



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

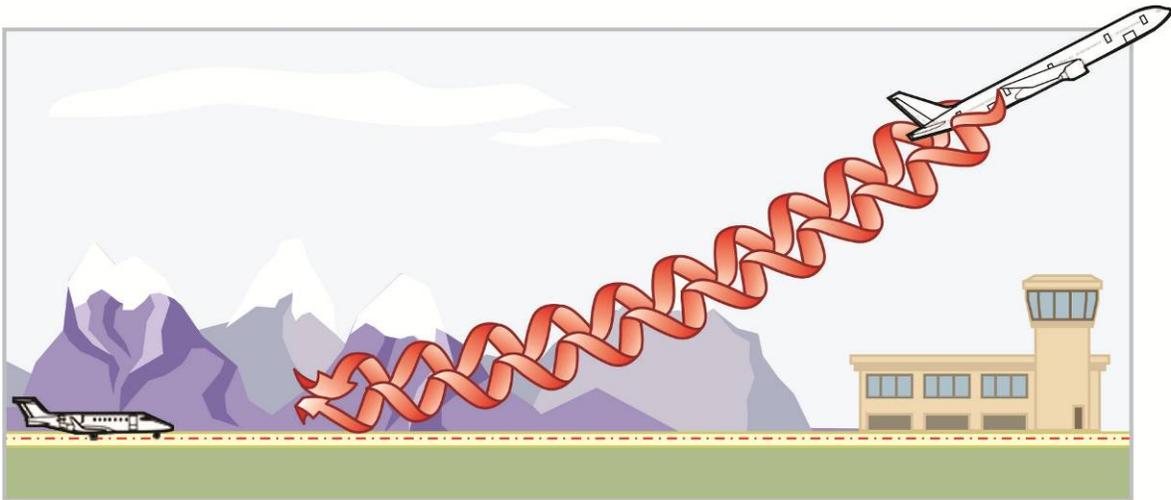
Subject: Aircraft Wake Turbulence

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Initiated by: AFS-400

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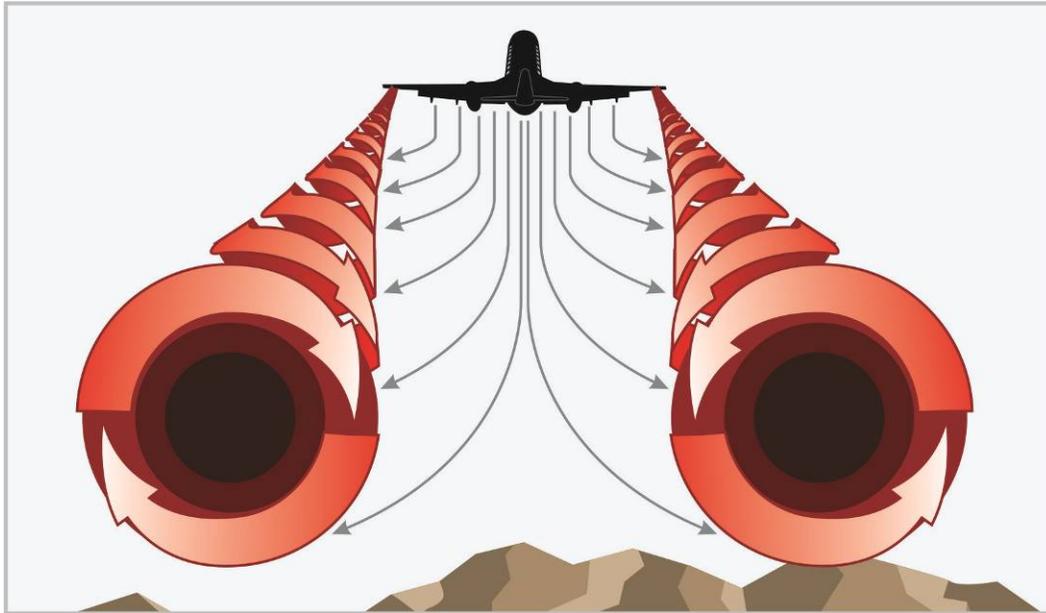


1. PURPOSE. This advisory circular (AC) presents basic information on wake vortex behavior, alerts pilots to the hazards of aircraft wake turbulence, and recommends operational procedures to avoid wake turbulence encounters.

2. CANCELLATION. AC 90-23F, Aircraft Wake Turbulence, dated February 20, 2002, is canceled.

3. INTRODUCTION. Every aircraft in flight generates wake vortices. These disturbances are caused by a pair of counter-rotating vortices trailing from the wing tips in cruise and nominally from the outboard edge of the outboard flap on approach and landing. The vortices from an aircraft can pose a hazard to encountering aircraft. For instance, the wake of larger aircraft can impose rolling moments that exceed the roll control authority of smaller encountering aircraft. Further, turbulence generated by vortices can damage aircraft components and equipment as well as cause personal injuries. Pilots must learn to envision the location and movements of the vortices generated by other aircraft and to adjust their flightpath accordingly.

4. VORTEX GENERATION. Lift is generated by the creation of a pressure differential over the wing surfaces. The lowest pressure occurs over the upper wing surface and the highest pressure under the wing. This pressure differential triggers the rollup of the airflow aft of the wing resulting in swirling air masses trailing downstream of the wing. After the rollup is complete, the wake consists of two counter-rotating cylindrical vortices (see Figure 1, The

FIGURE 1. THE ROLLUP PROCESS

5. VORTEX STRENGTH.

a. Terminal Area. The strength of the vortex is governed by the weight, speed, and wing shape and span of the generating aircraft. The extension of flaps or other wing configuring devices will change the vortex characteristics of an aircraft. However, as the factors which vary most significantly by phase of flight are weight and speed, the vortex strength increases proportionately with an increase in aircraft operating weight or decrease in aircraft speed. Peak vortex speeds up to almost 300 feet per second have been recorded. The greatest vortex strength occurs when the generating aircraft is heavy-slow-clean since the turbulence from a “dirty” aircraft configuration hastens wake decay.

b. En Route. Air density is also a factor in wake strength. Even though the speeds are higher in cruise at high altitude, the reduced air density may result in wake strength comparable to that in the terminal area. In addition, for a given separation distance, the higher speeds in cruise result in less time for the wake to decay before being encountered by another aircraft.

6. INDUCED ROLL.

a. Roll Control Capability. The most likely encountered hazard is an induced rolling moment that can exceed the roll control capability of the encountering aircraft. In flight experiments, aircraft have been intentionally flown directly through trailing vortex cores of larger aircraft. It shows that the capability of an aircraft to counteract the roll imposed by the wake vortex primarily depends on the wingspan and counter control responsiveness of the encountering aircraft.

b. Counter Control. Counter control is usually effective and induced roll minimal in cases where the wingspan and ailerons of the encountering aircraft extend beyond the rotational flow field of the vortex. It is more difficult for aircraft with short wingspans (relative to the vortex-generating aircraft) to counter the imposed roll induced by vortex flow (see Figure 2, Induced Roll). Pilots of short-span aircraft, even of the high performance type, must be especially alert to vortex encounters. The wake of larger aircraft requires the respect of all pilots (see Figure 3, Wake vs. Aircraft Size).

FIGURE 2. INDUCED ROLL

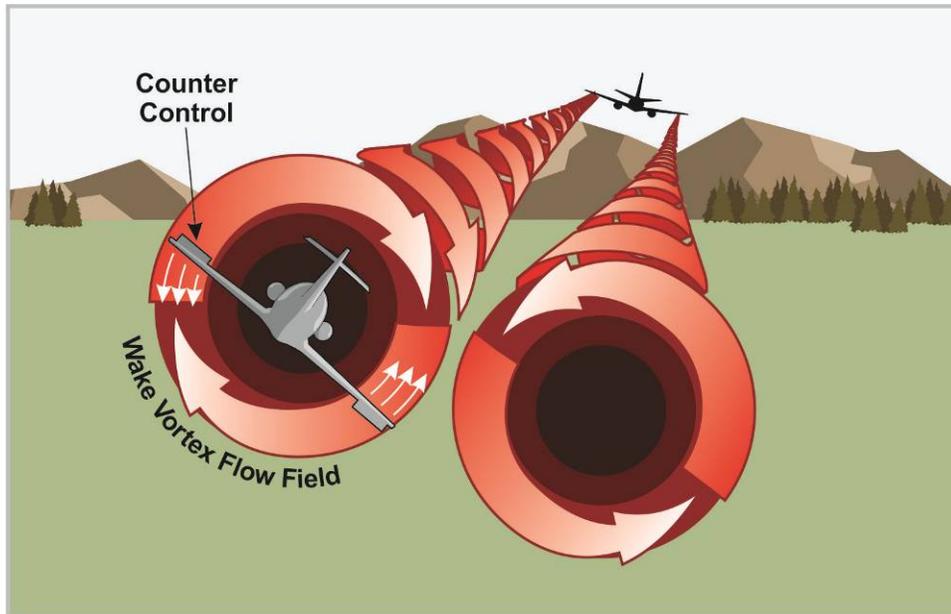
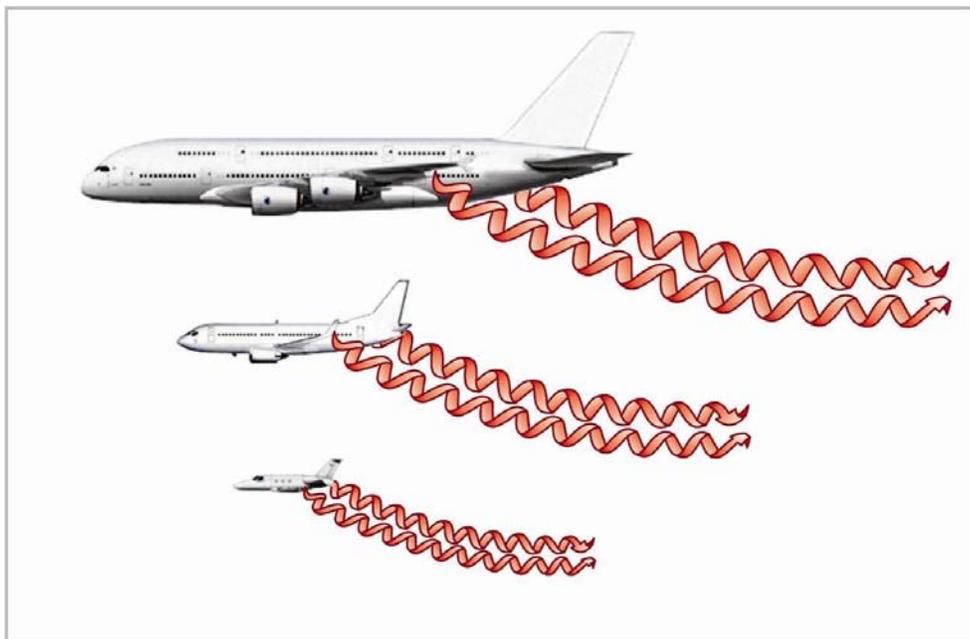


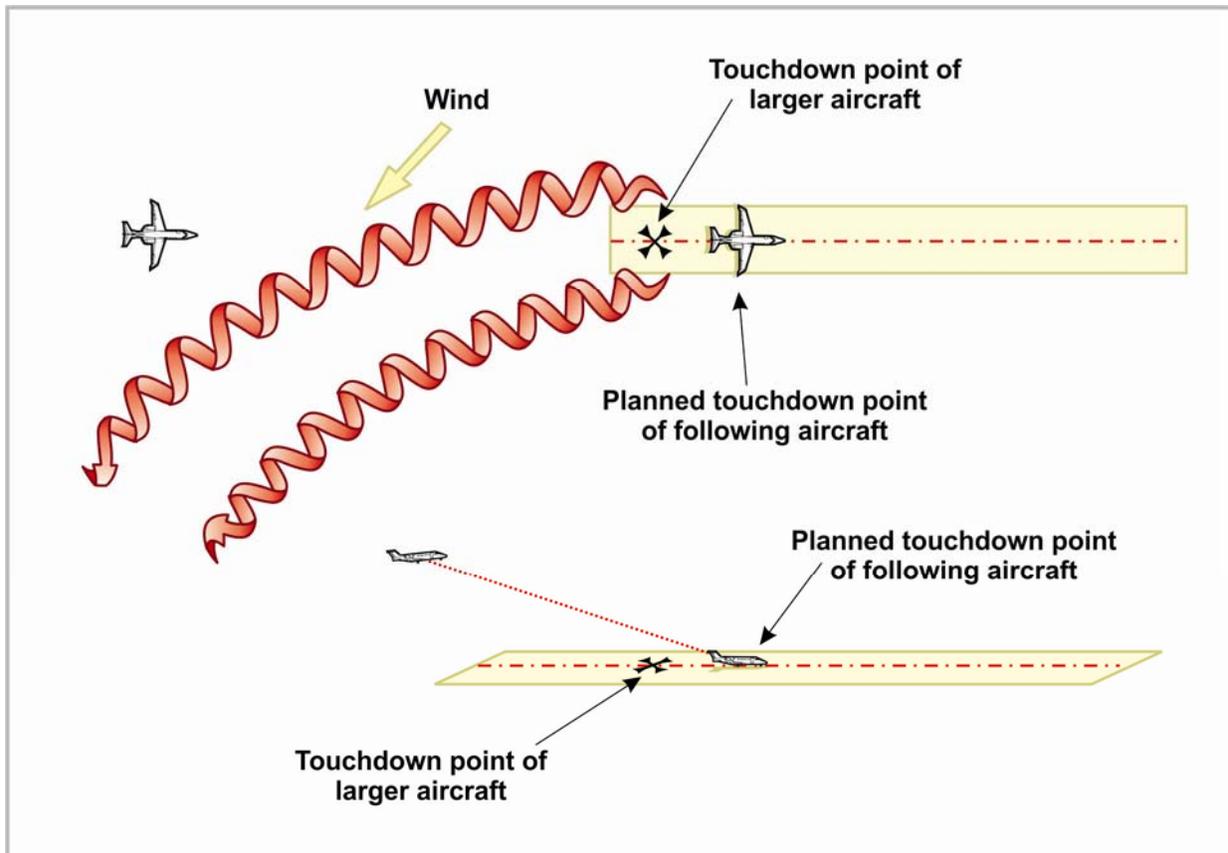
FIGURE 3. WAKE VS. AIRCRAFT SIZE



7. VORTEX BEHAVIOR. Trailing vortices have certain behavioral characteristics which can help pilots visualize the wake location and movement and take appropriate avoidance actions.

a. Vortex Generation. An aircraft generates vortices from the moment it rotates on takeoff to touchdown, since trailing vortices are a by-product of wing lift. Prior to takeoff or landing, pilots should note the rotation or touchdown point of the preceding aircraft (see Figure 4, Touchdown Points of Preceding and Following Aircraft).

FIGURE 4. TOUCHDOWN POINTS OF PRECEDING AND FOLLOWING AIRCRAFT

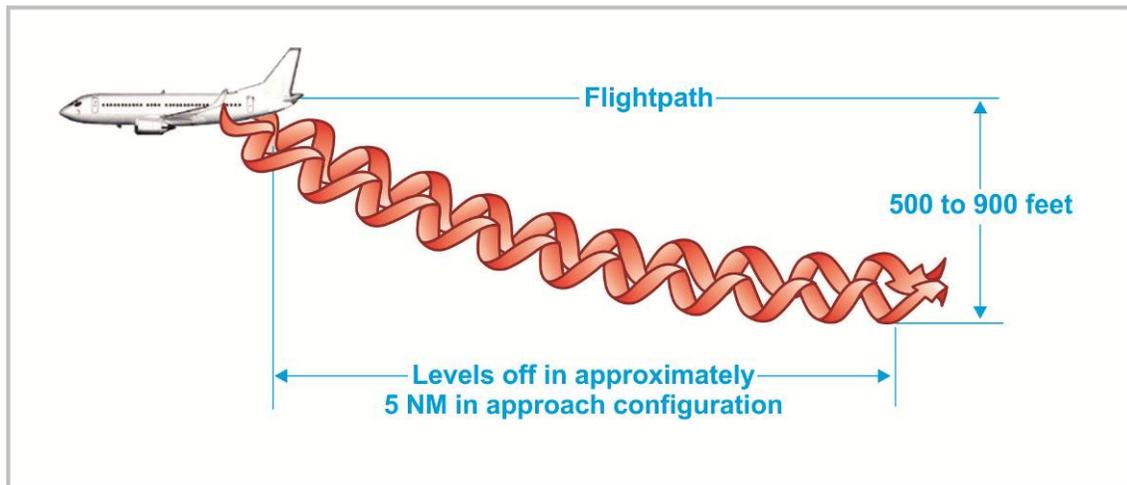


b. Vortex Circulation. The vortex circulation is outward, upward, and around the wing tips when viewed from either ahead or behind the aircraft. Tests with large aircraft have shown that the vortices remain spaced slightly less than a wingspan apart, drifting with the wind at altitudes greater than a wingspan from the ground. If persistent vortex turbulence is encountered, a slight change of altitude or lateral position (preferably upwind) will likely provide a flightpath clear of the turbulence.

c. Vertical Movement. Flight tests have shown that at higher altitude the vortices from large aircraft sink at a rate of several hundred feet per minute (fpm), slowing their descent and diminishing in strength with time and distance behind the wake-generating aircraft (see Figure 5, Descent of Vortices from Large Aircraft). Atmospheric turbulence hastens decay. Pilots should fly at or above the preceding aircraft's flightpath, altering course as necessary, to avoid the area behind and below the generating aircraft. It is also important that pilots of larger aircraft fly on

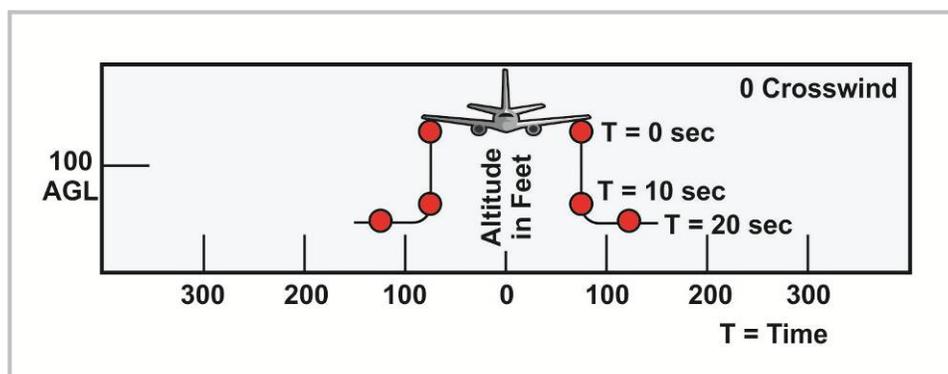
the glideslope (GS), not above it, whenever possible to minimize vortex exposure to other aircraft. The worst case atmospheric conditions are light winds, low atmospheric turbulence, and low stratification (stable atmosphere). In these atmospheric conditions, primarily in en route operations, vortices from Heavy and especially Super aircraft can descend more than 1,000 feet. In rare cases, wake turbulence can rise in an updraft or when it bounces off of a strong inversion layer where the strong inversion layer acts like the ground.

FIGURE 5. DESCENT OF VORTICES FROM LARGE AIRCRAFT



d. Lateral Movement. When the vortices of large aircraft sink close to the ground (within 100 to 200 feet), they tend to move laterally over the ground at a speed of 2 or 3 knots at an altitude of slightly less than one-half the wingspan (see Figure 6, Movement of Vortices from Low-Flying Large Aircraft).

FIGURE 6. MOVEMENT OF VORTICES FROM LOW-FLYING LARGE AIRCRAFT



e. Wind. A crosswind will decrease the lateral movement of the upwind vortex and increase the movement of the downwind vortex. Thus, a light wind with a cross-runway component of 1 to 5 knots (depending on conditions) could result in the upwind vortex remaining in the touchdown zone (TDZ) for a period of time and hasten the drift of the downwind vortex away from the runway (possibly toward an adjacent runway if one exists). Similarly, a tailwind condition can move the vortices of the preceding aircraft forward into the final approach and

TDZ. A light quartering tailwind requires maximum caution, as it presents a worst case scenario where a wake vortex could more likely be present along the final approach and TDZ. Pilots should be alert to larger aircraft upwind from their approach and takeoff flightpaths. See Figure 7, Effect of 3-Knot Crosswind on Vortices from Low Flying Aircraft, and Figure 8, Effect of 6-Knot Crosswind on Vortices from Low Flying Aircraft.

FIGURE 7. EFFECT OF 3-KNOT CROSSWIND ON VORTICES FROM LOW FLYING AIRCRAFT

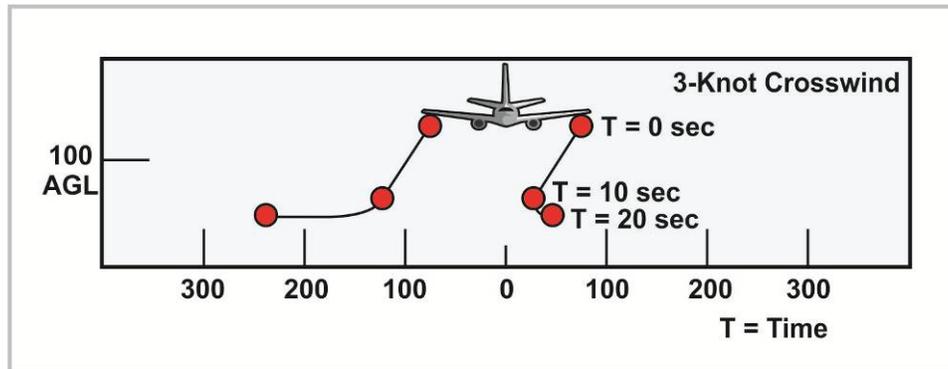
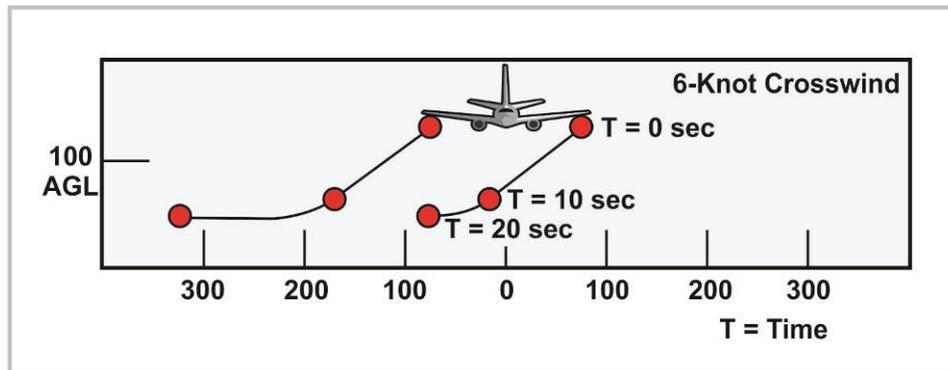


FIGURE 8. EFFECT OF 6-KNOT CROSSWIND ON VORTICES FROM LOW FLYING AIRCRAFT



8. VORTEX AVOIDANCE PROCEDURES.

a. Air Traffic Control (ATC) Responsibilities. Air traffic controllers apply procedures for separating instrument flight rules (IFR) aircraft that include required wake turbulence separations. However, if a pilot accepts a clearance to visually follow a preceding aircraft, the pilot accepts responsibility for both separation and wake turbulence avoidance. The controllers will also provide a Wake Turbulence Cautionary Advisory to pilots of visual flight rules (VFR) aircraft, with whom they are in communication and on whom, in the controller's opinion, wake turbulence may have an adverse effect. This advisory 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.

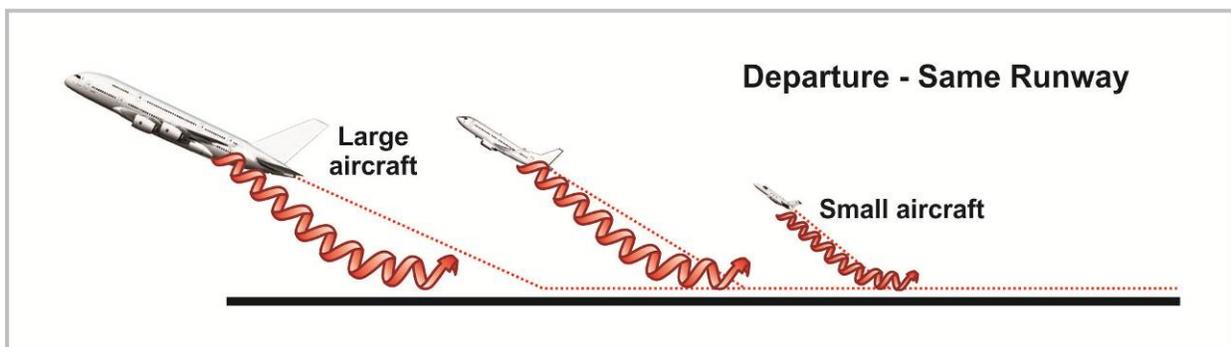
NOTE: Whether or not a warning or information has been given, the pilot is expected to adjust aircraft operations and flightpath as necessary to preclude wake encounters.

NOTE: When any doubt exists about maintaining safe separation distances between aircraft to avoid wake turbulence, pilots should ask ATC for updates on separation distance and groundspeed.

b. Departing Behind a Larger Aircraft—Same Runway. When departing behind a larger aircraft on the same runway, pilots should:

- (1) Note the larger aircraft's rotation point and rotate prior to the larger aircraft's rotation point.
- (2) Continue climb above the larger aircraft's climb path until turning clear of the wake (see Figure 9, Departing Same Runway Behind a Larger Aircraft).
- (3) Avoid subsequent headings which will cross below and behind the larger aircraft (see Figure 10, Critical Takeoff Situation and Crossing Departure Courses).
- (4) Be alert for any critical takeoff situation which could lead to a vortex encounter.

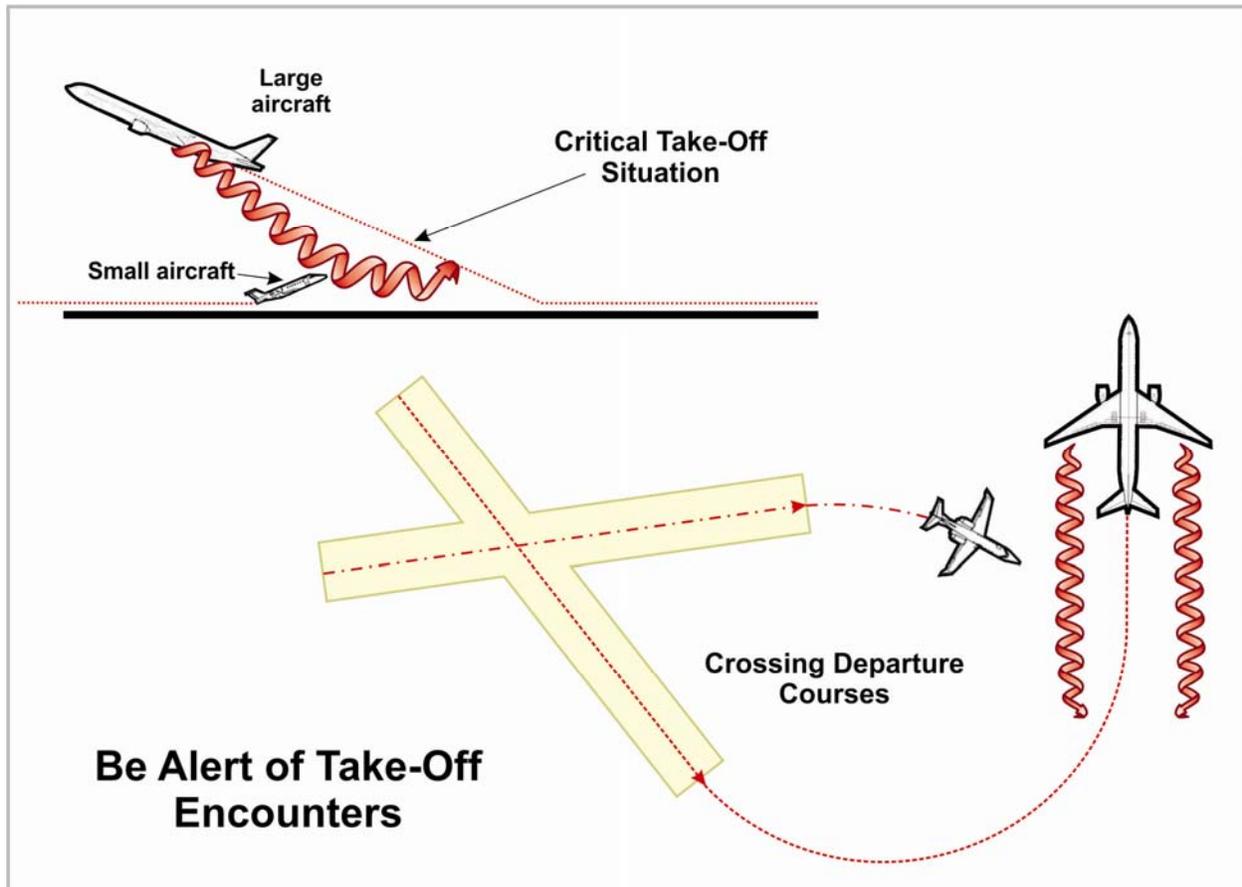
FIGURE 9. DEPARTING SAME RUNWAY BEHIND A LARGER AIRCRAFT



c. Intersection Takeoffs. When conducting intersection takeoffs, pilots should note the larger aircraft's rotation point and rotate prior to the larger aircraft's rotation point. Also, be alert to adjacent large aircraft operations, particularly upwind of your runway. If intersection takeoff clearance is received, avoid a flightpath which will cross below a larger aircraft's flightpath.

d. 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 takeoff or landing (and at least 3 minutes when operating behind super aircraft).

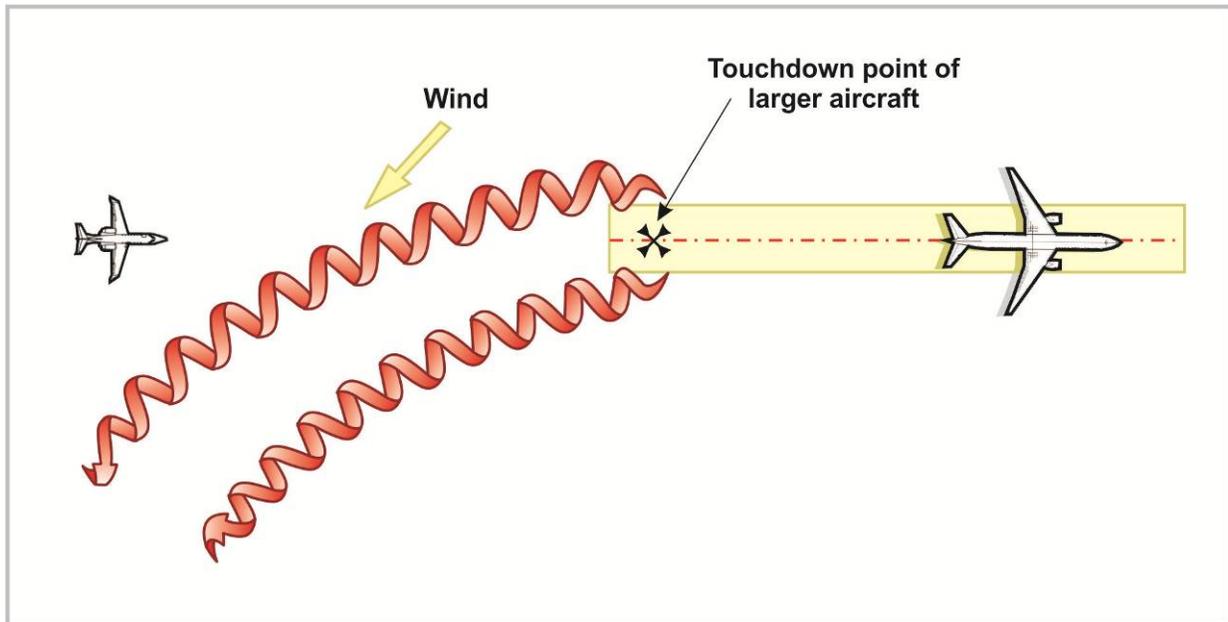
FIGURE 10. CRITICAL TAKEOFF SITUATION AND CROSSING DEPARTURE COURSES



e. En Route VFR (500 Feet Separation). 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.

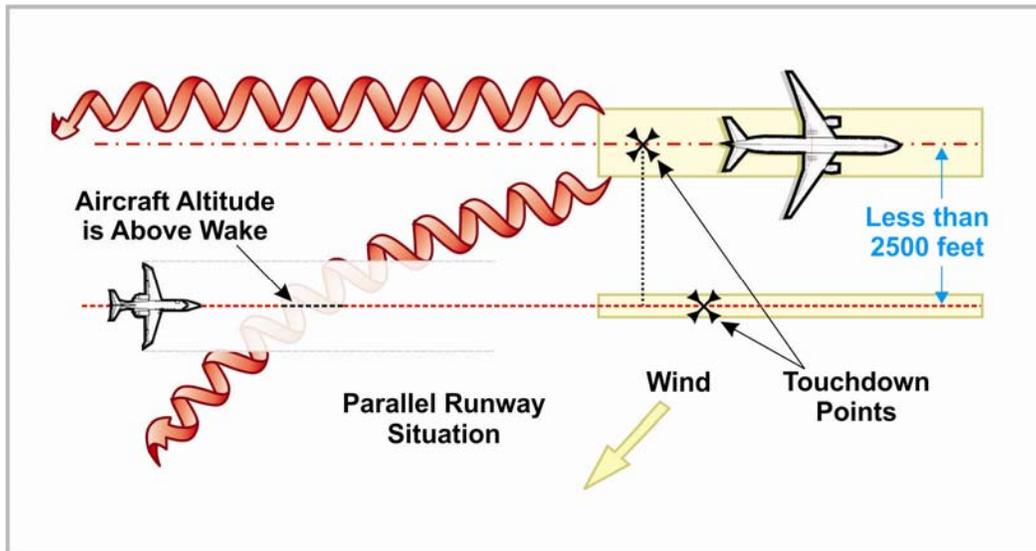
f. Landing Behind a Larger Aircraft—Same Runway. When landing behind a larger aircraft on the same runway stay at or above the larger aircraft's final approach flightpath. Note the touchdown point and land beyond it (see Figure 11, Avoidance Procedures Landing Behind Larger Aircraft on the Same Runway). See paragraph 11 for special procedures applicable to large, heavy, and super aircraft.

FIGURE 11. AVOIDANCE PROCEDURES LANDING BEHIND LARGER AIRCRAFT ON THE SAME RUNWAY



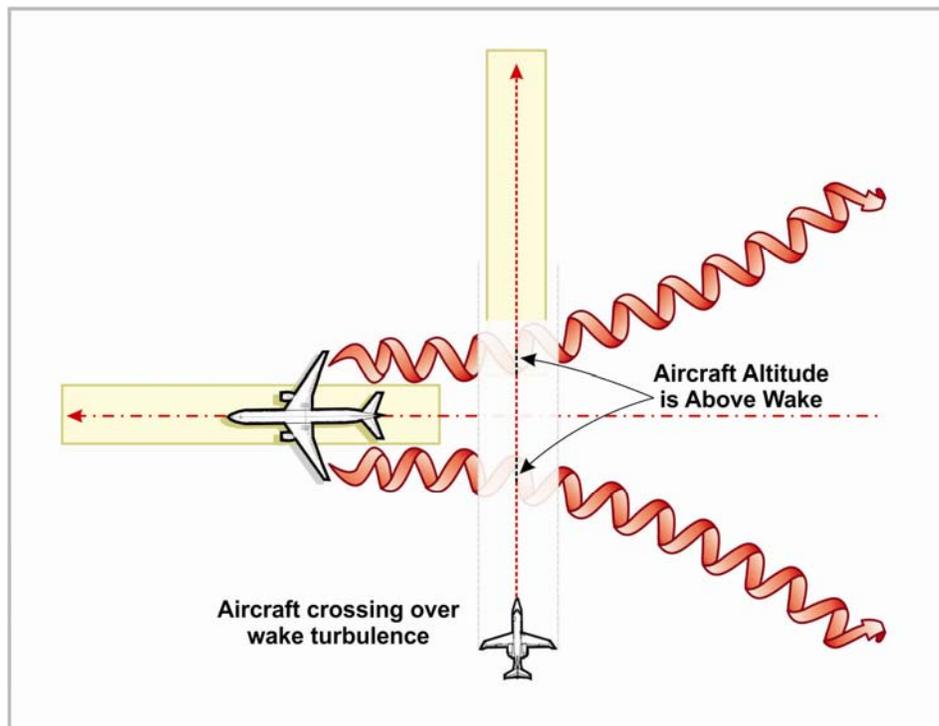
g. Landing Behind a Larger Aircraft—On a Parallel Runway Closer Than 2,500 Feet Apart. When landing behind a larger aircraft on a parallel runway closer than 2,500 feet apart (Figure 12), pilots need to consider the relationship between the runway threshold locations, the relative GS descent paths/locations and possible vortex drift onto your runway (see paragraph 12 for aircraft classification definitions). 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 12, Avoidance Procedure Landing on Parallel Runways Closer than 2,500 Feet.

FIGURE 12. AVOIDANCE PROCEDURE LANDING ON PARALLEL RUNWAYS CLOSER THAN 2,500 FEET



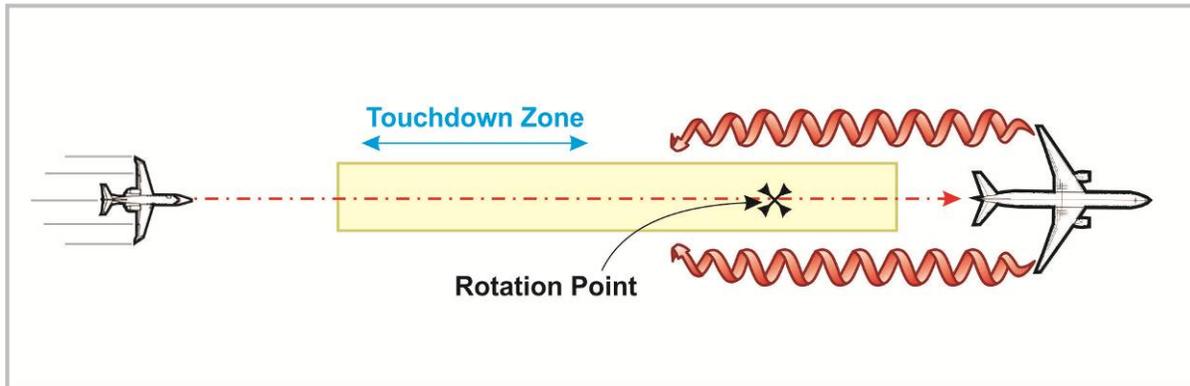
h. Landing Behind a Larger Aircraft—Crossing Runway. When landing behind a larger aircraft on a crossing runway, pilots should cross above the larger aircraft’s flightpath (see Figure 13, Avoidance Procedure for Landing Behind Larger Aircraft That is Using a Crossing Runway (No Wind)).

FIGURE 13. AVOIDANCE PROCEDURE FOR LANDING BEHIND LARGER AIRCRAFT THAT IS USING A CROSSING RUNWAY (NO WIND)



i. 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 land well before the rotation point (see Figure 14, Avoidance When Landing Behind a Departing Aircraft on the Same Runway).

FIGURE 14. AVOIDANCE WHEN LANDING BEHIND A DEPARTING AIRCRAFT ON THE SAME RUNWAY



j. 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. Abandon the approach unless a landing is ensured well before reaching the intersection (see Figure 15, Avoidance for Landing Behind Departing Larger Aircraft on a Crossing Runway When Rotation Point is Past the Intersection, and Figure 16, Avoidance for Landing When Larger Departing Aircraft Rotates Prior to the Intersection).

FIGURE 15. AVOIDANCE FOR LANDING BEHIND DEPARTING LARGER AIRCRAFT ON A CROSSING RUNWAY WHEN ROTATION POINT IS PAST THE INTERSECTION

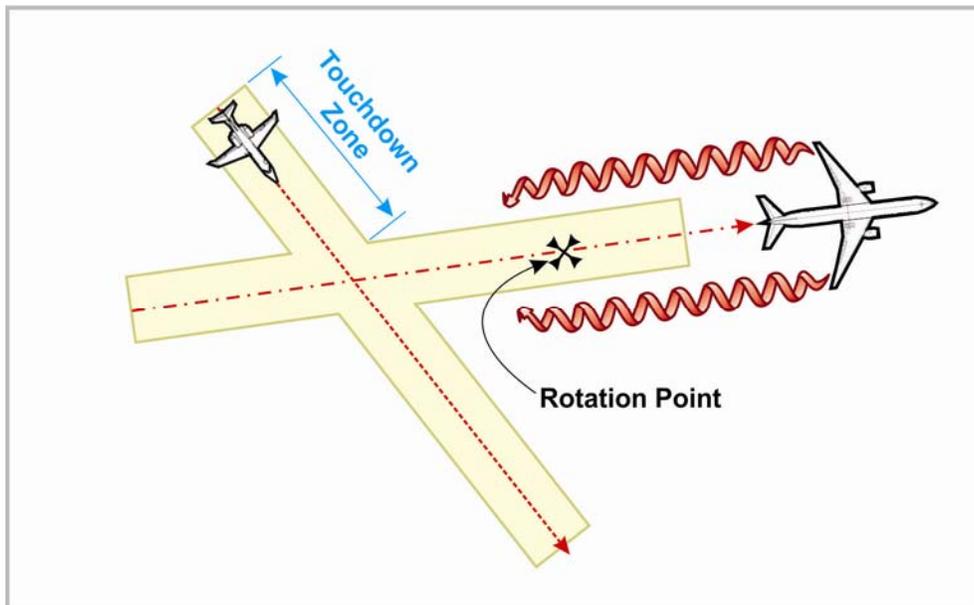
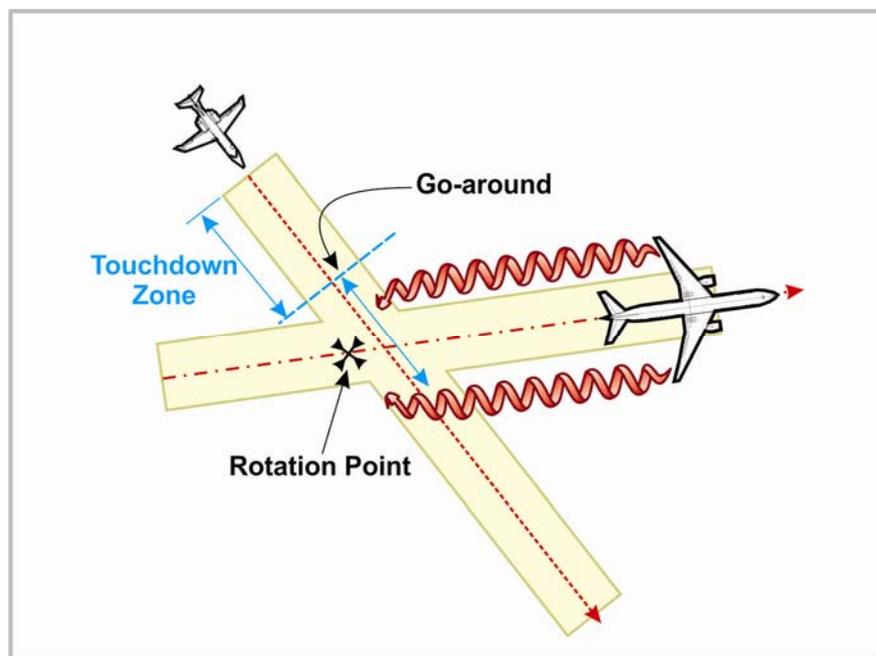


FIGURE 16. AVOIDANCE FOR LANDING WHEN LARGER DEPARTING AIRCRAFT ROTATES PRIOR TO THE INTERSECTION



9. VORTEX ENCOUNTER GUIDANCE.

a. Probability of Hazard. A wake encounter is not necessarily hazardous. It can be one or more jolts with varying severity depending upon the direction of the encounter (intercept angle),

weight and configuration of the generating aircraft, size of the encountering aircraft, distance from the generating aircraft, and point of vortex encounter. The probability of induced roll increases when the encountering aircraft's heading is generally aligned or parallel with the flightpath of the generating aircraft. Avoid the area below and behind the generating aircraft, especially at low altitude where even a momentary wake encounter could be hazardous. Pilots should be particularly alert in calm wind conditions and maneuvering situations in the vicinity of the airport where the vortices could:

- (1) Remain in the touchdown area,
- (2) Drift from aircraft operating on a nearby runway,
- (3) Sink into takeoff or landing path from a crossing runway, or
- (4) Sink into the traffic patterns from other airport operations.

b. Visualize the Vortex Trail. Pilots of all aircraft should visualize the location of the vortex trail behind larger aircraft and use proper vortex avoidance procedures to achieve safe operation. It is also important that pilots of larger aircraft fly on the GS, not above it, whenever possible, to minimize vortex exposure to other aircraft.

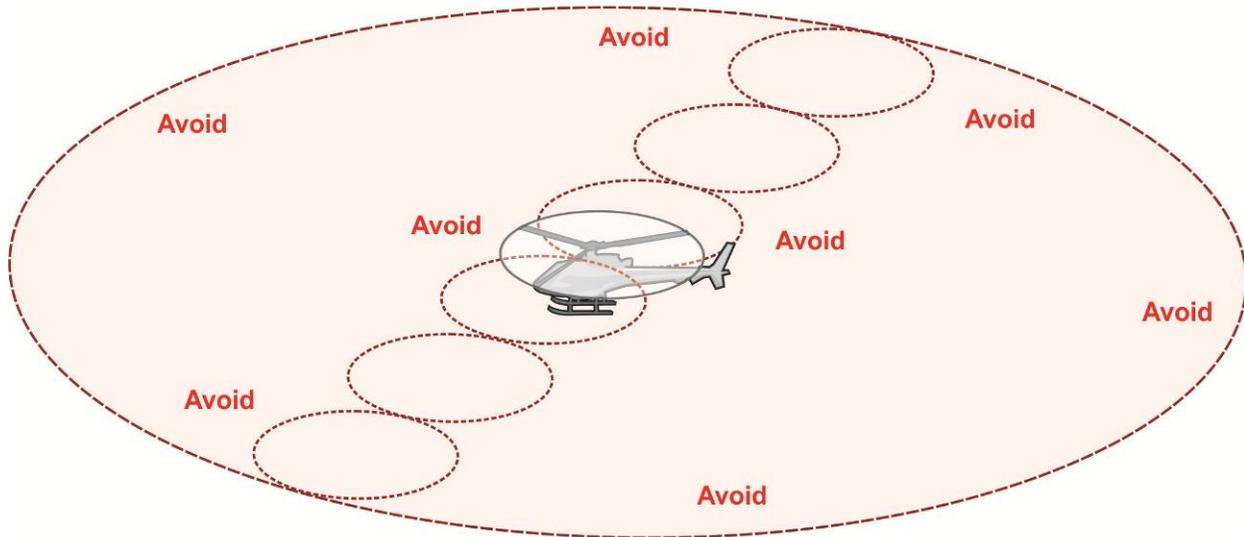
c. Control Inputs. There is a history of wake vortex encounter incidents in which pilot inputs exacerbated the unusual attitude situation caused by the wake vortex encounter. Upsets caused by wake vortex encounters may involve rapid roll reversals as the aircraft transitions across the wake. Pilots should 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. 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.

d. Rudder Inputs. Prior experience or training that emphasizes use of rudder input as a means to maneuver in roll may not apply to all aircraft operations. Using the rudder to counter roll rate during a roll upset may lead to an undesirable aircraft response. Large, aggressive control reversals can lead to loads that can exceed the structural design limits. Refer to your specific Aircraft Flight Manual (AFM) guidance.

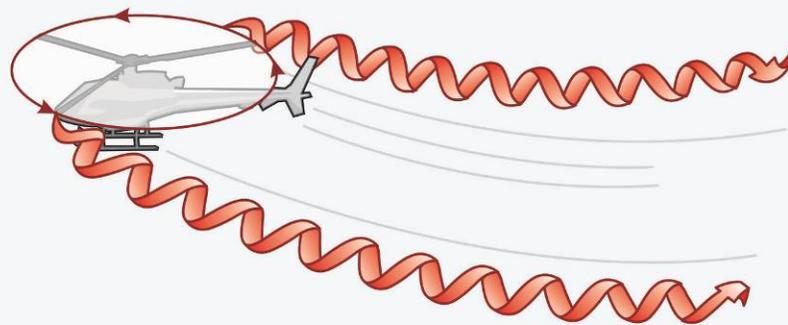
10. HELICOPTERS. A hovering helicopter generates a downwash from its main rotor(s). Pilots should avoid taxiing or flying within a distance of three rotor diameters of a helicopter hovering or in a slow hover taxi, as the downwash can contain high wind speeds. However, in forward flight, this energy is transformed into a pair of strong, high-speed, trailing vortices similar to wing-tip vortices of larger fixed-wing aircraft. Pilots should avoid helicopter vortices since helicopter forward flight airspeeds are often very low, which generate strong wake turbulence (see Figure 17, Helicopter Vortices).

FIGURE 17. HELICOPTER VORTICES

**Slow Hover Taxi or Stationary Hover:
Avoid Operations Within Distances of 3 Times
Rotor Diameter**



**Forward Flight, Landing and Departing Helicopters:
Small Aircraft, Use Caution Behind/Crossing Behind**



11. PILOT RESPONSIBILITY.

a. Vortex Avoidance. Government and industry groups are making concerted efforts to minimize or eliminate the hazards of trailing vortices. However, the pilot must exercise the flight awareness necessary to ensure vortex avoidance during visual meteorological conditions (VMC).

The pilot should exercise vortex visualization and avoidance procedures using the same degree of awareness as in collision avoidance.

b. ATC Instructions. Pilots should remember that, in operations conducted behind all aircraft, acceptance of instructions from ATC in the following situations is an acknowledgment that they will ensure safe takeoff and landing intervals, and accept the responsibility for providing wake turbulence separation:

- (1) Traffic information,
- (2) Instructions to follow an aircraft, and
- (3) Acceptance of a visual approach clearance.

c. Identify Heavy or Super Aircraft. For operations conducted behind Heavy or Super aircraft, ATC will specify the word “Heavy” or “Super” when this information is known. Pilots of these aircraft should always use the appropriately designated weight identifying term in radio communication within the terminal area.

d. Flying on the Glidepath. Larger aircraft operators should make every attempt to fly on the glidepath, not above it, whenever possible, to minimize vortex exposure to other aircraft. These procedures establish 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 GS indication, pilots should use a “300 ft to 1 mile” glidepath.

EXAMPLE: Fly 3,000 feet at 10 miles from touchdown, 1,500 feet at 5 miles, 1,200 feet at 4 miles, and so on, to touchdown.

e. Techniques for Lighter Aircraft. Pilots operating lighter aircraft behind aircraft producing strong wake vortices should consider the following techniques to assist in avoiding wake turbulence and should be aware of the wind direction and speed along the final approach path:

(1) If the pilot of the smaller following aircraft has visual contact with the preceding, larger aircraft and also with the runway, the pilot may further adjust the flightpath to avoid possible wake vortex turbulence by:

(a) Flying slightly above the glidepath and maintain that glidepath to a touchdown point beyond the touchdown point of the larger preceding aircraft.

(b) Establishing a line of sight to a touchdown point that is above and beyond the larger preceding aircraft.

(c) When possible, noting the touchdown point of the larger preceding aircraft and adjusting your 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 500 feet beyond. Be

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

(d) Landing beyond the point of landing of the preceding larger aircraft.

(2) During visual approaches, pilots may ask ATC for updates on separation and groundspeed 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.

12. AIRCRAFT WEIGHT CLASSES. ATC uses the following aircraft weight classes for the purposes of wake turbulence separation minima:

a. Heavy. Aircraft capable of takeoff weights of 300,000 pounds or greater, whether or not they are operating at this weight during a particular phase of flight.

NOTE: A new class, the Super, above the Heavy class, has been approved on an interim basis for aircraft such as the Airbus A380 and Antonov AN225.

b. Large. Aircraft of more than 41,000 pounds maximum certificated takeoff weight up to, but not including, 300,000 pounds.

NOTE: The Boeing B757 is classified as a Large, but special wake turbulence separation criteria apply.

c. Small. Aircraft of 41,000 pounds or less maximum certificated takeoff weight.

TABLE 1. FAA WAKE SEPARATION STANDARDS (AT THE THRESHOLD)

| Leader/Follower | Super | Heavy | B757 | Large | Small |
|-----------------|-------|-------|------|-------|-------|
| Super | MRS | 6 | 7 | 7 | 8 |
| Heavy | MRS | 4 | 5 | 5 | 6 |
| B757 | MRS | 4 | 4 | 4 | 5 |
| Large | MRS | MRS | MRS | MRS | 4 |
| Small | MRS | MRS | MRS | MRS | MRS |

NOTE: MRS: Minimum Radar Separation.

13. ADDITIONAL PILOT CONSIDERATIONS. Serious wake vortex encounters during terminal operations are rare. Pilots should be alert for possible wake vortex encounters in the following four situations.

a. Vortex Encounters.

(1) After initially descending, vortices can rebound. Test data have shown that vortices can rise with the air mass in which they are embedded. Wind shear, particularly, can cause vortex flow field “tilting,” where the downwind vortex may rebound but with an enhanced decay rate (see Figure 7). Also, ambient thermal lifting and orographic effects (rising terrain or tree lines) can cause a vortex flow field to rise.

(2) In certain atmospheric conditions, primarily in en route operations, vortices from Heavy and especially Super aircraft can descend more than 1,000 feet. Thus, in Reduced Vertical Separation Minimum (RVSM) operations aircraft in oceanic airspace can offset from the centerline of its track for wake turbulence avoidance (refer to the current edition of AC 91-85, Authorization of Aircraft and Operators for Flight in Reduced Vertical Separation Minimum Airspace).

(3) When crossing behind a lead aircraft, try to cross above its flightpath or, terrain permitting, at least 1,000 feet below.

(4) When a lead aircraft climbs or descends through your projected flight track, vertical separation is no longer in place and a vortex encounter is possible. Similarly, use caution when climbing or descending behind other aircraft.

b. Pilot Awareness. Pilots should be alert at all times for possible wake vortex encounters, particularly during takeoff, approach and landing operations. The pilot has the ultimate responsibility for the safe operation of the aircraft. Although ATC provides appropriate wake turbulence separation to IFR aircraft, all pilots should be aware of wake behavior and avoidance techniques and should follow the guidance and good operating procedures contained in this AC, the Aeronautical Information Manual (AIM), and applicable aircraft operations manuals.

14. WINGLETS. Winglets have been developed as a means to reduce the induced drag of a wing, making it more efficient during cruise. There is a common misperception that winglets are a means to decrease the wake vortex hazard. Studies conducted during approach and landing show no discernible differences between aircraft with or without winglets.

15. NEXT GENERATION AIR TRANSPORTATION SYSTEM (NEXTGEN) WAKE TURBULENCE INITIATIVES. Based on extensive analysis of wake vortex behavior, new procedures and separation standards are being developed and implemented. Over time, it is expected that the new separation standards will be implemented National Airspace System (NAS)-wide. Eventually, wake turbulence separation may evolve into a dynamic and specific aircraft-to-aircraft relationship based on individual aircraft wake characteristics.

a. Dependent Staggered Approaches to Closely Spaced Parallel Runways (CSPR). FAA Order JO 7110.308, 1.5-Nautical Mile Dependent Approaches to Parallel Runways Spaced Less Than 2,500 Feet Apart, enables the use of dependent 1.5-nautical mile (NM) diagonal separation between two aircraft on CSPRs during instrument approaches with large and small aircraft as leaders in the pairing sequence. More information on these procedures is in Appendix 1, FAA Order JO 7110.308, 1.5 NM Dependent Approaches to Parallel Runways Spaced Less Than 2,500 Feet Apart.

b. Wake Turbulence Recategorization. The Wake Recategorization Program replaces the traditional maximum-certificated-takeoff-weight-based separation standard with a separation matrix based on wake vortex physics and aircraft dynamics parameters, namely wingspan, maximum takeoff weight (MTOW), final approach speed, and roll moment capability. More information on the program is in Appendix 2, FAA N JO 7110.608, Guidance for the

Implementation of Wake Turbulence Recategorization Separation Standards at Memphis International Airport.

c. Wake Turbulence Mitigation for Departure (WTMD). WTMD is the first automation-driven wake separation change that enables dynamic separation for departures on parallel runways separated by less than 2,500 feet based on meteorology, namely the crosswind. More information on these procedures is in Appendix 3, FAA Order JO 7110.316, Wake Turbulence Mitigation for Departures (WTMD).

NOTE: In the near term, approval to use these new procedures will be on a runway and airport basis. Other NextGen wake turbulence initiatives are expected in the future.

A handwritten signature in black ink, appearing to read "John Barbagallo". The signature is stylized with a large, sweeping initial "J" and "B".

John Barbagallo
Acting Director, Flight Standards Service

APPENDIX 1. FAA ORDER JO 7110.308, 1.5 NM DEPENDENT APPROACHES TO PARALLEL RUNWAYS SPACED LESS THAN 2,500 FEET APART

Historically, the Federal Aviation Administration (FAA) has limited the use of parallel dependent instrument landing systems (ILS) approaches to runways with centerlines 2,500 feet or farther apart. The FAA recently approved criteria that will allow the use of the parallel dependent instrument approaches for specific airport parallel runways with centerline spacing less than 2,500 feet based on known wake vortex behavior, landing threshold stagger, and/or differential glideslopes (GS).

Criteria for Use.

- Parallel dependent ILS approaches to runways less than 2,500 feet apart can be conducted at only airport/runway combinations listed in FAA Order JO 7110.308.
- A minimum of 1,000 feet vertical or a minimum of 3 miles radar separation between aircraft will be provided until established on the localizer and cleared for the approach.
- The lead aircraft of the dependent separation pair is a Small or Large aircraft and must be assigned the lower approach based on glidepath angle or threshold location and must be established on the localizer.
- Any aircraft type may participate as the trailing aircraft in the dependent pair.
- The trailing aircraft of the dependent separation pair must be assigned the higher approach and must be established on the localizer.
- The lead and trailing aircraft will be cleared for the approach before the loss of standard separation.
- Provide a minimum of 1.5 miles radar separation diagonally with pairs of lead/trailing aircraft.
- Provide standard separation between the trailing aircraft of one pair and the leader of the next pair.
- Reduced separation is not permitted if either of the aircraft in a reduced separation pair is conducting an approach without vertical guidance.
- If the lead aircraft executes a missed approach and is larger than the trailing aircraft in the pair, the trailing aircraft will be instructed to execute a missed approach.

Definitions. For the purpose of this appendix, the following definitions are provided.

a. Lead Aircraft. The lead aircraft in the pair of reduced separation aircraft, authorized by Order JO 7110.308. The lead aircraft is restricted to be a Small or Large aircraft weight type.

b. Lead Approach. The approach assigned to the lead aircraft in a reduced separation pair. For each Closely Spaced Parallel Runways (CSPR) pair identified in appendix A of Order JO 7110.308, the lead approach is listed first and is typically the lower approach.

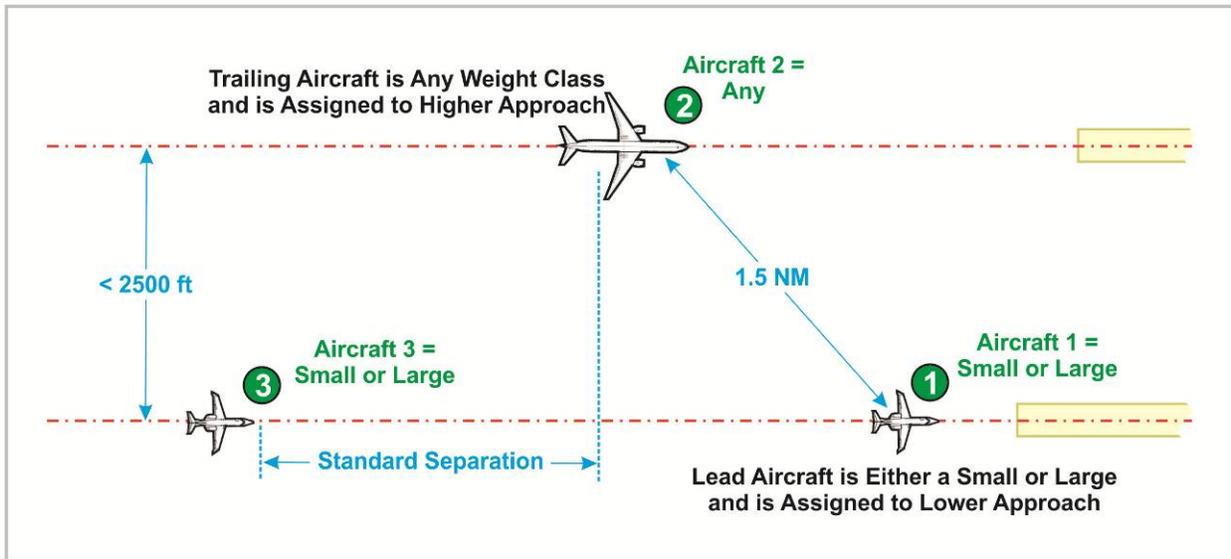
c. Higher Approach. The higher approach is the approach to the runway with the staggered landing threshold or higher glidepath angle.

d. Lower Approach. The lower approach is the approach to the runway with the nonstaggered (near) landing threshold or the lower glidepath angle.

e. Trailing Aircraft. The trailing aircraft in the pair of reduced separation aircraft, authorized by this order, and is not restricted by weight class.

f. Trailing Approach. The approach assigned to the trailing aircraft in a reduced separation pair is typically the higher approach.

FIGURE 1-1. 1.5 NM DEPENDENT APPROACHES TO PARALLEL RUNWAYS SPACED LESS THAN 2,500 FEET APART



**APPENDIX 2. FAA N JO 7110.608, GUIDANCE FOR THE IMPLEMENTATION OF
WAKE TURBULENCE RECATEGORY SEPARATION STANDARDS AT
MEMPHIS INTERNATIONAL AIRPORT**

The Federal Aviation Administration (FAA) recently approved a recategorization (RECAT) of wake turbulence separation minima from the current standard to a new standard (RECAT Phase I). This approval was based on years of joint research and development by the FAA, Eurocontrol, scientific experts in wake, and experts in safety and risk analysis. Categories are now based on weight, certificated approach speeds, and wing characteristics, along with special consideration given to aircraft with limited ability to counteract adverse rolls. RECAT places aircraft into six (6) categories (labeled A-F) for both departure and arrival separation.

Through a detailed system safety analysis, the six categories prove to be as safe, or safer, than today's total separation standards while providing the opportunity for increased efficiency for National Airspace System (NAS) operations. As RECAT is implemented at selected airports in the NAS, pilots may see changes (both reductions or increases) in the required and applied wake turbulence separation distances for some aircraft, while most will not notice any changes at all. Table 2-2 details the RECAT wake separation standards.

**NOTE: RECAT is in effect at Memphis International Airport (MEM) and
Louisville International-Standiford Field (SDF), with plans to expand to
other airports in the future.**

AIRCRAFT WAKE CATEGORIES. For the purposes of Wake Turbulence Separation Minima, aircraft are categorized as Category A through Category F. Each aircraft is assigned a category based on wingspan, approach speed and maximum takeoff weight (MTOW). Table 2-1 provides examples of some of the aircraft within the Categories:

- a. Category A.** Aircraft capable of MTOW of 300,000 pounds or more and a wingspan greater than 245 feet.
- b. Category B.** Aircraft capable of MTOW of 300,000 pounds or more and a wingspan greater than 175 feet and less than or equal to 245 feet.
- c. Category C.** Aircraft capable of a MTOW of 300,000 pounds or more and a wingspan greater than 125 feet and less than or equal to 175 feet.
- d. Category D.** Aircraft capable of a MTOW of less than 300,000 pounds and a wingspan greater than 125 feet and less than or equal to 175 feet; or aircraft with a wingspan greater than 90 feet and less than or equal to 125 feet.
- e. Category E.** Aircraft capable of a MTOW greater than 41,000 pounds with a wingspan greater than 65 feet and less than or equal to 90 feet.
- f. Category F.** Aircraft capable of a MTOW of less than 41,000 pounds and a wingspan less than or equal to 125 feet, or aircraft capable of a MTOW less than 15,500 pounds regardless of wingspan, or a powered sailplane.

TABLE 2-1. EXAMPLE AIRCRAFT ASSIGNMENT TO PROPOSED SIX CATEGORY SYSTEM

**NOTE: List is not all-inclusive. A complete list can be found at:
http://www.faa.gov/air_traffic/publications/media/aircraft_characteristics.pdf.**

| Category A | Category B | Category C | Category D | Category E | Category F |
|-------------|-------------|------------|-------------|------------|---------------------------|
| A380 | B747 series | MD11 | B757 series | AT72 | E120 |
| AN-225 | A340 series | B767 | B737 series | RJ100 | B190 |
| End of list | B777 series | A306 | A320 series | RJ85 | C650 |
| | A330 series | A310 | B727 series | B463 | H25B |
| | B787 series | DC8 | MD80 series | B462 | C525 |
| | C-5 | DC10 | F50 | E170 | GA multi-engine aircraft |
| | B-52 | C-17 | E190 | CRJ1/2 | GA single engine aircraft |
| | IL-96 | C-135 | B717 | CRJ7/9 | |
| | | B-1 | GLF5 | AT45 | |
| | | B-2 | DC95 | AT43 | |
| | | | DC93 | GLF4 | |
| | | | DH8D | SF34 | |
| | | | F100 | DH8A/B/C | |
| | | | F70 | E135/145 | |

TABLE 2-2. RECAT WAKE SEPARATION STANDARDS

| Leader | Follower (Nautical Mile) | | | | | |
|--------|--------------------------|-----|-----|-----|-----|-----|
| | A | B | C | D | E | F |
| A | MRS | 5 | 6 | 7 | 7 | 8 |
| B | MRS | 3 | 4 | 5 | 5 | 7 |
| C | MRS | MRS | MRS | 3.5 | 3.5 | 6 |
| D | MRS | MRS | MRS | MRS | MRS | 5 |
| E | MRS | MRS | MRS | MRS | MRS | 4 |
| F | MRS | MRS | MRS | MRS | MRS | MRS |

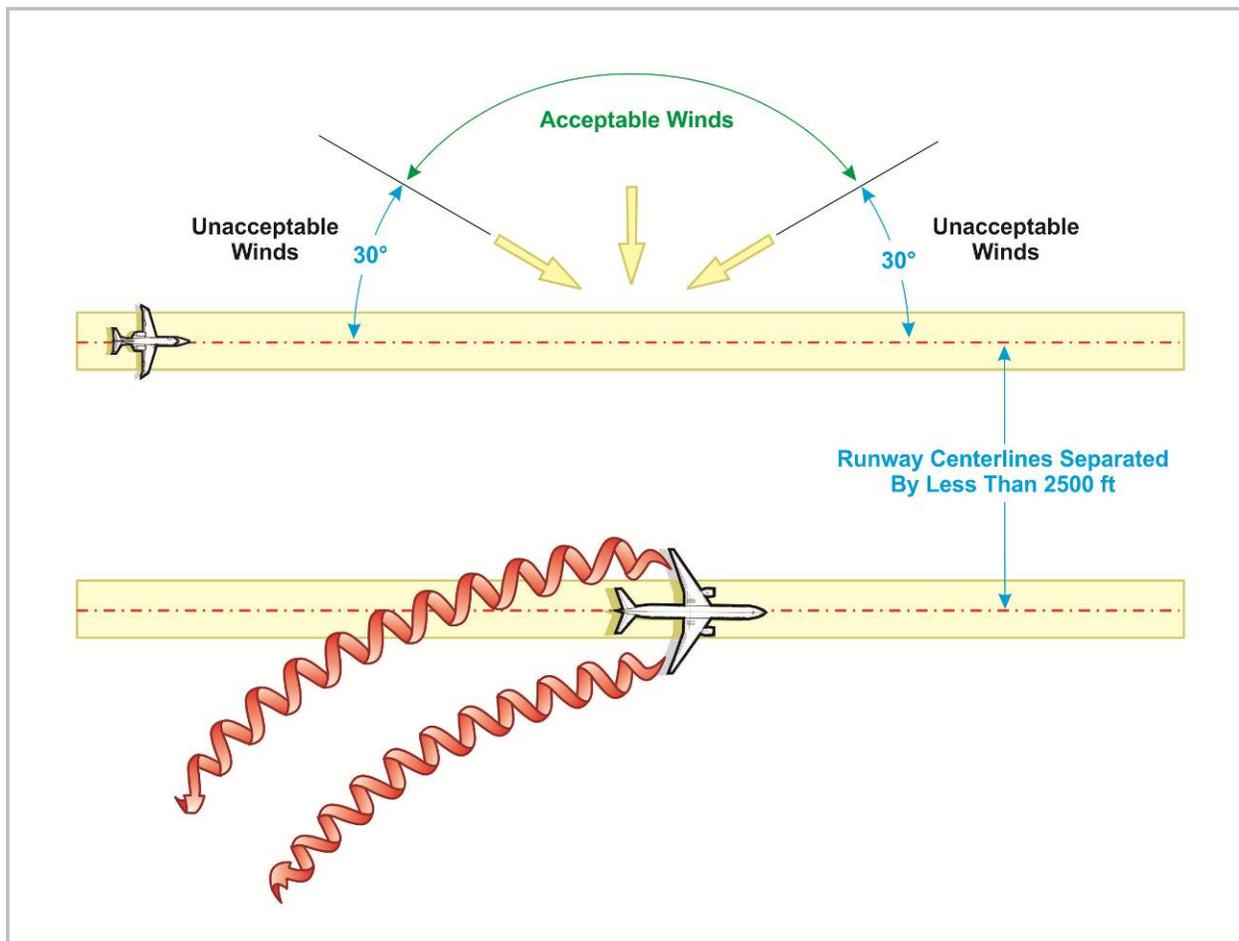
NOTE: MRS: Minimum Radar Separation.

APPENDIX 3. FAA ORDER JO 7110.316, WAKE TURBULENCE MITIGATION FOR DEPARTURES (WTMD)

WTMD allows a reduction in required wake turbulence separation for aircraft departing on specifically authorized parallel runways separated by less than 2,500 feet based on prevailing and predicted wind and weather conditions. Current wake separation standards require that a 2-minute delay or up to 5 miles radar separation be applied to a subsequent departure following a Heavy/B757 aircraft departing from an adjacent Closely Spaced Parallel Runway (CSPR) (parallel runways separated by less than 2,500 feet with the threshold offset by less than 500 feet). A safety analysis has shown these wake separation standards can be eliminated if the required conditions for use of WTMD are in place. See Figure 3-1, Wake Movement with Crosswind Component.

Under these conditions, the wake created by the departing Heavy/B757 aircraft (excluding Super aircraft) does not affect subsequent departures on the CSPR upwind runway. The upwind runway can be considered wake free— that is, unaffected by the wake of the departing Heavy/B757 aircraft.

FIGURE 3-1. WAKE MOVEMENT WITH CROSSWIND COMPONENT



The Federal Aviation Administration (FAA) recently approved the WTMD procedure. The system uses wind information at the surface and incrementally up to about 1200 feet above ground level (AGL) to ensure actual crosswinds and a conservative forecast of future crosswinds are sufficiently strong to allow the reduced separation operations. The WTMD system has been validated through a comprehensive collection and analysis of departure wake turbulence data. When the air traffic controller enables WTMD, a display informs the local controller which runway has been identified as wake independent from Heavy/B757 aircraft departure operations from the other parallel runway. The system also has an automatic alert to cease WTMD operations when monitored winds or forecasted winds are falling out of the conservative crosswind criteria required for reduced separation operations. WTMD operations will be included in the automated terminal information service (ATIS) message and communicated to the pilots via pilot/controller radiotelephony during transition to WTMD operations. The pilot will continue to have the option to request 2 minutes separation (or 3 minutes separation, if applicable), instead of controller applied reduced distance separation when WTMD is enabled. Figure 3-2 presents a graphic of reduced separation operations when WTMD is enabled.

FIGURE 3-2. REDUCED SEPARATION OPERATIONS WHEN WTMD IS ENABLED

