DUTCH
SAFETY BOARD

Takeoff with erroneous takeoff data, Embraer 195-E2

Learning to reduce the risk of using erroneous takeoff data

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Learning to reduce the risk of using erroneous takeoff data

The Hague, September 2023

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The Dutch Safety Board

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	Dutch Safety Board
Chairperson:	C.J.L. van Dam E.A. Bakkum
Secretary Director:	C.A.J.F. Verheij

Visiting address:
Lange Voorhout 9
2514 EA The Hague
The Netherlands

Postal address:
PO Box 95404
2509 CK The Hague
The Netherlands

Telephone: +31 (0)70 333 7000

Website: safetyboard.nl
E-mail: info@safetyboard.nl

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 English and Dutch version, the English text will prevail.

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SUMMARY

Occurrence

On 12 September 2021, a serious incident occurred with an Embraer 195-E2 at Berlin Brandenburg Airport in Germany. The aircraft took off with a selected amount of takeoff thrust, based on erroneous takeoff data. The Dutch Safety Board investigated the incident and found that the aircraft took off from intersection L5 - as the crew intended - while the performance calculation was based on intersection K5. The actual available runway length was 1320 metres less than the runway length used in the calculation of the performance parameters. The selected thrust setting was such that the acceleration of the aircraft was too slow to safely take off from intersection L5. As a result, the aircraft became airborne 443 metres before the end of the runway. Safety margins were reduced during the takeoff. The aircraft would likely not have been able to safely abort the takeoff at speeds close to V1.

The investigation

Incidents related to erroneous takeoff data occur frequently across all aircraft types and operators. The persistence of this type of occurrence is a long standing and complex problem. There is still no technical solution that addresses the wide range of factors underlying the use of erroneous takeoff data. It is therefore important that operators learn as much as possible both retroactively - from occurrences - and proactively with the aim of reducing the number of these incidents. This is why the Dutch Safety Board investigated the incident on 12 September 2021 with the focus on learning by the operator in relation to the risk of using erroneous takeoff data.

Contributing factors

The pilots stated they both accidentally selected intersection K5 instead of L5 in the takeoff performance calculation application. Contributing factors included touchscreen issues such as the lack of system feedback about the finger location and the 'fat finger' problem. Furthermore, lacking visual feedback in the performance calculation application (airport synoptic) and the presence of normally unused options (runway intersections) in the pull down menu played a role. The selection error could propagate because during the cross check the pilots likely only focused on the performance calculation outputs. Also, the crew trusted the performance calculation application.

Learning from the occurrence

The occurrence did not trigger the pilots to think the incident crossed the severity level for which it is necessary to immediately contact the Operations Control Centre of the operator. As a consequence, the Safety and Compliance Organisation (SCO) of the operator was not contacted immediately and therefore did not have the opportunity to secure the cockpit voice recorder nor to interview the crew shortly after the event. The flight crew filed an air safety report (ASR) to the SCO after landing on 12 September 2021.

The SCO initiated a limited investigation (an assessment) by conducting interviews, reviewing flight data, consulting previous investigations into similar incidents and analysing this information. The operator concluded that further investigation into the occurrence was not necessary as little could be learned and it could contribute little to the mitigations already in place from previous investigations. The fact that erroneous takeoff data was prioritised as a safety concern and the event was classified as high risk did not play a role in this decision.

The operator took two additional mitigating actions after the limited investigation by the SCO. First, the chief pilot sent an e-mail with general information about erroneous takeoff data in order to raise awareness. Second, airport information in the manuals was adjusted, to prevent confusion regarding runway designation.

Learning in order to prevent the use of erroneous takeoff data
The operator manages safety through their Safety Management System (SMS), in accordance with existing guidelines and regulatory frameworks. This provides the operator with a structured approach to manage risks in its operation. The operator has a structure in place to learn by carrying out safety investigations. In the period 2012-2021, several incidents related to erroneous takeoff data occurred and a safety concern was formulated. However, these incidents were not investigated by the SCO, because they reasoned that a predictive investigation (a safety investigation before a change is implemented) should be performed instead. Therefore, valuable lessons on a detailed technical and procedural level may have been lost. It seems that the balance between having enough occurrences to learn from and preventing multiple investigations from having similar findings is missing.

A hindering factor to learning about the hazard of the use of erroneous takeoff data is a lack of occurrence data, which is not unique to this operator. Pilots do not always recognize or report occurrences related to erroneous takeoff data and the current flight data monitoring program is unable to detect all occurrences. Therefore, the operator was not able to monitor the number of occurrences related to erroneous takeoff data, to carry out reliable data analyses, assess the need for safety investigations and measures, and monitor the effect of measures already taken to prevent the use of erroneous takeoff data. Also, the lack of safety goals directly related to erroneous takeoff data was due to a lack of data. Therefore, the safety goals did not trigger the operator to take measures that cover the entire breadth of the problem.

Learning from work-as-done
The operator recognises that employees play an important role in a learning organisation and takes actions to capture the knowledge of employees about existing processes, about how work is done in practice and about occurrences. Moreover, the operator works according to the principles of Just Culture and various aspects that may contribute to an open culture are present at the operator. The operator also has a structure in place for dialogue and discussion with pilots. However, the quality of the information obtained from employees might be improved by asking more open questions and ensuring a systematic approach to collecting pilot input. The operator does not have a structure in place to learn from work-as-done. The operator might learn more from work-as-done by

questioning their own operations and investigating why some work is not done as designed or imagined when that emerges from observations during training, audits or evaluations. Moreover, the operator is aware of the added value of learning from personal strategies and has additional opportunities to learn from personal strategies and by doing this can gain detailed understanding of the context of a particular personal strategy.

Lessons and recommendations

The Board formulates three lessons and a recommendation. The lessons aim to improve learning by operators. Operators may focus on improving data availability by increasing the amount of data and increasing the diversity of data sources, while they should also prioritise difficult to identify hazards or low-frequency occurrences with potentially catastrophic consequences for investigations and mitigating actions. The recommendation aims to stimulate the development of onboard technical solutions to reduce the risk of using erroneous takeoff data.

LESSONS TO OPERATORS

This investigation focused on learning by the operator in relation to the risk of using erroneous takeoff data. The Dutch Safety Board chooses to draw up lessons to operators rather than making recommendations, because the lessons apply to many operators who base their safety approach on the same existing regulatory framework. Therefore, the lessons - identified in this section - are universally applicable.

Lack of data may hinder learning when working with a data-driven safety approach. The Dutch Safety Board identifies the following lessons to deal with a lack of data and improve learning by operators:

1. Increasing the amount of data by boosting the occurrence reporting and by developing a flight data analysis tool in which flight data is combined with external data.

2. Increasing diversity of the data sources to prevent blind spots in types of occurrences. Learning from work-as-done might yield unique complementary lessons to learning from occurrences. Structures for dialogue and discussion with employees lower the threshold for them to raise ideas and concerns, which may contribute to integral learning instead of procedural learning.

Because it may be difficult to increase data availability the Board suggests the following approach to be taken simultaneously with the aforementioned actions:

3. Prioritising hazards which are hard to determine or low-frequency occurrences with potentially catastrophic consequences for investigations and mitigating actions.

RECOMMENDATIONS

The use of erroneous takeoff performance data is a safety issue of general concern and not specific to any aircraft type. The European Union Aviation Safety Agency (EASA) expects aircraft software and systems to provide hard barriers against erroneous data entry in the future. In 2020, the Dutch Safety Board recommended EASA to develop requirements for onboard systems. However, technical solutions will take some time to be developed and implemented in regulation. In order to speed up the availability of technical and software onboard systems the aviation industry needs to develop technical solutions to prevent the use of erroneous takeoff data. This investigation concludes that Embraer's performance application tool can be improved such that misselections are less likely to occur or more easily detected. Embraer started development of these improvements which are expected to be implemented in 2024. Therefore, the Dutch Safety Board does not make a recommendation on this issue and encourages Embraer to continue developing improvements for the performance application tool. The investigation also shows that Embraer has no plans to develop onboard systems that provide hard barriers against erroneous data entry, whereas some other manufacturers do. Therefore, the Dutch Safety Board makes the following recommendation:

To Embraer:

1. To start the development of an independent onboard system that detects gross input errors in the process of takeoff performance calculations and/or alerts the flight crew of abnormal low accelerations for the actual aeroplane configuration as well as insufficient runway length available.

C.J.L. van Dam
Chairperson Dutch Safety Board

C.A.J.F. Verheij
Secretary Director

ABBREVIATIONS

ACARS	Aircraft Communications Addressing and Reporting System
AMC	Acceptable Means of Compliance
ASD	Accelerated Stop Distance
ASDA	Accelerate Stop Distance Available
ASR	Air safety report
BFU	German Federal Bureau of Aircraft Accident Investigation
CAA UK	Civil Aviation Authority, United Kingdom
CVR	Cockpit voice recorder
DALPA	Dutch Airline Pilots Association
EAF	Event Assessment Form
EASA	European Union Aviation Safety Agency
EDDB	ICAO code for Berlin Brandenburg Airport
EHAM	ICAO code for Schiphol Amsterdam Airport
EFB	Electronic Flight Bag
ERC	Event Risk Classification
FDM	Flight Data Monitoring
FMS	Flight Management System
ft	Feet
hrs	Hours
ICAO	International Civil Aviation Organization
ISMS	Integrated Safety Management System
ISMM	Integrated Safety Management Manual
KLC	KLM Cityhopper
KLM	KLM Royal Dutch Airlines
kt	Knots
LINTOP	Lido Integrated Takeoff Performance Tool
LOE	Line operational evaluation
LOQE	Line oriented quality evaluation
OCC	Operations Control Centre
OM	Operations Manual

QAR	Quick Access Recorder
RAM	Risk Analysis Meeting
SAG	Safety Action Group
SCO	Safety and Compliance Organisation
SIRA	Safety Issue Risk Analysis
SMS	Safety Management System
T_{ASS}	Assumed temperature
TODA	Take Off Distance Available
TORA	Take Off Run Available
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Takeoff rotation speed

GLOSSARY

Accelerate Stop Distance Available (ASDA)
The length of the takeoff run plus the length of the stopway, where provided.

Clearway
A defined rectangular area on the ground or water under the control of the appropriate authority, selected or prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height.

Electronic Flight Bag (EFB)
An electronic information system for flight crew, which supports flight operations or duties. An EFB comprises of an electronic device (a laptop, a tablet or an iPad) and applications. EFB devices can store and display a variety of aviation data or perform basic calculations for aircraft performance or fuel loading purposes.

ePerf
ePerf is one of the installed applications on the iPad. ePerf is used for takeoff and landing performance calculations for Embraer aircraft. The content of ePerf is developed and updated by Embraer, however, they use a third party to provide them with an airport information database. To ensure ePerf uses the correct database files, crew members have to scan a QR (quick response) code in the cockpit of the specific aircraft variant with a scanner embedded in the ePerf application.

Erroneous takeoff data
Errors introduced during the calculation and/or entry of takeoff performance related parameters into aircraft Flight Management Systems (FMS) and other related systems (such as EFBs).

Indirect learning
Learning from occurrences in one organisation or in one industry sector can help prevent occurrences in another organisation or in another industry sector.

Just culture
Just culture is an atmosphere of trust in which people are encouraged, even rewarded, for providing essential safety-related information - but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour'.[1] Just culture contributes to an environment in which employees feel free to report unsafe events and situations and helps the organisation to learn from them. The starting point of just culture is that unsafe behaviour usually does not happen intentionally. Unsafe events are seen as opportunities for the organisation to learn.

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[1] Reason, J., *Managing the Risks of Organisational Accidents*. Aldershot: Ashgate, 1999.

Learning from work-as-done
Learning from work-as-done is learning from deviations in the prescribed working methods.

Meta-learning
An organisation reflects on the way it learns and thereby learns to learn.

Proactive learning
Proactive learning is learning without an occurrence.

Psychological safety
Psychological safety is 'the belief that one will not be punished or humiliated for speaking up with ideas, questions, concerns, or mistakes'.[2] People who do not see it as a risk to their career and happiness at work to openly share ideas, questions and concerns, will feel free to do so. Psychological safety in the work environment is necessary to learn, innovate and grow as an organisation.

Reactive learning
Learning from an incident, an accident or a number of incidents or accidents.

Safety concern
The operator defines a safety concern as a possible hazard which has not been investigated.

Safety goal
The operator uses the term safety goal for a target value for a safety performance indicator. Safety goals are used to manage safety.

Safety issues
The operator may formulate what it calls 'safety issues' as the output of a safety investigation. Subsequently a risk is assigned to each safety issue, which is called the 'analysed risks'.

Stopway
A defined rectangular area on the ground at the end of takeoff run available prepared as a suitable area in which an aircraft can be stopped in the case of an abandoned takeoff.

Takeoff configuration warning system
A safety device intended to help ensure that takeoff is not attempted with the aircraft in an inappropriate or unsafe configuration.

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[2] Edmondson, A.C., Lei, Z., *Psychological Safety: The History, Renaissance, and Future of an Interpersonal Construct.* Annual Review of Organizational Psychology and Organizational Behavior, 2014.

Take Off Distance Available (TODA)
The length of the Takeoff Run Available (TORA) plus the length of the clearway, where provided.

Take Off Run Available (TORA)
The length of runway declared available and suitable for the ground run of an aeroplane taking off.

GENERAL OVERVIEW

Identification number:	20211105
Classification:	Serious incident
Date, time of occurrence:	12 September 2021, 17.38 hours[3]
Location of occurrence:	Berlin Brandenburg Airport (Germany), EDDB
Operator:	KLM Cityhopper (KLC)
Registration:	PH-NXD
Aircraft type:	Embraer 195-E2
Aircraft category:	Fixed wing aircraft - passenger
Type of flight:	Commercial Air Transport (passenger)
Phase of flight:	Takeoff
Damage to aircraft:	None
Flight crew:	Two
Cabin crew:	Three
Passengers:	92
Injuries:	None
Other damage:	None
Light conditions:	Daylight

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[3] All times in this report are local times (UTC + 2 hour), unless otherwise specified.

1 INTRODUCTION

1.1 Reason for this investigation

1.1.1 The serious incident

On 12 September 2021, a takeoff performance related occurrence took place during takeoff of an Embraer 195-E2 at Berlin Brandenburg Airport in Germany. The aircraft took off from Runway 25R after it had lined up via intersection L5, while the takeoff performance calculation and the selected amount of engine thrust were based on a takeoff from intersection K5, near the beginning of the runway.[4]

The flight crew decided to perform a takeoff from intersection L5. Both pilots accidentally selected intersection K5 - which is located near the beginning of Runway 25R - in the performance calculation application on their Electronic Flight Bag (EFB). They were both independently performing the takeoff performance calculation. Neither of them detected the error during the cross check. As a result of the erroneous takeoff parameters being used, the aeroplane took off with an improper takeoff flap setting, improper takeoff speeds, and less thrust than required for that intersection. This resulted in the takeoff roll being longer than usual for a takeoff from the line-up position near L5. This is considered to be a dangerous situation because the runway length remaining was insufficient to safely abort the takeoff at speeds close to the takeoff decision speed (V_1).

On 24 September 2021, the operator reported the occurrence to the Dutch Safety Board, which subsequently reported it to the German Federal Bureau of Aircraft Accident Investigation (BFU), representing the state of occurrence. The BFU delegated the investigation to the Dutch Safety Board, representing the state of the operator and the state of registry. The Board classified the occurrence as a serious incident[5] for which an investigation and reporting obligation stands. The BFU and the Brazilian Aeronautical Accident Investigation and Prevention Center (CENIPA), representing the state of design and manufacture of the aircraft, provided assistance to the investigation. The European Union Aviation Safety Agency (EASA) appointed a technical adviser.

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[4] An intersection takeoff is a departure initiated from an intersection line-up position other than the runway threshold without using the entire runway length.

[5] Based on EU regulation 996/2010. One of the listed examples of serious incidents that are potentially serious is a gross failure to achieve predicted performance during takeoff or initial climb.

Erroneous takeoff data
The aircraft took off from an intersection that did not match the intersection used in the takeoff performance calculation. More generally speaking, the aircraft took off with a selected amount of takeoff thrust, an improper takeoff flap setting and improper takeoff speeds based on erroneous takeoff data. Erroneous takeoff data result from errors that are introduced during the calculation and entry of takeoff performance related parameters into aircraft Flight Management Systems (FMS) and other related systems (such as EFBs). A mistake in calculating values or when entering parameters into the aircraft systems, FMS or EFB, could lead to an error in the takeoff distance, the thrust, the speed or the trim setting required for takeoff, all with potentially catastrophic consequences. The definition for erroneous takeoff data, as used in this report, follows EASA's definition for erroneous performance parameters.[6] In this report, the term erroneous takeoff data is used for readability purposes.

1.1.2 Longstanding worldwide hazard

The use of erroneous takeoff data may result in takeoff initiation with inadequate thrust or attempted rotation at an airspeed which is too low for the actual aircraft mass/takeoff configuration or with insufficient runway length remaining. The known consequences of these erroneous data entries include tail strikes, collisions with obstacles and runway overruns following an aborted takeoff. In the most severe situations this type of error leads to loss of the aircraft and lives. The most recent fatal accident of this type was the crash of a Boeing 747 freighter in Halifax, Canada on 14 October 2004.[7] The majority of occurrences resulting from erroneous takeoff data being used during the takeoff performance calculation, however, only leads to reduced safety margins and no damage or loss of life.

Reliable figures on the number of occurrences involving the use of erroneous takeoff data are not available. Flight crews are not always aware that an erroneous takeoff incident occurred. This is one of the reasons operators under-report this type of occurrence to the authorities.[8] Nevertheless, a substantial number of occurrences in recent years involving erroneous takeoff data have been reported to the authorities (see Appendix F). In addition to investigations into such occurrences, scientific studies have been conducted.[9] The investigations and studies show that the persistence of this type of occurrence is a long standing and complex problem. EASA stated that the investigation reports and studies related to several accidents and serious incidents worldwide have highlighted the use of erroneous takeoff performance data as a safety issue of general concern and not specific to any aircraft type.[10]

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[6] Source definition: EASA's webpage on Erroneous Take-Off Performance Data, consulted on 25-11-2022, https://www.easa.europa.eu/en/erroneous-take-performance-data.

[7] Transportation Safety Board of Canada, *Reduced power at takeoff and collision with terrain*, Aviation investigation report A04H0004, April 2006.

[8] Benard, B., Nijhof, M., Van Es, G., *Take-Off performance incidents: do we need to accept them or can we avoid them?*, ISASI annual Seminar, 2019.

[9] NASA, Performance Data Errors in Air Carrier Operations: *Causes and Countermeasures*, June 2012;
ATSB, *Takeoff performance calculation and entry errors: A global perspective*, January 2011;
Laboratory of Applied Anthropology, *Use of erroneous parameters at takeoff*, May 2008.

[10] EASA, Safety Information Bulletin 2016-02R1, *Use of Erroneous Parameters at Take-off*, 2021.

The process of determining and entering takeoff data is inherently prone to human errors due to the amount of data selections, entries and transfers. Operational pressure, task interruptions and distractions may contribute to these errors. In the longer term, aircraft software and systems are expected to provide hard barriers against erroneous data entry. However, technical solutions will take some time to be developed and implemented in standard procedures.[11] In the meantime, it is important that operators take practical measures to remind their flight crews of this safety issue and ensure that it is suitably covered by both training, awareness and operational procedures.[12]

1.2 Aim and investigation questions

Since there is still no solution that addresses the wide range of factors underlying the use of erroneous takeoff data, it is important that operators learn as much as possible both retroactively from occurrences and proactively with the aim of reducing the number of these incidents. Therefore, the incident on 12 September 2021 is investigated by the Dutch Safety Board with the focus on learning by the operator in relation to the risk of using erroneous takeoff data. There was no specific reason to choose this incident involving this specific operator for this investigation with this focus. It involves both how the operator learned in the period before this incident took place and how the operator learned from this incident. The investigation goes beyond checking the operator's regulatory compliance. It includes incident reporting, insight in erroneous takeoff occurrences, the quality of safety investigations, improvement of the learning process and engaging employees. Through this report, the Board aims to stimulate operators to learn more from occurrences in which erroneous takeoff data are used, in order to reduce the number of serious incidents and accidents.

Given the aim of encouraging operators to learn more from occurrences in which erroneous takeoff data are used, the following investigation questions are central in the investigation.

1. Which factors played a role in selecting the wrong intersection and not recognising this?
2. How and what did the operator learn before and after the occurrence at Berlin Brandenburg Airport, to reduce the risk of making errors in the calculation and entry of takeoff performance related parameters?

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[11] EASA, Safety Information Bulletin 2016-02R1, *Use of Erroneous Parameters at Take-off*, 2021.

[12] EASA's webpage on Erroneous Take-Off Performance Data, consulted on 25 November 2022, https://www.easa.europa.eu/en/erroneous-take-performance-data.

1.3 Demarcation

The investigation by the Dutch Safety Board focuses on how the operator learns in order to reduce the risk of using erroneous takeoff data. How other operators learn in order to reduce the number of serious incidents and accidents related to erroneous takeoff data is not addressed in this investigation.

KLC and KLM have a shared safety and compliance organisation (SCO) since 1 February 2021.[13] This investigation focuses on KLC, the operator involved in this serious incident, and the shared SCO. Learning at KLM falls outside the scope of this investigation. The report refers to KLC as the operator.

1.4 Frame of reference: a learning organisation

The Dutch Safety Board used a frame of reference in this investigation: a set of criteria that is relevant to the investigation. These are often scientific insights, best practices, expert opinions, guidelines, standards or legislation. A frame of reference can be used to compare or understand findings. A frame of reference is closely related to the investigation questions and focus of the investigation. This frame of reference focuses on 'learning organisations' in relation to safety.

With regard to safety, this report defines a 'learning organisation' as an organisation that continuously evaluates and adjusts its safety approach, see Figure 1. A critical success factor for a learning organisation is that the employees feel free to speak up about these matters as well as a management (or leadership) that invites and stimulates employees to do so (Psychological safety and Just culture). Employees play an important role in a learning organisation. They have knowledge about existing processes, about how work is done in practice and sometimes about an occurrence. In addition, they can provide relevant suggestions about how the work can be done better and safer.

A learning organisation applies multiple strategies to learn. Two complementary safety learning approaches are reactive learning (learning from incidents and accidents) and proactive learning (e.g. learning before implementing changes, learning from work-as-done, learning from other organisations). Risk management decisions (implementation of risk management measures or adjustments) may be made both reactively and proactively. These are collectively referred to as the safety approach. This approach is followed up by checking whether the implementation has been completed and whether it had the desired effect. Continuous evaluation - which contributes to learning - is an important aspect of safety management.[14]

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[13] When the Board writes the SCO in this report it refers to the SCO and the KLM and KLC organisations for safety & compliance that existed before 2021, i.e. KLC Safety organization and KLM Integrated Safety Services Organization.

[14] Dutch Safety Board's general frame of reference, which comprises five principles that organisations should comply with in order to manage safety, see for example Chapter 2 of the report *Who is in control? Road safety and automation in road traffic*, 2019.

A safety risk management process - which is part of the Safety Management System (SMS) and required by law (see Appendix E.2) - may contribute to ensuring a continuous learning loop. A learning organisation may also plan moments of self-reflection, which can lead to improvement of the way the organisation learns.[15] This is called meta-learning. Meta-learning may take place regularly and is aimed at ongoing improvement.

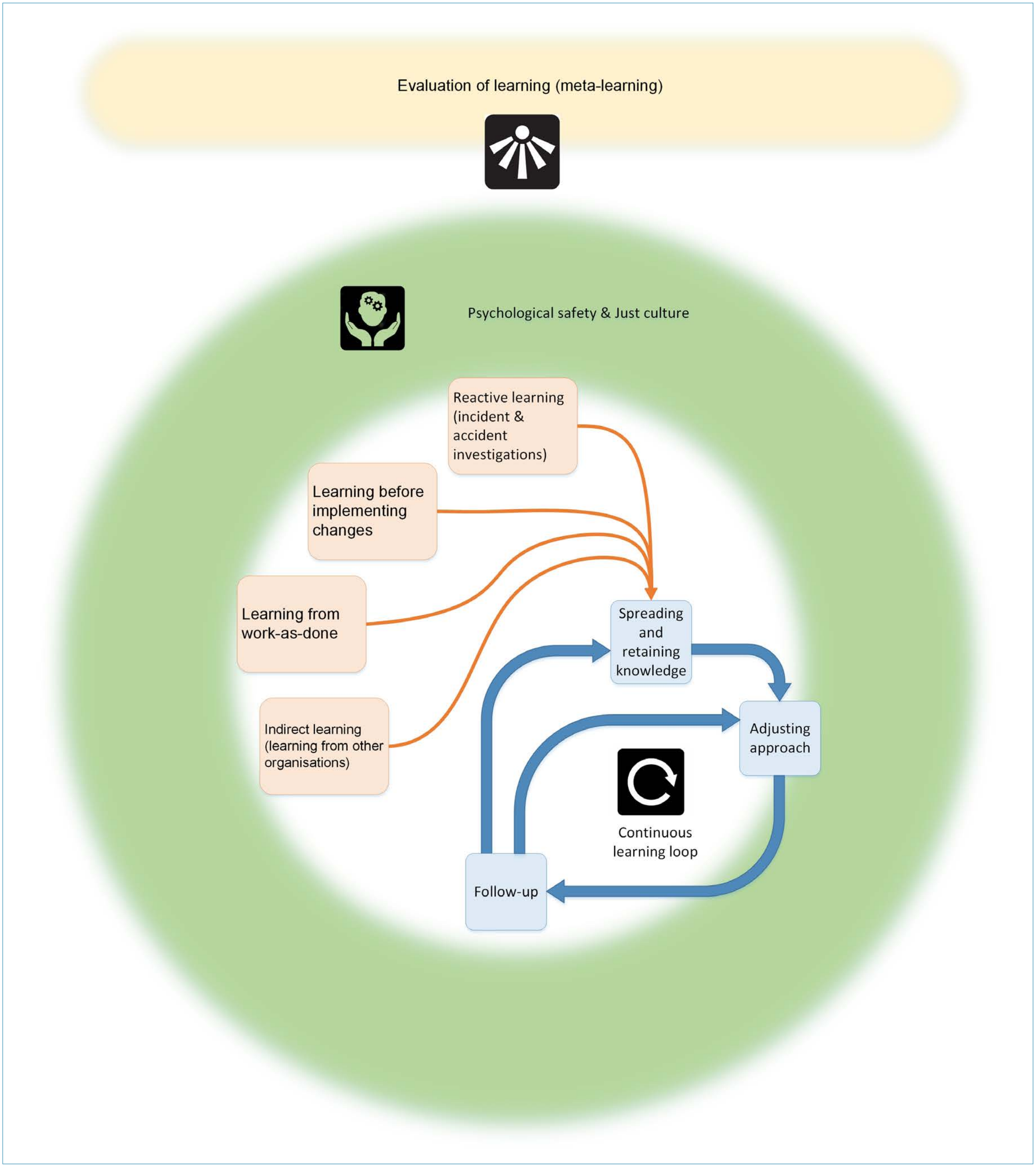

Figure 1: Learning organisation. (Source: Dutch Safety Board, based on literature on learning and accident investigation[16])

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[15] Dechy e.a., *Barriers to learning from incidents and accidents*, ESReDA guidelines, 2015. https://esreda.org/wp-content/uploads/2016/03/ESReDA-barriers-learning-accidents-1.pdf
Jacobsson A., *Methodology for Assessing Learning from Incidents - a Process Industry Perspective* (diss. Lund University/EAT), 2011;
Kjellén U., *Prevention of Accidents Through Experience Feedback*, London: Taylor & Francis, 2000.

[16] Bibliography on learning in Appendix C.

2 THE SERIOUS INCIDENT

2.1 Introduction

The Dutch Safety Board investigated the serious incident that occurred on 12 September 2021 in order to determine the factors that contributed to the occurrence. Thereby, this chapter addresses the first investigation question and presents contributing factors to the incident in order to learn from it and reduce the risk of using erroneous takeoff data.

The chapter presents a summary of the history of flight and the analysis of the serious incident. More details regarding the factual information can be found in Appendix D.

2.2 Factual information

The flight

On 12 September 2021, an Embraer 195-E2 with registration PH-NXD, was scheduled for a flight from Berlin Brandenburg Airport (EDDB, hereafter Berlin) in Germany to Amsterdam Airport Schiphol (EHAM, hereafter Schiphol) in the Netherlands. The scheduled departure time was 17.38 hours. The flight crew consisted of a captain and a first officer. The captain acted as pilot flying and the first officer as pilot monitoring. It was the third and last flight on the last day of the flight crew's four-day schedule.

Flight preparation

After a short break between flights, the crew began their flight preparations and they planned from which runway intersection to take off. The crew expected a takeoff from Runway 25R and, after some discussion, they both agreed that intersection L5 was suitable in the prevailing weather conditions. The crew members stated that they did their takeoff performance calculation independently from each other by using the ePerf[17] application on their Electronic Flight Bag (EFB). The pilots reported they compared the outcomes of their calculations: the takeoff mode, assumed temperature, flap position and takeoff speeds, see Table 1. They seemed to be realistic and within the range of what could be expected, according to the crew. After confirmation that the output parameters were identical, the data was entered into the Flight Management System (FMS).

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[17] Crew members are provided with an iPad, that is used as a portable Electronic Flight Bag (EFB). One of the installed applications on the iPad is Embraer's ePerf. ePerf is used for takeoff and landing performance calculations for Embraer aircraft.

Table 1: Calculated ePerf output parameters for takeoff from intersection K5 and the parameters that had to be calculated for intersection L5.

	K5	L5
T/O mode	TO-3	TO-3
Flaps	Flaps 1	Flaps 3
V_1	139 kt	120 kt
V_R	140 kt	121 kt
V_2	143 kt	124 kt
T_{ASS}	57 °C	35 °C

Takeoff

After the ground controller issued the taxi clearance, the flight crew taxied from their stand B12 via Taxiway C towards intersection L5. The captain selected takeoff power. The first officer, as pilot monitoring, noticed that the primary thrust indicator (N1) showed 75%. Although he considered this to be low, he believed it was correct. During the takeoff roll, he also felt the acceleration was slow and considered calling "full thrust". However, to avoid triggering the captain to abort the takeoff by a non-standard callout[18] he did not do this. The captain also thought that the aircraft accelerated slower than he was accustomed to. He attributed this to the variant type. According to him, the Embraer 195 E2 accelerates a little slower than the other variants he is used to. Moreover, the E2 is more automated than the other variants and he believed the selected thrust was correct.

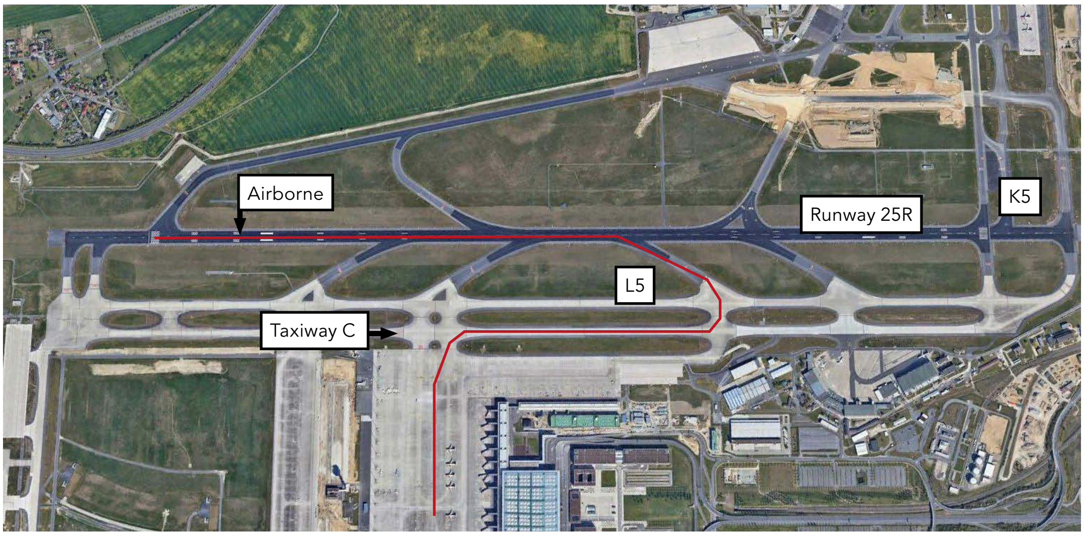

Figure 2: Aircraft route (red line), Runway 25R with taxiways towards intersections K5 and L5. (Source map: Google Earth)

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[18] It is common practice to abort the takeoff if a pilot makes a non-standard callout, because this means s/he observed something that could affect the safety of the flight.

The crew stated that during the first part of the takeoff roll, the red lights at the end of the runway were not visible because the runway is slightly curved. At a certain point, the aircraft reached the takeoff decision and rotation speeds and the red runway end lights became visible. The distance to the red lights gave both crew members the impression that the aircraft became airborne with little runway length remaining.

When the aircraft was stabilised during the climb, the crew discussed what happened during and before takeoff. After checking the parameters, they found that they had both selected intersection K5 instead of L5 in the ePerf takeoff performance calculation application. After recalculation, they found that the assumed temperature should have been 35 °C instead of 57 °C and that Flaps 3 should have been set instead of Flaps 1.

2.3 Performance calculation for wrong intersection

The aircraft took off from intersection L5 while the performance calculation was based on intersection K5. Therefore the engine's thrust and flap position were calculated and set for an available runway length (Take Off Run Available, TORA) of 3,385 metres, see Table 2. The acceleration of the aircraft to reach the calculated speeds V1 and Vr was also based on this distance. The actual TORA was 2065 metres, 1320 metres less. As a result, the acceleration of the aircraft was too slow to safely take off from intersection L5. This explains why the aircraft became airborne 443 metres[19] before the end of the runway (see Figure 2).

Table 2: available lengths of runway 25R from intersections K5 and L5.

Runway	Intersection	TORA	TODA	ASDA
25R	K5	3,385 m	3,445 m	3,385 m
25R	L5	2,065 m	2,125 m	2,065 m

After the occurrence 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, or just before, V1, which would have resulted in a runway excursion. The Accelerate Stop Distance (ASD) under the circumstances was 2565 metres while the Accelerate Stop Distance Available (ASDA), was 2065 metres. Furthermore, in case of an engine failure after V1 the aircraft would likely not have been able to attain the required climb performance. Therefore, the safety margins were reduced during the takeoff.

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[19] Source: FDR data.

[20] The available takeoff distance (TODA) consists of the available runway length plus the clearway of 60 metres.

A contributing factor to the occurrence was the selection error in the takeoff performance application (ePerf) by both pilots. As a consequence, the aircraft took off from intersection L5 - as the crew intended - while the performance calculation was based on intersection K5.

The actual available runway length was 1320 metres less than the runway length used in the calculation of the performance parameters. As a result, the set thrust setting was such that the acceleration of the aircraft was too slow to safely take off from intersection L5. The aircraft would likely not have been able to safely abort the takeoff at speeds close to V1. Safety margins were reduced during the takeoff.

2.4 Intersection selection error

Data entry into ePerf is a routine operation that is often repeated. Therefore, the pilots entered the required information quickly. All available runways and corresponding entry points of the selected airport were listed in a pull down menu. This listing was in numerical and alphabetical order and Runway 25R K5 was listed just above 25R L5, see Figure 3. Both crew members accidently touched and selected 25R K5 instead of 25R L5.

It is commonly understood that selection errors occur when working on a touchscreen with finger-touch interaction (tapping). Two factors explain the finger's inaccuracy with tapping. First, there is no system feedback about the location of the finger prior to completing selections by tapping the screen. Second, the 'fat finger' problem means that the finger is a large and relatively crude pointing device for small targets.[21] Items that are close to the desired target can be accidentally selected. Other incidents in which two crew members made the same error when selecting the runway and intersection have been investigated, namely the 2019 Nice incident[22] and the 2015 Lisbon incident.[23]

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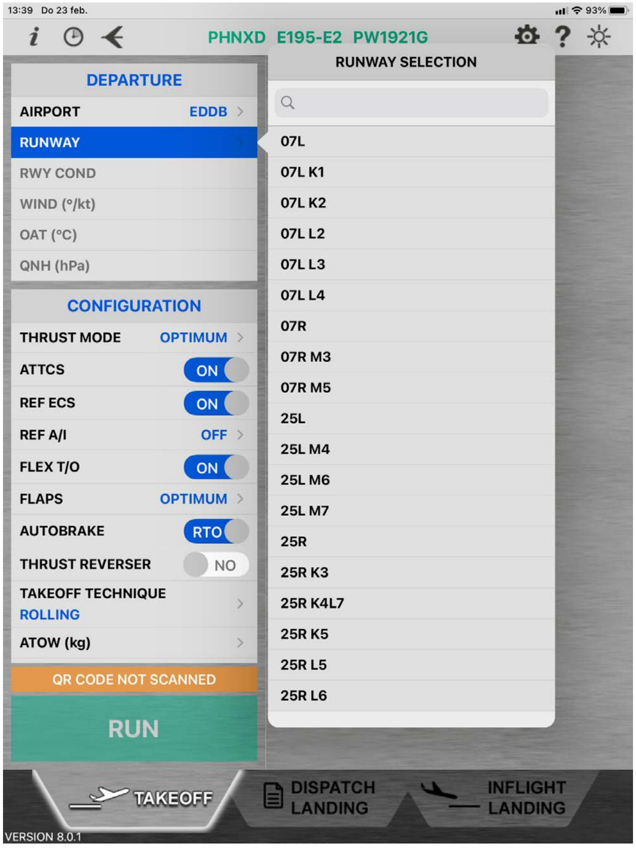
[21] Cockburn, A., Ahlström, D., Gutwin, C., *Understanding performance in touch selections: Tap, drag and radial pointing drag with finger, stylus and mouse*, International Journal of Human-Computer Studies, 70(3), 2012.

[22] AAIB, *Serious incident Airbus A319-111, G-EZBI*, 2020.

[23] Dutch Safety Board, *Insufficient thrust setting for take-off*, 2018.



DEPARTURE

AIRPORT EDDB

RUNWAY

RWY COND

WIND (°/kt)

OAT (°C)

QNH (hPa)

CONFIGURATION

THRUST MODE OPTIMUM

ATTCS ON

REF ECS ON

REF A/I OFF

FLEX T/O ON

FLAPS OPTIMUM

AUTOBRAKE RTO

THRUST REVERSER NO

TAKEOFF TECHNIQUE ROLLING

ATOW (kg)

Figure 3: Page of electronic flight bag.

ePerf does not have a graphical representation of the selected takeoff starting point (the so called runway synoptic). A runway synoptic provides visual feedback after selection of the runway and intersection. According to the aircraft manufacturer, adding this function to the ePerf was considered in the user forum[24] in 2022, but it did not become part of the short or mid-term list of improvements for this application based on operators' priorities. This feature was discussed again in 2023 and placed on the short-term list of improvements. According to the aircraft manufacturer, the inclusion of a graphical representation of the runway is under development and expected to be incorporated in the software in 2024.[25] Furthermore, Embraer was in the process of implementing two other modifications of ePerf in order to reduce selection errors. First, a two-step intersection selection (first the runway, then the intersection on a separate menu) on ePerf is intended to decrease the number of selection errors (release Q3 2023). Second, highlighting the intersection used for calculation (inverse video display) in the output page header is intended to increase the chance of detecting a selection error (release Q3 2023).

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[24] Embraer organises yearly meetings with the operators that use Embraer EFB applications.

[25] Embraer notes that the decision to develop this feature did not derive from this incident, but rather as result of a collaborative process with its operators.

The point from which pilots initiate the takeoff, was selected from a list containing all possible runway and intersection combinations, presented in a numerical and alphabetical order. Both intersections K and L were presented in ePerf, even though K intersections were not normally used by the operator. Runway 25R's intersections K5 and L5 were presented consecutively on the dropdown menu list, see Figure 3.

Both pilots selected the same wrong intersection in the application for takeoff performance (ePerf). When working on a touchscreen with finger-touch interaction, selection errors occur, among other things, due to a lack of system feedback about the location of the finger and the 'fat finger' problem.

The accidental misselection when working with a touch screen is common, especially if it is performed routinely and therefore quickly.

The application did not provide a runway synoptic feedback about the selected intersection and runway. The application contained intersections that are normally not used by the operator.

2.5 Error propagation

The Dutch Safety Board identifies three reasons why the selection error could propagate.

Crosscheck
The main barrier against selection errors in a performance calculation is a crosscheck between the calculations of both pilots. According to the operator's Operations Manual Part A, the flight crew must properly check input and output before accepting it for use. The crew reportedly compared the outcomes of their calculations, which had to be entered into the FMS: the takeoff mode, assumed temperature, flap position and takeoff speeds. As both pilots had reportedly selected the same wrong intersection, the outcomes were the same. In the investigation of the Board, it did not become clear whether the crew checked the input. While checking the input values, crew members may notice a potentially incorrectly selected parameter.

Expectation
Approaching Runway 25R, the aircraft passed the L5 intersection. The sign matched the crew's expectations, since they thought they had used L5 intersection for their takeoff performance calculation.

The calculated N1 became visible when the engines had been started and the system had calculated this value from all the data. When an N1 of 75% was presented, the pilots believed that the system had calculated this correctly. Calculations of the manufacturer showed that for a takeoff from L5 with flaps 1, N1 should have been 77,5%. In case of flaps 3 setting, the N1 should have been 74,8%. This shows that it was reasonable for the pilots to believe that 75% was calculated correctly.

The erroneous output data presented in ePerf did not raise the crew's attention, because it matched their expectations, which covered a wide range of values due to variant flying. During the four days of the pairing, the crew flew three different variants of the Embraer: Embraer 175, Embraer 190 and Embraer 195-E2. The flight crew was experienced in these variants and both crew members met the aim in the agreement of the Dutch Airline Pilots Association to fly each variant at least once every four weeks.[26] This agreement was based on the idea that the difference between this aircraft and the other variants requires regular crew exposure. Although switching between aircraft variants does not take much effort according to the crew, switching between Embraer aircraft variants may affect the feel for takeoff parameters (i.e. speeds and assumed temperatures) of a specific variant. The investigation could not determine whether this was a contributing factor in this occurrence. Switching between aircraft variants did play a role in the 2015 Lisbon incident[27] and the 2019 Glasgow incident[28].

Trust in the EFB

As a consequence of the optimisation algorithm in ePerf, the take-off configuration and or decision speeds may differ considerably under seemingly similar circumstances. As a consequence pilot's awareness and feel for numbers is reduced and a deviation from the required values will not easily be noticed. The Safety Board's interviews with the pilots made clear that it made sense for them to trust the data; after all, the EFB 'calculated it'. The trust of the crew in the calculated takeoff parameters, may be a contributing factor in the occurrence. This also played a role in the 2015 Lisbon incident[29].

The cross check did not reveal the selection error because the pilots likely focussed on the calculation outputs of the calculation, which did not differ as both pilots had reportedly selected the same wrong intersection.

The sign indicating intersection L5 could not reveal the selection error because the crew had this intersection in mind. Also the calculated N1 was within range of their expectations. Variant flying might have widened their range of expected performance parameters.

The crew's trust in the ePerf application may also have been a contributing factor in the occurrence.

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[26] The aim is to fly each variant at least once every four weeks. After 60 days without exposure on a particular variant Route instruction or Simulator training is mandatory.

[27] DSB, *Insufficient thrust setting for take-off*, March 2018.

[28] AAIB, serious incident Airbus A321-231, G-EUXJ, 2020.

[29] DSB, *Insufficient thrust setting for take-off*, March 2018.

2.6 Pilot intervention

After the runway controller had issued the takeoff clearance, the flight crew lined up on the runway without stopping and selected takeoff power. Both crew members perceived a slower, but not unusual acceleration than expected.

The pilot flying thought slow acceleration was due to the difference between aircraft variants; he thought it was normal for the Embraer 195-E2 and believed that the thrust was calculated correctly. The pilot monitoring thought about giving the command "full thrust". He did not do this, because he wanted to avoid triggering an unnecessary aborted takeoff. Pilots normally reject the takeoff for irregularities before V1 and do not select full thrust.

The crew realised something was wrong when the red lights at the end of the runway had become visible and the V1 and VR speeds were reached.

It is a well-known phenomenon that crew members do not select full thrust when the aircraft's acceleration is less than expected. Full thrust was selected in one out of 23 occurrences involving the use of erroneous takeoff data, which were investigated by accident investigation boards in the period 2013-2021.[30] A study by the AAIB[31] into the human factors behind this phenomenon concluded: '*In summary, the application of more thrust was not a trained, natural or dominant response, whereas inaction on the thrust levers would be familiar and probably dominant. It is likely that many crews would react in the same way that the incident crew did, given the same circumstances.*' Some of the human factors which were mentioned in the study were applicable to this incident:

1. Approaching the red lights at the end of the runway created a visual picture that would have been an indirect acceleration clue. However, due to the curvature of the runway and the human visual system generally being insensitive to the rate of acceleration, this clue did not develop above a triggering threshold.
2. Flight crews have a poor perception of time during takeoff as they are concentrating on other matters. Therefore, the pilots could not differentiate time to reach V1 from other takeoffs. Furthermore, acceleration rates vary due to the everyday variation in aircraft weight, runway and performance conditions.
3. The flight crew rarely added thrust settings during training, because most types of takeoff events do not require thrust adjustments. Moreover, it is unnatural and counter-intuitive to add thrust – and increase speed - when the red lights at the end of the runway are fast approaching.

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[30] Appendix F provides an overview of these occurrences.

[31] AAIB, *Report on the serious incident to Boeing 737-86J, C-FWGH Belfast International Airport on 21 July 2017*, 2018. https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017

The pilots did not select full thrust.

Not adding thrust is the dominant response for pilots as thrust should normally not be changed during takeoff. Furthermore, it is common that pilots are not required to add thrust for takeoff events in training situations.

2.7 The flight crew

The flight crew were properly licensed and qualified to perform the flight. The incident flight was the last flight on the fourth day of a flight pairing that consisted of three flights on the first day, four flights on the second and third day and three flights on the last day. At the end of the third day, the crew felt uncomfortable to continue because of work pressure and operational disruptions. They contacted crew control to discuss the problems they had experienced, but felt pressured to perform the three flights the next day. They decided to evaluate their level of fatigue after a night's sleep in Basel. In the morning, they felt sufficiently rested to perform the last three flights. The investigation did not further examine to what extent fatigue played a role or contributed to the occurrence of the incident.

During the turn-around in Berlin the crew had sufficient time preparing for the return flight to Schiphol as their flight was on schedule and there were no last-minute changes. They felt no need to rush and consequently did not experience any operational pressure.

The Board did not find any evidence that factors, such as rush, operational pressure, last minute changes and distraction, played a role. The investigation did not further examine to what extent fatigue played a role.

2.8 Technical systems

In the longer term, aircraft software and systems are expected to provide hard barriers against the use of erroneous data. As most aircraft currently in operation, the Embraer aircraft are not equipped with a system that detects erroneous takeoff data before or during takeoff. Therefore, these aircraft do not alert the flight crew during takeoff of abnormally low accelerations for the actual aeroplane configuration, nor for insufficient runway length available in case of intersection takeoffs. Embraer has stated that they are not currently developing such a system.

In October 2020, the Dutch Safety Board published the report 'Erroneous takeoff performance calculation, Boeing 777', in which both the manufacturer and the regulator received a recommendation.

The following recommendation was issued to the European Union Aviation Safety Agency and the Federal Aviation Administration:

'*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 initiated a new rule making task (RMT) regarding takeoff performance parameters and position errors for large aircraft. The industry, including Embraer, is involved in the working group. To date, the European Union Aviation Safety Agency has not decided on rulemaking activities regarding their Best Intervention Strategy (BIS) for erroneous takeoff data.

The following recommendation was issued to The Boeing Company in 2020:

'*For the existing and future commercial aeroplanes, to research on and develop 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.*'

The Boeing Company has developed a Takeoff Performance Alert (TPA) feature consisting of an algorithm and flight crew alert, which is being evaluated for certain existing and future Boeing models. Further testing and evaluation of the TPA function will continue into 2023 and beyond with on airplane testing anticipated in 2024.[32]

Airbus also developed some technical systems for takeoff surveillance and monitoring (TOS and TOM) that have been certified by EASA.[33] The TOS2 function that checks the available runway length before takeoff is available on the Airbus A320, A330 and A350 types. The TOM function that checks the acceleration during takeoff is available on the Airbus A350 and A380 types.

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[32] Source: Boeing update letter in response to the recommendation (December 2022).

[33] The website of the manufacturer provides more information about the systems: https://safetyfirst.airbus.com/takeoff-surveillance-and-monitoring-functions/

2.9 Conclusions

A contributing factor to the occurrence was the selection error in the takeoff performance application (ePerf). As a consequence, the aircraft took off from intersection L5 - as the crew intended - while the performance calculation was based on Intersection K5. The actual available runway length was 1320 metres less than the runway length used in the calculation of the performance parameters. As a result, the set thrust setting was such that the acceleration of the aircraft was too slow to safely take off from intersection L5. The aircraft would likely not have been able to safely abort the takeoff at speeds close to V1. Safety margins were reduced during the takeoff.

Both pilots said that they selected the same wrong intersection in the ePerf application. Contributing factors to the selection error were the following:

- The accidental misselection when working with a touch screen is common, especially if it is performed routinely and therefore quickly. When working on a touchscreen with finger-touch interaction, selection errors occur, among other things, due to a lack of system feedback about the location of the finger and the 'fat finger' problem. The misselected item is often close to the intended item.
- The application did not provide visual feedback about the selected intersection and runway (runway synoptic).
- The pull down menu contained intersections that are normally not used by the operator.

The cross check did not reveal the selection error, because the pilots likely only focussed on the calculation outputs of the calculation, which probably did not differ as both pilots had reportedly selected the same wrong intersection. The sign indicating intersection L5 and the available runway length could not reveal the selection error either, because the crew had this intersection in mind. Also the calculated N1 was within range of expectation.

The trust of the crew in the calculated values by the performance calculation application may also have been a contributing factor to the occurrence. On top of that, it is the dominant response, common and trained, that pilots do not add thrust during the takeoff.

The Board did not find any evidence that factors such as rush, operational pressure, last minute changes and distraction, played a role.

3 LEARNING FROM THIS OCCURRENCE

3.1 Introduction

This chapter describes how the operator learned from this occurrence and in addition gives examples of what else the operator could learn from it. The sections describe the consecutive steps taken by the Safety and Compliance Organisation (SCO) and the flight operations division after they became aware of the Berlin incident.

3.2 Reporting by the crew

Operator procedures
The operator states in the Operations Manual[34] that the Operations Control Centre (OCC) Flight Lead is the primary contact for, amongst others, any possible safety events. The captain must ensure that the OCC Flight Lead is informed of any incident, serious incident, accident, airprox or other possible safety and security events as soon as possible.[35] When an OCC Flight Lead is informed about an incident, s/he will contact the SCO risk analyst on duty, who will contact the crew.[36] The risk analyst will carry out an initial assessment to determine whether the cockpit voice recorder (CVR) must be secured and whether the crew must be released from duty.

Furthermore the OM states that the captain must fill out and submit an air safety report (ASR) for a number of occurrences. The list of specific types of occurrences that must be reported includes:

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

Incident reporting
During the flight, the flight crew discussed what went wrong and wrote an ASR. They submitted the ASR after landing on 12 September 2021. The pilots did not discuss the option to secure the CVR and did not pull the circuit breakers. The crew did not contact the OCC Flight Lead, because the aircraft took off normally – albeit closer to the runway

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[34] Operations Manual Part A – Basic Operations Manual.
[35] Operations Manual Part A – Flight Safety Instructions.
[36] Immediate contact is facilitated by the OCC Fleet Lead organising a conference call with the crew and other relevant parties.

end – and did not trigger the pilots to think the incident crossed the severity level for which a call to the OCC was necessary. As the OCC Flight Lead was not contacted, the SCO did not have the possibility to assess the situation. As a consequence, the SCO could not ensure securing of the CVR, nor interview the crew shortly after the incident occurred.

The captain stated that securing the CVR or contacting the flight operations division is only necessary in case of an accident.[37] The first officer stated that, at the time of the occurrence, he was not entirely familiar with the procedure for incident reporting.

Learning and improving reporting by crews
The SCO noticed that flight crews did not always follow procedures regarding incident reporting. As a mitigation measure, flight safety recurrent training was altered a few months after this incident. The follow-up after an incident and the purpose of calling the OCC Flight Lead were added to the training.

The crew was not entirely familiar with the incident reporting procedures. As a consequence, the CVR was not secured and the SCO could not interview the crew in a timely manner.

From this incident and others, the operator learned that pilot's knowledge of the reporting procedure needed improvement.

3.3 Assessment by the Safety Compliance Organisation

After the commander of the flight submitted the air safety report (ASR), the SCO accomplished safety risk management[38] by assessing the ASR and performing an Event Risk Classification (ERC), which is described in the operator's Integrated Safety Management Manual, see the blue box below and Figure 4.

The event risk classification process
A safety officer, in cooperation with an event analyst, pre-analyses an ASR and determines the risk level. For medium and high risk types of events, a risk analyst, in consultation with the safety officer, is responsible for collecting additional information (i.e. ASR, phone calls with the crew flight data analysis) and formulating a safety concern[39]. Furthermore, the SCO checked which investigations, related to the same type of event, had already been carried out, what had been found and which mitigating measures had been taken. The collected information was captured on an Event Assessment Form (EAF). Based on the information in the EAF, the Event Based Risk (EBR) was determined using an ERC Matrix.

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[37] The captain is legally responsible for securing the flight recorders in the event of an accident or serious incident. Regulation (EU) No 965/2012 on air operations, Annex IV (Part-CAT), CAT.GEN.MPA.105 (10) (iii).

[38] See Appendix G.4.

[39] The operator defines a safety concern as a possible hazard which has not been investigated.

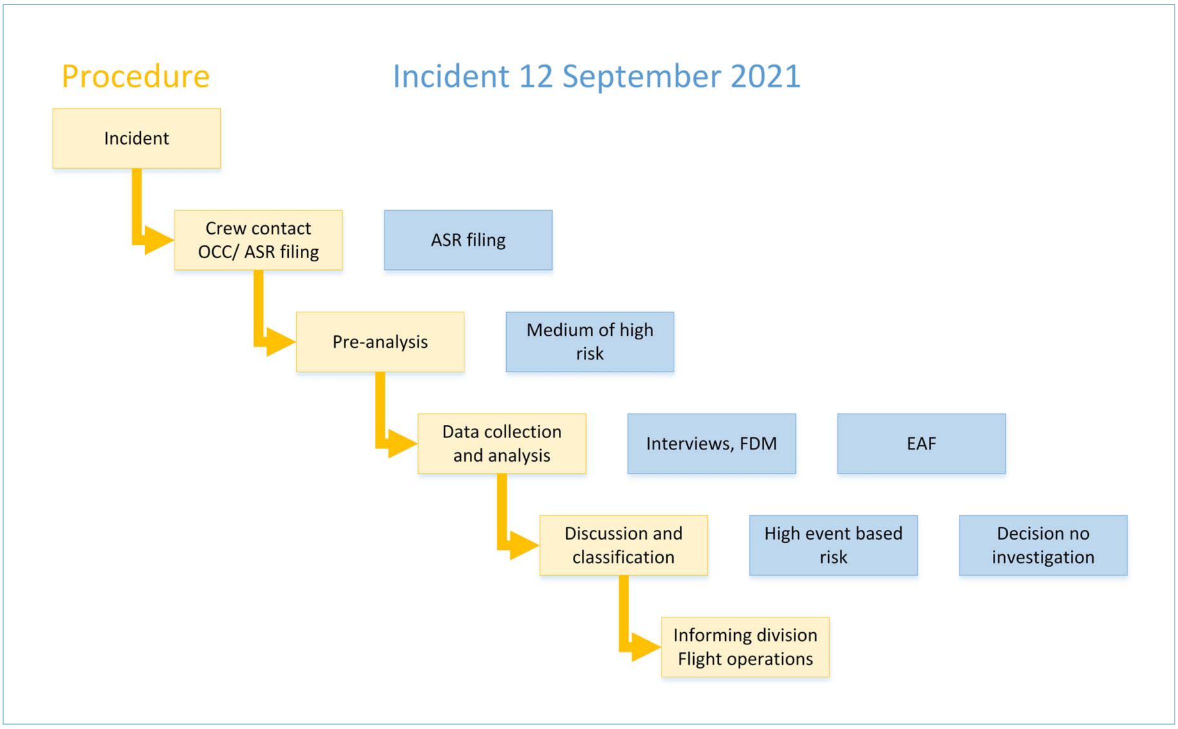

Figure 4: The event risk classification process of the operator.

After the SCO received the ASR, a safety officer and event analyst pre-analysed the incident and determined it could potentially be classified as medium or high risk. The risk analyst informed the process manager of the SCO, who informed the KLC Director Safety & Compliance and the KLC corporate safety action group (SAG[40]). The SCO assigned an investigator pilot to collect additional information and complete the EAF.

The investigator pilot interviewed the captain and the first officer involved in the incident separately by phone, the day after the incident. The flight crew stated that the investigator pilot created an open and constructive atmosphere. The investigator pilot asked to clarify their choices, their mutual interaction and their considerations. Flight data were analysed to determine at which height the aircraft flew over the runway end. The interviews and the flight data analysis formed the primary input for the assessment.

The investigator pilot analysed the event, based on his own operational experience, and described a brief analysis in the EAF:

'The performance calculation was done according to SOP. Both crews independently selected the same runway intersection (K5 at runway end), while their intention was to depart from L5 (shorter TODA), which they had addressed and confirmed with each other. The performance result of ePerf matched their experience so far with the E2, the outcome was plausible. The mind set they were in, departure from L5 and performance numbers looking familiar and acceptable match with earlier experience. There were no cues that

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[40] The organisation has several safety action groups (SAGs), namely a corporate SAG and local SAGs for the various divisions. The SAGs are part of the existing management structure. The SAGs are responsible for designing and implementing mitigating measures and the implementation of safety strategies. See also Appendix G.3 about the governance structure.

would invalidate their present mind set and trigger them to revise their setup. Also, during the takeoff roll everything looked familiar and as expected. A cue that might bring the crew in doubt was the visible runway, but the runway was curved so they could not see the runway end and the available TORA. A possible outcome variability of the current human machine interface (HMI) with ePerf and the layout and designation of the runway intersections is a takeoff from an intersection for which the performance has not been calculated.' […] 'More interesting in this case is the crew - company (crew control) interaction. Pairings are getting more and more demanding with the recovery from the COVID pandemic. Fatigue reports are rising […]'

Both data collection and analysis of the incident were carried out by a single investigator. The assessment was then verified by a second risk analyst. Previous safety investigations[41] by the operator on similar events were consulted by the risk analyst. Two safety issues[42] emerged from those investigations[43]:

1. The crew-interface of ePerf can lead to misselections (2018).
2. At the time the measure taken to mitigate this risk was a change in the layout of ePerf. The flight operations division requested the manufacturer to break down the selection of runway and intersection into two steps, i.e. the list of intersections appear after runway selection. This safety issue was closed at the time of consultation.
3. Performance outcome of Embraer E195-E2 ePerf does not match crew expectations (2020). The mitigation action at the time was adding a module to the recurrent training, which dealt with the feel for numbers, specifically for the Embraer E195-E2. This issue was still in the validation phase at the time of consultation[44].

The SCO stores safety issues resulting from safety investigations for two operators -. including the operator at which the Berlin incident took place - in a risk register. The safety issues in the risk register related to erroneous takeoff data are shown in Tabel 3. This table includes the two safety issues previously mentioned. It lists two additional safety issues resulting from safety investigations by the other operator. In 2020, this other operator conducted a safety issue risk analysis (SIRA), after which one of the mitigating measures was to visualise the intersection, selected in the performance calculation tool, in a synoptic runway representation. The runway synoptic is part of the new tools for takeoff performance calculations for the Boeing (Dynamic Source) and Airbus (Fly Smart) fleet.

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[41] Section 4.2.4 provides more information about safety investigations by the SCO into the use of erroneous takeoff data.

[42] The operator defines the output of a safety investigation as safety issues, which are also called analysed risks.

[43] The 2018 predictive safety investigation on the data base supplier and the 2020 predictive safety investigation on mixed fleet flying.

[44] See Appendix G.4.

Table 3: Safety issues related to the Berlin incident in the risk register of the SCO [status September 2021].

Year	Operator	Safety issue	Status
2018	KLC	The crew-interface of ePerf can lead to mis-selections resulting in: runway overruns, tail strikes or a collision with an obstacle in the takeoff path.	Mitigation measure: awareness campaign, ePerf lay-out: order intersections, ePerf search function on runway, warning regarding confusing intersections added in station information.[45]
2020	KLC	Performance outcome of E195-E2 ePerf does not match crew expectations.	Mitigation measure: awareness campaign.
2020	KLM	There is no structured approach that calls for flight crew to crosscheck the actual runway entry point with the calculated takeoff data.	Introduction of new performance calculation tools with runway synoptic for Airbus fleet (Flysmart) and Boeing fleet (Dynamic Source).
2013	KLM	Inaction of flight crew to increase thrust when it appears that takeoff performance is compromised.	Accepted because the mitigation of other safety issues covered this risk.

The investigator pilot and the risk analyst assessed the learning potential of the Berlin incident investigation and concluded that this was limited, because the SCO already carried out a number of investigations into erroneous takeoff data. Furthermore, they reasoned that further investigation of the incident was not feasible due to the required mitigation action (i.e. technological improvements) being outside of the influence of the operator. They suggested to not investigate the incident further, except to follow-up this incident with a proactive investigation[46] into fatigue, because the crew contacted the operator in the evening before the incident occurred to communicate they were not sure if they were fit to fly the next day.[47] Furthermore, multiple events had occurred where fatigue had been a contributing factor.

The incident was discussed in a weekly SCO Risk Analysis Meeting (RAM), where a risk analyst, event analyst and multiple safety officers were present. The incident was formally classified as a high risk event[48], because of insufficient runway remaining to come to a full stop after an aborted takeoff. The most credible outcome without any effective barriers remaining would have resulted in a catastrophic accident. During the RAM, it was decided not to conduct an incident investigation.

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[45] At the time of implementation of this risk mitigation, Berlin Airport was not part of the operator's network. When Berlin Brandenburg Airport was added as a destination, this mitigation action was not considered.

[46] Proactive safety investigation: investigation based on a trend or a safety concern.

[47] After spending the night in Basel, the crew felt they had slept well enough and were not fatigued, and decided to complete the last sectors, see also Appendix D.1.

[48] The number of events classified as high risk event varied between two and eighteen events per year at the operator in the years 2017-2021.

The EAF was checked by a second risk analyst and sent to the process manager for approval. The process manager registered the incident in the SMS risk register application Qpulse, according to internal procedures. Because it was a high risk event, the event information (EAF and ASR) was passed to the SAG of the flight operations division and the vice president of the SCO.

The incident was assessed following the operator's procedures and consisted of the following steps; pre-analysis, data-collection, analysis, discussion and classification.

The incident was pre-analysed as medium or high risk.

The operator's analysis showed that both crew members independently selected the same intersection (K5 at runway end), while their intention was to depart from L5 (shorter TODA). Furthermore, the error could propagate because the crew did not perceive any cues that would invalidate their present mind. The SCO identified two contributing factors: the outcome variability of the ePerf human machine interface and confusing runway designation at Berlin Brandenburg Airport.

The risk analyst and the investigator pilot advised against investigating the incident because of the perceived limited learning potential.

The SCO classified the Berlin incident as a high risk event, because of the potentially catastrophic outcome, however the SCO decided not to perform an investigation into the incident, which limited the potential to learn from this incident.

3.4 Assessment and mitigation actions by the flight operations division

Process
An operational division at this operator may propose to mitigate a particular risk regardless of whether the SCO starts an investigation into that risk. When they do, the mitigation actions are first discussed in a management team meeting and formalised in the local SAG, where both division and SCO representatives are present.

First assessment by management flight operations division
On 21 September 2021, the flight operations division held a management meeting where the Berlin incident was discussed. An SCO safety officer was present during this meeting. The de-identified information available to the flight operations division consisted of the ASR and the EAF. The flight operations division considered this information to be sufficient to be able to determine mitigation actions. The event was discussed in the management team meeting in order to determine whether immediate action was required and if further investigation and mitigating actions were necessary. They decided to focus on mitigation instead of starting up a new investigation first, because the accident scenario was assumed to be known from previous safety investigations. An investigation was assumed to contribute little to the safety issues identified in previous investigations and their implemented mitigation measures. They decided to use the

event to enrich the existing mitigations and to take action with regards to raising crew awareness, resulting in the chief pilot sending an e-mail to all pilots (see next section).

Assessment in the SAG meeting
On 6 October 2021, a local SAG meeting was convened to decide on the mitigation measures to be taken by the flight operation division. After a brainstorm, the flight operations division decided to extend existing mitigation measures[49] for takeoff performance issues with:

- An awareness campaign;
- An update of the procedure to scan aerodromes for confusing intersections in order to also scan new destinations.

The flight operations division also decided not to initiate a reactive SIRA[50]. According to flight operations personnel, this was because they suspected it would not reveal any new information and would contribute little to the erroneous takeoff data mitigation measures already in place. Erroneous takeoff data had been identified as a safety concern[51] for the operator since 2019, however this did not play a role in the decision not to initiate a reactive SIRA.

The awareness campaign consisted of an e-mail sent by the chief pilot to all pilots in response to the Berlin incident and to incidents regarding incorrect flap settings. The e-mail, which was sent on 7 October 2021, contained:

- The importance of adherence to standard operating procedures in general
- Background information regarding erroneous takeoff data:
  - an EASA SIB[52] on erroneous takeoff data which contained general information about erroneous takeoff data;
  - a Flight Data Monitoring (FDM) bulletin on takeoff configuration warnings. This bulletin did not apply to the present incident as an intersection selection error does not elicit a takeoff configuration warning.

The e-mail did not address specific details of the incident. The fact that both pilots made the same selection error was neither addressed in the e-mail nor in the attached EASA SIB.

According to the SAG meeting, the layout and designation of the runway intersections in Berlin was considered confusing. Intersections K5 and L5 on Runway 25R connect to different runway positions. The SAG meeting assumed that it is confusing when two intersections with the same number ('5') are not opposite each other. As a mitigation action, information was added to the Flight operations manual, Part C, Airport information. All airports were checked for similar layouts and a warning stating the possibility of confusion regarding airport intersections was added.

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[49] See Section 4.2.5 on the existing mitigating actions.
[50] Reactive SIRA: Incident investigation.
[51] See Section 4.2.3.
[52] EASA, *SIB 2016-02R1, Use of Erroneous Parameters at Takeoff*, September 2021.

Other mitigation measures were considered in the SAG meeting, but not implemented. Consideration was given to removing the option to select the intersections on the north side of the runway in Berlin ('K' intersections) from the ePerf application, since the operator normally only used the L intersections on the south side of Runway 25R.[53] The airport information in ePerf is provided by a supplier, who regularly delivers updates and the airport information is used by several operators Therefore, the provider could not remove the unused intersections. The operator also did not pursue removing the unused intersections by itself, as this would have to be repeated often due to frequent updates. Consideration was also given to changing the layout of the ePerf application by adding a runway synoptic[54], but this mitigation action was also not pursued any further. The flight operations division suspected that these changes to the ePerf application were not a priority for the manufacturer.[55]

Changing the crosscheck procedure was not considered in the SAG meeting as they had recently added an extra check of the flap setting and the flight operations division did not want to overload the pilots with additional procedures. The crosscheck, which is based on comparing input and output of the Electronic Flight Bag (EFB), was not designed such that it could reveal an intersection selection error when both pilots make the same error. The operator acknowledges that the present crosscheck procedure does not cover all eventualities. However, the flight operations division considered the new risks that might arise when imposing an extra procedure and decided against it.

The flight operations division acknowledges the severity of the incident. In a SAG meeting of this division it was decided that further investigation of the incident was not necessary as it was assumed little could be learned from the incident and it could contribute little to the mitigation already in place. The fact that erroneous takeoff data was prioritised as a safety concern and the event was classified as high risk did not play a role in this decision.

The flight operations division took two mitigation actions (awareness campaign and airport information update) based on – what they considered sufficient, but - limited information provided by the SCO. The awareness e-mail contained general lessons on erroneous takeoff data and lacked valuable lessons on a detailed level specific to intersection misselections.

3.5 Reporting to the safety investigation authorities

Operators play a role in improving safety of the aviation industry by reporting occurrences to the authorities (safety investigation authority and oversight authority) such that they are enabled to carry out their legal tasks. Authority investigations can be a valuable resource to improve safety and learn from incidents.

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[53] See Section 2.4.

[54] A visual representation of the selection of the departure point on a map.

[55] According to the manufacturer, changes in ePerf depend on the requirements of the majority of the users.

The operator notified the Civil Aviation Occurrences Analysis Department (ABL[56]) on 15 September 2021 and the Dutch Safety Board on 24 September 2021. The operator had not notified the Safety Investigation Authority of the State of Occurrence (BFU). As a consequence of the late reporting, the Dutch Safety Board could not interview the flight crew in a timely manner. Pilots' recall of the incident, the incident flight and the leading up to it had faded.

Regulation

According to EU regulation[57], the operator is obliged to notify serious incidents and accidents without delay to the competent Safety Investigation Authority of the State of Occurrence. The Safety Investigation Authority of the State of Occurrence shall subsequently notify without delay EASA, ICAO, the Member States and third countries concerned. The regulation lists examples of serious incidents, which includes gross failures to achieve predicted performance during takeoff or initial climb.

According to EU regulation[58], the operator shall also report all incidents and accidents related to the operation of the aircraft to their state's reporting system within 72 hours of becoming aware of the occurrence.

Operators established in the Netherlands shall report all occurrences to the ABL and serious incidents and accidents to the Dutch Safety Board and the Safety Investigation Authority of the State of Occurrence.

Procedure preceding notification

The operator took the following steps before reporting the incident to the Dutch Safety Board:

1. The incident report by the crew was received by the SCO.
2. Pre-analysis by SCO event and risk analyst.
3. Collecting and analyzing additional information.
4. In the RAM meeting, the risk was formally classified as high.
5. Coordination and approval of the process manager and the director of safety and compliance.

The incident was reported twelve days after its occurrence, even though it already became clear during the pre-analysis of the event that it was - in all probability - a serious incident. This was within a few days after the occurrence. The late reporting was due to the working method the SCO followed after the occurrence (see the timeline in Table 4).

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[56] In Dutch: Analysebureau luchtvaartvoorvallen.

[57] EU Regulation 996/2010, Article 9.

[58] EU Regulation 376/2014, Article 4.

Table 4: Timeline

12 September 2021	Incident occurred.
12 September 2021	Captain reported to the SCO (ASR).
	Event pre-analysis by SCO.
15 September 2021	Operator reported to the ABL.
	Collection of additional information (i.e. interviews and FDM).
	RAM meeting
21 September 2021	SCO informed flight operations division (ASR and EAF).
	Coordination and management approval for reporting to the authorities.
24 September 2021	Operator reported to the Dutch Safety Board.
29 September 2021	Event assessment form approved by the process manager.

Due to the late reporting the DSB was not able to examine to what extent fatigue played a role or contributed to the occurrence of the incident (see Section 2.7). Interviews with the crew within days of the incident are necessary to investigate fatigue. For example, people do not remember what their sleep hours were in the week before the incident when too much time has passed. Other volatile information, such as memories of the occurrence might also be lost over time.

The incident was reported to the Civil Aviation Occurrences Analysis Department three days after its occurrence and to the Dutch Safety Board after twelve days. The German Federal Bureau of Aircraft Accident Investigation was not informed by the operator.

Within a few days, pre-analysis of the event made clear that - in all likelihood - it was a serious incident. The additional steps taken by the operator delayed notification of the relevant authorities and important information was lost and subsequent learning was limited.

3.6 Conclusions

Reporting by the crew
The flight crew filed an ASR to the SCO. The aircraft took off normally – albeit closer to the runway end – and did not trigger the pilots to think the incident crossed the severity level for which a call to the OCC was necessary. As a consequence, the SCO did not have the opportunity to ensure securing of the cockpit voice recorder nor interview the crew shortly after the event. While this limited the information input for an investigation, the operator captured this hiatus knowledge and adjusted the flight safety recurrent training in order to improve pilot incident reporting.

Outcomes of the limited investigation

The SCO initiated an assessment (limited investigation) by conducting interviews, reviewing flight data, consulting previous investigations into similar incidents, and analysing this information. The operator concluded that further investigation into the occurrence was not necessary as little could be learned and it could contribute little to the mitigations already in place from previous investigations.

The analysis of the operator showed that both crew members independently selected the same erroneous intersection. Furthermore, the limited investigation concluded that the outcome variability of the takeoff performance calculation tool contributed to the occurrence as well as a confusing runway intersection designation at Berlin Brandenburg Airport. Additionally, the pilots did not perceive any cues that would invalidate their assumptions and erroneous takeoff data was used for takeoff.

As a result of this analysis, the flight operations division took two mitigating actions. First, the chief pilot sent an e-mail with general information about erroneous takeoff data in order to raise awareness. Second, airport information in the manuals was adjusted, to prevent confusion regarding runway designation at Berlin Brandenburg Airport.

Reporting to the Dutch Safety Board

The incident was reported to the Dutch Safety Board twelve days after its occurrence. In practice, it is not immediately obvious whether an incident is serious or not. In this case, within a few days, it became evident that - in all likelihood - it was a serious incident. The additional steps that the operator took, delayed notification of the authorities. This hindered the Board to carry out its legal task shortly after the occurrence and important information was lost, resulting in missed opportunities to learn from this event.

Decision for no further investigation

Both the SCO and the flight operations division acknowledged the severity of the takeoff performance related incident that occurred in Berlin on 12 September 2021. Although the seriousness of the incident was recognised at various levels of the operator's organisation, the operator decided after a limited investigation (an assessment) that further investigation into this occurrence was not necessary as little could be learned from the incident and it could contribute little to the mitigation already in place. The fact that erroneous takeoff data was prioritised as a safety concern and the event was classified as high risk did not play a role in this decision.

4 LEARNING ABOUT THE RISK OF USING ERRONEOUS TAKEOFF DATA

4.1 Introduction

This chapter describes the way the operator learns about the use of erroneous takeoff data in general. In aviation, learning by operators takes place under the umbrella of safety risk management, one of the main activities of a safety management system (SMS).[59, 60] Section 4.2 describes the analysis of how the operator addresses the risk of using erroneous takeoff data following the different phases of the safety risk management process, i.e. identification, prioritisation, investigation and mitigation (including validation).

A safety risk management process allows operators to achieve a higher level of safety. In order to further improve safety, in addition to setting up a process, an operator can expand its ways of learning, particularly by engaging, involving and listen to employees. These alternative learning concepts, and the way this is organised at the operator, is discussed in Section 4.3. Section 4.4 contains the conclusions.

4.2 Learning from safety risk management

The safety risk management process of the operator[61] can be seen as a learning circle, i.e. a continuous loop (re)design, (adjusting) approach and follow-up process[62], which is comparable to the Deming cycle (plan-do-check-act). The safety risk management process is designed and set up with checks to prevent safety issues from being ignored. The safety risk management process consists of several phases, which are analysed subsequently below.

4.2.1 Identification of erroneous takeoff data as a safety hazard

The operator identifies safety hazards by collecting and pre-analysing information about safety events or concerns among employees. The primary source of information are the air safety reports (ASRs), which must be filled out and submitted by the flight crew when an incident, serious incident or accident has occurred. The Safety and Compliance Organisation (SCO) received seven ASRs related to the use of erroneous takeoff data in

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[59] EU regulation requires operators to establish, implement and maintain an SMS, OR.GEN.200 (a) (1) Safety Management System. See Appendix E.2 for more information about regulation and guidelines on safety management.

[60] Guidance on the implementation of an SMS are provided by ICAO's Safety Management Manual (*Doc 9859, Safety Management Manual, Fourth Edition*, 2018), which is incorporated in the operator's SMS.

[61] The operator has an Integrated Safety Management System (ISMS) which is described in their Operations Manual (OM) Part A – Integrated Safety Management Manual (ISMM), see Appendix G. The safety risk management system of the operator is extensively described in appendix G.4.

[62] See Appendix C Frame of reference.

the period 1 January 2018 to 12 September 2021.[63] Three of these seven incidents involved erroneous intersection data, one of which is the present incident (Berlin 2021). Although seven air safety reports were filed, it is likely that several erroneous takeoff data events occurred that went unreported, because the issue was not identified by the flight crew during the takeoff.[64] Pilots are not necessarily aware that an erroneous takeoff data event occurs as there may still be sufficient runway available at lift-off, thus depriving the flight crew from a salient clue that takeoff data were compromised.[65]

The other source is the Flight Data Monitoring (FDM) programme.[66] The recorded data from the FDM is analysed in order to extract safety relevant information, such as deviations from operating procedures or abnormal parameter values. In the period 1 October 2020 to 30 September 2021, the operator detected one incident with erroneous takeoff data through the FDM analysis tool, which was the result of a wrong flap setting (Nurnberg, 2021, see Section 4.2.5). The operator's data analysis tool does not reveal incidents caused by the selection of the wrong runway or intersection. In order to reveal the selection of the wrong runway or intersection either location information (for instance height over threshold[67]) or Electronic Flight Bag (EFB) information is required.[68] A survey by EASA[69] shows that the majority of the airlines do not use this information, because operators do not prioritise development of the data analysis methods for this. As the majority of the other operators do not use data from the EFB nor environmental data in FDM analysis, the lack of data on the use of erroneous takeoff data and the resulting lack of insight in this matter also applies to other operators. The operator is aware that flight data analysis does not reveal all takeoff performance events.[70]

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[63] Takeoffs with wrong flap settings are excluded.

[64] According to EASA (*SIB 2016-02R1, Use of Erroneous Parameters at Takeoff, September 2021*) this is something that happens regularly.

[65] Benard, B., Nijhof, M., Van Es, G., *Take-Off performance incidents: do we need to accept them or can we avoid them?*, ISASI annual Seminar, 2019.

[66] This is required by international standards, see Appendix E.3.

[67] The height the aircraft flew over runway end.

[68] These precursors (data events that indicate that a particular risk is occurring) are recommended by the European Operators FDM forum (EOFDM), see Appendix E. According to the manufacturer, the recorded flight data on the factory installed Quick Access Recorder (QAR) of the Embraer E1 and E2 aircraft provides the possibility to monitor almost all precursors which are recommended as best practices by the European Operators FDM forum.

[69] EASA, *Guidance for the implementation of flight data monitoring precursors; Good Practices document*, September 2020.

[70] In autumn 2022, the SCO purchased a new FDM analysis tool. Implementation started with the KLM Boeing and Airbus fleet and will be completed for the operator's Embraer fleet by the end of 2023. At present, it is unclear which precursors related to erroneous takeoff data will be analysed by the new tool as the reason for the purchase was not an extension of the parameters to be analysed.

The operator identified the use of erroneous takeoff data as a safety hazard although the data provide little insight in the number of occurrences related to erroneous takeoff data and the operator's learning capabilities are limited by a lack of data.

Air safety reports provide little insight in the number of occurrences related to erroneous takeoff data because of underreporting. An important reason for underreporting is that pilots are often not aware that they experienced a takeoff performance event.

The operator's flight data analysis provides little insight in the number of occurrences related to erroneous takeoff data, because the operator does not prioritise development of the data analysis methods.

4.2.2 Prioritisation of reducing the risk of erroneous takeoff data

After the identification of safety hazards, the operator prioritises safety hazards for further investigation and mitigation. Therefore the operator uses safety concerns and safety goals.

A safety concern is an identified hazard which has not been investigated. The operator's safety and compliance organisation (SCO) determines what should be on the concern list on a monthly basis, based on occurrences, trend analysis, information from employees and outside sources. In the period 2016 to 2022 the operator placed 22 safety concerns on the concern list. One of these concerns was related to the use of erroneous takeoff data: "*Flight crew departing not in line with ePerf takeoff performance calculation*". This concern was placed on the concern list in August 2019, following an increase in the number of takeoff configuration warnings and three incidents, which were classified as medium risk. On 28 September 2021, this concern was updated and extended due to occurrence of the present incident (Berlin 2021): "*Concern not limited to wrong flap setting but broader concern of takeoff performance issues after another serious incident.*"

Safety goals are target values of safety performance indicators, which are selected to monitor safety performance for management purposes. Safety goals are usually expressed in the number of reported or measured events or the trend in these numbers. The operator uses dashboards to monitor each of the safety goals. In 2021 and 2022 the operator set three new safety goals in relation to the aforementioned concern[71]:

1. The number of ASRs on confusion due to variant flying is monitored.
2. The number of ASRs on takeoff configuration warnings does not exceed the level before the introduction of the Embraer 195-E2.
3. The number of FDM events on takeoff configuration warnings does not exceed the level before the introduction of the Embraer 195-E2.

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[71] In this period there were six safety goals in total.

The Board finds that these safety goals do not encompass all of the occurrences associated with the use of erroneous takeoff data, since some occurrences are not related to selecting the wrong variant (first safety goal) or did not trigger a takeoff configuration warning (second and third safety goal). For instance, selecting the wrong intersection as was the case in the occurrence this investigation is about, would not be measured with these safety goals. The lack of data also causes the absence of a safety goal directly related to erroneous takeoff data.

The operator recognised using erroneous takeoff data as potentially catastrophic and prioritised reducing the risk of using erroneous takeoff data by placing it on the concern list. The related three safety goals do not encompass all of the occurrences with erroneous takeoff data due to the lack of data. Therefore, they offer limited insight into how the risk of using erroneous takeoff data is managed.

4.2.3 Investigation of the risk of erroneous takeoff data

The next step in the process is the investigation of safety hazards. The operator's SCO carries out three types of safety investigations:

- Reactive Safety Issue Risk Analysis (SIRA): incident investigation. The operator's policy is to investigate incidents from which lessons can be learned.
- Proactive SIRA: investigation based on trends or safety concerns. For operational safety this means an investigation into several similar incidents.
- Predictive SIRA: safety investigation before a change is implemented in order to determine whether mitigating measures are needed.

In the period 2012-2021, the SCO performed 130 SIRAs for the operator, 54% of which were predictive, 28% proactive and 18% reactive.

Table 5: Safety investigations carried out by the SCO related to erroneous takeoff data in the period 2012-2021.

Year	Operator	SIRA type	Short description	Methods	Public information, e.g. scientific literature or reports
2013	KLM	reactive	incident Oslo	interviews, ACARS[72]	no
2013	KLM	reactive	incident Schiphol	extensive investigation, including comparing procedures various types, EFB data, FDM data, tests on simulator, database	no
2014	KLM & KLC	predictive	introduction i-pad	brainstorm, bow tie	no
2014	KLC	predictive	ePerf on ipad EFB (windows → ipad)	brainstorm, bow tie	no
2015	KLC	predictive	introduction E175 (new aircraft type added to the fleet)	brainstorm, database	no
2018	KLC	predictive	switch to ACFT database (new database supplier)	test new lay-out by crew, check procedures	yes, 1 report
2020	KLM	proactive	Three incidents: Schiphol 2018, Toulouse 2019, Entebbe 2016	bowtie, LINTOP[73] output, database, other operators	yes, several reports
2020	KLC	predictive	introduction E195 (new aircraft type added to the fleet)	brainstorm, performance calculations, manuals, E195 simulator, ASR en FDM	no
2021	KLM	predictive	replacement of LINTOP for Boeing fleet	brainstorm, other operator, bowtie	no
2021	KLM	predictive	replacement of LINTOP for Airbus fleet	brainstorm, database, bowtie	yes, 1 report

The SCO carried out ten safety investigations related to erroneous takeoff data in the period 2012-2021, of which five safety investigations were performed for the operator (KLC), see Table 5. These were all predictive, which means the SCO did not investigate

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[72] Aircraft Communications, Addressing and Reporting System.

[73] LINTOP stands for LIDO Integrated Takeoff Performance Tool and is a computer program on a centralised remote computer.

any incidents resulting from erroneous takeoff data at KLC in this period. Although the reporting rate was low, pilots did report incidents by filing ASRs (as mentioned in section 4.2.2). These incidents were not investigated even though these types of events had been formulated as a safety concern in 2019.[74] It is important to investigate as many incidents as possible, because there will always be specific lessons to learn, at least on a detailed level.[75] The operator's policy is to investigate incidents which can generate general lessons. Therefore, valuable lessons on a detailed technical and procedural level may be lost. It seems that the balance between having enough occurrences to learn from and preventing multiple investigations from having similar findings is missing.

The most important reason for the operator not to perform a reactive or proactive safety investigation in 2019 was that a predictive investigation regarding the introduction of a new variant had started. The operator considered that this predictive SIRA investigation would cover the risks related to erroneous takeoff data. However, the lessons that can be learned from an incident investigation differ from the lessons from a predictive investigation, because reality is less predictable than one can imagine beforehand. The present investigation reveals (in chapter 2) new contributing factors which were not known to the operator.

Table 5 shows that most predictive investigations used a brainstorm as the primary method of gathering information. These investigations depended strongly on the knowledge of the participants involved and the person conducting the analysis, while the quality of the investigations would benefit from more objectivity.

In the period 2012 – 2021, the SCO only performed predictive SIRA investigations regarding erroneous takeoff data for the operator. The SCO did not perform any reactive or proactive investigations for the operator on the matter even though several incidents did occur and a safety concern had been formulated in that period. Reactive or proactive incident investigations may provide the operator with insight into additional contributing factors on a more detailed level compared to predictive investigations, because reality is often different than one can imagine beforehand.

The conducted predictive investigations strongly depended on the knowledge of the participants involved in the brainstorm, while the quality of the investigations would benefit from more objectivity.

4.2.4 Mitigation of the risk of erroneous takeoff data

After a SIRA has been conducted, the responsibility for mitigation of the analysed risks lays with the operational division(s). The SCO validates the effectiveness of risk mitigations after implementation. After mitigation and validation the remaining risk is reassessed and accepted or mitigated. All analysed risks and their statuses are recorded and stored

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[74] See Section 4.2.3.

[75] Jacobson, A., Ek, A., Akselsson, R., *Method for evaluating learning from incidents using the idea of "level of learning"*, Journal of Loss Prevention in the Process Industries, 24(4), 2011.

in a risk register. When a medium or high risk event is not extensively investigated - because it is considered having no added value compared to previous investigations - the risk register is consulted in order to find safety issues that are related to the occurrence and new mitigating actions may be taken.

The operator has taken several mitigating actions in order to reduce the risk of erroneous takeoff data, including a QR scanner for entering aircraft variant, a redesign of ePerf colour scheme, an awareness campaigns (communication), training, new procedures for acceleration heights, a gross error check and a simulator scenario involving a takeoff with a tailwind. As there is little data regarding the use of erroneous takeoff data, validation takes place mainly by checking the implementation status of a particular measure.

Awareness campaigns are often used as mitigating measures by the operator. Awareness campaigns consist of written communication about takeoff performance-related incidents. Every month, the SCO shares several safety reports with all pilots. In addition to the frequent sharing of factual safety information, 'share your experience' articles are published in the operator's news application for all pilots. The flight operation division chooses this instrument because a personal story of a pilot, who shares his/her story, impresses more than just facts. The SCO published one 'share your experience' article about a takeoff performance-related occurrence on the operator's news application in the year preceding the Berlin incident, see the box below.

Summary of the 'Share your experience' - Nurnberg 2021
Both pilots made ePerf calculations for both Runway 10 and Runway 28. The pilots were distracted by the cabin crew and the ground staff while performing the calculations. The ePerf calculation resulted in a flap 4 setting for takeoff from Runway 28 via intersection B. The crew did not notice the flap 4 setting and entered flap 1 in the Flight Management System (FMS). The crew took off from Runway 28, Intersection A with an incorrect flap setting.

Just like awareness campaigns training is often used as a mitigating measure. The advantage of training over awareness campaigns is that during training it can be checked whether the information has come across. The disadvantage of training as a mitigating measure is that it takes at least six months to train all pilots. Newsletters, for example, have the advantage of being faster. It is also often decided to use both measures as mitigation.

The training documentation of the operator states the following standard to be achieved by ground and refresher training: crews [are] aware on possible recovery measures when confronted with erroneous takeoff data. Regarding variant flying on the E175 and E190, one of the objectives of training is to increase awareness on possible recovery measures when confronted with erroneous takeoff data.

Both training and awareness campaigns aim to improve adherence to existing procedures and working methods. These are soft barriers which aim to improve compliancy.[76] From a learning perspective, these measures may indicate that the system itself is not thoroughly evaluated or questioned.

The operator has taken several mitigating actions in order to reduce the risk of erroneous takeoff data. As there is little data regarding the use of erroneous takeoff data, validation takes place mainly by checking the implementation status of a particular measure. Awareness campaigns (communication) and training are often used as mitigating measures, which aim to improve adherence to existing procedures and working methods. From a learning perspective, these measures may indicate that the system itself is not thoroughly evaluated or questioned.

4.3 Other ways of learning by the operator

The previous section discussed the activities the operator employed under the umbrella of their Integrated Safety Management System (ISMS) to address the risk of using erroneous takeoff data. In this section the Board discusses other means of learning about safety problems in general and about the use of erroneous takeoff data in particular.

4.3.1 Learning by engaging employees

Management of the flight operations division is aware that employees[77] play an important role in a learning organisation and emphasises the importance of an open culture, such that each employee feels invited to speak up. Employees of this division who were interviewed during this investigation confirmed the open culture and the good working atmosphere.[78] They found it difficult to explain what contributes to the open culture. Some aspects that were mentioned are that the operator is relatively small and familial and most employees, including the management, are in the same age-group.

In order to improve and maintain a proper reporting culture, the operator pursues working according to the principles of Just Culture[79], which means that every employee is free and willing to report any possible unsafe situation, incident or accident. No punitive action will be taken against anyone reporting or involved with a safety occurrence or hazard, unless gross negligence or a deliberate or wilful disregard of regulations or procedures is established. The Board finds that the pilots of the present incident felt safe to report. Other interviewed employees of the operator confirmed that they feel free to speak up or to report safety related occurrences. The management communicates about the importance of safety and reporting. If there is a downward trend in the number of reports, they let the pilots know how important it is to report mistakes or errors. If they

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[76] See Appendix C3 on first and second order learning.

[77] See Appendix C.2 for literature on the role of employees in a learning organisation.

[78] Note that this was only a limited number of employees. No large groups were interviewed.

[79] In agreement with the ICAO manual on Safety Management: ICAO, Doc 9859, *Safety Management Manual*, Fourth Edition, 2018.

see an upward trend in the number of reports, they compliment the pilots. The Dutch Civil Aviation Authority (CAA) states that the number of incidents reported by the operator is relatively large compared to other operators.[80]

The operator endorses the importance of employees speaking up in order to improve safety both in the ISMM and in its communication with employees. Means of communication are newsletters, the operator's news application, online flight crew meetings, verbal communication highlighting examples in training and simulator exercises. The operator communicates that safety is an important value of the organisation and that employees play an important role in improving safety. The operator also communicates about safety incidents. The SCO shares multiple safety reports with all pilots every month.

The operator has a structure in place for dialogue and discussion. Pilots can join a monthly online flight crew meeting organised by the management of the flight operations division.[81] In the meetings employees and managers of the flight operations division can discuss a variety of topics, including safety issues, and pilots could raise ideas and concerns.[82] However, the management team sets the agenda and even though pilots can raise topics during the meetings, their ideas or concerns are not always discussed. The operator can do more to invite participation by creating and organising opportunities both by asking employees broad questions such as "Was everything as safe as you would like it to have been this week?" and "What do you need to work more safely?" as well as more specific and in-depth questions.[83] Not all pilots participate in the monthly online meetings, because attending the meetings is voluntary. Structures can be designed to ensure systematic collection of employee input.[84]

The operator is aware that employees play an important role in a learning organisation and works according to the principles of Just Culture, which aids in the identification of risks and hazards. Furthermore, various aspects that may contribute to an open culture are present at the operator and the operator communicates common values and goals regarding safety to the pilots. The operator also has a structure for dialogue and discussion with pilots. The operator might improve the quality of the information obtained from employees by asking more open questions and ensuring a systematic approach to collecting pilot input.

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[80] Source: Safety Board's interview with the Dutch Civil Aviation Authority

[81] See also Appendix G.5.

[82] For example, much attention was paid to the shortage of ground personnel at Schiphol in the May, June and September 2022 meetings. In that context, a SIRA on operational pressure and a recent safety assessment at the airport were discussed.

[83] Edmondson, A.C., *The fearless organization; Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth*, Hoboken, New Jersey : John Wiley & Sons, Inc., 2019.

[84] Amy Edmondson called this inviting participation, see also Appendix C.2.

4.3.2 Learning from work-as-done

During the interviews with the Board, several SCO and flight operations division employees emphasised the importance of learning from work-as-done (see blue box below), although the Integrated Safety Management Manual (ISMM) does not describe how the operator learns from work-as-done. Furthermore, learning from the work-as-done is not part of the existing EU regulation, ICAO standards and manuals.

Learning from work-as-done[85]

In reality work is never completely regular or orderly, except in very special cases. It is therefore inadvisable to assume that work is as we imagine and that compliance guarantees success.[86] Work-as-done will always be different from work-as-imagined because it is impossible to know in advance what the actual conditions of work will be, not least what the demands and the resources will be. Learning from work-as-done is learning from deviations in the prescribed working methods. On one hand, deviations from the described working methods might bypass existing mitigation measures and imply a new safety risk. On the other hand, spontaneous adjustments from the operation may lead to adaptability and, increase the organisation's ability to act resiliently and may have positive effects on safety:[87] Employers may assess deviations in the described working methods by observations, questionnaires and discussions with employees.

In order to gain insight in compliance with the working procedures, the operator uses audits and evaluations to gain insight in the behaviour of pilots or crews in certain situations. When non-compliance to specific procedures is found in an audit or evaluation, additional training or an awareness campaign is initiated to increase compliance with the existing procedures. So far, no safety investigation was started into why pilots did not comply with specific procedures. Audits and evaluations could provide the operator with opportunities to learn by questioning their own operations and investigating why some work is not done as designed or imagined, specifically when addressing the context of not complying, the appropriateness of and the assumptions underlying the standards, guidelines and procedures.[88] This may provide an opportunity to redesign the work process in order to better reflect practice.

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[85] See Appendix C3.3 for more insights in work-as-done.
[86] Hollnagel, E., Wears, R.L., Braithwaite, J., *From Safety-I to Safety-II: A White Paper*, 2015.
[87] The Safety II approach is a form of learning from work-as-done, where the presence of safety is investigated.
[88] This is called second order learning. See Appendix C3 on first and second order learning.

The flight operations division attempts to capture personal strategies that employees utilise to comply with procedures. Examples of such personal strategies are:

- Placing a cup over the flap selector handle as a trigger or reminder that the flap setting required for that particular flight is different than usual.
- Writing the takeoff speeds on a piece of paper so that pilots do not have to switch between applications on their tablet.
- Placing a checklist between the thrust levers as a reminder that a fuel crossfeed valve is open.
- Checking the outcome available runway distance with the airport chart or with the intersection takeoff sign that indicates the remaining Take Off Run Available (TORA).

Once captured, these strategies are discussed by the flight operations division. However, so far the operator does not gain detailed understanding of the context of any personal strategy. The management considers retaining autonomy of the pilots and the awareness of the risks s/he must actively mitigate as more effective than promoting the use of certain specific personal strategies. The operator would only impose a particular strategy by changing a procedure if data shows it is needed. Though, the management team of the flight operations division considered and decided against a survey to collect personal strategies and sharing these amongst the pilots. The division did not want to facilitate these personal strategies, because of a reluctance to promote anything other than procedures.[89]

Learning from work-as-done is not included in existing EU regulation, ICAO standards or manuals. Consistently, the operator does not have a structure in place to learn from work-as-done. However, the operator performs audits and evaluations that gain inside in work-as-done. This may provide the operator with opportunities to learn by questioning their own operations and investigating why some work is not done as designed or imagined. The operator is aware of the added value of learning from personal strategies and may learn more from personal strategies by gaining detailed understanding of the context of a particular personal strategy.

4.3.3 Indirect learning

Learning from occurrences in other organisations (indirect learning[90]) takes place at the operator on an individual basis. Employees of the SCO and the flight operations division gain safety knowledge based on their personal interest. They visit congresses and are connected to various platforms such as ESASI[91], EASA working groups, Embraer Safety

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[89] Management meeting on 21 October 2022.

[90] Dien, Y., Llory, M., *Effects of the Columbia Space Shuttle Accident on High Risk Industries or: Can We Learn Lessons from Other Industries?*, Hazards Conference 18, 2004.
Hayes, J., Hopkins, A., *Deepwater Horizon - lessons for the pipeline industry*, Journal of Pipeline Engineering (3), 2012.
Paltrinieri, N., Dechy, N., Salzano, E., Wardman, M., Cozzani, V., *Lessons learned from Toulouse and Buncefield disasters: from risk analysis failures to the identification of atypical scenarios through a better knowledge management*, Risk Analysis (8), 2012.

[91] European Society of Air Safety Investigators.

Manager Community, CAA UK[92] working group and organisations such as NLR[93] where they learn about literature, science and new developments in aviation safety. Employees read industry publications or have contacts at other airlines that could be used to exchange certain safety risks. Processing of knowledge from outside of the organisation, such as an investigation by a foreign safety investigation authority (see blue box below) or a scientific research paper, depends on the individual.

Investigations by safety investigation authorities

Safety Investigation Authorities around the world have been investigating occurrences involving the use of erroneous takeoff data resulting in insufficient thrust at takeoff. In the period 2013-2021, seven Safety Investigation Authorities investigated 23 occurrences.[94] These investigations contain a richness of various contributing factors.

The SCO used public information about erroneous takeoff data, for instance in the form of scientific literature or reports from Safety Investigation Authorities, in three of the ten performed safety investigations on erroneous takeoff data (see Table 5). It is not standard practice to carry out a literature study in safety investigations.

Indirect learning at the operator takes place on an individual basis. Employees of the operator gain safety knowledge from other organisations based on their personal interest. Knowledge from other organisations was not systematically collected and assessed during safety investigations by the SCO. Indirect learning might be improved by ensuring that information from other organisations is systemically collected, used and retained within the organisation.

4.3.4 Meta-learning

The operator applies meta-learning[95] to its learning process. The management team of the operator monitors and evaluates the performance of the safety risk management process by means of a monthly dashboard that displays numbers such as the average throughput time of safety investigations and mitigation plans and the number of air safety reports (ASRs) received. Another type of process evaluation applied by the operator is a safety management diagnostic carried out by an external party even though this was not legally required. Lastly, the operator discussed improving the SIRA approach (team composition, scope, methods) within the SCO.

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[92] Civil Aviation Authority, United Kingdom.

[93] Netherlands Aerospace Centre.

[94] See appendix F for an overview.

[95] Meta-learning means that an organisation reflects on the way it learns and thereby learns to learn. Meta-learning may lead to improvement of the way the organisation learns, see also Appendix C.5.

The operator might improve meta-learning by assessing the quality of the individual steps of the learning loop (phases of the risk management). The quality assurance of both the occurrence selection process and the safety investigations might benefit from a quality assessment.

Meta-learning at the operator involves mainly the process and its organisation. The safety risk management process is monitored and evaluated regularly. The quality assurance of both the occurrence selection process (prioritising) and the safety investigations might benefit from a quality assessment.

4.4 Conclusions

No incidents investigated
The operator has a structure in place to learn by carrying out safety investigations, which include investigations of incidents and accidents. In the period 2012-2021, several incidents related to erroneous takeoff data occurred at the operator and the operator formulated a safety concern. However, these incidents were not investigated by the SCO, because they reasoned that a predictive investigation could be performed instead. The operator does learn proactively by carrying out predictive investigations before implementing changes. In the period 2012 – 2021, the SCO performed five predictive SIRA investigations related to erroneous takeoff data for the operator.

Lack of data
A hindering factor to learning about the hazard of the use of erroneous takeoff data is a lack of data, which is not unique to this operator. Both ASRs and the present FDM analysis did not provide a full insight in the occurrences related to erroneous takeoff data. As a result of the lack of data, the operator was not able to monitor the number of occurrences related to erroneous takeoff data, to carry out reliable data analyses, assess the need for safety investigations and measures, and monitor the effect of measures already taken to prevent the use of erroneous takeoff data. Also, the lack of a safety goal directly related to erroneous takeoff data was due to a lack of data. Therefore, the safety goals did not trigger the operator to take broader measures to prevent these occurrences. Although, the data driven approach has many advantages, it contributes to not prioritising the hazard of the use of erroneous takeoff data because occurrences related to this hazard are difficult to identify and measure. Therefore, a different approach is required for these types of hazards, in addition to the data-driven approach.

Other ways of learning
The operator recognises that employees play an important role in a learning organisation and takes actions to capture the knowledge of employees about existing processes, about how work is done in practice and about occurrences. Moreover, the operator works according to the principles of Just Culture and various aspects that may contribute to an open culture are present at the operator. The operator also has a structure for dialogue and discussion with pilots. However, the quality of the information obtained from employees might be improved by asking more open questions and ensuring a systematic approach to collecting pilot input.

Learning from work-as-done is not included in existing EU regulation, ICAO standards or manuals. Consistently, the operator does not have a structure in place to learn from work-as-done. The operator might learn more from work-as-done by questioning their own operations and investigating why some work is not done as designed or imagined when that follows from observations during training, audits or evaluations. Moreover, the operator is aware of the added value of learning from personal strategies and has additional opportunities to learn from personal strategies do this by gaining detailed understanding of the context of a particular personal strategy.

Employees of the operator gain safety knowledge from other organisations out of their personal interest. The operator could improve indirect learning further by systematically collecting, using and retaining information from other organisations.

Meta-learning at the operator involves mainly the safety risk management process and its organisation. The operator may improve meta-learning by a systematic evaluation of the quality of each of the steps of the learning loop, for instance incident selection and safety investigations.

5 CONCLUSIONS

The occurrence

The Dutch Safety Board investigated the incident and found that the aircraft took off from Intersection L5 - as the crew intended - while the performance calculation was based on Intersection K5, because both pilots accidentally selected intersection K5 instead of L5 in the takeoff performance calculation application. The selection error resulted in a slower acceleration leading to a hazardous situation in which the aircraft became airborne 443 metres before the end of the runway.

The Dutch Safety Board found several contributing factors related to the selection error:

- Accidental misselections occur commonly when using a touchscreen tool with finger-touch interaction, especially if it is used routinely and therefore quickly. The lack of system feedback about the location of the finger and the 'fat finger' problem contribute to selection errors when working on a touchscreen.
- The takeoff performance calculation application does not provide visual feedback about the selected intersection and runway (airport synoptic).
- The pull down menu contains selection options (runway intersections) that are not normally used by the operator.

There were several contributing factors to the propagation of the misselection:

- The cross check did not reveal the selection error because the pilots likely only focused on the performance calculation outputs, which probably did not differ as both pilots had reportedly selected the same wrong intersection.
- Passing the sign indicating intersection L5 and the available runway length could not reveal the selection error either, because the crew had this intersection in mind. Also the calculated N1 was within range of expectation. Variant flying might have widened their range of expected performance parameters.
- The crew trusted the performance calculation application.

Limited learning from the occurrence

Although the seriousness of the incident was recognised at various levels of the operator's organisation, the operator decided after a limited investigation (assessment) that further investigation into this occurrence was not necessary.

The limited investigation concluded that the outcome variability of the takeoff performance calculation tool contributed to the occurrence as well as a confusing runway intersection designation at Berlin Brandenburg Airport. Additionally, the pilots did not perceive any cues that would invalidate their state of mind and erroneous takeoff data was used for takeoff.

While the investigation by the Dutch Safety Board and the operator's analysis cannot be compared, it does show that a more extensive investigation may yield greater understanding of the occurrence and mechanisms influencing the use of erroneous takeoff data. Moreover, the operator did not investigate any incidents regarding erroneous takeoff data although several incidents did occur and a safety concern had been formulated in the period 2012–2021. The operator's approach of reducing the risk of erroneous takeoff data depends on specific topics that were investigated in predictive investigations with limited scope.

Foundation for learning present

The Dutch Safety Board found that the operator predictably and reliably manages safety through their Safety Management System (SMS), in accordance with existing guidelines and regulatory frameworks. This provides the operator with a structured approach to managing risks in its operation. The operator also recognises that employees play an important role in a learning organisation and takes actions to capture the knowledge of employees about existing processes, about how work is done in practice and about occurrences. Furthermore, the operator works according to the principles of Just Culture and various aspects that may contribute to an open culture are present at the operator. The operator also communicates common values and goals regarding safety to the pilots and has a structure for dialogue and discussion with them.

Lack of data hinders learning

The operator has limited insight in the number of occurrences related to erroneous takeoff data, because they are difficult to measure. Pilots do not always recognize or report them. The flight data monitoring program is currently unable to detect all erroneous takeoff data, compounding the lack of occurrence data.

As a result of the lack of data, which is not unique to this operator, the operator was not able to monitor the number of occurrences related to erroneous takeoff data, to carry out reliable data analyses, assess the need for safety investigations and measures, and monitor the effect of measures already taken to prevent the use of erroneous takeoff data. Also, the lack of a safety goal directly related to erroneous takeoff data was due to a lack of data. Therefore, the safety goals did not trigger the operator to take broader measures to prevent these occurrences.

Although, the operator's current data-driven safety approach has many advantages, it also contributes to not fully recognising and prioritizing the potentially catastrophic hazard associated with the use of erroneous takeoff data, because occurrences related to this hazard cannot be easily identified and measured. Therefore, a different approach is required for these types of hazards, in addition to the data-driven approach.

Fragmented learning as a consequence of the operator's approach
Mitigation of the risk of the use of erroneous takeoff data is based on what the operator learns about this topic. The operator takes mitigating actions following a safety investigation and following incidents that were not extensively investigated. When the operator decides not to perform an investigation after an occurrence the mitigating actions are only based on safety issues previously identified in safety investigations that are related to the incident. Therefore, mitigation actions only took place when there was an analysed risk. As the operator did not perform any in-depth incident investigations nor a broad safety investigation into erroneous takeoff data, the operator's approach of reducing the risk of erroneous takeoff data is fragmented and depended on specific topics that were investigated in predictive investigations with limited scope. The operator might reach a more integrative approach for reducing the risk of using erroneous takeoff data by performing in depth incident investigations, setting up a structure for learning from work-as-done and taking a systematic approach of indirect learning. Every additional way of learning might yield unique complementary lessons.

6 LESSONS TO OPERATORS

This investigation focused on learning by the operator in relation to the risk of using erroneous takeoff data. The Dutch Safety Board chooses to draw up lessons to operators rather than making recommendations, because the lessons apply to many operators who base their safety approach on the same existing regulatory framework. Therefore, the lessons - identified in this section - are universally applicable.

Lack of data may hinder learning when working with a data-driven safety approach. The Dutch Safety Board identifies the following lessons to deal with a lack of data and improve learning by operators:

1. Increasing the amount of data by boosting the occurrence reporting and by developing a flight data analysis tool in which flight data is combined with external data.

2. Increasing diversity of the data sources to prevent blind spots in types of occurrences. Learning from work-as-done might yield unique complementary lessons to learning from occurrences. Structures for dialogue and discussion with employees lower the threshold for them to raise ideas and concerns, which may contribute to integral learning instead of procedural learning.

Because it may be difficult to increase data availability the Board suggests the following approach to be taken simultaneously with the aforementioned actions:

3. Prioritising hazards which are hard to determine or low-frequency occurrences with potentially catastrophic consequences for investigations and mitigating actions.

7 RECOMMENDATIONS

The use of erroneous takeoff performance data is a safety issue of general concern and not specific to any aircraft type. The European Union Aviation Safety Agency (EASA) expects aircraft software and systems to provide hard barriers against erroneous data entry. The Dutch Safety Board recommended EASA to develop requirements for onboard systems in 2020. However, technical solutions will take some time to be developed and implemented in regulation. In order to speed up the availability of technical and software onboard systems the aviation industry needs to develop technical solutions to prevent the use of erroneous takeoff data as soon as possible. This investigation concludes that Embraer's performance application tool can be improved such that misselections are less likely to occur or more easily detected. Embraer started development of these improvements which are expected to be implemented in 2024. Therefore, the Dutch Safety Board does not make a recommendation on this issue and encourages Embraer to continue developing improvements for the performance application tool. The investigation also shows that Embraer has no plans to develop onboard systems, whereas some other manufacturers do. Therefore, the Dutch Safety Board makes the following recommendation:

To Embraer:

1. To start the development of an independent onboard system that detects gross input errors in the process of takeoff performance calculations and/or alerts the flight crew of abnormal low accelerations for the actual aeroplane configuration as well as insufficient runway length available.

APPENDIX A

Investigation justification

A.1 Reason for investigation

On 12 September 2021, an erroeous takeoff performance related occurrence took place during takeoff of an Embraer 195-E2 at Berlin Brandenburg Airport in Germany. The aircraft took off from Runway 25R after it had lined up via intersection L5, while the takeoff performance calculation and the selected amount of engine thrust were based on a takeoff from the beginning of the runway.

On 24 September 2021, the operator reported the occurrence to the Dutch Safety Board, which subsequently reported it to the German Federal Bureau of Aircraft Accident Investigation (BFU), representing the state of occurrence. The BFU delegated the investigation to the Dutch Safety Board, representing the state of the operator and the state of registry. The Board classified the occurrence as a serious incident for which an investigation and reporting obligation stands.

A.2 Value of an investigation by the Dutch Safety Board

When accidents or disasters occur, the Dutch Safety Board investigates how it could have happened. The aim is to learn lessons for the future and, ultimately, improve safety in the Netherlands. The Board is independent and is free to decide which events to investigate. In particular, it focuses on situations in which people's personal safety is dependent on third parties, such as the government or private companies. In certain cases, the Board is under an obligation to carry out an investigation. Its investigations do not address issues of blame or liability.

A.3 Aim and investigation questions

The use of erroneous takeoff data is a long standing, worldwide and complex problem. This investigation report focuses on learning by the operator in relation to the risk of using erroneous takeoff data. There was no specific reason to choose this incident involving this specific operator for this investigation with this focus. It involves both how the operator learned in the period before this incident took place and how the operator learned from this incident. The investigation goes beyond checking the operator's regulatory compliance. It includes incident reporting, insight in erroneous takeoff occurrences, the quality of safety investigations, improvement of the learning process and engaging employees. Through this report, the Board aims to stimulate operators to learn more from occurrences in which erroneous takeoff data are used, in order to reduce the number of serious incidents and accidents.

Given the aim of encouraging operators to learn more from occurrences in which erroneous takeoff data are used, the following investigation questions are central in the investigation.

Investigation questions

1. Which factors played a role in selecting the wrong intersection and not recognising this?
2. How and what did the operator learn before and after the occurrence at Berlin Brandenburg Airport, to reduce the risk of making errors in the calculation and entry of takeoff performance related parameters?

A.4 Focus and demarcation

The present investigation by the Dutch Safety Board focused on the contributing factors of the occurrence as well as on how the operator learned in order to reduce the risk of using erroneous takeoff data. How other operators learned in order to reduce the number of serious incidents and accidents related to erroneous takeoff data is not addressed in this investigation.

KLC and KLM have a shared safety and compliance organisation (SCO) since 1 February 2021. This investigation focuses on KLC, where the present serious incident occurred, and the shared SCO. Learning at KLM falls outside the scope of this investigation. The report refers to KLC as the operator.

A.5 Investigation approach

Since the first investigation question focusses on the serious incident itself, interviews were conducted with the captain and first officer of the PH-NXD. The flight data recorder (FDR) data was analysed, but the cockpit voice recorder (CVR) data was not available for analysis. Information about the layout of Berlin airport was collected and KLC organised a demonstration of the ePerf system. Embraer and KLC provided the accompanying documentation. The BFU and the Brazilian Aeronautical Accident Investigation and Prevention Center (CENIPA), respectively representing the state of design and manufacture of the aircraft, provided assistance to the investigation. The European Union Aviation Safety Agency (EASA) appointed a technical adviser. A Tripod Beta model was used to map and analyse the collected information about the serious incident, in order to answer the first investigation question.

To be able to answer second investigation question, a wider perspective of KLC as a 'learning organisation' needed to be created. Therefore, interviews were conducted with employees of the SCO and flight operations division, as well as with the Human Environment and Transport Inspectorate (ILT). Documentation on safety management system (SMS), including policy, risk management, safety assurance and safety promotion were studied, as well as meeting notes, training manuals and key safety performance indicators. Reports about previous incidents involving erroneous takeoff data were collected from the aviation analysis bureau (ABL), KLC and KLM. Air safety reports (ASR) and Safety Issue Risk Analyses (SIRA) were then analysed and combined with a STAMP analysis to understand how the operator learns from incidents with erroneous takeoff data. Furthermore, information about proactive analyses that the operator conducted on the hazard was studied. Simultaneously, a frame of reference (Appendix C) was built by collecting and studying literature about how organisations learn. The investigation team discussed how this frame of reference relates to the information collected on how the operator learns from takeoff performance incidents. This approach provided the information needed to answer the second investigation question, but also enabled the investigation team to understand what more can be learned to counter the use of erroneous takeoff data, which leads up to the conclusions in chapter 5 and lessons in chapter 6.

A.6 Quality Control

Various elements of the investigation have been described in the previous text, such as the formulation of the investigation questions, the investigation process outline, the manner of data collection and the methods and techniques used in the analyses. Combined, these elements determine the quality of the investigation. The investigation process has a number of additional safeguards built in for the purpose of quality control. The project team is composed on the basis of variation in expertise and skills. This promoted the opportunity to view the subject from different angles and minimise negative effects, such as groupthink. There are various roles within the team, such as portfolio holder, investigation manager, project leader, investigator, secretary, and methodologist. Periodic consultations took place between the project leader, investigation manager and portfolio holder to monitor the progress and direction of the investigation. Lastly, the final report was subjected to an extensive review by several colleagues with varied backgrounds, who were not involved in the investigation, by the Board and by the external parties involved.

APPENDIX B

Responses to the draft report

In accordance with the Dutch Safety Board Act, a draft version 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:

- KLC
- Captain
- First Officer
- EASA
- Ministry of Infrastructure and Water Management
- Embraer
- CENIPA (State of Manufacturer)
- BFU (State of Occurrence)

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 (https://www.safetyboard.nl). Editorial comments were not included in the table, but have been incorporated into the report. All other comments are included in the table.

APPENDIX C

Frame of reference: Learning organisation

C.1 Introduction

The Dutch Safety Board uses a frame of reference in many investigations. A frame of reference is a set of criteria that are relevant to the investigation. These are often scientific insights, best practices, expert opinions, guidelines, standards and/or legislation. A frame of reference can be used to compare or understand findings. A frame of reference is closely related to the investigation questions and focus of the investigation. This frame of reference focuses on learning organisations in relation to safety.

With regard to safety, this report defines a learning organisation as an organisation that continuously evaluates and adjusts its safety approach. A learning organisation applies multiple strategies to learn.[96] For example, two complementary safety learning approaches are reactive and proactive learning:

1. Reactive learning: investigation of accidents, near misses and incidents (occurrences);
2. Proactive learning:
   a. Learning before implementing changes (as part of change management);
   b. Learning from work-as-done (e.g. learning from practical drift, personal strategies);
   c. Indirect learning (e.g. learning from other organisations).

Proactive learning offers added value to the more common form of reactive learning (cf. Safety-I and Safety-II[97]). The relevance of proactive learning is illustrated by the fact that the severity and frequency of certain hazards do not correspond with the pre-assessed situation. In addition, the implementation of measures in practice may also deviate from what was intended (practical drift). Hence, reactive and proactive learning both have their strengths and are complementary to one another.

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[96] Basten, D. and Haamann, T, *Approaches for Organizational Learning: A Literature Review*, SAGE Open, 8(3), 2018, https://doi.org/10.1177/2158244018794224.

[97] Hollnagel, E., *Safety-I and Safety-II – The Past and Future of Safety Management*, Taylor & Francis Ltd, 2014.

Employees play an important role in a learning organisation. They have knowledge about existing processes, about how work is done in practice, and oftentimes about occurrences. Based on their knowledge and experience, they can provide relevant suggestions about how the work can be done better and safer. A critical success factor for a learning organisation is employees feeling free to speak up about these matters (cf. just culture and psychological safety, see Appendix C.2).[98]

In a learning organisation, risk management decisions are made both reactively and proactively regarding implementation of risk management measures or adjustments, collectively referred to as the approach. The approach is then followed up to check whether the implementation has been completed and whether it had the desired effect. Ongoing evaluation - which contributes to learning - is an important aspect of safety management.[99] A safety risk management process - which is part of the Safety Management System (SMS) and required by law (see Appendix E.2) - may contribute to ensuring a continuous learning loop.

A learning organisation plans moments of self-reflection, which can lead to improvement of the way the organisation learns.[100] This is called meta-learning. Meta-learning may take place regularly and is aimed at continuous improvement, see Figure 5.

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[98] Dekker, S.W., *Just Culture: Balancing Safety and Accountability*, Aldershot: Ashgate Publishing 2012;
Edmondson, A.C., *Psychological Safety and Learning Behavior in Work Teams*, Administrative Science Quarterly (2), 1999;
Edmondson, A.C., *The Fearless Organization: Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth,* Hoboken, NJ: John Wiley & Sons, 2018;
Groeneweg, J., Ter Mors, E., Van Leeuwen, E., Komen, S., *The Long and Winding Road to a Just Culture*, SPE International Conference and Exhibition on Health, Safety, Security, Environment, and Social Responsibility, 2018.

[99] Dutch Safety Board's general frame of reference, which comprises five principles that organisations should comply with in order to manage safety, see for example Chapter 2 of the report *Who is in control? Road safety and automation in road traffic*, 2019.

[100] Dechy e.a., *Barriers to learning from incidents and accidents*, ESReDA guidelines, 2015.
https://esreda.org/wp-content/uploads/2016/03/ESReDA-barriers-learning-accidents-1.pdf
Jacobsson A., *Methodology for Assessing Learning from Incidents - a Process Industry Perspective* (diss. Lund University/EAT), 2011;
Kjellén U., *Prevention of Accidents Through Experience Feedback*, London: Taylor & Francis, 2000.

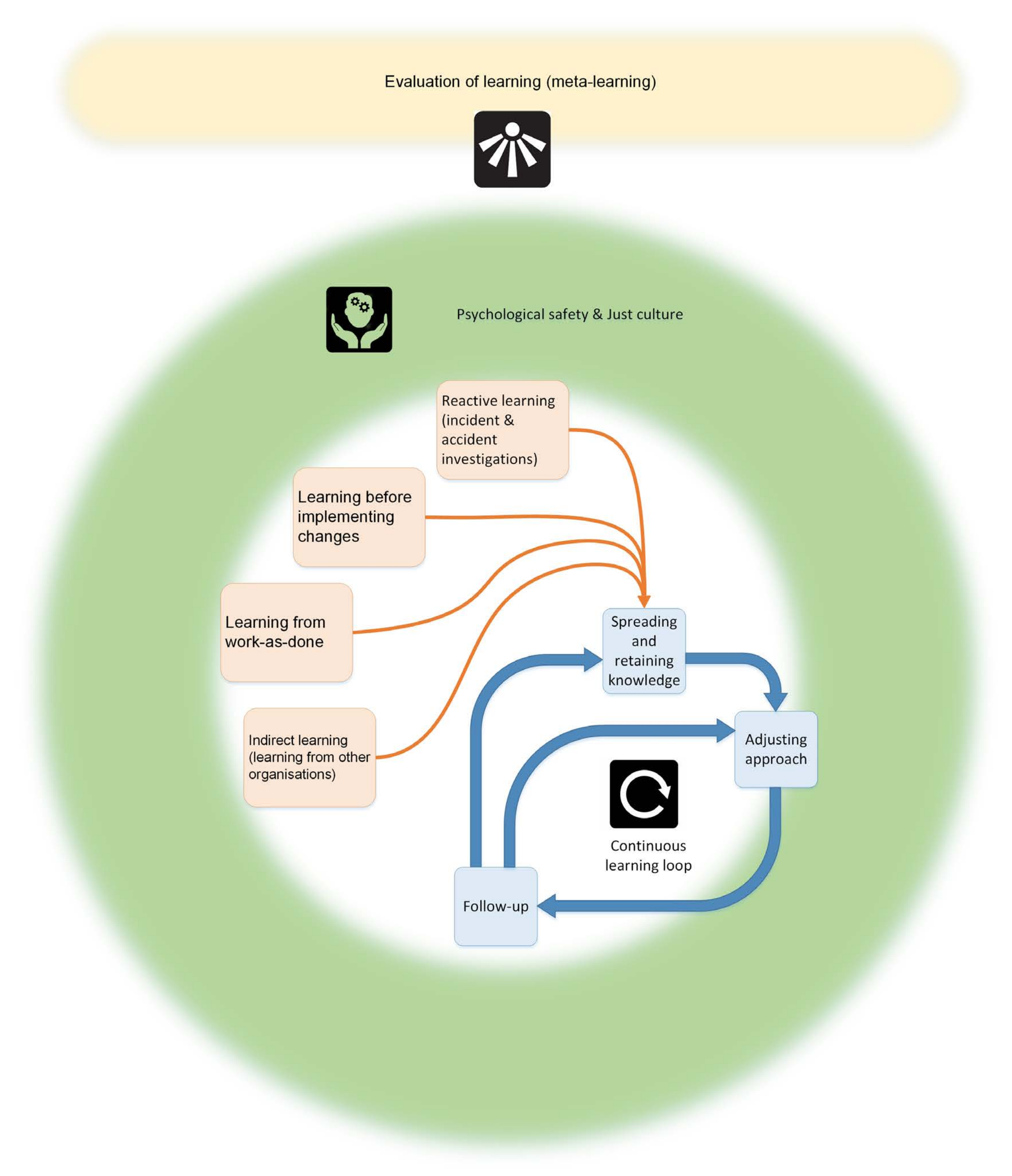

Figure 5: Learning organisation. (source: Dutch Safety Board, based on literature on learning and accident investigation[101])

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[101] Bibliography on learning described in this appendix.

C.2 A climate of psychological safety

The culture, including the social interaction within an organisation, determines the extent to which the organisation is able to learn. In order to make use of the knowledge and ideas of employees, employees should be able speak up freely and share their concerns, questions and ideas.[102] The theories about Just Culture[103] and Psychological Safety[104] offer tools to increase employee engagement and have a lot in common. Just Culture is mainly based on the assumption that employee trust grows through fairness of management decisions. Amy Edmondson's theory of psychological safety goes further. In addition to fairness of management decisions, essential factors are leadership, honesty, involvement, ownership and a willingness for synergy between all employees.

Psychological safety[105]
When there is a climate of psychological safety within an organisation, people feel safe enough to speak up and share their concerns, questions or ideas. When people see it as a risk to their career and happiness at work to openly share ideas, questions and concerns, they will not do so. This will hinder an organisation's learning and innovation. Psychological safety in the work environment is necessary to learn, innovate and grow as an organisation.

Just culture[106, 107]
A just culture is a climate of trust, where people are encouraged (and even rewarded) for providing critical safety information, but where people are also aware of the boundaries between acceptable and unacceptable behaviour. Just culture contributes to an environment in which employees feel free to report unsafe events and situations, and helps the organisation to learn from them. The starting point of just culture is that unsafe behaviour usually does not happen intentionally. Unsafe events are seen as opportunities for the organisation to learn.

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[102] Edmondson, A.C., *The fearless organization; Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth*, Hoboken, New Jersey : John Wiley & Sons, Inc., 2018.

[103] Dekker S.W., *Just Culture: Balancing Safety and Accountability*, Aldershot: Ashgate Publishing 2012; Ter Mors, E., Van Leeuwen, E., Komen, S., *The Long and Winding Road to a Just Culture*, SPE International Conference and Exhibition on Health, Safety, Security, Environment, and Social Responsibility, 2018.

[104] A.C. Edmondson, *Psychological Safety and Learning Behavior in Work Teams*, Administrative Science Quarterly (2), 1999.

[105] Edmondson, A.C., *The Fearless organization; Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth*, Hoboken, New Jersey : John Wiley & Sons, Inc., 2018.

[106] Reason, J., *Managing the Risks of Organizational Accidents*, Ashgate Publishing, 1997.

[107] Catino, M., *A Review of Literature: Individual Blame vs. Organizational Function Logics in Accident Analysis*, Journal of Contingencies and Crisis Management , 16(1), 2008.

Leaders – at the top and throughout an organisation – may motivate employees by an inspiring vision regarding safety. Leaders' communication and behaviour influence the extent to which employees take social risks, such as discussing unsafe behaviours, asking for help, or providing feedback. When leaders propagate the values of the organisation in communication and behaviour, they will intrinsically motivate employees to behave accordingly.

Amy Edmundson posits three types of actions that should be used repeatedly and alternately to build and reinforce a climate of psychological safety: (1) communicating common values and goals, (2) inviting participation, and (3) responding productively.

Setting the stage by communicating common values and goals

The first step towards a climate of psychological safety is working on shared expectations, goals and values. This provides guidance to all employees. The goals of the organisation should be regularly and clearly communicated. It should be emphasised what is at stake. In the case of civil aviation, at stake are the lives of the crew and all passengers on board. The importance of employees speaking up should also be communicated.

Inviting participation

Situational humility[108] and an open attitude towards colleagues make them feel more involved in safety, and make them show ownership and a willingness to cooperate. Situational humility includes acknowledging gaps in knowledge, modelling intense listening and asking good questions. Good questions involve both broad questions such as "What do you need to work even more safely?" as more specific and in-depth questions. In order to be able to ask such questions, it is necessary to set up structures and processes to ask such questions and elicit employee input.

Situational humility

Amy Edmondson describes situational humility as the willingness to transparently acknowledge the gaps in our knowledge and remaining relentlessly curious about the opinions of others. It leads to better outcomes in uncertain situations because the leader creates psychological safety for others to share their ideas. A leader who practices situational humility seeks to know what they don't know about situations.

Structures designed to elicit employee input may include working groups, focus groups, consultation meetings and discussion meetings. These structures lower the threshold for employees to raise ideas and concerns or to discuss incidents they experienced or which are relevant to them. Structures may ensure that input from employees is collected systematically. They should be designed such that they ensure a safe environment for open dialogue and discussion, in which everyone's input is respected. Lindberg et al. (2010) show that dialogue with interested parties, as opposed to merely providing

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[108] Edmondson, A.C., *The Fearless organization : how to build psychological safety for learning and innovation.* Newark: John Wiley & Sons, Incorporated, 2018.

information, has a positive effect on learning and retention of information.[109] In EU regulation on air operations, meetings with employees, where information, actions and procedures are discussed, are referred to as structures for discussing safety issues.[110]

Responding productively

Responding productively when an employee reports an incident or potential risk contributes to trust among employees.[111] Responding productively involves a positive first reaction, for example a thank you for the report. A blaming response is not productive. Subsequently, further questions should be asked to clarify what the employee wants to report.

Employees who actually do the work should be involved in a safety investigation in order to improve understanding of the work-as-done and to contribute to informal learning within the organisation.[112, 113] Finally, the reported and identified problems should be addressed. Feedback to the reporter about the mitigating actions – especially if the reporter is not involved in the safety investigation – is important to show that something is actually being done with the reports.

C.3 Learning from various sources

C.3.1 Learning from occurrences

Learning based on the investigation of occurrences (accidents, near misses, serious incidents and incidents) is called reactive learning. A goal of occurrence investigationsis to improve safety.[114, 115] Three questions should be answered in an occurrence investigation: "What happened?", "Why could it happen?" and "What can be learned from it?". The answers result in opportunities to prevent the recurrence of similar occurrences. According to (scientific) literature, the following steps should be carried out to learn lessons from incidents.

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[109] Lindberg, A.K., Hansson, S.O., Rollenhagen, C., *Learning from accidents – What more do we need to know?*, Safety Science 48(6), 2010.

[110] Regulation (EU) No 965/2012 on air operations, Annex III (Part-ORO), AMC1 ORO.GEN.200 (a)(4)(b)(2)

[111] The Joint Commission, *Developing a reporting culture: Learning from close calls and hazardous conditions*, Sentinel Event Alert, Issue 60, 2018.

[112] Eurocontrol, *Systems Thinking for Safety: Ten Principles; A White Paper; Moving towards Safety-II*, 2014

[113] Seddon, J., Freedom from command and control (Second edition), Vanguard, 2005.

[114] Zouridis, S., van Delden, L., Baart, M., & Hoekstra, L., *Ongevalsonderzoek en leren: Lessen voor toezichthouders*, Tijdschrift voor Toezicht, 2022.

[115] Other goals may include explaining what happened, explaining abnormalities, or explaining suffering. These goals are rarely compatible in the same study. Dekker,S., *The psychology of accident investigation: epistemological, preventive, moral and existential meaning-making*, Theoretical Issues in Ergonomics Science, 16(3), 2015.

Occurrence reporting

Occurrences should be identified as such and reported in order to learn from them. Conditions for a high reporting rate[116]:

- Psychological safety and a just culture are present in the organisation;
- Reports are used for safety purpose only. Employees are not penalised for their actions, omissions or decisions when they are consistent with their experience and training[117];
- Investments are made in the risk awareness of employees and reporting is promoted (see also communicating common values and goals and inviting participation). It is clear which situations must be reported and why incidents must be reported. Reporting is useful for the reporter ('something will happen to it') and that will be fed back to the reporter;
- Time is available to report;
- User-friendly resources and processes are available for reporting.

Detecting occurrences based on data

Underreporting may occur due to employees not being able to perceive an occurrence or to assess the situation and to identify an incident as such. Underreporting has also been linked to a blame culture[118], the perception of futility or normality as well as uncertainty what to report and unsuitable tools.[119] In general, underreporting appears to be related to the safety culture within an organisation.[120] Regular analyses of available data may reveal unreported incidents. Operational Flight Data Monitoring (OFDM) has been used in aviation to improve safety.[121]

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[116] Choularton, R., *Complex learning: organizational learning from disasters*, Safety Science, 1-2, 2001;
Drupsteen, L., Guldenmund, F.W., *A Review About Learning from Incidents*, Accidents and Disasters, Journal of Contingencies and Crisis Management, 22, 2014;
Drupsteen, L., Hasle, P., *Why do organizations not learn from incidents? Bottlenecks, causes and conditions for a failure to effectively learn*, Accident Analysis & Prevention, 72, 2014;
Le Coze, J.C., *What have we learned about learning from accidents? Post-disasters reflections*, Safety Science, 1, 2013;
Silva, S.A., Carvalho, H., Oliveira, M.J., Fialho, T., Soares, C.G., Jacinto, C., *Organizational practices for learning with work accidents throughout their information cycle*, Safety Science, 99, 2017;
Smith, E., Roels, R., King, S., *Guidance on learning from incidents, accidents and events*, Hazards Conference 25, 2015;
Stemn, E., Bofinger, C., Cliff, D., Hassall, M.E., *Failure to learn from safety incidents: Status, challenges and opportunities*, Safety Science, 101, 2018;
Sujan, M.A., Huang, H., Braithwaite, J., *Learning from incidents in health care: Critique from a Safety-II perspective,* Safety Science, 99, 2017.

[117] Europese Verordening (EU) nr. 376/2014 inzake de melding, analyse en monitoring van voorvallen in de burgerluchtvaart.

[118] Hood, C., *The Blame Game: Spin, Bureaucracy, and Self-Preservation in Government*, Princeton, NJ: Princeton University Press, 2010;
Resodihardjo, S.L., Carroll, B.J., Van Eijk, C.J., *Maris, S., Why traditional responses to blame games fail: The importance of context, rituals, and sub-blame games in the face of raves gone wrong*, Public Administration, 94, 2016;
Resodihardjo, S.L., *Crises, Inquiries and the Politics of Blame*, Cham: Palgrave Macmillan, 2020.

[119] Pransky, G., Snyder, T., Dembe, A., Himmelstein, J., *Under-reporting of work-related disorders in the workplace: a case study and review of the literature*, Ergonomics, 1, 1999.

[120] Probst, T.M., Brubaker, T.L., Barsotti, A., *Organizational injury rate underreporting: The moderating effect of organizational safety climate,* Journal of Applied Psychology, 5, 2008.

[121] ICAO Annex 6 - Operation of aircraft.

Selecting occurrences

The reported occurrences need to be analysed, compared and prioritised for further investigation. Literature does not provide a set of generic criteria for the selection of occurrences for further investigation. The selection of (series of) incidents for investigation is often based on the seriousness of an incident, its frequency, and/or the expected safety improvement.

The selection of incidents for further investigation has a major impact on the learning ability of an organisation. The likelihood of capturing a signal indicating a coming disaster partly depends on the quality of the selection process. Various cognitive processes play an important role in recognizing these kinds of signals. On the basis of seeing connections, pattern recognition, recognizing exceptions and recognizing discrepancies, events can be selected that are expected to yield the most safety gains. The selection process therefore requires employees with expertise and experience in incident investigation.[122]

Occurrence investigation

The depth of an investigation affects how much can be learned. There is more to learn when the situation in which the occurrence could take place is not only tested against the accepted procedures, principles, standards, regulation, et cetera, but when these frameworks are also questioned. This is called second-order learning.[123]

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[122] Le Coze, J.C., *What have we learned about learning from accidents? Post-disasters reflections*, Safety Science, 1, 2013.

[123] Argyris, C., Schön, D.A., *Organizational learning: a theory of action perspective*, Reading, MA: Addison Wesley 1978.

First- and second-order learning

First-order learning in occurrence investigation primarily concerns the questions of:

- whether the applicable procedures have been applied;
- whether the system functioned as it should; and
- whether it complies with the applicable standards, guidelines and procedures.

There are two possible answers to such questions: either the situation met the standards or it did not meet the standards. The system itself is not evaluated or questioned. From a learning perspective, the measures that follow are usually that the situation should become more norm-compliant. The perspective for action is therefore limited and there is a risk of a 'blame game' in which norms are used to detect 'mistakes' and to point out 'guilty'.

Second-order learning starts with the question of what made it understandable that the applicable procedures were not applied. Then, the context in which the incident could have taken place is part of the investigation. In addition, the norms themselves are questioned. The following questions can be asked:

- Did the standards, guidelines or procedures themselves play a role in the occurrence of the incident?
- Were the standards, guidelines and procedures appropriate?
- What assumptions are included in the standards, guidelines and procedures?

Asking these questions ensures that more insight is gained into how the incident could have happened. This increases the potential learning gain.

Reporting

The report should present the findings and conclusions of the investigation, in clear and unambiguous language, in line with practice. The emphasis should be on the lessons that can be learned, which should be formulated in recommendations with the aim of preventing such an incident.

C.3.2 Learning before implementing changes

New risks may arise due to changes in the work process. An organisation should manage change in a systematic way, identifying new hazards and mitigating increased risks before implementing a change.[124] This is also known as change management.[125]

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[124] Civil Aviation Organisation (ICAO) Annex 19, *Safety Management*, and the ICAO *Safety Management Manual* (Doc 9589).

[125] Regulation (EU) No 965/2012 on air operations, Annex III (Part-ORO), AMC1 ORO.GEN.200 (a)(3)(e) Definition: The management of change should be a documented process to identify external and internal change that may have an adverse effect on safety. It should make use of the operator's existing hazard identification, risk assessment and mitigation processes.

C.3.3 Learning from work-as-done

New risks may arise due to deviations in the work process. A system may have shortcomings or does not function as designed. In practice, employees are committed to getting the job done and apply local adjustments, temporary solutions and personal strategies. Therefore, it is important to periodically check the existing practice and learn why the work is not done as designed or imagined.

An in-depth investigation into the work-as-done ensures second-order learning and answers the question of what made it understandable that the working procedures were not applied.

On the one hand practical drift may bypass existing mitigation measures and imply a new safety risk. An organisation that is capable of second-order learning will redesign the work process in order to better reflect practice.

On the other hand, spontaneous adjustments from the operation may lead to adaptability and resilience of the organisation and may have positive effects on safety. Organisations may use the lessons employees learned by collecting and analysing data about how work almost always runs smoothly and safely, despite all the daily challenges.[126] This approach is called a Safety-II approach.[127] An advantage of this approach is that the amount of available data from day-to-day work that runs smoothly is many times greater than the amount of data from risks or incidents.

Adjustments of the described working methods may concern conscious adjustments that are discussed in advance when they are foreseen, for example through experience, but also unconscious adjustments. The latter is based on implicit learning. Employers may assess deviations in the described working methods by observations, discussions with employees, and questionnaires. In case of implicit learning the latter two methods are less/not suitable.

C.3.4 Indirect learning

The hard lessons one faces directly are easier for individuals to remember and have been a key factor in motivating people and organisations to take some actions to avoid the recurrence of a similar event. However, another key driving force for learning, has been to learn from other's hard lessons. This is a form of indirect learning. Learning from incidents in one organisation or in one industry might be helpful in preventing incidents in other organisations, sectors or industries.[128] Guidelines, standards and best practices from

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[126] Flight Safety Foundation, *Learning From All Operations: Expanding the Field of Vision to Improve Aviation Safety, Flight Safety Foundation white paper*, 2021.

[127] Hollnagel, E., *Safety-I and Safety-II – The Past and Future of Safety Management*, Taylor & Francis Ltd, 2014; Hollnagel, E., Wears, R.L., Braithwaite, J., *From Safety-I to Safety-II: A White Paper*, 2015.

[128] Dien, Y., Llory, M., *Effects of the Columbia Space Shuttle Accident on High Risk Industries or: Can We Learn Lessons from Other Industries?*, Hazards Conference 18, 2004;
Hayes, J., Hopkins, A., *Deepwater Horizon - lessons for the pipeline industry, Journal of Pipeline Engineering*, 3, 2012;
Paltrinieri, N., Dechy, N., Salzano, E., Wardman, M. Cozzani, V., *Lessons learned from Toulouse and Buncefield disasters: from risk analysis failures to the identification of atypical scenarios through a better knowledge management*, Risk Analysis, 8, 2012.

other organisations might also be considered.[129] Learning between industries is inherently difficult, in particular because it is necessary to translate events to one's own operating environment and compensate for the loss of context, which is unavoidable when describing what happens in complex systems.

Indirect learning
Learning from occurrences in one organisation or in one sector can help prevent occurrences in another organisation or in another sector.[130]

C.4 Continuous learning loop

A characteristic of a learning organisation is that employees make continuous efforts to improve the organisation. Employees at both management and operational level should have proper knowledge for this. The knowledge gained through both reactive and proactive learning may be disseminated and assured within the organisation. Based on this new knowledge, adjustments should be made to the work process. Subsequently, the effect of the adjustment should be validated.

Spreading and retaining knowledge
Safety lessons obtained in a reactive and proactive manner (for example, analysed risks, recommendations or lessons obtained from the work-as-done) contribute to the knowledge building of an organisation. Within an organisation, employees at both management and operational levels should be made aware of these lessons.

Adjusting approach
In a learning organisation, , reactive and proactive lessons about the implementation of risk management measures or adjustments drive management decisions (i.e., the approach). The management organises an environment in which input from operational level is taken into account in finding measures or adjustments - for example by setting up the necessary infrastructure and preconditions to invite, stimulate and facilitate employees to provide this input.

Follow-up
In a learning organisation, the approach requires follow-up to check whether the implementation has been completed and is having the desired effect.

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[129] Regulation (EU) No 965/2012 on air operations, Annex III (Part-ORO), AMC1 ORO.GEN.200 (a)(2)(b)(2)

[130] Dien, Y., Llory, M., *Effects of the Columbia Space Shuttle Accident on High Risk Industries or: Can We Learn Lessons from Other Industries?*, Hazards Conference 18, 2004;
Hayes, J., Hopkins, A., *Deepwater Horizon - lessons for the pipeline industry,* Journal of Pipeline Engineering, 3, 2012;
Paltrinieri, N., Dechy, N., Salzano, E., Wardman, M. Cozzani, V., *Lessons learned from Toulouse and Buncefield disasters: from risk analysis failures to the identification of atypical scenarios through a better knowledge management*, Risk Analysis, 8, 2012.

C.5 Meta-learning

A psychologically safe climate in combination with the presence of a safety management system are prerequisites for a learning organisation, but do not automatically lead to deeper insights and/or safety improvements. According to scientific studies[131], the following situations may indicate that there are barriers in the learning process and may therefore be a reason to evaluate the learning process.

- The lessons and recommendations do not reach the right people or divisions;
- The completion of an investigation and the resulting lessons and recommendations take longer than foreseen;
- Production is prioritised over safety at the operational level;
- The investigator is perceived as distant from the operational level;
- The changes entail (the perception of) new risks or other negative effects;
- Risk mitigation is not integrated and information is fragmented, resulting in a lack of overview and deeper insight. William Voss, former director of the Flight Safety Foundation, stated that four simple questions could be used to check whether an organisation has an effective safety management system:[132] (1) What is most likely to be the cause of your next accident or serious incident? (2) How do you know that? (3) What are you doing about it? (4) Is it working?;
- Information from the safety management system does not lead to adjustments in the planned spending.

A learning organisation plans moments of self-reflection, which can lead to improvement of the way the organisation learns.[133] This is called meta-learning. Meta-learning may take place regularly and is aimed at continuous improvement. In addition, meta-learning can take place when effective implementation of an approach failed; in case of such a failure, the underlying factors might be investigated. The evaluation of the learning process runs through its own cycle with data collection, analysis, decision-making, implementation and follow-up as well.[134]

Meta-learning[135]

Meta-learning means that an organisation reflects on the way it learns and thereby learns to learn. The organisation evaluates how learning is based on first and second order learning and develops methods to improve learning. Thereby, the investigators question the values and norms of the organisation and its dependence on other organisations and regulations.

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[131] Cedergren 2013; Dechy e.a. 2015; Lindberg and Hansson 2006.

[132] Voss, W.R., *SMS Reconsidered, Aerosafety World*, 2012.

[133] Dechy e.a., *Barriers to learning from incidents and accidents*, ESReDA guidelines, 2015.
https://esreda.org/wp-content/uploads/2016/03/ESReDA-barriers-learning-accidents-1.pdf
Jacobsson. A., *Methodology for Assessing Learning from Incidents - a Process Industry Perspective* (diss. Lund University/EAT), 2011;
Kjellén, U., *Prevention of Accidents Through Experience Feedback*, London: Taylor & Francis, 2000.

[134] Jacobsson 2011; Kjellén 2000.

[135] Argyris 2003; Tosey, Visser & Saunders, 2011; Visser 2007; Wijnhoven, 2001.

APPENDIX D

Factual information related to the occurrence

D.1 History of the flight

General
On 12 September 2021, an Embraer 195-E2 with registration PH-NXD, was scheduled for a flight from Berlin Brandenburg Airport (EDDB, hereafter Berlin) in Germany to Amsterdam Airport Schiphol (EHAM, hereafter Schiphol) in the Netherlands. The scheduled departure time was 17.38 hours. The flight crew consisted of a captain and a first officer. The captain was acting as pilot flying and the first officer as pilot monitoring.

Prehistory
It was the last flight on the last day of the flight crew's four-day schedule. The four-day schedule had a 3-4-4-3 pairing, meaning that on the first and the last day three flights, and the second and third day, four flights were made. During the four days, the crew flew three variants of the Embraer aircraft: the Embraer 175, Embraer 190 and the last two flights with the Embraer 195-E2.

The first two days were uneventful. At the end of the third day, the crew arrived at Basel Airport (hereafter Basel) in France. The first flight of the fourth day would be from Basel to Schiphol. From Schiphol they would fly to Berlin and the last flight was from Berlin to Schiphol. The crew stated that, after the flight to Basel, they felt uncomfortable, because of operational pressure and disruptions, like losing their luggage. They contacted the operator at the end of the third day, because they were not sure if they were fit to fly on the fourth day. The operator left the decision to them, but did inform the crew that the flights would have to be cancelled if they could not perform them. After spending the night in Basel, the crew discussed what to do. They felt they had slept well enough and were not fatigued, and decided to complete the last sectors.

After the crew had received a slot and they were almost ready to depart from Basel, one passenger still had not boarded. As a result, they missed their slot and had to wait for a new slot. Despite the late departure, the crew managed to make up for the delay. Upon arrival at Berlin Airport, they were back on schedule. After the landing, the aircraft taxied to stand B12. When the passengers had disembarked, the crew could relax for a short period, while the aircraft was being cleaned. The turn-around time was 45 minutes. According to the flight crew, this was ample time and they did not feel rushed.

Flight preparation

After a short break, the crew began their flight preparations and they planned from which intersection to take off. The captain had not often flown to Berlin before, but the first officer had been there frequently, sometimes with the Embraer 195-E2. The first officer had always used intersection L5 for takeoff.

The crew expected a takeoff from Runway 25R and after discussion they both agreed that intersection L5 was suitable because of the prevailing weather conditions. The first officer had used this intersection on previous flights, so this made sense to him. After this decision, both crew members stated that they did their takeoff performance calculation independently from each other by using the ePerf[136] application on their respective Electronic Flight Bag (EFB). Based on the pilot's input, ePerf provides a result card with loadsheet data for the Flight Management System (FMS).

The pilots compared the outcomes of their calculations (see Table 6): the takeoff mode, assumed temperature, flap position and takeoff speeds. They did not check the runway intersection and runway length. The outcome seemed to be realistic and was within the range of what could be expected, according to the crew. After confirmation that the loadsheet data on the result card were identical, they were entered into the FMS.

Table 6: ePerf output parameters for the entered intersection K5.

T/O mode	**TO-3**
Flaps	Flaps 1
V_1	139 kt
V_R	140 kt
V_2	143 kt
T_{ASS}	57 °C

Taxi

When the flight crew had entered the loadsheet data into the FMS, the aircraft was ready to taxi. After the engine start, the calculated fan rotation speed (N1) of 75% was displayed on the engine indication and crew alerting system (EICAS). Although this seemed to be low to the crew, it was not uncommon for them in circumstances when aircraft weights are low or when taking off from long runways.

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[136] See Appendix D3.3 for explanation of ePerf.

After air traffic control had issued the taxi clearance, the flight crew taxied from their stand B12 via Taxiway C towards intersection L5. When taxiing via Taxiway C and approaching intersection L5, signs on the left side of the taxiway indicated the direction towards L5. When taxiing on intersection L5 and approaching Runway 25R, signs on the left side indicated the name of the intersection and runway and the available runway length of 2065 metres.

Takeoff

After air traffic control had cleared the aircraft for takeoff between an aircraft that had landed and in front of another aircraft on final, the flight crew initiated a rolling takeoff. They had selected flaps 1. The captain selected takeoff power, after which the aircraft accelerated. The first officer, as pilot monitoring, noticed that the N1 was 75%. Although he considered this low, he assumed it was correct. During the takeoff roll, he also felt the acceleration was slow and considered calling 'max thrust'. However, to avoid creating a confusing situation, he did not do so.

The captain was also of the opinion that the aircraft accelerated slower than he was accustomed to and did not verbalize this. According to him, the Embraer 195-E2 accelerates a little slower than the other types he is used to, so this made sense to him. Moreover, the E2 is more automated than the other variants, so he assumed the selected thrust was correct.

The crew stated that during the first part of the takeoff roll, the red lights at the end of the runway, were not visible because the runway is slightly curved. At a certain point, the aircraft reached the takeoff decision and rotation speed and the red end lights became visible. At that point, the distance to the red lights gave both crew members the impression that the aircraft became airborne with little runway length remaining.

Flight

When the aircraft was stabilised during the climb, the crew discussed what went wrong. After checking the parameters, they found that they both had entered intersection K5 instead of L5 for the takeoff performance calculation in ePerf. After recalculation, they found that the assumed temperature should have been 35 °C instead of 57 °C and that Flaps 3 should have been set instead of Flaps 1.

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. Reduced takeoff thrust is mainly used for economic reasons; it reduces the exhaust gas temperature, improves engine reliability and extends engine life.

The remainder of the flight was uneventful and after landing at Schiphol the crew filed an air safety report (ASR).

The data from the Flight Data Recorder (FDR) was analysed and it was found that the aircraft rotated at the calculated rotation speed. The aircraft had become airborne around 144 metres before the end of the runway and crossed the threshold at an altitude of 20 feet. The remaining paved runway after this point was approximately 443 metres, including the clearway.

Figure 6: Relevant data of the takeoff projected on Runway 25R. (Source: the operator)

D.2 Personnel information

The flight crew consisted of a captain and a first officer. Both were qualified to fly an Embraer 195-E2. Because of the differences between the Embraer 195-E2 and other Embraer variants, agreements between the operator and the Dutch Airline Pilots Association (DALPA) have been made to aim that a pilot licensed to fly the Embraer 195-E2 does this at least once every four weeks.[137]

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[137] The aim is to fly each variant at least once every four weeks. After 60 days without exposure on a particular variant Route instruction or Simulator training is mandatory.

Table 7: Personnel information.

	Captain	First officer
Licence	ATPL (A)	ATPL (A)
Ratings	EMB 170 - IR(A)	EMB 170 - IR(A)
Medical	Class 1 – valid until 12 November 2021	Class 1 – valid until 19 January 2022
Total flight hours	8,400	3,535
Flight hours E175/E190/E195-E2		
Total	6,691	1,399
Last three months	85	107
Flight hours E195-E2		
Total	65	87
Last three months	19	31
Last flight	6 September 2021	3 September 2021

D.3 Aircraft information

D.3.1 General

Table 8: Aircraft information

Manufacturer	Yaborã Indústria Aeronáutica S.A.
Model	ERJ 190-400 (Embraer 195-E2)
Year of manufacture	2021
Serial number	19020054
Registration	PH-NXD
Certificate of airworthiness	14 May 2021
Airworthiness review certificate (ARC)	3 May 2022 through 13 May 2023
Engine model	Pratt & Whitney Canada Corp. PW1921G (Turbofan)
Maximum takeoff mass (MTOM)	56,700 kg

The aircraft had no deficiencies during the incident flight. According to the loadsheet, the Take Off Weight (TOW) was 47,270 kg and the centre of gravity during takeoff was 22.8% MAC.[138] These values were both within operational limits.

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[138] Mean Aerodynamic Chord; the position of the centre of gravity as percentage of the chord of the wing.

D.3.2 Difference between Embraer models

The Embraer 195-E2 was the most modern and largest model of the Embraer family at the time of the incident. One of the differences between the Embraer 195-E2 and the other variants was that the calculated N1, does not show on ePerf when the performance calculations are made. N1 was not displayed on the EICAS - until the data was entered into the FMS and the engines were started - and did not need to be checked against the ePerf calculated N1. Only the Thrust Mode (takeoff 1, 2 or 3) and the correct value of the assumed temperature have to be checked. Whether enough power is available on the engines can be verified by checking whether the indicated values are met.

D.3.3 Electronic Flight Bag

Crew members are provided with an iPad, that is used as a portable Electronic Flight Bag (EFB). One of the installed applications on the iPad is Embraer's ePerf. ePerf is used for takeoff and landing performance calculations for Embraer aircraft. To ensure ePerf uses the correct database files, crew members have to scan a QR (quick response) code in the cockpit of the specific aircraft variant with a scanner embedded in the ePerf application. The content of ePerf is developed and updated by Embraer; the information for the airport database is provided to the aircraft manufacturer by a third party.

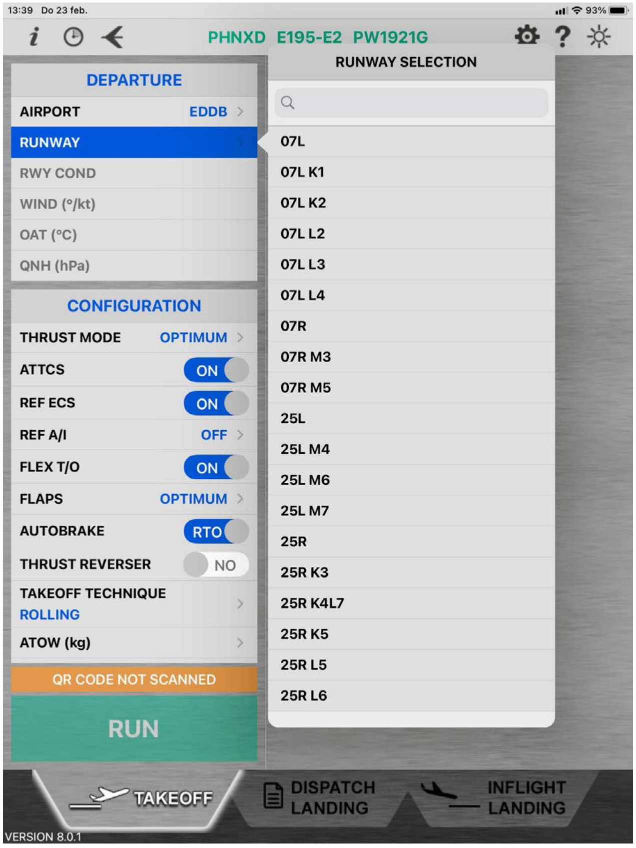
A number of departure and configuration selections (e.g. airport, runway, intersection, weather, aircraft weight and configuration) need to be made in ePerf in order to provide the pilots with a result card. This card presents the optimal takeoff parameters as loadsheet data. Amongst other things, these parameters are: T/O mode, Flaps, V_1, V_R, V_2 and an assumed temperature. These parameters are then manually entered into the FMS by the flight crew.

Intersection selection at Berlin

Using a search box, pilots had to first select the airport, EDDB in this case. This preloaded a dropdown menu on the runway selection search box. The pilot then opened the search box to enter the runway with the corresponding intersection.

Both intersections K and L were presented in ePerf, even though K intersections were not normally used by the operator. The K intersections were situated on the north side of the runway and were not normally used by passenger flights, as the terminal is located on the south side of the airport. The point from which pilots initiate the takeoff, was selected from a list containing all possible runway and intersection combinations. This list was presented in an alphabetical and numerical order. Runway 25R's intersections K5 and L5 were presented consecutively on the dropdown menu list, see Figure 7.

ePerf does not provide a visual representation of the selected runway (runway synoptic) and intersection. According to the manufacturer adding this function to the ePerf was considered, but it was not currently part of the short or mid-term list of improvements that is being considered for this application.



DEPARTURE
AIRPORT EDDB
RUNWAY
RWY COND
WIND (°/kt)
OAT (°C)
QNH (hPa)

CONFIGURATION
THRUST MODE OPTIMUM
ATTCS ON
REF ECS ON
REF A/I OFF
FLEX T/O ON
FLAPS OPTIMUM
AUTOBRAKE RTO
THRUST REVERSER NO
TAKEOFF TECHNIQUE ROLLING
ATOW (kg)

Figure 7: Page of electronic flight bag.

D.3.4 Manufacturer's calculations

The aircraft manufacturer was asked to calculate the Accelerated Stop Distance (ASD) for the aircraft starting from L5 with the settings for a takeoff from K5 under the same circumstances as encountered during the serious incident. The ASD is the distance required to accelerate to V_1 with all engines at takeoff power, experience an engine failure at V_1, and abort the takeoff and bring the airplane to a stop using braking action only.

The calculations of the aircraft manufacturer showed that in case of an aborted takeoff at V_1 (139 kt), the ASD was 2,575 metres.

The calculated N1 for a takeoff from intersection L5:

- with flaps 1: N1 = 77.5%
- with flaps 3: N1 = 74.8%

D.3.5 ePerf calculations

The Dutch Safety Board investigated the outcome of ePerf calculations for takeoff's from L5 and K5 under the same circumstances as encountered during the serious incident. The outcome is shown in Table 9:

Table 9: ePerf calculations

Runway	25R L5	25R K5
Thrust Mode	TO-3	TO-3
OAT (°)	21	21
T_{ASS}	46 °C	58 °C
Flaps	3	1
V_1	120 kt	139
V_R	121 kt	139
V_2	124 kt	142

D.4 Meteorological information

At Berlin Brandenburg Airport, the wind came from the west with a strength between 8 and 9 knots. Visibility was more than 10 kilometres and there were some rain showers in the vicinity. A few cumulonimbus clouds were present between 2,500 and 3,000 feet.[139]

D.5 Aerodrome information

Berlin Brandenburg Airport (EDDB), which is located 18 kilometres south-east of the city centre of Berlin, has two parallel runways, called 07L/25R and 07R/25L. Runway 07L/25R has a length of 3,600 metres and a width of 45 metres. Runway 07R/25L has a length of 4,000 metres and a width of 60 metres.

The aircraft took off from Runway 25R and had lined up via the taxiway towards intersection L5. The flight crew had entered K5 instead of L5 in ePerf. The table below lists the Take Off Run Available (TORA), the takeoff distance available (TODA) and the accelerate stop distance available (ASDA) for a takeoff aligned on Runway 25R via K5 and L5. Runway 25R 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.

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[139] METAR: SA 12/09/2021 15:20 > METAR EDDB 121520Z 28009KT 9999 VCSH FEW025CB 21/15 Q1016 NOSIG=, METAR: SA 12/09/2021 15:50 > METAR EDDB 121550Z 27008KT 9999 FEW030CB 20/16 Q1015 NOSIG=

Runway	Intersection	TORA	TODA	ASDA
25R	K5	3,385	3,445	3,385
25R	L5	2,065	2,125	2,065

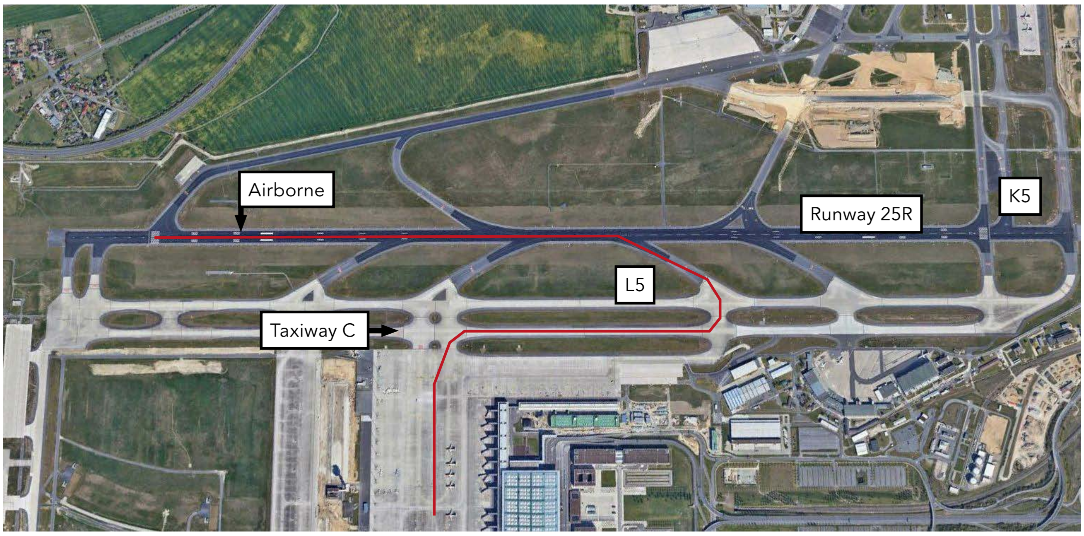

Figure 8: Driven taxi route (red line), Runway 25R and taxiways towards intersections K5 and L5. (Source map: Google Earth)

D.6 Flight recorders

The aircraft was equipped with two digital voice data recorder (DVDR) systems. This system combines the functionalities of a flight data recorder (FDR), cockpit voice recorder (CVR), and datalink recorder (DLR) in a single unit. The DVDRs are capable of recording the last 25 hours of flight data, 120 minutes of cockpit audio, and datalink messages. They are both located in the electronics (avionics) bay of the aircraft, below the cockpit.

The DVDR automatically starts recording audio information after the aircraft has been powered up and it begins recording flight data after the first engine has been started. After power down, audio recording continues for another ten minutes.

Following an incident, the operator can ensure that flight recorders are de-activated immediately after the flight is completed. This can be achieved by pulling the electronic circuit breaker (CB) of DVDR 2, using the CB menu on one of the two Multifunction Control Display Units (MCDU).

The circuit breaker to de-activate DVDR 2 was not pulled after the flight. Since the CVR only records the last 120 minutes of audio information of a flight, the audio recordings surrounding this occurrence were overwritten on the subsequent flight. CVR audio was therefore not available to the Dutch Safety Board for analysis.

The FDR data surrounding the event were available for analysis by the Dutch Safety Board.

The operator reported that their initial flight data analysis revealed the aircraft crossed the departure end of the runway at approximately 100 feet.

D.7 Procedures operator

Reducing engine thrust
In many situations, the aircraft takes off at weights lower than the maximum permissible takeoff weight. In consequence, it is possible to continue complying with performance limitations using a reduced engine thrust adapted to the actual weight.

The Aircraft operator manual[140] stated there are two approved methods to achieve this:

- Reduced Takeoff Thrust (Assumed Temperature)[141]
- Derated Takeoff Thrust (Modes other than TO-1)[142]

Application of reduced takeoff thrust is always at the pilot's discretion and can be cancelled at any time during the takeoff operation by advancing the thrust levers.

Using ePerf
Operations Manual Part A – Basic Operations Manual Amendment 13 states, amongst others, that pilots must use the following procedure under chapter 8.9.7 Performance application (ePerf):

- Calculations shall be conducted independently by each flight crew member.
- Properly crosscheck input and output before data outputs are accepted for use.

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[140] Aircraft Operator Manual, Chapter 2 Limitations, 2-40 Power plant.

[141] For any given outside air temperature (above the flat rated temperature) there is a specific thrust value. If the thrust requirement for a takeoff is known, the associated temperature at which this thrust would be produced can be extracted from the applicable charts. The "assumed" temperature is then entered into the FMS.

[142] A derate selection (Mode TO-2 or TO-3) electronically reduces the rated thrust of the engine to a selectable percentage of the normal flat rated thrust.

APPENDIX E

Legislation and guidelines

E.1 EFB takeoff performance applications

ICAO standards and manuals
The International Civil Aviation Organization (ICAO) Annex 6 provisions on Electronic Flight Bags (EFBs) have been applicable since November 2014. In accordance with the international standards[143], an operator shall:

a. assess the safety risk(s) associated with each EFB function[144];
b. establish and document the procedures for the use of, and training requirements for, the device and each EFB function; and
c. ensure that, in the event of an EFB failure, sufficient information is readily available to the flight crew for the flight to be conducted safely.

When issuing a specific approval for the use of EFBs, the state of the operator shall ensure that[145]:

a. the EFB equipment and its associated installation hardware, including interaction with aeroplane systems if applicable, meet the appropriate airworthiness certification requirements;
b. the operator has assessed the safety risks associated with the operations supported by the EFB function(s);
c. the operator has established requirements for redundancy of the information (if appropriate) contained in and displayed by the EFB function(s);
d. the operator has established and documented procedures for the management of the EFB function(s) including any database it may use; and
e. the operator has established and documented the procedures for the use of, and training requirements for, the EFB and the EFB function(s).

In 2018, ICAO published the second edition of Doc 10020, Manual on Electronic Flight Bags. It contains guidance material on among others the following topics: human factors. crew operating procedures, flight crew training and EFB risk assessment.

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[143] ICAO, Annex 6 to the Convention on International Civil Aviation, Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes, Standard 6.25.2.1 EFB functions.

[144] Guidance on safety risk assessments is contained in the Safety Management Manual (Doc 9859).

[145] ICAO, Annex 6 to the Convention on International Civil Aviation, Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes, Standard 6.25.3 EFB approval.

EU regulation and guidance

The ICAO Annex 6 provisions on electronic flight bags were transposed of into Regulation (EU) No 965/2012 (the Air Operations Regulation) in 2019.[146] The EU regulation, acceptable means of compliance and guidelines on EFB applications are more comprehensive than the ICAO standards and manual.

EU regulation on EFB distinguishes between two types of EFB applications. Aircraft performance calculation applications that perform calculations using software algorithms, such as takeoff performance applications are classified as type B EFB applications.[147, 148] In order to obtain an operational approval from the competent authority for the use of a type B EFB application, the operator shall provide evidence that a risk assessment has been conducted and the associated risks are being appropriately managed and mitigated.[149] The human–machine interfaces (HMI) of the EFB device and the EFB application have been assessed against human factors principles.[150] The HMI assessment is key to identifying acceptable mitigation means, e.g. to establish procedures for reducing the risk of making errors and to control and mitigate the additional workload related to EFB use. The operator should consider amongst others the following aspects:[151]

- The EFB system should provide a consistent and intuitive user interface within and across the various hosted applications and with flight deck avionics applications. This should include but is not limited to data entry methods, colour-coding philosophies, and symbology.
- During critical phases of the flight, information necessary to the pilot should be continuously presented without uncommanded overlays, pop-ups, or pre-emptive messages, except for those indicating the failure or degradation of the current EFB application.
- The system should be designed to minimise the occurrence and effects of flight crew errors and to maximise the identification and resolution of errors.
- The EFB system should provide feedback to the user when a user input is performed.

Specific standards for performance and mass and balance applications have been established in an Acceptable Means of Compliance (AMC)[152], including the following:

- The flight crew procedures should ensure that:
  - calculations are performed independently by each flight crew member before data outputs are accepted for use;
  - a formal cross-check is made before data outputs are accepted for use; such cross-checks should utilise the independent calculations, together with the output of the same data from other sources on the aircraft;

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[146] Annex IV (Part-CAT), mainly CAT.GEN.141 on the use of electronic flight bags is applicable for commercial passenger transport.

[147] AMC CAT.GEN.MPA.141(b).

[148] CAT.GEN.141 states that an operator shall not use a type B EFB application unless it is approved in accordance with Subpart M of Annex V (Part-SPA), mainly SPA.EFB.100 on the use of electronic flight bags – operational approval.

[149] SPA.EFB.100(b)(1).

[150] SPA.EFB.100(b)(2).

[151] AMC1 SPA.EFB.100(b)(2) human–machine interface assessment and human factors considerations.

[152] AMC5 SPA.EFB.100(b)(3) performance and mass and balance applications.

  - a gross-error check is performed before data outputs are accepted for use; such gross-error checks may use either a 'rule of thumb' or the output of the same data from other sources on the aircraft.
- training should emphasise the importance of executing all takeoff and landing performance or mass and balance calculations in accordance with the SOPs to assure fully independent calculations.
- due to optimisations included at various levels in performance applications, flight crew members may be confronted with new procedures and different aircraft behaviour (e.g. the use of multiple flap settings for takeoff). The training should be designed and provided accordingly.
- Input and output data (i.e. results) shall be clearly separated from each other. All the information necessary for a given calculation task should be presented together or be easily accessible.

  Inputs:
  - The application should allow users to clearly distinguish user entries from default values or entries imported from other aircraft systems.
  - Performance applications should enable the flight crew to check whether a certain obstacle is included in the performance calculations and/or to include new or revised obstacle information in the performance calculations.

  Outputs:
  - All critical assumptions for performance calculations (e.g. the use of thrust reversers, full or reduced thrust/power rating) should be clearly displayed. The assumptions made about any calculation should be at least as clear to the flight crew members as similar information would be on a tabular chart.
  - All output data should be available in numbers.
  - The application should indicate when a set of entries results in an unachievable operation (for instance, a negative stopping margin) with a specific message or colour scheme.
  - In order to allow a smooth workflow and to prevent data entry errors, the layout of the calculation outputs should be consistent with the data entry interface of the aircraft applications in which the calculation outputs are used (e.g. flight management systems).

EASA Safety Information Bulletin on the use of erroneous parameters at takeoff

In September 2021, EASA published a revised version of the Safety Information Bulletin on the use of erroneous parameters at takeoff.[153] In this document, EASA gives three recommendations:

1. Management system: EASA recommends that operators consider the risk related to the use of erroneous takeoff parameters. A dedicated safety risk analysis and assessment should be conducted to evaluate, if the procedures in place are adequate, or if additional/alternative mitigations should be defined. Note: The effects of workload, distraction, time pressure and fatigue should be considered, when studying the scenarios above.

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[153] EASA, SIB 2016-02R1, *Use of Erroneous Parameters at Takeoff*, September 2021.

2. Flight crew training: EASA recommends that operators emphasise, during initial and recurrent flight crew training, the following:
    - Prevention: consider the issue in the context of Crew Resource Management training, in particular to raise flight crew awareness on the following non-exhaustive topics: automation overreliance and the need to conduct appropriate consistency checks, management of last-minute changes, the impact of distraction.
    - Situational awareness during the takeoff roll to ensure detection of erroneous takeoff parameters (e.g. low acceleration, sluggish and/or nose heavy rotation, rough idea of the runway position where V1 or Vr should be passed).
    - Raise/ascertain flight crew awareness on possible recovery measures (e.g. abort takeoff, apply takeoff/go-around switch).
3. FDM: EASA recommends operators to implement specific FDM event algorithms (or FDM measurement algorithms) that are relevant to the monitoring of takeoff performance in their FDM programme and to analyse events and adverse trends detected by these algorithms. Some suggestions are provided in this SIB.

EASA website on Erroneous Take-Off Performance Data

The EASA's webpage on Erroneous Take-Off Performance Data[154] provides background information about erroneous takeoff. It also contains tips for safety managers in the form of a list of questions a safety manager should ask his- or herself regarding erroneous takeoff data, including:

- Is erroneous takeoff data a risk to your organisation?
- If it could be a safety issue, is it captured in the SMS?
- Does the organisation actively encourage the reporting of occurrences involving this issue, and are these occurrences thoroughly investigated to identify possible organisational and human factors?
- Are there alerts within the Flight Data Monitoring (FDM) system and has the organisation identified performance indicators in the reporting system and are they regularly monitored?
- Are relevant and robust procedures in place to mitigate against the risk of erroneous takeoff data?
- Are open discussions about the risk of erroneous takeoff data encouraged by the organisation?

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[154] EASA webpage on Erroneous Take-Off Performance Data, consulted 25-11-2022, https://www.easa.europa.eu/en/erroneous-take-performance-data.

E.2 Safety management

The SMS of a service provider such as a certified operator shall be established in accordance with the following framework elements according to international standards[155]:

1. Safety policy and objectives
    1.1 Management commitment
    1.2 Safety accountability and responsibilities
    1.3 Appointment of key safety personnel
    1.4 Coordination of emergency response planning
    1.5 SMS documentation
2. Safety risk management
    2.1 Hazard identification
    2.2 Safety risk assessment and mitigation
3. Safety assurance
    3.1 Safety performance monitoring and measurement
    3.2 The management of change
    3.3 Continuous improvement of the SMS
4. Safety promotion
    4.1 Training and education
    4.2 Safety communication

The Safety Management Manual[156] provides guidance on the implementation of the framework for an SMS.

EU regulation requires operators to establish, implement and maintain a management system that includes[157]:

1. clearly defined lines of responsibility and accountability throughout the operator, including a direct safety accountability of the accountable manager;
2. a description of the overall philosophies and principles of the operator with regard to safety, referred to as the safety policy;
3. the identification of aviation safety hazards entailed by the activities of the operator, their evaluation and the management of associated risks, including taking actions to mitigate the risk and verify their effectiveness;
4. maintaining personnel trained and competent to perform their tasks;
5. documentation of all management system key processes, including a process for making personnel aware of their responsibilities and the procedure for amending this documentation;
6. a function to monitor compliance of the operator with the relevant requirements. Compliance monitoring shall include a feedback system of findings to the accountable manager to ensure effective implementation of corrective actions as necessary; and
7. any additional requirements that are prescribed in the relevant Subparts of this Annex or other applicable Annexes.

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[155] ICAO, Annex 19 to the Convention on International Civil Aviation, Safety Management, Standard 4.1.1 and Appendix 2.

[156] ICAO, Doc 9859, *Safety Management Manual*, Fourth Edition, 2018.

[157] OR.GEN.200 (a) (1) Safety Management System.

E.3 Flight data monitoring

Operators are required to establish a flight data monitoring (FDM) programme, as one of the minimum conditions to obtain and maintain an air operator certificate (AOC), as of October 2012.[158] The FDM programme shall be non-punitive and contain adequate safeguards to protect the source(s) of the data. An FDM programme could be defined as the routine collection and analysis of flight data to develop objective and predictive information for advancing safety.

EASA recommends that commercial air transport operators invest in an FDM programme and/or make their FDM programme stronger, because a well implemented FDM programme will allow an operator to[159]:

- detect trends in operation that are adversely affecting safety, even before they result in a serious incident;
- reliably capture safety-relevant events during operation, even if they were not reported by the flight crew;
- build and maintain a complete and accurate picture of your safety risks, which is essential for an effective safety management system (SMS);
- verify the effectiveness of corrective actions (corrective training, change to operating procedures, equipment retrofit, etc).

EASA is running, in partnership with the industry, the European Operators FDM forum (EOFDM). Forum members collaboratively produced guidance material for the implementation of FDM precursors based on industry good practices and recommendations produced by the EOFDM.[160] It describes the precursors for the four main risk areas, i.e. runway excursion (RE), loss of control in-flight (LOC-I), controlled flight into terrain (CFIT) and mid-air collision (MAC). The following precursors identified to monitor takeoff performance:

- RE01 — Incorrect Performance Calculation
- RE03 — Monitoring the Centre-of-Gravity (CG) Position
- RE04 — Reduced Elevator Authority
- RE05 — Slow Acceleration
- RE07 — Late Rotation
- RE08 — Slow Rotation
- RE15 — Runway Remaining at Lift-off
- RE33 — Wrong runway or wrong runway entry point used
- LOC08 — Centre of gravity (CG) out of limits
- LOC10 — Incorrect Performance Calculation
- LOC11 — Overweight Takeoff

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[158] Annex III (Part-ORO), ORO.AOC.130 on Flight data monitoring – aeroplanes.

[159] EASA webpage on Flight data monitoring, consulted on 6 December 2022: https://www.easa.europa.eu/community/topics/flight-data-monitoring.

[160] EASA, *Guidance for the implementation of flight data monitoring precursors*; Good Practices document, September 2020.

EASA performed a survey in in the period October 2020 to February 2021 in order to assess the level of implementation of these precursors and to identify improvements. The survey shows that operators were using these precursor's. They did not implement all precursors, for various reasons, i.e. technical reasons, the precursors are still under development, the precursors (partly) overlap and some precursors can serve as an alternative for other precursors. Feedback from the survey resulted in improvements which will be implemented in the next version of the guidance material.

The survey suggests that following precursors could be implemented by the majority of operators[161]:

- RE01 — Incorrect Performance Calculation (Indirect indications e.g. change of thrust setting during takeoff roll or excessive difference between Flex. Temperature and Outside Air temperature at takeoff)
- RE05 — Slow Acceleration (during the takeoff roll)
- RE07 — Late Rotation (e.g. start of rotation after the rotation speed - VR)
- RE08 — Slow Rotation - (e.g. excessive duration of the rotation to take off or too low pitch rate during the rotation to take off)
- LOC08 — CG out of limits (e.g. CG position not consistent with longitudinal trim setting)

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[161] EASA, SIB 2016-02R1, *Use of Erroneous Parameters at Takeoff*, September 2021.

APPENDIX F

Investigations by accident investigation boards

F.1 Overview

In the period 2013-2021, seven accident investigation boards investigated 23 occurrences involving the use of erroneous takeoff data resulting in insufficient thrust at takeoff (see Table 10).

The majority of these occurrences was caused by errors in the data entry for calculating the takeoff parameters. Eight of these occurrences concerned a selection error in the EFB in which the wrong runway or intersection was selected as was the case in the present incident. For this investigation, relevant information of these eight occurrences is given in the next sections.

Table 10: Investigations on occurrences where the aircraft took off with insufficient thrust due to erroneous takeoff data, which were carried out by accident investigation boards.

Date	Aircraft type	Airport	Investigation board	Type of error
21-6-2013	Embraer 190	Perth	ATSB[162]	taxied to wrong intersection
1-10-2013	A320-214	Porto	STSB[163]	not reprogramming FMGS
14-10-2013	B737-800	Darwin	ATSB	wrong calculation entered in FMC
6-10-2014	A320-214	Basel Mulhouse	STSB	wrong input FMC
25-6-2015	A319-111	Belfast	AAIB[164]	software anomaly
16-7-2015	A320-214	London Luton	AAIB	wrong input FMGC[165]
16-9-2015	B777-300	Miami	QCAA[166]	departed from intersection instead of the full runway
16-10-2015	A319-111	Lisbon	AAIB	selection of wrong runway
3-12-2015	B737-800	Lisbon	DSB	selection of wrong runway
14-4-2016	A319-111	Malaga	AAIB	software anomaly
9-5-2016	A319-111	Lille	AAIB	selection of wrong intersection
30-8-2016	B777-300	Heathrow	India AAIB[167]	selection of wrong intersection
21-1-2017	A320-214	Cairns	ATSB	taxied to wrong intersection
21-7-2017	B737-86J	Belfast	AAIB	wrong input FMC
28-3-2018	B787-9	London Gatwick	AAIB	did not identify the beginning of the runway
10-6-2018	B737-800	Schiphol	DSB	old parameters
24-4-2019	A320-214	Lisbon	AAIB	selection of wrong intersection
7-5-2019	A320-214	Lisbon	AAIB	selection of wrong intersection
29-8-2019	A319-111	Nice	AAIB	selection of wrong intersection
16-9-2019	A320-214	Lisbon	AAIB	selection of wrong intersection
2-10-2019	A319-131	Heathrow	AAIB	old parameters
24-11-2019	A321-231	Glasgow	AAIB	wrong input FMC
3-3-2021	B737-800	Lisbon	GPIAAF[168]	entered wrong intersection in LINTOP

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[162] Australian Transport Safety Bureau.
[163] Swiss Transportation Safety Investigation Board.
[164] Air Accidents Investigation Branch, United Kingdom.
[165] Flight Management Guidance Computer.
[166] Qatar Civil Aviation Authority.
[167] Aircraft Accident Investigation Bureau.
[168] Portuguese Safety Investigation Authority.

F.2 Nice 2019[169]

385 metres shorter

During their pre-flight preparation, the flight crew chose to calculate the takeoff performance for Intersection B3, the most-limiting viable runway intersection on Runway 04R at Nice Côte d'Azur Airport (NCE). As the crew approached the runway, they were offered a departure from Intersection A3. Believing that they had the more-limiting B3 performance figures entered into the flight management computer, the flight crew accepted this clearance.

A takeoff performance calculation error was detected after flight by the operator's flight data monitoring (FDM) programme. Cross-checking FDM information with electronic flight bag (EFB) calculations indicated that both pilots had inadvertently selected the Q3 intersection, rather than B3, in their performance software. The mis-selection was not detected during an initial data validation '*departure distance check*' and cross-checking EFB calculation outputs did not trap the error.

The flight crew considered that the performance calculation software's user-interface was a factor in the intersection selection error being made and missed. According to the commander, the EFB data entry is clumsy and often requires re-entering especially runway details and, at NCE, B3 and Q3 appear next to each other and are easy to mis-select.

F.3 Three occurrences in Lisbon 2019[170]

1,395 metres shorter

Three flight crews of the same operator experienced similar incidents within six months. During pre-flight preparations, both pilots completed a takeoff performance calculation for a takeoff from Runway 21 at Lisbon Airport. They choose to perform a takeoff performance calculation for the shortest runway length available (from the intersection with Taxiway S1), but had, in fact, both used the runway full length (from intersection S4). This error was not detected during cross-check. They were offered a takeoff from the intersection with Taxiway U5, which they accepted believing that they had entered the more-limiting S1 performance figures entered into the flight management computer. During the takeoff roll, the flight crew realised there was something wrong and they reported the incident to the operator.

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[169] AAIB Bulletin: 4/2020, Airbus A319-111, G-EZBI.

[170] AAIB Bulletin: 2/2020, Airbus A320-214, G-EZTD.
AAIB Bulletin: 9/2020, Airbus A320-214, G-EZWE.

In all three cases the pilots were confused by the EFB intersection selections as they did not use the actual taxiway names. Also, there were two points on the runway which intersect Taxiway S (1 and 4) both of which might have been thought by the crew to be in the EFB as PSNSTMP, as the taxiway numbers are not used in the nomenclature. As a result of these incidents, the airport operator renamed part of Taxiway S to have only one intersection on Runway 21 with the letter S.

In all three cases, both pilots independently performed the performance calculations and both made the same error. Cross-checking EFB outputs did not trap the error as they made the same error. The procedures required the crew to crosscheck the takeoff distance shown in the EFB against the equivalent distance shown on the aerodrome ground chart, but the pilots did not notice the error when performing this crosscheck.

The aircraft operator moved onto a newer software version for performance calculations in December 2019 which gives a pictorial representation of the runway, see Figure 9.

LPPT/LIS	LISBOA
RWY	21PSNU
WIND	000°/0/G0 HD0 kt
OAT	10 °C (ISA -4)
QNH	1010 hPa
RWY COND	Dry
A-ICE	Off
TOW	65.0 T
T.O. THRUST	FLEX (STD)
CLB THRUST	CL
CONF	OPT CONF (STD)
AIR COND	On (STD)

21PSNU

CONF	2
THRUST	FLEX 65 °C
V1	134 kt
VR	137 kt
V2	141 kt
LIMITATION	TOW - TOW
ENG OUT ACC	1846 ft
Green dot	215 kt
REV FOR COMPUTATION	ALL REVERSERS INOPERATIVE
MTOW (perf)	73.2 T

STD. At 1900 turn RIGHT to EKMAR HP. EKMAR HP: Inbound 044°, LEFT turn.

Figure 9: New software calculation display for Runway 21 Position U of Lisbon Airport. (Source: AAIB)

F.4 Lille 2016[171]

560 m shorter

During pre-flight preparation, performance figures were calculated for a departure from Lille Airport using the full length of Runway 08. The subsequent takeoff was from Intersection Tango 5, from which less than the full length was available. The error was not revealed by the crew's standard cross-check because they misread the runway length. After takeoff the crew remarked to each other that the end of the runway seemed to be closer than normal as the aircraft became airborne.

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[171] AAIB Bulletin: 9/2020, Airbus A320-214, G-EZWE.

F.5 London Heathrow 2016[172]

1069 m shorter
The aircraft took off from Intersection S4W on Runway 27L using performance information (power setting, flap setting and takeoff speeds) appropriate for a takeoff from intersection N1 (full length).

The commander calculated aircraft takeoff performance from the first four intersections of Runway 27L (using the default OPT output corresponding to the full length), whereas the first officer calculated performance (correctly) for a takeoff from Intersection S4W. Even though there was no requirement to read aloud the runway and intersection used by the OPT for the performance calculation, the discrepancy was nevertheless identified during the post-calculation crosscheck of OPT output. This provided an opportunity for the crew to agree the correct intersection but the first officer changed her OPT entry to match that of the commander and the opportunity was lost probably due to the fact that Commander was much senior to the first officer.

F.6 Two occurrences in Lisbon 2015[173]

1,120 m shorter and wrong wind direction
Two flight crews of two different operators experienced incidents in which they selected the wrong runway at Lisbon Airport. Performance figures for takeoff from Runway 03, Position 3 (intersection with Taxiway U5) had been used for departure instead of figures for Runway 21, Position 3 (intersection with Taxiway N2).

In the October 2015 incident, the crew noted during pre-flight preparation that while Runway 21 was in use it was possible that Runway 03 could be in use as the wind was light and variable. Prior to pushback, the first officer entered the weather information and Runway 03 into the Electronic Flight Bag (EFB), despite Runway 21 being designated on the ATIS. The commander then calculated the takeoff performance for a departure from Runway 03 at Intersection November Two. Neither noticed that the runway in the EFB differed from the runway in use. When entering the data in the Flight Management Guidance Computer (FMGC), the Engine Out Standard Instrument Departure in the FMGC was not compared to the EFBs and the data entry error was not noticed. The crew considered the takeoff normal until the aircraft approached V_1 when they noticed there was limited runway remaining.

In the December 2015 incident, the pilots individually used the EFB performance module on their respective EFBs for the takeoff performance calculation. Both pilots selected inadvertently Position 3 of Runway 03 instead of Position 3 of Runway 21. However, they were both under the impression that they had selected Position 3 of Runway 21.

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[172] India AAIB, Final Investigation Report on Serious Incident to M/s Jet Airways aircraft VT-JEK at London Heathrow Airport on 30.08.2016.

[173] AAIB Bulletin: 5/2016, Airbus A319-111, G-EZIV.
Dutch Safety Board, Insufficient thrust setting for take-off, March 2018.

According the procedures, the crosscheck of the performance calculation was the comparison of the outcome of the two independent performance calculations. the existing crosscheck on the output parameters was not adequate to detect this type of input error. Towards the end of the takeoff roll (just prior to V_1) both pilots realised that the takeoff roll was longer than expected.

APPENDIX G

Safety management operator

G.1 Safety organisation

KLM and KLC have a shared safety and compliance organisation (SCO) since 1 February 2021. The SCO monitors compliance and safety performance and conducts audits and investigations, whereas the divisions of each of the operators design and implement mitigating measures. The SCO has a business partner at each division, who is a liaison between the division and the SCO. Both operators have their own safety management system, which are similar because they share the processes at the SCO. This appendix describes only the safety management of KLC (the operator), because the investigation focusses on KLC and the SCO.

G.2 Safety policy

The operator's safety vision states: The operator will have an industry-leading risk-based and performance-based safety management system so that risk-based decisions can be taken at all levels within the company. Safety includes all aspects of operational, occupational and environmental safety, security and fatigue. The accompanying strategic safety objectives are:

- To change current Safety and Compliance programs into a Safety Risk Management System of processes and procedures;
- To maintain and improve a Just and Learning Safety Culture;
- To ensure Continuous Conformity and Compliance;
- To manage safety based on safety performance indicators.

Safety goals

The operator set a limited number of safety goals each year. Safety goals are specific and measurable, related to specific areas or safety initiatives and are used to measure safety performance. Safety goals are monitored and discussed on a quarterly basis in the Safety Action Group (SAG).[174]

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[174] See Appendix G.3, Governance structure.

G.3 Safety management system

The safety management activities of the operator take place under the umbrella of the Integrated Safety Management System (ISMS) and are described in the OM Part A – Integrated Safety Management Manual (ISMM).[175,176] The objective of the ISMS is to continuously improve safety by collecting and analysing data, identifying hazards, and continuously analysing and assessing safety risks.

The ISMS is an integrated governance of various safety aspects in the operator's organisation, such as operational safety, occupational safety, operational security, environmental safety, conformity & compliance management and fatigue risk management system. The approved training organisation (ATO) and the Continuing Airworthiness Management Organisation (CAMO) management systems are included in the ISMS.

The main activities within the ISMS are:
1. Safety risk management, see Appendix G.4;
2. Safety promotion, see Appendix G.5;
3. Documentation control[177];
4. Compliance monitoring.[178]

Governance structure
The ISMS governance structure includes the accountable manager, a safety review board (SRB), a corporate safety action group (SAG) and local SAGs for the various departments.

The SRB is a strategic meeting integrated in the operator's management team meeting and is chaired by the accountable manager. The SRB sets strategic safety directives, including safety policy and strategic safety objectives. The SRB allocates safety resources, monitors safety and compliance performance against safety policy and objectives and can require changes of the ISMS.

The SAGs are responsible for designing and implementing mitigating measures. The implementation of safety strategies developed by the SRB is coordinated throughout the operator by means of SAGs. The SAGs are part of the existing management structure. For example, the management team of the flight operations division has a meeting every two weeks (MT flight) in which the division's SAG meeting is integrated. The director safety and compliance, representatives of the divisions Planning and Cabin Crew and a safety officer join the division's SAG meeting. Safety officers, who are accessible to all employees, are appointed in each division. Safety officers have a liaison role between

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[175] Internal document operator, *OM Part A – Integrated Safety Management Manual*, 4 November 2021.

[176] The operator states that the Integrated Safety Management Manual (ISMM) is in compliance with relevant national and international legislation (among with EASA Air Operations). The ISMS is also used to incorporate the requirements of industry standards, i.e. IATA Operational Safety Audit. Furthermore, the ISMS encompasses all safety management system components and elements as given in ICAO's Safety Management Manual.

[177] Processes that ensure positive control of content, revision, publishing, distribution, availability and retention of documents.

[178] The Safety Services Organisation monitors compliance through the compliance monitoring programme by audits and inspections.

the SCO and their work in the line organisation. The safety officer of the flight operations division is the Business Pilot Safety. Apart from the formal SAG of the flight operations division, safety issues are also discussed in the Discuss And Decide (DAD), an informal bi-weekly MT meeting of the division.

Qpulse and dashboards
Qpulse is a computer application that is used as a knowledge library. It contains all audits, findings with follow-up, reports and investigations with follow-up. Furthermore, Qpulse keeps track of open actions with a target dates.

Dashboards have been developed for overview. The SAGs use dashboards to see at a glance the status of the mitigating measures, whether they are complete, at what stage they are and when validation takes place. The dashboards get most of the information from Qpulse.

G.4 Safety risk management

Continuous process
Safety risk management can be seen as a continuous loop (re)design, (adjusting) approach and follow-up process. Conducting a safety investigation results in new knowledge (information about safety issues), which may lead to (re)design. The process is designed and managed in order to ensure a continuous learning loop. Information collected during the process is stored in Q-pulse.

Events and concerns
The safety risk management process consists of several phases. The first phase is identification. This exists of collecting and pre-analysing events (for instance an air safety report or a specific data trend), or information about concerns among employees collected by safety officers (see Figure 10, phase 1). The safety and compliance organisation (SCO) collects air safety reports, fatigue reports and data, which they analyse. Concerns can be raised by both the SCO and the division, for instance Flight Operations.

Safety reports are pre-classified by a safety officer in cooperation with an event analyst (of the SCO). For medium and high risk types of events, a risk analyst, in consultation with the safety officer, is responsible for collecting additional information and formulating a concern based on the incoming event(s). Incidents are not considered in isolation. For each of those events, it is checked which investigations, related to the same type of event, have already been carried out, what has been found and which mitigating measures have been taken. A new investigation is not always necessary. When there is an incident, an assessment is made as to why previous mitigations resulting from similar incidents have not worked. The event assessment form (EAF) is used for this.

Prioritisation of concerns (see Figure 10, phase 2) is performed by the Risk Analysis Meeting (RAM) and Safety Action Group (SAG). The prioritisation process:

- Classifies the event based risk of all reported events by the application of the Event Risk Classification (ERC) procedure and the use of the ERC Matrix;
- Assesses the potential to learn from events by the application of the EAF;
- Determines the necessity to inform investigative authorities;
- Results in an overview of RAM and SAG safety concerns that would qualify for analysis (safety investigation);
- May request a safety investigation by the SCO.

Based on the list of safety concerns, the SCO determines monthly which investigations are started. When an investigation is started, the safety concern disappears from the concern list and the outcome of the investigation is a number of analysed risks.

The RAM of the flight operations division is a weekly meeting in which all ASRs are discussed. The SCO sends between 200 and 300 anonymised ASRs to the flight operations division on a weekly basis. The risk of each reported event is classified and may lead to a concern. The division may decide to mitigate a particular risk regardless of the SCO starts an investigation or not. In that case, the mitigation actions are first discussed in the DAD and formalised in the SAG, where SCO representatives are present.

Safety investigation

Analysis (see Figure 10, phase 3) is the actual safety investigation, which is called Safety Issue Risk Analysis (SIRA). The oper*ator's SCO has three types of safety investigations it can perform*:

1. Reactive SIRA: incident investigation;
2. Proactive SIRA: investigation based on trends or safety concerns. For operational safety, this means an investigation into several similar incidents;
3. Predictive SIRA: safety investigation before a change is implemented in order to determine whether mitigating measures are needed.

All types of SIRA's and their follow-up go through the same process.

After the decision for a SIRA is taken, the scope is determined, including research question(s) and the SAG(s) of the involved divisions are notified. The suitable choice of the method of gathering data and information is at the discretion of the risk analyst or investigator. According to the work instructions of the SCO, the following options might be considered: brainstorm, interviews, observation, Flight Data analysis, literature study, testing (e.g. mechanical or laboratory testing), simulation, experimenting, prototyping. The risk analyst or investigator analyses the data in order to investigate the system in which people work. Individual behaviour of people is not investigated because this knowledge does not attribute to improvement of the organisation. When a critical interaction in the system or a threat is identified, a safety issue is formulated. A risk analysis of the identified safety issues is performed by means of the operator's risk matrix based on the impact of the worst credible accident scenario and the likelihood of the scenario.

The quality check of the investigation is a review of the SIRA report by another risk analyst or investigator. The SIRA process is checked by the Process Manager Continuous Safety Oversight who approves the draft report. The report is finalised and a briefing will be organised before assessment in the SAG.

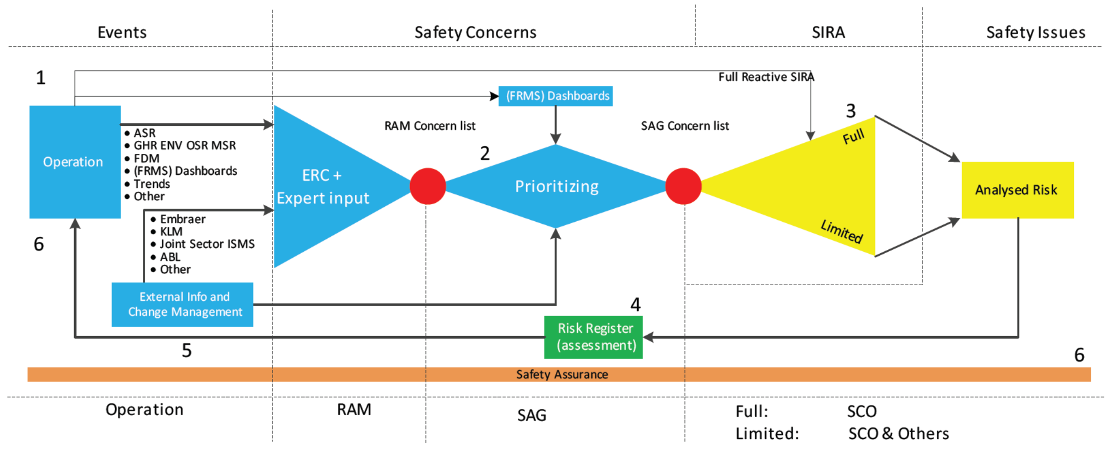

Figure 10: The Safety Risk Management process consists of six phases: 1. Identification; 2. Prioritisation; 3. Analysis; 4. Assessment; 5. Risk mitigation; 6. Safety assurance. (Source: Operator's Integrated Safety Management Manual)

(Re)design

The output of a SIRA consists of analysed risks, which are called safety issues. The responsibility for risk mitigation lies with the division(s). SCO has a controlling and supervisory role in the mitigation process.

An analysed risks resulting from a SIRA will be assessed on the tolerability in the SAG (see Figure 10, phase 4). An analysed risk that is checked for "acceptable" or "not acceptable" results in an assessed risk. Each decision and its ownership is recorded in the risk register. When risks are assessed to be "not acceptable", (changes to) mitigating measures should be proposed (mitigation action plan) in order to reduce the level of safety risk to an acceptable level. Participants of the concerning SAG meeting brainstorm and discuss possible mitigation measures. Relevant experts are invited for the meeting. The SAG decides on which mitigating measures should be proposed.

A high risk may be temporarily accepted when measures cannot be introduced in the short term. A mitigation action plan should be filed within two weeks. The mitigation action plan and also if no mitigating measures are proposed (if the risk is accepted) is assessed by the SCO on effectiveness and whether new risks may be introduced. It is also recorded in the risk register. Open and new analysed risks are monitored in dashboards.

(Adjusting) approach

(Adjusting) approach is implementation of the mitigation action plan (see Figure 10, phase 5) by the division(s). Mitigations must be implemented within three months after assessment in the SAG. If this fails, the involved division(s) have(has) to request an extension.

Follow-up
The effectiveness of a risk mitigations after implementation is validated by means of a process called safety validation. Safety validation is part of operator's Safety Assurance (see Figure 10, phase 6) and executed by the SCO. During validation it is checked whether the residual safety risk reached an acceptable level as was defined during the mitigation action plan (phase 5). Validation of the effectiveness of mitigations is done by:

- A safety review on the deployment of a change as a result of a SIRA;
- (Safety) audits on recently implemented mitigations;
- Trend monitoring on specified indicators related to the mitigation (e.g. data analysis on flight data, technical data, safety reports and training data). During validation, a safety dashboard can be used to check specific parameters continuously.

The validation period depends on what is being validated. After validation, the SCO determines the residual risk and reports it to the SAG. The SAG then determines whether they accept the residual risk. If not, there is an analysed risk where a mitigation action plan needs to be made and thus the cycle starts again. Both residual risks and analysed risks are recorded in the Risk Register.

Evaluation of the process
The SRB monitors the performance of the Safety Risk Management Process as a part of safety assurance (see Figure 10, phase 6). The Integrated Safety Management Dashboard is used for that purpose and contains Safety Performance Indicators, such as the number of received ASRs per 1,000 flights with risk classification medium and up, SIRAs (including progress), audits, analysed risks.

Another type of process evaluation is an evaluation carried out by an external party, for instance a safety management diagnostic.

Within the SCO, the approach of SIRAs (team composition, scope, methods) has been discussed in order to improve the approach.

G.5 Safety promotion

According to the ISMM, safety promotion follows implementation of measures. It involves training, education and communication. The operator's objectives of safety promotion are:

- Improve the safety culture and safety performance;
- Provide information on safety issues, safety metrics, specific threats and barriers;
- Raise awareness of initiatives to address known safety issues and anticipate new ones;
- Improve reporting to let every employee contribute to the corporate safety knowledge base;
- Provide employees with the necessary knowledge and skills to work safely and to address their responsibilities.

Safety culture

The ISSM shows that the operator attaches importance to open communication between employees. "*In order to improve our overall safety performance, open and timely written and oral communication between all parties concerned is crucial. Such communication enhances safety, lifts morale, and improves knowledge, awareness, productivity, efficiency, and profitability. Safety communication is not limited to specific safety magazines, but is also applicable, although not limited, to every communication method such as for example operational briefings, meetings, training sessions, manuals, procedures or feedback to employees. All personnel shall be aware of the safety management activities as appropriate for their safety responsibilities.*" The operator's ISMM states that the operator will ensure that all relevant personnel is trained to ensure adequate knowledge about safety reporting, hazard identification, fatigue risk management and risk management skills.

The operator describes its culture as a Just Culture, which means every employee is free and willing to report any possible unsafe situation, incident or accident and that no action will be taken against anyone reporting or involved with a safety occurrence or hazard, unless gross negligence or a deliberate or willful disregard of regulations or procedures is established. The ISMM contains a Just Culture decision tool and decision tool process in order to protect employees involved in occurrences and accidents. The interviewed employees of the operator confirmed that they felt free to speak up or to report safety related occurrences.

The pilots work for the division Flight Operations. Management of this division emphasises the importance of an open culture, such that each employee feels invited to speak up. Employees of this division who were interviewed during this investigation confirm the open culture and the good working atmosphere. They find it difficult to explain what contributes to the open culture. Some aspects that are mentioned are:

- The operator is relatively small;
- Short lines of communication within the organisation, for example through a WhatsApp group for Embraer captains. Many employees have multiple functions (pilot and trainer, pilot and safety officer, etc.);
- Most employees, including the management, are in the same age-group;
- The management communicates about the importance of reporting. If there is a downward trend in the number of reports, they let the pilots know how important it is to report mistakes or errors. If they see an upward trend in the number of reports, they compliment the pilots.

Means of communication

The operator communicates to pilots about safety to ensure personnel maintain an awareness of the Integrated Safety Management System, the fatigue risk management system and current operational safety issues. Media used are newsletters, the operator's news app, online flight crew meetings, verbal communication highlighting examples in training and simulator exercises. There are no meetings where all pilots are present.

DUTCH
SAFETY BOARD

Visiting address
Lange Voorhout 9
2514 EA The Hague
The Netherlands
T +31 (0) 70 333 70 00

Postal address
PO Box 95404
2509 CK The Hague
The Netherlands

www.safetyboard.nl