Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accidents Investigation

Investigation Report

EX006-1-2/04
February 2009

Identification

Type of Event:	Serious Incident
Date:	3 May 2004
Location:	Munich Airport
Aircraft:	1. Commercial Air Transport
	2. Commercial Air Transport
Manufacturer / Type:	1. Boeing / B737-306
	2. Aerospatiale / ATR 42-500
Injuries to persons:	None
Damage to Aircraft:	None
Third Party Damage:	None
Source of Information:	Investigation by BFU

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This investigation was conducted in accordance with the Federal German Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) 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.

The present document is the translation of the German Investigation Report. Although efforts are made to translate it as accurate as possible, discrepancies may occur. In this case the German version is authentic.

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Abbreviations

ASMR	Airport Surface Movement Radar
ASR	Airport Surveillance Radar
ATIS	Automatic Terminal Information Service
BAO	Operational Order
BA-FVK	Manual of Operations Air Traffic Control Services
DFS	DFS Deutsche Flugsicherung GmbH Air Traffic Control
ICAO	International Civil Aviation Organisation
RIM	Runway Incursion Monitoring
TCM	Taxiway Collision Monitoring

Illustrations

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4	Radar Trace Record 21:39:18	DFS
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13	Entry Point of Taxiway B4 to Runway 08 R	AIP
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Synopsis

On the morning of 4 May 2004 the German Federal Bureau of Aircraft Accidents Investigation (BFU) was informed by the DFS Deutsche Flugsicherung GmbH of a runway incursion on Runway 08 R at Munich Airport. This event was classified and investigated as a Serious Incident within the meaning of the Federal German Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*).

The occurrence had taken place on 3 May 2004 at 21:39:26[1]. The runway incursion occurred between an ATR 42-500 (AT 45) which was taxiing onto runway 08 R and a Boeing 737-300 (B 733) landing at the same time.

The AT 45 flight crew waited at the B4 Taxiway Hold Point for Runway 08 R, while an Airbus A 321 (A 321) received clearance to take-off from Runway 08R. Immediately afterwards, the AT 45 crew received clearance to enter Runway 08R and line up, immediately after the arrival and touchdown of another aircraft which was already on short final approach.

As soon as the Airbus A321 passed Taxiway B4 on its take-off run, the AT 45 crew began taxiing towards the runway for line-up. Just before the AT 45 reached the edge of the runway, a B 733 touched down on the runway threshold. The AT 45 continued taxiing and the B 733 missed the right wing of the AT 45 by a few metres. The B 733 crew had taken avoiding action. There were no personal injuries or damage to property.

This Serious Incident had the following causes:

Immediate Causes:

- Communications were unclear between the AT 45 and Tower with respect to the issue of and application of a conditional clearance.
- The AT 45 taxied onto Runway 08 R, for which a landing clearance had been given to another aircraft.
- The AT 45 crew had a restricted view of the final Approach to Runway 08 R.
- The Runway Incursion Monitoring (RIM) alarm function forming part of the Airport Surface Movement Radar (ASRM) had been de-activated.

Systematic Causes:

- The standard operational procedures for issuing conditional clearances were not comprehensive or precise.
- The fast exit taxiway B4 from Runway 26 L was used as a departure access taxiway for Runway 08 R, together with issue of a conditional clearance.
- The Runway Incursion Monitoring (RIM) alarm function, intended to trigger a warning on the Air Traffic Controller's display, was unreliable and faulty.

[1] Unless stated to the contrary, all times are local

1. Factual Information

1.1 History of the flight

At 21:39 on 03.05.2004 the AT 45 was waiting at the CAT-I Taxi Hold Point of taxiway B4 to Runway 08R, ready for an Instrument Flight Rule IFR departure from Munich (EDDM) to Villafranca (LIPX). On board were 25 passengers and four crewmembers.

At the same time, an incoming Boeing B 733 from Amsterdam (EHAM) with 46 passengers and five crewmembers was on final approach about 2 nm from the threshold of runway 08 R. At 21:37:20 the crew made R/T contact with the tower (TWR) and was advised that, due to the imminent departure of another aircraft, clearance to land would not be given until the Boeing had reached short final.

At the same time, an Airbus A 321 was ready for departure on Runway 08 R adjacent to the entry point from Taxiway B2 to Runway 08 R. At 21:38:03 the duty Air Traffic Controller gave take-off clearance and 20 seconds later the A 321 began the take-off run.

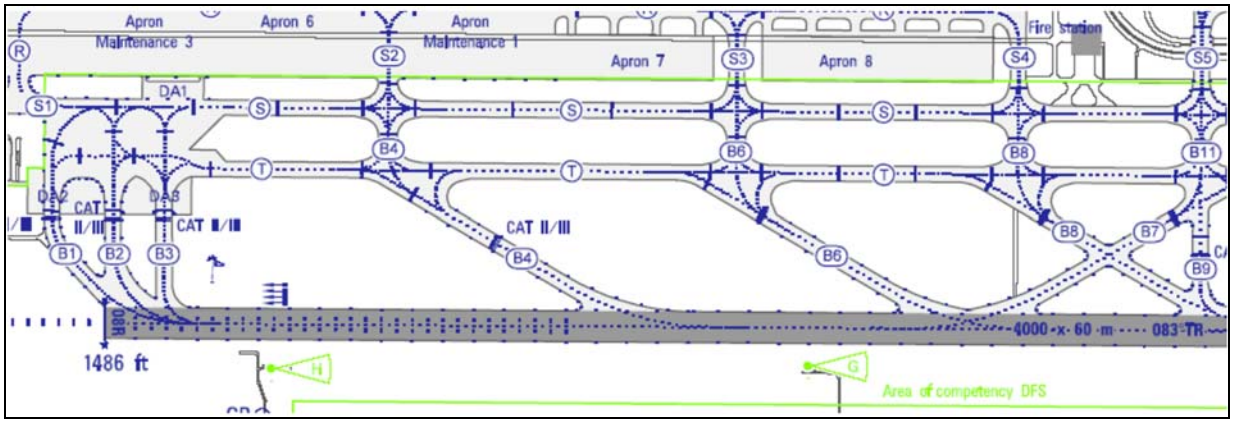

Illustration 1: Munich Airport in the vicinity of Runway 08R

At 21:38:35 the duty Air Traffic Controller issued a conditional clearance to the AT 45 crew, in the following words: "... behind next landing short final line up 08 right behind." This clearance was read back by the AT 45 crew. About 16 seconds later the Airbus A 321 passed the B4 taxiway intersection. At 21:39:00 the AT 45 started to move from the taxiway to the runway, and the A 321 was airborne at 21:39:03.

Illustration 2: Radar Trace Record 21:39:00: A 321 take-off run, shortly before rotation.

Two seconds previously at 21:39:01, the B 733 crew had received clearance to land on Runway 08R. The B 733 overflew the Runway threshold at 21:39:12. At this moment, the distance between the airborne A 321 and the Boeing B 733 was 2 685 m. The AT 45 had only advanced a minimal distance and was about 70 metres from the runway centreline.

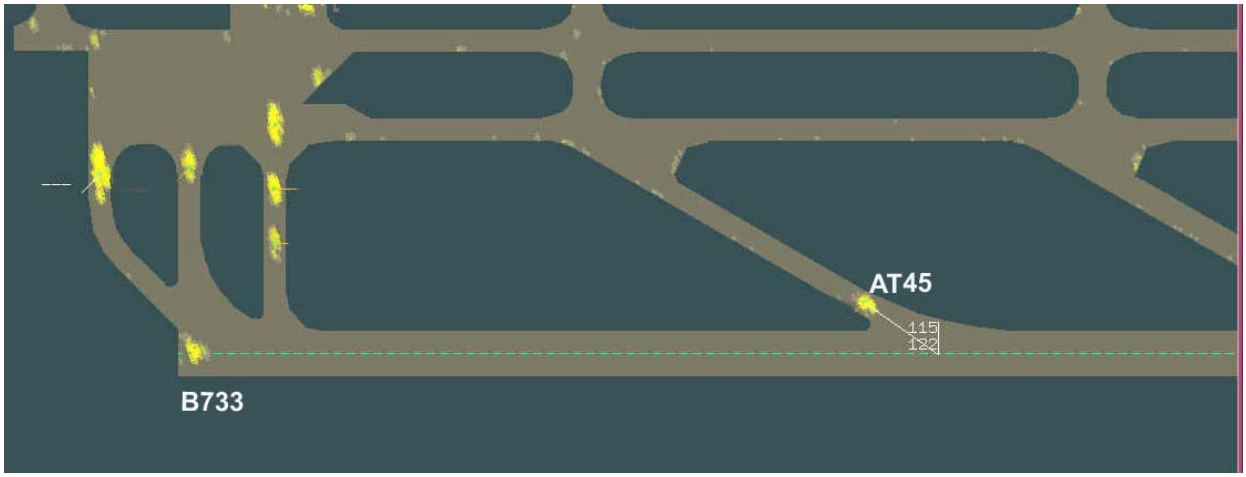

Illustration 3: Radar Trace Record 21:39:12: The B 733 overflew the threshold.

Illustration 4: Radar Trace Record 21:39:18: The B 733 was in the flare/touchdown on Runway 08R, while the AT 45 was still about 40 metres from the Runway centreline.

Shortly after the B 733 touched down at 21:39:20 the crew observed the AT 45 on the Runway a short distance in front, and took avoiding action during the deceleration rollout phase. The B 733 passed by the AT 45 on the right hand side with a very few metres to spare. The crew said that at this point the B 733 speed was about 110 knots.

Illustration 5: Radar Trace Record 21:39:24: The B 733 after touchdown. The crew observed the AT 45 taxiing onto the runway. The AT 45 was still about 25 m from the Runway centreline.

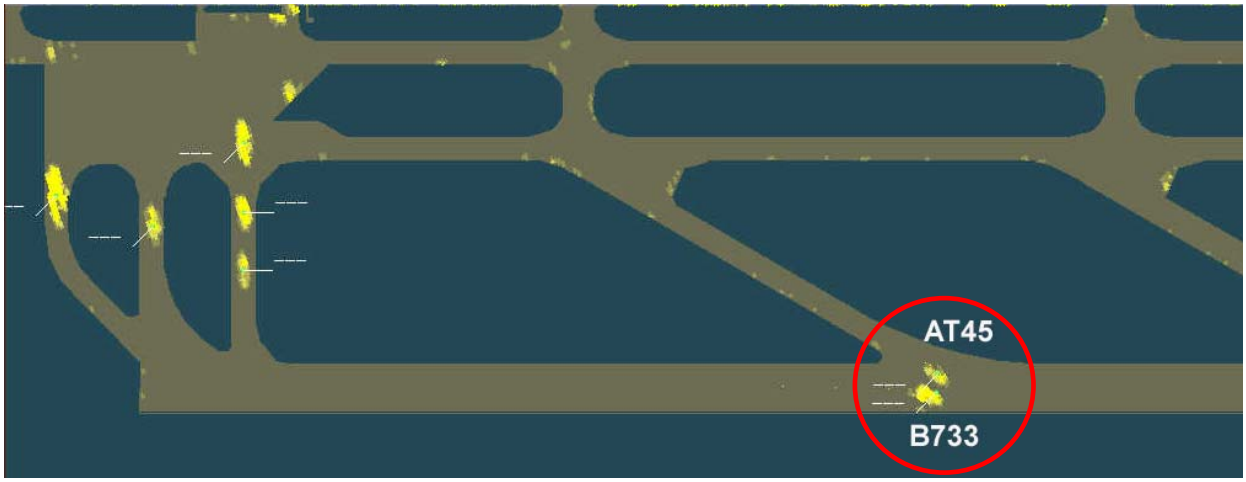

Illustration 6: Radar Trace Record 21:39:26: The AT 45 was about 10 metres from the Runway centreline. The B 733 passed the AT 45 on the right side at a speed of about 110 knots.

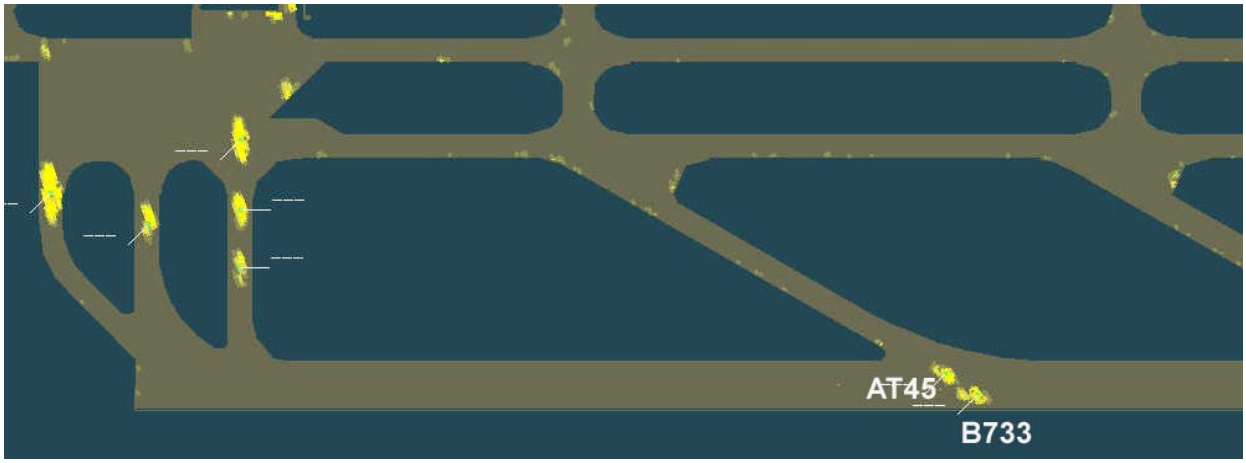

Illustration 7: Radar Trace Record 21:39:27: The B 733 has passed the AT 45.

1.1.1 Events as seen by the Air Traffic Controller

In response to questions by the BFU, the Air traffic Controller in the tower said she had given the AT 45 a conditional clearance, and that the essential prerequisites for the clearance were in place. In issuing the clearance for the AT 45, the condition related to the aircraft in the process of landing, not the aircraft in the process of taking off. She stated the AT 45 crew should have been able to see the aircraft on approach.

The Air Traffic controller added she had not looked at the Airport Surface Monitoring Radar (ASMR) screen again after giving the B 733 clearance to land. She had first seen the two aircraft on the runway as they passed each other. Also, she had not seen visual how far the AT 45 had advanced onto the runway.

She added that if the RIM had been switched on she would have been alerted to the conflict situation by acoustic and optical alarms.

1.1.2 Events as seen by the crew of the AT 45

The AT 45 crew said their aircraft had come to a stop at the CAT-1 hold point, when the 'condition lever' was shifted to the 'feather position'. After receiving the clearance “behind next landing line up runway zero eight right behind“, the two pilots saw the A 321 move past them along the runway and assumed this was the aircraft to which the conditional clearance related.

The commander was handling the controls. He said that he shifted the 'condition lever' to the position 'auto' and noted that one of the two levers was more difficult to operate than the other. After discussing the problem with the co-pilot, he allowed the aircraft to taxi slowly forwards.

The commander added that during this advance, he had turned the aircraft to the right in order provide his co-pilot with a view of the approach.

1.1.3 Events as seen by the crew of the B 733

The B 733 crew said they first saw the AT 45 on Runway 08 R at the moment of touchdown. The pilot said he took avoiding action at a speed of about 110 kt by using reverse thrust and “max. autobrake“ to pass the AT 45 on the right.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

The aircraft were not damaged

1.4 Other damage

There was no damage.

1.5 Personnel information

1.5.1 Flight Crews

1.5.1.1 ATR42-500 (AT 45)

Commander

Age: 41 years, male
Licence: Commercial Pilot's Licence (A), IFR, valid to 22.01.2005
Total Flight Hours.: 8 095
On ATR 42/72: 5 500
last 90 days: 182
previous 24 hours: 11:30
Duty time prior to the event: 10 hours
Rest period before the event: 12 hours
Medical valid to: 15.09.2004

Co-pilot

Age: 32 years, male
Licence: Commercial Pilot's Licence (A), IFR, valid to 20.06.2004
Total Flight Hours.: 3 100
on ATR 42/72: 2 500
last 90 days: 145
previous 24 hours: 11:30
Duty time prior to the event: 10 hours
Rest period before the event: 12 hours
Medical valid to: 16.12.2004

The crew had been on duty for four sequential days. On the day in question they went on shift at 11:40 . This was the fourth and last flight of the day.

1.5.1.2 B737-306 (B 733)

Captain

Age: 51 years, male
Licence: Air Transport Pilot Licence (ATPL)
Total Flight Hours: 13 075 hours
On B737-300: 4000 hours
last 90 days: 117 hours
previous 24 hours: 06:06 hours
Duty period prior to the event: 06:06 hours
Rest period prior to the event: 2 days
Medical Validity: No Information

Co-pilot

Age:	31 years, male
Pilot's Licence:	Air Transport Pilot Licence (ATPL)
Total Flight Hours:	4 572 hours
on B737-300:	3000 hours
last 90 days:	160 hours
previous 24 hours:	06:06 hours

Duty period prior to the event: 06:06 hours

Rest period prior to the event: 2 days

Medical Validity: No information

This crew had also been on duty since 11:40. It was the third and last flight of the day.

1.5.2 Air Traffic Control Personnel

Air Traffic Control: Aerodrome South (PL1S)

The 47 year-old female air traffic controller began her training as an air traffic controller in 1980. She completed her training successfully in 1984 and then undertook duty as an air traffic controller. Her licence covered duties as an Aerodrome Controller with Radar. She qualified as an Aerodrome Controller (PL) for Munich Airport on 17.11.1984. Her last aviation medical examination was on 29.03.2004 and was valid until 02.04.2006.

Her shift on 03.05.04 was her fifth in five days. She went on shift at 14:15 and was due to continue until 22:38. Prior to the incident in question, she had three rest breaks totalling 2 hours 15 minutes. The last rest break of 30 minutes was commenced at 20:20. The previous day she worked from 11:45 to 20:08 with commensurate rest breaks. She had assumed her post (PL1S) at 20:50, 49 minutes prior to the incident.

1.6 Aircraft information

1.6.1 B737-300 (B 733)

The B737-300 is a low-wing aircraft with two jet engines. The aircraft is used on medium-range routes. It can carry up to 150 passengers.

The aircraft was registered in the Netherlands and operated by a Netherlands company.

1.6.2 ATR 42-500 (AT 45)

The ATR42-500 is a shoulder-wing aircraft with two turboprop engines. The aircraft is used for feeder and shorter medium-range services. It can carry up to 50 passengers.

The aircraft was registered in Italy and operated by an Italian company.

1.7 Meteorological information

At the time of the incident, the weather was VMC and it was dark. Sunset was at 20:46.

The Munich Airport weather report for 21:20 was: Wind 290°/ 3 kt; Visibility >10 km; Clouds: none below 5 000 ft (1 500 m); Temperature 15°C; Dew Point 9°C: QNH 1001 hPa.

1.8 Aids to navigation

The Runway 08 R Instrument Landing system was fully operational.

Movements of the aircraft involved were intercepted by radar (TAR Terminal Approach Radar and ASMR Airport Surface Movement Radar) and presented on the Air Traffic Control monitor screen as radar target response symbols.

Airport Surface Monitoring Radar (ASMR):

Munich Airport Air Traffic Control has an ASMR whose data record was available for the investigation of this incident.

The ASMR incorporated a number of warning functions, including the function 'Runway Incursion Monitoring' (RIM). This function gives the Air Traffic Controller a visual alert warning on the ASMR monitor screen (RIM-Alert) and an acoustic warning, if an aircraft or vehicle threatens to move onto a runway currently in use by an aircraft in the process of landing or taking off. When a threat arises, the screen tag colour changes from yellow to red. The parameter settings of the conditions when an alarm was to be given, were the responsibility of the DFS Air Traffic Control.

During the course of the investigation it was determined that the system had generated both acoustic and optical warnings at 21:39:09, 17 seconds before the AT 45 and B 733 came closest to each other. This alarm related to the AT 45, and the B 733 was accordingly shown on the ASMR screen. Shortly prior to this event, an alarm had been generated relating to the B 733 and the departing A 321.

At the time of the incident, the RIM (Runway Incursion Monitor) alert function at the Air Traffic Controller's workstation (PL1S) was not switched on.

In discussions with DFS personnel in Munich, they reported that the RIM function was not in regular use because it gave an unacceptably high number of erroneous warnings.

Illustration 8: Radar Trace Record 21:39:09. The RIM threat alarm between the AT 45 and B 733. The B 733 was on short final to land. Shortly afterwards, it was detected by the Airport Surface Monitoring Radar.

1.9 Communications

The R/T communications were recorded. Both a transcription and the original recording were available for inspection.

The transmissions from all those aircraft involved – the landing B 733, the AT 45 taxiing onto the runway, and the taking-off Airbus 321 – were on the PL1S frequency and flight crews were able to hear the R/T transmissions from the other aircraft.

The PBS aircraft taxi Ground Control Frequency was frequency-coupled to the PL1S workstation, and the PL1S Controller also shared the task of issuing taxi instructions. The PBS controller aided the PL1S Controller in optimising the departure sequence. He coordinated tasks such as towing, via Ground Control Radio.

This is an abstracted verbatim transcription of the relevant words spoken in German and English on frequency 120.5 MHz (* English translation):

21:19:17	A 321	tower guten abend (Rufzeichen A 321)
		*TOWER GOOD EVENING (CALL SIGN a 321)
21:19:21	pl1s	guten abend (Rufzeichen A 321) taxi sierra bravo 2
		*GOOD EVENING (CALL SIGN A321) TAXI SIERRA BRAVO 2
21:19:24	A 321	sierra bravo 2
		*SIERRA BRAVO 2
21:21:14	AT 45	hello (Rufzeichen AT 45) sierra 8
		*HELLO (CALL SIGN AT 45) SIERRA 8
21:21:17	pl1s	hello (Rufzeichen AT 45) taxi sierra bravo 4
		*HELLO (CALL SIGN AT 45) TAXI SIERRA BRAVO 4
21:21:21	AT 45	sierra bravo 4 (Rufzeichen AT 45)
		*SIERRA BRAVO 4 (CALL SIGN AT 45)
21:36:15	pl1s	(Rufzeichen A 321) line up 08 right on departure route recleared altitude 5000 feet
		*(CALL SIGN A 321) line up 08 right on departure route recleared altitude 5000 feet
21:36:22	A 321	lining up 08 right (Rufzeichen A 321) and recleared 5000 feet on the departure route
		* lining up 08 right (CALL SIGN A 321) and recleared 5000 feet on the departure route

21:37:20	B 733	tower hello (Rufzeichen B 733) is established ils 08 right
		* tower hello (CALL SIGN B 733) is established ils 08 right
21:37:25	PL1S	hello (Rufzeichen B 733) number 1 departure in front expect landing clearance short final
		* hello (CALL SIGN B 733) number 1 departure in front expect landing clearance short final
21:37:31	B 733	roger standing by (Rufzeichen B 733)
		*roger standing by (call sign B 733)
21:38:03	pl1s	(Rufzeichen A 321) wind 310 4 knots cleared for take off 08 right
		*(CALL SIGN A 321) wind 310 4 knots cleared for take off 08 right
21:38:08	A 321	(Rufzeichen A 321) cleared for take off 08 right climbing 5000
		*(CALL SIGN A 321) cleared for take off 08 right climbing 5000
21:38:25	pl1s	(Rufzeichen AT 45) behind next landing short final line up 08 right behind
		*(CALL SIGN AT 45) behind next landing short final line up 08 right behind
21:38:30	AT 45	behind next landing line up and wait 08 right behind (Rufzeichen AT 45)
		* behind next landing line up and wait 08 right behind (CALL SIGN AT 45)
21:39:01	pl1s	(Rufzeichen B 733) wind is 310 4 knots cleared to land 08 right
		*(CALL SIGN B 733) wind is 310 4 knots cleared to land 08 right
21:39:05	B 733	cleared to land 08 right (Rufzeichen B 733)
		* cleared to land 08 right (CALL SIGN B 733)
21:39:25	B 733	die is op de baAn
		*SHE IS ON THE RUNWAY
21:39:39	B 733	tower (FlugGesellschaft AT 45) was lining up we had to ah turn away
		tower (COMPANY NAME AT 45) was lining up we had to ah turn away

21:39:45	pl1s	(Rufzeichen AT 45) you had line up behind the landing (CALL SIGN AT 45) you had line up behind the landing
21:39:50	AT 45	roger we have seen the other aircraft we suppose it was landed (different voice) the second one this one
21:40:19	B 733	what`s the callsign of the (Rufzeichen AT 45) we almost crashed into  * what`s the callsign of the (CALL SIGN AT 45) we almost crashed into
21:40:24	pl1s	it was (Rufzeichen AT 45) * it was (call sign AT 45)
21:40:27	B 733	(Rufzeichen AT 45) ok we will write a report *(ALL SIGN AT 45) ok we will write a report

1.10 Aerodrome information

Munich Airport Air Traffic Control services are provided by *Deutsche Flugsicherung GmbH* (DFS). The airfield has two parallel runways 4 000 m x 60 m orientated 082° /262°. These two runways have a lateral separation of 2280 m. The incident took place on runway 08 R. The 08 R runway threshold is 1486 ft MSL.

Taxiway B4 enters into Runway 08 R at an angle of 30°. The CAT-1 Hold Line is 90 m wide. The taxiway is 90 m wide.

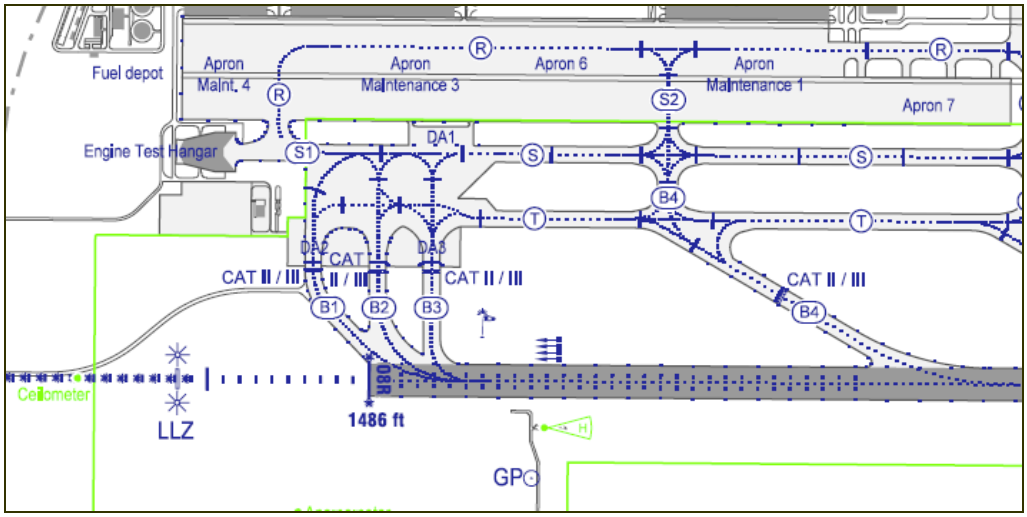

Illustration 9: Plan View Taxiway B4

The hold points for CAT-1 and CAT II/III are marked on the taxiway. Lights mark both the taxiway and runway.

Illustration 10: CAT-I Taxi Hold Point B4 Runway 08R

Illustration 11: Taxiway Sign B4, Runway 08R

1.11 Flight recorders

The Flight Data Recordings (FDR) and Cockpit Voice Recorders (CVR) were not available for inspection from either aircraft.

1.12 Wreckage and impact information

There was no damage to either aircraft.

The B 733 left tyre marks on Runway 08 R adjacent to the junction with Taxiway B4.

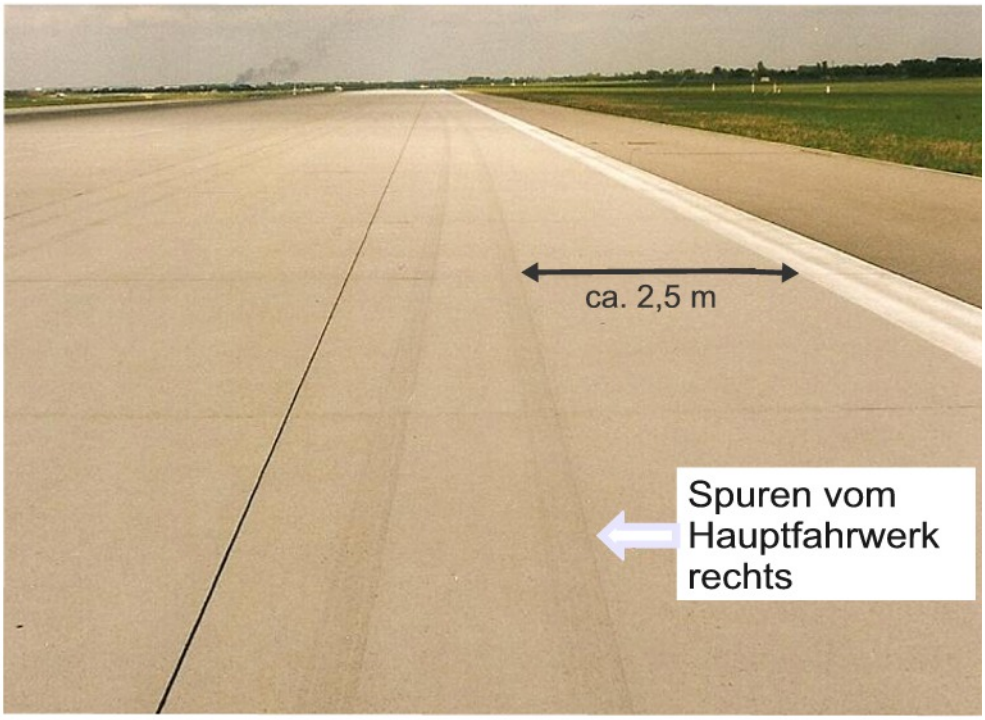

Illustration 12: Marks left by Right Main Landing Gear

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

During the course of a site visit by a BFU inspector, it was evident that the Approach to Runway 08 R could only be observed with difficulty from the B4 Cat-1 Hold position.

In addition, the inspector observed the night view of runway 08 R as seen from the cockpit of an aircraft at the B4 Cat-1 Hold. At night it was not possible to tell clearly whether an aircraft moving along Runway 08 R was landing or taking off until it had rotated or slowed down.

1.17 Organizational and management information

1.17.1 ICAO Procedures

The clearance given to the crew of the AT 45 to taxi onto Runway 08 R was a so-called conditional clearance. This form of clearance and procedure for its application in Airfield Air Traffic Control was defined in *Procedures for Air Navigation Services Air Traffic Management Doc 4444 ATM/501*, Issue 14, year 2001, published by the International Civil Aviation Organisation (ICAO).

Doc 4444 section 12.2.4 defines the 'phraseologies' to be used when issuing a conditional clearance by Air Traffic Control, together with the following remarks:

'Conditional Phrases, such as „behind landing aircraft“ or „after departing aircraft” shall not be used for movements affecting active runway(s), except when the aircraft or vehicles concerned are seen by the appropriate controller and pilot. In all cases a conditional clearance shall be given in the following order and consist of:

i) identification,

ii) the condition,

iii) the clearance and

iv) brief reiteration of the clearance.

Example: “SAS941, behind DC9 on final line-up behind”

The document incorporated the additional advice:

“This implies the need for the aircraft receiving the conditional clearance to identify the aircraft or vehicle, causing the conditional clearance.”

1.17.2 Procedure in the ICAO 'Manual of Radiotelephony' Doc 9432-AN/925, 2nd Edition 1990

In ICAO Doc 9432, the following passage was printed in association with the radiotelephony procedures to be used for the implementation of conditional clearances itemised in Chapter 4.5.7:

“Conditional clearances shall not be used for movements affecting active runway(s), except when the aircraft or vehicles concerned are seen by the appropriate controller and pilot. When the conditional clearance involves a departing aircraft and an arriving aircraft it is important that the departing aircraft correctly identifies the arriving aircraft on which the conditional clearance is based. Reference to the arriving aircraft type may be insufficient and it may be necessary to add a description of the colour or the company name to ensure correct identification. A conditional clearance shall be given as follows:

a) call sign,

b) the condition,

c) the clearance”.

1.17.3 DFS and its procedures as defined in *BA-FVK*

The standard operating procedures to be used by Air Traffic Controllers were defined in publication *BA-FVK*. Item 333 of section 3 in *BA-FVK* defined the conditions under which an aircraft reporting 'ready for departure' could be cleared to enter the runway, given the presence of other traffic.

The standard operating procedure given in *BA-FVK* 333.3 was as follows:

'If an aircraft is ready for departure but cannot yet be cleared for take off, to expedite traffic the aircraft may be allowed to enter the runway, line-up and hold under the following conditions:

- *Without restriction, provided that the line-up point is clear, and provided that the aircraft may proceed to the runway and hold without obstructing or hindering other traffic.*
- *With a specified restriction, if taxiing to the runway line-up point must be made conditional on the presence of other traffic.*

Such instructions must be unambiguous and formulated with the greatest clarity and precision. The clearance may only be given if the Air Traffic Controller can see all the aircraft concerned and any other vehicles, and is confident that the pilot given the clearance can see the other traffic.

In particular (...the Air Traffic Controller...) must ensure that the pilot reads back the clearance correctly and complies with the conditions.“

1.17.4 Air Traffic Control and radiotelephony procedures

The standard DFS R/T phraseology was published in Section 8 of the *BA-FVK*, in the German Air Pilot *Luftfahrthandbuch Deutschland* (AIP) and NOTAMS *Nachrichten für Luftfahrer* (NfL). The following guidance on the issuance of conditional clearances was given at item 852.251 of *BA-FVK*.

Conditional clearance:

- *G:* ***BEHIND LANDING / DEPARTING*** *(traffic information)* ***LINE UP RUNWA****Y (designator)* *******AND WAIT***** BEHIND***
- *A:* ***BEHIND LANDING / DEPARTING*** *(traffic information)* ***LINING UP*** *RUNWAY (designator)* *******AND WAITING***** BEHIND***

Note 1: Conditional figures of speech such as BEHIND THE LANDING AIRCRAFT or BEHIND THE DEPARTING AIRCRAFT should not be used in conjunction with movements relating to the runway in use, unless the duty Air Traffic Controller and the pilot can both see the aircraft or vehicle in question.

Note 2: When a conditional clearance is given, it should be repeated in full together with the condition(s), (e.g.: BEHIND LANDING...).“

1.17.5 Responsibilities of the Aerodrome Controller (abstract)

The functions and range of responsibilities of the Aerodrome Controller were given in section 221 of *BA-FVK*.

The functions of the Aerodrome Controller includes radiotelephony communications services as follows to:

- *Aircraft during take-off and landing*
- *Aircraft on the ground*

The Aerodrome Controller's essential responsibilities include:

- *The observation of all visible aircraft movements over and in the vicinity of the airfield, plus all aircraft, vehicles and persons on manoeuvring areas.*
- *Issuing clearances and instructions by radio or visual signals to ensure safe and expeditious airfield movements e.g.:*
- *Instructions that determine the take-off and landing sequence*
- *Taxi instructions for aircraft to the runway line-up point*
- *Clearances for take-off and landing*

The transmission of such information as is necessary for the safe, ordered and expeditious progress of flights, e.g.:

- *Local traffic information*

1.17.6 Use of Airport Surface Movement Radar

The use of Airport Surface Movement Radar for aerodrome control was regulated by *BA-FVK* Part 318.

Objective: Airport Surface Movement Radar should be used to monitor and manage the movement of aircraft and vehicles on the manoeuvring areas:

- *In conditions of limited visibility, in particular under weather conditions calling for CAT II / III procedures*
- *At night*
- *If parts of the manoeuvring areas are concealed*
- *If the aerodrome controller judges this necessary*

The uses of Airport Surface Movement Radar: Airport Surface Movement Radar information is used:

- *To confirm that the runway and its protected areas is free of vehicles or landed aircraft*
- *To confirm that an aircraft ready for departure is taxiing to the line-up point on the runway in use*
- *To confirm that a departing aircraft has begun its take-off run*
- *To confirm that a departing aircraft has become airborne*
- *To give taxi route instructions, or other information, to aircraft or vehicles*
- *To monitor correct execution of the Controller's instructions*

The DFS at Munich Airport had no list of Standard Operating Procedures relating to the use of ASMR, or RIM use and functions. This was at the discretion of the duty Aerodrome Controller.

1.17.7 Standard Operating Procedures for use of ASMR by Air Traffic Control at Munich

The Standard Operating Procedures *(BAO) 30/2003* and *40/2004* list the faults associated with ASMR, and the resulting limitations that could arise in Munich from technical deficiencies. Items 1.1. and 1.2 pf the *BAO* 40/2004 contain the following guidance:

BAO FVK 30/2003 Item 1.1:

*Radar reflections from aircraft on the manoeuvring areas north of Taxiway Sierra may result in mirror images arising from Taxiway Sierra, Bravo 4 and Tango; depending upon the position of the mirror image, this may result in a false alarm by the RIM and TC*M (Taxiway Collision Monitoring).

BAO FVK 30/2003 Item 1.2:

Depending upon the aircraft's reflective surfaces and the angle at which they are presented to the radar, so-called split targets images may be generated in the radar screen. Depending upon their position, these split targets can raise false RIM and TCM alarms.

1.17.8 Standard Operating Procedures Munich Aerodrome Control as defined in *BAO (OPS) Tower*

Local procedures in force in addition to those specified by the rules in *BA-FVK*, were defined in the above-mentioned *BAO*. Item 2.3.1 specified which taxiway entry points to runways could be used for take-off. For take-off on Runway 08 R the approved runway entry points were B1, B2, B3, B4, B6 and B9.

1.18 Additional information

The duty Air Traffic controller described the traffic density at the time of the incident as 'moderate'. The traffic situation was of normal complexity. In the 30 minutes preceding this Serious Incident there had been 24 aircraft movements: eight landings, 15 take-offs and a helicopter *en route* VFR to a landing in the city of Munich. At the time of the incident there were nine aircraft on the Tower frequency.

2. Analysis

2.1 General

The B 733 on runway 08 R passed the B4 taxiway intersection at a speed of about 110 kt, after the AT 45 had already left the B4 Hold Point. The radar trace showed the AT 45 as being about 10 m from the Runway centreline, with a clear risk of collision. A catastrophic accident was only avoided by a combination of luck and suitable avoiding action by the B 733.

Against this background, this incident was investigated by the BFU Federal German Aircraft Accident Investigation Bureau in accordance with the *Federal German Law on Aircraft Accident Investigations and Incidents resulting in disruption to the operation of civil aircraft (FlUUG*); it was classified as a Serious Incident and investigated accordingly.

One focal point of the investigation was the issue and implementation of Air Traffic Control clearances for the aircraft landing and taking off, and the use of conditional clearances.

2.2 Operational Evaluation of the clearances given

Air Traffic Control:

The duty Air Traffic Controller (PL1S) had the responsibility for issuing landing and take-off clearances. The use of a conditional clearance was a decision taken by the Controller to expedite traffic. Within the meaning of the definition, the conditional clearance was given by the controller with limitations and was dependent upon other traffic, whose crews had a duty to take note of and adhere to the limitations.

The conditional clearance, "…… BEHIND NEXT LANDING SHORT FINAL LINE UP 08 RIGHT BEHIND", was given to the AT 45 crew as the B 733 was on final and a departing Airbus A 321 was commencing its take-off run on runway 08 R. At the moment the conditional clearance was given, the Airbus had not travelled along the runway past the B4 taxiway intersection. The Controller did not inform the AT 45 crew that the aircraft on approach was a B 733, or that the departing aircraft was an Airbus A 321.

The clearance was not commensurate with the requirement that clearances must be so given that there is no possibility of mistakes. The phrase "BEHIND NEXT LANDING" could generate the impression, that the following aircraft was intended.

The Aerodrome Controller believed the clearance to be unambiguous. When the AT 45 crew confirmed "BEHIND NEXT LANDING LINE UP AND WAIT 08 RIGHT BEHIND …" she assumed the crew had visual contact with the aircraft concerned. She thus had no reason to follow progress on the ASMR radar after the B 733 had been cleared to land, and then turned her attention to other traffic.

In addition, the supplementary instruction "…AND WAIT…" read back by the AT 45 crew, was possibly regarded by the Controller as additional confirmation that the AT 45 should advance onto the Runway after the approaching aircraft had landed, and wait there for a new clearance.

It was not until the moment at which the B 733 crew reported "*Die is op de Baan*" that the Aerodrome Controller was alerted to the abnormal situation. This report was transmitted three seconds before the reaching the closest point between the aircraft. She then first had visual contact with the aircraft, after they had passed each other. Likewise, she had not seen how far the AT 45 had advanced onto the Runway.

The AT 45 aircraft:

Up to the point at which the AT 45 stopped at the B4 taxiway hold line, everything was routine. In line with normal operation, the aircraft came to a halt and the 'condition lever' was shifted to the 'feather-position'. After receipt of the clearance "…… BEHIND NEXT LANDING SHORT FINAL LINE UP 08 RIGHT BEHIND"; a short time later they observed an aircraft pass by on the Runway. The crew assumed that this was the aircraft which was the subject of the conditional clearance. This interpretation was confirmed by the commander's next action: he moved the 'condition lever' to 'auto' and was ready for departure.

Operation of the 'condition levers' called for extra attention by the crew because one of the two was harder to move than the other. After a brief discussion the two crew members regarded the problem as solved and the aircraft began to move. While moving from the B4 Taxiway Hold Line onto the Runway, they were unable to give their full attention to the approach airspace, because they were engaged with the final pre-flight checks.

The AT 45 crew was aware of the fact that the acute angle at which the aircraft moved from taxiway R4 onto Runway 08 R, limited their view of the approach. For that reason, just after crossing the R4 taxiway hold line the commander steered the aircraft to the right to give his co-pilot a better view.

The AT 45 crew said that on entering the Runway they had only seen a harsh light beam from the right and had brought their aircraft to an immediate halt. This statement of the crew was the explanation for the BFU as to why the B733 had in fact not previously been recognized as an aircraft. As the B733 passed by the AT45 with high speed and in close proximity the crew finally recognized the aircraft

Likewise, the radio conversations between the Tower, Boeing B 733 and Airbus A 321 had not alerted the AT 45 crew to the situation.

On observing the A 321 – which was actually taking off – pass by, both pilots on the flight deck of the AT 45 took it to be the landing aircraft mentioned by the conditional clearance.

The B 733 Aircraft:

It was not until the B 733 touched down that the crew spotted the AT 45 taxiing on to Runway 08 R. At this time and distance to the AT 45 a missed approach was no longer possible. The pilot at the controls of the B 733 correctly steered his aircraft to the right at a speed of about 110 kt, thus avoiding a collision.

Immediately before they were cleared to land the B 733 crew were on the same Tower frequency as the AT 45, and were thus able to hear the conditional clearance given to the AT 45. However, the B 733 crew was entitled to assume that the AT 45 waiting at the B4 Hold line would not advance onto the runway and line up until after the B 733 had landed.

2.2.1 Human Performance

Air Traffic Controller:

The Air Traffic Controller was properly licensed and qualified. She had been in the job for many years and had extensive experience.

The use of a conditional clearance was nothing unusual for the Air Traffic Controller. It was normal practice to use taxiway R4 for access to the Runway. Her decision to use this type of clearance was with the intention of expediting the flow of traffic. The traffic situation at the time of the incident – and in the earlier period – called for expeditious action to avoid the occurrence of delays.

In issuing the conditional clearance the Air Traffic Controller believed that it was clear and unmistakable, because it related to an aircraft landing, and not an aircraft taking off. Similarly, she was convinced that the AT 45 crew had seen the aircraft concerned, because the clearance issued had been read back correctly. She was so certain that she saw no further need to monitor the aircraft on the ASMR radar after she had cleared the B 733 to land. She turned her attention to other traffic.

As seen by the BFU, the high traffic density with nine aircraft on the Tower frequency, the general requirement for expeditious handling of aircraft movements, plus the belief that all the requirements had been met for a conditional clearance, were the reasons why the Air Traffic Controller turned her attention to other traffic immediately after she had issued the conditional clearance. For these reasons she abstained, for example, from further direct visual observation of the aircraft, or following the traffic development presented by ground radar.

AT 45 Crew:

Both AT 45 crew members were properly licensed and qualified for their duties. They were highly experienced both in terms of total flight time and experience on type.

Because the recording made by the Cockpit Voice Recorder (CVR) was not available for this investigation, it was not possible to undertake a comprehensive analysis of the decision-taking processes and cooperation in the cockpit.

Answers given by the AT 45 pilots in response to questions, and recordings of the radio communications, clearly indicate that both believed the A 321 to be landing, not taking off. Their attention was primarily focused on their own aircraft and following the clearance given by the Air Traffic Controller. No notice was taken of the approaching B 733.

Before advancing onto Runway 08 R, both pilots had been preoccupied with the stiff operation of the condition lever. This problem called for additional attention by both crew members.

The crew was aware of the fact that they had a restricted view of the approach to Runway 08, for which reason the commander had turned the aircraft slightly to the right at the Taxi Hold line. His expectation was that the co-pilot would look out at the approach path. The commander did not ask the co-pilot for confirmation that the approach was clear, nor did the co-pilot make such a statement of his own volition.

The crew had been on duty for four days in succession. On the day in question the crew had begun their duty at 11:40, had already been on duty for ten hours and flown four legs. For this reason, the possibility cannot be excluded that their performance and perceptive capacities might have been affected in following and implementing the Air Traffic Control clearance.

B 733 crew:

About two minutes before touchdown the B 733 crew was advised that final clearance to land would not be given until the aircraft was on short final. They were also advised that another aircraft would first be cleared for take-off. The clearance to land was not given until 17 seconds before touch down. In this phase, the crew was concentrating fully on the final approach and landing.

Even though the B 733 crew on final could see both the A 321 holding on the runway ready for departure and the AT 45, the B 733 crew was entitled to assume the AT 45 would wait.

Immediately before touchdown, the B 733 crew was suddenly confronted with a dangerous situation for which they bore no responsibility, but which called for split-second decision taking. Their on-the-spot and instant decision contributed greatly to the avoidance of an accident.

Because the recording made by the Cockpit Voice Recorder (CVR) was not available for this investigation, it was not possible to undertake a comprehensive analysis of the decision-taking processes and cooperation in the cockpit.

2.3 Specific Conditions pertaining at the moment of the incident

Traffic Density:

The Air Traffic Controller described the traffic at the moment of the incident as of average density and complexity. In the view of the BFU, the nine aircraft on the Tower frequency at that time called for prompt action. Any delay would have led to a backlog of arrivals and departures.

Meteorological Influences:

The incident happened about 50 minutes after sunset (20:46). In other words, the view seen by the AT 45 crew from the cockpit at the Taxiway B4 CAT-1 Hold Line onto Runway 08 R was in darkness. Field tests by the BFU have shown that the crew of an AT 45 in darkness at the taxiway Hold would have had great difficulty in telling whether an aircraft moving past along Runway 08 R was landing or taking off.

The other meteorological conditions had no effect upon the incident.

Taxiway B4:

From the planning point of view, Taxiway B4 was built as a fast exit taxiway from Runway 26L. Although the aerodrome Standard Operating Procedures (*BAO*) explicitly state the taxiway may be used by departing aircraft, the BFU judges this represents acceptance of higher risk. Taxiway R4 intercepts the Runway at an acute angle of 30°, giving a very restricted view to the right of the approach to Runway 08 R, especially as seen from the flight deck of a shoulder-wing aircraft.

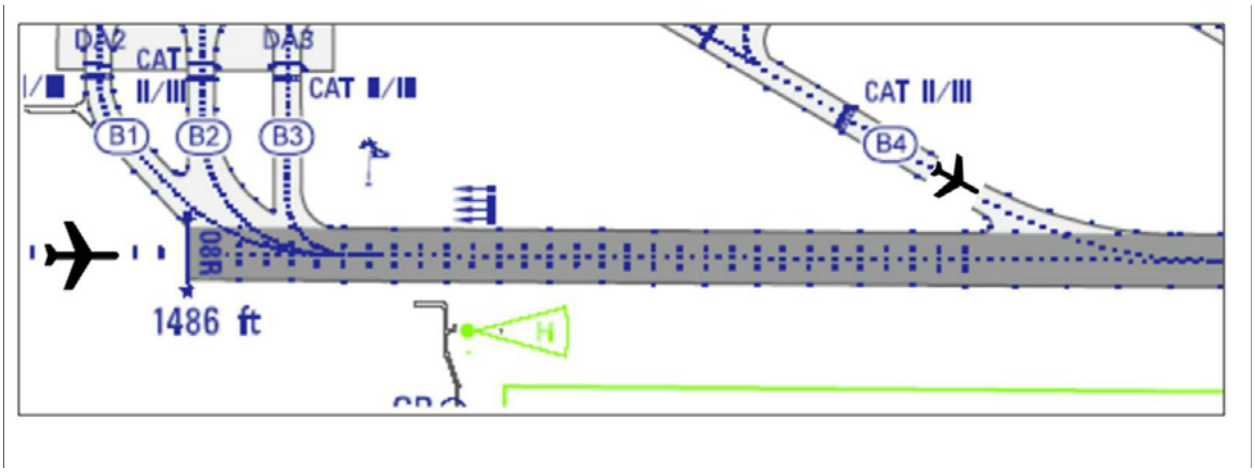

Illustration 13: Entry Point of Taxiway B4 to Runway 08 R

As far as the BFU is aware, there has been no risk analysis undertaken, either in the context of the formal Airport Planning Approval Process or the Standard Operating Procedures.

The Taxiway and Runway markings conformed with the directions contained in ICAO-Appendix 14, and directions issued by the Federal German Government Ministry of Transport, Construction and Town Planning (BMVBS).

2.4 Safety Precautions

The Air Transport System has a range of safety precautions whose objective is to identify faults in the decision-taking process, prevent human error and avoid or pick up faults in technical systems; these precautions had an influence on this Serious Incident.

2.4.1 Airport Surface Movement Radar (ASMR)

The Airport Surface Movement Radar had a Runway Incursion Monitoring (RIM) function whose task was to provide an additional safety net. Any error in the issue and implementation of a clearance resulting in a Runway Incursion should have been detected by the RIM Function and presented as an alarm.

The data recorded by the ASMR showed that the system recognised the dangerous conversion on Runway 08R early enough for the Air Traffic Controller to take corrective action.

At 21:39:09, 17 seconds before the closest convergence of the AT 45 and B 733 aircraft, the system generated both acoustic and optical alarm signals. The alarm related to the AT 45 and B 733 and was presented on the ASMR display screen. Shortly before, an alarm had been generated that related to the B 733 and the departing A 321.

The Air Traffic Controller was unaware of the optical and acoustic warnings because the ASMR RIM function was switched off at her workstation.

The system was switched off because, according to Air Traffic Controllers, it gave an unacceptably high number of false alarms and erroneous screen presentations. The high number of false alarms and faulty screen presentations reduced Air Traffic Controllers' trust in the system. As seen by the BFU, this assessment of the system by DFS Air Traffic Control personnel was understandable, but not acceptable.

DFS-Munich did not have a Standard Operating Procedure defining the use of ASMR and the RIM function - this was left to the discretion of the respective Air Traffic Controller.

The BFU shares the view of the Air Traffic Controller who was on duty at the time, namely that if the RIM had been switched on, she would have received both acoustic and optical warnings of the threat situation. The RIM was switched off due to the unreliability of the system.

Illustration 14: Radar Trace Record 21:39:09. RIM alarm between the AT 45 / B 733. The B 733 was on short final and was presented on the ASMR screen a short time later.

2.4.2 Standard Operating Procedures and Instructions

The application and issue of Air Traffic Control Clearances is standardised by a number of Standard Operating Procedures and Instructions. Those for Conditional Clearances were not fully satisfactory.

Manual of Operations Air Traffic Control Services *BA-FVK*:

The Standard Operating Procedures for the Air Traffic Controller were set down in the 'Manual of Operations Air Traffic Control Services' (*BA-FVK)*. Part 3 of *BA-FVK* 'Airfield Control Procedures' (*Flugplatzkontrollverfahren*) sets out the Standard Operating Procedures for Air Traffic Controllers. There is no mention in this section of *BA-FVK* of a 'conditional clearance'.

Item 333.3 of *BA-FVK* described a procedure to be used if an aircraft was ready for departure, but could not yet be cleared for take-off because of the presence of another aircraft.

Amongst other things, the procedure set out that the Air Traffic Controller's instruction must be absolutely clear and unambiguous; it should only be issued if the Controller could actually see the aircraft and any vehicles involved, and could be sure that the pilot concerned could actually see the traffic to which the instruction related.

Further, the Air Traffic Controller had to ensure that the pilot read back the instruction correctly, and followed any conditions.

At the time of the incident in question, there was no instruction in the *BA-FVK* section entitled 'Conditional Clearances' setting out the Standard Operating Procedures for Air Traffic Controllers and defining the circumstances under which a 'conditional clearance' could be applied.

Air Traffic Controllers told the BFU that conditional clearances were also given for aircraft and vehicle movements not listed under item 333.3, such as crossing runways between take-offs and landings.

ICAO Doc 4444 ATM/501 contains the heading *12.2.4 Phraseologies*, which was incorporated in *BA-FVK* section 8 *Sprechfunkverfahren* ('Radiotelephony Procedures').

ICAO Doc 4444:

At the time of the incident in question, the use of conditional clearances was defined under the heading 'Radiotelephony Procedures' in ICAO documents Doc 4444 ATM/501 and Doc 9432-AN/925, 2nd Edition 1990.

The section entitled 'Aerodrome Control Procedures' in Doc 4444 ATM/501 only described the application of conditional clearances and associated conditions in general terms.

Standard Operating Procedures and the use of ASMR:

DFS Munich had no Standard Operating Procedures for the use of ASMR and the use of the RIM function; this was at the discretion of the respective Air Traffic Controller.

2.5 Organisation

The system operator was aware of the high incidence of false ASMR alarms and erroneous screen presentations, especially in conjunction with the RIM function. This problem had been pointed out when the system was introduced into service. As seen by the BFU, the ASMR RIM function was not fit for operational use. It made no sense to permit the introduction into service of a system which was intended to operate as a safety net, but which was subject to false alarms and erroneous screen presentations.

The Standard Operational Procedure for the issue and application of a conditional clearance defined in *BA-FVK* was in accordance with the recommendations of ICAO Doc 4444. It was not until this investigation, that it became evident the process described in BA-FVL was not comprehensive or precise.

3. Conclusions

3.1 Findings

- The crews of the AT 45 and B 733 were both adequately licensed and qualified.
- The Air Traffic Controller was adequately licensed and qualified.
- The conditional clearance was chosen to increase the traffic flow.
- The B 733 had clearance to land for Runway 08 R, onto which the AT 45 was advancing.
- The conditional clearance given to the AT 45 crew could be misunderstood.
- The phraseology chosen was commensurate with ICAO recommendations and the radiotelephony procedures adopted by DFS.
- The Standard Operational Procedure for conditional clearances defined in *BA-FVK* was not comprehensive and precisely formulated.
- The Standard for conditional clearances and their application was not comprehensive and precisely formulated in ICAO Doc 4444..
- The Air Traffic Controller had assumed the AT 45 crew had seen the other traffic.
- After having issued the conditional clearance, the Air Traffic Controller did not follow the situation developing between the advancing AT 45 and the landing B 733.
- Because of their aircraft position, the AT 45 crew had an inadequate view of the final approach to Runway 08 R.
- During airport planning and definition of Standard Operational Procedures, no risk assessment had been made of the use of Taxiway R4 for access to departure line-up on runway 08 R.
- The AT 45 crew did not consciously follow the radiotelephony conversations between the Tower and other aircraft.
- The Air Traffic Controllers did not have an agreed Standard Operational Procedure for use of the ASMR with the RIM function.
- The ASMR RIM function at the controller's workstation was switched off.

3.2 Causes

The causes of this Serious Incident were as follows:

Immediate Causes:

- Communications between the AT 45 and Tower relating to the issue and implementation of a conditional clearance were unclear.
- The AT 45 advanced onto Runway 08 R when an aircraft had been cleared to land.
- The AT 45 crew had a only a restricted view of the approach to Runway 08 R.
- The Airfield Surface Movement Radar (ASMR) Runway Incursion Monitor (RIM) alarm was de-activated.

Systemic Causes:

- The Standard Operating Procedures for issue and application of conditional clearances was not comprehensive and precise.
- The fast exit from Runway 26 L to taxiway B4, was used for access to Runway 08 R in conjunction with a conditional clearance.
- The RIM alarm function to display Runway Incursions was unreliable and faulty.

4. Safety Recommendations

To avoid similar future incidents the BFU has issued the following safety recommendations:

Recommendation Nr. 30/2004:

German Air Traffic Control (*DFS Deutsche Flugsicherung GmbH*) should rewrite the document 'Standard Operational Procedures for Air Traffic Control' – *Betriebsanweisung Flugverkehrskontrolle (BA-FVK)* – Part 333.3, defining the procedure for issue of a conditional clearance. The wording should be clearer and incorporate conditional clearances in Part 3 of *BA-FVK*.

Recommendation Nr. 03/2007:

German Air Traffic Control (*DFS Deutsche Flugsicherung GmbH*) should ensure that Airfield Surface Movement monitoring systems that are equipped with conflict recognition and/or alarm systems give reliable indications.

Recommendation Nr. 30/2004 has been implemented by German Air Traffic Control *DFS Deutsche Flugsicherung GmbH*.

Braunschweig, December 2008

On behalf of the

Federal German Accident Investigation Bureau

Johann Reuss

Investigator-in-Charge

5. Appendices

None