Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Investigation Report

Identification

Type of Occurrence:	Serious Incident
Date:	5 December 2022
Location:	Dortmund Airport
Aircraft:	Airplane
Manufacturer:	Boeing
Type:	737-8AS
Injuries to persons:	No injuries
Damage:	Aircraft was not damaged
Other Damage:	None
State File Number:	BFU22-1204-EX

Published by:

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Glossary of Abbreviations

AFM	Airplane Flight Manual	Flight Manual
AGL	Above Ground Level	über Grund
AIP	Aeronautical Information Publication	Luftfahrthandbuch
AMSL	Above Mean Sea Level	über dem mittleren Meeresspiegel
AP	Autopilot	automatische Flugregelungs- und Steueranlage
ARC	Airworthiness Review Certificate	Bescheinigung über die Prüfung der Lufttüchtigkeit
ATC	Air Traffic Control	Flugverkehrskontrolle
ATIS	Automatic Terminal Information Service	Automatische Ausstrahlung von Lande- und Startinformationen
ATPL	Airline Transport Pilot Licence	Lizenz für Verkehrspiloten
COP	Co-pilot	Copilot
CPL	Commercial Pilot Licence	Lizenz für Berufspiloten
CVR	Cockpit Voice Recorder	
DWD	German Meteorological Service Provider	Deutscher Wetterdienst
ELEV	Elevation	Ortshöhe über dem Meer
EGPWS	Enhanced Ground Proximity Warning System	Bodenannäherungs-Warnsystem
FCL	Flight Crew Licensing	Lizenzierung von Flugbesatzungen
FDR	Flight Data Recorder	Flugdatenschreiber
ft	Feet	Fuß (1 Fuß = 0,3048 m)
FTL	Flight Time Limitation	Flugzeitbeschränkung
GND	Ground	Grund
GRF	Global Reporting Format	
GS	Ground Speed	Geschwindigkeit über Grund
HDG	Heading	Steuerkurs
IAF	Initial Approach Fix	Anfangsanflugpunkt
IAS	Indicated Airspeed	Angezeigte Fluggeschwindigkeit

ICAO	International Civil Aviation Organisation	Internationale zivile Luftfahrtorganisation
IFR	Instrument Flight Rules	Instrumentenflugregeln
ILS	Instrument Landing System	Instrumenten Landesystem
IMC	Instrument Meteorological Conditions	Instrumentenwetterbedingungen
IR	Instrument Rating	Instrumentenflugberechtigung
kt	knot(s)	Knoten (1 kt = 1,852 km/h)
LDA	Landing Distance Available	Verfügbare Landestrecke
LDR	Landing Distance Required	Benötigte Landestrecke
LM	Landing Mass	Landemasse
MCDU	Multipurpose Control and Display Unit	
MCP	Mode Control Panel	Mode Auswahl Bedieneinheit
METAR	Aviation Routine Weather Report	Routine Wettermeldung für die Luftfahrt
MLM	Maximum Landing Mass	Maximale Landemasse
MSL	Mean Sea Level	Mittlerer Meeresspiegel
MTOM	Maximum T/O Mass	Maximale Startmasse
NM	Nautical Mile(s)	Nautische Meile(n)
NOTAM	Notice to Airmen	
OAT	Outside Air Temperature	Aussentemperatur
OM	Operations Manual	Betriebshandbuch
OPT	Boeing Onboard Performance Tool	
PF	Pilot Flying	Steuerführender Pilot
PIC	Pilot in Command	Verantwortlicher Luftfahrzeugführer
PM	Pilot Monitoring	der Pilot, der den PF unterstützt
PSI	Pound-force per square inch	Maßeinheit des Drucks
QNH	Altimeter pressure setting to indicate altitude AMSL	Luftdruck in Meereshöhe
RA	Radio Altitude	Radarhöhe
RAAS	Runway Awareness and Advisory System	

RCAM	Runway Condition Assessment Matrix	Pistenzustand Matrix
RCR	Runway Condition Report	Bericht über den Zustand der Piste
REV	Reverse	Umkehrschub
RVR	Runway Visual Range	Sichtweite auf der Piste
RWY	Runway	Piste
RWYCC	Runway Condition Code	Pistenzustand Code
SOP	Standard Operating Procedure	Standard-Betriebsverfahren
T/D	Touch Down	Aufsetzen, Landung
T/R	Thrust Reverse	Umkehrschub
VHF	Very High Frequency	Ultrakurzwelle
VMC	Visual Meteorological Conditions	Sichtflugwetterbedingungen

Synopsis

The Boeing B737-8AS flight crew performed an instrument approach procedure to runway 06 of Dortmund Airport. The aircraft touched down in the centre of the touch down zone of runway 06, which was contaminated with snow. It came to a stop on the paved clearway beyond the end of runway 06.

The investigation of the occurrence revealed the following significant items:

- The landing occurred with a stabilised Autoland CAT II ILS approach.
- The Landing Distance Required (LDR) was calculated with the latest weather information available to the flight crew and the Runway Condition Code (RWYCC) and was within the Landing Distance Available (LDA).
- The two previous Runway Condition Reports (1205 UTC and 8 min prior landing) were identical, with no change to the RWYCC confirming that the runway was not reported as contaminated.
- Between the assessment of the runway condition and the landing, continuous precipitation occurred which resulted in a runway covered with wet snow. Subsequently, braking action of the main landing gear wheels was reduced.
- The Runway Condition Code indicating 5/5/5, measured 8 min before landing, the flight crew received from the radar approach controller, may not have corresponded with the actual runway condition.

1. Factual Information

1.1 History of the Flight

On the day of the occurrence, take-off was at London Stansted Airport, Great Britain. The flight was conducted in accordance with instrument flight rules to Dortmund Airport, Germany. It was a scheduled passenger flight. On board were 2 pilots, 4 cabin crew members and 169 passengers.

The Pilot in Command (PIC) occupied the left-hand seat and was Pilot Flying (PF) during this flight. The co-pilot in the right-hand seat was Pilot Monitoring (PM). Prior to departure, the flight crew had the weather data and NOTAMs for the flight path, the arrival aerodrome and the alternate aerodrome available.

Based on the ATIS and METAR information, the approach briefing for runway 06 was performed in cruise flight, according to the flight crew. Among other things, it included the calculation of the LDR and approach speed using the Boeing Onboard Performance Tool (OPT) software. An approach speed of V_{ref40} 136 kt was calculated. The flight crew selected a V_{fly} of 141 kt (V_{ref40} 136 kt+ 5 kt) in the IAS/MACH speed field of the Mode Control Panel (MCP)[1]. They decided to select auto brake position MAX AUTO. At the time of the approach, CAT II was active for the ILS approach and the flight crew configured the aircraft accordingly. Flap position 40 was selected and the Multipurpose Control and Display Unit (MCDU) displayed V_{ref40} accordingly.

At about 1412 UTC, the flight crew confirmed to the controller of Langen Area Control Centre that they had received ATIS information Tango[2] (Chapter 1.7.2).

At about 1419 UTC, the radar approach controller of Langen Area Control Centre issued the clearance for the Initial Approach Point LW009[3]. This point is located west of the airport on the extended runway centre line of runway 06.

At 1422 UTC, the radar approach controller issued a heading of 090° and the approach clearance for runway 06.

At about 1423 UTC, the flight crew received the corresponding Runway Condition Code (RWYCC) from the radar approach controller: “[Callsign] the runway code is triple five, it‘s one hundred percent wet and two millimetres wet snow.“ This information was

1 Located at the Glareshield panel.
2 Information based on the radio communications transcript.
3 Position: 51° 25' 47.73" N; 7° 21' 44.45" E

based on the aerodrome operator's runway condition assessment worksheet (Chapter 1.10.4).

At 1424 UTC, the aerodrome controller received the information from the coordinator of the airport winter services that the runway condition was unchanged to the published ATIS information U. The ATIS U also mentioned, like ATIS T, that light snowfall with mist prevailed.

> The following is an excerpt: […] *runway surface condition reported at time 1332 surface condition code 5 5 5 deposit total runway wet 100 percent 2 millimeters of wet snow wind 250 degrees 2 knots* […].

At 1425 UTC, the aerodrome controller issued the landing clearance and informed the flight crew about the wind from 260° with 1 kt and the runway visual range of runway 06. These corresponded with the radar approach controller's information and the reported SNOWTAM[4].

At 1426UTC, the Final Approach Fix KOLOT[5] was overflown and the flight crew initiated the descent in accordance with the approach profile of the ILS of runway 06 (ILS CAT II or LOC RWY 06[6]). The aerodrome controller informed the flight crew about the wind from 260° with 2 kt.

During the ILS approach, the flight crew extended the landing gear at 1,870 ft AMSL and at 1,500 ft AMSL set the flaps in position 40. The Auto Throttle[7] was active and controlled the airspeed to reach 141 kt IAS as it was selected on the MCP.

At 1428 UTC, the threshold was overflown at 55 ft AGL with an airspeed of 137 kt IAS.

The Digital Flight Data Recorder (DFDR) recorded no deviation from the localizer[8] or the glideslope[9] (Appendices 5.1 and 5.2).

The aircraft touched down for the first time with an airspeed of 137 kt IAS (139 kt GS). Then the DFDR recorded a short flight phase of one second. The aircraft touched down once again with an airspeed of 135 kt IAS (137 kt GS) (Appendix 5.2.2).

4 A special series of NOTAMs given in a standard format providing a surface condition report notifying the presence of hazardous conditions due to snow, ice, slush, frost, standing water or water associated with snow, slush, ice or frost on the movement area (SKYbrary).

5 Position 51° 27' 49.18" N; 7° 27' 26.64" E

6 AIP, AD 2 EDLW 4-2-2, 20 June 2019

7 The Auto Throttle is an electronic or electro-mechanical device which enables a pilot to control the engine thrust setting by selection of a specific flight profile, or parameter (SKYbrary).

8 The lateral component of the instrument landing system (ILS) for the runway centerline.

9 The vertical component of the instrument landing system (ILS).

The aircraft's landing mass was 61,400 kg, both autopilots (in Auto Land Mode) were activated and the tailwind component was 2 kt. The DFDR data showed that the aircraft had touched down at approximately the centre of the touchdown zone of runway 06 (Appendix 5.2.2). It also recorded the activation of the thrust reverser, the deployment of the ground spoilers[10] and the automatic activation of the wheel brakes. The DFDR data showed that the PIC braked with the pedals, deactivated auto brake and the autopilots. The data also showed that the maximum possible brake pressure[11] (PSI) value was achieved. According to the PIC, the Runway Awareness and Advisory System (RAAS)[12] did not generate any warning.

The aircraft decelerated on the runway and overran the beginning of the displaced threshold area of runway 24 with a ground speed of 60 kt.

At 1429 UTC, it came to a stop on the paved clearway beyond the end of runway 06 (Fig. 1 and Appendix 5.4).

Afterwards, the aircraft taxied via the taxiways D, M, L and the apron to parking position 1.

The flight crew informed the aerodrome controller via VHF radio that braking action was poor and the reported runway condition code 5 may not have corresponded with the actual condition.

Due to the poor braking action the flight crew had reported, the aerodrome operator had closed the airport temporarily and initiated another runway condition assessment (Chapter 1.10.5).

The following values of 1445 UTC were entered in the runway condition assessment worksheet and issued via the SNOWTAM:

Runway > 25 % coverage; 3/3/3; 100/100/100; 05/05/05. Afterwards the runway was again mechanically cleared and de-icing fluid applied.

10 Spoilers are secondary flight control surfaces that can be deployed manually by the pilot or, under certain circumstances, that extend automatically. Speedbrakes are purely drag devices while spoilers simultaneously increase drag and reduce lift (SKYbrary).

11 Parameter of the Digital Flight Data Recorder

12 RAAS: Smart Runway and Smart Landing are software options for the Enhanced Ground Proximity Warning System which increase flight crew situational awareness during taxi, take-off and landing (Honeywell).

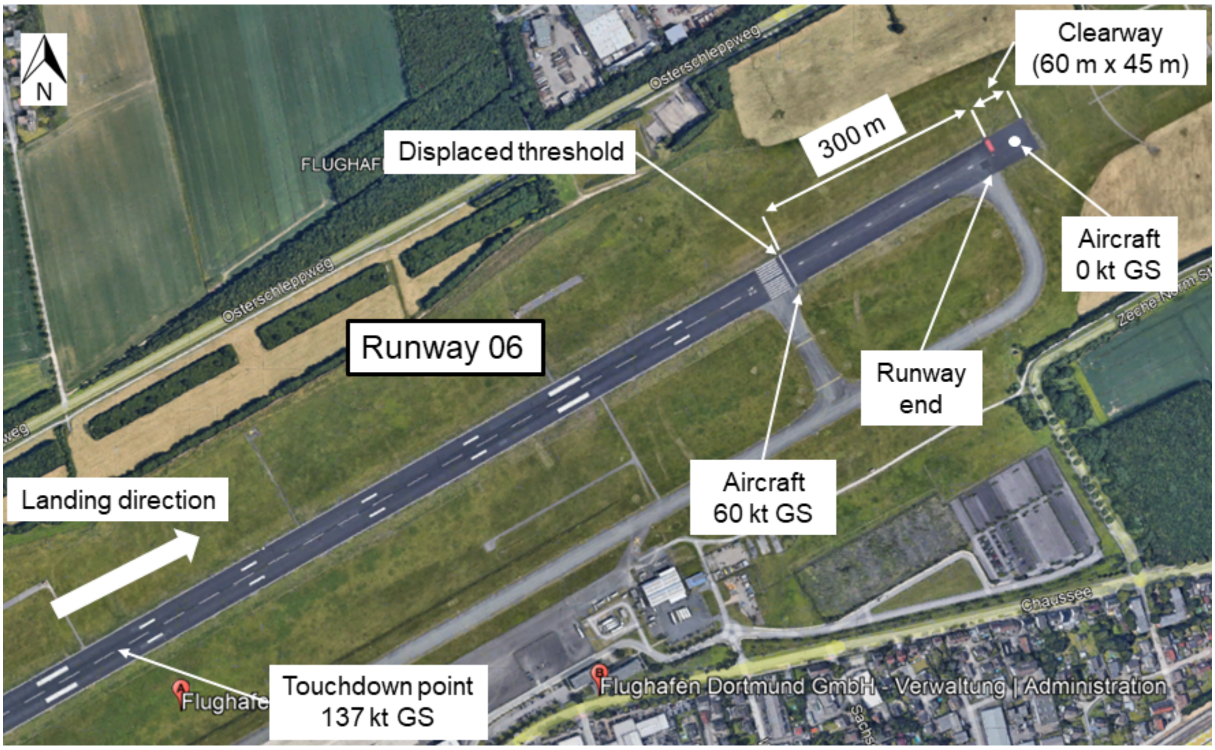

Fig. 1: Overview of Dortmund Airport with DFDR data and distances Source: Google Earth™, adaptation BFU

1.2 Injuries to Persons

Injuries	Flight Crew	Passengers	Total in aircraft	Other
Fatal				
Serious				
Minor				
None	6	169	175	
Total	6	169	175	

Tab. 1: Injuries to persons Source: BFU

1.3 Damage to Aircraft

The aircraft was not damaged.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 Flight Crew

1.5.1.1 Pilot in Command

The 42-year-old PIC held an Air Transport Pilot Licence (ATPL(A)) issued on 13 May 2014 by the Irish Aviation Authority. The licence listed the type rating Boeing B737 300-900 and was valid until 31 December 2022.

The licence also listed the Language Proficiency Level 6 for English in accordance with ICAO Annex 1. The BFU was provided with a class 1 medical certificate valid until 4 October 2023.

The PIC had a total flying experience of about 8,800 hours, of which about 8,600 hours were flown on Boeing B737.

1.5.1.2 Co-pilot

The 23-year-old co-pilot held a Commercial Pilot License (CPL(A)) issued by the Irish Aviation Authority on 19 October 2021. The licence listed the type rating Boeing B737 300-900 and was valid until 20 November 2023.

The licence also listed the Language Proficiency Level 6 for English in accordance with ICAO Annex 1. The BFU was provided with a class 1 medical certificate valid until 11 August 2023.

The co-pilot had a total flying experience of 768 hours, of which about 616 hours were flown on Boeing B737.

1.5.1.3 Flight Duty and Rest Time

The flight crew's duty roster was made available to the BFU.

It showed that check-in was at 0830 UTC at London-Stansted, Great Britain. According to the duty roster, four flights should have been performed with a flight time of 07:07 hours. The occurrence flight was the third flight. On that day, maximum permissible duty time was 12:30 hours, according to Regulation (EU) No. 965/2012 and OM-A, Chapter 7 Flight Time Limitation (FTL), Issue 11, Rev 0, 20 Oct, 2022. The flight crew had not submitted a fatigue report.

Prior to this day, the PIC had seven days off. The co-pilot had had two days of flying with one flight and four flights, respectively. Prior to that, he had four days off.

1.5.2 Airport Ground Handling Services Personnel

1.5.2.1 Training

The airport ground handling personnel were trained and certified in the use of the Global Reporting Format (GRF) in September 2021.

1.5.2.2 Experience

The measurements according to the Global Reporting Format have been required since 2021, previously the employees were using the SARSYS Friction Tester.

The employee who performed the measurement on the day of the occurrence had more than 10 years of experience in assessing the runway condition.

1.5.2.3 Duty time

This employee started work at 1230 UTC. He was not part of a night shift system. Prior to this shift, he had worked for four days and before that had two days off.

The ground personnel had not submitted a fatigue report.

1.6 Aircraft Information

1.6.1 General

The Boeing B737-8AS is a short and medium range transport aircraft. The aircraft is equipped with two CFM56-7B26/3 turbofan engines. The cockpit is a two-pilot cockpit with control columns typical for Boeing.

The aircraft had an Irish certificate of registration and was operated by an Irish operator in commercial passenger transport.

The BFU was provided with a valid Airworthiness Review Certificate (ARC).

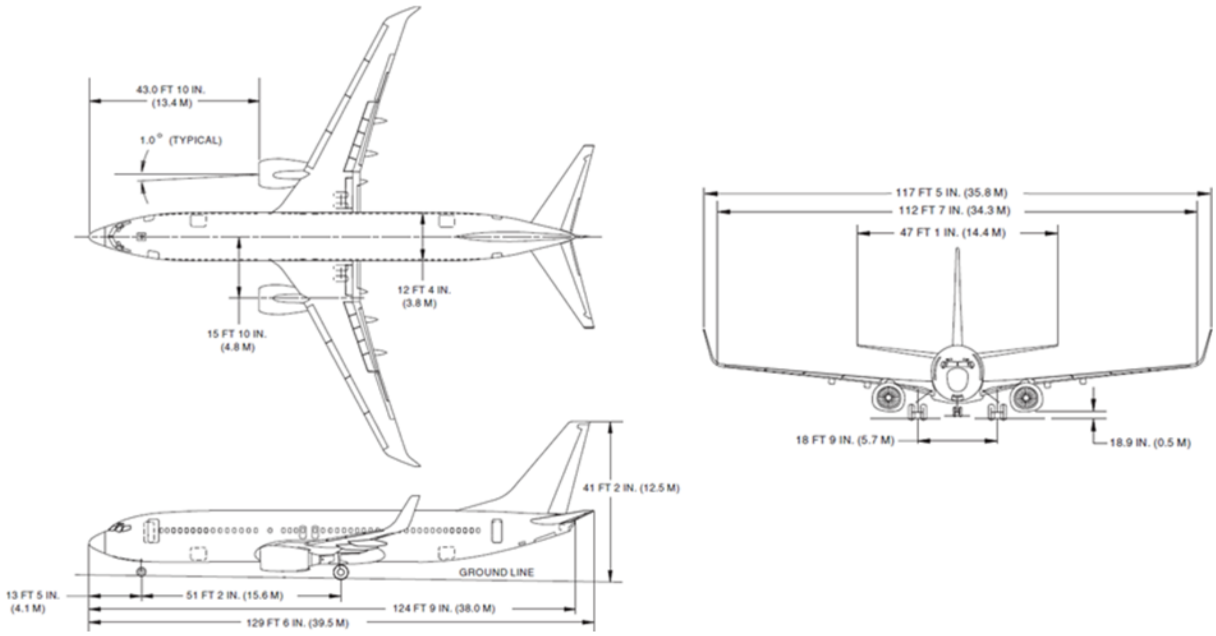

Fig. 2: Three-way view of Boeing B737-8AS Source: Aircraft manufacturer

1.6.2 Aircraft Data

Manufacturer	Boeing
Type	737-8AS
Year of Manufacture	2006
Serial number	33598
Operating Time	50,597 hours
Landings	29,694
MTOM	71,990 kg
MLM	65,317 kg

1.6.3 Maintenance Organisation

The operator's maintenance organisation performed a Hard Landing Inspection and an antiskid/autobrake control system component test after the occurrence. The maintenance organisation's technical findings showed that no damage occurred. The antiskid/autobrake control system component had not recorded any malfunction.

1.6.4 Runway Awareness and Advisory System

The aircraft was equipped with a Runway Awareness and Advisory System (RAAS).

RAAS is a software extension which is available in the Enhanced Ground Proximity Warning System. It was developed to improve the situational awareness of flight crews and decrease the risk of runway incursions and excursions and confusion of runways. Warnings are generated based on the position of the aircraft compared with the location of the runway, which is stored in the take-off and landing database of the EGPWS (SKYbrary)[13].

1.7 Meteorological Information

1.7.1 General

At the time of the incident, it was daylight.

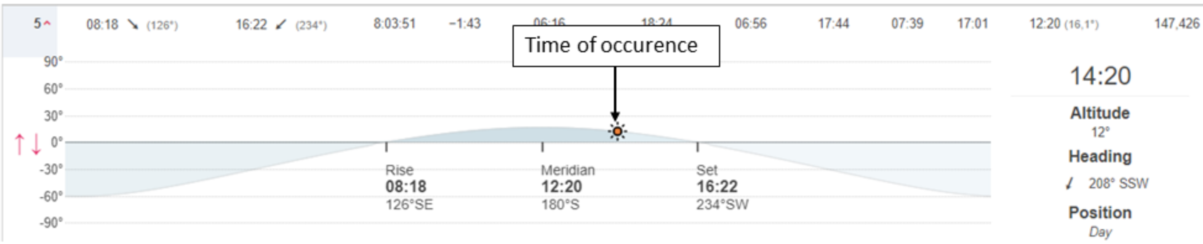

Fig. 3: At 1420 UTC, daylight prevailed (1520 hrs - UTC +1) Source: Timeanddate.com

1.7.2 ATIS and METAR

The ATIS information Tango (T) was received by the flight crew:

> Dortmund information T, met report time 1350, expect ILS approach runway in use 06, transition level 60, low visibility procedures in operation CAT 2 available, runway surface condition reported at time 1332 surface condition code 5 5 5, deposit total runway wet 100 percent, 2 millimetres of wet snow, wind 230° 2 kt, visibility 1,300 m, rvr runway 06 1,900 m, increasing light snow, mist, clouds broke 200 ft, temperature 0, dew point minus 0, QNH 1,018, trend not available.

[13] https://skybrary.aero/articles/runway-awareness-and-advisory-system-raas; last access 19 February 2024

From 0550 UTC onwards, the METARs continuously reported Light Snow (-SN). The METAR of 1420 UTC was valid for the landing.

According to the METAR of Dortmund Airport of 1420 UTC, which corresponds with the ATIS Information Uniform (U), the Runway Visual Range (RVR) for runway 06 was 1,900 m, change with increasing trend of the last 10 minutes. Wind direction was 250° with 2 kt. Light snowfall with mist prevailed. Cloud base was at 200 ft AGL with 5 to 7 octas. At 500 ft AGL, the sky was completely overcast. Temperature was 0°C, dewpoint -0°C, and QNH 1,018 hPa.

> METAR EDLW 051420Z 25002KT 1400 R06/1900U -SN BR BKN002 OVC005 00/M00 Q1018=

After the landing, the airport was temporarily closed. The ATIS report, one hour after the event, read:

> Dortmund ATIS Information ‘X-RAY’, observation time 1528, runway in use 24, however due to poor runway condition, the airport operator has closed the runway for any kind of landing. Departure off 24 might be possible.

1.7.3 Precipitation

The amount of precipitation at Dortmund Airport is generally not determined by the DWD. The DWD data of the precipitation station Kurl (elevation: 226 ft AMSL) about 3 km north-west of the airport was requested. Between 1240 UTC and 1450 UTC, the station measured continuous precipitation with a level of at least 0.2 mm/10 min.

1.7.4 Weather Chart

Figure 4 was taken from the archive of a private weather provider (Kachelmannwetter.com) and is a composite picture with a resolution of 1 x 1 km. It depicts the precipitation intensity in the region Dortmund on 5 December 2022.

The colour range Radar Standard (dBZ = decibel relative to Z) below the radar image depicts the reflectivity Z of the Hydrometeore. Higher dBZ values correspond with heavier precipitation and/or larger Hydrometeore, e. g. hail.

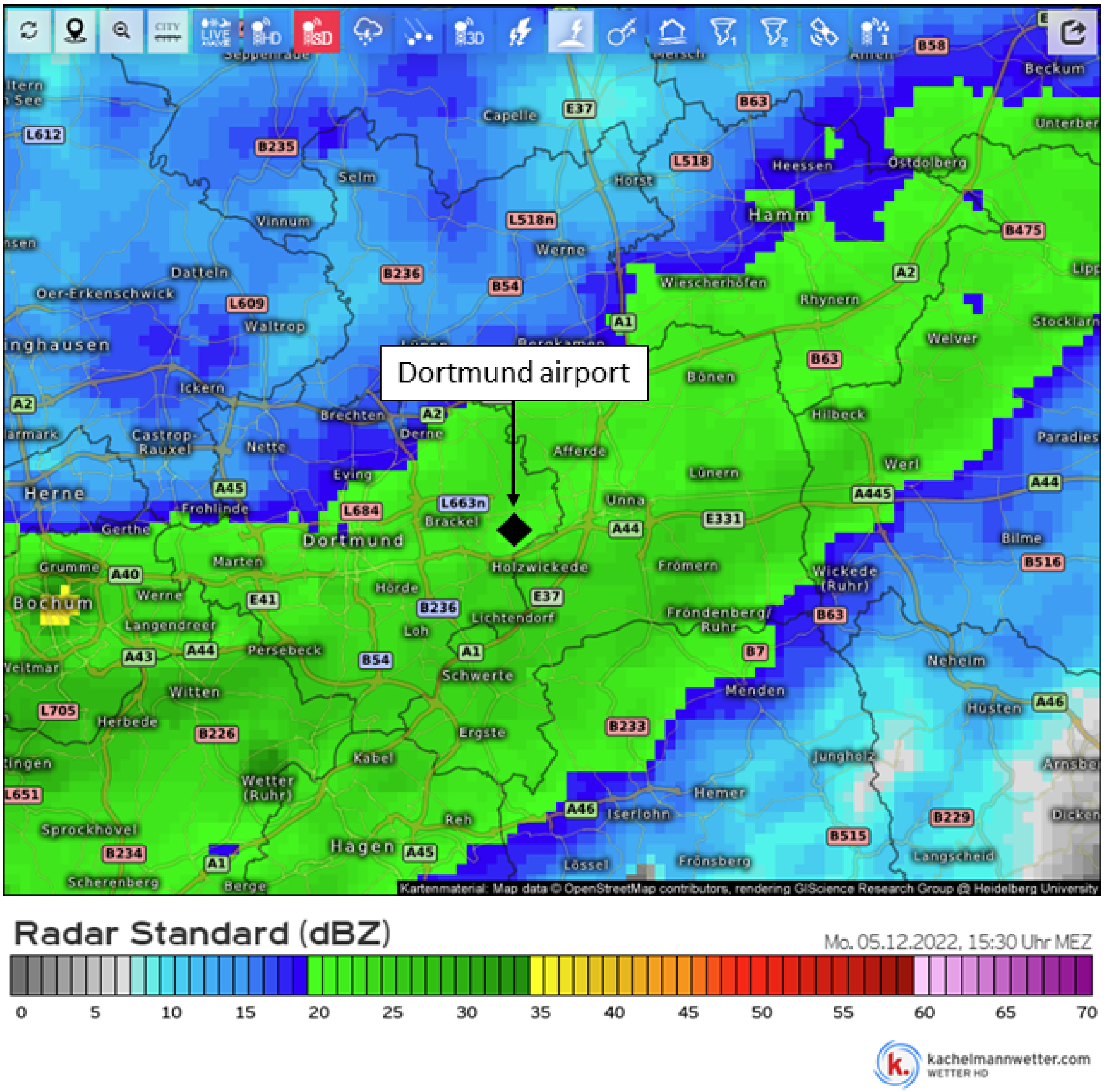

Fig. 4: Weather radar image with precipitation intensity Source: Kachelmannwetter.com, adaptation BFU

1.7.5 SNOWTAM

On the day of the occurrence, six SNOWTAMS (prior to and after the occurrence) were available. Not only the reports of the time of the occurrence but also the ones afterwards were considered to assess the weather situation in general and the precipitation intensity in particular.

This was the SNOWTAM in effect prior to the approach:

- SNOWTAM 0002 EDLW 12051235 06 5/5/5 100/100/100 02/02/02 WET SNOW/WET SNOW/WET SNOW MARKINGS ARE SLIPPERY.

Here is a list of four other reported SNOWTAMs from that day. The SNOWTAM 0001 was not relevant for the investigation.

- SNOWTAM 0003 EDLW 12051445 06 3/3/3 100/100/100 05/05/05 WET SNOW/WET SNOW/WET SNOW APN SLIPPERY. MARKINGS SLIPPERY. TWY SLIPPERY.
- SNOWTAM 0004 EDLW 12051535 06 2/2/2 100/100/100 10/10/10 SLUSH/SLUSH/SLUSH REDUCED RWY WIDTH 25M. APN SLIPPERY. MARKINGS SLIPPERY. TWY SLIPPERY.
- SNOWTAM 0005 12051635 06 5/5/5 100/100/100 01/01/01 SLUSH/SLUSH/SLUSH TWY SLIPPERY. RWY CHEMICALLY DEICED. APN SLIPPERY. MARKINGS SLIPPERY.
- SNOWTAM 0006 EDLW 12051805 06 5/5/5 100/100/100 NR/NR/NR WET/WET/WET RWY 06 CHEMICALLY TREATED. APN SLIPPERY. MARKINGS SLIPPERY. ALL TWYS SLIPPERY.

The BFU prepared a table (Tab. 2) with the runway condition measuring data. Appendix 5.3 depicts the Runway Condition Assessment Matrix. The measurement protocol of 1205 UTC was confirmed by the aerodrome operator eight minutes before the landing after the runway condition had been assessed again.

Time (UTC)	Runway condition code (1st/2nd/3rd)	Runway coverage in % (1st/2nd/3rd)	Contaminant Type (1st/2nd/3rd)	Contaminant depth in mm (1st/2nd/3rd)
12:05:00	5/5/5	100/100/100	wet snow/wet snow/wet snow	2/2/2
14:20:00	5/5/5	100/100/100	wet snow/wet snow/wet snow	2/2/2
14:45:00	3/3/3	100/100/100	wet snow/wet snow/wet snow	5/5/5
15:25:00	2/2/2	100/100/100	slush/slush/slush/	10/10/10
16:35:00	5/5/5	100/100/100	slush/slush/slush	01/01/01
18:05:00	5/5/5	100/100/100	wet/wet/wet	nil/nil/nil

Tab. 2: Runway condition measuring data. Touchdown occurred at 1428 UTC

Source: Aerodrome operator, adaptation BFU

1.8 Aids to Navigation

The instrument approach was conducted as category II precision approach (ILS 06 CAT II) to runway 06. It began with the Final Approach Point KOLOT at 2,500 ft AMSL.

The BFU entered the flight path as red line into the AIP Germany approach chart (Fig. 5) (AD 2 EDLW 4-2-2; 20 June 2019; ILS CAT II or LOC RWY 06).

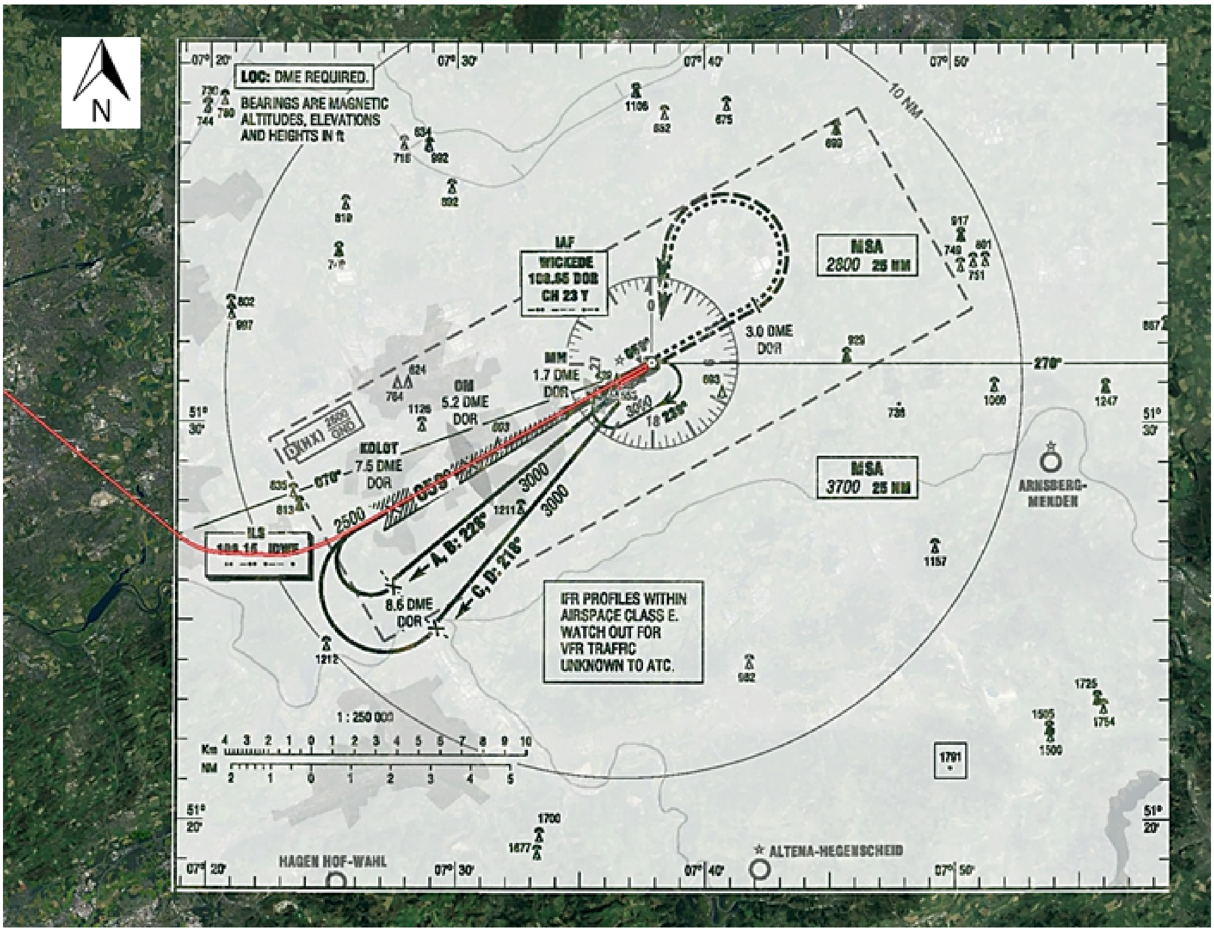

Fig. 5: Flight path in a GoogleEarth™ chart with an AIP overlay approach chart

Source: Air Navigation Service Provider, GoogleEarth™, adaptation BFU

1.9 Radio Communications

The air navigation service provider provided the BFU with the transcripts of the radio communications of the flight crew with Center Langen on the frequency 128,555 MHz between 1412:22 UTC and 1419:37 UTC and on 125,225 MHz between 1419:47 UTC and 1425:20 UTC.

The BFU was provided with the radio communications transcripts between the aerodrome controller and the flight crew and him and the winter service at the airport. The time period recorded was between 13:32:01 UTC and 14:43:30 UTC.

1.10 Aerodrome Information

1.10.1 General

Dortmund Airport (EDLW)[14] is located 10 km east of the city of Dortmund. Aerodrome elevation is 425 ft AMSL.

1.10.2 Airport Lighting

Runway 06 was equipped with approach lighting with Light Intensity High (LIH) and sequence flashing. The touch-down zone of the runway was also equipped with LIH lights.

The aerodrome operator provided the BFU with a status protocol of the active approach system and the aerodrome lighting. The protocol did not list any system failures for the time of the occurrence.

1.10.3 Runway Dimensions

At the time of the occurrence, the asphalt runway was 2,000 m long and 45 m wide. Either runway end had a 60 m long and 45 m wide clearway[15]. The threshold of both runways (06/24) was displaced by 300 m so that the Landing Distance Available (LDA) was 1,700 m in each direction (Fig. 7). The touch-down zone of runway 06 was 600 m long.

1.10.4 Runway Condition Measurement

Runways are divided into three sections for the measurement of the runway condition. The measurement data was allocated accordingly and subsequently published via a SNOWTAM. Chapter 1.7.5 includes the SNOWTAM information.

1.10.5 Measurements by the Aerodrome Operator

The following information was taken from the written statement of the aerodrome operator:

- The measurement equipment used to determine the level of precipitation on the runway was an aluminium ruler. There were no specifications regarding the measuring instrument to be used.

14 From the Aeronautical Information Publication (AIP) Germany, published 1 December 2022.
15 ICAO Annex 14 Chapter 3.6 defines “clearway”.

- The surface temperature was measured with an infrared thermometer and part of the respective runway condition assessment. It was +1°C.
- The runway was not icy and had been mechanically cleared by winter service vehicles during the light snowfall. The last action was done 8 min prior landing.
- A report of an Airbus A320 flight crew, who had landed about 45 min earlier, was available. They reported that the braking action had been good.

After the event and the report of the flight crew an assessment was performed. The following values of 1445 UTC were entered into the runway condition assessment worksheet and issued via the SNOWTAM:

Runway > 25 % coverage; 3/3/3; 100/100/100; 05/05/05

Afterwards the runway was again mechanically cleared and de-icing fluid applied.

1.10.6 Airport Ground Handling Services Personnel Training

Prior to the implementation of the procedure Global Reporting Format for Runway Surface Conditions, in September 2021, the airport ground handling services personnel had participated in a GRF training conducted by the Interessengemeinschaft der regionalen Flugplätze (IDRF) with a final exam and certificate.

1.10.7 Measuring Devices

According to the aerodrome operator, the measuring devices for the runway condition assessment were functional. After the wheels were changed, the measuring system had been calibrated. Due to the GRF procedure (Chapter 1.18.2), the values measured with the Sarsys Friction Tester only serve as decision support for the airport ground operations manager. The GRF procedure did not stipulate measurements with a friction tester.

1.10.8 Pilot's Report

Regulation (EU) No. 2019/1387 Chapter CAT.OP.MPA.311 described:

Whenever the runway braking action encountered during the landing roll is not as good as that reported by the aerodrome operator in the runway condition report (RCR), the commander shall notify the air traffic services (ATS) by means of a special air-report (AIREP) as soon as practicable.

Immediately after the occurrence, the flight crew informed the aerodrome controller about the low deceleration on the runway.

1.11 Flight Recorders

1.11.1 General

The airplane was equipped with a Digital Flight Data Recorder (DFDR) and a Cockpit Voice Recorder (CVR). Both recorders were read out at the BFU laboratory. The two recorders were undamaged.

Manufacturer DFDR	Honeywell
Model	SSFDR
Part number	980-4700-042
Serial number	12784

The DFDR had recorded 95,294 s (~26,47 hours).

Manufacturer CVR	Honeywell
Model	SSCVR
Part number	980-6022-001
Serial number	04836

The CVR had recorded five audio files. Three files had a recording time of 30 minutes each and two of two hours. The voice recording was understandable.

The power supply of the CVR had been deactivated very late and therefore, the time period of the approach and the runway excursion was overwritten.

1.11.2 Analysis of Digital Flight Data Recorder Parameter

Appendix 5.1 shows the DFDR plots in relation to time. Appendix 5.2 shows the examination of relevant DFDR parameter over the distance to the runway threshold.

In Appendix 5.1.1 relevant DFDR parameter, which allow the analysis of the approach, were analysed. During the ILS approach, there were no deviations of the aircraft from the localizer and the glideslope signal.

In Appendix 5.1.2, DFDR parameter, which are relevant for the touch-down until standstill, are depicted.

The aircraft touched down in the centre of the touch-down zone. Brake pressure (DFDR parameter) reached the maximum value. Shortly after touch-down, the ground spoilers were deployed.

The DFDR parameter T/R F. Deployed L and R (Thrust Reverser Left and Right deployed) were recorded shortly after touch-down. The engine rpm reached the value which corresponds with the maximum reverse thrust of both engines.

A warning of the RAAS was not recorded.

1.12 Wreckage and Impact Information

The aircraft came to a stop on the asphalt clearway, about 45 m beyond the end of runway 06 (Fig. 1 and Appendix 5.4). It was able to turn under its own power on the paved area and taxi via the taxiways D, M and L to parking position 1.

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

There was no evidence of in-flight fire or fire during the landing.

1.15 Survival Aspects

There was no evacuation. The passengers disembarked the aircraft at the parking position via the jetway.

1.16 Tests and Research

Not applicable.

1.17 Organisational and Management Information

1.17.1 Airfield Briefing Dortmund

In the Operations Manual (OM) Part C, Airfield Briefing Dortmund EDLW/DTM, Rev 010, 22 September 2022 on page 1 of 3, the operator described specific instructions for flight crews for landings at Dortmund Airport.

For operations to Dortmund Airport, the items ‘Captains only Landing’ and ‘Tailwind landing not Authorised’ were prescribed:

[…]

> *Refer to OPT for dispatch landing limit weights. En-route, plan Flap 40 and maximum reverse thrust. Refer to OPT for Minimum Auto Brake setting requirements and landing performance based on runway conditions reported at time of arrival.*
>
> *Anti-Skid and Auto-Speedbrakes must be serviceable for all landings.*
>
> - *Captains Only Landing*
> - *Visual approaches not approved*
> - *Practice autoland not authorised*
> - *Glideslope or PAPI must be serviceable for all approaches to Dortmund*
> - *CAUTION tankering inbound to Dortmund due LW restriction*
> - *No Cadet Line Training*
> - *Not to be used as an Alternate airfield*
> - *Landing only approved with RWYCC 5 or better*
> - *Tailwind landing not authorised*

[…]

1.17.2 Aircraft Configuration

Based on the PIC's statement and the DFDR parameters, the pilots had configured the aircraft for the ILS CATII approach to runway 06 as follows:

- Auto Land - Active
- Flaps - Full (40)
- Auto Brake - MAX AUTO
- Auto Throttle - Active

1.17.3 Landing Distance Calculation

For the calculation of the landing distance required, the operator had provided the flight crew with the Boeing Onboard Performance Tool (OPT), Version 4.7, on their Electronic Flight Bags.

The Operations Manual, Part B[16], Chapter 2, 2.7.7 Reverse Thrust, described that the Boeing OPT software considers the braking action of the thrust reversers only if the runway is Non-Dry when calculating the LDR. Boeing described in the Flight Crew Training Manual, Chapter Landing, Slippery Runway Landing Performance, of June 30, 2022, that the landing distance information for slippery and contaminated runways is based on assumptions and were not determined by test pilots of the aircraft manufacturer. Uniform contamination of the runway is assumed.

1.17.3.1 Landing Distance Calculation - Flight Planning

The operator's Operations Manual, Part B[17], Chapter 2, 2.7.1 Landing Dispatch described the calculation of the landing distance required during the flight planning as follows:

[…]

for destination and alternate aerodromes are:

• Dry Rwy LDR = Actual Dry Rwy LD × 1.67

• Wet Rwy LDR = Dry Rwy LDR × 1.15 (Note: 1.67 × 1.15 = 1.92)

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• *Contaminated Rwy LDR = The greater of the Wet Rwy LDR and the Calculated LDR for the contaminant type × 1.15 (Note: this calculation / comparison is performed automatically by OPT)*

[…]

The operator's Operation Centre provided the BFU with the calculations of the Dispatch Landing Distances. The landing distances for Auto Brake MAX MANUAL and MAX AUTO were within the available runway length. The BFU compiled a table with the calculation.

Entry conditions for the landing performance			**Results**	
Airport	EDLW		**Weight**	61,440 kg
Runway	06 (LDA: 1,700 m)		**Flaps**	40
Condition	Good		**VREF**	141 kt
Wind	250° / 2 kt			
OAT[18]	0°C		**Runway required distance**	
QNH	1,018 hPa		**MAX MANUAL**	1,421 m
PACKs	Auto		**MAX AUTO**	1,528 m
Anti-Ice	Off		**AUTO BRK 1**	3,025 m
MEL[19] **Items**	None		**AUTO BRK 2**	2,551 m
CDL[20] **Items**	None		**AUTO BRK 3**	2,017 m

Tab. 3: Dispatch Landing Calculation Source: Operator, adaptation BFU

18 Outside air temperature
19 Minimum equipment list
20 Configuration deviation list

1.17.3.2 Landing Distance Calculation - In-flight

The operator's Operations Manual, Part B[21], Chapter 2, 2.7.1 Landing Distance at Time of Arrival (LDTA) described the calculation of the landing distance required as follows:

[…]

> *The Landing Distance at Time of Arrival (LDTA) assessment ensures that no approach to land is continued unless the 1.15 factored landing distance is less than the landing distance available (LDA) for the intended runway in use. The LDTA assessment should be based on the latest available weather report and runway condition report (RCR) or equivalent information based on the RCR. The LDTA assessment should be initially carried out when the weather report and the RCR are obtained* […]*. The flight crew should monitor the evolution of the actual conditions during the approach, to ensure that they do not degrade below the condition that was previously determined to be the minimum acceptable*.

[…]

1.17.3.3 Landing Distance Calculation - Boeing Onboard Performance Tool

On site, the BFU was not able to seize the calculation documentation. The operator provided a copy to the BFU, re-created from trace files after the event (Fig. 6).

For the landing distance calculation during the flight, the actual landing mass of 61,400 kg, the aircraft's landing configuration, the runway condition and the environmental conditions (wind direction and speed, air pressure) were entered into the relevant fields of the Boeing OPT software. It calculated the LDR for runway 06 based on the landing speed for Auto Land of V_{ref40} + 5 kt (Flaps 40). It included a safety margin for a contaminated runway with the factor +1.15 compared with a dry runway.

Then the software compiled a list of the Auto Brake settings with the required landing distances.

The landing distances for Auto Brake MAX MANUAL and MAX AUTO were within the available runway length. The setting Auto BRK 1 to 3 were outside the available runway length.

The flight crew performed a CAT II ILS approach and configured the aircraft accordingly. The Operations Manual, Part B[22] Chapter 2, 2.8.8 OPT Autoland and

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Chapter 2, 2.10.4 QRH Autoland of the Operations Manual Part B described that the Autoland safety margin of 140 m for Flaps 40 must be added to the OPT calculated LDR and must be within the LDA.

To the LDR of 1,527 m with Auto Brake position MAX AUTO the Boeing OPT software had calculated, the Auto Land safety margin (Flaps 40) of 140 m had to be added. This resulted in a factored LDR of 1,667 m compared with an unfactored LDR of 1,438 m (1,298 m + 140 m). The landing distance available was 1,700 m. According to the flight crew's statement, they had entered a landing speed of V_{ref40} + 5 kt, equals 141 kt IAS, into the MCP.

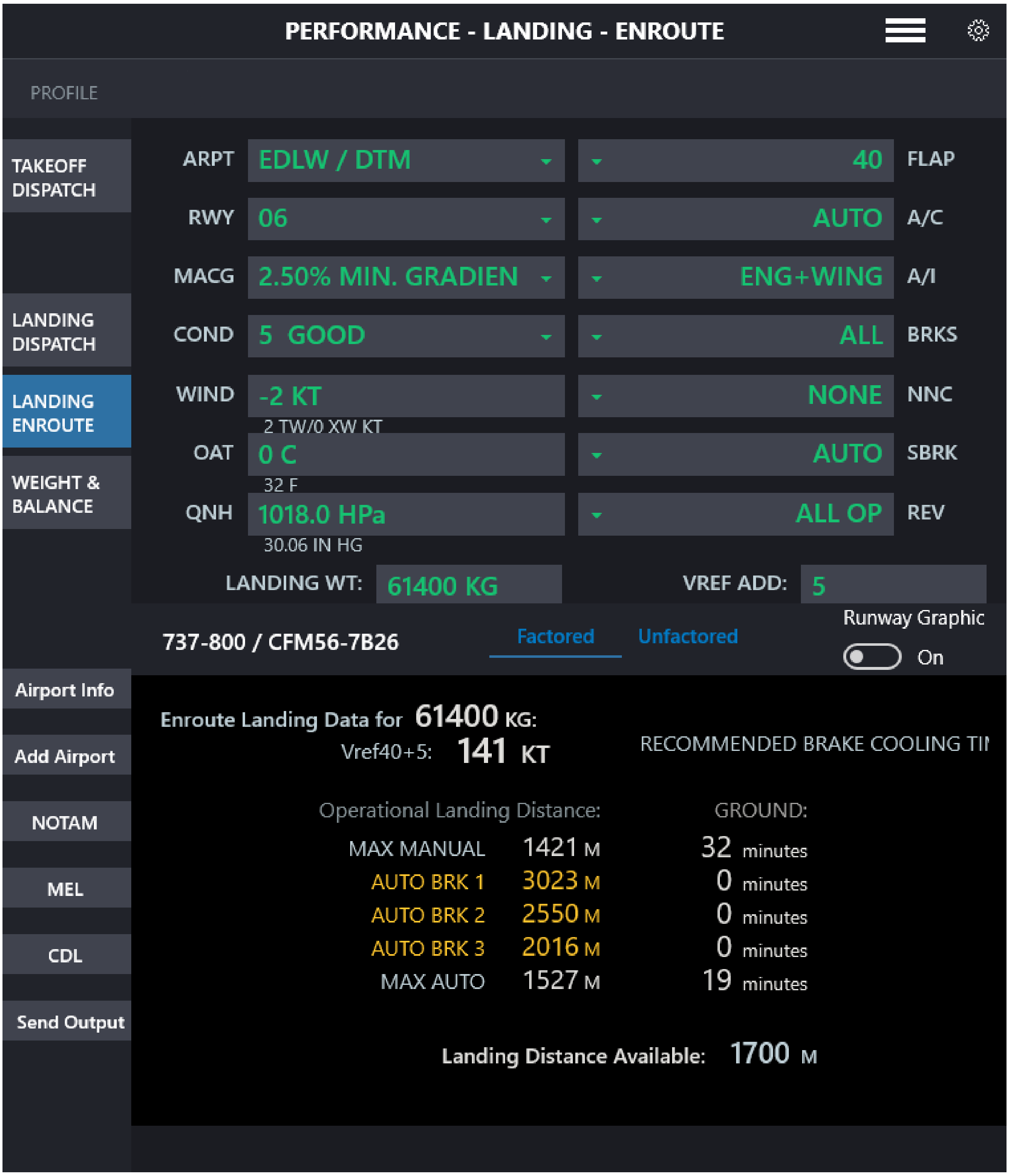

Fig. 6: Copy of the Boeing OPT Landing distance calculation, created after the event

Source: Operator, Boeing Onboard Performance Tool, Version 4.7

1.17.4 Menu Item of the Boeing OPT Software - Auto Land

At the time of the occurrence, the menu item Auto Land in the Boeing OPT software version 4.7 was not in use by the operator for Boeing B737-800W. The operator stated that the Auto Land calculation option was disabled for the Boeing B737-800W due to inconsistencies found in OPT calculations during evaluation when compared with published performance information in Boeing manuals and calculations made for other company aircraft types. The Operator had already been in dialogue with the software manufacturer about these inconsistencies at the time of the occurrence.

The pilots had to add the safety margin manually to the calculated landing distance. According to the PIC, they had done so.

1.17.5 Touchdown Point on the Runway

The operator's Operations Manual, Part B[23], Chapter 2, 2.7.3 Touchdown Point described the calculation as follows:

[…]

> *OPT will determine the Assumed Air Distance (AD). AD will vary as it is calculated as a function of the V_{ref} speed, with the touchdown speed assumed to be 98 % of the approach speed at the Rwy THR. QRH Performance data includes 455 m air distance from 50 ft above threshold to touchdown, with the touchdown speed assumed to be 98 % of the approach speed at the Rwy THR.*
>
> *Note: For runways with LDA ≤ 2 000 m airfield briefs provide the PAPI and aiming point marking distances from THR/Displaced THR. The position of the runway Aiming Point Markings on many runways are, as per ICAO Annex 14, at 400 m from THR.*

[…]

The touch-down zone of runway 06 was 600 m long. The Boeing OPT software calculation of the LDR was programmed to consider a 15 % safety margin within the Air Distance of 455 m. The touchdown point was approximately in the centre of the touchdown zone.

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1.17.6 Approach Speed

The Boeing OPT software calculated an approach speed of V_{ref40} of 136 kt, based on a landing mass of 61,400 kg. The selected speed on the MCP was V_{fly} 141 kt IAS (V_{ref40} 136 + 5 kt). The DFDR data showed an approach speed of 137 kt IAS during the first touchdown. The approach speed was controlled by the Computer Auto Throttle System. It is programmed to reduce the approach speed at the touchdown point by 5 kt so that the aircraft touches down with V_{ref40}.

1.18 Additional Information

1.18.1 ICAO Annex 14 Aerodromes

ICAO Annex 14, Chapter 2.9.2 described, among other things, that external circumstances (meteorological conditions) have to be considered to ensure safe flight operations. By using chemical de-icing fluids for runways, airport operations can be ensured (ICAO, 2022).

[…]

> *2.9.2 The condition of the movement area and the operational status of related facilities shall be monitored, and reports on matters of operational significance affecting aircraft and aerodrome operations shall be provided in order to take appropriate action, particularly in respect of the following:*
>
> […] *c) water, snow, slush, ice, or frost on a runway, a taxiway or an apron;*
>
> *d) anti-icing or de-icing liquid chemicals or other contaminants on a runway, taxiway or apron;*
>
> *e) snow banks or drifts adjacent to a runway, a taxiway or an apron;*
>
> *f) other temporary hazards, including parked aircraft;* […]

[…]

ICAO Annex 14, Chapter 2.9.3 described that assessment of the apron, of the taxiways and runways at runway condition code 4 or less must be conducted. The procedures how this is to be performed were listed in PANS, Aerodromes, Doc 9981. The document also contained descriptions of what significant changes of the runway surface or surface conditions mean.

[…]

2.9.3 To facilitate compliance with 2.9.1 and 2.9.2, the following inspections shall be carried out each day:

a) for the movement area, at least once where the aerodrome reference code number is 1 or 2 and at least twice where the aerodrome reference code number is 3 or 4; and

b) for the runway(s), inspections in addition to a) whenever the runway surface conditions may have changed significantly due to meteorological conditions.

[…]

ICAO Annex 14, Chapter 10.3 described the removal of contaminations.

10.3 Removal of contaminants

10.3.1 Snow, slush, ice, standing water, mud, dust, sand, oil, rubber deposits and other contaminants shall be removed from the surface of runways in use as rapidly and completely as possible to minimize accumulation.

Note - The above requirement does not imply that winter operations on compacted snow and ice are prohibited. Information on snow removal and ice control and removal of other contaminants is given in the PANS-Aerodromes (Doc 9981).

[…]

1.18.2 Global Reporting Format for Runway Surface Conditions

Regulations (EU) No. 2019/1387, No. 2020/469 and No. 2020/2148 defined the new measurement procedure for the international implementation of the Global Reporting Format (GRF) for Runway Surface Conditions. Since 12 August 2021, the GRF requirements are to be applied within the EU and since 4 November 2021, in the ICAO Member States. The determined runway conditions are published as Runway Condition Report (RCR) via ATIS and radio communications and as SNOWTAM, if required.

Friction measurements should not be published because they do not correlate with the performance data of aircraft. Friction measurements can be used in a comparative manner for upgrading or downgrading the runway condition code in combination with other local observations of the environmental circumstances.

In Regulation (EU) No. 2020/2148, ADR.OPS.B.037 - Assessment of runway surface condition and assignment of runway condition code, EASA stipulated that aerodrome operators shall state the runway condition for each third of the runway using a runway condition report. It must contain the runway condition code in numbers from 0 to 6 and the type and depth of the contaminant.

In the Nationale Implementierung des Global Reporting Format for Runway Surface Conditions, 16 March 2020, BMVI LF15/6111.4/17, the LBA described the national implementation of the international specifications.

The following is an excerpt.

[…]

The GRF methods include

- *New terms and definitions: Runway Condition Assessment Matrix (RCAM), Runway Condition Code (RWYCC), Runway Condition Report (RCR)*
- *For the RCR, the following elements are transmitted in the GRF format:*

  RWYCC, type of runway contamination, intensity and coverage for each third of a runway in relation to the lower runway designation
- *A new definition of the SNOWTAM which now includes hazards due to (standing >3 mm) water on the movement areas, i. e. the necessity to publish a SNOWTAM may also arise outside the winter season. This is accompanied by a new SNOWTAM form and a new form of SNOWTAM.*
- *The identification of the runway condition via the RWYCC which is derived from the RCAM, including the criteria for downgrades and upgrades.*
- *The maximum validity of a SNOWTAM was changed to 8 hours. At the end of these 8 hours, a new SNOWTAM must be issued until a report with the condition WET or DRY can be issued.*

[…]

1.18.3 Definition of a Contaminated Runway

According to the ICAO Annex IV, Attachment B. Aeroplane Performance Operating Limitations, Chapter 2. Definitions, 10th Edition, July 2016 a Contaminated Runway is defined as followed:

[…]

a) Contaminated runway. A runway is contaminated when more than 25 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by:

- water, or slush more than 3 mm (0.125 in) deep;

- loose snow more than 20 mm (0.75 in) deep; or

- compacted snow or ice, including wet ice.

[…]

1.18.4 Fatigue on Short-Haul Flights

Fatigue[24] can mean a reduction in physical and mental performance. This has been proven to impair a person's ability to safely control an aircraft. In aviation, mental fatigue and sleepiness are the most important forms of tiredness. Tiredness of a pilot was determined either as cause or as contributing factor in several severe accidents and serious incidents (Wingelaar-Jagt, 2021).

There are numerous factors in daily life that are associated with tiredness. ICAO defined the factors which are relevant for investigations in aviation: Sleep Loss, Extended Wakefulness, Circadian Phase, Workload (ICAO, 2020).

1.19 Useful or Effective Investigation Techniques

Not applicable

24 Fatigue is the general term used to describe physical and/or mental weariness which extends beyond normal tiredness (SKYbrary).

2. Analysis

The flight crew did not fully comply with the procedures of the operator. In particular, they accepted a slight tailwind component on landing, which was not in accordance with the prescribed procedures. The LDR the Boeing OPT software calculated was within the Landing Distance Available. The assessment procedures of the runway condition carried out by the airport operator were in line with the specifications. The aircraft nonetheless overran the runway end. There is a correlation between the continuous precipitation, the constant contamination of the runway and the overrun of the runway end because braking action was reduced. It indicates that the runway contamination assessment eight minutes prior to landing may not have corresponded with the real environmental circumstances.

2.1 Persons

2.1.1 Flight Crew

2.1.1.1 Flying Experience

Due to his long-term flying experience with winter operations, the PIC is considered as experienced. The co-pilot was appropriately licenced and had undergone the required training, including comprehensive aircraft performance and winter operations Training.

With 616 flight hours on the Boeing B737, he had experience in flight operations, but his experience in winter operations was limited. This could indicate that he was less experienced in dealing with winter weather conditions such as snow, ice formation or slippery runways. The BFU considers his contribution to supporting the PIC to be limited. Especially in the challenging weather conditions that prevailed that day. However, according to the operator's statement and according OM-A, Chapter 4.1.4, Issue 11, Revision 0, 20 October 2022, he is considered experienced due to his more than 500 flight hours.

2.1.1.2 Licences

The PIC and the co-pilot held the required and valid aeronautical licences and ratings.

2.1.1.3 Flight Time Limitation

The flight crew duty times complied with the EASA Flight Time Limitation and OM-A, Chapter 7 Flight Time Limitation. There was no indication of fatigue.

2.1.2 Airport Ground Handling Services Personnel

The Airport Ground Handling Services Personnel were trained and certified. The employee who performed the measurement on the day of the occurrence had more than 10 years of experience in assessing the runway condition. Based on the analysis of his training and experience, there is no indication of insufficient expertise to accurately assess the situation, even with the recent implementation of the GRF assessment procedure.

The employee started work at noon. He was not part of a night shift system. There were no indications of fatigue.

2.2 Flight Crew Actions

The PIC as PF conducted the entire flight, including the landing.

The flight crew received the runway condition codes 5/5/5, which the aerodrome operator had determined eight minutes prior to the landing. A landing mass of 61,400 kg, the aircraft landing configuration, the runway and the weather data (wind direction and speed, air pressure) were included in the landing distance calculation.

According to the aerodrome controller’s radio communication, the wind came from 250° with 2 kt. According to the OM-C, Airfield Briefing Document “Tailwind not authorised”, the landing was not permitted. The flight crew still accepted that during the landing a low tailwind component prevailed and decided to land.

Using the Boeing OPT software, they calculated the LDR during the flight. A list of the LDR for the possible Auto Brake selections MAX MANUAL and MAX AUTO was depicted. The calculated LDR were within the available runway length. The flight crew decided to use Auto Brake position MAX AUTO. The LDR for V_{ref40} + 5 kt with a landing mass of 61,400 kg and considering the runway condition code 5, the Boeing OPT software had calculated was 1,527 m (factored). At the time of the approach, ILS CAT II was active.

At the time of the occurrence, the Auto Land selection on the user interface of the Boeing OPT software had not been activated by the operator. According to the manufacturer’s OM (OM-B Chapter 2, 2.8.8 and OM-B Chapter 2, 2.10.4) and the operator, the pilots had to add the safety margin of 140 m for Flaps 40 to the LDR which the Boeing OPT software had calculated. The flight crew added them in the LDR calculation. In this case, the LDR was 1,667 m (factored LDR), i. e. at the end of the runway 33 m remained. The calculated LDR was within the limitation of the operational and legal framework. The operator performed the training of Auto Land during the bi-annual simulator trainings, because it was an official requirement of the pilots. The training included the note of the instructors to apply the 140 m for Flaps 40 safety margin to the Boeing OPT software calculation.

The operator had already discussed the missing menu item Auto Land before the occurrence with the aircraft manufacturer and had a well-established, approved alternative procedure at the time of the occurrence, which was correctly applied by the flight crew.

Visibility and cloud bases forced the flight crew to perform a CAT II approach. They configured the aircraft accordingly. According to the Auto Land procedure, both autopilots were activated. The landing occurred within the touch-down zone and the approach speed controlled by the Auto Throttle corresponded with the speed selected at the MCP. According to the flight crew, RAAS was not triggered. No corresponding DFDR parameter was recorded. The ground spoilers were activated and deployed, thrust reverse and Auto Brake in mode MAX AUTO were active. The flight crew accepted a minor tailwind component which was not authorised and permitted by the operator. The operator stated that the minor tailwind component was covered by the factored LDR the Boeing OPT software had calculated.

After touch-down, the Auto Brake system executed the automatic brake process MAX AUTO. The PIC may have perceived a possible reduction in the braking action of the main landing gear wheels and therefore, applied maximum manual braking via the pedals which overrides the Auto Brake system. He had control of the braking force of the main landing gear wheels and directional control of the aircraft on the runway centre line using the rudder and nose wheel. The extended ground spoilers and the active thrust reverse supported deceleration on the runway. This was not sufficient so that the aircraft came to a stop on the asphalt clearway beyond the end of runway 06.

The DWD weather station measured continuous snowfall. After the landing, the flight crew informed the aerodrome controller about their estimation of the low braking action. The aerodrome operator initiated another runway condition assessment 16 minutes later. The runway condition code was degraded to 3 and a corresponding SNOWTAM issued.

Since the aircraft had overrun the runway end, it has to be assumed that the determined values of the aerodrome operator did not correspond with reality at the time of the landing. There is a correlation between the continuous precipitation, the contamination of the runway surface and the subsequently reduced braking action of the main landing gear wheels. The LDR calculation, including the safety margin of 140 m (Flaps 40), was within the certified operational framework of the manufacture and the operator. The LDR for the actual landing weight, weather and reported 5/5/5 RWYCC was within the LDA after application of all safety margins. With a RWYCC, reflecting the actual runway surface condition, the flight crew would not have been permitted to perform the approach and landing, according to procedures.

The measurement of the wet snow on the runway by the aerodrome operator indicated that there was a layer of 2 mm present on the runway surface. The difference to a depth greater than 3 mm runway covered with wet snow is marginal. With a measurement of 3 mm wet snow the RWYCC would then indicate 3/3/3 and is assessed as contaminated. The landing would then not have been possible or permitted.

The operator planned the flight with weather conditions, which the flight crew also had available for their approach preparations. Given the time of year during which weather conditions can undergo rapid changes, the BFU recommends that the operator exercise heightened vigilance regarding weather-related risks. It is further advised that proactive measures be implemented, including, where appropriate, the selection of an alternate airport with longer runways to ensure operational safety.

the Based on the PIC's flying experience, especially his long-time experience with winter operations, the BFU is of the opinion that an alternate airport with longer runways should have been chosen in coordination with the operator and ATC.

2.3 Aircraft

As part of the Air Operator Certificate, the aircraft was certified for commercial passenger transport. In accordance with regulations by the Irish Aviation Authority, it had a certificate of registration.

The documentation the operator provided and the DFDR data of the flight did not contain any entries and indications, which would have suggested a defect of the Anti-Skid/Auto Brake Control system during the landing. No technical defects were determined, which could have affected a safe flight or distracted the flight crew.

2.4 Weather

The weather data and the METAR show that from 0550 hrs on, precipitation (light snow) prevailed. During and after winter service vehicles had mechanically cleared the runway surface, precipitation continued and remained on the runway.

According to the operator, both flight crew members were trained in low visibility and winter operations, with the PIC having received additional training for short and narrow runway operations. The weather situation, visibility, cloud base and the reported 2 mm of wet snow on the runway probably represented a demanding challenge for the flight crew to perform a safe landing. Since runway 06 was only 1,700 meters long, LDR was marginally within the operating limitations of a Boeing B737-800W. The LDR was increased due to the reported precipitation (wet now) and the continuous precipitation. This meant that the flight crew could expect a reduced braking action.

It is highly likely that the runway condition code published in the SNOWTAM did not correspond with the actual situation during the landing. There is a correlation between the continuous precipitation and the overrun of the runway end because braking action was reduced.

During the approach and the landing, a minor tailwind component prevailed, which was considered in the calculation of the Boeing OPT software. The tailwind component had a negative impact on the landing distance, i. e. it became longer. However, it was so minor that it was a contributory factor but not a causal one.

2.5 Aerodrome Operator

The aerodrome operator acted in accordance with the recommendations and guidelines of ICAO and arranged that the runway was cleared by winter service vehicles. They have taken the occurrence as an opportunity to discus and analyse the new measurement procedures (Regulations (EU) No. 2019/1387, No. 2020/469 and No. 2020/2148) with the responsible regional civil aviation authority. The aerodrome operator had determined that the existing procedures do not have to be amended (Chapter 4.1). There is no standard procedure for the measurement of a runway's contamination height. It is a subjective assessment of the person performing the measurement. This means measurements are imprecise and do not accurately reflect reality.

During winter operations, weather conditions change rapidly, i. e. the result of the measurement of a runway surface condition may have changed in the meantime.

2.6 Operator

All required and relevant documentations were provided and at the time of the occurrence, up to date.

The operator's OM-C contained the Airfield Briefing Dortmund EDLW/DTM document. It contained all relevant information and instructions for flight crews for the approach, the landing, ground handling and departure.

Based on an internal safety investigation, the airline has recommended a series of additional measures (section 4.2) to further improve operational safety. These measures are to be implemented in future through targeted training programmes for flying personnel and regular audits to check compliance with safety requirements. The aim is to identify potential risks at an early stage and increase safety awareness within the organisation.

3. Conclusions

3.1 Findings

3.1.1 Persons

3.1.1.1 Flight Crew

- PIC and co-pilot held the required licences and ratings to operate the aircraft.
- The flight experience of the PIC is rated as high.
- The co-pilot had less experience in winter operations compared to the PIC. This could relate in particular to dealing with winter weather conditions such as snow, ice formation, reduced visibility and slippery runways.
- Flight duty and rest times were adhered to.
- The flight crew had not submitted any fatigue report.

3.1.1.2 Airport Ground Handling Services Personnel

- The airport ground handling service personnel was properly trained.
- The employee who performed the measurement had more than 10 years of experience in assessing runway conditions.
- He had more than 12 months experience using the GRF procedure.
- Fatigue or tiredness was not a contributory factor.

3.1.2 Course of the Flight and Actions

- Prior to departure, the pilots had available weather data and NOTAMS to conduct the flight.
- Even before the approach, the METAR data indicated weather conditions that made it necessary to carry out a CAT II approach.
- The flight crew's decision to land on the runway with the runway condition codes 5/5/5 corresponded with the operational framework stipulated by the operator.
- The aircraft's approach configuration corresponded with the operator's stipulations in accordance with the OM-C, Airfield Briefing Dortmund EDLW/DTM, Rev 010, 22 September 2022.

- Above the threshold, the approach speed for the Auto Land approach was slightly lower than the flight crew had entered into the MCP. The aircraft touched down on the runway with the announced airspeed of V_{ref40}.
- At the time of the occurrence, the operator had not activated the selection of the item Auto Land in the Boeing OPT software version 4.7. The pilots had to add the correction of 140 m manually.
- The landing distance calculation was within the certified operational framework of the manufacturer and the operator.
- Landing performance calculations were compliant with regulatory requirements and manufacture guidance. Based on the RWYCC provided by the airport operator, the calculated LDR was within the LDA.
- During the landing, the flight crew accepted the low tailwind component of 2 kt, contrary to the OM-C, Airfield Briefing Dortmund EDLW/DTM.
- The PIC decided to control the brake pressure on the main landing gear wheels with the pedals and the direction with the rudder and the nose wheel.
- The aircraft touched down in the centre of the touchdown zone.
- The perceived braking action of the main landing gear wheels was lower as expected by the flight crew.

3.1.3 Aircraft

- The aircraft was equipped for operations in accordance with IFR.
- It had the required airworthiness certificate and was properly maintained.
- Technical malfunctions were not determined.

3.1.4 Weather

- Light snowfall prevailed. The RVR on runway 06 was 1,900 m and cloud base at 200 ft AGL.
- During and after the runway surface was mechanically cleared, precipitation, as snow, continued.
- The values measured before the landing, noted in the RCR, did not correspond with reality at the time of the occurrence.

- 16 minutes after the occurrence, the runway condition was measured again. The assessment and the runway condition code were published with the SNOWTAM.
- The runway condition code was degraded to 3.

3.1.5 Aerodrome Operator

- The aerodrome operator acted in accordance with the recommendations and guidelines of ICAO and arranged that the runway was cleared mechanically by winter service vehicles.

3.1.6 Operator

- Prior to and during the flight, the flight crew had current documentation available.
- The OM-C, Airfield Briefing Dortmund EDLW/DTM described the aircraft configuration, who should perform the approach, applicable procedures and limitations of the local weather conditions at the airport.

3.2 Causes

The Boeing B737-8AS flight crew performed an instrument approach procedure to runway 06 of Dortmund Airport. The aircraft touched down in the centre of the touch down zone of runway 06, which was contaminated with snow. It came to a stop on the paved clearway beyond the end of runway 06.

The investigation of the occurrence revealed the following significant items:

- The landing occurred with a stabilised Autoland CAT II ILS approach.
- The Landing Distance Required (LDR) was calculated with the latest weather information available to the flight crew and the Runway Condition Code (RWYCC) and was within the Landing Distance Available (LDA).
- The two previous Runway Condition Reports (1205 UTC and 8 min prior landing) were identical, with no change to the RWYCC confirming that the runway was not reported as contaminated.
- Between the assessment of the runway condition and the landing, continuous precipitation occurred which resulted in a runway covered with wet snow. Subsequently, braking action of the main landing gear wheels was reduced.
- The Runway Condition Code indicating 5/5/5, measured 8 min before landing, the flight crew received from the radar approach controller, may not have corresponded with the actual runway condition.

4. Safety Actions

4.1 Aerodrome Operator

The aerodrome operator has taken the occurrence as an opportunity to discuss and analyse the new measurement procedures – Global Reporting Format for Runway Surface Conditions in accordance with Regulations (EU) No. 2019/1387, No. 2020/469 and No. 2020/2148 – and the occurrence with the responsible regulating authority. This included the timing of the runway surface control, procedure regarding downgrading the runway condition code and the operational reporting channels, e. g. measuring vehicle to aerodrome controller. It was determined that the existing procedures did not have to be amended.

The aerodrome operator bought a Mobile Advanced Runway Weather Information Sensor (MARWIS[25]). The system provides an additional basis for the runway condition assessment and will be put into operation in the winter season 2024/2025.

Prior to the implementation of the procedure Global Reporting Format for Runway Surface Conditions, all airport ground operations managers had participated in a GRF training conducted by the Interessengemeinschaft der regionalen Flugplätze (IDRF) with a final exam and certificate. In addition, after the occurrence, one airport ground operations manager attended a Webinar about experiences with the new GRF procedure which EASA had performed.

On enquiry by the BFU, the aerodrome operator stated that there currently was no additional training on the market. Therefore, they decided to conduct an in-house refresher training on GRF for the airport ground handling services personnel during the winter season 2024/2025.

Thus, the BFU will not issue a safety recommendation to the aerodrome operator.

25 According to ICAO GRF (http://www.Lufft.com).

4.2 Operator

The operator analysed the occurrence and considered the risk of a runway excursion as a Key Operation Risk Area (KORA). The Safety Department addressed internal action to improve safety to different departments. The following actions[26] were initiated:

Flight Crew and Training:

- Starting in April 2023, the topic Runway Excursion Prevention Training was part of the briefing.
- The Airfield Briefing Dortmund EDLW/DTM in the OM-C was revised to emphasise the limitations for landing on contaminated runways more strongly.
- Guidelines for the interpretation of the GRF information were compiled for pilots.
- The occurrence will be part of future Winter Operation Trainings as case study.

Operations Control Centre:

- In March 2023, the applied internal operating procedures for publishing SNOWTAMS were audited. Changes of existing procedures were not required.

The investigation revealed that within the Boeing OPT software version 4.7 the selection item Auto Land was not customized by the operator. The operator has discussed this with the aircraft manufacturer already prior to the occurrence. An alternative method was published in the OM-B and approved by the responsible authority. The flight crews were trained accordingly and applied it correctly. The implementation of the Auto Land function in the Boeing OPT software will be achieved in September 2024 with Version 5.

Thus, the BFU will not issue a safety recommendation to the operator.

26 The listed actions are not quotes. The BFU reproduces the English communication with the operator in their own words.

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Assistance: Michel Buchwald, Martin Beckert, Ekkehart Schubert

Braunschweig, 10 April 2025

5. Appendices

Appendix 5.1: DFDR Plots

Appendix 5.2: DFDR Parameters - Depiction over Distance to the Threshold

Appendix 5.3: Runway Condition Assessment Matrix

Appendix 5.4: Approach and Taxiway on AIP Chart

5.1 DFDR - Plots

5.1.1 Approach and Landing

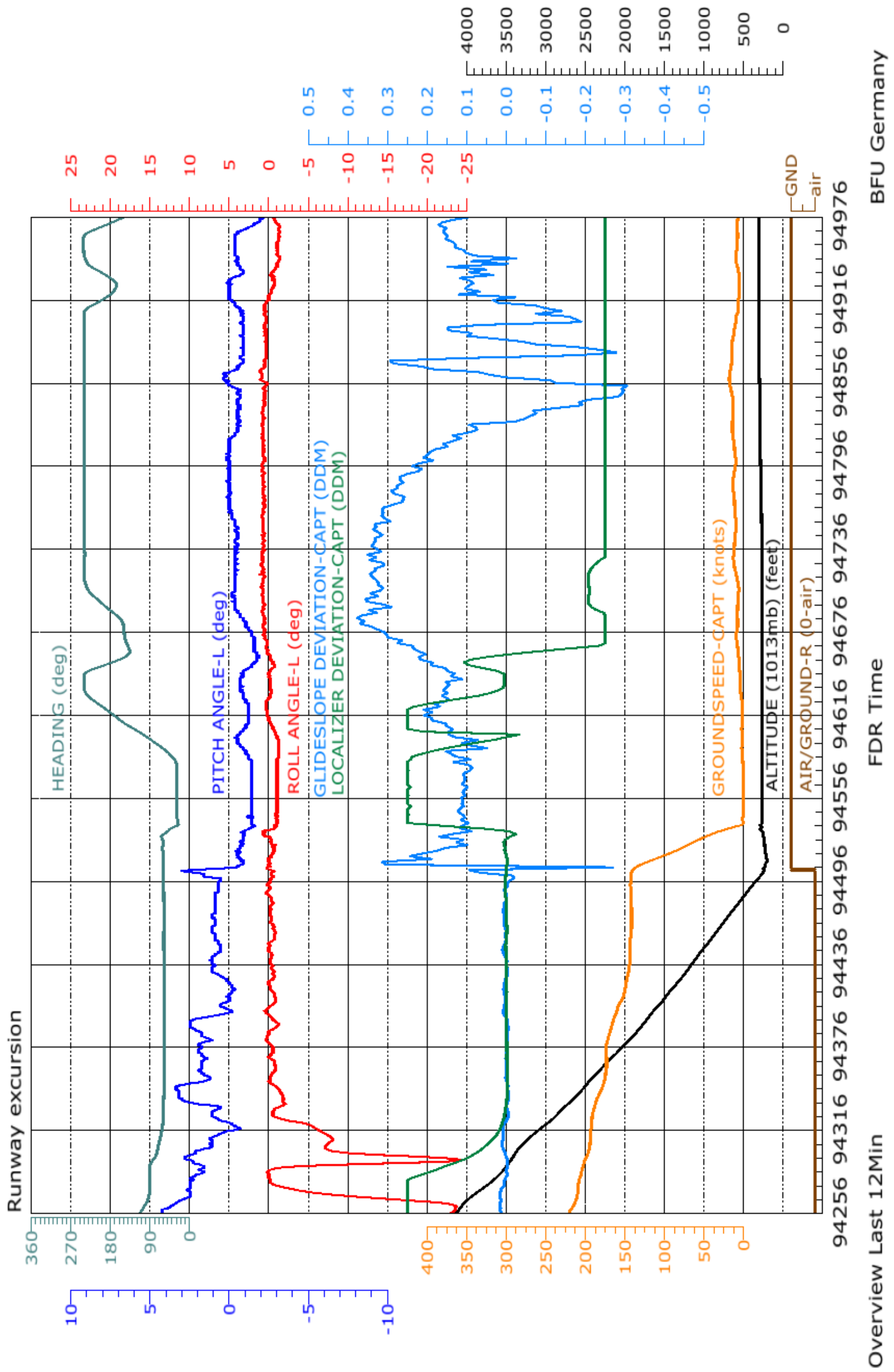


Fig. 7: DFDR parameters of the approach and landing Source: BFU

5.1.2 Touch-down until Standstill

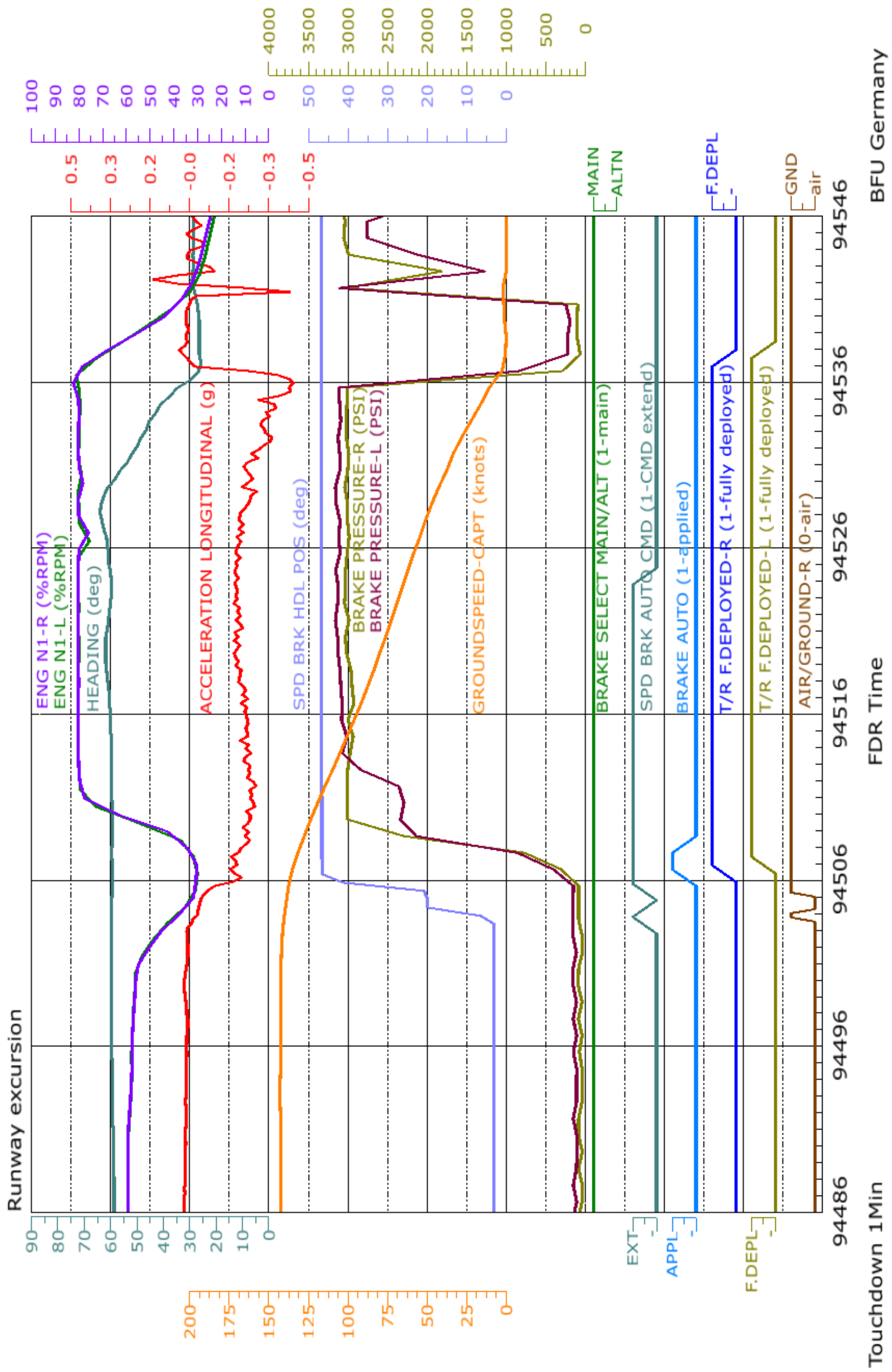
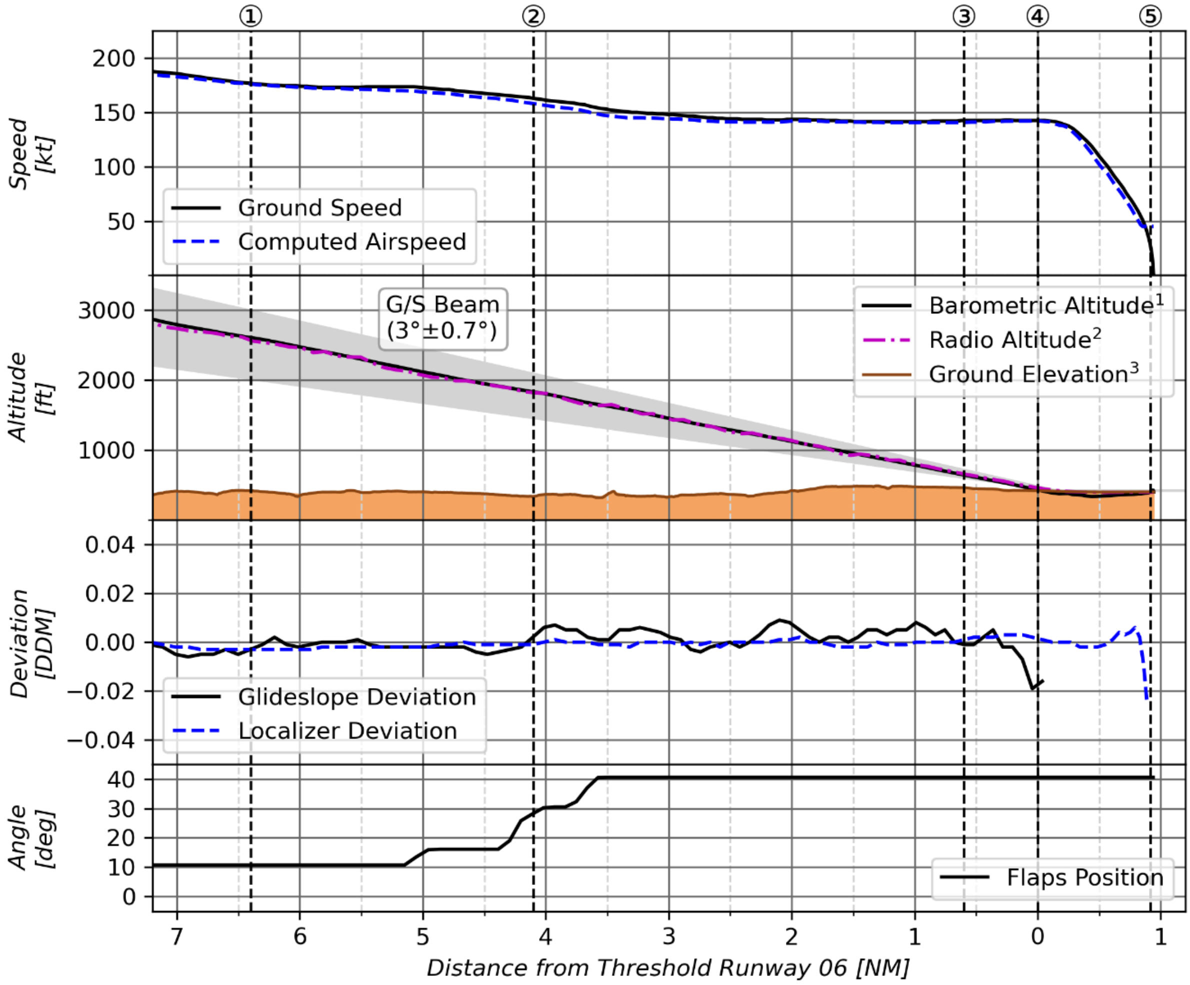


Fig. 8: DFDR parameters between touch-down and standstill

Source: BFU

5.2 DFDR Parameters - Depiction over Distance to Threshold

5.2.1 Approach



[1] Altitude pressure corrected acc. to EDLW airport METAR (QNH = 1018 hPa)

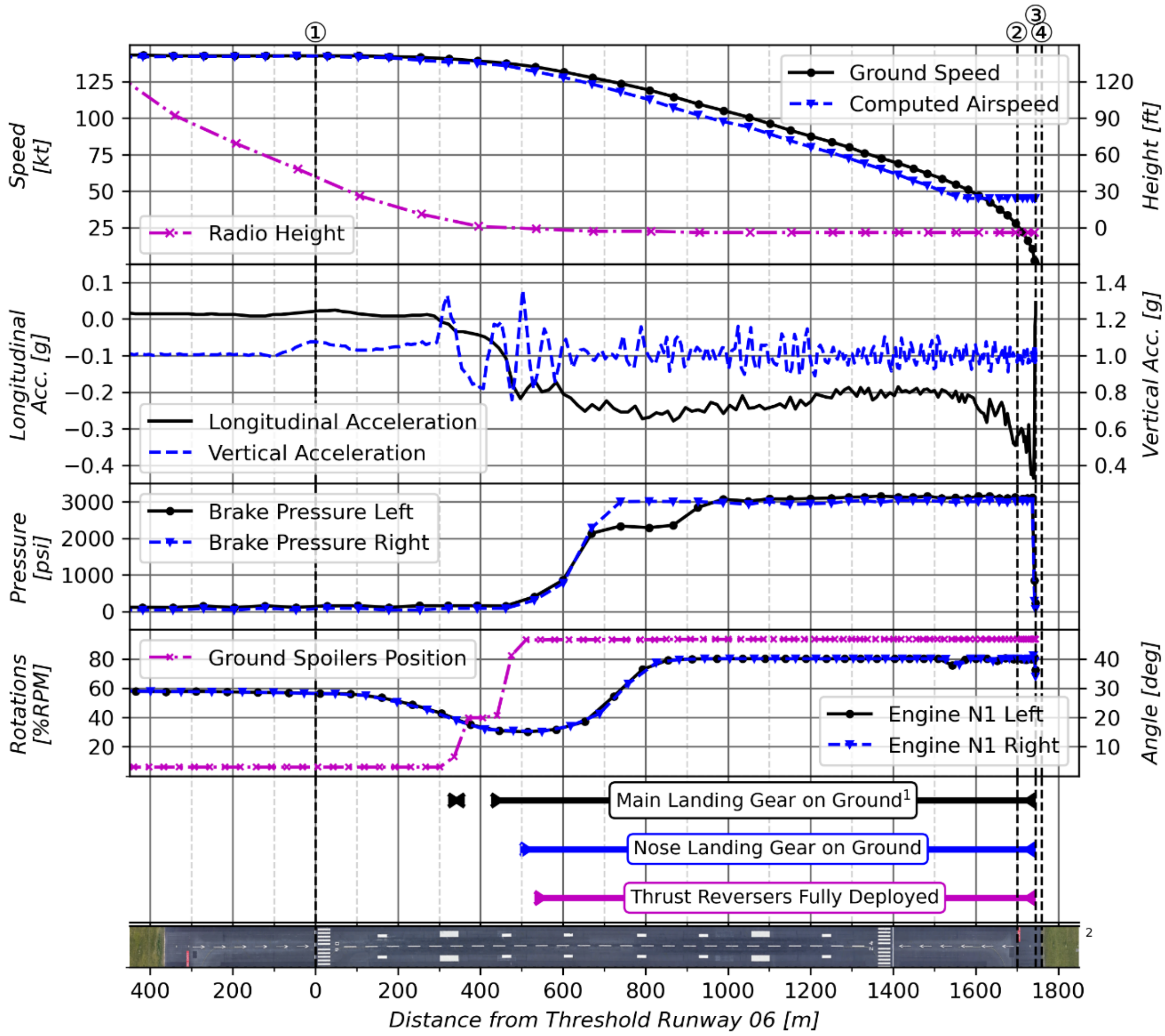
[2] Sum of "Displayed Radio Height" from Flight Data Recorder and "Ground Elevation"

[3] Google Maps Elevation API, retrieved January 10, 2023

Marker	Timestamp [UTC]	Explanation
1	14:26:03	Pickup point KOLOT (7.5 NM DME DOR)
2	14:26:51	ILS Outer Marker OM (5.2 NM DME DOR)
3	14:28:17	ILS Middle Marker (1.7 NM DME DOR)
4	14:28:32	Aircraft over threshold runway 06
5	14:29:06	Aircraft at end of runway 06 (a/c ground speed approx. 27 kt)

Fig. 9: Vertical flight path until touch-down Source: BFU

5.2.2 Touch-down



[1] The air/ground sensors on left and right main landing gear detected ground contact from 320 m to 360 m and after 430 m distance from runway threshold.

[2] Runway image EDLW retrieved from Google Earth, April 28, 2023

Marker	Timestamp [UTC]	Explanation
1	14:28:32	Aircraft over threshold runway 06
2	14:29:06	Aircraft at end of runway 06 (a/c ground speed approx. 27 kt)
3	14:29:10	Final position of aircraft (runway excursion approx. 45 m)
4		End of tarmac (60 m behind end of runway 06)

Fig. 10: Vertical flight path starting with touch-down until standstill Source: BFU

5.3 Runway Condition Assessment Matrix

Runway condition assessment matrix (RCAM)			
Assessment criteria		Downgrade assessment criteria	
Runway condition code	Runway surface description	Aeroplane deceleration or directional control observation	Pilot report of runway braking action
6	• DRY	---	---
5	• FROST • WET (The runway surface is covered by any visible dampness or water up to and including 3 mm depth) ***Up to and including 3 mm depth:*** • SLUSH • DRY SNOW • WET SNOW	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	GOOD
4	***−15ºC and Lower outside air temperature:*** • COMPACTED SNOW	Braking deceleration OR directional control is between Good and Medium.	GOOD TO MEDIUM
3	• WET ("slippery wet" runway) • DRY SNOW or WET SNOW (any depth) ON TOP OF COMPACTED SNOW ***More than 3 mm depth:*** • DRY SNOW • WET SNOW ***Higher than −15ºC outside air temperature***[1]: • COMPACTED SNOW	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	MEDIUM
2	***More than 3 mm depth of water or slush:*** • STANDING WATER • SLUSH	Braking deceleration OR directional control is between Medium and Poor.	MEDIUM TO POOR
1	• ICE [2]	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	POOR
0	• WET ICE [2] • WATER ON TOP OF COMPACTED SNOW [2] • DRY SNOW or WET SNOW ON TOP OF ICE [2]	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	LESS THAN POOR

Fig. 11: Runway Condition Assessment Matrix (Rodriguez, 2019) Source: ICAO

5.4 Approach and Taxiway on AIP Chart

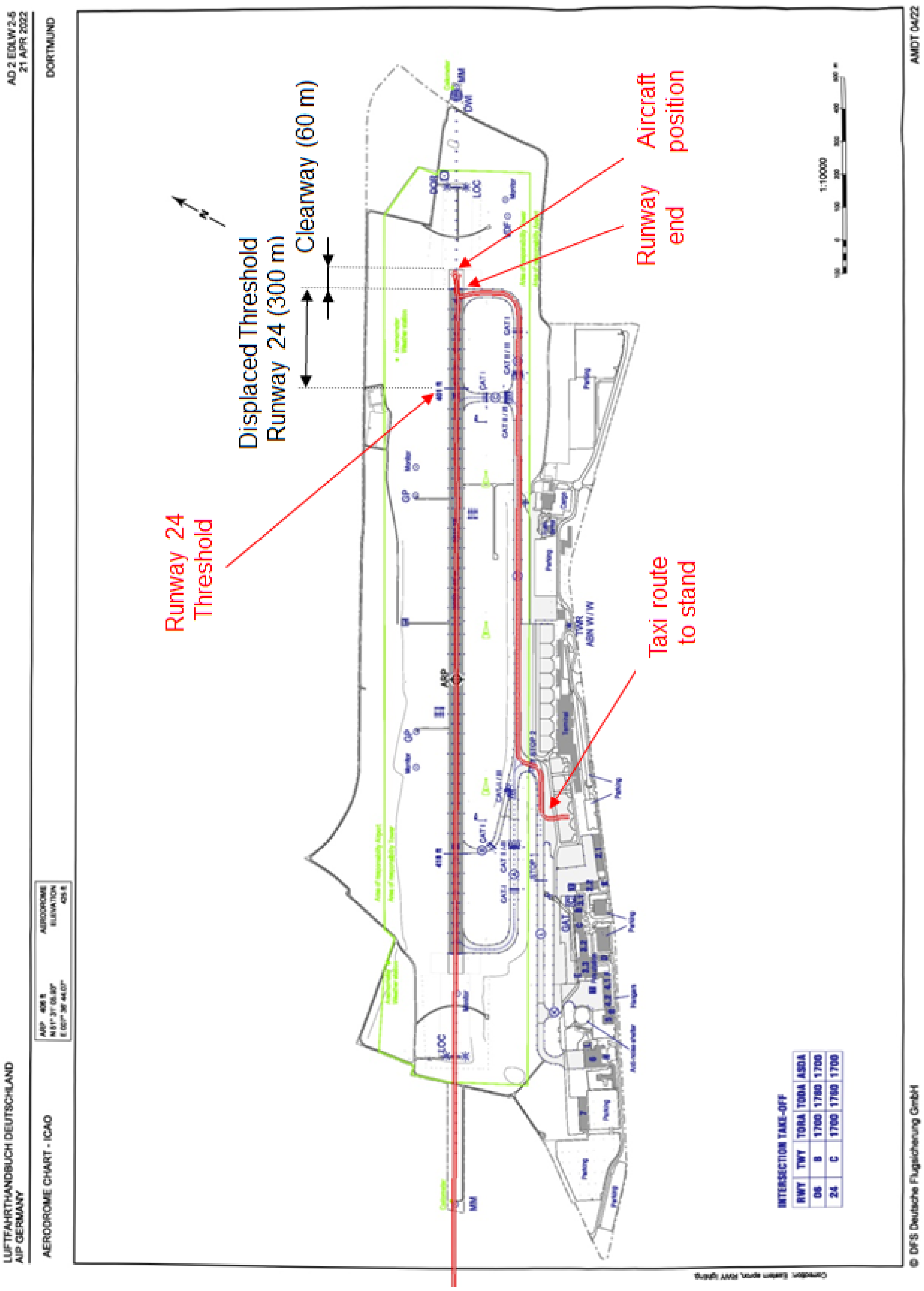


Fig. 12: AIP Chart AD 2 EDLW 2-5, 21 April 2022 including approach and taxiway (red)

Source: Air navigation service provider, adaptation BFU

6. References

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