

# Investigation Report

## Identification

Type of Occurrence:	Serious Incident
Date:	3 November 2011
Location:	Munich
Aircraft:	Transport aircraft
Manufacturer / Model:	Boeing / B 777-300 ER
Injuries to Persons:	None
Damage:	None
Other Damage:	Crop damage
State File Number:	BFU EX010-11

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
AFCS	Automatic Flight Control System
AFDC	Autopilot Flight Director Computer
AFDS	Autopilot Flight Director System
AGIS	Air Ground Indication System
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ATIS	Automatic Terminal Information Service
ATPL	Air Transport Pilot's Licence
CET	Central European Time
CMC	Centralised Monitoring Computer
CRM	Crew Resource Management
CSB	Carrier Sideband
CVR	Cockpit Voice Recorder
DDM	Difference in Depth of Modulation
DFS	Deutsche Flugsicherung (German Air Traffic Service Provider)
DH	Decision Height
DME	Distance Measuring Equipment
F/D	Flight Director
FCOM	Flight Crew Operations Manual
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FMC	Flight Management Computer
GP	Glide Path
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System

KIAS	Knots Indicated Airspeed
LIP	Line Instructor Pilot
LOC	Localizer
LVP	Low Visibility Procedures
LW	Landing Weight
MCP	Mode Control Panel
METAR	Meteorological Aerodrome Report
NDB	Non Directional Beacon
NfL	Nachrichten für Luftfahrer (notices for airmen)
NM	Nautical Mile
PF	Pilot Flying
PFD	Primary Flight Display
PIC	Pilot in Command
PM	Pilot Monitoring
RVR	Runway Visual Range
SBO	Side Band Only
SOP	Standard Operating Procedures
SPD	Speed Mode
TO/GA	Take-off/Go-around
TOW	Take-off Weight
UTC	Universal Time Coordinated
VOR	VHF omnidirectional Radio Range
WOW	Weight on Wheels

## Synopsis

During the landing shortly after touch-down the airplane veered left off the runway, then crossed the runway and came to a stop on the other side next to the runway.

The serious incident was caused by the following:

### Immediate Causes:

- The crew decided to conduct an autoland landing even though the conditions on the ground for a safe conduct were not given.
- Shortly before touch-down the airplane was deviated to the left of its flight direction by a disturbed LOC signal. A BAE 146-RJ85 taking off a short distance ahead of the B 777 caused the interference.
- The two pilots could not keep the airplane on the runway after touch-down because the autopilot was still engaged.
- The crew was confused by the behaviour of the airplane. They had not noticed that the go-around mode had already been deactivated by the initial touch-down of the left main landing gear.

### Systemic Causes:

- The recommendation concerning the conduct of autoland landings under CAT I conditions published in the FCOM of the operator allowed the decision for an autoland landing without having to consider the required conditions on the ground.

# 1. Factual Information

## 1.1 History of the Flight

On 1 November 2011 the crew had conducted the flight from Singapore to Munich. After a 48-hour stay, on 3 November 2011, the crew conducted the flight from Munich to Manchester and back. Both pilots stated they had slept well, felt rested, and almost adjusted to Central European Time (CET). At 0515 hrs<sup>1</sup> the crew reported for duty. The flight to Manchester occurred without incident. On the subsequent return flight to Munich 147 passengers, 13 flight attendants and 2 pilots were on board.

According to crew statements the co-pilot was initially Pilot Flying (PF) during the flight Manchester - Munich. Based on the latest weather information at Munich, visibility 2,000 m, cloud base 300 ft, the Pilot in Command (PIC) decided to assume the role of PF, as the SOPs (FCOM/NORMAL PROCEDURES/OPERATION) of the operator required, and the co-pilot became Pilot Monitoring (PM). The PIC decided to conduct an automatic approach and autoland.

At 1152:13 hrs during descent to Flight Level (FL) 110 the crew contacted Munich approach control for the first time. The crew did not acknowledge receiving the valid ATIS Information X of 1150 hrs (1050 UTC). The crew received several instructions, such as heading and rate of descent, from the controller.

At 1158:19 hrs the crew was advised to call Munich Director on frequency 118,825 MHz.

At 1158:42 hrs the crew contacted Munich Director and received heading and descent instructions for the final approach to the Instrument Landing System (ILS) of runway 08R.

At 1200:43 hrs the crew received the approach clearance to runway 08R "[...] descend 5,000 feet cleared ILS zero eight."

At 1203:23 hrs the crew was instructed to reduce speed to 170 kt and contact Munich Tower on 120,500 MHz.

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<sup>1</sup> All times local, unless otherwise stated.



At 1204:37 hrs the crew contacted Munich Tower.

At 1208:47 hrs the crew received the latest wind information and was cleared to land: "[...] one three zero degrees, seven knots runway zero eight right, cleared to land".

As the B 777 was about 50 ft above the runway in the flare phase the airplane began to slowly bank left up to 3.5°. The PIC called out: "Okay, flaps twenty." At approximately 420 m beyond the runway threshold the airplane touched down with the left main landing gear and 132 kt (KIAS). At that time the Auto Flight System (AFS) switched to rollout mode.

The autopilot was still engaged as the airplane moved toward the left runway edge and veered off the runway with a speed of 123 kt (KIAS) about 944 m beyond the threshold in the area of taxiway B4. For about 400 m the airplane rolled through the grass north of runway 08R in a slightly curved right hand turn. The largest lateral deviation from the runway was reached at about 1,242 m beyond the threshold; speed was 109 kt KIAS. Because of the system design the autopilot disengaged due to crew inputs via the rudder pedals. The airplane turned right by about 40°, re-entered the runway close to the intersection with taxiway B6, about 1,566 m beyond the threshold. The aircraft crossed the runway with a heading of about 120°. Speed was still 71 kt KIAS. The airplane veered off the runway again, turned left by about 40°, and came to a stop in the grass south of and parallel to runway 08R. At 1209:09 hrs the airplane crossed the threshold; at 1209:51 hrs it came to a stop.

According to the pilots there was no need to evacuate the passengers via the slides, because no one had suffered any injuries and the airplane was apparently not damaged. About two minutes after the airplane had come to a stop the fire brigade arrived at the scene. The passengers disembarked the airplane via two stairs from the fire brigade.

The crew stated that during the approach and the landing there were no indications as to malfunctions or system failures. The PIC stated he had tried to initiate a go-around procedure by pushing the TO/GA buttons on the thrust levers and thereby triggering the go-around mode once it had been noticed that the airplane banked to the left. But the airplane did not respond. At the same time he retracted the ground spoilers manually which had automatically been deployed at the time of the touch-down.

## 1.2 Injuries to Persons

Injuries	Crew	Passengers	Third Party
Fatal			
Serious			
Minor / None	15	147	

## 1.3 Damage to Aircraft

None

## 1.4 Other damage

There was minor crop damage

## 1.5 Personnel Information

### 1.5.1 Pilot in Command

Sex: Male

Age: 45 years

Seat: Left seat

License: Air Transport Pilot's Licence (ATPL(A)) issued by the Civil Aviation Authority of Singapore (CAAS) on 21 April 1993; valid until 30 September 2012.

Ratings: B 747, B 777  
PIC since 21 October 2004  
Line Instructor Pilot (LIP) since 29 May 2010

With the company since 23 January 1992

Last line check: 13 January 2011

Last base check: 21 June 2011

Last recurrent training: 20 October 2011

Last medical: 13 September 2011

Flying experience

Total: 12,416 hours

On type: 4,712 hours

Last 24 hours: approx. 3 hours

Last 90 days: 219 hours  
Crew Resource Management  
Initial Training: 18 March 2005  
Recurrent: 6 May 2010  
Last day of duty: 1 November 2011 (Singapore – Munich)  
Rest period: 48 hours.

### 1.5.2 Co-pilot

Sex: Male  
Age: 35 years  
Seat: Right seat  
Licence: Air Transport Pilot's Licence (ATPL(A)) issued by the Civil Aviation Authority of Singapore (CAAS) on 1 February 2008; valid until 29 February 2012  
Ratings: B 777  
With the company since: 5 September 2002  
Last line check: 19 January 2011  
Last base check: 8 August 2011  
Last recurrent training: 22 November 2010  
Last medical: 21 January 2011  
Flying experience  
Total: 3,681 hours  
On type: 3,681 hours  
Last 24 hours: Approx. 3 hours  
Last 90 days: 182 hours  
Crew Resource Management  
Initial Training: 16 June 2006  
Recurrent: 7 December 2009  
Last day of duty: 1 November 2011 (Singapore - Munich)  
Rest period: 48 hours

### 1.5.3 Air Traffic Service Personnel

#### Approach controller (pick-up)

Sex: Male  
Age: 37 years  
Licences / Ratings: Approach and area control including Flight Information Service; training rating  
With the company Since January 1999

At the day of the occurrence a trainee was trained.

#### Director (feeder)

Sex: Female  
Age: 33 years  
Licences / Ratings: Approach and area control including Flight Information Service; training rating;  
With the company Since November 1999

At the day of the occurrence a trainee was trained.

#### Tower Controller

Sex: Male  
Age: 26 years  
Licences / Ratings: Aerodrome control with radar including Flight Information Service;  
With the company Since January 2010

## 1.6 Aircraft Information

Aircraft type: B 777-300 ER  
Manufacturer: Boeing Commercial Airplane Group, Seattle, Washington, USA  
Year of manufacture: 2008  
Serial number: 34582  
Engine: Two General Electric GE90-115B/2-115BL  
Maximum Take-off Mass (MTOM): 351,534 kg  
Maximum Landing Mass (MLM): 251,291 kg

Actual landing mass: 210,300 kg  
Airframe operating hours: 5,539 hours and 25 seconds

The tech log did not list any entries relevant for the serious incident.

The airplane was certified for CAT IIIB approaches with a Runway Visibility Range (RVR) of 100 m and a Decision Height (DH) of 20 ft.

There were no restrictions concerning the airplane's equipment.

The last autoland was conducted on 26 October 2011 in Singapore.

The last C-check was conducted on 28 November 2010.

### 1.6.1 Automatic Flight Control System

#### General Description

The Automatic Flight Control System (AFCS) consists of the Autopilot Flight Director System (AFDS) and the autothrottle system. Both, AFDS and autothrottle, are operated via the Mode Control Panel (MCP) and the Flight Management Computer (FMC). During normal operation the FMC supplies the AFDS with data. The AFDS controls the airplane during climb, cruise flight, descent, and approach until the landing.

#### Autopilot Flight Director System

The AFDS consists of three Autopilot Flight Director Computers (AFDCs) and the Mode Control Panel (MCP).

The MCP provides control of the autopilot, the flight director, the altitude alert, and the autothrottle system. The MCP is used to select and activate the AFDS modes and to enter parameters such as altitude, speed, climb and descent profiles. The Primary Flight Display (PFD) displays the flight director information. The autopilot controls the elevator, the ailerons, the flaperons and spoilers through the fly-by-wire-system. The autopilot can control the rudder only during approach and landing. The autopilot controls the nose wheel steering after an automatic landing.

#### Engaging the Autopilot

The autopilot is engaged by pushing either one of the two MCP autopilot engage switches.

#### Disengaging the Autopilot

During normal operation the autopilot can be disengaged via the autopilot disconnect switch on either of the two control columns. The autopilot can also be disengaged on the MCP autopilot disengage bar.

In this case the autopilot was not disengaged manually. After the airplane had veered left off the runway and the two pilots had applied right rudder input to correct direction, the autopilot disengaged at 1209:26 hrs. At the time of the autopilot disengagement at the PIC's side a maximum of 23 lbs and at the co-pilot's side of 41 lbs force effect were recorded.

```

IFDE03.004
CPM/Comm Hardware PN: 4089450-901
CPM/Comm LDI: 3110-BCG-00W-12
CPM/GG OPS: HNP5E-AL03-1007
SQ9V-SWQ
PAGE: 1
DATE: 03NOV11
TIME: 1732z

INBOUND FLIGHT DECK EFFECTS SIA327 EGCC/EDDM
Leg start was 0906z 03NOV11
This data is from the Left CMCF

Flight Deck Effects Recorded During the Inbound Leg (1)

FDE: AUTOPILOT DISC Warning NOT ACTIVE
Fault Code: 221 002 00 1109z 03NOV11

[] Maintenance Message: 22-14110 NOT ACTIVE
Rudder pedal position does not agree with commanded
position

Detected By:
Autopilot Flight Director Computer (Right)

Occurred at 1109z 03NOV11 during Taxi In
Message is ACTIVE only during operational mode shown in FIM.

Recommended Maintenance Action:
Possible causes:
1. Pilot moved pedals during LAND 2 or LAND 3
2. Rudder pedals do not move freely
3. See Fault Isolation Manual (FIM)

END OF INBOUND FLIGHT DECK EFFECTS REPORT

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Excerpt of the Centralised Monitoring Computer

Source: BFU

## ILS Signal Interference Monitor

The autopilot flight director system can detect ILS signal interferences which are caused by vehicles or aircraft on the ground. In such cases the autopilot disregards the ILS signals and switches in the attitude stabilizing mode which is based on data from the on-board inertial navigation system. These interferences generally only last

for short periods of time and no error is indicated. If the interferences last longer the flight director mode is downgraded from LAND3 or LAND2, for example.

#### **1.6.1.2 Operating Modes of the Auto Flight System**

##### **Flare Mode**

During an autoland the airplane in flare mode is guided toward the ground in a slight flare curve. The flare mode is only active if the PFD indicates LAND2 or LAND3 and starts about 50 ft above the runway. Between 50 ft and 25 ft the thrust levers are automatically pulled into idle. On the PFD the indication changes from SPD to IDLE. After touch-down of the nose landing gear on the runway the indication on the PFD changes from Flare into Rollout Mode.

##### **Rollout Mode**

The rollout mode is armed when the airplane is at about 1,500 ft radio height and becomes active once the aircraft is below 2 ft above the runway. After touch-down the autoflight system uses rudder and nose wheel steering to follow the localizer signal.

##### **Go-Around Mode**

The automatic go-around mode is on stand-by when the flaps are beyond their neutral position or the ILS glide slope is activated. The automatic go-around becomes active once one of the two push switches on the thrust levers (TO/GA button) is pushed.

The manufacturer stated that the go-around mode is deactivated when the AFDC logic signals that the airplane is on the ground. This logic takes into account the radio height and the Weight on Wheels (WOW) signal from the Air Ground Indication System (AGIS). The autopilot calculates the height of the landing gear based on the radio altitude and the aircraft geometry. The calculated landing gear height has to be less than 2 ft and the left or right WOW signal has to be present.

## **1.7 Meteorological Information**

Until 0920 UTC fog and visibilities between 600 and 900 m prevailed at Munich Airport. After 0940 UTC visibility improved slowly to 2,000 m at the time of the landing.

Prior to landing, the crew had received two aviation routine weather reports (METAR) via the Air Traffic Information Service (ATIS) Munich. Information W of 1030 UTC and Information X of 1050 UTC included:

Slight wind from easterly directions with 8 kt; visibility 2 km with light mist. Cloud base at 300 ft, partially descending to 200 ft. Temperature and dewpoint were 4°C. Barometric air pressure was 1,011 hPa. No significant weather changes were to be expected.

## 1.8 Aids to Navigation

For the approach to runway 08R an Instrument Landing System (ILS), a Distance Measuring Equipment (DME), a Non-Directional Beacon (NDB), and an Omnidirectional Radio Beacon (VOR) were available. The ILS used the frequency 109.3 MHz with the identifier IMSE and had a glide slope of 3°. The ILS glide slope transmitter (GP) was a GP 422 dual-frequency system manufactured by Thales.

The ILS localizer (LOC) was a LOC 421 dual-frequency system manufactured by Thales. The system had been installed in May 2010. The location of the antenna had been changed to about 650 m farther east of the old location which means about 1,000 m from the end of runway 08R. Initial survey took place between 8 and 12 May 2010. On 31 May 2010 the technical clearance for CAT I occurred. The technical clearance to CAT II and CAT III occurred on 28 July 2010 and the operational clearance on 3 August 2010. Technical clearance to CAT II and CAT III occurred on 28 July 2010 and operational clearance on 3 August 2010.

On 20 October 2011 the Aeronautical Information Publication (AIP) published these changes on the respective aerodrome chart. The pages AD 2 EDDM 1-9 Radio Navigation and Landing Aids still showed the coordinates for the old location of the antenna.

The last recurring calibration flight took place on 17 May 2011. The calibration record was made available to the BFU.

### 1.8.1 Instrument Landing System

The ILS is a radio-navigation system and basically consists of ground based localizer and glide slope systems and the respective receivers and indicators on board an aircraft. The localizer provides the indication of the deviation from the extended runway centre line for the approaching airplane; the glide slope provides signals for the indication of the deviation from the optimal descent profile to the touch-down point. This part of the system does not play any part in further considerations.



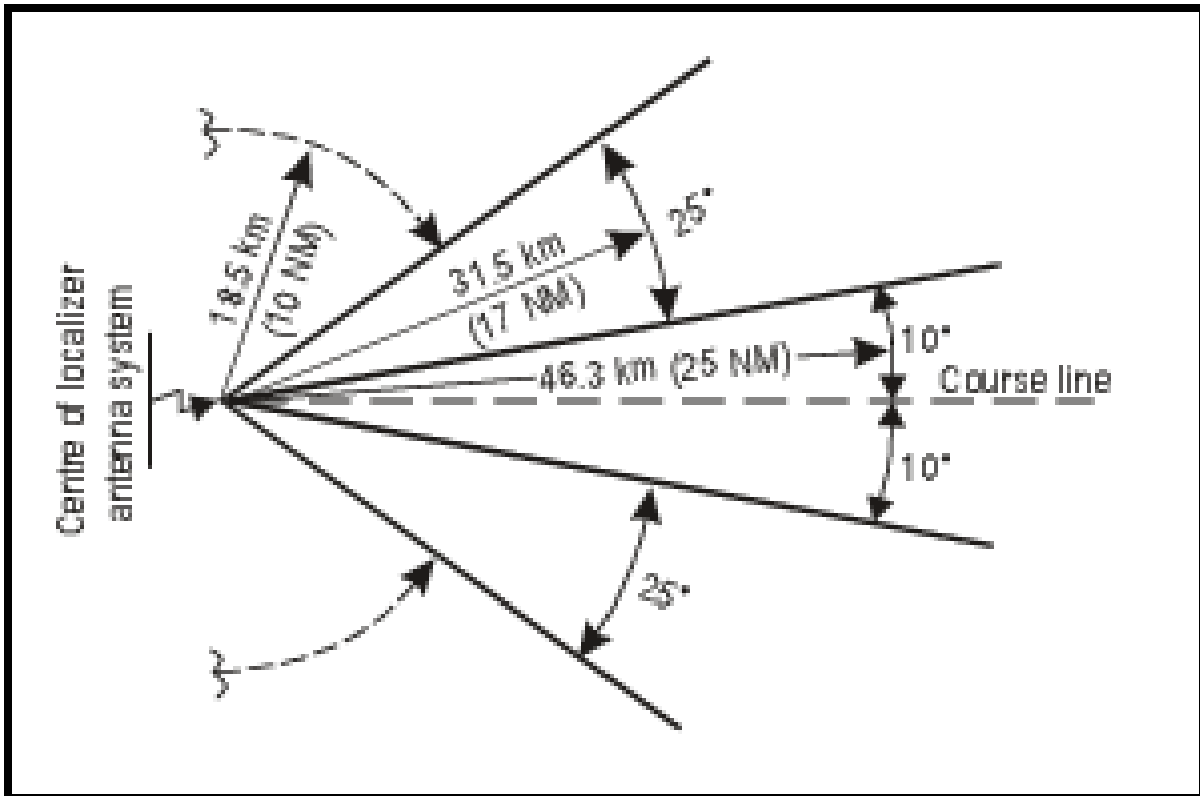
### Purpose of the Localizer

The localizer generates and emits high-frequency signals which provide course guidance to the runway during the approach. The localizer also provides course guidance during rollout if equipment and runways are certified for all-weather operations in accordance with CAT III.

### Course and Clearance

The deviation from the extended runway centre line indicated in the aircraft is deduced from an angular information: the indication varies depending on the difference between the direction of the extended runway centre line and the direction of the prevailing flight direction in relation to the localizer antenna. Therefore, the displacement sensitivity of the indication, in regard to the absolute deviation, is in reverse proportion to the distance to the antenna.

ICAO Annex 10 requires a coverage, i.e. a clear indication, [...] The localizer coverage sector shall extend from the centre of the localizer antenna system to distances of: 46.3 km (25 NM) within plus or minus 10 degrees from the front course line; 31.5 km (17 NM) between 10 degrees and 35 degrees from the front course line [...].



Required coverage

Source: ICAO Annex 10

In a limited area around the extended runway centre line the indicated deviation shall be proportional to the actual deviation. This area is called course sector and is about  $\pm x^\circ$ . The exact value depends on the local circumstances, the distance between the localizer antenna and the runway threshold.

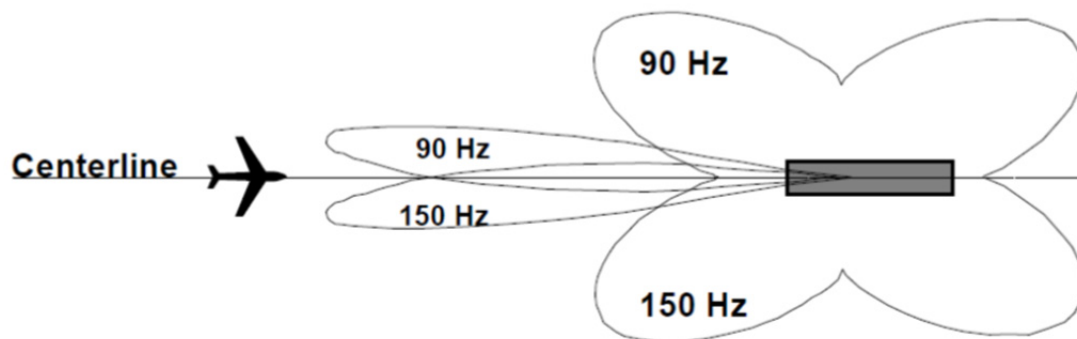
With larger actual deviations the indication shall definitely indicate a full scale deflection (Clearance outside the course sector).

#### Technical Implementation of a Two-Frequency Localizer

Data is transmitted through a high-frequency carrier signal with the frequencies 90 Hz and 150 Hz amplitude modulated: 90 Hz indicates "left" and 150 Hz "right". The signal is generated as Carrier Sideband (CSB) and as Side Band Only (SBO). The radiation of the radio frequency signals occurs at the far end of the runway opposite to the approach direction using an array of dipole antennas located at right angles and symmetrically to the extended runway centre line. The signals are fed into the individual antennas through phase shifters. Thus, an electro-magnetic field is created in the approach sector which results from the superposition of individual an-

tenna fields. In this field, depending on the deviation, the depth of modulation of the 90 Hz signal decreases from left to right (seen in approach direction) and the depth of modulation of the 150 Hz signal increases from left to right.

The difference in depth of modulation within an sector of typically  $\pm 3^\circ$  to  $5^\circ$ , in the present case about  $2.5^\circ$ , around the extended runway centre line is directly proportional to the magnitude and direction of the lateral deviation (course sector). Outside the course sector the 90- and 150-modulation, respectively, predominate and an Off Course Indication is the result - full scale deflection of the course deviation indicator.



Localizer antenna diagram

To minimise interferences of the electro-magnetic field in the clearance sector due to reflective components from the course sector, two-frequency localizer systems are used. Thereby, the carrier frequencies of the signal components which are fed to the dipole antennas for the course sector and the clearance sector differ by a few kHz. The power level of the clearance signal is considerably lower.

Localizer System:

The localizer ground system consists of the components:

Transmitter

It generates the high-frequency carrier signals and the low-frequency signals 90 Hz (left) and 150 Hz (right). From these originate modulated high frequency signals with carrier (CBS course, CBS clearance) and with suppressed carrier (SBO course, SBO clearance). It is located in a building apart from the antennas.

Feeder

Through phase splitters or dispatchers, respectively, the four signal parts are fed to the antennas. The phase and amplitude relations of the signal components to each other for each dipole of the antenna array are set.

#### Antenna Array

The antenna array consists of a row of dipole antennas which are located at right angles and symmetrically to the runway. In general, the antennas are located about 300 m to 400 m beyond the end of the runway; in this case it was approximately 1,000 m.

#### Near Field Monitor

It consists of antenna, receiver and signal analysis. Its antenna is located some 10 m ahead of the localizer antennas. The near field monitor monitors the localizer signal to detect possible corruption due to dysfunctional system components. The near field monitor is not mandatory.

#### Far Field Monitor

It, too, consists of antenna, receiver and signal analysis. Its antenna is located some km ahead of the localizer antennas often prior to the beginning of the runway in the area of the approach lighting. The far field monitor monitors the localizer signal to detect possible corruption coming from the area of the runway and its surroundings, e. g. signal reflections. The far field monitor is mandatory for the all-weather operations CAT II and CAT III.

#### Integral Monitor

In the antenna array the emitted signals are probed via sensors, recombined into signal components and monitored.

#### Monitoring System

It signals and records, respectively, the disturbances detected by the near field, the far field and integral monitors and either shuts down the system or switches to the back-up transmitter.

### 1.8.2. ILS Dysfunctions due to Outside Influences

#### Antenna Characteristics

The antenna characteristics describe the directionality of the radiation viewed from the antenna.

The electromagnetic field of the localizer transmitter antenna originates from the superposition of the four signal components, CSB and SBO for the course sector and the CSB and SBO for the clearance sector (see chapter Technical Realisation) which are fed to the antenna components via adjusted phase shifters.

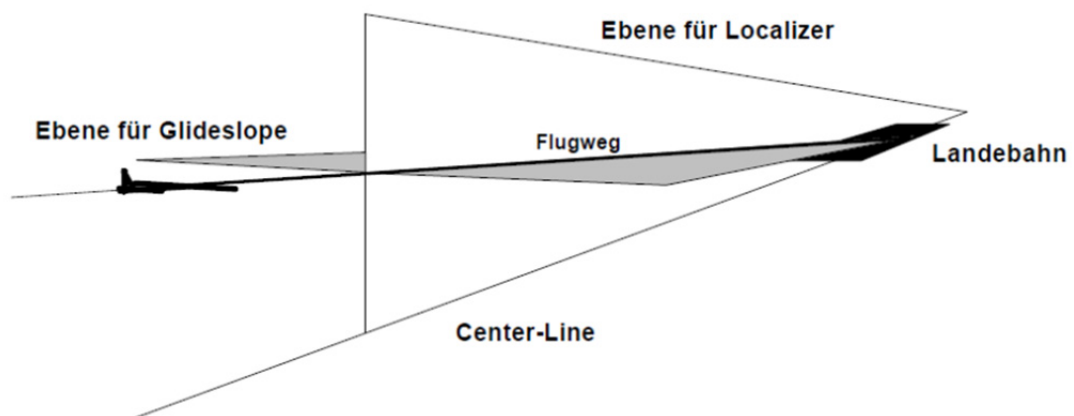
Due to the phase-shifted and amplitude adjusted feed-in, each of the four signal components has its own antenna characteristic; the superposition of these characteristics constitutes the antenna radiation pattern.

The relation between the DDM of the signal received on board the aircraft and the lateral deviation from the extended runway centre line is required to be proportional. This is achieved with a zero within the antenna characteristic of the SBO component for the course sector.

Therefore originating from this signal component no power is radiated along the centre line. However in the proximity of the centre line the radiated power increases substantially, even if the lateral deviation is small compared to the width of the course sector.

In addition to the horizontal antenna characteristic the vertical antenna characteristic is also significant.

In order to receive the localizer signal already prior to commencing the final approach in several thousand feet above the touch-down zone the localizer antenna not only radiates horizontally but also slanted at an angle upward into the approach sector.



Localizer and glideslope level

## Electromagnetic Interference

Basically electromagnetic waves propagate in a straight line. This can be affected by:

- Refraction - is the change in direction of a wave due to a change in its transmission medium (while propagating in an inhomogeneous medium it is bent toward the denser area).
- Diffraction - waves are bent around edges.
- Diffusion - radiation originally propagating in one direction is being diffused by an object and then propagates in different directions.
- Reflection - whenever radiation meets a plain or slightly bent surface it is being refracted (like a mirror).

## Interference Sources

Surfaces and edges of objects affect the propagation of electromagnetic waves. Metallic surfaces have a special importance due to their electromagnetic characteristics.

Objects in the area of the extended runway centre line are directly in the propagation path from the localizer antenna to the approaching or rolling-out aircraft.

Outside the course sector full scale deflection of the course deviation indicator is required and in order to ensure it, electromagnetic energy is also radiated in areas which are further away from the extended runway centre line.

Sources of interference can therefore be:

- Buildings such as terminals, hangars, antenna support and masts
- Aircraft and other vehicles on the ground
- Aircraft flying ahead in the area of the approach path or above the approach path.

They can be divided in stationary and moving sources of interference (e.g. hangar doors, airplanes, vehicles, etc.).

## 1.9 Radio Communications

Radio communications in English were initially conducted on frequency 118.825 MHz, Munich Director, and later on frequency 120.5 MHz, Munich Tower. The BFU received transcripts of the recorded radio communications.

## 1.10 Aerodrome Information

Munich Airport is located 28.5 km north-east of Munich at an aerodrome elevation of 1,487 ft AMSL. It has two parallel 4,000-meter-long runways each with a width of 60 m. Their true bearings are 082° and 262°, respectively. The lateral distance between the two runways is 2,280 m.

Runway 08R has a grooved concrete surface. At the time of the landing, the runway was dry and braking action good.

All runways were equipped with an instrument landing system for all-weather operations up to CAT IIIb.

The installation of the instrument landing system for runway 08R was conducted in accordance with the guide line for the installation of ILS equipment dated 1 July 2008, version 2.2. It corresponded with ICAO Annex 10, Chapter 3, Specifications for Radio Navigation Aids.

The ILS was subject to continuous control. Regular calibration flights or surface surveys were conducted.

## 1.11 Flight Recorders

The Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR) were removed from the airplane in the presence of the BFU and transported to Braunschweig for analysis.

The FDR was a Honeywell Solid State Flight Data Recorder (SSFDR) with the part number 980-4700-042 and the serial number 14429. It can record 1,312 parameters.

The CVR was a Honeywell Solid State Cockpit Voice Recorder (SSCVR); it had five recording channels of 3 x 30 minutes and 2 x 120 minutes recording capacity.

The recordings of the aerodrome surface movement radar were seized and analysed at the BFU.

The analysis of the FDR determined (Appendix 1):

Until 1209:00 hrs (1109:00 UTC) approach occurred without incidents. Between 1209:02 hrs (altitude about 110 ft) and 1209:10 hrs (altitude about 30 ft) the three parallel working localizer antennas on board the airplane recorded signals which showed an irregular beam deviation. From 1209:10 hrs on signals were recorded

which showed an increasing beam deviation from the extended runway centre line or runway centre line, respectively, towards the right.

The airplane began to roll to the left and on touch-down reached a maximum bank angle of 3.5°. At 1209:16 hrs the airplane touched down with the left main landing gear, three seconds later the right main landing gear followed and a further two seconds later the nose landing gear touched down on the runway.

At the time the autopilot was still engaged; the localizer mode changed to rollout mode.

The autopilot followed the LOC signal with rudder inputs and steered the airplane left.

According to the FDR data, at about 1109:18 UTC the PIC began to apply the right rudder to keep the airplane on the runway. At this time the autopilot was still engaged and therefore the control inputs remained ineffective.

According to FDR data at 1209:23 hrs the co-pilot also applied right rudder pedal input. At 1209:23 hrs the airplane veered off the runway.

The maximum recorded force on the pedal was 23 lbs on the PIC's side and 41 lbs on the co-pilot's. Immediately afterwards, the autopilot disengaged.

At 1209:28 hrs the airplane reached the largest lateral deviation from the runway centre line.

Between 1209:16 hrs and 1209:24 hrs the ground spoilers deployed briefly and retracted again.

The FDR did not show any indications for the initiation of a go-around procedure. However, at the time of the touch-down the CVR recorded the PIC's command "okay, flaps twenty" together with several sounds which indicate the clicking of the TO/GA button and the movement of speed brake handle.

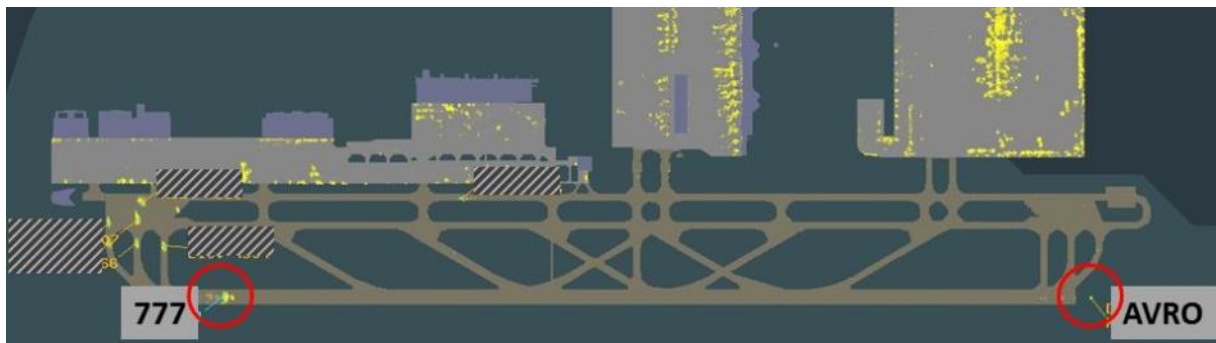
Preparation of a Sonogram:

The BFU compiled a sonogram in order to analyse the sounds recorded on the CVR and assign them with crew actions at the time of touchdown. The first two sounds in the sonogram could be from pushing the TO/GA buttons. The subsequent three sounds could be from the activation of the speed brake handle (deploying and retracting the speed brakes). It could confirm the crew's statement that the PIC had tried to initiate a go-around procedure; it is not an unambiguous proof, however.



### Analysis of the Aerodrome Surface Movement Radar

At 1207:53 hrs as the B 777 was about 2.9 NM ahead of the threshold of runway 08R, one aircraft each was at the CAT II/III holding position of taxiways B1, B2 and B3 and two aircraft were farther north of them. An additional airplane taxied west on taxiway S. At the same time a BAE 146-RJ85 taxied over the high speed taxiway B4 onto runway 08R and started the take-off run about 20 seconds later. At that time the B 777 was about 2.1 NM prior to the runway threshold in an altitude of about 700 ft AMSL. At 1209:09 hrs the B 777 crossed the threshold of runway 08R in an altitude of 50 ft. Six seconds later the BAE 146-RJ85 overflowed the end of the runway in about 380 ft. At 1209:29 hrs the BAE 146-RJ85 overflowed the ILS localizer antenna of runway 08R in 740 ft.



Position of the BAE 146-RJ85 at the time the B 777 touched down

Source: Air Traffic Control

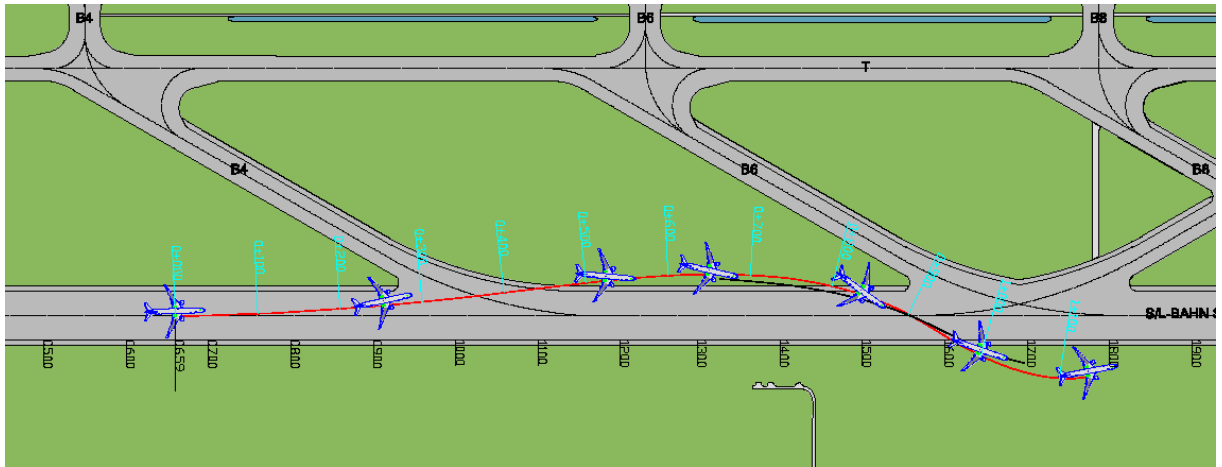
## 1.12 Wreckage and Impact Information



Aircraft position after complete stop

Photo: Police

The first visible traces were determined about 659 m after the beginning of runway 08R. The main landing gears and the nose wheel landing gear left distinct tyre marks from the moment the airplane veered off the runway at taxiway B4, to the crossing of the runway, until it came to rest on the south side of the runway. After about 1,242 m the airplane reached, with about 40 m, the largest lateral deviation to the north of the runway centre line. At 1,740 m the largest lateral deviation to the south was about 60 m. The tyre tracks were up to 15 cm deep. After about 1,780 m beyond the threshold of runway 08R the airplane came to a stop on the grass.



## Rolling traces of the airplane

Source: Munich Airport

There were no damages on the airplane safe for some grass and dirt on the right engine and the landing gear.



Right main landing gear and contamination on the right engine

Photos: BFU



Rolling traces in landing direction

Photo: Police



Rolling traces opposite to the landing direction

Photo: BFU

## 1.13 Medical and Pathological Information

Not applicable

## 1.14 Fire

There was no fire.

## 1.15 Survival Aspects

Not applicable

## 1.16 Tests and Research

The operator used three B 777 simulators to train flight crews. One was a Thales and the other two CAE simulators. The investigation determined that the go-around button of all three simulators were ineffective if ground mode was active. Both simulator manufacturers used aircraft data and system logics which were provided by the aircraft manufacturers to program their simulators. All three simulators met the requirements of the aircraft manufacturers.

The simulator manufacturers used the same system logic to activate the ground mode as was used in B 777 aircraft.

When the autopilot or flight director is engaged

- *Gear altitude < 2 feet AND either main gear is on-ground (determined using weight on wheels sensors), or*
  - *Gear altitude < 0 feet for 4 seconds*
- *If the autopilot and the flight director is not engaged*
  - *Radio height < 2 feet for 3 seconds or more, or*
  - *Radio height < 2 feet AND either main gear is on-ground (determined using weight on wheels sensors), or*
  - *Ground speed is less than 35 knots.*

It was determined that the Thales simulator changed to ground mode a little later than the CAE simulators once the main landing gear had ground contact.

## 1.17 Organisational and Management Information

### 1.17.1. Air Traffic Service Procedures

The area of responsibility of the aerodrome controller (PL1N/1S) is stipulated in the operating instructions (BAO-OPS Tower ) dated 28 August 2008 as follows:

In general, the AC1N is responsible for the conduct of air traffic control services in accordance with the Manual of Operations Air Traffic Services, item 221 on the north runway and in the northern part of airspace D-EDDM (Division East - West in the middle between the runways); AC1S is responsible for the south runway and the southern part of airspace D-EDDM. In addition, the AC1N and AC1S are responsible for operation of the aerodrome lighting system. According to the stipulations regarding all-weather operations, the controller on whose workstation the monitoring and indication system for such flights is installed has to perform all arising tasks. The controller has to attend to aircraft at least until they have landed or a go-around procedure was initiated.

Until about 1100 hrs Munich Airport conducted all-weather operations according to CAT II/III. At the time of the occurrence (and at least for the last 45 minutes) visibility and cloud bases for the approach met the criteria for CAT I operations. The prevailing cloud base of 300 ft required the provision phase CAT II/III. Therefore, the controller did not have to consider special procedures in regard to the sensitive and criti-

cal areas for runway 08R. Due to the prevailing weather the increased separation minima which are required for CAT II/III did not have to be applied.

#### Use of the ILS

It is known that ILS (localizer and glide slope) are very sensitive to outer influences. Different reports from different operators indicate that during autoland approaches under CAT I conditions the localizer and/or glide slope can dysfunction due to airplanes taking off or vehicles on the ground which may lead to a critical situation for approaching airplanes.

#### **1.17.1.1 General National Regulations**

In accordance with the guidelines for all-weather operations (NfL I/1-99 in combination with NfL I/188-10) Low Visibility Procedures (LVP) are applied when the following conditions prevail: a Runway Visibility Range (RVR) of less than or equal to 600 m and/or a cloud base of 200 ft. Under the above-mentioned conditions and as soon as the approaching airplane is within 2 NM ahead of the runway threshold, the separation between an approaching aircraft and another approaching or departing airplane has to be such that the ILS signals will not be distorted by departing or approaching aircraft. Item 5.7.2 of the NfL stipulates that during approaches (also trainings) under better weather conditions than CAT II or CAT III the pilot has to specifically request the application of all-weather operations on the ground if the higher (more restrictive) category is desired. The air traffic control unit informs the pilot if and with which restrictions all-weather operations on the ground can be conducted. The stipulations published in the guidelines for all-weather operations are in accordance with the Manual of Operations Air Traffic Services (MO-ATS) of 2011.

#### **1.17.1.2 International Regulations**

Excerpt EUR DOC 13 "Third Edition" (June 2008):

Item 6.1.1 The type of operations that may be considered in Low Visibility Conditions are departure operations in RVR conditions less than a value of 550 m and CAT II and CAT III approach and landing operations. The primary focus for developing these procedures must be a safety driven exercise to ensure the protection of the runway and of the guidance signals [...]

Item 6.8.3: Autoland operations when LVP are not in operation: When LVP are not in operation, it is possible that aircraft and vehicles may cause disturbance to ILS signal. This may result in sudden and unexpected flight control movements at very low



altitude or during the landing and rollout when the autopilot attempts to follow the beam bends. As a result pilots are advised to exercise caution during these operations according to the instructions provided in their operation manual.

EUR DOC 013 Draft 8 of the Fourth Edition Items 7.5.6.1.1.12 and 13 stipulate this.

#### **1.17.1.3 ICAO PANS ATM DOC 4444**

Item 7.12.5. f 2. stipulates the following:

Provisions regarding low visibility operations should specify special procedures for the control of traffic on the maneuvering area, including the minimum distance between an arriving and a departing aircraft to ensure protection of the sensitive and critical area.

These stipulations were implemented with the publication of the guideline for all-weather operations and the Manual of Operations Air Traffic Services (MO-ATS).

#### **1.17.1.4 ICAO DOC 9365 All Weather Operations**

This document is to be viewed as guideline not as standard or recommended practices.

Item 3.2.7 stipulates the following:

Critical areas must be protected if the weather conditions are less than 250 m (800 ft) cloud base or 3,000 m visibility when instrument approach operations are being carried out.

ILS critical and sensitive areas must always be protected if the weather conditions are lower than 60 m (200 ft) cloud base or 600 m RVR when instrument approach operations are being carried out. **In the latter case, aircraft which will overfly the localizer transmitter antenna after take-off should be passed the antenna before an aircraft making an approach has descended to a height of 60 m (200 ft) above the runway [...]**

#### **1.17.1.5 European Regulations**

European Interim Guidance Material on Management of ILS Localizer critical and sensitive Areas.

Departure-Arriving Operations

Departing aircraft may cause short-time ILS signal distortions due to shadowing effects by the aircraft body. These fluctuations are considered acceptable in CAT I operations. This is applicable irrespective of arriving aircraft position.

#### **1.17.1.6 Categories for Precision Approaches and Landings**

For ILS precision approaches and landings, the guideline for all-weather operations of 13 November 1998 of the Deutsche Flugsicherung (German air traffic service provider, DFS) stipulates the following categories:

##### **Category I (CAT I)**

Approaches and landings at a decision height of not less than 200 ft and a RVR of not less than 550 m; if a RVR is not available than a RVR of not less than 550 m calculated from the meteorological visibility.

##### **Category II (CAT II)**

Approaches and landings at a decision height of less than 200 ft but not less than 100 ft and a RVR of not less than 300 m.

##### **Category IIIa (CAT IIIa)**

Approaches and landings at a decision height of less than 100 ft but not less than 50 ft and a RVR of not less than 200 m.

##### **Category IIIb (CAT IIIb)**

and landings at a decision height of less than 50 ft or without any decision height and a RVR of less than 200 m but not less than 75 m.

##### **Category IIIc (CAT IIIc)**

Approaches and landings without decision height and no minimum RVR.

#### **1.17.1.7 Guideline for All-Weather Operations**

Item 5.2 stipulates the following:

If a RVR of 600 m is reached or infringed and or the cloud base of 200 ft is infringed ATIS will broadcast that CAT II is in operation on the ground with the wording "Low Visibility Procedures CAT II in Operation. The visual approach slope indicator and the electronic flash approach lighting is deactivated.

5.2.1 At RVR of 400 m at the latest, the stop bars and runway centre line lighting are activated. If there are no stop bars, the protection of the runway for unintended line-up is to be ensured.



5.2.2 Provision of Low Visibility Take-Off procedures (LVTO) is broadcast via ATIS with the following wording: Low Visibility Take-Off Procedures in Operation.

5.2.3 If RVR of 325 m is reached or infringed TIS will broadcast that CAT III is in operation on the ground with the wording "Low Visibility Procedures CAT III in Operation."

5.2.4 As soon as the approaching airplane is within 2 NM ahead of the runway threshold, the separation between an approaching aircraft and another approaching or departing airplane has to be such that the ILS signals will not be distorted by departing or approaching or rolling aircraft or vehicles.

5.7.1 A special requirement of the pilot to ask for clearance to conduct an approach in accordance with CAT II, CAT IIIa, or CAT IIIb at the commensurate weather situation is not necessary. If the runway and the approach direction are certified for such approaches and ATIS has broadcast all-weather operations on the ground, all preparations on the ground for such approaches have been made.

[...]

5.7.2 During approaches (also trainings) under better weather conditions than CAT II or CAT III a special requirement of the pilot is necessary if the use of all-weather operations on the ground for the higher (more restrictive) category is desired. The air traffic control unit informs the pilot if and with which restrictions all-weather operations on the ground can be conducted. Emergency power supply for visual and non-visual approach aids can only be provided under the conditions listed under 5.1.

#### **1.17.1.8 Air Traffic Order Para 42 Go-Around**

The pilot has to reject the approach and initiate a missed approach procedure in accordance with para 27a if, for the used instrument approach procedure, the required values for the missed approach are reached and he cannot finish the approach with visual flight rules.

#### **1.17.2 Flight Operations of the Operator**

##### **1.17.2.1 Flight Operations Regulations and Indications**

The Flight Crew Training Manual (FTCM) of the operator indicated the possibility of interferences of the ILS localizer and glide slope if automatic approaches and landings under CAT I conditions are conducted. Special ILS critical areas and ILS sensi-

tive areas and the influence of vehicles and reflections on the ground were described as follows:

#### ILS Critical Areas

Areas of defined dimensions about the localiser transmitter antenna and glide path transmitter antenna in which environmental changes including the presence of vehicles and aircraft will cause disturbances to the ILS signals which will probably be unacceptable to an aircraft using the ILS.

#### ILS Sensitive Areas

*An area extending beyond the critical areas where the parking and/or movement of vehicles and aircraft will affect the ILS signals and may be unacceptable to aircraft using the signals for automatic landing or rollout guidance.*

#### Interference Effects

Taxiing aircraft, ground vehicles, cranes, etc. can all produce reactions which cause the beam to move in space. Perhaps the most serious form of interference of this kind is caused by an aircraft taking off and overflying the localizer. (The pulsation may result in a LOC warning annunciation appearing briefly, which will disturb the autopilot operation). As a result of these factors, aircraft movements are restricted during actual CAT II/CAT III operation. This may hamper the traffic now and affect the capacity of the airport.

*Flight crews must remember that the ILS critical areas are not protected when the weather is above 800 foot ceiling and /or 2 mile visibility.*

*As a result, ILS beam bends may occur because of vehicle or aircraft interference. Sudden and unexpected flight control movements may occur at a very low altitude or during the landing and rollout when the autopilot attempts to follow the beam bends. At ILS facilities where critical areas are not protected, flight crews should be alert for this possibility and guard the flight controls (control wheel, rudder pedals and thrust levers) throughout automatic approaches and landings. Be prepared to disengage the autopilot and manually land or go-around.*

#### Flight Crew Operation Manual (FCOM) Normal Procedures / Operation

*An autoland is recommended if the following weather conditions exist:*

- 1. Cloud Base at or below 500 ft AAL, or*
- 2. Visibility of 2 km or less, or*
- 3. Any time RVR is quoted.*

## Publications

In January 2011 a Flight Safety Operation Information with the title Performance of Autoland Systems and ILS Multipath Effects in CAT I or Better Weather Conditions was published by Air Services Australia which described this problem in detail.

Crew should note that most ILS installations are subjected to signal interference by surface vehicles, aircraft or both. To prevent ILS signal beam disturbances, ILS critical areas are established near the localizer and glideslope antenna. Airport operators are responsible for installing and maintaining appropriate signs and markings delineating taxi lanes, hold lines and no parking areas associated with these ILS critical areas.

Although ILS critical areas may not be protected in Cat I or better weather conditions, it is common for airlines to conduct autoland operations in order to meet maintenance, training or reliability program requirements. Sometimes, autolands are accomplished on runways that are approved only for Cat I ILS operations.

The periodic flight inspection of an ILS approach facility serving a Cat I airport/runway do not include an analysis of the ILS performance inside the runway threshold or along the runway. Therefore, the quality of the signal beam in this area is unknown. However, Cat I ILS approach facilities have sufficient signal characteristics (e.g., beam quality, alignment, etc.) to support autoland operations up to Cat I weather minima.

Flight checks of ILS approach facilities serving an airport/runway with a published Cat II/III instrument approach include an analysis of the ILS performance along the runway through roll out to ensure that the ILS approach facility will support Cat II/III operations as appropriate.

ILS multipath effects may be caused by an aircraft passing in front of the glide path antenna or operating in close proximity to the localiser antenna. These effects consist of signal fluctuations of the glide path or localiser. There seems to be a widespread expectation that ILS signals are protected by ATC

whenever an aircraft is flying an ILS approach in IMC. **This is not the case.** ILS signals are only protected in certain conditions.

Furthermore, localiser interference restrictions are not applied when a preceding aircraft passes over or through the protected area while taking off, landing, or making a missed approach on the same or another runway.

The summary indicated that interferences of the localizer and/or the glide slope can occur during automatic approaches under CAT I conditions. The crew has to be prepared to immediately disconnect the autopilot and take over manual control.

In certain airports and situations where protection of the ILS signals is not required, advise ATC early when the need arises to conduct 'coupled', 'autoland' or similar approaches. Crew are to remain vigilant and alert for ILS signal disturbances (beam bending) when conducting autoland on any category ILS in VFR conditions as the critical area protection is not assured by ATC. This will ensure that all crew are able to manage any unexpected flight control movements quickly and safely.

Guard your controls throughout and be prepared to **disconnect** the autopilot immediately. Take appropriate action whenever an unsatisfactory autoland performance occurs. Do not attempt to override the autopilot in lieu of disconnect as considerable forces are required to overpower the autopilot servos and in a number of cases, some crew has misinterpreted these forces to overpower the autopilot as a jammed control condition.

It becomes a crew responsibility to continue or discontinue in a particular approach mode or condition.

This article was published within the operator to call the pilots' attention to the danger of interference of ILS due to external influences during automatic approaches under CAT I conditions.

The flight crew operations manual and the training manual stipulate the following:

B 777 Flight Crew Operations Manual

NORMAL PROCEDURES

Operation

Note: When low visibility procedures are not in effect, the ILS critical areas are not protected and ILS signal interference may occur. Pilots must, therefore, guard the controls throughout the approach and landing.

SQ.NP.3.56, 15 Mar 2011

#### B 777 Flight Crew Training Manual

Flight crews must remember that the ILS critical areas are not protected when the weather is above 800 foot ceiling and /or 2 mile visibility. As a result, ILS beam bends may occur because of vehicle or aircraft interference. Sudden and unexpected flight control movements may occur at a very low altitude or during the landing and rollout when the autopilot attempts to follow the beam bends. At ILS facilities where critical areas are not protected, flight crews should be alert for this possibility and guard the flight controls (control wheel, rudder pedals and thrust levers) throughout automatic approaches and landings. Be prepared to disengage the autopilot and manually land or go-around.

The Autopilot Flight Director System (AFDS) includes a monitor to detect significant ILS signal interference. If localizer or glideslope signal interference is detected by the monitor, the autopilot disregards erroneous ILS signals and remains engaged in an attitude stabilizing mode based on inertial data. Most ILS signal interferences last only a short period of time, in which case there is no annunciation to the flight crew other than erratic movement of the ILS raw data during the time the interference is present.

No immediate crew action is required unless erratic or inappropriate autopilot activity is observed.

#### 1.17.3 Procedures of the Aircraft Manufacturer

The aircraft manufacturer Boeing writes the following regarding a go-around procedures after touch-down:

If a go-around is initiated after touchdown but before thrust reverser selection, auto speedbrakes retract and autobrakes disarm as thrust levers are advanced. The F/D go-around mode will not be available until go-around is selected after becoming airborne. Once reverse thrust is initiated following touchdown, a full stop landing must be made.

## 2. Analysis

### 2.1 Technical Aspects

After analysing and assessing the facts, the BFU came to the conclusion that the airplane veered off the runway because the localizer signals had been distorted by a departing aircraft. All three receiver antennas of the airplane received identical signals from the localizer on the ground so that on board no malfunction was indicated. Because there was only a short interference of the localizer signal neither the near field nor the far field monitor - which monitor the proper function of the ILS - registered a malfunction of the ILS. This means, the airplane followed the localizer signal.

The crew only realised about 30 ft above the runway that something was not correct as the airplane slightly banked to the left and then drifted left. The left main landing gear touched down directly afterwards which resulted in the disengagement of the go-around mode. This prevented the crew from being able to initiate an automatic go-around.

### 2.2 Crew Behaviour

The preparation and conduct of the approach and the intended automatic landing were in accordance with the valid flight operations procedures of the operator. The fact that both pilots had arrived from Singapore two days prior to this flight suggests that, at the time of the occurrence, they did not experience an increase in psychological stress due to jet lag. The flight occurred at a favourable time for the crew - in Singapore it would have been afternoon - and therefore fatigue is not really feasible.

The crew did not inform the approach controller of their intention to conduct an automatic landing.

The crew knew that under the prevailing CAT I flight operations the safety measures of all-weather operations CAT II/III were not present.

Therefore, the crew had to take into consideration that ILS interferences due to other airplanes on the ground or in the air were possible.

Based on the crew statements the BFU is of the opinion that the crew was prepared to initiate a go-around procedure in case of an incident. The PIC stated that as the airplane dipped the left wing shortly before touch-down he wanted to initiate a go-around and pushed the TO/GA button. Even though the PIC's command "Okay, flaps



twenty.” did not completely meet the requirements of the standard phraseology for a go-around “Go-Around Flaps 20” it was his command to go-around. The analysis of the FDR showed that the co-pilot did not set the flaps to 20°. The crew stated that in their estimate a go-around procedure initiated manually with an airplane already on the ground would have been much more dangerous than remaining on the ground.

The FDR analysis in combination with the sonogram indicates that the TO/GA button was pushed simultaneously with the initial ground contact of the left main landing gear. The crew anticipated that the Go-Around Mode would initiate a go-around, but nothing happened. The Go-Around Mode had deactivated as designed by Boeing (system logic) by the initial ground contact of the main landing gear.

The PIC realised that the ground spoilers had already been deployed automatically and retracted them manually. This would not have been necessary. Had he pushed the thrust levers forward the ground spoilers would have been retracted automatically and the autobrake function deactivated.

The BFU is of the opinion that both pilots, the PIC due to him being an instructor pilot and the co-pilot having enough flying experience on type, were sufficiently familiar with the go-around procedure. These procedures were sufficiently described in the FCTM and had been trained sufficiently in the simulator in accordance with effective regulations.

## 2.3 Relocation of the Instrument Landing System

At Munich Airport the localizer antennas were moved from 350 m to 1,000 m beyond the runway threshold. The air traffic service provider stated that it had become necessary because of the Airbus A380 operation to prevent localizer interferences through reflections off airplanes.

The BFU is of the opinion that the position change of the LOC antenna effected the separation of approaching and departing aircraft. In order to prevent interferences with the LOC antenna separation inevitably would have to be increased. Furthermore, the broadcast antenna diagram has to be pooled better by about 3.6° to ensure the required accuracy for CAT II and CAT III approaches which results in an increase in energy supply by approximately 0.1 W.

## 2.4 Behaviour of the Air Traffic Controllers

The controller stated that he had been under a high workload, because of all-weather operations in the morning (CAT II/III), delays had occurred which, at the time of the occurrence, resulted in an increased departure rate in combination with approaches on runway 08R. This forced the controller to work on the edge of the separation minimum so that aircraft waiting to depart could do so quickly and traffic situation would become normal. Since the controller did not have any information that the crew intended to conduct an automatic landing he did not separate the aircraft in accordance with the required separation minima for CAT II/III but for CAT I conditions; i.e. separation between departing and approaching aircraft was one runway length. The air navigation service provider stated that if the controller had been informed he would not have allowed the BAE 146-RJ85, waiting on taxiway B4, to take off ahead of the B 777.

At the time of the occurrence the provision phase for CAT II/III was still active even though the weather situation would have allowed for the cancellation of all-weather operations CAT II/III in accordance with the Manual of Operations Air Traffic Services (MO-ATS). Air traffic had already begun to separate the aircraft in accordance with CAT I. Provided the crew had informed the controller about the planned autoland the option would have existed to return to CAT III operations. This would have been possible with relatively little effort because the protection zones were still free since the change from CAT II/III to CAT I conditions and the waiting departing aircraft still stopped at the CAT II/III holding point.

## 2.5 Accident Site

Because the shoulders of the runway had been paved with macadam and it had not rained in quite some time, the wheels of the airplane did not sink in too much and the landing gear was not damaged.

## 2.6 Automatic Landing

The investigation determined that autoland landings under CAT I conditions are conducted without informing air traffic control. If an international regulation for such cas-



es existed that air traffic control had to be informed about an intended autoland the controllers would have been better prepared and might have made appropriate preparations.

If the airport does not operate on LVP, it should become global standard to inform air traffic control on time about an intended autoland landing.

### 3. Conclusions

#### 3.1 Findings

- Both pilots held the required licenses and ratings for the conduct of the flight.
- The airplane was properly certificated and maintained in accordance with existing regulations and approved procedures.
- At the time of the occurrence the airplane was in proper technical condition.
- Two days prior to the flight the crew had arrived from Singapore. Considering the time lag of six hours the flight took place during the day (according to their circadian rhythm) and therefore fatigue was not a factor.
- At a visibility of 2 km and a cloud base of 300 ft CAT I was in operation.
- Due to the CAT II/III provision phase the protection zones of the ILS 08R were ensured but the separation criteria for CAT II/III were no longer in use.
- The separation of the airplanes corresponded with CAT I.
- The crew did not inform the controller of the intended autoland landing.
- The decision to conduct an automatic landing under the prevailing weather conditions was understandable.
- The position of the localizer antenna for landing direction 08R was moved from 350 m beyond the runway threshold 26L to 1,000 m.
- To avoid interferences the relocation of the localizer antenna requires a larger separation of airplanes when all-weather operation CAT II/III is in service.
- The larger distance of the localizer antenna to the runway requires a stronger pooling (about 0.36°) of the signal which results in an increased energy supply (about 0.1 W) which increases the susceptibility to dysfunction slightly. These effects were taken into account and the respective protection areas extended.
- A BAE 146-RJ85 taxied along taxiway B4 to runway 08R as the B 777 was about 2.9 NM ahead of the runway threshold 08R and 3.4 NM behind the BAE 146-RJ85 when it received take-off clearance.
- As the B 777 flew above the runway threshold 08R, the BAE 146-RJ85 was in front of the localizer antenna and interfered with the localizer signal.
- The BAE 146-RJ85 was significantly lower in front of the localizer antenna compared to other airplanes having taken off earlier due to it taken off from the taxiway B4 intersection and its lower climb rate. This resulted in a significantly greater localizer interference.
- The B 777 followed the disturbed localizer signal with engaged autopilot.
- The crew realised the interference too late and was confused by the deviation of the airplane to the left.

- Neither the near nor the far field monitor recorded a dysfunction of the ILS due to the shortness of the interference.
- The intention of the PIC to conduct a missed approach procedure with engaged autopilot failed because the go-around mode had been deactivated by the initial ground contact.
- The airplane touched down with a bank angle of  $3.5^{\circ}$  to the left and about 7 seconds later veered off the runway to the left.
- The autopilot was not disconnected in time because the PIC had been prepared for an automatic go-around. The PIC decided against a manual go-around procedure due to safety reasons because the airplane had switched to ground mode.
- Due to the sudden disconnection of the autopilot and the rudder full deflection induced by the pilots, the airplane turned back around the yaw axis by about  $40^{\circ}$  to the right.
- The airplane crossed the runway in about  $45^{\circ}$  to the approach direction and came to rest at the right side of the runway in the direction of the flight.
- Because of the gravel runway shoulder area and the long dry weather the airplane did not sink in very far and remained almost undamaged.
- The passengers and the crew could leave the airplane without injuries via attached stairways.

## 3.2 Causes

The Serious Incident was caused by the following:

Immediate Causes:

- The crew decided to conduct an automatic landing even though the conditions on the ground for a safe conduct were not given.
- Shortly before touch-down the airplane was deviated to the left of its flight direction by the disturbed LOC signal. A BAE 146-RJ85 taking off a short distance ahead of the B 777 caused the interference.
- The two pilots could not keep the airplane on the runway after touch-down because the autopilot was still engaged.
- The crew was confused by the behaviour of the airplane. They had not noticed that the go-around mode had already been deactivated by the initial touch-down of the left main landing gear.

Systemic Causes:

- The recommendation concerning the conduct of autoland landings under CAT I conditions published in the FCOM of the operator allowed the decision for an autoland landing without having to consider the required conditions on the ground.

## 4. Safety Recommendations

Actions by the Operator

After the occurrence the operator implemented the following safety actions:

Additional guidelines for flight crews for the successful conduct of go-around procedures after touch-down.

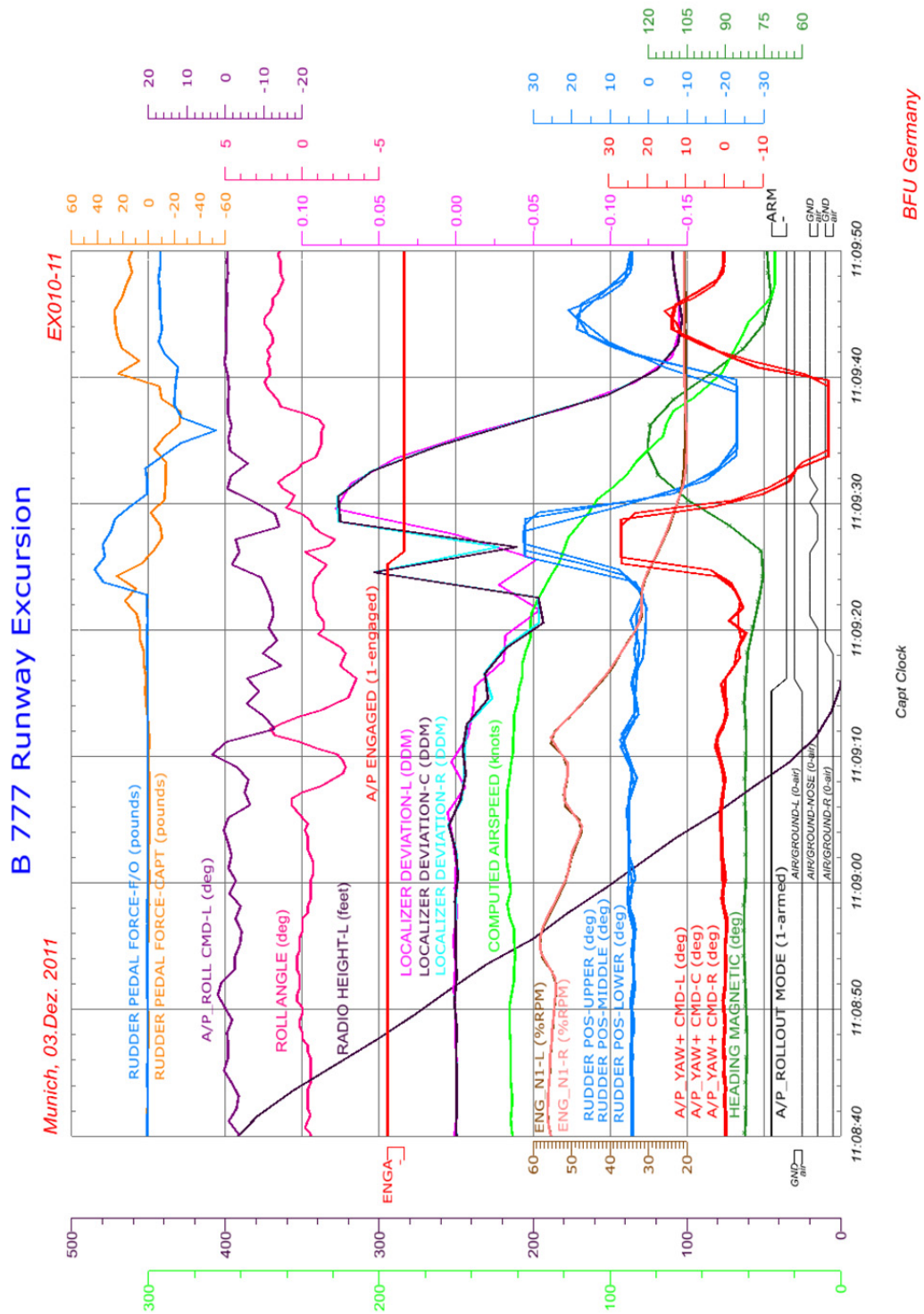
Improved simulator training for flight crews during recurring and re-training to train go-around procedures after the aircraft has switched to ground mode.

Improved simulator training for flight crews to train LOC deviations during flare mode below 50 ft.

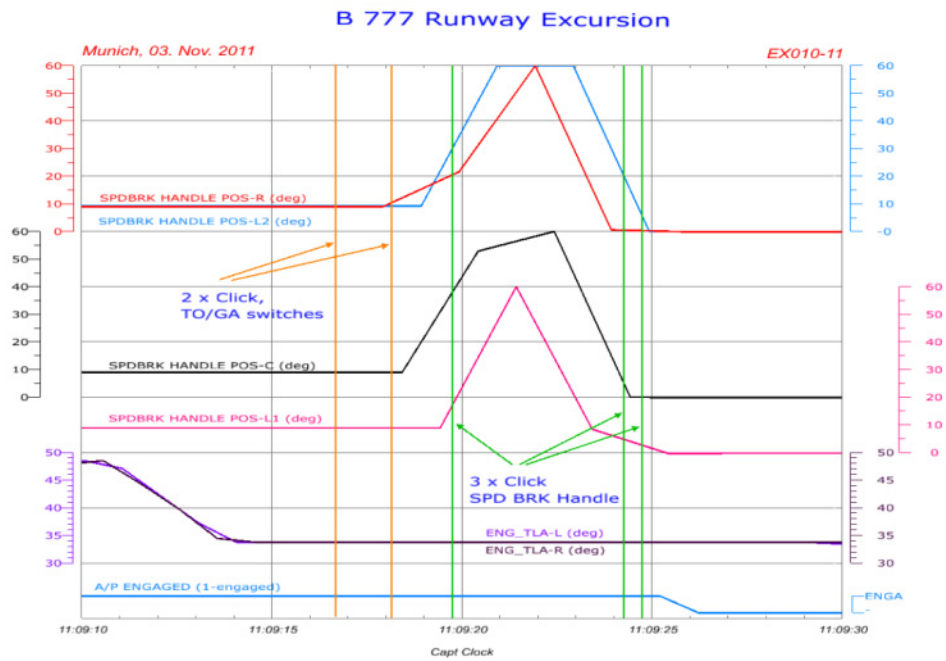
Investigator in charge: L. Müller  
Assistance: Himmeler  
Ritschel  
Blanke  
Report finalisation: Friedemann

## 5. Appendix

## Appendix 1



## Appendix 2



Flight data recorder print-out

BFU Germany