



# *Wake Turbulence*



**/// CIVIL AVIATION AUTHORITY  
OF NEW ZEALAND**



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## CAA Web Site

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[www.caa.govt.nz](http://www.caa.govt.nz)

# Wake Turbulence

All pilots need to be aware of wake turbulence. Depending on the type of aircraft, the phase of flight, and the weather conditions, the potential effect of an aircraft's wake turbulence on other aircraft can vary. Encountering wake turbulence can be especially hazardous during the landing and takeoff phases of flight, where the aircraft's close proximity to the ground makes a recovery from the turbulence-induced problems more difficult.



*Photograph: Paul Bowen*

*Photograph series above: The RNZAF airtrainer was caught in a wake vortex while landing. Photographs courtesy of Brian Greenwood.*

*Cover: Wake vortices generated behind a light agricultural aircraft (Thrush Commander) in a wake vortex study conducted by NASA. Photograph courtesy of NASA Langley Research Center.*

Every effort is made to ensure that the information in this booklet is accurate and up-to-date at the time of publishing, but many changes can occur over time, especially in regard to airspace and legislation. Readers are reminded to obtain appropriate up-to-date information.



## What is Wake Turbulence?

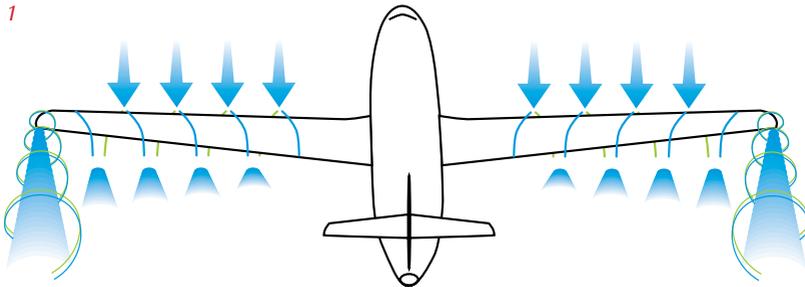
All aircraft produce wake turbulence<sup>1</sup>, more correctly called wingtip vortices or wake vortices. Wake vortices are formed any time an aerofoil is producing lift. Lift is generated by the creation of a pressure differential over the wing surfaces. The lowest pressure occurs over the upper surface of the wing, and the highest pressure is formed under the wing. Air will always want to move towards the area of lower pressure. This causes it to move outwards under the wing towards the wingtip and curl up and over the upper surface of the wing. This starts the wake vortex.

The same pressure differential also causes air to move inwards over the wing. Small trailing edge vortices, formed by outward and inward moving streams of air meeting at the trailing edge, move outwards to the wingtip and join the large wingtip vortex. Swirling air masses trail downstream of the wingtips. Viewed from behind, the left vortex rotates clockwise and the right vortex rotates counter-clockwise (see Figure 1).

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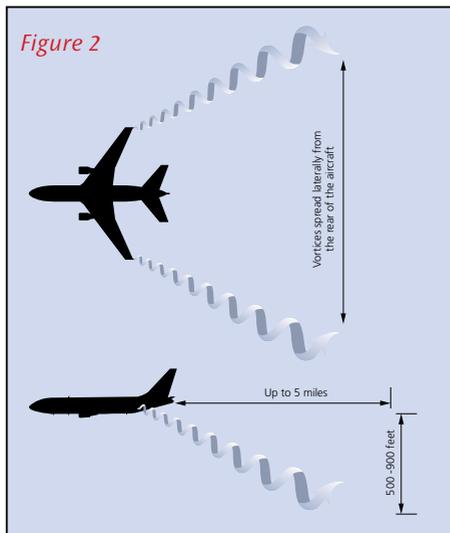
<sup>1</sup> The definition of wake turbulence also includes jet blast, propeller wash and rotor wash.

*Figure 1*



*Viewed from behind the generating aircraft, the left vortex rotates clockwise and the right vortex rotates counter-clockwise.*

Typically, a vortex develops a circular motion around a core region. The core size can vary in size from only a few centimetres in diameter to a metre or more, depending on the type of aircraft. From larger aircraft, the speed of the air inside this core can be up to 100 metres per second. The core is surrounded by an outer region of the vortex, as large as 30 metres in diameter, with air moving at speeds that decrease as the distance from the core increases (see Figure 2). Wake vortices can persist for three minutes, or longer, in certain conditions.



*Wake vortices spread laterally away from the aircraft and descend approximately 500 to 900 feet at distances of up to five miles behind it. These vortices tend to descend at approximately 300 to 500 feet per minute during the first 30 seconds.*

## Effects of Wake Turbulence

The greatest hazard from wake turbulence is induced roll and yaw. This is especially dangerous during takeoff and landing when there is little altitude for recovery. Aircraft with short wingspans are most affected by wake turbulence.

The effect of wake turbulence on an aircraft depends on many factors, including the weight and the wingspan of the following aircraft and relative positions of the following aircraft and wake vortices. In its mildest form, you may only experience a slight rocking of the wings, similar to flying through mechanical turbulence. In its most severe form, a complete loss of control of the aircraft may occur. The potential to recover from severe forms of wake turbulence will depend on altitude, manoeuvrability and power of your aircraft.

In general, you can expect induced roll and yaw. Small aircraft following larger aircraft may often be displaced more than 30 degrees in roll. Depending on the location of the trailing aircraft relative to the wake vortices, it is most common to be rolled in both directions.

The most dangerous situation is for a small aircraft to fly directly into the wake of a larger aircraft. This usually occurs while flying beneath the flight path of the larger aircraft. Flight tests conducted in this situation have shown that it is not uncommon for severe rolling motions

to occur with loss of control. In other instances, if the aircraft is flown between the vortices, high roll rates can coincide with very high sink rates in excess of 1000 feet per minute. Depending on the altitude, the outcome could be tragic.

Flight tests conducted by pilots attempting to fly into the vortex at a slightly skewed angle resulted in a combination of pitching and rolling, which typically deflects the aircraft away from the wake. Research shows the greatest potential for a wake turbulence incident occurs when a light aircraft is turning from base to final behind a heavy aircraft flying a straight-in approach. The light aircraft crosses the wake vortices at right angles, resulting in short-lived pitching motions that can result in structural damage to the aircraft from a sudden increase in load factors.

## Intensity and Persistence

The initial intensity of the wake vortices is determined by the weight, speed, configuration, wingspan and angle of attack of the aircraft. The most important variables in determining the intensity of the vortex beyond a distance of 10 to 15 wingspans from the aircraft are atmospheric stability, wind strength and direction, ground effect, and mechanical turbulence.

The strongest vortices are produced by heavy aircraft flying slowly in a clean configuration at high angles of attack.



*A CX 747-200 on approach to Kai Tak airport, Hong Kong.*



*Taken from the chequerboard at a time when there was a fire in Kowloon City, thus making the vortices very visible.*



*Photographs: Cathay Pacific 'Crews News'.*

Considerable wake vortices can also be generated by manoeuvring aircraft, for example, during aerobatics.

Aircraft with smaller wingspans generate more intense wake vortices than aircraft with equivalent weights and longer wingspans. The Boeing 757, for example, has a relatively short wing and large power plant for the weight of the aircraft. The wake turbulence that is produced by the 757 is equivalent to that of a much heavier aircraft.

Wake vortices near the ground are most persistent in light wind conditions (3 to 10 knots) in stable atmospheric conditions. Light crosswinds may cause the vortices to drift. A 3 to 5 knot crosswind will tend to keep the upwind vortex in the runway area and may cause the downwind vortex to drift toward another runway. Atmospheric turbulence generally causes them to break up more rapidly.

## Helicopters

Depending on the size of the helicopter, significant wake turbulence can be generated. Helicopter wakes may be of significantly greater strength than those from fixed-wing aircraft of similar weight. The strongest wake turbulence can occur when the helicopter is operating at lower speeds (20 to 50 knots). Some mid-size or executive-class helicopters produce wake turbulence as strong as that of heavier helicopters.

The majority of accidents that involve helicopters and small aircraft occur when small aircraft are taking off or landing while

helicopters are hovering near the runway or flying in the circuit traffic pattern.

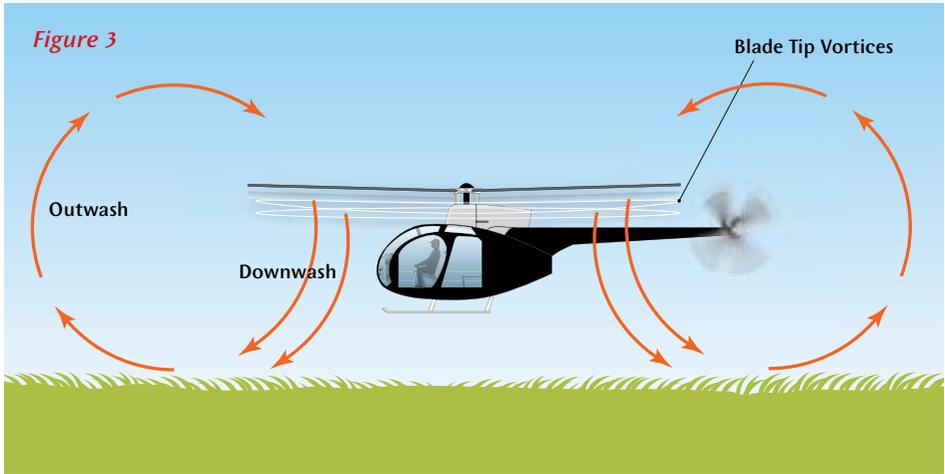
Helicopter wake turbulence takes different forms, depending on how a helicopter is flown:

- During a stationary hover or a slow hover taxi, a helicopter generates considerable downwash – high velocity outwash vortices that extend to a distance three times the diameter of the rotor (Figure 3). The outwash vortices circulate outward, upward, around and away from the main rotor (or main rotors) in all directions. It is recommended that pilots should not operate small aircraft within three rotor diameters of a helicopter in a stationary hover or a slow-hover taxi. If you are taxiing an aeroplane past a helicopter in the hover, then do so on the upwind side if possible. Helicopter pilots should be mindful of hover operations around aircraft with open doors and windows.
- During forward flight, a helicopter generates a pair of spiralling wake vortices from the rotor blades (Figure 4). Wake turbulence also occurs in the rotating air beneath the helicopter. In this situation, the wake vortices are similar to those of larger fixed-wing aircraft. It is therefore recommended that small aircraft should exercise caution when in the vicinity of a helicopter in forward flight.

Flight tests conducted by the FAA found that wake vortices were generated differently, depending on whether the helicopter was climbing or descending. The vortex cores were observed to be

closer together during ascents and further apart during descents. The wake vortices also did not sink in a predictable manner, and in some cases remained at a similar altitude to where they were generated.

The area affected by the wake turbulence of a helicopter is larger than the area affected by the wake turbulence of an aeroplane of comparable size and weight, especially at speeds below 70 knots.



*Simplified flow pattern around a helicopter during a stationary hover close to the ground.*



*Simplified wake vortices generated from a helicopter in forward flight.*

## Weight Categories

For the purpose of assessing wake turbulence separation, aircraft are divided into the following categories by their Maximum Certificated Takeoff Weight (MCTOW):

### Light (L)

Aircraft types of less than 7000 kg MCTOW – some of the heavier examples of these are: Metro 3, Cessna 402 and 421, Islander, Nomad, and Piper Navajo.



*Life Flight NZ Air Ambulance*

*The Metro can sometimes fall into the medium category of over 7000 kg MCTOW. Pilots should be aware that Metro wake turbulence can have a bigger bite than you would expect from a light category aircraft.*

### Medium (M)

Aircraft types of more than 7000 kg and less than 136,000 kg MCTOW – some examples of these are: Airbus A320, Boeing B757, B737, Dash 8, ATR–72, Saab 340, and Beech 1900D.



*Photograph: Rob Neil, courtesy of Vincent Aviation.*

### Heavy (H)

All aircraft types of 136,000 kg MCTOW or more – some examples of these are: Airbus A340, Boeing B747, B767, B777, and the McDonnell Douglas MD–11.



*Even though the B757 is a medium category aircraft, when applying following distances it is categorised as heavy.*

*Photograph: Paul Harrison.*

## Separation

ATC will apply wake turbulence separation standards as shown by Table 1 and Table 2, except for:

- Arriving VFR aircraft following a medium or heavy-weight aircraft;
- IFR aircraft on a visual approach where the pilot has reported sighting the preceding aircraft and has been instructed to follow or maintain visual separation from that aircraft.

*Note that controllers will give a wake turbulence caution in both situations.*



Table 1 shows the wake turbulence separation applied to all aircraft in all phases of flight, while under radar control. These distances apply when one aircraft is operating directly behind (within 1/2 NM laterally) another, or is crossing behind, at the same level and up to 1000 feet below. In this same situation when the separation will be less than 2 minutes, radar controllers should issue a caution of possible wake turbulence.

**Table 1 – Cruise**

Leading Aircraft	Aircraft Following or Crossing Behind	Minimum Separation Distance
Heavy	Heavy	4 NM
	Medium	5 NM
	Light	6 NM
Medium	Light	5 NM

Table 2 shows the non-radar separation standards for arriving aircraft using the same runway (or parallel runway separated by less than 760 meters) or if the projected flight paths are expected to cross at the same altitude or less than 1000 feet below.

**Table 2 – Arriving Aircraft**

Leading Aircraft	Following Aircraft	Minimum Time
Heavy	Heavy	2 Minutes
	Medium	2 Minutes
	Light	3 Minutes
Medium	Light	3 Minutes

Table 3 shows the non-radar separation standards for departing aircraft using the same runway (or parallel runway separated by less than 760 meters) or if the projected flight paths are expected to cross at the same altitude or less than 1000 feet below.

**Table 3 – Departing Aircraft**

Leading Aircraft	Following Aircraft	Minimum Spacing at Time Aircraft are Airborne	
		Departing from same takeoff position	Departing from intermediate takeoff position
Heavy	Heavy	2 Minutes	3 Minutes
	Medium		
	Light		
Medium	Light	2 Minutes	3 Minutes

These separation standards are the **minimum** and the effects of wake turbulence may still be experienced even beyond these distances.

## Pilot Options

If you consider wake turbulence separation standards are inadequate in controlled airspace, you can request increased separation. This may be achieved by vectoring, a change of flight path, or a change in the requested altitude to be above the suspected wake turbulence. Conversely, if pilots indicate that they will take responsibility for their own wake turbulence separation, then they may request exemption from these separations. This option should be treated with caution.

In New Zealand, there are no wake turbulence separation standards between two medium-weight category aircraft, or between two light-weight aircraft. In these situations it is entirely up to the pilot to ensure adequate wake turbulence separation.

At uncontrolled aerodromes it can be easy to forget about wake turbulence. There are, however, a number of uncontrolled aerodromes around New Zealand where relatively heavy-weight aircraft mix with light-weight aircraft.

## Occurrence Reporting

If you do encounter wake turbulence, the CAA would like you to report it. The overall objective in recording this detailed information is to use it to improve the level of flight safety.

### Part 12

Advisory Circular, AC12–1 *Mandatory Occurrence Notification and Information*,

defines a wake turbulence encounter during approach to land or on climb after takeoff as an aircraft incident, and as such it should be reported. Details must be provided within 14 days by the operator or organisation involved.

## ICAO Review

The International Civil Aviation Organization (ICAO) is undertaking an overall review of wake turbulence provisions, including its current wake turbulence categorisation scheme. In order to provide a sound basis for any amendments, ICAO are collecting and analysing information on the wake vortex encounters of all aircraft types on a worldwide basis.

Pilots who experience wake vortex encounters, aircraft operators who are informed of encounters, and Airways New Zealand personnel, are encouraged to report these occurrences to the CAA. The information will then be passed on to ICAO.

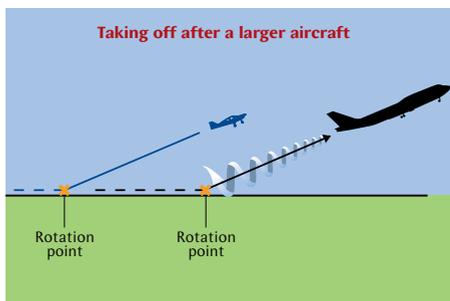
## How to Report

There are a number of ways wake turbulence encounters can be reported: by radio to the appropriate air traffic services (ATS) unit, to the operator, or by yourself.

If reporting yourself, use the ICAO forms on the CAA web site, see “Forms” – there is one for pilots, and one for air navigation service providers. Completed forms can be emailed to: ca005@caa.govt.nz, faxed to: 0–4–560 9469, or posted to: Civil Aviation Authority, PO Box 31-441, Lower Hutt 5040.

If the wake turbulence occurrence includes other aspects that you need to report to the CAA, use the usual form, CA005, and tick the “other” box in the “type of occurrence” section and write “wake turbulence”.

You are encouraged to report any wake turbulence encounter to your employer or organisation first – they can report to the CAA on your behalf.



## How to Avoid Wake Turbulence

Pilots should remember three basic warnings concerning wake turbulence:

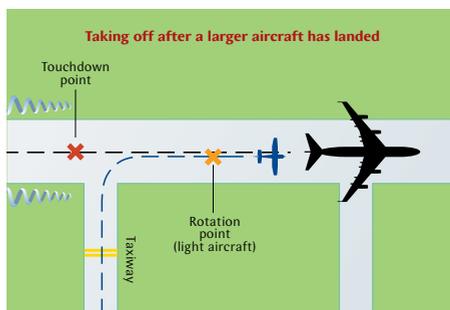
- Do not get too close to the leading aircraft.
- Do not get below the leading aircraft’s flight path.
- Be particularly wary when light wind conditions exist.

The following drawings are designed to assist your understanding of wake turbulence avoidance procedures – the distances and aircraft are not to scale.

### Takeoff

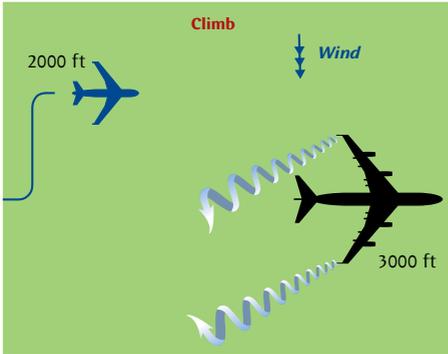
Strong wake turbulence will occur from the rotation point and during the climb as the preceding aircraft is flying slowly at a high angle of attack. It will also be present right up until the touchdown point of a landing aircraft.

During takeoff, plan to liftoff before the rotation point of the preceding aircraft and to stay upwind of the touchdown point of the landing aircraft. If you can’t do this, apply the separation standards from Tables 1, 2, or 3.



In light wind conditions, light category aircraft following aircraft at the heavier end of the light category are advised to observe the light following medium separation standards. Don’t be afraid to request a longer period of separation from the tower if you feel it is necessary.

## Climb



After takeoff; if you cannot out-climb the preceding aircraft's flight path, turn off the extended centreline as soon as possible. If you cannot deviate significantly from the preceding aircraft's flight path, track slightly upwind and parallel its course.

## Crossing

Avoid headings that cause you to cross behind and below a preceding aircraft. If you must cross behind, cross above its flight path, and if you can't do that and with terrain permitting, cross at least 1000 feet below.

## Following

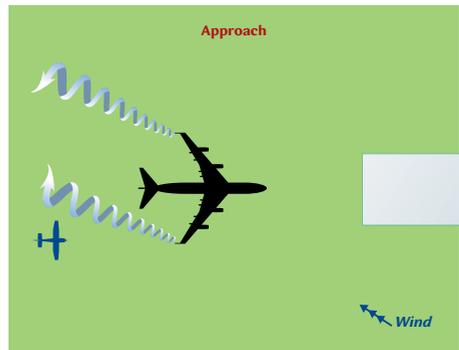
Stay either on or above the preceding aircraft's flight path. If that is not possible, use one of the methods above; either stay slightly upwind and parallel its course or with terrain permitting, stay at least 1000 feet below and well behind.

## Head On

If approaching a heavier aircraft that is less than 1000 feet above you, alter course to the upwind side to avoid the wake turbulence.

## Approach

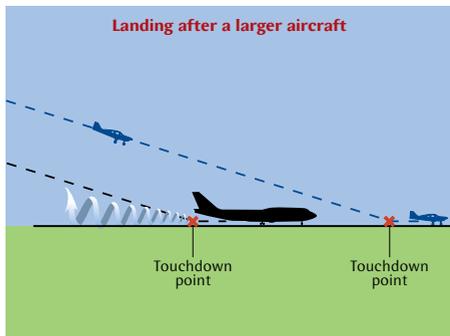
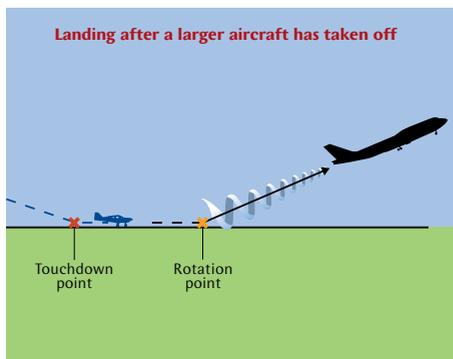
Most wake turbulence accidents occur in visual meteorological conditions. Think twice before accepting a visual approach close behind a large aircraft, as you then become responsible for maintaining your own wake turbulence separation. When flying a visual approach, do not assume the aircraft you are following is on the same or lower flight path. If practicable stay away from the localizer centreline, the larger aircraft are likely to be following it, offset your flight path slightly to the upwind side.



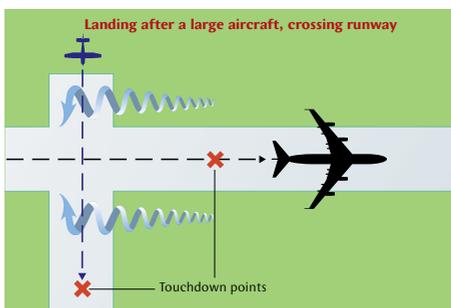
VFR pilots of slower light aircraft need to be especially wary of wake turbulence when landing at busy aerodromes with heavier aircraft on the approach.

*“VFR pilots of slower light aircraft need to be especially wary of wake turbulence when landing at busy aerodromes with heavier aircraft on the approach”*

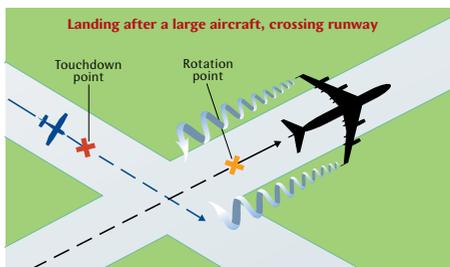
## Landing



## Crossing Runways

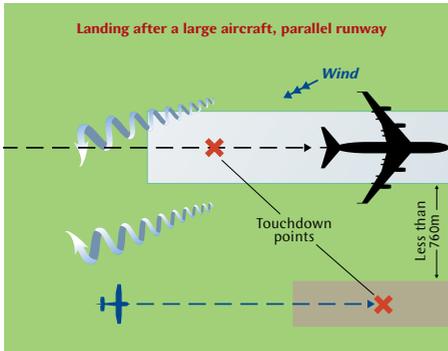


Land well before a departing aircraft's rotation point. When landing behind another aircraft stay above its flight path and if possible, land beyond its landing point. Research has identified that wake vortices in ground effect do not necessarily move laterally away from the runway, but can rebound after reaching the ground, to the height of twice the wingspan of the aircraft. Be wary of this possibility when passing over the previous aircraft's landing point.



When landing behind another aircraft on a crossing runway aim to avoid their wake by either landing over the portion affecting your runway, or by landing well before it.

## Crosswinds



Crosswinds may affect the position of wake vortices and can be very dangerous during parallel runway operations. Adjust takeoff and landing points accordingly.

## Recovery Techniques

If you unfortunately find yourself in wake turbulence, your recovery will depend on a number of factors but the following technique is suggested by Fighter Combat International (USA).

### POWER – PUSH – ROLL

**POWER** – Increase the power especially at low altitudes or slow speeds.

**PUSH** – Unload the wings or “push” on the control column until you are slightly “light in the seat.” This reduces the angle of attack of the wings which gives you better roll control with the ailerons. It also reduces the drag on the aircraft for better acceleration, and if you are rolling over, slows your descent towards the ground.

**ROLL** – If possible roll in the direction that will reduce the loading on the wings (this will depend on the direction of the roll of the vortex) or roll to the nearest horizon. If there isn’t a nearest horizon, or if you have rolling momentum, continue to roll (unloaded) in that direction to the horizon. If there is induced yaw, prompt rudder inputs will also be required.

Note that this technique is primarily designed for wake turbulence encounters for aerobatic aircraft manoeuvring in tailchase or dogfight conditions. It may work when flying at altitude, but the ability of a pilot to ‘unload’ or ‘push’ may not be that great when operating close to the ground, during takeoff or landing.

## Summary

Wake turbulence affects aircraft of all sizes and therefore all pilots need to be aware of it. Wake turbulence incidents are not confined to operations involving heavier aircraft – there are incidents involving all aircraft types.

In general, the risk of unexpected wake turbulence is greatest during the approach in visual conditions where all aircraft are maintaining their own wake turbulence separation.

Be aware of the situations where wake turbulence may be encountered, and take measures to avoid it.





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*Wake Turbulence* was revised in July 2008.  
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