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SAFETY BOARD

Touchdown before threshold

Risks associated with a large aircraft landing on a short runway

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The Hague, 18 July 2024

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The Dutch Safety Board

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

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SUMMARY

On 12 January 2023, an Airbus A330-300, registered N802NW, encountered a complicated landing scenario at Amsterdam Airport Schiphol (EHAM). The aircraft, carrying 220 passengers, one captain, two first officers, and 10 flight attendants, faced a multitude of technical, environmental, and operational factors. The flight, which departed from Detroit Metropolitan Wayne County Airport (KDTW) on 11 January 2023 at 18.51 local time, ended up with the rear wheels of the main landing gear touching down on the grass 11 metres before the threshold of Runway 22 at 07.52 local time. The landing was executed under conditions of strong gale-force winds, with severe gusts, a light drizzle, and reduced visibility of 5,000 metres, one hour before sunrise.

Incident Overview
The Airbus A330, equipped with autopilot (AP) and autothrust (A/THR), followed a stabilized approach towards the Runway 22 touchdown zone, in adherence to the Instrument Landing System (ILS) glideslope. As the aircraft descended below the clouds, the pilots observed the Precision Approach Path Indicator (PAPI), which signalled an accurate trajectory towards the touchdown zone. Despite Runway 22's sufficient length of 2,020 metres for an A330-300 landing, the flight crew perceived the runway length as short. This influenced their approach strategy. Additionally, the reduced threshold clearance for this type of aircraft was a challenge that the flight crew did not foresee.

Key Factors Leading to the Incident
Manual Control and Trajectory Alteration: The captain manually controlled the aircraft's flight path after disengaging the autopilot at 240 ft radio altitude, allowing a descent below the ILS glide slope and PAPI glide path. This led to compromised safety margins intended to prevent undershoots.

Flight Crew's Preoccupation with Runway Length: The crew focused on speed management more than maintaining the glide path due to concerns about a potential overrun. This focus was further intensified by their limited experience on the Airbus A330 with short runways and their understanding of the Ground Speed Mini function of the A/THR.

Environmental Challenges: The aircraft encountered a wind gust and downdraft at approximately 60 ft above ground level, altering its trajectory and leading to an early touchdown before the runway threshold.

ILS and PAPI System Limitations: The ILS and PAPI system on Runway 22, designed for smaller aircraft, did not meet the International Civil Aviation Organisation (ICAO) and European Union Aviation Safety Agency (EASA) criteria for a minimum threshold crossing height for the A330-300's main landing gear, contributing to the reduced safety margin.

Human Factors and Operator's Risk Management

The crew's collective judgment was shaped by their perception of the risks associated with a runway overrun, which overshadowed the risk of an undershoot. This may have been further influenced by visual illusions, common during an approach under their circumstances.

Additionally, ambiguities in the operator's Standard Operating Procedures (SOPs) and a limited specific training for landing on short runways like Runway 22 led to deviations from intended procedures. Fatigue factors, analysed in Appendix F, suggest the captain and both first officers may have been affected. This may have impacted their cognitive functions and decision-making during the critical phases of flight, despite the operator's comprehensive fatigue risk management system.

The operator's risk management approach, including the provision of theoretical knowledge and operator's SOPs, did not fully address the specific risks associated with Runway 22 operations for larger aircraft. Furthermore, the incident brings to light the need for a comprehensive approach to safety risk analysis, particularly in considering the suitability of ILS and PAPI systems for wide-body operations, according to ICAO, FAA and EASA standards.

Conclusion

The incident on 12 January 2023 highlighted a complex interplay of technical, environmental and human factors. While the Airbus A330-300 was capable of safely landing on Runway 22, the crew's skewed risk perception, influenced by environmental challenges, a lower than desired threshold crossing height following the PAPI, and operational decisions, led to the aircraft touching down before the runway threshold. This event underscores the necessity of comprehensive risk analysis, pilot training tailored to specific operational scenarios and a systemic review to ensure better awareness and decision-making regarding the suitability of runways for different types of aircraft. The incident highlights the importance of an integral approach to safety, encompassing both operational planning and runway suitability evaluation.

RECOMMENDATIONS

While Runway 22 at Amsterdam Airport Schiphol is structurally capable of accommodating the landing of an Airbus A330, the configuration of the instrument landing system (ILS) and precision approach path indicator (PAPI) system offers insufficient threshold crossing clearance for large and long aircraft. The ILS and PAPI do not meet ICAO and EASA standards for Eye-to-Wheel Height Category 4 aircraft. The minimum eye height over the threshold (MEHT) is published in the aeronautical information publication (AIP), giving operators the opportunity to assess whether the runway is suitable for landing with their aircraft. However, the continued use of the runway by Eye-to-Wheel Height Category 4 aircraft of other operators is evidence that the risk of crossing the runway threshold at a low altitude is not sufficiently mitigated.

The Dutch Safety Board therefore makes the following recommendation:

To Amsterdam Airport Schiphol:

Restrict the use of Runway 22 for Eye-to-Wheel Height Category 4 aircraft landings, until adjustments have been made to ensure the minimum threshold clearance for such aircraft can be achieved.

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

C.A.J.F. Verheij
Secretary Director

ABBREVIATIONS

Abbreviation	Description
AAL	Above Aerodrome Level
ACARS	Aircraft Communications Addressing and Reporting System
A/B	Auto Brake
AGL	Above Ground Level
AIP	Aeronautical Information Publication
ALS	Approach Lighting System
ALW	Actual Landing Weight
AMSL	Above Mean Sea Level
ASAP	Aviation Safety Action Program
A/THR	Autothrust
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATP	Airline Transport Pilot
BHI	Black Hole Illusion
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
EFB	Electronic Flight Bag
EASA	European Union Aviation Safety Agency
EBBR	Brussels-Zaventem Airport
EGPWS	Enhanced Ground Proximity Warning System
EHAM	Amsterdam Airport Schiphol
EWH	Eye to Wheel Height
FAA	Federal Aviation Administration
FAR	FAA Regulations

FCOM	Manual Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FDA	Flight Data Analysis
FDR	Flight Data Recorder
FMGES	Flight Management Guidance and Envelope System
FMA	Flight Mode Annunciator
FOM	Flight Operations Manual
FPM	Flight Path Management
FRMP	Fatigue Risk Management Plan
ft	Feet
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IOE	Initial Operating Experience
KDTW	Detroit Metropolitan Wayne County Airport
KNMI	Royal Netherlands Meteorological Institute
LDA	Landing Distance Available
LDR	Landing Distance Required
LPR	Landing Performance Request
LTP	Latest Touchdown Point
LVNL	Air Traffic Control the Netherlands
m	Metre
MEHT	Minimum Eye Height over Threshold
MEL	Minimum Equipment List
METAR	Meteorological Aerodrome Report
MLG	Main Landing Gear
MLW	Maximum Landing Weight
ODM	Operational Data Manual
PAPI	Precision Approach Path Indicator

PF	Pilot Flying
PFD	Primary Flight Display
PM	Pilot Monitoring
PHOG	Kahului Airport
PWS	Predictive Windshear
QRH	Quick Reference Handbook
RA	Radio Altitude
RE	Runway Excursion
RESA	Runway End Safety Area
SOP	Standard Operating Procedure
TAF	Terminal Aerodrome Forecast
TEM	Threat and Error Management
USA	United States of America
UTC	Universal Time Coordinated
VMC	Visual Meteorological Conditions
V_{ref}	Reference Landing Speed
V_{app}	Approach Speed
WOCL	Window Of Circadian Low

GENERAL OVERVIEW

Information Type	Information Detail
Identification number:	2023005
Classification:	Serious Incident
Date, time of occurrence:	12 January 2023, 07.52 hours[1]
Location of occurrence:	Amsterdam Airport Schiphol (Netherlands), EHAM
Operator:	Delta Air Lines
Registration:	N802NW
Aircraft type:	Airbus A330-323X
Serial number:	MSN 0533
Engines:	2x Pratt & Whitney PW4168A
Aircraft category:	Fixed-wing, multi engine turbofan
Type of flight:	Commercial Air Transport
Phase of operation:	Landing
Damage to aircraft:	Minor
Injuries	None
Flight crew:	Three
Cabin crew:	Ten
Passengers:	220

1 All times in this report are Amsterdam local times (UTC + 1 hour), unless otherwise specified.

1 INTRODUCTION

On 12 January 2023, a large commercial air transport aircraft flew an approach to the shortest of six runways at Amsterdam Airport Schiphol, Runway 22. The Airbus A330-300 descended below the final approach path. During the subsequent landing, the main landing gear touched down in the grass, 11 metres before the runway threshold. The aircraft continued the landing, slowed down before the end of the runway and taxied to the gate uneventfully. The aircraft sustained only minor damage. None of the crew or passengers were injured.

The airport authorities reported the occurrence to the Dutch Safety Board. The Dutch Safety Board classified the occurrence as a serious incident[2] for which an investigation and reporting obligation[3] stands. The Dutch Safety Board conducted the investigation on behalf of the state of occurrence. The National Transportation Safety Board (USA) and the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (France), representing the state of the operator and the state of design and manufacture of the aircraft, provided assistance to the investigation. The European Union Aviation Safety Agency and the aircraft manufacterer Airbus appointed a technical adviser.

The aim of this investigation is to increase insight into the risks associated with large aircraft landing on this relatively short runway. Given the aim of the investigation, the following question is central:

What caused the aircraft to touch down before the Runway 22 threshold?

The investigation focuses both on the characteristics and use of Runway 22 as well as on the (human) factors contributing to flying below the glide path. In this context, weather conditions, standard operating procedures, human factors, operator risk management and use of navigation aids will form part of this investigation.

This investigation is presented in the ICAO Annex 13 recommended final report format. The report includes factual information in Chapter 2, the event's analysis in Chapter 3, the conclusions in Chapter 4, and is followed by the recommendations in Chapter 5.

2 Based on Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation. Among the examples of potentially serious incidents listed in the EU regulation are takeoff or landing incidents that involve undershooting, overrunning, or veering off the side of runways.

3 EU regulation 996/2010 and the Dutch Safety Board Act.

2 FACTUAL INFORMATION

2.1 History of the flight

On 11 January 2023, the captain and the first officer met at Detroit Metropolitan Wayne County Airport (KDTW) in the United States to prepare for a flight to Amsterdam Airport Schiphol (EHAM) in the Netherlands. The flight was to be operated with an Airbus A330-300, registered as N802NW. The augmented first officer arrived later and caught up with the other pilots at the aircraft. During the flight preparation, the captain and first officer noticed that, during the expected time of landing, the winds were forecast to be strong from a south-westerly direction. Forecast wind conditions at Amsterdam Airport were 240 degrees at 25 knots, gusting to 40 knots.

During the preflight checks on board the aircraft, the pilots loaded the navigation computer with the planned route, including an arrival at Amsterdam Airport and approach to Runway 18R.

The flight departed Detroit Airport at 18.51 hours local time. The takeoff, departure, climb and initial cruise portions of the flight were performed by the captain in the left hand seat and first officer in the right hand seat. The flight crew divided the time in cruise by three to take a break in the crew rest area on board the aircraft. The augmented first officer took the first break, the captain the second and the first officer the third. The last part of the cruise, descent, approach and landing were performed by the captain in the left hand seat, the augmented first officer in the right hand seat and the first officer on the jumpseat.

A few minutes before completing the North Atlantic crossing[4], close to the west coast of Ireland, the pilots decided to make a Landing Performance Request (LPR), based on the Automatic Terminal Information Service (ATIS) report issued at 05.55 hours local time on 12 January 2023 at Amsterdam Airport. After an LPR, the operator's central performance computer calculates the landing distance based on pilot input parameters such as wind, intended landing flap setting, runway condition and runway friction.

At 06.10 hours local time at Amsterdam Airport, the pilots made this LPR for Runway 18R and 22, based on the following wind input: Direction 200 degrees, Speed 26 knots and Gust 36 knots. The LPR response indicated that for Runway 18R, a landing distance of 5,900 feet (ft) using autobrake setting medium was required and that the latest touchdown point (LTP) was a standard 3,000 ft from the runway threshold. The crosswind component for this runway was 10 knots. For Runway 22, the LPR response also indicated that the

4 Exiting the Oceanic airspace SHANWICK near MALOT.

required landing distance was 5,900 ft using autobrake setting medium, however the LTP was now 2,200 ft from the runway threshold. The crosswind component was 13 knots.

The three pilots discussed which runway would be most suitable for landing. The captain had a preference for Runway 18R, because it is longer than Runway 22; 3,800 metres (m) (10,000 ft) versus 2,020 m (6,600 ft). However, given the wind forecast, they were concerned that the crosswind during landing on Runway 18R could exceed the Airbus A330 crosswind limit of 40 knots (including gusts). At this time, they concluded that both runways could be suitable for landing. The operator had an additional restriction in place for Runway 22 that required a minimum 20 knots headwind component.

At 06.25 hours, Amsterdam Airport ATIS indicated the wind changed to direction 220 degrees at 23 knots. Runway 18R had been the primary landing runway at Amsterdam Airport. Based on the wind change, Runway 22 became the primary runway for landing at 06.28 hours. Runway 18R would be used as a secondary landing runway. The pilots requested new landing performance data for Runway 22 at 06.44 hours, based on the updated winds. The resulting landing distance, autobrake setting and LTP were the same as the previous LPR.

The three pilots again discussed the suitability of the landing runways, now with the updated wind information. The crosswind component for Runway 18R was below the Airbus A330 maximum, however the pilots were concerned that would not remain the case, considering the previously reported gusts. The crosswind component for Runway 22 was almost zero.

At 06.55 hours, Amsterdam Airport ATIS indicated the wind changed to direction 230 degrees at 28 knots. Shortly after, at 07.02 hours the pilots sent a message[5] to the operator's dispatch expressing they are not entirely comfortable landing on Runway 22. Dispatch replied that the pilots can request other runways. The pilots made another LPR for Runway 22 with the new winds, again resulting in the same required landing distance, autobrake setting and LTP.

All three pilots had never landed on this runway before. They were concerned with the short length of the runway in relation to the landing distance required for an Airbus A330 and its approach speed. This was discussed while preparing for the approach before and during the descent.

At 07.14 hours, the pilots set the autobrake to medium and two minutes later, started their descent. At 07.25 Amsterdam Airport updated the ATIS and winds were from the direction 240 degrees at 29 knots, gusting 39 knots.

At 07.29 hours, the aircraft entered Dutch airspace and the pilots checked in on the radio with Dutch Air Traffic Control (ATC). The pilots asked if another runway, besides Runway 22, was available for landing. ATC replied that Runway 18R was also available.

5 "ATIS IS SAYING LANDING RWY 22. ITS ONLY 6700 LONG. DOES AMS USUALLY LAND HEAVIES ON SHORT RWY. NOT SURE I AM COMFORTABLE WITH RWY 22".

The pilots discussed the weather conditions and concluded that Runway 22 was the most suitable runway for landing. They decided to continue their descent and plan to land on Runway 22. They reprogrammed the navigation computer to an arrival and Instrument Landing System (ILS) approach to Runway 22.

The captain, as pilot flying, briefed the other pilots on the details of the approach as they were given vectors by ATC towards the final approach path. Using the autopilot and autothrust, the captain reduced the indicated airspeed using the "select speed" function of the autothrust system (A/THR) and asked the augmented first officer to configure the aircraft to flap 1 at 07.41 hours, followed by flap 2 at 07.42 hours. The aircraft subsequently intercepted the ILS localizer at approximately 12 nautical miles from the runway threshold at an altitude of 2,300 ft above ground level (AGL). At 07.47 hours flap 3 was selected at approximately 11 nautical miles from the runway threshold.

At 07.49 hours, the captain asked the augmented first officer to select the gear down and the aircraft started its descent guided by the ILS glideslope signal. The captain reduced the indicated airspeed to 160 knots as required on this approach. The augmented first officer checked in with the tower controller, who advised the pilots that they were "number two" on the approach and that the current winds were 240 degrees at 28 knots, gusting 41 knots.

The autopilot and autothrust kept the aircraft on the lateral and vertical path towards the runway as indicated by the localizer and glideslope signal from the ILS. The light conditions around this time were dark. It was night and light rain and drizzle were present. The aircraft descended below the clouds and the pilots saw the approach lights, the runway and Precision Approach Path Indicator (PAPI) as expected. However, during post-incident interviews, the captain stated he felt as if he was descending towards a black hole due to the lack of runway centreline lighting and the shorter – than he was accustomed to – array of approach lights.

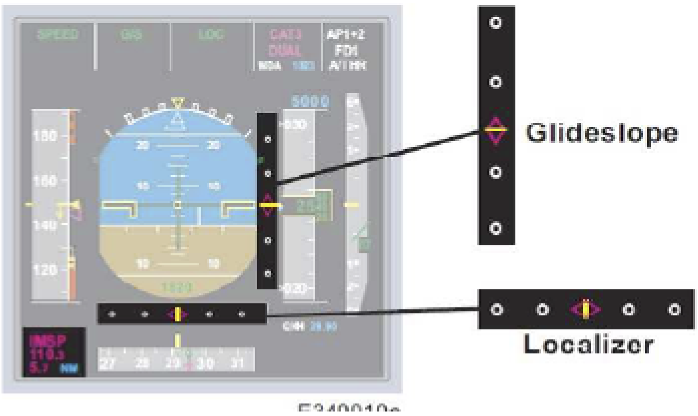
At 07.50 hours, the captain requested the augmented first officer to select full flaps at approximately 5 nautical miles from the runway threshold. ATC had instructed the pilots to maintain 160 knots on approach until 4 nautical miles from the runway threshold. At this point, the captain activated "managed speed" function and the A/THR commanded the aircraft to fly 165 knots indicated airspeed (V_{app} + 24 knots). This 5 knot speed increase surprised the pilots and the captain deployed the speed brakes for 20 seconds in an attempt to reduce the speed, triggering a master caution. He then stowed the speed brakes and the master caution extinguished.

At 07.52 hours, the tower controller cleared the pilots to land on Runway 22 and advised them that the wind was 240 degrees at 30 knots, gusting to 41 knots. The captain once again briefly deployed the speed brakes, this time for 8 seconds and stowed them at 1.2 nautical miles before the threshold.

Approximately 0.6 nautical mile from the threshold of the runway at around 240 ft AGL, the captain disengaged the autopilot and continued the approach manually controlling the aircraft's flight path using the sidestick. One second later, the flight data recorder

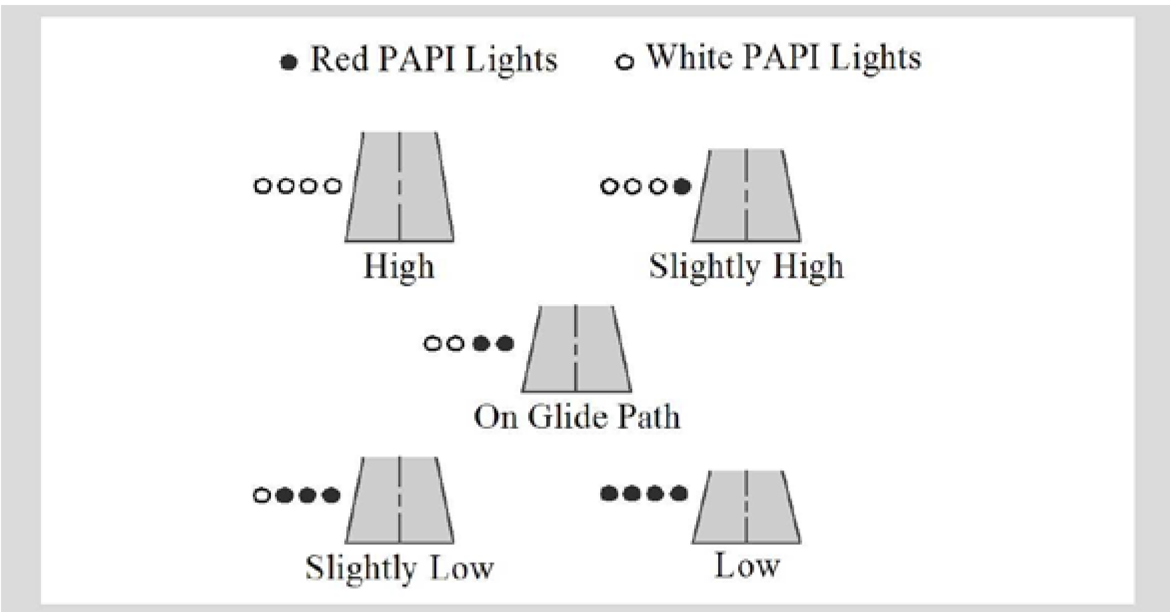
(FDR) recorded a nose-down input from the captain's sidestick, decreasing the aircraft's pitch attitude from 1.4° nose up, to 0.3° nose down. The vertical speed increased and the aircraft started to descend below the glidepath. Two seconds later, the FDR recorded a nose-up input and the aircraft's pitch attitude increased to 2.5° nose up, however the descent below the glidepath continued to increase.

The glideslope indication[6] on the pilot's primary flight displays (PFD) (see figure 1) was now ½ dot below the glideslope and the aircraft continued to deviate further from the glideslope to 2 dots below the glideslope. The augmented first officer stated during the post-incident interview that he was confident that the captain was in control of the flight's trajectory.



▲ *Figure 1: PFD Glideslope and Localizer indications. (Source: Operator Flight Crew Operating Manual)*

The captain and the augmented first officer noticed the deviation below the glidepath also evidenced by the PAPI indicating three red lights and one white light (see figure 2).



▲ *Figure 2: PAPI Landing Geometry. (Source: Operator Flight Crew Training Manual)*

6 A needle deviates from centre on a scale marked by dots to indicate whether the aircraft is flying above or below the glideslope.

Six seconds before touchdown, at 59 ft AGL, the aircraft experienced a downdraft and descended shortly below two dots below the ILS glideslope. The captain and the augmented first officer stated they felt the aircraft 'sink', shortly before touchdown.

Four seconds before touchdown, at 40 ft AGL, the FDR recorded a nose-up input on the captain's sidestick, increasing the aircraft's pitch attitude to reach 6.3° nose up at touchdown. The recorded vertical load during the landing was 1.543 G.

The aft wheels of the right main gear bogie touched down in the grass, 11 m before the runway threshold. The aft wheels of the left main gear bogie touched down 8 m before the runway threshold. Both main gear bogie's subsequently hit a traverse concrete slab, situated 5.5 m in front of the threshold, before reaching the threshold of Runway 22, where they broke off two threshold lights.

The captain retarded the thrust levers to idle and selected reverse thrust one second thereafter. He lowered the nose of the aircraft and the subsequent roll-out was uneventful. The aircraft slowed down to taxi speed and turned off the runway at runway intersection G7. During the taxi towards the gate, all three pilots expressed they felt the touchdown was close to the threshold, but not before. The aircraft taxied to the gate where passengers disembarked. The captain and the first officer performed an exterior post flight inspection together with an aircraft technician. They did not notice any abnormalities.

About two hours after the incident, a police helicopter flew by the Runway 22 threshold and noticed debris on the runway. They reported this to the airport authorities, who reviewed video recordings of aircraft landing on the runway and traced it back to the operator's Airbus A330. When the airport authorities notified the operator of the broken threshold lights, the operator inspected the aircraft again in daylight and discovered one bogie sustained minor damage and the rear of the aircraft was marked with traces of mud.

2.2 Injuries to persons

No injuries to persons were reported in the incident, as detailed in Table 1. This table provides a comprehensive overview of the personnel on board and the absence of injuries.

▼ *Table 1: The number of injuries and fatalities.*

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
None	13	220	0

2.3 Damage to aircraft

Anti-rotation brake rod restraint cable
The aircraft sustained minor damage. The aft anti-rotation brake rod restraint cable of the right main landing gear was broken (see figure 3). Mud traces were visible on the rear of the fuselage (see figure 4).

As both main landing gears impacted objects during this undershoot occurrence, an analysis by Safran Landing Systems (manufacturer of the landing gear) was conducted to assess the experienced load levels. The conclusion of that analysis confirms that the landing gear components did not exceed their design limit loads.

▲ *Figure 3: Anti-rotation brake rod restraint cable. (Source: Operator)*

▲ *Figure 4: Mud traces on the aft fuselage of the Airbus A330.*

2.4 Other damage

Runway threshold lights
Two runway threshold lights were sheared off (see *figure 5*). The ground before the runway threshold showed two tracks consistent with the dimensions of the Airbus A330-300 main landing gear wheels. The left track, positioned 9.2 m left of centerline, was approximately 8 m in length and had a maximum depth of 5 centimeters. The right track, positioned 1.5 m right of centerline, was approximately 11 m in length and had a maximum depth of 5 centimeters.

◀ *Figure 5: One of the sheared off runway lights. (Source: Amsterdam Airport Schiphol)*

2.5 Personnel information

All three pilots were current and qualified in accordance with the operator and Federal Aviation Administration (FAA) requirements.

Captain
The captain, age 57, was the pilot flying (PF), occupying the left hand seat. He held a valid United States airline transport pilot (ATP) certificate with type ratings for the Airbus 320, Airbus A330, Boeing 737, Boeing 757, Boeing 767, Boeing DC-9, and Dornier 228 aircraft. The certificate noted the following limitations: Airbus A330, Boeing 757 and Boeing 767 Circling Approaches – VMC Only. Dornier 228 Second in Command Required. He held a current first-class airman medical certificate, dated 16 August 2022, with no limitations.

The captain had been employed by the operator since 1991. Before the captain transitioned to the A330 in 2021, he accumulated about 6,520 hours on the A320. A review of the operator's records indicated that the captain had about 18,236 hours total flight time, of which 601 hours were in the A330. His most recent pilot-in-command line check was accomplished on 1 July 2022, and his most recent proficiency training and check were accomplished on 03 April 2022.

At the time of the incident, the captain was based at Detroit Airport and reported for duty coming from home. During post-incident interviews, the captain described his general health as good. On the day of the flight, the captain woke up around 07.30 hours Detroit local time. He indicated he slept well. He reported for duty at 17.00 hours Detroit local time.

The captain did not have any flying duties in the month prior to the incident. His biological clock was adjusted to Detroit time. The incident happened at 01.52 hours Detroit local time, during the window of circadian low[7] (WOCL).

In the twelve months prior to the incident, the captain had flown 444 hours and had flown to Amsterdam Airport on three previous flights. On all three of those flights, the captain acted as PF and approached and landed on Runway 18R. The captain had flown into Amsterdam Airport eight times prior to these twelve months and none of these flights landed on Runway 22.

Augmented First Officer
The augmented first officer, age 59, was the pilot monitoring (PM) for the second half of the incident flight, occupying the right hand seat. He held a valid United States airline transport pilot (ATP) certificate with a type ratings for the Airbus A330 aircraft. He held a first-class airman medical certificate, dated, with no limitations.

The augmented first officer had been employed by the operator since 2000 as a first officer on the Boeing B727. He started as a first officer on the A330 in March 2021. A review of the operator's records indicated that the augmented first officer had about

7 Window during night time, typically between 02.00 – 06.00 hours where performance is reduced.

11,228 hours total flight time, of which 1,083 hours in the A330. His most recent line check was accomplished on 19 August 2021, and his most recent proficiency training and check were accomplished on 16 November 2022.

At the time of the incident, the augmented first officer was based in Seattle-Tacoma International Airport (KSEA). He reported for duty coming from his hotel. During post-incident interviews, the augmented first officer described his general health as good. He stated being tired during the flight.

In the twelve months prior to the incident, the augmented first officer had flown 738 hours. The augmented first officer had flown to Amsterdam Airport on 38 previous occasions and on all of those flights, he had not landed on Runway 22.

First Officer
The first officer, age 49, acted as first officer during the first half of the flight and occupied the jumpseat during the approach and landing at Amsterdam Airport. He held a valid United States airline transport pilot (ATP) certificate with a type ratings for the Airbus A330 aircraft. He held a first-class airman medical certificate, dated, with no limitations.

The first officer had been employed by the operator since 2010 as a first officer on the Boeing DC-9. He started as a first officer on the A330 in July 2018. A review of the operator's records indicated that the first officer had about 6,366 hours total flight time, of which 1,622 hours were in the A330. His most recent line check was accomplished on 10 August 2021, and his most recent proficiency training and check were accomplished on 26 April 2022.

At the time of the incident, the first officer was based at Detroit Airport. He reported for duty coming from home. During post-incident interviews, the first officer described his general health as good.

In the twelve months prior to the incident, the first officer had flown 660 hours. The first officer had flown to Amsterdam Airport on 36 previous occasions and on all of those flights, he had not landed on Runway 22.

2.6 Aircraft information

2.6.1 Airbus A330

The Airbus A330-300 aircraft (MSN0533) was equipped with two Pratt & Whitney PW4168A engines. The aircraft had 69,252 total flight hours with 19,353 total flight cycles at the time of the incident.

The aircraft is classified into the ICAO Aircraft Approach Category C. This is based on the indicated airspeed (V_{ref}[8] = 137 knots), in the landing configuration, at the certificated

8 Threshold speed is calculated as 1.3 times stall speed V_{s0} or 1.23 times stall speed V_{s1g} in the landing configuration at maximum certificated landing mass.

maximum flap setting and Maximum Landing Weight (MLW) of 187,000 kg (412,264 lb), in standard atmospheric conditions.
The actual final approach speed (V_{ref} + 5 knots) for the incident flight was 141 knots, based on the Actual Landing Weight (ALW) of 172,500 kg (380,297 lb).

Aircraft Documents
The Registration Certificate was issued on 31 December 2009 and was valid until 30 June 2025. The Airworthiness Certificate was issued 9 July 2003 and the operator maintained the aircraft under the Continuing Airworthiness Program.

A review of weight and balance, and loading information for the incident flight revealed the aircraft was within weight and centre-of-gravity limits.
The flight from Detroit to Amsterdam was dispatched with a flight plan that was compliant with the operator[9] and regulatory standards. The planned arrival fuel at Amsterdam Airport was 22,800 pounds, which included approximately 40 minutes of holding fuel. The planned alternate airport was Brussels-Zaventem Airport (EBBR).

The technical log indicated some aircraft equipment and furnishings were inoperative and deferred according to the minimum equipment list (MEL). None were relevant to this occurrence.

2.6.2 Landing performance
The performance data for landing the A330 can be obtained from the Operational Data Manual (ODM) via the Electronic Flight Bag (EFB)[10] or from the Aircraft Communications Addressing and Reporting System (ACARS) Landing Performance Request (LPR). The LPR provides interpolated ODM data for normal landing configurations and applies adjustments for specified conditions. Landing performance tables are also found in the Quick Reference Handbook (QRH). The performance data will state the distance required[11] to bring the aircraft to a stop under ideal conditions, assuming the aircraft crosses the runway threshold at a height of 50 ft[12], at the correct speed. The actual landing performance of an aircraft is affected by many variables, which must be taken into account. These variables include aircraft weight, wind direction and speed, runway surface, aircraft configuration, temperature and sea level pressure.

Landing Performance Request
The pilots requested landing performance data using ACARS. The landing performance request (LPR) required the pilots to input the intended landing runway and wind direction and speed (see table 2). The system calculated and adjusted the landing performance based on 150% of the entered tailwind and 50% of the entered headwind. The resulting output included the landing distance required (LDR), autobrake (A/B) setting, and latest touchdown point (LTP) (see table 3).

9 Flight Operations Manual 14.1.2.1.
10 EFB: e.g. iPad with designated software.
11 This landing distance required includes an additional 15% safety margin and assumes the thrust reversers, anti-skid system and autospoilers are operative.
12 If the aircraft is flying the ILS G/P, the G/P antenna position is the reference; If flying a PAPI the pilots eye height is the reference.

▼ *Table 2: LPR crew input parameters.*

EHAM local time	Runway	Wind direction, speed and gust	Temperature (Celsius)	QNH[13] (inHg)	Runway braking action
06.10 hours	22	200/26G36	9	29.54	Good
06.13 hours	18R	200/26G36	9	29.54	Good
06.44 hours	22	220/23	10	29.54	Good
07.11 hours	22	230/20	10	29.54	Good

▼ *Table 3: LPR system output parameters.*

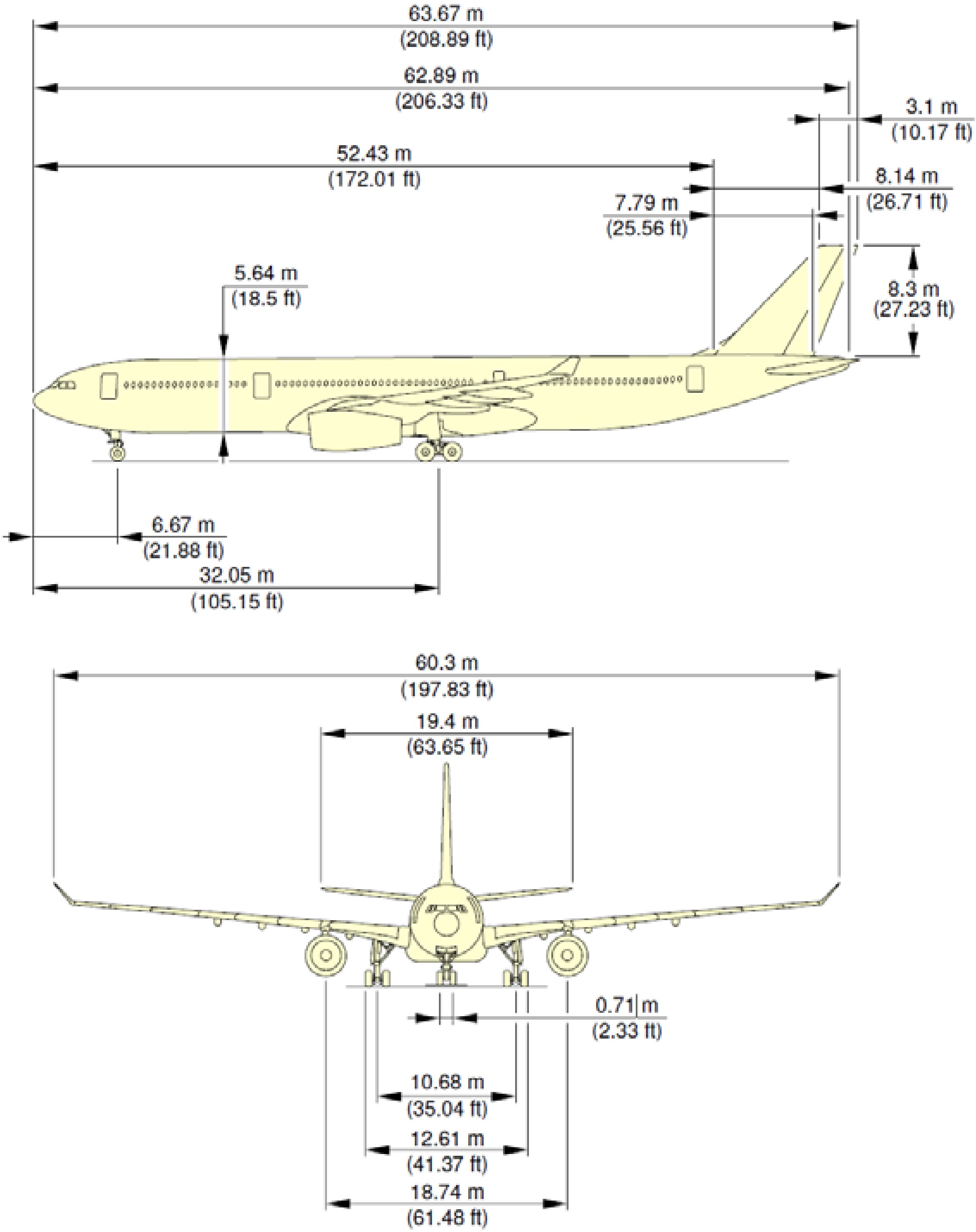
EHAM local time	Runway	Landing Distance Required (ft)	Latest Touchdown Point (ft)	Headwind component (knots)	Crosswind component (knots)	Autobrake setting
06.10 hours	22	5,900	2,200	24	13	Medium
06.13 hours	18R	5,900	3,000	25	10	Medium
06.44 hours	22	5,900	2,200	23	1	Medium
07.11 hours	22	5,900	2,200	20	3	Medium

Airbus Flysmart+
The aircraft manufacturer Airbus analysed the data from the FDR and calculated the landing performance for Runway 22 using the Airbus EFB application Flysmart+ and concluded the landing distance required was 5,682 ft (Converted from 1,732 metres. This number includes a 15% margin).

2.6.3 Landing Gear geometry

The aircraft is 63.67 m (208.9 ft) long and the main landing gear is positioned 29.66 m (97.3 ft) behind the pilots (see figure 6). The aircraft has two main landing gears (MLGs), each with a four wheel bogie assembly. In-flight, with the MLG extended, the bogie is held in a trailing condition (rear wheels low) by an articulation linkage and a pitch trimmer.

13 The pressure set on the subscale of the altimeter so that the instrument indicates its height above sea level. The altimeter will read runway elevation when the aircraft is on the runway.



▲ *Figure 6: Aircraft Dimensions. (Source: Airbus)*

Threshold Crossing Height[14]

On an approach to Runway 22, flying a 3.12˚ glide path following the ILS glide slope signal, the Airbus A330-300 crosses the threshold at:

- ILS antenna: 14.17 m (46.5 ft)
- MLG: 6.01 m (19.72 ft)

14 Values are obtained from the Airbus Aircraft Data for Visual Aids Calibration of 1 September 2023 (reference X06ME2319992).

On an approach to Runway 22, following the lower bound of the 'on path' indication of the PAPI, the Airbus A330-300 crosses the threshold at:

- MEHT: 14.48 m (47.51 ft)
- MLG: 3.64 m (11.95 ft)

Eye to Wheel Height
According to the aircraft manufacturer, the Eye-to-Wheel Height (EWH) of an Airbus A330-300 is 8.23 m (27 ft) when the aircraft is on the approach in the flaps full configuration and the aircraft angle is 3.7° pitch nose up. This puts the aircraft into ICAO EWH Category 4, for aircraft with an eye to wheel height between eight metres (26.2 ft) up to but not including fourteen metres (45.9 ft). The minimum height at which the main landing gear wheels must cross the threshold is six metres (19.7 ft) for aircraft in this category.

2.6.4 Surveillance systems

Predictive Windshear
The A330 is equipped with a two multiscan weather radar systems with a Predictive WindShear[15] (PWS) function that operates when the aircraft radio height is below 2,300 ft (See Appendix B.1). The system scans the airspace for windshear within a range of 5 Nautical Miles ahead of the aircraft. When the system detects windshear, it alerts the pilots.
No windshear alerts were generated during the approach on runway 22.

Enhanced Ground Proximity Warning System
The A330 is equipped with an Enhanced Ground Proximity Warning System (EGPWS) and its purpose is to warn the flight crew of potentially hazardous situations, such as a collision with terrain (See Appendix B.2). It detects terrain collision threats and triggers applicable aural and visual indications. The EGPWS triggers below 2,500 ft height about excessive rates of descent, based on the radio height, and the rate of descent of the aircraft. It also triggers when the aircraft descends below the glideslope, outside of certain parameters.
No EGPWS warnings or alerts were generated during approach.

2.6.5 Speed Control

Autothrust
The autothrust (A/THR) manages the engine thrust and, when active, can adjust the thrust to acquire and maintain a target speed. The target speed is "selected" by the flight crew or "managed" by the flight management guidance and envelope system (FMGES).

When the aircraft is in the full flap landing configuration, the A/THR behaviour is optimized:

- Above 100 ft RA, to be more responsive to speed variations
- Below 100 ft RA, to be less responsive to speed variations

This logic exists to avoid large thrust increases during the lower segment of the approach that may lead to destabilization and possible long flare.

15 Wind shear is a change in wind speed and/or direction over a short distance, which can occur either horizontally or vertically.

Ground Speed Mini
When the aircraft flies an approach in managed speed, the V_{app} target is corrected by the Ground Speed Mini function.

The Ground Speed Mini function takes advantage of the aircraft inertia when the wind varies during the approach in order to provide an appropriate indicated target speed. When the flight crew flies this indicated target speed, the energy of the aircraft is maintained above a minimum level that ensures standard aerodynamic margins versus the stall.

The minimum energy level is the energy level the aircraft will have at touchdown with an indicated airspeed equal to V_{app}, and with the wind equal to the tower reported wind. The ground speed then equals the Ground Speed Mini. During the approach, the FMGES continuously computes the managed target speed in order to keep the ground speed at or above the Ground Speed Mini.

2.7 Meteorological information

Sunrise time at Amsterdam Airport Schiphol on 12 January 2023 was at 08.46 hours; 54 minutes after touchdown of the incident aircraft. Moonset time at Amsterdam Airport Schiphol on 12 January 2023 was 11.24 hours. At the time of landing, the moon altitude was 30° degrees over the horizon, heading in a west south-westerly direction. It was in the Waning Gibbous[16] phase and 80% illuminated.

The Royal Netherlands Meteorological Institute (KNMI) reported that at the time of the occurrence, moist subtropical air was brought in with a strong south-westerly current (See Table 4). A frontal system passed over Amsterdam Airport Schiphol in the early morning and lay right over the field at about 08.00 hours.

▼ *Table 4: Winds at Amsterdam Airport Schiphol at 08.00 hours on 12 January 2023. (Source: Royal Netherlands Meteorological Institute)*

Height	Surface	500 ft	1,500 ft	3,000 ft
Direction/speed	240/27G38	240/35	240/45	240/50

Weather forecast available before the flight
During the flight crew's flight preparation, the Amsterdam Airport Schiphol Terminal Aerodrome Forecast (TAF) issued at 18.09 hours on 11 January 2023 (See Appendix C) was available to them. It indicated that at the estimated time of arrival of the flight at Amsterdam Airport the weather conditions were expected to be: visibility 6,000 m in rain, scattered clouds at 800 ft above ground level (AGL), broken clouds at 1,400 ft AGL and wind direction 240, speed 25 knots, gust 40 knots. Between 04.00 hours and 07.00

16 The surface area of the moon that you see is decreasing and the shape of the lit-up part of the moon looks like a hump-back.

hours visibility and clouds were expected to change temporarily to 4,000 m and broken at 800 ft AGL, but between 07.00 hours and 09.00 hours conditions were expected to increase to unlimited visibility, no significant weather and broken clouds at 2,500 ft AGL.

Weather updates during the flight
The Amsterdam Airport TAF issued at 00.21 hours (See Appendix C), indicated that the wind conditions at the expected time of arrival were expected to change gradually between 04.00 hours and 07.00 hours from: direction 230, speed 15 knots, gust 25 knots to: direction 240, speed 25 knots, gust 40 knots.

Amsterdam Airport issued a new TAF at 06.07 hours (See Appendix C) indicating the wind conditions were forecast to be: direction 240, speed 25 knots, gust 40 knots, gradually changing between 07.00 hours and 10.00 hours to: direction 240, speed 22 knots, gust 32 knots.

At Amsterdam Airport, observations are made and reported at half-hourly intervals. The Meteorological Aerodrome Report (METAR) at 07.25 hours[17] indicated the following wind conditions: direction 240, speed 28 knots, variable between direction 210 and 270. At 07.55 hours[18], the Amsterdam Airport METAR reported winds: direction 240, speed 27 knots, gust 38 knots.

Weather conditions encountered during approach
Amsterdam Airport has several cup anemometers and wind vanes at various locations on the airfield. They are located at 105 m from the centerline near the touchdown zone of Runway 06, 18C, 18R, 27, 36C, 36L and 36R and 105 m from the centerline and 100 m from the touchdown zone of Runway 22.
Additional measuring equipment recorded the following (See Table 5) weather conditions for Runway 22 in the period before the incident at the indicated times:

▼ *Table 5: Recorded weather conditions for Runway 22.*

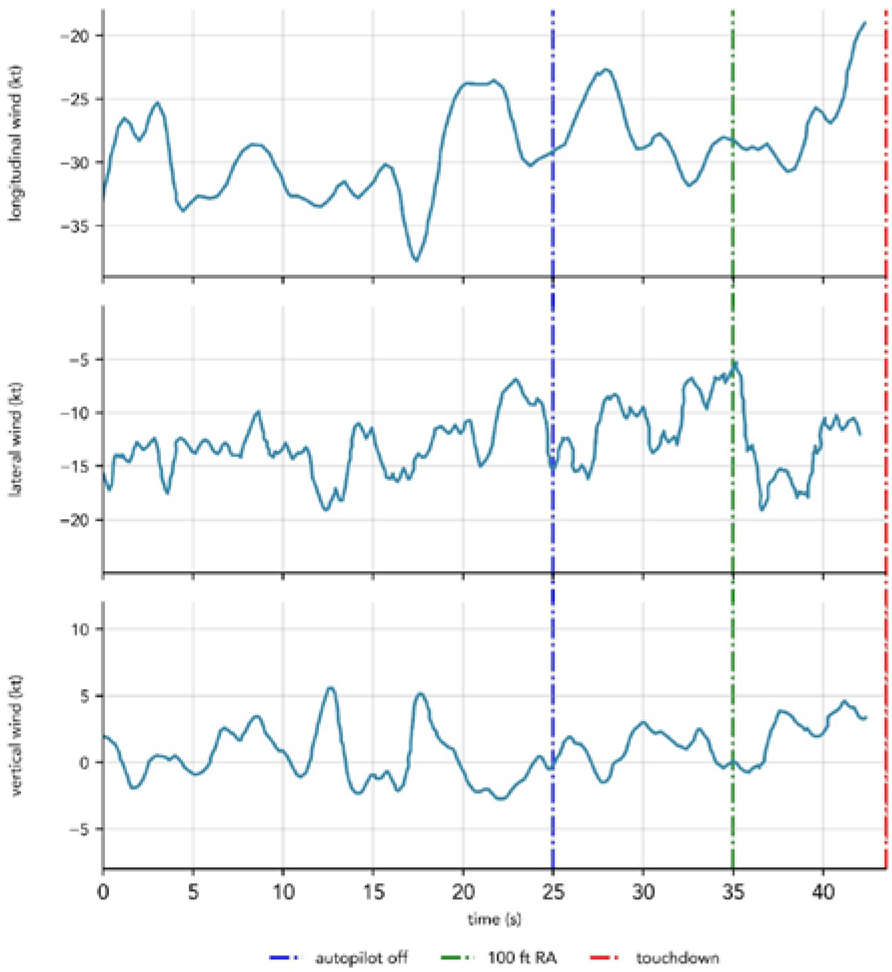
Time	Wind	Visibility	Weather	Cloud	Cloud	Cloud	Temperature / Dewpoint
06.06	210/27G34	3,500	RA	FEW007		BKN008	09/09
06.16	220/23G33	3,500	-DZRA	FEW006		BKN008	09/09
06.25	220/23G30	4,500	-DZRA	FEW006		BKN009	09/09
06.29	220/23G30	4,500	-DZRA	FEW006		BKN009	09/09
06.36	220/23G32	6,000	-DZRA	FEW006		BKN010	10/09
06.47	230/31G41	6,000	-DZRA	FEW006		BKN010	11/09
06.55	230/27G41	4,500	-DZRA	FEW006	SCT007	BKN010	10/10

17 EHAM 120625Z 24028KT 210V270 5000 -DZRA FEW007 SCT008 BKN010 11/10 Q1000 TEMPO 8000
18 EHAM 120655Z 24027G38KT 6000 -DZ FEW007 SCT009 BKN011 11/10 Q1000 TEMPO 8000 BKN015

Time	Wind	Visibility	Weather	Cloud	Cloud	Cloud	Temperature / Dewpoint
07.25	240/29G39	5,000	-DZRA	FEW007	SCT008	BKN010	11/10
07.55	240/29G41	6,000	-DZ	FEW007	SCT009	BKN011	11/10

Weather conditions from FDR analysis
The aircraft manufacturer Airbus reconstructed the longitudinal, lateral and vertical wind components using the input parameters from the FDR, which is shown in Figure 7. The wind speed is decomposed into three components: longitudinal (top graph), lateral (middle graph) and vertical (bottom graph).

The longitudinal wind component shows large wind variations, consistent with the gusty weather conditions. A 10 knot gust (headwind reduction) can be observed close to touchdown (red line). The lateral wind component shows a significant crosswind component from the right, averaging 15 knots. The vertical wind component is generally low (less than 5 knots) after autopilot disconnection (blue line). A small downdraft of 5 knots is visible shortly before touchdown.



▲ *Figure 7: Wind speed derived from FDR data. (Source: Airbus analysis)*

2.8 Aids to navigation

Instrument Landing System
Runway 22 at Amsterdam Airport Schiphol is equipped with a category I ILS, and is therefore classified as a precision approach runway Category I. The ILS glide slope antenna is installed 260 m from the threshold and has a 3° 07′ 12″ (3.12°) glideslope angle. The ILS Reference Datum Height (RDH) is listed as 46 feet in the Aeronautical Information Publication (AIP) The Netherlands. This is the height at which the glideslope signal crosses the threshold.

PAPI
The PAPI is located 45 m to the left of the Runway 22 centerline and 277,5 m beyond the runway threshold at a height of 0.545 m in relation to the runway. Evidence obtained from Amsterdam Airport indicates the lights were installed in the year 1994, due to the planned installation of an ILS system for Runway 22. The documentation shows that the PAPI was intended for ICAO EWH Category 3 aircraft, with an Eye-to-Wheel Height between 5 m (16.4 ft) up to but not including 8 m (26.2 ft). This is in accordance with the current EASA CS ADR-DSN.M.650 "Approach slope and elevation setting of light units for PAPI and APAPI".

The last maintenance took place at the end of November 2022, approximately eight weeks before the incident. During the maintenance, the four projector lights were cleaned and the horizontal and vertical angles verified to emit their red and white beams, and found to be within limits. Table 6 shows the angles of each projector at the time of inspection. Below each light angle the pilot would observe a red light and above the light angle the pilot would see a white light.

▼ *Table 6: PAPI Projector light angles.*

Projector	1	2	3	4
Angle (degrees, minutes)	2° 36′	2° 55′	3° 17′	3° 38′

The nominal 'on glide path' angle is 3° 6′.

On 16 December 2022, Amsterdam Airport Schiphol inspected the PAPI lights and found no abnormalities.

At the time of the incident, the Minimum Eye Height over Threshold (MEHT) was listed as 62 ft for Runway 22 at Amsterdam Airport Schiphol in the aeronautical information publication (AIP) (See Appendix C.4).

2.9 Communications

Communications between the pilots and Air Traffic Control and between the pilots and the operator's dispatcher were unremarkable.

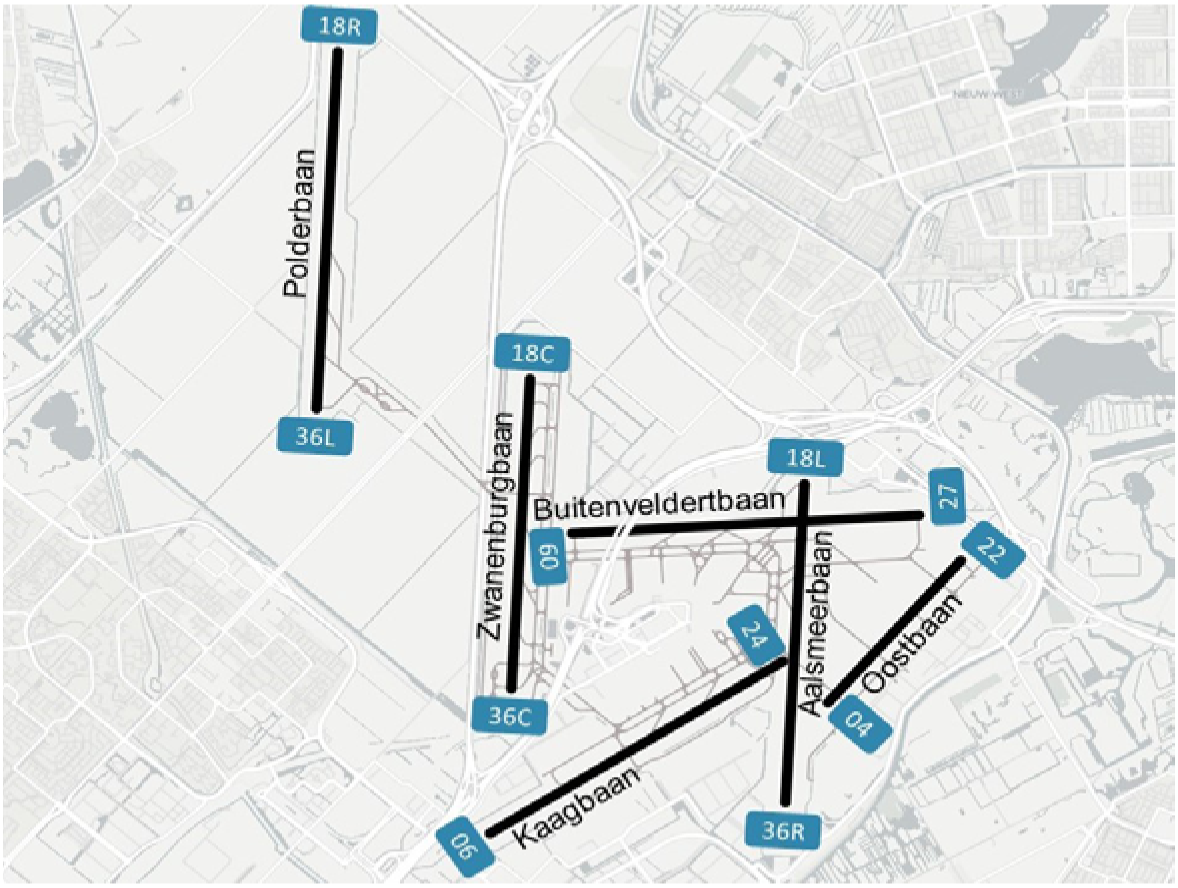
2.10 Aerodrome information

2.10.1 Amsterdam Airport Schiphol

Amsterdam Airport Schiphol is located 4.9 nautical miles southwest of Amsterdam at an elevation of -11 ft Above Mean Sea Level (AMSL). It has six runways: 18R/36L, 18C/36C, 18L/36R, 06/24, 09/27, and 04/22 (See figure 8).

Runways 04, 09, 22 and 24 conform to EASA certification specifications for non-precision approach runways, whereas the others are precision approach runways Category III or takeoff runways. Runway 04 and 09 are rarely used for landings of commercial aircraft.[19]

Runways 6, 18C, 18R, 22, 27, 36C and 36R are equipped with an ILS.



▲ *Figure 8: Layout of runways at Amsterdam Airport Schiphol. (Source map: OpenStreetMap)*

19 No landings in the period 1 November 2022 to 31 January 2023. (Source: *Bewoners Aanspreekpunt Schiphol)*

2.10.2 Runway 22

Runway 04/22 is the shortest of the six runways at Schiphol. In the year 2011, it was completely resurfaced and strengthened which allowed larger aircraft (including the Airbus A330-300) to land. The so-called 'Oostbaan' is 2,020 m (6,627 ft) long and 45 m wide with a slope of less than 0.01%. The runway has an asphalt surface. Beyond the paved runway, a 60 m unpaved clearway[20] is located at both ends of the runway. A 220 m Runway End Safety Area[21] (RESA[22]) is present for undershoots and a 180 m RESA for overruns of Runway 22. The landing distance available (LDA) is 2,020 m (See Appendix C).

Runway markings

Runway 22 has white threshold, designation, touchdown zone, aiming point, centreline and edge markings, see figure 9. The markings conform to ICAO and EASA standards[23],[24] for a precision runway of 2,000 m length. The touchdown zone contains an aiming point located at 300 m (1,000 ft) from the threshold[25].

▲ *Figure 9: Amsterdam Airport Schiphol Runway 22. (Source: Google Earth)*

Approach and Runway lighting

Runway 22 has a Simple Approach Lighting System (SALS) with a length of 450 m (1,500 ft) and high intensity lights[26], which conforms to the EASA certification specification for a non-precision approach runway. EASA CS ADR-DSN.M.625 stipulates that on a precision

20 A clearway is an area beyond the paved runway, free of obstructions and under the control of the airport authorities.
21 An area symmetrical about the extended runway centre line and adjacent to the end of the strip primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway.
22 https://skybrary.aero/articles/runway-end-safety-area-resa.
23 ICAO Annex 14; 5.2.2 Runway designation marking.
24 EASA CS-ADR-DSN Issue 6.
25 On runways longer than 2400m the aiming point for touchdown is a minimum of 400 m from the threshold.
26 At the time of the incident, AIP EHAM AD 2.14 indicated medium intensity lights were installed.

approach runway Category I, a 900 m (3,000 ft) Approach Light System (ALS) should be provided, where physically practicable. The runway is equipped with yellow and white edge lights, green threshold lights, and red runway-end lights.

AIP
The aeronautical information publication (AIP) of the Netherlands states that Runway 22 is suitable for approach category A-D aircraft.

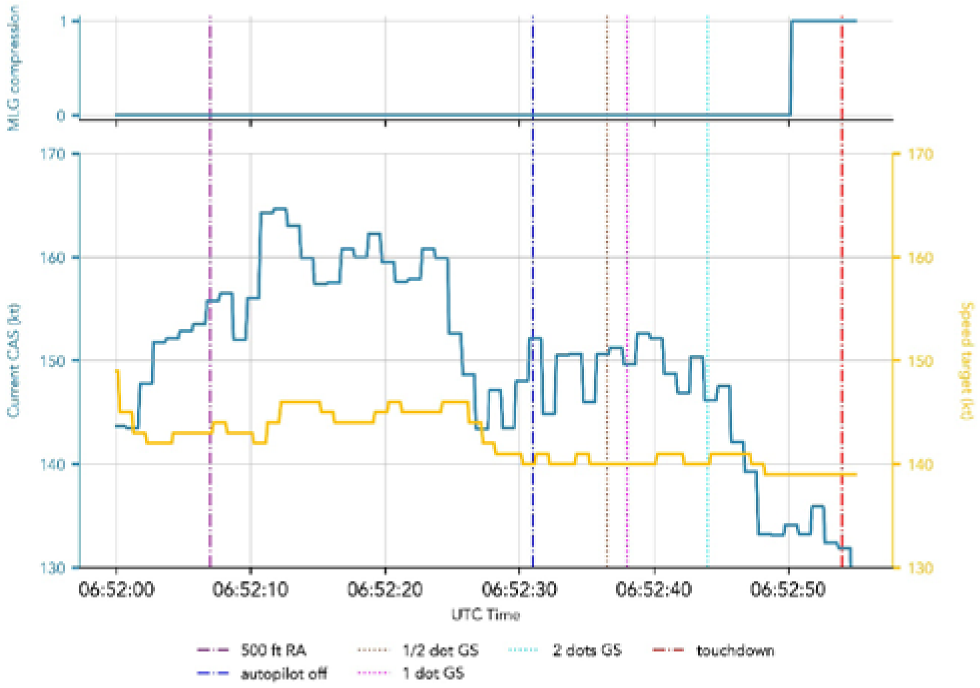
Additional information in the AIP states that during approaches to Runway 22, pilots must be prepared for turbulence, wind shear and wind gradient (possibly simultaneously) due to the presence of large buildings and an engine run-up area underneath the circuits. Pilots are advised to obtain information in advance concerning ATC instructions to be expected and the resulting flight paths.

2.11 Flight recorders

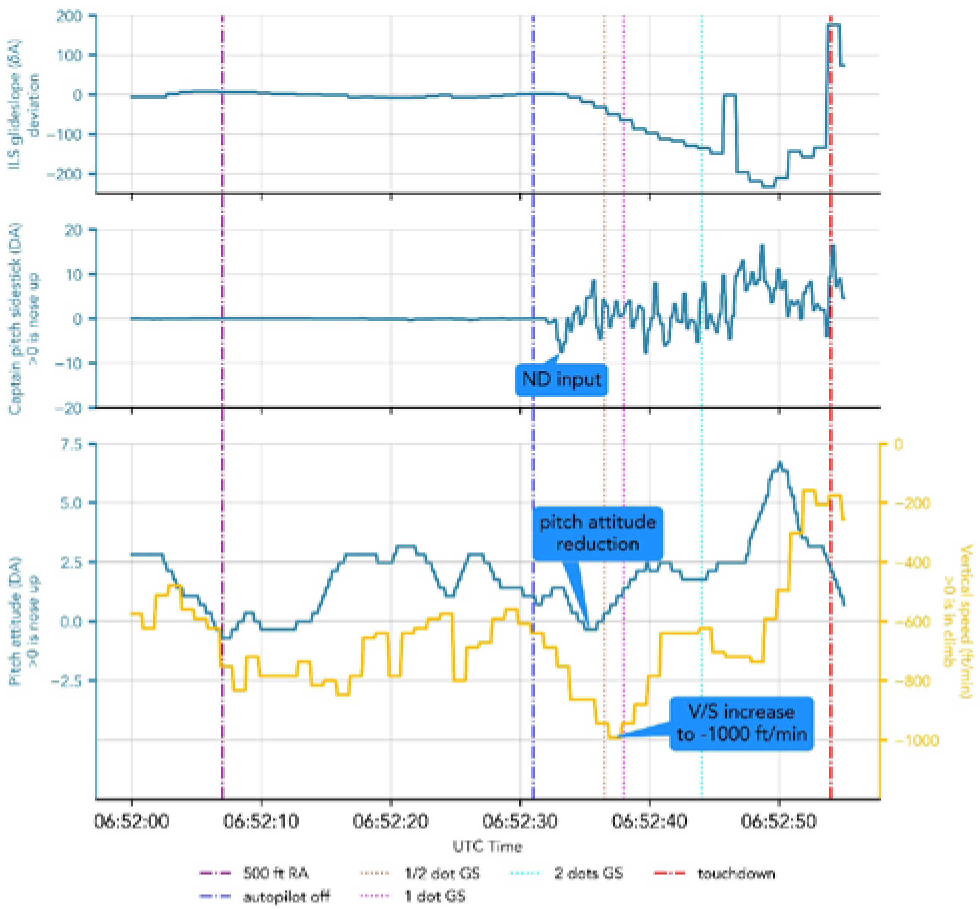
The airplane was equipped with a Honeywell 960-6022 Solid State Cockpit Voice Recorder (CVR) and a Honeywell 980-4700 Solid State Memory Flight Data Recorder (FDR). The CVR was designed to record at least 2 hours of digital audio, and the FDR was capable of recording at least 25 hours of digital flight data. Both recorders were removed from the aircraft and examined at the Dutch Safety Board's laboratory in The Hague, The Netherlands. The memory modules were downloaded using the Dutch Safety Board's hardware.

CVR
The CVR memory module was downloaded and contained audio recorded from multiple channels that captured audio from various sources in the cockpit, however, the audio from the approach and landing was not available. The CVR continued recording for more than two hours after the landing and in preparation for the subsequent flight, which led to the overwriting of audio of the incident.

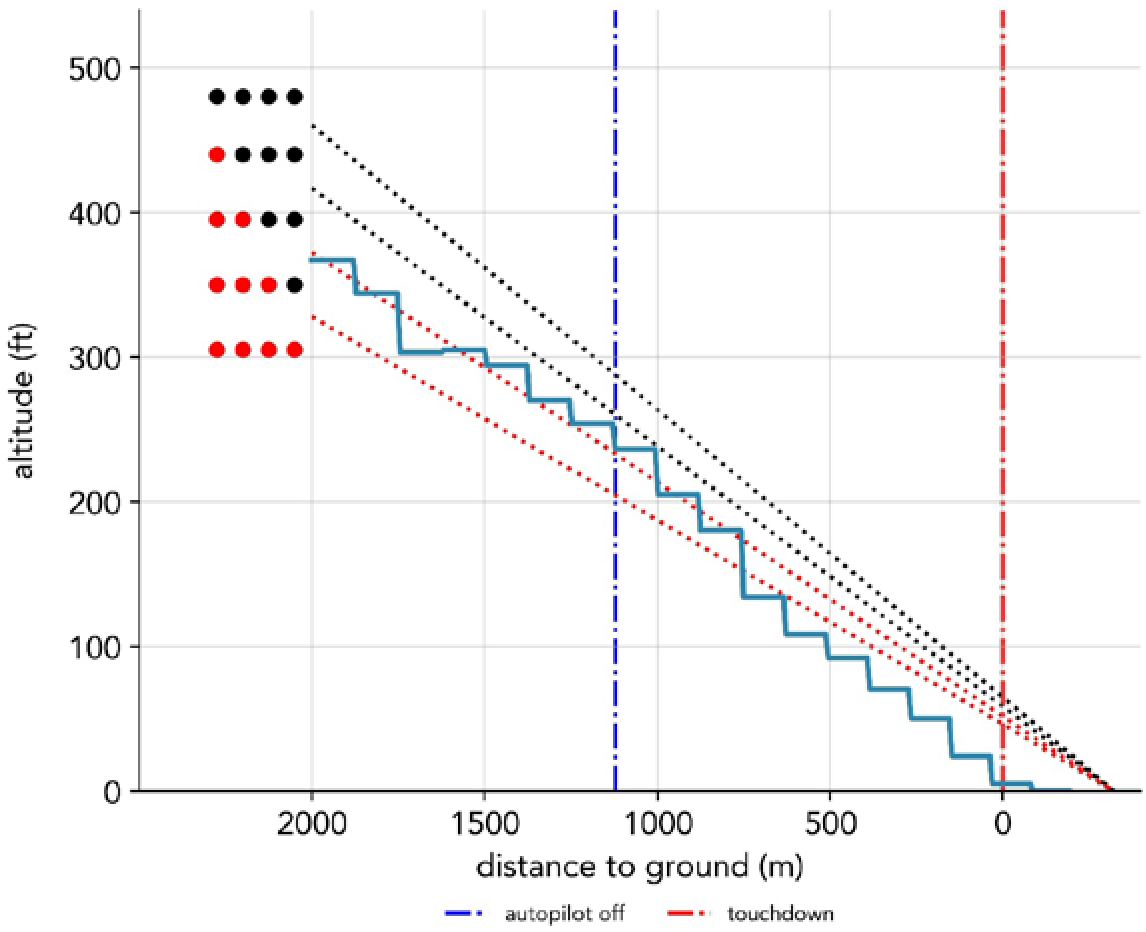
FDR
The FDR memory module contained the data of the entire incident flight and was analysed for this report.



▲ *Figure 10: FDR data prior to touchdown showing main landing gear compression (top graph) and the current CAS and speed target (bottom graph). (Source: FDR data and Airbus analysis)*



▲ *Figure 11: FDR data prior to touchdown showing ILS glideslope deviation (top graph), captain pitch of the sidestick (middle graph) and the pitch attitude and vertical speed (bottom graph). (Source: FDR data and Airbus analysis)*



▲ *Figure 12: FDR data of aircraft descent including the PAPI. (Source: FDR data and Airbus analysis)*

2.12 Operator information

The operator is one of the major airlines of the United States of America (USA). The airline has 936 aircraft of which 173 are wide-body aircraft, including 65 Airbus A330s. The airline has nine hubs in the USA, including Seattle and Detroit and serves over 300 destinations worldwide.

2.12.1 Standard Operating Procedures – Approach and Landing

Crewmember Roles

According to the operator's Flight Operations manual, flight crews must ensure effective flight path management and share responsibility to coordinate efforts to safely control the trajectory and energy state of the aircraft. Normally, the PF controls and monitors the aircraft's flightpath and the PM monitors the aircraft's flightpath and performs non-flightpath actions. If a third pilot is present, they monitor the flightpath and non-flight path actions. When flight parameters or flight path deviations are observed, they must be brought to the attention of the PF and an appropriate response must follow. The Flight Crew Training Manual states there are many reasons that one pilot may fail to alert another about an observed error. One reason might be an inexperienced pilot assuming the experienced pilot knows what he or she is doing.

Stabilized approach criteria
During approach, while in landing configuration, the stabilized approach criteria apply. In the Flight Crew Operating Manual, the operator defines a stabilized approach as maintaining a stable speed and thrust, and flying the correct lateral and vertical flight path (See Appendix E4).

Transition from ILS to PAPI
The operator's A330 Manual Volume 1 Paragraph 4.3.13, "Visual Approach Guide" states that if an underlying approach procedure, such as an ILS, is available it must be used.

- Note 1:
  When flying to a runway served by an instrument approach procedure with vertical guidance, operate the aircraft at an altitude at or above the glide path between the final approach fix and published DH. Use normal flight path management to remain at or above the glide path
- Note 2:
  If available, stay at or above the PAPI glide path until a lower altitude is necessary for a safe landing[27]

The operator's Flight Crew Training Manual states that a descent below the vertical guidance on a visual approach can expose the flight crew to threats such as obstacles and terrain.

Threshold Crossing Height
Threshold height is determined by the glide path angle and the targeted landing gear touchdown point. It is crucial to establish a final approach that ensures safe clearance over the threshold and enables gear touchdown at least 1,000 ft (300 m) down the runway. Pilots often use radio altimeters to gauge terrain clearance, threshold height, and the appropriate flare initiation height, especially if automatic callouts are not available.

Short runways
The operator defines a runway as short for Airbus A330 operations when the runway length is less than 9,000 ft (2,743 m)[28]. It operates scheduled flights to Kahului Airport's (PHOG) Runway 02 at 6,998 ft (2,133 m) and Amsterdam Airport Schiphol's Runway 22 at 6,627 ft (2,020 m). The operator restricts the use of Runway 22 at Amsterdam Airport and requires a minimum headwind of 20 knots for landing.

Factors affecting landing distance
Several factors influence the stopping distance during landing: mass, height and speed over the threshold, glide path angle, landing flare, transitioning the nose to the runway, reverse thrust, ground spoilers, wheel brakes, wind and runway surface conditions. Effective use of reverse thrust and ground spoilers during the high-speed portion of the landing, in combination with maximum manual antiskid braking, minimizes stopping distance. Excessive floating before touchdown should be avoided as it consumes a significant part of the runway. Additionally, the height of the aircraft over the runway threshold and the

27 Note 2 is specific to the Operator SOP and not present in the Manufacturer SOP.
28 Flight Operations Manual, Section on Takeoff and Landing

glide path angle have substantial impacts on total landing distance. A higher altitude over the threshold or flatter approach path can considerably increase the landing distance.

Training
At the time of the incident the operator did not provide short runway training to Airbus A330 pilots. Initial Operating Experience (IOE) training was provided to pilots new to flying the Airbus A330, which included specifics related to the aircraft. Some instructors included the Airbus A330 landing gear geometry in relation to the threshold crossing height, but this depended on the individual instructor and was not structurally included in the training the operator provided.

2.12.2 Fatigue Risk Management

Fatigue Risk Management Plan
The operator manages fatigue risk through a comprehensive Fatigue Risk Management Plan (FRMP), designed to identify and mitigate fatigue risks within their flight operations. This plan, as outlined in their Flight Operations Policies & Procedures, is a response to the Federal Aviation Administration's (FAA) regulations and a commitment to maintaining the highest standards of flight safety. The FRMP includes policies and procedures for managing fatigue risk, along with a detailed fatigue reporting policy and incident reporting process. Key elements of the plan include a strong focus on open communication and non-punitive reporting, encouraging flight crew members to report any conditions or actions that adversely affect fitness for duty.

Scheduling
The operator utilizes Title 14 Code of Federal Regulations Part 117 Flight and Duty Limitations and Rest Requirements and applicable FAA approved fatigue risk management system to schedule and manage flight time, duty periods, and rest.

2.13 Air Traffic Control information

Air Traffic Control the Netherlands (LVNL), is responsible for managing air traffic in the civil airspace of the Kingdom of the Netherlands and provides Air Traffic Control (ATC) at Dutch civil airports, including Amsterdam Airport Schiphol.

Preferential runway system
Under the Dutch Aviation Act of 2003, Schiphol Airport operates within a framework aimed at reducing environmental impacts, notably aircraft noise. The Preferential Runway Use system (See table 7) is a key component of this, designed to limit noise exposure around the airport. It dictates the usage of runway combinations based on their impact on surrounding areas.

The system adjusts to varying traffic demands: three runways during peak times, two outside peaks, and sometimes only one under specific conditions like extreme weather.

▼ *Table 7: Runway preference for the period 06.00 - 23.00 hrs local time when runway 18C/36C is out of use. (Source: Air Traffic Control The Netherlands)*

Preference	Landing 1	Landing 2	Start 1	Start 2
1	06	36R	36L	09
2	06	36R	09	36L
3	18R	27	24	18L
4	27	18R	24	18L
5	18R	22	24	18L
6	22	18R	24	18L

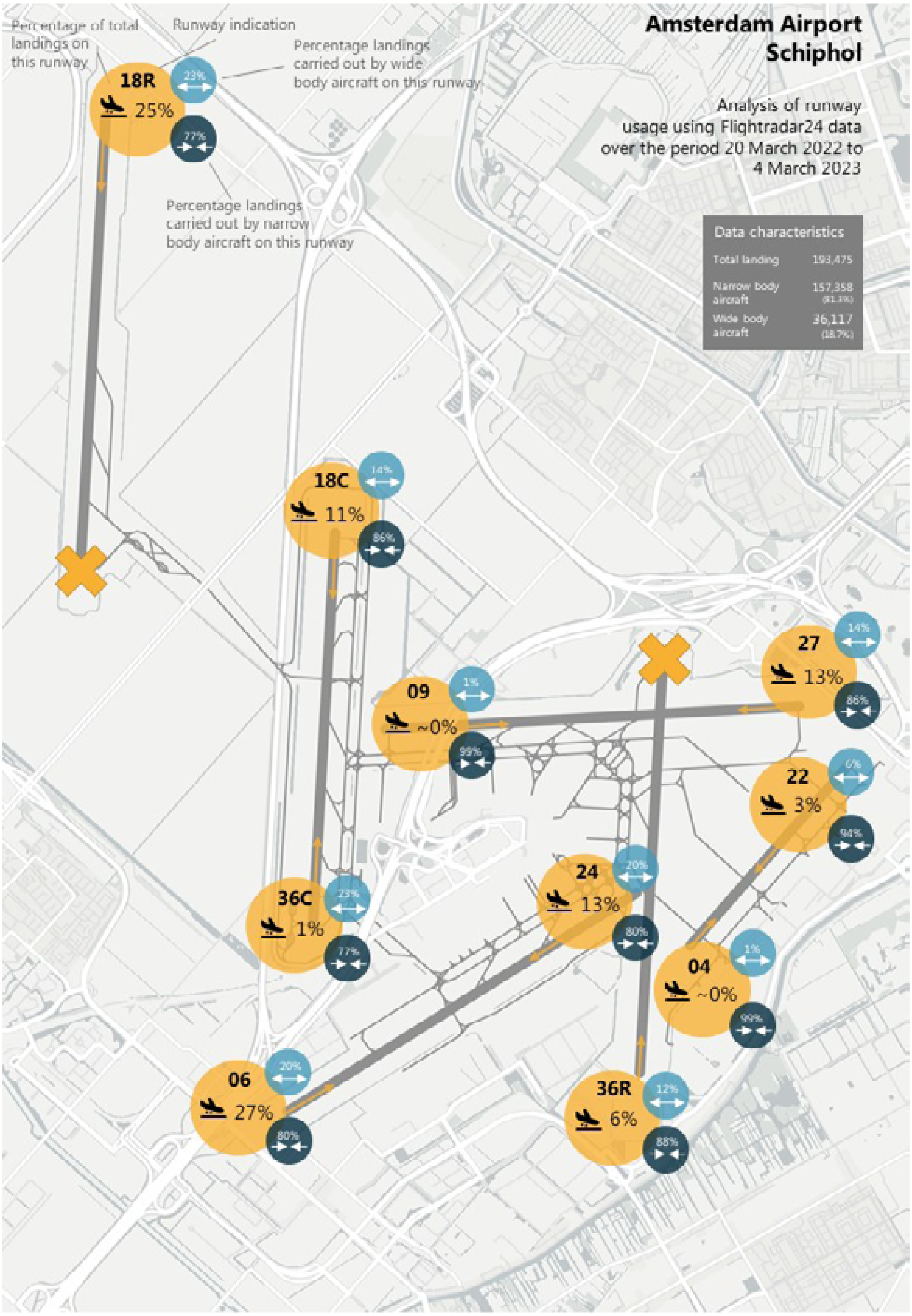
Coordinating Runway Usage
Amsterdam Airport Schiphol determines available runways, considering weather, traffic demands, and noise regulations. LVNL then applies the Preferential Runway Use schedule for selecting runways. For instance, during the arrival of the flight under conditions of strong winds and a low cloud base, a limited choice of runways was available, leading to the use of runway combination 18R and 22 for landing and 24 for takeoff.[29]

Crosswind Policy and Safety Considerations
LVNL's internal procedures specify maximum crosswind limits for primary and secondary landing runways. The limit for the primary runway is 20 knots and for the secondary it is 30 knots. On the day of the incident flight's landing, runway 22 was designated as the main landing runway based on these criteria.

At the time of the incident, wind conditions prevented LVNL from using 18R as the primary landing runway. Runway 27 could also not be used as the primary landing runway due to the fact that Runway 18R was the secondary runway used for landing. The reason for this is that in case of a Go-Around on Runway 27, LVNL needs to be able to separate traffic visually from traffic using Runway 18R, which at the time of the incident was not possible due to the low cloud base.

Specific Use of Runway 22
Runway 22 is typically used for non-scheduled traffic. However, within the Preferential Runway Use system, it is employed for reasons of traffic capacity, especially during peak hours. Its usage is limited and strategic: 3% of all traffic landing at Amsterdam Airport uses Runway 22, with approximately 6% of these landings being wide body aircraft (see figure 13).

29 Two landing runways were required during the inbound landing peak. Runway 27 could not be used for landing due to the low cloud base.

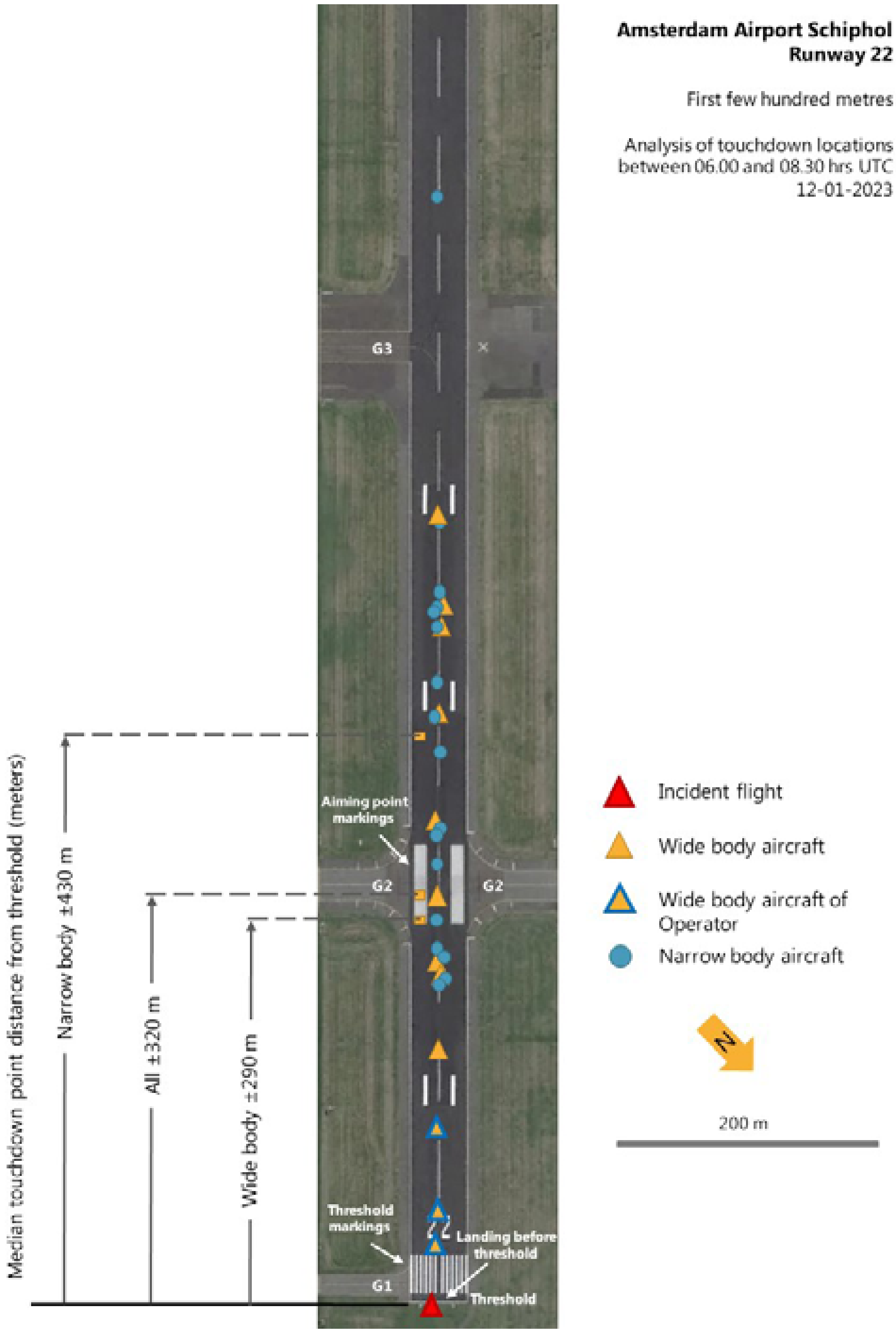


▲ *Figure 13: Runway use of Amsterdam Airport for landings in the period 20 March 2022 to 4 March 2023. (Source data: Flightradar 24)*

2.14 Additional information

Analysis on touch down point

Data from Runway 22 at Amsterdam Airport Schiphol indicates that a number of wide body aircraft by the operator, identifiable by the triangles with blue outlines, have touched down earlier than other aircraft in the same timeperiod (see figure 14). Although the dataset is limited, the possible pattern observed stands out from the broader landing data. This could suggest the need for a detailed review to determine the consistency of this pattern and to explore potential operational implications.



▲ *Figure 14: Touchdown point of all aircraft that landed on Runway 22 on 12 January 2023 between 6.00 and 8.30 hours.*

2.15 Post Incident Safety Actions

Training
As part of the operator's Continued Qualification (CQ) curriculum, short field landing techniques have been incorporated.

Risk management
The operator has implemented a new policy to mitigate the risks associated with landing on Runway 22. It has prohibited the use of Runway 22 for the Airbus A350 and A330 and Boeing B767 aircraft models.

Aeronautical information
The Aeronautical Information Publication (AIP) has been updated after the occurrence: The Minimum Eye Height over Threshold (MEHT) for Runway 22 at Amsterdam Airport Schiphol was changed from 62 to 48 ft. The Runway 22 light intensity was also changed from medium to high.

PAPI
On 15 November 2023, Amsterdam Airport Schiphol organized a check for Runway 22's PAPI (Precision Approach Path Indicator) to verify the angle settings and their compatibility with the ILS (Instrument Landing System).

The findings of this check, conducted using the NLR (Netherlands Aerospace Centre) research aircraft PH-LAB equipped with an Aerodata Flight Inspection system, confirm that the PAPI settings align with the values for angle setting and Minimum Eye Height over Threshold (MEHT) published in the Aeronautical Information Publication (AIP). The angle settings for each lamp conform to nominal settings, within acceptable tolerances. During an ILS approach to CAT I Decision Height (DH), the PAPI correctly indicated: 2 red and 2 white lights.

The compatibility of the PAPI with the ILS is partly dependent on the geometry of the aircraft used for measurement. The research aircraft PH-LAB falls into the category of aircraft with an Eye-to-Wheel Height (EWH) of less than 3 metres. For this class, conformity was verified, however these observations cannot necessarily be extrapolated to larger aircraft.

Key Findings:
The PAPI and ILS for Runway 22 were found to be compatible, with a particular focus on the transition from two red to three red lights.
The research aircraft used, PH-LAB, falls into the category with an EWH of less than 3 metres, confirming the PAPI's suitability for aircraft of this size, but not necessarily for larger aircraft.
The findings are consistent with established standards, with all measured values within regular tolerances.

3 ANALYSIS

3.1 Causes of Touchdown Before the Threshold

3.1.1 Initial Approach

The Airbus A330 flew a stabilized approach towards the Runway 22 touchdown zone following the Instrument Landing System (ILS) glideslope. Because the autopilot (AP) and autothrust (A/THR) were engaged, the flight path and speed were managed by the aircraft and it maintained the ILS glideslope. During the approach in managed speed, the Ground Speed Mini system functioned as designed. As soon as the aircraft descended below the clouds, the pilots could see the precision approach path indicator (PAPI), which indicated the aircraft was on the trajectory towards the touchdown zone (two red lights and two white lights). This trajectory would have the aircraft's main landing gear cross the Runway 22 threshold at six metres (19.72 ft) and touch down 110 m (362 ft) beyond the runway threshold in the touchdown zone.

> The initial approach trajectory followed the ILS glide slope towards a landing in the Runway 22 touchdown zone.

Despite being shorter than other runways at Schiphol, Runway 22's length of 2,020 metres was sufficient for an A330-300 landing. Calculation from the Landing Performance Request and Airbus confirmed this, accounting for a 15% safety margin.

> Runway 22 was long enough for the A330 in the circumstances to land on.

3.1.2 Manual Control and Trajectory Alteration

The flight crew's apprehension about Runway 22's length, perceived as short despite being adequate for an A330-300, influenced their approach strategy. The flight crew were particularly preoccupied with the potential for an overrun and focused more on speed management than maintaining the glide path. During an aircraft's landing, it carries an amount of energy based on its weight and speed. Excess speed has a higher influence on the landing distance than weight as the force required to stop the aircraft increases with the speed squared. It is therefore important to land at the appropriate speed. However, it is equally important to land at a point on the runway (in the touchdown zone) that leaves the aircraft sufficient runway to bring it to a stop before the end of the runway.

According to the operator's Flight Operations Manual, automatic landings are not authorized on category 1 ILS approach runways. After disengaging the autopilot at 240 ft radio altitude (RA), the captain manually controlled the aircraft's flight path using the sidestick. The A/THR was still controlling the aircraft's speed. The captain commanded a nose down input to the aircraft, leading to an increased vertical speed and descent below the ILS glideslope and PAPI glide path[30]. The ILS glide slope indications on the PFDs gradually changed to indicate the aircraft was two dots below the glide slope and the PAPI lights gradually changed from two red and two white lights, to three red and one white light and eventually four red lights. Despite correcting to necessary vertical speed for a 3 degree glide path, the aircraft did not recover from its below- glide-path position. The aircraft was now on a trajectory towards a touch down close to the Runway 22 threshold.

The aircraft descended below the glide path after the autopilot disconnection, because the flight crew focused more on speed management than on flightpath management, thereby compromising safety margins for preventing undershoots.

3.1.3 PAPI configuration

The precision approach path indicator (PAPI) system at Amsterdam Airport Runway 22 is designed for smaller aircraft. When it was installed in 1994, it met the existing criteria for aircraft commonly using Runway 22, such as general aviation traffic and the occasional Boeing 737.

Calculation of the minimum eye height over the threshold shows that the main landing gear of an Airbus A330-300 crosses the Runway 22 threshold at a height of 3.64 metres (11.95 feet). Therefore, the PAPI system did not provide guidance that aligned with larger wide body aircraft specifications. The Eye-to-Wheel Height (EWH) requirements for wide body aircraft dictate that the main landing gear wheels must cross the threshold at a minimum of six metres (19.7 feet).[31] This discrepancy reduces the safety margin when an Airbus A330-300 crosses the threshold on the minimum eye height over the runway threshold.

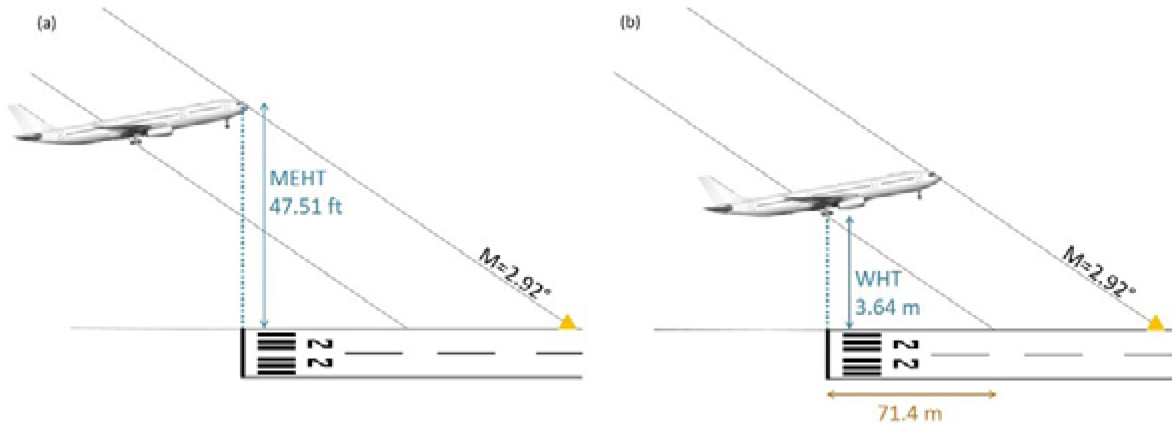
▼ *Table 8: The calculated values for the Airbus A330-300 Runway 22 height over threshold (THR) when following the PAPI glide path compared with the requirements.*

???		Runway 22 PAPI	ICAO/EASA EWH Cat 4 minimum height
Height over THR (ft)	Pilot's eyes	47.51	50.69[32]
Height over THR (ft)	Main Landing Gear	11.95	19.7

For the calculation of the Minimum Eye Height over Threshold (MEHT), one makes use of the lower bound of the designed 'on path' indication[33] minus a margin of 2 arc minutes. At Amsterdam Airport Runway 22, this results in a path of 2.92°. Therefore, the MEHT is equal to 47.51 ft, which is also visualised in figure 15. Now, subtracting the eye-path-to-

30 The aircraft flew within the Surveillance and Warning systems' boundaries and therefore, no warnings were generated.
31 According ICAO Annex 14 and EASA CS-ADR-DSN.M.650
32 Derived from EWH Cat 4 Aircraft MLG threshold crossing requirement
33 The lower bound of the designed 'on path' indication of the PAPI is 2° 57'.

wheel-path height from the MEHT for the Airbus A330-300, gives a value of 11.95 ft (3.64 m) for the height that the main landing gear crosses the threshold (WHT).



▲ *Figure 15 Airbus A330-300 descent at Amsterdam Airport Runway 22 indicating the Minimum Eye Height over Threshold (MEHT) and the Wheel Height over Threshold (WHT). Note: The figure is not drawn to scale and is intended for illustrative purposes.*

The PAPI system, originally configured for aircraft profiles common in 1994, does not align with the current ICAO and EASA criteria for the threshold crossing height of larger aircraft such as the A330-300. This discrepancy contributed to the reduced safety margin.

3.1.4 ILS configuration

The Instrument Landing System (ILS) of Runway 22 is more or less aligned with the PAPI system. The ILS has a glideslope of 3.12 degrees, which is close to the optimum of 3.0 degrees as recommended by ICAO[34]. The glideslope signal crosses the threshold at 46 feet, where ICAO recommends 50 ft.

As the Airbus A330-300 is a large aircraft, the vertical distance between the aircraft glide slope antenna and the path of the lowest part of the wheels when crossing the threshold is 28 feet instead of the basic assumption of 19 feet used in the ICAO standard. Therefore, the height over threshold of the main landing gear when a A330-300 follows the ILS glide slope is 19 feet, see Table 9.

34 3.1.5.1.2 Recommendation — The ILS glide slope angle should be 3 degrees. ILS glide slope angles in excess of 3 degrees should not be used except where alternative means of satisfying obstruction clearance requirements are impracticable.

▼ *Table 9: The calculated values for the Airbus A330-300 Runway 22 height over threshold (THR) when following the ILS glide slope compared to the requirements.*

A330-300		Runway 22 ILS	ICAO recommended minimum height
Height over THR (ft)	ILS antenna	46.5	50
Height over THR (ft)	Main Landing Gear	19.72	31[35]

The Runway 22 ILS configuration results in a threshold crossing height for an Airbus A330-300 that is lower than the ICAO standard.

3.1.5 Wind Gust and Downdraft Dynamics

Encountering a wind gust and downdraft at approximately 60 ft RA further altered the aircraft's trajectory. A negative longitudinal wind gust and small vertical down draft resulted in an indicated airspeed reduction and loss of lift. The captain felt the aircraft 'sink' and shortly after, commanded a nose up input to the aircraft to counteract the sinking of the aircraft and flare for touchdown. The A/THR adjusted the amount of thrust, however, it is designed to be less responsive to speed variations below 100 ft RA and avoid large thrust increases during the lower segment of the approach to prevent destabilization. Nevertheless, this did not change the trajectory of the aircraft enough in time and it touched down 11 metres (36 ft) before the Runway 22 threshold.

The aircraft encountered a wind gust and downdraft, which further altered its trajectory and resulted in the aircraft touching down before the threshold.

3.2 Role of the Runway in the Undershoot

3.2.1 Runway Length and Pilot Perception

The pilots were concerned about the length of the runway. Although the landing distance calculation indicated that safe landing using normal landing techniques could be made, they were concerned with the short length of the runway in relation to the landing distance required for an Airbus A330 and its approach speed. The operator's classification of the runway as short and the additional 20 knot headwind restriction to this runway, increased the pilot's risk perception. The pilots' experience with Runway 22 and shorter runways was limited, contributing to a heightened focus on managing approach speed.

Furthermore, the pilots were concerned about the approach speed calculated by the GS mini function of the A/THR, even though the GS mini function behaved the way it was designed. The pilots had never seen such a large speed increment of 24 knots on short final and were concerned they would cross the threshold with an excess of speed. As excess speed during the landing translates directly into a longer landing distance, the pilots

35 Based on ICAO assumption of 5,8 ILS beam to wheel height.

were concerned that the speed increment would not be reduced before crossing the threshold.[36] This further increased the pilots' focus on speed in order to prevent a runway overshoot.

> The pilots' attentional resources to switch focus were reduced due to their concern about the correct functioning of the GS mini system, the operator's classification of the runway as short, and the limited experience landing on short runways. The pilots therefore focused more on speed management than flight path management.

3.2.2 Runway use by wide body aircraft

In 2011, Runway 22 was completely resurfaced and strengthened which allowed larger aircraft (including the Airbus A330-300) to land. The original ILS and PAPI systems that were installed in 1994 and designed for smaller aircraft, remained unchanged. Even though only 1% of all wide body aircraft landing at Amsterdam Airport use Runway 22, the ILS and PAPI system's design for aircraft with a significantly smaller Eye-to-Wheel Height than the Airbus A330-300 led to a reduced safety margin to the appropriate threshold crossing height of the main landing gear wheels.

> Runway 22's ILS and PAPI systems do not provide sufficient wheel clearance for wide body aircraft like the Airbus A330-300.

3.2.3 Lighting Systems

Runway 22 is certified as a non-precision approach runway. Differing notably from Amsterdam Airport's precision approach runways. It has a short approach lighting system of 450 meters, without touchdown and centerline lighting. The runway's distinct lighting features in combination with the featureless terrain surrounding the airport, especially in low light or adverse weather conditions could contribute to a black hole illusion (BHI), which might have contributed to the depth perception challenges. This potentially influenced the pilot's judgment of the correct approach altitude.

As Runway 22 occasionally serves as the main landing runway, especially under certain weather scenarios, its limitations are brought into sharper focus. In such context, the runway's subpar lighting infrastructure presents additional risks.

> Runway 22's fewer lighting systems, compared with Amsterdam Airport's other main landing runways, could have contributed to the occurrence.

36 GS mini logic reduces target speed to V_{app} near T/D. Flight data analysis showed that speed increase by the GS mini function was reduced to zero at touch down.

3.3 Human Factors Contributing to the Occurrence

3.3.1 Collective Decision Dynamics

The approach strategy adopted by the crew, influenced by an implicit understanding, aimed at ensuring a safe touchdown within the constraints of perceived runway overrun risks. The pilot flying, without explicitly communicating his intent, initiated a descent below the glide path. From the interviews after the event, it became clear that the monitoring pilots, adhering to common practice on shorter runways, did not vocalize any deviations, assuming the pilot flying's strategy was deliberate. This scenario underscores the importance of explicit communication and decision-making within the cockpit, especially under unconventional operational circumstances.

Aiming for an earlier touchdown is not an uncommon practice on shorter runways; the pilots did not vocalize the deviation when the aircraft descended below the glide path.

3.3.2 Use of Information regarding Threshold Crossing Height

Wide-body aircraft, such as the Airbus A330-300, should not follow Runway 22's PAPI glide path, because it does not provide sufficient wheel clearance. This can be can be determined from the Eye-to-Wheel Height (EWH), which is available in the Airbus flight manual, combined with the minimum eye height over the threshold (MEHT) from by the PAPI system, which is available in the Aeronautical Information Publication (AIP). Despite the availability of this information, pilots frequently rely on the PAPI system's design and regulatory approvals for navigation aids, assuming these are adequate to mitigate risks associated with the aircraft's approach and landing clearance. The continued use of this runway by other wide-body aircraft operators (approximately 360 landings yearly) indicates the need for additional mitigating measures.

In practice, flight crews do not calculate wheel clearance over the threshold when a PAPI system is in place, relying instead on the system's design and regulatory approval. This may have contributed to the occurrence.

3.3.3 Analysis of Fatigue Factors

Analysis (See Appendix E) suggests that both the captain and augmented first officer may have been affected by fatigue to some extent, impacting their cognitive functions, such as attention, and vigilance during the critical approach and landing phases of flight. The dissonance between the crew's natural circadian rhythms and the timing of the flight possibly exacerbated the fatigue, influencing their decision-making and reaction times.

Information for the analysis was derived from the flight schedules and the interviews. During the reviewing process several fatigue risk factors were identified that were present at the time of the landing. The landing of this flight took place after a flight through the night. The captain was awake for 18 hours and 22 minutes. His circadian rhythm was desynchronized as the landing in AMS occurred at 01.52 Detroit time. The augmented first officer had five to six hours of sleep in the 24 hours prior to the event. A sleep debt of

2.5 to 10 hours was built up in five days. The augmented first officer was awake for 16 hours 47 minutes and his circadian rhythm was desynchronized.

Both the captain and the augmented first officer may have been fatigued to a certain degree at the time of the occurrence. The augmented first officer confirmed, during post incident interviews that he felt fatigued. It is considered that fatigue - a known challenge in long-haul operations, particularly for the pilot monitoring - may have had some impact on the flight crew's general cognitive functioning, such as reaction time, attention and vigilance.

> Fatigue may have been a contributing factor in the occurrence.

3.4 Operator's Risk Management

3.4.1 Crew Training and SOP Interpretation

The operator's SOPs contain some ambiguities regarding flying under the glide path. The SOPs allow transitioning to visual approaches using the PAPI, yet they do not provide explicit guidance on adjusting descent in the final approach phase when below the glide path, especially critical for short runways. The operator's guidance on how to fly a stabilized approach in the Flight Operations Manual (FOM) could be interpreted as contradictory for the situation when both an ILS and a PAPI system are present. The notes (See Appendix D.7) might give the impression that a descent below the glide path is allowed or even desired in order to make a safe landing.

Enhanced training on the interpretation of visual approach guides could further align crew operations with existing operator SOPs, reducing room for variability in approach execution. Furthermore, short runway training to Airbus A330 pilots could increase pilots' experience with short runways.

> The ambiguities in the operator's SOPs, especially regarding descent below the glide path, coupled with the crew's limited experience with Runway 22 and limited specific training for landing on short runways, led to deviations from standard procedures.

3.4.2 Touchdown point analysis

The Dutch Safety Board's analysis of touchdown points on Runway 22 on 12 January 2023 reveals a noteworthy possible pattern. Between 06.00 and 08.30 hours, several aircraft from the same operator stand out with touchdown points closer to the Runway 22 threshold than touchdown points from other operators. Without investigating these events, it is difficult to determine whether they are exemplary or the exception. However, due to the associated undershoot risk, further study of the operator's use of short runways seems prudent.

> It stands out that several of the operator's aircraft landed close to Runway 22's threshold.

3.4.3 Rostering

Crew pairing and working relationships in aviation involve the scheduling and interaction dynamics among flight crew members. In this scenario, a typical crew rotation for a long-haul flight includes a captain and a first officer, with an additional first officer added as a relief pilot to extend the legal duty work period, known as the flight duty period (FDP). This augmented first officer, designated for rest and work regulations, may have a different rotation schedule than the basic crew for efficiency reasons.

In the incident flight, the crew consisted of one captain and two first officers, with the captain and one first officer based at Detroit (DTW), while the augmented first officer was based at Seattle (SEA). The rotation for the captain and DTW-based first officer started at DTW, whereas the augmented first officer's rotation began in SEA, including previous flights to Amsterdam (AMS) and back to DTW. Due to a late arrival at DTW, the augmented first officer missed the initial crew briefing and only caught up with the team at the aircraft. This delay meant he missed the opportunity to establish a working relationship with the other crew members during the briefing.

The flight to AMS was led by the captain as the pilot flying, and the crew's rest schedule was discussed and arranged. Typically, the pilot flying the landing takes the middle break, and the pilot monitoring both takeoff and landing takes the last break, leaving the first break for the augmented first officer. However, for the augmented first officer, already fatigued from his ongoing rotation and sleep debt, taking the first rest break might not allow him to be adequate rested for the landing.

The Flight Operations Manual (FOM) underlines that rest break scheduling should be flexible and based on crew needs, with a focus on the alertness of the landing pilot. Despite not sleeping during his rest period, the augmented first officer felt fit enough to act as the Pilot Monitoring (PM) for the landing in AMS. This situation also allowed some time for the pilots to familiarize themselves with each other's experience and capabilities, albeit briefly, before the approach and landing in Amsterdam. This interaction revealed that while the captain was experienced with Airbus aircraft, he had limited experience with the A330 and Amsterdam airport, important information for the crew's situational awareness and operational safety.

> Rest break scheduling is typically focused on needs of the pilot flying for landing, underestimating the need for managing fatigue of all flight crew members.

4 CONCLUSIONS

On 12 January 2023, the crew of an Airbus A330-300, in an attempt to mitigate the perceived risk of an overrun on Runway 22 at Amsterdam Airport Schiphol, inadvertently increased the risk of an undershoot. This contributed to the aircraft touching down before the threshold.

The psychological impact of landing on a seemingly short runway under adverse conditions, without specific training, likely led to a subconscious effort to land as early as possible. The crew therefore, focused more on speed control over maintaining the glide path, and descended below the published glide path as they perceived an overrun as a greater threat than an undershoot. This imbalance between the risk of a runway overrun and an undershoot, and additional operator-imposed constraints, skewed their risk assessment. By continuing below the glide path, the crew eliminated critical safety margins.

Fatigue may have influenced the crew's performance, particularly in controlling and monitoring the aircraft's flight path, though the exact extent remains uncertain.

After the occurrence, the operator incorporated short field landing techniques in the training program. However, there is an opportunity for the operator to enhance their training programs and SOPs to include specific guidance for threshold crossing height and landing performance on shorter runways for wide body aircraft. The operator also prohibited landing on Runway 22 at Amsterdam Airport Schiphol, however, this investigation suggests that the operator may need to evaluate threshold crossing height and runway suitability for different aircraft types at other runways to effectively mitigate risks that played a role in this incident. Multiple early touchdowns on Runway 22 by the same operator on that day reveals a possible pattern that warrants further study.

While Runway 22 was adequately long for the Airbus A330-300, the configuration of the instrument landing system (ILS) and precision approach path indicator (PAPI) system were optimized for smaller aircraft like the B737, and did not meet ICAO and EASA standards for an Airbus A330-300 with regard to the recommended minimum wheel height over the threshold. The mismatch between the PAPI and the size of the aircraft left insufficient margin for unexpected deviations, which – combined with wind gusts and pilot reactions, caused the Airbus A330 to land before the threshold.

5 RECOMMENDATIONS

While Runway 22 at Amsterdam Airport Schiphol is structurally capable of accommodating the landing of an Airbus A330, the configuration of the instrument landing system (ILS) and precision approach path indicator (PAPI) system offers insufficient threshold crossing clearance for large and long aircraft. The ILS and PAPI do not meet ICAO and EASA standards for Eye-to-Wheel Height Category 4 aircraft. The minimum eye height over the threshold (MEHT) is published in the aeronautical information publication (AIP), giving operators the opportunity to assess whether the runway is suitable for landing with their aircraft. However, the continued use of the runway by Eye-to-Wheel Height Category 4 aircraft of other operators is evidence that the risk of crossing the runway threshold at a low altitude is not sufficiently mitigated.

The Dutch Safety Board therefore makes the following recommendation:

To Amsterdam Airport Schiphol:

Restrict the use of Runway 22 for Eye-to-Wheel Height Category 4 aircraft landings, until adjustments have been made to ensure the minimum threshold clearance for such aircraft can be achieved.

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:

- Delta Air Lines
- Captain
- Augmented First Officer
- First Officer
- Air Traffic Control the Netherlands (LVNL)
- Airbus
- Amsterdam Airport Schiphol
- Ministry of Transport and Water Management
- EASA
- BEA
- NTSB

The responses received were processed in the following way:

- If the Dutch Safety Board decided to adopt responses, they were amended into the final version of the report
- If the Dutch Safety Board did not adopt responses, an explanation is given of why it decided to do so

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 (safetyboard.nl).

APPENDIX A
AIRCRAFT SYSTEMS INFORMATION

A.1 Windshear detection and avoidance

The A330 is equipped with a two multiscan weather radar systems with a Predictive WindShear function that operates when the aircraft radio height is below 2,300 ft. The system scans the airspace for windshear within a range of 5 Nautical Miles ahead of the aircraft. Below 1,300 ft, when the system detects windshear, it alerts the pilots. During landing, alerts are inhibited below 50 ft. The weather radar system provides weather, turbulence, ground mapping, and predictive windshear displays. The A330 FCOM states: *"Predictive windshear detection is also available independent of the weather radar display. The predictive windshear function uses the Doppler effect to detect windshear conditions in front of the aircraft during takeoff and landing. Moisture must generally be present for windshear to be detected; however, tests have indicated that dust and other particulate matter present in dry microbursts may also be able to provide sufficient radar returns for alerts to trigger. The radar analyzes the velocity and direction patterns in the reflected signal and generates an alert when certain criteria are met. Three levels of alert are available: advisory, caution, and warning, depending on proximity of the windshear to the aircraft."*

The system is operational when the following conditions are met:

- The PWS (Predictive Wind Shear) switch is in the AUTO position
- The aircraft is below 1,300 ft AGL
- The radar is selected on or the takeoff has begun (acceleration sensed or ground speed above 30 knots)

A windshear detection signal is generated whenever the aircraft encounters a windshear and the predicted energy level falls below a predetermined safe minimum energy threshold (reactive windshear detection).
Note: The energy threshold is expressed as an angle of attack threshold αo.
The aircraft predicted energy level is $\alpha + \Delta\alpha$ where:

- α is the current angle of attack
- $\Delta\alpha$ is the equivalent AOA computed from measured vertical drafts and longitudinal shears

If $\alpha + \Delta\alpha > \alpha o$ the windshear conditions are detected.

The windshear detection function is provided in takeoff and approach phase under the following conditions:

- At takeoff, 3 s after liftoff, up to 1,300 ft RA
- At landing from 1,300 ft RA to 50 ft RA
- With at least CONF 1 selected

The warning consists of:

- A visual "WINDSHEAR" red message displayed on both PFDs for a minimum

In the FCTM the crew can find more information on detecting windshear conditions. *"Unacceptable flight path deviations are recognized as uncontrolled changes from normal steady-state flight conditions below 1,000 ft AGL, in excess of any of the following:*

- *15 knots indicated airspeed*
- *500 fpm vertical speed*
- *5° pitch attitude*
- *1 dot displacement from the glideslope."*

A.2 EGPWS

The purpose of the Enhanced Ground Proximity Warning System (EGPWS) is to warn the flight crew of potentially hazardous situations, such as a collision with terrain. It detects terrain collision threats and triggers applicable aural and visual indications.

The GPWS includes:

- Five basic modes active up to radio height of 2,500 ft:
  - Excessive rate of descent (Mode 1)
  - Excessive terrain closure rate (Mode 2)
  - Altitude loss after takeoff or go-around (Mode 3)
  - Terrain clearance not sufficient, if not in landing configuration (Mode 4)
  - Excessive descent below the glide slope (Mode 5)

Mode 1 triggers aural and visual alerts about excessive rates of descent, based on the radio height, and the rate of descent of the aircraft.
Mode 5 triggers aural and visual alerts, when the aircraft descends below the glideslope.

APPENDIX B
METEOROLOGICAL INFORMATION

TAFs

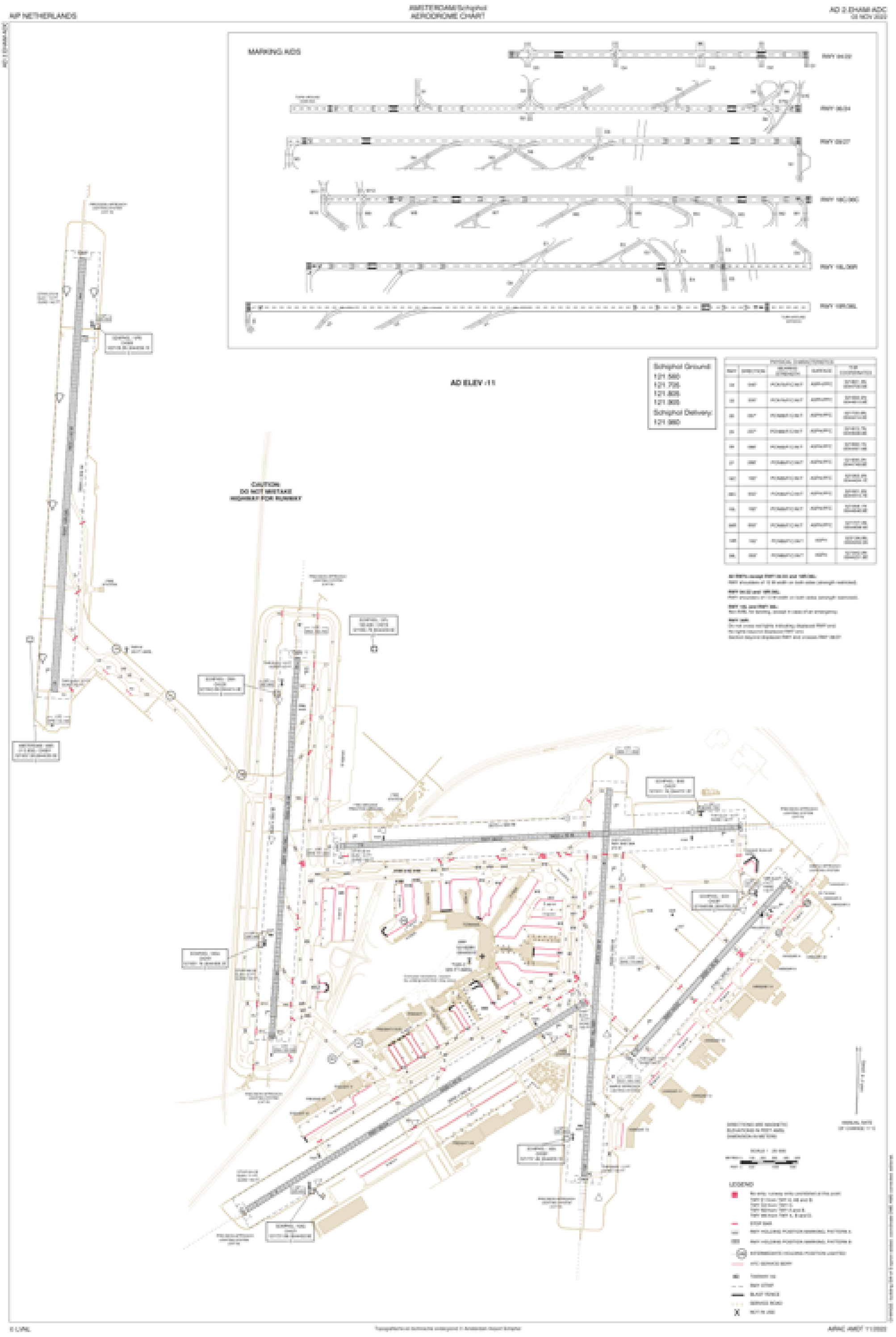
EHAM 111709Z 1118/1224 21017G27KT 9999 FEW022 TEMPO 1118/1122 23025G35KT 5000 SHRA RA SCT018CB BKN020 PROB30 TEMPO 1119/1122 25027G40KT 3000 TSRA SCT015CB BKN018 BECMG 1200/1203 6000 RA SCT008 BKN014 BECMG 1203/1206 24025G40KT TEMPO 1203/1207 4000 BKN008 BECMG 1206/1208 9999 NSW BKN025 BECMG 1209/1212 23020G30KT BECMG 1212/1215 6000 RA SCT008 BKN014 BECMG 1218/1221 25022G32KT 9999 NSW SCT022 PROB30 TEMPO 1219/1222 7000 -SHRA FEW018CB BKN022

EHAM 112321Z 1200/1306 23015G25KT 9999 BKN030 BECMG 1200/1203 6000 RA SCT008 BKN014 BECMG 1203/1206 24025G40KT TEMPO 1203/1207 4000 BKN008 BECMG 1207/1209 23022G32KT 9999 NSW BKN025 PROB40 TEMPO 1209/1212 7000 RA BKN014 BECMG 1212/1215 6000 RA SCT008 BKN014 TEMPO 1215/1219 4000 RADZ BKN008 BECMG 1219/1222 9999 NSW SCT022 PROB30 TEMPO 1219/1222 7000 -SHRA FEW018CB BKN022

EHAM 120507Z 1206/1312 24025G40KT 6000 RA BKN014 BECMG 1206/1209 24022G32KT 9999 NSW BKN025 TEMPO 1206/1209 4000 DZRA BKN008 PROB40 TEMPO 1209/1212 7000 RA BKN014 BECMG 1212/1215 6000 RA SCT008 BKN014 TEMPO 1215/1219 4000 RADZ BKN008 BECMG 1219/1222 9999 NSW SCT022 PROB30 TEMPO 1219/1222 7000 -SHRA FEW018CB BKN022 PROB40 TEMPO 1308/1312 7000 -SHRA FEW018CB BKN022 BECMG 1309/1312 26024G37KT

APPENDIX C AIP NETHERLANDS

C.1 Amsterdam/Schiphol Aerodrome Chart



C.2 Runway Physical Characteristics

Designations RWY NR	True BRG	Dimensions of RWY (M)	Strength (PCN) and surface of RWY and SWY	THR co-ordinates RWY end co-ordinates THR GUND	THR elevation and highest elevation of TDZ of precision APCH RWY
22	221.27˚	2,020 x 453	79/F/C/W/T ASPH/PFC[1, 2, 4]	521850.51N 0044810.89E 521801.38N 0044700.60E 142 FT	-13.7 FT -12.1 FT
18R	183.20˚	3,800 x 60	89/F/C/W/T ASPH[1, 2]	522136.93N 0044242.21E 521942.89N 0044231.81E 142 FT	-13.0 FT -13.2 FT

Designations RWY NR	Slope of RWY-SWY	SWY dimensions (M)	CWY dimensions (M)	Strip dimensions (M)	RESA dimensions (M)	Location and type of arresting system	OFZ
22	< 0.01%	NIL	60 x 150	2,140 x 300	180 x 90	NIL	NA
18R	0.01%	NA	NA	3,920 x 300	240 x 120	NIL	NA

1. Regarding RWY strength, an unlimited use will be permitted for aircraft with an AUW ≤ 5700 KG
2. RWY shoulders of 7.5 M width on both sides (strength restricted)
3. RWY 04/22 prohibited for ICAO/EASA code letter F aircraft
4. RWY 04/22, 06/24, 09/27 and 18L/36R prohibited (landing and takeoff) for aircraft with a MTOM exceeding 600.000 KG due to insufficient load bearing capacity of related runway and taxiway bridges

C.3 Declared Distances

RWY Designator	TORA (M)	TODA (M)	ASDA (M)	LDA (M)
22	2,015	2,075	2,015	2,020
18R	NU	NU	NU	3,530[1]

1. DTHR 270 metres

C.4 Approach and Runway Lighting[37]

RWY Designator	APCH LGT type, length, INTST	THR LGT colour, WBAR	VASIS (MEHT) PAPI	TDZ LGT length	RWY centre line LGT length, spacing, colour, INTST	RWY edge LGT length, spacing, colour, INTST	RWY end LGT colour, WBAR	SWY LGT length, colour
22	SALS 450 M LIM	G -	PAPI left/3° (62 FT)	NIL	NIL	2,020 M 50 M[1] W/Y LIM	R -	NIL
18R	CAT III 900 M LIH	G -	PAPI left/3° (70 FT)	900 M	3,800 M 15 M[2] LIH	3,800 M 60 M[3] LIH	R -	NIL

1. RWY 04/22: irregular interval between edge LGT at intersection with TWY G3
2. RCLL
   White from THR to 900 M before RWY-end;
   White/red from 900 M before RWY-end to 300 M before RWY-end;
   Red from 300 M before RWY-end to RWY-end
3. REDL
   Red from beginning of RWY to DTHR;
   White from DTHR to 600 M before RWY-end;
   Yellow from 600 M before RWY-end to RWY-end

37 Information from AIP the Netherlands current at January 11th 2023

APPENDIX D OPERATOR STANDARD OPERATING PROCEDURES FOM

D.1 Flight Path Management

Flight Path Management (FPM) is the planning (clearance), execution (control), and assurance (monitoring) of the guidance and control of aircraft trajectory and energy, in flight or on the ground. Crews are responsible at all times to know where the flight path is (clearance), to put the aircraft there (control), and to keep it there (monitor).

To achieve the highest level of safety, all flight deck crewmembers must ensure effective flight path management (EFPM) is their primary and shared responsibility during all phases of flight.

EFPM is achieved when crewmembers have a shared mental model of the clearance, proactively coordinate efforts to safely control the trajectory and energy state of the aircraft, anticipate changes to the flight path, and trap flight path errors through monitoring before they become flight path deviations.

D.2 Crewmember Roles and Responsibilities

The PF's primary responsibility is to control and monitor the aircraft's flight path (including autoflight systems, if engaged). The PF is secondarily responsible for monitoring non-flight path actions (radio communications, aircraft systems, other crewmembers and other operational activities) but he must never allow this to interfere with his primary responsibility, controlling and monitoring the flight path.

The PM's primary responsibility is to monitor the aircraft's flight path (including autoflight systems, if engaged) and to immediately bring any concern to the PF's attention. The PM is secondarily responsible for accomplishing non-flight path actions (radio communications, aircraft systems, other operational activities, etc.) but he must never allow this to interfere with his primary responsibility, monitoring the flight path.

During critical phases of flight, high workload or areas of vulnerability (AOVs), the Relief Pilot(s)' primary responsibility is to monitor the aircraft's flight path (including autoflight systems, if engaged) and to immediately bring any concern to the PF's attention. The Relief Pilot is secondarily responsible for monitoring non-flight path actions (radio communications, aircraft systems, other operational activities, etc.).

D.3 Fatigue Risk Management

Flight time and flight duty period limitations and rest requirements must be scheduled in accordance with FAR Part 117. Pilots and the Company have joint responsibility to ensure that a pilot does not fly a flight segment for which they are illegal due to flight time, flight duty period, and/or rest requirements. The operator has automation in place to monitor legalities.

Rest breaks are the primary method for mitigating in-flight fatigue and enhancing pilot alertness. The senior captain is charged with coordinating and assigning flight deck duties and rest breaks.

Rest break scheduling is intended to be flexible and crew-needs based, as discussed during the preflight briefing. The primary concern is the alertness of the landing pilot.

Each pilot will take advantage of available in flight rest opportunities.

Equal rest breaks may not be possible or desirable, depending on crew augmentation level (e.g., three vs. four pilots) and FAR Part 117 requirements.

Standard Operating Procedures FCOM

D.4 Stabilization Criteria

The stabilization height is defined as one of the following:

- 1,000 ft above airfield elevation (AAL) in Instrument Meteorological Conditions (IMC), or
- 500 ft above airfield elevation (AAL) in Visual Meteorological Conditions (VMC), or
- Any other height defined in Operator policies or regulations

In order for the approach to be stabilized, all of the following conditions must be satisfied before, or at the stabilization height:

- The aircraft is on the correct lateral and vertical flight path
- The aircraft is in the desired landing configuration
- The thrust is stabilized, usually above idle, and the aircraft is at target speed for approach

Note: In IMC, a later speed and thrust stabilization can be acceptable provided that:

- It is in accordance with Operator policies and regulations
- The aircraft is in deceleration toward the target approach speed
- The flight crew stabilizes speed and thrust as soon as possible and not later than 500 ft AAL

- The flight crew does not detect any excessive flight parameter deviation

If one of the above-mentioned conditions is not satisfied, the flight crew must initiate a go-around, unless they estimate that only small corrections are required to recover stabilized approach conditions.

D.5 Monitoring flight parameters

The PF announces any FMA modification

The PM calls out, if:

- The speed goes lower than the speed target -5 kt, or more than the speed target +10 kt
- The pitch attitude goes lower than 0˚, or more than +10˚ nose up
- The bank angle becomes more than 7˚
- The descent rate becomes more than 1,200 ft/min

Following PM flight parameter exceedance callout, the suitable PF response will be:

- Acknowledge the PM callout, for proper crew coordination purposes
- Take immediate corrective action to control the exceeded parameter back into the defined stabilized conditions
- Assess whether stabilized conditions will be recovered early enough prior to landing, otherwise initiate a go-around

The PM calls out if excessive deviation occurs:

- LOC: ½ dot
- G/S: ½ dot

Standard Operating Procedures FCTM

D.6 Vertical Guidance On a Visual Approach

Descending prematurely below the 3:1 path or the vertical guidance on a visual approach can expose the crew to threats such as obstacles and terrain. If below a 3:1 descent profile/vertical guidance, climb to re-establish the desired descent profile/vertical guidance or execute a go-around.

D.7 Landing Geometry

Visual Aim Point

During visual approaches many techniques and methods are used to ensure main landing gear touchdown at the desired point on the runway. One of the most common methods used is to aim at the desired gear touchdown point on the runway, then adjust the final approach glide path until the selected point appears stationary in relation to the aircraft (the point does not move up or down in the pilot's field of view during the approach).

This method is acceptable in smaller aircraft because of the small difference between landing gear path and eye level path. Flare distance accounts for the small difference in paths. Gear touchdown occurs very near the visual aim point. However, in larger aeroplanes, the difference in gear path and eye-level path has increased because of the longer wheelbase and the increased flight deck height. Consequently, the main gear do not touch down on the runway at the selected visual aim point.

The main gear touchdown point versus the visual aim point varies with the angle of the approach. For example on a low angle or flat approach, the gear will touch down much closer to the approach end of the runway given the same visual aim point on the runway. This difference between gear path and eye level path must be accounted for by the pilot.

Threshold Height
Threshold height is a function of glide path angle and landing gear touchdown target. Special attention must be given to establishing a final approach that assures safe threshold clearance and gear touchdown at least 1,000 ft down the runway. If automatic callouts are not available, the radio altimeter should be used to assist the pilot in judging terrain clearance, threshold height, and flare initiation height.

Factors Affecting Landing Distance
Factors that affect stopping distance include: height and speed over the threshold, glide slope angle, landing flare, lowering the nose to the runway, use of reverse thrust, ground spoilers, wheel brakes, and surface conditions of the runway.

- Note 1:
  Reverse thrust and ground spoiler drag are most effective during the high speed portion of the landing. Activate reverse thrust with as little time delay as possible after MLG touchdown
- Note 2:
  Ground spoilers fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking provides the minimum stopping distance

Floating above the runway before touchdown must be avoided because it uses a large portion of the available runway. The aircraft should be landed as near the normal touchdown point as possible. Deceleration rate on the runway is approximately three times greater than in the air.

Height of the aircraft over the runway threshold also has a significant effect on total landing distance. For example, on a 3° glide path, passing over the runway threshold at 100 ft altitude rather than 50 ft could increase the total landing distance by approximately 950 ft. This is due to the increased runway used before the aircraft actually touches down.

Glide path angle also affects total landing distance. As the approach path becomes flatter, even while maintaining proper height over the end of the runway, total landing distance is increased.

D.8 Monitoring
Monitoring the flight path, the last core CRM skill and the final element of flight path management, is clearly identified as a primary task for all crewmembers, refer to FOM - Flight Ops Manual Section 4.3 Flight Path Management. Yet in virtually every ASAP report of a flight path deviation, inadequate monitoring has been identified as a root cause. As important as stick and rudder control, monitoring is an essential skill to maintain SA and prevent flight path deviations. For this reason, monitoring is covered here in more detail than any of the other core CRM skills.

Monitoring is generally defined as adequately watching, observing, keeping track of, or cross-checking. That definition adequately describes the observe function of monitoring, but is insufficient for aviation purposes. Simply stated, observing without challenging is ineffective if the PM does not say anything about observed deviations. Similarly, monitoring is ineffective if the PF does not respond appropriately.

There are many reasons that one pilot fails to alert another about an observed error. One common reason has been identified within the Communications CRM skill as the power distance that exists between captains and first officers. Another might be an inexperienced pilot assuming the experienced pilot knows what he or she is doing. Regardless, all inhibitions must be overcome and observed deviations must be verbalized as soon as identified. Failure to challenge is a failure to monitor.

D.9 Human Performance Considerations

Aggregate pilot performance is typically very high. However, on an individual basis, all pilots are susceptible to internal and external factors that can result in performance degradation.

By signing the Flight Dispatch Release Acknowledgment (FDRA), each pilot is broadly affirming their fitness for duty. An awareness of fatigue is an integral part of assessing an individual's mental and physical fitness:

Physiological studies and real-world experience both validate the negative effects on pilot performance of performing duties while fatigued. While scheduling and crew rest policies endeavor to mitigate the worst impacts of fatigue, responsibilities for personal habits and maintaining a disciplined approach to limiting the effects of fatigue also reside with the pilot. In addition, when fatigue is noted in one's self or another crewmember simply recognizing the situation and advising the other crewmember(s) can be an effective mitigation strategy. If fatigue is a certainty, and it cannot be effectively mitigated, and it is believed that it would compromise the safety of flight, then the flight should not be attempted and the duty pilot should be contacted. It is the pilot's responsibility to be properly rested, but it is also the pilot's responsibility to recognize the existence and impacts of fatigue and handle it appropriately.

APPENDIX E FATIGUE ANALYSES

E.1 Analysis[38] of fatigue factors of captain

▼ *PART 1: ESTIMATING THE LEVEL OF FATIGUE (TEST FOR EXISTENCE) CPT*

Test for existence – Determine the level of fatigue *The purpose of this step is to review the evidence related to the six risk factors and determine if there is sufficient information to conclude that fatigue was present at a level sufficient to impact performance*			
Fatigue Risk Factor	Description of evidence	Strength of evidence (strong, medium, weak)	Assessment of risk factor: likely exists, may exist, likely does not exist
1. Acute sleep disruption	None		
2. Chronic sleep disruption	None		
3. Continuous wakefulness	The captain was awake for 18 hours and 22 minutes 1)	Medium	May exist
4. Circadian rhythm effects	The landing in AMS occurred at 01.52 Detroit time 2)	Strong	Likely exists
5. Sleep disorders	None		
6. Medical, psychological conditions, illnesses or drugs	None		
Conclusion: *Is there a sufficient number and/or degree of risk factors present to conclude that the individual was sufficiently fatigued to affect performance?*			Yes, two risk factors were present, with medium to strong evidence.
Other evidence: Describe any other indications of fatigue observed – declared fatigue, yawning, napping, micro-sleeps, unusual behaviour consistent with fatigue (irritability, risk-taking, taking shortcuts), occurrence happened during circadian low, late in the shift			

38 Based on https://in-scope.ca/wp-content/uploads/2021/10/Fatigue-Incident-Investigation-Guide-2014-Tran.pdf The Canadian TSB's quick reference guide for the assessment of the fatigue risk factors, pilot's rosters, and pilot interviews.

1. Although the captain mentioned he 'may have napped for a little while' during his break, he also indicated that he had not much sleep due to noise and disturbance. Since naps of less than an hour do not reduce the time of continuous wakefulness, the possible nap of the captain (not more than 1 hour) is not taken into account.
2. The captain had a month off in Detroit and was adjusted to Detroit time. For the captain, although local time at the incident was at 07.52, the incident happened at 01.52 for his biological clock, which is near the WOCL, during circadian low.

The occurrence happened at the end of the shift.
The captain had one coffee approximately 2,5 hours before the occurrence.

Rationale: *Describe your reasoning (e.g. Based on [], the fatigue risk factors of [] were present, and the individual was [likely, may have been] fatigued at the time of the occurrence.*

Based on the sleep-wake data of the captain and the time of landing at AMS, the fatigue risk factors of continuous wakefulness and circadian rhythm effects were present during the landing. The landing took place after more than 18 hours of continuous wakefulness and in the middle of the night circadian rhythm trough, after a number of hours of wakefulness at night time. Therefore the captain was possibly fatigued at the time of the occurrence.

▼ *PART 2: LINKING FATIGUE TO HUMAN PERFORMANCE (TEST FOR INFLUENCE)*

Test for influence – Determine whether fatigue contributed to performance
The purpose of this step is to review the safety significant events and determine if there is sufficient evidence to conclude fatigue contributed to the human performance.

Safety significant event	Area of human performance	Evidence (for and against)	Strength of evidence
Fixation on speed	General cognitive functioning	For	medium
Getting below glideslope	Attention and vigilance	For	medium
Not promptly correcting glideslope	Reaction time	For	medium
Conclusion: *Is there sufficient evidence to conclude that the fatigue played a role in the occurrence? (Yes/ No)*			yes

Rationale: Describe your reasoning in a sentence (e.g. The presence of [human performance effects] are consistent with a person in a fatigued state and it is [possible, likely] that fatigue was a contributing factor.

The presence of reduced cognitive functioning, vigilance and reaction time are consistent with a person in a fatigued state and it is possible that fatigue was a contributing factor.

E.2 Analysis of fatigue factors of augmented first officer

▼ *PART 1: ESTIMATING THE LEVEL OF FATIGUE (TEST FOR EXISTENCE) AFO*

(augmented first officer)

Test for existence – Determine the level of fatigue *The purpose of this step is to review the evidence related to the six risk factors and determine if there is sufficient information to conclude that fatigue was present at a level sufficient to impact performance*			
Fatigue Risk Factor	Description of evidence	Strength of evidence (strong, medium, weak)	Assessment of risk factor: likely exists, may exist, likely does not exist
7. Acute sleep disruption	The FO had 5 to 6 hours sleep in the 24 hours prior event 1)	Medium - Strong	May/ likely exist
8. Chronic sleep disruption	A sleep debt of 2,5 to 10 hours was built in 5 days 2)	Medium	May exist
9. Continuous wakefulness	The FO was awake for 16 hours 47 min 3)	Medium	May exist
10. Circadian rhythm effects	Desynchronized circadian rhythm 4)	Medium	May exist
11. Sleep disorders	None/ unknown		
12. Medical, psychological conditions, illnesses or drugs	None		
Conclusion: *Is there a sufficient number and/or degree of risk factors present to conclude that the individual was sufficiently fatigued to affect performance?*			Yes, four risk factors were present, with medium evidence.
Other evidence: Describe any other indications of fatigue observed – declared fatigue, yawning, napping, micro-sleeps, unusual behaviour consistent with fatigue (irritability, risk-taking, taking shortcuts), occurrence happened during circadian low, late in the shift			

1. There were restrictions to optimal sleep quantity and there were one or more awakenings during last 3 sleep periods.
2. The period taken is from 119 hours prior event, which was the beginning of the second last local night before the flight roster started, until the event. Sleep quantity and quality were disrupted by less than optimal sleep, and by bi- or poly-phasic sleep.
3. Awake time was 20 hours 47 minutes with a 2 hour nap approximately 12 hours before the occurrence, with a number of hours of wakefulness at night.
4. Circadian desynchronization is likely to occur when a person's sleep schedule is very irregular.

Rationale: *Describe your reasoning (e.g. Based on [], the fatigue risk factors of [] were present, and the individual was [likely, may have been] fatigued at the time of the occurrence.*

Based on the sleep-wake data of the FO and the time of landing at AMS, the fatigue risk factors of acute sleep disruption, chronic sleep disruption, continuous wakefulness and circadian rhythm effects were present during the landing, and the FO may have been fatigued at the time of the occurrence.

▼ *PART 2: LINKING FATIGUE TO HUMAN PERFORMANCE (TEST FOR INFLUENCE)*

Test for influence – Determine whether fatigue contributed to performance *The purpose of this step is to review the safety significant events and determine if there is sufficient evidence to conclude fatigue contributed to the human performance.*			
Safety significant event	Area of human performance	Evidence (for and against)	Strength of evidence
More quiet/ less assertive than usual	General cognitive functioning	For	medium
Not calling out glideslope or PAPI deviation	Attention and vigilance/ reaction time	For	medium
Conclusion: *Is there sufficient evidence to conclude that the fatigue played a role in the occurrence? (Yes/ No)*			yes
Rationale: Describe your reasoning in a sentence (e.g. The presence of [human performance effects] are consistent with a person in a fatigued state and it is [possible, likely] that fatigue was a contributing factor.			
The presence of reduced cognitive functioning, vigilance and reaction time are consistent with a person in a fatigued state and it is possible that fatigue was a contributing factor.			

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