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Safety Study Report for Cleveland-Hopkins International Airport Simultaneous Offset Instrument Approach Wake Vortex Evaluation

Dr. David Lankford, AFS-440
George Greene, AFS-400
Shahar Ladecky, ATSI
Carl Moore, CRC & Associates

August 2005

Flight Operations Simulation
and Analysis Branch, AFS-440
6425 S. Denning, Room 104
Oklahoma City, Oklahoma 73169
Phone: (405) 954-8191

Flight Systems Laboratory

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Flight Operations Simulation and Analysis Branch
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Safety Study Report for Cleveland-Hopkins International Airport Simultaneous Offset Instrument Approach Wake Vortex Evaluation

Reviewed by:

8/30/05

Stephen W. Barnes **Date**
Manager, Flight Operations Simulation and Analysis Branch

Released by:

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John McGraw **Date**
Manager, Flight Technologies and Procedures Division

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12. Abstract

This report presents the results of a wake vortex evaluation performed on the proposed CLE SOIA operations by the FAA's Flight Operations Simulation and Analysis Branch (AFS-440) and ATSI. The proposed SOIA operations at CLE incorporate straight-in Instrument Landing System (ILS) approaches to runways 24R and 6L and Localizer-type Directional Aid (LDA) approaches with glide slope to runways 24L and 6R. After the LDA MAP, the SOIA aircraft must perform a lateral maneuver to align with the landing runway. It is during this, the visual segment of the approach, that the landing aircraft get laterally closer to one another and where wake vortex concerns must be addressed. The analysis shows that the proposed SOIA operation to runways 6L/R at CLE poses no wake turbulence hazard. Thus any and all aircraft wake turbulence classes (except Heavy) may be paired for the SOIA operation.

Unrestricted use of the proposed SOIA operation to runways 24L/R, however, does pose a wake turbulence hazard for the participating aircraft; therefore, in accordance with FAA Order 8260.49, specific wake turbulence mitigation strategies are recommended. The LDA approaches developed for the CLE SOIA were not designed for Heavy wake turbulence class aircraft, therefore, this analysis does not address Heavy aircraft as part of the SOIA operation.

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DOT-FAA-AFS-440-13 **August 2005**

Executive Summary

One of the major challenges facing commercial aviation within the United States in the 21st century is that of airport capacity, especially during periods when inclement weather prevails. Airport capacity is the capability of an airport to handle arriving and departing aircraft and is often referred to as the Airport Acceptance Rate (AAR), usually expressed as arriving aircraft per hour. Maintaining the AAR during adverse weather conditions at airports with closely spaced parallel runways, i.e., centerline to centerline spacing of less than 3,000 feet, is particularly challenging. Cleveland-Hopkins International airport (CLE) is such an airport with its main operating runways, 6L/24R and 6R/24L, separated by only 1,241 feet.

Instrument approach operations to closely spaced parallel runways less than 3,000 feet apart cannot be conducted independently, but due to many factors (including collision avoidance and wake turbulence), must be conducted in a dependent fashion. To address approach operations to closely spaced parallel runways spaced less than 3,000 feet apart, the Federal Aviation Administration (FAA) has developed Simultaneous Offset Instrument Approach (SOIA) operations. In a SOIA operation, a straight-in Instrument Landing System (ILS) approach is used to one runway. A Localizer-type Directional Aid (LDA) with glide slope approach which has a final approach course (FAC) "offset" between 2.5 and 3.0 degrees from the adjacent ILS course is used to the other runway. The offset approach Missed Approach Point (MAP) is placed so that, during the instrument portion of the approach, collision avoidance and wake turbulence issues are minimized. For example, the MAPs for the proposed SOIA approaches to runway 24L and runway 6R are separated by approximately 3,000 feet from the FACs for runway 24R and runway 6L, respectively.

The proposed SOIA operations at CLE incorporate straight-in ILS approaches to runway 24R and runway 6L and LDA approaches with glide slope to runway 24L and runway 6R. After passing the LDA MAP and while keeping the ILS aircraft in sight, the LDA aircraft must perform a lateral transition or side-step maneuver to align with the landing runway. It is during this, the visual segment of the approach, that the landing aircraft get laterally closer to one another and wake vortex concerns must be addressed. The basic concept of SOIA is that the aircraft on the ILS approach is the leading aircraft and the aircraft on the LDA approach is the trailing aircraft. Depending on the results of a wake vortex analysis, wake mitigation procedures during the visual segment of the procedure may result in the trailing aircraft having to remain within a certain distance behind the leading aircraft to ensure there is no encounter with the wake as it migrates from the leading aircraft. In addition, in cases where the runway thresholds are staggered, such as at CLE, the LDA approach should serve the far-threshold runway. In this case, the trailing aircraft can remain above the flight path of the leading aircraft and thus avoid its

descending wakes. Notwithstanding this preference, the runway 24L LDA as evaluated in this study serves the near-threshold runway.

This report presents the results of a wake vortex evaluation performed on the proposed CLE SOIA operations by the FAA's Flight Operations Simulation and Analysis Branch (AFS-440) and Air Traffic Simulation, Inc. (ATSI). Due to an absence of a large number of Heavy aircraft operating at CLE, the SOIA LDA approaches were not designed for Heavy aircraft. As a consequence, this analysis did not include Heavy aircraft conducting the LDA approach or participating in the SOIA. Also, since the percentage of B757 aircraft operating at CLE is so small, this study did not evaluate the case of two B757 aircraft paired in the SOIA.

The proposed SOIA operation to runways 6L/R at CLE, i.e., ILS to runway 6L and LDA to runway 6R, poses no wake turbulence hazard. Thus any and all aircraft wake turbulence classes, except Heavy class, may be paired for the SOIA operation. A maximum crosswind limitation of 10 Knots applies.

Unrestricted use of the proposed SOIA operation to runways 24L/R, i.e., ILS to runway 24R and LDA to runway 24L, does pose a wake turbulence hazard for the trailing aircraft conducting the LDA approach. Therefore, in accordance with FAA Order 8260.49, specific wake turbulence mitigation strategies must be developed and applied. There are a number of possible mitigation strategies, all of which place some restriction on the operation. One such mitigation strategy, as described in this study, could involve operational implementation of an in-trail distance/airspeed combination scheme. For example, if the SOIA operation speed is 150 Knots and if Air Traffic Control (ATC) can guarantee 2 NM or less in-trail spacing between the ILS aircraft and the LDA aircraft from the MAP to the runway threshold, any and all aircraft (except Heavy and two B757s) can be paired for a SOIA. In this case, ATC would be required to issue a missed approach instruction to the LDA aircraft if in-trail spacing exceeded 2 NM between the LDA MAP and the landing threshold. For aircraft operating at speeds of 120 Knots the required in-trail distance is reduced to 1.5 NM.

To alleviate the need for a specific wake vortex mitigation strategy as suggested above for the runways 24L/R SOIA operation, it is recommended that CLE move the LDA approach to the far landing threshold of runway 24R. This threshold stagger would insure that the trailing aircraft remains above the flight path of the leading aircraft and thus would provide added protection from wake turbulence encounters. If this were done, there would be no wake turbulence mitigation requirements for the runways 24L/R SOIA operation, except for the prohibition of Heavy wake turbulence class aircraft and B757 pairs as previously stated. In addition, if this were done, the runways 24L/R SOIA operation would conform with similar operations in the National Airspace System (NAS) and to existing wake avoidance guidance such as the following excerpt from chapter 7 of the Aeronautical Information Manual: "**Landing behind a larger aircraft - when parallel runway is closer than 2,500 feet.** Consider possible drift to your runway. Stay at or above the larger aircraft's final approach flight path- note its touchdown point."

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1.0. Introduction

One of the major challenges facing commercial aviation within the United States in the 21st century is that of airport capacity, especially during periods when inclement weather prevails. Airport capacity is the capability of an airport to handle arriving and departing aircraft and is often referred to as the Airport Acceptance Rate (AAR), usually expressed as arriving aircraft per hour. Maintaining the AAR during adverse weather conditions at airports with closely spaced parallel runways, i.e., centerline to centerline spacing of less than 3,000 feet, is particularly challenging. Cleveland-Hopkins International airport (CLE) is such an airport with its main operating runways, 6L/24R and 6R/24L, separated by only 1,241 feet.

Instrument approach operations to closely spaced parallel runways less than 3,000 feet apart cannot be conducted independently, but due to many factors (including collision avoidance and wake turbulence), must be conducted in a dependent fashion. To address approach operations to closely spaced parallel runways spaced less than 3,000 feet apart, the Federal Aviation Administration (FAA) has developed Simultaneous Offset Instrument Approach (SOIA) operations (see Reference1). In a SOIA operation, a straight-in Instrument Landing System (ILS) approach is used to one runway. A Localizer-type Directional Aid (LDA) with glide slope approach which has a final approach course (FAC) "offset" between 2.5 and 3.0 degrees from the adjacent ILS course is used to the other runway. The offset approach Missed Approach Point (MAP) is placed so that, during the instrument portion of the approach, collision avoidance and wake turbulence issues are minimized. For example, the MAPs for the proposed SOIA approaches to runway 24L and runway 6R are separated by approximately 3,000 feet from the FACs for runway 24R and runway 6L, respectively.

The proposed SOIA operations at CLE incorporate straight-in ILS approaches to runway 24R and runway 6L and LDA approaches with glide slope to runway 24L and runway 6R. The runway 6R LDA is shown in Appendix A. After passing the LDA MAP and while keeping the ILS aircraft in sight, the LDA aircraft must perform a lateral transition or side-step maneuver to align with the landing runway. It is during this, the visual segment of the approach, that the landing aircraft get laterally closer to one another and wake vortex concerns must be addressed. The basic concept of SOIA is that the aircraft on the ILS approach is the leading aircraft and the aircraft on the LDA approach is the trailing aircraft. Depending on the results of a wake vortex analysis, wake mitigation procedures during the visual segment of the procedure may result in the trailing aircraft having to remain within a certain distance behind the leading aircraft to ensure there is no encounter with the wake as it migrates from the leading aircraft. In addition, as Reference 1 states, in cases where the runway thresholds are staggered, such as at CLE, the LDA approach should serve the far-threshold runway. In this case, the trailing aircraft can remain above the flight path of the leading aircraft and thus avoid its descending wakes. This wake avoidance concept is described in the following excerpt from chapter 7 of the Aeronautical Information Manual (Reference 2):

"**Landing behind a larger aircraft - when parallel runway is closer than 2,500 feet.** Consider possible drift to your runway. Stay at or above the larger aircraft's final approach flight path - note its touchdown point." Notwithstanding the recommendation of Reference 1 and the guidance in Reference 2, the runway 24L LDA as evaluated in this study serves the near-threshold runway.

This report presents the results of a wake vortex evaluation performed on the proposed CLE SOIA operations by the FAA's Flight Operations Simulation and Analysis Branch (AFS-440) and Air Traffic Simulation, Inc. (ATSI). Due to an absence of a large number of Heavy aircraft operating at CLE, the SOIA LDA approaches were not designed for Heavy aircraft. As a consequence, this analysis did not include Heavy aircraft conducting the LDA approach or participating in the SOIA operation. Also, since the percentage of B757 aircraft operating at CLE is so small, this study did not evaluate the case of two B757 aircraft paired in the SOIA.

2.0. Description of the Model

2.1. Airspace Simulation and Analysis Tool (ASAT)

The primary analysis tool for this safety evaluation was ASAT. ASAT is a multifaceted, highly adaptable computer-based tool for aviation related simulations and safety evaluations. ASAT consists of high fidelity models and in some cases, empirical data representing the following major components of a typical real world operational aviation scenario:

a. At the heart of the system is flight dynamics models enhanced and tailored by empirical data collected in flight simulators and flight tests. Aircraft avionics are modeled based on requirements of the particular scenario. ASAT can model a broad range of advanced navigation systems such as Flight Management System (FMS), Global Positioning System (GPS), and Required Navigation Performance (RNP), as well as other navigation systems such as ILS, Microwave Landing System (MLS), and Distance Measuring Equipment (DME).

b. ASAT has access to a wide range of environmental models including temperature, atmospheric pressure, and both lateral and vertical wind profiles. The aerodynamic flight models described above respond to the ASAT generated atmosphere around them in the same manner as actual aircraft.

c. The environment in which ASAT scenarios are run is further defined by official FAA databases providing precise geographic locations of airports, runways, navaids, routes, fixes, waypoints, and other facilities, such as radar site locations. In addition, ASAT incorporates the FAA's obstacle and terrain database for use in obstacle clearance studies.

d. Air traffic equipment impact on scenarios is based on computer models of radar systems using manufacturer and government provided specifications. When and where necessary, the human factors contribution of air traffic controllers is measured during simulations, and statistical distributions of controller response times can then be determined and made available to ASAT.

e. ASAT uses statistical distributions derived from real time tests to determine the response of humans involved in the modeled operation. This applies to both controllers and pilots.

Once the scenario(s) of interest are defined and the components above statistically characterized, ASAT can perform many thousands of runs in a Monte Carlo type simulation. ASAT is also capable of statistically analyzing the results of the Monte Carlo simulation.

For purposes of this evaluation, ASAT was modified to include a wake vortex model. The wake vortex model simulated the wake generation, transport, and decay characteristics of the wake turbulence aircraft classes, i.e., B757 and Large. Using information from the wake vortex model coupled with its Monte Carlo capability, ASAT was able to simulate various combinations of environmental conditions (primarily cross wind), leading and trailing aircraft positions on localizer and glide slope, position of trailing aircraft relative to lead aircraft (referred to as in-trail spacing) and wake turbulence class for the lead and trailing aircraft. Ultimately, the outcome of the ASAT simulation was to determine whether the simulated SOIA aircraft encountered a wake generated by the leading aircraft.

2.2. Aircraft Vortex Spacing System (AVOSS) Prediction Algorithm

For this study, the National Aeronautics and Space Administration's (NASA) AVOSS Prediction Algorithm (APA) version 3.2 was integrated into (ASAT). (A more complete description of AVOSS and its prediction algorithm is found in Reference 3.)

The APA accepts as input meteorological data and aircraft data. After accepting the above parameters, the APA computes a transport and decay time for a wake. The decay time expresses the decrease in wake strength versus time. The analysis in this report used the APA's transport and decay times coupled with the ASAT's Monte Carlo simulation capability to determine if aircraft on numerous and varied simulated approaches to CLE encounter a wake.

The APA is able to handle both wakes out of ground effect and wakes in ground effect. Wakes out of ground effect descend from the point at which they are generated and are transported horizontally by any cross winds. Wakes in ground effect, i.e., close to the ground, can no longer descend and can even bounce back into the air upon contact with the ground.

A major contributor to the speed at which a wake decays is the level of atmospheric turbulence present in the immediate vicinity of the wake. Significant crosswinds are required to transport wakes to an adjacent runway in an operationally significant time. In general, significant winds do not occur at the same time as very low levels of atmospheric turbulence. Since atmospheric turbulence levels are not monitored at airports, these studies were conducted with a very low turbulence level, as represented by Eddy Dissipation Rate (EDR), of 1×10^{-6} m^2/sec^3.

This turbulence level is lower than might be typically expected for the 10 Knots crosswind used in the study and was chosen to provide a conservative result in the absence of known or measured turbulence levels.

2.3. Wake Turbulence Aircraft Classes

Wake turbulence separation minima for Air Traffic Control (ATC) purposes are given in FAA Order 7110.65, Air Traffic Control (Reference 4). For wake turbulence purposes, Reference 4 classifies aircraft as Heavy, Large, and Small based on the following criteria:

a. Heavy - aircraft capable of takeoff weights of more than 255,000 pounds whether or not they are operating at this weight during a particular phase of flight.

b. Large - aircraft of more than 41,000 pounds, maximum certificated takeoff weight, up to 255,000 pounds. (While technically a large aircraft, the B757 has its own set of wake turbulence separation minima, which closely resembles that of a Heavy aircraft.)

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

2.4. CLE Runway Configurations

Two different runway configurations at CLE were evaluated:

a. Runways 6L and 6R: The position of the runways 6L and 6R thresholds are shown in Figure 1. Runway 6L and runway 6R landing thresholds are staggered by approximately 2,218 feet with runway 6L being the near threshold.

b. Runways 24R and 24L: The position of the runway 24R and runway 24L thresholds are shown in Figure 1. Runway 24R and runway 24L thresholds are staggered by approximately 2,218 feet with runway 24L being the near threshold.

2.5. ASAT Graphic Depiction of Proposed Runways 24L/R SOIA Scenario

Figure 2 is an ASAT screen capture showing the major components of the study from a top down geographic perspective. While Figure 2 shows the proposed runways 24L/R SOIA operation, a similar ASAT scenario was developed for the runways 6R/L SOIA.

As Figure 2 shows, the runway 24R aircraft is performing a straight-in ILS approach, while the runway 24L aircraft is conducting the LDA. Crosswinds and the initial in-trail spacing of trailing aircraft are selectable by the windows as shown. The LDA MAP (PRNCO) and the lateral transition or side-step maneuver to align with runway 24L are prominently displayed.

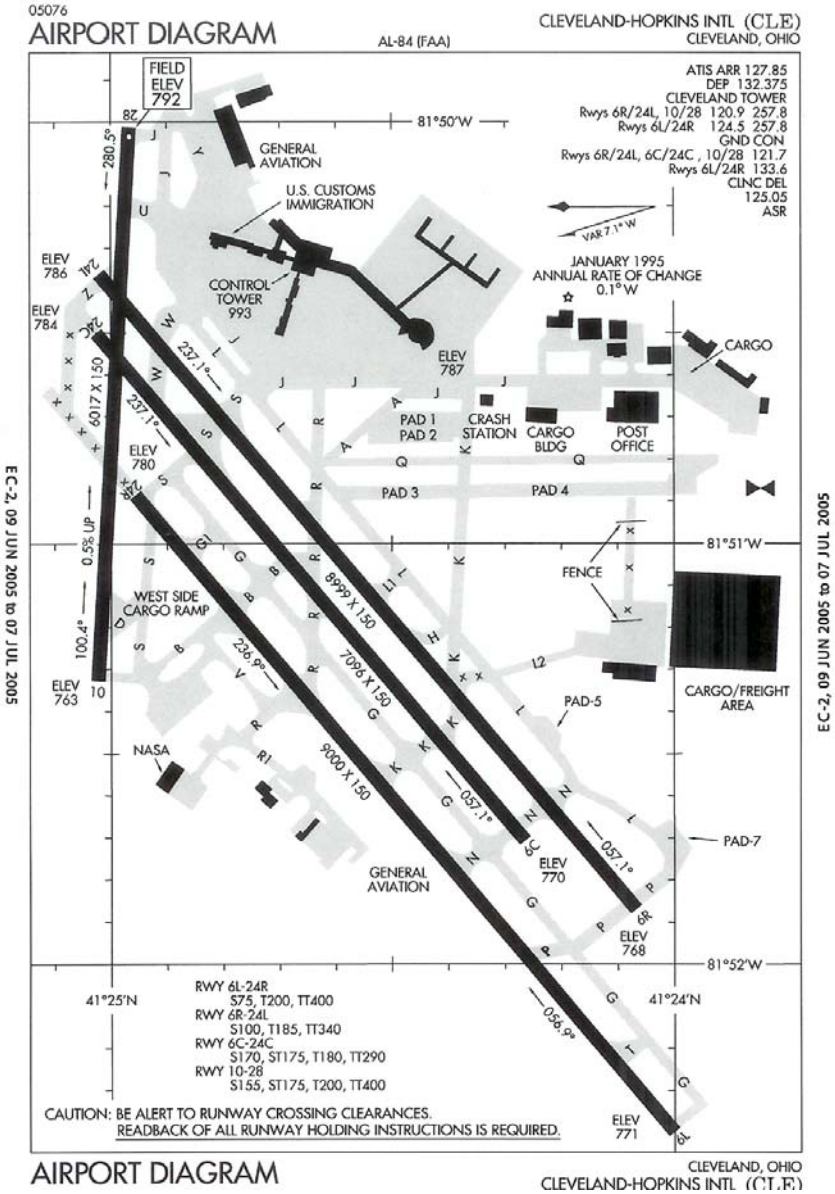

Figure 1: CLE Airport Diagram

2.6. Initial ASAT Simulation Conditions

A crosswind of 10 Knots at 30 feet, increasing logarithmically to 20 Knots at 2,000 feet above runway threshold, was set at a true direction of 327 degrees, blowing from the northwest towards the southeast, i.e., from the ILS runway toward the LDA runway. This wind direction is essentially perpendicular to the runways resulting in the total wind and the crosswind being the same. This represents the worst-case scenario for a wake encounter. The LDA aircraft (runway 24L or runway 6R) was placed 1 NM prior to the appropriate runway MAP. The ILS aircraft (runway 24R or runway 6L) was placed at one of the predetermined initial leading distances ranging from 1.0 NM to 2.5 NM relative to the aircraft approaching the LDA runway (runway 24L or runway 6R). Both aircraft were placed laterally and vertically using localizer and glide slope error distributions from the ICAO Collision Risk Model (CRM) for the Instrument Landing System (ILS).

The study was performed using a B757 (B757 wake category) as the lead aircraft and an A320 (Large wake category) as the trailing aircraft. This selection resulted in the shortest wake transport times to the trailing aircraft's Area of Interest, which is discussed in paragraph 2.9. The B757 is the highest wake turbulence class aircraft approved for SOIA operations at CLE. Gross weight and final approach indicated air speeds (IAS) were assigned to each aircraft across a range of operational values.

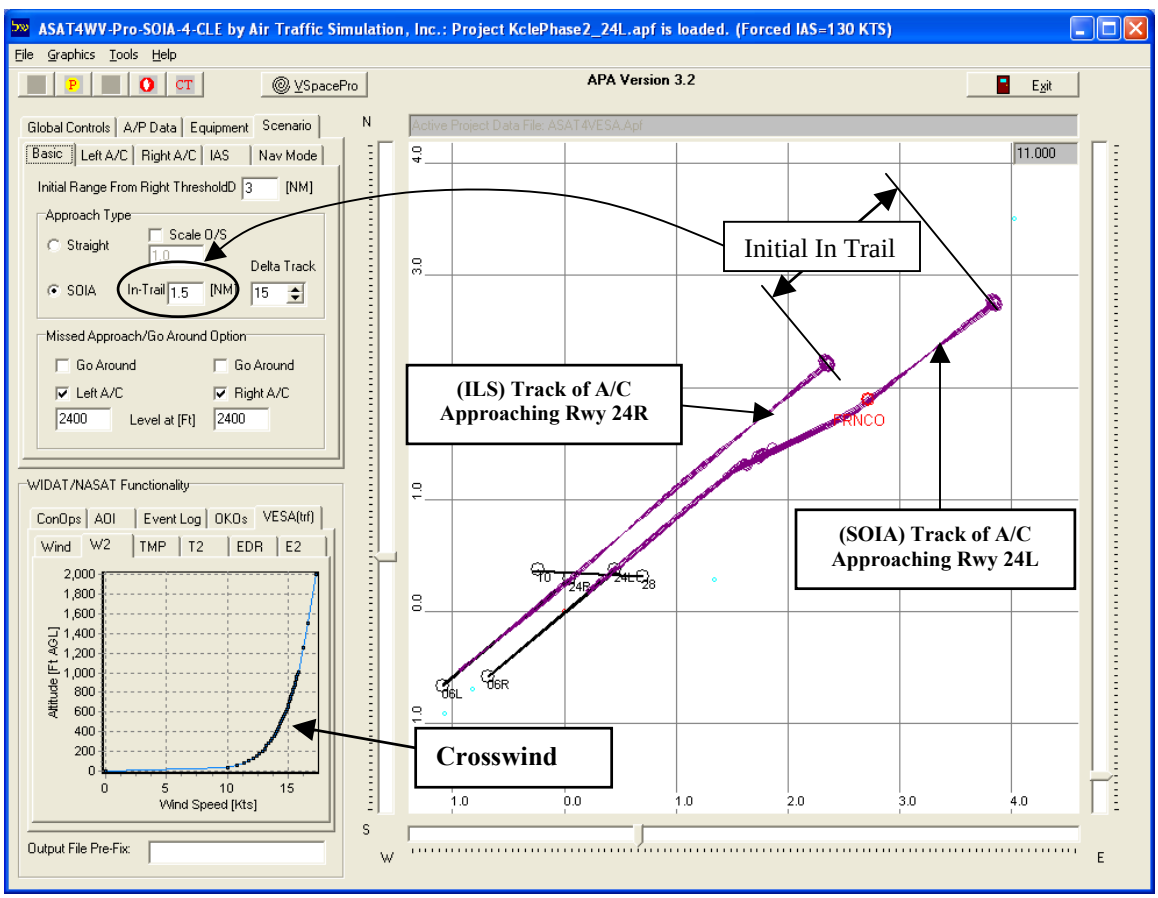

Figure 2: ASAT Graphic Depiction of Proposed Runways 24L/R SOIA Scenario

2.7. ASAT Simulation of the SOIA Flight Phase

After all initial conditions were set as described in paragraph 2.6, the simulation was "released" and both aircraft were set into flight mode. The aircraft approaching runway 24R or runway 6L executed a straight-in ILS approach. The ILS aircraft were placed so that they led the aircraft approaching the SOIA runway.

The aircraft approaching runway 24L or runway 6R executed a LDA procedure. The LDA procedure was simulated in the following manner:

a. Up to the MAP, the aircraft tracked the respective runway glide slope and LDA navigation signals.

b. At the MAP, a turn was initiated to establish a new heading that resulted in closing the lateral distance between the MAP and the extended runway centerline. The turn was expected to start at the MAP. However, the true location of the first turn was determined from probability distributions based upon variations observed during real time flight simulator tests flown by qualified and current airline pilots. A normal probability distribution was used to determine the bank angle and the bank rate used to perform the first turn. See Appendix A.

c. Once the required heading was achieved, the aircraft rolled back to wings level flight. The nominal change in heading was +19 degrees (right turn) for aircraft approaching to runway 24L and –19 degrees (left turn) for aircraft approaching runway 6R. A normal probability distribution of heading change was used to determine actual heading change values. See Appendix A.

d. At an ASAT computed point, the second turn (left bank for aircraft approaching to runway 24L and right bank for aircraft approaching to runway 6R) was initiated to intercept the extended runway centerline. The second turn was initiated at a point and performed at conditions that resulted in a varying amount of overshoot. The overshoot value was determined from a probability density function based upon data gathered during real-time flight simulator tests flown by qualified and current airline pilots during a St. Louis Lambert Field offset approach study (Reference 5). A normal probability distribution was used to model the bank angle and the bank rate used to perform the second turn. See Appendix A.

e. Once on runway centerline extended, the aircraft navigated towards the threshold of the appropriate runway (runway 24L or runway 6R).

2.8. Wake Vortex Simulation Description

To establish the occurrence of a wake vortex encounter, the location of the trailing aircraft must be determined relative to the location of the leading aircraft wake vortices. This complex task was accomplished by simulating the location of each one of the two leading aircraft vortices at discrete locations along the approach path of the aircraft. These discrete locations are called "tiles" and can be described as large planar surfaces located at regularly spaced distances from the threshold as illustrated in Figure 3. Once the leading aircraft penetrates a "tile," a simulation of its two wing-tip vortices began. Figure 3 illustrates the simulation of the vortices on two consecutive tiles. The first tile (tile # i) was penetrated at a given time T. At that moment, an analysis of the two simulated vortices began on tile # i. Some time later, $T + \Delta T$, the aircraft penetrates the

next tile, (tile # i + 1). Meanwhile, the simulation that was started on tile # i at time T was continuing as it evaluates the movement of the vortices due to crosswind and the inherent nature of wakes to descend. The AVOSS Prediction Algorithm described in paragraph 2.2. was used to model the transport and decay characteristics of the simulated wakes. Figure 3 illustrates the movement of the vortices on tile # i. The crosswind serves to move the vortices from left to right in the illustration and the wakes descend. The illustration depicts the position of the vortices after ΔT/2 and ΔT seconds. When the trailing aircraft penetrated a given tile, the position of the vortices on that particular tile was "frozen" and ASAT then computed the relative position between the trailing aircraft and the vortices of the leading aircraft. Additional ASAT analysis took place to determine if the wake strength is sufficiently strong to trigger a wake encounter on that particular tile.

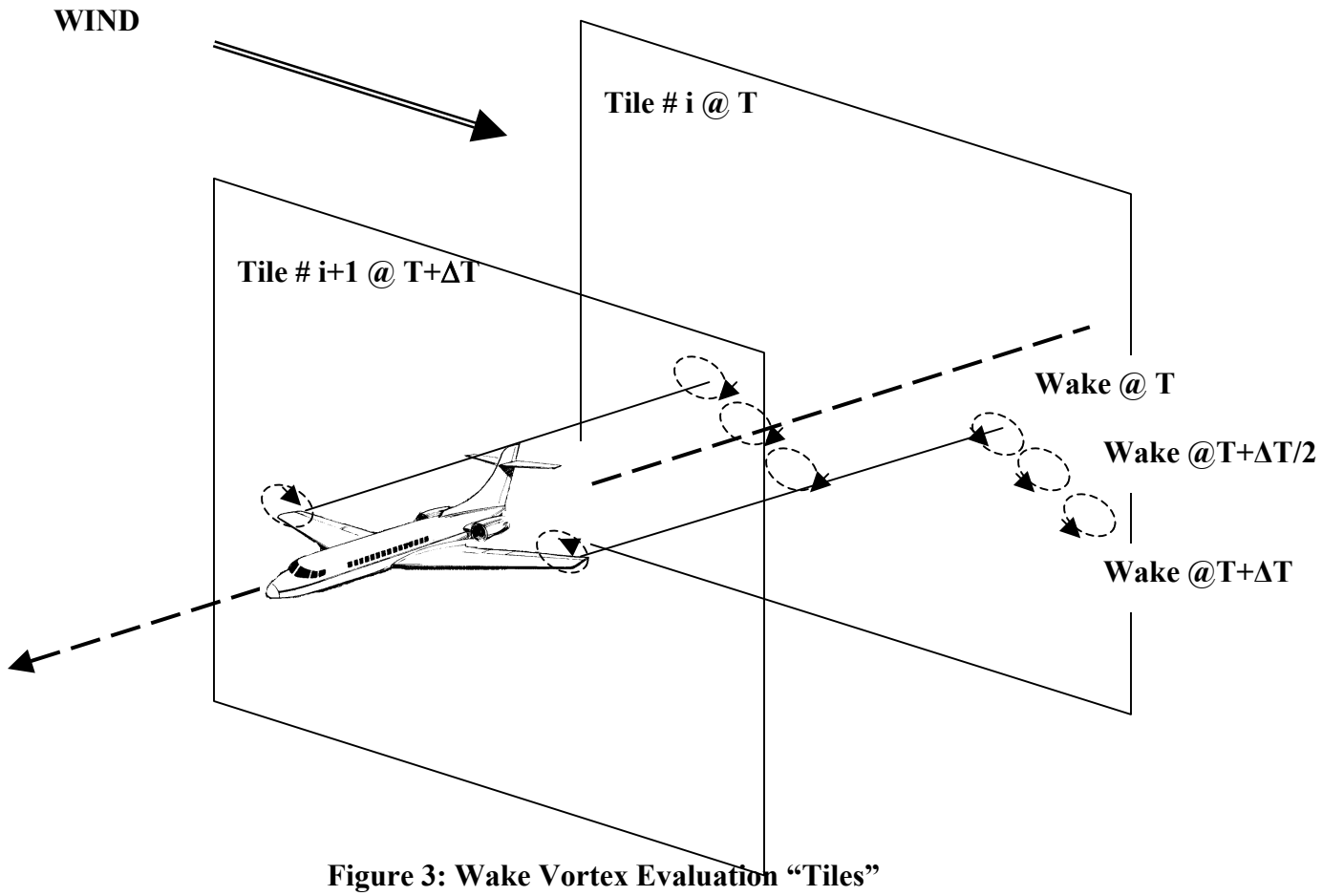

Figure 3: Wake Vortex Evaluation "Tiles"

2.9. Wake Vortex Encounter Criteria

For purposes of this study, an aircraft was considered to have encountered a wake vortex if a wake exceeding a strength of 60 m^2/sec penetrated a circular area of interest (AOI) centered on the trailing aircraft. The radius of the AOI is equal to the sum of the semi-spans of the leading and trailing aircraft. The reasoning behind this selection of AOI size is that the vortex of the leading aircraft induces velocities at distances proportional to the wingspan of the generating aircraft therefore, the greater the wingspan of the generator, the larger the AOI. The AOI for the B757/A320 combination is 118.2 feet.

3.0. Summary of Data Analysis

The analysis reported in this section was based on a maximum crosswind of 10 Knots.

3.1. Runways 6L and 6R SOIA Results

Table 1 shows the results of the ASAT wake vortex evaluation conducted on the runways 6L/R SOIA.

Table 1: Runways 6L and 6R SOIA ASAT Results

In-trail spacing (NM)	Wake Encounter?
1.0	No
1.5	No
2.0	No
2.5	No

As Table 1 shows, for the runways 6L and 6R SOIA at CLE, no wakes were encountered at the in-trail spacing distances evaluated. In addition, analysis of the simulation results at these specific distances confirms that there would be no encounters for in-trail spacing values between the values listed in the table.

3.2. Runways 24L and 24R SOIA Results

The runways 24L and 24R SOIA analysis does show the potential for wake encounters by the trailing aircraft. During the ASAT simulation runs, these wake encounters were primarily observed while the LDA aircraft (runway 24L) was past the landing threshold at an altitude of less than 50 feet. This circumstance is illustrated in Figures 4, 5, 6, and 7. (Figures 4, 5, 6, and 7 are visualizations generated by ATSI's Wake Interactive Display Design and Analysis Tool (WIDAT™)). These figures show the results of an ASAT run with a B757 leading the SOIA operation and landing runway 24R and an A320 in a trailing position and landing runway 24L. The B757/A320 SOIA pairing is the most critical from a wake encounter standpoint; because the B757 is the highest wake turbulence class aircraft approved for CLE SOIA use and the wing semi-spans of the B757 and A320 combine to make the largest AOI for wake encounter determination at CLE. Since the B757/A320 pairing is the most critical, the wake vortex encounter results for these aircraft can be applied to all other allowed CLE SOIA aircraft pairings.

Figure 4 shows the lead aircraft, i.e., the B757, over the landing threshold of runway 24R. The red lines emanating from the wingtips of the B757 are the wake vortices. Following the wake vortices back up the approach path, notice how the wake vortices move, under the influence of a right crosswind, toward the approach path of the runway 24L aircraft. Figure 5 depicts the same situation as Figure 4 except from a different perspective.

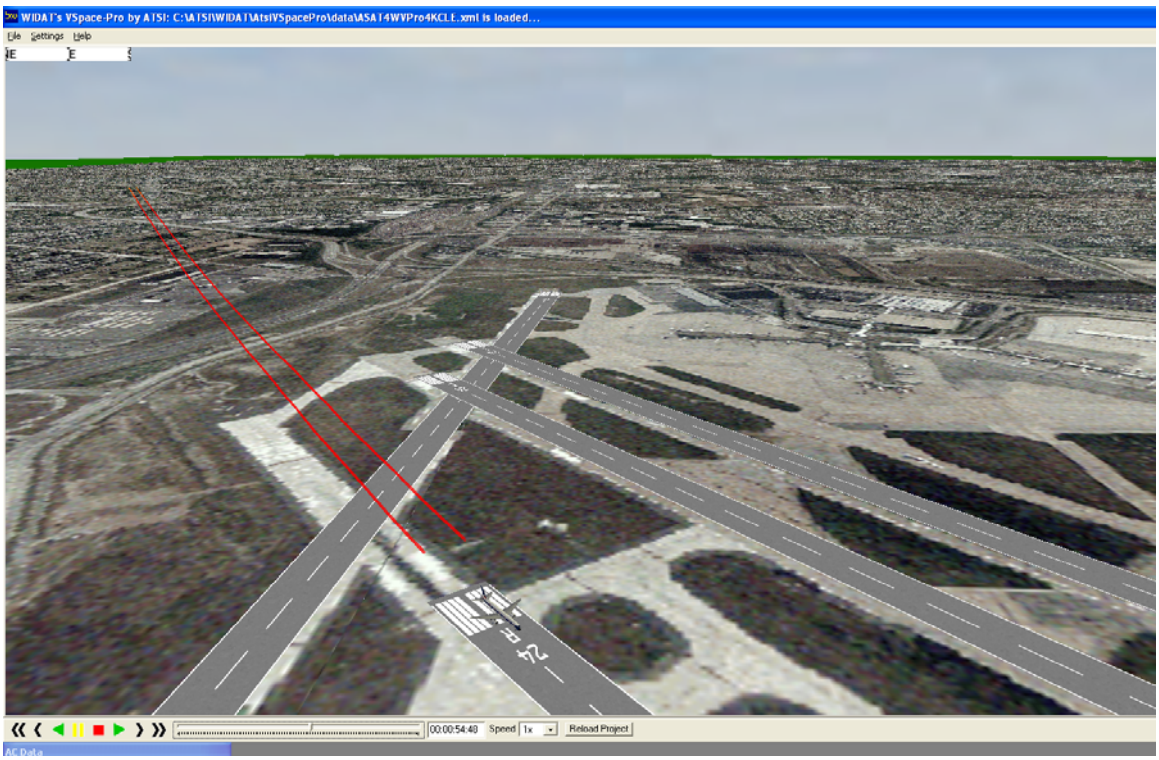

Figure 4: Leading Aircraft (B757) over Runway 24R Landing Threshold

Figure 5: Leading Aircraft (B757) over Runway 24R Landing Threshold (rear view)

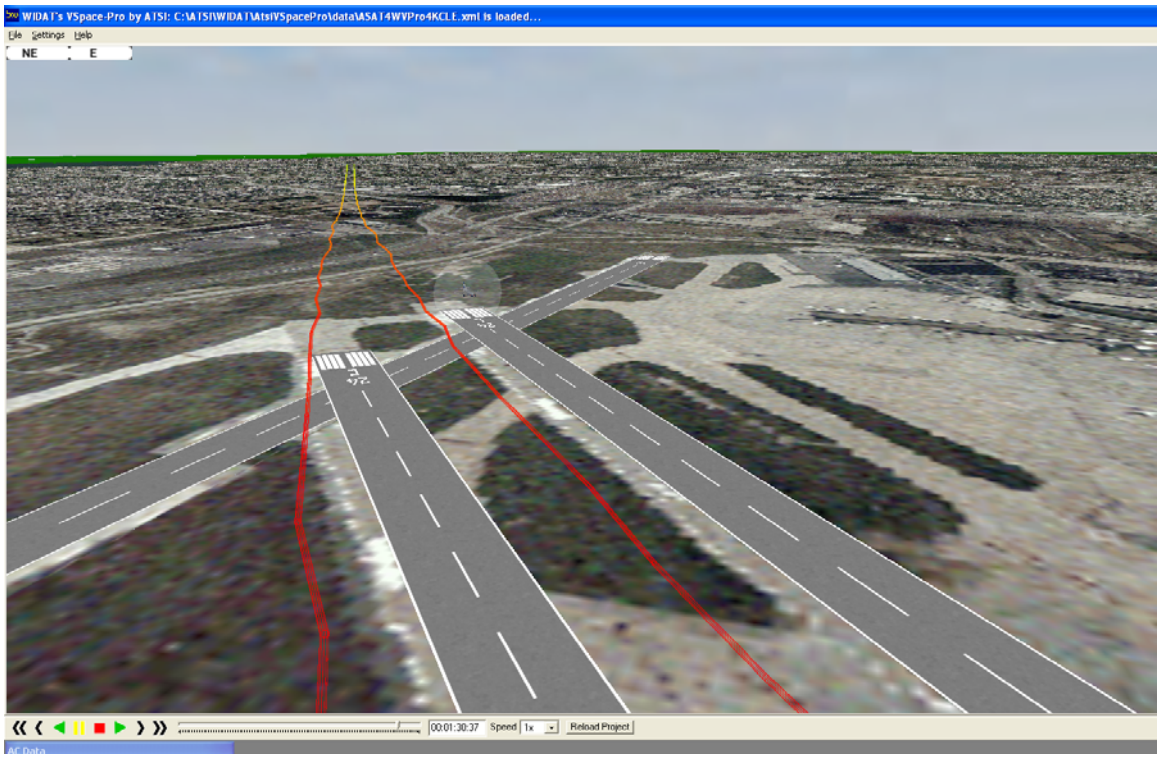

Figure 6: Trailing Aircraft over Runway 24L Landing Threshold

Figure 7: A320 Wake Vortex Encounter

In Figure 6, the trailing aircraft, i.e., the A320, is over the runway 24L landing threshold. The wake vortex encounter AOI as described in paragraph 2.9 is visible in light green around the aircraft. The green color indicates that no wake encounter has been detected.

In Figure 7, the simulated A320 has moved past the landing threshold and is at an altitude of approximately 30 feet. Notice that the wake vortex encounter AOI has turned red, indicating that a wake vortex encounter has been detected.

The results also indicate that under the environmental conditions stipulated in this study, a wake generated by an aircraft landing on runway 24R will be transported to the vicinity of the landing threshold of runway 24L in 45 seconds for a B757 traveling at 120 Knots, and 48 seconds for a B757 traveling at 150 Knots. (Aircraft traveling at slower speeds generate comparatively stronger and faster wakes.) If the trailing aircraft can stay within a predetermined distance behind the leading aircraft, it can land before wakes have time to travel to the runway 24L approach path. Knowing the transport time of the wakes allows computation of these predetermined in-trail distances as a function of aircraft speed. (Since SOIA at CLE for runways 24L/R is a dependent operation and in order to stay within the proper in-trail distance, the trailing aircraft is assumed to match the speed of the leading aircraft.)

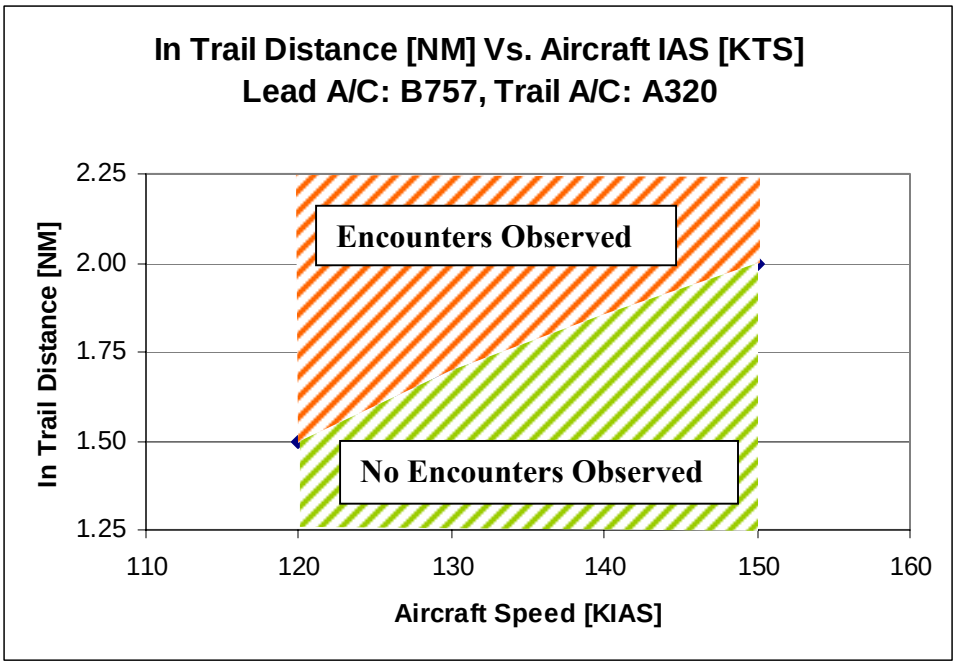

Figure 8: Depiction of CLE Runways 24L/R SOIA Results

Figure 8 shows these results in graphical form. If the speed of the SOIA operation, i.e., basically that of the leading aircraft, was 120 Knots or more and the trailing aircraft stayed within 1.5 NM of the lead aircraft, then no wakes were encountered by the trailing aircraft under the conditions evaluated in this study. Similarly, if the speed of the SOIA operation was 150 Knots or more and the trailing aircraft stayed within 2.0 NM of the lead aircraft, then no wakes were encountered by the trailing aircraft under the conditions evaluated in this study.

As stated previously, the B757/A320 combination resulted in the shortest wake transport times to the trailing aircraft's AOI. This represents a conservative result for all other combinations of aircraft approved for the CLE SOIA.

4.0. Results and Conclusions

1. The proposed SOIA operation to runways 6L/R at CLE, i.e., ILS to runway 6L and LDA to runway 6R, poses no wake turbulence hazard. Thus any and all aircraft wake turbulence classes, except Heavy class and two B757s, may be paired for the SOIA operation. A maximum crosswind limitation of 10 Knots applies.

2. Unrestricted use of the proposed SOIA operation to runways 24L/R, i.e., ILS to runway 24R and LDA to runway 24L, does pose a wake turbulence hazard for the trailing aircraft conducting the LDA approach. Therefore, in accordance with FAA Order 8260.49 (Reference 1), specific wake turbulence mitigation strategies must be developed and applied.

There are a number of possible mitigation strategies that might be developed and applied such as restrictions on aircraft size or pairing, restrictions on the crosswind direction, or further restriction on the crosswind magnitude to a lower value. One other mitigation strategy, which was part of this study, could involve operational implementation of the in-trail distance/airspeed combinations shown in Figure 8. For example, if the SOIA operation speed is 150 Knots or more and if Air Traffic Control (ATC) can guarantee 2 NM or less in-trail spacing between the ILS aircraft and the LDA aircraft from the MAP to the runway threshold, any and all aircraft (except Heavy and two B757s) can be paired for a SOIA. In this case, ATC would be required to issue a missed approach instruction to the LDA aircraft if in-trail spacing exceeded 2 NM while the LDA aircraft is between the LDA MAP and the landing threshold.

3. To alleviate the need for a specific wake vortex mitigation strategy as suggested in 2. above, it is recommended that CLE move the LDA approach to the far landing threshold of runway 24R. This threshold stagger would insure that the trailing aircraft remains above the flight path of the leading aircraft and thus would provide added protection from wake turbulence encounters. If this were done, there would be no wake turbulence mitigation requirements for the runways 24L/R SOIA operation, except for the prohibition of Heavy wake turbulence class aircraft and B757 pairs. In addition, the runways 24L/R SOIA operation would then conform with similar operations in the National Airspace System (NAS) and to existing wake avoidance guidance such as the following excerpt from chapter 7 of the Aeronautical Information Manual:

"**Landing behind a larger aircraft - when parallel runway is closer than 2,500 feet.** Consider possible drift to your runway. Stay at or above the larger aircraft's final approach flight path - note its touchdown point."

4. Separation between the trailing aircraft in a SOIA pair and the leading aircraft in the next SOIA pair is in accordance with standards in FAA Order 7110.65 Air Traffic Control (Reference 4).

5. Airport runway orientation is usually based on long-term weather data so the runways can be aligned with the prevailing winds. However, due to normal wind direction variability, there is usually a crosswind component that can transport a wake toward an adjacent runway. Light winds and low turbulence levels are conducive to long lasting wakes. However, when winds are light, the crosswind will not be large enough to transport a wake to an adjacent runway prior to wake decay. Increasing crosswinds can transport wakes more quickly but are generally associated with higher levels of atmospheric turbulence and more rapid wake decay. The practical result is that there is a maximum distance that wakes can be transported by the wind in a given time as the increased transport rate of the higher wind is offset by faster decay, particularly near the ground. This maximum transport distance depends on the size of the generating aircraft and is greater for larger aircraft.

In addition, as atmospheric turbulence increases, wakes become less coherent spatially so that an aircraft may encounter a smaller region of the wake. This phenomenon provides a significant additional safety factor relative to wake decay alone. However, there is currently no accepted way to quantify this additional safety benefit so the results of this study should be viewed as conservative in this regard.

5.0. References

1. FAA Order 8260.49, Simultaneous Offset Instrument Approach (SOIA), 8/8/02.

2. Federal Aviation Administration Aeronautical Information Manual, U. S. Department of Transportation, Change 3, 8/4/05.

3. Hinton, D.A.: "An Aircraft Vortex Spacing System (AVOSS) for Dynamical Wake Vortex Spacing Criteria," AGARD 78th Fluid Dynamics Panel Meeting and Symposium on the Characterization & Modification of Wakes from Lifting Vehicles in Fluids, Trondheim, Norway, 20-23 May 1996, AGARD CP-584, Paper 23.

4. FAA Order 7110.65, Air Traffic Control, 2/19/2004.

5. Lankford, David N., et al: "St. Louis Lambert Field Close Parallel Approaches Using 3° Offset LDA with Glideslope to Runway 30L," DOT-FAA-AFS-420-79, April 1999.

Appendix A. CLE LDA Aeronautical Charts
Figure A1: CLE LDA PRM 6R

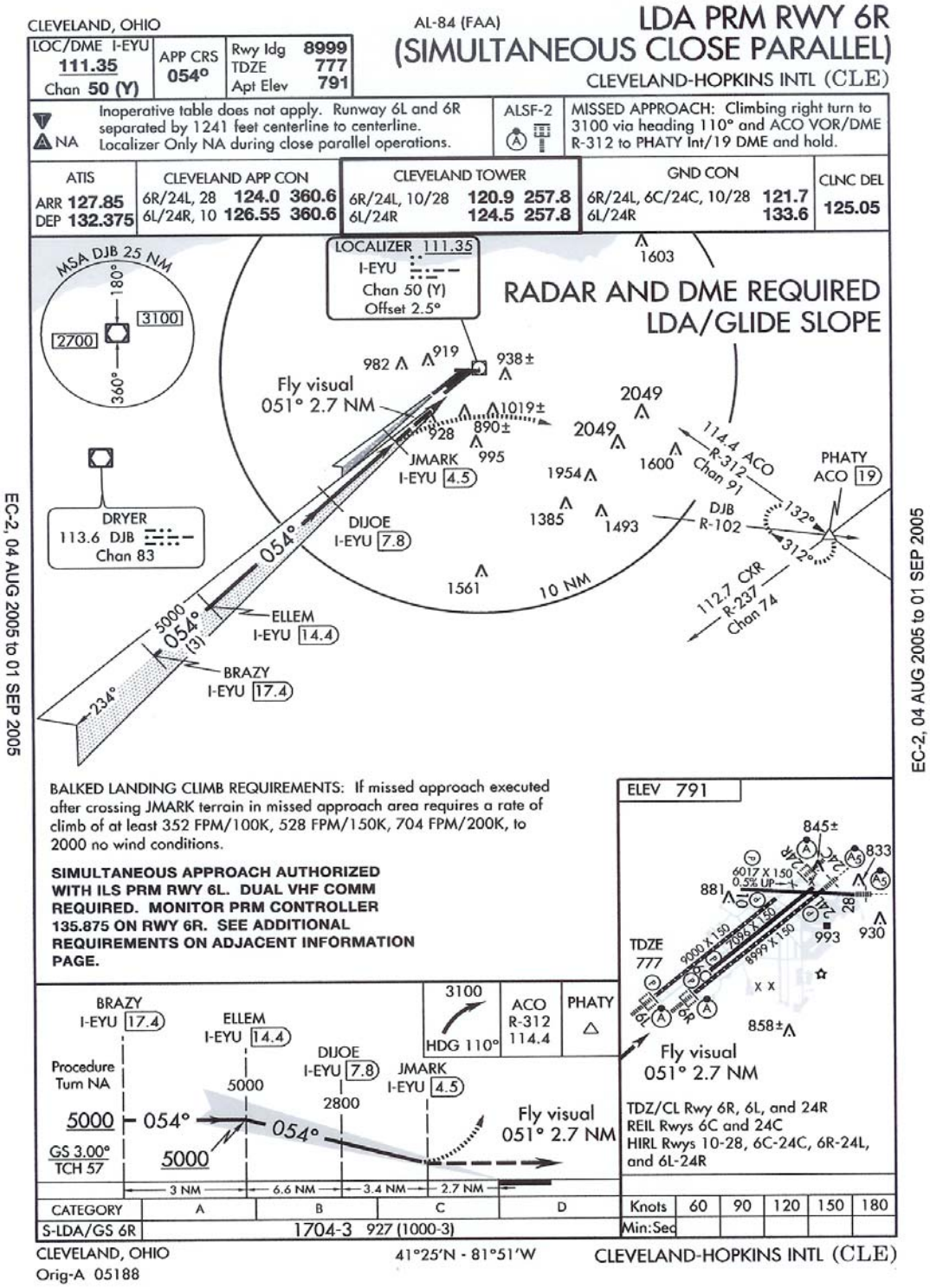

Figure A2: CLE LDA PRM 6R Attention All Users Page

LDA PRM RWY 6R Orig 05132
(SIMULTANEOUS CLOSE PARALLEL) AL-84 (FAA)

CLEVELAND-HOPKINS INTL (CLE)
CLEVELAND, OHIO

EC-2, 04 AUG 2005 to 01 SEP 2005

ATTENTION ALL USERS OF LDA PRECISION RUNWAY MONITOR (PRM)

Special pilot training required. Pilots who are unable to participate, or dispatchers on their behalf, must contact the FAA Command Center prior to departure (1-800-333-4286 or 703-904-4452) to obtain an arrival reservation. Non-participating pilots enroute to CLE as an alternate, or trained pilots that are unexpectedly unable to participate due to in-flight circumstances will be afforded appropriate arrival services as operational conditions permit and shall notify the Cleveland ARTCC as soon as practical, but at least 100 miles from CLE.

Condensed Briefing Points:
-- When instructed, immediately switch to the tower frequency and select the monitor frequency audio.
-- Report the ILS traffic in sight as soon as practical and prior to JMARK. DO NOT PASS.
-- Remain on the LDA until passing the LDA MAP so as not to penetrate the NTZ.

1. **ATIS.** When the ATIS broadcast advises that simultaneous ILS PRM and LDA PRM approaches are in progress, pilots should brief to fly the LDA PRM approach. If later advised to expect an LDA DME approach, the LDA/PRM chart may be used after completing the following briefing items:

(a) Minimums and missed approach procedures are unchanged.
(b) Monitor frequency no longer required.
(c) Lower LDA intercept altitudes may be assigned when advised to expect LDA DME 6R approach.

Simultaneous parallel approaches will only be offered/conducted when the weather is at least 1,200 feet (ceiling), and 3 miles (visibility).

2. **Dual VHF Communication required.** To avoid blocked transmissions, each runway will have two frequencies, a primary and a monitor frequency. The tower controller will transmit on both frequencies. The Monitor controller's transmissions, if needed, will override both frequencies. Pilots will ONLY transmit on the tower controller's frequency, but will listen to both frequencies. Select the monitor frequency audio only when instructed by ATC to contact the tower. The volume levels should be set about the same on both radios so that the pilots will be able to hear transmissions on at least one frequency if the other is blocked. If executing a missed approach at JMARK, begin the turn as soon as practical.

3. **All "Breakouts" are to be hand flown** to assure that the maneuver is accomplished in the shortest amount of time. Pilots, when directed by ATC to break off an approach, must assume that an aircraft is blundering toward their course and a breakout must be initiated immediately.

(a) ATC Directed "Breakouts:" ATC directed breakouts will consist of a turn and a climb or descent. Pilots must always initiate the breakout in response to an air traffic controller instruction. Controllers will give a descending breakout only when there are no other reasonable options available, but in no case will the descent be below minimum vectoring altitude (MVA) which provides at least 1,000 feet required obstuction clearance. The applicable MVA is 2,700 feet at CLE.

(b) Phraseology - "TRAFFIC ALERT:" If an aircraft enters the "NO TRANSGRESSION ZONE (NTZ)," the controller will breakout the threatened aircraft on the adjacent approach. The phraseology for the breakout will be:

"TRAFFIC ALERT, (aircraft call sign) TURN (left/right) IMMEDIATELY, HEADING (degrees), CLIMB/DESCEND AND MAINTAIN (altitude)".

4. **CLE LDA Visual Segment.** If advised that there is traffic on the 6L ILS, pilots may continue past the LDA MAP if:
a) the ILS traffic is in sight and is expected to remain in sight.
b) ATC has been advised that "traffic is in sight." (ATC is not required to acknowledge this transmission)
c) the runway environment is in sight.

Otherwise, execute a missed approach at the LDA MAP. Between the LDA MAP and the runway threshold, pilots are responsible for separating themselves visually from the traffic on the ILS approach, which means maneuvering the aircraft as necessary to avoid the ILS traffic until landing (do not pass), and providing wake turbulence avoidance, if applicable. If visual contact with the ILS traffic is lost, advise ATC as soon as practical and execute the published missed approach unless otherwise instructed by ATC.

EC-2, 04 AUG 2005 to 01 SEP 2005

(SIMULTANEOUS CLOSE PARALLEL) 41°25'N - 81°51'W

CLEVELAND, OHIO
CLEVELAND-HOPKINS INTL (CLE)

Appendix B. CLE SOIA Simulation Probability Density Functions

B1 - First Turn Bank Angle

The following values were used to generate the bank angle value of the first turn:

Function Type	:	Normal
SigmaBank1	:	3.2 degrees
MeanBank1	:	10.6 degrees
MaxBank1	:	15.6 degrees
MinBank1	:	7.0 degrees

B2 - Second Turn Bank Angle

The second turn is in the opposite direction of the first turn. The following values were used to generate the bank angle value of the second turn:

Function Type	:	Normal
SigmaBank2	:	4.4 degrees
MeanBank2	:	-14.0 degrees
MaxBank2	:	-11.0 degrees
MinBank2	:	-19.0 degrees

B3 - Definition of the Runway Centerline Overshoot

Function Type	:	Normal
SigmaOs	:	78.75 feet
MeanOs		106.50 feet
MinOs	:	0.00 feet
MaxOs	:	454.00 feet