AIRCRAFT WAKE TURBULENCE

1. INTRODUCTION

1.1 This AIC provides basic information on wake vortex behaviour, alerts pilots to the hazards of aircraft wake turbulence, and recommends operational procedures to avoid or deal with wake turbulence encounters.

2. WHAT IS WAKE TURBULENCE?

2.1 All aircraft generate wake vortices, also known as wake turbulence. When an aircraft is flying, there is an increase in pressure below the wing and a decrease in pressure on the top of the aerofoil. Therefore, at the tip of the wing, there is a differential pressure that concentrates the roll up of the airflow aft of the wing tip. Limited smaller vortex swirls exist also for the same reason at the tips of the flaps. Behind the aircraft all these small vortices mix together and roll up into two main vortices turning in opposite directions, clockwise behind the left wing (seen from behind) and anti-clockwise behind the right one wing (see Figure 1).

3. CHARACTERISTICS OF WAKE VORTEICES

3.1 Wake vortex generation begins when the nose wheel lifts off the runway on take-off and continues until the nose wheel touches down on landing.

3.2 Size: The active part of a vortex has a very small radius, not more than a few metres. However, there is a lot of energy due to the high rotation speed of the air.
3.3 **Intensity:** The characteristics of the wake vortices generated by an aircraft in flight are determined initially by the aircraft’s gross weight, wingspan, aircraft configuration and attitude. Generally, the heavier the aircraft, the more intense will be the wake vortices. However, there are exceptions – for example, the Boeing 757 generates particularly intense wake vortices that require special treatment for wake turbulence separation purposes (see Section 9).

3.4 **Descent rate:** In calm air, a wake vortex descends slowly. As an order of magnitude, in cruise, it could be 1,000FT below and behind the generating aircraft at a range of around 15NM. Then, when far away from the generating aircraft, the rate of descent becomes very small. In approach, the descent is usually limited to around 700FT. However, depending on weather conditions the descent rate may vary significantly and may even be very small. One of the key factors affecting this descent rate is the variation of the temperature with the altitude. A temperature inversion can limit the rate of descent.

3.5 **Decay rate:** One important parameter of a wake vortex is the decay of its strength with time. The decay rate varies slightly from one aircraft type to another and is also affected by environmental conditions. Unfortunately, in calm air, due to low external interference, the rate of decay is rather low and this is why the separation between aircraft needs to be so large. In the en route environment, wake can be encountered more than 25NM behind the generating aeroplane. The most significant encounters are reported within a distance of 15NM.

3.6 **Ground effect:** When the aircraft is close to the ground, less than a wingspan, the two vortices tend to drift out from the centre line, each towards its own side, at a speed of around 2 to 3KT. It is this phenomenon, when associated with a light crosswind component that tends to ‘hold’ the ‘into wind’ vortex roughly on the centreline, whilst the ‘downwind’ vortex moves away. Wake vortex decay is much faster in ground effect compared to higher levels.
3.7 **Helicopter vortices**

3.7.1 A hovering or slow hover-taxiing helicopter generates a downwash from its main rotor(s). The downwash can contain high wind speeds within three rotor diameter of the helicopter. In forward flight even when slow, the downwash energy is transformed into a pair of strong, high-speed, trailing vortices similar to wing-tip vortices of larger fixed-wing aircraft. (See Figure 2 and Figure 3).

![Figure 2: Downwash during slow hover taxi and stationary hover](image)
4. VORTEX ENCOUNTERS

4.1 When an aircraft enters in the vortex of another aircraft, the situation is called an encounter. The aircraft emitting the vortex is called the generator and the one experiencing it, the follower.

4.2 How likely is an encounter?

4.2.1 It is not possible to implement navigation procedures such that the probability of an encounter is zero. For example, during Airbus wake vortex flight tests in the cruise, A319 vortices were identified at a range of 42NM. An encounter with such a vortex is obviously very weak but it exists and it would have been stronger behind an aircraft with a wake turbulence classification of Super or Heavy. During terminal area operations, it is also common to encounter wake turbulence at distances greater than the air traffic control (ATC) minimum wake turbulence separation distances.

4.2.2 Avoiding all encounters would require very significant spacing and would dramatically limit the traffic on all airports and airways without significantly improving safety. It is also to be noted that statistics show that the probability of injury to passengers and crew is about five times greater in turbulence due to weather, than with a wake vortex encounter.
4.3  **How does it feel to encounter a wake vortex?**

4.3.1  In most cases the effect of the vortex is mainly felt in roll. Consider the case of an aircraft entering laterally in a vortex, which is the most frequent situation. Assuming the lead aircraft is crossing the track of the following aircraft from left to right, the following aircraft will enter the right vortex of the leading aircraft on the following aircraft’s left side. Seen from behind, this vortex is rotating anticlockwise. When the left wing of the follower first enters the vortex, there is on this wing a local angle of attack increase and therefore the lift becomes higher than on the right wing. The initial roll motion is therefore to the right. Then, when the aircraft is in the middle of the vortex, it will be subjected to the full strength of the vortex and roll in the same direction as the vortex, to the left (see Figure 4). This is the main rolling motion that creates the strongest roll acceleration.

4.3.2  The typical signature of a severe encounter is an initial small roll in one direction followed by a much more significant roll in the other direction. When in cruise, this roll motion may be associated with significant load factor variations.

![Figure 4: Aircraft behaviour in a wake vortex encounter (bank angle exaggerated to show the effect)](image)
4.4  **Effect on the trajectory of the follower**

4.4.1  To experience a severe roll encounter, it is necessary for the follower to have a trajectory with a small closing angle with the vortex. However, if this angle is too small, the aircraft will be smoothly ejected from the vortex (due to the initial roll in the example above). When perpendicular, there will be no rotation, and any encounter will be a very brief but sharp turbulence effect. To experience a severe encounter, the most critical angle between the trajectory of the follower and the vortex is around 10 degrees.

4.5  **Severity of the encounters**

4.5.1  When aircraft are separated by the appropriate ATC separation minimum, the severity of the encounters should not result in an unsafe control situation. When the aircraft is not in ground effect, the order of magnitude of the bank angle for a severe encounter on the approach is around 20°. But when in ground effect, as explained above, the decay is much faster and the worldwide experience during many years shows that the bank angle achieved is much lower and does not lead to a risk of touching the ground with the wingtip.

4.6  **Duration of an encounter**

4.6.1  A severe encounter, as described above, where the trajectories of both aircraft have an angle around 10 degrees, typically lasts around 4 to 6 seconds. It is not possible to remain for a long time in a severe vortex as the rotating airflow on the wing and on the fin, will eject the aircraft from the vortex. Recent Airbus flight tests showed that a large aircraft can only be stabilised inside a vortex if a large sideslip angle is established. Therefore, a vortex should not be the cause of long duration turbulence during normal flight.

5.  **WAKE TURBULENCE ENCOUNTER – PILOT ACTION**

5.1  When an encounter occurs, the pilot’s actions can lessen or aggravate the situation.

5.2  Considering the way a vortex acts on an aircraft, if the pilot reacts at the first roll motion, to the right in the example previously given, the natural correction is to roll to the left. When in the core of the vortex, the main roll motion to the left will then be amplified by this initial piloting action. The result will be a final bank angle greater than if the pilot had not moved the controls.
5.3 In addition, in-flight incidents have demonstrated that the pilot inputs may exacerbate the unusual attitude situation with rapid roll control reversals carried out in an 'out of phase' manner.

5.4 A pilot’s best response to a wake turbulence encounter is to follow the recommended procedure from the aircraft manufacturer. Refer to the specific Aircraft Flight Manual for further guidance.

5.5 In the absence of specific aircraft manufacturer procedures, pilots should exercise caution with pilot control inputs, especially avoiding abrupt reversal of aileron and rudder control inputs. If altitude and conditions permit, it may be better to allow the aircraft to transition through the wake and then recover from any resultant unusual attitude, rather than aggressively trying to control the aircraft during the wake encounter.

5.6 As a rule of thumb:

When encountering serious wake turbulence:

- **INITIALLY JUST WAIT**
- **RESIST THE URGE TO IMMEDIATELY MOVE THE CONTROLS**
- **DO NOT USE THE RUDDER TO COUNTERACT THE EFFECTS**

*Only once clear of turbulence:* start recovery control inputs.

5.7 If the autopilot is engaged and remains engaged, it may be better to allow the autopilot to recover from the wake vortex encounter rather than disconnecting the autopilot and using manual control inputs. However, be prepared to assume manual control of the aircraft if the autopilot disengages.

5.8 **Use of rudder warning**

5.8.1 Rapid and gross side-to-side deflection of the rudder in response to a wake turbulence encounter can give rise to very large forces on the fin that may exceed structural limits. An accident has already occurred for this reason. It is important to be aware that use of the rudder does not reduce the severity of the encounter nor does it improve the ease of recovery.
6. **VORTEX AVOIDANCE - PILOT ACTION**

6.1 This section provides general guidance for wake turbulence avoidance and is most applicable in situations where ATC is not providing wake turbulence separation (e.g. operations at non-controlled aerodromes or when a pilot accepts responsibility for own separation from another aircraft – which includes avoiding the wake vortices) or in situations where a wake turbulence separation is not required but the pilot wishes to take action to reduce the likelihood or severity of a wake turbulence encounter.

6.2 For any advice in this section about noting a larger aircraft’s rotation or touchdown point, be aware that the prevailing wind will displace the vortices. For example, a 20KT headwind in one minute will displace the vortices by 600M in the direction of the threshold.

6.3 **Departing behind a larger aircraft—Same Runway.** When departing behind a larger aircraft on the same runway, pilots should:

- If possible, note the larger aircraft’s rotation point and visualise the movement of the vortices as a result of the prevailing wind
- Endeavour to rotate prior to the larger aircraft’s rotation point or anticipated position of the wake vortices as a result of the surface wind
- Continue climb above the larger aircraft’s climb path until turning clear of the wake (see Figure 5)
- Avoid subsequent headings which will cross below and behind the larger aircraft (see Figure 6)
- Be alert for any critical take-off situation which could lead to a vortex encounter.
6.4 **Intersection take-offs.** When conducting intersection take-offs, pilots should note the larger aircraft’s rotation point and visualise the movement of the vortices as a result of the prevailing wind. Rotate prior to the larger aircraft’s rotation point or anticipated position of the vortices. Also, be alert to adjacent large aircraft operations, particularly upwind of your runway. If intersection take-off clearance is received, avoid a flightpath which will cross below a larger aircraft’s flightpath.

6.5 **Departing or landing after a larger aircraft executing a low/missed approach or touch-and-go landing.** Because vortices settle and move laterally near the ground, the vortex hazard may exist along the runway and in your flightpath after a larger aircraft has executed a low/missed approach or a touch-and-go landing, particularly in light quartering wind conditions. You should ensure that an interval of at least 2 minutes has elapsed before your take-off or landing (and at least 3 minutes when operating behind Super aircraft).
6.6 **Landing behind a larger aircraft—Same runway.** When landing behind a larger aircraft on the same runway stay at or above the larger aircraft’s final approach flightpath. Note the touchdown point and land beyond it (see Figure 7). See Section 7 for advice relevant to larger aircraft.
6.7 **Landing behind a larger aircraft—Parallel runways.** When landing behind a larger aircraft on a parallel runway, particularly runways spaced closer than 760M apart, pilots need to consider the relationship between the runway threshold locations, the relative descent paths/locations and possible vortex drift onto your runway. If you have visual contact with the larger aircraft landing on the parallel runway, whenever possible, stay at or above the larger aircraft's final approach flightpath. Note its touchdown point. Be aware that the aircraft descending to the more distant threshold will generally be slightly higher depending on the amount of threshold stagger (see Figure 8).

![Figure 8: Avoidance procedure landing on parallel runways closer than 760M apart](image)

**Note:** While the guidance refers to parallel runways spaced less than 760M apart, wake vortex encounters can occur during operations on parallel runways with wider spacing. Hence the guidance is relevant for parallel runways generally.

6.8 **Landing behind a larger aircraft—Crossing Runway.** When landing behind a larger aircraft on a crossing runway, pilots should adjust the aircraft’s flight path to create at least 3 minute’s spacing at the point of intersection with the other aircraft’s vortices (see Figure 9). Avoid crossing above the larger aircraft’s flightpath because this can result in a long landing.
6.9 **Landing behind a departing larger aircraft—Same runway.** When landing behind a departing larger aircraft on the same runway, pilots should note the larger aircraft’s rotation point and visualise the movement of the vortices as a result of the prevailing wind. Endeavour to touch down well before the larger aircraft’s rotation point or anticipated position of the wake vortices as a result of the surface wind (see Figure 10).
6.10 **Landing behind a departing larger aircraft—Crossing Runway.** When landing behind a departing larger aircraft on a crossing runway, pilots should note the larger aircraft’s rotation point. If rotation is past the intersection, continue the approach and land before the intersection. If the larger aircraft rotates prior to the intersection, avoid flight below the larger aircraft’s flightpath. Consider abandoning the approach unless a landing is ensured well before reaching the intersection (see Figure 11). Account for anticipated movement of the wake vortices as a result of the surface wind.

![Figure 11: Avoidance for landing when larger departing aircraft rotates prior to the intersection](image)

6.11 **En route—Outside controlled airspace.** Pilots should avoid flight below and behind a larger aircraft’s flightpath. If a larger aircraft is observed above on the same track (meeting or overtaking), adjust your position laterally, preferably upwind.

6.12 **En route—Controlled airspace/Oceanic**

6.12.1 In surveillance airspace, Australian ATC may provide air traffic advice when aircraft will pass with the minimum vertical separation spacing and will provide a wake turbulence caution when opposite direction aircraft will pass and a lighter category aircraft will enter the wake turbulence envelope of a heavier category aircraft.

6.12.2 If appropriate, request ATC clearance for offset or change of level. In oceanic airspace, pilots can use Strategic Lateral Offset Procedures (SLOP) to strategically offset horizontally from their route for up to 2NM without seeking ATC permission (see Figure 12).
6.12.3 However, it can be difficult to detect whether or not the other aircraft is also flying with an offset. Therefore, offsetting is no guarantee that an encounter will be avoided (unless the vortices are clearly visible by contrails).

6.12.4 If crosswind exists and if the two aircraft are flying exactly on the same track, the wind will move the vortices out of the track of the following aircraft whilst they are descending. In this situation, if a lateral offset is decided for reasons other than wake vortex avoidance, an offset upwind by the follower is to be preferred, since a downwind one may potentially create an encounter.

![Figure 12: Use of Track offset or SLOP](image)

6.13 Operating near helicopters

6.13.1 Pilots of light aircraft should avoid operating within three rotor diameters of any helicopter in a slow hover taxi or stationary hover. As a visual indicator: if the skids/wheels of the helicopter are resting on the surface then the helicopter will be producing a much reduced downwash. Caution should be exercised however since the helicopter may lift into the hover with little or no notice, thus increasing downwash significantly.
7. WAKE VORTICES – FURTHER PILOT ACTION

7.1 Flight crew and passenger safety. In addition to the situations where flight crew and passengers must be seated with seat belts fastened, pilots should always remind passengers of the safety benefits of having safety belts fastened when seated irrespective of seat belt sign illumination, unless moving around the cabin. This minimises the risk of passenger injury in case of a turbulence encounter en-route (wake or atmospheric).

7.2 ATC instructions and advice. Several aspects of ATC instructions and advice are relevant:

- IFR aircraft — a clearance to maintain own separation with another aircraft or to follow another aircraft includes a requirement for the pilot to provide own wake turbulence separation
- VFR aircraft — ATC does not provide wake turbulence separation for VFR aircraft in flight
- Pay careful attention to a ‘CAUTION – WAKE TURBULENCE’ advice
  - This generally means the time or distance spacing between the relevant aircraft is less than the equivalent wake turbulence separation minimum for the aircraft involved.

7.3 Vortex avoidance. Pilots must have keen awareness in order to avoid wake vortices in all stages of flight. It is useful to exercise vortex visualisation and avoidance procedures using the same degree of awareness as for collision avoidance.

7.4 Identify Heavy or Super aircraft. Pilots of aircraft in the Super or Heavy wake turbulence categories must include the word ‘SUPER’ or ‘HEAVY’ respectively immediately after the aircraft callsign in the initial radio telephony contact with approach, departures, director or the aerodrome control tower.

7.5 Larger aircraft - Fly on the glide path. Larger aircraft should make every effort to fly on the glide path, not above it, to minimize vortex exposure to other aircraft. This establishes a dependable baseline from which pilots of in-trail, lighter aircraft may reasonably expect to make effective flightpath adjustments to avoid serious wake vortex turbulence. At airports without glide path indication, pilots should use a ‘300 feet per mile’ glide path.

EXAMPLE: Fly 3,000FT at 10NM from touchdown, 1,500FT at 5NM, 1,200FT at 4NM, and so on, to touchdown.
7.6 **Techniques for lighter aircraft.** Pilots operating lighter aircraft behind heavier aircraft should consider the following techniques to assist in avoiding wake turbulence:

- Flying slightly above the glidepath, but following the glidepath angle, to a touchdown point beyond the touchdown point of the larger preceding aircraft

*However, be aware of the risk associated with long landings including potential for runway excursion.*

- When possible, note the touchdown point of the larger preceding aircraft and adjust the touchdown point as necessary.

**EXAMPLE:** A puff of smoke may appear at the touchdown point of the lead aircraft; adjust your touchdown point to approximately 150M beyond.

*Be aware that some Heavy or Super aircraft may require a longer touchdown point to ensure adequate clearance over the landing threshold.*

- During visual approaches, pilots may ask ATC for updates on separation and ground speed with respect to larger preceding aircraft, especially when there is any question of safe separation from a wake turbulence perspective, and to enable the pilot to adjust the flightpath.

- When any doubt exists about maintaining safe separation distances between aircraft to avoid wake turbulence, pilots should ask ATC for additional spacing.

8. **WAKE VORTEX SEPARATION – ATC MEASURES**

8.1 ATC will apply wake turbulence separation measures between aircraft depending on weight differential and category of flight (whether VFR or IFR). These measures include delaying a take-off or increasing the spacing between aircraft to achieve a specified minimum time interval or specified minimum distance interval. ATC can also give a wake turbulence warning to alert a pilot when the minimum time interval or distance spacing may be compromised or when a pilot agrees or is required to follow another aircraft or to maintain own separation with another aircraft.

8.2 It is important for pilots to be aware that wake turbulence separation minima are only intended to reduce the probability of encountering wake turbulence to an acceptably low level and to minimise the magnitude of the upset when an encounter occurs. Wake turbulence separation minima cannot entirely remove the possibility of a wake turbulence encounter.
8.3 In controlled airspace, ATC will normally apply wake turbulence separation measures between IFR aircraft. ATC will also apply wake turbulence separation measures between a VFR aircraft that is taking off and a larger aircraft that has taken off ahead.

8.4 ATC is not required to apply wake turbulence separation:

- For VFR aircraft already in flight
- For IFR aircraft – when the pilot of the IFR aircraft is maintaining own separation or is visually following another aircraft
- For an IFR or VFR aircraft on take-off – if the pilot of an aircraft has requested a waiver of wake turbulence separation (see section 8.6 for advice about wake turbulence waivers)

In these situations, the pilot is solely responsible for avoiding wake turbulence.

8.5 The controllers will provide a wake turbulence warning to pilots when, in the controller’s opinion, wake turbulence may have an adverse effect. This warning includes the position, altitude and direction of flight of larger aircraft followed by the phrase “CAUTION–WAKE TURBULENCE.” After issuing the caution for wake turbulence, the air traffic controllers generally do not provide additional information to the following aircraft.

8.6 Pilot initiated waiver

8.6.1 The pilot of a departing aircraft may request ATC to waive wake turbulence separation by using the phrase “ACCEPT WAIVER”.

8.6.2 A request for waiver should only be made:

- In Visual Meteorological Conditions by day
- After careful assessing that the wake vortices of the preceding aircraft can be avoided or safely managed

8.6.3 A pilot requesting a waiver of wake turbulence separation is taken to be accepting responsibility for wake turbulence separation with preceding aircraft.

8.6.4 If other traffic permits, ATC may then issue a take-off clearance, since the pilot has accepted the responsibility for wake turbulence separation.

8.6.5 However ATC will not waive wake turbulence separation if the preceding aircraft is a HEAVY or SUPER wake turbulence category aircraft (e.g. Airbus A330 or larger).
8.6.6 Pilots should be extremely cautious about requesting a waiver because an encounter with wake vortices at low altitude and low airspeed can be particularly hazardous.

9. AIRCRAFT WAKE TURBULENCE CATEGORIES

9.1 ATC uses the following aircraft weight classes for the purposes of wake turbulence separation minima:

- SUPER (H) – Airbus A380 and Antonov AN225 aircraft;
- HEAVY (H) -- All other aircraft types of 136,000 kg maximum take-off weight or more;
- MEDIUM (M) -- Aircraft types of less than 136,000kg maximum take-off weight but more than 7,000 kg maximum take-off weight;
- LIGHT (L) -- Aircraft types of 7,000 kg maximum take-off weight or less.

NOTE: Due to their wake turbulence characteristics, ATC will consider Boeing B757, Sikorsky CH-47 Chinook and the Sikorsky CH-53 Sea Stallion as HEAVY aircraft if leading and MEDIUM aircraft if following.
## 10. ATC WAKE TURBULENCE SEPARATION MINIMA

### 10.1 Time-based separation

<table>
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<tr>
<th>Aircraft Categories</th>
<th>Leading Aircraft</th>
<th>Following Aircraft</th>
<th>Arrival</th>
<th>Displaced Landing Threshold</th>
<th>Opposite Direction</th>
<th>Departure– Full Length</th>
<th>Departure – Intermediate *</th>
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*Intermediate minima will be applied when the following aircraft will depart from the same runway, or a parallel runway separated by less than 760M from a point more than 150M after the take-off commencement point of the preceding aircraft.*
10.2 **Distance-based separation**

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<th>Aircraft Categories</th>
<th>Distance Separation Minima</th>
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11. **ACKNOWLEDGEMENTS**


12. **CANCELLATION**

12.1 This AIC provides information of an ongoing nature and has no cancellation date.

13. **DISTRIBUTION**

13.1 By Airservices Australia website only.