Docket No. SA-522

Exhibit No. 2-U

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Excerpts from FAA's
Wake Turbulence Training Aid

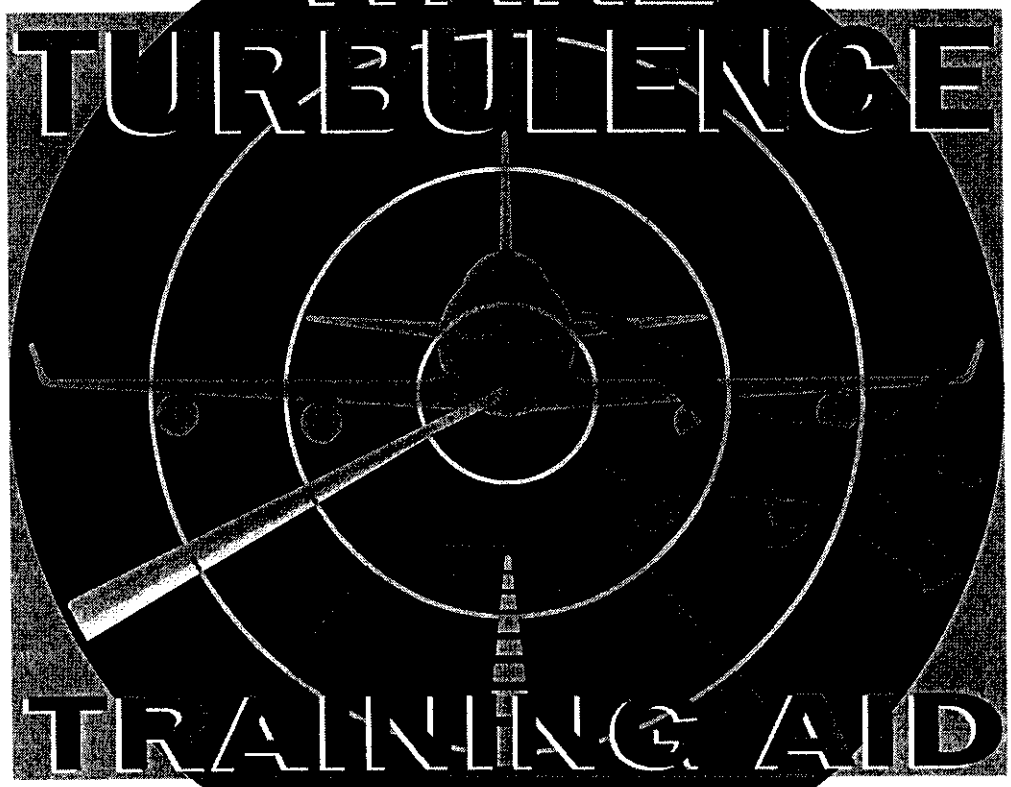
(13 Pages)

U.S. Department
of Transportation
**Federal Aviation
Administration**

DOT/FAA/RD-95/6
DOT-VNTSC-FAA-95-4

Final Report
April 1995

WAKE TURBULENCE TRAINING AID



A cooperative effort between the U.S. Department of Transportation, Federal Aviation Administration, and the international and domestic aviation community in the interest of safety

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U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

March 24, 1995

Dear Sir/Madam:

It is a pleasure to recommend this "Wake Vortex Training Aid" for use throughout the aviation industry. This training tool is the culmination of an aggressive, painstaking effort on the part of an industry and Government working group representing a broad segment of the aviation community.

Throughout 1994, this ATA sponsored, Boeing led, joint Government/ industry team comprised of both domestic and international experts, representing a wide range of knowledge and interests, developed this consensus document. This fact gathering effort led to the group's recommendations that pilots and air traffic controllers share the responsibility for reducing aircraft encounters with wake turbulence. The Federal Aviation Administration supports this view and offers this aid as a means of enhancing wake turbulence training for both pilots and air traffic controllers.

This training aid represents the most recent information available on wake turbulence avoidance in addition to providing a comprehensive discussion of the characteristics of this hazard. We are continuing to examine this threat; therefore, you should be alert for changes to existing wake turbulence guidance.

My thanks to the members of the Wake Turbulence Working Group. I strongly support the industry and Government partnership represented by the group's activities. Through efforts such as these we can effectively and efficiently promote safety for the flying public.

Sincerely,

David Hinson

David R. Hinson
Administrator

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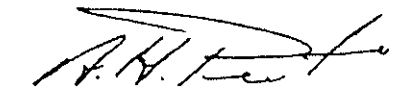
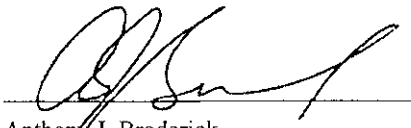
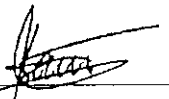


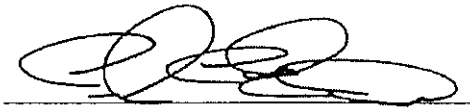
Albert H. Prest
V. P., Operations
Air Transport Association (ATA)



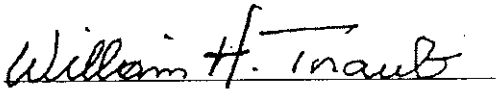
Anthony J. Broderick
Assoc. Administrator
Regulation & Certification, AVR-1
Federal Aviation Administration (FAA)



Pierre Baud
V. P., Flight Operations Support Division
Airbus Industrie



Chester L. Ekstrand
Director, Flight Training & Regulatory Affairs
Boeing Commercial Airplane Group

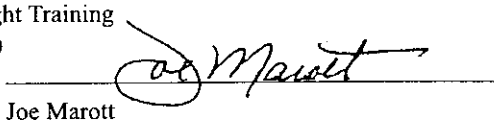


William H. Traub
V. P., Flight Standards & Training
United Airlines (UA)

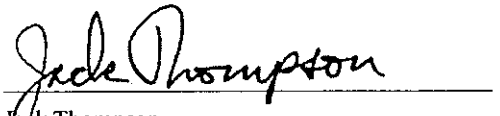
Kenneth J. Mase
Flight Training Manager
United Parcel Service (UPS) Training Center

Lee R. Schumacher
Managing Director, Flight Training
American Airlines (AA)

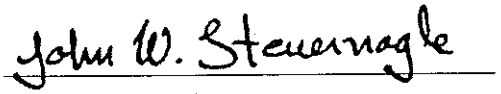
Diane Shapiro
General Manager, Flight Operations
McDonnell Douglas Aircraft Co.



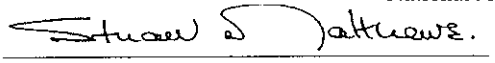
Joe Marott
Manager, Flight Training
Southwest Airlines Training Center



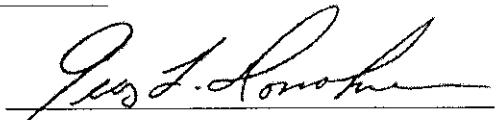
Jack Thompson
Manager, Flight Operations
National Air Transportation Association (NATA)



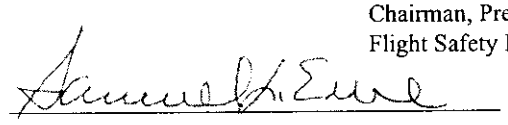
John W. Steuernagle
Director, Program Development
AOPA Flight Safety Foundation



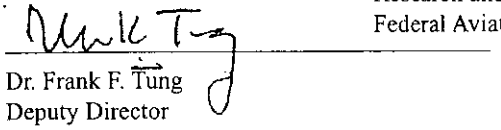
Stuart Matthews
Chairman, President, & CEO
Flight Safety Foundation



Dr. George L. Donohue
Associate Administrator
Research and Acquisitions, ARA-1
Federal Aviation Administration (FAA)

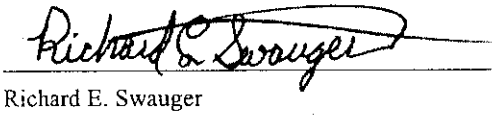


Mr. Samuel L. Eure
Program Manager
Science and Technology Corp.

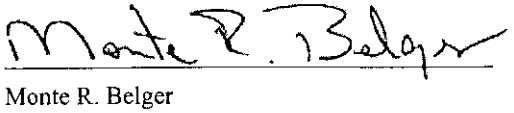


Dr. Frank F. Tung
Deputy Director
Volpe National Transportation Systems Center
U.S. Department of Transportation

Russell J. Danwin
Chairman, National Safety Committee
Allied Pilots Association (ALPA)



Richard E. Swauger
Technology Director
National Air Traffic Controllers Association
(NATCA)



Monte R. Belger
Associate Administrator
Air Traffic Services, ATS-1
Federal Aviation Administration (FAA)

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Prepared under the direction of:
Project Manager: George C. "Cliff" Hay and
Assoc. Project Manager: Robert H. Passman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Department of Transportation
Volpe National Transportation Systems Center
Office of Operations Engineering and Assessment
Surveillance and Sensors Division
Kendall Square
Cambridge, MA 02142-1093

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13. ABSTRACT *(Maximum 200 words)*

Wake-turbulence accidents and incidents have been, and continue to be, a significant contributor to worldwide safety statistics. The National Transportation Safety Board (NTSB), in a report on safety issues related to wake-vortex encounters, stated that between 1983 and 1993 there were at least 51 accidents and incidents in the United States that resulted from probable encounters with wake vortices.

The goal of the Wake Turbulence Training Aid is to reduce the number of wake-turbulence related accidents and incidents by improving the pilot's and air traffic controller's decision making and situational awareness through increased and shared understanding and heightened awareness of the factors involved in wake turbulence. The major three objectives of the Wake Turbulence Training Aid are: (1) to educate pilots and air traffic controllers on wake turbulence and avoidance of the phenomenon; (2) to increase the wake-turbulence situational awareness of pilots and air traffic controllers; and (3) to provide usable information to develop a ground training program.

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SECTION 2

2

Pilot and Air Traffic Controller Guide to Wake Turbulence

2.10.8 Estimating Movement of Wake Turbulence

Basic surface wind indications can aid pilots with estimating the movement of wake turbulence. Blowing dust, smoke or wakes on lakes and ponds provide indications that may be used in determining wind direction which may be applied to wake-turbulence movement. Use any on-board avionics equipment i.e., inertial reference, Doppler radar, global positioning system, etc. to determine wind direction. Aircraft drift angles will also give the pilot an indication of wind direction.

2.11 Pilot Responses Upon Encountering Wake Turbulence

An encounter with wake turbulence usually results in induced rolling or pitch moments; however, in rare instances an encounter could cause structural damage to the aircraft. In more than one instance, pilots have described an encounter to be like "hitting a wall". The dynamic forces of the vortex can exceed the roll or pitch capability of the aircraft to overcome these forces. During test programs, the wake was approached from all directions to evaluate the effect of encounter direction on response. One item that was common to all encounters, without a concerted effort by the pilot the aircraft would be expelled from the wake. Refer to Section 2.4, Figures 2.4-4 through 2.4-9, for the effects on an aircraft when encountering wake turbulence from several directions. While this information provides a better understanding of wake turbulence, its usefulness is limited since wake-turbulence encounters are inadvertent and pilots will not be aware of their entry location.

Counter control is usually effective and induced roll is 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 wingspan (relative to the generating aircraft) to counter the imposed roll induced by the vortex flow. Pilots of short span aircraft, even of the high performance type, must be especially alert to wake-turbulence encounters.

It may be difficult or impossible for pilots to differentiate between wake turbulence and turbulence generated from another source. Apply appropriate corrective action if wake turbulence is encountered. A wake-turbulence encounter at low altitude is much more hazardous than an encounter at cruise altitude or early during the approach phase of flight.

2.12 Cooperative and Efficient Management of Capacity

The worldwide number of aircraft continues to increase each year for reasons that reach from the desire for greater recreational use to responding to commercial demand. As this number increases, so must the necessary support or infrastructure. The critical or limiting factor of this infrastructure continues to change. For example, in the early years of aviation, the small number of runways often limited where a pilot could land. As more runways were built, adverse weather became the critical element which was slowly overcome with the advent of better and better terminal approach aids and air traffic systems. We have evolved from few pilots to many pilots; from few air traffic controllers to many air traffic controllers. Most of the limiting factors have gradually been mitigated though improved technology. Currently, wake turbulence and the application of existing IFR separation and avoidance procedures are a limiting factor at many major airports. This situation, coupled with high air traffic density, creates an environment that requires pilots and air traffic controllers to cooperate to safely and efficiently conduct flight operations.

Air traffic controllers should understand that many times the pilot's situational awareness is limited to information provided by ATC until the pilot enters visual meteorological conditions. This means that initially it may be difficult for pilots to visually detect whether they may be overtaking the leader aircraft or where they are, relative to the leader's flightpath. Any pertinent information that can be given to the pilot during a radar controlled arrival, will help the pilot transition to a visual approach and landing.

2.8.1.8 Departing or Landing After a Heavy Aircraft Executing a Low Approach, Missed Approach or Touch-and-Go Landing (Figure 2.8-11)

- Ensure that an interval of at least two minutes has elapsed before your take off or landing.

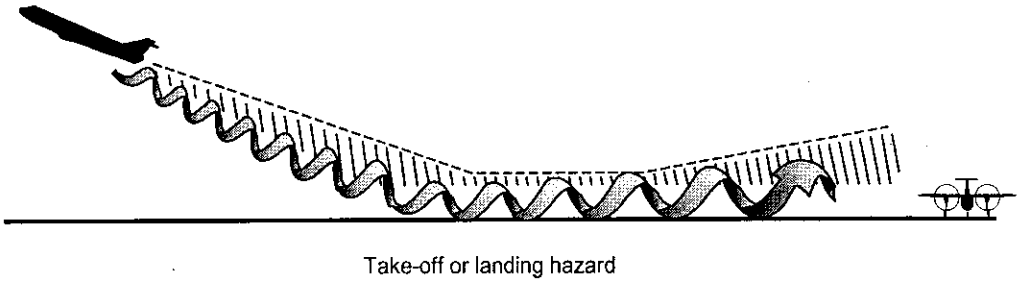

Figure 2.8-11 Departing or landing after a heavy aircraft executing a low approach, missed approach or touch-and-go landing

2.8.1.9 En Route Within 1000 Feet Altitude of a Large Aircraft's Altitude (Figure 2.8-12)

- Avoid flight below and behind a large aircraft's path.
- If a larger aircraft is observed above and on the same track (meeting or overtaking), adjust your position laterally, preferably upwind.

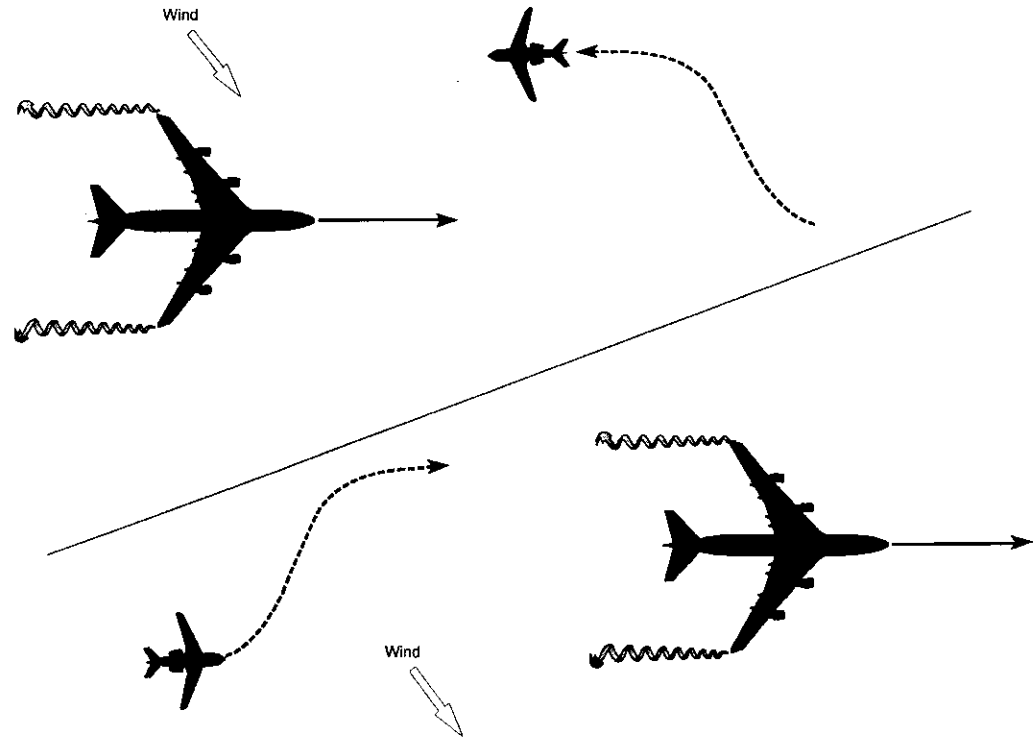

Figure 2.8-12 En route VFR (1000 foot altitude plus 500 feet)

9

2.8.1.6 Departing Behind a Larger Aircraft (Figures 2.8-7,-8,-9)

- Note the larger aircraft's rotation point.
- Delay, do not begin take-off roll unless your rotation point will be prior to the larger aircraft's rotation point.
- Climb displaced upwind of larger aircraft.
- Continue climb above the larger aircraft's climb path until turning clear of its wake. **Caution:** This may not be possible because of the larger aircraft's performance.
- Avoid subsequent headings which will cross below and behind a larger aircraft.
- Be alert for any critical take-off situation which could lead to a wake-turbulence encounter.

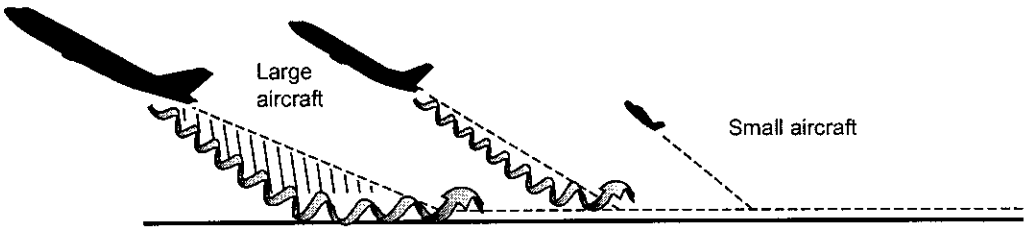

Figure 2.8-7 Departing behind a larger aircraft - same runway

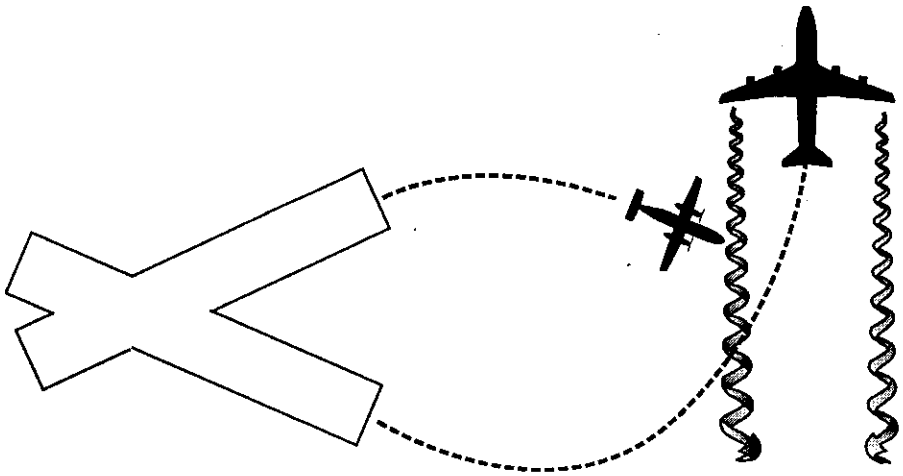

Figure 2.8-8 Departing behind a larger aircraft - crossing departure courses

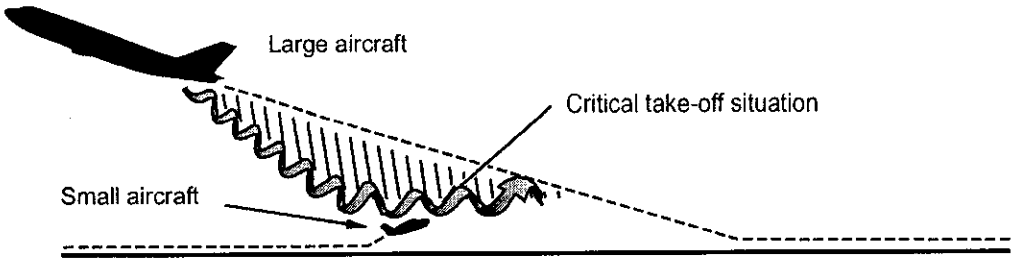

Figure 2.8-9 Departing behind a larger aircraft - opposite direction

2.6.4 Visual Separation

Aircraft may be separated by visual means when other approved separation is assured before and after the application of visual separation. To ensure that other separation will exist, air traffic controllers should consider aircraft performance, wake turbulence, closure rate, routes of flight and known weather conditions. Reported weather conditions must allow the aircraft to remain within sight until other separation exists. Controllers should not apply visual separation between successive departures when departure routes and/or aircraft performance preclude maintaining separation.

2.6.4.1 Visual Separation-Terminal Area

Visual separation may be applied between aircraft under the control of the same facility within the terminal area provided:

a. communication is maintained with at least one of the aircraft, involved or the capability to communicate is immediately available; and the aircraft are visually observed by the tower controller and visual separation is maintained between the aircraft by the tower controller.

b. a pilot sees the other aircraft and is instructed to maintain visual separation from the aircraft as follows:

   (1) The pilot is informed by the ATC of the other aircraft, including position, direction and, unless it is obvious, the other aircraft's intention.

   (2) Acknowledgment is obtained from the pilot that the other aircraft is in sight.

   (3) The pilot is instructed to maintain visual separation from the other aircraft.

   (4) The pilot is advised if the radar targets appear likely to converge.

   (5) If the aircraft are converging, the other aircraft is informed of the traffic and that visual separation is being applied.

The tower controller shall not provide visual separation between aircraft when wake-turbulence separation is required or when the lead aircraft is a B-757.

2.6.4.2 Visual Separation - En Route

Air traffic controllers may use visual separation in lieu of radar separation in conjunction with visual approach procedures. Refer to Section 2.6.4 for those procedures.

2.6.4.3 Visual Separation - Nonapproach Control Towers

Nonapproach control tower controllers may be authorized to provide visual separation between aircraft within surface areas or designated areas provided other separation is assured before and after the application of visual separation. This may be applied by the nonapproach control tower providing the separation or by a pilot visually observing another aircraft and being instructed to maintain visual separation with that aircraft.

2.7 Pilot Responsibilities for Maintaining Wake-Turbulence Separation

Pilots and air traffic control share the responsibility for assuring that aircraft avoid wake turbulence.

2.7.1 Who Does What and When

There is clear delineation of who and when responsibility is assumed for avoiding wake turbulence. The pilot is responsible for avoiding wake turbulence when:

a. flying in VFR and not being vectored by ATC.

b. maintaining visual separation.

c. cleared for a visual approach.

Air traffic control (ATC) assumes wake-turbulence responsibility while providing the pilot instrument flight rules (IFR) control in instrument meteorological weather conditions and when vectoring VFR aircraft. [A discussion of ATC procedures is included in the ATC responsibility Section, 2.6.] A discussion of several situations will help to clarify a pilot's responsibility.

When the pilot is being radar controlled by ATC, the aircraft will be spaced, for wake turbulence, behind a preceding aircraft at a distance determined by the weights of the two aircraft. Based on the known movements of wake turbulence, this separation has been successful in preventing wake-turbulence encounters. The minimum separation is designed not only to allow time for the wake turbulence to begin to dissipate, but also to allow time for it to descend below the following aircraft's flightpath. Longitudinal separation is but one element of avoidance. If VFR weather conditions exist when ATC is providing radar control, the pilot is not relieved of the responsibility for assuring the flightpath will avoid an encounter with wake turbulence. If instrument meteorological conditions (IMC) exist, only the ATC established separation distances are available to prevent wake-turbulence encounters, since the pilot is unable to visually apply avoidance procedures.

When it is operationally beneficial, ATC may authorize the pilot to conduct a visual approach to an airport or to follow another aircraft in VFR weather. The pilot must have the airport or an identified preceding aircraft in sight before the clearance is issued. If the pilot has the airport in sight but cannot see the aircraft he or she is following, ATC may still clear the aircraft for a visual approach; however, ATC retains both normal separation and wake-turbulence separation responsibility. When the pilot is able to visually follow a preceding aircraft, and accepts the visual approach clearance, this transfers responsibility for avoiding wake turbulence to the pilot. To summarize this point, the pilot accepts wake-turbulence avoidance responsibility when:

a. ATC instructions include traffic information.

b. Instructions to follow an aircraft are given and the pilot is able to comply.

c. The pilot accepts the visual approach clearance.

ATC is also responsible for assuring proper wake-turbulence separation before issuing clearance for takeoff by applying time and distance intervals. Pilots, after considering possible wake-turbulence effects, may specifically request a waiver to the interval. Controllers may acknowledge this request as acceptance of responsibility for wake-turbulence separation. If traffic permits, takeoff clearance will be issued. A wake-turbulence cautionary advisory will be given.

During cruise flight in VFR weather, altitude separations could be as little as 500 feet between IFR and VFR aircraft. In this situation the same principle applies: pilots must use proper avoidance procedures.

2.7.2 Communications

To aid other pilots and ATC within FAA controlled airspace, pilots of heavy aircraft should always use the word "Heavy" in their radio communications. Radio communications are usually country specific, therefore pilots should check appropriate regulations regarding wake turbulence prior to operations outside FAA controlled airspace.

ATC is required to provide a "CAUTION WAKE TURBULENCE" advisory when VFR aircraft are not being radar vectored and are behind heavy jets or B-757s and to IFR aircraft that accept visual separation or a visual approach. ATC controllers may also issue a wake-turbulence caution when, in their opinion, wake turbulence may have an adverse effect on an aircraft following another aircraft. Because wake-turbulence movement is variable, the controller is not responsible for anticipating its existence or effect. Although not mandatory during ground operations, controllers may use the words jet blast, propwash, or rotorwash, in lieu of wake turbulence, when issuing a caution advisory.

Wake Turbulence Training Aid - Background Data

4.0 Introduction

The avoidance of wake-turbulence encounters will take the coordinated efforts of pilots of all sizes of aircraft and controllers throughout the ATC system. It is the goal of this Training Aid to reduce the number of accidents and incidents attributable to wake turbulence. This section, Wake Turbulence Training Aid - Background Data, is an excellent source of information for an instructor or user needing a more detailed explanation of the material contained in Section 2, the Pilot and Air Traffic Controller Guide to Wake Turbulence or the video, *Wake Turbulence Avoidance - A Pilot and Air Traffic Controller Briefing.* Additionally, this section contains charts and graphs in Appendix 4-A which could be utilized by an instructor to emphasize specific points. The material in this section is intended to be an additional resource for training and answering questions raised in the training process.

4.0.1 Goal of the Background Data Section

The goal of this section is to provide to users, particularly instructors, additional information and sources of information that can be utilized in instruction or understanding of wake turbulence. Periodically, this information will be updated as new information is gathered and additional reports, findings, and issues are addressed by the wake turbulence industry team.

4.0.2 Overview of the Contents

Appendix 4-A, the NTSB Special Report of Wake Turbulence, addresses specific incidents, wake turbulence issues, and makes recommendations regarding wake turbulence; Appendix 4-B, the 1991 Report of Where We Are Today in Wake Turbulence, gives an historical accounting of the efforts and history of research regarding wake turbulence; Appendix 4-C, Wake Turbulence Training Aid Guidelines and Issues, outlines some of the guidelines used in developing this training aid and addresses issues that were discussed at length by the industry team; Appendix 4-D, the FAA Integrated Wake Vortex Program Plan, outlines present and future efforts to assist pilots and controllers in avoiding wake turbulence encounters; Appendix 4-E is a bibliography of further research issues related to wake turbulence. Lastly, Appendix 4-F is added, as desired by the distributor of the aid, to inform pilots and controllers of the wake turbulence take-off weight categories and the latest IFR separation standards in effect that deal with wake turbulence. It is expected that these standards will change periodically.