

Investigation Report

Identification

Type of Occurrence:	Serious incident
Date:	13 December 2011
Location:	Frankfurt/Main
Type of aircraft:	<ul style="list-style-type: none">1) Airplane2) Airplane
Manufacturer / Model:	<ul style="list-style-type: none">1) Airbus / A380-8002) Airbus / A320-214
Injuries to Persons:	None
Damage:	None
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU 5X013-11

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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Abbreviations

AAL	Above Aerodrome Level
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
BAF	Federal Supervisory Authority for Air Navigation Services
BAO	Operational Order (OO)
BFU	German Federal Bureau of Aircraft Accidents Investigation
CAS	Calibrated Airspeed
hPa	Hectopascal
ICAO	International Civil Aviation Organization
KIAS	Knots indicated airspeed
QAR	Quick Access Recorder
SID	Standard Instrument Departure
TCAS	Traffic Alert and Collision Avoidance System
TO/GA	Take-Off / Go-Around
VOR	Very High Frequency Omnidirectional Radio Range
WTC	Wake Turbulence Category

Synopsis

One day after the occurrence, the German Federal Bureau of Aircraft Accident Investigation (BFU) was advised by the air traffic service provider that at 1426 hrs¹ on 13 December 2011 an Airbus A320-214 (A320) taking-off from runway 25C of Frankfurt/Main Airport suffered an air proximity with an Airbus A380-800 (A380) which had aborted the landing on runway 25L and conducted a missed approach. According to the radar data the closest proximity was 0.97 Nautical Miles (NM) horizontally and approximately 200 ft vertically, respectively. The minima for the separation of aircraft were 7 NM horizontally and 1,000 ft vertically. The BFU classified the occurrence as a serious incident and initiated an investigation.

The Serious Incident was caused by the following:

Immediate causes:

- The take-off clearance was given even though the landing of the A380 on the parallel runway was not yet definite.
- A rejected take-off was not instructed.
- The erroneous mental approach of solving a problem of the controller resulted in the instruction to the departing airplane to fly a turn toward the airplane conducting a go-around on the parallel runway.

Systemic causes:

- The increased coordination effort between the controllers due to the working position organisation (tower) and the organisation of the runway operation has contributed to the separation infringement and to the approximation of the wake turbulence.
- The stipulations for the controllers to separate the departure routes of runway 25C and the missed approach procedures of runway 25L were insufficient.

¹ All times local, unless otherwise stated.

1 Factual Information

1.1 History of the Flight

An Airbus A380 coming from Tokyo was on approach to runway 25L of Frankfurt/Main Airport. The Tower Controller South (TCS) responsible for runway 25L issued a landing clearance at 1423:22 hrs and passed on the wind information as 200° with 17 kt and a maximum of 25 kt.

On the parallel runway 25C an Airbus A320 standing in the area of the threshold received take-off clearance for a flight to Moskow-Sheremetyevo Airport at 1425:30 hrs from Tower Controller Centre (TCC) with the words: „... wind is two hundred one eight knots and two five knots, two five centre cleared for take-off.“ The departure was to be conducted according to the Standard Instrument Departure Route (SID) TOBAK1M (Appendix 1).

The radar data showed that the A380 was above the touch-down zone of runway 25L at time of the take-off clearance for the A320. According to the data of the A380's Quick Access Recorder (QAR) the height above ground was 55 ft at the time of passing the runway threshold. At 1425:33 hrs the A380 crew independently initiated a missed approach. The flight data recordings showed that the aircraft had approached with flaps and slats in position 3 (26°/23°). The radio height had decreased to zero and had then increased again. The Calibrated Airspeed (CAS) was about 146 kt.

The QAR showed that the A320 crew began to increase the thrust at about 1425:32 hrs. At 1425:43 hrs the N1 of both engines reached approximately 88.5 %. At 1425:45 hrs, 12 seconds after the A380 had begun the missed approach, the take-off run of the A320 on runway 25C began.

According to the aerodrome surface movement radar the A380 was at that time about 900 m beyond the threshold of runway 25L. The TCS noticed the missed approach procedure of the A380 and instructed the crew at 1425:56 hrs: „... follow standard missed approach“.

The A320 QAR data showed that about 26 seconds after the take-off roll had begun the nose landing gear and further two seconds later the main landing gear lifted off the ground. According to the QAR the decision speed V_1 of 147 KIAS calculated in the flight documentation was exceeded at 1426:05 hrs or approximately 35 seconds after receiving take-off clearance. The QAR data of the A320 recorded an increase of rate of climb of up to 4,656 ft/min within the first 30 seconds of the climb.

When the TCC noticed the A380 performing a missed approach he instructed the A320 crew at 1426:18 hrs: „... proceed on runway heading, proceed on runway heading three eighty from the southern runway has pulled up.” The A320 crew acknowledged this instruction. At that time the A320 was in 296 ft above ground, according to the radio altimeter.

Both airplanes were in climb on almost parallel headings. The radar data showed that the A320 was behind and to the right of the A380 when at 1426:53 hrs the air proximity occurred with a horizontal distance of 0.97 NM and a vertical distance of about 200 ft.

At 1427:00 hrs the TCS radioed the A380 crew: „... turn left heading one eight zero ...”.

The TCC instructed the A320 crew at 1427:01 hrs: „... continue now in a left turn please.” The crew acknowledged the instruction and the aircraft began to turn south. At 1427:27 hrs the TCC instructed the A320 crew: „... proceed on heading two seven zero, two seven zero please.” The crew replied: „... right heading two seven zero”.

At 1427:35 hrs the TCS instructed the A380 crew to turn to a heading of 070°. This was affirmed.

Both airplanes continued their flights to their respective destination airports.

The A380 crew stated that they had aborted the approach because the flare had been too high and together with the prevailing gusts made touch-down within the touch-down zone doubtful. The QAR data showed that during the missed approach the A380 TCAS communicated with the A320 TCAS and monitored the approximation.

The A320 pilots reported there were no technical problems during the flight. Take-off was conducted with TO/GA. During climb the air traffic controller issued vectors. There was neither any TCAS information nor commands during take-off and climb.

The TCS stated that he had realised the missed approach of the A380 as the A320 had already begun its take-off roll. He had had the intention to increase the distance to the A320 taking off from runway 25C by instructing the A380 to fly a left-hand turn. In order to do so he had to coordinate the missed approach with the Tower Controller West (TCW) responsible for runway 18. At the same time, he wanted to coordinate the take-off of the A320 with the TCC to have it fly straight ahead.

The TCC stated that once he saw the A380 going around with a "good rate of climb" he instructed the A320 crew to maintain "runway heading" and issued traffic information regarding the A380. Once he estimated the A380 having reached a sufficient altitude he instructed the A320 crew to initiate a left-hand turn to adhere to the required departure route. He said to the TCS sitting at the working position to the right of him: "I will turn mine to the left".

The TCS stated he had understood he should turn his airplane to the left.

After the TCC realised that the A380 also turned south he had tried to increase the distance of the two aircraft by issuing another heading correction to the A320.

1.2 Injuries to Persons

None

1.3 Damage to Aircraft

There was no damage to the aircraft.

1.4 Other damage

None

1.5 Personnel Information

1.5.1 A380-800 Crew

The 53-year-old Pilot in Command (PIC) held an Air Transport Pilot's Licence (ATPL (A)) initially issued by the Luftfahrt-Bundesamt (German civil aviation authority, LBA) on 11 November 1983 and valid to 8 August 2014 with the type rating for Airbus A380 valid to 30 May 2012 including Instrument Rating (IR). His medical class 1 certificate was valid until 30 May 2012. His total flying experience was about 18,700 hours, about 400 hours of which were on the type in question.

The 33-year-old co-pilot held an Air Transport Pilot's Licence (ATPL (A)) initially issued by the Luftfahrt-Bundesamt on 12 June 2001. His class 1 medical certificate was first issued on 8 December 1998, and was valid to 30 April 2012. His total flying experience was about 7,500 hours; 602 hours of which were on the A380.

1.5.2 A320-214 Crew

The 31-year-old PIC held an Air Transport Pilot's Licence (ATPL (A)) first issued by the Russian Federation civil aviation authority on 10 September 2003 with the type rating for A319/320/321. His total flying experience was about 4,596 hours, about 1,770 hours of which were on the type.

The 31-year-old co-pilot held an Air Transport Pilot's Licence (ATPL (A)) first issued by the Russian Federation civil aviation authority on 24 June 2006 with the type rating for A319/320/321. His total flying experience was 1,450 hours; 1,231 hours of which were on the type.

1.5.3 Tower Controller South (TCS)

The 25-year-old tower controller held a licence for aerodrome control with radar including Flight Information Service (FIS) issued by the Federal Supervisory Authority for Air Navigation Services. For Frankfurt Tower he held the ratings for the working position as Tower Controller South and additional controller's working positions.

He had been with the air navigation service provider since 2007 and since April 2008 had been working at the Tower Frankfurt as tower controller.

He had reported for duty at 1400 hrs and had been at his working position for four minutes when the occurrence happened.

1.5.4 Tower Controller Centre (TCC)

The 49-year-old tower controller held a licence for aerodrome control with radar including Flight Information Service (FIS) issued by the Federal Supervisory Authority for Air Navigation Services. For Frankfurt Tower he held the ratings for the working position as Tower Controller Centre and additional controller's working positions.

He had been with the air navigation service provider since 1979 and since 1996 had been working at the Tower Frankfurt as tower controller.

He also had reported for duty at 1400 hrs and had been at his working position for three minutes when the occurrence happened.

1.6 Aircraft Information

1.6.1 Airbus A380-800

The Airbus A380-800 is a low-wing transport aircraft powered by four jet engines. The wingspan is 79.80 m

Manufacturer: Airbus
Type: A380-800
Manufacturer's Serial Number (MSN): 070
Year of manufacture: 2011
MTOM: 560,000 kg
MLM: 386,000 kg
Engines: Rolls-Royce Trent 970

The aircraft had a valid German certificate of registration and was operated by a German air operator.

The aircraft gross weight at the time of the go-around was 383,494 kg. The airplane was equipped with a *Traffic Alert and Collision Avoidance System* (TCAS).

1.6.2 Airbus A320-214

The Airbus A320 is a low-wing transport aircraft powered by two jet engines. The wingspan is 34.10 m

Manufacturer: Airbus
Type: A320-214
Manufacturer's Serial Number (MSN): 2116
Year of manufacture: 2003
MTOM: 78,000 kg
Engines: CFM 56

The aircraft was registered in the Bermudas and operated by a Russian air operator.

The flight documentation showed that the take-off mass of the airplane was 63,900 kg. The airplane was equipped with a TCAS.

1.7 Meteorological Information

The incident occurred at daylight. At the time of the occurrence Visual Meteorological Conditions (VMC) prevailed.

There was a wind warning for Frankfurt/Main Airport valid to 1900 hrs. It contained a warning about southerly winds with speeds of 20 to 25 kt and a maximum of 35 to 40 kt. The wind was supposed to increase during the day.

The aviation routine weather report (METAR) of 1350 hrs (12:50 UTC) gave the following weather conditions:

Wind:	200°/18 kt, gusts up to 28 kt
Clouds:	5-7 oktas in 2,500 ft Above Aerodrome Level (AAL), 5-7 oktas in 2,800 ft AAL
Visibility:	More than 10 km
Temperature:	7°C
Dewpoint:	5 °C
Barometric air pressure (QNH):	1,001 hPa

1.8 Aids to Navigation

Not relevant.

1.9 Radio Communications

Radio communications were recorded and made available as transcripts for evaluation purposes.

The A380 crew was in radio communication with the TCS on frequency 119.900 MHz; the A320 crew with the TCC on frequency 118.775 MHz.

The Tower Frankfurt was not equipped with a recording device to record background communication and the aural environment as is recommended in ICAO Annex 11.

1.10 Aerodrome Information

Frankfurt/Main Airport has three parallel runways oriented 069°/249°. The runways 07R/25L and 07C/25C have a lateral distance of about 520 m, a length of 4,000 m

each and a width of 45 m and 60 m, respectively. Runway 07L/25R, available for landings only, is 2,800 m long and 45 m wide. Runway 18 is available for take-offs only and is 4,000 m long and 45 m wide. Aerodrome reference point is 364 ft AMSL.

1.11 Flight Recorders

The radar data relating to the flight was recorded and made available to the BFU.

Both aircraft were equipped with a Cockpit Voice Recorder (CVR) and a Flight Data Recorder (FDR). The recordings were not available for analysis.

Data from the Quick Access Recorder (QAR) of both aircraft were made available to the BFU for investigation of the serious incident.

1.12 Wreckage and Impact Information

Not relevant.

1.13 Medical and Pathological Information

Not relevant.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Not relevant.

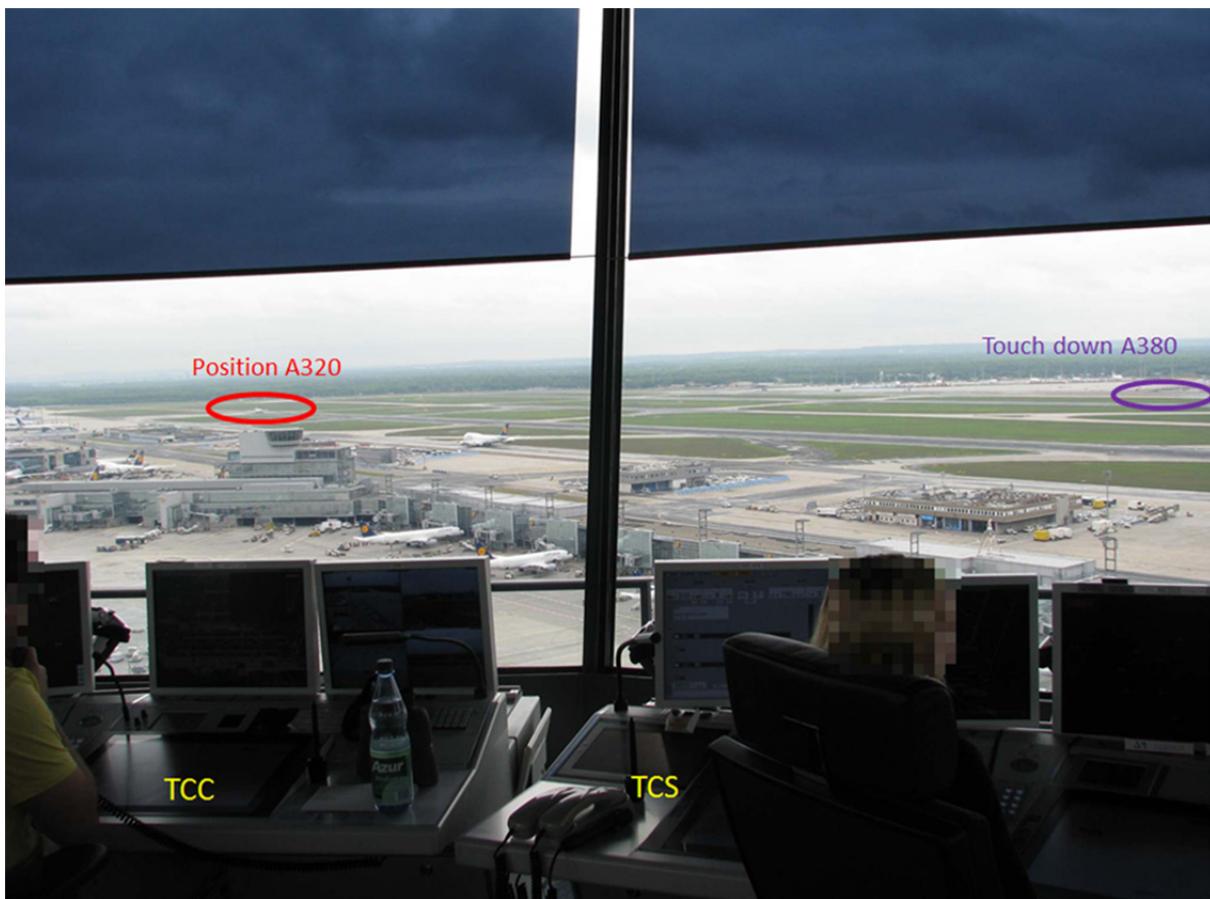
1.16 Tests and Research

Not relevant.

1.17 Organisational and Management Information

About seven weeks prior to the serious incident the newly built runway in the north-west part of Frankfurt/Main Airport was put into operation.

Substantial changes, also concerning air traffic control services, became effective once the north-west runway (07L/25R) was put into operation. Up to four controllers were working in the Tower Frankfurt. The flight operations on runways 07C/25C and 07R/25L were handled by one controller each on different frequencies.



Controllers' working positions TCC (left) and TCS (right)

Photo: BFU

The conduct of the air navigation service operation at Frankfurt/Main Airport was regulated by the following policies of the air navigation service provider:

- Manual of Operations Air Traffic Services (MO-ATS)
- Operational Order (OO) to establish additional and local procedures on the basis of the MO-ATS.

1.17.1 Manual of Operations Air Traffic Services (MO-ATS)

The MO-ATS stipulated, among other things, that in the vicinity of an airport the separation minima can be reduced if the tower controller ensures a sufficient distance between the aircraft and can observe all aircraft involved at all times.

The MO-ATS, chapter Wake Turbulence Separation contained the separation stipulations to minimise the hazards caused by wake turbulences. The separation minima were stipulated for the respective weight categories of the preceding and the succeeding aircraft (heavy, medium, light).

The separation minima valid for the A380 in and below Flight Level (FL) 100 were stipulated as follows:

Preceding Aircraft	Succeeding Aircraft	Separation Minima
A388 / HEAVY (non A388)	A388	not required
A388	HEAVY (non A388)	6 NM
A388	MEDIUM	7 NM
A388	LIGHT	8 NM

These separation minima shall be applied, among other things, when

- an aircraft is operating behind a preceding aircraft at the same level or less than 1,000 ft below;
- both aircraft use the same runway or parallel runways with a lateral distance of less than 760 m;

The separation minima did not need to be applied if:

- The pilot of the succeeding aircraft has declared that he has the preceding aircraft in sight and will attend to an appropriate distance himself;
- the pilot of a preceding aircraft renounces wake turbulence separation;
- the area within which wake turbulence is expected will not be penetrated.

1.17.2 Operational Order for the Tower Frankfurt/Main

The Operational Order (OO) stipulated that during 4-runway operation at Frankfurt Airport take-offs should generally occur on runways 18 and 07C/25C and landings generally on runways 07L/25R and 07R/25L.

5.4 Missed approach procedure

5.4.1 In case of a missed approach

- *under the conditions for the reduced radar separation minimum on final approach or*
- *using reduced separation in the vicinity of an airport or*
- *under the conditions of independent parallel departure operation*

is the Tower not responsible for the resulting separation infringement. As quickly as possible, separation in accordance with the MO-ATS is to be established.

Note: At any time, it can be necessary to deviate from the standard missed approach procedure to establish or maintain separation. A deviation is not necessary to favour departing traffic. If traffic allows without any danger it can be made use of. In general, however, departing traffic has to be subjected to the standard missed approach procedure.

5.4.2 A missed approach is to be called out loudly by the respective controller mentioning the runway.

[...]

6.1.4 Departures runway 25C with south-turning heading vs. missed approaches runway 25L

6.1.4.1 A release between the TCC and the TCS does not necessarily have to be coordinated, however, the take-off run cannot be started on runway 25C as long as an approaching aircraft is within the marked taboo zone of the final approach to runway 25L.

6.1.4.2 The taboo zone requirement alone is no guarantee for a sufficient separation in case of a missed approach to runway 25L. Together with the other additional tools in chapter "General" it is only to be considered a minimum requirement to establish the required radar or wake turbulence separation as quickly as possible.

[...]

6.1.9 Departures runway 18 vs. possible missed approaches runway 25L

6.1.9.1 *If the responsible TC estimates that based on the meteorological conditions an increase of missed approaches on runway 25L is possible, departures on runway 18 must have passed the extended runway centreline of 25L before approaching aircraft pass the threshold of runway 25L.*

[...]

6.4 Simultaneous and parallel flight operations on parallel runways

6.4.1 Approaches

The independent parallel approach is the general operating mode for approaches. In cases where no independent parallel approach operation takes place the rules for reduction of separation in the vicinity of airports can be used. Overtaking an aircraft is only permissible if the preceding aircraft agrees.

6.4.2 Departures

6.4.2.1 *The simultaneous take-off of two aircraft from the centre and south runways is only permissible if:*

- *The meteorological conditions allow visual contact between the two aircraft until an IFR separation can be initiated and*
- *traffic information is issued to both pilots and*
- *based on the Standard Departure Routes (SID) used there is neither a flight path crossing nor do the SIDs meet within 3 NM nor was a parallel flight path of more than 3 NM after take-off given.*

6.6 Wake turbulence separation

6.6.1 *The procedures and separation minima stipulated in the MO-ATS are effective. If the stipulations are adhered to a pilot can renounce these separation minima or declare that he has the preceding aircraft in sight and will attend to an appropriate distance himself.*

6.6.2 *In case of aerodrome control radar failure the stipulated separation minima (distance) are supplemented by the following time separation:*

Take-off on the same or parallel runway, or take-off on runway 18 after landing on runway 07R		
Preceding Aircraft	Succeeding Aircraft	Minimum
WTC M	WTC L	2 min.
H	M / L	2
H	H	2
A388	M / L	3
A388	H	2

Take-off on the same or parallel runway and preceding aircraft has shorter TORA		
Preceding Aircraft	Succeeding Aircraft	Minimum
WTC M	WTC L	3 min.
H	M / L	3
H	H	2
A388	M / L	4
A388	H	2

The separation in case of aerodrome control radar failure

Source: Air navigation service provider

The OO described the individual working positions and the tasks of the controllers in detail.

The following stipulations were effective, among others, for the working position TCS:

The area of responsibility of the TCS in the airspace encompassed mainly the approach and departure area of the south runway within the control zone and the south-east area including runway 07R/25L and sector Egelsbach. On the ground, he was responsible for runway 07R/25L and the associated taxiways, among other things.

Part of his main tasks was the establishment of separation using radar or ensuring appropriate distances by visual estimation in accordance with the OO and local agreement. The control and observation of the airspace and the airfield using radar and vision were also part of his responsibilities as well as the coordination with other TCs concerning procedures in all separation-relevant areas.

His job specifications also stipulated the departure coordination with other TCs involved, the military aerodrome control service Wiesbaden Tower, Langen Information or Egelsbach Info. In agreement with other TCs he was responsible for the separation and distance guarantee between aircraft but also with the traffic of other runways. In case of missed approaches it was his responsibility to control and monitor

them but also to coordinate actions which may have to be taken immediately with the other TCs and Langen Radar (EDDF, APP).

The following stipulations were effective, among others, for the working position TCC:

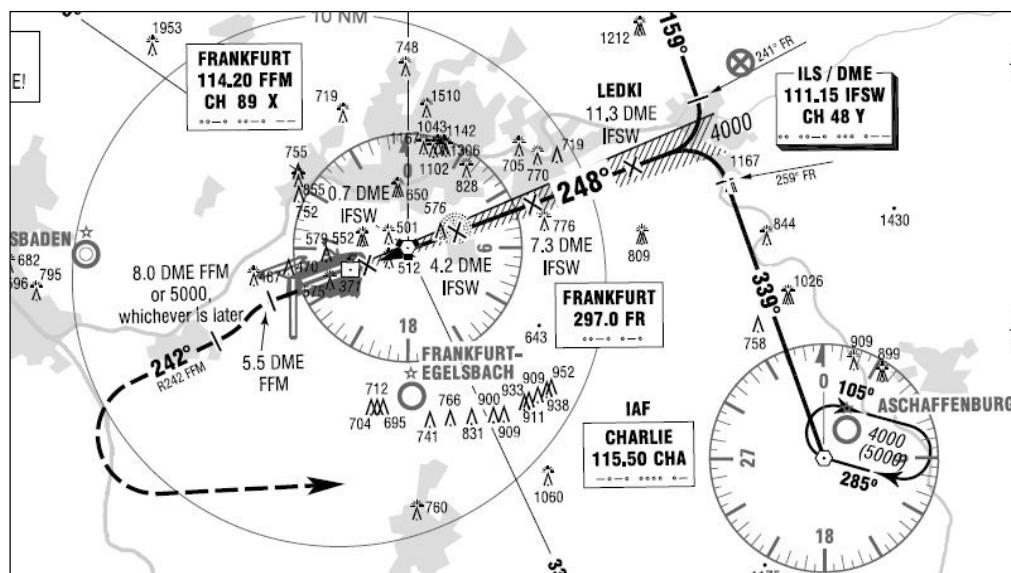
The TCC was mainly responsible for the airspace of the approach and departure sector of runway 07C/25C within the control zone including the runway. On the ground, he was responsible for runway 07C/25C and the associated taxiways, to the north his responsibility ended at the edge of the apron and toward the south it ended at the CAT II/III taxi-holding position.

One of his main tasks was the establishment of separation using radar in accordance with the OO and the coordination with TCS and TCW concerning procedures in all separation-relevant areas.

His tasks included the issuance of take-off clearances for the departures on runway 07C/25C according to IFR and VFR and in agreement with other responsible TCs the separation between aircraft but also with the traffic of other runways.

1.17.3 Missed Approach Procedure Runway 25L

The standard missed approach procedure for the ILS approach to runway 25L stipulated: climb straight ahead to 5.5 NM to DVORTAC FFM; left-hand turn, intercept radial 242 FFM to 8.0 NM DME FFM 5,000 ft AMSL, whichever is later, left-hand turn to CHA VOR, maintain 5,000 ft.



Excerpt standard missed approach procedure runway 25L

Source: AIP

1.17.4 Departure Procedure Runway 25C

In connection with putting the fourth runway at Frankfurt/Main Airport into operation the so-called south by-pass (term for all departure routes of runways 25 in north and north-west direction) for operation direction 25 was implemented. This means all departing aircraft of the weight categories Medium (M) and Light (L) shall initially turn south shortly after passing runway 18.

The SID TOBAK1M stipulated: On RWY track to 5.0 DME FFM/2.0 DME FRD or 800 ft, whichever is later; left-hand turn (MAX IAS 185 KT until established on track 195°), on track 195° to 10.1 DME FFM; RT, on track 279° to ROXAP; right-hand turn, on track 336° to LISKU; right-hand turn, on track 017° to TABUM; right-hand turn, on track 040° to TESGA; left-hand turn, on track 038° to TOBAK. Cross 10.1 DME FFM at 2,500 or above. Then several right-hand turns should be flown, initially north-west and then north-east to reporting point TOBAK.

1.17.5 Safety Assessment by the Air Navigation Service Provider

The air navigation service provider had conducted an extensive safety assessment of the 4-runway operation in preparation of putting the fourth runway (runway 07L/25R) at Frankfurt/Main Airport into operation. The safety assessment was completed in May 2011. The different operations conditions and directions which already existed or will exist were determined and analysed. For different risks different measures were determined which were to mitigate the risks. These measures included, for example, procedural instructions, personnel planning and training in the tower simulator.

The analysed flight safety risks included scenarios like: air proximity of aircraft during a missed approach on runway 25L, during departure from runway 25C under VFR or IFR, air proximity between departing aircraft from runway 25L or 25C and departures from runway 18. As a measure to minimise risks it was stipulated that take-off from runway 25C should occur only if the approaching aircraft to runway 25L has touched down and/or if preceding traffic is at least 6 NM away. The so-called "no-fly zone" or "taboo zone" was displayed on the TC's screen. This should create separation by time which guarantees a lateral separation of 3 NM and/or 1,000 ft vertically. This action resulted in classification D (Acceptable) where it originally had been C (Tolerable). During the safety assessment the requirement of a fixed minimum separation was considered but discarded due to variables like wind and other weather conditions and different types of aircraft and in favour of flexibility and less limits on capacity.

The crossing departure routes were identified as a risk. It was described "[...] a large portion of the departure routes of runway 25C cross or approximate the missed approach path of runway 25L within the first 30 seconds after take-off. A missed approach usually happens without prior notice and, therefore, makes the quick intervention of a controller necessary to establish separation to departing aircraft. Since both aircraft involved are in critical flight phases at that time the options for avoidance manoeuvres are limited. The safety assessment showed that in general, sudden flight manoeuvres in these flight phases pose a safety risk for pilots." A possible separation of the departure routes of runway 25C and the missed approach routes of the approaches to runway 25L and 25R was seen as an effective action to minimise the risk but its implementation was considered to be unattainable. The safety assessment classified the remaining risk as classification C (Tolerable). This means the risk should only be borne with the agreement of the higher-ranking management level.

According to the safety assessment a "*complete and systematic revision of the safety assessment or validation*" was intended for the spring of 2012.

1.17.6 Federal Supervisory Authority for Air Navigation Services (BAF)

The Federal Supervisory Authority for Air Navigation Services was founded on 9 August 2009 and had the following organisational structure: ANSP finance; safety supervision for air navigation services and air navigation personnel; safety supervision for air navigation technology; air space, flight operations and justice as well as central administration.

The department safety supervision for air navigation services and air navigation personnel had 14 employees. It was responsible for the certification, the reporting and registration system, the notification of change and the Air Proximity Evaluation Group (APEG). Five auditors were responsible for the supervision part.

The department airspace, flight operations and justice stipulated flight procedures and passed them as regulations.

As part of their safety management systems, air navigation service providers had to conduct corresponding safety assessments and report them to the BAF, if appropriate, whenever they intended to make changes in safety-relevant areas. On 19 May 2011 the risk assessment of the air navigation service provider concerning the 4-runway operation was submitted to the BAF. The intended south by-pass at Frankfurt/Main Airport was approved without restrictions.

According to the BAF until September 2012, the air navigation service provider had not submitted a validation of the risk assessment based on the serious incident.

1.18 Additional Information

The aircraft manufacturer Airbus had published information on the development and the avoidance of wake turbulences in the *Flight Operations Briefing Notes*, edition *Wake Turbulence Awareness / Avoidance*.

The main characteristics of aircraft wake vortices are:

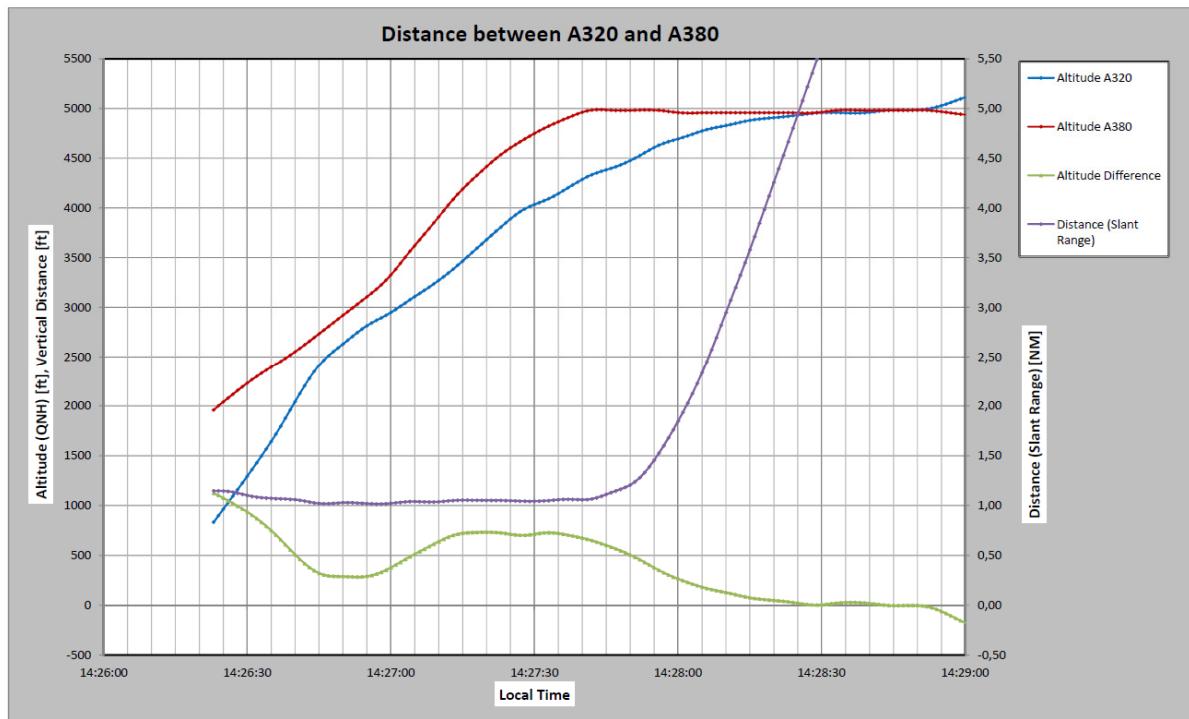
- *Sink rate: 300 to 500 feet/minute*
- *Stabilization at 500 to 900 feet under the aircraft at the origin of the vortices*
- *Lateral movement at 5 knots, when reaching the ground*
- *Life span:*
 - *Approximately 30 seconds, with a wind speed between 5 and 10 knots*
 - *Up to 85 seconds, when the wind speed is less than 5 knots*
 - *Up to 100 seconds in still air.*

The publication also contained a wake vortex avoidance strategy. For the take-off and the climb phase the following items were listed:

- *When the flight crew identifies the factors that increase the life span of wake turbulence, they should request a 2 to 3 minute delay in takeoff.*
- *If possible, the flight crew must ensure that the aircraft climbs above the leading aircraft trajectory. If not, the aircraft must remain upwind of the leading aircraft trajectory.*
- *Headings that may lead the aircraft to cross the preceding aircraft trajectory, behind and below the leading aircraft, should be avoided.*

1.19 Useful or Effective Investigation Techniques

For illustration purposes the vertical and lateral distances resulting from the position and altitude indications of the radar recordings of both aircraft were depicted in a graph.



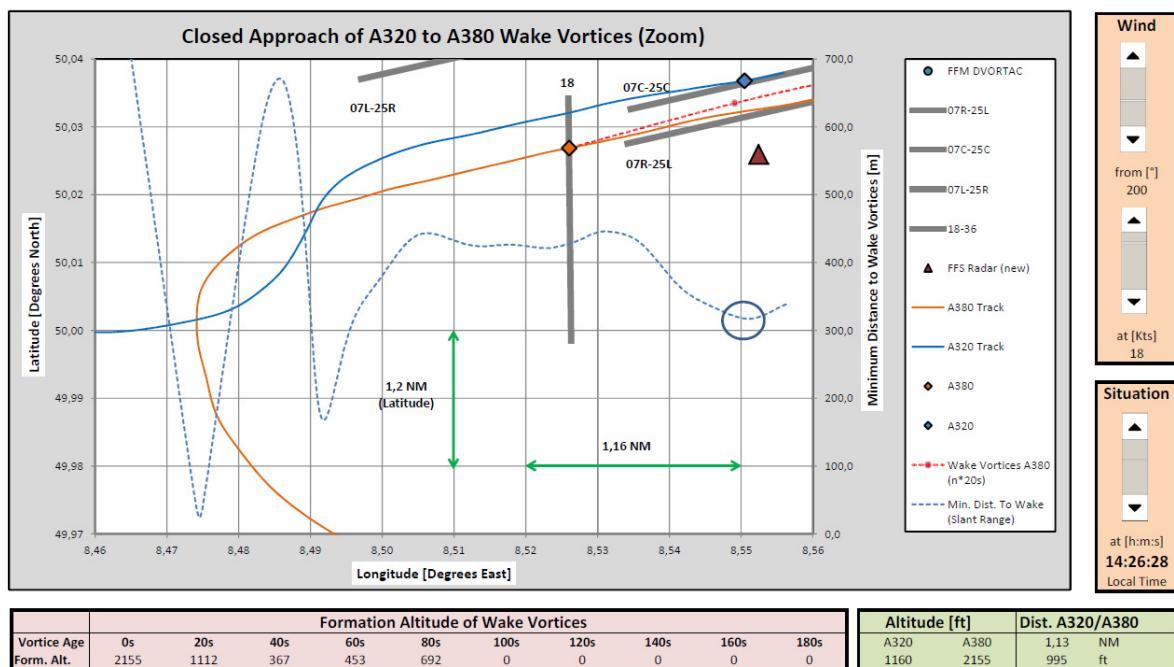
Distance between aircraft

Source: BFU

The radar data showed that from 1426:22 hrs on the lateral distance of the two aircraft in climb decreased to about one nautical mile. The altitude difference of the two aircraft had initially been more than 1,000 ft and had reduced to about 200 ft by 1426:45 hrs. Ten seconds later the altitude difference began to increase and at 1427:30 hrs reached approximately 800 ft. At 1427:40 hrs the A380 had reached 5,000 ft AMSL. From then on the lateral distance of the two aircraft increased continuously. At 1428:30 hrs the A320 had reached 5,000 ft AMSL. The horizontal distance to the A380 was at that time about 5.5 NM.

Based on the radar data and the submitted wind data the propagation of the wake turbulence of the A380 and the approximation of the A320 were calculated and depicted in a graph.

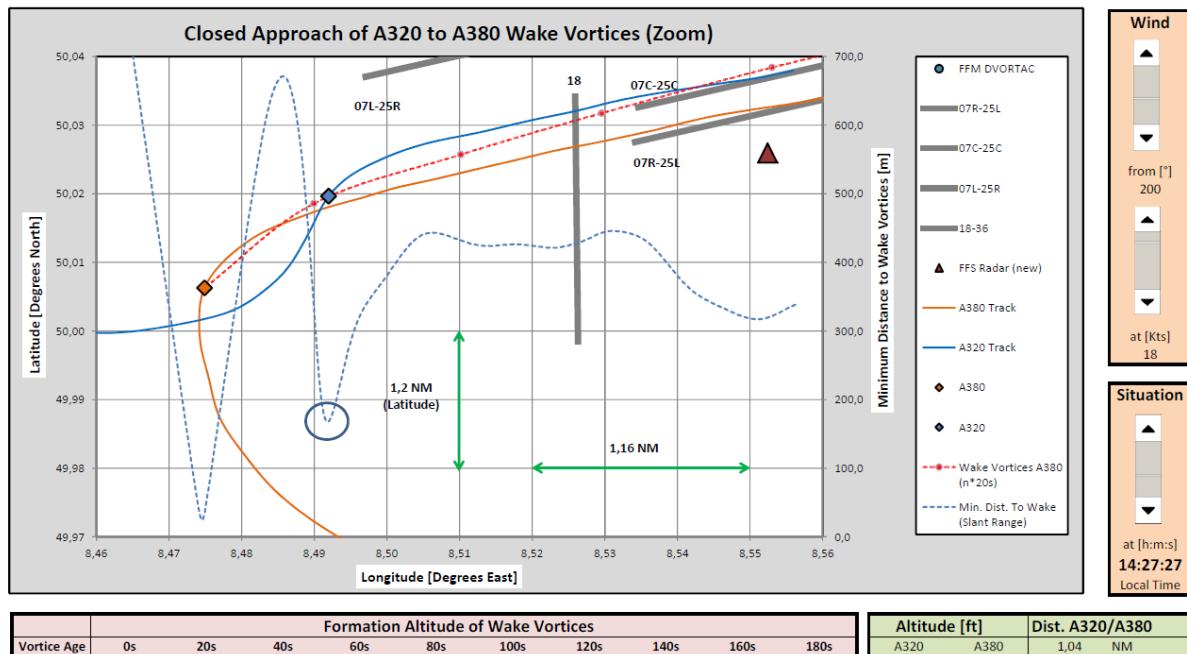
As the A380 passed the threshold of runway 18 at 1426:28 hrs the distance between the A380's wake vortices and the A320 was about 320 m.



Situation at 1426:28 hrs

Source: BFU

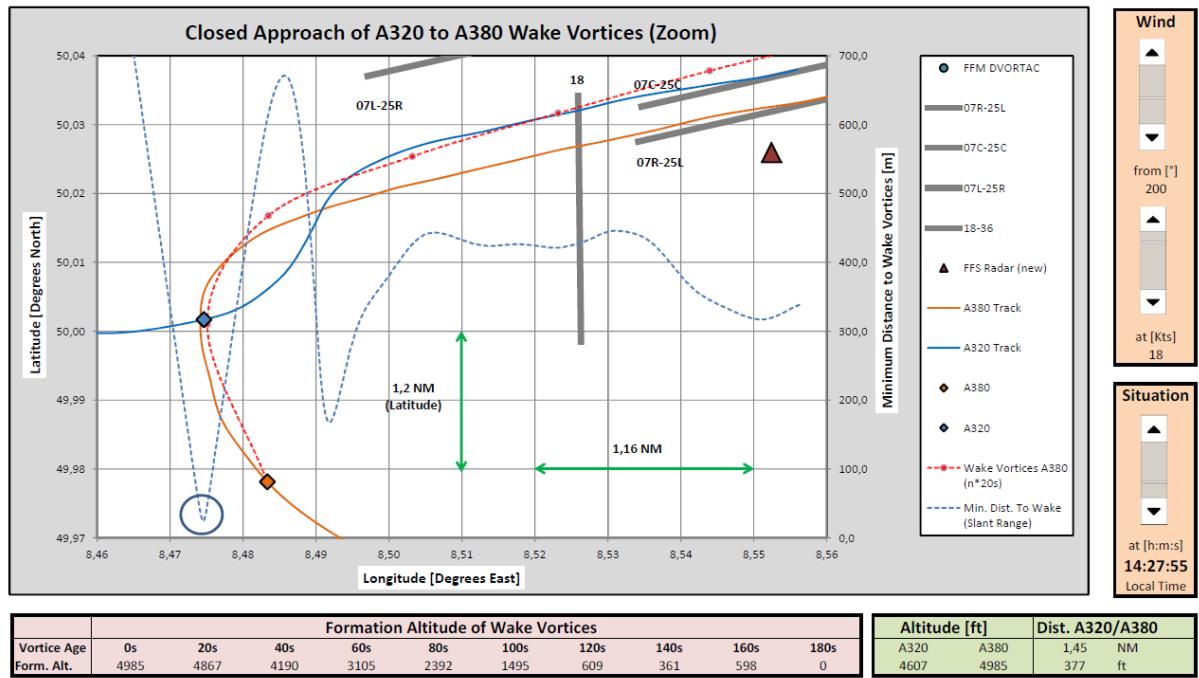
At 1427:27 hrs as both airplanes had begun to turn south the distance of the A320 to the wake vortices of the A380 decreased to about 180 m.



Situation at 1427:27 hrs

Source: BFU

At 1427:55 hrs as the A320 was turning right in western direction the distance to the wake vortices was about 30 m.



Situation at 1427:55 hrs

Source: BFU

2 Analysis

2.1 General

Both airplanes approximated each other up to 0.97 NM horizontally and 200 ft vertically. That means the required minimum separation was infringed significantly. The BFU is of the opinion that due to the aircraft's position to each other and the similar airspeed there was no danger of a collision.

The calculations the BFU did show, however, that because of the weather prevailing at the time the A320 had the risk of penetrating the wake turbulence of the A380. If a succeeding aircraft flies into the wake turbulence of a preceding aircraft a sudden attitude change of the succeeding aircraft might occur and may even result in loss of control. During climb the aircraft are configurated for take-off or a go-around, i.e. corresponding flap and slats configuration, and, in addition, they are in close proximity to the ground.

There are accidents and serious incidents connected to wake turbulences occurring worldwide. The BFU has knowledge of cases where airplanes of similar weight categories encountered the influence of wake turbulences which resulted in sudden and significant changes in flight attitude and altitude in spite of adhering to the separation criteria.

2.2 Flight Operational Aspects

2.2.1 Airbus A380

From the point of view of the A380 crew the need arose immediately prior to touch-down to initiate a go-around procedure. The reason for the decision was given by stating that a touch-down within the touch-down zone did not seem definite.

The data recorded by the QAR showed that the airplane had touched down before the go-around had been initiated.

The aircraft mass was a little below the Maximum Landing Mass (MLM). At the chosen configuration 3 the flaps and slats were not fully extended.

2.2.2 Airbus A320

Fifteen seconds after the controller had begun to issue the take-off clearance and 12 seconds after the A380 had begun the climb the A320 started the take-off run.

The QAR data shows that the A320 crew implemented the take-off clearance without any particular delays and began the take-off run.

Because of the different frequencies the A320 pilots had no chance to hear the radio communication between the A380 crew and the TCS.

It is probable that during the take-off run the Pilot Flying (PF) looked out toward the runway centre line and the other pilot focused on the cockpit instrument panel. It could not be determined if either one of the two pilots noticed the A380 during the take-off run. The pilots would have had the option to reject take-off up until the time the decision speed V_1 was reached (about 20 seconds after the take-off run was begun). The controller, however, did not instruct the crew to do so and the crew did not decide to reject take-off.

Within the first 30 seconds after take-off the A320 reached a rate of climb of 4,656 ft/min which was an unusually high value and contributed to the fact that the vertical distance of the two airplanes decreased significantly. Afterwards the rate of climb of the A320 was decreased again.

The analysis of the A320 QAR data and the statements of the A320 crew show that the airplane did not penetrate the wake turbulence of the A380.

2.3 ATC Operational Aspects

At the time of the occurrence Frankfurt Tower had relatively little traffic to handle.

The TCS and the TCC had begun their shift only a few minutes prior to the serious incident.

Because Frankfurt Tower does not have a recording device to record background communication and the aural environment it was not possible to fully reproduce the sequence of events, type and content of the communication and coordination in the tower. The reconstruction of the sequence of events in the tower was, therefore, solely based on the statements of the controllers and the radar and radio communication recordings. Had the tower been equipped with a recording device to record background communication and the aural environment as recommended by ICAO Annex 11 it would have contributed significantly to the clarification of the circumstances.

2.3.1 Tower Controller South (TCS)

Once the TCS had realised the go-around of the A380 due to it gaining altitude and speed, he instructed the crew to fly the standard missed approach. The subsequent radio communication began 23 seconds after the A380 had started the go-around. The Operational Order stipulated that he should have called out "*Missed Approach Runway 25L*" to call the attention of the controllers working at the other working positions to the missed approach. The BFU does not have any statements which prove such a call-out. Furthermore, it was his task to immediately coordinate the missed approach of the A380 with the controller responsible for runway 18 which would be crossed a short time later and with the approach controller.

With the intention to increase the distance to the departing A320 the controller instructed the A380 crew to fly a southern heading instead of flying left toward radial 242 as was the standard missed approach procedure.

He misinterpreted the words of the TCC "I will turn mine left" to be an instruction to let his airplane, the A380, turn left. This also met his cognitive model for a solution of the problem.

The BFU is of the opinion that this was suitable to quickly establish an ever increasing distance between the two airplanes.

2.3.2 Tower Controller Centre (TCC)

The TCC had observed the A380 shortly before the landing and since he was convinced the landing would be successful, concentrated on the A320 poised to depart and issued the take-off clearance. It is highly likely that he focused visually on the A320 as he was communicating with them by radio. In doing so, he was not aware that in the meantime the A380 had begun a go-around. The air navigation service provider stated that a go-around once the threshold has been crossed is rather rare. That is why the controller assumed, based on his operational experience, that the airplane would land and did not wait any longer. It is probable that his motivation was to allow the A320 a speedy take-off.

During the take-off run of the A320 up until the take-off there were no instructions of the controller.

The A320 had been airborne for nine seconds and had reached an altitude of 296 ft above ground when the TCC instructed the A320 crew to maintain runway heading with the words „... proceed on runway heading, proceed on runway heading three

eighty from the southern runway has pulled up". With this instruction he wanted to prevent further approximation and to call the A320 crew's attention to the traffic. The BFU is of the opinion that by repeating the instruction the controller wanted to emphasise its execution. He did not consider limiting the rate of climb of the A320.

Once he estimated the A380 had reached a sufficient altitude he instructed the A320 crew to initiate a left-hand turn to adhere to the required departure route. That is why he said to the TCS: "I will turn mine to the left".

The BFU is of the opinion that this attempt at a solution was not suited to establish separation between the airplanes within a short time period. In addition, this change in flight path led to an approximation of the wake turbulence of the A380 since the A320 flew below. This would occur no matter whether the A380 would turn left or continue straight ahead as the controller thought.

Later he changed his instruction and requested the A320 crew to now turn right to a heading of 270°. He stated he did so once he realised the A380 was also turning south. 26 seconds passed between the instruction to turn left until the corrective instruction. It could not be determined in detail what the TCC did during the intervening time and if and how the communication in the tower occurred. The BFU is of the opinion that the time until the correction was too long.

2.4 Specific Conditions

At the time of the serious incident daylight and, below the clouds, good visual meteorological conditions prevailed. The cloud base of the 5-7 oktas cloud cover was at 2500 ft AAL; the one of the upper cloud layer at 2,800 ft AAL. This means the two airplanes were not visible for the controller, without him using the radar monitor, once they had over-flown runway 18 since, by then, they were in or between layers of clouds. The visibility from the cockpit of the A320 toward the A380 was at least severely restricted. At the time of the closest vertical and lateral proximity the two airplanes were in clouds.

The wind blew from a southern direction crossways to the runway. This resulted in the wake vortices of the A380 drifting north in the direction of runway 25C.

The BFU is of the opinion that the departure procedures of the so-called south bypass mainly serve the purpose to reduce noise pollution of the densely populated urban area located in the extended take-off direction 25. It results in the fact that transport aircraft have to turn less than one minute after take-off. The result is an in-

creased workload of the pilots. For the controllers the situation is that they have to establish separation between an airplane who unexpectedly conducts a go-around and a departing airplane within a short time period and in limited space. In addition, the controllers have to immediately conduct coordination communication with several other controllers.

The BFU is of the opinion that because the departures 25C and the missed approaches 25L cross they pose a systemic risk for flight safety due to low error tolerance. The controllers have to compensate this risk by heightened alertness. The case at hand shows that due to delays in the recognition of a go-around, a spontaneous wrong decision by the controller and the intention to adhere to the departure route a situation develops which can cause air proximity between aircraft. In addition, there are risks which can occur when an aircraft penetrates the wake vortices of a preceding airplane.

2.5 Defences

In the scope of this investigation, the term "Defences" means technical systems, actions, procedures and institutions which shall minimise the effects of technical and human errors to protect flight safety.

There was a time period of about 30 seconds while the A320 was still on the ground, between the initiation of the go-around of the A380 at 1425:33 hrs and reaching V_1 speed, in which the A320 increased speed from standstill until take-off but had not yet reached V_1 . During this time period the controller could have revoked the take-off clearance or instructed a rejected take-off. Once the A320 had exceeded V_1 , a rejected take-off was no longer permissible nor safely possible.

In general, standardised departure and approach procedures are to be considered to be defences with regard to minimising the effects of errors controllers make, such as a delayed recognition or erroneous instructions. In the case at hand the trajectories of the aircraft did not result in diverging flight paths due to the crossing departure routes shortly after take-off. Therefore, they were ineffective to prevent an approximation or a possible penetration of the wake vortices.

The controller let the A320 turn to the left even though the A380 also flew to the left. The action of the TCC to correct this mistake by instructing the A320 to change heading was meant to prevent increasing air proximity with the A380. Because of the long

time until the correction was issued the A320 once again passed the area behind the A380 before it moved away for good.

A standardised procedure for this concrete situation was not provided and not trained. Therefore, it was up to the controller to find a spontaneous solution to the problem.

During the investigation it became clear to the BFU that the avoidance of aircraft noise during approaches and departures from Frankfurt/Main Airport was of great importance. Although general regulations of the air traffic service provider stipulate a safe and orderly conduct of air traffic as task of the air traffic service provider it should be clear to all controllers that in case of doubt safety has priority over noise control.

Both airplanes were equipped with a TCAS. The QAR data of the A380 shows that the flight path of the succeeding A320 was detected and the rate of approximation monitored. The conditions for a Traffic Advisory or a Resolution Advisory were not met.

2.6 Safety Assessment by the Air Navigation Service Provider

The BFU is of the opinion that the safety assessment already recognised and named essential factors of this serious incident as risks.

In the safety assessment the non-recognition of a missed approach in a very early phase and the premature issuance of a take-off clearance, respectively, is the result of an error in judgement in combination with an insufficient attention distribution and was identified as possible source of errors.

Even if traffic was rather low at the time of the serious incident the sequence of events shows that within a very short time period the controllers involved had to handle a high workload. This resulted from the dynamic of the processes and the high coordination effort arising from the constellation of the runways and the specialities of the departures.

However, the BFU is of the opinion that the risks arising from wake turbulences particularly of large transport aircraft and lighter aircraft possibly penetrating them were not sufficiently taken into consideration when the departure routes were specified and during the safety assessment.

The BFU concurs with the air navigation service provider, that the separation of the departure and missed approach procedures would be the safest and most efficient action to minimise the conflict potential and to give the controllers more time and space to solve possible conflicts and minimise the effect of working mistakes.

The systematic of the safety management system to tolerate certain higher risks only with the agreement of the higher-ranking management level is principally acceptable. The BFU is of the opinion, however, that the case at hand shows that actions which separate departure and missed approach procedures should be conducted with the aim to minimise risks.

3 Conclusions

3.1 Findings

- The pilots of both airplanes held the required licenses and ratings to conduct the flight.
- No indications for technical irregularities on the aircraft were found.
- The two tower controllers had the required licenses and ratings.
- The investigation did not reveal any indications that the performance of the pilots or controllers was limited.
- Because the A380 crew estimated touch-down within the touch-down zone was not certain they decided to conduct a missed approach immediately prior to touch-down. The airplane touched down briefly on the runway before it began to climb.
- The controller responsible for the A320 had observed the landing A380 shortly before the touch-down and issued the take-off clearance although the A380 had not yet landed.
- The A320 pilots basically would have had the option to reject take-off up until the time the decision speed V_1 was reached (about 20 seconds after the take-off run was begun). The controller, however, did not instruct the crew to do so and the crew did not decide to reject take-off.
- Because of the different frequencies the pilots of both airplanes had no opportunity to hear the radio communication concerning the other aircraft.
- Up until 2,500 ft AAL the airplanes were below the clouds in good visual meteorological conditions. In the further course of events they were among cloud layers.
- The initially high rate of climb of the A320 of up to 4,656 ft/min added to the significant decrease of the vertical separation of the airplanes in this phase.
- During the approximation of up to 0.97 NM horizontally and 200 ft vertically the separation minima were significantly infringed.
- Due to the aircraft's position to each other and the similar airspeed there was no direct danger of a collision.

- The A320 had the risk of penetrating the wake vortices of the A380. The investigation showed that the A320 approximated the A380's wake vortices up to about 30 m but did not penetrate it.
- The action to separate departing airplanes and airplanes conducting a go-around by time was not sufficiently implemented by the TCC when he issued the take-off clearance.
- A rejected take-off was not instructed.
- There existed no procedure for an effective conflict resolution in case of a scenario where both airplanes are airborne already. Therefore, the controller had to make a spontaneous decision.
- There was no procedure where a controller could prevent the penetration of wake vortices by accepting an increased noise pollution.
- Even though the systematic of the safety management system to tolerate certain higher risks only with the agreement of the higher-ranking management level is principally acceptable, there should be additional measures to separate the departure and missed approach procedures.
- The course of events, type and content of the communication and coordination within the Tower could not be fully determined. Had the tower been equipped with a recording device to record background communication and the aural environment as is recommended by ICAO Annex 11 it would have contributed significantly to the clarification of the circumstances.

3.2 Causes

The Serious Incident was caused by the following:

Immediate causes:

- The take-off clearance was given even though the landing of the A380 on the parallel runway was not yet definite.
- A rejected take-off was not instructed.
- The erroneous mental approach of solving a problem of the controller resulted in the instruction to the departing airplane to fly a turn toward the airplane conducting a go-around on the parallel runway.

Systemic causes:

- The increased coordination effort between the controllers due to the working position organisation (tower) and the organisation of the runway operation has contributed to the separation infringement and to the approximation of the wake turbulence.
- The stipulations for the controllers to separate the departure routes of runway 25C and the missed approach procedures of runway 25L were insufficient.

4 Safety Recommendation

The BFU has issued the following safety recommendations:

34/2012

The air navigation service provider should develop actions to reduce the coordination effort for the parallel operation of runways 07R/25L and 07C/25C particularly in case of a missed approach.

It should also be investigated if and under what circumstances the approaching and departing airplanes on runways 07C/25C and 07R/25L can be handled on one frequency.

35/2012

The Federal Supervisory Authority for Air Navigation Services (BAF) should ensure that the air navigation service provider at Frankfurt/Main Airport separates the departure routes of runway 25C and the missed approach procedure of runway 25L by changing flight procedures and/or operational procedures.

The aim should especially be to give the controllers more time to recognise possible air proximities in time and establish sufficient vertical and/or lateral separation between the aircraft involved.

36/2012

Even if the adherence to approach and departure routes stipulated due to noise avoidance has a high priority, the air navigation service provider should explicitly stipulate for Frankfurt/Main Airport that air traffic controllers should deviate from these stipulations in case of special organisational situations and make decisions in favour of a safe conduct of flight. Such situations should be trained in the scope of simulator trainings.

37/2012

The Federal Supervisory Authority for Air Navigation Services (BAF) should ensure that air navigation service providers in combination with their risk assessment establish processes to guarantee the adherence to validation procedures. There should be validation processes after safety-relevant incidents and in accordance with stipulated time intervals.

38/2012

The Federal Ministry of Transport, Building and Urban Affairs (BMVBS) should pass a decree regarding the implementation of the ICAO recommendation in Annex 11, Chapter 3.33. Based on this decree the air traffic service providers should equip their air traffic control units with suitable equipment so that the recording of background communication and the aural environment is ensured.

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5 Appendices

Standard departure route runway 25

Appendix 1: Standard instrument departure route

AIP GERMANY

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Effective: 20 OCT 2011