ANSV AGENZIA NAZIONALE PER LA SICUREZZA DEL VOLO

FINAL REPORT

ACCIDENT
Boeing B777-300ER, registration marks PT-MUG,
Milan Malpensa “Silvio Berlusconi” Airport,
9th of July 2024

OBJECTIVE OF THE SAFETY INVESTIGATION

The Agenzia nazionale per la sicurezza del volo (ANSV), instituted with legislative decree No 66 of 25 February 1999, is the Italian Civil Aviation Safety Investigation Authority (art. 4 of EU Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010). **It conducts, in an independent manner, safety investigations.**

Every accident or serious incident involving a civil aviation aircraft shall be subject of a safety investigation, by the combined limits foreseen by EU Regulation No 996/2010, paragraphs 1, 4 and 5 of art. 5.

The safety investigation is a process conducted by a safety investigation authority for the purpose of accident and incident prevention, which includes the gathering and analysis of information, the drawing of conclusions, including the determination of cause(s) and/or contributing factors and, when appropriate, the making of safety recommendations.

The only objective of a safety investigation is the prevention of future accidents and incidents, without apportioning blame or liability (art. 1, paragraph 1, EU Regulation No 996/2010). Consequently, it is conducted in a separate and independent manner from investigations (such as those of Judicial Authority) finalized to apportion blame or liability.

Safety investigations are conducted in conformity with Annex 13 of the Convention on International Civil Aviation, also known as Chicago Convention (signed on 7 December 1944, approved and made executive in Italy with legislative decree No 616 of 6 March 1948, ratified with law No 561 of 17 April 1956) and with EU Regulation No 996/2010.

Every safety investigation is concluded by a report written in a form appropriate to the type and seriousness of the accident or serious incident. The report shall contain, where appropriate, safety recommendations, which consist in a proposal made with the intention of preventing accident and incidents.

A safety recommendation shall in no case create a presumption of blame or liability for an accident, serious incident or incident (art. 17, paragraph 3, EU Regulation No 996/2010).

The report shall protect the anonymity of any individual involved in the accident or serious incident (art. 16, paragraph 2, EU Regulation 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**.

ACRONYMS

(A): Aeroplane.
ACARS: Aircraft Communications Addressing and Reporting System.
ACC: Area Control Centre.
ADIRS: Air Data Inertial Reference System.
ADIRU: Air Data Inertial Reference Unit.
ADS-B: Automatic Dependent Surveillance Broadcast.
AFM: Airplane Flight Manual.
AFS: Automatic Flight System.
AGL: Above Ground Level.
AIP: Aeronautical Information Publication.
ALD: Actual Landing Distance.
AMC: Acceptable Means of Compliance.
AMSL: Above Mean Sea Level.
ANAC: Agência Nacional de Aviação Civil.
ANSV: Agenzia nazionale per la sicurezza del volo.
AOA: Angle of Attack.
AOC: Air Operator Certificate.
APP: Approach control office o Approach control o Approach control service.
APU: Auxiliary Power Unit.
AQP: Advanced Qualification Program.
ARP: Airport Reference Point.
ARPA: Agenzia regionale per la protezione dell'ambiente.
ASDA: Accelerate-Stop Distance Available.
A/T: Autothrottle.
ATC: Air Traffic Control.
ATIS: Automatic Terminal Information Service.
ATL: Aircraft Technical Logbook.
ATM: Reduced Take-off Thrust Assumed Temperature.
ATPL: Airline Transport Pilot Licence.
ATS: Air Traffic Services.
ATSB: Australian Transportation Safety Bureau.
BEA: Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile.
BFU: Bundesstelle für Flugunfalluntersuchung.
BIS: Best Intervention Strategy.
CAA: Civil Aviation Authority.
CAM: Cockpit Area Microphone.
CAS: Calibrated Air Speed.
CAS: Computed Air Speed.
CAT: Commercial Air Transport.
CAVOK: Ceiling and visibility OK.
CDU: Control Display Unit.
CENIPA: Centro de Investigação e Prevenção de Acidentes Aeronáuticos.
CG: centre of gravity.
CM 1/2/3: Crew Member 1, Crew Member 2, Crew Member 3.
CPT: Captain, comandante.
CRM: Crew Resource Management.
CVR: Cockpit Voice Recorder.
DGAC: Direzione generale dell'aviazione civile.
DOV: Despachante Operacional de Volo.
DSB: Dutch Safety Board.

EASA: European Union Aviation Safety Agency.
EFB: Electronic Flight Bag.
EGT: Exhaust Gas temperature.
EICAS: Engine Instrument and Crew Alerting System.
ENAC: Ente nazionale per l'aviazione civile.
ENAV SPA: Ente Nazionale Assistenza al Volo.
EOBT: Estimated Off Block Time.
EOFDM: European Operators Flight Data Monitoring Forum.
ETA: Estimated time of arrival.
ETOW: Estimated Take-off Weight.
EUROCAE: European Organisation for Civil Aviation Equipment.
EZFW: Estimated Zero Fuel Weight.
FAA: Federal Aviation Administration.
FC: Flight Control or also Flight Cycle.**FCOM**: Flight Crew Operating Manual.
FCTM: Flight Crew Training Manual.
FD: Flight Director.
FDM: Flight Data Monitoring.
FDR: Flight Data Recorder.
FEW: From 1 to 2 octaves of clouds.
FH: Flight Hour.
FLEX: Flexible take off thrust procedure.
FMA: Flight Mode Annunciator.
FMC: Flight Management Computer.
FMGS: Flight Management and Guidance System.
FMS: Flight Management System.
FO: First Officer.
FT: Foot (piede), 1 ft = 0,3048 meter.
GM: Guidance Material.
GND: Ground.
GR: Gross.
HDG: heading.
IAS: Indicated Air Speed.
IATA: International Air Transport Association.
ICAO/OACI: International Civil Aviation Organization.
IFR: Instrumental Flight Rules.
ILS: Instrument Landing System.
IOSA: IATA Operational Safety Audit.
KIAS: IAS in knots (kt).
KT: Knot.
LBS: pounds (1 lb = 0,45 kg).
LDA: Landing Distance Available.
LH: Left Hand.
LNAV: Lateral Navigation.
LTC: Line Training Captain.
MAC: Mean Aerodynamic Chord.
MACTOW: Mean Aerodynamic Chord at Take-off Weight.
MCDU: Multifunction Control and Display Unit.
MEL: Minimum Equipment List.
METAR: Aviation routine weather report.
MGO: Manual Geral de Operacoes (LATAM).
MHZ: Megahertz.

MIC: Microphone.
MLG: Main Landing Gear.
MLW: Maximum Landing Weight.
MOPS: Minimum Operating Performance Standards.
MSL: Mean Sea Level.
MSN: Manufacturer Serial Number.
MSP: Most Significant Part.
MTOM: Maximum Take Off Mass.
MTOW: Maximum Take Off Weight.
MZFW: Maximum Zero Fuel Weight.
N1: Fan rotation speed.
N1_CMD: N1 command, auto throttle target.
NASA: National Aeronautics and Space Administration.
NC: Normal Checklist.
ND: Navigation Dislay.
NLG: Nose Landing Gear.
NM: Nautical Mile (1 nm = 1852 meters).
NNC: Non Normal Checklist.
NPA: Notice of Proposed Amendment.
NOSIG: No Significant Changes.
NOTAM: Notice To Air Men.
NTSB: National Transportation Safety Board.
OAT: Outside Air Temperature.
OBWBS: On-Board Weight and Balance System.
OFP: Operational Flight Plan.
OM: Operations (or Operational) Manual.
OPT: Onboard Performance Tool.
ORO: Organization Requirements for Air Operations (Part ORO EASA).
PA: Public Address.
PAN, PAN: International radio distress signal, of less urgency than a mayday signal.
PED: Portable Electronic Device.
PF: Pilot Flying.
PFC: Primary Flight Controls.
PFD: Primary Flight Display.
PIC: Pilot in Command.
PM: Pilot Monitoring, or PNF.
PNF: Pilot Not Flying.
POB: Persons on Board.
QNH: Altimeter setting providing the airfield altitude.
QRH: Quick Reference Handbook.
RA: Radio Altimeter or Radar Altimeter.
RADALT: Radio altimetric height.
RCL: Runway Centre Line.
REF SPDS: Reference Speeds.
RH: Right Hand.
RHP: Runway Holding Position.
RMLG: Right Main Landing Gear.
RMT: Rule Making Task.
RWY: Runway.
SIB: Safety Information Bulletin.
SID: Standard Instrument Departure.

SKC: Sky Clear.
SMR: Surface Movement Radar.
SMS: Safety Management System.
S/N: Serial Number.
SOP: Standard Operating Procedures.
SP: Supplementary Procedure.
SV: Synthetic Voice.
TAF: Aerodrome Forecast.
TAT: Total Air Temperature.
TCO: Third Country Operator.
TBT (or **T-B-T**): Air ground communications.
THR: Threshold.
TLA: Thrust Lever Angle.
TLAR: That Looks About Right.
T/O: Take Off.
TOC: Transfer of Control.
TODA: Take-Off Distance Available.
TOF: Take-off Fuel.
TOGA (or **TO/GA)**: Take Off/Go Around.
TOM: Take-off Monitoring.
TOPMS: Take-off Performance Monitoring System.
ToR: Terms of Reference.
TORA: Take-Off Run Available.
TOW o TOGW: Take Off Weight or Take Off Gross Weight.
TRI: Type Rating Instructor.
TSB (Canada): Transportation Safety Board of Canada.
TWR: Aerodrome Control Tower.
TWY: Taxiway.
UTC: Universal Time Coordinated.
V1: Decision Speed.
V2: Take-off Safety Speed.
VMCA: Minimum Control Speed in Air.
VNAV: Vertical Navigation.
VR: Rotation Speed.
VRB: Variable.
VREF: Velocity of Reference.
WT: Weight.
ZFW: Zero Fuel Weight.

FOREWORD

The accident occurred on July the 9th, 2024, at 11:26 UTC (13:26 local time), on the take-off phase at Malpensa “Silvio Berlusconi” Airport, and involved a Boeing B777-32WER aircraft, registration marks PT-MUG.
In fact the aircraft, operating flight LATAM LA8073 from Malpensa to São Paulo (Brazil) with 398 occupants on board, suffered a tail strike during take-off from RWY35L.
The ANSV sent notification of the event, in accordance with relevant international and EU regulations (Annex 13 to the Convention on International Civil Aviation, EU Regulation No. 996/2010), to the following Civil Aviation Safety Investigation Authorities: CENIPA (Brazil) State of Operator and Registration, NTSB (USA) State of Design and Manufacture of the Aircraft and Engines.
CENIPA (Brazil) and NTSB (USA) accredited their own representatives to the investigation conducted by ANSV and availed themselves of the collaboration of their own consultants, respectively from the operator, LATAM, and the aircraft manufacturer, Boeing, as required by the above-mentioned regulations. Based on the provisions of the Regulation EU 996/2010, the ANSV appointed EASA as its technical adviser.

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

CHAPTER I
FACTUAL INFORMATION

1. GENERAL INFORMATION

The objective evidence gathered during the safety investigation is outlined below.

1.1. HISTORY OF THE FLIGHT

On the 9th of July 2024, LATAM aircraft B777-32WER, registration PT-MUG, operating flight LA8073, call sign TAM8073, directed to São Paulo (Brazil) with 398 occupants on board, suffered a tail strike during take-off from RWY35L at Malpensa.

However, the aircraft took off at 11.26’ and headed West of Vercelli, where the crew performed several holding patterns at an altitude of 6,000 ft from 11.49’ to 12.25’ to dump fuel. The flight then landed at Malpensa on RWY35R at 12.36’. The aircraft sustained significative damage to the tail skid and damage was reported to the pavement of RWY35L, which had to be temporarily closed for repair work.

1.2. INJURIES

None.

1.3. AIRCRAFT DAMAGE

The aircraft sustained numerous damages, the most visible of which are those to the tail skid assembly (Photo 1 and Photo 2), a drain mast (Photo 3), and the tail strike sensor (tail strike warning sensor, Photo 4).

Photo 1: detail of the tail skid assembly.

Photo 2: parts of the tail skid assembly found on the runway.

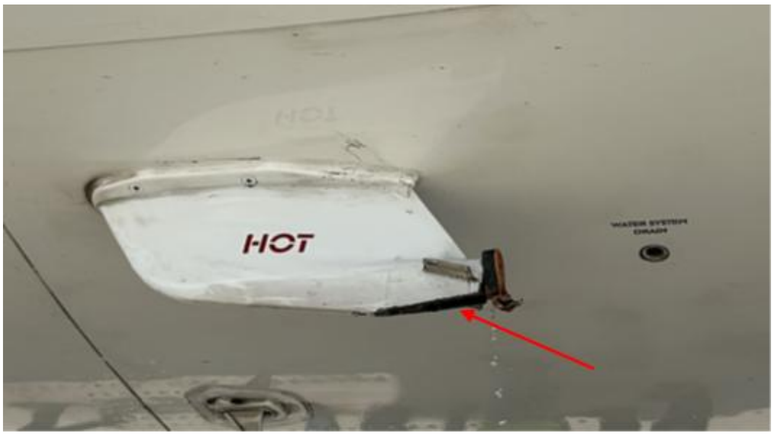

Photo 3: drain mast, indicated by the arrow, detail of the damage.

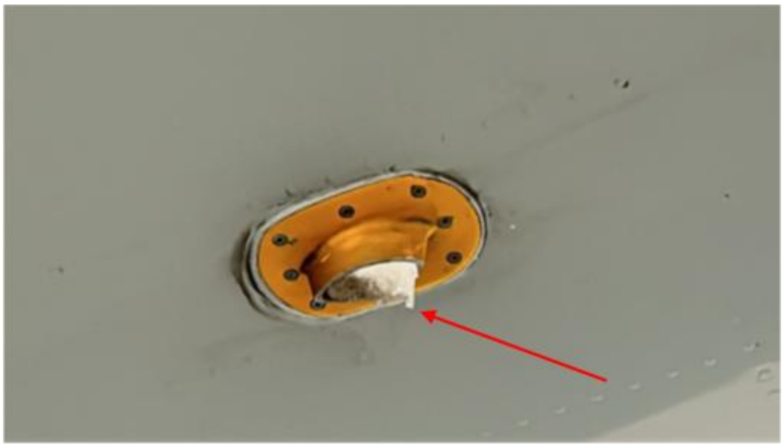

Photo 4: tail strike sensor, indicated by the arrow, detail of the damage.

In addition, the tail strike caused damage to the APU fire extinguishing system, activating the BOTTLE DISCH APU warning light.

The aircraft remained at Malpensa from the 9th of July until the 14th to allow maintenance to be carried out in preparation for the ferry flight to the manufacturer maintenance facilities. During the detailed inspections that followed, numerous other damages were identified. Based on the results of the above activities, the duration and level of maintenance required to restore airworthiness, the event was reclassified from "serious incident" to "accident". The aircraft resumed service on the 22th of February 2025.

1.4. OTHER DAMAGE

Damage to the pavement of RWY35L.

1.5. PERSONNEL INFORMATION

1.5.1. Flight Crew

The flight crew consisted of a Line Training Captain (LTC)[1] seated in the right seat (CM2) and PF for the route, a captain in line training on the B777, seated in the left seat (CM1) and PM for the route, and a second captain (cruise captain) in the cockpit (CM3).

Line Training Captain (LTC)

General information:	54 years old, Brazilian nationality.
License:	ATPL, valid.
Ratings (current):	B777/787, IFR.
Ratings (non-current):	A320, A330, B767, F100, FK50, Cessna 208.
Qualification:	LTC.
English proficiency level:	5.
Periodic check:	valid.
Medical check:	first class, valid (corrective lenses required).
Flight experience:	18.921 f/h total, 1.333 f/h on B777.
Last 12 months:	795 f/h.
Last 90 days:	241 f/h.

[1] About the instructor captain's qualification, the operator clarified that: In Brazil, instructors are qualified by the operator and can only operate as instructors for that specific operator. The qualification requires initial and recurrent training in accordance with the approved training program and subject to local regulations (RBAC 121.414). This qualification is checked by the operator and subject to supervision by local authorities. This qualification is not shown on the pilot's license as it is not considered a rating. In order to avoid ambiguity with the TRI rating, the instructor captain will be referred to as the Line Training Captain throughout this report.

Last 30 days: 60 f/h.

Last 7 days: 24 f/h 40’.

LTC’s professional history:

In service with the operator since 1996. He has operated as FO on Cessna 208, Fokker 50, Fokker 100, A32F, and A330. He has served as captain on Fokker 100, A32F, A330, B767, B777, and B787. At the time of the event, the pilot was captain and LTC on B777 and B787.

Captain in line training

General information: 53 years old, Brazilian nationality.

License: ATPL, valid.

Ratings (current): B777/787, IFR.

Ratings (non-current): A32F, A330, B733, F100, LR30, LRJT, PC12.

Qualification: N/A.

English proficiency level: 5.

Periodic check: valid.

Medical check: first class, valid (corrective lenses required).

Flight experience: 16.689 f/h, 95 f/h on B777.

Last 12 months: 640 f/h.

Last 90 days: 94 f/h.

Last 30 days: 35 f/h.

Last 7 days: 13 f/h 24’.

Professional history of the captain in line training:

In service with the operator since 2001. He operated as FO on Fokker 100, A32F, and A330. He was promoted to captain in 2007 on A320, operating until March 2024 as captain on A32F. At the time of the event, the pilot was undergoing line training as captain on B777. In May, he had completed simulator training, and, in the same month, he had completed his first line training shift. The flight in question was the return leg of his fifth shift on the B777 (tenth leg overall) and he was due to undergo a check flight on his next shift.

Cruise Captain

General information: 56 years old, Brazilian nationality.

License: ATPL, valid.

Ratings (current):	B777/787, B757/767, IFR.
Ratings (non-current):	A32F, A330, F100.
Qualification:	N/A.
English proficiency level:	5.
Periodic check:	valid.
Medical check:	first class, valid (corrective lenses required).

Flight experience:	17.530 f/h, 418 f/h on B777.
Last 12 months:	602 f/h.
Last 90 days:	216 f/h.
Last 30 days:	54 f/h.
Last 7 days:	13 f/h 24’.

Professional history of the second pilot

Employed by the operator since 1997. He worked as an FO on Cessna 208, then became captain on C208. FO on Fokker 100, then becoming captain on Fokker 100. Captain on A32F (four years), on A330 (three years), on B767 (eleven years) and, at the time of the event, captain on B777, on which he had been operating for five months.

1.6. AIRCRAFT INFORMATION

1.6.1. General information

The Boeing 777 is a twin-engine wide-body aircraft designed and built by the US company Boeing for long-haul commercial transport. The model supplied to the operator LATAM is the Boeing 777-32WER, which has the following specifications of interest:

MTOW	346544 kg
MZFW	239950 kg
MLW	251290 kg
Max fuel	145538 kg
Max payload	28625 kg
Max passengers	410
Number of seats	430

1.6.2. Specific information

Aircraft

Manufacturer:	Boeing Company.
Model:	B777-32WER.
Serial number:	MSN 38888.
Year:	2012.
Registration:	PT-MUG.
Certificate of registration:	n° 21243 Registro Aeronautico Brasileiro.
Holder:	TAM LINHAS AEREAS.
Owner:	LATAM AIRLINES GROUP S.A.
Airworthiness certificate:	valid.
Airworthiness review certificate:	valid.
Flight Hours:	42262 f/h, 4909 f/c.

Engines

Manufacturer:	General Electric.
Model:	GE90-115BG02 s/n 906700 (48073 f/h) and 906701 (41939 f/h).

Fuel

Authorized fuel type:	Jet Fuel JET A-1.
Fuel type used:	JET A-1.
Fuel in onboard tanks:	The aircraft was refueled in a single operation (without additions or top-ups) to a total of 109625 kg in accordance with the planned fuel quantity reported in the OFP and the quantity requested (Fuel Order Document). The delivery note for the refueling carried out at Malpensa reported a total of 122702 liters of Jet-Fuel A-1 delivered. The email message with the total fuel data of 109700 kg on board the flight was sent by the ramp handling company to the LATAM operator at 10:35. According to FDR data, the aircraft began taxiing with 109500 kg of fuel, began take-off with 109100 kg, and landed with 29900 kg.

1.6.3. Additional information

Mass and balance

For the information pertaining to the mass and balance, reference was made to the final loadsheet (Figure 1), verified with the fuel and load data recorded and transmitted by the handling company to the operator's coordination office. The final load sheet is a document prepared for each flight that shows the distribution and total weight of passengers, cargo, and fuel on board, which is necessary to calculate take-off performance and verify the weight and balance of the aircraft, ensuring that it is loaded within the specified safety limits. This document is sent by the operator via a LATAM proprietary application on the pilots' mobile device (tablet). The final loadsheet is accepted via this application by the captain.

In particular, for the purposes of this discussion and with reference to Figure 1, the fields relating to the following information are highlighted: date and time of issue (1), Zero Fuel Weight (2), Take Off Weight (3), number of passengers and total occupants (4), Mean Aerodynamic Chord for take-off (5), fuel in tanks (6), CG (7).

QU ASRV1LA
MUCKMLA 091055
FEA
AN PTMUG/FI LA8073/GL MXP
LOADSHEET FINAL 1255 EDNO1
[redacted] 09JUL24 **1**
MXP GRU PTMUG 3/0/12
ZFW 219460 MAX 239950 **2**
TOF 108965
TOW 328425 MAX 346544 L **3**
TIF 96453
LAW 231972 MAX 251290
UNDLD 18119
PAX/38/343 TTL 383 **4**
TOB 398
MACZFW 31.8
MACTOW 29.7 **5**
MACLAW 31.6
A38 B164 C179
SEATROW TRIM
SI DOW 170601
FUEL IN TANKS 109625 **6**
LOAD IN CPTS 0/0 1/1785 2/5913 3/7091 4
2534 5/632
PREPARED BY [redacted]
ALTERNATE FORWARD CG LIMIT FOR TAKE-OFF
CG CONDITION IS T2 (28.7 %MAC) **7**

Figure 1: the load sheet final for flight LA8073.

Among the cited data, pilots enter the total weight of the aircraft (including passengers and cargo) excluding fuel, defined as Zero Fuel Weight (ZFW 219460 kg), and the average aerodynamic chord for take-off (MACTOW 29.7) into the FMC CDU. The aircraft's FMC adds the weight of the fuel in the tanks (FUEL IN TANKS) to the ZFW value and displays the Gross Weight, i.e., the total weight of the aircraft, on the CDU. The take-off weight (TOW or TOGW) of 328425 kg was calculated by adding the TOF (Take-off Fuel, 108965 kg) to the ZFW (219460 kg). The TOF was calculated as FUEL IN TANKS minus the fuel used for starting and taxiing, which in this specific case was calculated as 660 kg.

The OFP (Figure 2) initially provided for an estimated ZFW (EZFW) of 222000 kg (+2540 kg) and an ETOW (estimated TOGW) of 330965 kg (+2540 kg).

				ESTIMATED		ACTUAL		MAX	
	FUEL	TIME				APLD	_____		
DEST SBGR	96453	1105	_____	EZFW	222000	AZFW	_____	MZFW	239950
RRSV	726	0007	_____	ETOW	330965	ATOW	_____	MTOW	346544
ALT SBGL	5239	0037	_____	ELDW	234512	ALDW	_____	MLDW	251290
HOLD	3210	0030	_____						
MFR	105628	1219							
EXTRA:WEATHER	3337	0030							
TOF	108965	1249		LDGWT INCLUDES RESERVE FUEL				FOD	12512
TAXI	660	0020						MFOD	8449
BLOCK	109625	1249							
EXTRA	_____		REASON	_____					
TOTAL	_____								

Figure 2: OFP for flight LA8073 on July the 9th, 2024. The red box shows the estimated values for ZFW (EZFW) and TOGW (ETOW).

1.6.4. Aircraft systems and accessories

1.6.4.1. Tail skid

The airplane is equipped with a tail skid system. The tail skid extends for take-off and landing and retracts during flight. It helps protect the pressurized part of the airplane from contact with the runway. The tail skid uses the main landing gear actuation system. The EICAS advisory message TAIL SKID is displayed when the tail skid is not in the correct position (Tail skid position disagrees with landing gear lever position)[2].

[2] Fonte LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 14.20.8/.9.

1.6.4.2. Tail Strike Detection System

The tail strike alert system detects ground contact which could damage the airplane pressure hull. A two-inch blade target and two proximity sensors are installed on the aft body of the airplane. The EICAS caution message TAIL STRIKE is displayed when a tail strike is detected. The inhibition of the TAIL STRIKE master caution during take-off begins at 80 kt and ends at 400 ft radio or 20” after take-off, whichever comes first[3].

1.6.4.3. Tail Strike Protection

During take-off or landing, the PFCs calculate if a tail strike is imminent and decrease elevator deflection, if required, to reduce the potential for tail strike. Activation of tail strike protection does not provide feedback to the control column.[4] The TSP input is limited to 10 units (from 0 to 10), which allows the crew to counter the protection, if necessary, by a nose-up input.

1.6.4.4. On-board systems

Flight Management, Navigation - FMC Preflight (B777-300ER Flight Crew operations Manual)

Below is a description of some avionics systems, taken from the B777-300ER Flight Crew Operations Manual LATAM Airlines Brasil (FCOM), relevant to understand the calculation and entry of take-off performance data.

1.6.4.4.1 Flight Management System

The flight management system (FMS) aids the flight crew with navigation, in–flight performance optimization, automatic fuel monitoring, and flight deck displays. Automatic flight functions manage the airplane lateral flight path (LNAV) and vertical flight path (VNAV). The flight crew enters the applicable route and flight data into the CDUs. The FMS then uses the navigation database, airplane position, and supporting system data to calculate commands for manual and automatic flight path control.

1.6.4.4.2. Flight Management Computer (FMC)

The FMC uses flight crew–entered flight plan data, airplane systems data and data from the FMC navigation database to calculate airplane present position and pitch, roll, and thrust

[3] Fonte LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 15.20.10 and pag 15.20.31/.32

[4] Fonte LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 9.20.13.

commands necessary to fly an optimum flight profile. The FMC sends these commands to the autothrottle, autopilot and flight director. Map and route data are sent to the NDs.

1.6.4.4.3. Control Display Unit (CDU)

The flight crew controls the FMC using three CDUs (Figure 3), one on the CM1 side (left), one on the CM2 side (right), and one in the center of the pedestal as a backup in case of failure of one of the first two. Entering data into the FMC on one CDU automatically updates the data on the other CDU.

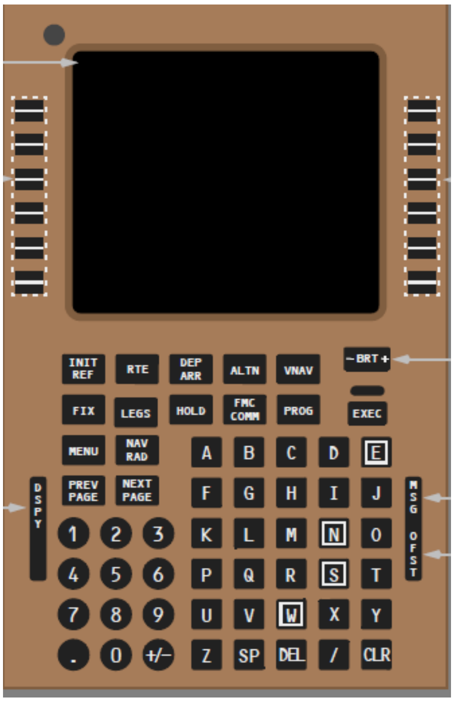

Figure 3: CDU (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.10.1).

The CDU *scratchpad* is the lower portion of the CDU screen where, in addition to the pilots' inputs being entered via the physical keyboard, certain text messages from the FMC itself are also displayed (message).

1.6.4.4.4. FMC pre-flight preparation

During the preflight phase, the crew enters the flight plan and load sheet (final load sheet) data into the CDU.

Completing the FMC pre-flight preparation procedure requires entering data in all the minimum required fields (i.e., those “boxed” fields consisting of a series of white squares[5]). The data that must be entered are:

- initial position;
- route;
- performance data;
- take-off data.

Entering optional data in addition to the mandatory data optimizes the accuracy of the FMC. When FMC is activated, the identification page (IDENT) is usually displayed. The preflight flow continues in this sequence of CDU screens (page):

• identification (IDENT) page;
• position initialization (POS INIT) page;
• route (RTE) page;
• DEPARTURES page;
• navigation radios (NAV RAD) page;
• performance initialization (PERF INIT) page;
• thrust limit (THRUST LIM) page;
• take-off reference (TAKE-OFF REF) page.

PERF INIT

The PERF INIT page (performance initialization, Figure 4) allows to enter aircraft and route data to initialize performance calculations.

The gross weight of the aircraft (Gross Weight GR WT, field 1 in Figure 4) cannot be entered by the flight crew. This field remains empty until the fuel weight and the weight of the aircraft without fuel (Zero Fuel Weight, ZFW, field 3) are available for the FMC to calculate the Gross Weight.

The fuel on board (FUEL, field 2 in Figure 4**)** is displayed when the fuel totalizer calculations are valid. The source for the display is included in the line:

• SENSED – fuel quantity is from the totalizer. Manual entry is not possible.
• CALC (calculated) – fuel quantity is from FMC calculations. Manual entry is possible.
• MANUAL (manual) – fuel quantity has been manually entered.

[5] In figure 4 examples for 3, 4, 7 and 8 data fields.

Normally, the ZFW (field 3 in Figure 4**)** is entered from the dispatch papers (final load sheet) relating to the flight, allowing the FMC to calculate the aircraft's gross weight.

Valid entry is XXX or XXX.X.[6] . The entry of a value after take-off speeds are selected removes the speeds and displays the scratchpad message TAKE-OFF SPEEDS DELETED. ZFW can be manually entered or uplinked.

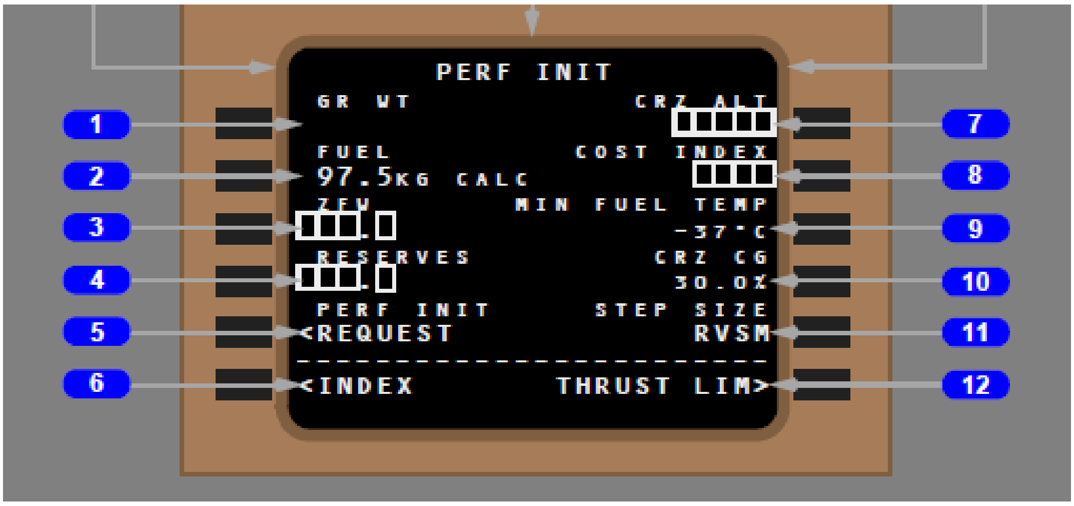

Figure 4: CDU Performance Initialization page (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.35).

THRUST LIM

The thrust limit page allows selection and display of reference thrust for take-off. Take-off thrust derate by use of assumed temperature is also accomplished on this page (field 1 in Figure 5)[7]. In field 6, the "D" indicates that a thrust reduction based on an assumed temperature is active. Field 7 indicates the N1 value for take-off calculated by the thrust management system.

[6] Fonte LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.36.

[7] Normally, take-offs are conducted with less than full rated take-off thrust whenever performance capabilities permit. Lower take-off thrust reduces EGT, improves engine reliability, and extends engine life. Reduced take-off thrust (ATM) is a take-off thrust level less than the full rated take-off thrust. Reduced take-off thrust is achieved by selecting an assumed temperature higher than the actual ambient temperature (source Boeing 777 Flight Crew training manual).

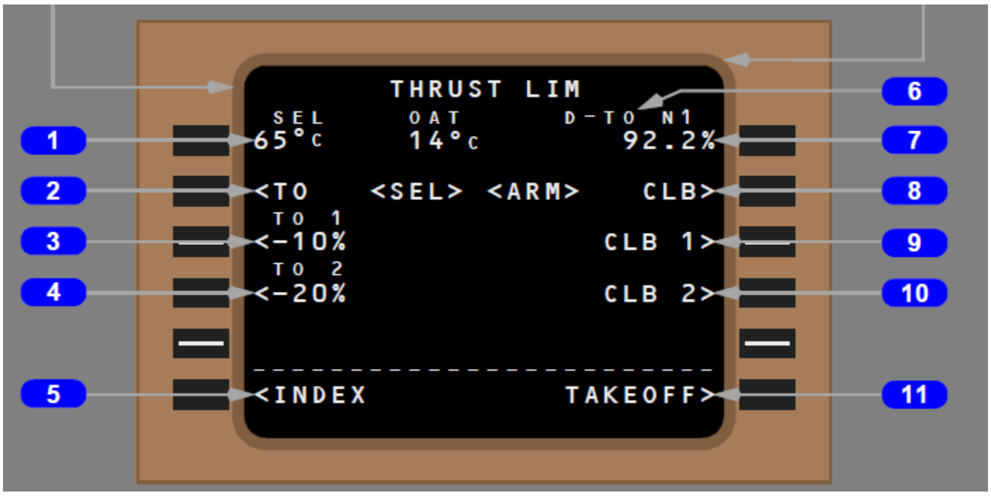

Figure 5: CDU Thrust Limit page (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.39).

TAKE-OFF REF

The take-off reference page (Figure 6 e Figure 7) allows the flight crew to manage take-off performance.

Take-off flap setting and V speeds (decision speed V1, rotation speed VR[8], safety speed in case of engine failure V2) are entered and verified. Thrust limits (THRUST), take-off position (RWY/POS), and take-off gross weight (TOGW) can be verified or changed. Preflight completion status is annunciated until complete. Take-off reference page (TAKE-OFF REF) entries finish the normal preflight. The take-off flap setting must be entered, and V SPEEDs should be set before completion.

[8] Rotation Speed, VR - The speed at which rotation from the three-point attitude to the take-off attitude is initiated. The scheduled rotation speed must be equal to or greater than 1.05 VMCA and V1.

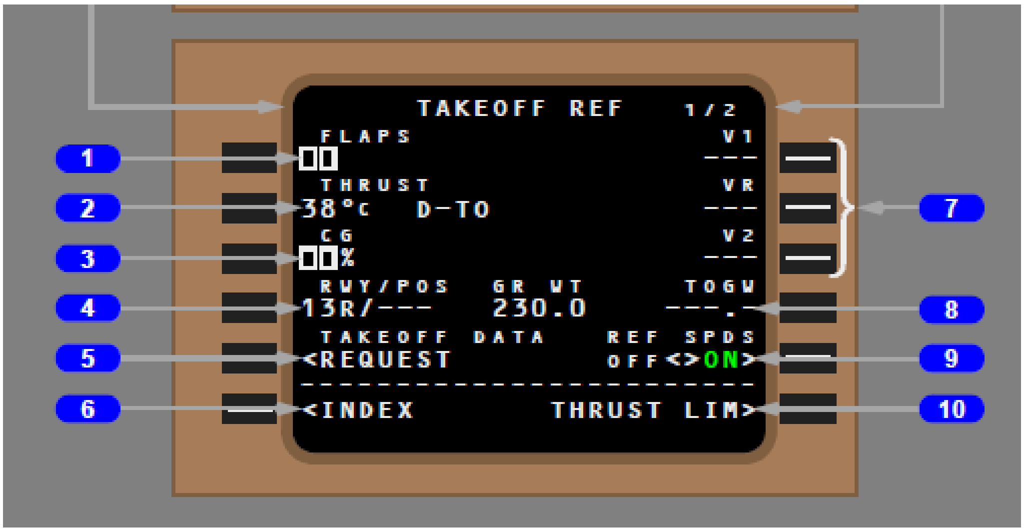

Figure 6: CDU take-off refernce page (1 of 2) for data insertion (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.42).

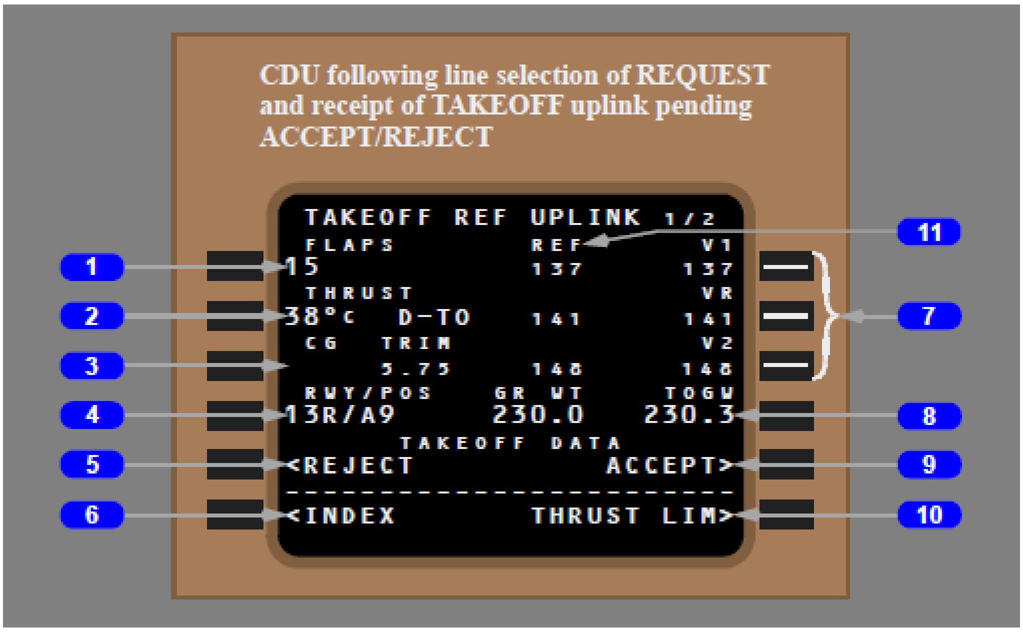

Figure 7: CDU take-off reference page (1 of 2) with data entered and reference take-off speed calculated by the FMC (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.43).

V SPEEDS (V1, VR, V2)

Displays dashes when (V1, VR, V2 field 7 in Figure 7):

• required information not entered

• performance calculations are inhibited

• ADIRU is not aligned

Calculated speeds are displayed in small font[9].

[9]In this context, small characters refer to the sizes shown, for example, for V1, VR, and V2, fields 7 in the Figure 7. Large characters refer, for example, to those used to indicate the flap setting, field 1 in Figure 7.

Manually entered or accepted uplink speeds, replace calculated (REF) speeds. Speeds equal to or greater than calculated speeds are allowable. Entries less than calculated minimum V1, VR, or V2 speeds result in “MINV1”, “MINVR”, or “MINV2” are displayed in line titles; minimum V1, VR, or V2 values are displayed in large font on data lines. Minimum VR or V2 speeds may be up to five knots lower than calculated VR or V2 speeds. The FMC Take-off Speed Relative Value check ensures V1 is less than or equal to VR and VR is less than or equal to V2. Entry of V speeds not passing the check results in the scratchpad message TAKE-OFF SPEEDS DELETED.

Push –

• selects V1, VR, and V2 to be sent to using systems, or;

• crew entered V speeds replace calculated speeds;

• display changes to large font; REF and caret no longer display;

If performance data changes:

• FMC replaces existing speeds with FMC calculated speeds in small font;

• V speeds are removed from the PFD;

• PFD speed tape message NO V SPD displays;

• scratchpad message TAKE-OFF SPEEDS DELETED displays.

Note: After an engine is started, the FMC recalculates the take-off speeds. Any combination of gross weight, OAT, or pressure altitude resulting in a take-off speed change of two or more knots from the previously calculated speeds, causes the FMC to recalculate take-off speeds[10].

REF SPDS

Enables or disables display of the FMC calculated reference (V) speeds in the center column to the left of the V speed lines.

Push toggles between ON and OFF.

ON – displays FMC calculated take-off speeds for comparison with the V speeds in the right column.

OFF – deletes speeds from the center column.

The active state, ON or OFF, displays in large green font; the inactive state displays in small white font[11].

[10] Source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.45.

[11] Fonte LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.40.46.

REFERENCE (REF)

Field 11 in Figure 7 shows the reference V-speeds calculated by the FMC for comparison with the values entered by the flight crew or transmitted via uplink. The display is enabled and disabled by the REF SPDS prompt.

1.6.4.5. FMC Entry Error Messages

Among the messages that can be displayed by the FMC on the CDU scratchpad, the FCOM displays the message V-SPEEDS UNAVAILABLE (Figure 8), meaning that the reference take-off speeds, normally computed by the FMC after the necessary data has been entered, have not been calculated and are therefore not present on the TAKE-OFF REF page. The flight manual states the following in this regard:

V–SPEEDS UNAVAILABLE – for certain high thrust/low gross weight or low thrust/high gross weight take-off conditions, FMC V–speeds are not calculated. Adjust gross weight and/or take-off thrust limit to enable V–speed calculations.

LATAM **Flight Management, Navigation - EICAS Messages**

B777 Flight Crew Operations Manual

V–SPEEDS UNAVAILABLE – for certain high thrust/low gross weight or low thrust/high gross weight takeoff conditions, FMC V–speeds are not calculated. Adjust gross weight and/or takeoff thrust limit to enable V–speed calculations.

Figure 8: excerpt from the LATAM flight manual relating to FMC entries Error Messages V-SPEEDS UNAVAILABLE (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. 11.60.11.

1.6.4.5.1 V-SPEEDS UNAVAILABLE

Following requests for clarification made to Boeing during the investigation, aimed at understanding the logic behind the V-SPEED UNAVAILABLE message, which is only briefly mentioned in the applicable documentation (FCOM), it was established that:

the V-SPEEDS UNAVAILABLE message indicates that the FMC is unable to calculate a valid take-off solution for the given conditions. This could be caused by conditions such as high altitude/high temperature, which extend the calculated take-off run beyond the available runway, an inadequate power reduction setting in the take-off calculations, other environmental factors in the take-off performance calculation, or incorrect information entered into the FMC.

LATAM B777 FCOM Performance Dispatch (LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR PD.14.2)

LATAM B777 FCOM Performance Dispatch section, reports verbatim that take-off is not permitted with the message V SPEEDS UNAVAILABLE present.

The FMC will protect for minimum control speeds by increasing V1, VR and V2 as required. However, the FMC will not compute take-off speeds for weights where the required speed increase exceeds the maximum certified speed increase. This typically occurs at full rated thrust and light weights.

In this case, the message "V SPEEDS UNAVAILABLE" will appear on the FMC scratchpad and the take-off speed entries will be blank. Take-off is not permitted in this condition as certified limits have been exceeded. The options are to select a smaller flap setting, select derate thrust and/or add weight (fuel). Selecting derate thrust is the preferred method as this will reduce the minimum control speeds.

1.6.5. Operational Procedures description.

The context in which the event took place relates to the application of the EFB (iPad) Preflight Procedure, as outlined in the LATAM B777-300ER Flight Crew Operations Manual (supplementary procedures), and the EFB (iPad) Before Start Procedure.

These are part of the CDU Preflight Procedure - Captain and First Officer and the Before Start Procedure (Normal Procedures).

At the date of the event, the applicable procedures were as follows [12]:

1. Normal Procedures – Amplified Procedures:
    a. CDU Preflight Procedure - Captain and First Officer (NP.21.3/4);
    b. Before Start Procedure (NP.21.27) including TAKE-OFF BRIEFING.
2. Supplementary Procedures – Flight Instruments, Displays – Electronic Flight Bag – Class 1 (iPad) Operation:
    a. EFB (iPad) Preflight Procedure (SP.10.2/3);
    b. EFB (iPad) Before Start Procedure (SP.10.4).

Furthermore, with reference to the LATAM B777-300ER Flight Crew Operations Manual Quick Reference Handbook:

[12] B777-300ER Flight Crew Operations Manual LATAM Airlines Brasil (Revision Number: 32, Revision Date: January 15, 2024, Based on Boeing FCOM Document Number: D632W001-TPR).

1. Normal Checklists – Before Start (NC.1)
2. Non- Normal Checklists – Warning Systems Section 15 – Tail strike (NNC.15.4)

1.6.5.1 CDU Preflight Procedure - Captain and First Officer

Figure 9 and Figure 10 show the CDU Preflight Procedure - Captain and First Officer. The CDU Preflight Procedure is to be started at any time after the Preliminary Pre-flight procedure. The performance data entries must be completed before the Before Start Checklist. The captain or first officer may enter data into the CDU when acting as pilot flying (PF), except when performing the external inspection procedure. The other pilot must verify the data entered. When one of the two pilots performs the external inspection, he/she must then verify the entries made. It is at this stage that the ZFW values on the PERF INIT page are entered, checking the amount of fuel on board and obtaining the Gross Weight to be verified with the flight documents. With regard to the step "verify that the GR WT on the CDU and the dispatch papers agree," it is interesting to note that the GR WT data is not present on the final loadsheet, which only shows the TOGW.

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Normal Procedures -
Amplified Procedures

Parking brake .... As needed C

Set the parking brake to check the brake wear indicators during the exterior inspection.

ACARS .... Initialize C

CDU Preflight Procedure - Captain and First Officer

Start the CDU Preflight Procedure anytime after the Preliminary Preflight Procedure. The Initial Data and Navigation Data entries must be complete before the flight instrument check during the Preflight Procedure. The Performance Data entries must be complete before the Before Start Checklist.

The Captain or First Officer may make CDU entries when he/she is the Pilot Flying (PF), except when he/she is performing the Exterior Inspection procedure. The other pilot should verify the entries. When either one of them performs the external inspection, he/she is the one who must verify the entries.

Enter data in all the boxed items on the following CDU pages.

Enter data in the dashed items or modify small font items that are listed in this procedure. Enter or modify other items at pilot's discretion.

Failure to enter enroute winds can result in flight plan time and fuel burn errors.

Initial Data .... Set

IDENT page:

Verify that the MODEL is correct.

Verify that the ENG RATING is correct.

Verify that the navigation data base ACTIVE date range is current.

POS INIT page:

Verify that the time is correct.

Enter the present position on the SET INERTIAL POS line. Use the most accurate latitude and longitude.

Navigation Data .... Set

RTE page:

Enter the route.

Enter the FLIGHT NUMBER.

July 15, 2022 FCOM-TPR NP.21.3

Figure 9: CDU Preflight Procedure, highlighted by the red dotted line showing how to enter data (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. NP.21.3).

Normal Procedures -
Amplified Procedures

LATAM

B777 Flight Crew Operations Manual

Activate and execute the route.

DEPARTURES page:

Select the runway and departure routing.

Execute the runway and departure routing.

Verify that the route is correct on the RTE page. Check the LEGS pages as needed to ensure compliance with the flight plan.

Note: If there is a published EOSID and it is not contained on database, it must be manually enter on RTE 2. Otherwise, use RTE 2 as necessary.

Verify the correct RNP for the departure.

NAV RADIO page:

Tune the navigation radios as needed.

Performance Data .... Set

PERF INIT page:

Enter the ZFW.

Verify that the FUEL on the CDU, the dispatch papers, and EICAS agree.

Verify that the fuel is sufficient for flight.

Verify that the GR WT on the CDU and the dispatch papers agree.

Enter step size according to route requirements (ICAO / 2.000 ft. / 1.000 ft. increment block level).

THRUST LIM page:

Select an assumed temperature, or a fixed derate takeoff, or both as needed.

Select the APU to pack mode, if needed.

Select a full or a derated climb thrust as needed.

TAKEOFF REF page:

Make data entries on page 2/2 before page 1/2.

Figure 10: CDU Preflight Procedure, highlighted in the red square are the steps for entering and verifying ZFW and GR WT data (sorce LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. NP.21.4).

The Before Start procedure (Figure 11) begins when refueling is complete and all documentation is on board, i.e., when the final loadsheet has been received. The pilot flying (PF) must conduct the take-off briefing (Figure 12). The take-off briefing includes checking the FMC Take-off Ref, and to do this, the take-off performance must first be calculated on the OPT (EFB procedure).

LATAM
B777 Flight Crew Operations Manual

Normal Procedures -
Amplified Procedures

Before Start Procedure

Start the Before Start Procedure after papers are on board and airplane refueling is completed.

Flight deck door .... Closed and locked F/O

Verify that the LOCK FAIL light is extinguished.

Do the CDU Preflight Procedure ....Performance Data steps before completing this procedure.

CDU display .... Set C, F/O

Normally the PF selects the TAKEOFF REF page.

Normally the PM selects the LEGS page.

MCP .... Set C

IAS/MACH selector ....Set V2

Arm LNAV as needed.

Arm VNAV.

Initial heading or track .... Set

Initial altitude .... Set

Taxi and Takeoff briefings ....Complete C, F/O

The pilot who will do the takeoff does the taxi and takeoff briefings. Use the following chart as guide:

Figure 11: Before Start Procedure, highlighted in red, the requirement to carry out the procedure once all documentation has been received and to complete the CDU Preflight Procedure before completing the Before Start procedure. (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. NP.21.27).

Normal Procedures -
Amplified Procedures

LATAM
B777 Flight Crew Operations Manual

TAKEOFF BRIEFING

Threats / Potential Safety Risks /Countermeasures (CRM-TEM)
Airplane Type, Status and Bulletins
MEL Requirements and Operations Procedures
NOTAMS
HAZMAT
Weather / Runway Condition
FMC Takeoff REF
Route Review
- Taxi (Low Visibility Procedures, Hot Spot and Runway Incursions)
- Takeoff (Low Visibility Procedures)
- SID (NADP)
- RTE 1 (ATC 1) / EDTO

Abnormal Briefing
- Before V1 (Captain only)
- After V1 (PF) / Engine Out SID / Return To Land

MCP (V2-HDG-ALT-LNAV-VNAV)/XPDR Code
Terrain considerations
Additional Comments

Figure 12: take-off briefing, part of the Before Start Procedure. Highlighted in red the FMC Take-off Reference CDU Page check. (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. NP.21.28).

1.6.5.2. EFB (iPad) Preflight Procedure

The procedure (Figure 13, Figure 14 e Figure 15) requires one crew member to calculate preliminary data related to take-off and landing performance based on aircraft conditions and/or any other criteria that may affect performance data (e.g., NOTAM, runway conditions, aircraft configuration), and the other crew member to verify these calculations. The procedure specifies which data must be entered, including TAKE-OFF WEIGHT. It should be noted that TOGW is not among the data displayed on the CDU, which automatically calculates only GR WT. After selecting the calculation function, the results must be checked.

Supplementary Procedures -
Flight Instruments, Displays

LATAM

B777 Flight Crew Operations Manual

If the QFE altimeter setting is beyond the range of the altimeters, QNH procedures must be used with QNH set in the altimeters.

Electronic Flight Bag - Class 1 (iPad) Operation

This procedure may accomplished for use of the Electronic Flight Bag (EFB) System - Class 1 (iPad)

EFB (iPad) Preflight Procedure

Start the EFB Preflight Procedure anytime after the CDU/EFB Preflight Procedure.

One crewmember computes the preliminary takeoff and landing performance data in accordance with the technical condition of the aircraft and/or any other criteria that may impact the performance data (e.g. NOTAM, runway condition, aircraft configuration and the other crewmember crosscheck that computation.

Figure 13: supplementary procedures Electronic Flight Bag (iPad) Preflight Procedures (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. SP.10.2).

Boeing OPT app .... Start/Init/Open

New Tail Number .... SELECT

MEL/CDL.. SELECT Items and Check

AIRFIELD DATA..OBTAIN

Obtain airfield data that will be use for preliminary takeoff performance computation.

TAKEOFF page:

Enter the selections in accordance with the estimated departure condition:

- Select the Airport (ARPT SEARCH), runway (RWY). Modify the runway, as appropriate. Any NOTAM affecting the airport data should be considered.
- Enter the weather conditions (WIND, OAT, QNH, COND). Enter the aircraft Takeoff Weight, and the aircraft configuration (FLAP, A/C, CG, A/I).

CALC .... Select and Crosscheck

Launch the calculation and crosscheck the results

Note: If required to switch to the full thrust view, simply tap the FULL/ATM button just above the output section.

Figure 14: supplementary procedures Electronic Flight Bag (iPad) Preflight Procedures (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. SP.10.3).

EFB (iPad) Before Start Procedure

Boeing OPT app ....Start/Init/Open F/O

Final Takeoff data ....Confirm and Recalculate

If takeoff condition did not change:

Verify and confirm that the preliminary take off data still valid

If takeoff conditions have changed:

Calculate the final takeoff performance, using the TAKEOFF page

Launch the calculation and crosscheck the results C

Figure 15: supplementary procedures Electronic Flight Bag (iPad) Before Start Procedures (source LATAM B777-300ER Flight Crew Operations Manual, FCOM-TPR pag. SP.10.4).

With the Normal Checklist Before Start (Figure 16), the crew verifies that they have completed all the procedures listed above, including the calculation of V1, VR, V2, and the CDU preflight .

LATAM

B777 Flight Crew Operations Manual

Normal Checklists **Chapter NC**

PREFLIGHT

Oxygen. . . . . Tested, 100%

Flight instruments . . . . Heading___, Altimeter___

Parking brake . . . . .Set

Fuel control switches. . . . . CUTOFF

BEFORE START

Flight deck door . . . . Closed and locked

Passenger signs . . . . ___

MCP . . . . V2___, HDG/TRK___, ALTITUDE___

Takeoff speeds . . . . V1___, VR___, V2___

CDU preflight. . . . . Completed

Trim . . . . ___ Units, 0, 0

Taxi and takeoff briefing . . . . Completed

Beacon. . . . . .ON

Figure 16: Normal Checklists, Before Start (source LATAM B777-300ER Quick Reference Handbook, QRH-TPR pag. NC.1).

1.6.6. LATAM procedure

The LATAM operating manual, or Manual Geral de Operacoes (MGO) in the relevant sections referring to flight dispatch and operational control phases – Weight and Balance, specifies that the *loadsheet* is the final document issued by the DOV (Flight Dispatch Manager), which contains information on aircraft weights, center of gravity, loading, and number of passengers. MGO states that this document can be delivered to pilots via ACARS or printed (by any means, “por qualquer meio”). The accuracy and preparation of the loadsheet always lies on the DOV and the Captain (PIC), who sign the document.

It is captain’s duty the final analysis of the information presented in the loadsheet, having to verify the weight limits relating to performance on the EFB. In case of unavailability, the procedure provided for in the MEL will be followed. The DOV’s signature is made electronically by means of identification in the document, consisting of name and ANAC code. The captain signs either via ACARS or by hand on a paper copy. The manual does not mention acceptance via iPad.

1.6.6.1. Calculation and validation of take-off and landing performance

The MGO requires that before each take-off and landing, with flight documentation and updated weather data in hand, pilots must individually follow the steps outlined below (Figure 17):

1. Perform performance calculations in the respective applications individually.
2. Validate the calculations (by comparing the data entered with the results obtained).
3. After validation, enter the results in the CDU (Boeing) or MCDU (Airbus), as required by the FCOM (Flight Crew Operating Manual).

Manual Geral de Operações
LATAM
DOUTRINA OPERACIONAL
PROCEDIMENTOS OPERACIONAIS

4.1.3.3 Cálculo e validação de performance de decolagem e pouso

Antes de cada decolagem e pouso, de posse da documentação de voo e com os dados meteorológicos atualizados, os pilotos deverão seguir os passos abaixo, de maneira individual, conforme abaixo:

1. Efetuar os cálculos de performance nos respectivos aplicativos de forma individual.
2. Validar os cálculos (comparando os dados inseridos resultados obtidos).
3. Após a validação, inserir os resultados no CDU (Boeing), MCDU (Airbus), conforme FCOM.

(IOSA FLT 4.1.4, FLT 3.11.51)

Página	Título/Capítulo	Efetividade	Revisão
14	4.1	15/05/2024	19.08

Figure 17: excerpt from the Manual Geral de Operacoes.

1.6.6.2. LATAM RTM 023/2024 R00 procedure, 29 August 2024

After the event, the operator introduced procedure RTM 023/2024 R00, entitled *“Calculation and validation of take-off and landing performance”*, with the aim of reinforcing the importance of individual calculation and performance validation for safety.

The document specifies that the calculation can only be considered individual if the information to be used has been obtained independently. Therefore, pilots are expressly prohibited from verbally communicating to each other the data used for performance calculations.

The text is as follows:

4.1.3.3 Calculation and validation of take-off and landing performance

Before each take-off and landing, in possession of the flight documentation and updated meteorological data, pilots must perform performance calculations in their respective applications, according to the sequence specified in the FCOM for each device.

Performance calculations must be performed individually by each pilot, who must obtain the necessary information directly from the relevant official document (e.g., OFP, Loadsheet, ATIS, etc.), as it is prohibited to request or obtain information verbally from the other pilot.

After performing the calculations, pilots must validate and enter the results into the CDU (Boeing) / MCDU (Airbus), according to the FCOM.

1.6.6.3. Clarifications from the operator regarding the procedure for calculating and validating take-off data

Calculation of take-off data

Reportedly, the TOGW value to be entered into the iPad/OPT for take-off calculation is obtained directly from the final loadsheet. This value is then compared with the GR WT displayed on the CDU PERF page (which reflects the TOGW plus taxi fuel, or ramp weight, derived from the ZFW and fuel on board entered). This cross-check ensures consistency between the final loadsheet and the FMS before proceeding with the iPad/OPT take-off calculations, as outlined in FCOM procedures N.P. 21.27, S.P. 10.3, and S.P. 10.4.

Take-off data validation

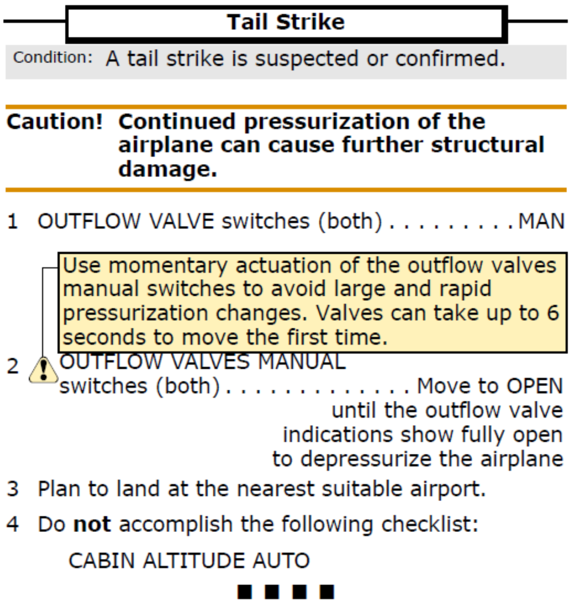
To validate take-off performance data, pilots check the TOGW value entered in the iPad/OPT by comparing it directly with the gross weight (GR WT) displayed on the PERF (or TAKE-OFF REF) page of the FMC. This GR WT value represents the sum of the ZFW and FOB entered, as indicated on the load sheet. The REF function of the 777 on the TAKE-OFF REF page provides additional speeds calculated by the FMC to be compared with those entered by the pilot.

From the operator's explanation, it can therefore be inferred that a check of the TOGW data entered in the OPT cannot be directly verified with the FMC as this data is not present, but only a consistency check with the GR WT can be performed. Furthermore, this procedure would not be present in the applicable documentation consulted (FCOM, MGO).

1.6.7. Tail Strike procedure

A tail strike occurs when the lower part of the rear fuselage or tail skid comes into contact with the runway during take-off or landing.

In the event of a tail strike, the procedure to be followed is described in the QRH (Figure 18) and involves starting to depressurize the aircraft cabin to prevent further structural damage. It is also necessary to land at the nearest available airport.



Tail Strike

Condition: A tail strike is suspected or confirmed.

Caution! Continued pressurization of the airplane can cause further structural damage.

1 OUTFLOW VALVE switches (both) . . . . MAN

Use momentary actuation of the outflow valves manual switches to avoid large and rapid pressurization changes. Valves can take up to 6 seconds to move the first time.

2 OUTFLOW VALVES MANUAL switches (both) . . . . Move to OPEN until the outflow valve indications show fully open to depressurize the airplane

3 Plan to land at the nearest suitable airport.

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

CABIN ALTITUDE AUTO

■ ■ ■ ■

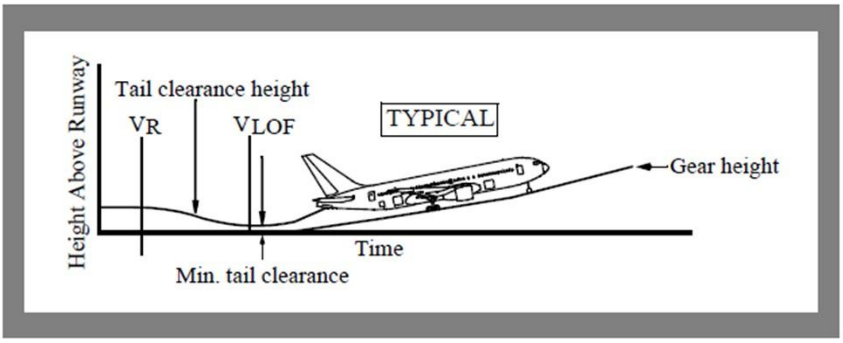
Figure 18: tail strike procedure described in the QRH (source LATAM B777-300ER Quick Reference Handbook, QRH-TPR pag. 15.5).

1.6.7.1. Take-off Risk Factors

Among the risk factors identified as precursors to a potential tail strike, the FCTM manual cites rotation at an inappropriate speed. This situation is usually caused by early rotation due to an abnormal situation or a speed that is too low in relation to the weight and/or flap position.

1.6.7.2. Attitude data relating to the distance of the tail from the runway during take-off (Typical Take-off Tail Clearance)

The Boeing 777 Flight Crew Training Manual for the 777-300ER version (Figure 19) reports an expected take-off attitude value of 8.5°. This attitude ensures a tail height of 76 cm above ground. Tail strike occurs at an attitude relative to the pitch axis of 10°.



Model	Flaps	Liftoff Attitude (degrees)	Minimum Tail Clearance inches (cm)	Tail Strike Pitch Attitude (degrees)
777-200	5, 15, 20	8.5	37 (94)	12.1
777-200LR	5, 15, 20	8.5	37 (94)	12.1
777-F	5, 15, 20	8.5	37 (94)	12.1
777-300	5, 15, 20	7.0	36 (91)	8.9
777-300ER	5, 15, 20	8.5	30 (76)	10.0

Note: 777-300ER values valid when the Semi-Levered Gear (SLG) is operative. When the SLG is inoperative, use 777-300 values.

Figure 19: take-off configuration, tail separation from the ground, and tail strike attitude (source: Boeing 777 Flight Crew Training Manual, FCT777 (TM) pag. 3.10).

The recommended technique involves a rotation rate varying between 2° and 2.5° per second (the latter value for longer models, such as the B777-300ER). The take-off attitude is then reached in approximately 4 seconds from the start of rotation. (Figure 20).

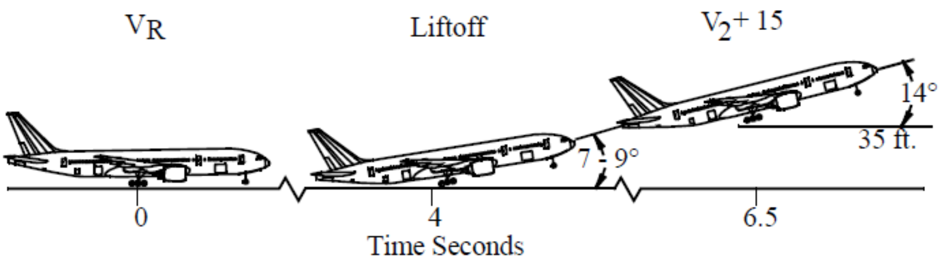


Figure 20: normal rotation (source: Boeing 777 Flight Crew Training Manual, FCT777 (TM) pag. 3.8).

1.7. WEATHER INFORMATION

The METAR at the time of take-off was as follows:

LIMC 091120Z VRB01KT 9999 FEW040 30/19 Q1018 NOSIG

The forecast (TAF LIMC) stated:

091100Z 0912/1018 VRB05KT CAVOK=

At the time of take-off of flight LA8073, the ATIS *Departure Information* “LIMA” was in effect, the full text of which is reproduced below.

[2024/07/09 11:26:22 F2 L LIMA] THIS IS MALPENSA ATIS DEPARTURE INFORMATION LIMA AT 1 1 2 0 RUNWAY IN USE 3 5 LEFT TRANSITION LEVEL 7 0 WIND STOP END 1 5 0 DEGREES 4 KNOTS DIRECTION VARIABLE BETWEEN 0 6 0 AND 2 2 0 DEGREES CAVOK TEMPERATURE 3 0 DEGREES DEW POINT 1 9 DEGREES QNH 1 0 1 8 HECTOPASCAL QFE 0 9 9 2 HECTOPASCAL YOU HAVE RECEIVED ATIS INFORMATION LIMA.

1.8. NAVIGATION AID

Not applicable.

1.9. COMMUNICATIONS

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

1.9.1. ATC units

Flight TAM8073 established contact with the following air traffic control units.

Malpensa Delivery (120.9 MHz): at 10:58 (transcripts are not available; the time is taken from the communication recorded by the CVR).

Malpensa GND: from 11:04:55 to 11:20:48.

Malpensa TWR (departure): from 11:21:41 to 11:28:44.

Milan ACC: from 11:28:59 to 12:33:18.

Malpensa TWR (arrival): from 12:33:30 to 12:39:41.

1.9.2. ATC communications

All communications between the aircraft and air traffic control units, and vice versa, took place normally both during normal operations and in the phases following the tail strike.

The times of the communications relevant to the reconstruction of the sequence of events are reported below:

1.9.2.1. Radio communications with Malpensa Ground

At 11:04:55, flight TAM8073 requests pushback.

At 11:14:27, TAM8073 requests taxiing instructions. Ground control instructs taxiing to intersection GW, which corresponds to a lineup with the entire length of RWY35L available.

1.9.2.2. Radio communications with Malpensa TWR (departure).

At 11:21:41, TAM8073 contacts TWR to report that it has reached the GW holding point.

At 11:25:34, TWR clears TAM8073 for take-off on RWY35L.

At 11:27:10, TWR advised TAM8073 that a tail strike had been observed during the take-off run.

At 11:28:44, TAM8073, in response to a request from TWR regarding its intentions, reported its intention to proceed to the INLER point at 6000 ft.

1.9.2.3. Radio communications with Milan ACC sector NW

At 11:32:32, TAM8073 declares PAN, PAN, PAN, due to tail strike and the intention to maintain 6000 ft. Communications follow for the coordination of fuel dumping.

At 11:50:38, TAM8073 reports the start of fuel dumping operations.

At 12:23:39, TAM8073 reports that it is ready for approach.

At 12:24:18, TAM8073 declares the end of PAN PAN and a return to normal flight operations to proceed with landing.

1.9.2.4. Radio communications with Tower

At 12:33:30, TAM8073 is stable on ILS Z 35R at 8.3 NM.

At 12:33:54, TWR clears the flight for landing on RWY35R.

1.10. AERODROME INFORMATION

Malpensa Airport (ICAO: LIMC, IATA: MPX) has two parallel runways with a heading of 349°/169°. Its ARP coordinates are 45°37’48’’ N 8°43’23’’ E and its elevation is 768 ft.

Take-off took place on runway 35L, which has the following declared distances (AIP Italia LIMC AD 2.13):

TORA 3914 m

TODA 3974 m

ASDA 3914 m

RWY 35L has a longitudinal slope of 0.58%.

The 35L THR elevation (where the take-off run began) is 696 ft. The 18R THR elevation (overflown at the end of take-off) is 764 ft.

The landing took place on runway 35R, which has the following declared landing distance (AIP Italia LIMC AD 2.13):

LDA 3919 m.

The local time (daylight saving time) is UTC-2 hours. Compared to São Paulo, Brazil (standard time) UTC+3, there was a 5-hour difference.

1.11. FLIGHT RECORDERS

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

1.11.1. General information

FDR: Honeywell HFR5-D, p/n 980-4750-009 and s/n FDR-01023 with solid-state memory and total recording time of 26 hours 48 minutes 30 seconds.

CVR: Honeywell HFR5-V, p/n 980-6032-001 and s/n CVR-01686 with solid-state memory.

With regard to the audio recording, there were four audio files relating to the Captain Mic (CM1, duration 2 hours 10 minutes 51 seconds), the First Officer Mic (CM2, duration 2 hours 10 minutes 51 seconds), the Third Crew Mic (CM3, duration 2 hours 10 minutes 51 seconds), and the Cockpit Area Mic (CAM, duration 3 hours 12 minutes 28 seconds).

1.11.2. FDR Data

The FDR begins recording parameters relating to flight TAM8073 at 11:10:41, corresponding to the start-up phase of the right engine.

1.11.2.1. Preflight

The data entered by the crew into the FMC and relating to take-off performance are as follows (*Figure 21*):

ZFW	219460 kg (483840 lbs)
V1	145 kt

VR	149 kt
V2	156 kt
Assumed Temp	56°C
Flaps	5°
CG	30%
Stab Trim	-1,148°

The FMC reports the fuel on board as 109500 kg and the gross weight as 328909 kg (725120 lb). The TAT was 30°.

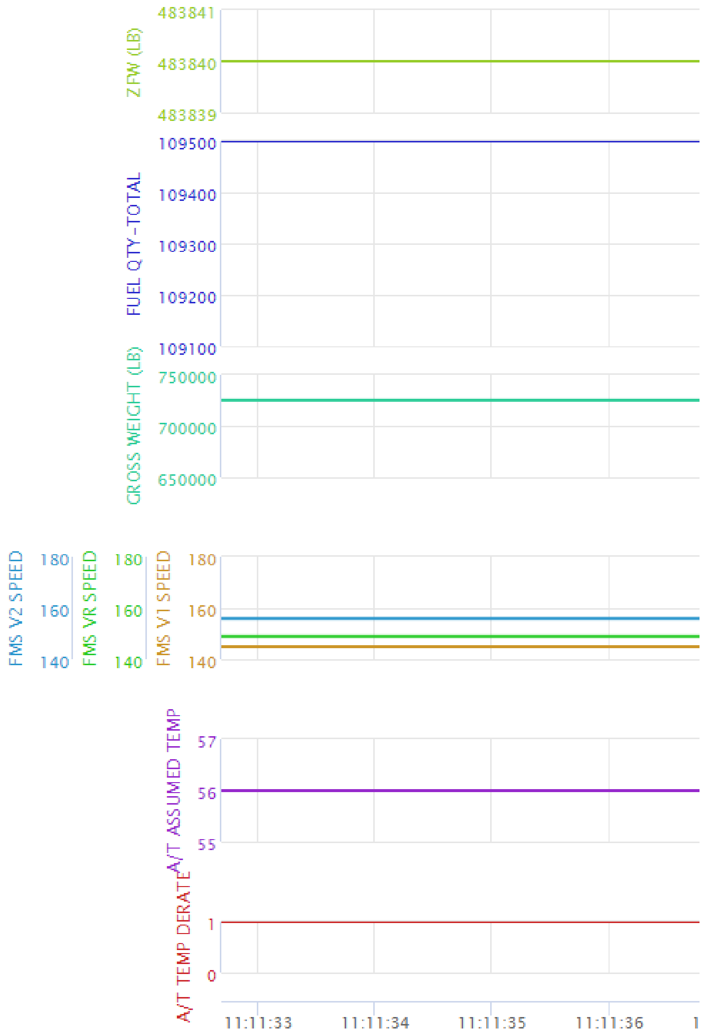


Figure 21: data entered or recorded on the FMC recorded by the FDR, including the ZFW (on the FDR in pounds) corresponding to the actual value and V1 145 kt, VR 149 kt, V2 156 kt, Assumed Temp 56°C, Flaps 5°.

1.11.2.2. Take-off

At 11:25:42, the aircraft lines up for RWY35L with the entire length of the runway available. The take-off configuration is 5° flaps.

At 11:25:58, the take-off phase begins with an assumed temperature of 56°C, resulting in N1_CMD=92.8%, N1=92.8%, N2=113%, and TLA=72°[13].

At 11:26:33, the V1 synthetic audio warning is activated.

At 11:26:36, rotation begins at the indicated speed of 150 kt (Figure 22).

At 11:26:37, the NLG switches from "ground" to "air" at IAS=153 kt.

At 11:26:40, IAS=160 kt, Pitch=8.3°, the tail strike Protection Command is active and remains active until 11:26:49.5 (6 units up to 9 units on a scale with maximum of 10).

At 11:26:42, based on a comparison of the recorded GPS coordinates and the location of the damage on the runway (see also section 1.12.2), it was determined that this was the moment when the tail strike physically began.

At 11:26:48, TLA gradually changes from 72° to TO/GA in 5" (both throttles on TOGA at 11:26:53, N1 106% at 11:26:54).

At 11:26:48, IAS=178 kt, Pitch 11.2°, LH MLG Tilt.

At 11:26:48, low pressure is recorded in cylinder "A" of the APU extinguishing system. One second later, low pressure is recorded in cylinder "B" (APU Bottle Press Low A and B).

At 11:26:48.5, RH MLG tilt (LH MLG lifts first, 0.5 seconds after RH MLG).

At 11:26:49, the aircraft is in flight (Figure 24, Figure 25).

At 11:26:53, the EICAS TAIL STRIKE CAUTION indication is activated to indicate that a tail strike has occurred.

At 11:26:57, the aircraft was directly above THR 18R (i.e., the opposite end of the runway in the direction of take-off, 45.646°N 8.7185°E) at a height of 155 ft radar altimeter at an IAS of 181 kt (*Figure 26*).

At 11:27:38, the EICAS TAIL SKID ADVICE indication was activated, indicating a discrepancy between the position of the tail skid and the position of the landing gear.

A plot of the significant positions relating to the take-off run is shown in Figure 27.

[13] The N1_CMD value is the value of N1 (fan rotation) commanded by the automatic thrust system calculated by the FADEC based on the selected thrust mode, throttle position, environmental conditions, and engine limits.

Figure 22: time 11.26’36” start rotation at 150 kt.

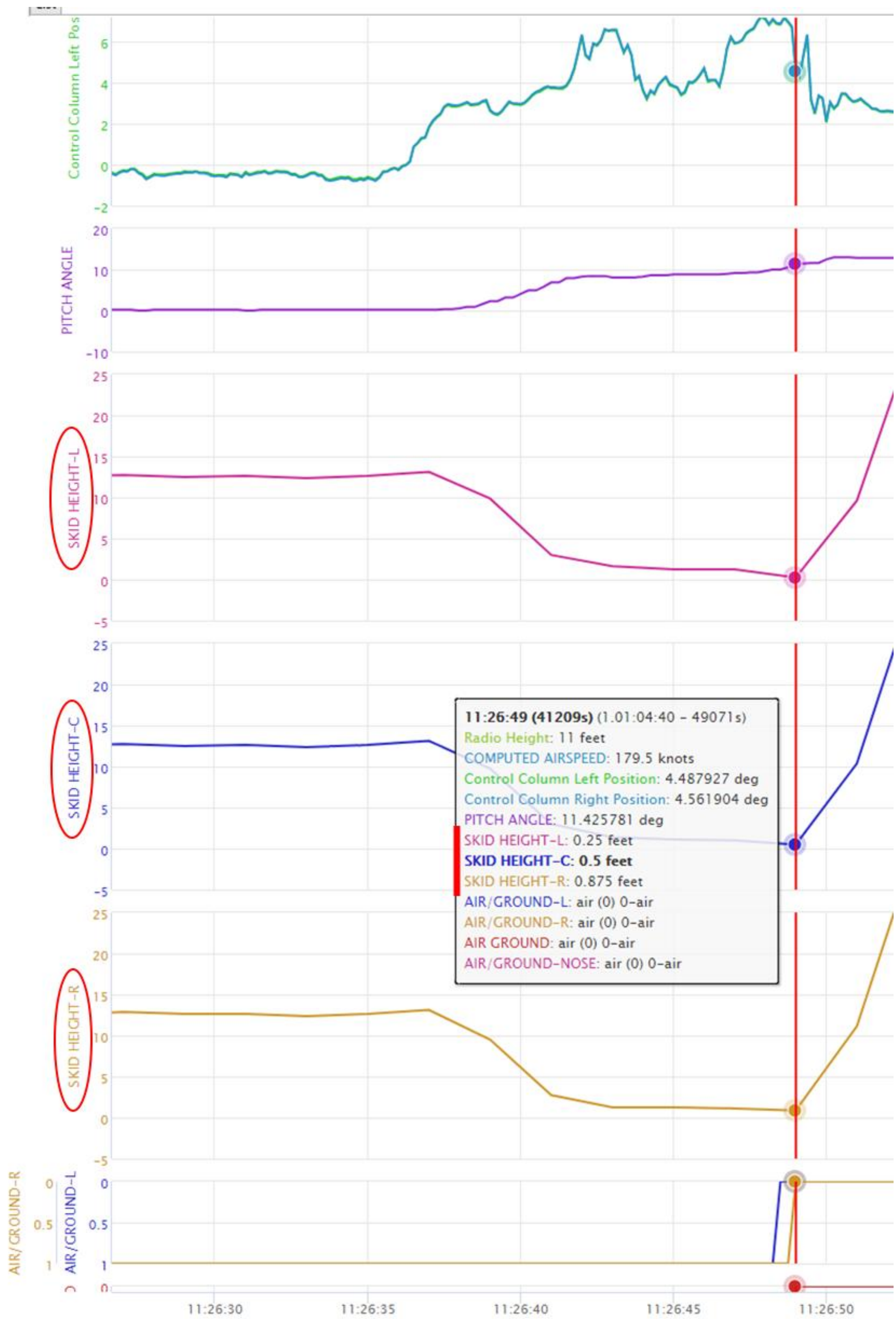


Figure 23: in the highlighted lines, the radio altimeter measurement of the tail skid at the moment of take-off. (L=0,25 ft, C=0,5 ft, R=0,875 ft).

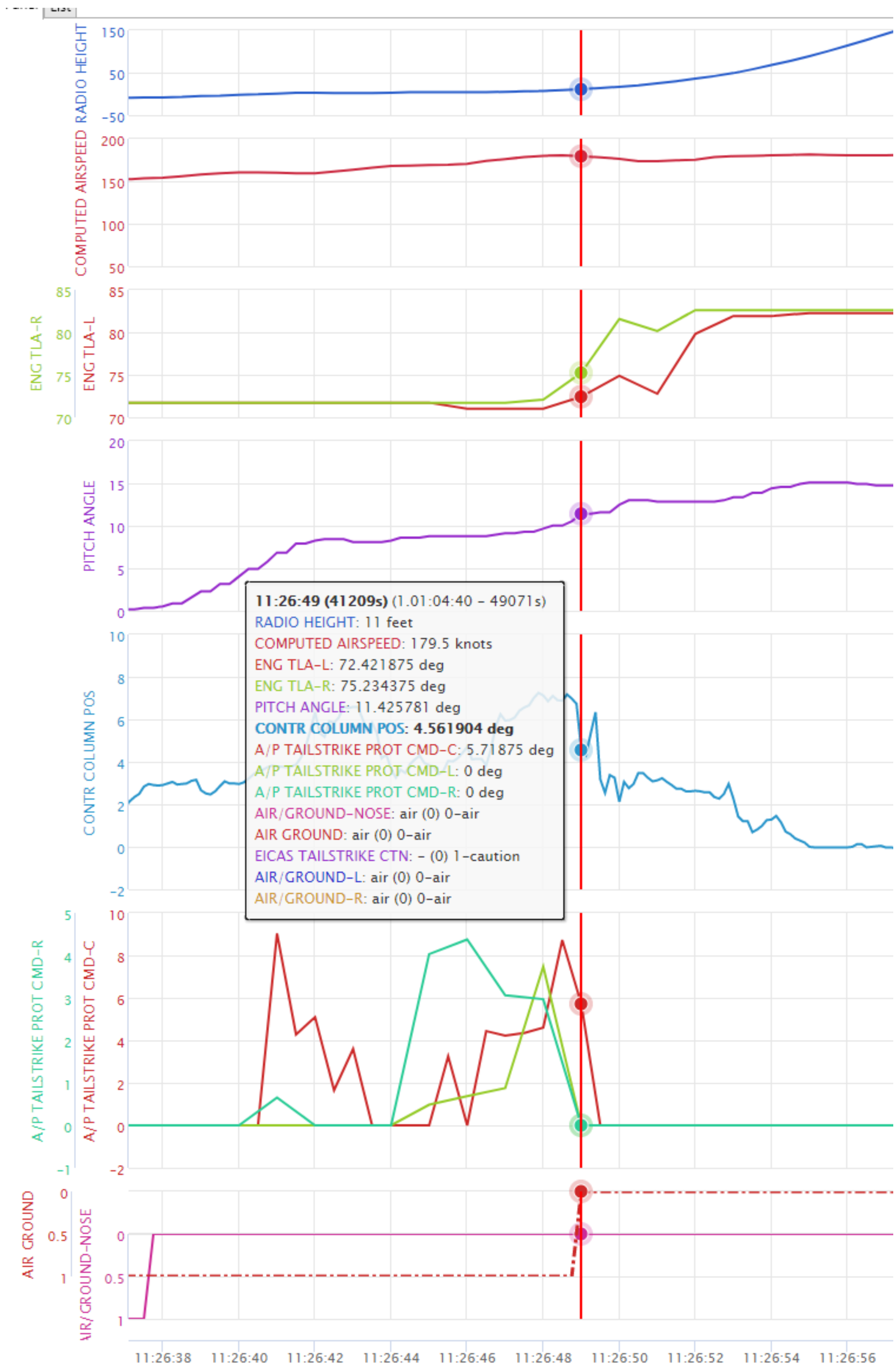


Figure 24: time 11.26’49” aircraft inflight. The pitch angle is 11.4°. Activation of the tail strike protection command channels from 11:26:40 to 11:26:49.

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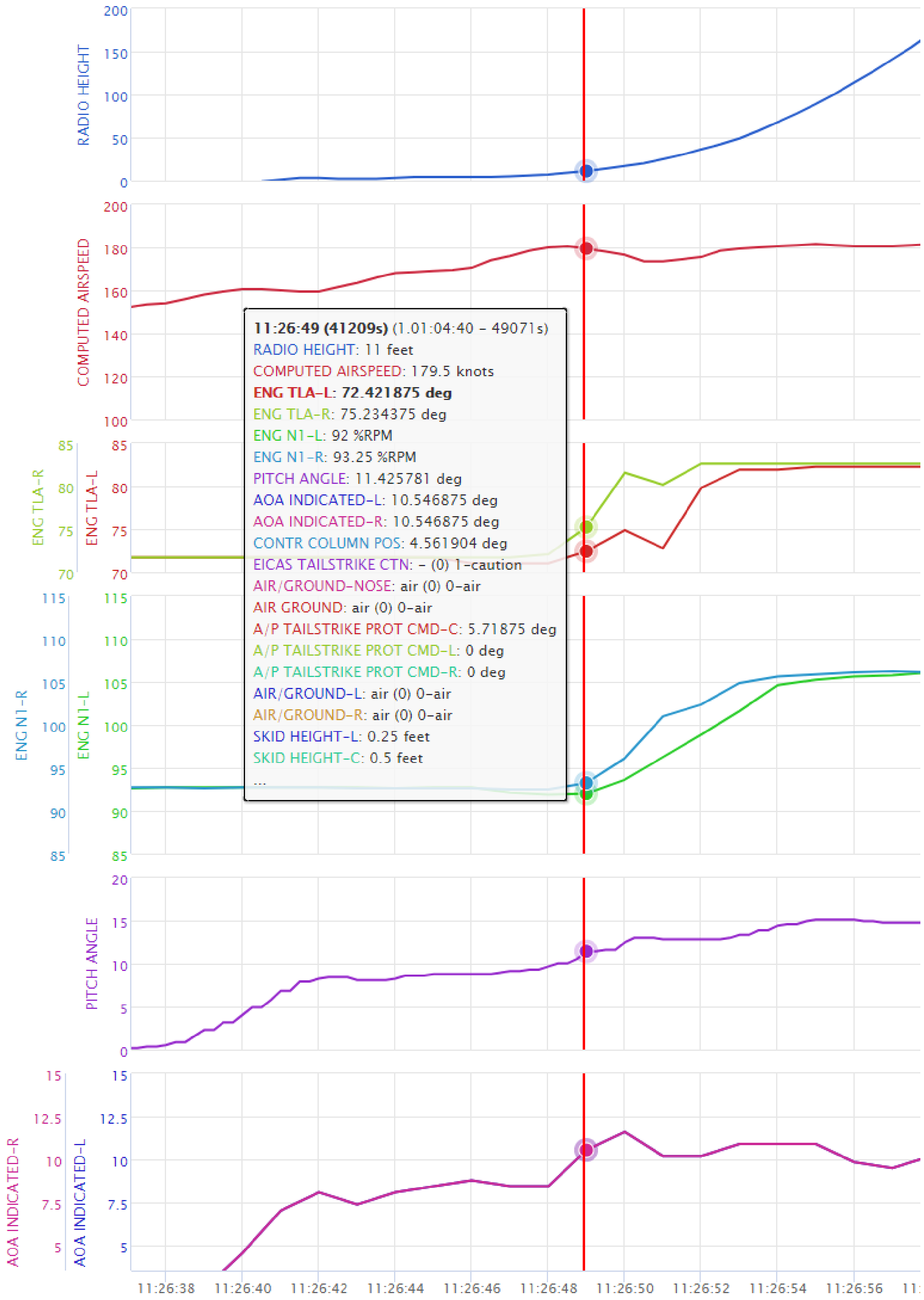

Figure 25: time 11:26:49, take-off at 179 kt. AOA is 10.5°. TLA moving toward TOGA.

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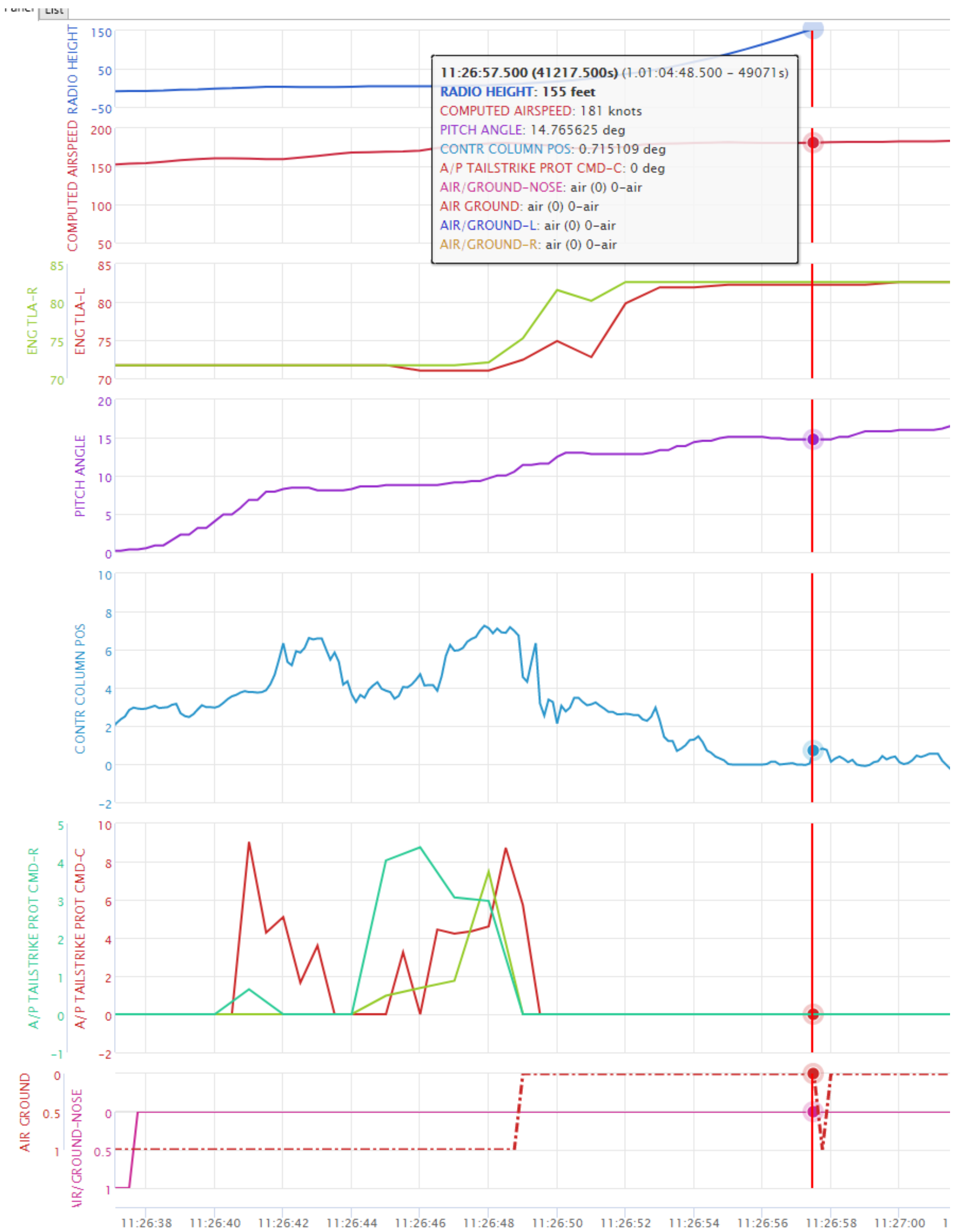

Figure 26: time 11:26:57 overfly of THR18R at 155 ft and 181 kt.

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Figure 27: plotting of notable points with corresponding times referring to the take-off of flight TAM8073.

1.11.2.3. Fuel Dumping

Flight TAM8073 performed the fuel dumping procedure from 11:51:05 (valves opening) at position 45°19' N, 8°09' E with a total fuel reading of 103700 kg at 12:23:17 (valves closing) at position 45°20' N 8°07' E with a fuel reading of 31600 kg. The total amount of Jet A-1 discharged in approximately 32 minutes therefore amounts to 72000 kg. The fuel dumping took place at an altitude of 6000 ft, at an indicated speed of 190 kt (equivalent to approximately 240 kt ground speed) and was carried out during seven holding turns in the area between the following coordinates:

45°23'N 08°06'E - 45°23'N 08°16E - 45°20'N 08°18'E - 45°18'N 08°16'E - 45°18'N 08°07'E - 45°20'N 08°05'E.

1.11.2.4. Landing

At 12:36:35, flight LA8073 landed on RWY35R, with 29900 kg of fuel indicated on board and a GR WT of 249180 kg, for a total flight duration of 1 hour and 10 minutes.

1.11.3. CVR data

The recording of the Cockpit Area Mic (duration 3 hours 12' 28") covers part of the ground procedures. The audio quality, being an ambient microphone, is not excellent, but it allows to understand the meaning of most of the communications. These took place in Portuguese between the three pilots. For the transcription of the relevant parts, the collaboration of the accredited representative of the Brazilian CENIPA was used.

1.11.3.1. Before Start Procedure

Time 10:50:01, CAM recordings begin. At that moment, the captain in training (CM1) is going through the items on the take-off briefing checklist (Figure 11), which is part of the Before Start Procedure (Figure 12), during the ground preparation phase prior to start-up. This takes place under the direct control of the LTC (CM2), who essentially confirms what the captain in training is stating.

The "MEL" is the first item recorded by the CVR, followed by "NOTAM," "hazardous material," and "weather and runway condition."

10:50:22, the captain in training announces the item "FMC Take-off REF." The captain in training and the LTC simultaneously say "Stand by."

The captain in training then moves directly to the Route Review item and briefings related to taxiing, take-off (normal), and the SID until 10:56. At this stage, the LTC explains how to check the SID, with reference to speeds and altitudes.

10:56, the cruise captain (CM3) informs the LTC that he has received the final loadsheet and has sent it to him. The LTC thanks him.

The LTC tells the captain in training to continue with the take-off briefing and to wait for the final loadsheet.

The captain in training states the item "abnormal briefing" and the LTC states the briefing of any actions before and after V1.

The captain in training completes the "take-off briefing" with the items "terrain consideration" and "additional comments."

10:57:33, the LTC begins to check the final loadsheet aloud, reading the ZFW (219.5) and the CG (29.7). In his comments on the final loadsheet data, the LTC states that the ZFW was 1500 kg less than planned (OFP), and the captain in training confirms this.

10:58, the procedure is interrupted by a communication from Malpensa Delivery, which assigns flight TAM8073 the sequence order for pushback (i.e., number 2). The LTC acknowledges the information. During this radio call, the volume of the speaker is likely raised and remains high throughout the sequence of operations, with numerous communications involving other aircraft and constituting considerable background noise recorded by the CAM.

10:58:13, the LTC explains that it is time to move on to calculating the take-off data on the OPT.

10:58:19, the LTC says “one moment... OPT...228.8” and repeats it a few seconds later.

10:58:36, the trainee captain begins to read the OPT results, saying “Flap 5,” but the LTC interrupts him, referring to an error.

10:58:47, the LTC tells the captain in training that he must enter “T2.”

10:58:57, the captain in training begins reading the OPT calculation results again, starting with “Flap 5.” The LTC corrects him, instructing him to read all the fields.

10:59:02, the captain in training begins to read, from top to bottom, first on the left and then on the right, all the fields entered in the OPT.

10:59:18, the LTC confirms.

10:59:19, the captain in training continues to read the OPT results, including speeds V1=145, VR=149, V2=156, and Vref 30=143.

10:59:40, the LTC confirms the validation of the result.

10:59:45, the LTC dictates the results, which are entered into the CDU by the captain in training.

11:00:31, the LTC states “V-SPEEDS UNAVAILABLE,” adding that he does not understand why the message appeared, but that it is present.

11:00:43, the cruise captain (CM3) suggests checking that the reference speed function selector on the CDU is set to ON in order to display the speeds. The function was already enabled, but the reference speeds did not appear.

11:01:03, the LTC says to proceed.

11:01:05, the captain in training announces V2 (1-5-6).

11:01:28, The captain in training reads the MCP entry and the applicable data (V2-HDG-ALT-LNAV-VNAV).

11:01:35, the cruise captain confirms that, as indicated by the ground technician, boarding operations have been completed.

11:01:40, the LTC instructs the captain in training to order the doors to be closed.

11:01:55, the LTC comments that they managed to complete all operations in an hour, facilitated by the fact that they checked the flight documentation on the bus during the transfer. He adds that it would be preferable to arrive at the aircraft an hour and a half earlier and that an hour is not enough time.

11:04:55, the LTC, on the instructions of Malpensa Delivery, requests authorization for pushback and engine start on the Malpensa Ground frequency.

11:05:20, the LTC begins reading the items on the 'before start checklist'. Under 'take-off speeds', the captain in training reads: V1=145, VR=149, V2=164, then corrected to 156, and confirms that the CDU preflight is complete.

11:06:20, the LTC states that the before start checklist has been completed.

11:06:48, the ground technician announces that pushback has begun.

11:10:41, the crew starts the first engine (right).

11:14:35, the crew starts taxiing.

1.11.3.2. Take-off

11:19:40, LTC requests to have the control of the aircraft and, approximately 30 seconds later, confirms that it has control of the aircraft in the final stages of taxiing.

11:25, the aircraft lines up on RWY35L.

11:25:50, the flight is cleared for take-off.

The following communications are recorded during take-off:

UTC TIME	CVR TIME	Source	Text	Note
11.25'53"	35'52"	CM2	Take off.	Confirmation of take-off phase activation.
11.25'57"	35'56"	CM1	Checked.	
11.26'06"	36'05"	CM1	Thrust set.	Confirmation of engine power set.
11.26'07"	36'06"	CM2	Checked.	
11.26'12"	36'11"	CM1	Eighty Knots.	Speed check.
11.26'13"	36'12"	CM2	Checked.	
11.26'33"	36'32"	AURAL	V one.	Decision speed, synthetic voice.

11.26’34”	36’33”	CM1	V one.	
11.26’36”	36’35”	CM1	Rotate.	Call for rotation.
11.26’41”	36’40”	CM2	*[???]* [***]... Não tá indo, [***]... Tem algo estanho *[???]*! Não tá indo!	?= unintelligible. *= Exclamations. It’s not working, something’s strange, it’s not working.
11.26’48”	36’47”	CM3	TOGA!	Maximum engine thrust call.
11.26’49”	36’48”	CM2	Ah?	
11.26’50”	36’49”	CM3	TOGA!	Maximum engine thrust call.
11.26’54”	36’53”	CM1	Positive climb	
11.26’55”	36’54”	CM2	Gear up.	Gear retraction order.
11.26’57”	36’56”	CM3	Tail strike.	
11.27’00”	36’59”	AURAL	*Ding, ding, ding, ding.*	Audible warning, once at activation level.
11.27’03”	37’02”	CM1	Tail strike.	Reading the EICAS message.
11.27’10”	37’09”	CM2	Autopilot ON	Autopilot engagement order.

1.12. INFORMATION ABOUT THE LOCATION OF THE ACCIDENT

This section contains information obtained from the examination of the site of the event.

1.12.1. Accident site

The tail strike occurred during take-off from Malpensa for RWY35L (Figure 28).

Figure 28: the red circle highlights the area of the scars on the ground. The red arrow indicates the direction of take-off.

1.12.2. Markings on ground

On RWY35L, a ground mark (groove with varying depths of up to 6 cm) was found, measuring 723 linear meters, originating between intersections DM and DE and 2 meters to the left of the centerline, and ending at a point just before intersection EM, 8.5 meters to the left of the centerline (Figure 29).

Figure 29: the green line indicates the ground scar between intersections DM and EM on RWY35L.

1.13. MEDICAL INFORMATION

Not applicabile.

1.14. FIRE

Not applicable.

1.15. SURVIVAL RELATED ASPECTS

Not applicable.

1.16. TRIALS AND RESEARCH

Not applicable.

1.17. ORGANIZATIONAL AND MANAGEMENT INFORMATION

TAM -LINHAS AÉREAS S/A holds Airline Certificate - ETA No. 1997-09-0TAM-03-01, which came into effect on June the 26th 2012, and is authorized to provide public air transport services for passengers and cargo as an airline.

Its headquarters and main base of operations is Congonhas Airport - CGH São Paulo / SP - Brazil.

The operator operates under the technical regulation, certification, and supervision of the Agência Nacional de Aviação Civil (ANAC) and is a member of IATA. The last audit (IOSA) prior to the event was conducted in August 2022 and certification was dated January 2023. The audit was conducted on a compliance basis.

The operator is listed on the EASA list of Authorized Third Country Operators with code TCO EASA BRA-0002.

TAM LINHAS AEREAS S.A. applied to EASA for TCO authorization in June 2014 and obtained initial TCO authorization (TCOA) in March 2016.

The operator is authorized to operate with the following fleet:

- Boeing B777-300ER, 10 aircraft;
- Boeing B787-8 Dreamliner, 1 aircraft;
- Boeing B787-9 Dreamliner, 26 aircraft.

The rules and procedures relating to aircraft operations, intended primarily for pilots and flight dispatchers, are contained in the LATAM MGO (Manual Geral de Operações) manual.

The document describing the safety management system, in accordance with ICAO Annex 19, is the Manual del Sistema de Gestion del la Seguridad Operacional (SGSO). At the time of the events, Rev. 2 of February 14, 2022, was in force.

The operator is certified according to IATA Operational Safety Audit (IOSA) standards, which are renewed every two years[14].

During the investigation, ANSV asked TA LATAM what SMS mitigation actions the operator had in place to mitigate the risk of tail strikes, with particular reference to the use of FDM and the compilation of hazard logs.

In this context, LATAM reported the following mitigation actions taken only after the event in question:

[14] The IATA Operational Safety Audit (IOSA) program is an internationally recognized and accepted assessment system designed to evaluate an airline's operational management and control systems. IOSA uses internationally recognized quality audit principles and is designed to conduct audits in a standardized and consistent manner. It was created in 2003 by IATA. Airlines are listed in the IOSA registry for a period of two years following an audit conducted by an IATA-accredited organization.

- publication of a safety notice to all flight crew, with recommendations on the prevention of tail strike-related events, including the entry of data into the FMC/FMGS;
- conducting a gap analysis with the aim of identifying possible risks and/or opportunities for improvement;
- introduction of a third IPAD in the cockpit for the B777 fleet, thus requiring the third pilot to cross-check and validate performance data together with the other pilots;
- implementation of the Advanced Qualification Program (AQP) in the wide-body fleet;
- development, through FDM, of a specific trigger to identify the crossing height at the end of the TORA for each take-off, with the aim of identifying any trends (performance degradation or errors).

1.18. ADDITIONAL INFORMATION

1.18.1 Witness statements

1.18.1.1. Line Training Captain

1.18.1.1.1. General information (LTC)

The captain reported that the previous flight shift had begun on the 1st of July, departing from Brazil and arriving in Italy on the 2nd of July. Departing from Italy on the 3rd of July, the shift ended with the return to Brazil on the night of the 4th of July (23 UTC). He benefited from two days of rest, on the 5th and 6th of July.

The new flight shift followed the same schedule: taking off from Brazil at approximately 18 local time (21 UTC) on July the 7th and he landed in Italy on the 8th of July.

He reported that the rest period between the outbound flight and the scheduled return flight was adequate, especially with the new schedule in place, which provides for arrival in Italy in the morning (Brazilian time) and departure the following morning (again, Brazilian time), with 24 hours of rest in between.

1.18.1.1.2. Flight preparation and ground procedures (LTC)

The minibus left the hotel about three hours before take-off.

Upon arrival at the airport, security checks were carried out as usual, and administrative procedures were completed without delays or unexpected events. Once on board the plane, he took his seat on the right.

All documentation relating to the flight (including the Operational Flight Plan - OFP, fuel requirements, weather conditions, NOTAM, required climb gradients, and take-off and landing weight limits) had already been received by the operator via a dedicated application on the pilots' smartphones. This documentation had been analyzed during the transit from the hotel to the airport with all the necessary checks. The only thing left to check once on board was the final loadsheet, which is the last document to be received by the crew before start-up.
The LTC confirmed that the flight schedule called for the captain in training seated on the left to be the pilot monitoring (PM), while he would take the right seat as PF. A second captain was present in the cockpit as cruise captain.
The assignment of duties during the flight was dictated by the training requirement for the captain in training to fly one leg as PM and by the need to maintain the LTC's currency in terms of the minimum number of take-offs and landings performed within the established time frame.
The cruise captain, as third pilot, in accordance with standard procedures, has the duty of inspecting the exterior of the aircraft, monitoring operations relating to the passenger cabin and coordinating with the cabin crew, as well as making intercom announcements.
When the crew arrived at the aircraft, refueling was still in progress. The amount of fuel being loaded was as specified in the OFP, with a surplus of about two or three hundred kilograms, as is normally the case at the end of refueling operations when the specified amount is slightly exceeded. There was no need to request additional fuel, which is rare, and there were no additional requests or last-minute changes. There were no last-minute changes to the load. There were no interferences or interruptions caused by people entering the cockpit other than the flight crew.
When asked how the CDU preflight procedure and EFB procedure took place, the captain reported that, as required by the procedure, the final loadsheet is received, checked, acknowledged, and then the data is entered into the CDU. He reported that he had not received it on his cell phone but that it had first been received on the cruise captain's cell phone. After accepting it, the cruise captain then sent it to the iPads. The pilots (LTC and captain in training) checked the data on the final loadsheet together and then entered it into the CDU. In this regard, he reported that he was sure that the data entered at this point was correct.
He also reported that the procedure requires both pilots (there are two iPads on board) to individually enter data into the iPad's OPT application to calculate take-off performance. This procedure must be performed individually, but in this specific case, he reported that he verbally stated the incorrect takeoff weight, which was 100000 kg (228 tons instead of 328)

lower that deemed. He reported that he believed this to be the source of the calculation error: instead of entering the data into the OPT individually and then jointly checking the resulting performance data, he had stated the TOGW data aloud. This resulted in the incorrect TOGW being entered on both devices, which consequently provided the same result. Therefore, when the pilots cross-checked, they verified the same speed result on their respective iPads, but based on an incorrect take-off weight.

These take-off performance data resulting from the calculation on the iPad were entered into the CDU.

The subsequent entry of data from the OPT to the CDU was done by dictation, with one pilot reading the data from the iPad and the other entering the data into the CDU. He reported that he did not remember who physically entered the data into the CDU, although it is likely that if he had read the speeds, the captain in training would have entered them. When asked how the aircraft weight data to be entered into the OPT is extrapolated, the captain reported that the ZFW is entered into the CDU, and the FMC adds the ZFW to the weight of the fuel in the tanks, thus providing the total GR WT.

He reported that in order to obtain the TOGW to be entered in the OPT, he would read the GR WT data displayed on the CDU and subtract the fuel he expected to be consumed during taxiing (approximately 400 kg for a taxiing distance that was not particularly long, as in the case of Milan Malpensa).

After entering the data, the captain in training asked why the FMC V-speeds, i.e., the take-off speeds calculated by the FMC, were not displayed on the CDU. The cruise captain had indicated in this circumstance to check that the function allowing the display of speeds was set to "ON" on the CDU page. However, this function was already enabled.

Listening to the CVR audio relating to the CDU preflight procedure phase and the EFB iPad procedures, he explained that once the final loadsheet had been received, during the check and entry of data from the loadsheet to the CDU, a radio call had been made by Malpensa Delivery. This was regarding instructions for the estimated departure time of 11:30. In addition, they had received an update to the schedule, anticipated to 11:05 or 11:10, he did not remember exactly; in this framework, he reported that they did not expect to be number two in sequence to push. The LTC confirmed that when the captain in training was about to enter the speeds into the CDU, he commented that the speeds calculated by the FMC (FMC V-speeds) were not indicated; even though these should have been present, the pilots did not pay sufficient attention to this fact.

When asked about the data entry sequence, he reported that once they received the final loadsheet, they entered the ZFW and CG on the CDU; to complete the CDU data with speeds, they first had to calculate them on the OPT. After calculating the performance on the OPT, they returned to the CDU, entering the assumed temperature for selecting the engine thrust at take-off, then returning to the TAKE-OFF REF page and entering the take-off speeds.

Regarding the selection of 5° flaps for take-off, he reported that it is not unusual, even with the actual weight of the aircraft, for the OPT to provide this flap setting as the preferred configuration.

Normally, based on his experience, the difference between the speeds calculated by the FMC and those calculated by the OPT, for the same configuration, does not exceed two knots. He reported that he assumed the difference was within that range and, only a few days after the event, he thought that the speeds calculated by the FMC were not being displayed because there was a difference between the speeds of more than 5 knots[15]. In his opinion, this should have been a signal to pay attention to.

He reported that he remembered that the ZFW they read on the final loadsheet was, as far as he could remember, about 1500 kg less than initially expected, and that this difference between the expected and actual weight calculated before take-off is a normal occurrence.

He explained that the difference between the planned and actual number of passengers was within the limit beyond which it is necessary to request a new final loadsheet[16].

The speeds resulting from the individual calculations on the OPTs of the two iPads are checked without verifying the weight entered (TOGW) in the OPT with the weight of the aircraft presented on the CDU and with that of the final loadsheet. He believed an operating procedure including the cross-check between the final loadsheet, the data presented on the CDU and the data entered on the iPad OPT, could be more effective in identifying the entry of incorrect data.

1.18.1.1.3. Take-off and flight phase (LTC)

When asked what indications he remembered having during take-off, he reported that the first and only indication observed was that upon rotation, the aircraft lifted its nose but did not take

[15] This consideration, repeated several times during the interview, fits into the context mentioned in the report of the lack of a precise definition in the FCOM or other applicable Boeing documentation of the conditions under which the FMC is unable to calculate take-off speeds (see paragraph on FMC Entry Error Messages and Figure 8).

[16] Following a last-minute change consisting of a difference of more than 10 passengers or more than 1,000 kg of cargo in excess of what was previously notified, it is necessary to request a new final loadsheet. Following a last-minute change exceeding 2,000 kg of cargo in excess of the previously calculated ZFW, it is necessary to request a new flight plan (OFP).
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off, with no other indications. He remembers saying something like “it’s not climbing”. The cruise captain said “TOGA”. Once TOGA was selected, the aircraft began to climb. After take-off, he saw a TAIL STRIKE indication on the EICAS along with a BOTTLE DISCH APU indication.
Since the aircraft was not vibrating and the situation appeared to be under control, he considered it preferable to land below the maximum landing weight, discharging fuel as the cruise captain had also suggested. The decision to wait and discharge fuel or to land immediately above the maximum landing weight is dictated by the urgency of the situation. The fuel was jettisoned in accordance with Brazilian regulations, i.e., above 6,000 ft, avoiding populated areas or areas indicated by the air traffic control authority. He reported that a bird strike occurred during the final approach. Landing took place without further consequences.

1.18.1.1.4. Training (LTC)

He reported that he began the ground training on the B777 in August 2022 and started flying that model in November 2022. He logged between 1,000 and 1,500 flight hours on the B777. Starting in October 2023, he flew the B787, operating both the B777 and B787. He had previously served as LTC on the Fokker 100, A320, and, prior to the B777, on the B767. The duty limit is a maximum of 95 hours in a 28-day cycle.
When asked if he often flew as PF from the right seat, he reported that he only flew on the right occasionally, mainly when training a captain in the role of LTC.
When asked if, during his initial training on the B777, emphasis had been placed on the criticality of possible errors in performance calculations, the captain replied in the negative. When asked whether, in light of other similar events that had occurred in the past, there had been any emphasis on highlighting this type of risk, it would appear that he had never been subjected to safety promotion initiatives in this regard.

1.18.1.2. Captain in line training on B777

1.18.1.2.1. General information (captain on training)

The pilot had been off duty for a few days. Before leaving Brazil, the pilot had adequate rest. On July the 7th , the crew reported for duty at 16:30 local time (Brazil) to depart from São Paulo at 18:20 local time (21:20 UTC).
The arrival at Malpensa took place on July the 8th at 10:05 local time (08:05 UTC).
He reported that he had rested adequately and had regularly eaten the meals provided during the stopover in Italy.

The flight documents arrived on the LTC's iPad before leaving the hotel. During the bus transfer to the airport, the crew studied all the flight documentation and the briefing.

1.18.1.2.2. Flight preparation and ground procedures (captain in training)

Upon arrival at the airport, the crew had already completed their flight preparations by studying the documentation. Security checks took place without any hindrance. Once at the aircraft, the ground crew requested confirmation of the amount of fuel to be loaded, thus completing the refueling operation at the planned total without any changes.

The captain in training, together with the LTC, focused on preparing the cockpit, while the cruise captain was assigned the task of checking the documentation relating to the load, carrying out external checks, and cabin communications.

The emphasis related to the procedures of the cockpit preparation was also motivated by the fact that, with few flights available, the captain in training wanted to take advantage of the opportunity to practice and speed up ground procedures, such as checklists, briefings, OPT, and data entry into the CDU.

The procedure had changed a few months earlier, with the final loadsheet now being sent to the pilots' smartphones. Previously, the loadsheet had been sent to the aircraft and the crew had printed it out, keeping a copy on the *pedestal* for consultation with the most important data highlighted. In this specific case, the captain in training had not yet received the final loadsheet on his device. The first to receive it was the cruise captain on his iPad.

The final loadsheet was therefore read using his iPad.

The captain in training had entered the *ZFW* data into the CDU as dictated by the LTC, obtaining the *GR WT* with the automatic sum of the fuel.

The captain in training recalls that the LTC read the TOGW, stating 228.8 (tons). Although the captain in training had looked at the GR WT in the CDU, this figure did not remain in his memory, and he entered the value enunciated by the LTC into the OPT/iPad.

Therefore, the calculation on the OPT was performed individually but with an incorrect TOGW value for both.

For this reason, the data for an incorrect TOGW was calculated and the incorrect data was validated. He had a vague feeling that the take-off speed data was strange because he had preliminarily performed calculations that gave much higher speeds and flaps at 15°. However, this data was not recorded because when the new OPT calculation was performed, the previous data had been overwritten. In addition, the captain in training noticed that the reference speeds that are normally displayed on the CDU were not present; instead, there were only dashes, and he did not understand why. The captain in training asked for clarification as to why they were not present. The cruise captain suggested selecting ON to enable them to appear, but even when ON was selected, the FMC reference speeds were not present. No one could understand why the reference speeds calculated by the FMC were not present. He therefore considered in retrospect that, if the reference speeds had been present, it would have been possible to notice a discrepancy of more than twenty knots between the speeds calculated by the FMC and the data entered. Given his limited experience on the B777, he did not consider it necessary to investigate further. Finally, he recalls that, while the calculations were being made, a radio call was received informing them that they would be number two in sequence for pushback and that the take-off time had been brought forward.

1.18.1.2.3. Take-off and flight phase (captain in training)

The take-off procedure was carried out with the LTC as pilot flying, as the captain in training had to fly one leg as PM, as required by the training program. He reported that during the take-off run, the application of the planned power (thrust set) was verified, the speed indication of 80 kt and V1 were announced, and finally VR was called. He recalls that the PF rotated the aircraft but it did not take off. He described how this phase was characterized by a startle effect[17], reporting that at a certain point the cruise captain first commanded TOGA to be selected and then had to do so again to achieve the desired effect. Only then did the aircraft take off; the captain in training observed a positive indication to climb and announced it. The LTC commanded the landing gear to be retracted and the EICAS TAIL STRIKE indication appeared, a situation that was also confirmed by the TWR. At this point, the LTC reiterated that all operations should be carried out calmly and in the planned sequence and priority. The LTC carried out all coordination with the ATC.

It followed the EICAS procedures at a safe altitude, selecting the pressurization system to manual and preparing for a return.

After completing the after-take-off checklist, leaving the flaps at 5°, the LTC ordered the change of positions. The cruise captain took the place of CM2 and the LTC took the place of CM1. The cruise captain suggested performing fuel dumping. All operations following the tail strike were carried out with due calm.

[17] The startle effect is a natural physiological and psychological response to a sudden and unexpected stimulus, such as a loud noise, a sudden shock, or a visual signal that contradicts expectations. Cognitively, it can cause temporary mental "freezing", confusion, and difficulty in making decisions.

1.18.1.2.4. Training (captain in training)

The captain in training reported that he had been with the operator since 2001. He had served as first officer on Fokker 100, A32F, and A330 aircraft. He was promoted to captain in 2007 on the A320, serving in that position until March 2024. His previous experience with Boeing aircraft was limited to the B737 300/400 (approximately 150 hours) in 2000 with another operator.

At the time of the event, the captain was undergoing line training on the B777. In May, he had completed simulator training and, in the same month, he had made his first line training flight on the B777. In June, he had completed three flight shifts. The flight in question was the fifth and final training flight on the B777. The line check was to be taken on the next flight. During the flight in question, he was operating for the second time at Milan Malpensa.

During his line training, the pilot always flew with different instructors and this was his first service with the LTC involved in the event.

When asked whether the critical issue relating to the incorrect calculation of take-off performance had been highlighted in any way during training, both initial and in-line, he reported that this had never happened. He recounted the experience of a colleague working for another operator, who had performed a take-off with incorrect speeds during simulator training in order to raise awareness of the issue.

1.18.1.3. Cruise captain

1.18.1.3.1. General information (cruise captain)

The cruise captain reported that from July the 1st to July the 5th, he had been on standby duty. On July the 6th, he was off duty. The flight shift began on July the 7th for the flight to Milan, arriving in Milan from São Paulo on the morning of July the 8th. He reported that he had adequate rest before the flight. He left the hotel at 10 local time (8 UTC) and arrived at the airport about an hour and a half later (9:30 UTC).

1.18.1.3.2. Flight preparation and ground procedures (cruise captain)

As the third pilot, required by ANAC regulations in view of the duration of the flight, his duty was external inspection, coordination with the cabin crew, documentation, and intercom communications.

During the transfer, the OFP was received on his mobile device and on that of the LTC. At that point, the route documentation, weather conditions, NOTAMs, etc. were studied.

Once customs formalities had been completed, the crew headed for the aircraft.

Once in the cockpit, the third pilot waited for the captain in training to check the ATL and then went downstairs to perform the external check. Once back on board, the captain in training and the LTC were making preparations for departure. The cruise captain then coordinated with the cabin manager and boarding procedures.

When the final loadsheet arrived, the LTC was unable to download it to his iPad. The cruise captain received it first and informed the LTC that he was sending it to his iPad. The captain in training and the LTC cross-checked the final loadsheet and entered the data into the FMC. The cruise captain reported that he was not sure what happened at this stage, as he was busy with other tasks at the time. He reported that the normal procedure requires each pilot to individually check the data entered into the FMC (ZFW, CG), enter the data for performance calculations on the OPT, and then cross-check the OPT speeds for entry into the FMC. He understood, according to what he was told after the event, that there was an exchange of information between the two pilots about the weight data to be entered on the OPT. As a result, both entered the incorrect weight on the iPad's OPT, thus generating incorrect speeds.

When entering data into the FMS, when the captain in training commented on the lack of V-speeds, the third pilot noticed that the speeds calculated by the FMC were not present in the central column of the CDU. In the limited period (five months) of operations on the B777, he had never observed this situation and thought it depended on the ON/OFF position of the selector.

He remembered reading in the FCOM that if speeds lower than the minimum computed V1/V2/VR are entered, the system warns with a message on the scratchpad, but this was not the case. He did not realize that the message V-SPEEDS UNAVAILABLE had appeared on the CDU. The crew discussed the possible reasons but could not explain the situation.

He reported that the procedure for receiving the final loadsheet had recently changed, as the final loadsheet was previously received in paper form.

He reported that the iPads are aircraft equipment and not personal property; there are two of them, one on the CM-1 side and one on the CM-2 side. The cruise captain reported that, in his opinion, the presence of a third iPad could have provided an additional opportunity for cross-checking.

He reported that he had come to the conclusion that the aircraft's FMC system was not sufficiently clear and direct in rejecting inconsistent data entered by the crew or in indicating that incorrect data had been entered.

1.18.1.3.3. Take-off and flight phase (cruise captain)

The cruise captain recalled that, after rotation, the PF commented that the aircraft was not climbing; at this point, he told him twice to select TOGA. The aircraft then took off.

Once in flight with the landing gear retracted, the EICAS messages TAIL SKID and BOTTLE DISCH APU appeared.

He suggested to the LTC that he perform circles and dump fuel, since the aircraft was behaving normally without vibrations or malfunction warnings.

The pilots were swapped, with the cruise captain taking the place of CM-2 and the LTC taking the place of CM-1 PF.

He reported that during the final approach for landing, there was a bird strike without further consequences.

1.18.1.3.4. Training (cruise captain)

The captain reported that he had worked for LATAM for 27 years, starting with the Cessna C208, Fokker 100, A32F, A330, and 11 years on the B767 as captain. He also reported that he had started working as captain on the B777 five months earlier. When asked, he reported that during training on the B777, the discussion of aspects related to the risk of error in calculating take-off performance was never emphasized, unlike what he remembered happening during training on the B767.

1.18.2 ATC radar and SMR recordings

The flight was monitored continuously by radar, from the ground phases (SMR) and throughout all phases of taxiing, alignment, and take-off, fuel dumping, and return for landing. In particular, Figure 30 to Figure 32 show the moment of rotation, tail strike, and take-off. It can be inferred that take-off was performed using the entire length of the runway.

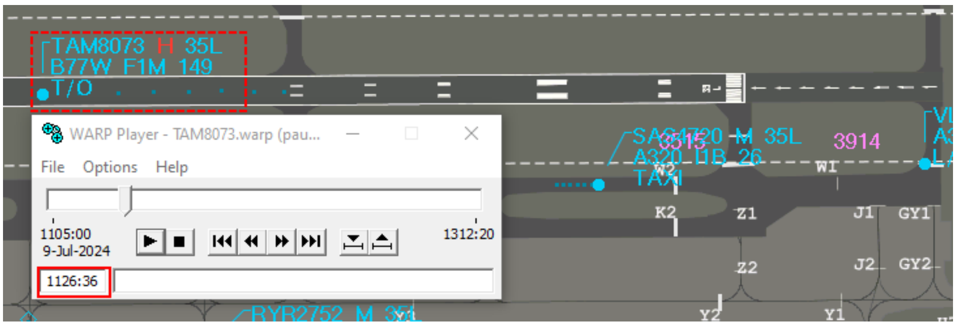

Figure 30: screen shot of the SMR referring to the time 11:26:36: start of rotation.

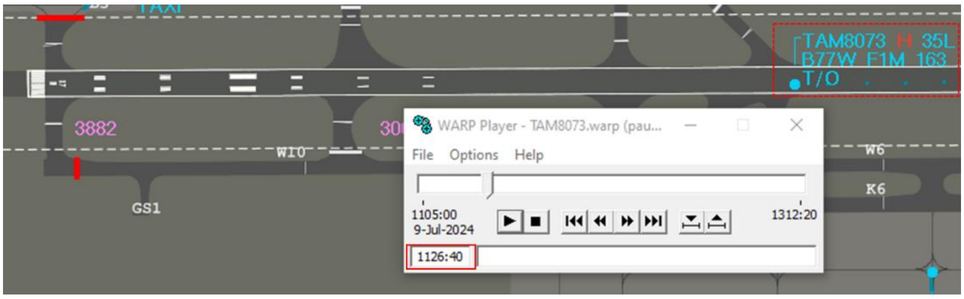

Figure 31: screen shot of the SMR referring to the time 11:26:40: start of tail strike.

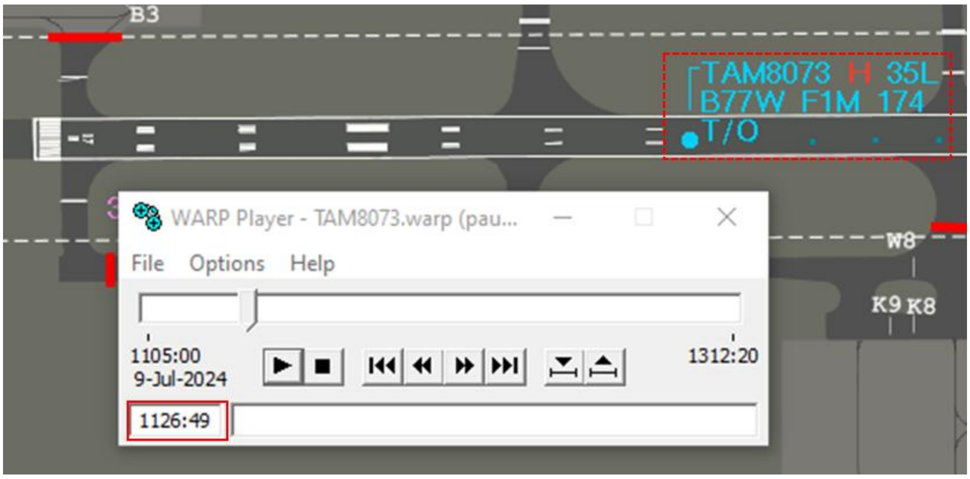

Figure 32: screen shot of the SMR referring to the time 11:26:49: inflight.

1.18.3 Flightradar24 ADS-B

The FDR and radar data are essentially consistent with each other and with the ADS-B data available on Flightradar24. For ease of representation, the latter will be commented on in relation to the flight track covered by this report (Figure 33). In particular, it is possible to view the area where the fuel was dumped in relation to the opening and closing of the fuel dump valves: from 11:51:05 (valves opened, FDR data) at position 45°19’ N, 8°09’ E, to 12:23:17 (valves closed, FDR data) at position 45°20’ N 8°07’ E.

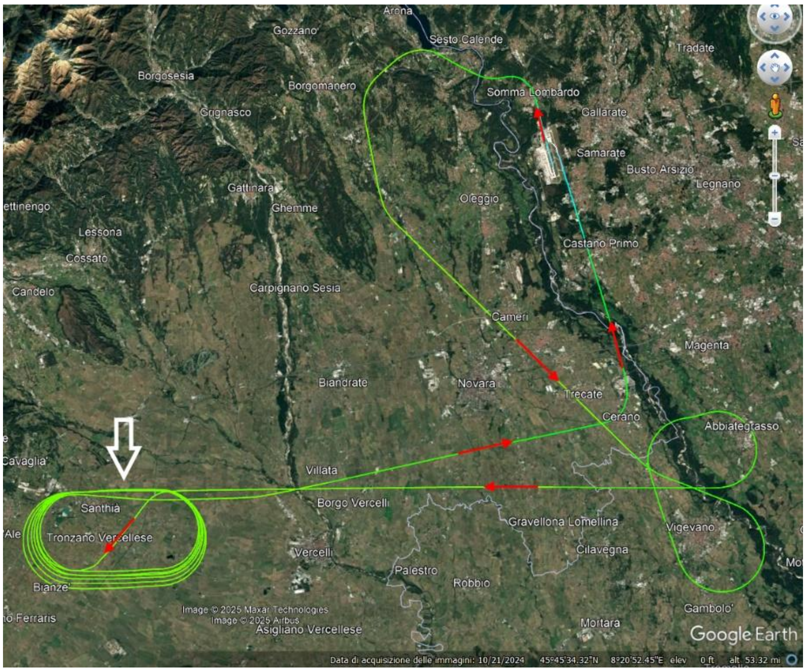

Figure 33: flight path of TAM8073, recorded by Flightradar 24. The white arrow indicates the area of the fuel dumping.

1.18.4 Airport surveillance cameras

The airport surveillance system cameras recorded the take-off phase of the B777 with registration marks PT-MUG.

In particular, the recordings from the camera facing south, i.e., in the direction from which the aircraft arrived, made it possible to document the following events:

11.26'39''	the aircraft has begun its rotation, the NLG lifts up (Photo 5);
11.26'42''	tail strike starts (Photo 6);
11.26'43''	a stream of smoke forms, originating from the tail (Photo 7);
11.26'49''	Sparks are still visible from the tail skid area in contact with the runway, the two MLGs separate from the ground, the left one first (Photo 8);
11.26'50''	the aircraft is airborne (Photo 9).

Photo 5: 11.26’39’’ rotation maneuver with lifting of the NLG from the ground.

Photo 6: 11.26’42’’ start of contact between the tail of the aircraft and the runway.

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Photo 7: 11.26’43’’ smoke is clearly visible following the rear end skidding on the runway.

Photo 8: 11.26’49” main landing gear detached, tail skid still in contact with runway.

Photo 9: 11.26’50”- aircraft airborne.

1.18.5 Take-off performance data calculated using the OPT application (Boeing)

To calculate performance, the operator used the Boeing-developed Onboard Performance Tool (OPT) application installed on a Class 1 Electronic Flight Bag, i.e., a portable electronic device (PED) such as an iPad. Class 1 EFBs are not interfaced with the aircraft’s FMS.

With regard to the calculation of performance for the take-off phase of the accident flight, reference is made to Photo 10 (photo of the screen of one of the iPads actually used in the accident flight; it therefore shows the actual selections made); the red box contains the input data entered by the pilots:

- take-off weight (in the dotted box 228800 kg);
- runway length and conditions;
- ground wind and temperature;
- flap selection options (optimized by the system);

- thrust rating and maximum assumed temperature;
- status of air conditioning and anti-icing systems;

Based on these inputs, the system calculates the output data, highlighted in the yellow box. In more detail:

- flap setting (5°);
- acceleration altitude in case of engine failure (1500 ft);
- decision speed V1 (145 kt);
- rotation speed VR (149 kt);
- V2 take-off speed (156 kt);
- Vref 30° landing reference speed with flaps at 30° (143 kt).

The assumed sel temp (56°C) and the maximum engine derating for reduced thrust take-off, D-MAX (92.6%), are also indicated.

The screenshot clearly shows that the take-off weight entered was approximately 100000 kg less than the TOW reported on the final loadsheet.

The calculations made after the event using the take-off weight from the final loadsheet resulted in the data shown in Photo 11. The difference between the calculated and entered take-off parameters and the parameters predicted for the actual TOGW is summarized in the comparative table (Table 1).

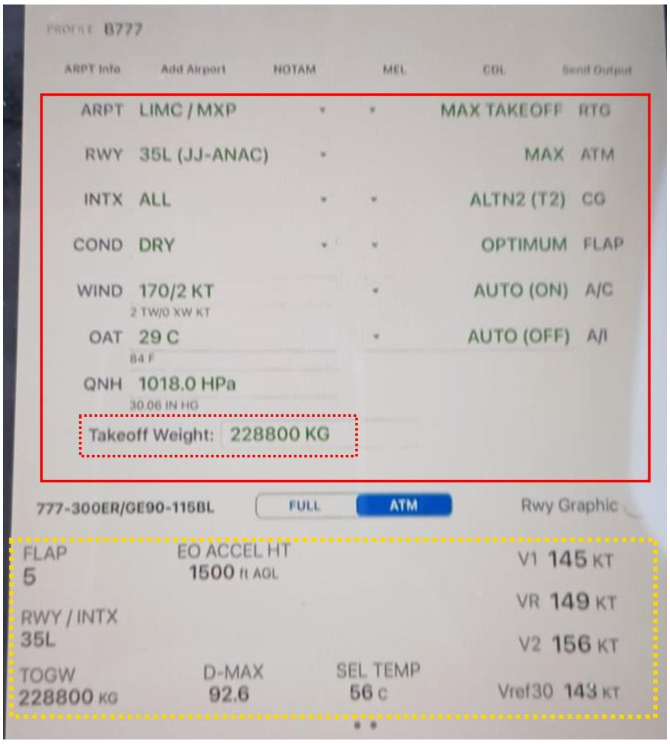

Photo 10: OPT/iPad screen. The red box shows the data and selections made by the pilots. The dotted red box shows the Take-off Weight entered, equal to 228,800 kg. The yellow box shows the data resulting from the OTP calculation.

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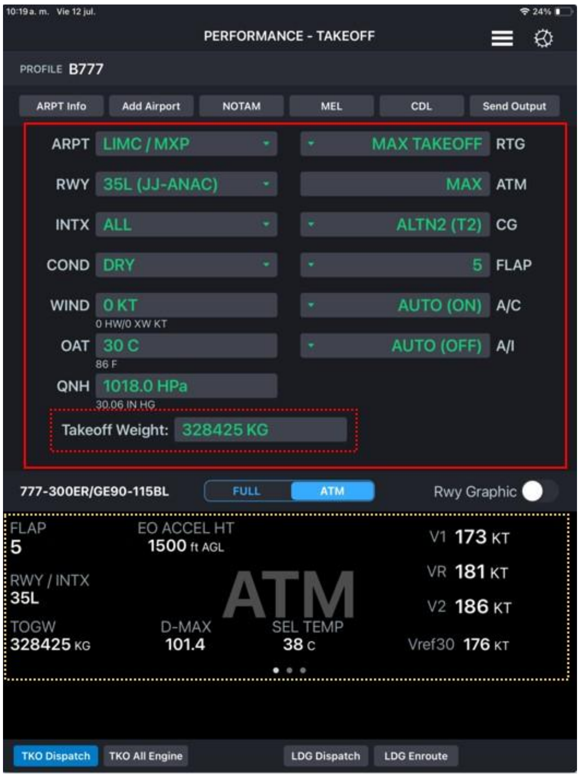

Photo 11: calculations performed after the event using the Take-off Weight from the final loadsheet (in the red dotted rectangle), entering the flap configuration at 5° for comparison with the speeds entered in the event flight.

	Incorrect TOGW	**Actual TOGW**	**Difference**
TOGW	228800 Kg	328425 kg	-99625 kg
Flap setting	5°	5°	0°
V1	145 kt	173 kt	-28 kt
VR	149 kt	181 kt	-32 kt
V2	156 kt	186 kt	-30 kt
Sel. Temp.	56°	38°C	-18°C
D-Max	92.6%	101.4%	-8.8%

Table 1: Comparison of take-off data calculated on OPT with incorrect TOGW with data with actual TOGW.

With regard to the fields that are included in the OPT, the TOGW data is required, as it is not present on the CDU and it can be found on the final loadsheet.

1.18.6. Issues relating to the use of incorrect take-off performance data

There is extensive literature on the use of incorrect performance data during take-off. The investigation into LA8073 referred to:

- studies on the issue (from 2008 to 2012);
- investigation reports on tail strike events or insufficient thrust during take-off and related safety recommendations addressed to manufacturers and aviation authorities in an attempt to mitigate the phenomenon (in particular those formulated by the BEA, the DSB, and the AAIB UK);
- actions taken by the aviation authority (starting in 2010 with the issuance by EASA of Notice of Proposed Amendment 2025-01, which took place after the event, when the safety investigation was underway).

Studies related to the use of incorrect performance parameters during take-off.

During the investigation, the following were consulted:

1. *Use of erroneous parameters at take off,* Laboratory of Applied Anthropology (LAA) published by BEA, 2008[18];
2. *Take-off performance calculation and entry errors: a global perspective,* published by ATSB, 2009[19];
3. *Performance Data Errors in Air Carrier Operations: Causes and countermeasures, published by NASA, 2012*[20].

[18] https://bea.aero/fileadmin//uploads/tx_scalaetudessecurite/use.of.erroneous.parameters.at.take-off_03.pdf
[19] https://www.atsb.gov.au/publications/2009/ar2009052
[20] https://ntrs.nasa.gov/api/citations/20140004900/downloads/20140004900.pdf

Studies on the issue of using incorrect parameters during take-off agree that this type of error represents a real and recurring risk in aviation operations, even in highly standardized professional contexts.
The documented cases concern, in particular, the incorrect entry or management of critical data such as aircraft weight (ZFW, TOW) and reference speeds (V1, Vr, V2), with consequences ranging from rotation anomalies to more serious events such as tail strikes, take-off with insufficient thrust, or significantly degraded performance.
The investigations conducted agree that these errors are not attributable to individual behavior, but develop within a complex system in which technical, organizational, cognitive, and ergonomic factors interact. In many cases, input errors are facilitated by the similarity between different data (e.g., between ZFW and TOW), unclear interfaces in onboard systems, or procedural flows that do not reflect the actual operational order of activities in the cockpit. Additional critical elements include time pressure, interruptions during preparation phases, and the tendency to consider values that appear consistent with experience or expectations to be reliable.
Field observations have shown that the procedures set out in the operating manuals, although formally correct, are often reorganized or simplified to adapt to actual conditions, especially in the event of last-minute changes, delays in receiving the load sheet, or changes in the runway in use or the take-off alignment point. This discrepancy reduces the effectiveness of cross-checks, which tend to lose their independence or be perceived as redundant.
To mitigate these risks, all studies recommend multi-level interventions. Some of the main corrective actions proposed are:

- improved ergonomics of human-machine interfaces (FMS, CDU/MCDU, EFB);
- greater automation and consistency in data transmission between different onboard and ground systems;
- introduction of alerts for detecting inconsistent data, and a strengthening of functional and symbolic barriers (i.e., more intuitive interfaces, use of colors, clear feedback).
- culture of independent verification and specific training for the effective management of last-minute changes.

1.18.7. Investigation reports relating to similar occurrences, Boeing 777-F registration F-GUOC, May 22, 2015 at Paris Charles-de-Gaulle Airport.

Among the numerous events recorded, here is a summary of the information published by the BEA regarding the serious incident involving the Boeing 777-F registered F-GUOC that occurred in 2015[21]. This event is very similar to that of flight LA8073 B777 PT-MUG.

The serious incident involving the Boeing 777-F registered F-GUOC occurred on May 22, 2015, during a cargo flight taking off from Paris Charles-de-Gaulle airport with four pilots on board. The investigation established that the crew, when calculating the take-off performance, used an incorrect weight, which was 100 tons less than the actual weight. As a result, the aircraft rotated at a lower speed than necessary, and the tail strike protection was automatically activated. The aircraft flew over the opposite threshold of the runway at an altitude of only 170 feet and continued to climb at maximum thrust.

During the climb, the crew realized their mistake but decided to continue the flight to its destination.

Among the causes and contributing factors identified, the BEA report lists the following:

The flight over the end of the runway at a low height, during take-off, is the result of a take-off being started with erroneous parameters (take-off speeds too low, and insufficient flap deflection and thrust).

The erroneous parameters, entered in the FMS and used for the take-off were the result of a performance calculation based on a weight which was 100 tonnes below the actual weight of the aeroplane.

The error of 100 tonnes occurred when each member of the crew estimated the planned weight and entered it in their EFB.

The following elements may have contributed to the 100 tonnes error not being detected and its propagation:

- *The crew's handling of take-off weight data in numerous formats, on various media and with various denominations.*
- *The non-mobilisation of orders of magnitude partly related to the increasing use of performance optimization tools.*
- *Insufficiently robust procedures including numerous basic checks, incompletely taking into account the operational context and how the crew works. These procedures are*

[21] https://bea.aero/en/investigation-reports/notified-events/detail/serious-incident-to-the-boeing-777-f-registered-f-guoc-and-operated-by-air-france-on-22-05-2015-at-paris-charles-de-gaulle-95/

notably based on a double calculation supposed to be independent, whereas a simple verbalization may undermine this independence. These procedures do not include a means of detecting gross errors or a simultaneous check of the three media using weight data (Final Loadsheet, OPT and FMS).

- *The absence on this aeroplane, as on the majority of commercial air transport aeroplanes, of systems to detect or prevent such gross errors and to warn the crew of them, or of systems to warn the crew that the performances measured during the take-off run are insufficient*

1.18.8. Safety recommendations previously issued by other investigative authorities

Investigations conducted by various investigative authorities into tail strike or insufficient thrust during take-off occurrence, with particular reference to BEA, AAIB UK, and DSB, have resulted in numerous safety recommendations addressed to aviation authorities and manufacturers.

The recommendations agree that in order to mitigate the issue, it is important to intervene at various levels to:

1. Improve the consistency and readability of critical data (weight and speed): differences in formats, names, and units of measurement between various media (flight files, load sheets, EFB interfaces) increase the risk of errors and confusion between ZFW, TOW, etc.; it is therefore desirable to harmonize such data to facilitate verification and reduce the cognitive load on crews.

2. Strengthen operating procedures by validating them in a real-world context: the fragility of many procedures has been repeatedly noted, as they are often poorly adapted to the actual operating conditions in which flight preparation takes place. The recommendations call for verification of the robustness of procedural sequences under operating conditions, with attention to time and organizational constraints.

3. Strengthen protections against the entry of incorrect speeds, inconsistent or unrealistic data: the lack of protections in FMS systems that allow the manual entry of values below the minimum thresholds (V1MIN, VRMIN, V2MIN) has been highlighted. A review of the systems is recommended to ensure explicit and visible alerts, and more comprehensive technical documentation from manufacturers to better explain the functions of existing systems.

4. Promote and develop advanced technical systems, where broad agreement has been expressed on the need for:
- automatic on-board weighing and balancing systems (OBWBS);
- take-off performance monitoring systems (TOPMS);
- detection/warning systems for incorrect, unrealistic, or inconsistent data entry.

These are considered key tools for breaking the chain of error by detecting anomalies before they can have operational consequences.

5. Overcoming exclusive reliance on procedural barriers: the investigating authorities emphasize that operational measures alone (such as manual cross-checks between crew members) are not sufficiently reliable, especially in complex or pressured contexts. It is therefore recommended that technical and automated barriers be integrated as structural support for the decision-making process.

6. Encourage an active role for regulatory authorities: the recommendations urge EASA and FAA to take a proactive role, not just observing industry developments, but promoting the definition of technical requirements, standardization, and dissemination of existing or developing solutions. In particular, they call for the development of system-level action plans, without waiting for ongoing projects to reach full maturity.

1.18.9. Actions taken by EASA

In recent years, EASA has received numerous recommendations from aviation safety investigation authorities following accidents and serious incidents related to the use of incorrect take-off performance parameters or the start of the take-off run from incorrect positions.

Despite previous non-regulatory actions, such as safety information bulletins (SIBs), safety promotion activities, and procedural updates, such events have continued to occur.

Occurrences per Manufacturer		Accidents per Manufacturer		Fatal Accidents per Manufacturer	
Airbus	42	Airbus	3	Airbus	0
ATR	1	ATR	0	ATR	0
Boeing	64	Boeing	10	Boeing	3
Bombardier	1	Bombardier	1	Bombardier	1
Dassault Aviation	1	Dassault Aviation	0	Dassault Aviation	0
Embraer	4	Embraer	0	Embraer	0
Gulfstream Aerospace	1	Gulfstream Aerospace	0	Gulfstream Aerospace	0
Ilyushin	1	Ilyushin	1	Ilyushin	1
McDonnell Douglas	3	McDonnell Douglas	3	McDonnell Douglas	0
Total	**118**	Total	**18**	Total	**5**

Table 2: events characterized by errors in the calculation or entry of take-off and/or runway positioning parameters for take-off, broken down by aircraft manufacturer, recorded between 1998 and 2023. Source: EASA Notice of Proposed Amendment 2025-01(A).

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In view of this and considering that the technology for onboard detection and warning systems is now mature (in some cases already certified), EASA launched the ToR RMT.0741[22] regulatory initiative in 2023, which led to NPA 2025-01 in 2025[23].

This proposal includes amendments to the certification specifications (CS-25), additional airworthiness requirements (Part 26 of Regulation (EU) 2015/640), and guidance material (CS-26). In summary, it provides for:

- For new large aircraft designs (new CS-25 type certifications), the requirement to equip a Take-Off Performance Monitoring System (TOPMS) with functions:
  - F1 – verification and alerting of errors in take-off performance parameters;
  - F2 – verification and alerting of errors in the position and orientation of the aircraft at the moment of take-off;
  - F3 – real-time monitoring of performance during take-off (required only for so-called "large transport aeroplanes").
- For aircraft already certified but still in production, intended for commercial air transport, the compliance obligation will apply to those with airworthiness certificates issued after a

[22] Within EASA, a "Term of Reference" (ToR) for a rulemaking activity is a document that defines the purpose, objectives, scope, and responsibilities of a working group or committee tasked with developing new regulations or amending existing ones. Essentially, the ToR provides clear and detailed guidance on what needs to be done and how, ensuring that the rulemaking process proceeds efficiently and consistently.
In particular, ToR RMT.0741 can be consulted at the following link: https://www.easa.europa.eu/en/document-library/terms-of-reference-and-rulemaking-group-compositions/tor-rmt0741.

[23] An NPA, or "Notice of Proposed Amendment," is a proposal to amend or update a regulation or technical specification by EASA (European Aviation Safety Agency). It is a document that is published to inform industry, stakeholders, and the general public of a proposed change to aviation safety regulations or certification specifications.
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cut-off date, expected to be six years after the entry into force of the amended regulation (assuming that the RMT ends in 2027, approximately from 2033).

These measures aim to standardize protection against take-off errors in the fleet of large aircraft, imposing requirements proportionate to the risk and encouraging the adoption of technologies already available on the market.

NPA 2025-01 does not provide for mandatory retrofits for aircraft already in service (i.e., those that have already received their airworthiness certificate before the established date).

In fact:

- The requirement to install TOPMS applies only to large aircraft (CS-25) that:
    - receive new type certifications after the amendment to CS-25 enters into force; or; or
    - receive their first individual airworthiness certificate starting from 6 years after the entry into force of the amendment to Regulation (EU) 2015/640 (i.e., approximately from 2033).

During consultations with manufacturers, EASA rejected the retrofit option for the following reasons:

- high cost and technical complexity of adapting existing systems;
- lack of standardization in onboard avionics systems;
- opinion shared by many stakeholders (Airbus, Boeing, Embraer, ATR, Dassault, De Havilland, etc.) that a generalized retrofit would not be justifiable in terms of cost/benefit ratio.

However, some manufacturers (e.g., Airbus) offer optional retrofits on a voluntary basis for certain types of aircraft that are already certified, responding to demand from operators interested in improving the safety levels of their fleets.

1.18.10. EASA SIB No.: 2016-02R1 06 September 2021 Use of Erroneous Parameters at take-off.

EASA has published a Safety Information Bulletin SIB n° 2016-02R1 dated 6 September 2021 entitled “Use of incorrect parameters during take-off” to alert operators and flight crew to the issue and recommend the implementation of operational mitigation measures (https://ad.easa.europa.eu/ad/2016-02).

SIB EASA focuses primarily on errors made by flight crew when entering data into the Electronic Flight Bag (EFB) or Flight Management System (FMS) during flight preparation. The main human factors contributing to these errors are pressure during time-sensitive operations and interruptions to activities, with consequences such as taking off without adequate engine thrust or attempting to rotate at a speed that is too low for the actual aircraft mass/take-off configuration or with insufficient runway length remaining. In most of the cases examined, the flight crew had entered inadequate values in the FMS for take-off weight, safety speed values, or target take-off thrust in relation to the runway in use.

The purpose of the SIB, in conjunction with the procedures and guidelines provided by aircraft manufacturers, is to:

- raise awareness among flight crews, operators, and relevant authorities about the specific hazard;
- provide recommendations to operators on completing a specific safety risk analysis and assessment related to this issue, in order to evaluate the effectiveness of existing mitigation measures and determine the need for additional or alternative actions;
- provide recommendations on training elements to emphasize during initial and recurrent flight crew training to increase awareness of the issue.
- provide recommendations on the use of the FDM program to identify precursor events.

Analysis of the EASA survey on incorrect take-off parameters suggests that implementing even a few algorithms specific to FDM events or measurement algorithms could help improve the detection of related events and assess their frequency and severity.

FDM can be used to systematically detect signals of insufficient take-off performance. Once the FDM software detects a take-off with insufficient performance, the operator can request a report from the flight crew (in accordance with the agreed procedure for preventing disclosure of the crew's identity). They can then analyze the event to determine whether it was caused by incorrect input of take-off parameters or other factors. FDM can also help operators assess the frequency and severity of events related to this issue as part of their established safety risk management processes and, consequently, evaluate the effectiveness of the risk mitigation measures implemented in their organization. The European Operators Flight Data Monitoring forum (EOFDM)[24] has proposed several methods for monitoring take-off performance with

[24] See https://www.easa.europa.eu/en/domains/safety-management/safety-promotion/european-operators-flight-data-monitoring-eofdm-forum

FDM. In particular, the “FDM precursors” listed are considered relevant. The survey conducted by EASA suggests that these precursors could be implemented by most operators.

1.19. USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

Not applicable.

CHAPTER II

ANALYSIS

2. GENERAL INFORMATION

The objective evidence gathered during the investigation, 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. Conduct of operations

2.1.1. Flight preparation and ground procedures.

The flight preparation activities were carried out regularly and without unexpected events, although at the end of the pre-flight procedure, the LTC commented that the time available for ground operations had been just sufficient to complete the procedures by the scheduled departure time.

Throughout some of the pre-flight procedures and checks, the LTC provided guidance and suggestions to the captain in training, in view of the latter's upcoming check flight, which was to take place on the flight following the event; this resulted in some interruptions in the flow of procedures.

The final loadsheet was received about ten minutes before pushback. The pilots checked the data together and entered it into the CDU. The ZFW data was entered in the CDU correctly.

To obtain the TOGW to be entered in the OPT, the LTC read the GR WT data presented on the CDU and mentally subtracted the fuel that he expected would be consumed during taxiing (approximately 400 kg in the case of Malpensa). The LTC announced the result of the subtraction aloud, which was approximately 100000 kg (228.8 tons instead of 328.4 tons) less than the correct result, thus causing both pilots to enter the incorrect data on the iPad. Even at this stage, the LTC actively followed the data entry and reading operations of the OPT carried out by the captain in training, providing instructions on how to perform them. In addition, at that moment, a radio call was made by Malpensa Delivery communicating the push order, to which the LTC responded.

In addition, the LTC corrected the captain in training regarding the entry of a setting on the OPT (the parameter relating to the CG, indicated on the final loadsheet as T2). When cross-checking the results, the two pilots found the same speed, configuration, and engine settings data on their respective iPads, but both were based on an incorrect take-off weight. The check was carried out only on the data on the two iPads without checking the data entered in the iPad/OPT with the final loadsheet and the CDU.

The subsequent entry of data from the OPT to the CDU was done by dictation, i.e., the LTC read the data from the iPad and the captain in training entered the data on the CDU. While the captain in training was entering the data, the LTC observed and commented on the appearance of the message V–SPEEDS UNAVAILABLE on the CDU scratchpad.

The captain in training asked why the FMC calculated V-speeds (reference) were not displayed on the CDU. The cruise captain pointed to the selector that should have enabled their display, which was already in the correct position, but no one could explain why the FMC V-speeds were not appearing on the CDU.

To explain the appearance of the message and the absence of the FMC V-speeds, it should be borne in mind that the OPT calculation based on the (incorrect) TOGW entered by the crew (228,800 kg) resulted in a flap setting (5°), D-max (92.6), Sel Temp (56°) for a 35L take-off runway with the entire length available. The resulting speeds based on the entered take-off weight (228,800 kg) were V1 145/ VR 149 /V2 156 kt.

After the flight crew entered the flap setting (5°), D-max (92.6), Sel Temp (56°) for a T/O RWY 35L resulting from the OPT calculation with the incorrect take-off weight (228800) on the CDU TAKE-OFF REF page, the FMC, based on the actual GR WT of 328800 kg, was unable to calculate a valid take-off solution for the given conditions, which caused the FMC to not display valid FMC V-speeds and to display the message V-SPEEDS UNAVAILABLE on the CDU scratchpad.

In particular, the failure of the FMC to display FMC V-speeds and the V-SPEEDS UNAVAILABLE message was caused by the selected assumed temperature of 56 °C, calculated for a weight 100000 kg less than the actual TOGW, which, when entered into the FMC, prevented the latter from calculating a valid take-off solution within the available runway length for the given conditions.

If the performance calculations had been made using the correct weight, both the OPT and the FMC would have returned, as expected, valid V-speeds of approximately 172/181/186 kt.

Although the speeds obtained based on an aircraft weight of 100000 kg less than the actual weight were significantly lower than those that would have been obtained with the actual weight and those obtainable with the weights typically used for that type of aircraft, the crew did not pay sufficient attention to the problem of the V-SPEEDS UNAVAILABLE message.

2.1.2. Take-off phase

During the take-off run, the captain in training (CM1 PM) called out 80 kt, then the synthetic voice announced V1 at 145 kt.

At 148 kt, CM1 announced VR and CM2 LTC PF began rotation at 150 kt, raising the NLG after one second.

The LTC set the intended take-off attitude at a rotation speed 32 knots lower than the intended rotation speed for the aircraft's actual TOGW. In addition, due to an assumed sel temp 18°C higher than the value intended for the aircraft's TOGW conditions, the engines were delivering less power.

Four seconds after the start of rotation, the aircraft's attitude was 8.3° pitch and, at a speed of 160 knots, the tail strike protection command was active (6 units). Immediately afterwards, the tail strike began. Five seconds after rotation began, the LTC exclaimed that the aircraft was not behaving as usual. At that point, the aircraft had already greatly exceeded the decision speed, which was unreliable as it was calculated on an incorrect weight and with an inadequate engine thrust selection; therefore, the option of aborting the take-off was not feasible. At the same time, the aircraft was not responding to the take-off input.

This situation caused the LTC to experience a startle effect[25]. This reaction is plausible given that, until the rotation occurred, the PF had no warning or parametric reference to alert him to the problem. Twelve seconds after the start of rotation, the cruise captain, who was not directly involved in the maneuver and therefore had a greater margin of cognitive capacity, ordered TOGA to be selected, issuing the command twice in quick succession. On the second command, the LTC selected TOGA. The aircraft lifted off the ground at a speed of 178 kt, when it was about 800 meters from the end of the runway. It took an additional 6 seconds for the engines to accelerate to maximum power of 106% N1. Once positive climb indications were obtained, the LTC ordered the landing gear to be retracted. Twenty-one seconds after the start of rotation, the aircraft was directly above THR18R at an altitude of 155 ft and an IAS of 181 kt.

After completing the after-take-off checklist, the LTC ordered a change of positions. The cruise captain took the place of CM2 and the LTC took the place of CM1.

[25] See note 17.

2.1.3. Abnormal procedure management and landing

The subsequent phases of managing the abnormal procedure, the checks after take-off and before landing, and the fuel dumping procedure were carried out in accordance with company standards and without any significant incident.

2.2 Environmental factor

Environmental conditions at the time of take-off were good: optimal visibility (CAVOK), light and variable winds, a temperature of 30°C, and QNH 1018 hPa. No meteorological factors were identified that negatively affected the take-off or directly contributed to the occurrence of the event. The length of the runway (TODA = 3974 meters), used in its entirety for take-off, contributed to the successful take-off and separation from obstacles. The pilots had previously operated at Milan Malpensa, so they were familiar with the airport environment and related procedures.

2.3 Technical factor

No technical issues were recorded that could have contributed to the accident. There were no technical limitations (MEL) to be taken into account when calculating performance. The EICAS TAIL SKID indication (indicating a discrepancy between the position of the tail skid and the landing gear, i.e., that the tail skid is not in the correct position) was consistent with the damage sustained by the system during the tail strike. The BOTTLE DISCH APU indication (indicating low pressure in the APU extinguishing cylinder) is also attributable to the consequences of the tail strike.

2.4 Human factor

The crew was engaged in the return flight to Brazil. The pilots met the requirements for performing the flight and rested the required periods. Although the rest period had been guaranteed, the crew was still outside their normal circadian rhythm (Brazilian local time), as Italy was five hours ahead of local time in São Paulo during the summer. Air travel involving crossing multiple time zones can cause disturbances to the internal biological clock, which can lead to jet lag[26].

[26] For the definition of jet lag, reference is made to the ICAO definition (Doc 9966 FRMS Manual for Regulators): *Desynchronization between the circadian biological clock and the day/night cycle caused by flights crossing a significant number of meridians (perceived as a sudden change in the day/night cycle). It also causes internal desynchronization between the rhythms of different bodily functions. Common symptoms include the desire to eat and sleep at times that are*

During the delicate phase of entering the data necessary for calculating take-off performance, the LTC dictated aloud (at the time of the event, the procedures did not yet indicate that this practice was prohibited) the incorrect take-off weight (100000 kg lower) instead of having the pilot in training perform the calculation independently and verify it by cross-checking the data, as required by the procedures. This deviation from the standard procedure (which at the time of the events was not unequivocally detailed) created a cognitive dependency and eliminated a key opportunity to detect the error: LTC's action transformed a formally redundant and protected procedure (independent calculation and verification of data) into a "single point of failure" procedure. In fact, since both pilots used the same incorrect data communicated verbally, the calculation on their respective OPT apps produced the same incorrect result, which, due to the consistency of the two results, was considered correct.
In order to carry out its duties as LTC, and in particular by explaining how to perform tasks and supervising them at the same time, LTC has taken on multiple roles (instructor, procedure validator, and supervisor).
Furthermore, during the accident flight, he was acting as PF from the right seat (CM2), which was not his usual position. This probably required him to adapt to differences in movements and work organization in the cockpit. The above could plausibly have increased the LTC's cognitive load, reducing his level of attention when performing calculations and his ability to correctly evaluate weak signals, such as the V SPEEDS UNAVAILABLE message. Neither the captain in training nor the cruise captain had ever experienced such a message. The crew was unaware of the mechanisms that generate this warning and attributed its occurrence to a minor discrepancy between the speeds calculated by the system and those entered manually.
In any case, the errors made when entering the data used to calculate take-off performance could have been recognized by any member of the crew by making a quick mnemonic comparison with what would have been expected under similar conditions for that type of aircraft.
In this context, it should be noted that the LTC operated on both B777 and B787 aircraft. Operating on different aircraft models may have made it more difficult to memorize the characteristic parameters.
The captain in training, was about to make his tenth flight on a B777 and had no further experience on aircraft of comparable size, having mainly operated as captain on A32F aircraft.

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not in line with the local routine, digestive problems, decreased mental and physical performance, and mood changes. It resolves when you spend enough time in the new time zone for your circadian clock to fully adjust to the local time.

This could also explain why this crew member lacked knowledge of the typical parameters of the B777. In addition, the next flight was to be a line check, and the LCT, in preparing for the flight, was being didactic in order to facilitate his preparation. This inadvertently led to deviations from the normal flow of standard procedures, with a loss of clarity regarding the division of duties. In addition, a sort of functional and psychological dependence on the captain in training was likely to have developed. In fact, the LTC was the technical and hierarchical authority figure. Any doubts that arose in the pilot in training (who in fact "suspected that something was wrong") may not have been explored with sufficient critical thinking.

Since the LTC took control of the procedural flow and personally dictated the data, the commander in training may have unintentionally abandoned his critical judgment in consideration of the authority gradient. This led to an erosion of the safety barriers provided by CRM[27].

Finally, the second in command (cruise captain) had mainly experience on B767 but not on B777, which he had only been flying for a few months.

The crew completed the ground operations required before start-up at the time of pushback authorization, to the extent that the LTC commented that it would have been better, as a procedure, to opt for a presentation at the aircraft an hour and a half before take-off. The need to comply with the EOBT may have created a form of operational pressure and prevented a more in-depth examination of the issue relating to the message that appeared on the CDU.

Once again, as demonstrated by past events and emphasized by numerous studies on the issue, due to the variety and unpredictability of the factors that influence such calculation and data entry errors (fatigue, distraction, haste, reduced concentration, cognitive process saturation), it is clear that existing procedures, while minimizing the incidence of the phenomenon, are not able to prevent these factors from occurring in every situation and under all circumstances.

For this reason, it is crucial to implement technologies, some of which already exist and are certified, through the introduction of regulatory requirements that provide for the presence of systems designed to promptly inform or alert the flight crew of any inconsistencies in the data entered.

[27]Standard crew resource management (CRM) procedures require each crew member to operate independently within clear roles and structured cross-checks (which at the time and in reference to the circumstances of the event would not appear to have been sufficiently clear and detailed).

With regard to the crew's reaction during take-off, it may be interesting to note that the sequence of events recorded in the accident involving the PT-MUG, is mirrored in terms of reaction times by what was recorded in the aforementioned F-GUOC event. In this regard, the BEA report states the following comment:

"Eight seconds were then necessary for the crew to opt for TOGA thrust and to apply it. This period seems consistent with the element of surprise, that the problem was not understood and that the application of full thrust is not the sole and obvious solution.".

2.5 Organizational factor

2.5.1. Operator LATAM

At the time of the event, the procedure with EFB on the LATAM FCOM required one crew member to calculate preliminary data relating to take-off and landing performance and the other crew member to verify these calculations. The MGO specified that this procedure had to be performed individually; therefore, the two publications were not perfectly aligned.

In addition, it was not defined how the TOGW calculation is performed or where the data is taken from, nor is it specified whether the TOGW field on the CDU, which is present but not automatically calculated by the system, should be filled in or not.

At the time of the event, it was not specified that the calculation should be performed without stating the result aloud.

TOGW is a fundamental piece of data in calculating performance using OPT. However, this data is not automatically present on the CDU, but must be entered manually. If standard procedures are not sufficiently clear in establishing that the data must be read on the final loadsheet, it is possible that pilots, as in the case of the accident, may perform a subtraction operation starting from the GR WT and removing the taxi fuel, exposing themselves to a risk of error. The same applies to the subsequent check of the TOGW data entered on the OPT to validate the performance calculation results, which cannot be read on the CDU/FMC.

The data entry error was not detected due to weak operational barriers and an FMC system interface that did not clearly highlight the loss of protections in the take-off speed calculation.

There was no codified procedure for cross-checking ZFW, TOGW, and OPT data, i.e., not only the result from the OPT calculations but also the data entered to perform the calculations.

In addition, crew training, both in terms of instruction and flight safety promotion, did not appear to adequately emphasize the importance of correct weight data entry and FMC anomaly message management.

At SMS level, there is no evidence that FDM tools were implemented at the time of the events to monitor exposure to the risk of using incorrect take-off performance calculations. Furthermore, there is no evidence that tail strike was indicated in the hazard log.

2.5.2. Aircraft manufacturer (Boeing)

The accident involving the B777 registration PT-MUG is one of a series of events[28] involving a B777 in which the flight crew did not detect or understand the V-SPEEDS UNAVAILABLE message and the concomitant absence of V-speeds computed by the FMC.

The FCOM indications, cited in the FMC Entry Error Messages section, for this message include the need to modify the GR WT or takeoff thrust limit to allow the calculation of V-speeds.

It should be noted, however, that the FMC Entry Error Messages section regarding the V-SPEEDS UNAVAILABLE provides generic indications (for certain high/thrust/low gross weight or low thrust/ high gross weight takeoff conditions) and does not mention the possibility of entering performance data that would make it impossible for the FMC to calculate a valid takeoff solution for the given conditions.

Boeing explained that data that may inhibit the calculation of FMC in takeoff performance includes high altitude/high temperature conditions extending a calculated takeoff run beyond the available runway, by an inappropriate derate setting in the takeoff calculations, or by other environmental factors in the takeoff performance calculation or inaccurate information input into the FMC.

The fact that none of the three pilots understood the reason for the message appearing, i.e., the system's inability to compute a valid takeoff solution for the given conditions, would confirm critical issues identifiable in insufficient clarity in the documentation (FCOM) and the message itself.

In any case, the Performance Dispatch section of the FCOM states that takeoff is not allowed when the V SPEEDS UNAVAILABLE message is displayed. The examples cited to explain the conditions under which this situation can occur do not cover the actual situation that led to the accident. This situation was in fact the result of the use of incorrect parameters when calculating takeoff performance and the subsequent entry of the resulting data into the FMS. The corrective measures proposed by the FCOM suggest changing the flap selection, selecting reduced thrust, and/or adding weight. However they do not warn of the need to verify the data

[28] PH-BVG occurred in 2013, F-GUOC in 2015, VT-JEW in 2017. .

entered, which may be incorrect and prevent the FMS from calculating a valid takeoff solution for the given conditions.

Since the flap configuration and engine power settings, resulting from the incorrect calculation of the aircraft weight, do not allow the system to perform the calculation, the FMS protection that prevents the entry of values lower than the calculated minimum speed (V1, VR, V2) is no longer available. Therefore, the event demonstrated that it is possible to enter speed data below V1MIN, VRMIN, and V2MIN (normally calculated by the FMS), potentially reinforcing the belief that the action is correct even in the face of a calculation error.

2.5.3. Aeronautical authority EASA

NPA 2025-01 and Safety Information Bulletin (SIB) 2016-02R1

The latest initiative by EASA, namely the regulatory proposal contained in NPA 2025-01, *takes into account* the safety recommendations already issued on this matter by BEA (France), the Dutch Safety Board (Netherlands), and the UK AAIB (United Kingdom). In any case the measures implemented will affect only new designs or aircraft in production.

The above recommendations essentially called for:

- the mandatory introduction of take-off performance monitoring systems (TOPMS);
- the requirement for onboard weight and balance monitoring systems;
- the detection of gross errors in the data entered on board.

EASA concluded that mandatory retrofits should not be imposed in light of the following considerations:

- cost and technical complexity of retrofitting aircraft already in service are high.
- existing fleets are very heterogeneous.
- some manufacturers have not even planned to develop these systems.

Regulatory proposal NPA 2025-01 represents a significant and consistent step toward increasing operational safety during take-off, addressing a known and well-documented risk in a structured manner. However, the impact of the proposal is limited in the short and medium term, as it excludes aircraft currently in service, i.e., those most exposed to the risk to be mitigated, from the TOPMS installation requirements. The accident involving the B777 PT-MUG at Malpensa in 2024 is a concrete and actual example of this.

In this context, the practices already suggested in Safety Information Bulletin (SIB) 2016-02R1, could represent a fundamental risk mitigation for the period associated with the implementation of NPA 2025-01 (at least until 2033) and for all aircraft not affected by the related implementations.

CHAPTER III

CONCLUSIONS

3. GENERAL INFORMATION

This chapter reports the facts ascertained during the investigation and the causes of the event.

3.1 EVIDENCE

- The flight crew members possessed the necessary aeronautical qualifications to perform the flight in question.
- The aircraft was airworthy.
- Weather conditions at the departure airport were suitable, with an OAT of 30°C.
- Runway 35L had a TODA of 3974 m.
- The crew consisted of a captain in training on the B777 in the left seat (CM1) as PM, an LTC in the right seat (CM2) as PF, and a second captain (CM3) as cruise captain.
- The LTC intervened verbally, occasionally providing indications to the captain in training during the execution of some of the pre-flight phases (CDU preflight procedures, EFB procedures, before start procedures).
- To obtain the data to be entered in the OTP for performance calculation, the LTC considered the GR WT displayed in the CDU, mentally subtracted the taxi fuel, made a calculation error, and announced the result aloud.
- The take-off weight taken into account in each OPT for the calculation of the parameters was incorrect by 100 tons.
- The crew entered into the FMS the take-off parameters (flap configuration, thrust, speed, etc.) calculated with the OPT based on a take-off weight 100 tons lower than the actual take-off weight.
- The way in which cross-checks were performed in the cockpit did not allow the 100-ton error for the takeoff weight inserted in the OPT and the resulting incorrect parameters, to be detected.
- Infact the cross-check for validation was performed on the results provided by the OTP on the iPad without comparing the values entered (TOGW) on the iPad with those reported on the final loadsheet and entered on the FMC CDU (ZFW and resulting GR WT).

- The operator procedures in the FCOM did not provide sufficiently detailed instructions for selecting the TOGW data and the need to perform calculations without stating them aloud.
- The pilot in training noted that the FMC computed speeds were not available on the CDU, and the LTC read the message V-SPEEDS UNAVAILABLE on the scratchpad.
- The B777 FCOM manual explains in broad terms only the logic behind the speed calculations and the meaning of the V-SPEEDS UNAVAILABLE message (in this specific case, low thrust/high weight).
- The procedures did not provide for simultaneous verification of the take-off weights considered in the final load sheet, the OPT (EFB), and the FMS.
- The procedures did not include a systematic means of detecting gross errors (e.g., orders of magnitude or reference speeds).
- The issues identified in the accident had already been identified at least in three international studies on the use of incorrect parameters.
- Following the entry of take-off parameters into the FMS, the meaning of the V-SPEEDS UNAVAILABLE message and the absence of the FMC computed speeds were not understood by the crew. This message should have allowed the crew to detect inconsistencies in the data entered.
- The FMS allows take-off speed values to be entered that are inconsistent with the take-off weight calculated by the FMS.
- When the FMS is unable to calculate the reference speeds (V-SPEEDS UNAVAILABLE message), the crew is not warned of the loss of protection against entering speeds that are too low, below V1 MIN, VR MIN, and V2 MIN normally calculated by the FMS.
- Ground preparation procedures were completed at the same time as the pushback and start-up authorization. The LTC commented on the advisability of arriving at the aircraft early in order to have time to carry out the procedures within the scheduled time and more calmly.
- The aircraft was preparing for take-off from RWY35L with a planned rotation speed of 149 kt with a flap configuration of 5° and a selected temp of 56° (N1 92.6%). The appropriate parameters for the actual weight were a rotation speed of 181 kt and a sel temp of 38° (N1 101.4%).

- Tail strike protection was activated during rotation and the pitch stabilized at approximately 8.3°.
- The LTC PF found himself in a situation where the option to abort take-off was not feasible and at the same time the aircraft was not responding to take-off inputs.
- TOGA thrust was applied by the PF on the command of CM3 approximately eight seconds after the tail strike began.
- The aircraft took off at a speed of 178 knots, approximately 800 meters from the end of the runway, and flew over the opposite threshold at an altitude of approximately 155 feet.
- Once airborne, the crew declared PAN, PAN and coordinated with air traffic control to perform fuel dumping, discharging approximately 72 tons of fuel.
- The landing took place approximately one hour and ten minutes after take-off on RWY35R.
- Between 1999 and 2015, at least 31 serious incidents and accidents in commercial aviation were investigated that were caused by incorrect parameters being entered at take-off, including three with fatalities.
- International studies and reports by investigative authorities have all highlighted the advantages, but above all the limitations, of operational safety barriers.
- International studies and reports by investigative authorities have all suggested the development of new technical solutions to reduce input errors and their consequences.

3.2. CAUSE

The tail strike during take-off was caused by a rotation that occurred at a speed significantly lower than that expected for the actual weight of the aircraft. This occurred after the flight crew entered take-off performance data (rotation speed and engine settings) into the FMS that was calculated for a take-off weight significantly lower than the actual weight of the aircraft. The following factors contributed to the event:

- the deviation from standard procedures by the two pilots with regard to the requirement to perform individually the take-off performance calculation.
- the lack of understanding from the flying crew of the meaning and implications of the V SPEEDS UNAVAILABLE message.
- the absence on board the aircraft of automatic on-board weighing and balancing systems (OBWBS) and take-off performance monitoring systems (TOPMS), for which there is no regulatory requirement.

CHAPTER IV

SAFETY RECOMMENDATIONS

4. RECOMMENDATIONS

The safety investigation analyzed the evidence gathered in order to identify, as far as possible, the potential critical issues that likely contributed to the event.

During the investigation, the available studies on errors in calculating takeoff performance were examined. While emphasizing the importance of operating procedures, these studies highlight that the most effective barrier to countering the systemic risk associated with the human component can be found in the introduction of dedicated takeoff performance monitoring and verification systems, such as the Takeoff Performance Monitoring System (TOPMS) and the On-Board Weight and Balance System (OBWBS).

In this context, consideration was given to the numerous safety recommendations made over time by various investigative authorities to operators, manufacturers, and regulatory and supervisory authorities, aimed not only at the adoption of more structured operating procedures, but above all at the introduction of dedicated systems designed to mitigate the risk of events resulting from errors in the entry, selection, or validation of takeoff performance parameters. Based on its own independent assessments, ANSV agrees with the findings of the studies and also concurs with the rationale expressed in the safety recommendations already issued by other safety investigation authorities on this subject.

However, Notice of Proposed Amendment 2025-01 launched by EASA already considers the generalized introduction of such systems on the fleet currently in operation and concludes that it would not be considered sustainable or proportionate, assuming the requirement for newly designed or constructed aircraft, starting from around 2033.

During the investigation, the information provided by the operator LATAM regarding the initiatives taken following the event was also evaluated. According to the operator, the actions already implemented or initiated are considered appropriate to mitigate the risk of similar events. These initiatives include, among others:

- the dissemination of fleet safety communications containing specific instructions for the prevention of tail strike events, with particular reference to how to enter data into flight management systems;
- conducting a discrepancy analysis aimed at identifying potential risk factors and possible areas for improvement;

- introducing a third EFB device in the B777 fleet, assigning the third pilot specific tasks of cross-checking and validating performance data;
- launching dedicated training programs applicable to the wide-body fleet;
- implementation, within the scope of Flight Data Monitoring, of analysis criteria aimed at identifying the flyover height at the end of TORA during takeoff, in order to identify any trends attributable to performance degradation or operational errors.

With regard to the involvement of industry organizations, according to IATA, which certainly plays a central and globally recognized role in promoting operational safety, audit programs (IOSA) and dedicated initiatives are already in place, which are considered adequate for the purpose of preventing errors in the calculation of takeoff performance on an international scale.

In light of the above, ANSV does not consider it necessary to make further safety recommendations.