Australian Government
Australian Transport Safety Bureau

Wake turbulence event involving a Boeing 737, VH-YIO

258 km SE of Bali International Airport (Denpasar), Indonesia, 13 September 2012

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Wake turbulence event involving a Boeing 737, VH-YIO

What happened

On 13 September 2012, at about 1619 Coordinated Universal Time (UTC)[1], a Virgin Australia Boeing 737 aircraft (B737), registered VH-YIO (YIO), departed Bali International Airport (Denpasar), Indonesia on a scheduled passenger service to Brisbane, Queensland. On board the aircraft were six crew and 132 passengers. The first officer (FO) was designated as the pilot flying.

Wake vortices

Source: NASA

During the climb, the crew requested a cruise altitude of flight level (FL)[2] 370 from Indonesian air traffic control (ATC), however, due to traffic at FL360, the crew were assigned FL350. The crew reported calm wind conditions at the time.

At 1639, the aircraft became established in the cruise and the seat belt sign was turned off. Shortly after, the crew observed opposite direction traffic on the aircraft's traffic alert and collision avoidance system (TCAS), about 1,000 ft above and slightly to the left. The crew observed the aircraft pass to the left. Airservices Australia surveillance data indicated the aircraft passed at about 1640, with about 0.9 NM lateral and 1,400 ft vertical separation (Figure 1).

At 1641, the FO reported that they felt 'cobblestone' like turbulence. The aircraft then experienced a wake-induced roll, initially to the right and then suddenly to the left, which the crew estimated to be to an angle of 45°. The crew received an enhanced ground proximity warning system (EGPWS) bank angle warning and the autopilot control wheel steering mode[3] engaged. As the roll to the left commenced, the crew immediately responded by applying full right aileron deflection. The crew reported that the aircraft initially continued to roll left, but the roll then arrested and straight-and-level flight was resumed.

Radar surveillance data indicated that, at the time of the event, there was about 2.1 NM lateral and 1,400 ft vertical separation (Figure 2) between the aircraft and the correct ATC separation standards were being applied at the time.

The captain spoke to the cabin supervisor (CS) who advised of nil injuries. He then contacted ATC requesting information on the passing aircraft. Air traffic control advised that the aircraft was an Airbus A380 (A380) aircraft operated by Emirates. The captain then made a passenger announcement over the public address system (PA) and also went out into the cabin. He spoke to the CS again who advised that all the passengers were seated at the time of the incident. The flight continued without further incident.

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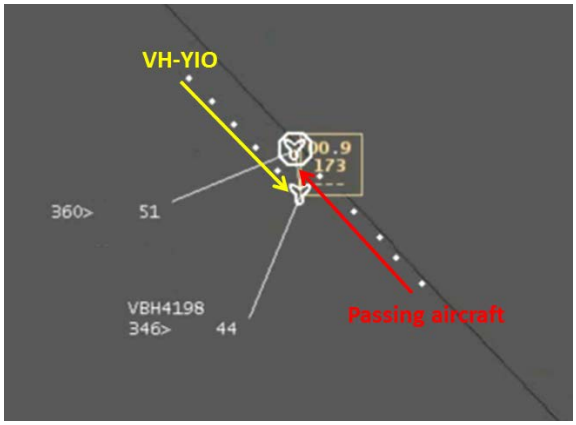
1 Coordinated Universal Time (abbreviated UTC) is the time zone used for civil aviation. Local time zones around the world can be expressed as positive or negative offsets from UTC.

2 At altitudes above 10,000 ft, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 370 equates to 37,000 ft.

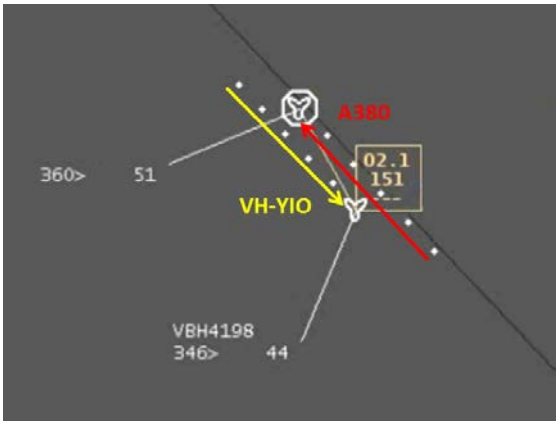
3 Autopilot mode giving manual control of heading; aircraft speed and/or attitude are maintained by the autopilot.

Figure 1: Aircraft positions at time of passing



Source: Airservices Australia

Figure 2: Incident location



Source: Airservices Australia

Recorded information

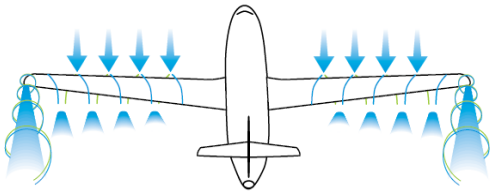
The B737 flight data recorder (FDR) was downloaded from the aircraft and the data provided to the Australian Transport Safety Bureau (ATSB). The data indicated that the aircraft initially rolled to the right to a maximum angle of 6.5° and then left to 40.4°, with a 40 ft loss in altitude. It also showed that the crew's control inputs had commenced before the maximum left roll angle was achieved, which subsequently reduced the aircraft's roll rate. The duration of the incident was about 10 seconds.

Wake turbulence

The phenomenon that creates wake turbulence results from the forces that lift the aircraft. Lift is produced by a differential in pressure over the wing surfaces. High pressure air below an aircraft's wing flows around the wingtips to the low pressure air on top of the wing. This results in vortices being generated from the wings. When viewed from behind, the left wing vortex rotates clockwise and the right wing vortex rotates counter-clockwise. The region of rotating air behind the aircraft is where the wake turbulence occurs (Figure 3). The strength of the vortices is predominantly determined by the weight, speed and wingspan of the aircraft.

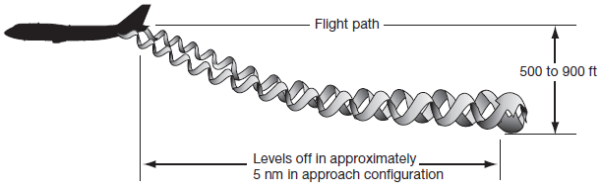
Wake vortices spread laterally away from the aircraft and generally descend at an initial rate of about 300 to 500 feet per minute for about 30 seconds. The descent rate decreases and eventually approaches zero when about 500-900 ft below the flight path (Figure 4). The life span of the wake vortices is about 30 seconds for a wind speed of 5-10 kts; up to 85 seconds for wind speeds less than 5 kts; and up to 100 seconds in still air.

Figure 3: Wake vortices



Source: New Zealand Civil Aviation Authority

Figure 4: Movement of wake vortices



Source: Flight Safety Foundation

A380 wake vortex safety report[4]

In June 2008, the A380 Wake Vortex Steering Group published the *Safety Case for Wake Vortex Encounter Risk due to the Airbus A380-800* (4th Ed.). One of the key objectives of the safety case was to define and justify the safety requirements for the A380 to ensure that the wake vortex encounter (WVE) risk was acceptably low. The results indicated that, based on data collected since 2006, the WVE risk was considered acceptable and the current vertical or horizontal separation criteria used by ATC (ICAO Procedures for Air Navigation Services — Air Traffic Management) remained applicable to the A380. Furthermore, it showed that the WVE risk that resulted from an A380 during the cruise was not noticeably different from that of aircraft such as the Boeing 747-400 (B747), Airbus A340-600 (A340) and Boeing 777-300. Appendix A provides a summary of a selection of wake turbulence occurrences reported to the ATSB involving the A380, the B747 and the A340, during the cruise phase of flight.

A380 wake turbulence classification

The wake turbulence separation standards applied by ATC are determined by grouping aircraft into four categories (light, medium, heavy and super) based on the aircraft's maximum certified take-off weight. The A380 is the only aircraft currently assigned the category of 'super'.

Guidance issued by the International Civil Aviation Organization (ICAO) on the subject of Airbus A380 wake vortex aspects states that[5]:

> For A380-800 aircraft the expression "SUPER" should be included immediately after the aircraft call sign in the initial radiotelephony contact between such aircraft and ATS [air traffic service] units.

Prior to the incident, at about 1624, the crew of a preceding aircraft also outbound from Denpasar heard a broadcast from opposite direction traffic. The term 'Super' was used as part of that broadcast, which alerted the crew that the traffic ahead was an A380. The A380 was at about 1,000 ft above. The captain reported that, as the wind conditions at the time were light, he predicted that there would be little 'drift' of the A380's wake vortices. Consequently, to avoid any possible wake turbulence, at about 1629, the crew requested a 5 NM diversion off track from ATC. The captain reported that no wake turbulence was experienced and the flight proceeded normally.

The captain of YIO could not recall hearing a broadcast regarding the A380.The FO recalled hearing broadcasts from several aircraft operating on the frequency at the time, but could not recall hearing any broadcasts with the term 'Super' appended. The FO reported that, if he was aware that the passing aircraft was an A380, he would have considered deviating off track as a precaution.

An Airbus Flight Operations Briefing Note on *Wake Turbulence Awareness/Avoidance* also recommends that, during the cruise (if necessary), the crew may offset from the cleared track by up to a maximum of 2 NM, in order to alleviate the effects of wake turbulence[6].

Jet upset recovery training

A 'jet upset' occurs when the aircraft unintentionally exceeds the parameters normally experienced in flight: where the nose up pitch attitude is greater than 25°; or the nose down pitch attitude is greater than 10°; or the bank (roll) angle is greater than 45°; or within the above parameters, but flying at airspeeds inappropriate for the conditions.

The captain reported conducting his 6 monthly jet upset simulator training within the week prior to the incident, while the FO had completed his training about 2 months before. While, based on the above criteria, a jet upset did not occur; both the captain and FO reported that the training was

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4 www.jaa.nl/operations/Public%20Area/SafetyCase%20v4%200%2020Jun08%20(2).pdf
5 www.skybrary.aero/bookshelf/books/160.pdf
6 www.airbus.com/fileadmin/media_gallery/files/safety_library_items/AirbusSafetyLib_-FLT_OPS-OPS_ENV-SEQ07.pdf

invaluable. The FO further stated that his response to the wake turbulence encounter was instinctive and that the incident was similar to that experienced in the simulator.

Pilot comments

The crew provided the following comments regarding the incident:

- **Seat belts*:*** The captain reported that, when he made a PA to the passengers advising that the seat belt sign had been turned off, he encouraged them to keep the belt fastened when seated. The FO also stated that, due to the time of the incident the majority of passengers were sleeping, with their seat belts secured.
- **Track offset*:*** The FO reported that, when conducting international operations, he had observed some aircraft diverting off track slightly to minimise the effects of wake turbulence from passing aircraft.

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Virgin Australia

As a result of this occurrence, Virgin Australia has advised the ATSB that they have issued a notice to all flight crew detailing the incident involving VH-YIO and summaries of other wake turbulence incidents involving Virgin Australia aircraft.

Safety message

Recurrent training

Periodic recurrent training ensures that pilots continue to be knowledgeable of, and proficient in their specific aircraft type, and operating procedures: pilots are better prepared for responding to a situation. This incident demonstrated the value of such training, allowing the crew to react to the wake turbulence encounter intuitively and promptly.

Seat belts

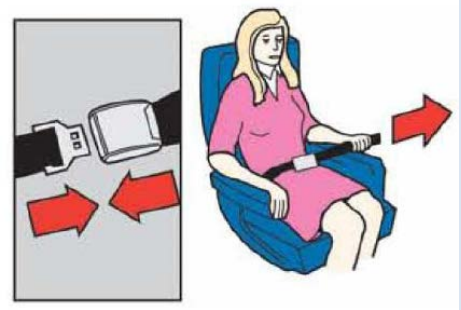
A wake turbulence encounter can be a surprising experience for both the crew and passengers and usually results in induced rolling or pitch moments. A safety bulletin published by the ATSB in June 2008, *Staying Safe against In-flight Turbulence*, noted that almost all turbulence[7] injuries involve people who are not properly seated and do not have their seat belt fastened. This incident is a timely reminder of the benefits of having the seat belt fastened, even when the seat belt sign is turned off, so that injuries during a turbulence encounter can be minimised.

Staying Safe against In-flight Turbulence

What can you do to stay safe?

- Put your seatbelt on, and keep it fastened when you are seated.
- Pay attention to the safety demonstration and any instructions given by the cabin crew.
- Read the safety information card in your seat pocket.

www.atsb.gov.au/media/27791/ar2008034.pdf



[7] This may include thunderstorm turbulence, mountain wave turbulence, wake turbulence, or clear air turbulence.

The following publications provide additional information on wake turbulence:

- Federal Aviation Administration Advisory Circular AC 90-23F ' Aircraft wake turbulence' www.rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%2090-23F/$FILE/AC90-23f.pdf
- Flight Safety Foundation 'Airplane Upset Recovery Training Aid' www.flightsafety.org/archives-and-resources/airplane-upset-recovery-training-aid
- New Zealand Civil Aviation Authority 'Wake Turbulence' www.caa.govt.nz/safety_info/gaps/wake_turbulence.pdf
- United Kingdon Civil Aviation Authority aeronuatical information circular 'Wake Turbulence' www.skybrary.aero/bookshelf/books/1166.pdf
- Wake turbulence training aid www.ntl.bts.gov/lib/42000/42200/42251/DOT-VNTSC-FAA-95-04.pdf

Appendices

Appendix A – Other wake turbulence occurrences (cruise)

- During the cruise, an opposite direction B747 passed 1,000 ft above. The crew observed the wake and immediately requested a diversion left of track from ATC. The aircraft experienced significant roll (ATSB occurrence 200802765).
- While maintaining FL370, in smooth air, the aircraft encountered moderate to severe turbulence from a passing B747 at FL380. The turbulence was reported as a 'thump' and of sufficient strength to alarm the crew and passengers (ATSB occurrence 200808246).
- During the cruise, moderate wake turbulence was experienced from a preceding A380, 33 NM ahead (ATSB occurrence 200900625).
- During the cruise, an A380 passed about 1,000 ft above. About 1 minute later, significant turbulence was experienced, with bank angle excursions to the left and right of up to 20°. After about 30-45 seconds, normal flight was resumed. Nil wind conditions were reported at the time (ATSB occurrence 200900778).
- While maintaining FL370, in smooth air, the aircraft experienced 'abrupt' moderate to severe turbulence for about 2 seconds. The crew were subsequently advised by ATC that an A380 had crossed their path on descent (ATSB occurrence 200900783).
- An opposite direction B747 passed 1,000 ft above. Shortly after, strong wake turbulence was experienced, resulting in the aircraft rolling left and right, and the autopilot and auto-throttle disengaging. The aircraft climbed about 280 ft above it's cruise altitude of FL390 (ATSB occurrence 201003614).
- While maintaining FL390, an opposite direction A380 passed 1,000 ft above. Soon after, the aircraft experienced wake turbulence for about 10 seconds, with minimal displacement in roll and pitch. Light and variable wind conditions were reported (ATSB occurrence 201009234).
- While maintaining FL360, an opposite direction A340 passed 1,000 ft above. The crew reported experiencing severe wake turbulence and a loss of control resulting in an angle of bank exceedance greater than 40° (ATSB occurrence 201100111).
- While maintaining FL390, a B747 passed the aircraft about 1 NM away and 1,000 ft above. Shortly after, the aircraft experienced moderate wake turbulence for about 10-15 seconds (ATSB occurrence 201101069).
- While maintaining FL310, severe to moderate wake turbulence was experienced from an opposite direction A380, which passed 1,000 ft above and 3-5 NM to the right of track (ATSB occurrence 201103206).

- During the cruise, in smooth air, the aircraft abrubtly rolled left 10° injuring two cabin crew members. About 2 minutes prior, a B747 was observed passing the aircraft to the left, about 2 NM away and 1,000 ft above (ATSB occurrence 201104284).
- About 90 seconds after passing an opposite direction A380, 1,000 ft above, moderate turbulence was experienced (ATSB occurrence 201105306).
- During the cruise, shorts bursts of severe wake turbulence were experienced from an A380. A cabin crew member received injuries (ATSB occurrence 201202150).

Additionally, the ATSB conducted an investigation (AO-2008-077) into an A380 wake turbulence encounter during the approach phase of flight, where a passenger sustained minor injuries. When tracking to join a 7 NM final and descending through about 2,400 ft, the aircraft experienced an uncommanded 52° roll to the left, in conjunction with an 8° nose-down pitching moment. Immediately after, the aircraft rolled through wings level to a 21° right bank angle. The aircraft also experienced an altitude loss of 300-400 ft. The momentary upset was likely the result of wake turbulence from an A380 conducting a parallel approach.

General details

Registration:	VH-YIO	
Manufacturer and model:	The Boeing Company 737-8FE	
Operator:	Virgin Australia Airlines	
Type of operation:	Air transport – high capacity	
Occurrence category:	Serious incident	
Primary occurrence type:	Turbulence event	
Location:	258 km SE of Bali International Airport (Denpasar), Indonesia	
	Latitude: 10° 26.40' S	Longitude: 116° 47.13' E
Persons on board:	Crew – 6	Passengers – 132
Injuries:	Crew – Nil	Passengers – Nil
Damage:	Nil	

About the ATSB

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; and fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

About this report

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope, fact-gathering investigation was conducted in order to produce a short summary report, and allow for greater industry awareness of potential safety issues and possible safety actions.