

Factual Report

The Investigation Report was written in accordance with para 18 of the Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft stating facts only.

Identification

Type of Occurrence:	Serious incident
Date:	5 November 2005
Location:	East of Frankfurt/Main
Aircraft:	Transport aircraft
Manufacturer / Model:	Airbus / A 320-200
Injuries to Persons:	None
Damage:	None
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU 5X020-05

Factual Information

During the approach to Frankfurt/Main Airport the airplane underwent an uncontrolled roll movement. It initially rolled 28° right and then 8° left. The rolling motion was connected with an increased pitch angle and decrease in speed.

History of the Flight

The following information was deduced from crew statements, radar and flight data recordings. The Airbus A320-200 (A320) with two pilots on board was on a ferry flight from Berlin/Schönefeld to Frankfurt/Main. The Pilot in Command (PIC) stated that at about 0540 hrs¹ they were on approach to runway 25R when in approximately 3,800 ft AMSL during glide-slope intercept of the Instrument Landing System (ILS) a sudden uncontrolled yaw movement occurred. A Boeing B747 was flying ahead. During a time span of approximately 3 seconds the airplane first rolled left and then right. The rolling motion was connected with an increased pitch angle and decrease in speed. The pilot disengaged the autopilot and the automatic thrust and stabilised the flight attitude. The incident ended in approximately 400 ft above the glide-slope. Since they had visual contact with the runway the approach was continued and the landing occurred without further problems. The crew stated that since this was a ferry flight the Airbus was very light; it had a mass of approximately 46 t. The distance of the airplanes to each other during the approach was never less than 6 NM.

Aircraft Information

The Airbus A320-200 is a transport aircraft in all-metal construction, equipped with two jet engines. It was manufactured in 2001 and had the manufacturer's serial number 1381. The airplane is 37.57 m long and has a wing span of 34.1 m. Maximum take-off mass is 77,000 kg.

The Boeing B747-400 is a transport aircraft in all-metal construction, equipped with four jet engines. It is 70.6 m long and has a wing span of 64.44 m. Maximum take-off mass is 396,893 kg.

Meteorological Information

The German meteorological service provider (Deutscher Wetterdienst, DWD) stated that at the time of the serious incident the wind in approximately 4,000 ft AMSL came from 270 - 290° with 10 - 15 kt.

Aids to Navigation

For the approach the ILS for runway 25R was used.

¹ All times local, unless otherwise stated.

Radio Communications

The aircraft was in radio contact with the responsible Air Traffic Control (ATC) unit. Radio communications were recorded and made available to the BFU as transcript. The information was not relevant for the investigation.

Aerodrome Information

At the time, Frankfurt/Main Airport had two asphalt runways. The two runways were oriented 07L/25R and 07R/25L and each was 4,000 m long. Runway 07R/25L was 45 m wide and runway 07L/25R 60 m wide. A third runway had the direction 18 and was 4,000 m long and 45 m wide. It was a concrete runway.

Flight Recorders

The Airbus A320-200 Flight Data Recorder (FDR) and the ATC radar recordings were available for analysis.

Based on the FDR data, Image 1 (Appendices) depicts the situation prior to and after the disengagement of the autopilot. Initially the airplane rolled 28° to the right and then within 3 seconds 8° to the left.

Tests and Research

The German Aeronautic and Space Centre (DLR) Institute of Flight Systems participated in the investigation of the serious incident. Based on the available data, the task of the Institute was to verify if the A320 had flown into the wake turbulence of the preceding B747. The analysis was based on the FDR data of the Airbus, the radar data of both airplanes and the weather data.

First, the flight paths were determined using radar data. The radar positions of both airplanes were recorded every five seconds.

The Images 2 and 3 (Appendices) depict the 3D images of the approach sequence and the flight path above ground. The ILS glideslope is shown in black.

The distance between the two airplanes was calculated based on the radar data. At the time the autopilot of the Airbus A320 was disengaged the two airplanes had a distance of 6.2 NM. At the time the wake turbulence was generated by the preceding B747, the two airplanes had a distance of about 8 NM.

The speed and altitude of the B747 when the wake turbulence was generated was determined based on radar data. The altitude in which the wake turbulence was generated and the radar height were equated. The speed was determined by differentiation of the radar positions. The result was that the wake turbulence, which the Airbus encountered, had been generated in 1,500 m at a speed of 90 m/s (175 kt). The speed information was used to determine the initial intensity of the wake turbulence. In addition, it was assumed that the B747 had an approach mass of 278 t: Operating Empty Weight (OEW) 180 t, maximum payload 64 t, and fuel 34 t (20% of maximum fuel). In accordance with KUTTA-JOUKOWSKY (describes in aerodynamics the proportionality between dynamic lift and circulation) an initial circulation of 490 m²/s was calculated based on the approach speed of 90 m/s. Using a calculation model the decay of the wake turbulence was calculated for calm atmosphere based on the data available. This resulted in a certain strength of the wake turbulence at a certain age.

Needed were the values for the wind, speed, and direction. The FDR and meteorological data provided them. The FDR data was only available for an altitude of less than 2,100 m and showed a strong variance. In the respective altitudes the FDR data showed high peak values for wind speed and direction. Observations during in-flight tests showed, that these peaks are typical for the generation of wake turbulences and are signs for atmospheric disturbances.

The behaviour of the wake turbulence was simulated based on the radar positions of the B747. The simulation included the data for the decay of the wake turbulence, the drift from the wind data, and the induced descent of the wake turbulence.

Image 4 (Appendices) depicts the 3D image of the flight paths of the two airplanes at the moment the autopilot of the A320 had been disengaged. The wake turbulence of the Boeing 747 is marked green. Images 5 and 6 (Appendices) depict the side view and the flight path above ground. The variance of the wind data caused the bumpy course of the wake turbulence graph. A "black diamond" indicates the area of the wake turbulence closest to the A320 at the time of the autopilot being disengaged. The area where the wake turbulence was generated is also marked on the flight path of the preceding B747.

Because of the higher altitude of the B747 (above the ILS) the wake turbulence descended toward the succeeding A320 approaching the glideslope below the ILS. Based on the simulation the distance between the wake turbulence and the Airbus was estimated as 72 m vertically and 44 m laterally. The resulting circulation of the wake turbulence at an age of 129 s was then approximately 360 m²/s. For a category

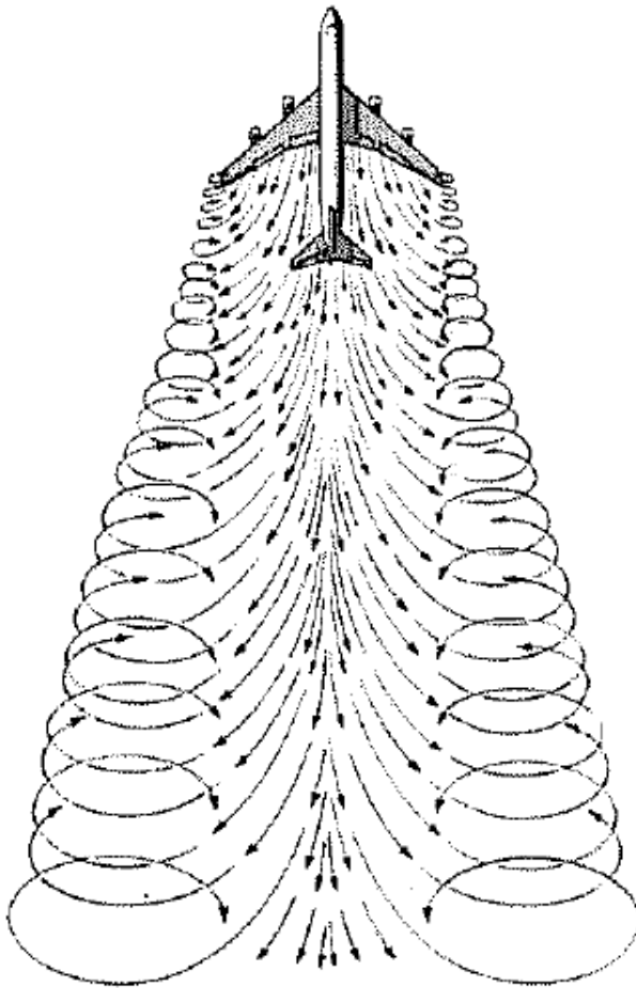
Medium airplane this is strong wake turbulence which can cause this particular reaction if encountered in relevant distance. Based on the layout of the runways, the prevailing wind direction, the estimated distances, and the inaccuracy of the prevailing wind data, it can be assumed that the succeeding airplane had come close to strong wake turbulence or had encountered it.

Additional Information

Wake Turbulence

All airplanes produce wake turbulence during a flight. It consists of a pair of wake turbulences originating at the wing tips, rotating against each other. The lift is responsible for the generation of the turbulence and the resulting wake turbulence.

The lift is generated by creation of a pressure differential over the wing surfaces. The lowest pressure occurs over the upper wing surface. On the upper wing surface the air flows inward from the wing tip toward the fuselage. The highest pressure therefore occurs in the middle of the wing lower surface. There the air flows outwards from the fuselage toward the wing tip. The resulting circulation and the downwash effect above the wing cause air turbulence at the wing trailing edge which rolls up in a spiral pattern at the wing tip. After the rolling-up is complete the wake turbulence of an airplane consists of two vortexes rotating against each other.



Der Aufrollvorgang

Source: ICAO

The strength of the vortex is determined by the mass, the speed, and the form of the aircraft's wing generating it. The wake characteristic of an aircraft is influenced by extended flaps, and other devices and a change in flight attitude. The main factor is the mass. The strength of the wake increases with the increase in mass and load factors in the direction of the wing span.

If an aircraft encounters the wake turbulence of a preceding airplane, structural damages can be the result. The real danger, however, is that the induced and irresistible roll and yaw makes the controllability of the airplane much harder. In-flight tests, where an aircraft was intentionally flown into the core of wake turbulence, showed that the airplane has the tendency to roll with the vortex. If the induced roll can be effectively counteracted depends on the wing span and the effectiveness of the manoeuvrability of the affected airplane.

Aircraft Separation during Approach

Basis for the conduct of air traffic is Document 4444-ATM/501 Air Traffic Management of the International Civil Aviation Organisation (ICAO). It describes the separation of airplanes during approach to an airport in accordance with their Wake Turbulence Category (WTC). Chapter 4.9 Wake Turbulence Categories lists all three categories which are based on the Maximum Take-off Mass (MTOM) of an airplane; Heavy, Medium and Light. There the following stipulations: Heavy (H) - all aircraft with a MTOM of 136 t or more, Medium (M) - all aircraft with a MTOM of less than 136 t but more than 7 t, and Light (L) - all aircraft with a MTOM of 7 t or less.

Chapter 8.7.4 Radar Separation Minima stipulates the following distances between two aircraft:

Succeeding Aircraft	Preceding Aircraft		
	HEAVY ≥ 136 t	MEDIUM < 136 t > 7 t	LIGHT ≤ 7 t
HEAVY	7.4 km (4.0 NM)	5.6 km (3.0 NM)	5.6 km (3.0 NM)
MEDIUM	9.3 km (5.0 NM)	5.6 km (3.0 NM)	5.6 km (3.0 NM)
LIGHT	11.1 km (6.0 NM)	9.3 km (5.0 NM)	5.6 km (3.0 NM)

In this case a Medium category airplane succeeded a Heavy category airplane. Therefore the minimum separation was 9.3 km (5.0 NM).

The ICAO Document Air Traffic Services Planning Manual (DOC 9426 - AN/924), Part II, Section 5, Chapter 3 Wake Turbulence states further information in regard to wake turbulences in air traffic.

Useful or Effective Investigation Techniques

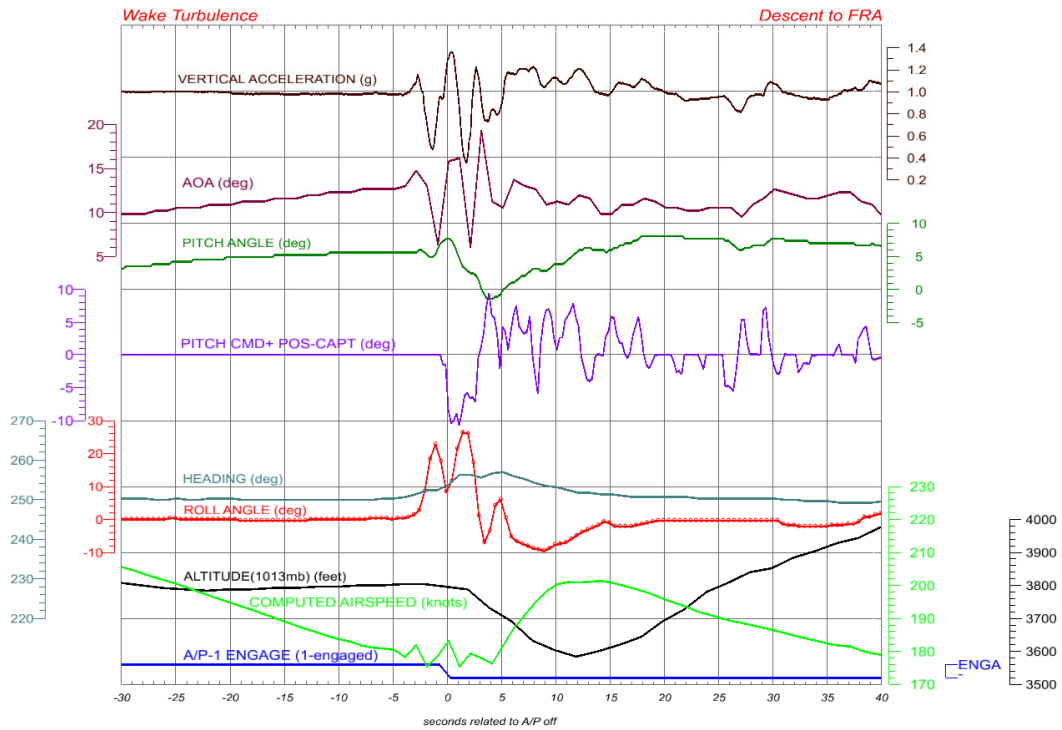
For the simulation of the wake turbulence of the preceding aircraft the P2P Probabilistic Two-Phase WV transport & decay model developed by the DLR was used.

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Braunschweig, 25 June 2015

Appendices

Image 1 FDR data A320
Image 2 3D Flight path overview, A320 behind B747
Image 3 3D Flight path above ground, A320 behind B747
Image 4 3D View of the flight paths and the wake turbulence position
Image 5 Side view of the glideslope and the wake turbulence position
Image 6 Flight paths and wake turbulence position above ground



file: pitch_z

Created: July 29, 2014

BFU Germany

Image 1: FDR Data A320

Source: BFU

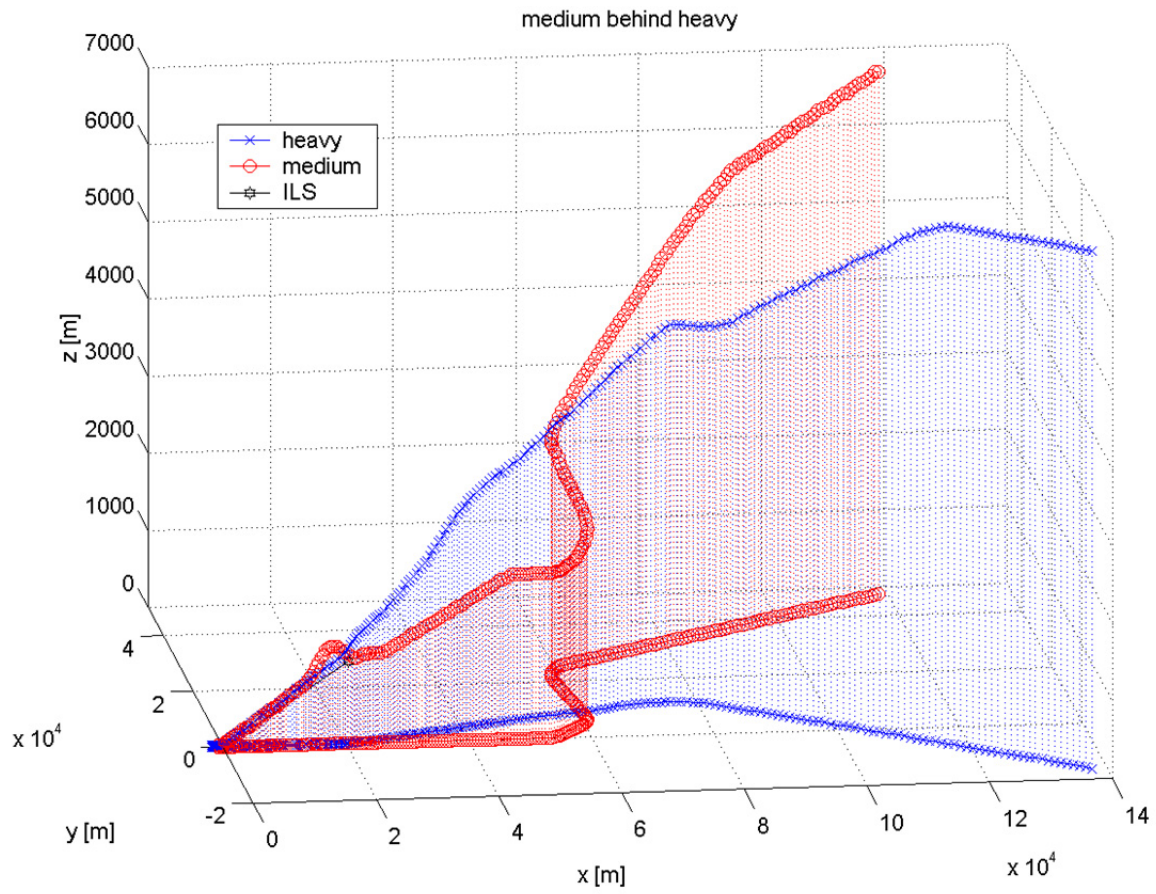


Image 2: 3D Flight path overview, A320 (red o) behind B747 (blue x)

Source: DLR

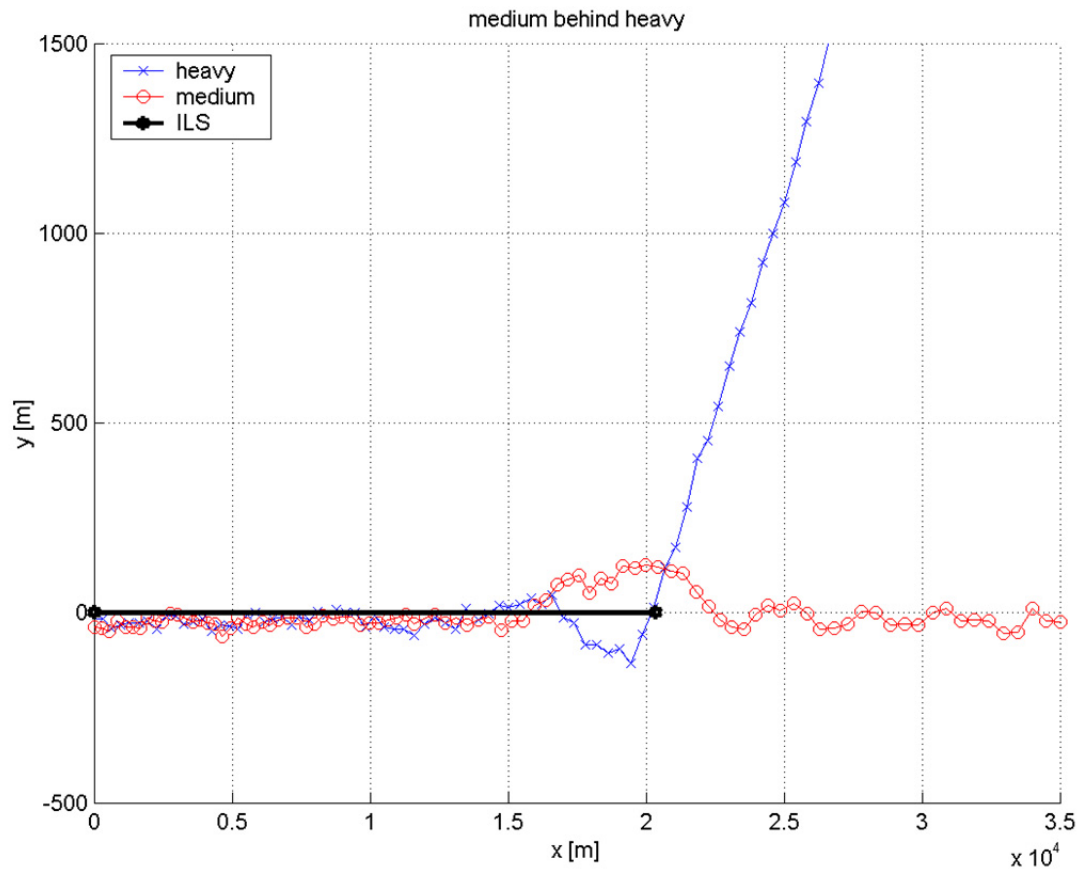


Image 3: Flight path above ground, A320 (o) behind B747 (x) (ILS as reference in black)

Source: DLR

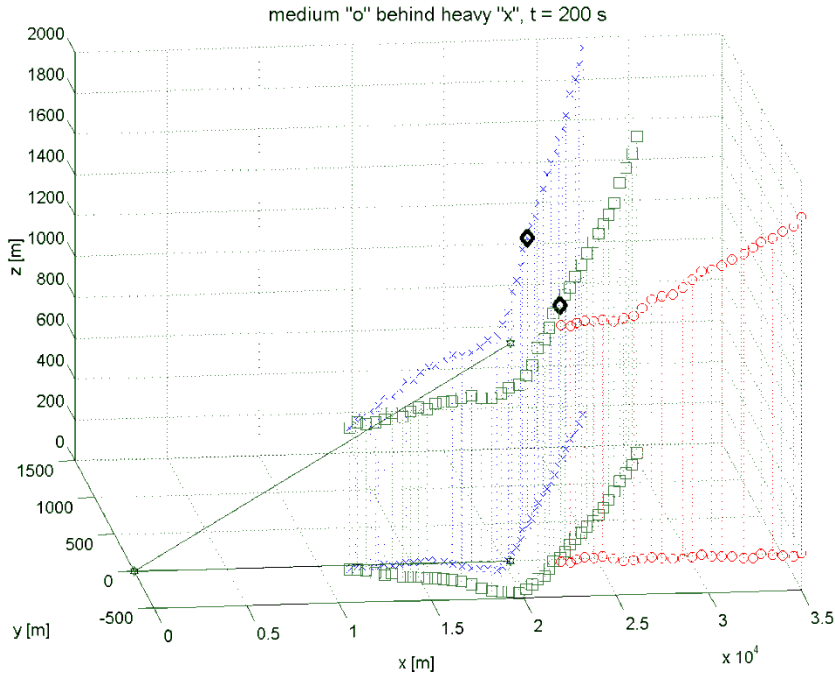


Image 4: 3D View of the flight paths and the wake turbulence position

Source: DLR

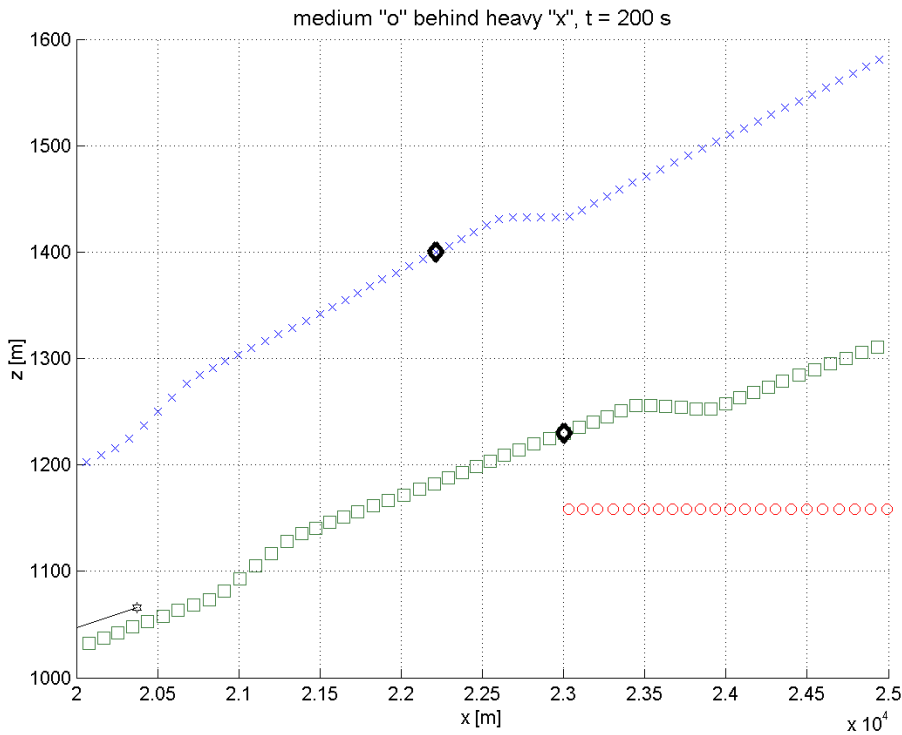


Image 5: Side view glideslopes and wake turbulence position

Source: DLR

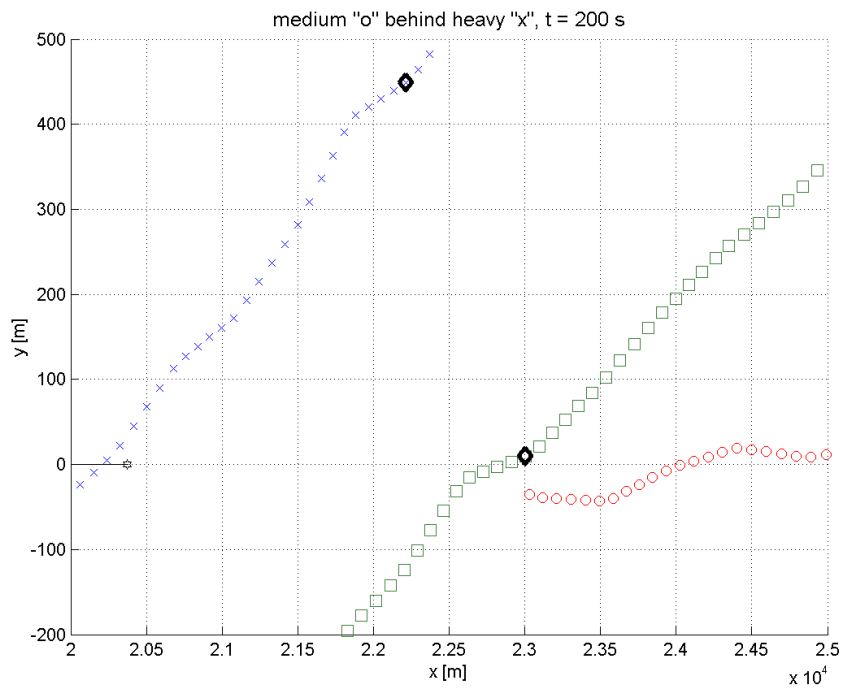


Image 6: Flight paths and wake turbulence position above ground

Source: DLR

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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