturer issued a telex to all operators recommending that they modify their checklists to include a check of the TOWS prior to each flight. Since it was only a recommendation, some operators adopted it while others did not. Not all European operators of MD aircraft included the check of the TOWS prior to each flight. Specifically, SAS, the owner of Spanair at the time of the accident, and from which Spanair inherited its MD82 checklists, did not include the TOWS check even though SAS was one of the companies to which McDonnell Douglas sent the aforementioned telex.

Other differences between the manufacturer's and operator's checklists were described earlier. An effort was made in this investigation to identify the reasons for these differences. In order to ascertain the evolution of the Spanair checklists, a study was undertaken of the operator's process for preparing and modifying checklists. Based on the information obtained, whenever a change was proposed, the checklists were not compared against the manufacturer's, nor was a risk assessment done. The effect of the modification on operations was also not verified in the simulator or during an in-flight test. An internal audit conducted in November 2008, after the accident, revealed deficiencies in basic aspects involving the operating procedures and checklists. There was no set policy for drafting, developing or using procedures or checklists to tasks sharing between the PF and PNF. Cross-checks and verifications of critical actions were also not addressed.

According to operational regulations (EU-OPS) and the interpretive guidelines published by the various JAA[120], which list instructions on those parts of the operations manual requiring approval or acceptance by the authority, the checklists are accepted as part of the manual's contents. The European authority, the EASA, makes no great distinction between the concepts of approval and acceptance. Acceptance implies doing an in-depth evaluation of the checklists to check their suitability. In Spain, the AESA's viewpoint is that the checklists do not need to be accepted by national authorities. In its case, the AESA evaluates an operator's checklists using the criteria that they be relevant to the intended operation, that they not add superfluous information and that they contain data and limitations applicable to the routes, aircraft or equipment. There appears to be no unanimity in Europe regarding the role of the aviation authority in establishing the checklists that appear in operations manuals. The term "acceptance" that is defined in the regulations could be at the root of these interpretation problems. In practical terms, the weight of an authority's "approval" implies that their involvement in those matters requiring approval must be much more direct. However, the type and level of detail of the checks or reviews that the authority must make in order to "accept" something is left to its own judgment, meaning that differences could arise among national authorities when considering what is and is not acceptable when dealing with the "acceptance" process. In order to standardize practices in the European Union, the EASA should clarify this issue.

Before the accident, the AESA examined the Spanair Operations Manual as part of the preparations for the annual inspection to renew the Air Operator's Certificate (AOC). All of the company's operational aspects were reviewed as part of this process, including the Operations Manual. The most recent inspection prior to the accident, for example, conducted in June 2008, lasted two days and involved three inspectors. Under these conditions, the time devoted to reviewing the flight procedures and checklists, considering the variety of the Spanair fleet, would necessarily have been limited. There is no record in the findings from this inspection, or from any inspection conducted since 2003, of any deficiencies in this regard.

There are no specific stipulations in European regulations on operations that require operators to have a procedure for creating and modifying checklists. Although there are also no guidelines on a European level that define the operator's role in the handling of checklists, the latest regulations being developed at the EASA[121] are introducing the

[120] Administrative and Guidance Material. Section Four: Operations. Part two: Procedures (JAR-OPS). 1 October 2008.
[121] The regulatory proposal contained in NPA 2008-22 introduces the principles of Safety Management Systems into the design of SOPs and also includes the design of acceptable means of compliance with regulations and supporting material (AMC1-OR.GEN.200(a)(3)y GM2-OR.OPS.GE.200(a)(5)).

principles of Safety Management Systems into the writing of SOPs, and therefore also into the design of and changes to checklists.

The FAA approves all checklists and makes available guidelines to its inspectors (POI, Principle Operations Inspections) that describe the process and the standards that operators must follow in order to obtain FAA approval.

To summarize, there is no regulation in Europe that defines the process for modifying checklists. The sole example found was guidance developed by the British authority for the design and modification of emergency checklists, CAP 676, which not only included the design principles, but also indicated the process to follow when making a change to the checklists.

As noted in Section 1.18.9, there are examples of incidents that resulted as a consequence of changes that were made to checklists without a correct evaluation of their impact or a proper risk analysis.

In the case of Spanair, we have seen how the checklist acceptance process used by the AESA could not have detected deep-rooted problems in the the preparation of the checklists that have been identified by the operator itself. It seems logical that a system like the one in place in the European Union, in which checklists are not subject to the approval of aviation authorities, should be based on much more robust operator practices, procedures and guarantees that serve to complement the direct oversight normally provided by authorities as part of the approval process. Not having specific regulatory requirements that force operators to implement such oversight procedures for their checklists does not mean that there are no obligations in those rules which may be interpreted as requiring operators to implement suitable mechanisms for dealing with any issue related to checklists or operating procedures. After all, if the responsibility of defining and applying airplane flight procedures is left to operators, then the civil aviation system must be able to rely on said operators to undertake these tasks properly. The CIAIAC believes that proper operator behavior in this regard is covered under the quality systems referred to in OPS 1.035, which states that "*The Quality System must include a Quality Assurance Programme that contains procedures designed to verify that all operations are being conducted in accordance with all applicable requirements, standards and procedures*". The CIAIAC believes that this instruction implies the obligation to have an entire set of procedures, in which they must base their function. Given the importance of checklists to ensuring safe operations, a process must be in place to allow for an assessment of any changes that are made to the checklists and of any consequences those changes might entail.

The conclusion drawn from the preceding arguments is that operators must be given material that allows them not only to design, but to maintain, their checklists properly. The involvement of manufacturers in this operator process of modifying and reviewing the checklists should not be overlooked. The regulation should also include the need for operators to have procedures for modifying their checklists and provide guidance to national authorities for objectively assessing the procedures developed by operators. Some of these questions are starting to be addressed by the EASA, though this Commission believes a quicker implementation is needed. As a result:

REC 24/11. It is recommended that the European Aviation Safety Agency (EASA) develop guidance material for the preparation, evaluation and modification of checklists associated with normal, abnormal and emergency procedures that is based on the criteria that govern safety management systems.

REC 25/11. It is recommended that the European Aviation Safety Agency (EASA) clarify whether or not checklists are subject to the acceptance of national authorities and, if so, that it draft instructions so that said authorities apply uniform criteria and methodologies, such as methods for assessing the systems and procedures in use at the operators for managing checklists and quality assurance systems in general.

2.3.7. *CRM and other flight crew training aspects*

The circumstances of the accident revealed the existence of several factors potentially related to knowledge and training deficiencies resulting in human errors at various stages of the operation.

To summarize the findings described in previous points, the captain could have been frustrated during the pre-flight phase by the fact that the RAT probe malfunction was not resolved as expected, resulting in a substantial delay that only served to add more pressure and stress. This may have forced him to act precipitately (hurry-up syndrome), which is estimated to have been the primary conditioning factor for his subsequent behavior and the leading cause of his mistakes. As a consequence, omissions were made in the verification of the checklists, the cross-checks failed and his coordination and communications with the captain suffered, as evidenced by the captain's failure to appreciate the first officer's concerns regarding the operation of the Authrottle System (ATS).

With regard to operational pressure and precipitation (hurry-up syndrome), it is true that any unforeseen delay can have a negative effect on crew flight performance. The ability of flight crews is degraded by the real or perceived need to execute tasks quickly. In this case, the pressure to accelerate task executions was self-imposed by the captain himself, who wanted to adhere to the schedule following the maintenance delay. Although not very recent, a safety study conducted by the NTSB in 1994 reported that 55% of the 31 transport aircraft accidents considered had departed late or were behind schedule. Another study[122] based on checks of the ASRS database, which contained 1142 events involving some kind of time pressure, concluded that 90% of mistakes were made during the flight preparation or initial taxi phases.

The first officer, for his part, focused much of his attention on the possible repercussions that the RAT probe malfunction would have on the operation of the ATS, resulting in a lack of assertivenees that manifested itself in two ways:

- By failing to draw the captain's attention to his own concerns, and
- By not reacting to the procedural deviations that he should have noticed in the captain when the latter anticipated checklist items or when the check of the flaps and slats was omitted.

The first officer was also affected by the expectation bias phenomenon, which prevented him from conducting an effective check of some check items, such as the position of the flaps and slats.

All of these factors (stress induced by operational pressures, hurry-up, coordination among crew members, assertiveness, focus on attention, expectation bias, procedural compliance) are well-known in the field of human factors and have been exhaustively addressed in recent years from every angle in the field of civil aviation, including those involving regulations, industry practices and training. And yet they continue to be present in accidents, sometimes significantly so, as in this case. Both pressure and precipitation, as well as the remaining factors involved in this case, are concepts that are addressed specifically as part of crew resource management (CRM). As stated in the Human Factors Training Manual (ICAO DOC 9683): "*Especially under stress (physical, emotioinal or managerial) there is a high risk that crew coordination will break down. The result is a decrease in communication (marginal or no exchange of information) and a lower probability of correcting deviations either from standard operating procedures...*".

Based on the data provided by the company and on the training records consulted, the captain and first officer were given an initial CRM training course upon joining the company and received recurrent training every year. Their last CRM training had been on 3 October 2007 for the captain, and 5 March 2008 for the first officer. Both sessions lasted one day. The courses covered topics such as the hurry-up syndrome, the stress resulting from environmental pressures (operational, psychological and self-induced), oversights, carelessness, deliberate infractions, incident and accident analysis, communications and coordination, assertiveness and the expectation bias phenomenon, as referenced in Part D of the Operations Manual (SOM). The CRM instructors, for their part, took an initial course before starting to teach under the supervision of an

[122] Time Pressure as a Causal Factor in Aviation Safety Incidents. The Hurry-Up syndrome. Jeanne McElhatton, Charles R. Drew. May, 1993. The Ohio State University. 7th Intenational Symposium on Aviation Psychology.

experienced instructor. Lastly, before the instructor started to provide training, approval was requested from the AESA.

Investigators also ascertained other information about the operator's CRM training. Boeing had visited Spanair in 2007 to evaluate its operations. Based on its observations of simulator sessions and line practices, it judged Spanair's CRM to be good, though it noted that some call outs were omitted when performing procedures, a defect that Boeing suggested be emphasized in training. En route monitoring of Spanair by AESA inspectors was also intended to assess the company's CRM. Of the 75 inspections reviewed, spanning a period of one year before the accident, no weaknesses were noted in this area. This is regarded as a positive, even in light of the fact that the efficiency of the evaluation methods based on direct observation of in-flight cockpit operations that were used during the Boeing visit or the AESA's inspections is not very high, since under those conditions flight crews are very aware that they are being examined, which makes them pay special attention to the proper performance of procedures. As a result, the normal context of operations is distorted, meaning the reality of operations is not accurately portrayed.

One audit conducted by Aviation Quality Services (AQS) in 2007 as part of the IOSA program detected the lack of a process at Spanair for selecting instructors. An internal audit done in November 2008, after the accident, also accentuated this point

As a whole, it may be said that the CRM material taught, the syllabus, method and the instructors complied with the regulations set out in the EU-OPS, and adhered to the recommendations and guidelines specified in said regulations. Furthermore, the various evaluations conducted revealed a good use of CRM techniques with no trouble areas being noted.

The circumstances of the accident, however, point to bad coordination and improper CRM that failed to mitigate the individual errors made by both pilots. Notwithstanding the aspects involving the design and execution of the standard operating procedures (SOP) and checklists, which have been shown can contribute to the making of mistakes; the barriers that should have been provided by the crew's training were circumvented here as well. There is nothing in this crew's records that indicates any specific personal or professional shortcomings. Their profiles were in keeping with what may be considered as average for the airline. This case revealed the low efficiency of the efforts expended in the area of CRM. There are expert opinions[123] that have analyzed how the regulation of CRM has highlighted the separation between the principles that inspired the adoption of CRM and its actual application[124]. According to these opinions, which

[123] Barriers to Regulating Resilience: Example of Pilots' Crew Resource Management Training. Stéphane Deharvengt. Direction Générale de l'Aviation Civile (France).

[124] The result of the investigations carried out after recent accidents highlights the improper application of CRM principles in crews that have received the mandatory training in this area. Examples of this nature could be accidents cited in this report, such as that involving Colgan Air in February 2009, or the Helios Airways event in August 2005.

are supported by information obtained through formal and informal channels, the general belief is that the CRM training provided is of low quality, and yet this situation seems to be accepted by all. In practice, CRM training becomes a mere formality intended to fulfill a regulatory requirement "on paper".

The lack of experience of those who have had to face these problems regarding CRM, both from the standpoint of operators and civil aviation authorities, could explain why there is no real oversight regarding the enforcement of CRM training at airlines. To the uncertainties involving the qualifications of CRM instructors at Spanair, as evidenced by the absence of a suitable monitoring mechanism in their procedures, we have to add the lack of training given to AESA inspectors in this area, as is obvious from their training records.

An in-depth review should be conducted, then, of possible solutions for changing the status quo in CRM training at airlines so as to ensure that a greater level of knowledge is transferred and that all parties involved are cognizant of its importance in order to achieve truly beneficial training. As a result,

REC 26/11. It is recommended that the European Aviation Safety Agency (EASA) perform investigations or studies intended to know the status of application and the real effectiveness of the current UE requirements applicable to Crew Resources Management (CRM). The results of these studies should permit to identify the weak points existing in this field and should contain proposals on how to strengthen them.

REC 27/11. It is recommended that the European Aviation Safety Agency (EASA) standardize the CRM training that must be provided to the operations inspectors of national authorities, and define the criteria that must be met by said inspectors in order to exercise their duties as inspectors in the area of CRM.

Other problems with this accident attributable in part to training and in part to the lay out of operational procedures are the defects noted in connection with the actions for selecting and checking the flaps/slats.

It was noted earlier that the accounts provided in interviews with Spanair pilots after the accident revealed that the captain was the kind "who asked for the flaps". Other interviewees responded that the selection of flaps was the typical item deferred after a set of actions. Such is the case when it is the first officer who requests permission from the captain to set the lever, and it was normal for the request to interrupt the captain's actions, or for the area around the airplane not to be clear, such that the captain was forced to postpone the selection of flaps. The existence of "deferred items" in the execution of procedures increases the possibility that they will be forgotten. In any case, there was a certain disagreement among the pilots regarding how to execute the procedure for selecting and verifying the flaps that was not spelled out in the operations manual.

Moreover, as noted in the company's operations manual, in the expanded checklists, the item to select the flaps/slats contains five tasks: three (3) of them to be executed by the pilot in the RH seat (R/P), one (1) by the pilot in the LH seat (L/P) and another by both. In the normal checklists, however, which are the ones really used by the pilots when executing procedures, the flaps/slats item is the last one (ninth) in the "After start" checklist, and is intended to be carried out by the pilot in the RH seat. There exists, therefore, an inconsistency between the two checklists that could lead to confusion in pilots regarding the actions to be carried out by each when executing the tasks necessary to configure the airplane. In contrast, examples that do not exhibit such inconsistencies can be seen by reviewing the remaing items in the "After start" checklist, whose execution is assigned to a pilot (R/P, L/P or P) based on the actions being carried out in the expanded checklist. Therefore, in keeping with the guidelines listed in the manual itself, it would have been more appropriate to have specified in the normal checklists that the flaps/slats item contains actions and checks to be performed by both pilots, using the letter "P" instead of "R/P".

No written guidelines were found either that specified how to select flaps/slats during simulator sessions. As mentioned earlier, an internal Spanair audit in November 2008 discovered that the establishment, development and use of procedures and checklists, the tasks sharing between the PF and PNF, cross-checks and the verification of critical actions were all areas that exhibited a notable lack of clarity at the company.

The deficiencies in the design of the checklist to check the flaps/slats and the absence of detailed explanations in the operations manual arose during simulator training and resulted in the uncertainties that were evident in the pilots during the interviews.

As a result, it is recommendable that Spanair clarify the method for setting the position of the flaps/slats and verifying the setting both in its operating and training procedures.

REC 28/11. It is recommended that Spanair expand its operations and instructional procedures to clearly specify the methodology and tasks sharing to be used by flight crew members when executing and verifying critical actions, like selecting the position of the flaps and slats.

REC 29/11. It is recommended that Spain's Aviation Safety Agency (AESA) ensure that the operational and instructional procedures at companies that operate MD-80 series airplanes clearly specify the methodology and tasks sharing to be used by flight crew members when executing and verifying critical actions, like selecting the position of the flaps and slats.

2.3.8. *Safety culture within the Spanair operations organization. The Flight Data Monitoring (FDM) program*

The operator had an accident prevention and flight safety program as specified in EU OPS 1.037. As required by regulations, it had an event reporting system and a program for analyzing flight data.

The investigation revealed that very few events were reported. Despite that, the Flight Safety Department studied the information reported and communicated its findings via publications. Therefore, a greater number of reports would have given the department a better knowledge of the conduct of operations.

In order for these systems to be effective, confidence must be instilled in flight crews. The limits must be clearly established, then, so that all of the players involved know the rules of the game. As has been established in various forums, a safety culture is an informed culture where members of the organization are alert to the ways in which the system's defenses can be breached or bypassed[125]. Only when the proper guarantees are given that allow the members of the organization to know the limits will information flow adequately.

The Flight Data Monitoring (FDM) programs mandated by EU OPS 1.037 had only been implemented on the A320 fleet. In fact, the study and analysis of the data obtained through this program had already identified discrepancies and resulted in corrective measures.

The data analysis program had also been started for the MD fleets, but had not been implemented to the same degree as that for the A320 fleet, meaning that all of the data had not yet been analyzed. As a result, no possible deviations were identified. During an internal check made in April 2008 intended to verify the degree of compliance with the new operational regulations that would go into effect in July 2008, it was noticed that the installation of the QARs in the MD fleet had not been completed yet. EC-HFP had been outfitted with the QAR for two months before the accident, and its data had been downloaded at some point. The last time that the storage disk was replaced was in early August. Apparently it still had storage capacity left on the day of the accident. When an effort was made to recoved the data after the accident, it was noticed that they had not been recorded correctly and that the disk still contained data from an earlier period when it had been installed in another aircraft's recorder. The program was still being phased in at that time and the presence of such errors during this period is regarded as normal. As more time elapses after the implementation of these programs, it would be recommendable to ensure that the operators' programs mature by reviewing the lessons learned from the implementation phase and the progress made in terms of incidents and errors.

[125] Achiving a safe culture: theory and practice. James Reason. Departament of Psychology, University of Manchester. Work & Stress, 1998, vol. 12, No. 3 293-306.

The investigation also revealed that the data being provided to the FDAU by the number 2 digital flight guidance computer (DFGC) for recording on the DFDR were corrupt, and thus unusable. The EU OPS regulation in effect at the time of the accident, and now, has no requirement to check for the proper operation of the cockpit voice and flight data recorders, not only in terms of ensuring that the recorders are recording data, but that the data have sufficient quality and consistency. Such a requirement is now in effect in European countries like France and the United Kingdom, pursuant to ICAO Annex 6, and the EASA has initiated a regulatory process with the same aim that is scheduled for completion in April 2012. It is hoped, then, that this measure will resolve data integrity problems such as those encountered during this investigation.

2.3.9. *Procedural compliance. Line Operations Safety Audits (LOSA)*

We have already noted that one of the basic tenets of CRM is discipline in executing procedures and checklists. In a multicrew cockpit setting, this concept includes having one pilot perform or verify tasks while the other pilot verifies or cross-checks to ensure that the actions or verifications, as required, are carried out.

Over the course of the operations of the aircraft at Barajas Airport, there were deviations in the execution, verification and cross-check of actions and checklists. In chronological order, they may be summarized as follows:

- In the first taxi phase, the crew reported to Control that they had a problem when they were on the runway. They should have noticed earlier, while doing the "Taxi" checklist, that the EPR limit was too low.
- The captain called the Maintenance Control Center (MCC) in Palma on his cellular phone from the taxiway, even though the use of cellular phones was not allowed, as per company instructions, once the fasten seat belt sign was turned on.
- Upon returning to stand R11, the parking brake was engaged before the flaps were retracted, even though the procedure states to retract the flaps first, as part of the "After Landing" checklist, and then to activate the brake, in the "Parking" checklist, which comes later.
- While preparing for the accident flight during the performance of the "Before Start" checklist, the captain anticipated the replies to some of the items before they were read by the first officer. It is unlikely that the first officer could have checked the replies given by the captain before he himself had read the items.
- They then tried to contact Control to request start-up clearance, but they did so on the ground (GND) frequency, which was tuned in on the radio, instead of the clearance delivery (CLD) frequency. This confirms that the cockpit was not fully configured and that some systems and equipment were still in the same position as they had been after the engines were shut down upon arriving at stand R11.
- During the scan flow after engine start-up, the pilots are not heard on the CVR requesting flaps.

- Then, upon reading the "After Start" checklist, the captain interrupted the first officer before he could read the last item on said checklist, flaps and slats. The first officer, for his part, did not correct the captain or caution him that the checklist was not completed.
- Once cleared to taxi, the items on the "Taxi" checklist were done before the corresponding items were read on the checklist. There was no reply to last item, T/O Briefing. They should have seen, as part of the fifth item on the checklist, that the green READY light indicating the availability of additional reserve thrust was very likely off (as is the case when the slats are retracted (0°/RET)), instead of on, as required.
- While taxiing to the head of the runway there were conversations on the cockpit between the crew and a third individual who was in the cockpit on issues not related to flight operations.
- While reading the Final Items on the "Takeoff Imminent" checklist, the captain did not properly check the status of the flap lever or the flap and slat indicators, and the captain did not verify whether or not the replies being given by the first officer corresponded to the real condition of the systems.

Not all of these deviations were of the same nature or equally serious. From a human factors standpoint, some omissions or inadvertent actions can be explained, but other actions cannot be justified and could involve violations committed under the perception of underestimating the importance of procedures.

And yet the information obtained from various evaluations, whether internal or by companies like Boeing, SAS and AQS, and from the AESA inspections, as well as accounts from fellow crew members, show that the procedural compliance by the pilots involved in the accident and by the rest of the operations department as a whole was high. We have already commented on the adequacy of the methods that rely on the presence of authority inspectors or internal instructors inside cockpits to analyze crew performance, the associated resources required and the reliability of the results such methods yield.

In addition to Flight Data Monitoring (FDM), already in use, which aid in evaluating the real performance of flight crews during normal line operations, there are other reliable methods to improve human performance on cockpits.

Studies of deviations during the execution of checklists and monitoring[126], based on cockpit observations, highlight how difficult the task of identifying a gradual erosion in checklist execution is, since crews are not normally given feedback when they make a mistake. In robust systems, such as aviation, with regulations, practices and procedures that prioritize safety, errors made by crews very rarely have consequences that allow them to be identified, be noticed and recognized after the fact.

[126] Checklist and Monitoring in the Cockpit: Why Crucial Defenses Sometimes Fail. R. Key Dismikes and Ben Berman. NASA/TM-2010-216396.

Experiments have been conducted in which after a simulator session, each participant reviews and shares the deviations he noticed in others to show that receiving immediate feedback on how procedures are carried out makes crews much more aware of their drop in performance, which prompts them to remain alert.

Another formula for promoting fewer deviations in the execution of checklists and monitoring, and which has been shown effective in detecting threats and mistakes, is the use of inspections based on the LOSA (Line Operations Safety Audits) method. This type of audit has been promoted by the ICAO since 1994 and is based on cockpit observations during normal operations. Confidentiality and anonymity are guaranteed in the data gathering process. Quantitative data obtained from LOSA evaluations place the number of deviations and non-compliances during normal operating procedures at 1.85 per flight. The effectiveness of traditional methods such as supervision or line checks is clearly inferior.

As part of the initiatives being carried out in the European Union aimed at complying with the requirements listed in ICAO Annex 6[127] on the implementation of Safety Management Systems (SMS), consideration could be given to promoting and enhancing the conduct of LOSA audits so as to better identify the weak and strong points of normal operations at companies, and not simply develop strategies for controlling the risks that are identified, but rather promote those strategies that have been proven effective during normal operations and that cannot be implemented with a purely reactive approach. This would serve to complement the data gathering that is done as part of event reporting and the flight analysis program, as recommended by the ICAO Safety Management Manual (Doc 9859).

REC 30/11. It is recommended that the European Aviation Safety Agency (EASA) undertake regulatory initiatives intended to require commercial air transport operators to implement a program of line operations safety audits, as part of their accident prevention and flight safety programs.

2.4. Design aspects. The takeoff warning system (TOWS)

2.4.1. *The failure of the TOWS to provide a warning to the crew*

2.4.1.1. The relationship between the TOWS and the RAT probe. The R2-5 relay in the ground sensing system

The high temperature noticed by the crew during the first taxi phase indicated that the probe heater was energized on the ground. The system, however, is only designed to heat the probe when the airplane is in flight.

[127] ICAO Annex 6, amendment 30, published on 23 November 2006. The standards and practices recommended involving SMS were required by the ICAO as of 1 January 2009.

The way that the airplane detects whether it is on the ground or airborne is by way of electrical switches located in the nose gear. When the strut on the nose gear leg is compressed with the gear down and locked, i.e. when the aircraft is on the gorund, the switches close a circuit that energize a group of relays, the signal from which provides the ground mode indication. When the strut on the nose gear leg is extended, a condition that occurs when the nosewheel is not in contact with the ground, the switches open the circuits, deenergizing the relays, which is interpreted as air mode. Each of these relays supplies a ground-air signal to various systems that rely on this information in order to function properly. According to the manufacturer's Wiring Diagram Manual (WDM), the R2-5 relay routes electrical current to the RAT probe heater, such that with the airplane in the air the electrical circuit is closed and open when the airplane is on the ground. The R2-5 relay also supplies control signals to indications for avionics compartment fan (radio rack venting), to the AC cross tie and to the TOWS.

During normal operations, a signal is routed through the R2-5 relay to the TOWS when the airplane is on the ground. This signal is interrupted when the airplane is in flight. The R2-5 relay also connects the RAT probe heater when the airplane is in flight and disconnects it when on the ground.

As a result of this, the high temperature indication with the airplane on the ground and the failure of the TOWS to sound a warning during the takeoff run could be related to a possible malfunction of the R2-5 relay, which was recovered from the accident site and studied in an effort to determine whether it might have failed.

The initial analysis consisted of a visual inspection, a borescope inspection and a radiographic test, which included a high-resolution computerized tomography scan. Continuity and functional tests were also performed.

The radiographic test did not reveal any defects. The conductivity tests yielded values consistent with the relay's specifications. A ground fault was measured at one of its contacts, but it was also within admissible design limits.

The functional test that was done, however, revealed an anomalous behavior in the relay when it remained energized at a nominal 115V:

1. A general drop in the resistance values between terminals.
2. In section C, corresponding to the RAT probe heating circuit, contacts C1 and C2, which should be closed, managed to separate when the relay was heated. This behavior would not have any effect on the probe, since having contacts C1 and C2 join or separate does not open or close any circuits since contact 1 is unused. When this happened with contacts C1 and C2, no abnormality was noted with contacts C2 and C3, which are in the same section and do correspond to the RAT probe heating circuit. With the coil energized (airplane on ground), contacts C2 and C3

were apart, meaning the RAT probe would not be energized. With the coil deenergized (airplane in flight), the resistance measurements between these contacts indicated that they were touching, which would have heated the probe, consistent with their normal operating condition.

This test, therefore, failed to reproduce the condition in which RAT probe heating is energized on the ground.

During the second analysis, the relay's outer casing was opened so that its internal components could be studied. The continuity and functional tests were performed once again both before and after opening the casing. These tests showed normal values based on the relay's specifications. In this case, all of the relay's sections worked properly when the coil was energized with 115V. The insulation problems detected in the first analysis disappeared when the wire fragments that were joined to the relay's terminals were removed. Based on this, those problems could have been caused by noise induced by the power supply used or by electromagnetic interference between the field of the relay's own coil and the remaining wires.

In this second analysis, several configurations with "stuck" contacts were also simulated by clamping the contacts together.

- C2-C3, corresponding to a situation in which the RAT probe is heated in flight (normal operation)
- B2-B3, corresponding to the TOWS disabled in flight (normal operation), and
- B2-B1, corresponding to the TOWS disabled on the ground (faulty operation).

It was noted that in all of these conditions, the other sections, whose movement was unimpeded, worked normally. This implies that faults could result from a lack of movement in the contacts in one section that would not affect the operation of other sections.

During a third analysis, a metallographic test of the C2-C3 contacts, where signs of possible sticking had been detected visually, was conducted. This test showed that contacts C2 and C3 had fused together and later separated again. Since the surface features resulting from the separation of the contacts disappear when the two contacts fuse again, it was impossible to determine how often the two contacts had fused together, or whether the last time the contacts separated was before, during or after the accident. This finding is considered important to the events of the accident, since the fusing together of the C2 and C3 contacts could have prevented them from separating when the coil was energized (airplane on ground), meaning that the RAT probe heating circuit would remain closed through the fused contacts, heating the resistance element. If the joined contacts did not separate when the coil was energized and attracted the armature, then the RAT probe could have been heated on the ground on certain occasions, as happened on the day of the accident. This proven failure mode of the relay would explain the malfunction in the RAT probe heater. Moreover, the fusion and subsequent separation of the contacts could be indicative of an intermittent failure mode of the relay. If the contacts stuck weakly together, they could have separated as the relay vibrated during the airplane's motion on the ground, for example, which would impede the malfunction from being repeated on purpose, as could have happened during episodes of excessive RAT probe heating in the days prior to the accident.

The above, however, would not be related to a problem with the TOWS. The tests conducted during the second analysis showed that the restricted motion of one section of contacts did not affect the other sections. This restriction could result, as we have seen, from the contacts fusing together. If the fused contacts were C2 and C3, the operation of section B, which controls the operation of the TOWS, would remain unaffected, as shown by the tests. The analyses conducted, therefore, did not reveal any evidence of a fault in the relay that would have prevented the TOWS from working during the takeoff run immediately preceding the accident.

There might be other failure modes of the R2-5 relay that result in the simultaneous malfunction of the RAT probe heater and the TOWS. This would require a fault in the coil, such as a short circuit between the windings rendering it useless, or a problem with the relay's power supply, as shown by the ground test carried out by the NTSB over the course of the investigation using an MD-88 airplane at Washington Airport (see Section 1.16.7), and which showed how a limited failure of the R2-5, with the relay's power supply simulated disconnected, led to a fault of the TOWS. Both possibilities can be ruled out with regard to the accident, however. First, the tests conducted on the relay showed that the coil was working properly, meaning that its windings were in good condition. Second, the data from the investigation revealed no problems with the relay's power supply, which also supplies other relays on the left side of the ground sensing system and whose performance was also analyzed.

- The approach idle system
  As described in Section 1.6.2.8, this system uses the ground-flight signal from section A of relay R2-380 for the left engine, and the signal from section B of the R2-8 relay (which belongs to the right part of the ground sensing system) for the right engine. Both relays provide information to the engines on whether the airplane is on the ground or in the air, allowing the engine rpm's to be adjusted accordingly. In flight, the N2 rpm's in idle are higher than on the ground. If the R2-380 coil had not been energized on the ground, then flight idle rpm's would have been detected on the left engine, and therefore a higher N2 than on the right engine. This difference in rpm's was verified to be 15% in the tests carried out in October 2008 on the MD-88 in Washington. The DFDR recording revealed that while the aircraft was on the ground prior to the accident, both engines maintained similar idle rpm's. When the throttles were retarded, both engines showed N1 and N2 rpm values corresponding to ground idle (see Section 1.6.2.8). The R2-308 relay, then, must have had power available on the ground to energize its coil, and therefore so must relay R2-5.

- The stall warning system
  SWC1 on this system uses the ground-flight signal from section D on relay R2-58, which belongs to the left side of the ground sensing system, with SWC2 taking its ground-flight signal from section D on relay R2-6, part of the right ground sensing system. If for any reason the information between the left and right systems does not match, such as one system transmitting a ground signal and the other a flight signal, a Stall Indicator Failure (SIF) light illuminates in the cockpit. This condition was also reproduced in the MD-88 tests in Washington and also appeared during the MAP MD-83 incident in June 2007 (see Section 1.18.8.4 in this report). There is no evidence in this case, however, to suggest that such a warning was received. With the presence of the crew, maintenance personnel and other persons in the cockpit during the efforts to solve the RAT probe heater malfunction, such a warning could hardly go unnoticed, especially considering that a less significant indication such as a high probe temperature prompted the return of the aircraft to the stand. It is very probable, therefore, that the left stall warning system was working properly, which necessarily implies that the coil on relay R2-58 was energized on the ground, and thus so too was the coil of R2-5.

Continuing with the implications of a possible fault in relay R2-5 leading to joint failures of the RAT probe and TOWS, the maintenance records of several operators of MD-80 airplanes were analyzed. Information spanning 15 years was obtained on over 100 airplanes. These records revealed 26 cases of RAT probe heating on the ground. In 25 of them, the malfunction was solved by replacing the R2-5 relay. It was not possible to determine how long the relays that were replaced had been installed since these components are not traceable. The replaced relays were also not tested, thus it was impossible to ascertain their condition and whether the relays were within specification when they were replaced.

Data gathered by Boeing between the years 2000 and 2008 show 103 cases of improper RAT probe heating on the ground, though the problem in 13 of those cases was not a high temperature per se, but rather a deviation with respect to ambient temperature. This leaves 90 valid cases for the purposes of the study. In 72 of them, the problem was isolated to the R2-5 relay. The information provided by Boeing also revealed faults in the TOWS that appeared during the pre-flight operational test and which focused on the R2-5 relay. The investigation was also able to contrast an additional similar case based on an event involving Spanair in July 2009 (see Section 1.18.6.2.3 of this report).

In the days before the accident, three abnormal ground heating events involving the RAT probe were logged in the ATLB. When the operator's maintenance personnel attempted to resolve the problem, they could not duplicate the fault. What is more, the DFDR data indicate that an additional three cases of probe heating on the ground took place between 18 August and the day of the accident that were not recorded in the ATLB. These six cases were studied in order to obtain behavior patterns and correlations with other parameters recorded on the DFDR.

Some important conclusions can be drawn from all these data:

- Most (about 80%) of the reported RAT probe heating malfunctions were associated with a fault in the R2-5.
- There are cases in which a fault of the TOWS during its pre-flight check was directly linked with a fault in the R2-5. No information is available to estimate what percentage of faults detected during the pre-flight check of the TOWS are attributable to malfunctions in the R2-5 relay.
- Episodes of RAT probe heating on the ground are intermittent, such that periods of normal probe operation alternate with periods of abnormal heating.
- The probe temperature decreases as the aircraft's taxi speed increases, which hampers detection efforts by the crew.
- There may have been cases in which the probe heater was improperly energized and that went unnoticed by both flight crews and maintenance personnel.
- The high probe temperature anomaly can not always be reproduced when troubleshooting.
- None of the six high probe temperature episodes recorded on the accident airplane's DFDR took place during the first flight of the day, when the TOWS check would also have been performed.

In summary, all of the information analyzed leads to the probable conclusion that the high RAT probe temperature in this case resulted from the energization of its heater as a consequence of contacts C2 and C3 fusing together on the R2-5 relay. It is uncertain whether this possible fault in the relay led to the TOWS fault, leaving the TOWS operative and the RAT probe heater energized on the ground. There are other data, however, that directly link the RAT probe heating on the ground, faults in the TOWS and replacements of the R2-5 that suggest that a more exhaustive review of the reliability and the effects on the TOWS of a failure of relay R2-5 is warranted.

There is evidence that the R2-5 is the source of the malfunctions that affect the RAT temperature probe heater in a large percentage of cases. The 100-hour sample recorded in the accident airplane's DFDR was very valuable to ascertaining the symptoms that are present during episodes of RAT probe heating on the ground. The R2-5 has also been shown to be the direct cause of TOWS malfunctions. These factors may be related, which would mean that the R2-5 has failure modes that affect the RAT and the TOWS, modes that may be difficult to detect.

In addition, the R2-5 relays installed on a specific airplane are not trackable, since these components are replaceable and not identified individually. It is typical for parts like relays, including R2-5, to be treated "on condition", meaning that the maintenance actions that are carried out depend on the condition of the part. There are no specific checks involved, and therefore the data available to determine their reliability or service life are limited. Neither the manufacturer of the R2-5 relay or of the airplane have those data. In this case, the R2-5 relay had been manufactured in 1992, though as follows from the aforegoing discussion, it is unknown whether it was installed on the airplane when its assembly was completed in November 1993. Suposssing that the relay had been installed new on the airplane, it would have shared in the airplane's 28133 cycles. For each airplane cycle (number of takeoffs), the relay can be estimated to have used two cycles[128], for an accumulated total of 56266 lifetime cycles, which is less than its expected service life of 100000 cycles. Even if the R2-5 relay did fail in this case, this would not suffice to draw general conclusions regarding the reliability of these relays. That would require an exhaustive check of service histories, if available, so as to draw more rigorous conclusions.

In summary, given the importance of the R2-5 relay to the operation of the TOWS, an evaluation should be conducted of the relay's operating conditions, its real service life, its reliability and its failure modes. Specific maintenance instructions should be defined for this component based on the findings of said evaluation. Therefore:

REC 08/09. It is recommended that the European Aviation Safety Agency and the Federal Aviation Administration (FAA) of the United States require the Boeing Company to evaluate the operating conditions, in-service life, reliability and failure modes of relays in position R2-5 of the ground sensing system in the DC-9, MD-80, MD-90 and B-717 series of airplanes and that it specify a maintenance program for this component based on the results of said evaluation.

2.4.1.2. Other possible TOWS failure modes

Based on the characteristics of the TOWS system, a takeoff warning fault with the flaps/slats retracted could result as a consequence of different failure modes of the components that comprise it. In addition to those already studied in relation with the R2-5 relay, basic TOWS faults could result from the following:

1. Failure in wiring associated with the R2-5 relay

   With contacts B1 and B2 in the relay open with the airplane on the ground, the relay transmits a flight signal, leaving the TOWS inhibited. The same effect would result from an open circuit in the wiring that connects the relay to the CAWS or in the wiring that supplies 17.3V DC to section B of the relay. These potential faults could not be checked, since as a consequence of the accident and the resulting fire, entire sections of electrical cables from every airplane system were destroyed.

[128] An airplane cycle comprises a ground-air-ground sequence. Assuming the airplane's electrical power is disconnected on each stopover, the relay's winding will be energized twice during each airplane cycle, once on landing and then again when power is supplied for the next flight.

2. Fault of microswitches in the engine levers or in their associated wiring.

   In order for the TOWS to work, it is necessary that both engine throttle levers be advanced. A failure of any of the microswitches or their associated wiring could inhibit the TOWS. As indicated in 1.12.9.7.2, the center pedestal of the throttle quadrant had been severely damaged by the impact and had detached from its structure. This made it impossible to analyze the microswitches on the throttles or the wires connected to them.

3. Simultaneous faulty signals for slats in takeoff position and of the flaps adjusting wheel in the takeoff elevator trim position calculator.

   As described in Section 1.6.2.1.2.2, there is a small wheel on the adjustment panel where the flaps value is set for takeoff. When the flaps value is input, an axle moves that crosses the pedestal until it reaches the right side, where it moves a hinge that positions a flaps warning microswitch for takeoff. When the selection input into the flaps/slats control panel matches the value input into the wheel on the takeoff adjustment panel, a cam presses the flaps warning microswitch, which sends a signal to the TOWS, indicating that the flaps selection is correct. In this case, the TOWS flaps warning will not activate. If this switch failed, the TOWS flaps warning may not be activated in the event that the selection input on the wheel in the adjustment panel did not match the position of the flaps/slats control lever, but this would not affect the slats warning signal from the TOWS.

   In order for the slats warning not to activate if the slats were not in a takeoff position, there would have to be a fault in the transmission of the slats signal from the PSEU to the TOWS.

   In other words, in order for the TOWS flaps and slats warnings not to activate, there would have to be two simultaneous independent faults, which is considered to be highly unlikely.

4. Fault of the Central Aural Warning System (CAWS) in the cockpit, either due to a fault in one of its internal components or by the interruption of electricity from the number 2 power supply.

   As indicated in Section 1.12.9.6, only the front panel of the CAWS unit was recovered. Thus, it was not possible to examine its internal components or the connections between them or between the unit and other aircraft systems. The conversations recorded on the CVR during the maintenance tasks make no mention or reference to the CAWS FAIL light being on in the EOAP (Electronic Overhead Annunciator Panel), indicative of a fault in the unit. It seems unlikely that during the maintenance activities that were being carried out in connection with the RAT probe heater that such a light would have gone unnoticed. Thus, a fault of the TOWS caused by this factor can be ruled out.

The sounds recorded on the CVR from the stall warning system were used to verify that the TOWS power supply was available. As noted in Sections 1.6.2.2 and 1.6.2.5, the CAWS components involved in the generation of TOWS warnings, and the SSRS1 module, which is also a part of the TOWS, receive their power from the same source, the number 2 power supply, of the three that supply the CAWS unit. The presence of an echo in the sound of the synthetic "stall" voice heard on the CVR was used to verify that both of the two modules, SSRS1 and SSRS2, were sending a signal to their respective speakers, SSRS1 to the captain's and SSRS2 to the first officer's. Thus, the CAWS components that trigger the TOWS were powered, meaning that a TOWS failure from this cause can be ruled out.

No definitive conclusions can be drawn from the material evidence or the data collected regarding the fault that affected the TOWS. Even so, this analysis and the circumstances of the accident require focusing also on the means available to the crew for receiving an indication that the TOWS is inoperative, in light of the possibility that some failure modes may be difficult to detect.

The ground test conducted in an MD-88 at Washington's Reagan Airport showed how a limited failure of the R2-5, which was simulated by disconnecting the relay from its power source, resulted in a failure of the TOWS. With a flaps and slats configuration that was inappropriate for takeoff, when the throttle levers were advanced, the TOWS alarm did not sound. The simulated failure of the R2-5 was also not apparent to test participants in that the inoperable condition of the TOWS would not have been noticeable. The only abnormal reading was an elevated RAT probe temperature. This indication by itself does not send a clear and unequivocal message to the crew that there may be a problem with the R2-5 relay and that the TOWS is inoperative. What is known about the Spanair accident is consistent with the conditions that were reproduced during the test. If these same circumstances existed, the Spanair crew could hardly have correlated the high temperature of the RAT probe, the failure of relay R2-5 and the inoperability of the TOWS. Maintenance personnel who reported to the airplane to solve the problem were also unaware of these connections[129].

There are other TOWS faults that are unrelated with the RAT probe and R2-5 relay that would be undetectable by the crew. Of those considered here, both the failure modes associated with the loss of the CAWS power supply and with the microswitches in the throttle levers, as well as those involving continuity faults in the wires of section B of relay R2-5, are not identifiable by the crew since they yield no cockpit indications. Even if the TOWS had been checked while preparing the cockpit, if any of these faults had appeared subsequent to that check, it would have gone unnoticed by the crew, which would have taken off with the TOWS inoperative.

[129] The subject of the maintenance instructions available for detecting the source of and solving the problem of RAT temperature probe heating on the ground on these airplanes was addressed in a safety recommendation issued by the CIAIAC in February 2009 (REC 01/09).

2.4.2. *Checks of TOWS prior to takeoff*

In keeping with the company's Operations Manual in effect at the time of the accident, the crew should check the operation of the TOWS during the performance of the Prestart checklist before the first flight of the day[130]. On subsequent flights, only the switch positions have to be checked, but not the operation of the systems.

The manufacturer's Operations Manual (FCOM) specified that the check of the TOWS should be done prior to the first flight of the day and on "through flights", although the meaning of that expression was not defined in the manual. After the accident, in October 2008, the operator revised its Operations Manual and specified in the Prestart checklist that the TOWS operation be verified prior to each flight.

As a result of the accident of a Northwest Airlines MD-82 at the Detroit airport[131], McDonnell Douglas issued a telex in September 1987 to all the operators of that airplane type, recommending that the TOWS be checked prior to each flight. At the time the accident report was issued, it was stated that every operator in the United States had incorporated that change to its operating procedures. The manufacturer modified the FCOM in March 2009 to include the meaning of the term "through flight", clarifying that it referred to intermediate flights in a series of flights with the same crew and the same airplane.

Based on the initial data on the investigation provided by the CIAIAC, the EASA issued Airworthiness Directive AD 2008-0197 on 29 October 2008. This directive amends the Airplane Flight Manual for DC-9, MD-90 and B717 series airplanes by including a mandatory check of the TOWS before engine start-up on each flight. It is applicable to every operator of these aircraft in the European Union.

After the EASA issued Airworthiness Directive 2008-0197, the FAA in the United States, on 5 November 2008, issued a Safety Alert For Operators (SAFO 08021[132]). The SAFO makes reference to the McDonnell Douglas telex recommending that operators perform the TOWS test prior to each flight. The SAFO emphasizes that the risks of improperly configuring the slats and flaps can be mitigated by adhering to TOWS operating procedures (SOP) and maintenance procedures. The message recommends that Operations, Maintenance, Flight Safety and Training Managers revise their procedures to make them effective in ensuring a proper TOWS operation, and that they train their maintenance and operations personnel properly. The SAFO refers to the procedures recommended by the manufacturer as the primary reference.

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130 In this case the first flight of the day was defined as the first flight made after 00:00 UTC.
131 The NTSB conducted the investigation of the accident, whose results are presented in report No. NTSB/AAR-88/05.
132 "Importance of Standard Operating Procedures (SOP) as Evidenced by a Take-off Configuration Hazard in Boeing DC-9 series, MD-80 series, MD-90, and B-717 Airplanes".

As mentioned previously, the data from the investigation suggest that the TOWS did not generate an improper configuration warning. In this case, a check of the system prior to the flight could have detected a potential fault, or would have at least increased the chances of detecting it. Spanair's procedures did not stipulate that the system be always checked prior to each flight. The instructions contained in the manufacturer's FCOM at the time of the accident were not fully clear on the matter since the meaning of the expression "through flight" had not been defined. The telex used by McDonnell Douglas over twenty years ago to inform of the procedural changes after the MD-82 accident in Detroit, and which recommended the TOWS be checked before each flight, may not have had the desired effect on some airlines. Moreover, both the manufacturer's FCOM and the recommendations in the telex are guidelines for the operators to aid them in drafting their own procedures. The operators are free to deviate from the manufacturer's recommendations with the involvement[133] of the civil aviation authorities under whose regulations the operators engaged in their activities.

Both the operator and the manufacturer revised their procedures following the Barajas accident. Spanair now requires that the TOWS check be performed before every flight, in accordance with the recommendations of the manufacturer, which has provided a detailed definition of the term "through flight". Additionally, the European Aviation Safety Agency now requires all operators in the European Union to conduct the check, in keeping with the changes made to the procedures section in the MD-80 series aircraft flight manuals.

The CIAIAC shares in the philosophy expressed in the SAFO issued by the FAA, stressing the need to adhere to the operational and maintenance procedures made available by the manufacturer for that system, including the recommendation that it be checked before each flight. By not being obligatory, however, the measures proposed in the SAFO may not have the desired effectiveness from an operational safety standpoint.

In this sense, the action taken by the EASA, which modified the flight manual for airplanes of this type, is thought to be a more appropriate response, though it is restricted exclusively to operations in the European Union. The issuance of mandatory instructions, in the way of airworthiness directives, by the Authority responsible for the type design for these airplanes, would undoubtedly have a more wide-reaching effect on the global MD-80 fleet, due to the adoption of this Airworthiness Directive that would in practice take place in many of the States of registration, increasing the

[133] The involvement of civil aviation authorities with regard to the procedures and checklists of airline operators has different effects, depending on the legal terms (approval, acceptance, oversight, etc.) customary for describing the responsibilities of said authorities. For example, the EU OPS regulations define the terms accepted and approved as follows:

"accepted" or "acceptable" means not objected to by the Authority as suitable for the purpose intended
"approved (by the Authority)" means documented (by the Authority) as suitable for the purpose intended.

likelihood that both operators in the United States and around the world outside the European Union performed the TOWS check prior to each flight.

Therefore:

REC 07/09. It is recommended that the Federal Aviation Administration (FAA) of the United States establish mandatory airworthiness instructions to modify the procedures contained in the aircraft flight manuals for the Boeing DC-9, MD-80, MD-90 and B-717 series so as to include a functional check of the TOWS prior to each flight.

2.4.3. *Condition of RAT for dispatch*

A high percentage of the reported cases of RAT probe heating on the ground were solved by replacing the R2-5 relay. In some of these cases, the relay was found "stuck" in the "air" position.

Given that a failure of the R2-5 relay of these characteristics would not only result in the RAT probe being heated on the ground, but also in the TOWS receiving an "air" signal, and thus be inhibited, it stands to reason that item 30.8 of the MMEL should include a check of the TOWS as a required maintenance procedure (M) before the airplane could be dispatched, especially considering that the design of the TOWS on this airplane model, which is a NO GO[134] component, does not provide any warning to the crew when it is inactive. This situation raises a possible inconsistency in the MMEL, since the TOWS can fail after its pre-flight check without providing any indication to the crew, meaning the airplane could be in a non-airworthy condition without the crew being aware of this fact.

Item 30.8 of the MMEL might be interpreted to mean that a TOWS check is not necessary since the TOWS must be checked prior to each flight, in keeping with Boeing's procedures for the MD-80 model.

If these reasoning were valid for item 30.8 of the MMEL, it should have applied to other items as well. And yet, item 32.8, which deals with the PARKING BRAKES ON annunciator system, states that this system can be inoperative as long as the TOWS is working properly[135]. That is why it includes a maintenance (M) procedure for checking the operation of the TOWS.

[134] The NO GO components are those that affect the airworthiness of the airplane and which are not included in the MMEL/MEL, and which therefore must be operable before the start of the flight. Such is the case with the TOWS.

[135] The MMEL also requires that the anti-skid system work properly in order for the airplane to be dispatched with the PARKING BRAKES ON annunciator system inoperative.

We must conclude then that the performance of the TOWS check could be a consideration in every MMEL item, such as 30.8, involving systems that are linked to the TOWS, since a malfunction in the TOWS could manifest itself through a fault in a different system, such as the RAT probe heating.

2.4.4. *Considerations on the criticality and reliability of takeoff warning systems in the MD-80 generation of airplanes*

At the time of the MD-80 series certification[136], there were no requirements for TOWS. This requirement was imposed in March 1978 with the inclusion of paragraph 25.703 in the FAR 25 certification regulation. Even so, many airplanes, including the MD-80, that had been certified previously, had a TOWS.

FAR paragraph 25.703 requires that the TOWS provide the crew with an aural warning during the initial phase of the takeoff run when the airplane is configured such that a safe takeoff cannot be guaranteed. The criterion used by the FAA to certify these systems was to consider them as a back-up for crews, meaning they were classified as non-essential systems when it came to defining their criticality. This category is reserved for those systems whose faults are not considered to result in an unsafe condition in the aircraft, nor reduce its performance nor the crew's ability to handle adverse operating conditions.

In the European Union, the European Aviation Safety Agency adopted specification CS-25 as the certification code for large airplanes in October 2003. This regulation comes from the JAR-25 standard, developed within the framework of the JAA[137]. The requirement to install a TOWS is in paragraph CS25.703, in effect since January 1979[138]. In general, the requirements and criteria of the FAA and European Aviation Safety Agency with regard to the TOWS are the same.

The study[139] undertaken by the FAA after the Northwest Airlines MD-82 accident in Detroit shows that over the period from 1958 to 1987, there were 12 accidents or major incidents worldwide that involved an inadequate takeoff configuration, excluding the Detroit accident. Six of those accidents involved an improper flaps or slats configuration. In every case, the TOWS outfitted in those airplanes was designed

[136] The certification regulation for the MD-82 was FAR 25, up to amendment 25-40, which went into effect on 2 May 1977.

[137] The Joint Aviation Authorities (JAA) comprises the civil aviation authorities of most European, and some non-European, States. Its mission is to standardize civil aviation regulations in Europe and to harmonize them with those of other States. Its responsibilities in this domain ceased on 30 June 2009, at which time they were under the purview of the European Aviation Safety Agency.

[138] JAR-25, Amendment 5.

[139] Review of take off configuration warning systems on large jet transports. Aicraft Certification Division. FAA. April 29, 1988, pp., 22-23.

according to the requirements applicable to systems whose level of criticality was classified as non-essential. As a result, a reliability analysis was not required when they were certified, even if in seven of these accidents, the configuration problems involved were not covered by the first rudimentary designs of the TOWS.

Counting only the accidents referred to in this report (see Section 1.18.8), including the accident involving EC-HFP, in which there were errors in the takeoff configuration, there were 475 fatalities. According to NTSB figures, there have been 49 accidents of this nature worldwide since 1968.

In the Northwest Airlines MD-82 accident in Detroit, the NTSB concluded that there was an absence of electrical power to the TOWS that impeded it from warning the crew of the inadequate takeoff configuration. The investigation was able to narrow down the electrical fault to a circuit breaker in the CAWS power supply circuitry. Whether this absence of electrical power was due to a breaker malfunction or to an intentional action that opened the breaker could not be determined.

In the accident of the Delta Airlines B727 in Dallas, the TOWS failure occurred because the electrical switch for the circuit that activates the TOWS horn did not close. That switch is associated with the advance of the throttle for the number 3 engine. The accident report revealed that the TOWS installed on the B727 suffered from intermittent failures that were not easily detectable and that the system had significant reliability concerns. As a result it was recommended that the FAA study the system in depth, placing special emphasis on the installation of the switch on the throttle lever and that an airworthiness directive be issued making mandatory whatever changes were derived from the study[140].

In the accident report for the Mandala Airlines B737-200, the Indonesian NTSC thought it was possible that the TOWS had not sounded during takeoff with the flaps and slats retracted. The investigation did not go any further in confirming that possibility.

Data from the Spanair MD-82 accident indicate that it is possible for a fault in relay R2-5 to render the TOWS inoperative.

The Detroit, Dallas and Barajas accidents show that the TOWS can be disabled on the ground by a simple fault in one of its components. The reports for the Detroit and Dallas accidents called into question the reliability of certain TOWS components in airplanes like the B727 and the MD-82. The investigation into the Spanair accident has shown that a fault in one of the TOWS components, the R2-5 relay, can lead to a failure of the system. Its classification as a non-essential system is behind these problems. The TOWS on airplanes of the MD-80, B-727 and B737-200 series lack redundancy because

[140] NTSB Safety recommendations A-88-125 and A-88-126.

the function of the TOWS is viewed as one of back-up for the crew in its preparations for the flight. Experience, however, has shown that the human factor, in conjunction with first-generation takeoff warning systems, is not enough of a barrier to prevent accidents resulting from configuration errors.

In contrast, the MD-80 series Master Minimum Equipment List (MMEL) does not allow the airplane to be dispatched with the TOWS inoperative.

A fault of the TOWS requires that the airplane be grounded until the system is repaired prior to flight, as per the Master Minimum Equipment List. The same fault can go unnoticed by the crew since the system does not provide any type of warning to alert it that the TOWS has failed.

Another possibility is that a failure of the TOWS could occur after the TOWS is checked by the crew but before takeoff, thereby leaving the airplane in a non airworthy condition without the crew being aware of the situation.

It is inconsistent, therefore, to maintain the "NO GO" [141] nature of the TOWS in the MEL without modifying its condition as a non-essential system and which exempts it from having additional safety devices such as, among others, a crew warning in case of a system failure or a redundant design that makes it less vulnerable to a simple fault, as was the loss of electrical power to the TOWS in the case of the Detroit accident in 1987, or as might be the case of a failed R2-5 relay that supplied the ground-flight signal in the Barajas accident.

In reply to a safety recommendation[142] issued by the NTSB in its report on the Detroit accident, the FAA published circular AC 25.703.1 in 1993. The EASA counterpart is AMC 25.703, which establishes the criteria currently accepted by the European Authority for certifying the TOWS designs in transport airplanes. According to these criteria, previously designed TOWS could not be regarded as having a suitable level of safety when the consequences of a fault in the system coupled with an inadequate takeoff configuration could lead to major or catastrophic fault conditions[143]. Therefore, in keeping with these guidelines, the safety level of these systems should be increased to classify them as essential, in accordance with FAA AC 25.1309-1A and its EASA counterpart, AMC 25.1309, such that both the FAA's and the EASA's current interpretation is that of considering the inoperability of the TOWS as having severe effects on safety.

[141] A "NO GO" element refers to those systems or components whose fault prevents the dispatch of the airplane as per the MEL.

[142] Recommendation A-88-66 issued by the NTSB asked the FAA to develop and issue guidelines for the design of the CAWS to include a determination of the warning to be provided, the criticality of the provided warning and the degree of self-monitoring these systems should have.

[143] AC 25.1309 defines system criticality based on the severity of the effects that a failure would have on safety. The failure conditions are classified according to the severity of their effects as minor, major and catastrophic.

The 1988 FAA study mentioned earlier (see footnote 139) stated that the TOWS like the one outfitted on airplanes of the MD-80 generation would comply with requirements in place at the time in terms of reliability if the checks recommended by the manufacturers were followed. But it also recommended that the reliability of the TOWS be improved by requiring that these systems meet the same requirements as essential equipment. In the end, however, the in-service experience available at the time and the record of accidents until then apparently did not justify the adoption of that measure.

Given the current situation, and keeping in mind the history and the consequences of accidents due to faults in the takeoff configuration which coincided with single failures in the warning systems, it does not seem sufficient to address only those problems which have been discovered with the design of these systems, such as the switch on the B727 throttle lever or the reliability of the breakers in the power supply circuit as was the case with the MD-82 in Detroit, or a possible fault in the R2-5 relay now. These systems have to be revised in depth so that they can provide crews with an effective defense while minimizing latent fault conditions that could affect their components. Therefore:

REC 09/09. It is recommended to the European Aviation Safety Agency and to the Federal Aviation Administration (FAA) of the United States that the design of Takeoff Warning Systems (TOWS) be reviewed in transport airplanes whose certification standards did not require the installation of such systems or which, if they did require it, did not apply to them the guidelines and interpretation provided by AMC 25.703 in the case of the EASA, or circular AC 25.703 in the case of the FAA. The goal of this review should be to require that the TOWS comply with the applicable requirements for critical systems classified as essential in CS 25.1309 and FAR 25.1309.

2.4.5. *Certification of critical systems*

Apart from accidents, the database of the NASA notification system (ASRS) yielded 52 cases in which pilots reported TOWS warnings on various airplanes which fortunately did not end in an accident. The rate of these errors, which are normally the result of oversights, could hardly have been anticipated at the time airplanes of the MD-80 generation were certified. It seems necessary, then, that certifying authorities take into consideration the history of these events along with all the design options available when certifying current and future airplanes.

The history of accidents has shown that pilots alone cannot provide an adequate barrier against mistakes. Takeoff warning systems have become extremely useful tools for alerting the crew and in practice represent one of the last safety barriers available to them to keep from taking off without a correct configuration. These systems must be considered as essential in light of the obvious human limitations against errors. The criteria currently applied by certification authorities consider these factors when evaluating the suitability of the TOWS, but they are not applied systematically since they were not properly incorporated into the regulations. We have seen how the TOWS in airplanes of the MD-80 generation can be rendered inoperative by a simple fault for which the crew has no warning. Current certification standards would also allow these conditions to be present in the design of modern airplanes. As a result, this Commission believes that certifying authorities should review the requirements demanded of these systems so as to increase their reliability and the protection they provide. Therefore:

REC 10/09. It is recommended that the European Aviation Safety Agency and the Federal Aviation Administration (FAA) of the United States revise regulations CS-25 and FAR 25, respectively, on the certification of large transport airplanes to add a requirement that ensures that Takeoff Warning Systems (TOWS) are not disabled by a single failure or that they provide the crew with a clear and unequivocal warning when the system fails.

An NTSB study[144] on critical systems in transport airplanes published in 2006 made two safety recommendations[145] that highlighted the need to consider the human error variable in evaluating the operational safety requirements for the certification of critical systems subject to structural failures. It also asked that the aviation industry import those methods already adopted by other transportation sectors, such as the automotive, for the ongoing assessment of these evaluations throughout the life cycle of the airplanes in keeping with operational experience.

These recommendations are also considered pertinent to the systems, such as the TOWS, whose designs should make allowances for the lessons learned from accidents and serious incidents and for how these systems interact with human actions. The TOWS, therefore, should be understood as being within the intended scope of these recommendations that the NTSB issued to the FAA, and thus the EASA should also consider the history of pilot errors when configuring airplanes for takeoff when assessing the behavior of these systems to determine whether the assumptions made during the certification of the design are still valid. Therefore:

REC 11/09. It is recommended that the European Aviation Safety Agency revise the accompanying guidelines and the clarifying material for the CS-25 certification regulations for large transport airplanes so as to consider the human errors associated with faults in takeoff configurations when analytically justifying the safety of the TOWS, and to analyze whether the

[144] National Transportation Safety Board, Safety Report on the Treatment of Safety-Critical Systems in Transport Airplanes, Safety Report NTSB/SR-06/02 (Washington, DC: NTSB, 2006).
[145] NTSB recommendations A-06-37 and A-06-38.

assumptions used when evaluating these systems during their certification are consistent with existing operational experience and with the lessons learned from accidents and incidents.

2.5. Maintenance aspects

2.5.1. *Instructions in the manufacturer's manual involving a malfunction of the RAT probe heater*

Over the course of the investigation, the information contained in the various manuals written by the airplane's manufacturer for both the MD-82 and for other models derived from the same original type design (DC-9) was analyzed in an effort to determine if the causes for RAT probe heating on the ground can be clearly identified.

The airplane manufacturer's maintenance manual (AMM) contains, in Chapter 30-30-00, on anti-ice protection, a section titled "PITOT AND STATIC – TROUBLESHOOTING", which specifies the maintenance actions to take in order to detect the source of malfunctions in different heating devices, including the RAT temperature probe heater.

The instructions only consider the case in which the heating system does not supply heat to the probe when it should, namely, in flight. No specific indications are provided regarding the actions to take when heat is being supplied when it should not be, that is, when the airplane is on the ground.

Boeing states that the multiple references in its Maintenance Manual (AMM) and in its Wiring Diagram Manual (WDM) to the RAT probe show that the heating should not be on when the airplane is on the ground. The information from this accident also reveals that both Spanair maintenance personnel and crews realized that having the RAT probe heater energized on the ground was an abnormal occurrence. In the manufacturer's opinion, there are several pages in chapters 30-30-00, 34-16-02 and 34-18-00 of the Maintenance Manual (AMM) and in chapter 30-31-02 of the Wiring Diagram Manual (WDM) that would be useful for detecting the source of this malfunction. These pages contain a basic description of the RAT heating system and block diagrams of electrical circuits that show the circuit and its components, including the relationship between the RAT heater and the R2-5 relay, which label the electrical wires and the positions of the contacts on relay R2-5, and which also include tests to check for the proper operation of the RAT heater. There is, however, no section specifically devoted to detecting the source of RAT probe heating on the ground.

According to the manufacturer, it does not seem necessary to include a troubleshooting process specifically for this problem, since applying reasoning similar to that contained in the section "PITOT AND STATIC – TROUBLESHOOTING", which is intended to aid in detecting the origin of a fault in which heating is not supplied to the probe while in flight, would help to identify the reason as to why heat is being supplied when the airplane is on the ground.

However, in keeping with the very criteria used by Boeing to assess the need to provide troubleshooting procedures, the malfunction exhibited by the RAT heater met the conditions that required that it be specifically addressed. This was a fault that manufacturers knew about through operator reports. Records show that Boeing had received 103 reports of improper RAT probe heating. The operators had solved the problem in various ways, with the replacement of the R2-5 relay being the most common, but some had also replaced the probe, changed out the TRI or reset the K-33 breaker. The investigation has also gathered practical information from operators of this airplane model regarding the actions that were actually used to detect the source of this malfunction and its subsequent resolution. In general, there was no unique series of steps taken by maintenance personnel, even within the same operator; rather, these steps often depended on the experience of the maintenance personnel. This information implies that the descriptions or diagrams in the manuals might be insufficient to easily locate the source of the malfunction, which satisfies one of the criteria utilized by Boeing to determine the need for troubleshooting instructions.

In light of this information, it may be concluded that there is no specifically titled section in the Maintenance Manual, such as "High RAT temperature indication on the ground", whose sole purpose is to detect the source of the fault involving the heating of the temperature probe on the ground. The information necessary for detecting said source is contained in different paragraphs and block diagrams in a chapter in the Maintenance Manual, which could be complemented with that material present in the Wiring Diagram Manual. This, then, would require additional effort by maintenance personnel to interpret this information in order to locate the source of the malfunction.

The steps to take, then, are not specifically outlined in the manufacturer's manual; instead, the process relies on the ability of maintenance personnel to look for and interpret the information provided.

The CIAIAC believes that this situation should be corrected since equal weight is not given in the instructions for ensuring continued airworthiness to the two possible anomalies involving the probe heating system, namely:

- Not heating when it should (airplane in flight).
- Heating when the airplane is on the ground (as was the case here).

REC 01/09. It is recommended that the Federal Aviation Administration (FAA) of the United States and the European Aviation Safety Agency (EASA) require the manufacturer, the Boeing Company, to include in its Aircraft Maintenance Manual (AMM) for the DC-9 and MD-80 series, in the Troubleshooting Manual (TSM) for the MD-90 series, and in the Fault

Isolation Manual (FIM) for the 717 series, specifically identified instructions to detect the cause and to troubleshoot the fault involving the heating of the RAT temperature probe while on the ground.

2.5.2. *Instructions in the Minimum Equipment List (MEL) concerning the RAT probe heating malfunction. Interpretation of the definition of an inoperative element*

During the investigation it was noted that the interpretations regarding the use and applicability of the MEL are varied insofar as the operation of the RAT probe heating on the ground.

According to the definition contained in the preface to the MMEL, an aircraft system and/or component is considered inoperative when it exhibits a fault that prevents it from complying with its intended purpose and/or it is not operating consistently and normally within its approved limits or tolerances. This definition is practically identical to the one contained in the Spanair Operations Manual, of which the MEL is a part.

According to the maintenance documentation of Boeing[146], the manufacturer, the RAT probe heater is designed to provide heat to the probe when the airplane is in the air, and only after the crew energizes the heater by selecting it on the rotary dial in the cockpit.

The description of the ground control relays contained in Part B of the Spanair Operations Manual states that the circuit for the RAT probe heater is deenergized on the ground and operational in the air.

Based on the above, the intended purpose of the RAT probe heater is that it not supply heat to the probe when the airplane is on the ground, and that it do so only while the airplane is in the air.

It would be reasonable to assume, then, that when the heater is supplying heat to the RAT probe on the ground, it is not fulfilling its intended purpose, nor is it functioning consistently and normally within its approved limits, which is to supply heat while airborne and not to supply it when on the ground. Under these circumstances, a valid interpretation would be that when the RAT probe heater is supplying heat to the probe

[146] AMM 30-30-00, Nov. 01/2004, page 101, "PITOT AND STATIC – TROUBLE SHOOTING", item 1 "General", paragraph D: "*The heater (for the ram air temperature probe) is interlocked with the left ground control relay to prevent heater operation while the aircraft is on the ground*", and AMM 30-00-00, Aug 01/2004, page 7, "PITOT AND STATIC – DESCRIPTION AND OPERATION" ítem 1 "General" paragraph B: "*The ice protection meter selector and heat switch, on the overhead switch panel, connects power to the heating elements of such static ports, ram air temperature probe, rudder Q-limiter pitot tube and angle-of-attack transducers. Power is supplied to all heaters when the switch is any position except OFF*".

on the ground, it may be considered inoperative in keeping with the MMEL definition for an inoperative element.

To conclude this line of reasoning, item 30.8 of the MEL could be consulted when faced with a situation in which the RAT probe heater is energized on the ground.

Another possible interpretation of an inoperative element is based on the idea that this only occurs when the element in question is "off (or is not functioning)". In this case, item 30.8 of the MMEL would not be applicable when the heater is supplying heat on the ground, since then the heater would be "on (or functioning)". That is the interpretation of the FAA, Boeing and the AESA, who maintain that the temperature probe heater is not inoperative when it is supplying heat on the ground precisely because they interpret that to be its sole intended function, to supply heat.

The CIAIAC considers the intended function of the RAT probe heater as not only to supply heat to the probe, but to do so at a specific time, namely, when the airplane is in flight, and not to do so when the airplane is on the ground. The CIAIAC's view on this subject is that the terms "operative" and "on" do not represent the same concept. Using reverse reasoning, the term "inoperative" would likewise not represent the same concept as "off". Some experts at the EASA who were questioned on the matter were concur with the CIAIAC.

In any case, this analysis supports the argument that various experts from aviation authorities and organizations, who hold key positions in the civil aviation system, do not share the same interpretation for a definition that, due to its inclusion in a manual such as the MEL, can result in different actions with serious consequences to the safe conduct of operations.

It seems inconsistent that in the usual scenarios in which the MEL is used, and which are affected by circumstances such as operational pressure, that such disparate interpretations be allowed, interpretations on which decisions to dispatch airplanes are based.

REC 31/11. It is recommended that the United States Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) clarify the definition of an inoperative element that is contained in the preamble to all Master Minimum Equipment Lists (MMEL), so as to avoid interpretation errors in its application.

Although it was not possible to show that the R2-5 failed in a way that disabled the TOWS, there is a possibility that this was the case. Considering that both the RAT probe heater and the TOWS share a common component, the R2-5 relay, that the TOWS lacks an indication to warn the crew of a malfunction, and that it is a NO GO component, it would be desirabe that the MMEL have a maintenance (M) and/or operating (O) procedure that requires verifying the proper operation of the TOWS as part of those items involved with the RAT probe heater (item 30.8) or with the RAT probe itself (item 34.9).

Other aspects of the MMEL are consistent with the above. Specifically, item 32.8 of the MMEL on the PARKING BRAKES ON Annunciator System states that this system may be inoperative if after completing the maintenance procedure specified, the Anti-Skid and TOWS systems are verified to be operating properly.

As a consequence of the above, the CIAIAC issues the following safety recommendation:

REC 32/11. It is recommended that the United States Federal Aviation Administration (FAA) modify the Boeing DC-9, MD-80 and MD-90 Master Minimum Equipment List (MMEL) items 30.8, 34.9 and others that may be related to RAT probe heating on the ground so that said items include maintenance (M) and/or operating (O) instructions to check the TOWS.

2.5.3. *Aspects of the Minimum Equipment List (MEL). Interpretation and application*

The circumstances of the accident raise the question of using the MEL to handle on-ramp malfunctions. Specifically:

1. Whether operators should attempt to locate and identify the source of a malfunction and try to resolve it prior to resorting to the MEL, or
2. Whether they can resort directly to the MEL.

Regarding the identification and attempt to solve a malfunction prior to using the MEL, paragraph M.A. 403 of Commission Regulation No. 2042/2003 of 20 November 2003 (commonly referred to as Part M) states that any aircraft defect that hazards seriously the flight safety shall be rectified before further flight. It also designates the authorized certifying, or Part 145, staff as the only personnel empowered to decide, using applicable maintenance information, whether a given defect posed a serious hazard to safety, and what rectification actions are necessary and what can be proposed. It also specifically states that the foregoing is not applicable if the pilot in command decides to resort to the MEL.

According to this, then, the operator has two possible alternatives to determine whether a defect has to be corrected before the flight or if it can be deferred: having certifying personnel assess the seriousness and consequences of the defect based on applicable maintenance data; or having the pilot in command resort to the MEL. Since the volume of information contained in the applicable maintenance sources (AMM, TSM, WDM, etc.) is considerably more than that included in the MEL, the process of locating the necessary information in maintenance manuals would, in most cases, be considerably slower than resorting directly to the MEL, offering the operator a much faster and direct option when handling malfunctions before a flight, considering the operational pressure under which such decisions are made.

In contrast, AMC 403 b), which provides guidance for complying with paragraph MA 403 b), states that when faced with a malfunction in the aircraft, an evaluation should be conducted of both the cause as well as of any potentially hazard effects of the defect or combination of defects that might affect safety. The goal is that any additional investigation and analysis that is required be performed so as to identify the root cause of the defect.

In addition to the regulatory requirements of Part M, there are other references, both regulatory as well as in orientative texts and guidelines, that together comprise a set of recommendations and good practices with respect to using the MEL:

a) It is not the purpose of the MEL to encourage the operation of aircraft with equipment inoperative[147, 148].
b Aircraft operators must ensure that inoperative equipment is corrected as soon as possible[149, 150].
c The MEL should be consulted only after a failure has been fully identified and confirmed[151].

The captain must be informed as soon as possible if the inoperative equipment cannot be fixed prior to the airplane's departure[152].

In all, and to summarize, we may conclude that although the MEL may be consulted and used directly without first attempting to fix the malfunction or identify its source, the conservative approach would suggest first locating the source of the malfunction and attempting to solve it. Only after that fails is it acceptable to resort to the MEL to seek relief to dispatch the flight.

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147 ICAO, Annex 6, Attachment G: "Minimum Equipment List (MEL)", supplementary to Chapter 6, 6.1.2: "*The minimum equipment list is not intended to provide for operation of the aircraft for an indefinite period with inoperative systems or equipment. The basic purpose of the minimum equipment list is to permit the safe operation of an aircraft with inoperative systems or equipment within the framework of a controlled and sound programme of repairs and parts replacement".*

148 Item 1.1 of Section 2 "MEL Procedures" of JAA TGL-26: *"The MMEL and its associated MEL are relief documents. However, their purpose is not to promote the operation of the aircraft with inoperative equipment".*

149 Article 7.1 of Royal Decree 1762/2007 of 28 December, which specifies the requirements for the master minimum equipment list and the minimum equipment checklist for civil aircraft intended for commercial air transport and for aerial work.

150 Preamble to the FAA MMEL: "*It is important that repairs be accomplished at the earliest opportunity*".

151 Airbus – Getting to grips with MMEL/MEL, 4.4.1 "General Principles on MEL Use", page 136.

152 MEL Preamble Specimen, item 4 "*Maintenance Action*".

There are opinions from authorities such as the AESA that hold that the source of a fault must be identified prior to using the MEL. This opinion differs from that of the EASA, which sees no clear benefit in attempting to find the source of a fault before resorting to the MEL. In light of this situation, the CIAIAC believes it is necessary to clarify the interpretation to be followed as regards the use of the MEL when identifying and attempting to resolve a malfunction.

REC 33/11. It is recommended that the European Aviation Safety Agency (EASA) issue an interpretation regarding the need to identify the source of a malfunction prior to using the MEL, and that it assure that national authorities accept and apply the same standards with regard to their procedures for overseeing operators in their respective States.

2.5.4. *Actions of maintenance personnel*

2.5.4.1. Events of previous days

As for the maintenance actions involved in the events of 18 and 19 August regarding the handling of the entries made in Madrid and Barcelona, respectively, the following similarities and differences were noted:

- In neither case was it possible to duplicate the malfunction logged by the pilots in the ATLB.
- In both cases maintenance technicians had easy and immediate access to all applicable maintenance data.
- The malfunction was intermittent and could be hidden or inactive at certain times.
- There was more operational pressure in Madrid than in Barcelona. Madrid was a stopover and the airplane was scheduled to fly on to Barcelona, while in Barcelona the airplane was staying overnight until the next day.
- Maintenance technicians approached the malfunction differently.

The fact that AMT 1 in Madrid simulated the airplane being in air mode by opening breaker K-33 seems to indicate that he knew the relationship between RAT probe heating on the ground and the ground-air signal. The opening of breaker K-33 is among the steps contained in the Airplane's Maintenance Manual[153] as part of the check of the RAT probe heating. Since this check did not reveal any anomalous behavior, AMT 1 decided to perform the TRS test, which is contained in the AMM[154], though he performed it almost completely "from memory", only resorting to the Maintenance Manual to verify one engine parameter needed to complete the test.

[153] AMM 30.30-00, page 204, paragraph D "Test Ram Air Temperature Probe Heater".
[154] AMM34-18-00, page 201, "RAM AIR TEMPERATURE AND THRUST RATING SYSTEM".

Risks are obviously taken when either maintenance tasks are performed that are not in any applicable maintenance data or when said tasks are done from memory. The former can result in ignoring some of the interconnections present among airplane systems, while the latter can lead to errors if some of the steps are omitted.

With regard to the handling of the problem in Barcelona, in this case AMT 2 did follow the applicable maintenance actions specified in the AMM. Specifically, he performed the RAT and TRS functional tests and, since he could not duplicate the malfunction, did not attempt any further maintenance actions. He closed out the pilots' entry in the ATLB by noting that the tests performed had been satisfactory.

When AMT 2 was asked if he had checked the ATLB for the maintenance action taken by AMT 1 in response to the same entry that he was now dealing with, he replied that though he had taken notice of it, he had not given it much thought, and focused instead on the maintenance actions he himself was performing. In fact, even though the company also had information in its computer database regarding how the same ATLB entry had been handled in May 2008, neither of them consulted said database in an effort to gather information on similar events. Had they checked, they would have seen that the heating of the RAT probe on the ground in the May 2008 event had been solved by replacing the R2-5 relay.

In neither case was assistance requested from the Engineering or Maintenance and Control Departments (MCC).

In summary, even though both maintenance actions involved steps to check whether specific systems were functioning properly, these checks were not verified to be appropriate to resolving the malfunction at hand, and therefore did not offer sufficient guarantees as mitigative measures for the intermittent malfunction that was being reported.

It is precisely because of the added complexity posed by intermittent faults as opposed to verifiable faults, in that the former may be hidden or latent and may recur at a later time, that maintenance organizations should, as a first course of action when dealing with malfunctions, redouble their efforts to treat them as cautiously as possible. Every resource available should be used, such as consulting the organization's records database, requesting support from other departments such as Engineering or MCC in the case of Spanair, or resorting to the manufacturer's support line.

2.5.4.2. Unscheduled maintenance actions taken before the accident on 20 August 2008

Several scenarios exist when analyzing the maintenance actions taken on the day of the accident.

Scenario 1. Attempt to locate and fix the malfunction based on the first step in the flow diagram contained in the MOE.

In keeping with this scenario, the first step in this flow diagram requires carrying out an analysis to determine the source of the malfunction involving the heating of the RAT probe on the ground and attempting to fix it prior to considering the remaining steps. As concerns the first actions taken by the technicians who responded to the maintenance call, the action to verify the current indication in the cockpit was intended to confirm the fault. The action of visually inspecting the probe could have been intended to verify that the probe's air inlet and outlet holes were not plugged (by insects, dirt, etc.), which is a known cause of RAT overheating problems in flight due to a lack of adequate ventilation. A more exhaustive evaluation was not carried out after the fault was confirmed. This would have required maintenance personnel to resort to maintenance data such as the AMM or WDM to identify the components that could have resulted in the heater being energized on the ground.

It must be noted that the prerequisite in the Spanair MOE to locate and attempt to fix the fault is a self-imposed requirement that is not found in the relevant regulation, which allows resorting directly to the MEL without first having to locate the source of the malfunction or attempt to fix it, as mentioned earlier.

The consequences stemming from this scenario would be:

- Since it was not possible to show that the heating of the RAT probe on the ground and the TOWS fault had a common cause, then even if maintenance personnel had found the source of the fault and resolved the situation with the RAT probe heater, this would not have ensured that the TOWS fault would also have been resolved, meaning that the TOWS fault could have remained hidden and unresolved.
- The aircraft could have been dispatched with the RAT heating fault fixed, but with the possibility that the TOWS was disabled.
- Even if the source of the fault had been properly detected, the MEL could still have been used if for any reason the fault could not to be repaired (such as due to a lack of spare parts).
- Nothing in the approved maintenance data would have suggested checking for the proper operation of the TOWS.

Scenario 2. Resort to the MEL and only consider directly applicable item 30.8 for the situation in which the RAT probe heater is energized on the ground.

Based on the information gathered, this was the actual scenario that occurred. After reading the MEL, maintenance personnel interpreted that item 30.8 could be applied. The decision by maintenance personnel to apply the MEL may fall outside the intended scope of item 30.8 if the probe heater is interpreted to be operative in that it is fulfiling its design purpose, which is to heat. Based on an initial theory, however, maintenance personnel were able to make the heater inoperative by interrupting its current. This was likely the intended purpose of opening breaker Z-29, an action that impedes the flow of current to the RAT probe resistance, leaving it inoperative both on the ground and in the air, after which it would be possible to apply MEL item 30.8 literally while at the same time eliminating the symptoms of the malfunction.

Another theory that could have driven maintenance personnel to resort to MEL item 30.8 is that they interpreted the heater as being inoperative by not fulfilling its function of turning off on the ground. Had this been the case, the maintenance actions could have stopped there without the need to open breaker Z-29, since a deactivation action such as this should appear in the MEL as a maintenance (M) procedure to be carried out before deferring the malfunction. Opening the breaker, then, could have resulted from the desire to avoid the continuous operation of the heater.

In either case, both theories share the same action of opening the Z-29 breaker, an action that may not have been preceded by an exhaustive analysis.

If maintenance personnel had noticed that opening Z-29 deactivated the TRS and had conveyed this to the crew, this would probably have alleviated the first officer's concern in this regard and changed the ensuing scenario, at least insofar as the first officer's actions regarding his flight activities were concerned. However, by resorting exclusively to the MEL, the effects of opening Z-29 on the TRS were not made readily apparent. There was no link, for example, between item 30.8 and 34.9, which refers to the RAT probe and to the TRS. Nor did the label on breaker Z-29 make any reference to the TRS, only to the RAT probe. All of this leads one to conclude that a detailed analysis of opening Z-29 was very likely not performed as a consequence of resorting exclusively to the MEL as the reference document. Maintenance personnel would probably only have been able to carry out such an analysis if they had used applicable maintenance data (AMM, WDM, etc.) in conjunction with their experience and knowledge.

In all, the actions taken by maintenance personnel were incorrect mainly due to the incomplete analysis of the RAT probe malfunction. The specialized[155] literature identifies three aspects involving the theories made when dealing with malfunctions:

1. Maintenance personnel tend to place more importance on the most immediate information available during the diagnosis process (that is, an idea is very quickly formed about what is causing the problem);
2. Maintenance personnel tend to adopt only a few theories, though the symptoms may point to a far greater range of possibilities; and
3. Once maintenance personnel adopt one theory, they tend to look for evidence to support it and rule out information that opposes it.

[155] Decision making in Engineering Psychology and Human Performance". Wickens,CD // "Human Factors Issues in Aircraft Maintenance and Inspection". FAA

It is possible that in this case, maintenance pesonnel could have been affected by the phenomenon known as tunnel vision, causing them to see the situation facing them as if through a tunnel, noticing only one thing and eliminating information coming from other sources. In an aircraft maintenance environment, this phenomenon is well-known as a danger inherent to the human condition. One of the most common causal factors leading to this phenomenon lies in suggesting causes for a malfunction to maintenance personnel when reporting a problem, instead of limiting the information given to said personnel to merely describing the symptoms.

The crew's apparent acceptance at the time the decision was made and their lack of objections could have a definite bearing on the eventual execution of the working theory held by maintenance. The final acceptance of the airplane with the fault deferred by the captain without demanding information on the condition that other systems were left in after the maintenance action was carried out (specifically, the uncertainty about whether or not the autothrottle would work during takeoff) did nothing to contribute to the maintenance personnel's questioning of the decisions and consulting additional maintenance documents to check for potential cross effects. In order to have a greater assurance regarding the safety of how these situations is handled, information about other systems/components that may be rendered inoperative should be shared not only between maintenance personnel and flight crews, but also properly recorded in the ATLB.

As was the case with the flight crew, the time pressure and haste to complete the task quickly are factors that could have degraded the maintenance personnel's analysis and decision-making abilities. This pressure was probably self-induced since they had to resolve an anomaly with passengers onboard following an extended delay.

In summary, the most relevant consequences and conclusions drawn from this scenario are:

- Opening breaker Z-29 has no effect on the TOWS.
- The aircraft could have been dispatched without carrying out any maintenance or operating activity and with the RAT probe heater energized on the ground, as happened on five of the flights prior to the accident on 18 and 19 August 2008.
- Nothing in MEL item 30.8 would have prompted a check of the proper operation of the TOWS.
- Nothing in MEL item 30.8 would have prompted a check of item 34.9 involving the RAT probe and the thrust rating system.
- The fault in the TOWS would have remained undetected.

Scenario 3. Resort to the MEL and consider items 30.8 and 34.9, or only the latter, to be directly applicable.

Item 34.9 could be considered acceptable in this situation since the RAT probe reading was clearly higher than the ambient temperature at that time, meaning the RAT probe could have been considered inoperative since the reading was out-of-spec high. In any case, resorting to the MEL would have required that the malfunction be identified down to the element level (component, system or function) before applying the MEL.

The consequences of this scenario would be:

- In accordance with both items, the aircraft could have been dispatched in adherence with the operating and maintenance procedures contained in item 34.9 and with the RAT probe heater energized on the ground.
- The first officer's doubts concerning the operation of autothrottle on takeoff would have been alleviated.
- Nothing in either of the two MEL items mentioned would have prompted a check of the proper operation of the TOWS.
- Nothing in MEL item 34.9 would have prompted a check of item 30.8 on the RAT probe heater.
- The failure of the TOWS would remain undetected.

2.5.5. *Organizational culture in terms of maintenance records*

The purpose of the applicable maintenance data is, among other things, to describe the tasks to be performed on an airplane intended to maintain it in a continuously airworthy condition or to return it to said condition. The use of valid maintenance data and properly logging activities has benefits, like:

- Providing proper tracking of the maintenance tasks that have been performed and facilitating the task of analyzing and detecting the source of recurring malfunctions.
- Providing an exact record of what steps were taken to fix a problem and check their utility.
- Providing sufficient guarantees to assure continued airworthiness since the maintenance instructions used have been subjected to an analysis, study and ellaboration by the manufacturer or type certificate holder and been approved by the relevant aviation authority.
- Allowing for the identification of shortcomings or errors in the maintenance manuals themselves which, properly notified and corrected, would allow for the continuous improvement of the documentation. This would benefit not only the operator's entire maintenance organization, but every operator of that type of airplane.

As noted earlier, airplanes like the MD-80 require additional analysis by maintenance personnel when deciding on the proper strategy for diagnosing malfunctions in comparison to more modern airplanes. In the MD-80, maintenance tasks rely on applicable maintenance data, normally in the maintenance and wiring diagram manuals (AMM, WDM). They also rely heavily on the knowledge and experience of personnel. In more modern aircraft, on the other hand, the work required by these diagnostic tasks relies much more on fault isolation or troubleshooting manuals (FIM, TSM), which provide a much more detailed description of the steps to take.

The investigation into the entries made in the ATLB on airplane EC-HFP showed that a high percentage (76%) of these entries did not make any reference to applicable maintenance data or provide information regarding the application of the maintenance personnel's knowledge or experience. In most cases, only a basic description of the tasks performed was provided. While this cannot be taken to imply that these tasks were not performed in accordance with valid data, the little information provided by these records reveals a deficiency in the way they are used. In addition, this dearth of descriptive data in the ATLB was noted both in tasks performed during quick stopovers, when time is usually at a premium, and in tasks performed on longer stops, which offer greater access to maintenance documentation and more time to write reports or fill out records. This could be indicative of the widespread use of this practice in the organization as a whole, since several departments are involved with the ATLB.

The fact that audits conducted by the company's Quality Department were ineffective in detecting these deficiencies indicates that either the audits were not properly conceived or that the way in which technical flight records were kept was not a concern, which proves that such a culture was accepted and shared within the organization.

The audit performed in 2009 by the company AQS as part of the IOSA program did detect a specific problem in the use of unapproved maintenance data, as a result of which Spanair modified its MOE to emphasize that the maintenance data used when working with specific documents, such as the ATLB, must be indicated. ATLB entries made after this change to the MOE, however, continued to lack this information.

The inspections carried out by the AESA for the purpose of renewing the airworthiness certificates in 2007 and 2008 also noted cases involving incomplete entries and missing references in maintenance records. In 2009, after the implementation of the continuous oversight plan, inspections involving Spanair's CAMO and Part 145 organizations continued to reveal such deficiencies, which show that the corrective actions taken within Spanair to avoid repeat occurrences, such as those detected by the IOSA audit, were insufficient.

Apart from the fact that the applicable regulation requires that all maintenance actions carried out on an airplane be properly recorded, this deficient practice, if rooted and prevalent among a high percentage of certifying personnel, can lead to the establishment of a belief within the organization that it is normal and acceptable. It could even pave the way for the performance of tasks that are not incluced in said data, with the organization not considering that such a practice would reduce safety standards.

Spanair appears to be struggling to implement all of the corrective measures for the discrepancies noted in this area throughout its CAMO and Part 145 organizations, nor does it seem to be following up to ensure the effectiveness of the measures. As a result, this system should be reviewed.

REC 34/11. It is recommended that Spanair revise its mainenance procedures and draft instructions for relevant personnel so that any maintenance tasks performed are adequately described in maintenance records and provide sufficient details.

REC 35/11. It is recommended that Spain's Aviation Safety Agency (AESA) ensure that all of the maintenance tasks performed by Spanair be described adequately and with sufficient detail in the aircrafts' technical records.

REC 36/11. It is recommended that Spanair revise its quality assurance system so that the implementation of any corrective measures adopted by its maintenance organization is effectively monitored.

REC 37/11. It is recommended that Spain's Aviation Safety Agency (AESA) ensure that the Spanair quality assurance system provides effective monitoring of any corrective measures that are adopted by its maintenance organization.

2.6. The emergency response

The accident was immediately noticed by the crew of flight IB6464, which informed the control tower at 14:24:36. The alarm was activated in the tower and sounded simultaneously in all three fire stations at the airport. The first team to respond was from the satellite station, located between runways 36L and 36R. At that time, there was no information as to where the accident had taken place, so the firefighters proceeded to the smoke plume that they saw rising from the 18R threshold.

En route to the accident site they encountered an obstacle in the internal perimeter fence that surrounds the runway 36L/18R strip and which they were unable to cross. They had reached that point two minutes and twenty seconds after the alarm was sounded. This fence consisted of a concrete base some 40 cm high and then a chain link segment some 2 m high. There were several locked gates all along the fence. One of the heavy vehicles crossed it without any problems. Another, the lightest, opted to go around and access the wreckage via a point on the external fence. There is no precise information regarding the rest of the crew and the problems the encountered circumventing the fence. There is also no exact record of the time it took the first responders to reach the accident site, though the obstacle posed by the fence hampered their efforts.

Annex 14 specifies a maximum response time of three minutes for the rescue and firefighting services to reach the ends of the runways and start providing assistance. In this case, the response time was very fast, and the goal in Annex 14 would probably have been met had the accident taken place on a runway. The obstacle posed by the inner fence, however, prevented a faster response time and also limited the number of responders initially arriving on the scene. An analysis of this situation is thus warranted.

This fence comprised the outer limit of the airport prior to the last expansion of the facilities in 2005. It had not been demolished. The fence was probably kept in to keep out unauthorized personnel, but no evaluation was done to assess the consequences its presence might have in case of an accident occurring within the airport grounds but beyond that fence.

Annex 14 also recommends that easy access be provided, even to areas outside the complex, such as the runway approaches, and mentions fences as an element to consider. Thus, the need to retain the inner fence surrounding runway 36L should be evaluated and if retained, consideration should be given to the modifications that should be made so as to ensure more expeditious access to airport grounds located beyond the fence.

REC 38/11. It is recommended that Spanish Airports and Air Navigation (AENA) evaluate the need to retain the internal fence surrounding runway 36L, and if it is retained, that modifications be made to said fence to ensure more expeditious access to all areas of the airport situated beyond the fence.

The factor that contributed the most at first to finding the accident was the smoke plume caused as the accident airplane burst into flames. This allowed RFFS personnel in the satellite station to ascertain the approximate location of the accident. The RFFS observation post, which is located in the apron station, requested information from the tower at 14:25:25, though the tower only specified that the accident had taken place on runway 36L. Tower personnel undoubtedly had a better view as well as a more accurate picture of the situation by virtue of having last been in contact with the aircraft. Under other lighting conditions, at night or with reduced visibility, the smoke would not have been as evident. Measures should be considered, therefore, that will enable the RFFS to quickly ascertain the exact location of an emergency.

Along these lines, AENA drafted a new emergency plan, now called the Self-Protection Plan, which has been in effect since October 2009 and which takes into account various accident scenarios. These are classified into two types and consider 20 locations within the airport complex. The plan details the information that the tower must relay to RFFS, including the number of people onboard the affected aircraft, the amount of fuel and the possible presence of dangerous goods.

The findings also indicate that communication problems existed between the tower and the RFFS resulting from a lack of coordination in the frequencies used. Specifically, RFFS radio traffic on the emergency frequency was not answered by the tower. This prevented the flow of information between the first responders on the scene, and who had first-hand information on the situation, and the tower. The problem was noticed because controllers continued monitoring their operational traffic frequencies (ground, clearance delivery, takeoffs and landings) and using the hotlines to talk to the Airport Operations Office (AOO). There was, therefore, an increase in the workload in the tower that could have exceeded the capacity of the control staff present at that time. The findings show that, in addition to the supervisor, there were seven controllers on duty in the tower at the time of the accident. Control positions were then closed once takeoffs from runway 36L, and, twenty minutes later, from 36R were suspended. This freed up two controllers. Even so, priorities need to be clearly defined and the support given to rescue and firefighting personnel from the control tower in emergencies has to be enhanced, with the service given to said services being recognized as one of those priorities.

REC 39/11. It is recommended that Spanish Airports and Air Navigation (AENA) enhance the assistance provided by control tower personnel to Rescue and Firefighting Services (RFFS) in the event of an accident at an airport.

The presence of the airport's entire RFFS staff and resources at the accident site is regarded as a positive. There were a total of 15 firefighters from the satellite and apron stations who arrived first, followed by seven from the central station, who arrived 15 minutes after the accident. According to AENA procedures, however, the central station personnel should have stayed at the T4S apron as required to maintain the airport operational. Under these circumstances, and with all three firefighting crews at the accident site, the airport was left without RFFS coverage in the event of another emergency for a period of about 20 minutes.

The response of the RFFS personnel is understandable and laudable. Given the gravity of the situation, they understood the need to report to the accident site to assist in the firefighting and rescue efforts. The situation may have justified the resulting risk, but the fact that the firefighters' decision to take that risk was not made at higher levels is cause for concern. Emergencies are complicated affairs that must be managed so as to minimize their consequences to the maximum extent possible. This requires taking fast, effective and appropriate measures. Steps must be taken to ensure that all of the information that is generated during such crisis periods flows smoothly to those locations and individuals who make the decisions, so that they have the right information available.

REC 40/11. It is recommended that Spanish Airports and Air Navigation (AENA) inform all the persons and groups involved in carrying out emergency plans and who are not under its authority, or to instruct them when under its authority, of the importance of respecting the decision-making process and to promote the flow of information.

2.6.1. *Survival of the victims*

Those passengers seated aft of row nine had no chance of survival. The autopsies revealed that the leading cause of death was the fire (73%). Of the 27% remaining victims, the causes of death were: 32 from traumatic injury, 2 from drowning in water and 1 from smoke inhalation. The 18 survivors were seated in rows 1 to 9 in the passenger cabin. Most of them suffered traumatic injuries but were not burned, except for one. Another survivor suffered from smoke inhalation.

Based on these data, those individuals who were affected solely by trauma had the best chances of surviving. The forces transmitted to the occupants by the seats and the restraint systems did not exceed the limits of human survival for those who were injured. Had there not been a fire, the number of survivors would probably have been higher.

Having the wreckage come to a stop in a stream could have contributed to the survival of the injured, since the stream acted like a firewall, confining the fire to the rear of the aircraft. Another positive factor is the fact that there were RFFS personnel on the left bank of the stream, which is how they had gained access to the crash site. However, the stream was the direct cause of two fatalities by drowning. The water level was higher than normal for that time of year, and the victims who drowned had been trapped under the water by sunken pieces of wreckage. The investigation was unable to determine whether these persons would have survived had RFFS personnel reached the site sooner, considering how little time is available to rescue drowning victims. The firefighters were able to carry out extraction and rescue maneuvers in the area, but they admitted that the stream hampered their efforts due to the large volume of water present.

The training program for RFFS members emphasized live fire drills. There was also a 20-hour training module on rescuing victims. They had been trained on these topics on several occasions, but not on first aid, which was given after the accident, in keeping with the schedule in place since April 2008. The investigation could not determine whether the training given took into consideration the specific features of the airport environment, like the stream.

The CIAIAC believes that even though the response of the airport services was very good and contributed significantly to saving the lives of some victims, the training of RFFS personnel could be enhanced in the area of first aid. Their training should also be complemented with a course on water rescue, in light of the characteristics of the setting in which Barajas is located.

REC 41/11. It is recommended that Spanish Airports and Air Navigation (AENA) enhance the training of Rescue and Firefighting Services (RFFS) personnel in the area of first aid, and that it complement their training with courses on water search and rescue at those airports with water environments in which the use of special rescue services external to the airport is not anticipated.

2.7. Oversight by the aviation authority

Based on the information provided during the investigation (see Section 1.17.3), the Authority's continuous supervision consisted primarily of inspecting and checking various functional (operations, maintenance, etc,) and financial and administrative departments.

More specifically, the AESA engaged in a large number of oversight activities at Spanair before the accident in 2008 as a result of the protocols associated with the process of renewing the Airworthiness Certificate, the company's AOC, maintenance checks and other activities such as SANA/SAFA inspections and crew fatigue and flight inspections. The AESA's oversight inspections and activities involving Spanair in the area of flight operations up until the date of the accident did not reveal any deficiencies with the organization or related to the circumstances of the accident.

In 2007 the company was audited and evaluated by several agencies apart from the aviation authority (see Section 1.17.2), such as the audit conducted by the company AQS as part of the IATA's IOSA program, another by Boeing and one by SAS. Despite not being required, the last inspection conducted by the AESA in June 2008 for the renewal of the AOC could have used the results of those audits to better ascertain Spanair's situation, but no such mention is made in that inspection's report.

As for the en route inspections, the way in which they were conceived, the inspectors did not necessarily have to be rated on the types of airplanes in Spanair's fleet. Thus, their goal could not have been to assess the precise level of knowledge of procedures (normal, abnormal or emergency) specific to that airplane, since the inspectors were themselves not required to be familiar with the airplane type. The discrepancies detected in these inspections in the year before the accident boiled down to documentary deficiencies. The practice of using en route inspections to capture the reality of flight operations, not to mention the high cost/efficiency ratios they present, was already questioned in Section 2.3.7.

In any event, better qualified personnel, though not necessary more experienced, but trained in areas such as CRM or adherence to and performance of standard operating procedures (SOP) could improve the efficiency of inspections. Along these lines, these same shortcomings were noted in the EASA's standardization visit to the AESA in 2007. The AESA, then, should make a greater effort in this area.

The investigation also focused on the financial situation at Spanair at around the date of the accident. At that time, Spanair was immersed in a workforce reduction process that affected 25% of both its maintenance and operations employees. A cost-cutting plan was also in effect. The number of aircraft had been reduced by 24%, or 15 airplanes. Five of its large maintenance bases were being eliminated so that its resources could be focused on Palma de Mallorca, where its headquarters were, and on Madrid and Barcelona.

The aviation authority had been monitoring Spanair's financial situation since 2007. This monitoring involved analyzing the company's accounts and focused on identifying details of the cost-cutting plan prepared by the company to improve its situation.

The monitoring was done through the Air Operators Safety Committee, which proposed measures to mitigate risks and/or revoke the AOC. It also issued periodic alerts.

As a result of this monitoring process, the authority raised the company's alert level to sustained negative situation in July 2008. The frequency of SANA inspections was increased, but no other measures intended to improve the quality of the inspections were taken.

This oversight was in response to the requirements in Regulation (EEC) no. 2407/92 on conceding and maintaining licenses of air carriers, which were later superseded by Regulation no. 1008/2008, still in effect, and according to which national aviation authorities can, at any time, evaluate the financial situation of airlines. Furthermore, if there is any indication that financial problems may pose a threat to the safety of operations, they can even suspend or revoke their operating licenses. More modern oversight strategies[156] take into account the speed at which changes occur at airlines so that, instead of merely watching the financial situation, the monitoring and oversight activities can be adapted. These systems employ the concepts of the Safety Management System (SMS), which are based on defining risk indicators and on developing tools so that inspectors can assess the risks taken by operators and document and analyze their observations so that the monitoring plans and programs in those areas with the greatest perceived risks can be enhanced.

FAA Order 8900.1[157] defines the following risk indicators, among others: rapid expansion or growth of the company; significant financial problems; labor disputes; mergers or acquisitions; personnel movements and rotations. The situation at Spanair undoubtedly exhibited many of these indicators at the time of the accident. These factors could have degraded the level of safety at the company.

That these processes were underway was known to the aviation authority. That is why we must insist that authorities establish the mechanisms that will, as quickly as possible, allow them to identify the risks inherent in the changes that are taking place at air operators, and that they properly train their inspectors to recognize risk factors and situations.

All of the above points to the need to implement a culture of inspection that, insofar as is possible, should be based on quality rather than on quantity. As a result,

[156] Examples of these systems are the FAA's ATOS (Air Transport Oversight System) and SEP (Surveillance and Evaluation Program) programs, which have been in place since 2004.
[157] Volume 6. Surveillance, Chapter 2. Parts 121, 135 and 91 Subpart K Inspections. Section 18.

REC 42/11. It is recommended that the European Aviation Safety Agency (EASA) draft orientative texts and guidelines and instructions so that national authorities are better able to assess the general situation of commercial air transport operators that undergo notable changes, such as rapid expansions, a significant growth in their resources, or the opposite situation, a reduction in their activity or resources, such as through personnel layoffs, the purpose being for authorities to constantly adapt their monitoring plans to consider their evaluation of these changes so as to proactively detect and assess risk factors that point to a possible degradation in safety level.

3. CONCLUSION

3.1. Findings

1. The airplane was properly certified, its documentation was in order and it was equipped as required by existing regulations.
2. All of the scheduled maintenance had been performed on the airplane.
3. The crew's licenses and medical certificates were valid and in force for the type of aircraft in question.
4. The maintenance technicians who worked on the airplane on 19 and 20 August 2008 had valid licenses and ratings for the aircraft type.
5. The weight and balance of the airplane at takeoff were within approved limits.
6. The weather was not a factor in the accident in terms of airplane performance.
7. During the first taxi phase when on the runway threshold, the captain decided to return to parking to fix a malfunction involving excessive heating of the RAT probe on the ground.
8. According to DFDR data, in the days before the accident, there were five (5) cases of RAT probe overheating on the ground. Three (3) of these were not recorded in the ATLB because they were not detected. The other two (2) were noticed and logged by the crews.
9. Different maintenance practices were used to deal with the two recorded cases of RAT probe temperature overheating on the ground.
10. The captain decided not to use a reserve airplane that was ready and standing by.
11. Maintenance technicians consulted the MEL, opened breaker Z-29 and annotated in the ATLB that the malfunction was being deferred in accordance with item 30.8 in the MEL.
12. Opening breaker Z-29 interrupts the flow of electricity to the RAT probe heater and to the TRP, but has no effect on the TOWS.
13. The maintenance tasks did not succeed in solving the problem with the aircraft which, along with the high temperature in the cabin and the prolonged delay, could have made the captain feel a need to hurry up.
14. The airplane was dispatched despite the doubts expressed by the first officer regarding the possibility of taking off with the autothrottle engaged.
15. The crew made use of their cellular telephones during the flight preparation and taxi phases.
16. The crew did not observe the sterile cockpit principle. In addition to using cellular telephones while taxiing, they held conversations in the cockpit with a third person on topics that were irrelevant to their flight activities. This contributed to distracting the crew from its flight duties.
17. The Spanair Operations Manual and European Union regulations define when the sterile cockpit is in effect, but do not specify what activities detrimental to crew attention are prohibited during this period.
18. The pilots used the Spanair checklists, but did not fully complete them. Some items in the checklists were omitted and the actions required in other items were not carried out. Deviations occurred during the execution of operation procedures

and the lack of oversight resulted in the flaps and slats not being selected and in the selected position not being verified.

19. When the "After start" checklist was interrupted, the crew missed its first opportunity to verify that the airplane was properly configured for takeoff.
20. By omitting the "Takeoff Briefing" item in the "Taxi" checklist and doing a visual inspection during the "Takeoff imminent" checklist that did not constitute an actual confirmation of the position of the flaps and slats, the crew missed additional opportunities to notice and correct their error in configuring the airplane.
21. There are discrepancies in the task assignments for selecting the flaps/slats position between the operator's expanded and reduced checklists.
22. Checklists in the European Union do not require approval. The national aviation authority only accepts them as part of the contents of the operations manual. There is also no regulation in the European Union that requires operators to develop procedures for maintaining or for tracking modifications made to the checklists.
23. The first officer's attention was focused on the possibility of doing a takeoff with the autothrottle engaged to the detriment of properly carrying out his duties in the cockpit.
24. The first officer may have been affected by the "expectation bias" phenomenon, since his check of some checklist items, such as the position of the flaps and slats, was not effective.
25. Improper crew resource management favored the crew's procedural deviations when they were distracted during the flight preparations.
26. The crew did not select or check the flaps and slats for takeoff.
27. The takeoff warning system (TOWS) did not issue any warnings during the takeoff run regarding the improper configuration of the airplane.
28. The airplane took off with an improper flaps/slats configuration.
29. When the aircraft became airborne, it stalled, a situation the crew did not identify.
30. After takeoff, various visual and aural warnings were received simultaneously in the cockpit notifying of the stall condition and the excessive bank angle. The stick shaker was activated.
31. The simulaneous occurrence of various warnings in the cockpit, the crew's mistaken perception regarding the airplane's configuration and the little time available contributed to not recognizing the stall condition and therefore to not carrying out the stall recovery procedure.
32. The first officer wondered if the situation was caused by an engine failure and momentarily retarded the throttle levers.
33. The training that the crew had received did not include takeoff stalls, nor was such training required by existing regulations.
34. The analyses and examinations of the aircraft wreckage did not reveal any structural failure or an engine malfunction.
35. The slats components recovered from the accident site showed signs consistent with a slats retracted position.
36. The flaps components recovered from the accident site did not allow for a determination of their position.

37. The components of the flat/slat control lever recovered from the wreckage showed signs that pointed to its being in the retracted (UP/RET) position when the aircraft impacted the ground.
38. The slat indicating lights exhibited characteristics consistent with the indication corresponding to the flap/slat control lever being in the UP/RET position when the aircraft impacted the ground.
39. The R2-5 relay is a component of the airplane's ground sensing system that is common to the TOWS and to the RAT probe heating system.
40. Insofar as this case is concerned, the R2-5 relay is responsible for activating the RAT probe heater in flight and turning it off when the airplane is on the ground. It also provides ground-flight information to the TOWS, enabling the system when the airplane is on the ground and inhibiting it when in flight.
41. The functional tests carried out on relay R2-5 did not show evidence of any faults that justify the malfunction of the RAT probe heater on the ground or of the TOWS.
42. The metallographic tests conducted on relay R2-5 showed that contacts C2 and C3, which open and close the electrical circuit for the RAT probe heater, were on occasion fused closed. It is possible that this situation could have occurred with the airplane on the ground.
43. Episodes involving the fusing and separation of contacts C2 and C3 on relay R2-5 with the airplane on the ground could explain the malfunction with the RAT probe heater and its intermittent nature.
44. The fault of the R2-5 relay involving the fusing of contacts C2 and C3 has no effect on the TOWS.
45. There are failure modes for relay R2-5 that can simultaneously affect the RAT probe system and the TOWS. Among these faults are the failure of the relay coil power supply or a fault in the coil winding themselves that prevents their operation.
46. It is unlikely that a power supply fault occurred involving the R2-5 relay coil.
47. In 71 of 103 incidents reported to Boeing by DC-9/MD-80 operators from around the world involving a high RAT probe temperature indication in the MD-80, the problem was solved by replacing the R2-5 relay.
48. The connection between the RAT probe overheating on the ground and the fault in the TOWS could not be reliably established in this case.
49. There are failure modes of the TOWS that are not related to a malfunction of the RAT probe heater on the ground. The data available could only rule out some of these possible failure modes.
50. There are failure modes for the TOWS that would not give an indication in the cockpit, such as a fault in the electricity being supplied to the CAWS through power supply no. 2, or a fault in any of the microswitches on the throttle levers that activate the TOWS.
51. The TOWS is required to be operational prior to dispatching the flight.
52. The TOWS check was only mandatory on the first flight of the day, according to the checklists in the Spanair operations manual. In contrast, in its FCOM,

Boeing's checklists recommended that it be checked on the first flight of the day and on "through flights", a term that was not clearly defined at the time of the accident.

53. The TOWS on DC-/MD-80 series airplanes could be rendered inoperative after its operation is verified before the flight by failure modes that would not give any warning in the cockpit.
54. The design criteria for the TOWS like the one installed in airplanes of the DC-/MD-80 series was that of a back-up system.
55. The TOWS on transport airplanes certified according to the current version of the document on acceptable means of compliance, AMC 25.703 in the European Union and its counterpart, AC 25.703 in the United States, are classified as an essential system.
56. The aircraft's Maintenance Manual contains information on the RAT probe in chapters 30-30, on the Ice and Rain Protection System, 34-16, on the Thrust Rating System, and 34-18, on the Air Data Computer System.
57. The aircraft's Maintenance Manual did not contain a specific troubleshooting procedure for detecting a malfunction involving the heating of the RAT probe on the ground. It did contain troubleshooting steps for the case in which the probe heater does not work in flight.
58. The Madrid-Barajas Airport is a maintenance base for the airline Spanair, with sufficient certifying technicians, facilities, spare parts and equipment.
59. The maintenance personnel who handled the malfunction with the RAT probe heater in the days prior to the accident in Madrid and Barcelona performed tests to confirm the malfunction, but were unable to reproduce it. They did not request assistance from other company departments.
60. The Spanair maintenance personnel that handled the RAT probe heater malfunction at Barajas before the accident did not consult the aircraft's Maintenance Manual.
61. The actions taken by Spanair maintenance personnel at Barajas to detect the source of the problem and fix the RAT probe heater were limited and the MEL was used for the purpose of allowing the airplane to be dispatched.
62. Item 30.8 in both the operator's MEL and the MMEL applicable to the DC-9/MD-80 model contained instructions only for a malfunction involving the RAT probe heater not being energized in flight, but did not consider the case in which the heater is energized on the ground, as happened with the accident airplane.
63. The ATLB entries often described only the basic details of the tasks performed and without making specific reference to applicable maintenance data.
64. There is no regulatory requirement in the European Union that mandates diagnosing faults or defective operations prior to recurring to the MEL for dispatching an aircraft.
65. Spanair's Maintenance Organization Manual and its Airworthiness Manual directed that efforts be made to resolve a malfunction. Only once it became obvious that it could not be fixed could the MEL be consulted as an alternative to dispatching the airplane.

66. The preamble to the MEL specifies that Maintenance must do everything possible to correct technical defects as soon as practical and that the aircraft be returned to service fully operational.
67. The captain's decision to fix components before the flight that the MEL allows to be inoperative takes priority over the stipulations contained in the MEL.
68. Maintenance personnel performed an incomplete analysis of the RAT probe heater malfunction on the ground. They likewise did not consult the AMM or used the information in the Technical Log System, hence the failure to locate the fault. Maintenance personnel took an improper action by opening breaker Z-29 to deactivate the RAT probe heater, thus enabling them to apply item 30-8 of the MEL to dispatch the airplane.
69. Tests conducted on a similar airplane confirmed that opening breaker Z-29 does not affect the operation of the TOWS.
70. Another admissible alternative for dispatching the airplane would have been to check item 34.9 of the MEL on the RAT probe and Thrust Rating System (TRS), which included additional maintenance and operating procedures for manually setting the EPR limits.
71. Maintenance personnel could have been affected by the "tunnel vision" phenomenon, which kept them from taking into account other theories regarding the cause of the malfunction consistent with the symptoms present.
72. According to the stipulations in Regulation (EC) no. 859/2008, Annex III, Subpart A, OPS 1.085, paragraph f.11, the Captain "shall decide whether or not to accept an airplane with unserviceabilities allowed by the CDL or MEL".
73. The presence of smoke coming from the crash site aided RFFS personnel in finding the site of the accident.
74. The emergency response by airport and outside services was good, though it was not strictly in accordance with the emergency plan.
75. The characteristics of the accident allowed some of the victims seated at the front of the passenger cabin to survive.
76. RFFS personnel had received training on victim rescue several times before the accident. In April 2008, first aid training was scheduled, a training that was given after the accident.
77. All RFFS personnel on duty took part in rescue and firefighting activities at the accident site, as a result of which the airport was without this type of coverage for 20 minutes.
78. There were communications problems between the tower and RFFS stemming from a lack of coordination in the frequencies used.

3.2. Causes

The CIAIAC has determined that the accident occurred because:

The crew lost control of the airplane as a consequence of entering a stall immediately after takeoff due to an improper airplane configuration involving the non-deployment of the slats/flaps following a series of mistakes and omissions, along with the absence of the improper takeoff configuration warning.

The crew did not identify the stall warnings and did not correct said situation after takeoff. They momentarily retarded the engine throttles, increased the pitch angle and did not correct the bank angle, leading to a deterioration of the stall condition.

The crew did not detect the configuration error because they did not properly use the checklists, which contain items to select and verify the position of the flaps/slats, when preparing the flight. Specifically:

- They did not carry out the action to select the flaps/slats with the associated control lever (in the “After Start” checklist);
- They did not cross check the position of the lever or the status of the flap and slat indicating lights when executing the “After Start” checklist;
- They omitted the check of the flaps and slats during the “Takeoff briefing” item on the “Taxi” checklist;
- The visual check done when executing the “Final items” on the “Takeoff imminent” checklist was not a real check of the position of the flaps and slats, as displayed on the instruments in the cockpit.

The CIAIAC has identified the following contributing factors:

- The absence of an improper takeoff configuration warning resulting from the failure of the TOWS to operate, which thus did not warn the crew that the airplane’s takeoff configuration was not appropriate. The reason for the failure of the TOWS to function could not be reliably established.
- Improper crew resource management (CRM), which did not prevent the deviation from procedures in the presence of unscheduled interruptions to flight preparations.

4. SAFETY RECOMMENDATIONS

4.1. Safety recommendations issued during the investigation

REC 01/09. It is recommended that the Federal Aviation Administration (FAA) of the United States and the European Aviation Safety Agency (EASA) require the manufacturer, the Boeing Company, to include in its Aircraft Maintenance Manual (AMM) for the DC-9 and MD-80 series, in the Troubleshooting Manual (TSM) for the MD-90 series, and in the Fault Isolation Manual (FIM) for the 717 series, specifically identified instructions to detect the cause and to troubleshoot the fault involving the heating of the RAT temperature probe while on the ground.

The EASA has not replied to the recommendation yet.

The FAA has replied to the recommendation saying that "…the Maintenance Manual used in conjunction with the wiring diagrams is sufficient for solving malfunctions in the RAT probe system". Additionally, the FAA believes that the publication of the alert for operators SAFO 08021, which emphasizes the importance of adhering to standard operating procedures, is the most effective way to avoid risks associated with improper takeoff configurations in aircraft of this model.

The CIAIAC believes that, even if including each and every possible malfunction that can manifest itself in airplanes of this type in a single document, like the Maintenance Manual, is not feasible, the specific case of "RAT probe heating on the ground" has been shown to have sufficiently relevant implications to justify that it be specifically addressed. Moreover, such instructions should be placed in a single document, the AMM, TSM or FIM, as applicable to the various models of this type, so as to facilitate its location. As for document SAFO 08021, the CIAIAC acknowledges that while it contains very useful information for improving operational safety, it has no bearing on the objectives of the recommendation.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is:

- With regard to the EASA: Open. Awaiting reply
- With regard to the FAA: Open. Reply unsatisfactory

REC 07/09. It is recommended that the Federal Aviation Administration (FAA) of the United Stated establish mandatory airworthiness instructions to modify the procedures contained in the aircraft flight manuals for the Boeing DC-9, MD-80, MD-90 and B-717 series so as to include a functional check of the TOWS prior to each flight.

The FAA has replied to the recommendation recalling, first, the historical evolution of the "Flight Manual" concept for transport airplanes as said airplanes became more complex, and how the original concept of a single manual containing details on the normal, abnormal and emergency procedures needed by the crew to operate the airplane developed into the current concept, in which the Flight Manual contains a minimum amount of information in comparison with the Flight Crew Operating Manual (FCOM), where all of the information needed by the crew to operate an aircraft (such as checklists, system diagrams, detailed procedures) is included.

The FAA idicated that, in the United States, any company devoted to commercial air transport is required, by the regulations that govern this type of operation (FAR 121), to have FCOMs approved for each of its airplanes, and that in the case of the DC-9, MD-80 and MD-90, the Boeing FCOMs already contain instructions for crews to check the operation of the TOWS prior to each flight.

The CIAIAC is of the opinion that the best way to ensure that instructions concerning the check of the TOWS are effectively transferred to the procedures of operators all over the world, not just in the United States, is not to include them in the FCOM, a reference document that is distributed by the manufacturer, but to modify the Flight Manual, which is linked to the aircraft's Type Certificate, so that it includes these instructions. This modification would then be mandatory for all aircraft of the type still in service by means of the corresponding Airworthiness Certificate.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is: Open. Reply unsatisfactory.

REC 08/09. It is recommended that the European Aviation Safety Agency and the Federal Aviation Administration (FAA) of the United States require the Boeing Company to evaluate the operating conditions, in-service life, reliability and failure modes of relays in position R2-5 of the ground sensing system in the DC-9, MD-80, MD-90 and B-717 series of airplanes and that it specify a maintenance program for this component based on the results of said evaluation.

The EASA has acknowledged receipt of this recommendation, but has not reported on what measures it plans to take or on the reasons for not taking any actions, as the case may be.

The FAA has replied to the recommendation stating that after analyzing the in-service data available on relays with part number 9274-3642, it has concluded that their reliability is typical for any electromechanical relay. The data likewise show that its use in this specific application (position R2-5 of the ground sensing system in airplanes of the DC-9, MD-80, MD-90 and B-717 series) does not introduce any factor that shortens the useful service life of these components. Moreover, levels of operational checks currently defined for these relays are the highest possible that can be specified for a non-monitored component. Based on these analyses, the FAA does not plan to take any additional action with regard to this recommendation.

The CIAIAC does not view this recommendation as having been issued based on whether the physical location of the R2-5 introduces factors (such as temperature, vibration, electrical stress, etc.) that may shorten the service life of the relays, but rather based on the function provided by this component within the ground sensing system. In the CIAIAC's opinion, this is a function that has proven to be sufficiently relevant from a safety standpoint that the component that provides it deserves to be categorized as a "monitored component".

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is:

- With regard to the EASA: Open. Awaiting reply
- With regard to the FAA: Open. Reply unsatisfactory

REC 09/09. It is recommended to the European Aviation Safety Agency and to the Federal Aviation Administration (FAA) of the United States that the design of Takeoff Warning Systems (TOWS) be reviewed in transport airplanes whose certification standards did not require the installation of such systems or which, if they did require it, did not apply to them the guidelines and interpretation provided by AMC 25.703 in the case of the EASA, or circular AC 25.703 in the case of the FAA. The goal of this review should be to require that the TOWS comply with the applicable requirements for critical systems classified as essential in CS 25.1309 and FAR 25.1309.

The EASA has acknowledged receipt of this recommendation, but has not reported on what measures it plans to take or on the reasons for not taking any actions, as the case may be.

The FAA has provided a reply to the recommendation based on the conclusions of the CAST (Commercial Aviation Safety Team), a group of experts from industry and the American government that worked from 1999 to 2001 on introducing safety improvements to commercial aviation and that anlyzed, among other cases, the accident of a Northwest Airlines MD-80 in 1987, in which the TOWS did not work properly. The FAA's position on this issue is:

- That the current requirements for certifying transport airplanes, as well as the associated guidelines, are satisfactory,

- that changes to the design of already certified airplanes have been introduced through the issuance of Airworthiness Directives in those cases where it was deemed necessary, and
- that, additionally, the continuous improvement of the safety of in-service airplanes is geared toward operator practices and pilot training that ensures the crews' adherence to pre-takeoff procedures and checklists.

The CIAIAC believes that the accumulated experience based on accidents involving airplanes, like the MD-82, in which the changes made since their original conception, both in the design of the TOWS and in the procedures for properly configuring the airplane for takeoff, have proven insufficient, makes the FAA's reply unsatisfactory in terms of the recommendation's intended purpose.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is:

- With regard to the EASA: Open. Awaiting reply
- With regard to the FAA: Open. Reply unsatisfactory

REC 10/09. It is recommended that the European Aviation Safety Agency and the Federal Aviation Administration (FAA) of the United States revise regulations CS-25 and FAR 25, respectively, on the certification of large transport airplanes to add a requirement that ensures that Takeoff Warning Systems (TOWS) are not disabled by a single failure or that they provide the crew with a clear and unequivocal warning when the system fails.

The FAA has replied to the recommendation by recalling the policy commonly followed in the certification of transport airplanes of applying the "no inoperability resulting from a single failure" requirement only to the most critical functions, those whose loss would be considered catastrophic. While acknowledging the importance of the operability of the TOWS, the FAA believes that a failure of this system does not, in and of itself, constitute a condition that is incompatible with the safe conduct and landing of a flight.

The FAA believes that, after the publication of advisory circular AC 25.703-1, there has been a clear tendency toward more robust and reliable TOWS designs. This document, which was published after the DC-9 and MD-80 series were certified, established, via the MMEL, that an airplane with an inoperative TOWS could not be dispatched. This, in the FAA's opinion, provides sufficient guarantee that any TOWS designed after the publication of AC 25.703-1 will give an immediate warning to the crew in the event of a fault or power supply failure. Therefore, no additional actions are considered necessary.

The EASA replied to the recommendation saying that in models certified more recently under specification CS-25, it has noted a satisfactory in-service record for Takeoff Warning Systems (TOWS) and that accidents associated with this system occurred in airplanes as old or older than the MD-82. In the EASA's opinion, there has been a gradual improvement in this system's reliability, an improvement that is not actually attributable to the introduction of changes to the certification requirements (the current text of paragraph 25.703 of CS-25 has barely changed with respect to that in paragraph 25.703 in the JAR in 1979), but rather due to the definition of acceptable means of compliance.

The EASA believes that with the current wording in the document on acceptable means of compliance, AMC 25.703, the TOWS's category has been upgraded to that of an essential system. Paragraph 5.b.3 classifies the inoperability of the TOWS as a "major" fault condition, while paragraph 5.c.11 excludes the possibility of allowing the use of the MMEL to dispatch an airplane with the TOWS inoperative. The EASA's conclusion, then, is that the aim of the recommendation, to improve the reliability of TOWS in new airplanes, has already been achieved.

The CIAIAC regards both replies as stemming from a similar premise: that the goal of the recommendation has been achieved without having to change the certification requirements (which in the EASA's terminology is called "Book 1", and in the ICAO's, Standard). Rather, it was sufficient to change the "Acceptable Means of Compliance" (which in the EASA's terminology is called "Book 2", and in the ICAO's, recommended practices).

In order to accept this position, the CIAIAC would need;

- First, available data that show that in fact in all transport airplane models for which a type certification was requested from the FAA after the date of publication of AC 25.703-1, as well as in all large airplanes for which a type certification was requested from the EASA after the publication of AMC 25.703, the TOWS was designed based on the criterion that the crew be provided with a clear and unequivocal indication if the system fails.
- Second, available data that show that this criterion will be followed in all TOWS designs that will be certified in the future, which would only be possible if the certification standards are changed, as suggested by the recommendation, since the acceptable means of compliance do not offer sufficient legal guarantees that a given criterion will be maintained over time.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is:

- With regard to the EASA: Open. Reply unsatisfactory
- With regard to the FAA: Open. Reply unsatisfactory

REC 11/09. It is recommended that the European Aviation Safety Agency revise the accompanying guidelines and the clarifying material for the CS-25 certification regulations for large transport airplanes so as to consider the human errors associated with faults in takeoff configurations when analytically justifying the safety of the TOWS, and to analyze whether the assumptions used when evaluating these systems during their certification are consistent with existing operational experience and with the lessons learned from accidents and incidents.

The EASA has replied to the recommendation saying that requirement 25.1302 in the European airworthiness code for the certification of large airplanes, CS-25, since the entry into force of Amendment 3 on 19 September 2007, already requires that an analysis be done so that potential errors that a flight crew might reasonably be expected to make be taken into consideration when designing systems.

The EASA added that, in the case of the TOWS, requirement CS 25.703 and its acceptable means of compliance (AMC) already consider the implications that, from a safety standpoint, are involved from a combination of an unsafe takeoff configuration and a fault of the TOWS. That is why a failure of the TOWS is considered major and the MMEL cannot be used to provide relief to dispatch an airplane if the TOWS is inoperative. Therefore, the design of these systems should be sufficiently reliable.

The EASA believes that the available in-service history shows all of these stipulations to be adequate. A review of reported events revealed that all of them involved airplanes as old as or older than the MD-82. In its opinion, then, CS-25 does not need to be modified.

The CIAIAC considers the EASA's reply to be satisfactory as regards the recommendation's first goal. An analysis of potential human errors is already incorporated into CS-25, not only in the part on "Acceptable Means of Compliance" ("Book 2"), as requested by the recommendation, but also in the part on "Requirements" ("Book 1"), which has a specific section, 25.1302, that applies not only to errors in selecting the takeoff configuration, as requested by the recommendation, but to all errors that a flight crew might reasonably be expected to make.

The CIAIAC believes, however, that the EASA has not replied to the proposal in the second part of the recommendation. Currently, in Book 2 of CS-25, the EASA has published an entire set of criteria for conducting the safety analyses of systems (System Safety Assessments, SSA). In the case of the TOWS, these criteria are basically located in AMC sections 25.1309 and 25.703. The aim of the recommendation is that an additional criterion be added to analyze whether the hypotheses used to evaluate a given TOWS prior to its entry into service were consistent with the operational experience gained afterwards and with the lessons learned from accidents and incidents.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is: Open. Reply unsatisfactory.

REC 12/09. It is recommended that the International Civil Aviation Organization (ICAO), the Federal Aviation Admministration (FAA) of the United States and European Aviation Safety Agency (EASA) jointly promote the holding of an international conference, to be attended by every civil aviation representative organization, such as authorities, industry, academic and research institutions, professional associations and the like, for the purpose of drafting directives on good industry practices in the area of aviation operations as they apply to checklist design, personnel training and improved procedures and cockpit work methods so as to ensure that crews properly configure aircraft for takeoffs and landings.

Both the ICAO and the EASA replied referring to the work carried out at the High-Level Conference on Operational Safety that is discussed in Section 1.18.11.1 of this report.

The FAA replied that, in its opinion, the information on checklist design, personnel training and procedures and cockpit work methods that is currently at the disposal of members of the aviation community are pertinent, suitable and easily accessible. As a result, despite agreeing with the purpose of the recommendation, it does not consider necessary that an international conference like the one described be held. Nevertheless, the United States still took part in the High-Level Conference on Operational Safety.

The CIAIAC believes that the High-Level Conference on Operational Safety organized by the ICAO and referenced in point 1.18.11.1 of this report constituted a worldwide forum at which topics in line with the spirit of this recommendation were debated.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is: Closed. Reply satisfactory.

REC 13/09. It is recommended that the European Aviation Safety Agency (EASA) compile the results of studies and works done, as well as of any instructions and directives issued by civil aviation authorities to date, concerning the principles and guidelines relative to the:

- design of checklists and
- working methods in the cockpit

so as to allow European operators and manufacturers and national authorities to have clear references on the state of the art in the design and application of checklists.

The EASA has acknowledged receipt of this recommendation, but has not reported on what measures it plans to take or on the reasons for not taking any actions, as the case may be.

Therefore, insofar as the CIAIAC is concerned, the implementation status of this recommendation is: Open. Awaiting reply.

4.2. New safety recommendations issued with this report

REC 18/11. It is recommended that the United States Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) require takeoff stall recovery as part of initial and recurring training programs of airline transport pilots.

REC 19/11. It is recommended that the United States Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) study and assess the stall recovery procedure in the flight manuals of large transport airplanes to include a check of the flap/slat lever and its adjustment, if required.

REC 20/11. It is recommended that the European Aviation Safety Agency (EASA) establish requirements for flight simulators so as to allow simulator training to cover sustained takeoff stalls that reproduce situations that could exceed the flight envelope limits.

REC 21/11. It is recommended that the European Aviation Safety Agency (EASA), in keeping with ICAO initiatives, introduce in its regulations the concept of critical phases of flight and define those activities considered acceptable during said phases.

REC 22/11. It is recommended that the European Aviation Safety Agency (EASA) and national civil aviation authorities, when evaluating operator training programs, expressly ensure that:

- the concept of sterile cockpit is stressed,
- the importance of adhering to said concept is stressed, along with the consequences of even minor distractions, and
- examples of accidents are included in which non-compliance with regulations involving the sterile cockpit was a relevant factor.

REC 23/11. It is recommended that the European Aviation Safety Agency (EASA) ensure that national authorities require commercial air transport operators to prohibit their crews from using portable personal electronic devices on the flight deck.

REC 24/11. It is recommended that the European Aviation Safety Agency (EASA) develop guidance material for the preparation, evaluation and modification of checklists associated with normal, abnormal and emergency procedures that is based on the criteria that govern safety management systems.

REC 25/11. It is recommended that the European Aviation Safety Agency (EASA) clarify whether or not checklists are subject to the acceptance of national authorities and, if so, that it draft instructions so that said authorities apply uniform criteria and methodologies, such as methods for assessing the systems and procedures in use at the operators for managing checklists and quality assurance systems in general.

REC 26/11. It is recommended that the European Aviation Safety Agency (EASA) perform investigations or studies intended to know the status of application and the real effectiveness of the current UE requirements applicable to Crew Resources Management (CRM). The results of these studies should permit to identify the weak points existing in this field and should contain proposals on how to strengthen them.

REC 27/11. It is recommended that the European Aviation Safety Agency (EASA) standardize the CRM training that must be provided to the operations inspectors of national authorities, and define the criteria that must be met by said inspectors in order to exercise their duties as inspectors in the area of CRM.

REC 28/11. It is recommended that Spanair expand its operations and instructional procedures to clearly specify the methodology and tasksharing to be used by flight crew members when executing and verifying critical actions, like selecting the position of the flaps and slats.

REC 29/11. It is recommended that Spain's Aviation Safety Agency (AESA) ensure that the operational and instructional procedures at companies that operate MD-80 series airplanes clearly specify the methodology and tasksharing to be used by flight crew members when executing and verifying critical actions, like selecting the position of the flaps and slats.

REC 30/11. It is recommended that the European Aviation Safety Agency (EASA) undertake regulatory initiatives intended to require commercial air transport operators to implement a program of line operations safety audits, as part of their accident prevention and flight safety programs.

REC 31/11. It is recommended that the United States Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) clarify the definition of an inoperative element that is contained in the preamble to all Master Minimum Equipment Lists (MMEL), so as to avoid interpretation errors in its application.

REC 32/11. It is recommended that the United States Federal Aviation Administration (FAA) modify the Boeing DC-9, MD-80 and MD-90 Master Minimum Equipment List (MMEL) items 30.8, 34.9 and others that may be related to RAT probe heating on the ground so that said items include maintenance (M) and/or operating (O) instructions to check the TOWS.

REC 33/11. It is recommended that the European Aviation Safety Agency (EASA) issue an interpretation regarding the need to identify the source of a malfunction prior to using the MEL, and that it assures that national authorities accept and apply the same standards with regard to their procedures for overseeing operators in their respective States.

REC 34/11. It is recommended that Spanair revise its mainenance procedures and draft instructions for relevant personnel so that any maintenance tasks performed are adequately described in maintenance records and provide sufficient details.

REC 35/11. It is recommended that Spain’s Aviation Safety Agency (AESA) ensure that all of the maintenance tasks performed by Spanair be described adequately and with sufficient detail in the aircrafts’ technical records.

REC 36/11. It is recommended that Spanair revise its quality assurance system so that the implementation of any corrective measures adopted by its maintenance organization is effectively monitored.

REC 37/11. It is recommended that Spain’s Aviation Safety Agency (AESA) ensure that the Spanair quality assurance system provides effective monitoring of any corrective measures that are adopted by its maintenance organization.

REC 38/11. It is recommended that Spanish Airports and Air Navigation (AENA) evaluate the need to retain the internal fence surrounding runway 36L, and if it is retained, that modifications be made to said fence to ensure more expeditious access to all areas of the airport situated beyond the fence.

REC 39/11. It is recommended that Spanish Airports and Air Navigation (AENA) enhance the assistance provided by control tower personnel to Rescue and Firefighting Services (RFFS) in the event of an accident at an airport.

REC 40/11. It is recommended that Spanish Airports and Air Navigation (AENA) inform all the persons and groups involved in carrying out emergency plans and who are not under its authority, or to instruct them when under its authority, of the importance of respecting the decision-making process and to promote the flow of information.

REC 41/11. It is recommended that Spanish Airports and Air Navigation (AENA) enhance the training of Rescue and Firefighting Services (RFFS) personnel in the area of first aid, and that it complement their training with courses on water search and rescue at those airports with water environments in which the use of special rescue services external to the airport is not anticipated.

REC 42/11. It is recommended that the European Aviation Safety Agency (EASA) draft guidelines and instructions so that national authorities are better able to assess the general situation of commercial air transport operators that undergo notable changes, such as rapid expansions, a significant growth in their resources, or the opposite situation, a reduction in their activity or resources, such as through personnel layoffs, the purpose being for authorities to constantly adapt their monitoring plans to consider their evaluation of these changes so as to proactively detect and assess risk factors that point to a possible degradation in safety level.

APPENDICES

APPENDIX 1
Spanair MEL. RAT probe system and heating

Spanair Operator	OM-B MD-80	Page: 3
Section: 09 - MEL	Subchapter: 30 – ICE AND RAIN PROTECTION	Revision: 02
Chapter: 01 – Equipment List		Edition: 12.12.03

1. System & sequence numbers Item	2. Category	3. Number installed	4. Number Required for dispatch	5. Remarks or exceptions
30.6 Static Port Heaters	C	4	0	May be inoperative provided: (PL) Airport temperatures are above + 5º C, or runaway is not covered with slush or standing water.
30.7 Stall Sensor Heaters				
1)				Not applicable.
2) Stall Warning Vane Heaters	C	2	0	Both may be inoperative provided: (PL) Flight is not made in known or forecast icing conditions.
30.8 Ram Air Temp Probe Heater	C	1	0	May be inoperative provided: (PL) Flight is not made in known or forecast icing conditions.
30.9 Rudder Limit Pitot Heater				Combined with Item 30-4.
30.10 Water Service Panel Heater	C	1	0	May be inoperative.
30.11 AIRFOIL ICE PROT PRESSURE ABNORMAL Annunciator System	C	1	0	May be inoperative provided: (PL) Flight is not made in known or forecast icing conditions.
30.12 ICE PROTECT SUPPLY PRESSURE HI Annunciator System	C	1	0	May be inoperative provided: (PL) Flight is not made into known or forecast icing conditions.

Spanair Operator	OM-B MD-80	Page: 3
Section: 09 - MEL	Subchapter:	Revision: 02
Chapter: 01 – Equipment List	34 – NAVIGATION	Edition: 12.12.03

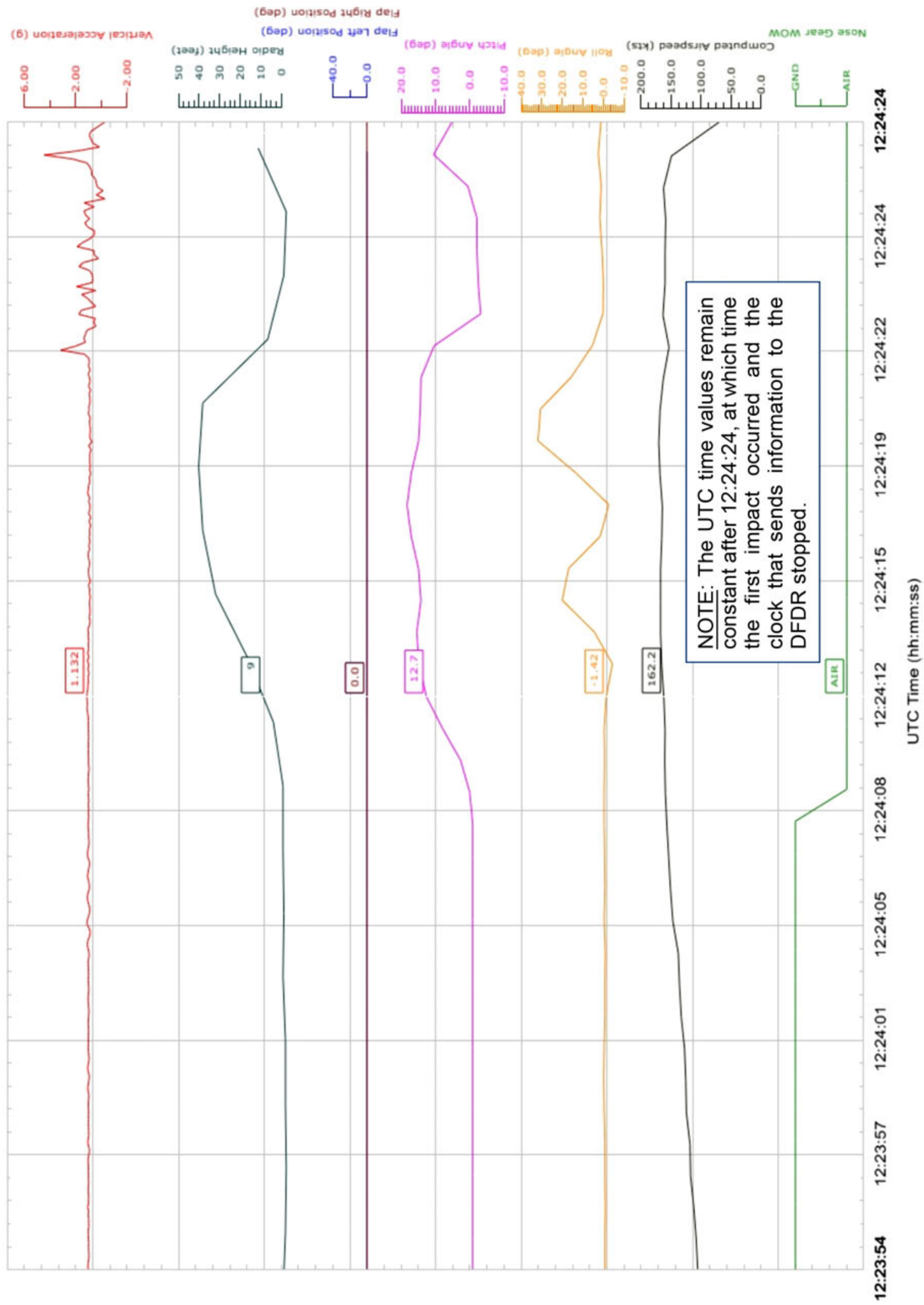
1. System & sequence numbers Item	2. Category	3. Number installed	4. Number Required for dispatch	5. Remarks or exceptions
34.8 Vertical Speed Indicator		2	2	Must be operative.
34.9 Ram Air Temperature (RAT) /Thrust Rating Systems				
1)				Not applicable.
2)				Not applicable.
3) RAT/ Thrust Rating System	C	1	0	(M)(O) The RAT portion may be inoperative provided: a) A SAT or Standby RAT Indicating System or PMS SAT readout is available, b) Other systems affected by the RAT Probe (DFGS, CADC, Thrust Rating, FMS, PMS) are considered, and c) Procedures are established to verify engine power settings. (M) Evaluate the effect of the inoperative component on related systems. (O) Use SAT or standby RAT indicator when temperature information is required. Convert SAT to TAT by using chart on OM-B 0.2. General Information and Units Measure. **or**
	C	1	0	(O) The EPR Limit/Thrust Rating portion may be inoperative provided: (PL) a) A RAT or SAT Indication System or PMS SAT readout is available, b) The EPR Limit Chevron Automatic Mode is considered inoperative, c) EPR Limit Mode of the auto throttle is placarded inoperative, and is not used, and d) Procedures are established to verify engine power settings.

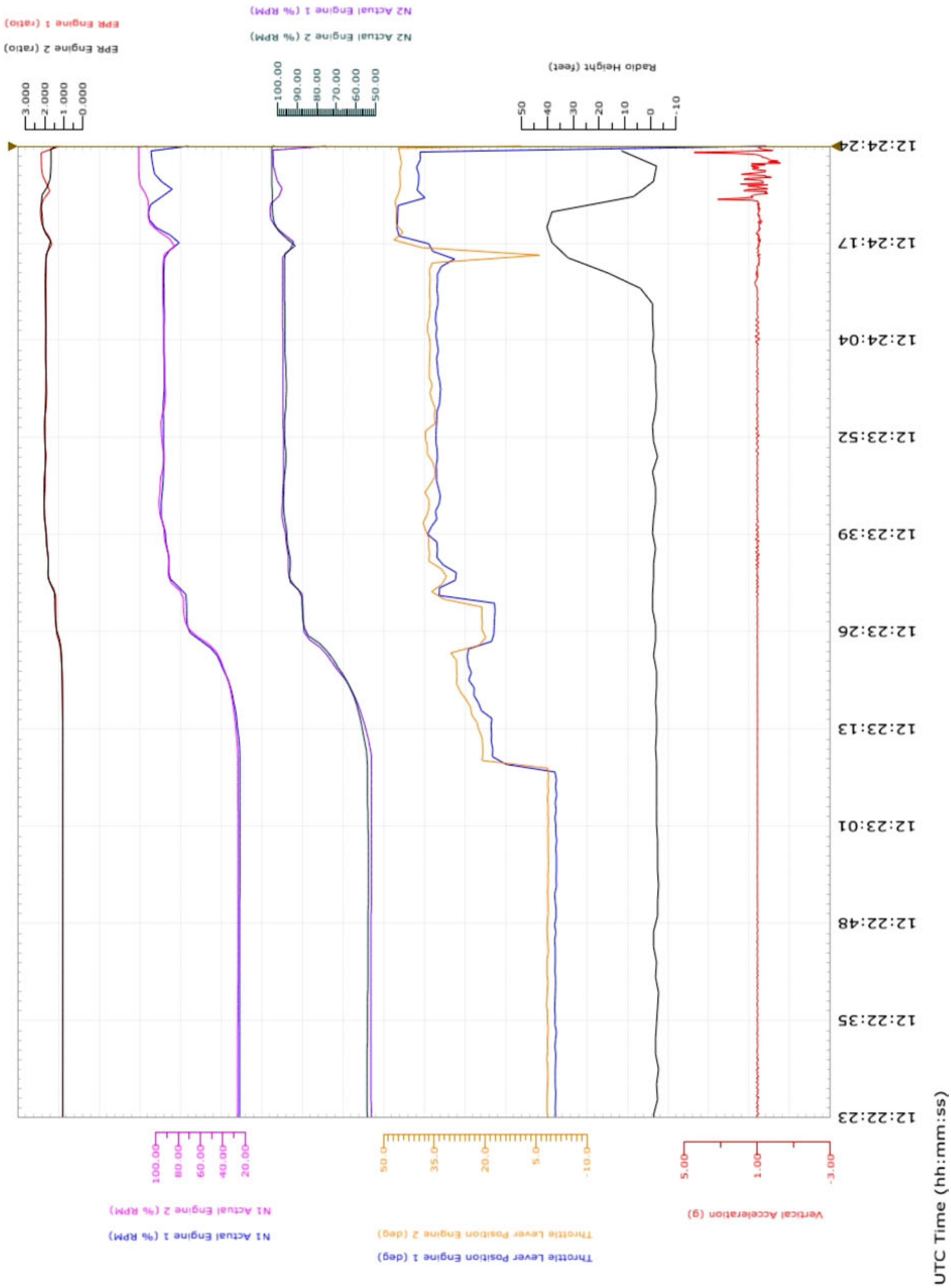
Spanair Operator	OM-B MD-80	Page: **4**
Section: **09 - MEL**	Subchapter:	Revision: **09**
Chapter: **01 – Equipment List**	**34 – NAVIGATION**	Edition: **14.06.07**

1. System & sequence numbers Item	2. Category	3. Number installed	4. Number Required for dispatch	5. Remarks or exceptions
34.9 Ram Air Temperature (RAT) /Thrust Rating Systems (Cont'd)				
3) RAT/ Thrust Rating System (Cont'd)				(O) a) Determine EPR limits from QRP and set EPR gage limit manually. b) If Autothrottles are used (Speed Select/Mach Select Modes), flight crew must ensure EPR does not exceed limits. Automatic EPR Limit Bug will be invalid. c) CAT III capability affected. *NOTE: The autothrottle may be used in the SPD SEL or MACH SEL modes with EPR limit set manually.*
34.10 Static Air Temperature Indicator	D	1	0	(O) May be inoperative provided: (PL) Ram Air Temperature (RAT) System is operative. (O) Use RAT indicator when temperature information is required.
34.11 Horizon Indicators		2	2	Must be operative.
34.12 Vertical Gyros (Excludes Standby Attitude Indicator) Three V.G. installed in All, except 2 installed in: GAT-S/N 49709 GVO-S/N 49642	C	3	2	If a third Vertical Gyro is installed, one may be inoperative provided independent Primary Attitude information is available on each pilot's panel. *NOTE: Refer to Item 34-38 for AHRS dispatch restrictions.*

APPENDIX 2
Parameters recorded on DFDR

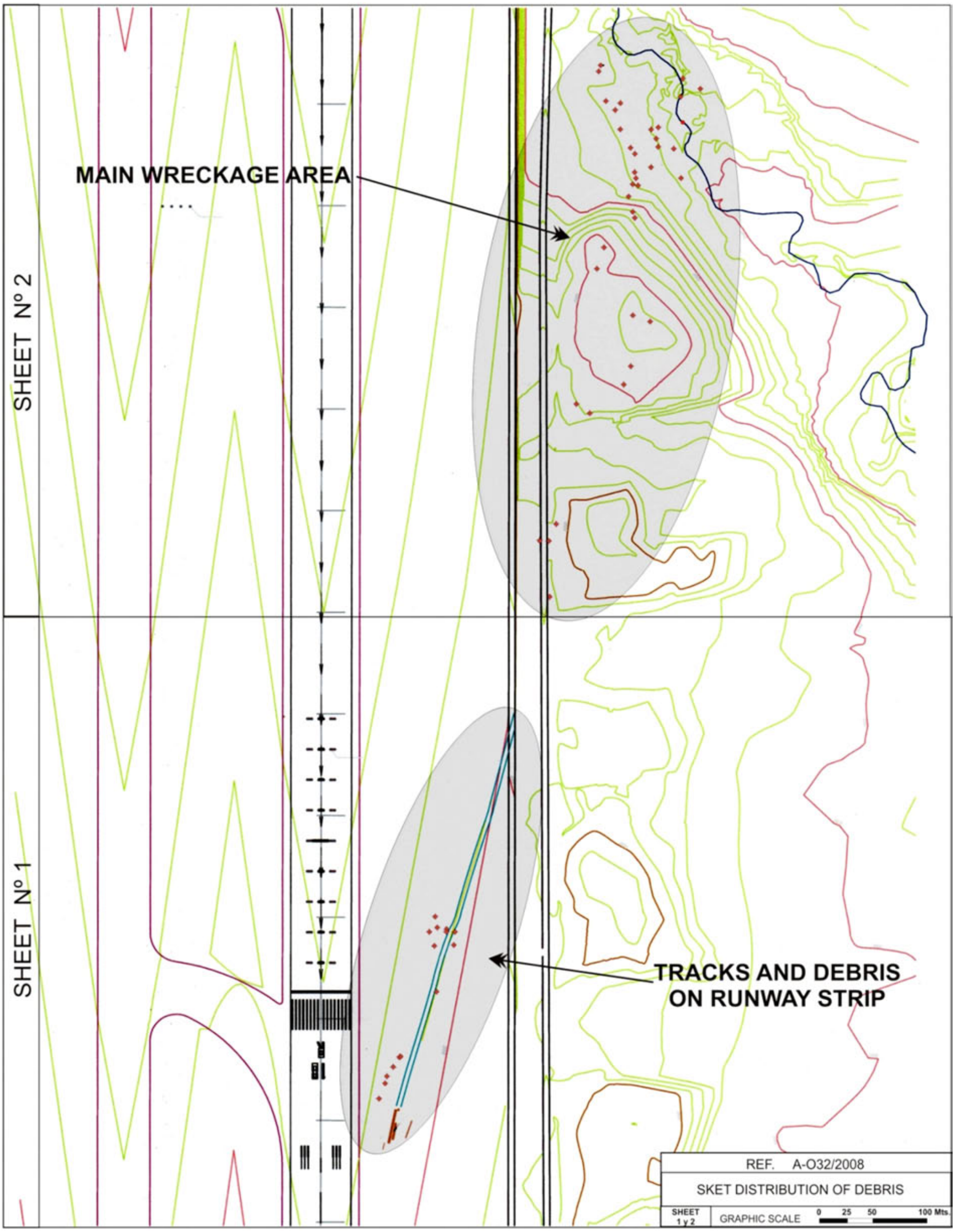
Take off roll



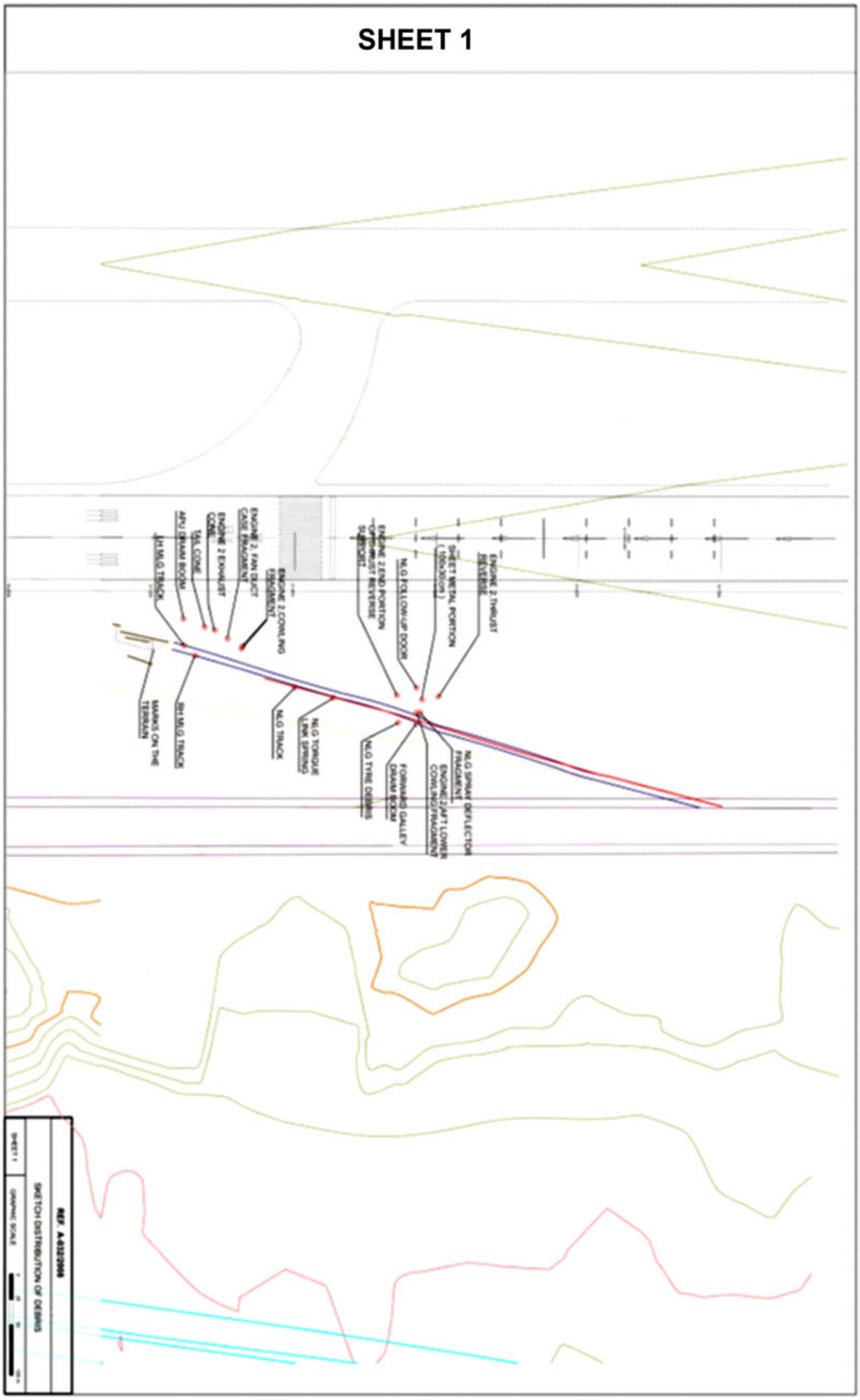

EPR Engine 1 (ratio)
EPR Engine 2 (ratio)
N2 Actual Engine 1 (% RPM)
N2 Actual Engine 2 (% RPM)
Radio Height (feet)
N1 Actual Engine 2 (% RPM)
N1 Actual Engine 1 (% RPM)
Throttle Lever Position Engine 2 (deg)
Throttle Lever Position Engine 1 (deg)
Vertical Acceleration (g)
12:24:24
12:24:17
12:24:04
12:23:52
12:23:39
12:23:26
12:23:13
12:23:01
12:22:48
12:22:35
12:22:23
UTC Time (hh:mm:ss)

APPENDIX 3
Diagram of debris field

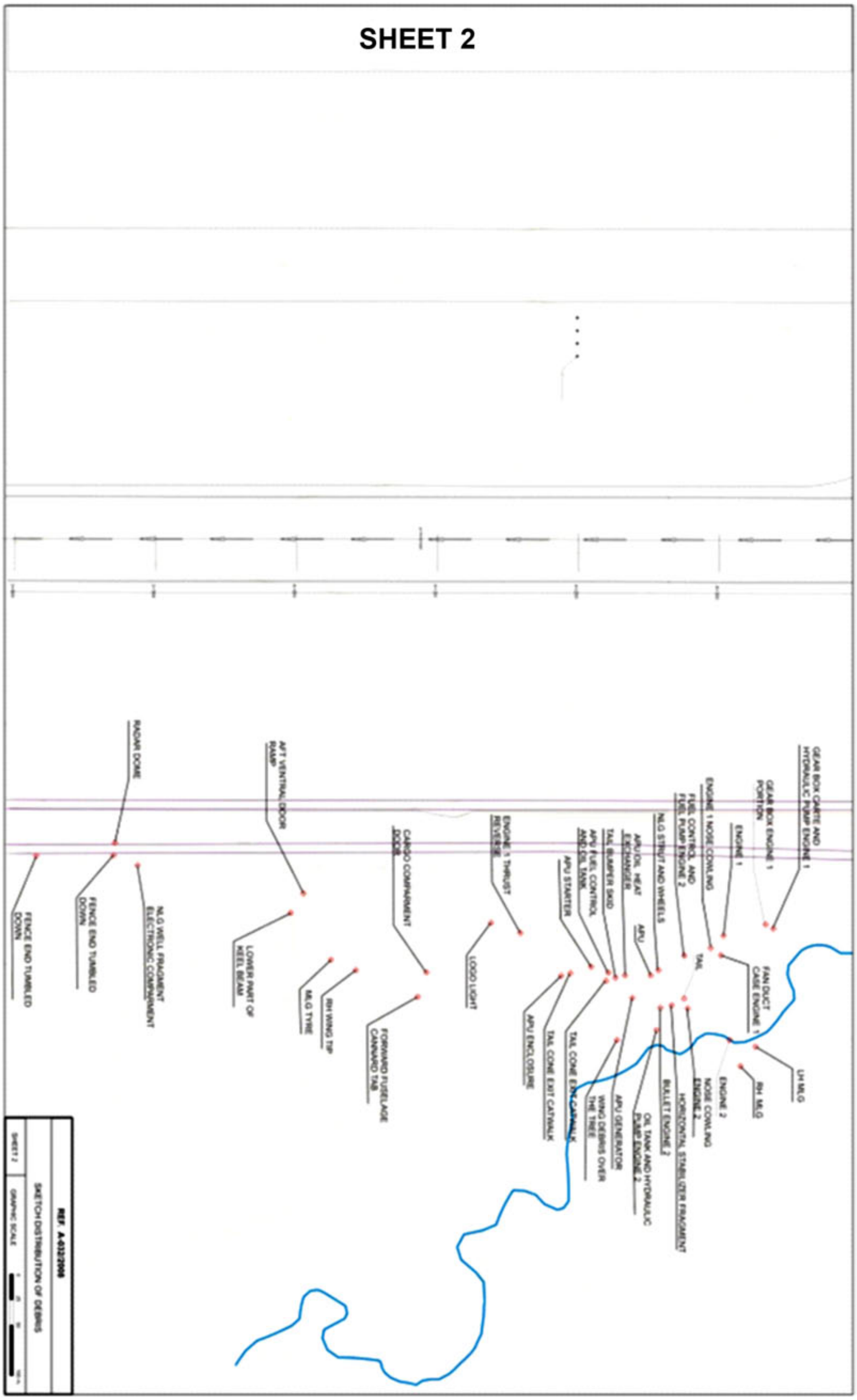
Area of main wreckage



Area of drag marks and remains on strip (Sheet 1)



Area of tracks and debris on strip (Sheet 2)



APPENDIX 4
Normal Before-takeoff checklist in the Spanair Operations Manual

Spanair Operator	OM-B MD-80		Page: 1
Section: 02 – Normal Procedures		Subchapter:	Rev: 01
Chapter: 01 – NORMAL CHECK LIST		01 – NORMAL CHECK LIST	Issue: 15.02.08

Spanair NORMAL CHECK LIST MD-80

PRESTART

1.	T.L.G./Crew & A/C Documentation	CHECKED
2.	Pins	REMOVED
3.	Circuit Breakers	CHECKED
4.	Battery Switch	ON & LOCKED
5.	Ground Service Elec. Pwr Switches	ALL OFF
6.	Fire Detect Loops & Fire Warning	CHECKED
7.	APU/External Power	SET
8.	Reinforced Cockpit Door	CHECKED
9.	Air Conditioning	SET
10.	Instruments NAV Selectors	NORMAL
11	IRS (if installed)	NAV/CHKD
12.	Eng. Syncro	OFF
13.	EGPWS/GPWS.	CHECKED
14.	Voice & Flight Recorder	CHECKED & SET
15.	HF Radios	SET
16.	Anti-Skid	CHECKED & ARMED
17.	Stall Warning System	CHECKED
18.	Max. Speed Warning & Mach Trim	CHECKED & NORMAL
19.	PWIDS/Wing Heaters (If installed)	CHECKED & SET
20.	Yaw Damper	ON
21.	Electrical Power Switches	SET
22.	Emergency Power	CHECKED & OFF
23.	Radio Rack	FAN
24.	Air Cond. Shutoff	AUTO
25.	Ram Air	SET
26.	Cabin Pressure Controller	CHECKED & SET
27.	Fuel pumps & X-Feed Lever	CHECKED, SET & OFF
28.	Ignition	OFF
29.	Emergency Lights	CHECKED & ARMED
30.	No Smoking & Seat Belts	SET
31.	Ice Protection	CHECKED & SET
32.	Annunciator & Digital Lights	CHECKED
33.	Exterior & Logo Lights	SET
34.	D.F.G.S	TESTED & SET
35.	T.R.I. & A.R.T. Swt	CHECKED & SET
36.	Gear Lights & Aural Warning	CHECKED
37.	Fuel/Oil/Hyd. Quantity	CHECKED
38.	Engine Instruments	CHECKED
39.	Hydraulic Pumps	CHECKED & SET

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Section: 02 – Normal Procedures		Subchapter:	Rev: 01
Chapter: 01 – NORMAL CHECK LIST		01 – NORMAL CHECK LIST	Issue: 15.02.08

40. Brake Press. & Temp .... CHECKED
41. Flight Instruments & HSI/ND Mode .... CHECKED
42. Altimeters .... SET & CHECKED
43. Static Air .... NORMAL
44. FMS/ACARS .... CHECKED & SET
45. Radar .... CHECKED & OFF
46. Stabilizer Trim .... CHECKED
47. Spoilers .... DISARM
48. Rudder Control Lever .... POWER
49. T/O Warning & Throttles .... CHECKED & IDLE
50. Fuel Levers .... OFF
51. Flaps & Slats .... UP & RETRACTED
52. Transponder/TCAS .... CHECK/STBY
53. Pneumatic X-Feed Levers .... OPEN
54. Trim Tabs .... SET
55. Emergency Equipment .... CHECKED
56. Oxygen Supply .... CHECKED

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57. Stabilizer/C.G. & Flap T.O. Window .... SET
58. Zero Fuel Weight & P.M.S. .... INSERT/UPDATE
59. T/O Data .... SET & XCHECKED

BEFORE START/PUSH BACK

1. Parking Brakes .... ON
2. Seat belts Sw. .... ON
3. Doors .... CLOSED
4. Anti-Collision .... ON
5. Cabin Report .... RECEIVED
6. Flight Deck Door .... CLOSED & LOCKED
7. Transponder/TCAS .... TA/RA
8. Start Procedure .... COMPLETED

AFTER START, NORMAL

1. Ignition .... OFF
2. Air Conditioning & A.P.U. .... AUTO & SET
3. Electrical Pwr. .... CHECKED
4. Ice Protection & Fuel Heat .... SET
5. Annun. Panel & Lights .... CHECKED
6. Hydraulic pumps & press .... SET&CHECKED
7. Pneum.X-Feed Valve Levers .... SET
8. Clear Signal & Lights .... RECEIVED/ON
9. Flaps & Slats .... SET & CHECKED

Spanair Operator	OM-B MD-80	Page: 3
Section: 02 – Normal Procedures Chapter: 01 – NORMAL CHECK LIST	Subchapter: 01 – NORMAL CHECK LIST	Rev: 01 Issue: 15.02.08

TAXI

1. Brakes.......... CHECKED
2. Flight Controls .... CHECKED
3. Flight Instruments .... CHECKED
4. NAV. AIDS, DFGS & TAWS.......... SET & CHECKED
5. T.R.I./A.R.T. Sw. & E.P.R. Bugs .... SET & CHECKED
6. Air Conditioning .... SET
7. Transponder .... SET
8. T/O Briefing .... PERFORMED

TAKE OFF IMMINENT

1. Cabin .... ALERTED
2. Ignition .... SET
3. Spoilers & ABS .... ARMED
4. Brake Press & TEMP .... CHECKED
5. Windows .... CLOSED
6. Final Items .... PERFORMED

TAKEOFF EPR ERROR CHECK – Only when Icing Conditions exists

	JT8D-217C/219 MINIMUM N_1 (% RPM)							
	OUTSIDE AIR TEMPERATURE (°C)							
EPR	-20°	-10°	0°	10°	20°	30°	40°	50°
2.10	90,9	92,7	94,5	96,3	97,9	--	--	--
2.05	88,0	89,8	91,6	93.3	94.9	96,5	--	--
2.00	85,4	87,1	88,8	90,5	92,1	93,6	--	--
1.95	82,9	84,6	86,2	87,9	89,5	91,0	92,5	--
1.90	80,5	82,1	83,7	85,3	86,8	88,3	89,8	91,2
1.85	78,9	80,5	82,0	83,6	85,0	86,5	87,9	89.3
1.80	77,4	79,0	80,5	82,0	83,4	84,8	86,2	87,6
1.75	75.9	77,5	79,0	80.5	81.9	83,3	84,7	86,0
1.70	74.4	75.9	77.4	78.8	80,2	81.5	82.9	84,2
1.65	72.7	74,2	75.6	77,1	78.5	79.8	81,1	82.4

NOTE:......TO BE USED ONLY AS A CROSSCHECK FOR EPR ERROR DUE TO PLUGGED PT2 PROBE, NOT FOR SETTING TAKEOFF THRUST. THE ACTUAL N_1 DURING TAKEOFF WILL NORMALLY BE HIGHER THAN THE MINIMUM VALUES TABULATED ABOVE