International Civil Aviation Organization

Middle East Regional Monitoring Agency Board

Fifteenth Meeting (MIDRMA Board/15)
(Muscat, Oman, 29 – 31 January 2018)

Agenda Item 4: RVSM Monitoring and related Technical Issues

WAKE TURBULENCE SEPARATION IN RVSM AIRSPACE

(Presented by the Secretariat)

SUMMARY

This paper presents an overview of the provisions related to Wake Turbulence Separation and addresses the incident that took place between an A380 and CL604 in the RVSM airspace and to review the initial draft RSA related to wake turbulence in the RVSM Airspace.

Action by the meeting is at paragraph 3.

REFERENCES

- ATM SG/3 Report
- CIR 331
- Doc 4444
- Doc 9426
- Interim Report BFU17-0024-2X
- RASG-MID/6 Report

1. INTRODUCTION

1.1 The provisions related to Wake Turbulence Minima are contained in PANS-ATM (ICAO Doc 4444) and detailed characteristics of wake vortices and their effect on aircraft are contained in the *Air Traffic Services Planning Manual* (ICAO Doc 9426).

1.2 The term "wake turbulence" is used in this context to describe the effect of the rotating air masses generated behind the wing tips of large jet aircraft, in preference to the term "wake vortex" which describes the nature of the air masses.

1.3 Wake vortices are present behind every aircraft, but are particularly severe when generated by a large and wide-bodied jet aircraft. These vortices are two counter-rotating cylindrical air masses trailing aft from the aircraft. The vortices are most dangerous to following aircraft during the take-off, initial climb, final approach and landing phases of flight. They tend to drift down and when close to the ground move sideways from the track of the generating aircraft, occasionally rebounding upwards.

This picture from a NASA study on wingtip vortices qualitatively illustrates the wake turbulence.

1.4 Flight tests have shown that vortices from large aircraft sink at a rate of about 2 to 2.5 m/s (400 to 500 ft/min). They tend to level off at about 275 m (900 ft) below the flight path of the generating aircraft. Wake turbulence strength diminishes with time and distance behind the generating aircraft. (**Figure 1** refers).

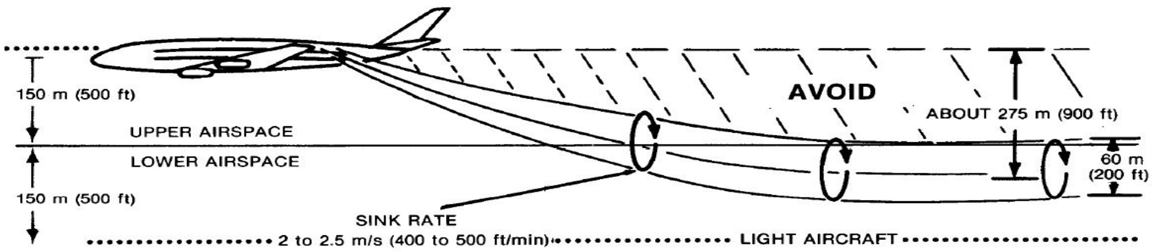


Figure 1.

2. DISCUSSION

2.1 Wake turbulence separation minima shall be based on a grouping of aircraft types into three categories according to the maximum certificated take-off mass as follows:

1. HEAVY (H) — all aircraft types of 136 000 kg or more;
2. MEDIUM (M) — aircraft types less than 136 000 kg but more than 7 000 kg; and
3. LIGHT (L) — aircraft types of 7 000 kg or less.

2.2 The following distance-based wake turbulence separation minima shall be applied to aircraft being provided with an ATS surveillance service in the approach and departure phases of flight:

Aircraft category		
Preceding aircraft	*Succeeding aircraft*	*Distance-based wake turbulence separation minima*
HEAVY	HEAVY	7.4 km (4.0 NM)
	MEDIUM	9.3 km (5.0 NM)
	LIGHT	11.1 km (6.0 NM)
MEDIUM	LIGHT	9.3 km (5.0 NM)

2.3 The minima set out in 2.2 shall be applied when:

a) an aircraft is operating directly behind another aircraft at the same altitude or less than 300 m (1000ft) below; or

b) both aircraft are using the same runway, or parallel runways separated by less than 760 m (2500ft); or

c) an aircraft is crossing behind another aircraft, at the same altitude or less than 300 m (1 000ft) below.

2.4 Wake turbulence separation minima are intended to greatly reduce the potential hazards of wake turbulence. However, when the separation minima normally applied to Instrument Flight Rules (IFR) flights are greater than those for wake turbulence, no special measures need to be taken by Air Traffic Control (ATC) since the IFR minima apply.

Accident A380-CL604

2.5 The meeting may wish to recall that on 7 January 2017 at 06:52 UTC the Challenger 604 jet took off from Malé, Maldive Islands, for a flight to Al-Bateen, UAE. Three crew members and six passengers were on board the airplane. At 07:20 UTC, the airplane reached cruise level FL340. After entering Mumbai FIR the aircraft was cleared to fly to reporting point KITAL via route L894. At approximately 08:18 UTC, the co-pilot radioed reaching reporting point GOLEM.

2.6 At 06:55 UTC, an Airbus A380 had taken off at Dubai Airport, UAE, for flight EK412 to Sydney, Australia. The aircraft flew at FL350 with a southern heading.

2.7 At 08:38:07 UTC, the A380 had passed the Challenger overhead with a vertical distance of 1,000 ft. At 08:38:54 UTC, the Challenger, with engaged autopilot, began to roll slightly to the right. At the same time, a counter-rotating aileron deflection was recorded and fluctuation of the vertical acceleration began. The airplane had continued to roll to the left thereby completing several rotations. Subsequently both Inertial Reference Systems (IRS), the Flight Management System (FMS), and the attitude indication failed. The Flight Data Recorder (FDR) recorded a loss of altitude of approximately 8,700 ft and large control surface deflections and acceleration. The speed increased and at 08:39:31 UTC reached approximately 330 KT.

2.8 At about 08:56 UTC, the Pilot in Command informed the air traffic controller in Mumbai of the occurrence, declared emergency, and reported their position, altitude and their intention to fly via KITAL to Oman. At 11:05 UTC, the Challenger landed at Muscat Airport. The aircraft manufacturer determined that the Challenger's airframe structure could not be restored to an airworthy state as it exceeded the airframe certification design load limits during the upset encounter. The A380 continued the flight to Sydney and landed there at 19:58 UTC.

2.9 The investigation Agency Bundesstelle für Flugunfalluntersuchung (BFU) – Germany, issued on 17 May 2017 the Interim Report of the accident as at **Appendix A**.

Strategic Lateral Offset Procedures (SLOP)-PANS-ATM

2.10 SLOP are approved procedures that allow aircraft to fly on a parallel track to the right of the centre line relative to the direction of flight to mitigate the lateral overlap probability due to increased navigation accuracy and wake turbulence encounters. Unless specified in the separation standard, an aircraft’s use of these procedures does not affect the application of prescribed separation standards.

2.11 Annex 2 requires authorization for the application of strategic lateral offsets from the appropriate ATS authority responsible for the airspace concerned.

2.12 Information concerning the implementation of strategic lateral offset procedures is contained in the Circular 331-*Implementation of Strategic Lateral Offset Procedures*.

2.13 Strategic lateral offsets shall be authorized only in en-route airspace as follows:

a) where the lateral separation minima or spacing between route center lines is 23 NM or more, offsets to the right of the center line relative to the direction of flight in tenths of a nautical mile up to a maximum of 2 NM; and

b) where the lateral separation minima or spacing between route center lines is 6 NM or more and less than 23 NM, offsets to the right of the center line relative to the direction of flight in tenths of a nautical mile up to a maximum of 0.5 NM.

2.14 The routes or airspace where application of strategic lateral offsets is authorized, and the procedures to be followed by pilots, shall be promulgated in aeronautical information publications (AIPs). In some instances, it may be necessary to impose restrictions on the use of strategic lateral offsets, e.g. where their application may be inappropriate for reasons related to obstacle clearance.

2.15 The decision to apply a strategic lateral offset shall be the responsibility of the flight crew. The flight crew shall only apply strategic lateral offsets in airspace where the appropriate ATS authority has authorized such offsets and when the aircraft is equipped with automatic offset tracking capability.

Note 1.— Pilots may contact other aircraft on the inter-pilot air-to-air frequency 123.45 MHz to coordinate offsets.

Note 2.— The strategic lateral offset procedure has been designed to include offsets to mitigate the effects of wake turbulence of preceding aircraft. If wake turbulence needs to be avoided, an offset to the right and within the limits specified in 2.14 may be used.

Note 3.— Pilots are not required to inform ATC that a strategic lateral offset is being applied.

2.16 The subject was addressed by the Third meeting of the MIDANPIRG Air Traffic Management Sub-Group (ATM SG/3, Cairo, Egypt, 22-25 May 2017). The meeting agreed that the a RASG Safety Advisory (RSA) related to the risk associated with 1000ft vertical separation between A380 and lighter aircraft should be issued by October 2017. The meeting agreed that the GCAA UAE would be issuing a safety advisory on the subject, which could be considered for the development of the RSA. UAE published the Safety Advisory (Issue 01) dated 5 July 2017 related to Wake Turbulence Awareness as at **Appendix B**.

2.17 The subject was also addressed by the RASG-MID/6 meeting (Bahrain, 26-28 September 2017). The meeting agreed that a RASG-MID Safety Advisory (RSA) related to Wake Turbulence in the RVSM Airspace should be developed by ICAO, UAE and IATA, taking into consideration UAE safety alert 2017-10 dated 5 July 2017; and other existing practices. Accordingly, the meeting agreed to the following Decision:

DECISION 6/15: RASG-MID SAFETY ADVISORY (RSA)− WAKE TURBULENCE IN THE RVSM AIRSPACE

That, a RASG-MID Safety Advisory (RSA) on Wake Turbulence in the RVSM Airspace, be developed by ICAO, UAE and IATA, taking into consideration UAE safety alert 2017-10 dated 5 July 2017; and other existing practices.

2.18 The RASG-MID/6 meeting recognized the need for the amendment of the ICAO provisions related to wake turbulence taking into considerations the measures implemented in Europe and USA. The meeting noted that UAE presented a Working Paper on the subject to the ATMOPS Panel

3. ACTION BY THE MEETING

3.1 The meeting is invited to encourage States and the MIDRMA to support the development of the RSA related to Wake Turbulence in the RVSM Airspace.

Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

BFU

Interim Report

Identification

Type of Occurrence:	Accident
Date:	7 January 2017
Location:	Enroute, above the Arabian Sea
Aircraft:	1) Airplane 2) Airplane
Manufacturer / Model:	1) Bombardier / CL-600-2B16 (604 Variant) 2) Airbus / A380-861
Injuries to Persons:	1) Two severely injured passengers, two passengers and one flight attendant suffered minor injuries 2) None
Damage:	1) Aircraft severely damaged 2) None
Other Damage:	None
State File Number:	BFU17-0024-2X
Published:	May 2017

Factual Information

During cruise flight above the Arabian Sea, Indian Ocean, approximately one minute after it had been passed overhead by an Airbus A380 on opposite course, the CL604 was subject to temporary loss of control.

After it had lost approximately 9,000 ft of altitude the pilots regained control of the aircraft and subsequently landed at an alternate aerodrome at Muscat Airport, Oman.

The accident occurred over international waters. Thus the BFU as representative of the State of Registry of the accident aircraft is responsible for the conduct of the investigation. In accordance with international regulations, the air accident investigation authorities of Oman, India, the United Arab Emirates, Canada, USA, and France will assist the BFU in this investigation.

History of the Flight

At 1152 hrs[1] (0652 UTC) the CL604 had taken off from runway 36 at Malé, Maldive Islands, for a flight to Al-Bateen, United Arab Emirates. Three crew members and six passengers were on board the airplane.

The Flight Data Recorder (FDR) recordings show that the CL604 autopilot had been engaged approximately one minute after take-off. At 0720 UTC the airplane reached cruise level FL340. At 0729 UTC the aircraft entered Indian airspace (Mumbai FIR) at the reporting point BIBGO and had received the clearance to fly to reporting point KITAL via route L894. At approximately 0818 UTC the co-pilot radioed reaching reporting point GOLEM.

At 0655 UTC an Airbus A380-861 (A380) had taken off at Dubai Airport, United Arab Emirates, for a flight to Sydney, Australia. The aircraft flew at FL350 with a southern heading.

The analysis of the flight data of both aircraft showed that at 0838:07 UTC the A380 had passed the CL604 overhead with a vertical distance of 1,000 ft.

At 0838:54 UTC the CL604, with engaged autopilot, began to slightly roll right. At the same time a counter-rotating aileron deflection was recorded and fluctuation of the vertical acceleration began. In the subsequent approximately 10 seconds the airplane had a right bank angle of 4° to 6°. At 0839:03 UTC the right bank angle

1 All times local, unless otherwise stated.

began to increase. Within one second the bank angle increased to 42° to the right. At the same time the aileron deflection to the left increased to 20° and the vertical acceleration to 1.6 g. In the following second vertical acceleration changed to -3.2 g.

At 0839:04 UTC a lateral acceleration of 0.45 g to the right was recorded. The pitch angle changed from about 3° to about 1°, then within one second increased to 9° and decreased again in the following second to -20°. At the same time the FDR recorded a rudder deflection to the left reaching 11.2° after about two seconds whereas the bank angle changed from 42° right to 31° left.

Between 0839:05 UTC and 0839:10 UTC Indicated Airspeed (in knots) changed from approximately 277 KIAS to 248 KIAS. The N1 of the left engine of 95% began to decrease.

At 0839:07 UTC the validity of IRS parameter is lost, the lateral acceleration reached 0.94 g left, the autopilot disengaged, and a master warning, lasting seven seconds, was recorded.

Between 0839:09 UTC and 0839:41 UTC the FDR recorded a loss of altitude of approximately 8,700 ft. Large control surface deflections and acceleration were recorded. The speed increased and at 0839:31 UTC reached approximately 330 KIAS. At 0839:30 UTC the spoilers extended and 13 seconds later were retracted again. The N1 of the left engine had decreased to approximately 40% when the Interstage Turbine Temperature (ITT) began to increase and nine seconds later had reached 850°. The left engine was shut off.

At about 0856 UTC the Pilot in Command (PIC) informed the air traffic controller in Mumbai of the occurrence, declared emergency, and reported their position, altitude and their intention to fly via KITAL to Oman.

At about 0915 UTC the crew restarted the left engine. Subsequently the airplane climbed to FL250. At about 0956 UTC the autopilot was re-engaged.

At 1105 UTC the CL604 landed at Muscat Airport.

The A380 continued the flight to Sydney and landed there at 1958 UTC.

The recordings of the Omani air traffic control services show that at about 0920 UTC the neighbouring Indian regional air traffic control Mumbai informed them that the CL604 was at FL230 and would probably pass the reporting point KITAL at 0937 UTC. Mumbai also informed ATC that via a relay station the information had been received that the airplane would divert to Oman. Initially, the reason for the low altitude was given by Mumbai ATC as being due to engine failure. At 0957:50 UTC the airplane was depicted on the Omani ATC radar. At 1014:14 UTC the CL604 reached reporting point KITAL.

Statements of the CL604 Pilots

According to the statement of the CL604 pilots the PIC was Pilot Flying (PF) and the co-pilot Pilot Non Flying (PNF). The PIC stated that TCAS had drawn his attention to the opposite traffic. He then recognised the aircraft type A380, the airline, and informed the co-pilot. The PIC also stated that the A380 had passed them in opposite direction, slightly to the left and according to TCAS 1,000 ft above. He further stated that a short time later the airplane had been hit by the wake turbulence of the A380. The airplane had shook briefly, then rolled heavily to the left and the autopilot disengaged. Both pilots had actuated the aileron to the right in order to stop the rolling motion. But the airplane had continued to roll to the left thereby completing several rotations. Subsequently both Inertial Reference Systems (IRS), the Flight Management System (FMS), and the attitude indication failed. According to the pilots' statements at the time of the accident both pilots had fastened their lap belts and in addition the co-pilot had worn his shoulder belts. According to the PIC he had lost his headset during the rolling motion of the airplane. The Quick Reference Handbook (QRH) had flown around the cockpit and was damaged. As a result individual pages had been scattered around the cockpit. The PIC explained since the sky had been blue and the ocean's surface almost the same colour he had been able to recognise the aircraft's flight attitude with the help of the clouds. Later both pilots had been able to recover the airplane at FL240 using control inputs on the aileron and later the rudder and slight elevator deflection. Regarding the left engine the PIC stated that he had observed that N1 and N2 had "run apart". N1 had decreased severely. ITT had increased, reached more than 1,000°C, and the indication flashed red. Subsequently the engine was shut off. Based on the memory items the pilots were able to reactivate the IRS in attitude mode and fly the airplane again towards reporting point KITAL. Then the pilots used the cross bleed of the right engine to restart the left. After the second IRS had been reactivated and position and heading been entered manually into the FMS the autopilot was engaged again. After they had assessed the situation the flight crew decided to fly to Muscat.

Statements of the CL604 Flight Attendant

The flight attendant stated in an interview conducted by the BFU that during take-off and climb she had been seated in the jump seat with the seat belt fastened. She had opened the seat belt while they were passing FL100. At the time of the accident she had been standing in the middle of the cabin preparing the service. Four of the six passengers had also not been seated. In her recollection the airplane had turned three times around its longitudinal axis, during which the occupants had been thrown against the ceiling and the seats. Several of the passengers suffered injuries, some of which were bleeding. She herself suffered minor injuries. Using the on-board first aid kit she had attended to the passengers. In the further course of the flight she informed the pilots of the situation in the cabin and reassured the passengers.

Personnel Information

Pilot in Command CL604

The 39-year-old PIC held an Air Transport Pilot's License (ATPL(A)) of the European Union issued in accordance with Part-FCL. It was first issued by the Luftfahrt-Bundesamt (LBA) and valid until 6 June 2014. The licence listed the ratings as PIC for CL604/605 and the Instrument Rating (IR) valid until 31 March 2017, and for single engine piston land (SEP).

His class 1 medical certificate was last issued on 26 September 2016 and valid until 8 October 2017.

His total flying experience was about 5,334 hours, about 4,564 hours of which were on type.

He had been employed by the operator as a pilot since October 2012.

On the day of the accident the entire crew had begun their shift at 0500 UTC.

Co-pilot CL604

The 41-year-old co-pilot held an Commercial Pilot's License (CPL(A)) of the European Union issued in accordance with Part-FCL. It was first issued by the LBA on 31 October 2013. The licence listed the ratings as co-pilot for CL604/605 and the Instrument Rating (IR), valid until 31 October 2017, and for single engine piston land (SEP) and Touring Motor Glider (TMG).

His class 1 medical certificate was last issued on 8 March 2016 and valid until 8 April 2017.

The co-pilot had a total flying experience of about 1,554 hours; of which 912 hours were on type.

Since November 2015 the co-pilot had been employed by the operator.

Flight Attendant CL604

Between 2009 and 2010 the 28-year-old flight attendant had completed her training. Since 2010 she had been working as flight attendant for different operators on a total of five aircraft types. Since September 2015 she had been working for the operator involved.

Aircraft Information

Bombardier CL604

The CL604 is a twin-engine business jet. It is a low-wing, t-tail aircraft, with landing gear in standard retractable tricycle configuration.

The cabin of the occurrence aircraft had been fitted with a total of 10 seats; eight of them in club arrangement. In the right aft part of the cabin a couch had been installed at right angles to the flight direction.

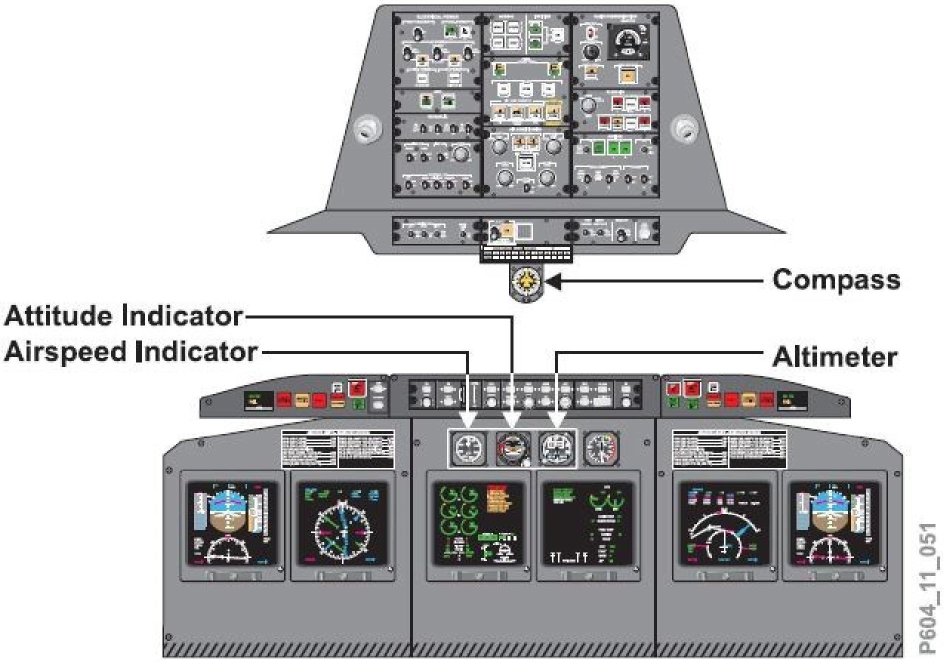
Manufacturer:	Bombardier Inc. Canadair Group
Type:	CL-600-2B16 (604 Variant)
Manufacturer's Serial Number (MSN):	5464
Year of manufacture:	2000
MTOM:	21,863 kg
Engines:	General Electric CF34-3B
Total operating time:	approx. 10,211 hours and 5,504 flight cycles.

The aircraft had a valid German Certificate of Registration and was operated by a German operator.

According to the Airworthiness Review Certificate (ARC) airworthiness was last certified on 8 November 2016 at total operating time of 10,109 hours.

The aircraft's Mach Maximum Operating (MMO) value in altitudes between 30,990 ft and 41,000 ft was 0.85. Between 22,150 ft and 26,570 ft MMO was 0.78 and Velocity Maximum Operating (VMO) between 26,570 ft and 30,990 ft 318 KIAS.

Among other things, the aircraft was equipped with two Inertial Reference Systems (IRS). The IRS provided the different aircraft systems with attitude, directional, position and three-axis rate/acceleration data.



Standby instruments Source: Bombardier

The airplane was equipped with an Electronic Flight Instrument System (EFIS). Part of the standby instruments were airspeed indicator, barometric altimeter, artificial horizon, and a magnetic compass.

Airbus A380

The Airbus A380 is a double-deck, wide-body transport category aircraft with four engines. The low-wing airplane with a fuselage mounted tail plane was manufactured in mixed construction.

Manufacturer:	Airbus
Type:	A380-861

MSN:	224
Year of manufacture:	2016
MTOM:	569,000 kg
Mass at the time of the accident:	522,990 kg
Engines:	Engine Alliance GP7270

The aircraft was registered in the United Arab Emirates and operated by a United Arab Emirates operator.

Meteorological Information

Pre-flight Meteorological Preparation CL604

The BFU was provided with the pre-flight preparation documentation of the CL604 flight crew including the weather data of 6 January 2017 at 2336 UTC.

According to the forecast tropopause was at approximately FL525 at a temperature of -82°C.

For cruise level FL340 wind with 20 kt from north-west and a temperature of -42°C were forecast.

The Significant Weather Fixed Time Prognostic Chart for the planned flight did not contain any warnings of Clear Air Turbulence (CAT) for the area of the Arabian Sea.

Weather at the Time of the Accident

At the time of the accident it was daylight. According to the CL604 pilots' statements very good Visual Meteorological Conditions (VMC) with blue skies prevailed. The ocean's surface had been visible. In an estimated altitude of 3,000 to 4,000 ft AMSL the cloud cover had been 1/8 to 2/8. Condensation trails had not been visible.

No significant meteorological information (SIGMET) had been issued for the flight information region Mumbai (VABF).

According to the Digital Access Recorder (DAR) of the A380 the wind at their cruise level at FL350 came from about 315° with about 23 kt. The Static Air Temperature (SAT) was -44°C.

The BFU has asked the Deutscher Wetterdienst (German meteorological service provider, DWD) to prepare an expert opinion.

Weather Conditions at Muscat Airport

According to the aviation routine weather report (METAR) of 0950 UTC the following weather conditions prevailed at Muscat Airport:

Wind:	030°/8 kt
Clouds/Visibility:	CAVOK
Temperature:	24°C
Dewpoint:	5°C
Barometric air pressure (QNH):	1,015 hPa

Radio Communications

At the time of the accident an HF radio contact had been established between CL604 flight crew and Mumbai ACC. The transcript of the radio transmissions was made available to the BFU.

The radio transmissions between the Omani air traffic control units (Muscat ACC, APP, and TWR) and the CL604 flight crew and the coordination calls between the air traffic control units in Muscat and Mumbai were recorded and made available to the BFU as transcripts.

Flight Recorder

Radar Recordings of the Flight Paths of the Aircraft

The BFU does not have any radar data of the flight path of the CL604. There is no radar coverage over large areas of the Arabian Sea. Therefore during the relevant period of time the flight path of the A380 involved was also not recorded by radar.

Flight Data Recording of the CL604

The airplane was equipped with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR).

Flight Data Recorder CL604

The aircraft was equipped with a Digital Flight Data Recorder (DFDR).

Manufacturer:	L3 Communications
Type:	F1000 (Solid State)
P/N:	S800-2000-00
S/N:	000169408
Number of parameters:	166
Recording Length:	25.8 hours

Reconstruction of the CL604 flight path (according to FDR data) Source: Google Earth map service^{TM} / BFU

Using FDR data the flight path of the CL604 was reconstructed.

Cockpit Voice Recorder CL604

The airplane was equipped with a Digital Cockpit Voice Recorder (DCVR).

Manufacturer:	L3 Communications
Type:	FA2100 (Solid State)
P/N:	2100-1020-00
S/N:	000483570
Number of channels:	4
Recording Length:	120 minutes

After the occurrence the flight had lasted for another two hours. Therefore the CVR recording did not include the time of the accident. Conversations, which had occurred in Muscat after landing, had been recorded.

Maintenance Diagnostic Computer

The aircraft was equipped with a Maintenance Diagnostic Computer (MDC). The computer stored maintenance messages, the LRU fault history, data regarding engine parameter exceedance, and trend information concerning the engines.

The MDC recordings were made available to the BFU for evaluation purposes.

At 0840:32 UTC the MDC recorded the message ENG ITT LVL 3 with an ITT of 900°C relating to the left engine, and 22 seconds later ENG ITT LVL 4 with an ITT of 928°C at a peak of 1,097°C.

Flight Recorders A380-800

The airplane was equipped with a FDR, CVR, and Quick Access Recorder (QAR). The flight recordings of these recorders were no longer available.

The airplane was also equipped with a Digital Access Recorder (DAR) which stores data of the Aircraft Condition Monitoring System (ACMS). The operator's Flight Data Monitoring utilized these recordings. Due to a BFU request the air accident investigation authority of the United Arab Emirates provided the DAR data of the flight for evaluation purposes. The recording encompassed 1,803 parameter, including position data, course, altitudes, speeds, wind direction, and velocity, TCAS messages, etc.

Reconstruction of the A380 flight path (according to DAR data) Source: Google Earth map service™ / BFU

Using DAR data the flight path of the A380 was reconstructed.

Wreckage and Impact Information

The accident occurred above international waters, the Arabian Sea, approximately 500 NM from any land.

The aircraft manufacturer determined that the airframe structure could not be restored to an airworthy state as it exceeded the airframe certification design load limits during the upset encounter. Therefore the aircraft is considered to be damaged substantially.

During a BFU investigation of the airplane no outer damages on fuselage, wings, and empennage, including control surfaces, were visible. There was no evidence of leakages (oil, fuel).

Outer condition of the airplane Source: BFU

The inside of the passenger cabin showed damages on the seats and the panelling, as well as traces of blood. The armrests of the four seats in the front, installed in club arrangement, were either deformed or had fractured.

On the left side of the cabin two oxygen masks had fallen from their casings.

Damages in the cabin (viewed opposite to the direction of flight) Source: BFU

In addition to the CVR and the FDR a Rockwell Collins TCAS and a Honeywell Enhanced Ground Proximity Warning System (EGPWS) (P/N 965-0976-003-210-210, S/N 6346) of the aircraft were seized and transported to the BFU in Braunschweig for evaluation purposes.

Medical and Pathological Information

According to the operator four passengers were treated at the hospital in Muscat.

One passenger suffered from head injuries and a broken rib; another passenger had fractured a vertebra. The two passengers and the flight attendant, who had sustained minor injuries, suffered bruising and a fractured nose, respectively.

The two other passengers and the pilots remained unharmed.

Fire

There was no fire.

Organisations and their Procedures

The German operator had an operations certificate issued by the LBA to transport passengers, mail and/or freight in commercial air traffic.

The operator operated a fleet of 24 aircraft of 10 different types, of which four were CL604.

Additional Information

In accordance with international regulations for airspaces with Restricted Vertical Separation Minima (RVSM) the RVSM for Mumbai FIR between airplanes with RVSM approval was 1,000 ft vertical between FL290 and FL410.

The ICAO document *Doc 4444 PANS-ATM (16th Edition November 2016)* describes a so-called *Strategic Lateral Offset Procedure (SLOP)*.

It defines SLOP as:

> *SLOP are approved procedures that allow aircraft to fly on a parallel track to the right of the centre line relative to the direction of flight to mitigate the lateral overlap probability due to increased navigation accuracy, and wake turbulence encounters.*

The following specifications were given for SLOP implementation:

> *[…]*
>
> *16.5.2 Strategic lateral offsets shall be authorized only in enroute airspace as follows:*
>
> > *a) where the lateral separation minima or spacing between route centre lines is 23 NM or more, offsets to the right of the centre line relative to the direction of flight in tenths of a nautical mile up to a maximum of 2 NM; and*
> >
> > *b) where the lateral separation minima or spacing between route centre lines is 6 NM or more and less than 23 NM, offsets to the right of the*

centre line relative to the direction of flight in tenths of a nautical mile up to a maximum of 0.5 NM.

16.5.3 The routes or airspace where application of strategic lateral offsets is authorized, and the procedures to be followed by pilots, shall be promulgated in aeronautical information publications (AIPs).

16.5.4 The decision to apply a strategic lateral offset shall be the responsibility of the flight crew. The flight crew shall only apply strategic lateral offsets in airspace where such offsets have been authorized by the appropriate ATS authority and when the aircraft is equipped with automatic offset tracking capability.

Note 1. Pilots may contact other aircraft on the inter-pilot air to air frequency 123.45 MHz to coordinate offsets.

Note 2. The strategic lateral offset procedure has been designed to include offsets to mitigate the effects of wake turbulence of preceding aircraft. If wake turbulence needs to be avoided, an offset to the right and within the limits specified in 16.5.2 may be used.

Note 3. Pilots are not required to inform ATC that a strategic lateral offset is being applied.

[…]

The Indian Aeronautical Information Publication (AIP India) ENR 3.0-7 stipulates:

5.1.3. The Strategic Lateral Offset Procedures [SLOP], as described below are applicable in oceanic airspace in Chennai, Kolkata and Mumbai FIRs on route segments mentioned in part 3 below.

[…]

5.2 Strategic Lateral Offset Procedures (SLOP)

5.2.1 The following basic requirements apply to the use of the Strategic Lateral Offset Procedures (SLOP)

i) Strategic Lateral Offset Procedures shall be applied only by aircraft with automatic offset tracking capability.

ii) The decision to apply a strategic lateral offset is the responsibility of the flight crew.

iii) The offset shall be established at a distance of one or two nautical miles to the RIGHT of the centerline of the ATS route relative to the direction of flight.

iv) The offsets shall not exceed 2NM right of centerline of the ATS route.

v) The strategic lateral offset procedure has been designed to include offsets to mitigate the effects of wake turbulence of preceding aircraft. If wake turbulence needs to be avoided, one of the three available options (centerline, 1NM or 2NM right offset) shall be used.

vi) In airspace where the use of lateral offsets has been authorized, pilots are not required to inform Air Traffic Control (ATC) that an offset is being applied.

vii) Aircraft transiting areas of radar coverage in airspace where offset tracking is permitted may initiate or continue an offset.

viii) Aircraft without automatic offset tracking capability must fly the centerline of the ATS Route being flown.

5.3. ATS route segment in Oceanic airspace where SLOP is applied

5.3.1 The segments of ATS Routes in Bay of Bengal and Arabian Sea area, where Strategic Lateral Offset Procedure is applicable are identified below.

[…]

Subsection 5.3.4 listed 17 routes for Mumbai FIR where SLOP was permitted; route L894 was not among them.

Safety Case for Wake Vortex Encounter Risk due to the A380-800

An *ad hoc* Steering Group (SG) and a technical Work Group, comprising representatives from Joint Aviation Authorities (JAA), Eurocontrol, Federal Aviation Administration (FAA), Airbus and Det Norske Veritas (DNV), was set up in 2003 to specify safety requirements to ensure Wake Vortex Encounter (WVE) risk from the Airbus A380 will be acceptable. A safety case (A380 SG, 2006a) and supporting documentation has been produced.

Among others the following recommendations have been made:

4. Measurements of WV descent indicate that during the cruise WVs from B744, A346 and A388 aircraft can descend more than 1000 feet; other Heavy aircraft are expected to have similar WV characteristics. WVE frequency is probably highest, but still low in absolute terms, for aircraft flying counter-flow parallel tracks vertically separated by 1000 feet, compared to all other encounter geometries. At cruise speeds measurements indicate that the vortex trajectory crosses the flight level 1000 feet below the generator aircraft at about 10 to 20NM behind the generator aircraft in calm atmospheric conditions. Lighter aircraft should be aware of possible encounters for up to 20NM behind (horizontal longitudinal) and 1000 feet below a Heavy or A388 generator aircraft, especially when the aircraft are flying close to parallel tracks (see also Recommendation 5). Based on current separation criteria, WVE risk is considered to be acceptable at this time; however it is recommended that this issue be investigated further.

5. There are some WVE incident reports that indicate that current operational aircraft can generate moderate to severe WVEs for an encountering aircraft during climb or descent. Such encounters have *very low probabilities*, but controllers and pilots should be aware that *if* they occur then the encountering aircraft may experience significant accelerations. These reports are consistent with the limited cruise flight test measurements involving A388, B744 and A346 generator aircraft, and with the intentional encounters that were flown with an A318.

   Though this is not an A388 specific issue, and it is beyond the scope of this group, the Work Group ***strongly recommends*** review, as a matter of urgency, of spacing for non-Heavy encounterers that climb or descend behind all Heavy aircraft generators (including the A388).

Investigator in charge: Jens Friedemann

Appendix

Reconstruction of the encounter of the two airplanes

Excerpt of the CL604 FDR at the beginning of the occurrence

Excerpt of the CL604 FDR during altitude loss

Excerpt of the CL604 FDR during recovery

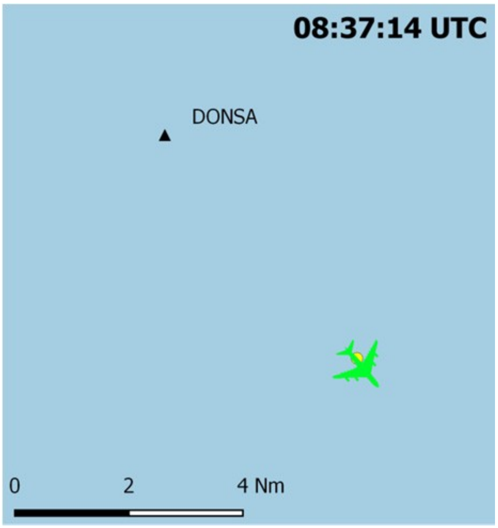
Reconstruction of the encounter of the two airplanes

A380

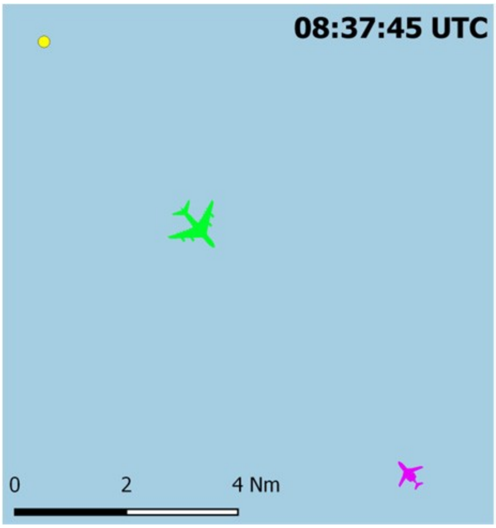
CL604

Beginn unkontrollierte Fluglage / Begin of loss of control

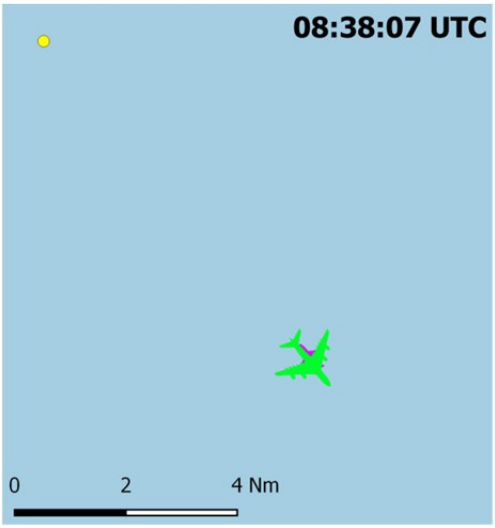
Flugzeuge nicht im Maßstab / Aircraft not to scale



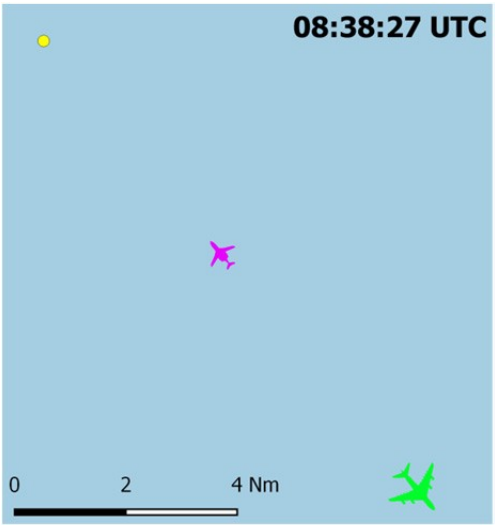
At about 0837:14 UTC the A380 passed at FL350 the position, where later the CL604 was subject to temporary loss of control.



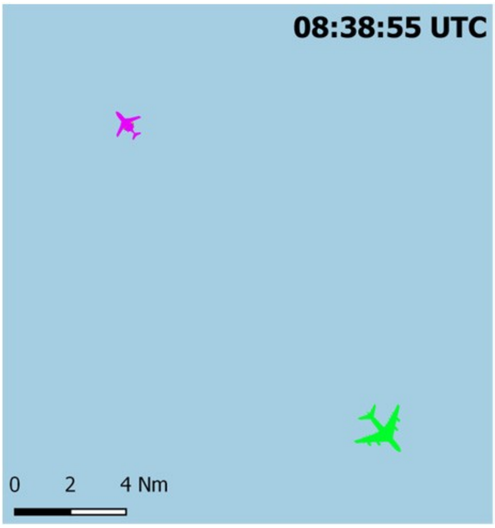
At about 0837:45 UTC the A380 TCAS captured the CL604 on opposite track (TCAS message proximate). At that time the distance between the two aircraft was 6 NM and 1,000 ft vertical.



At about 0838:07 UTC the A380 passed the CL604 overhead with a vertical distance of 1,000 ft slightly to the right.

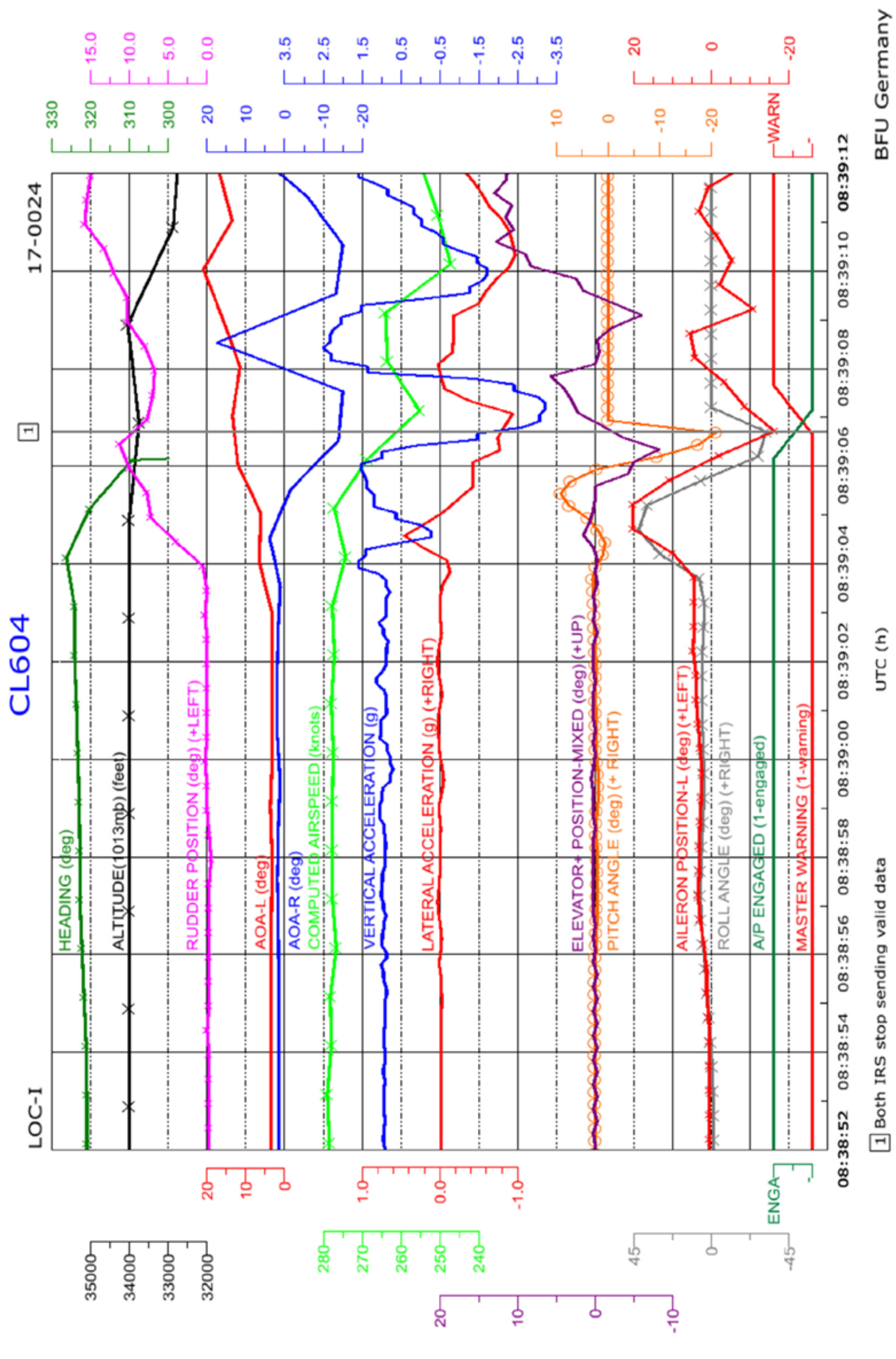


At about 0838:27 UTC the two aircraft left the capture area of their respective TCAS (TCAS message proximate). At that time the distance between the two aircraft was about 6 NM.

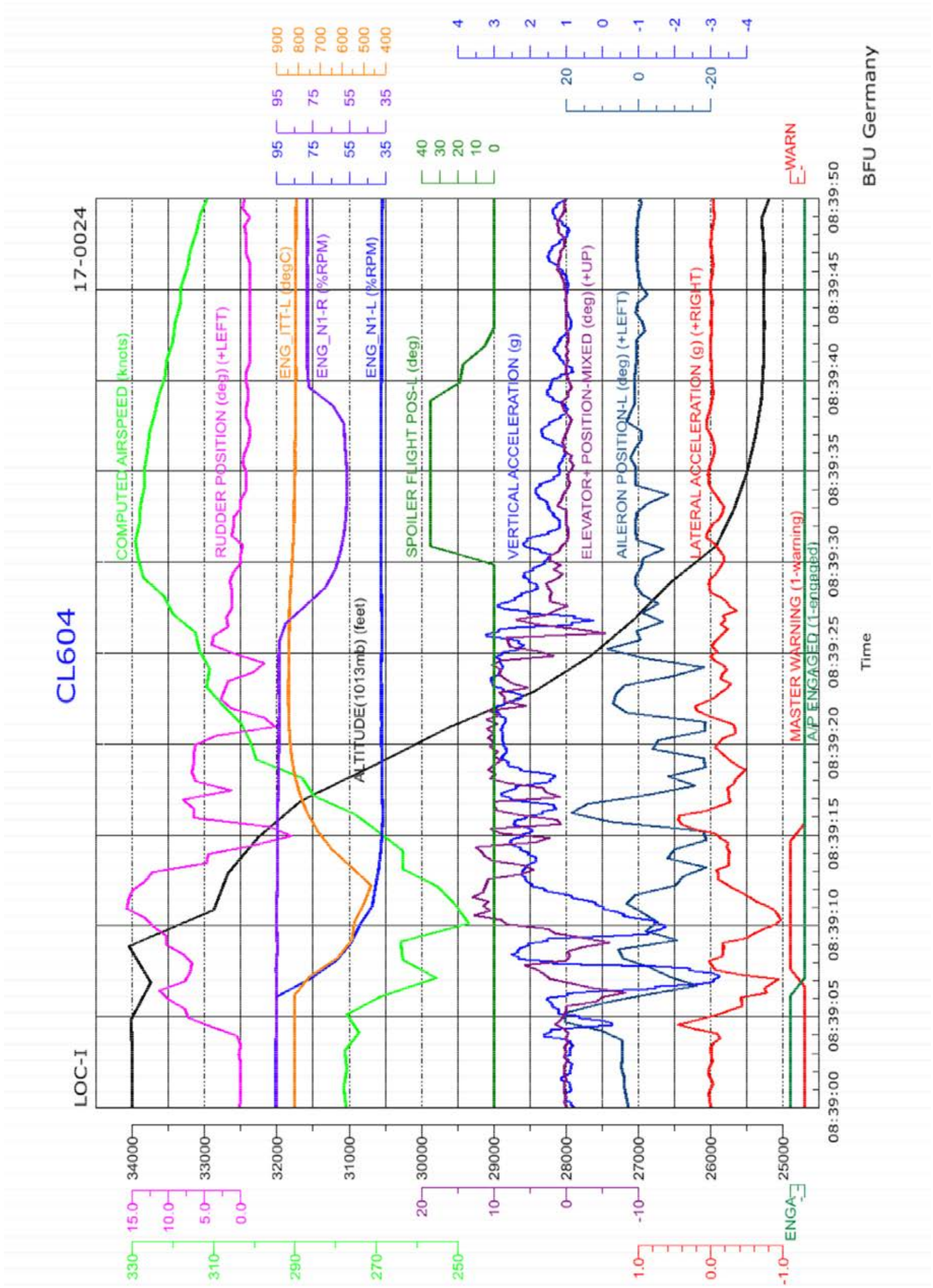


At about 0838:55 UTC at FL340 the CL604 encountered the wake vortex. At that time the A380 was about 15 NM south-east.

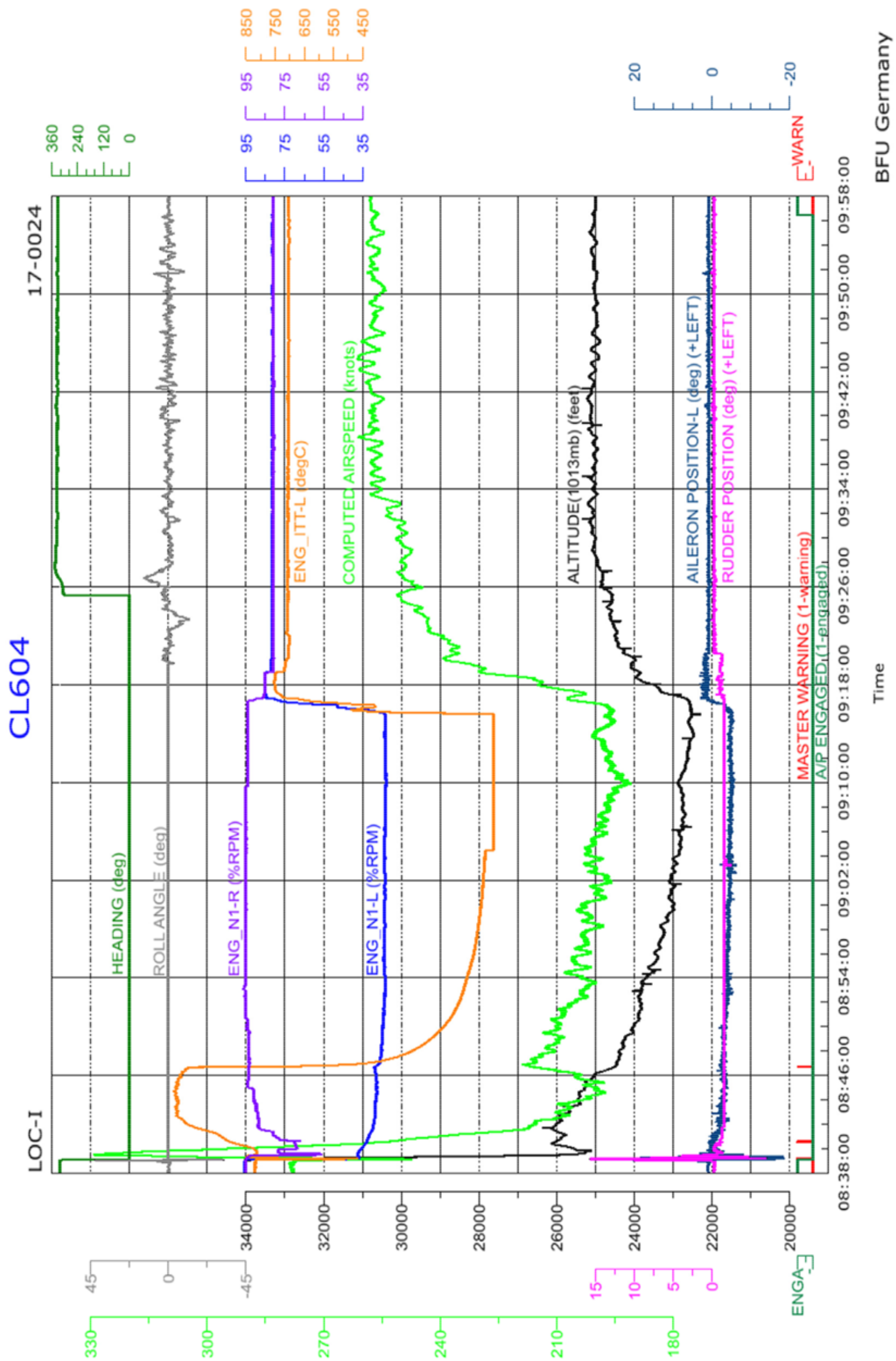
Excerpt of the CL604 FDR at the beginning of the occurrence



Excerpt of the CL604 FDR during altitude loss



Excerpt of the CL604 FDR during recovery



This investigation is 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 - 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.

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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GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

SAFETY ALERT 2017-10

Issue 01

Date of Issue: 05th July 2017

SUBJECT:

WAKE TURBULENCE AWARENESS

REFERENCE PUBLICATIONS:

CAR-X

CAR-OPS1

CAR PART VIII Subpart 4

REASON:

This Safety Alert is issued to highlight the possibility of wake turbulence events in all phases of flight, including when operating in excess of the current wake turbulence separation minima on approach and departure phases of flight. It contains guidance and recommendations for air traffic controllers and flight crews and their respective employers.

GUIDANCE

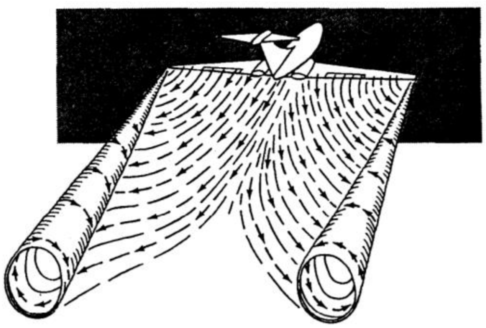
The recognised ICAO standards related to wake turbulence separation minima are intended for the approach and departure phases of flight. Wake turbulence encounters do however occur occasionally in other phases of flight such as 'enroute' or 'cruise' phase. For simplicity throughout this guidance, the term *'enroute'* will be used to refer to any time other than 'approach' or 'departure'. The only globally harmonised approach to the management of wake turbulence enroute is the Strategic Lateral Offset Procedure (SLOP) that had been introduced by ICAO following the introduction of RVSM.

An international task force under the auspices of ICAO has been developing revised wake turbulence standards (known as RECAT) over the past few years, however these remain focused on the approach and departure phases primarily aimed to improve airport efficiency. There may be scope to have the issue of enroute wake turbulence addressed by ICAO but this will take some time and is not expected in the near future.

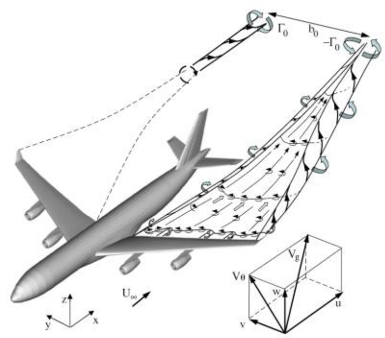
Enroute wake turbulence events can manifest as unexpected in-flight disruptions and have the potential to be hazardous. Accordingly, this Safety Alert is intended to enhance awareness of possible wake turbulence events that occur in the enroute phase of flight.

WAKE VORTEX CHARACTERISTICS

Every aircraft generates turbulence as a result of the creation of lift, this is known as 'wake turbulence', wake vortex/vortices', or simply 'wake'. The amount and severity of the wake is dependent on the size, wing shape, and mass of the aircraft. The vortices normally move down (~700ft/min) and outwards behind the generating aircraft, generally levelling around 900ft below the initial level, however for large aircraft they may continue to descend beyond this. The vortices can persist for several minutes after the aircraft has passed and this equates to a considerable distance in nautical miles at cruise speed.



Wake vortex visualization. [1]



Wake vortex evolution & roll-up process. [2]

Meteorological conditions will alter the dispersal of the vortex; prevalent strong winds or turbulence will normally contribute to a swift decay of the vortex, whereas the strength and existence is maintained for a few minutes in calm or low wind conditions. Contrails may be used as a guide however these do not behave the same as the wake vortex and are not an accurate representation of the location of the vortices.

The wake vortex is most hazardous in the approach and departure phase of flight as the high flap/low speed of the lead aircraft generates larger vortices, and the following aircraft is in a critical state with a similar configuration. In the enroute phase, the likelihood of entering the critical part of the vortex is significantly less, and the aircraft affected is in a better state to recover than when on approach/departure. Consequently, the current ICAO procedures consider that there is no need for additional separation in enroute airspace other than that normally applied for standard separation.

Existing procedures mitigate wake effects by requiring distance based on the Maximum Take-Off Mass (MTOM) of the aircraft concerned; both leading and following. This approach does not consider differences of aircraft characteristics (within the same weight category) or the effects of meteorological conditions on the movement of, or decay of the wake.

The nature of wake turbulence presents difficulty in reliably determining its exact position and strength. As a result, the procedures are designed to reduce the risk of adverse or severe encounters, but cannot remove the possibility altogether.

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[1] (International Civil Aviation Organization (ICAO), 1984, pp. II-5-3 Fig 1)

[2] (Breitsamter, 2011, p. 93)

"It follows that the application of the wake turbulence minimum is not an assurance against a wake turbulence encounter; its application only minimizes the hazard."[3]

LESSONS LEARNED FROM PREVIOUS EVENTS

While reports on wake encounters during the approach phase of flight are extensive, there are considerable less reports in regard to wake encounters in other phases of flight. Nevertheless, recent investigations into incidents which occurred at higher altitudes have provided some useful guidance on best practices.

Experience has shown that the initial air crew response is critical to the outcome of an encounter, and that some actions can result in amplification of the upset and a deterioration of the situation. Due to the rotating nature of the vortex, an encounter will result in the affected aircraft normally experiencing a roll in one direction followed shortly thereafter by an abrupt roll in the other direction, and then ejection from the vortex. The time for this to occur and pass is usually very short; a matter of seconds. Therefore, it is important that any actions by the flight crew are minimised until the encounter has completed, otherwise those actions can be compounded into an adverse situation as the direction of the upset changes very quickly.

For large aircraft, under normal circumstances the autopilot is capable of managing the actual encounter, and following some stabilisation, the flight crew can perform any remaining actions to resume normality.

For aircraft with a short wing span (relative to that of the generating aircraft) the ability to counter the imposed roll induced by vortex flow is considerably more difficult. Flight Crew of these aircraft, even of the high performance type, should be especially vigilant with regard to wake turbulence[4].

In any event the use of rudder in reaction to cruise wake encounters is not recommended as it provides minimal assistance and can cause a sudden and large lateral deflection placing structural stress on the rudder[5].

Detailed training on wake turbulence characteristics provides valuable understanding for both air crew and air traffic controllers, allowing them to more reliably predict and manage wake events.

[3] (International Civil Aviation Organization (ICAO), 1984, pp. II-5-3.3.1)
[4] (International Civil Aviation Organization (ICAO), 1984, pp. II-5-3.3.6.3)
[5] (Airbus, 2017)

UAE REGULATIONS & GUIDANCE[6]

The UAE has implemented wake turbulence regulations generally in line with the ICAO provisions. Where further clarification on the definition of 'approach & departure' is necessary, the UAE has deemed that this should be interpreted as "at or below 6000ft".

Regulations and associated procedures require ATC to issue traffic information to a possible encountering aircraft with regards to aircraft type, distance, level and relative position of potential generating aircraft.

Air Navigation Service Providers are required to provide training to Air Traffic Controllers on wake turbulence separation and further awareness of safety issues linked to wake vortices.

A ROSI is required to be submitted for wake turbulence events where a pilot reports encountering moderate or severe wake turbulence from generating aircraft and the impact had a significant effect on the control of the aircraft, e.g. roll, pitch or altitude deviation; speed loss/gain.

SUMMARY OF THE GUIDANCE

a) ICAO wake turbulence procedures are focused on approach and departure and do not encompass enroute encounters.

b) Wake turbulence separation standards do not guarantee avoidance of encounters, they only attempt to minimise the risk.

c) Wake turbulence is somewhat predictable and can be generalised as the vortices descending at 700ft/min and extending for up to 25nm behind the aircraft.

d) Lateral offsets can reduce the risk in some circumstances. In UAE airspace any offset must be requested, and approved by ATC, prior to the application of the manoeuvre.

e) The anticipation and correct handling by flight crew is currently the best mitigation.

f) It is recommended that flight crew avoid disengagement of the autopilot, wait for stabilisation, and then resume normal operations.

g) ATC should monitor flight profiles, and consider giving wake vortex warning in the event that an aircraft will fly in the airspace below the trajectory of either a heavy aircraft, or an aircraft of a heavier weight category than the experiencing aircraft.

h) All wake turbulence events that have a significant effect on the aircraft should be reported.

[6] (UAE GCAA, 2016)

RECOMMENDATIONS:

***RECOMMENDATION No. SA 2017-10(01)*:**

Aircraft Operators should:

a) *train flight crews on the recognition of potential wake situations;*
b) *review flight crew procedures for the management of wake turbulence encounters and provide training to flight crews accordingly; and*
c) *include the recommendations for flight crew below in their training programme.*

***RECOMMENDATION No. SA 2017-10(02)*:**

As precautionary measures, *Flight crew should be aware that:*

a) *Passengers should be advised to keep their seat belts fastened, even when the seat belt sign is off, unless moving around the cabin. This minimises the risk of passenger injury in case of any atmospheric or wake turbulence encounter enroute.*
b) *As indicated in ICAO PANS-ATM, for aeroplanes in the heavy wake turbulence category or for Airbus A380-800, the word "HEAVY" or "SUPER", respectively, shall be included immediately after the aeroplane call sign in the initial radiotelephony contact between such aircraft and ATS units.*
c) *Lateral offsets may provide additional mitigation in certain circumstances. All lateral offsets are subject to authorization. In the UAE specific ATC approval is required.*
d) *Timely selecting seat belt signs to 'ON' and instruct cabin crew to secure themselves constitute precautionary measures in case of likely wake encounters.*

***RECOMMENDATION No. SA 2017-10(03)*:**

In case of a wake encounter, Flight crew should:

a) *Be aware that it has been demonstrated during flight tests that if the pilot reacts at the first roll motion, when in the core of the vortex, the roll motion could be amplified by this initial piloting action. The result can be a final bank angle greater than if the pilot would not have moved the controls.*
b) *Be aware that in-flight incidents have demonstrated that pilot inputs may exacerbate the unusual attitude condition with rapid roll control reversals carried out in an "out of phase" manner.*
c) *Be aware that if the autopilot is engaged, intentional disconnection can complicate the scenario. The autopilot will in most cases – when engaged – facilitate the response to the wake encounter.*
d) *Avoid large rudder deflections when encountering wake turbulences. These can create lateral accelerations, which generate very large forces on the vertical stabiliser that may compromise the structural integrity. Use of the rudder could increase the severity of the encounter and rarely improves the ease of recovery.*
e) *Make use of OEM guidance for their specific aircraft type.*

RECOMMENDATION No. SA 2017-10(04):

Recognizing that the wake turbulence separation standards can only minimize, and not prevent wake encounters, Air Navigation Service Providers should provide detailed training and guidance to air traffic controllers on the characteristics of wake vortices, including the following wake turbulence management principles:

a) Controllers should be aware that wake vortices will likely extend beyond the applicable wake turbulence separation standards, as these separation standards are only intended to minimize the risk of severe encounters. Additionally, wake vortex encounters may be experienced during all phases of flight.
b) Controllers should factor wake vortex behaviour into their situational awareness, and provide a caution to pilots of any increased risk of a wake turbulence encounter.
c) Controllers should recognize that pilots may request lateral offsets or additional space to mitigate actual or anticipated wake turbulence. In these circumstances controllers must carefully assess such requests and accommodate them when practicable.
d) Controllers should report wake provide as much information as possible when a wake turbulence reports including as many details as available regarding both the Generating and Experiencing Aircrafts and any known weather conditions.

RECOMMENDATION No. SA 2017-10(05):

In order to ensure that acceptable levels of safety are maintained, Air Navigation Service Providers should, using their SMS, conduct comprehensive analysis of any wake turbulence incident, including review of ATC procedures, route structure and the effectiveness of the wake turbulence management requirements indicated above.

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- END -