ANSV AGENZIA NAZIONALE PER LA SICUREZZA DEL VOLO

INVESTIGATION REPORT

SERIOUS INCIDENT
involving the aircraft
B737-8200, registration EI-IGI,
at Caravaggio Airport (Orio al Serio – Bergamo),
1st October 2024

COURTESY TRANSLATION

TABLE OF CONTENTS

TABLE OF CONTENTS II
OBJECTIVE OF THE SAFETY INVESTIGATION IV
GLOSSARY V
INTRODUCTION VIII
CHAPTER I 1
FACTUAL INFORMATION 1
1. GENERAL INFORMATION 1
1.1. HISTORY OF THE FLIGHT 1
1.2. INJURIES TO PERSONS 1
1.3. DAMAGE TO AIRCRAFT 2
1.4. OTHER DAMAGE 3
1.5. PERSONNEL INFORMATION 3
1.5.1. Flight crew 3
1.5.2. Cabin crew 5
1.5.3. Maintenance staff 5
1.6. AIRCRAFT INFORMATION 6
1.6.1. General information 6
1.6.2. Specific information 6
1.6.3. Further information 7
1.7. METEOROLOGICAL INFORMATION 26
1.8. AIDS TO NAVIGATION 26
1.8.1. Air navigation and landing aids 26
1.9. COMMUNICATIONS 26
1.9.1. Mobile communications 26
1.9.2. Land communications 27
1.9.3. Transcript of communications 27
1.10. AERODROME INFORMATION 28
1.11. FLIGHT RECORDERS 29
1.11.1. General Information 29
1.11.2. FDR Transcript 29
1.11.3. Transcription of the CVR 32
1.12. WRECKAGE AND IMPACT INFORMATION 35
1.12.1. Location of the serious incident 35
1.12.2. Ground marks and distribution of debris 35

1.12.3. Examination of the wreckage 36
1.12.4. Impact dynamics 41
1.12.5. Malfunctions related to the event 42
1.13. MEDICAL AND PATHOLOGICAL INFORMATION 42
1.14. FIRE 42
1.15. SURVIVAL ASPECTS 42
1.16. TESTS AND RESEARCH 42
1.17. ORGANIZATIONAL AND MANAGEMENT INFORMATION 43
1.17.1. Maintenance 43
1.17.2. Training 44
1.17.3 S.M.S 45
1.18. ADDITIONAL INFORMATION 47
1.19. USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES 50
CHAPTER II 51
ANALYSIS 51
2. GENERAL 51
2.1. FLIGHT OPERATIONS 51
2.2. TECHNICAL FACTOR 53
2.3. ORGANISATIONAL FACTOR 56
2.3.1 SMS 58
2.4. HUMAN FACTORS 58
2.5. ENVIRONMENTAL FACTOR 62
2.6. SURVIVABILITY 62
CHAPTER III 63
CONCLUSIONS 63
3. GENERAL 63
3.1. FINDINGS 63
3.2. CAUSES AND CONTRIBUTING FACTORS 66
CHAPTER IV 67
SAFETY RECOMMENDATIONS 67
4. RECOMMENDATIONS 67
4.1. RECOMMENDATION ANSV-6/408-24/1/SI/26 67
4.2. RECOMMENDATION ANSV-7/408-24/1/SI/26 67
4.3. RECOMMENDATION ANSV-8/408-24/1/SI/26 68

OBJECTIVE OF THE SAFETY INVESTIGATION

The National Flight Safety Agency (ANSV), established by Legislative Decree No 66 of 25 February 1999, is the civil aviation safety investigation authority of the Italian State, as referred to in Article 4 of Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010. **It conducts safety investigations independently**.

Every accident and serious incident involving a civil aircraft is subject to a safety investigation, within the limits set out in the combined provisions of paragraphs 1 and 4 of Article 5 of EU Regulation No 996/2010.

A safety investigation is defined as a set of operations comprising the collection and analysis of data, the drawing of conclusions, the determination of the cause and/or contributing factors and, where appropriate, the formulation of safety recommendations.
The sole objective of the safety investigation is to prevent future accidents and incidents, not to apportion blame or liability (Article 1(1) of EU Regulation No 996/2010). Consequently, it is conducted independently and separately from investigations (such as those by the judicial authorities) aimed at establishing fault or liability.
The safety investigation is conducted in accordance with the provisions of Annex 13 to the Convention on International Civil Aviation (signed in Chicago on 7 December 1944, approved and brought into force in Italy by Legislative Decree No 616 of 6 March 1948, ratified by Law No 561 of 17 April 1956, No. 561) and by EU Regulation No. 996/2010.

Every safety investigation shall be concluded with a report drawn up in a form appropriate to the type and severity of the accident or serious incident. It may contain, where appropriate, safety recommendations, which consist of a proposal formulated for the purposes of prevention.
A safety recommendation does not, in itself, constitute a presumption of fault or an attribution of liability for an accident, a serious incident or an incident (Article 17(3) of EU Regulation No 996/2010).
The report shall ensure the anonymity of those involved in the accident or serious incident (Article 16(2) of Regulation (EU) No 996/2010).

This report has been translated and published by the ANSV for the English-speaking concerned public. The intent was not to produce a factual translation and as accurate as the translation may be, **the original text in Italian is the work of reference**.

GLOSSARY

AACU: Antiskid Autobrake Control Unit.
AAIU (Ireland): Air Accident Investigation Unit, the Irish civil aviation safety investigation authority.
AFM: Airplane Flight Manual.
AGP: Malaga Airport
AML: Aircraft Maintenance License.
AMM: Aircraft Maintenance Manual.
ANSV: National Flight Safety Agency.
AOC: Air Operator Certificate (COA).
AOG: Aircraft On Ground.
AOM: Aircraft Operating Manual.
A/P: AutoPilot.
ARC: Airworthiness Review Certificate.
ARFF: Airport Rescue and Firefighting.
ARP: Airport Reference Point.
A/T: Autothrottle.
ATC: Air Traffic Control.
ATIS: Automatic Terminal Information Service.
ATL: Aircraft Technical Logbook.
ATPL: Airline Transport Pilot Licence.
BCN: Barcellona Airport.
BEA: Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile.
BITE: Built in Test Equipment.
BRIEFING: preliminary description of maneuvers or procedures.
CHECK LIST (also written as **CHECKLIST**).
CM 1/2: Crew Member 1, Crew Member 2.
COCKPIT: flight deck.
CPL(A): Commercial Pilot License, commercial pilot license, fixed-wing aircraft.
CPT: Captain.
CRM: Crew Resource Management, defined as the effective use by the flight crew of all available resources to ensure safe and efficient flight operations.
CVR: Cockpit Voice Recorder, a device that records comms, voices and noises in the cockpit.
DDG: Deferred Deviation Guide.
EASA: European Union Aviation Safety Agency.
EEC: Electronic Engine Control.
FC: Flight Cycle **(**also written as **F/C)**, flight cycles.
FCL: Flight Crew Licensing or Flight Crew License.
FCOM: Flight Crew Operating Manual.
FCTM: Flight Crew Training Manual.
FDR: Flight Data Recorder.
FH: Flight Hours **(**also written as **F/H)**.
FI: Flight Instructor.
FIM: Fault Isolation Manual.
FO: First Officer (co-pilot).
FSTD: Flight Simulator Training Device.
FT: Foot, unit of measurement, 1 ft = 0.3048 meters.
GPWS: Ground Proximity Warning System.
GS: Ground Speed.

HIL: Hold Item List**,** list of open MEL items.
IAA: Irish Aviation Authority.
IAS: Indicated Air Speed, indicated airspeed.
ICAO/OACI: International Civil Aviation Organization.
IDLE: position of the throttle levers corresponding to idle power.
IFIM: Interactive Fault Isolation Manual.
ILS: Instrument Landing System.
IR: Instrument Rating, instrument flight rating.
KIAS: IAS expressed in knots (kt).
KT: Knot, unit of measurement, nautical mile (1,852 meters) per hour.
LDA: Landing Distance Available.
LFUS: Line Flying Under Supervision.
LMA: aircraft maintenance license.
LPC: Line Proficiency Check.
LTC: Line Training Captain, captain authorized to conduct line training.
LVTO: low-visibility takeoff.
LW: Landing Weight.
MACTOW: Mean Aerodynamic Chord Take-off Weight.
MAINTROL: maintenance-control, centro di manutenzione dell'operatore.
ME: Multi-engine.
MEL: Minimum Equipment List.
MEP: Multi-Engine Piston, rating to fly multi-engine aircraft with an auxiliary engine.
MLG: Main Landing Gear.
MMEL: Master Minimum Equipment List.
METAR: Aviation routine weather report, routine meteorological observation message.
MP: Multi-Pilot, flight crew comprising more than one pilot.
MPA: Multi-Engine Aircraft, rating to fly an aircraft with more than one engine.
MTOM: Maximum Take Off Mass.
NNC: Non-Normal Configuration.
OM: Operation Manual.
OPC: Operator Proficiency Check.
OSD: Operational Suitability Data.
PF: Pilot Flying.
PM: Pilot Monitoring.
PPL: Private Pilot License.
PSI: Pounds per Square Inch, unit of pressure measurement.
QRH: Quick Reference Handbook.
RADALT: radio altimeter reading.
RT: Recurrent Training.
RXO: Specialist Ophthalmological Examination.
RWY: Runway.
SACBO: Società per l'Aeroporto Civile di Bergamo Orio al Serio.
SCCM: Senior Cabin Crew Member.
SEP: Single Engine Piston, rating to fly single-engine piston-engine aircraft.
SMS: Safety Management System.
TBT (also written **T-B-T**): ground-to-air-to-ground radio communications.
TCDS: Type Certificate Data Sheet.
TEM: Threat and Error Management.
THR: Threshold.
TOW: Take-off Weight.

TSN: Time Since New, hours of operation since new.
TWR: Aerodrome Control Tower, airport control tower.
UTC: Universal Time Coordinated.
VDL: Visual Distance Limitation.
VREF: Velocity of Reference, reference speed for landing.
VS: Vertical Speed.
WO: Work Order.
WOW: Weight on Wheel, aircraft weight on landing gear.

All times given in this investigation report, unless otherwise specified, are expressed in **UTC** (Coordinated Universal Time), which, at the time of the incident, corresponded to local time minus two hours.

Revision number	Date	Note
Revision 0	27.7.2026	Pubblication.
Revision 1	7.9.2026	Information about MLW evaluated before take-off and then en-route (paragraphs *Weight and balance*, *Operating procedures related to the approach and landing phases, 3.1 Findings*).

INTRODUCTION

The serious incident occurred on 1st October 2024 at 05:55 (07:55 local time) at Caravaggio Airport (Orio al Serio, Bergamo) and involved a Boeing B737-8200 aircraft registration EI-IGI, serial number 67077, arriving from Barcelona.

The aircraft was cleared from Barcelona (BCN) for flight with the anti-skid system deactivated. The flight took off at 04:41 and landed at 05:55 at Orio al Serio Airport (BGY).

Following a normal touchdown, all four MLG tyres burst. The aircraft came to a halt on the runway and, following the intervention of the Airport Rescue and Firefighting (ARFF), who confirmed there was no risk of fire, the aircraft and the area were secured; passengers were disembarked onto the runway using the normal disembarkation and passenger handling procedures, with passengers being transferred to buses without further incident.

The pilots, crew and passengers were unharmed following the incident.

The aircraft sustained significant damage to its wheels and braking system; however, the airport operator managed to remove it from the runway and move it to a hangar.

The runway sustained extensive damage to the asphalt surface, which was, however, repaired quickly enough to resume airport operations at 17:26.

The ANSV has sent an initial notification of the serious incident, in accordance with the relevant international and EU legislation (Annex 13 to the Convention on International Civil Aviation, EU Regulation No 996/2010), to the following entities:

- ICAO;
- AAIU – Air Accident Investigation Unit (AAIU) Department of Transport Ireland (State of aircraft registration and operator);
- NTSB – National Transportation Safety Board, United States (State of manufacture of the airframe);

The AAIU and NTSB accredited their representatives and their own technical advisors to the investigation conducted by ANSV.

CHAPTER I
FACTUAL INFORMATION

1. GENERAL INFORMATION

The objective findings gathered during the safety investigation are set out below.

1.1. HISTORY OF THE FLIGHT

On 1st October 2024 at 04:41, the B737-8-200 aircraft registration EI-IGI, serial number 67077, call sign FR 846, took off from Barcelona Airport (BCN) bound for Orio al Serio Airport, Bergamo (BGY), with 162 passengers and 6 crew members on board.

The day before the event, the anti-skid system was deactivated following maintenance checks.

On the morning of the day of the event, after further checks regarding the anti-skid system malfunction, the aircraft was released to service with the anti-skid system still inoperative.

The flight proceeded without incident until the landing phase at the destination airport, which took place at 05:55.

Following the touchdown on the runway, all four MLG tyres burst. The aircraft came to a halt on the landing runway 28 approximately 1.700 meters from THR28.

The crew requested assistance from the ARFF and, following their confirmation that the aircraft and the area had been secured, the captain ordered and coordinated the disembarkation of the passengers and crew, whilst the aircraft was still on the runway, using the normal disembarkation.

1.2. INJURIES TO PERSONS

Injuries	Crew	Passengers	Total persons on board	Others
Fatalities	0	0	0	
Serious	0	0	0	
Minor	0	0	0	not applicable
None	6	162	168	not applicable
Totals	6	162	168	

1.3. DAMAGE TO AIRCRAFT

The 4 main landing gear tires had burst, and wheels 1, 2, and 3 showed significant damage caused by friction against the runway, most severe on wheel 1 and less so on the other two. Additional damage was observed on the main landing gear, the actuators for the right-wing control surfaces, the control surfaces themselves (immediately aft of the landing gear), and the right side of the fuselage.

Below are some images taken at the scene of the serious incident.

Photo 1 : close-up of wheel damage – rear view (source: SACBO).

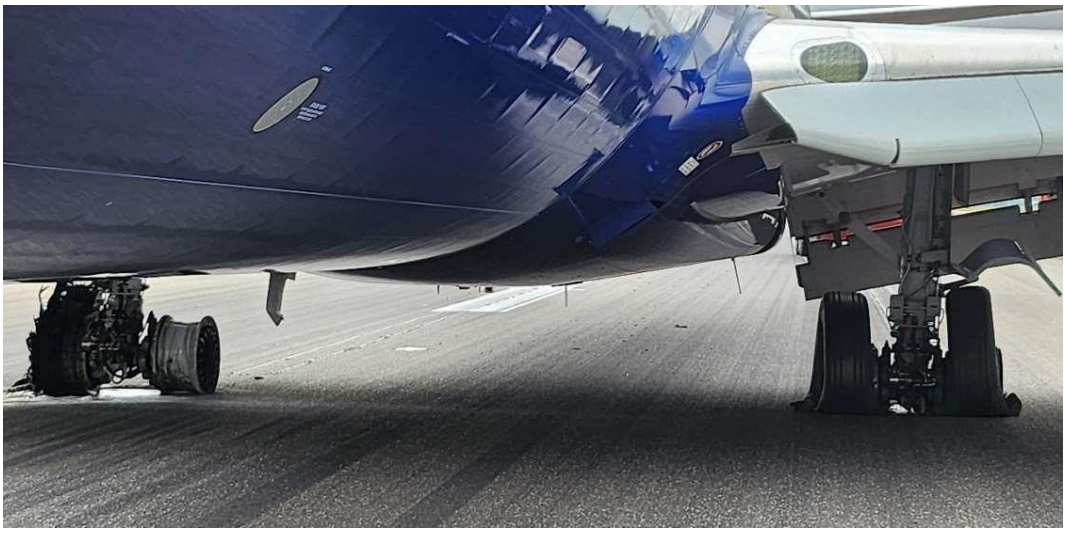

Photo 2 - Detail of wheel damage - front view (source: SACBO).

The damage sustained by the aircraft is discussed in detail in the following section 1.12.

1.4. OTHER DAMAGE

The aircraft came to a halt on RWY28, approximately 1700 m from THR28, at the point with coordinates 45°40’06.982” N 9°42’09.859” E.

Surveys on the runway were carried out by the airport operator, who then undertook repairs to the damaged asphalt surface.

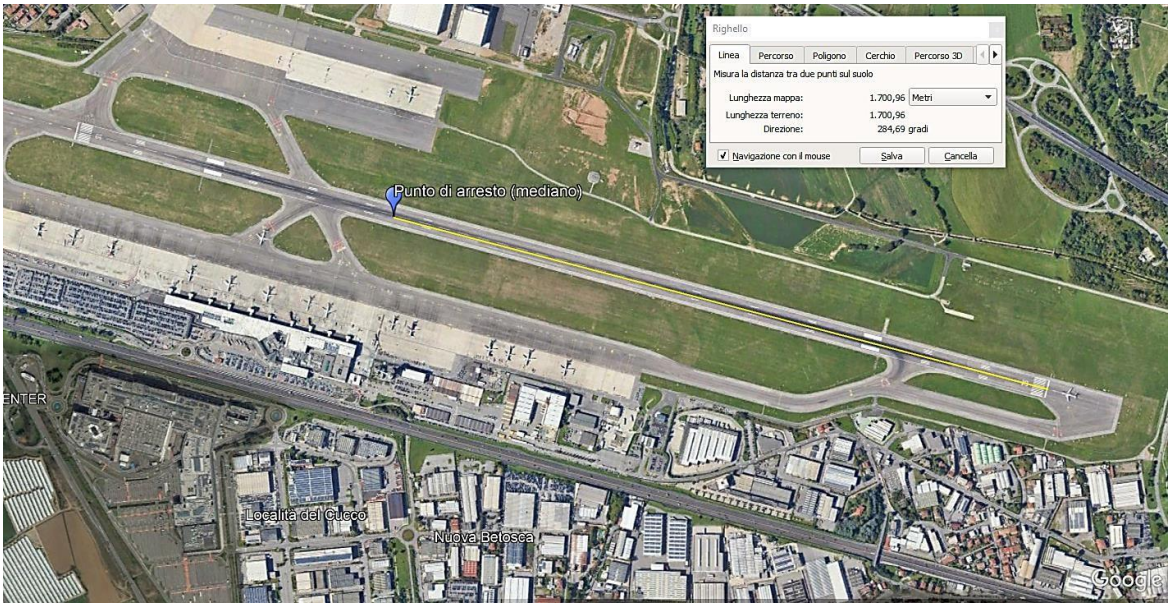

Image1 : aircraft stopping point on the runway and distance from the threshold (Source: SACBO)

Once the repairs were completed, the runway was reopened at 17:26, to allow sufficient time for the repairs to set.

1.5. PERSONNEL INFORMATION

1.5.1. Flight crew

Captain

Personal details:	Age 40,
License:	ATPL(A) issued by the Irish Aviation Authority (IAA) on 23 May 2016 (first issued by the same authority on 30 June 2011)
Current ratings:	B737 300-900, ME, IR(MPA), expiry date 31/03/2025
Non-active ratings:	None
Authorizations:	B737 company approval: Line Trainer, RHS (Right Seat – Either Pilot Seat), CAT3A, LVTO 125m.
English proficiency level:	ICAO Level 6 (unlimited validity).

Periodic checks:	LPC/OPC carried out on 20/03/2024. Line Check carried out on 18/03/2024.
Periodic training:	Recurrent Training (RT) carried out on 19 March 2024.
Medical examination:	Class 1, valid until 28/06/2025, no restrictions.

Captain's professional history

The captain began his commercial flying career as a cadet with Ryanair in 2007, then became a First Officer and was appointed Captain in 2012, followed by Line Trainer (LTC) in 2015. After a brief period with another operator, from 2018 to 2019, he was hired again by Ryanair in 2019.

The airline's roster shows that the captain had reported for duty on the day of the serious incident, 1st October, after 13 days' rest.

The captain's flying experience at the time of the event was over 10,000 flight hours, almost all on the B737 type.

- Flight hours in the last 12 months: 527 hours;
- Hours flown in the last 90 days: 133;
- Hours flown in the last 30 days: 37;
- Hours flown in the last 7 days: 1h 51'(event flight);
- Hours flown in the last 24 hours: 1h 51'(event flight).

The captain's most recent training regarding inoperative anti-skid systems took place in March 2024 via an e-learning module—covering both anti-skid and autobrake systems—as part of his recurrent training.

First Officer

Personal details:	30 years old
Licence:	ATPL(A) issued by the Irish Aviation Authority (IAA) on 12/02/2024.
Current ratings:	B737 300-900 ME IR, expiring on 31/01/2025; SEP(Land) expiring on 31/05/2025; FI(A) SEP(Land) expiring on 30/06/2026.
Ratings not currently held:	SE IR (expiry 31/07/2024); MEP(Land), expiring on 31/07/2024.
Authorisations:	CAT3A, LVTO 125m

English proficiency level:	ICAO Level 6 (unlimited validity).
Regular checks:	LPC/OPC carried out on 29/01/2024, OPC carried out on 22/07/2024.
Periodic training:	Recurrent Training (RT) 22/07/2024.
Medical check-up:	Class 1, valid until 25/10/2025; VDL and RXO restrictions.

First Officer's professional history

The First Officer commenced flying in 2011; PPL obtained in April 2013. ATPL theory (Frozen) obtained in February 2019; CPL(A) obtained in May 2019. He began his training at Ryanair as a commercial pilot 'Cadet' in November 2023; he obtained his Type Rating on the B737 300-900 in January 2024 and began Line Training (LIFUS) in July2024.

The first officer's total flight experience at the time of the event was 3.175 total flight hours, of which 2.300 hours as an FI(A) and 75 simulator hours on the B737-800 and 8200 type prior to commencing his training programme with the operator. Recent flight activity is as follows:

- Hours flown in the last 12 months: 331h;
- Hours flown in the last 90 days: 153h;
- Hours flown in the last 30 days: 55h;
- Hours flown in the last 7 days: 12h;
- hours flown in the last 24 hours: 1h 51' (event flight).

According to the company's duty roster, the First Officer commenced duty on 1st October, following a day off (30 September), preceded by a day on duty (29th September), which in turn was preceded by 4 days off.

The most recent training covering the inoperative anti-skid scenario for the co-pilot was conducted during his type rating in January 2024. This included a discussion of the topic during an FSTD session.

1.5.2. Cabin crew

Not applicable

1.5.3. Maintenance staff

The following technical personnel was involved in the checks and fault investigations relating to reports made by the crews, in the application of the MEL and the transcription of the HILs

onto the ATL of the aircraft, resulting in the deactivation of the Anti-Skid system on 30/09/2024 at 11:05.

The technician on duty at the Dublin maintenance center who authorized the application of the MEL was found to hold a valid AML for the aircraft in question and was authorized to carry out maintenance on the aircraft in question (Category B1.1) as of 17/11/2003.

The maintenance technician, based at Malaga (AGP), who carried out the initial checks on the system and subsequently deactivated the anti-skid system completely and opened the HIL, was also in possession of a valid AML and authorized for the incident aircraft (Category B1.1) from 15/12/2023.

Finally, the maintenance engineer, based at Barcelona (BCN), who carried out the subsequent checks on the system in accordance with the instructions received from the Dublin Centre, and who cleared the aircraft for the incident flight, hold a valid AML (Category B1.1) since 15/12/2022 and employed in accordance with the duty roster, compliant with rest requirements.

1.6. AIRCRAFT INFORMATION

1.6.1. General information

The aircraft involved is the B737-8200 MAX, a low-wing commercial airliner fitted with winglets, featuring a predominant metal structure and retractable tricycle landing gear; the aircraft is equipped with two CFM LEAP 1-B turbofan engines.

Its dimensions are shown in the table below; the MTOM is 76.200 kg.

Model	Fuselage Length	Height	Wingspan with Winglets
737-8200	39.5 m (129 ft 6 in)	12.29 m (40 ft 4 in)	35.92 m (117 ft 10 in)

1.6.2. Specific information

Aircraft

Manufacturer:	BOEING Company, Seattle (USA).
Model:	B737-8200 MAX.
Serial number:	67077.
Year of manufacture:	Delivery date: 22/03/2023.

Country of registration and registration mark: Ireland, EI-IGI.

Registration certificate: Valid and issued on 22/03/2023, No.: IGI/COR/01.

Operator: Ryanair Limited, AOC IE 07/94.

Owner: Ryanair.

Airworthiness Certificate: Valid and issued on 22/03/2023, No.: IGI/COA/01.

Airworthiness Review Certificate: Valid. Irish Aviation Authority (IAA) ARC Ref. IGI/ARC15a/01 (ARC 005 IE. CAMO.007).

Total hours: 6094 FH (2824 FC).

Hours since last overhaul: N/A

Hours since last inspection: 1 (carried out on 01/10/2024).

Hours since last service: 1251 (carried out on 19/06/2024).

Technical documentation compliant with current regulations/directives: YES.

Engine(s)

Manufacturer: CFM International

Model: CFM LEAP 1-B

Serial No.: 60B061; Total hours (TSN): 6,094; CSN: 2,824

Serial No.: 60A056; Total hours (TSN): 5,377; CSN: 2,616

Engine position	Serial No.	Total hours (TSN)
1	60B061	6,094
2	60A056	5,377

Fuel

Authorized fuel type: Jet A-1 (F35).

Fuel type used: Jet A-1 (F35).

The fuel on board at the time of the incident was 3,760 kg.

1.6.3. Further information

Recording of inefficiencies or malfunctions and related maintenance actions.

This section lists the records entered ATL from 30 September onwards, in chronological order, type of problems encountered, the measures taken and the date of accomplishment of working orders.

Date of registration	Type of problem	Measures taken	Date of restoration to working order
30/09/2024 TIME: 08:53 *(at AGP - Flight BCN-AGP)* (ATL page **55475102)**	*Crew report:* "ANTISKID ACTIVATED UNEXPECTEDLY DURING TAXI OUT"	*Maintenance:* **AACU Operational Test** CS SATIS IAW AMM: **32-42-00-720-801** REV22 A/C SVC PLEASE PROVIDE FURTHER INFORMATION FIM/SPIN CODE: 32-42-00; REV 22	30/09/2024 TIME: 09:22
30/09/2024 TIME: *no time has been entered c/o AGP, after Taxi out* (ATL page **55475103**)	*Crew report:* "RETURN TO STAND DUE TO ANTISKID LIGHT"	*Maintenance:* **AACU BITE TEST** CCO in accordance with **AMM 32-42-00-740-801** R22 **NO FAULT FOUND.** ITEM TR TO HIL in accordance with **MEL: 32-42-01** REV2 CAT2 **BOTH INBOARD AND OUTBOARD CHANNEL CB/S REMOVED AND SECURED.** *LIDO ITEM AND MAINTROL INFORMED*	30/09/2024 TIME: 11:05
30/09/2024 (ATL ref. **55475104**)	None *(4 flights operated)* *Last landing at BCN: 22:00*		
01/10/2024 *Start TIME: 00:00* (ATL p. **55475104**)	None	*Maintenance: Routine inspection and "Release to Service"*	01/10/2024 TIME: 00:15
01/10/2024 TIME: *None specific start time* *c/o BCN* (ATL ref. **55475105**)		*Maintenance:* REF HIL 55475103 ANTI SKID FAIL Action: ANTISKID/AUTOBRAKE CONTROL UNIT BITE TEST FAILURE IN ACCORDANCE WITH (AM) IFIM 32-42(*)-00-810-815 REV.93 XDCR 3 FAULT DETECTED. IFIM 32-42-00-810-815 REV. 93 C/OUT ANTISKID WHEEL SPEED TRANSDUCER #3 TO BE REPLACED PARTS ADDED TO HIL	01/10/2024 TIME: 02:00
01/10/2024 TIME: *None specific time c/o BCN* (ATL ref. **55475104**)	None *(A/C acceptance by the captain of the flight from BCN to BGY)*		
01/10/2024 (ATL p. **55475106**	*Crew report following the incident:* BRAKES LOCKED UP DURING LANDING, RESULTING IN 4 MAIN TYRES BLOWN		

As summarized in the table above, on 30 September, whilst taxiing for the flight departing from Barcelona (BCN) to Malaga (AGP), the intermittent illumination of the 'ANTISKID' warning light was detected.

The Antiskid/Autobrake Control Unit Operational Test (AMM TASK 32-42-00-720-801 Rev 22) was carried out in Málaga, as required by AMM 32-42-00, and no faults were found; at

09:22 the aircraft was cleared for flight as serviceable.

AMM 32-42-00 is the reference document detailing tests and maintenance procedures for, amongst others, the ANTISKID and AUTOBRAKE systems.

The manufacturer specifies a recommended sequence of tests to be carried out, but the operator's maintenance team may nevertheless decide, based on their experience, to carry out tests and maintenance in a different sequence, with the aim of identifying the specific fault as quickly as possible and isolating it.

During taxiing operations for the next flight, the aircraft returned to the parking area because the antiskid warning light had come on. At this point, the Antiskid/Autobrake Control Unit BITE Procedure (AMM TASK 32-42-00-740-801) was carried out, which forms part of the tests listed in AMM 32-42-00, where no fault was again detected in the ANTISKID system.

From the ATL it is possible to understand that it was decided to deactivate both channels of the anti-skid system, in accordance with MEL 32-42-01.

The deactivation was carried out by the maintenance technician who, in accordance with WO 55475103, removed and secured, using a collar, the circuit breakers (CBs) for the two channels (INBOARD and OUTBOARD) and opened the HIL. The HIL was entered into the LIDO airline's management system, and the MAINTROL was informed.

The 'antiskid inoperative' restriction, as stated in the HIL, had an expiry date of 10/10/2024.

Following this maintenance, the aircraft was cleared for flight at 11:05 and operated four flights the same day, with the final flight to BCN which ended at 22:00.

Between 00:00 and 00:15 on 1st October, routine maintenance was carried out; among the various checks, tyre pressure was also measured, with no problems found. Upon completion of the work, the maintenance technician issued the *'Release to Service*", leaving the anti-skid system inoperative.

In the early hours of 1st October, as consequence of the anti-skid system failure of the anti-skid system, the Anti-skid/Autobrake Control Unit BITE Test was carried out and highlighted the fault code XDCR3, the IFIM 32-42-00-810-815 Rev.93 was carried out and highlighted the failure of transducer #3 as a result of the trouble shooting.

The technician requested its replacement and updated the HIL in the company's LIDO system.

The maintenance work was completed at 02:00, without a new *"Release to service"* being issued.

The technician stated that he had verified the unavailability of a transducer at the Barcelona base via the operator's maintenance management system (AMOS). He closed the position in AMOS at 04:11 and released the aircraft for flight in accordance with MEL Item 32-42-01, without applying any further procedures or maintenance work, leaving both anti-skid channels

disabled.

The aircraft moved from the apron at 04:41 to operate the BCN-BGY flight. After landing at BGY, the captain reported in the ATL that the brakes had locked during landing and that the four MLG tyres had burst.

Additional checks on transducer no. 3.

Following the serious incident, transducer no. 3 was removed and sent to the manufacturer to identify the causes of its failure. It was initially inspected and released for return to service. However, the repair carried out was reviewed and deemed unsatisfactory, as no fault was found with the unit, therefore, it was decided to send it back to the manufacturer for overhaul, which, again, did not identified any fault.

Load and center of gravity

The *LOADSHEET* approved by the captain prior to release contained the following weight and center of gravity data:

- for take-off, a TOW of 65.314 kg, with flaps in position 5, a take-off thrust of TO2 and a dry runway (DRY conditions).

  As a result of the application of the limitations provided for inoperative anti-skid, the maximum permissible take-off weight for the expected conditions (MAX TOW) was 66.908 kg; therefore, with a residual load margin (*"Underload Before* LMC") of 1.594 kg.

  The center of gravity data for take-off was within the specified limits. A MACTOW of 20.2 is specified, referring to the following permissible limits: 14.0 – 26.5;
- for landing, because of an estimated fuel consumption "TRIP FUEL" of 2.944 kg, a landing weight ("LW") of 62.370 kg is planned.

  As a result of applying the limitations provided for inoperative anti-skid, the maximum permissible landing weight at Bergamo Airport and for the expected conditions was 67.501 kg.

  Although this value was above the MLW as it should be evaluated at dispatch[1], it was within the limits of the MLW evaluation en-route[2].

[1] The MLW calculation is made before take-off in agreement with the previsions for the dispatch phase. This is done according Reg. EU 965/2012 CAT.POL.A.230 that determines the MLW based on 60% of the LDA.

[2] Under the provisions of Reg. EU 965/2012 CAT.OP.MPA.303, the necessary lenght of the runway is newly verified in flight based on the actual landing weight, based on the actual runway condition, actual weather (In-flight check of the landing distance at time of arrival – aeroplanes). The safety factor to apply in this case is 15%. The operator's provision in this specific aspect is to further increase the resulting value of 30%.

Aircraft equipment and systems

The operations of certain systems relevant to this investigation are described below.

Braking system

The braking system includes the following components: “Normal brakes”, “Alternate brakes”, “Antiskid protection”, “Autobrake system”, “Parking brake” and “Brake accumulator”, all of which are hydraulically powered.

The Boeing 737 MAX’s hydraulic system is divided into three independent systems (A, B and standby) which operate at a pressure of 3,000 PSI.

This is illustrated in the figure below; for the purposes of this discussion, only the “Normal brakes”, “Alternate brakes” and “Antiskid protection” functions will be considered, with a brief mention of the “Autobrake” system.

Each of the 4 main wheels has independent “Multi-disc” brakes.

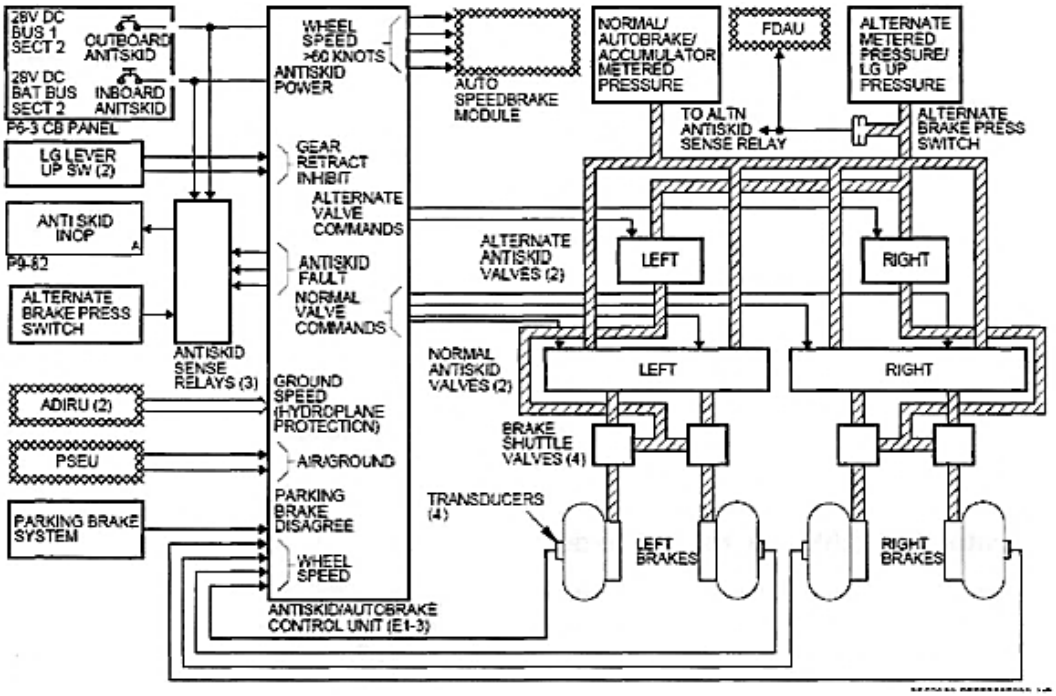

Figure 1 -Braking System in “Normal” mode *(Image copyright company Boeing. Reproduced with permission)*

In “Normal brake” mode, the system is powered by hydraulic circuit B, and in “Alternate brakes” mode, the braking system is powered by hydraulic circuit A.

The “Antiskid protection” functions are available both on the “Normal brakes” line (where, if necessary, pressure from the accumulator also comes into play) and on the “Alternate brakes” line.

These functions allow the deceleration of the wheels, to be controlled via the signal provided by the speed sensors ("Transducer"), thereby enabling the anti-skid system to brake by appropriately modulating the brake pressure.
The trasducers are fitted to each individual wheel and send a signal indicating their rotational speed to the anti-skid and autobrake systems.
The anti-skid system has two separate channels: INBOARD, corresponding to wheels #2 and #3, and OUTBOARD, corresponding to wheels #1 and #4. These channels can be deactivated individually via a specific maintenance procedure.
During the landing manoeuvre, the "Anti-skid protection" system prevents the following phenomena:

- "Skid", in case of tyre skidding;
- "Locked wheel", in case of tyre locking up;
- "Touchdown", in case of the activation of the braking system when there is no contact with the ground, triggered by the "Air/Ground" system sensors;
- "Hydroplane", in case of tyre skidding caused by runway contamination.

In "Normal" mode, the "Antiskid" function is applied individually to each wheel.
In "Alternate brakes" mode, the system is powered by hydraulic system A, braking modulation is provided on the left and right wheel pairs.
In the event of a failure of hydraulic systems A and B, braking is provided by the hydraulic pressure supplied by the accumulator, and can always be modulated via the pedals, differentially (left – right), whilst the antiskid function remains available.
Deactivating the channel also deactivates the signals from the relevant speed sensors, thereby losing the anti-skid protection described above.

A malfunction or deactivation of the anti-skid system is indicated on board by the illumination of the amber "ANTISKID INOP" warning light (Fig. 2, point 3) located on the anti-skid control panel in the cockpit.

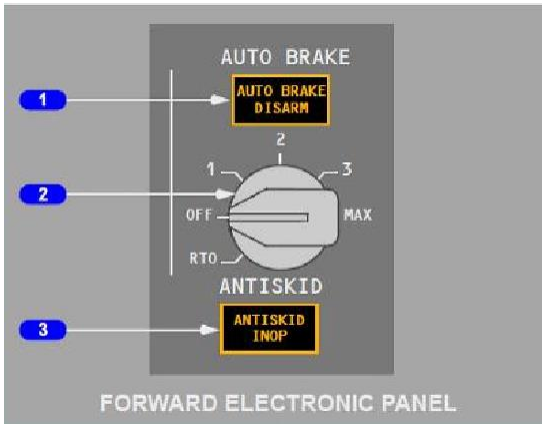

Figure 2 - Antiskid and autobrake systems control panel (Ref. FCOM) *(Image copyright company Boeing. Reproduced with permission)*

Autobrake system

The autobrake operates only in the NORMAL BRAKES condition, with hydraulic system B in operation.

Deactivation is possible by setting the autobrake selector to OFF (Fig. 2, point 2). . In this case, the "AUTO BRAKE DISARM" light remains off (Fig. 2, point 1).

Air/Ground System

The Air/Ground system provides various on-board systems with the aircraft's "in flight" (AIR) or "on the ground" (GROUND) status, using six sensors, two on each landing gear leg.

Speedbrake System

The system allows the spoilers to be deployed, some of them in flight, all on the ground, via the control lever located to the left of the center console.

Photo 3 : Speedbrake control lever

Figure 4 - Position of the speedbrakes in the cockpit

Images copyright company Boeing. Reproduced with permission)

The spoilers are hydraulically actuated by hydraulic systems A and B and electrically controlled by the “Spoiler Control Electronics Unit” (SCE). In particular, the “Ground Spoilers” are controlled by the “Ground Spoiler Control Module” (GSCM), in accordance with the signal provided by the air/ground system and the system logic.

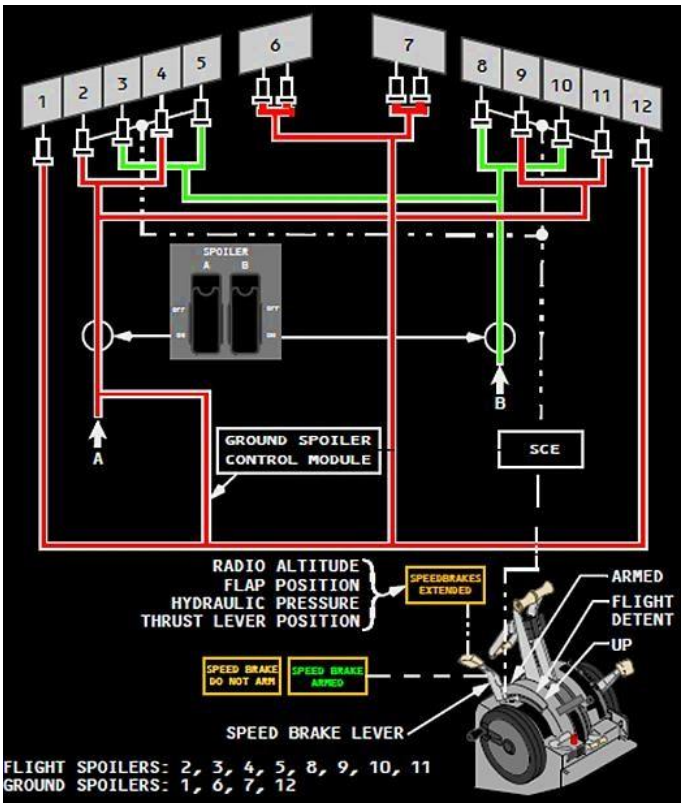

Figure 4 – Speedbrake/ground spoiler operating diagram. Ref. FCOM *(Image copyright company Boeing. Reproduced with permission)*

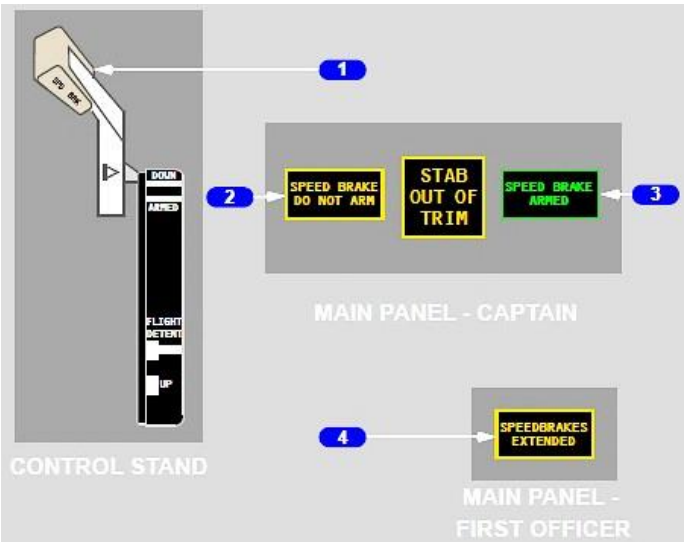

Figure 5 - Speedbrake system controls and indicators diagram. Ref. FCOM *(Image copyright company Boeing. Reproduced with permission)*

In case of landing, the SPEED BRAKE lever can be set to ARMED or DOWN; the latter position operates according to two distinct modes.

During normal operations, it is set to ARMED. In this position, the green “SPEED BRAKE ARMED” indicator light (Fig. 5, item 3) illuminates on the main panel on the CAPTAIN side (CM1).

The SPEED BRAKE lever will automatically move to the “UP” position and all spoilers will extend under the following conditions:

- radio altimeter reading below 6 ft;
- compression of the landing gear shock absorbers on landing[3];
- both thrust levers in the “IDLE” position;
- the MLG wheels rotating at a speed greater than 60 kt.

If, for the purpose of landing, the speedbrake lever is set to “DOWN”, the Auto Speedbrake system operates automatically under the following conditions:

- the MLG wheels rotating at a speed greater than 60 kt;
- both thrust levers in the “IDLE” position;
- the thrust reverse levers set to reverse thrust (which is possible only after WOW).

If there is no speed signal from the transducers and the lever is set to “DOWN”, the only way to deploy the speed brakes is manually. However, the presence of a speed signal from transducers on a single channel does not guarantee automatic operation, as stated in the QRH.

Thrust Reverse System

Thrust reversers allow the direction of airflow from the engine fans to be inverted. They can be used after touchdown to slow the aircraft, reducing the deceleration distance and brake wear.

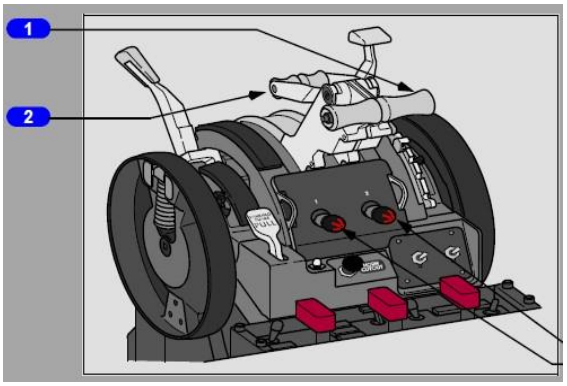

Figure 6 - illustration of engine throttle and reverses control levers. Ref. FCOM *(Image copyright company Boeing. Reproduced with permission)*

[3] Wheel rotation or the compression of any shock absorber enables flight spoiler extension. Compression of both main landing gear shock absorbers also enables ground spoiler extension.

Each engine is individually equipped with thrust reversers which are hydraulically actuated and are enabled only when:

- for the type B737-8200, the engine control levers (Fig. 6, item 1, Forward Thrust Levers) are set to IDLE; and either radio altimeter is below 10 ft combined with an air/ground safety sensor in the "Ground" mode;
- For type B737-800, the engine control levers (Fig. 6, item 1, Forward Thrust Levers) are set to IDLE; and either radio altimeter is below 10 ft or when an air/ground safety sensor in the "Ground" mode;

Once the above conditions are met, the REVERSE THRUST levers are actuated (Fig. 6, item 2), initially reaching the INTERLOCK position (Fig. 7). By continuing to apply light pressure to the REVERSE THRUST levers, the system allows the INTERLOCK to be released, confirming the start of the deployment of the reverse thrusts.

When the DETENT NO. 1 s reached (Fig. 10), this corresponds to reverse thrust at IDLE.

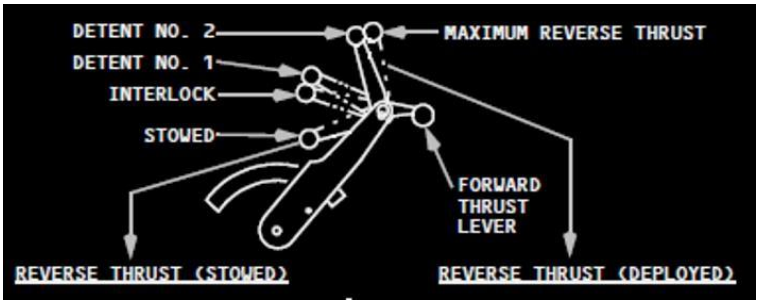

Figure 7 - Illustration of the position of the control levers for Thrust Reverse *(Image copyright company Boeing. Reproduced with permission)*

Following full deployment, the indication "REV" in green will appear on the engine display screen for each individual engine, as shown in Fig. 8:

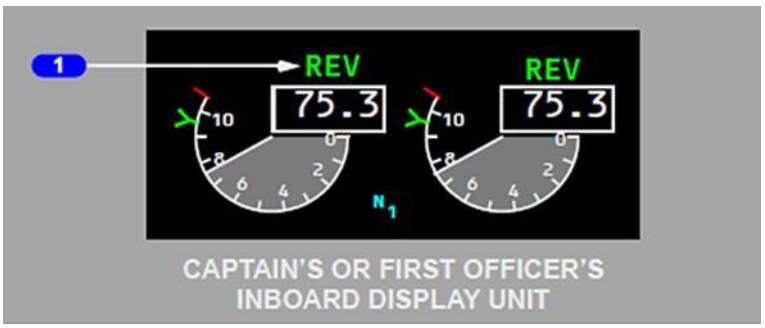

Figure 8 - Thrust Reverse indications on the engine parameter display *(Image copyright company Boeing. Reproduced with permission)*

In this condition, the control lever can be raised to DETENT NO. 2, which allows the requested reverse thrust to be applied. If necessary, the control levers can be positioned beyond Detent No. 2 to provide maximum reverse thrust.

Electronic Engine Control (EEC) – Idle operation

The EEC automatically selects the thrust/engine speed threshold for Ground, Flight, Icing and Approach IDLE.

Approach Idle is selected when the flaps are set to 15° or higher, or when the flaps are not in the 'UP' position and the engine anti-ice system is active.

Approach Idle reduces acceleration times in the event of a Go-Around (GA) and is maintained until after touchdown, or until the conditions for selecting Ground Idle are met.

The EEC selects Ground Idle 1 second after touchdown, unless the relevant thrust reverse has already been selected to deploy the reverses. With the thrust reverse lever in the open position, the EEC initially selects the Flight Idle setting, maintaining it for 8 (eight) seconds after touchdown; thereafter, the Ground Idle setting is selected.

Warning systems

Overrun Warning (ORW) System and Runway Awareness and Advisory System (RAAS) Inhibit Operation – RUNWAY INHIBIT switch.

The aircraft is equipped with a "Runway Awareness and Advisory System (RAAS)" Inhibit Operation, integrated into the GPWS system, which provides improved situational awareness during ground operations, approach, landing and go-around (GA). When activated, such system provides visual and audible warnings that should prompt the pilot to apply maximum manual braking and maximum reverse thrust.

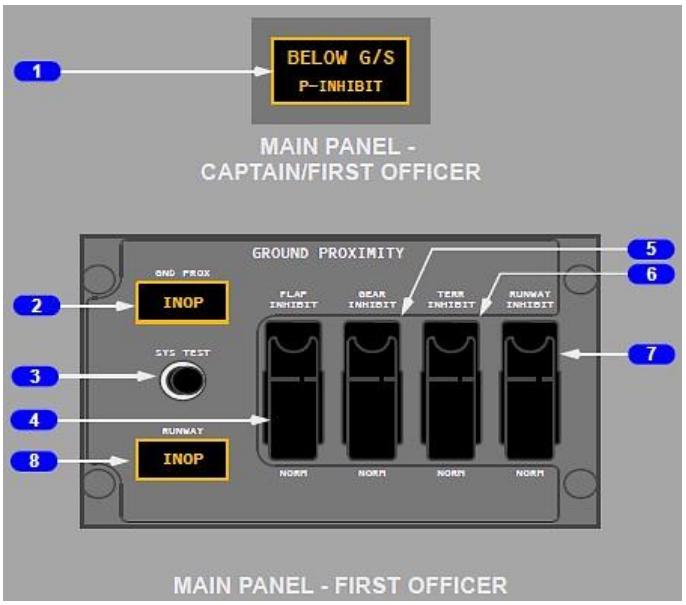

Figure 9 - Illustration of the panels related to the control and indicators for the Ground Proximity Warning System functions *(Image copyright company Boeing. Reproduced with permission)*

Where required by procedures, this function can be disabled using the protected "RUNWAY INHIBIT" switch (Fig. 9, item 7). If the airspeed is below 250 kt, no warnings will appear on the "GROUND PROXIMITY" panel.

Maintenance and operating procedures related to anti-skid system inoperative.

The AMM and MELs[4] in use by the operator essentially incorporate the manufacturer's specifications and are approved by the competent authority.

In the event of a general failure of the antiskid system, the manufacturer requires the application of the provisions set out in AMM 32-42-00 - ANTISKID/AUTOBRAKE SYSTEM - ADJUSTMENT/TEST. The document contains the following tasks:

(1) An Antiskid/Autobrake Control Unit Operational Test

(2) A Normal and Alternate Anti-skid Valve Functional Test

(3) An anti-skid transducer functional test

(4) A Normal and Alternate Anti-skid Valve Operational Test

(5) An Autobrake Pressure Control Module Functional Test

(6) An Autobrake Shuttle Valve Operational Test

(7) An Antiskid Transducer Operational Test

(8) An Antiskid/Autobrake Control Unit BITE Procedure

This sequence is recommended by the manufacturer, but it is acceptable to apply a different 'Trouble shooting' sequence to identify the fault as quickly as possible.

If the antiskid system is not operational, MEL 32-42-01 may be applied. In this case, maintenance and flight crews must follow the instructions contained in the relevant Deferred Deviation Guide (DDG).

The following company MEL & DDG in use at the time of the incident, to be applied in the event of inoperative antiskid, it serves as the reference document for technical maintenance personnel and flight crews.

[4] MELs are derived from MMELs (Master Minimum Equipment Lists) and constitute a list of minimum equipment that must be operational to ensure the safety of operations. MMELs are published by the manufacturer (in this case, Boeing) for the specific aircraft (i.e. aircraft type, configuration and modifications applied to that specific aircraft). In the case of the specific Operator, in accordance with EASA Regulations, the MELs are drawn up by the Operator and approved by the competent authority. The competent authority is the National EASA Authority which, in fact, approves the Air Operator Certificate (AOC).

32-42-01 Antiskid System

Interval	Installed	Required	Procedure	LIDO
C	1	0	(M) (O)	32-42-01

May be inoperative provided:

a. Inoperative antiskid channels are deactivated.

b. Autobrake system is not used.

c. Appropriate performance adjustments for antiskid inoperative are applied.

NOTE: *Defect may prohibit operations to or from narrow and or short runways. Please refer to Airfield Brief for further guidance.*

LIDO

Dispatch under this MEL Item will be entered into the LIDO System and Dublin Maintenance Control must be contacted.

PLACARD

INOP – As appropriate

MAINTENANCE (M)

NOTE: An operative antiskid channel should not be deactivated. Antiskid channels that are faulted, must be deactivated.

Deactivate the inoperative antiskid system channels (AMM 32-00-00/901).

1. For inboard antiskid channel inoperative, open and collar the P6-3 panel LANDING GEAR ANTISKID INBD circuit breaker.
2. For outboard antiskid channel inoperative, open and collar the P6-3 panel LANDING GEAR ANTISKID OUTBD circuit breaker.

OPERATIONS (O)

NOTE 1: Reduced thrust takeoff using the assumed temperature method is not permitted.

NOTE 2: Takeoff on wet runways is not permitted unless AFM performance for wet skid-resistant surfaces and antiskid inoperative is applicable and used.

NOTE 3: Operations may be affected at contiguous United States airports impacted by 5G C-Band interference [Ref FAA Airworthiness Directive (AD) 2023-12-11 and associated Boeing Flight Crew Operations Manual Bulletin (OMB)]

1. Base takeoff and landing performance on AFM antiskid inoperative.
2. Set autobrake system OFF.
3. Operate speed brakes manually.

4. Use AFM antiskid inoperative braking procedure for rejected takeoffs and landings, including the following guidance.
   A. Use minimum braking consistent with runway length and conditions to reduce the possibility of a tire blowout.
   B. Do NOT apply the brakes until the nose wheel is on the ground and the speedbrakes have been manually deployed.
   C. Brake initially using light steady pedal pressure Increase pressure as ground speed decreases. Do NOT pump the brakes.
5. Prior to landing, set the GROUND PROXIMITY RUNWAY INHIBIT switch to RUNWAY INHIBIT (if the overrun warning system and GROUND PROXIMITY RUNWAY INHIBIT switch are installed).

NOTE: *Use Boeing OPT MEL 32-42-01 selection as per techlog/HIL status.*

Figure 10 : MEL & DDG Item 32-42-01 - Antiskid System (pages merged)

The text in light blue represents the procedural elements required by the operator, in this case additional ones, which distinguish the MEL from the MMEL from which they were derived. Insofar as it is relevant to the present investigation, MEL provides the following information:

- in the 'Interval' column, a rectification interval (Rectification Intervals) for restoring system functionality, of category 'C', corresponding to 10 calendar days, excluding the day of entry into the HIL; in the case in question, 10 October 2025.

  The MEL defines four categories of intervals: A, B, C and D, they determine the timeframe within which a defect or failure must be repaired. Specifically, the operator defines the following categories:

  - Category A: no standard interval is specified; however, items/components in this category shall be rectified in accordance with the conditions specifically indicated in the MEL;

    where a time is specified in days, the period excludes the day on which the defect is detected;

    where a time other than days is specified, it shall commence from the time the defect is reported in accordance with the MEL approved by the operator;
  - Category B: items in this category must be rectified within three (3) calendar days, excluding the day on which the defect is detected;
  - Category C: items in this category must be rectified within ten (10) calendar days, excluding the day on which the defect is detected;
  - Category D: items in this category must be rectified within one hundred and twenty (120) calendar days, excluding the day on which the defect is detected;
- in the "Required" column, the number of systems/equipment required for the flight; in our case, the unavailability of the anti-skid system is covered, even for flights with passengers on board "Revenue Flight";
- in the "Procedures" column, information is provided on the applicable procedure sections, which are subsequently detailed. In our case, the sections concerned are (M) Maintenance, a reference for maintenance personnel, and (O) Operations, a reference for the flight crew;
- in the final column, "LIDO" – the operational management system used by the Operator – the reference code of the specific MEL is listed, for the tracking and control of operations and associated interventions, as well as to enable the completion of the operational documentation provided to flight crews;
- in point a. that inoperative anti-skid channels are deactivated;

- in point b. that the Autobrake system is not used;
- in point c. that the appropriate settings for performance with the anti-skid system inoperative are applied. In particular, the Company NOTE refers to the "Airfield Brief" as a guide for operations on narrow and/or short runways.

The MEL continues by setting out instructions relating to the single sections, in particular:

- in the LIDO section, the operator is required to enter the MEL into the company's management system and, in any case, to contact Dublin maintenance control;
- the PLACARD section requires the 'INOP' label to be affixed as appropriate.

  As previously noted, during the site inspection it was found that only the label relating to the anti-skid system had been affixed. Further information regarding the affixing of labels (PLACARD) is provided below, in the context of the detailed discussion of certain specific maintenance procedures;
- The MAINTENANCE (M) section states, in the initial NOTE, that an operational anti-skid channel should not be deactivated (*An operational anti-skid channel should not be deactivated*) , whilst anti-skid channels that are inoperative must be deactivated (*Anti-skid channels that are faulted must be deactivated*).

  The MEL goes on to instruct to deactivated the inoperative channels, with a general reference to AMM 32-00-00/901 (in brackets); then specifies in detail that deactivation of the Antiskid INBOARD channel must be carried out by opening and installing the collar on the CB, located on the panel labelled "LANDING GEAR - ANTISKID - INBD" , P6-3; similarly, it is specified in detail that the deactivation of the Antiskid OUTBOARD channel must be carried out by opening and installing the collar on the CB located on the panel labelled "LANDING GEAR - ANTISKID - OUTBD", P6-3.

  With reference to the specific maintenance instructions contained in AMM 32-00-00/901, it is noted that this procedure is applied to prepare the aircraft for flight with inoperative systems or components forming part of the landing gear. Furthermore, the same document contains references to the TASKs required to restore the aircraft to its original condition. In the case of an inoperative anti-skid system, point (15), it requires the application of DDG 32-42-01-01 - *Antiskid System Inoperative – Preparation*, in accordance with the detailed instructions and the associated TASK 32-00-00-040-808 DDG 32-42-01-01 *Antiskid System Inoperative – Preparation.*

  Regarding this TASK, the following points of interest are highlighted:

- with the NOTE in paragraph A. (1), instructions are provided for deactivating the single Antiskid channels, following the identification of the inoperative channel via the BITE Test, conducted in accordance with the results of TASK 32-42-00-740-801, as reported in AMM 32-42-00 (Troubleshooting number 8);
- under point E. Antiskid System Preparation, (2) Deactivate the applicable antiskid channel: this NOTE states: *"An operational antiskid channel must not be deactivated. Antiskid channels that are faulty must be deactivated*". This note differs from the one in the initial NOTE of the MAINTENANCE (M) section, where 'SHOULD' is used instead of 'MUST': *"An operative antiskid channel should not be deactivated"*;
- Point E. (2) provides the specific maintenance actions to be carried out in response to the fault messages encountered. Considering our case, regarding the XDCR3 fault, it is required to remove and install the safety lock on the CB LANDING GEAR – ANTISKID – INBD, located on the FO-side electrical panel P6-3. This instruction is consistent with what is summarized in the MEL;
- point E. (3) requires applying a placard with the inscription: "AUTOBRAKE INOP – LEAVE OFF" near the AUTOBRAKE selector switch, located on the relevant control panel, P9-82.

  From the evidence gathered during the on-site inspection, it appears that this placard was not applied.

- The **OPERATIONS (O)** section, insofar as it is relevant to this investigation, states:
  - for performance and procedures relating to the take-off and landing phases, under points 1 and 4, reference is made generally to the contents of the AFM. Regarding operating procedures, the following is noted:
    - Point 1 states that performance for both take-off and landing must be based on the information in the AFM for the condition where the anti-skid system is inoperative;

      on this point, the blue NOTE at the bottom of the page, added by the operator, refers to the use of the OPT[5], which enables compliance with the requirements for both take-off and landing;
    - point 2 states that Autobrake must be set to "OFF";

[5] The Boeing 737 On-Board Performance Tool (OPT) is a software application integrated into the Electronic Flight Bag (EFB) that allows pilots and ground staff to perform real-time calculations relating to flight performance, such as take-off and landing, considering weather conditions, the runway and company regulations.

- point 3 states that the speed brakes should generally be operated 'manually', without providing specific methods or procedures for either the take-off or landing phases;
- point 4 includes further instructions, such as:
  A. Use the minimum braking consistent with the length and conditions of the available runway;
  B. DO NOT apply the brakes until the NLG is on the ground and the speed brakes have been deployed;
  C. Brake by applying light, continuous pressure to the pedals and increase the pressure as ground speed decreases. DO NOT 'pump' the brakes;
- point 5 states that, prior to landing, the "RUNWAY INHIBIT" must be selected on the GROUND PROXIMITY RUNWAY INHIBIT system control panel, if installed. This action, which should be carried out in flight prior to landing, is listed as the final point in the MEL

Operating procedures related to the approach and landing phases.

The following are some manufacturer-provided operational procedures for the flight crew, related to certain systems used during approach and landing, both in their normal condition and in the non normal condition (Non-Normal Configuration - NNC).

In the context of normal operations:

- OM Part A, Chapter 8.3.0.3.12.4 – Reverse Thrust Policy: in the absence of NNC conditions and for all landings, the captain is encouraged to use the Reverses and AutoBrake to clear the runway via the planned exit and minimize the time taken to reach the designated parking bay, whilst ensuring operational safety;
- FCOM (MAX-RYR), "Normal Checklist" section, QRH[6] . NC.5 (which follows), during pre-landing checks, the crew is required to check the deployment of the speedbrakes and the AutoBrake setting:

[6] The QRH is a checklist that considers abnormal or emergency conditions. The QRH developed by the individual operator is based on the procedures described in the AOM and adapted to 'cultural' requirements and the operator's own operational practices. It is obvious that every procedure, as well as every call and response, should comply with HF criteria aimed at optimizing work organization; however, it is equally obvious that company standards may incorporate elements derived from the culture and experience acquired over time by the crews, which are then formalized by those responsible for standards and training. All checklists must subsequently be approved by the competent authorities and the manufacturer.

LANDING (RYR)

START SWITCHES	CONT
RECALL	CHECKED
SPEEDBRAKE	ARMED, GREEN LIGHT
LANDING GEAR	DOWN, 3 GREEN
AUTOBRAKE	___ SET
FLAPS	___ / ___, GREEN LIGHT
LANDING LIGHTS	ON

Figure 51 - FCOM (MAX-RYR) - Normal Checklist", QRH NC.5)

- FCTM (MAX), paragraphs 6.8 and 6.9: in the absence of wind corrections (headwind and gusts), the minimum selected "Command Speed" is VREF + 5 kt and must be maintained until the start of the "Flare" phase. By applying the correct "Flare" technique, 5 kt of added speed (in addition to any correction due to headwind alone) can be reduced before touchdown. The "Flare" phase (landing pull-back maneuver) should be initiated when the MLG is approximately 20 ft above the runway;

  At "Touchdown", contact with the MLG should occur simultaneously with the Thrust Levers reaching the IDLE position; after contact, the NLG should not be kept raised any longer than necessary .

  These procedures apply equally in the *NNC – Antiskid Inoperative* context;
- FCOM (MAX-RYR), paragraph NP.21.139: for the *"Landing Rollout"*, after touchdown, both the PF and the PM must verify that the "SPEED BRAKE" lever is in the UP position, which should be accompanied by the PM's call regarding their deployment; then, both pilots should check the operation of the autobrake. Next, the PF, without delay and after the MLG has touched down, must select the thrust reverses to the "Interlocks" position, maintaining light pressure until the "interlocks" are released, and finally apply reverse thrust as required. During this phase, the PM must monitor the reverse thrust indicators and report back to the PF for appropriate action.

  This procedure is equally applicable in the NNC – Antiskid Inoperative context
- OM Part B Chapter 2.7.6 – Speedbrakes (Ground Spoilers): the function of the 'Speedbrakes' in Ground Spoiler mode is emphasised, in order to increase the weight on the wheels and thereby enhance the effectiveness of the brakes.

  This information applies to all landing conditions.
- OM Part B, Section 2.7.7 – Reverse Thrust: Reference is made to the Company's policy on the use of reverse thrust, which emphasises that, in order to achieve the required braking distance, reverse thrust must be selected in the 'interlock' position within 2 seconds of the

MLG touching down and before the NLG touches down. If this selection is delayed until the NLG touches down (normally 3 to 5 seconds after the main gear touches down), the distance required to come to a stop would increase.

The following are the relevant procedures for the approach and landing phases carried out under NNC conditions:

- OM Part B Chapter 2.7.9 – Antiskid System Inoperative: the use of the autobrake system is not permitted, and the speed brakes may only be deployed in "Manual" mode.
- OM Part B Chapter 2.10.6 – QRH NNC Landing Performance: in the event of manual deployment of the speed brakes, they must be deployed within 2 seconds of 'Touchdown'. This action by the PF is not provided for in the procedures for normal operations, where the speed brakes are deployed automatically.
- MEL 32-42-01 provides for the disconnection of one or more anti-skid channels (section MAINTENANCE (M): *Anti-skid channels that are faulty must be deactivated*), and this condition is in any case comparable to an *NNC – Anti-skid Inoperative* procedural scenario.

In addition to the guidance in the MEL, the QRH-NNC, provides addional flight crew procedures for a landing with the antiskid system inoperative.

In particular, the document states:

- under 'Caution', that the wheel lock protection is not available;
- in point 1, that AUTO BRAKE must be set to OFF;
- in point 2 that the speed brakes must not be armed, and that they must be manually deployed immediately upon landing;
- in the reference to 'Deferred Items', namely the 'Landing Procedure Review', the following actions are highlighted:
  - use the minimum braking force appropriate to the runway length and conditions, in order to reduce the risk of tyre blowouts;
  - do not apply the brakes until the nose wheel is on the ground and the speed brakes have been manually deployed;
  - begin braking by applying light, continuous pressure to the pedals, then increase the pressure as ground speed decreases. Do not pump the brakes;
- the checklist continues, in chronological order of actions, taking into account the specific checks to be carried out during descent (Descent Checklist), the approach

(Approach Checklist), the deactivation of the GROUND PROXIMITY RUNWAY system and the landing (Landing Checklist), where, in particular, the check of the speedbrake lever position set to "DOWN" and the autobrake set to "OFF" is highlighted.

The crew verified in flight the landing performance, evaluated following the parameters of the Performance Landing Enroute. Based on the estimated landing weight, 62370 kg, and the actual weather conditions, the minimum length of the runway was 2603 m, calculated applying the operator's safety factor of +30%, considering the Bergamo RWY 28 LDA of 2741 m.

Other operators' operating procedures related to the inoperative anti-skid system are covered in Chapter 1.17 (ORGANIZATIONAL AND MANAGEMENT INFORMATION) of the present report.

1.7. METEOROLOGICAL INFORMATION

The weather conditions at LIME at the time of landing can be deduced from the METAR, which corresponds to the ATIS, close to the landing time.

The weather conditions reported at the airport at 05:50, with the landing taking place at 05:55, were as follows:

METAR LIME 010550Z AUTO 02002KT 9999 FEW055/// 15/11 Q1017=

Thus, the wind was almost calm, visibility was excellent, there was light cloud cover at approximately 7.000 ft, the temperature was 15°C and the pressure was 1017 hPa.

1.8. AIDS TO NAVIGATION

This section provides information regarding the aids available for air navigation and their operational status.

1.8.1. Air navigation and landing aids

The approach was conducted in accordance with ILS Z procedure for RWY 28. The ground-based radio aids, necessary for the precision approach and landing, were operational at the time of the serious incident.

1.9. COMMUNICATIONS

This section sets out the most relevant information regarding the available means of communication and their operational status.

1.9.1. Mobile communications

The quality of radio communications has always been clear, and no reception or transmission difficulties have been reported on the frequencies in question.

1.9.2. Land communications

The communications provided for in the airport emergency plan were carried out without any technical issues being detected.

1.9.3. Transcript of communications

The following is a transcript of the T/B/T communications that took place from the first contact between E-IGI and TWR until the ARFF intervention.

Orario UTC	*Stazione Che Chiama*	*Testo Della Comunicazione*
Col. 1	Col. 2	Col. 3
05:52:08	RYR3LD	Orio Tower Ryanair3LD buongiorno, we are fully established runway 28 and we need full length since the performance issues.
05:52:18	LIME	Ryanair28WV runway 28 clear for take off, wind variable 2 knots.
05:52:22	RYR28WV	Clear for take off Ryanair28WV.
05:52:25	LIME	Ryanair3LD goodday, QNH 1017, wind 010 degrees 2 knots, continue approach and roger, vacate AF at the end.
05:52:35	RYR3LD	And we continuing, 1017, and copied AF Ryanair3LD.
05:53:16	LIME	Ryanair3LD clear to land, wind 010 degrees, 2 knots.
05:53:20	RYR3LD	Clear to land runway 28 Ryanair3LD
05:53:40	LIME	Ryanair28WV radar contact, Milano 1263. Ciao.
05:53:43	RYR28WV	1263 ciao Ryanair28WV.
05:55:31	LIME	Ryanair3LD ok, we saw the fire on the….on the engines, did you make a backtrack?

05:55:37	RYR3LD	Negative we had brake issues Ryanair3LD, stand by.
05:55:42	LIME	Ok roger.
05:55:48	RYR3LD	Aaaah tower what do you see please?
05:55:51	LIME	I saw just something like an explosion and fire eeeh and it seemed eeeh coming out from the engine, but I'm not sure about that.
05:56:02	RYR3LD	Ok, thank you. Stand by.
05:56:19	RYR3LD	Tower Ryanair3LD we need some assistance. We cannot taxi on our own for the moment.
05:56:23	LIME	Yeah Yeah, no problem, maintain that position. We have the….fire brigades and something eeeh someone is coming.
05:56:30	RYR3LD	Thank you very much.
05:56:32	LIME	Welcome sir.
05:56:53	LIME	3LD tower.
05:56:55	RYR3LD	Eeeeh go ahead.
05:56:56	LIME	Yeah mmm observing the runway I see eeeh pieces of tyres, I suppose, like 200 metres behind you. So maybe it was an explosion of the tyres.
05:57:01	RYR3LD	AAH yeah, thank you.
05:57:18	RYR3LD	Aaaah Ryanair3LD we are stuck over here. Can you send us the fire brigades please?
05:57:22	LIME	Yeah, they are coming. 30 seconds and they will be there.
05:57:26	RYR3LD	Perfect, thank you.

Figure6 – T/B/T communications on the TWR frequency (source ENAV)

The key points from these communications are:

- on first contact with TWR, at 05:52:08, the crew reported that they were completely stable on the ILS and that, for performance reasons, they would consider using the full length of the runway.
- TWR authorized the landing at 05:53:20.
- The same TWR, at 05:55:31, made an initial communication suggesting engine problems; subsequently, following a request for assistance from the crew at 05:56:19, the TWR confirmed the activation of the ARFF;
- At 05:56:56, the TWR reported the presence of tyre debris attributable to the tyre blowout.

1.10. AERODROME INFORMATION

Bergamo Orio al Serio Airport (ICAO LIME) has ARP coordinates of 45°40'08''N 009°42'01''E and an elevation of 782 ft. The runway is 10/28 (4E) and measures 2874x45 m. The LDA for RWY28 is 2741 m.

Figure73 – LIME Airport (Bergamo)

1.11. FLIGHT RECORDERS

This section contains the most relevant information regarding the recording equipment on board.

1.11.1. General Information

The aircraft is equipped with a Honeywell FDR and CVR; the former is DMF 102021 PN D51728-1-0 ISS01, SN A25584-001, and the latter is DMF 062022 PN D51728-0-0 ISS01, SN A26743-002. These recorders are of recent design and employment. Data downloading was carried out with the support of the French BEA.

1.11.2. FDR Transcript

At 05:54:47, the aircraft was at a height of 55 ft above the runway, with A/T and A/P disconnected, correctly configured (Gear DOWN, Flaps at 40°), stable on the planned path of the Instrument Landing System (ILS) approach and with flight parameters within the expected limits.

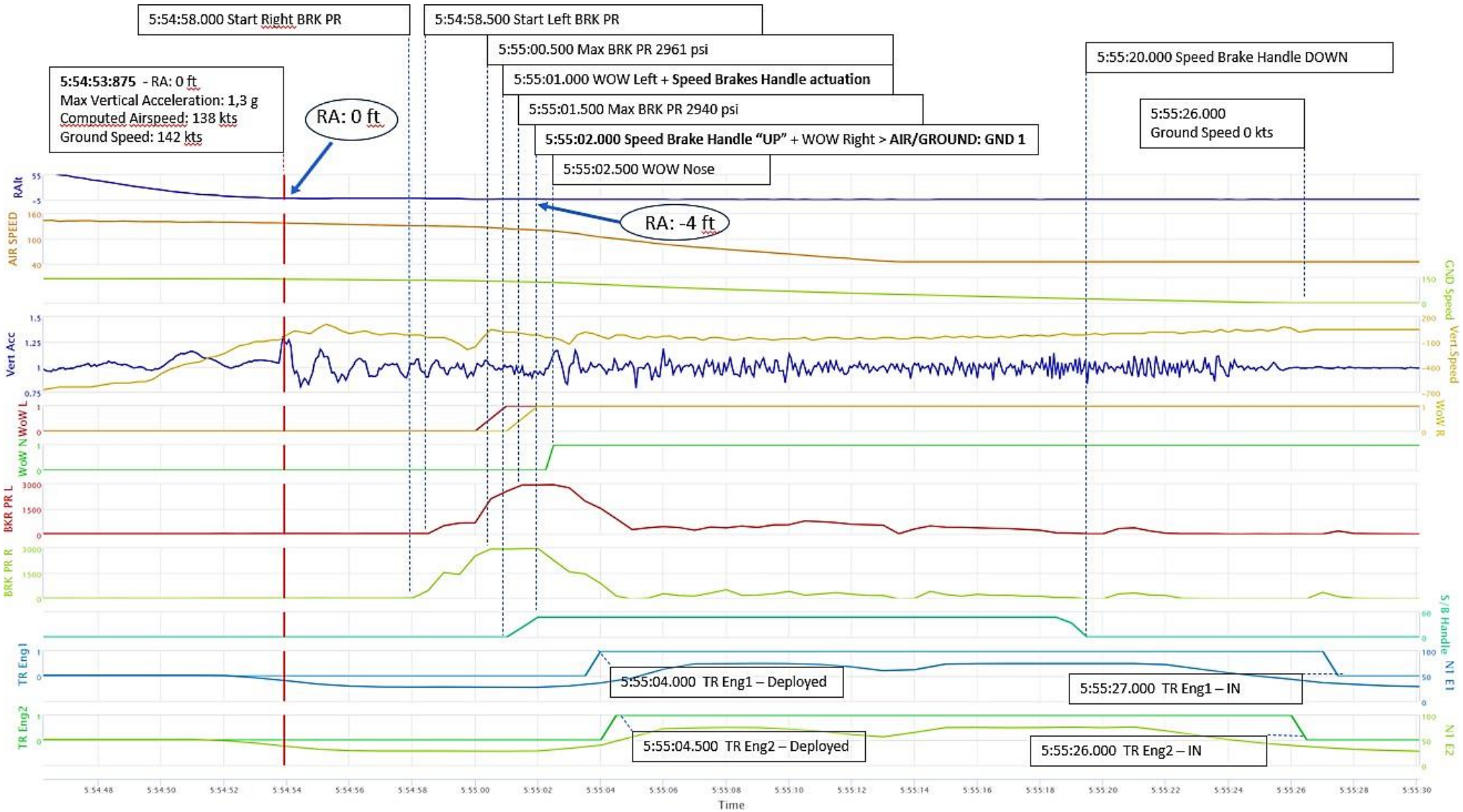

Figure 84 - timeline of events from the final approach to the stop on the runway (FDR data, processed by FAS)

At 5:54:53.875, with radalt at 0 ft and maximum vertical acceleration of 1.3 g, the first contact with the runway likely occurred, with a KIAS of 138 kt, a GS of 142 kt and a VS of 100 ft/min. At this time, neither the AIR/GROUND signal nor any of the WOW sensors had yet been activated.

At 05:54:58.000, pressure begins to be applied to the right-hand brakes, starting at 1500 psi and rapidly increasing up to 2961 psi.

At 5:54:58.500, pressure begins to be applied to the left-hand brakes, initially at 660 psi and then rising in 2" to 2940 psi.

At 5:55:01.000, the deployment of the speed brakes occurs, at 5:55:01.000, the presence of the WOW signal from the left landing gear is recorded. The radio altimeter reading is -4 ft[7] , consistent with the aircraft being on the ground.

At 5:55:02.000:

- the 'Speedbrake/Spoiler' control lever is fully extended, with all speedbrakes deployed in the Ground Spoiler mode (not shown in the graph);
- the WOW signal from the right landing gear is present and the AIR/GROUND signal is set to GROUND;
- the start of brake pressure release on the right side is recorded.

At 5:55:02.500, the reference signal indicating the presence of the front landing gear WOW is recorded.

At 5:55:03, the start of brake pressure release on the left side is recorded.

At 5:55:04.000, the deployment of engine #1's thrust reverse is recorded.

At 5:55:04.500, the deployment of engine #2's thrust reverser is recorded.

At 5:55:20.000, the activation of the "Speedbrake/Spoiler" control lever in the closing position, i.e. the "DOWN" position, is recorded.

At 5:55:26.000, the aircraft came to a halt on the runway approximately 1,680 m from the threshold of RWY 28 and about 1,000 m from the runway end.

At the same time, 5:55:26, the retraction of the thrust reverser on engine #2 is recorded; at 5:55:27, the retraction of the thrust reverser on engine #1.

The aircraft comes to a stop on the runway approximately 1.680 m from the RWY 28 threshold and about 1.000 m from the end of the runway.

[7] In accordance with the provisions of the AMM, TASK-34-33-00-710-801 – Low Range Radio Altimeter (LRRA) System – Operational Test, the calibration of the radio altimeter for an aircraft on the ground (Air/Ground System on Ground) corresponds to a RA reading of – 4 ft ± 2 ft (-1.2 ± 0.6 m).

1.11.3. Transcription of the CVR

A summary of the communications between the two pilots in the cockpit, relevant to this investigation, is provided below.

At 05:22:05, the PF is still the FO and the crew begins the approach briefing.

At 05:22:50, the PM/CPT drew attention to the planned landing procedure with the anti-skid system inoperative, emphasizing the need not to apply the brakes heavily unless necessary (CPT: *So… braking because of the runway length. Basically, don't brake hard if not needed*; FO*: OK).*

At 05:23:28, the PM/CPT specifies that the brakes must only be applied after the nose wheel has touched down and following the manual deployment of the speed brakes, asking the FO to pay attention to the aforementioned sequence (CPT: *Do not apply the brakes until the nose wheel is on the ground and the speedbrakes have been manually deployed; I'll try to do that, look up, yeh.).*

The PM/CPT goes on to specify that braking must initially be carried out by applying steady pressure to the pedals, in line with the decrease in ground speed *(*CPT: *Braking initially using like steady pedal pressure as ground speed decreases, you know?*).

This is followed by some discussion between the CPT and FO regarding the term "gently", used by the CPT, which the FO interprets as "light" (CPT: *I'll try to be gentle on the brakes, basically, OK;* FO:*... Or light?).*

At 05:23:38, control of the aircraft is transferred; the CPT becomes PF, and the latter calls for the 'DESCENT CHECKLIST' to be carried out, which is completed at 05:23:45.

At 05:24:10, the PF/CPT reiterates that the speed brakes must be selected manually and that he does not intend to use the brakes, at least initially (CPT: *So that those things, manually speed brakes and no brakes, basically).*

At 05:24:25, the FO asks the CPT if there are any restrictions on the use of reverse thrust. The CPT confirms that there are no restrictions (FO: *"On the reverse, is there any restriction?"; CPT: "No, there is no restriction").*

At 05:25:05, the CPT reiterates that the landing data has already been entered into the FMS, given that the anti-skid system is inoperative (CPT: *... landing on the FMS, Anti-skid already OFF; FO: Already OFF).*

Subsequently, the CPT continues by stating that the speed brakes would be deployed manually, as required by the QRH landing checklist, and noting that these must, in fact, be set to "DOWN" (CPT: *Speedbrake is manual, ok. I just have to ... it's not a real point, I'll use the QRH checklist for the landing. So, we ... remember that it should be DOWN).*

At 05:25:20, the CPT selects the Ground Proximity Runway Limit at the Runway Limit position, followed by confirmation from the FO (PF: *... Set the Ground Proximity Runway Limit to Runway Limit. So, Runway Limit Switch is here, confirm? FO: Yes).*

At 05:45:28, the pilots complete the required approach checks, confirmed by the FO's announcement upon their completion (FO: *"APPROACH CHECKLIST completed")*.

This is followed by the CPT's request to the FO to inform the cabin crew that there are "10 minutes to land", a message which is relayed by the FO via PA at 05:46:41 (*CPT: Give ten minutes on that; FO: Cabin crew, ten minutes to land).*

At 05:48:57, the PF/CPT, having confirmed the selection of the next altitude of 4000 ft and that he had received the message that the passenger cabin was ready for landing, instructed the PM/FO to set the flaps to 1. The PM/FO, after checking the speed, set the flaps to 1 and confirmed that the passenger cabin was secure for landing (CPT: *Next altitude 4000, we are ready with the cabin ... Flaps 1; FO: Speed Check, Flaps 1, Cabin secure).*

At 05:49:38, the PF/CPT calls for the flaps to be set to 5, the PM/FO replies with a speed check, followed by confirmation that the flaps have been extended to the required position, which is, in turn, acknowledged by the PF/CPT.

At 05:52:43, the PF/CPT suggests reviewing the landing procedures; he announces that the autobrake selector is in the 'OFF' position, that braking (presumably referring to the speed brakes) will be carried out 'manually', and that the brakes will be applied as late as possible. He then reiterates that his expectation is for the aircraft to come to a halt 'on its own' (CPT: *I suggest to review: Autobrake is OFF; this one will be manual, and I'll try to brake as late as possible. In general, the plane will kind of stop on itself, we'll see how ... (not intelligible).*

At 05:52:58, the PF/CPT requests the landing gear to be extended, to which the PM/FO replies by checking the airspeed; Subsequently, a number of landing checks are carried out, verifying that the speedbrake control lever is in the 'DOWN' position, that the landing gear is extended as indicated by the three green lights, and that the autobrake is set to 'OFF' *(CPT: Lets go for Gear down, FO: Gear Down, Speed check .. (not intellegible) .. landing checks: turn switch? CPT: Continuous; FO: recall?; CPT: Checked; FO: Speedbrakes?; CPT: Is down; FO: Landing Gear; CPT: Down three green; FO: Autobrake? CPT: OFF).*

Continuing with the final landing configuration, the PF/CPT first calls for the flaps to be set to 25, then to 40, followed, at 05:53:30, by the PM/FO's final confirmation of the flaps being correctly set to 40 *(FO: Flaps forty green light).*

At 05:54:05.500, the PF/CPT decides to disengage the autopilot and autothrottle (*CPT: ok, disengaging*), followed by the sound generated by the warning system and the PM/FO's agreement to continue the landing (FO: *Continue*).

The aircraft first touched down at 05:54:54 (corresponding to the red line on the FDR graph shown in Fig. 14); 3 seconds later, at 05:54:57, the PF/CPT announces, *"REVERSE AND SPEEDBRAKE*".

At 05:54:58, distinct vibration noises are audible inside the cockpit; at 05:54:59, the PF/CPT realizes that the wheels may be locked. (*CPT: Wheels are locked)*

At 05:55:03, 9 seconds after first contact, the PM/FO calls out *"SPEEDBRAKE"* and subsequently announces that the speed brakes are extending and that the reverse thrust is normal *(FO: Speedbrake coming here, Reverse is Normal).*

At 05:55:16, the PF/CPT initially attributes the vibrations to a lack of anti-skid but subsequently expresses his uncertainty regarding the effects he was experiencing, eventually asking the PM/FO to inform the TWR that they had experienced brake problems during landing.

From this point onwards, internal discussions and communications with the TWR follow to clarify the causes of the problem and coordinate with the SCCM (Senior Cabin Crew Manager) regarding the management of the passenger cabin.

At 05:56:13, the need for assistance is confirmed to the TWR, given that it is impossible to move from the current position; at the same time, coordination efforts to manage the passengers continue.

At 05:56:26, the TWR confirms that the ARFF was on the way.

From 05:56:34 to 05:56:44, the flight crew consider the possibility of a tyre blowout, but at the same time the PF/CPT expresses his conviction that he had not applied the brakes.

From this point onwards, a series of internal communications and conversations, as well as exchanges with the TWR, take place, aimed at providing information and coordinating actions regarding passenger management, analyzing the situation and the steps to be taken to manage the incident, and considering the possibility of disembarkation using standard means and buses.

During this period, the crew also confirms that the parking brake had not been applied, proceeded to start the APU, and shut down both engines.

ARFF personnel inform the crew of an oil leak near the right-hand landing gear, which is, however, under control.

Passengers then are disembarked.

At 06:23:06, the CVR stops recording.

1.12. WRECKAGE AND IMPACT INFORMATION

This section contains the information obtained from the examination of the wreckage and the site of the incident.

1.12.1. Location of the serious incident

The aircraft came to a halt on RWY28 at Bergamo Airport (LIME), at coordinates 45°40’06.982” N 9°42’09.859” E, approximately 1700 m from THR28.

1.12.2. Ground marks and distribution of debris

Below are some pictures showing the skid marks and damage on the runway.

Photo 4 - skid marks on the runway

Photo 5: runway damage and debris on the runway (Source: SACBO)

Photo 6 - area of the runway, near the aircraft, affected by damage and debris (Source: SACBO)

The detachment of two tyres from the right-hand landing gear is evident. The debris appears to be distributed as shown in the illustration below.

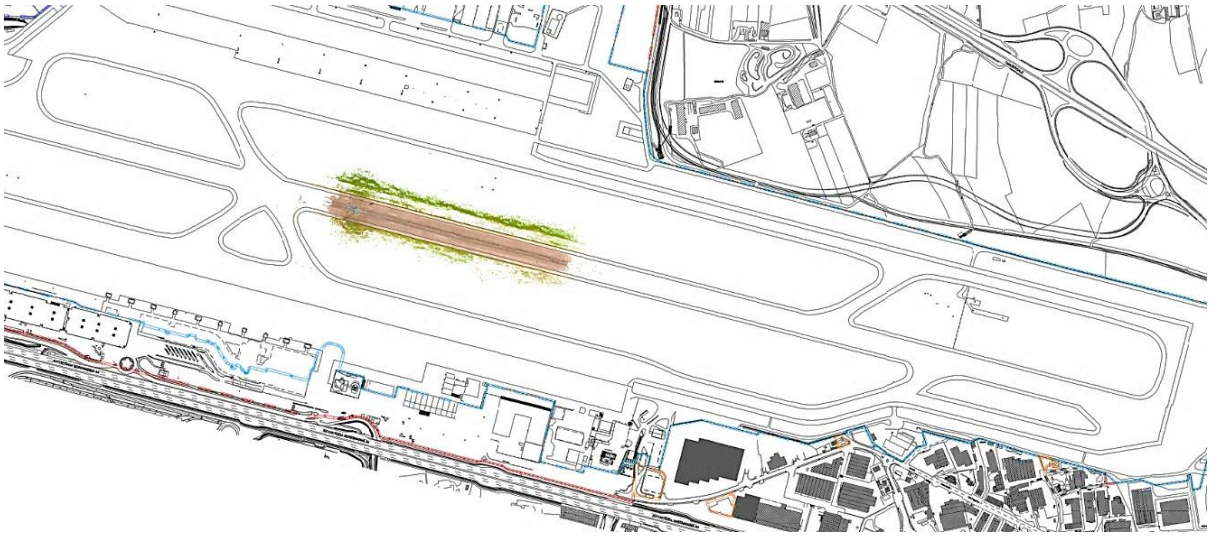

Figure15 – Illustration of the distribution of debris on the runway (Source: SACBO)

1.12.3. Examination of the wreckage

This section will present the damaged parts of the aircraft in greater detail.

The following images show the condition of the wheels, on the left and right sides, with the aircraft still on the runway.

Photo 7 - photo of the MLG taken from the left side of the aircraft

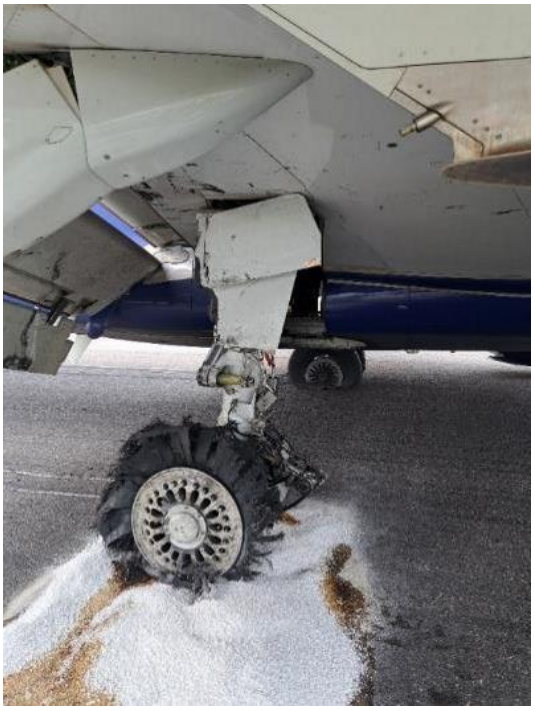

Photo 8 - photo of the MLG taken from the right side of the aircraft

(Source: SACBO)

Photo 9 – Front view of left MLG

Photo 10 - Rear view of the right MLG

(Source: SACBO)

Below is a detailed description of the parts of the aircraft that were damaged.

MLG wheels and tyres #1 and 2 (i.e. left side)

The brake assemblies on wheels #1 and #2 were locked in the retracted position; the burst tyres were still in place, the wheels showed evidence of considerable wear due to friction on the tarmac, more so on wheel #1

Foto 31 - Detail of brake and wheel #1

Photo 12 - Detail of the tyre #1

Photo4 - Detail of wheel and tyre #2

MLG wheels and tyres #3 and 4 (right side)

The tyres on wheels #3 and 4 had burst. In particular, the tyre on wheel #3 had been torn off and the wheel showed signs of friction with the tarmac. Wheel #4 was still able to rotate.

Photo 6 - Detail of the wheel #3

Photo 55 - Tyre #3

Photo 76 - Detail of wheel with tyre #4

Further damage to the aircraft was found on the right-hand side, caused by fragments from tyres #3 and #4 being thrown out following their burst and detachment: the right-hand side sustained more secondary damage than the left-hand side.

MLG

Regarding the structure of the right MLG, a rupture of the panel and the door linkage was found, along with damage to the 'air-to-ground' sensor. Detailed photos follow.

Photo 17: Structure, panels, linkages of the right MLG

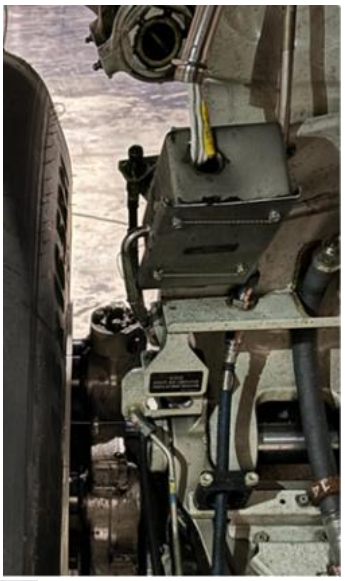

Photo 18 - air-ground sensor of the right MLG

Fuselage

Numerous damages were found on the rear right section of the fuselage.

Photo 19 - Detail of damages to the right side of the fuselage

Wings and associated moving surfaces

Damage was found to the structures of the right wing. In particular, the right flap panels and their linkages were affected.

Photo 20 - Detail of damage to the right-hand ‘inner flap’

Transducers

Following the incident, the four sensors were removed; trasducer #3, shown in the photo below, was the one found to be faulty following the braking system tests and troubleshootings carried out by the maintenance team.

Photo 21 - Wheel transducer #3

Cockpit

The autobrake selector was in the “OFF” position.

The circuit breakers relating to the LANDING GEAR – ANTISKID, both INBOARD and OUTBOARD (position P6-3), were found to have been removed and protected with a ‘collar’; furthermore, the label had been put on the relevant panel of the antiskid system, as shown in the following picture.

Photo 22 - detail of the removal and protection, using a 'collar', of the ANTISKID switches (INBOARD and OUTBOARD)

Photo 238 - Antiskid INOP warning light and the yellow label indicating the system is inoperative

System A indicated 14RF (RF: Refill) and system B indicated 85.

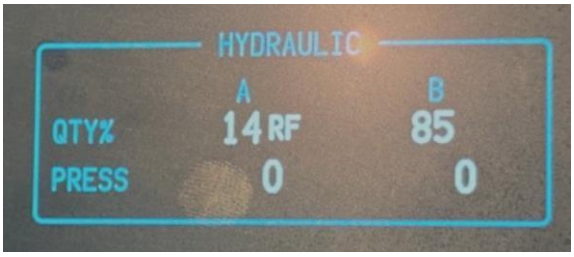

Photo 24 - Hydraulic system indications

1.12.4. Impact dynamics

After a stable approach, the aircraft made first contact with the runway at 05:54:54, with a vertical acceleration of 1.3 g, corresponding to an initial radio altimeter reading of 0 ft, at a KIAS of 138 kt, GS of 142 kt and a VS of -100 ft/min.

Immediately after this first contact, the PF/CPT announces: *"REVERSE AND* SPEEDBRAKE".

Approximately 4 seconds after the first contact, the application of brake pressure is recorded, vibration noises begin to be audible inside the cockpit.

Approximately 6 seconds after contact, maximum pressure is applied to the right brakes; approximately 7 seconds later, maximum pressure is applied to the left brakes and WOW on the left side.

After approximately 8 seconds, the 'Speedbrake/Ground Spoiler' control lever is manually actuated and the WOW is deployed on the right-hand side; this created the conditions for the activation of the AIR/GROUND signal set to GROUND, corresponding to a radio altimeter reading of –4 ft.

Approximately 10 seconds after touchdown, the reverse thrust is activated and the aircraft comes to a halt approximately 32 seconds after initial contact and around 1700 m from the runway threshold, about 1.000 m from the runway end.

1.12.5. Malfunctions related to the event

From the crew's statements, the technical documentation examined and the FDR data, no evidence emerged of malfunctions in the on-board systems during the flight, apart from the deactivation of the anti-skid system following the application of the MEL.

1.13. MEDICAL AND PATHOLOGICAL INFORMATION

Not applicable.

1.14. FIRE

The ARFF carried out the necessary checks and operations to secure the area, without finding any signs of fire.

They contained a significant hydraulic leakage from the right landing gear, using specific absorbent materials.

1.15. SURVIVAL ASPECTS

Once the ARFF had secured the area, the passengers and crew disembarked from the aircraft in accordance with standard procedures and using the standard equipment, without any further problems. The passengers were taken to the terminal by coach.

1.16. TESTS AND RESEARCH

An incident attributable to landing difficulties with the anti-skid system inoperative occurred in Singapore on 3 December 2021 and involved the 737-8 (MAX) registration marks 9V-

MBF. The aircraft had departed with the anti-skid system deactivated, following the application of MELs 32-42-01 and 31-42-03 (Anti-skid and Autobrake deactivated).

These maintenance actions were carried out following the identification of the 'Box AB/B' fault, which indicated a fault in the AACU or the anti-skid valve. No further technical investigations were carried out and the aircraft was released with the anti-skid system, and the associated autobrake system, disconnected.

During landing, following a light touch-down (1.1g), pressure was applied to the left-hand wheels (1500 psi) before the speed brakes were extended and whilst the MLG struts had not yet been compressed (sensors in 'AIR' condition). This resulted in the explosion of the outer wheel and the deflation of the inner wheel on the left side.

The causes of this serious incident were attributed to a deviation from procedures by the flight crew, who did not first select the speed brakes, but instead insisted on achieving the reverse thrust.

The operator conducted remedial training for the flight crew involved and shared the incident internally as a 'lesson learnt'.

The recommendation made by the SIA in Singapore to the operator was to ensure that flight crews are made aware of the need to comply with the provisions of the MEL.

1.17. ORGANIZATIONAL AND MANAGEMENT INFORMATION

1.17.1. Maintenance

On 30th September, following two fault reports concerning the antiskid system, for which ATL indicated that it had not been possible to determine the specific cause, MEL Item 32-42-01 (WO 55475103) was included in the HIL, informing of the deactivation of the antiskid system by pulling out the CBs related to the INBOARD and OUTBOARD channels.

Following the aircraft's release at 11:00, it flown four flights that day, with the final landing at BCN at 22:00.

According to ATL, on the following day, 1st October, at 02:00, the technician on duty at BCN (shift: 30th September 19:00 – 1st October 07:00), completed some tests and trouble shootings on the anti-skid system in accordance with instructions received from MAINTROL, detected the XDCR3 fault message and after applying the relevant IFIM, identified the transducer #3 as faulty.

As previously reported, the technician received no further instructions and, using the AMOS maintenance management system, noted that the faulty transducer was unavailable at Barcelona Airport; he therefore requested its replacement.

At 04:11, he closed the position on AMOS and released the aircraft, without carrying out any further work.

In addition to the anti-skid tasks, the same technician also carried out a RAMP 1 inspection, an engine compressor wash and an aircraft disinfection during his shift.

The aircraft moved from the stand at 04:41 to operate flight BCN-BGY, at the end of which the event occurred.

Ryanair conducted a maintenance investigation, finding that on 30th September the 'Duty Materials Coordinator' initiated the procurement order for the transducer as an AOG (Aircraft On Ground) at 17:42 (while the aircraft EI-IGI was in flight), and that it was dispatched via flight FR9044 from Stansted to Barcelona, which landed in BCN at 21:40 on the same day. The internal investigation also found that, due to delays in customs clearance and the temporary unavailability of the company's LAN/Ethernet line, the part was not available at BCN until 13:17 on 1st October.

1.17.2. Training

The application of MEL 32-42-01 requires the disconnection of one or more anti-skid channels (MAINTENANCE (M) section: *Anti-skid channels that are faulted must be deactivated*).

Although the MEL contains the necessary and sufficient information and instructions, as stated by the airline, crews encountering an NNC condition are nevertheless trained, as part of TEM[8] and CRM, to use the most specific and additional procedural references relevant to that particular condition.

In the present case, the crew referred to the FCOM/QRH (MAX-RYR), NNC paragraphs 14.1 and 2, covering the procedures to be followed in the event of ANTISKID INOPERATIVE.

The manufacturer's OSD[9] (Operational Suitability Data - Boeing 737-8/-8200/-9 (MAX) ed. 19th February 2021), approved by EASA for the "B737 300-900" type certification, does not include any training guidance for antiskid inoperative for flight crews.

[8] Threat and Error Management (TEM) is a proactive aviation safety training programme designed to help flight crews manage operational complexities by anticipating, recognizing and mitigating risks. It focuses on managing external threats (e.g. weather conditions, traffic), internal errors (e.g. checklist errors, calculation errors) and undesirable aircraft states to maintain safety margins, utilizing CRM (Crew Resource Management).

[9] OSD – Operational Suitability Data.

The guidelines contained in the sections "Master Differences Requirements (MDR)", "Specifications for Pilot Training" and "Training Area of Special Emphasis" (TASE), applicable to the B737 MAX in initial, conversion, differences and triennial recurrent training, do not include any specific training in case of antiskid inoperative.

The Operator's OM Part D, in the recurrent training scenarios provided, addresses the MEL covering inoperative anti-skid; however, no FSTD activities are associated with this MEL, in line with OSD requirements, whilst the landing braking manoeuvre is always carried out with the anti-skid system operational.

In the operator's standard training programmes it is included a tyre blowout.

The familiarization document for the differences between B737-800 and B737-8200 issued by the operator does not highlight the subtle differences between the two variants regarding system logic for the deployment of the thrust reversers.

1.17.3 S.M.S

Following the internal investigation, the operator took the action to mitigate the risk by reducing the maximum time interval for fault rectification, originally specified in the MMEL, from 10 days (C in the 'Interval' box) to just one flight cycle, as shown in point "d" in the figure below.

In general terms, the principle of Operational Suitability Data (OSD) is that aircraft manufacturers are required to establish certain data considered important for the safe operation of the aircraft type. Specifically, within the EASA framework, this data are approved by the Agency as part of the Type Certificate (TCDS) and are then used by training organizations and operators.

Article 5 of the Basic Regulation has been amended to include Operational Suitability Data (Operational Suitability Data – OSD) as part of the type-certification procedure, and the relevant implementing standards have been defined in Regulation (EU) No 1321/2014, which takes into account the OSD for aspects relating to Continuing Airworthiness proposed by EASA with Opinion No 07/2011.

This data consists of the following elements:

1- the Master Minimum Equipment List (MMEL);
2- data for pilot training;
3- data for cabin crew;
4- data for the training of maintenance personnel; and
5- data for simulator qualification.

Therefore, the OSD serves as the reference point for customised training courses and MELs developed by operators and training organisations, thereby helping to bridge the gap between the Airworthiness and Operations sectors, and constituting a key element in achieving the expected positive impact on safety. The new requirements involve aircraft manufacturers, modification designers, operators and training organizations. Consequently, to make the regulatory changes proposed in EASA Opinion No. 07/2011 binding, this was followed by the issuance of four European Commission regulations that considered the OSDs' involvement in the areas of 'Initial Airworthiness', 'Continuing Airworthiness', 'Air Operations' and 'Aircrew'.

RYANAIR

Section 2 B737-8200 MEL & DDG ATA 32

32-42-01 Antiskid System

Interval	Installed	Required	Procedure	LIDO
A	1	0	(M) (O)	32-42-01

May be inoperative provided:

a. Inoperative antiskid channels are deactivated.
b. Autobrake system is not used.
c. Appropriate performance adjustments for antiskid inoperative are applied.
d. *INOP Antiskid system is limited to 1FC, Contact Maintenance Control & Duty Pilot prior to dispatch under this MEL item to ensure engineer is available at downline station.*

NOTE: *Defect may prohibit operations to or from narrow and or short runways. Please refer to Airfield Brief for further guidance.*

LIDO

Dispatch under this MEL Item will be entered into the LIDO System and Dublin Maintenance Control must be contacted.

PLACARD

INOP - As appropriate

MAINTENANCE (M)

NOTE: An operative antiskid channel should not be deactivated. Antiskid channels that are faulted, must be deactivated.

Deactivate the inoperative antiskid system channels (AMM 32-00-00/901).

1. For inboard antiskid channel inoperative, open and collar the P6-3 panel LANDING GEAR ANTISKID INBD circuit breaker.
2. For outboard antiskid channel inoperative, open and collar the P6-3 panel LANDING GEAR ANTISKID OUTBD circuit breaker.

OPERATIONS (O)

NOTE 1: Reduced thrust takeoff using the assumed temperature method is not permitted.

NOTE 2: Takeoff on wet runways is not permitted unless AFM performance for wet skid-resistant surfaces and antiskid inoperative is applicable and used.

NOTE 3: Operations may be affected at contiguous United States airports impacted by 5G C-Band interference [Ref FAA Airworthiness Directive (AD) 2023-12-11 and associated Boeing Flight Crew Operations Manual Bulletin (OMB)]

1. Base takeoff and landing performance on AFM antiskid inoperative.
2. Set autobrake system OFF.

Apr 28, 2025 2.32-42-01.1

Figure 96 : 28 April 2025 edition of MEL & DDG 32-42-01

By amending MEL 32-42-01, the operator aimed to reduce exposure to the risk of operating in a scenario where the anti-skid system is inoperative.

Furthermore, the operator has introduced an additional step, whereby the crew must contact the Duty Pilot, who is available 24 hours a day, 7 days a week, and receive a detailed operational briefing on the procedures, limitations and risks associated with this MEL.

In addition to these amendments to the MEL, the operator produced an eLearning training package that covers this event as case of study, along with highlighting the correct sequence of actions set out in the MEL as well as in the QRH NNC Antiskid Inoperative.

In the maintenance context, the internal investigation identified the lack of clarity in the MELs and specific IFIMs as a contributing factor. This led the technician at BCN not to complete the IFIM related to the failure of transducer #3, detected via BITE, due to the absence of the spare part, consequently he considered the actions taken to open the HIL (antiskid inoperative) as still valid. The same investigation identified a series of preventative measures to avoid a recurrence of the error:

1. add the note "An inoperative antiskid channel MUST not be deactivated" and "Antiskid channels that are faulted MUST be deactivated", or similar, within the antiskid FIM tasks 32-42-00-810-815 XDCR3 (present only in AMM Task 32-00-00-040-808 Antiskid inoperative - Preparation);
2. publication of instructions for technicians advising them to always refer to the applicable AMM DDG and MEL when a HIL remains open following troubleshooting;
3. update of the MOE with additions concerning HILs and the management of WOs;
4. revision of procedures for the dispatch of urgent parts (AOG).

1.18. ADDITIONAL INFORMATION

The following are the key points emerging from the statements given by the pilots and technicians involved in the event and considered as relevant for the present investigation.

1.18.1. Interviews and statements

Pilots interview

The flight crew was interviewed in ANSV.

The following points deemed as relevant for the investigation have been taken from the interviews:

- both were certainly aware that they had to land without the anti-skid system;
- both pilots confirmed that the procedure to follow is the one in the MEL for inoperative anti-skid, however, considering what they had learnt in CRM and TEM training, they were able to use other additional procedures, such as the one provided in the QRH;
- neither was aware that, during the landing, the brakes had been applied before the speedbrakes deployment and the nose wheel lowered;

- the FO/PM stated that he had seen the captain persist with the thrust reverse levers and had observed the CPT/PF moving the speed brake lever few seconds after the presumed contact with the runway, and made the consequent call-out;
- neither pilot recalls having undertaken training on FSTD related to landing with the antiskid system inoperative; only CPT stated that he had performed this procedure in an operational environment two, perhaps three times, throughout his entire career.

Maintenance personnel statements

The technician on duty at MAINTROL in Dublin stated the following:

- following the failure to detect any faults after the Operational Test, carried out by a technician at AGP on 30th September, and the subsequent return of the aircraft due to the recurrence of the fault, it was decided to place the aircraft on AOG status with the scope to allow the necessary technical investigations;
- still at AGP, the BITE procedure was subsequently carried out, without any faults being detected;
- Following the occurrence of multiple spurious faults and to prevent their recurrence, it was decided to deactivate the Antiskid system by applying the relevant MEL; this was entered into the HIL and the LIDO management system.

The technician on duty at Barcelona Airport stated:

- that his duty shift began at 19:00 on 30th September and ended at 07:00 on 1st October, thus complying with the prescribed rest periods;
- that he had detected, via BITE, the failure of transducer #3, he then requested its substitution and added it to the HIL already open in LIDO;
- that, having no reason to believe that the procedure applied previously at the time of the HIL opening was incorrect, he did not check the MEL or carry-out further maintenance work on the anti-skid system.

1.18.2. Footage from the airport CCTV cameras.

Bergamo Airport is equipped with a closed-circuit cameras system. From the various recorded footages, it was possible to extract several images documenting key moments of the landing. The first image shows the right brakes being applied:

the second shows the left brakes also being applied:

From the next image (enlarged), the speed brakes/spoilers have not yet been deployed:

The next two images show that the speed brakes/spoilers have been deployed; according to the FDR data, this occurred when the WOW occurred on the MLG and the NLG:

The aircraft continues its run with the MLG wheels locked, accompanied by fire and detachment of parts:

1.19. USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

Not applicable

CHAPTER II
ANALYSIS

2. GENERAL

The objective evidence gathered during the investigation, as described in the previous chapter, is analyzed below.

The aim of the analysis is to establish a logical link between the evidence gathered and the conclusions.

2.1. FLIGHT OPERATIONS

The flight crew of the B737-MAX aircraft, registration EI-IGI, operating flight FR846, were on their first leg of the day; the prescribed rest periods had been observed.

The scheduled flight, carrying 162 passengers, was also a training flight as part of the FO's LIFUS training programme, with the captain acting as LT.

The captain accepted the aircraft subject to a MEL procedure, 32-42-01, with both antiskid channels (INBOARD and OUTBOARD) deactivated.

The flight proceeded normally; as the aircraft approached Bergamo Airport, the flight crew prepared to land with the anti-skid system inoperative by conducting a briefing on the limitations and the correct sequence of actions to be taken.

From the CVR recording, it can be understood that the flight crew was fully aware of the implications to land without the anti-skid system, which was in-line with the training they had received and the guidance available to them in the MEL and the QRH.

The crew conducted an ILS approach to runway 28 at Bergamo Airport, maintaining a stable flight profile with correct flight parameters.

The crew received landing clearance at 05:53:20, in almost calm conditions (10°, 2 kt).

Moments before touchdown, as part of the flare, the rate of descent was reduced to a VS of approximately -100 ft/min, until contact with the runway.

The aircraft's first contact with the runway occurred at 05:54:53, when the radalt reached 0 ft and the vertical acceleration reached its peak. For the purposes of the following analysis, this time will be taken as T0.

At T0 time, the KIAS was 138 kt (VREF + 4 kt) and the GS was 142 kt (VREF + 8 kt), suggesting the presence of a slight tailwind component.

The PF/CPT announces: *"Reverse and Speedbrake"*, however in the interview stated that he initially had difficulty engaging the thrust reverses.

The AIR/GROUND is not in GROUND condition yet and, although the throttle levers are set to IDLE, the engine thrust is still at APPROACH IDLE.

It is likely that the aircraft was in a state of "ground effect"[10] which prevented the aircraft's weight from fully pushing down the MLG struts, thereby increasing the landing distance and deceleration time, in absence of any corrective action by the pilot.

At time T0+4.125 seconds, pressure was applied to the right-side brakes, initially reaching 1500 psi and subsequently increasing to 2961 psi (effectively the maximum pressure) by time T0+7.125".

At T0+4.625 seconds (0.500 seconds after the initial pressure was applied to the right-hand brakes), pressure was applied to the left-hand brakes, initially reaching 700 psi, before increasing to 2940 psi at T0+6.625 seconds.

During this period, the noises caused by vibrations began to be clearly audible in the cockpit; the PF/CPT believed that these might be attributable to a wheel lock.

At T0+7.125 seconds, the start of speedbrake deployment was recorded, coinciding with the WOW signal from the left landing gear.

At T0+8.125 seconds, the 'Speedbrake/Spoiler' control lever was recorded as being set to 'UP' (corresponding to the actual deployment of the surfaces) and, at the same time, the WOW signal from the right landing gear was recorded, resulting in the system recognizing that the aircraft was on the ground.

Subsequently, the FO/PM announced that the speed brakes had been extended (a check that can only be carried out by observing the position of the speed brake control lever) and that the reversers had been deployed (the 'REV' indicator in green above the engine N1 indicators); the PF acted to increase thrust on the reversers.

At the same time, T0+8.125seconds, the release of brake pressure on the right-hand side was recorded.

At T0+8.650 seconds, the WOW signal from the front NLG was recorded.

At T0+9.125 seconds, the start of brake pressure release on the left side was recorded.

[10] Ground effect. The pressure difference between the upper and lower surfaces of a wing causes air at its tip to be forced to move from the lower to the upper surface, generating conical vortices known as wing tip vortices, which are among the sources of induced drag. Proximity to the ground hinders the formation of these vortices, resulting in reduced drag and thus increased wing efficiency. Furthermore, at high angles of attack during the final phase of landing, the air beneath the underside of the wing is slightly compressed between the wing and the ground, forming a 'cushion' that tends to lift the aircraft more than would be the case, under the same flight conditions, when the aircraft is further from the ground. In the absence of corrective action, the practical effect of this phenomenon results in an undesirable increase in landing distance.

At T0+10.125 seconds, the deployment of engine #1 thrust reverse was recorded.

At T0+10.625, the deployment of engine #2 thrust reverse was recorded.

At T0+26.125 seconds, the actuation of the "Speedbrake/Spoiler" control lever in the closing position "DOWN" (indicating the actual closure of the surfaces), was recorded.

At T0+32.125 seconds, the aircraft came to a halt on the runway. At the same time, the retraction of engine #2's thrust reverser was recorded, followed, at T0+33.125 seconds, by the retraction of engine #1's thrust reverser.

At T0+37.125 seconds, the TWR reported a probable engine fire.

At T0+43.125 seconds, the crew, having assessed the situation, informed TWR that they had experienced brake problems during landing and therefore requested emergency assistance.

The crew then decided to carry out the necessary procedures and coordination to ensure the safety of the aircraft, the passengers and the emergency services personnel who had arrived at the scene of the serious incident. The aircraft comes to a stop on the runway approximately 1.700 m from the runway threshold and about 1.000 m from the end of the runway.

Finally, the passengers were disembarked using the usual disembarkation procedures and buses.

2.2. TECHNICAL FACTOR

The aircraft's anti-skid system was inoperative due to the failure of transducer no. 3.

A discrepancy was identified within the maintenance procedures.

Specifically, the MAINTENANCE (M) section of MEL 32-42-01 states, in the initial NOTE, that "*an operative anti-skid channel **should** not be deactivated"*, whereas "*antiskid channels that are faulted, must be deactivated".*

Once a fault has been detected in the antiskid system, AMM 32-00-00/901 – Landing Gear – Maintenance Procedures (15) DDG 32-42-01-01 Antiskid System Inoperative – Preparation (corresponding to the document in use by the Operator AMM RYR D633AM101-RYR, TASK 32-00-00-040-808, point 16. DDG 32-42-01-01 Rev. 23 Antiskid System Inoperative – Preparation) specifies that the BITE test should be used to determine which of the antiskid channels is faulty.

The NOTE in paragraph E. (2) of the same document states: "**An operative antiskid channel must not be deactivated**". This differs substantially from the note contained in the MMEL/MEL, which states **"An operative channel should not be deactivated".**

Of the two notes, the one in the AMM should take precedence, as previously discussed, because it provides more specific technical and maintenance information than the ones contained in the MMEL/MEL.

This discrepancy between *'must'* and *'should'* could reasonably have led to a sub-optimal decision taken by the maintenance personnel to confirm the deactivation of both anti-skid channels.

Specifically, in the event under consideration, maintenance personnel carried out an initial BITE Test which yielded no specific result; following this, the deactivation of both anti-skid channels and the associated HIL open were recorded in the ATL (page 55475103).

From the contents of page 55475105 of the ATL, it can be inferred that a second BITE test was carried out, which enabled the identification of the inoperative anti-skid channel (INBOARD), This was followed by the application of the IFIM (Interactive Fault Isolation Manual) 32-42-00-810-815 Rev. 93, by means of which the technician identified the fault in the ANTISKID WHEEL SPEED TRANSDUCER #3.

In light of these findings, he requested the trasducer replacement.

The outcome of the troubleshooting should have led to the deactivation of the INBOARD channel only.

Disabling a single anti-skid channel would reasonably have mitigated the damage caused by an incorrect landing procedure performed with both anti-skid channels inoperative, as occurred in the present event.

In addition to the above, the MMEL/MEL constitutes reference documentation for the flight crew, including for in-flight operations, to manage a landing without anti-skid. In fact, the OPERATIONS section (O) of the MMEL/MEL specifies a non-standard procedure for take-off and landing with the anti-skid system inoperative.

However, the content of the MEL procedure is generic and does not provide specific guidance, as is the case with other manufacturers or operator manuals applicable to landing without anti-skid.

Specifically, the procedure states only in step 3, "Operate speedbrakes manually," and in step 4.B "Do NOT apply the speedbrakes until the nose is on the ground and speedbrakes have been deployed".

For landing under these conditions, provisions and actions are required that are not currently included in the operating procedures reported by the MMEL/MEL. In greater detail, considering the provisions of the manufacturer's manuals (AFM, QRH and others), as well as the operator's OM, it is necessary that:

- the speed brakes must be set to the "DOWN detent" (QRH NNC Antiskid Inoperative);
- the speed brakes must be deployed immediately after touchdown, and their automatic operation may not be available (QRH NNC Antiskid Inoperative);
- the deployment of the speed brakes must be done to reduce the risk of tyre blowouts (QRH, NNC Antiskid Inoperative – Deferred Items);
- the deployment of the speed brakes must be done to put the aircraft's weight on the MLG, providing as such the best braking effectiveness, and further to prevent an 'over-run' (FCTM chapter 'Landing Roll', p. 6.44)
- the deployment of the speed brakes (ground spoilers) muest be done to increase the WOW (OMB Chapter 2.7.6. – Speedbrakes (Ground Spoiler))
- the deployment of the speed brakes must take place within 2 seconds after touchdown (AFM A180643 and OM Part B Chapter 2.10.6. QRH NNC Landing Performance);

Regarding the use of brakes, the MMEL/MEL, in point 4. B, state: "Do not apply the brakes until the nose wheel is on the ground and the speed brakes have been manually deployed."
This instruction does not adequately emphasize or highlight that the brakes must not be applied before the nose wheel is on the ground and the speedbrakes have been deployed.
This aspect should be adequately highlighted via a dedicated CAUTION, and, to better reflect the real sequence of actions, the order should be reversed to pay attention first to the speedbrakes and then on the nose landing gear.

The MMEL/MEL is also lacking in terms of the checks to be carried out during the Descent Approach, Application of Additional Deferred Items and Landing phases, checks which are certainly considered useful for the safe conduct of the flight.
For landing, the operational instructions contained in the MMEL/MEL are also included in the FCOM/QRH Antiskid Inoperative, but in these latter documents they are supplemented with a series of instructions and checks that cover all the phases mentioned in the previous paragraph.

The QRH, in point 2, reports the following in full:

> 2 Do **not** arm the speedbrakes for landing. Manually deploy the speedbrakes immediately upon landing.
>
> Automatic speedbrake extension may be inoperative.

This procedure, an NNC, involves a different sequence of actions from the one used in normal operations, where the PF actions to be carried out, are monitored by the PM.

The procedure outlined above would be more effective if the sentence: "Manually deploy the speed brakes immediately upon landing", were numbered separately and clearly highlighted, possibly enriched with important information regarding the potential delay in the WOW signal being received.

Such a delay in receiving the WOW, combined with the inadvertent application of the brakes, could cause the tyres to burst; therefore, it would be reccomended to include these instructions in a dedicated CAUTION.

The QRH already includes a CAUTION regarding the lack of protection against wheel lock-up, but this is certainly not enough to give the flight crew a clear understanding of the required sequence of actions and the consequences associated with not following such sequence.

2.3. ORGANISATIONAL FACTOR

The MMEL/MEL allow the use of aircraft even with the anti-skid system inoperative and the crew had duly covered the procedure to be followed during the pre-landing briefing.

An analysis of the training carried out by the operator reveals that is compliant with regulations (including the OSD), crew members within the operator receive training relating to antiskid inoperative via dedicated eLearning module.

Therefore, the incorrect sequence of actions taken was not due to a lack of knowledge of the procedures, but rather to the practical execution of the procedure itself which, as established by the interviews, had never been practiced in an FSTD simulator by either pilot and, in the case of the captain alone, had been applied only two or three times during actual flight operations carried out in previous years.

In fact, given the possibility of landing without antiskid, the OSDs do not provide any specific type of dedicated training.

It should be noted, however, that the Boeing 737 NG/MAX Flight Crew Training Manual (FCTM) provides the following guidance in section 6 "Landing – Landing roll – Wheel brakes" under the heading "Braking with Antiskid Inoperative"

When the antiskid system is inoperative, the NNC provides the following guidance:

- ensure that the nose wheels are on the ground and the speedbrakes are extended before applying the brakes;
- initiate wheel braking using very light pedal pressure and increasing pressure as ground speed decreases;
- apply steady pressure;
- use minimum braking consistent with runway length and conditions to reduce the possibility of tire blowout;
- do not pump the brakes - each time the brakes are released, the required stopping distance is increased. Also, each time the brakes are reapplied, the probability of a skid is increased.

According to the manufacturer, flight testing has demonstrated that braking effectiveness on a wet grooved runway is like that of a dry runway. However, caution must be exercised when braking on any wet, ungrooved portions of the runway with antiskid inoperative to avoid tire failure.

The maintenance organization, having ascertained via BITE and related IFIM that transducer #3 was faulty, nevertheless confirmed the decision, already taken the previous day, to deactivate both channels (INBOARD and OUTBOARD) of the anti-skid system, despite the faulty transducer belonging to the INBOARD channel.

This decision was taken disregarding the provisions of the relevant MEL, which states "An operative antiskid channel should not be deactivated", and more importantly disregarding the provisions of DDG 32-42-01-01 - Antiskid System Inoperative – Preparation TASK 32-00-00-040-808 Antiskid System Inoperative – Preparation, where, under point E, with the NOTE states: "An operative Antiskid channel must not be deactivated. Antiskid channels that are faulty must be deactivated".

This last instruction is set out in the Deferred Deviation Guide (DDG), which forms an integral part of the AMM; consequently, as mentioned, it is a manual that is certainly more specific than the MEL in terms of troubleshooting and therefore it is more relevant than the latter.

The decision to exclude both channels, despite the indication from BITE that only one of the two was inoperative, is not justified by the provisions from both MEL and AMM, and has removed an important mitigation measure, which would certainly have resulted in a lower level of damage had the pilots applied an incorrect sequence of actions required for a landing without antiskid.

As regards maintenance personnel, there is no evidence that, following the serious incident, any training or awareness-raising activities were carried out for them, emphasizing the importance of keeping those not faulty anti-skid channels operational and, more generally, how to follow a sound decision-making process in the maintenance context.

2.3.1 SMS

One action taken by the operator, following the serious incident, was to organize a briefing on the event to be delivered as part of the CRM recurrent training, in which emphasis is placed on adhering to the correct sequence of actions to be carried out in the event of a landing with the antiskid system inoperative.

The operator has also reduced the frequency of landings with the anti-skid system inoperative by rectifying the fault after just one flight (compared to the previous 10 days of operation).

Additionally, the operator now also mandates that crew contact their Duty Pilot, which is available 24/7, for an operational briefing on the procedures, restrictions and threats to operate with antiskid inoperative.

The operator carried out an internal maintenance investigation, which identified several causes and the following preventive actions:

- the addition of the note "An inoperative antiskid channel MUST not be deactivated" and "Antiskid channels that are faulted MUST be deactivated" within the antiskid FIM tasks, where absent;
- publication of instructions for technicians advising them to always refer to the applicable AMM DDG and MEL when an HIL remains open after troubleshooting;
- revision of procedures for the dispatch of urgent parts (AOG)

2.4. HUMAN FACTORS

As already discussed, managing the abnormal condition caused by the absence of the antiskid system is clearly an unusual situation for pilots.

In the present case, the MEL is considered a needed and sufficient tool for flight crews to deal with NNC conditions such as flying with the antiskid system inoperative.

As discussed previously, such conditions are covered with indications and procedures which are fragmented and scattered across various manuals, in some cases repeated, however not providing a precise chronological sequence of the actions to be taken.

Through basic flight crew training, which also covers TEM and CRM, the operator is confident that flight crews will be able to make use of any other available documentation able to assist them in managing the NNC condition.

In the present case, the flight crew decided to refer to the QRH NNC ANTISKID INOPERATIVE, applicable whether one or both antiskid channels are inoperative.

Even the QRH, which provides a more comprehensive procedure than other manuals, does not indicate a sequence that is sufficiently clear to the flight crew, leaving it up to the crew themselves, in particular the PF, to construct a mental sequence of the actions to be performed during the landing.

The PM's monitoring tasks in case of landing with the anti-skid system inoperative are the same as for normal operations, namely: checking the deployment of the speed brakes, checking the application of braking, and calling out the availability of reverse thrust.

The actions the PF must perform during a landing with the anti-skid system inoperative differ from those in case of landing under normal conditions, the very short interval between one action and the next may not allow the PM to carry out the monitoring functions in a timely and effective manner.

The sequence of actions, for both the PF and the PM, in the event of a landing with the anti-skid system inoperative is set out below, accompanied by an illustration of the center console showing the location of the controls involved in the procedure.

The sequence of actions that the PF (in this case the CPT/CM1) must carry out during a landing without anti-skid, consistent with the instructions set out in the various procedures (AFM, FCOM, QRH, FCTM, OM), is as follows:

1. The PF begins the flare at approximately 20 ft from the runway and sets the thrust levers to idle (although the engines remain at Approach Idle until WOW, levers no. 1 in the image below);
2. immediately after touchdown, he moves his hand from the thrust levers to the speedbrake lever to deploy them manually (levers no. 2);
3. once the spoilers/speed brakes have been fully deployed, as checked by the PM (Call-out: "SPEED BRAKE UP"), the PF moves his hand to the reverse thrust control levers (levers no. 3), applying continuous light pressure and awaiting confirmation from the WOW to release the interlocks. At the same time, the PM checks and makes the standard calls regarding the availability of the individual reverse thrust units, followed by the PF applying the reverse thrust deemed necessary;

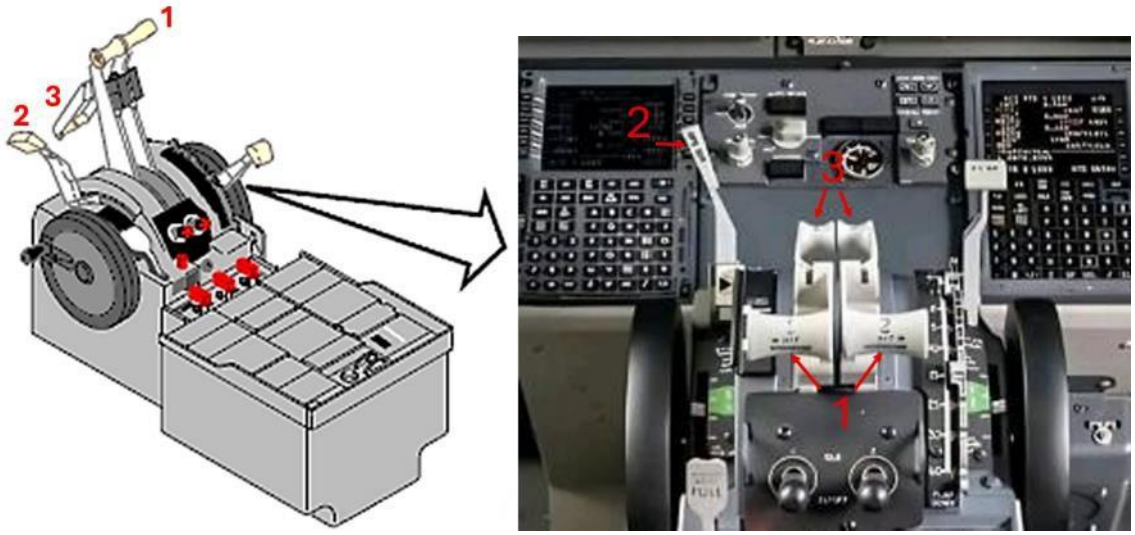

Figure 17: timeline of the actions that the PF (in our case the CPT/CM1) must apply during a landing without antiskid.

4. the PF must monitor and assist the lowering of the nose wheel and, once it is on the ground, apply the brakes with light and continuous pressure, increasing it if needed in line with the actual reduction of ground speed.

The sequence above described differs from a landing with the anti-skid system operational; the main differences are highlighted below.

The deployment of the speed brakes, normally set to "ARM", and the brakes, normally selected to "Autobrake", occurs automatically.

Regarding the application of reverse thrust, the pilot is encouraged to deploy it as soon as possible, in accordance with company policy (OM Part A, Section 8.3.0.3.12.4 – Reverse Thrust Policy) which requires, for all landings (not for NNCs) its application immediately after MLG touchdown. The same OM, in Part B, Chapter 2.7.7 – Reverse Thrust, notes that reverse thrust must be selected to the "interlock" position within 2 seconds from MLG touchdown and before NLG touchdown. It notes that if this selection is delayed until the NLG gear touches down (normally 3 to 5 seconds after the MLG touches down), the stopping distance required increases.

Furthermore, it is useful to note that the training for differences between the B737-800 and the B737-8200 does not consider the differences between the two variants regarding system logic for the deployment of the thrust reversers. After having positioned the engine throttle to idle, in the case of the B737-800, only one consent out of the two available (radio altitude

below 10 feet or air/ground safety sensors are in ground mode) is required for the deployment of the reverses, while on B737 MAX both are required.
Even if the landing is procedurally identical for all aircraft variants, the different consents required to successfully deploy the reverses may have contributed to the PF's prolonged action on the reverses lever and possibly delayed the deployment of the speedbrakes.
Prior to the approach, the PF (CPT) repeatedly referred to the procedure and sequence of actions he would shortly have to carry out for a landing with the anti-skid system inoperative, indicating his intention to assess the aircraft's deceleration response before applying the brakes, which should be modulated in accordance with the deceleration actually achieved.
Immediately after touchdown, the PF (CPT) announced *"REVERSE AND SPEEDBRAKE"*.
This behavior stems from procedural memory automatisms (*motor programme*) resulting from the many landings carried out with the anti-skid system operational, in which the automatisms and consequent safeguards are active and where the pilot is primarily focused on deploying the reverses rather than on the unusual manual extension of the speed brakes/spoilers.
As previously discussed, the lack of specific training has played a role in properly managing a situation with the anti-skid system inoperative, preferring to rely on the pilot's ability to adequately manage a situation that was unusual and outside his recent experience.

As regards maintenance, it was noted that, although the technician identified transducer #3 (unavailable in Barcelona) as the cause of the problem, he nevertheless left both anti-skid channels inoperative.
This decision was influenced by the fact that the technician in question did not refer to the AMM or the MEL, but exclusively to the IFIMs relating to the anti-skid system, which do not mention the requirement (stated as 'must' in the AMM or 'should' in the MEL) to disable only the faulty channel.
This lack of knowledge and of unambiguous information sources, which led to a sub-optimal decision by the maintenance engineer, formed the basis of the preventative measures undertaken and reported in the previous point, in the section analysing the shortcomings from an SMS perspective.

2.5. ENVIRONMENTAL FACTOR

The conditions reported in the METAR at 05:50 and those in the landing clearance issued by the TWR (at 05:53:20) indicate a wind direction between 010° and 020° and a speed of 2 kt, i.e. virtually calm.

Data recorded by the FDR indicate that the landing took place at a KIAS of 138 kt, i.e. VREF +4 kt, corresponding to a GS of 142 kt (VREF +8 kt).

This condition can likely be attributed to the presence of a slight tailwind component, which may have contributed to make the 'flare' longer and also a delayed WOW.

2.6. SURVIVABILITY

The crew handled the event calmly and in accordance with established procedures.

CHAPTER III
CONCLUSIONS

3. GENERAL

This chapter sets out the facts established during the investigation and the causes of the incident.

3.1. FINDINGS

- None of the people involved in the serious incident sustained any injuries;
- the aircraft sustained considerable damage to the MLG wheels and minor damage to the fuselage and the right-hand inner flap;
- further damage was caused to the tarmac surface of the runway, which was repaired a few hours later by the airport operator following the removal of the wreckage;
- the flight crew members held the necessary aviation licenses and were qualified to operate the incident flight;
- the technicians held the necessary aviation licenses and were qualified to carry out the maintenance work performed;
- the aircraft's mass and center of gravity before landing in Bergamo were within the prescribed limits;
- following technical anomalies detected by the flight crew (at AGP), the technicians applied the provisions of the 'troubleshooting' procedures contained in AMM 32-42-00, and in the absence of evidence of specific faults, the aircraft was cleared for flight with the anti-skid system deactivated;
- after 4 uneventful flights, further checks (carried out in BCN), including a further BITE test and troubleshooting, confirmed the failure of Transducer #3;
- the dispatch of the component (Transducer #3) as an AOG, although carried out prior to the BITE, did not, however, allow the fault to be rectified due to logistical issues that arose;
- the on-duty technician, having established that the component was unavailable – despite the BITE test and IFIM procedure having detected a fault in a transducer relating to the INBOARD channel – left both Antiskid channels deactivated, without referring to the MEL;

- the procedures in the MMEL and the relevant MEL highlighted critical issues regarding interpretation and implementation of the maintenance instructions set out in the AMM. In the MMEL/MEL, under the MAINTENANCE (M) section, the note states: An operative antiskid channel should not be deactivated" and differs from the wording in AMM TASK 32-00-00-040-808 DDG 32-42-01-01 Antiskid System Inoperative – Preparation, which states: "An operative antiskid channel must not be deactivated";
- the MEL, whilst complying with regulations, does not provide the same operational instructions in the event of an inoperative antiskid system as set out in the OM;
- the MELs allow operations without Antiskid even for flights with passengers on board "Revenue Flight";
- on comparing the MMEL/MEL with the QRH NNC Antiskid Inoperative, it was found that the latter provides much more detailed information for operations with the antiskid system inoperative whilst in flight;
- although the QRH provides more specific instructions and information than those contained in the MEL, it does not, however, provide a chronological sequence applicable to the actual actions that the PF and PM must carry out, forcing pilots to devise their own mental sequence;
- the QRH does not adequately highlight the manual deployment of the speedbrakes;
- the QRH does not highlight the need to refrain from applying the brakes before deploying the speed brakes and lowering the NLG, in that order;
- the weather conditions were not significant and were not a contributing factor;
- the crew correctly planned and prepared the aircraft for landing without the anti-skid system and demonstrated to be aware of the implications of landing without anti-skid; the PF (CPT) attempted to create a mental sequence of the actions to be performed during the landing;
- the crew used the QRH relating to the inoperative anti-skid system to manage the descent, approach, application of the relevant 'Deferred Items' and landing;
- the speed brakes were set to "DOWN", the autobrake was set to "OFF" and the "GROUND PROXIMITY RUNWAY INHIBIT" switch was set to "RUNWAY INHIBIT";
- the flare was initiated at the correct altitude, and, during the flare, the aircraft 's rate of descent was reduced to -100 ft/min;
- the aircraft's interaction with the runway occurred at the correct speed and rate of descent (KIAS equal to VREF+4 kt, GS equal to VREF+8 kt);

- the PF did not manually deploy the speed brakes within 2 seconds of the presumed contact;
- the PF initially attempted to engage the reversers, as in normal operations, which require the reversers to be activated within the same 2-second following contact;
- the WOW signal was delayed due to the lack of timely speebrake deployment and due to the thrust provided by the Approach Flight Idle, which likely caused a 'ground effect' condition for approximately 7–8 seconds;
- in the time elapsed between the first ground contact and the activation of the speedbrakes, pressure was inadvertently applied to the brakes, first on the right wheels and then on the left wheels, reaching applied pressure values close to the system's maximum;
- the pressure on the brakes, applied before the speed brakes were deployed, caused the brakes to lock, resulting in tyre blowouts, contact between the runway surface and the wheel rims with consequent severe friction with the runway, causing damage to the aircraft and to the runway;
- with the aircraft stationary, the flight crew carried out all necessary and appropriate assessments; they subsequently requested the TWR to call the ARFF and then applied procedures and coordination to ensure the safety of the aircraft, the passengers and the rescue personnel attending the scene of the serious incident; passengers were then disembarked using standard procedures;
- the serious incident did not result in injury to anyone on board the aircraft, the crew or the rescue personnel who attended;
- the OSD does not provide any type of practical training on an FSTD for flight crews (Part FC - Flight Crew);
- the operator's programmes for initial and recurrent training do not include practical training sessions in FSTDs with the anti-skid system deactivated;
- as part of the SMS, following the internal investigation, the operator took action to mitigate the risk by reducing the maximum time limit for fault rectification from 10 days to just one flight cycle;
- the operator now mandates that crew contact their Duty Pilot, which is available 24/7, for an operational briefing on the procedures, restrictions and threats to operate with antiskid inoperative.
- in the maintenance context, certain internal procedures have been improved, new instructions have been issued to refer to the MEL and AMM DDG Tasks whenever an HIL remains open following troubleshooting;

3.2. CAUSES AND CONTRIBUTING FACTORS

The serious incident was caused by the MLG wheels locking, due to an incorrect sequence of actions unintentionally applied by the fight crew during landing, occurred with antiskid inoperative.

The delayed deployment of the speedbrakes caused a delayed WOW, the latter with effects on the timely activation of the thrust reversers; the application of the brakes preceded the speedbrakes and the WOW, leading to the blockage of the wheel brakes and consequent damage of both aircraft and runway.

The following contributing factors have been identified:

- The prevalence of automatic responses in procedural memory (motor programme) due to the many landings carried out with the anti-skid system active;
- the crew's lack of FSTD training in landing with the anti-skid system inoperative;
- the deactivation of both anti-skid channels, despite indications that only the inboard channel was ineffective.

Furthermore, it is thought that the following may also have contributed:

- the discrepancy between the mandatory requirement set out in the AMM and the conditional requirement set out in the MEL regarding the need to disable only anti-skid channels that are faulted;
- the less than adequate evidence in the applicable manuals of a clear and timely sequence of the required actions to perform a landing with the anti-skid system inoperative;
- the differences between the two variants regarding system logic for the deployment of the thrust reversers may have contributed to the PF's prolonged action on the reverses levers and possibly delayed the deployment of the speedbrakes.

CHAPTER IV
SAFETY RECOMMENDATIONS

4. RECOMMENDATIONS

Considering the evidence gathered and the analyses carried out, ANSV considers it necessary to issue the following safety recommendations.

4.1. RECOMMENDATION ANSV-6/408-24/1/SI/26

Reason: The MMELs allow the use of the aircraft even with the anti-skid system inoperative; despite this provision, the OSDs do not provide any specific training guidance.

This means, as in the present event, that flight crews find themselves in a situation where they have never exercised operations with antiskid system inoperative and must apply a sequence of actions different from the one in normal configurations and operations.

Given the potential consequences of an incorrect sequence of such actions in a landing with antiskid inoperative, it is envisaged the need to include practical training for such event in the initial and recurrent training within the OSD.

Addressee: Boeing

Text: The ANSV recommends that the OSD should include appropriate training for inoperative anti-skid systems, providing training on a suitable FSTD, both initial and recurrent.

4.2. RECOMMENDATION ANSV-7/408-24/2/SI/26

Reason: The MMEL/MEL constitutes reference documentation for the flight crew, including for operations to be carried out in flight, to handle a landing without anti-skid.

The OPERATIONS (O) section of the MMEL/MEL specifies an unusual procedure for take-off and landing with the anti-skid system inoperative. The content of the MEL procedure is generic and does not provide specific guidance, nor do other manufacturers or operator manuals applicable to land without anti-skid.

The procedure states in point 3 "*Operate speed brakes manually*", and in point 4.B "*Do NOT apply the speedbrakes until the nose is on the ground and speedbrakes have been deployed"* while providing the actions to be carried out, does not sufficiently emphasize the importance of manually deploying the speed brakes before using the brakes.

The manufacturer's manuals (AFM, FCOM, QRH and FCTM), as well as the operator's OM, contain actions and information that are not present in the MMEL/MEL operating procedures. This information and these actions are scattered across various publications and in none of these publications a comprehensive sequence of actions is provided, in which the critical steps in the sequence are adequately highlighted with a CAUTION, such as manually extending the speed brakes on touchdown and doing so before engaging the thrust reversers and, above all, the brakes.

The brakes themselves must not be applied before the nose wheel makes contact and the speed brakes are deployed.

These aspects of the procedure should be adequately highlighted by means of dedicated CAUTIONS.

Addressee: Boeing

Text: The ANSV recommends including in the MMEL or other publications, for landings with the anti-skid system inoperative, a comprehensive sequence of actions to be carried out, in which the critical actions in the sequence are adequately highlighted via CAUTIONS.

4.3. RECOMMENDATION ANSV-8/408-24/3/SI/26

Reason: A discrepancy has been found between the maintenance instructions in the MMEL/MEL and the instructions in the tasks included in AMM 32-00-00/901 for the deactivation of one or more antiskid channels.

The documents included in the AMM, being specific, should be prevalent with respect to the provisions included in the MME/MEL.

In the Operator's MEL 32-42-01 Antiskid system, under point a., it is stated that non-operational antiskid channels are deactivated. The channels are the INBOARD and OUTBOARD. In the same MEL, under the MAINTENANCE (M) section, the first NOTE confirms in its second part that non-operational anti-skid channels must be deactivated but also adds that an operational anti-skid channel should not be deactivated.

Once a fault has been detected in the anti-skid system, AMM 32-00-00/901 – Landing Gear – Maintenance Procedures (15) DDG 32-42-01-01 Anti-skid System Inoperative – Preparation (corresponding to the document in use at the Operator AMM RYR D633AM101-RYR, TASK 32-00-00-040-808, point 16. DDG 32-42-01-01 Rev. 23 Antiskid System Inoperative – Preparation) indicates the use of the BITE to determine which of the antiskid channels is the faulty one.

The note in the AMM stating "*An operative channel must not be deactivated"* differs substantially from the corresponding note in the MMEL/MEL, which states "*An operative channel should not be deactivated".*

Of the two notes, priority should be given to the note in the AMM which, as argued above, provides more specific technical and maintenance information than that contained in the MMEL/MEL.

This discrepancy between *'must'* and *'should'* could reasonably have led to a sub-optimal decision making from maintenance personnel to disactivate and keep disactivated both antiskid channels.

Addressee: Boeing

Text: The ANSV recommends standardizing the instructions in the MMEL/MEL and the AMM regarding the non-deactivation of operational anti-skid channels, by adopting the term 'must' in all relevant procedures.