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SAFETY BOARD

Takeoff with erroneous takeoff data, Boeing 737-800

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N.B: This report is published in the English language, with a separate summary in the Dutch language. If there is a difference in interpretation between the Dutch and English texts, the English text will prevail.

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SUMMARY

On 10 June 2018 a Boeing 737-800 was scheduled for a passenger flight from Amsterdam Airport Schiphol in the Netherlands to Munich Airport in Germany. On board the aircraft were three flight crew members, four cabin crew members and 182 passengers. According to the Air Traffic Control (ATC) clearance, the aircraft was scheduled to depart from Runway 09. When the aircraft arrived near Runway 09, ATC asked whether a takeoff from Intersection N4 was possible; the crew answered negatively. Due to the wind conditions and the takeoff mass being close to the maximum takeoff mass, the aircraft had to depart from the beginning of the runway, using Intersection N5. The corresponding takeoff data were entered into the Flight Management Computer (FMC). During taxi-out to the runway, it turned out that the wind conditions had sufficiently changed and that a takeoff from Intersection N4 was possible. Using Intersection N4 enabled the crew to reduce the delay as the aircraft was already behind schedule.

After ATC instructed the aircraft to taxi to Intersection N4, new takeoff data had to be calculated with the actual wind conditions for this Intersection. This was done by a crew member just before the plane lined up on the runway. The investigation revealed that only the new wind data were entered into the FMC, whereas the intersection remained N5 instead of N4. The newly entered takeoff data were not checked by the other crew members. Because the new calculated and entered data were not checked, the computation of the takeoff parameters was based on an available runway length that was 3,494 metres instead of the actual 2,460 metres. After the takeoff roll, the aircraft became airborne 176 metres before the end of the runway and passed the runway threshold at a height of 28 feet. Although the crew noticed that the takeoff roll did not develop as expected, no full thrust was selected.

The available runway length was actually 1,034 metres shorter than the runway length used by the auto thrust system to calculate the required thrust setting. As a result, the available thrust was insufficient to take off safely.

In this investigation, it turned out that operational pressure caused the crew to choose for an unplanned, last minute change of the runway intersection. As other cases of this operator and multiple industry occurrences show, it was not an isolated event, nor a new phenomenon. Some similar occurrences with this operator became known and are referenced in this report. One of the conclusions of a safety audit in 2017 was that the *'Airline operational pressure threat prevalence'* was identified as the second major element of the operator's threat profile.

The serious incident was not reported by the crew to the operator nor were the flight recorders secured after landing. Although the lack of reporting was mentioned in the internal report of the operator, it was not labelled as a safety hazard. The internal report did not mention that the flight recorders were not secured.

The Dutch Safety Board's investigation focused on the use of erroneous takeoff data and factors that played a role in this. Other subjects, such as safety culture, crew resource management and air traffic control were not investigated in depth.

Takeoff accidents and serious incidents as a result of the use of erroneous takeoff data take place with some regularity. Last minute changes, time pressure, rushing and failure to cross-check are the factors most frequently contributing to takeoff performance incidents. Despite continuous developments, there are currently no technical solutions that completely prevent erroneous takeoffs. Therefore prevention must currently be sought in operational solutions. To allow the crew more time to independently check and enter the changed data in case of a last minute change, it is advisable to stop the aircraft to perform these actions. This stationary moment should be considered as one of the key practices against preventing erroneous take data entry. Furthermore, it has been found that flight crew usually hold on to a derated takeoff and do not select full thrust if there is a suspicion that the takeoff roll does not develop as expected.

RECOMMENDATIONS

Aircraft taking off with erroneous takeoff data cause hazardous situations that may lead to loss of aircraft or loss of life. A number of safety investigation reports, including those published by the Dutch Safety Board, have been written on this long standing and complex problem. These reports have led to recommendations to regulatory authorities, standardization bodies, aviation industry and airline operators to develop procedural, technical and operational safety improvements. These developments are ongoing and some of these improvements show the potential to adequately detect take off data input errors or insufficient take off performance; however, a comprehensive solution for this complex problem has not been developed and operationalized across the world wide air transport fleet yet.

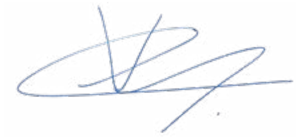
Taking off with erroneous takeoff data is frequently a result of operational pressure when last minute changes take place during taxiing. To allow the crew more time to independently check and enter the changed data, it is advisable to stop the aircraft to perform these actions. This stationary moment should be considered as one of the key practices against preventing erroneous takeoff data entry. As this investigation has shown, this is already included in the procedures of several airlines. It has also been found that flight crew usually hold on to a derated takeoff and do not select full thrust if there is a suspicion that the takeoff roll does not develop as expected.

In addition to previous recommendations, the Dutch Safety Board therefore makes the following recommendations:

To the European Union Aviation Safety Agency (EASA):
To recommend to operators and their flight crews to allow for a stationary moment when calculating, checking and entering takeoff performance data in case of last minute changes and implement this advice as recommended practice in guidance material, Safety Information Bulletin 2016-02R1 and other safety promotion material.

To KLM Royal Dutch Airlines:
To implement the following measures to prevent crews from taking off with incorrect takeoff data:

- Calculate, check and enter changed takeoff performance data only when the aircraft is stationary.
- Develop a procedure to have flight crews prepare an alternative plan in advance and encourage the use of full thrust for when last minute changes occur.
- Train flight crews to take action if they suspect that the takeoff roll does not develop as expected; make this training an element of the recurrent training program.



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ABBREVIATIONS

A	Aeroplane
ACARS	Aircraft Communications and Reporting System
ACMS	Aircraft Condition Monitoring System
AFM	Airplane Flight Manual
ASD	Accelerated Stop Distance
ASDA	Accelerated Stop Distance Available
ASDR	Accelerated Stop Distance Required
ASR	Air Safety Report
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Assumed Temperature Method (Reduced Takeoff Thrust)
ATPL	Airline Transport Pilot License
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
BOM	Basic Operations Manual
C	Celsius
CDU	Control Display Unit
CVR	Cockpit Voice Recorder
DTHR	Displaced Threshold
EASA	European Union Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning System
EGT	Exhaust Gas Temperature
FCOM	Flight Crew Operations Manual
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FE	Flight Examiner
FI	Flight Instructor
FMC	Flight Management Computer
FOTB	Flight Operations Technical Bulletin
Ft	Feet
HPa	Hectopascal
Hrs	Hours
IR	Instrument Rating

Km	Kilometre
Kt(s)	Knot(s)
LDA	Landing Distance Available
LFUS	Line Flying Under Supervision
LINTOP	Lido Integrated Take Off Performance calculation module
LOD	Lift Off Distance
LOSA	Line Oriented Safety Audit
MAC	Mean Aerodynamic Chord
MCP	Mode Control Panel
ME	Multi Engine
MTOW	Maximum Takeoff Weight
OAT	Outside Air Temperature
OM	Operations Manual
OPT	On Board Performance Tool
PBN	Performance Based Navigation
PF	Pilot Flying
PLTOW	Performance Limited Takeoff Weight
PM	Pilot Monitoring
RA	Radio Altitude
RAAS	Runway Awareness and Advisory System
SE	Single Engine
SEP	Single Engine Piston
SIB	Safety Information Bulletin
TASS	Assumed Temperature
TODA	Takeoff Distance Available
TODR	Takeoff Distance Required
TO/GA	Takeoff/Go-around
TOM	Takeoff Mass
TOPMS	Takeoff Performance Monitoring System
TORA	Take Off Run Available
TOS	Takeoff Surveillance
TOW	Takeoff Weight
TRE	Type Rating Examiner
TRI	Type Rating Instructor

GENERAL OVERVIEW

Identification number:	2018095
Classification:	Serious incident
Date, time of occurrence:	10 June 2018, 16.06 hours[1]
Location of occurrence:	Amsterdam Airport Schiphol
Registration:	PH-BXG
Aircraft type:	Boeing 737-800
Aircraft category:	Commercial - fixed wing
Type of flight:	Commercial Air Transport (Passenger)
Operator:	KLM Royal Dutch Airlines
Phase of flight:	Takeoff
Damage to aircraft:	None
Number of flight crew:	Three
Number of cabin crew:	Four
Passengers:	182
Injuries:	None
Other damage:	None
Light conditions:	Daylight

1 All times in this report are local times (UTC + 2 hours).

1 FACTUAL INFORMATION

1.1 Introduction

On 10 June 2018, a Boeing 737-800 took off from Runway 09 at Amsterdam Airport Schiphol. As a result of erroneous takeoff data, the aircraft became airborne just before the end of the runway. Despite the fact that there was a failure to achieve the predicted performance during takeoff, the involved flight crew did not file an Air Safety Report (ASR) about this occurrence. By the end of August 2018, the operator became aware of the incident. The Aircraft Condition Monitoring System (ACMS) data revealed the exceedance of the "low threshold crossing height" parameter. Although the incident was captured by the Flight Data Monitoring (FDM) program a few days after its occurrence, the incident was believed to be invalid, as many events are. It was put aside for further analysis. The analysis took place in the last week of August, and showed the incident to be valid. This occurrence was consequently classified as a serious incident. Consequently the occurrence was reported to the Dutch Safety Board on 7 September 2018. A preliminary investigation revealed that the serious incident was caused because incorrect takeoff data was entered into the flight management computer (FMC).

Referring to Regulation (EU) No 996/2010 and the Kingdom Act Dutch Safety Board, this occurrence was classified as a serious incident for which an investigation obligation applies. The investigation into this serious incident answers the following questions:

1. Which operational factors contributed to this erroneous takeoff performance incident?
2. Which organizational factors can be identified that contributed to the incident?
3. What are the similarities with other investigated takeoff data performance incidents?

In this investigation, relevant information was gathered from the flight crew, Air Traffic Control the Netherlands, Boeing Corporation and the operator.

Four other, similar takeoff performance incidents by the same operator are also mentioned in this report. Like the incident at Schiphol, one of these occurrences was not reported by the flight crew but found via the operator's FDM program. It turned out that the flight crew concerned had not been aware that an incident had occurred.

Two of these four incidents were reported to the Dutch Safety Board. One incident had happened in France, however the French Investigation Authority BEA decided not to investigate this incident separately but agreed to include it in this report.

On 15 October 2020, the Dutch Safety Board published its report of an erroneous takeoff performance incident of a Boeing 777.[2] Because of similarities between the two incidents, some information of that investigation is used in this report.

1.2 History of flight

The Boeing 737-800 with registration PH-BXG, was scheduled for a flight from Amsterdam Airport Schiphol in the Netherlands (hereafter named Schiphol) to Munich Airport in Germany. The scheduled departure time was 15.53 hrs local time. The flight crew consisted of a captain, a first officer and a safety pilot. The safety pilot, also a first officer, was added to the crew because the acting first officer was flying the first flight of the LFUS[3]-training program. The safety pilot acted for the first time in this role. It was also the captain's first flight as a route instructor during an LFUS-flight.

The crew met one hour before the departure time of the flight. The captain had planned extra time for the crew briefing because this was an instruction flight. During the briefing, he explained the role and duties of the safety pilot. The safety pilot was expected to take over some tasks of the first officer if needed. The captain was seated on the left hand seat, the first officer on the right hand seat and the safety pilot on the observer seat behind the two other seats. Because of the captain's preference to give the first officer in training ample time for the flight preparation, he and the safety pilot took over some tasks that normally should have been done by the first officer. The first officer was acting as pilot flying, the captain as pilot monitoring.

Initially the crew expected and prepared for a takeoff from Intersection V3 of Runway 36L. However, when the departure clearance was received, it turned out that ATC had planned the flight to depart from Runway 09. Subsequently, the crew requested a new takeoff performance calculation via Lintop[4] for Runway 09 for which they used the meteorological information that they had received via ATIS.[5] Initially a takeoff performance calculation for a departure from Intersection N4 of Runway 09 was requested. A valid performance calculation could not be generated for this Intersection because the available runway length was insufficient under the prevailing weather conditions and aircraft weight. Only a takeoff from Intersection N5 at the beginning of Runway 09 was possible. At 15.45 hrs, the crew received the following Lintop calculation for a Runway 09, Intersection N5 takeoff:

2 https://www.onderzoeksraad.nl/en/page/4808/erroneous-takeoff-performance-calculation-boeing-777
3 Line flying under supervision. (see Paragraph 1.8.6)
4 Lido Integrated Take Off Performance calculation module (see Paragraph 1.4.2).
5 Automatic Terminal Information Service; automatic broadcast of actual airport conditions, normally updated every 30 minutes.

Table 1: Takeoff data

		Explanation
Runway	09 - N5	
Wind	330/17	Wind direction 330 degrees with 17 kts.
V_1	151 kts	Decision speed - the maximum speed at which a rejected takeoff can be initiated, and the minimum speed at which the takeoff can be continued in the event of an engine failure.
V_R	154 kts	Rotation speed - the speed at which the aeroplane rotation is initiated. This speed ensures that, in the event of an engine failure, lift-off is achievable and the takeoff safety speed (V_2) is reached at 35 ft above ground level at the latest.
V_2	157 kts	Takeoff safety speed - the minimum speed that needs to be maintained up to the acceleration altitude, in the event of an engine failure after V_1. A speed at V_2 ensures that the minimum climb gradient required is achieved, and that the aeroplane is controllable.
TASS	44 °C	Assumed temperature - By using an assumed (higher) temperature, the engines produce just as much thrust as needed for a safe takeoff.

The FMC[6] was programmed accordingly. When the aircraft was cleared to taxi to Runway 09 at 15.56 hrs, it left the gate with a delay of around 17 minutes due to the late boarding of several passengers. Despite the delay, the flight remained within the limits of the timeslot.

The first officer, acting as pilot flying, taxied to Runway 09 via Taxiway B. Approaching Runway 09, the flight joined the queue behind other aircraft waiting to depart from the same runway. At 16.01:23 hrs, ATC asked the crew if an Intersection N4 takeoff was possible. The crew informed ATC that this was not acceptable due to performance reasons. Some moments later another aircraft, that was about to depart from Runway 09, asked ATC for the present wind conditions, to which ATC responded with a wind direction of 020° at 8 kts. Based on his experience, the captain knew that an Intersection N4 takeoff was possible under these circumstances.

6 The Flight Management Computer is a part of the Flight Management System: an on-board multi-purpose navigation, performance, and aircraft operations computer designed to provide data and information used during a flight from pre-engine start and takeoff, to landing and engine shut-down.

Figure 1: Picture of the intended (dotted line) and actual (solid line) taxi route to Runway 09. (Source: Amsterdam Airport Schiphol)

Because the captain was busy with instructing the first officer, the safety pilot informed the captain that he would request a new Lintop calculation. The safety pilot entered the new wind conditions into the Aircraft Communications and Reporting System (ACARS). However, Intersection N5 was not changed to N4. At 16.02 hrs, Lintop produced the following takeoff data with a fixed flaps 5 setting:

Table 2: Actual takeoff data

Runway	09 - N5
Wind	020/08
V_1	154 kts
V_R	157 kts
V_2	160 kts
TASS	48 °C

At 16.02:17 hrs the captain informed ATC that, with the actual wind conditions, they could accept a takeoff from Intersection N4. Subsequently ATC immediately instructed the aircraft to taxi to Intersection N4. At 16.02:52 hrs ATC instructed to hold short of the runway and to contact Schiphol Tower. Meanwhile, the first officer taxied the aircraft to the assigned Intersection N4 and during taxiing the safety pilot handed over the ACARS print with the changed data to the captain, who entered the data into the FMC, without further checking the used input variables. The entire process of changing the Intersection and entering the new data into the FMC was not monitored by the first officer. At 16.03:18 hrs the V_1, V_R and V_2 speeds were were re-inserted into the FMC. The aircraft was cleared to line-up on Runway 09 at 16.04:20 hrs and subsequently cleared for takeoff at 16.05:51 hrs. Together with the takeoff clearance, ATC informed the crew that the actual wind was 010° with 8 kts.

The first officer performed the takeoff. After stabilisation of the engines at 40%, the TO/GA[7] switch was pushed at 16.06:10 hrs. The aircraft accelerated down the runway when both the captain and the safety pilot realized that they were approaching the runway end very quickly without being airborne. No adjustment of the power setting was made. The aircraft became airborne at the very end of the runway.

After the climb out, the captain and the safety pilot discussed the situation because both had noticed the abnormal takeoff characteristics. After checking the takeoff performance calculation, they discovered that the performance was based on an Intersection N5 takeoff instead of Intersection N4. The first officer had not noticed any abnormalities during the takeoff. The remainder of the flight was uneventful. The occurrence was not reported to the operator by means of an Air Safety Report (ASR).

Analysis of the Aircraft Maintenance System (ACMS) data showed that the aircraft rotated at the calculated rotation speed and became airborne 176 metres before the end of Runway 09 and crossed the threshold at an altitude of 28 ft.

1.3 Personnel information

Table 3: Information of the cockpit crew

	Captain	First officer	Safety pilot
Licence	Valid ATPL	Valid ATPL	Valid ATPL
Ratings	B737-300/900, F70/100, TRI , TRE, SEP (land), IR (A) SE/ ME, PBN, FI (A), FE (A).	B-737-300/900, IR (A).	B-737-300/900, IR (A) ME, SEP (land), TRI (A).
Medical	Valid medical certificate Class 1	Valid medical certificate Class 1	Valid medical certificate Class 1
Total flight experience	Around 14,000 hrs	Around 1,200 hrs	Around 8,000 hrs

7 The Takeoff/Go-Around switch automatically selects the calculated thrust setting by the FMC.

1.4 Aircraft information

1.4.1 General

Manufacturer	Boeing Commercial Airplanes
Model	737-8K2
Year z manufacture	2000
Serial number	30357
Registration	PH-BXG
Engine model	CFM56-7B24
MTOW[8]	73,708 kg

The aircraft had no known deficiencies during the incident flight. According to the load sheet, the Take Off Weight (TOW) was 68,047 kg and the centre of gravity was 20.9% MAC.[9]

1.4.2 LINTOP takeoff calculations

After the required parameters are known, the crew sends the data from the aircraft to the LINTOP system. LINTOP is a computer program running on a centralized remote computer and is designed to calculate the minimum amount of takeoff thrust necessary for a given runway and aircraft weight taking into account the environmental circumstances.

LINTOP calculates the takeoff performance data and presents the required thrust to the flight crew as well as the corresponding reference speeds (V_1, V_R, V_2) and assumed temperature. Then the crew enters the results of the LINTOP calculations into the FMC and in case the auto throttle system is used, the calculated takeoff thrust will be set.

Communication between the aircraft and LINTOP is done via ACARS.[10]

8 Maximum takeoff weight.
9 Mean Aerodynamic Chord; the position of the centre of gravity as percentage of the chord of the wing.
10 Aircraft Communication Addressing and Reporting System.

The following text is from the operator's B737 Flight Crew Operations Manual (FCOM), section Performance Dispatch 14.2:

> *LINTOP allows crews to accurately calculate the Performance Limited TOW. The application calculates the Performance Limited TOW (PLTOW) for a selected runway/ intersection and airplane configuration at a given OAT, wind and QNH, taking into account the following:*
> - *Field Length Limit Weight*
> - *Obstacle Limit Weight*
> - *Climb Limit Weight*
> - *Minimum Control Speeds*
>
> *For a given TOW (planned or actual) the program will calculate the assumed temperature and the takeoff speeds. Line-up distances are taken into account, although this is not shown on the ACARS print. (…)*

1.4.3 Aircraft takeoff performance

The takeoff performance calculation is based on the requirement to be able to stop on the runway in case of an aborted takeoff at or before V_1 and the requirement to reach at least 35 ft over the runway threshold with an engine failure after V_1 in case of a dry runway. The Lintop takeoff performance calculation program is designed to meet these criteria while reducing the amount of takeoff thrust as much as possible.

Lower takeoff thrust is mainly used for economic reasons; it reduces Exhaust Gas Temperature (EGT), improves engine reliability and extends engine life. Reduced takeoff thrust by means of the Assumed Temperature Method (ATM) is a takeoff thrust level less than the full rated takeoff thrust. Reduced takeoff thrust is achieved by selecting an assumed temperature that is higher than the actual ambient temperature.[11] When the selected (assumed) temperature is above the actual ambient temperature, the engines will give less thrust.

For calculating the maximum reduction in takeoff thrust possible the Lintop program is taking into account stop ways, clearways and improved climb performance by using higher V-speeds when ample runway length is available.

Initially the assumed temperature of 44 °C was calculated for an N5 intersection takeoff under the prevailing weather conditions with a wind value of 330 degrees and 17 kts. The new assumed temperature that was calculated for the same N5 intersection takeoff but with changed wind conditions of 020 degrees and 8 kts was 48 °C. The actual outside temperature was 21 °C.

11 Ref: Boeing 737 FCTM.

The operator made a Lintop calculation of the required data for an Intersection N4 takeoff. The data is presented in the table below together with the takeoff data used by the flight crew.

Table 4: Used and required takeoff data

Runway	09 - N5		Runway	09 – N4
Wind	020/08		Wind	020/08
V_1	154 kts		V_1	143 kts
V_R	157 kts		V_R	144 kts
V_2	160 kts		V_2	149 kts
TASS	48 °C		TASS	35 °C

In the second column the Lintop program uses improved climb performance resulting into higher V-speeds when compared to the fifth column.

During the investigation, the aircraft manufacturer was asked to calculate the distance where the aircraft rotated during the takeoff, where it lifted off and at what position the aircraft reached the altitude of 35 ft, using Intersection N4. Furthermore, the manufacturer was asked if the aircraft could have stopped on the runway in case of a rejected take off at V_1. ACMS data and the same environmental circumstances were used for these calculations.
The calculations of the aircraft manufacturer showed that:

- The aircraft rotated at 1,974 metres.
- The aircraft lifted-off at 2,217 metres.
- The aircraft reached an altitude of 35 ft at 2,542 metres, using all of the clearway of 60 metres.
- In case the takeoff had to be aborted at V_1, with maximum manual braking and full reverse thrust both engines, the Accelerated Stop Distance (ASD) would have been 2,647 metres, exceeding the available runway length by 247 metres.

1.5 Meteorological information

ATIS information P for Runway 09.14:51 hrs[12]
Wind direction 020° at 10 kts, variable between 290° and 100°, wind speeds max. 19 kts min. 05 kts, visibility: more than 10 km, cloud: scattered 2,700 ft, temperature: 21 °C, dew point: 14 °C, air pressure: 1013 HPa.[13]

ATIS information R for Runway 09.15:21 hrs
Wind direction 010° at 8 kts variable between 330° and 130°, wind speeds max. 17 kts min. 03 kts, visibility: more than 10 km, cloud: scattered 2,700 ft, temperature: 21 °C, dew point: 14 °C, air pressure: 1013 HPa.[14]

Actual wind near Runway 09 as radioed by ATC:

Time	Direction	Speed
16.01:35	020°	08 kts
16.05:54	010°	08 kts

1.6 Aerodrome information

The aircraft taxied via Taxiway B to Runway 09. Runway 09 has three intersections available for aircraft to takeoff: N3, N4 and N5. The declared distances for Runway 09 are listed in the table below.

Table 5: Declared Distances Runway 09 (Source AIP Netherlands)

Runway	TORA (m)	TODA (m)	ASDA (m)	LDA (m)	Remarks
09	3,434	3,494	3,434	3,363	Takeoff from Intersection N5. DTHR 90 m.
	2,400	2,460	2,400	NA	Takeoff from Intersection N4.
	1,881	1,941	1,881	NA	Takeoff from Intersection N3.

Runway 09 has an additional clearway of 60 metres. A clearway is an area beyond the paved runway, free of obstructions and under the control of the airport authorities. The length of the clearway is included in the length of the TODA.

Figure 2: Picture of Runway 09. (Source: Amsterdam Airport Schiphol).

12 ATIS-information is updated each 30 minutes at fixed times.
13 020/10kt vrb btn 290 and 100 deg max 19kt min 05kt vis 9999 sct 027, 21/14, 1013.
14 010/08kt vrb btn 330 and 130 deg max 17kt min 03kt vis 9999 sct 027, 21/14, 1013.

1.7 Flight recorders

The aircraft was equipped with a digital Flight Data Recorder (FDR) and a digital Cockpit Voice Recorder (CVR). A Quick Access Recorder is available for the purpose of the Aircraft Condition Monitoring System (ACMS).

1.7.1 Flight Data Recorder

Because the operator became aware of the occurrence two-and-a-half months after the incident date, information from the FDR was not available anymore.

1.7.2 Cockpit Voice Recorder

CVR data was also not available for the same reason.

1.7.3 Quick Access Recorder

ACMS data was obtained from the operator. This data was used in the investigation.

1.8 Organizational information

1.8.1 Basic Operations Manual[15]

Aircraft operators issue a Basic Operations Manual (BOM), also called Operations Manual part A. This part comprises all non-type related operational policies, instructions and procedures needed for a safe operation.

Chapter 11 of the operator's BOM: *'Handling, notifying and reporting occurrences and CVR/FDR recordings'*, describes how the crew and commander should act in case of an incident, serious incident or accident. It is stated that:

- *The commander must ensure that Flight Dispatch is informed in case of an (serious) incident or accident and after evaluation of the (reported) occurrence fill out and submit an Air Safety Report. An ASR may be submitted anonymously to the company, to protect the identity of the reporter. An ASR will be handled in a confidential manner.*
- *In the event of an (serious) incident or accident that is subject to mandatory reporting the commander shall ensure that flight recorders:*
  - *are not intentionally erased;*
  - *are deactivated immediately after the flight is completed;*
  - *are reactivated only with the agreement of the investing authority.*

In the Reference Guide, belonging to the BOM, several occurrences are stated that have to be reported. Two of these occurrences are:

- *Use of incorrect data or erroneous entries into equipment used for navigation or performance calculations which has or could have endangered the aeroplane, its occupants or any other person.*
- *Inability to achieve required or expected performance during takeoff, go-around or landing.*

15 Operations manuals are updated regularly. The manuals valid on the date of occurrence have been used in this report.

1.8.2 Flight Crew Operations Manual and Flight Crew Training Manual

Aircraft manufacturers also issue manuals how to operate an aircraft type safely. A Flight Crew Operations Manual (FCOM, also called Operations Manual part B) provides systems descriptions and procedures, while the Flight Crew Training Manual (FCTM) explains how the aircraft should be operated and how procedures should be applied. The operator's Boeing 737 FCOM and FCTM are based on the original Boeing FCOM and tailored by the operator to its specific needs of the operation, thereby personalizing the manuals as operator manuals, while following the original Boeing FCOM as close as possible. According to the preface introduction of the operator's FCOM, the purpose is to:

- *Provide the necessary operating limitations, procedures, performance, and systems information the flight crew needs to safely and efficiently operate the 737 airplane during all anticipated airline operations.*
- *Serve as a comprehensive reference for use during transition training for the 737 airplane.*
- *Serve as a review guide for use in recurrent training and proficiency checks.*
- *Provide necessary operational data from the FAA approved Airplane Flight Manual (AFM) to ensure that legal requirements are satisfied.*
- *Establish standardized procedures and practices to enhance the operator's operational philosophy and policy.*

1.8.3 Operator general crew tasks and division of duties

According to the operator's manuals, tasks and crew duties during the preflight and postflight phases are divided between the captain and first officer. Duties during flight are divided between pilot flying (PF) and pilot monitoring (PM). The general responsibilities of the PF are: taxiing, flight path and airspeed control, aircraft configuration and navigation. The general responsibilities of the PM are: checklist reading, communications, tasks asked for by the PF, monitoring taxiing, flight path, airspeed, aircraft configuration and navigation. The captain remains overall responsible for a safe execution of all tasks.

1.8.4 Control Display Unit (CDU) Procedures

In the operator's B737 FCOM several procedures are laid down on the use and operation of the Flight Management Computer (FMC) with the aid of the Control Display Unit (CDU) interface. Procedures in relation to entering and changing takeoff data into the FMC are described below.

Control Display Unit (CDU) Procedures, (NP.11.2)

- *Before taxi, the captain or first officer may make CDU entries. The other pilot must verify the entries.*
- *Make CDU entries before taxi or when stopped, when possible. If CDU entries must be made during taxi, the PM makes the entries. The PF must verify the entries before they are executed.*

CDU Amplified procedures (NP.21.4)
Preflight Procedure - Captain and First Officer
Start the CDU Preflight Procedure any time 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. When available, enter the assumed temperature (if applicable) and takeoff V speeds any time during the CDU Preflight Procedure.
CAUTION: Always check the entered assumed temperature and takeoff V speeds when a new takeoff performance calculation has been performed. Accept or correct the entered assumed temperature and takeoff V speeds as needed.

The captain or first officer may make CDU entries. The other pilot must verify the entries

Takeoff Performance Calculation Procedure - Captain and First Officer (NP.21.5)
To reduce workload prior to departure it is recommended to perform the Takeoff Performance Calculation Procedure before the high workload phase.

Takeoff Performance Data ....Calculate

When possible, apply a TOW margin of +1000 kg to reduce the need for last minute recalculations. Before making CDU entries, both input and output parameters of the takeoff performance calculation shall be agreed upon by two flight crew members.

1.8.5 Before Takeoff Procedure

Specific procedures or checklists for last minute runway changes are not incorporated in the FCOM nor in the FCTM[16] of the operator. With regard to changes before takeoff, the FCOM (NP21.33 Before Takeoff Procedure) states: *'The pilot who will do the takeoff updates changes to the takeoff briefing as needed'* while the FCTM (Takeoff-General) states: *'After changes to the takeoff briefing have been updated during the Before Takeoff Procedure, the PF may elect to display the CLB page for takeoff.'*

1.8.6 Operator's Line Training

The flight was marked as line flying under supervision (LFUS). The operator's document LFUS F/O B737 states, amongst other things: *'During the first phase of LFUS for a new First Officer, an experienced First Officer will be added to the crew. This extra First officer is also known as a "buddy Pilot". This experienced First Officer will occupy the observer seat.*

16 The FCOM defines procedures while the FCTM is comprised of guidelines and techniques.

The Route Instructor shall brief the buddy pilot regarding his duties, amongst which:
- *Extra flight safety monitoring*
- *Extra pilot to allow certain duties to be delegated during high workload/ training load situations.'*

In the investigation, the safety pilot stated that he was a little confused because he was unaware whether he had been assigned as safety or buddy pilot. According to his schedule, he had been scheduled as first officer, together with another first officer and the captain. He initially was of the opinion that he should act as first officer himself, and the other first officer was an observer. Nothing was mentioned like 'safety or buddy pilot' on the schedule. The safety pilot was unfamiliar with his role, also because this was the first time he was acting as safety pilot. During the briefing, he was instructed by the captain about his role.

For the captain, it was also the first time on the Boeing 737 to act as line training captain. He stated that he knew a safety pilot would be present, but was not quite sure what the exact tasks should be.

1.8.7 *Line Oriented Safety Audit*

The operator was subject to a Line Oriented Safety Audit (LOSA) in 2017. One of the conclusions was that the *'Airline Operational Pressure threat prevalence*' is significantly higher than the industry average: *'61% of flights vs. LOSA Archive Average: 35%'*. It was identified as the second major element of the operator's threat profile. The executive summary states, amongst others, that:

'Combined with other atypically high prevalence rates for Cabin, Ground Maintenance and Ground/Ramp threats, a picture emerges of preflight events and pressures interrupting and disrupting the crews' preflight work flows, cross-checks and crew briefing. As in all airlines, some crew made procedural adaptations to accommodate these pressures, such as starting checklists before all items were prepared or completing items out of sequence, hasty or no cross-verification of calculations and FMC selections, performing an abbreviated briefing, accepting a clearance prematurely, starting engines before ground crew are informed and taxiing into position with an unready cabin.'

1.8.8 Other takeoff occurrences of the operator

As stated earlier in this report the operator became aware of the incident 2,5 months after the occurrence. Partly due to the late discovery of the incident the operator decided to add this incident to an ongoing, internal, study following three other erroneous intersection takeoffs.

A short summary of four similar incidents in relation to the operator is described below. The fourth incident occurred during the Dutch Safety Board investigation process. By this time, the operator's study had already been completed.

Takeoff incident, Boeing 737-800, Oslo (Norway), July 2013
Before taxi, it was suggested to plan a Runway 19R Intersection A6 takeoff, as this would result in the shortest taxi route. Because the aircraft was behind schedule, this would save time. The LINTOP takeoff data for Intersection A6, which included an assumed temperature of 31 °C, were entered into the FMC. In addition, a calculation was made for Intersection A7 (which provided 453 metres extra runway), as the captain preferred to use a more reduced takeoff thrust setting. Because it turned out that the load sheet takeoff weight (TOW) was two tons below the flight plan TOW, the first officer made a new LINTOP request, only entering the load sheet TOW and not also changing the intersection, which read A7, back to A6. During taxi-out, the first officer showed the LINTOP print-out to the captain and stated that only the TOW had been changed. The captain checked the TOW and the assumed temperature on the LINTOP print-out, noticing the assumed temperature now read 49 °C instead of 31 °C. This somewhat puzzled him. The first officer entered the revised figures into the FMC. While the captain still tried to find an explanation for the large increase in assumed temperature, the first officer suggested to the captain to ask ATC for an A6 intersection takeoff. The request was made, followed by ATC asking if an immediate takeoff from Intersection A6 was acceptable. This was confirmed and shortly thereafter the aircraft started a rolling takeoff from Intersection A6. During the takeoff roll the crew realized that the takeoff performance was compromised. Thrust was increased and the V_1 call was made 10 kts below V_1. The aircraft was rotated within the confines of the runway. After takeoff, the crew discovered that the LINTOP performance calculation for the load sheet TOW was based on Intersection A7 instead of A6.

After this incident, the crew filed an ASR. This incident was not reported to neither the Norwegian Air Safety Investigation Authority nor to the Dutch Safety Board.

Takeoff incident, Airbus A330-200, Entebbe (Uganda), January 2016
The flight had been planned to arrive at AMS after its scheduled arrival time. The flight crew therefore worked at a pace that would minimize the delay as much as possible. Following an uneventful preparation the aircraft departed the gate about 20 minutes ahead of the scheduled departure time. During taxi-out, the flight crew decided to takeoff from Intersection B of Runway 35 instead of using Intersection A, representing the full runway length. A new LINTOP request was made while taxiing. However, Intersection A was inadvertently re-entered. The revised takeoff data were subsequently entered into the FMC. Full takeoff thrust was used. Rotation was started at the calculated V_R. The aircraft lifted off between 340 metres and 263 metres before the runway end and crossed the runway end at a height between 19 and 40 ft RA. By using Intersection B instead of A, the takeoff distance was shortened with 700 metres.

This incident was not reported to the Ugandan Air Safety Investigation Authority nor to the Dutch Safety Board. The crew filed an ASR.

Takeoff incident, Boeing 737-800, Toulouse (France), April 2019
During taxi-out, the flight crew decided to takeoff from Intersection N4 of Runway 32R instead of Intersection N2. Believing they had calculated the takeoff data for Intersection N4, they started the takeoff from this intersection. Reduced takeoff thrust was used. During the last part of the takeoff roll, the end of the runway became visible and the crew realized that they were much closer to the runway end than expected. Thrust was not increased though. Rotation was started at the calculated V_R and the aircraft lifted off 248 metres before the runway end. The runway end was crossed at 32 ft RA. After takeoff, the flight crew reviewed the performance data, which revealed the entry error.

This serious incident was reported to the Dutch Safety Board, who reported the incident to the French Air Safety Investigation Authority BEA. The BEA had decided not to open an investigation into this event but was willing to delegate it to the Dutch Safety Board if desired. Since the nature of this serious incident was similar to the investigated serious incident at Schiphol, it was decided to incorporate the occurrence in France in this report. The crew filed an ASR.

Takeoff incident, Boeing 737-800, Lisboa (Potugal), 3 March 2021
Three Lintop requests were made before departure due to changed circumstances. Partly due to confusion about the intersection designators, the aircraft took off from an intersection of Runway 21 while data of the full runway length was used for calculation. As a result, the available runway length was 1,395 metres less than had been entered into the system. The aircraft became airborne at the end of the runway. The crew did not report the incident nor was an ASR filed as the crew had not noticed anything abnormal during the takeoff roll and was therefore unaware that an incident had occurred. The incident emerged some weeks later by the use of Flight Data Monitoring.

This serious incident was reported to the Dutch Safety Board, who reported the incident to the Portugese Air Safety Investigation Authority GPIAA. This incident was investigated by GPIAA which published a factual report.[17]

1.8.9 The operator's internal report
In the internal report into the erroneous takeoffs, the following findings were reported:

Findings related to the incident flights
- *All incident flights were delayed and the crew were eager to limit the delay.*
- *During taxi-out all flight crew decided to depart from a different intersection than planned during preflight.*
- *In two of the incidents a new LINTOP takeoff data request was made and the takeoff data were entered into the FMC while taxi-out was continued. Although the crew planned to takeoff from a different intersection the runway intersection in the LINTOP request was not changed.*

17 GPIAA, *Factual Report of Incident with Boeing 737-800, registration PH-BCD, occurred on 3rd March 2021, at Lisbon Airport*, 29 juni 2021. www.gpiaa.gov.pt/

- *None of the flight crew compared the runway/intersection designator on the LINTOP Output with the actual runway/intersection sign near the runway.*
- *In two of the incidents derated takeoff thrust was used. When it became evident to the flight crew that takeoff performance was compromised takeoff thrust was not increased.*

Findings related to the organization
- *The operator does not require its crew to explicitly verify the runway/intersection sign next to the runway actually used for takeoff with the runway/intersection on the takeoff LINTOP Output.*
- *Not all pilots structurally check the runway/intersection on the LINTOP Output with the sign of the intersection actually used for takeoff, nor are they required to do so.*
- *The runway/intersection designator on the LINTOP Output is susceptible to being overlooked, especially under the dynamic conditions which are inherent to flight operations.*
- *Due to underreporting the number of takeoffs from intersections with inappropriate takeoff data is larger than currently known.*
- *The operator's current Flight Data Monitoring program is limited in capturing takeoffs from intersections with inappropriate takeoff data.*
- *Unlike several other major carriers the operator does not employ a checklist related to runway changes.*
- *Flight Crew Training on runway changes and increasing thrust when takeoff performance is compromised is not overall effective.*

The internal report identified four safety issues:
- *There is no structured approach that calls for flight crew to crosscheck the actual runway entry point with the calculated takeoff data.*
- *The current presentation of the runway/intersection designator on the LINTOP Output is susceptible to being overlooked, especially under dynamic conditions inherent to flight operations.*
- *There is no structured approach that aids flight crew in properly configuring the aircraft configuration and FMS following a runway change.*
- *Inaction of flight crew to increase thrust when it appears that takeoff performance is compromised continues to be a safety issue.*

Referring to the addressed safety issues, the operator took the following actions:
- The LFUS-manual was amended with the instruction: *'When entering a runway intersection for takeoff, crosscheck the actual runway intersection designator versus the intersection designator on the LINTOP print'.*
- Changes of OM Part A (BOM)
    - Crew coordination with regard to normal and non-normal departure and approach considerations during crew briefings, which include, amongst other things, the planned intersection for take off/vacating after landing.
    - Policy and procedures for takeoff performance with regard to causes, effects and reduction of takeoff performance errors, including runway position verification.
- Changes were made to the layout of the Lintop-print in order to improve the readability.

- After each incident, details of the incident were shared with all flight crew on the operator's safety news app in order to raise awareness.
- OM Part A (RG) 8.3-1.16 – Policy and procedures for takeoff performance, was amended with a section concerning runway position verification.

Based on the addressed safety issues, the company did not take actions to assure the reporting of this type of serious incidents.

1.9 Additional information

1.9.1 Use of erroneous parameters at takeoff problems

Incidents involving a takeoff without adequate thrust, or attempted rotation at an airspeed which is too low for the actual aircraft mass/takeoff configuration, or with insufficient runway length remaining, have been occurring regularly. However, reliable figures are not available. Only in cases involving an accident or a serious incident or where the operator decides to report the occurrence to the authorities, it will become known that such an event has occurred. The actual number of events is therefore likely to be considerably higher than the number of reported incidents to investigation authorities. This is due to a number of causes:

- Sometimes the crew does not notice at all that there is insufficient speed or an incorrectly calculated speed because aircraft takes off without problems.
- Sometimes the crew does notice this, but the aircraft takes off without any problems, and the crew does not report this for various reasons.
- In other cases, it will be reported to operator but the incident is only investigated internally.

Because these types of incidents occur often and pose a high risk of an accident, several investigations and studies have been performed to find out the backgrounds, causes and possible solutions for these occurrences.[18] The most common cause cited in these studies and investigations are the erroneous calculation of aircraft weights, in combination with the use of reduced-thrust takeoff. In one of the studies[19] called *'Use of erroneous parameters at takeoff'* conducted by the Applied Anthropology Laboratory in France, the following conclusions were drawn:

- *The variety of events show that the problem of determining and using takeoff parameters is independent of the operating airline, of the aircraft type, of the equipment and of the method used.*
- *Errors relating to takeoff data are frequent. They are generally detected by application of airline operating modes or by personal methods, such as mental calculation.*
- *Half the crews who responded to the survey carried out in one of the airlines taking part had experienced errors in parameters or configuration at takeoff, some of which involved the weight input into the FMC.*

18 https://skybrary.aero/articles/use-erroneous-parameters-take
19 https://bea.aero/etudes/use.of.erroneous.parameters.at.takeoff/use.of.erroneous.parameters.at.takeoff.pdf

- *The real-time availability of the final weight information a short time before departure obliges the crew to perform a large number of tasks, inputs and parameter displays under strong time pressure.*
- *Time pressure and task interruptions are frequently cited in surveys as common factors contributing to errors. The observations showed that the crews' work load increases as the departure time approaches and that the normal operation actions of the crew were all the more disrupted.*
- *In several cases, crews perceived abnormal aeroplane behavior during takeoff. Some took off 'normally'. Others were able to adopt different strategies: stopping takeoff, increasing thrust, or delayed rotation.*

In 2012, NASA issued the report *'Performance Data Errors in Air Carrier Operations: Causes and Countermeasures'*.[20] Although the report describes many different types of data errors, especially relating to weights, a number of issues are mentioned that also apply to this incident. In the paragraph *'Role of Cognitive and Other Human Factors'* an analysis is given of the ways in which cognitive factors and other human factors might have contributed to 112 investigated errors. In the analysis twelve distinct factors are identified, as well as the frequency with which they contributed to errors. NASA found that the factors most frequently contributing to errors were: discrepancies not being salient; time pressure; rushing and failure to cross-check.

Appendix B of this report presents a number of accident and incident investigation reports of aircraft taking off with thrust setting being too low or taking off from an intersection providing less TORA than used for calculation of takeoff data.[21]

1.9.2 Other operators

In the investigation, the Dutch Safety Board asked ten European operators with similar operations how they have organized the crew tasks with respect to last minute changes during taxi. All operators require, in line with the manufacturers, an independent verification by the flight crew members of the takeoff performance calculation. These procedures have been incorporated in the FCOM and FCTM, or normal checklists, by these operators. Most operators have a specific procedure for a change in takeoff conditions such as a runway change.[22] Five out of ten operators have stipulated in their procedures that the aircraft have to be stationary in order to perform the performance data change or crosscheck. One of those five operators is ambiguous in the procedure whether or not the aircraft needs to be stopped. An example of an FCOM procedure mentioning to stop the aircraft is shown below.

20 https://humansystems.arc.nasa.gov/flightcognition/Publications/NASA_TM2012-216007.pdf
21 Martinair, KLM, NLR, *Take-off performance incidents: do we need to accept them or can we avoid them?*, ISASI annual seminar, September 2019.
22 A takeoff from a different intersection is considered in this respect as a runway change.

CHANGE OF RUNWAY/TAKE-OFF DATA DURING TAXI

- If takeoff conditions changed during taxi *Refer to FCTM/PR/NP/SOP/BEFORE PUSHBACK OR START/TAKEOFF DATA):*
  - Stop the aircraft and set the parking brake at an appropriate place (advise ATC about the time needed);
  - Calculate take-off performance (both crew members independently) using the same TOW as during initial calculation;
    Refer to OMB/13-2-2-1 T/O PERFORMANCE CALCULATION for take-off performance calculation.
  - Prepare updated take off data as follows:

The operator of the incident flight does not have an additional procedure for a last minute change in takeoff conditions. It only has the general requirement that the entered assumed temperature and takeoff V speeds must be checked when a new takeoff performance calculation has been performed.

1.9.3 Boeing Technical Bulletins

Because the manufacturer Boeing was aware of multiple takeoffs that had been performed with erroneous takeoff performance data, Flight Operations Technical Bulletin 737-16-02 was issued on 16 February 2016. After this incident, Flight Operations Technical Bulletin 737-18-02 was issued on 21 December 2018. Both bulletins were issued to inform operators about the causes and consequences of this phenomenon.

Bulletin 737-16-02 emphasizes, amongst other things, that performance related FMC CDU entries made by one pilot must be verified by the other pilot. Airlines are encouraged to confirm the importance of having robust procedures in place to ensure the use of accurate entry data for performance calculations and to stress the importance of independent verification of CDU entries by the flight crews.

Bulletin 737-18-02 states amongst other things: *'Despite current error trapping techniques, takeoffs with erroneous takeoff performance data continue to occur. A 2012 NASA study (NASA/TM—2012–216007, Performance Data Errors in Air Carrier Operations: Causes and Countermeasures) found that pilot recognition of committed errors is about 20% effective overall. Regarding takeoff performance errors, researchers conducting line observations did not find any cases in which pilots compared the dispatch forms, the performance tool calculated outputs, and the CDU entries to catch errors. Had this comparison been done, the errors would likely have been caught.'*

It further states, referring to takeoffs '*Pilots should be reminded of the following steps in the FCOM along with comments:*

- *Before Takeoff Procedure: The pilot who will do the takeoff updates changes to the takeoff briefing as needed.*
- *Takeoff Procedure: Before entering the departure runway, verify that the runway and runway entry point are correct.*'

The operator has incorporated the content of these Technical Bulletins in Amendment no. 23 to OM part A – Reference Guide (RG) of 8 October 2020.

The generic Boeing B737 FCOM procedures and FCTM guidelines do not provide any specific details on last minute runway changes during taxi.

2 ANALYSIS

2.1 Operational factors

2.1.1 Reduced safety margins

The takeoff information that was used for the Lintop calculation, mentioned intersection N5 for takeoff instead of N4. The takeoff data calculated by Lintop was loaded into the FMC without being checked by either the captain or the first officer. Therefore the thrust setting was based on the assumption that the available runway length was 1,064 metres (the difference between the two intersections) longer than it actually was.

As a result of the reduced takeoff thrust application, the engines produced the thrust required for a runway with a TODA of 3,494 metres, resulting in a slower acceleration than needed. This explains why the aircraft became airborne at the very end of the runway. The speed at which the takeoff could still be safely rejected (V_1, 154 kts) was based on these erroneous data. Calculations afterwards showed that the correct V_1 should have been 143 kts in the current conditions. The actual rotation speed V_R, as calculated was 157 kts, while the correct V_R should have been 144 kts.

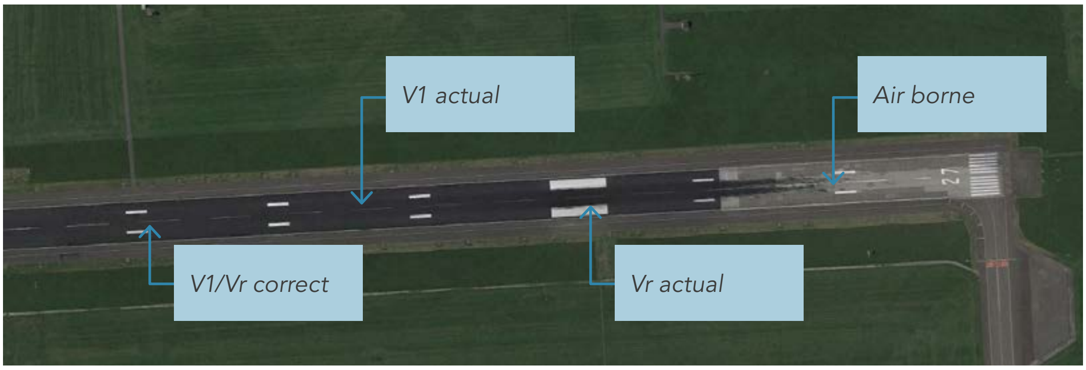

Figure 3: Significant places of the takeoff. (Source: Google Earth)

During the investigation, the aircraft manufacturer calculated that the aircraft would have been unable to stop on the runway in case the takeoff had to be aborted at V_1. Due to the slower than required acceleration of the aircraft during the takeoff roll, the aircraft reached the calculated V_1 further down the runway with insufficient runway length remaining to stop the aircraft within the confines of the runway.

In the event of an engine failure after V_1, there would have been insufficient runway length remaining to accelerate the aircraft to the minimum V_2 speeds.

The risk of the aircraft reaching the end of the runway without being able to become airborne, would have been significant. This all resulted in reduced safety margins during the takeoff.

The takeoff performance data was based on an available runway length that was 1,034 metres longer than the length that was actually available. The use of erroneous takeoff performance data led to a situation where no safety margins remained.

2.1.2 Last minute changes and time pressure

On every flight, regardless of aircraft type, the takeoff performance calculation has to be conducted. In their procedures, both the operator and Boeing stress the importance of an independent takeoff performance calculation by each crewmember as well as crosschecking both results. This also applies to last minute calculations in case of a runway change or changing weather conditions. The most important safety net to avoid takeoff performance errors will be removed if this procedure is not followed.

Cross checking of the new data by the captain and the first officer was not done for several reasons. The captain did not crosscheck the takeoff performance data because the time between changing and inserting takeoff data into the FMC and lining up on the runway was very short and ATC-instructions followed in quick succession. Further was the captain's attention aimed at monitoring the first officer and he omitted the crosschecking procedure due to the perceived time pressure. The acting first officer was focused on aligning the aircraft on the runway without paying attention to the changed takeoff performance parameters. The first officer trusted and relied on the two other, experienced crewmembers to have correctly processed the new Lintop calculation.

As it turned out, assumptions were made by all crewmembers, resulting in three different situational awareness states, which were a direct precursor of the incident. The safety pilot trusted and assumed more or less that the captain would check the new performance, while inserting it into the FMC, and the captain omitted the crosschecking procedure due to the perceived time pressure. This resulted in the newly entered data not being checked by anyone, although the procedures do require doing so, hence the entry error for the performance calculation went unnoticed.

One of the factors that played a role was that the crew continued taxiing after they had accepted the intersection change. The captain had indicated to ATC that they could also accept an intersection takeoff from N4, before the outcome of the performance calculation was received, based on his experience while they were taxiing. While his estimation proved to be correct, it precluded any risk evaluation by the crew.

Continuing taxi while the crew had accepted, or requested, a runway or an intersection change resulting in new takeoff data, was also the case with the other occurrences of the operator.

It is known that continuing taxiing puts a great strain on the principle of cross checking new data, as time pressure and distractions are present or lurking. This kind of erroneous performance errors in general are less likely to occur when the aircraft is parked during the preflight procedure.

The likelihood of errors by entering changed data while taxiing can be reduced by stopping the aircraft before entering the new data. Some European operators have included this as an obligation in their manuals or checklists, however this is not the case with this operator.

During the completion of this report, Skybrary published a video with information to avoid erroneous takeoffs after changes of the initial takeoff data. Amongst other things it is advised to perform planning, performance calculations, cross-checks and re-briefings without rushing and with the aircraft stationary.[23]

Due to time pressure just before takeoff, the crew did not allow themselves time to check the changed data and the respective entries into the CDU. This allowed the use of erroneous takeoff data to go unnoticed.

Operator's procedures do not require the aircraft to be stopped for checking and inserting revised takeoff data.

2.1.3 Crew composition

The interviews made clear that all the crewmembers felt unsure about their specific role in this LFUS-flight and what exactly their crew duties would be.

The composition of the crew and the division of tasks of the three-man cockpit during this flight also had influence on the occurrence of the incident. The captain gave his attention to the first officer. This accounts for the fact that the safety pilot took care of the new takeoff performance calculation. The captain relied entirely on the experience of the safety pilot. Due to his full attention to the first officer, the confidence in the safety pilot and the self-imposed time pressure, the new takeoff data was not checked.

According to the safety pilot omitting the intersection alteration might be caused by two reasons. He was not used to act as a safety pilot, having a different task at a different seat, and changing two items is exceptional for him because usually only the intersection will change while the wind remains the same.

The crew had not prioritized the first officer's learning experience in executing operational tasks in relation to a safe and resilient operation of the flight, but instead was trying to minimize the delay.

23 https://skybrary.aero/video/changing-departure-runway-while-taxiing

The process of independent performance calculation and crosschecking should be independent of crew composition as well as the timing of the calculation. Nevertheless, the composition of the crew and the division of tasks of the three-man cockpit had influence on the occurrence of the incident.

2.1.4 Crew response not adding thrust

The crew did not recognize the need to add more thrust when they approached the end of the runway. All crew members stated that they recognized the close proximity of the runway end lights during the takeoff run. However, the captain and safety pilot felt confident that the aircraft would become airborne before the runway end. Although the captain had the feeling that something was wrong during the later stages of the takeoff roll, he did not add extra thrust. Nor did the safety pilot, who had the same feeling, call for extra thrust. Adding more thrust would have increased the safety margins, especially in the case of an engine failure.

The crew did not recognize the need to add more thrust when they were approaching the end of the runway. Adding more thrust would have increased the safety margins that were compromised.

Not adding thrust in these situations had been identified in other, previous investigations as well. In one of these investigations[24], a study into the human factors behind this phenomenon has been conducted. In relation to this subject that study concluded:

"Once the aircraft began its takeoff run with insufficient thrust, the risk controls in place did not alert the crew to act to recover the situation because, in general:

a. *Pilots are unlikely to recognize that actual acceleration is below a threshold value for a particular runway.*
b. *The use of auto thrust de-couples pilots from the thrust levers.*
c. *Pilots are disposed only to reduce thrust to idle during takeoff (in case of RTO).*
d. *Pilots remove their hands from the thrust levers at V_1.*
e. *Pilots do not have to increase thrust during a takeoff in the event of an engine failure."*

Also in the Toulouse incident of the operator (see Paragraph 1.8.8 of this report), the crew did not add thrust. According to the internal report, adding thrust, when it becomes evident that takeoff performance is compromised, has been addressed in recurrent training twice during the last ten years, and is incorporated in the initial type rating course. It can therefore be concluded that two training sessions in ten years are not effective.

Not adding thrust in the case of a takeoff with insufficient thrust has also been identified in other investigations.

24 https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017

2.1.5 Operational pressure

Studies and other investigations as mentioned before, teach that time pressure, rushing and failure to cross-check were the factors most frequently contributing to the use of erroneous takeoff data. Although this is known by the airline industry, operational pressure is still present and a major contributor to incidents related to performance errors during takeoffs.

Operational pressure is influenced by two factors: the role played by the operators and the behavior of the pilots.

Firstly, the operator plays a role in operational pressure. Delays can result in financial and operational disadvantages. The operator is therefore dependent on aircraft departing and arriving on time. The operators regularly emphasize this issue. This interest could interfere with flight safety. Although safety will always be the highest priority, time pressure can indeed negatively affect safety-critical procedures. Already in 2017, in the LOSA evaluation, operational pressure was identified as the second major element of the operator's threat profile. This operational pressure leads, amongst other things, to hasty or no cross-verification of calculations and FMC selections. This investigation shows that this threat still exists. For instance, on the one side the operator states in safety publications that safety always comes first, and to '*never compromise on safety*'. On the other side, crew and other personnel know that it is important to depart at the scheduled time. A delay may result in a high risk of financial consequences for the operator. Personnel is made aware of this, for instance by issuing of a monthly punctuality chart presenting the deviation from planned arrival times (A0) and departure times (D0). This may cause operational pressure on safety critical procedures, as this incident illustrates.

Operational pressure can also be imposed by pilots themselves. It is in their nature to operate the aircraft according the flight schedule and they will do everything they can to make up for a delay. Therefore, sometimes procedures may be skipped or shortened.

To diminish the delay, the crew was eager to shorten the time to taxi and when the opportunity arose to depart from N4 instead of N5, the captain seized this opportunity. In order not to lose the advantage of *"jumping the queue"* the crew had to be ready when arriving at N4. That meant that the captain had to check the performance calculation, insert it into the FMC, pay attention to the new co-pilot taxiing for the first time, perform the before takeoff checklist and contact the tower. The timeframe in which all this had to be done by the captain caused time pressure resulting in not checking the performance calculations done by the safety pilot, nor consulting or informing the co-pilot on the outcome of the calculation. Consequently, the incorrect updated performance figures were loaded into the FMC by the captain without further checking.

> Time pressure, as well as rushing and failure to crosscheck calculations are the factors most frequently contributing to takeoff performance calculation errors.

The pursuit of punctuality can create operational pressure. Decisions are taken, in which operational procedures are sometimes overlooked or shortened which can have consequences for the safe execution of the flight.

2.1.6 Reporting of takeoff incidents

The crew did not report this incident to the operator by means of an Air Safety Report (ASR) although Operators Basic Operations Manual (BOM) clearly describes how to handle in case of a serious incident. This was caused by the fact that the aircraft took off without any problems and the crew did not recognize the seriousness of the situation. As a result, the flight recorders were not deactivated after the flight was completed. Therefore no CVR and FDR data were available for investigation purposes. As there was no CVR data available for the investigation, the communication between the crew members before and after the event could not be used to understand the decision making process of the crew. Although the lack of reporting was mentioned in the internal report of the operator, no follow-up was mentioned to raise awareness to adhere to the procedures in order to enhance safety.

In other aviation studies and reports it was found that crews do not always report a takeoff incident caused by erroneous takeoff data. Takeoff performance incidents might happen without the crew noticing any abnormalities due to the presence of ample runway length or it may be masked by a successful takeoff and an uneventful flight. Also a reason for not reporting takeoff performance incidents is the fact that although in most cases the runway threshold is overflown below the minimum altitude, this is not experienced as a safety issue by the crew, hence not seen as a reportable incident.

The operator's Safety and Compliance Organization is very vigilant about receiving notifications, according to the operator. When events are not reported by means of an ASR and only come up by FDM, the crew concerned will be approached and requested to draw up and send an ASR. This can occur occasionally. According to the operator a healthy reporting culture is considered one of the pillars of the safety management system. Part of this is actively approaching crews to send safety reports if they were not yet received.

Two other, similar, serious incidents were not reported to Air Safety Authorities by the operator although this is a mandatory action. This excluded the possibility of an independent safety investigation. The operator could not explain why these serious incidents had not been reported to the authorities because it was too long ago.

Because the aircraft took off without any problems and the crew did not recognize the seriousness of the situation, the flight recorders were not deactivated after the flight. No CVR and FDR-data were available for investigation purposes.

Although mentioned in the internal report of the operator, no actions were taken to raise awareness of the importance of reporting and securing flight recorders following a serious incident.

2.1.7 Flight Data Monitoring-program

This, and another incident became only known after the operator analysed the flight data at a later date.

The presence of FDM filters capable of detecting takeoff performance errors even when ample margins exist, are crucial to improve reporting by flight crews when errors are identified and to counteract underreporting when they are not.

The FDM program should be capable of detecting performance errors to be able to identify the magnitude of the takeoff performance risk. The operator developed several FDM filters to detect takeoff performance incidents including filters for comparing actual used runway intersection versus used Lintop calculation. Although not all filters are fully operational yet the testing of the additional filters proved that they are capable of detecting a wide variety of takeoff performance errors.

FDM filters are an important tool in detecting takeoff performance errors and should therefore be implemented without delay.

2.1.8 Risk management

The last minute, unplanned and unprepared performance change introduced risks which have influenced the flight safety. In the event of (unforeseen) changes or disruptions, all actions of the crew should focus on the possibility that these disruptions may introduce risks. The crew shall ensure that potential risks are managed in such a way that the resulting operations respect the necessary safety margins. In this way, they can maintain their intended level of safety for the required operation; threat and error management.

According to Hollnagel and co-authors (2006) "*Resilience is the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions*." This principle is called Resilient Operations.[25]

When deviating from the planned operation or procedures, the possible risks must be identified and managed. By accepting the unplanned diverging of procedures under time pressure, there was no more tolerance for faults, as the crew had no time to appreciate the associated risks fully, and by that maintain the required level of safe operations.

The crew accepted the last minute changes without taking their time to identify and assess the risks. As a result the safety margins were compromised.

25 Hollnagel, Woods and Levenson, *Resilient Engineering; Concepts and precepts*, 2006.

2.1.9 Checking of correct runway and intersection

The crew of the current incident did not compare the calculated takeoff point with the actual one used either. At the time of this incident no procedures were in effect that required the crew to do so. Some other operators have chosen to issue a runway change checklist to be used in case of runway or intersection changes. No such checklist has been issued by the operator though, nor has an item been incorporated in the before takeoff checklist with the operator.

Between 2013 and 2019 the operator had experienced, as far as known, three similar incidents. All these incidents involved a last minute decision to change a planned runway or intersection during taxi out or just prior to pushback. In all three incidents, the flight crews involved did not compare the inserted runway or intersection for which the takeoff data were calculated with the actual runway or intersection used for departure.

As a result of this incident the operator has incorporated explanatory notes in the reference guide of the Basic Operating Manual (OM-A). Despite these explanatory notes, which are based on Boeing's Flight Operations Technical Bulletins (FOTB), in OM part A or part B, there is still no call for an explicit check of the runway or intersection used with the runway/intersection used in the performance calculations.

Furthermore, neither the Boeing FOTB, nor the operator's notes do give any practical directives to crews on *how* to use or implement them in day to day practice or routines. In absence of a specific procedure that calls for a check for the calculated runway or intersection with the actual used runway or intersection, crews have to decide for themselves *how* to apply the considerations and directives of the Reference Guide with the risk that misunderstandings within the crew will develop.

Checking whether the runway or intersection used corresponds to the location used in the performance calculations should be included in the before takeoff procedures.

A procedure or a checklist item in the operator's manuals to check before takeoff if the aircraft is on the correct location in relation to the performance calculation, can prevent the aircraft commencing the takeoff roll with erroneous takeoff data. It is most effective when aircraft manufacturers include this procedure in the aircraft manuals and checklists.

2.2 Developments

Most of the mentioned takeoff incidents can be avoided by complying with the FCOM procedures and crosschecks that enable the flight crew to identify discrepancies. Because takeoff incidents continue to happen, both the aviation industry and regulators have been taking steps to prevent takeoff incidents. Below is a brief description of these developments.

2.2.1 *Industrial developments*

Both major aircraft manufacturers, Boeing and Airbus, have been developing systems that can detect incorrect settings at takeoff. If an incorrect setting is detected by a system, it can generate warnings or cautions.

Boeing

Boeing has developed a runway disagree functionality, but this feature does not discern for an intersection takeoff. Further it has developed an onboard performance tool (OPT) which sends the performance calculations directly to the FMC and helps eliminating entry errors while inserting performance figures. While this system is not developed to detect performance errors, a feature has been implemented to compare OPT inputs between flight crew members for inconsistencies. OPT is available as a standalone tablet option for the 737, however the 737-version does not contain the feature that sends data directly to the FMC as developed on other Boeing models. Finally, Boeing is also developing a Takeoff Acceleration/ Performance Monitoring System which will be evaluated in simulator and aircraft flight testing, as part of the development process and is presently not available on any type.

Airbus

Airbus has developed takeoff surveillance and monitoring systems, TOS and TOM. Takeoff Surveillance consists of two parts, TOS1 and TOS2. TOS1 checks for gross errors on weight or takeoff speeds inserted into the FMC during the preflight phase. TOS2 computes the Lift Off Distance (LOD) expected with the performance dataset entered by the crew. The LOD computation takes into account any takeoff shift[26] entered. When the flight crew applies takeoff thrust, TOS2 performs a final LOD check based on the real aircraft position. If the runway distance available in front of the aircraft is lower than the computed LOD this will trigger a warning.

Takeoff monitoring (TOM) provides an additional safety tool during the takeoff roll. From 30 kts, it compares the expected acceleration with the real acceleration of the aircraft. If the difference between the real aircraft acceleration and the expected acceleration is more than 15 % when the aircraft reaches 90 kts, TOM will trigger a warning.

2.2.2 Software developments

Another development are programs that visually present the performance calculation on a tablet. Those (software) programs not only provide the necessary output of the entered

26 For instance: an intersection takeoff, or a runway shortening.

performance data, but also give a visual representation of the outcome of the calculation on the runway. Looking at this incident, but also at other similar incidents, a visual presentation of the erroneous takeoff performance calculations might well have made the crew realize they had made an error.

2.2.3 *Regulators*

As a result of several investigation reports and recommendations, EASA published Safety Information Bulletin (SIB) 2016-02 "Use of erroneous parameters at take-off" on 16 February 2016. This SIB was revised by SIB 2016-02R1, published on 6 September 2021.[27]

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

- raise flight crews, operators and competent authorities' awareness of the specific hazard;
- provide recommendations to operators on the completion of a specific safety risk analysis and assessment related to this issue, in order to assess the effectiveness of mitigations in place and determine the need for additional or alternative action(s);
- provide recommendation on training items to be emphasized during flight crew initial and recurrent training to increase awareness on the issue; and
- provide recommendations on the use of the FDM programme to identify precursor events.

According to this SIB, possible mitigation elements that can be implemented are:

1. Adequate flight crew procedures and training related to takeoff parameter calculation, verification methods, common errors, contributing factors and error trapping.
2. Flight crew training related to the identification of inadequate takeoff performance and the initiation of appropriate actions. This training should, if possible, include de-identified information and examples stemming from the FDM program and flight crew reports.
3. Aircraft systems software performing automated gross error checks of values entered and computed.

The content of SIB 2016-02R1 largely corresponds to the findings in this report, although the influence of derated takeoffs and takeoffs with assumed or flex temperature, are not mentioned.

In 2020, the Dutch Safety Board published the report '*Erroneous takeoff performance calculation B777'*. This report states that the Board already investigated several takeoff performance related occurrences in the period 2009-2019.[28] In its report '*Insufficient thrust setting for takeoff*' of 2018[29] two recommendations were made to EASA:

27 https://ad.easa.europa.eu/ad/2016-02R1
28 Dutch Safety Board, *Erroneous takeoff performance calculation B777*, October 2020. https://www.onderzoeksraad.nl/en/page/4808/foutieve-berekening-van-startprestatie-boeing-777
29 Dutch Safety Board, *Insufficient thrust setting for takeoff,* March 2018. https://www.onderzoeksraad.nl/nl/media/inline/2018/7/10/dc88ab83e9f820183230_engelse_b_rapportage_onvoldoende_vermogen_ingesteld_voor_de.pdf

1. *To prioritize the development of specifications and the establishment of requirements for onboard weight and balance systems.*
2. *To, in cooperation with other regulatory authorities, standardization bodies, the aviation industry and airline operators, start the development of specifications and the establishment of requirements for Takeoff Performance Monitoring Systems without further delay.*

EASA's reaction on the recommendations at that time was that Erroneous Takeoff Performance Parameters are recognized and embedded in the Safety Risk Portfolio and integrated in the Safety Risk Management process, where they have already been identified as a priority safety issue. Besides, the overall feasibility of a Takeoff Performance Monitoring System (TOPMS) has still not been demonstrated, and no specifications could be developed at that stage.

In the 2020 report the following recommendation was made to (amongst others) EASA:
To take the initiative in the development of specifications and, subsequently, develop requirements for an independent onboard system that detects gross input errors in the process of takeoff performance calculations and/or alerts the flight crew during takeoff of abnormal low accelerations for the actual aeroplane configuration as well as insufficient runway length available in case of intersection takeoffs. Take this initiative in close consult with the aviation industry, including manufacturers of commercial jetliners amongst which in any case The Boeing Company.

EASA's response on this recommendation was that measures were planned on short, medium and long term. The short and medium term plans included a reinforcement and review of the SIB. In the long term EASA intends to re-evaluate the feasibility of development of requirements for onboard system aimed to detect gross input errors, given the maturity evolution of some technical solutions.

Furthermore, in 2020 the following actions were under review through EASA's Best Intervention Strategy:
- Review technical solutions related to EUROCAE WG 88 (MOPS) and cost benefit;
- Recommendation for technical solutions to capture wrong T/O parameters;
- Recommendation for technical solutions to capture inadequate acceleration versus expected or insufficient runway length.

2.3 Reducing the risk of erroneous takeoffs

Erroneous performance calculations and entries are a longstanding problem in the aviation industry, which is still present. A lot of these erroneous performance calculations find its origin in last minute changes in the performance calculations while the aircraft is not stationary, as can be seen with this operator. Standard Operator Manuals of the manufacturers do not provide specific procedures or policies to prevent erroneous performance happening during standard line operations.

Performance calculations should be regarded as a critical process, with all associated risks, that deserves undivided attention of the flight crew under all circumstances. Changing the takeoff performance while taxiing, precludes this undivided attention of the flight crew by default.

Existing technical warning systems do not cover all situations for all aircraft, and thus will not be an absolute prevention against erroneous performance. As long as these technical systems are not an absolutely effective way to prevent takeoff incidents, operational solutions must be sought also. Including a standard procedure for last minute changes in the aircraft operating manuals by the aircraft manufacturer, could reduce the risk of erroneous takeoff data.

Changing performance data during taxiing deserves full and undivided attention of flight crews. As long as no effective technical solutions are available, operational solutions have to be sought.

3 CONCLUSIONS

Direct cause
The serious incident was caused because the aircraft accelerated too slowly to the incorrect takeoff speeds in relation to the available runway length. This was the result of using erroneous takeoff data, based on the wrong intersection.

Operational factors
The crew had planned an N5 intersection takeoff. They were not able to comply with Air Traffic Control's request for an N4 intersection takeoff due to performance requirements. Having heard new wind information, the crew reconsidered and determined an N4 intersection was possible which would reduce the delay. New takeoff performance calculations were completed during taxiing out just before lining up the aircraft for takeoff.

Because the initial intersection had not been changed into the actual intersection in the data necessary for the performance calculation, erroneous takeoff data were generated.

The changed data and the output of the performance calculation were neither checked nor cross checked, although this is included in the procedures. Time pressure and the division of tasks of the three-man cockpit had influence on the occurrence of the incident.

Operator's procedures do not require the aircraft to be stopped when new takeoff performance calculations have to be made during taxiing out. Some other operators do have included this requirement in their procedures.

The erroneous takeoff performance data resulted in an effective runway length that was 1,034 metres less than the length used for the calculation. In case of an aborted takeoff at V_1 the aircraft would have been unable to stop on the runway. In the event of an engine failure after V_1 there would have been insufficient runway length remaining to accelerate the aircraft to the minimum V_2 speeds. This all resulted in reduced safety margins during the takeoff.

Despite some training, the crew did not recognize the need to add more thrust when the end of the runway approached and therefore did not add thrust. Not adding thrust in these situations has been identified in other earlier investigations.

Organizational factors
The process of independent performance calculation and crosschecking should be independent of crew composition as well as the timing of the calculation.

Operational pressure caused the crew to choose for an unplanned, last minute change in runway intersection. As other cases of this operator show, it was not an isolated event, nor a new phenomenon. Although the existence of operational pressure was already signalled in 2017, it still appears to exist.

The serious incident was not reported by the crew to the operator nor were the flight recorders secured.

Although mentioned in the internal report of the operator, no actions were taken to raise awareness of the importance of reporting and securing flight recorders following a serious incident.

Two other, similar, serious incidents were not reported to the Air Safety Investigation Authorities by the operator. This excluded the possibility of an independent safety investigation.

The known problem of takeoff data performance occurrences
Over the past, several takeoff incidents have occurred. Despite developments, no technical solutions are yet available to prevent this. Therefore, the solution must be sought in operational measures. Changing takeoff data during taxiing is a critical process and deserves full and undivided attention of flight crews. Continuing taxiing precludes this, as the majority of related incidents have shown.

4 RECOMMENDATIONS

Aircraft taking off with erroneous takeoff data cause hazardous situations that may lead to loss of aircraft or loss of life. A number of safety investigation reports, including those published by the Dutch Safety Board, have been written on this long standing and complex problem. These reports have led to recommendations to regulatory authorities, standardization bodies, aviation industry and airline operators to develop procedural, technical and operational safety improvements. These developments are ongoing and some of these improvements show the potential to adequately detect take off data input errors or insufficient take off performance; however, a comprehensive solution for this complex problem has not been developed and operationalized across the world wide air transport fleet yet.

Taking off with erroneous takeoff data is frequently a result of operational pressure when last minute changes take place during taxiing. To allow the crew more time to independently check and enter the changed data, it is advisable to stop the aircraft to perform these actions. This stationary moment should be considered as one of the key practices against preventing erroneous takeoff data entry. As this investigation has shown, this is already included in the procedures of several airlines. It has also been found that flight crew usually hold on to a derated takeoff and do not select full thrust if there is a suspicion that the takeoff roll does not develop as expected.

In addition to previous recommendations, the Dutch Safety Board therefore makes the following recommendations:

To the European Union Aviation Safety Agency (EASA):

To recommend to operators and their flight crews to allow for a stationary moment when calculating, checking and entering takeoff performance data in case of last minute changes and implement this advice as recommended practice in guidance material, Safety Information Bulletin 2016-02R1 and other safety promotion material.

To KLM Royal Dutch Airlines:

To implement the following measures to prevent crews from taking off with incorrect takeoff data:
- Calculate, check and enter changed takeoff performance data only when the aircraft is stationary.
- Develop a procedure to have flight crews prepare an alternative plan in advance and encourage the use of full thrust for when last minute changes occur.
- Train flight crews to take action if they suspect that the takeoff roll does not develop as expected; make this training an element of the recurrent training program.

APPENDIX A

COMMENTS ON DRAFT REPORT

In accordance with the Dutch Safety Board Act, a draft version (without recommendations) of this report was submitted to the parties involved for review. The following parties have been requested to check the report for any factual inaccuracies and ambiguities:

- KLM Royal Dutch Airlines
- The cockpit crew members
- European Union Aviation Safety Agency
- Human Environment and Transport Inspectorate
- Ministry of Infrastructure and Water Management
- National Transportation Safety Board
- Air Accidents Investigation Branch
- Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

The responses received, as well as the way in which they were processed, are set out in a table that can be found on the Dutch Safety Board's website (www.safetyboard.nl). Those responses can be divided into the following categories:

- Corrections and factual inaccuracies, additional details and editorial comments that were taken over by the Dutch Safety Board (insofar as correct and relevant). The relevant passages were amended in the final report.
- Not adopted responses; the reason for this decision is explained in the table.

SUMMARY OF OCCURRENCES OF AIRCRAFT TAKINGOFF WITH ERRONEOUS TAKEOFF DATA

Below a number of accident and incident investigation reports are listed of aircraft taking off with thrust setting being too low or taking off from an intersection providing less TORA than used for calculation of takeoff data.

Table 1: Takeoff with thrust setting being too low

Date	Model	Safety Board / Report No./ Incident or accident	Description
11 Dec 18	Embraer 190	AAIB EW/ G2018/12/05 Serious incident	Takeoff with too low thrust setting. Rotation was delayed, takeoff otherwise uneventful.
16 Nov 17	Boeing 737-700	TSIB AIB/AAI/ CAS.154 Serious incident	Takeoff with too low FMS thrust setting. Aircraft struck approach lights beyond end of runway.
21 Jul 17	Boeing 737-800	AAIB 2/2018 Serious incident	Takeoff with too low FMS thrust setting. Aircraft struck eight approach lights beyond end of runway.
15 Jul 17	Boeing 747-8F	JTSB AI2019-2 Serious incident	Takeoff with too low thrust setting. Case regarded as equivalent to runway overrun.
20 Apr 16	Boeing 717	ATSB AO-2016-065 Incident	Takeoff with too low thrust setting. Adjusted thrust setting was reduced by auto-throttle. Takeoff uneventful.
21 Nov 10	Boeing 737-700	AAIB EW/ C2010/11/06 Incident	Runway change during taxi-out. A too high assumed temperature was inserted. Aircraft became airborne before the end of the runway.

Table 2: Takeoff from an Intersection providing less Takeoff Run Available (TORA) than TORA used for calculation of takeoff data

Date	Model	Safety Board / Report No./ Incident or accident	Description
21 Jan 17	Airbus A320	ATSB AO-2017-008 Incident	ATC prevented aircraft from departing from intersection providing less runway than intersection used for takeoff data calculation. (Δ 403 m)
30 Aug 16	Boeing 777-300	CAA India VT-JEK inquiry Serious incident	Aircraft departed Runway 27L Intersection S4E, with takeoff data full runway (Δ 1,069 m). Aircraft airborne with approx. 97 m runway left. No thrust was increased.
9 May 16	Airbus A319	AAIB EW/ G2016/03/07 Serious incident	Aircraft departed intersection, with takeoff data assuming full runway length (Δ 560 m). Aircraft lifted off closer to runway end than expected.
3 Dec 15	Boeing 737-800	DSB Insufficient thrust setting for takeoff - Serious incident	Takeoff data were based on Runway 03 instead of Runway 21 (Δ 1,120 m) Although the flight crew observed there was less runway than expected, thrust was not increased.
16 Oct 15	Airbus A319	AAIB EW/ G2015/10/08 Serious incident	Aircraft departed Runway 21 Intersection U5, with takeoff data for Runway 03 INT N2 (Δ 1,120 m). Aircraft airborne with approx. 213 m runway left.
16 Sep 15	Boeing 777-300	QCAA 001/2015 Accident	Aircraft departed from intersection with takeoff data full runway length (Δ 1,000 m). Aircraft collided with approach light structure, puncturing pressure hull. Unaware of collision flight was continued to its destination.
16 Jul 15	Airbus A319	AAIB EW/ G2015/07/11 Serious incident	Aircraft departed from intersection with takeoff data full RWY length (Δ 474 m) Aircraft airborne with approx. 180 m runway left. No thrust was increased.
6 Oct 14	Airbus A320-200	SUST No.2256 Serious incident	Aircraft departed Runway 15 intersection with takeoff data full runway length (Δ 1,530 m). Aircraft passed runway end at height of 50 ft. Thrust was increased.
14 Oct 13	Boeing 737-800	ATSB AO-2013-195 Incident	Aircraft departed from intersection with takeoff data full runway length (Δ 1,116 m). Takeoff was uneventful.

Date	Model	Safety Board / Report No./ Incident or accident	Description
1 Oct 13	Airbus A320-200	SUST No.2246 Serious incident	Aircraft departed Runway 17 from intersection with takeoff data full runway length (Δ 1,580 m). Aircraft passed runway end at height of 104 ft. Thrust was not increased.
21 Jun 13	Embraer 190	ATSB AO-2013-112 Incident	Takeoff from intersection providing less runway than required. Aircraft lifted off within confines of runway.
8 Dec 11	Airbus A340-300	Cenipa IG-556/ Cenipa/ A/2018, Serious incident	Aircraft departed Runway 10 Intersection BB, with takeoff data of Intersection AA (Δ 600 m). Aircraft collided with app light structure and localizer antenna, damaging gear. Unaware of collision flight was continued to its destination.
22 Nov 11	Boeing 737-400	ATSB AO-2012-020 Incident	Aircraft departed from intersection with takeoff data full runway (Δ approx. 1,300 m). Aircraft was rotated early. Takeoff otherwise uneventful.
12 Jun 11	Airbus A321	ATSB AO-2011-073 Incident	Aircraft departed from intersection with takeoff data full runway (Δ approx. 1,090 m). Aircraft airborne with approx. 450 m runway left.
26 Sep 09	Boeing 777-200	AAIB 4/2010 Serious incident	Aircraft departed Runway 07 Intersection B, with takeoff data of Intersection A (Δ 695 m). Aircraft passed runway end at height of 80 ft. Thrust was not increased.

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