Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)

Flight Systems Laboratory
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Released by:

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December 2008

Technical Report
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A Simultaneous Offset Instrument Approach (SOIA) procedure to runways 24R and 24L at Cleveland Hopkins International Airport has not been implemented because of wake turbulence concerns. Runway 24L, served by the Localizer-type Directional Aid (LDA), has a landing threshold that is staggered approximately 1,100 feet northeast of the runway 24R landing threshold. In SOIA, the arrival aircraft are paired with the LDA aircraft trailing the Instrument Landing System (ILS) aircraft. With the runway 24R and 24L threshold geometry, the LDA aircraft is operating behind and below the ILS aircraft, a position that increases the probability of a wake encounter. In order to minimize the effect of wake encounter exposure, the FAA has developed the Wake Protection Zone (WPZ) concept, in which the trailing LDA aircraft is protected from the wake migrating from the aircraft on the 24R final approach course if the aircraft on the approach to 24L remains within the WPZ. This study addresses an analysis of the wake transport characteristics for the 24R/24L runway pair, and calculates the theoretical maximum WPZ size. The theoretical maximum WPZ size was found to be dependent on crosswind strength and aircraft approach speed. For a 10-knot crosswind and 120 knot approach speed, the theoretical maximum WPZ size is 1.5 NM. For a 10-knot crosswind and 140 knot approach speed, the theoretical maximum WPZ size is 1.75 NM.
Executive Summary

Because the parallel runways at Cleveland Hopkins International Airport, (KCLE) are closely spaced (1,241 feet), standard simultaneous arrival operations cannot be conducted. The FAA designed and installed Simultaneous Offset Instrument Approach (SOIA) procedures for runways 6R and 6L, and 24R and 24L at KCLE as a means to increase arrival capacity in marginal weather conditions. However, because of wake turbulence concerns brought about by the arrival threshold staggers that placed the trailing Localizer-type Directional Aid (LDA) aircraft behind and below the leading Instrument Landing System (ILS) aircraft, SOIA has not been implemented for runways 24L and 24R, the runways predominantly used at KCLE.

Wake turbulence encounters during SOIA operations, to date, have been minimized by runway geometry, pilot procedures, and crosswind restrictions. Recently, the FAA has developed the Wake Protection Zone (WPZ) concept as another means of mitigating wake turbulence on closely spaced runways. The Flight Systems Laboratory, AFS-450, Oklahoma City, was tasked to conduct an updated study of Simultaneous Offset Instrument Approaches (SOIA) designed for runways 24R and 24L to determine the maximum theoretical size of the WPZ so that SOIA operations can be conducted.

The study concluded that SOIA can be conducted to 24R and 24L with wake mitigation provided by the WPZ. The theoretical size of the WPZ for a 10-knot crosswind depends on the approach airspeed of the aircraft flying the ILS approach. If the airspeed of the ILS aircraft is 120 knots or more, then the theoretical size of the WPZ is 1.5 NM. If the airspeed of the aircraft flying the ILS approach is 140 knots or more, then the theoretical size of the WPZ is 1.75 NM. Therefore, if there will be aircraft with approach speeds as slow as 120 knots, then the WPZ should be set at 1.5 NM. Note that 1.5 NM will also work for aircraft flying at 140 knots or more. In either case, it is assumed that aircraft are not paired behind a Heavy on 24R and Heavies are not authorized to conduct the LDA Precision Runway Monitor (PRM) 24L approach. There may be airspace, communication, or other issues that would affect the implementation of SOIA wake mitigation using the WPZ that need careful consideration at the local level.
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1.0. Introduction

Because the parallel runways at Cleveland Hopkins International Airport (KCLE) are closely spaced (1,241 feet), standard simultaneous arrival operations cannot be conducted. The FAA designed and installed Simultaneous Offset Instrument Approach (SOIA) procedures for runways 6R and 6L, and 24R and 24L at KCLE to increase arrival capacity during marginal weather conditions. However, because of wake turbulence concerns brought about by the arrival threshold staggers that placed the trailing LDA aircraft behind and below the leading ILS aircraft, SOIA has not been implemented for runways 24L and 24R, the runways used predominantly at KCLE.

Wake turbulence encounters during SOIA operations, to date, have been minimized by runway geometry, pilot procedures, and crosswind restrictions. Recently, the FAA has developed the Wake Protection Zone (WPZ) concept as another means of mitigating wake turbulence on closely spaced runways. The Flight Systems Laboratory, AFS-450, Oklahoma City, was tasked to conduct an updated study of SOIA designed for runways 24R and 24L to determine the maximum theoretical size of the WPZ so that SOIA operations can be conducted.

2.0. Simultaneous Offset Instrument Approach (SOIA)

The concept of SOIA offers one method to increase capacity in marginal weather conditions by enabling aircraft to simultaneously land on both closely spaced parallel runways. In SOIA, a straight-in ILS approach is used for one runway, and a Localizer-Type Directional Aid (LDA) approach with glideslope, offset between 2.5 and 3.0 degrees from the ILS course, is installed on the adjacent runway. To achieve the lowest cloud ceiling and visibility minimums when runway spacing is less than 3,000 feet, SOIA criteria are used that require a one-second update rate Precision Runway Monitor (PRM) radar system or equivalent to monitor the No Transgression Zone (NTZ) between the two approach courses. The missed approach point (MAP) for the LDA approach is located at the point where the ILS and LDA courses converge to a distance of 3,000 feet, the minimum course separation permitted for PRM monitored simultaneous approaches. The authority to conduct SOIA is contained in FAA Orders 7110.65, paragraph 5-9-9, and 8260.49a. Outside of the LDA MAP, conventional closely spaced approach criteria are used. The aircraft are paired so that the ILS aircraft is in the leading position when the LDA aircraft approaches the LDA MAP. Before passing the LDA MAP, the crew of the LDA aircraft must report the ILS aircraft in sight. Having visually acquired the ILS aircraft, the LDA aircraft can proceed past the LDA MAP and execute an alignment maneuver with the runway served by the LDA. Collision avoidance becomes the responsibility of the pilot of the trailing aircraft after visual acquisition.

If the probability of a wake encounter cannot be minimized by runway threshold stagger or other techniques, pilots also must provide wake turbulence avoidance between the LDA MAP and the runway threshold. In this case, the ceiling must be raised at least 500
feet above the Minimum Vectoring Altitude (MVA)\(^*\) so that pilots conducting the LDA approach can identify the leading ILS aircraft and develop a wake avoidance strategy. Wake turbulence separation between the heaviest class aircraft in a given aircraft pair and aircraft in the succeeding pair is always provided by Air Traffic Control (ATC).

### 3.0. The Wake Protection Zone (WPZ) Concept

The WPZ concept provides a method to minimize wake vortex concerns during SOIA operations by giving controllers a display tool for establishing the trailing LDA aircraft within the prescribed WPZ. The concept also calls for warnings to be generated to Air Traffic Control (ATC) by the PRM between the LDA MAP and runway threshold if the trailing aircraft exits the rear boundary of the WPZ. The theoretical size of the WPZ is a function of runway geometry, permitted crosswind, wake vortex transport and dissipation characteristics and generating aircraft wake turbulence class, and is the focus of this study.

Implementation of the WPZ concept in an operational ATC environment requires that the theoretical size of the WPZ be adjusted to account for several additional factors. In order to ensure with a high level of confidence that the system can display in a timely manner a trailing aircraft excursion outside of the WPZ, consideration must be given to appropriate factors such as radar data processing latencies, ATC broadcast time, crew/pilot response time and aircraft acceleration, when determining the maximum in-trail distance as displayed to ATC. These factors were evaluated by a separate Air Traffic Control study.

When the ILS aircraft passes the end of the NTZ farthest from the runway threshold, the WPZ will be depicted on the LDA final approach course as seen on the PRM monitor controller’s display. During SOIA operations, ATC would be responsible for positioning and maintaining the trailing aircraft within the WPZ prior to the LDA MAP. This task would be primarily accomplished by issuing, when needed, speed control instructions over ATC radio frequencies to the trailing aircraft. The trailing aircraft’s crew would then respond to the ATC instruction and the aircraft would begin to accelerate or decelerate as required. Audible alerts are not issued by the PRM in this phase of the approach. At KCLE, a WPZ will be depicted for each set of paired aircraft, regardless of the weight class. Controllers retain the option to remove the WPZ in cases where wake turbulence is not an issue.

When the LDA aircraft passes the LDA MAP, the audible alerting function is activated. If the LDA aircraft exits the WPZ after passing the LDA MAP, the PRM will issue an audible alert that will be broadcast in the tower cab and visually depicted on the PRM monitor controller’s display. The local controller will be responsible for issuing a wake warning to the affected aircraft, followed by appropriate instructions. The WPZ alerting

\(^*\) The criterion for having a cloud ceiling of at least MVA plus 500 ft for pilot provided wake turbulence mitigation is in the process of being changed to read, “500 ft above the minimum ceiling (clear-of-clouds point) authorized to conduct SOIA operations.”
function is completely automatic. Controllers are only required to respond to generated alerts.

4.0. SOIA Design for Runways 24R and 24L

AFS-450 previously conducted a design and wake turbulence evaluation for runways 6R/6L and 24R/24L at KCLE. The study concluded that the threshold stagger (about 2,500 feet) between 6R and 6L mitigated wake concerns because the LDA aircraft was landing on the far threshold and remained above the wake of the leading ILS aircraft. On 24R and 24L however, the LDA aircraft was landing on the near threshold, and was operating below and behind the leading ILS aircraft in a position where the wake encounter probability was greater. At the time of the study, the threshold stagger was about 2,200 feet between 24R and 24L. During 2008, the landing threshold of runway 24L is being shifted, and when construction is completed in late 2008, the new stagger distance between 24R and 24L will be reduced to about 1,100 feet. However, the LDA runway will still be the near threshold. In this case, wake turbulence is still an issue. Wake mitigation options include:

- Sorting of arrival aircraft by ATC so that the heavier wake class trails. The pairing of aircraft in the same wake class is permitted except for two Heavies. The option is considered unrealistic from an ATC perspective and undesirable from a pilot perspective because aircraft flying the LDA approach are still susceptible to potentially significant wake encounters when paired behind aircraft on the ILS course that are larger but still in the same weight class (regional jet behind a B737-800 as an example).

- Having the lead ILS aircraft downwind of the trailing LDA aircraft. This is a viable option, but as a sole mitigation of wake, it restricts the use of SOIA to certain wind conditions.

- Emerging technology in which the PRM depicts a WPZ behind the ILS aircraft. ATC can use the PRM to provide guidance to ensure that the LDA aircraft, when between the LDA MAP and the runway threshold, remains within the WPZ. In this case, aircraft of any wake category can be paired, and there are no limitations based on wind direction.

The shifted 24L landing threshold at KCLE has necessitated an additional study by AFS-450 to determine the effect of wakes that are transported between 24R and 24L during SOIA operations. Using this data, AFS-450 determined the maximum theoretical size of the WPZ that could be used at KCLE to mitigate wake turbulence. The remainder of this paper addresses the methods and results of that investigation.

5.0. Airspace Simulation and Analysis Tool Modeling.
The analysis was performed using the Airspace Simulation and Analysis Tool (ASAT) and was divided into 8 scenarios as shown in table 1. Each scenario was simulated with a crosswind of 10 knots, blowing from the straight-in ILS runway to the LDA runway. This wind direction represents the worst case scenario for a wake encounter. The initial position of the straight-in ILS aircraft was set abeam of the MAP of the LDA approach, since this point represents a closing of the lateral distance between the approaches. The initial longitudinal or in-trail position of the LDA procedure aircraft was varied in 0.25 NM increments between 1.5 and 2.25 NM behind the straight-in ILS aircraft. The in-trail separation between aircraft was kept constant throughout the simulation. The initial overshoot position of the LDA aircraft was varied by using randomly selected overshoot distances. The simulation concluded when either a potential wake encounter was detected or the LDA procedure aircraft landed.

<table>
<thead>
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<th>Scenario</th>
<th>IAS (knots)</th>
<th>In-Trail Distance (NM)</th>
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<td>1</td>
<td>120</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>1.75</td>
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<td>7</td>
<td>140</td>
<td>2.0</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
<td>2.25</td>
</tr>
</tbody>
</table>

The probability of a wake vortex encounter is affected, not only by crosswinds, but also by overshoots when the LDA aircraft intercepts the final approach course to the runway. Data from a study (Lankford, McCartor, et. al., 2) conducted to determine the acceptability of a 3° offset LDA with glideslope at St. Louis Lambert Field (STL) were used to develop a probability density function of overshoot distances to include in the ASAT simulation.

The basic purpose of the 1999 study was to evaluate whether the flying qualities of the visual segment after leaving the LDA will be improved by the addition of a glideslope. LDA approaches without glideslope were approved in 1990 to runways 12R and 30L at STL. Although the approaches were being used successfully, a proponent believed that an offset LDA with an electronic glideslope usable throughout the visual approach segment and a PRM system would significantly enhance the flying qualities of the LDA and provide additional operational efficiency and safety. Obviously the MAP point of the LDA approach could be placed in several different positions relative to the runway threshold. Therefore, a flight test was designed to compare several different possible positions of the MAP. The primary purpose of the flight test was to determine an optimal position of the MAP.
In order to determine an optimal placement of the MAP relative to the runway threshold, three types of LDA procedures to RWY 30L were tested. The approaches were designed to evaluate the significance of the distance of the MAP from the runway threshold and abeam the adjacent localizer course. Six test scenarios were flown using FAA qualified, level C flight simulators. The simulators used were the FAA’s B-727, Trans World Airline’s (TWA) MD-80, and a South West Airline (SWA) B-737. The evaluation was conducted with line pilots from the following airlines: American, Delta, Kiwi, Reno Air, Southwest, TWA, and USAir. In addition, FAA Aviation Safety Inspectors also served as pilots in the test.

Although the scenarios were not intended to evaluate wake vortex encounters, one of the recorded parameters was the overshoot of the LDA aircraft when it intercepted the extended runway centerline. The application of the STL overshoot data to the CLE ASAT simulation is discussed in Appendix A, section A1.2.

6.0. Included Appendices

Appendix A, Design methodology and results
Wake Evaluation for Runways 24R and 24L
SOIA approach design Runways 24R and 24L

Appendix B, Operations Data
Airport diagram
Approach plate LDA DME Runway 24L (prior to runway threshold shift)
Approach plate LDA PRM 24R
Approach plate LDA PRM 6R
Attention All Users Page (AAUP) 24R
Draft Attention All Users Page (AAUP) 24L
Depiction of a WPZ
7.0. Conclusion

SOIA can be conducted to the runways 24R and 24L using the WPZ concept. The theoretical size of the WPZ for a 10-knot crosswind depends on the approach airspeed of the aircraft flying the LDA approach. If the airspeed of the LDA aircraft is 120 knots or more, then the theoretical size of the WPZ is 1.5 NM. If the airspeed of the aircraft flying the LDA approach is 140 knots or more, then the theoretical size of the WPZ is 1.75 NM. Therefore, if there will be aircraft with approach speeds as slow as 120 knots, then the WPZ should be set at 1.5 NM. Note that 1.5 NM is also satisfactory for aircraft flying at 140 knots or more. In either case, it is assumed that aircraft are not paired behind a Heavy on 24R and Heavies, because of procedure design, are not authorized to conduct the LDA PRM 24L approach. When a WPZ length is chosen and the surveillance system is programmed for that length, the actual displayed size of the WPZ will be slightly smaller than the programmed value (Ladecky, Lintzenich, and Moore, 1).

There may be airspace, communication, or other issues that would affect the implementation of SOIA wake mitigation using the WPZ that need careful consideration at the local level.
BIBLIOGRAPHY

1. Ladecky, Shahar; Lintzenich, Joe; Moore, Carl. *Determination of Maximum Displayed In-trail Distance during Simultaneous Offset Instrument Approach (SOIA) Operations to Ensure Aircraft Remain within the Wake Protection Zone*. CR-ATSI-2006-58; Air Traffic Simulation, Inc. (ATSI); 3317 Deer Valley; Edmond, Oklahoma 73034. 2007

2. Lankford, David, N.; McCartor, Gerry; et.al.. *St. Louis Lambert Field Close Parallel Approaches Using 3° Offset LDA with Glideslope to Runway 30L*. DOT-FAA-AFS-420-79; Federal Aviation Administration, Standards Development Branch, P. O. Box 25082, Oklahoma City, OK, 73125. 1999.
APPENDIX A: Design methodology and results
A1.0. ASAT WAKE VORTEX RISK ANALYSIS MODULE

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 aviation scenario.

a. At the heart of the system are 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, navigational aids (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.

For purposes of this evaluation, ASAT was modified to include a wake vortex model based on the National Aeronautics and Space Administration (NASA) Aircraft Vortex Spacing System (AVOSS) model described in the next section. The wake vortex model simulated the wake generation, transport, and decay characteristics of the wake turbulence aircraft classes, i.e., 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 crosswind), lateral and vertical errors along the approaches, wake turbulence generated by the leading ILS aircraft, and the movement of the wake turbulence as the result of crosswind.

A1.1. 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.

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 Monte Carlo simulation capability to determine whether an aircraft on numerous and varied simulated SOIA approaches encounter wake turbulence.
The APA is able to simulate 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 crosswinds. 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. The APA is also capable of simulating wakes generated near ground effect, where they descend vertically, similar to out of ground effect, and then enter ground effect where bouncing may occur as the wake is affected by ground effect and then transported horizontally.

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. Crosswinds are necessary 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 relatively low turbulence level, as represented by Eddy Dissipation Rate (EDR), of $1 \times 10^{-3} \text{ m}^2/\text{sec}^3$. This turbulence level is lower than might be typically expected for crosswinds as high as the 10 knots used in the study and was chosen to provide a conservative result in the absence of known or measured turbulence levels.

A1.2. OVERSHOOT SIMULATION

In order to determine an optimal placement of the MAP relative to the runway threshold at STL, the 1999 study (Lankford, McCartor, et. al., 2) considered three types of LDA procedures to runway 30L. The approaches were designed to evaluate the significance of the distance of the MAP from the runway threshold and abeam the adjacent localizer course. Line pilots, current and qualified, were enlisted to fly flight simulators programmed to emulate the following:

(a) Approaches using the current published LDA that is parallel to the adjacent approach path, scenario LDA 0, beginning from a DME of 18 NM and an altitude of 5,500 feet. Pilots flew the entire instrument approach even though only the visual segment was to be evaluated.

(b) Approaches using a $3^\circ$ angled offset LDA with glide slope to the missed approach points (MAPs). These MAPs were spaced 3,400 feet from the adjacent approach path with MAP to threshold distances of 1.59 and 2.59 NM for scenarios LDA A and B.

(c) Approaches using a $3^\circ$ angled offset LDA with glide slope to the missed approach points (MAPs). These MAPs were spaced 3,000 feet from the adjacent approach path with MAP to threshold distances of 1.94 NM, 2.58 NM, and 2.27 NM for scenarios LDA C, D, and E.

Winds were introduced to test the effect of head winds and quartering tailwinds. The simulated winds were as follows:
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)


(a) 13 KT from 080°; a right quartering tailwind,
(b) 13, 14, and 15 KT from 165°; a left quartering tailwind,
(c) 9 and 10 KT from 300°; a head wind,
(d) and 14 and 15 KT from 350°; a right quartering head wind.

Statistical tests indicated that the overshoot distance means, in feet, among the six LDA approaches were the same. The overshoot distance means among the four wind conditions were significantly different. The largest means were produced by the left quartering tailwinds. All the data from the various scenarios were pooled into one data set. The left quartering tailwind data were also included to make the ASAT simulation more conservative.

Statistical tests indicated that the probability density function (pdf) that would best fit the combined data was the Johnson SB. The Johnson SB is a family of pdf’s that are a translation of the standard normal (Gaussian) pdf. The mean of the standard normal pdf is zero and the variance is one. The Johnson SB is a bounded pdf, i.e., it does not have infinite tails like a normal or Gaussian pdf. Instead the possible values that the pdf can return are bounded between two finite numbers. The translation equation of the Johnson SB is given in equation 1.

\[
\begin{align*}
\frac{x - \varepsilon}{\lambda + \varepsilon} - z = \gamma + \delta \ln \left( \frac{x - \varepsilon}{\lambda + \varepsilon - x} \right), & \quad \varepsilon < x < \lambda + \varepsilon \\
\end{align*}
\]  

In equation 1, the letter z indicates a value from the standard normal pdf. The letter x indicates an overshoot value in feet. The Greek letters represent four parameters that must be estimated from the data to “fit” the curve to the data. The Greek letter \( \varepsilon \) represents the lower bound of the values that will be produced by the Johnson SB pdf. The sum, \( \lambda + \varepsilon \), is the upper bound of the Johnson SB pdf.

The values of the Johnson SB parameters that provided the best fit to the data are the following.

- \( \gamma = 0.3209360184E+01 \)
- \( \delta = 0.1015586214E+01 \)
- \( \lambda = 0.3267452501E+03 \)
- \( \varepsilon = -0.3048906856E+01 \)

From the list of parameters, the Johnson SB pdf will produce overshoot values between -3.05 feet and 323.7 feet.

**A1.3. INITIAL ASAT SIMULATION CONDITIONS**

A crosswind of 10 knots was set perpendicular to the runways, blowing from the straight-in ILS runway to the LDA runway. Due to wake transport, this represents the worst case scenario for a wake encounter. The initial position of the straight-in ILS aircraft was set
abeam of the MAP of the LDA approach, since this point represents a closing of the lateral distance between the approaches. The initial longitudinal position of the LDA procedure aircraft behind the ILS aircraft was varied in 0.25 NM increments between 1.5 and 2.25 NM. The in-trail separation between aircraft was kept constant throughout the simulation. The initial overshoot position of the LDA aircraft was varied by using randomly selected overshoot distances provided by the Johnson S_B distribution. The simulation concluded when either a wake encounter was detected or the LDA procedure aircraft landed.

The study was performed using a mix of Large aircraft on the lead ILS approach and LDA approach. Gross weight and final approach indicated air speeds (IAS) were assigned to each aircraft across a range of operational values.

### A1.4. WAKE VORTEX SIMULATION DESCRIPTION

To establish the occurrence of a wake vortex encounter, the location of the succeeding 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 of the two aircraft vortices at discrete locations along the approved path of the leading 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 A1. Once the leading aircraft penetrated a “tile,” a simulation of its two wake vortices began. Figure A1 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 penetrated the next tile (tile \(i + 1\)). Meanwhile, the simulation that was started on tile \(i\) at time \(T\) was continuing as it evaluated the movement of the vortices due to crosswind and the inherent nature of wakes to descend and decay.

**Figure A1: Wake Vortex Evaluation “Tiles”**
The crosswind serves to move the vortices from left to right in the illustration while the wake vortices descend. The illustration depicts the position of the vortices after $\Delta T/2$ and $\Delta T$ seconds. When the succeeding 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 succeeding aircraft and the vortices of the leading aircraft. Additional ASAT analysis took place to determine if the wake strength was sufficiently strong to count as a potential wake encounter on that particular tile (see section A1.4).

### A1.5. WAKE VORTEX ENCOUNTER CRITERIA

For purposes of this study, an aircraft was considered to have encountered a wake vortex if a wake exceeding 100 m$^2$/sec penetrated a spherical Area of Interest (AOI) centered on the succeeding 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. For example, the AOI for the B737/MD80 combination is 110.25 feet.

### A1.6. KCLE SOIA ASAT RESULTS

Table A 1 provides the ASAT results for the wake analysis. The 120 knot IAS case started resulting in wake encounters at an in-trail distance of 1.75 NM. The 140 knot IAS case encountered wake at an in-trail distance of 2.0 NM. No wake encounters were detected for either case when the in-trail distances were maintained at 1.5 NM.

<table>
<thead>
<tr>
<th>In-Trail Distance</th>
<th>1.5 NM</th>
<th>1.75 NM</th>
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<td></td>
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<td>Total Aircraft Pairs</td>
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<td>120</td>
<td>0</td>
<td>31618</td>
</tr>
<tr>
<td>140</td>
<td>0</td>
<td>26522</td>
</tr>
</tbody>
</table>

Figures A 2 and A 3 are screen captures taken from the ASAT simulations. The graphical depictions indicate the approximate area of intersection between the wake turbulence generated by the leading ILS aircraft and the approach path of the trailing LDA aircraft. The marked distances of 1.5, 2.0, and 2.5 NM represent the trailing distance behind the ILS aircraft. Figure A 2 shows a scenario with 10 knots of crosswind.
and both aircraft at an approach IAS of 120 knots. The EDR chosen for the simulation was $1 \times 10^{-3}$ m$^2$/sec$^3$. This turbulence level is lower than might be typically expected for crosswinds as high as the 10 knots used in the study and was chosen to provide a conservative result in the absence of known or measured turbulence levels. The wake turbulence can be seen in figure A 2 as it intersects the LDA approach path at an in-trail distance of approximately 2.3 NM.

Figure A 3 depicts the same scenario with a 15-knot crosswind and the same EDR of $1 \times 10^{-3}$ m$^2$/sec$^3$. This turbulence level is lower than might be typically expected for crosswinds as high as the 15 knots used in the study and was chosen to provide a conservative result in the absence of known or measured turbulence levels. The wake turbulence with a 15 knot crosswind intersects the LDA approach path at an in-trail distance of approximately 1.6 NM. This comparison demonstrates the sensitivity of the lateral transport of the wake vortex to a 5-knot increase in crosswind.
Figure A 2: ASAT Simulation - 10 knots crosswind with 120 knots IAS

10 knots crosswind

2.5 NM

2.0 NM

1.5 NM

Figure A 3: ASAT Simulation - 15 knots crosswind with 120 knots IAS

15 knots crosswind

2.5 NM

2.0 NM

1.5 NM
A2.0. SOIA Design Tool

The SOIA design tool was developed to apply accurately the design criteria of TERPS Order 8260.49a for the LDA approach to the geometry of the runways planned for the SOIA operation. The tool uses inputs that include the runway centerline separation, glideslope threshold crossing altitude, runway threshold elevation, runway course, the localizer offset (2.5 to 3.0 degrees), maximum acceptable runway centerline overshoot, the course angle of the straight segment between the Missed Approach Point (MAP) and SAP-500 feet AGL on the extended runway center, and the aircraft with the highest approach speed authorized to fly the LDA approach. The tool uses these values to calculate the latitude and longitude of the LDA missed approach point, and the altitude of the glideslope at the MAP, which translates into the Decision Altitude (DA). Once the MAP position is fixed, airport designers can establish the location of the LDA antenna along a line that passes through the MAP at the chosen offset value, taking into account runway and taxiway locations, and other airport obstructions.

Figure A 4: SOIA LDA approach runway 24L (shifted threshold)
APPENDIX B: Operations Data
B1.0. Included Operational Data

The operational data included in Appendix B are:

- The airport diagram
- Approach plate LDA DME 24L (prior to threshold shift)
- Approach plate LDA PRM 6R
- Attention All Users Page (AAUP) 24R
- Draft Attention All Users Page (AAUP) 24L
- Depiction of a WPZ

The data are presented in figures B 1, B 2, B 3, B 4, B 5, and B 6.
Figure B 1: Cleveland Hopkins International Airport
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)


Figure B 2: LDA DME 24L (prior to threshold shift)

Note: LDA-DME and LDA-PRM approach plates are identical except that the LDA-PRM approach plate contains the notations required for simultaneous PRM operations.

The fixes will be shifted about 1,000 feet to the southwest when the new approach plates are published, reflecting the location of the relocated landing threshold on 24L.
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)

Figure B 3: Approach LDA PRM 6R

Note: LDA PRM 6R and 24L Approach plates contain the same notations relative to simultaneous approaches. A new approach plate should will be published 1-15-09.
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)

Figure B 4: Attention All Users Page (AAUP) 24R

ILS PRM RWY 24R
SIMULTANEOUS CLOSE PARALLEL
Cleveland Hopkins International Airport (KCLE)
Cleveland, Ohio

ATTENTION ALL USERS OF ILS PRECISION RUNWAY MONITOR (PRM)

Condensed Briefing Point:

- When instructed, immediately switch to the tower frequency and select the monitor frequency audio.

1. **ATIS.** When the ATIS broadcast advises that simultaneous ILS/PRM 24R and LDA/PRM 24L approaches are in progress, pilots should brief to fly the ILS/PRM 24R approach. If later advised to expect an ILS 24R approach, the ILS PRM 24R 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. A lower glideslope intercept altitude may be assigned when advised to expect ILS 24R 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.

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 obstruction clearance. The applicable MVA is 2,600 feet at KCLE.
   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. **LDA Traffic:** While conducting this ILS/PRM 24R approach, other aircraft may be conducting the Offset LDA/PRM 24L approach. These aircraft will approach from the left-rear and will re-align with 24L after making visual contact with the ILS traffic.

5. **Glide slope Navigation:** Descent on the glide slope meets any published crossing restriction.
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 KCLE 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 KCLE.
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)

DOT-FAA-AFS-450-53
December 2008

LDA PRM RWY 24L
CLEVELAND HOPKINS INTL AIRPORT (KCLE)
(SIMULTANEOUS CLOSE PARALLEL)
Cleveland, Ohio

ATTENTION ALL USERS OF LDA PRECISION RUNWAY MONITOR (PRM)

Condensed Briefing Points

- When instructed, immediately switch to tower frequency and select the PRM monitor frequency audio.
- Report the ILS traffic in sight as soon as practical and prior to FRNCO. DO NOT PASS.
- Remain on the LDA until passing FRNCO so as not to penetrate the NTZ
- Wake turbulence protection provided by ATC, see #6 below.

1. ATIS. When the ATIS broadcast advises that simultaneous ILS PRM 24R and LDA PRM 24L approaches are in progress, pilots should brief to fly the LDA/PRM 24L approach. If later advised to expect an LDA DME 24L approach, the LDA PRM 24L 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 24L 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 PRM monitor frequency. The tower controller will transmit on both frequencies. The PRM 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 PRM 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 FRNCO, 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 obstruction clearance. The applicable MVA is 2,600 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)."


5. CLE LDA Visual Segment. If advised that there is traffic on the 24R 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 FRNCO. Inside FRNCO, pilots are responsible for separating themselves visually from the ILS traffic, maneuvering as necessary to avoid the ILS aircraft until landing (do not pass). If visual contact with the ILS traffic is subsequently lost, advise ATC as soon as practical and execute the published missed approach unless otherwise instructed by ATC.

6. Wake Turbulence Separation: Wake protection with the leading ILS aircraft between FRNCO and the 24L runway threshold is based on ATC procedural separation; see adjoining "Wake Turbulence Protection" page. Maximum wake protection is achieved by following the ILS aircraft as closely as practical.

Special pilot training required. See the ILS PRM 24R AAUP for detailed information.
Simultaneous Offset Instrument Approach (SOIA) Wake Protection Zone (WPZ) Theoretical Size for Runways 24R and 24L at Cleveland Hopkins International Airport, Cleveland, Ohio (KCLE)


LDA PRM RWY 24L  6/11/08      CLEVELAND HOPKINS INTL AIRPORT (CLE)
(SIMULTANEOUS CLOSE PARALLEL) Cleveland, Ohio

ATTENTION ALL USERS OF LDA PRECISION RUNWAY MONITOR (PRM)

Wake Turbulence Protection

ATC will provide wake turbulence protection for all aircraft conducting the LDA PRM 24L approach. Between FRNCO (LDA PRM 24L MAP) and the runway 24L landing threshold, the procedure is as follows:

Within the SOIA pairs, at distances greater than 5 NM from the runway threshold, ATC will issue speed instructions as necessary to establish the LDA aircraft behind the ILS aircraft and inside the wake protection zone (WPZ) prior to reaching the FRNCO INT. The WPZ is nominally defined as the airspace beginning abeam the ILS aircraft and continuing 1.4 NM in-trail of the ILS aircraft, see graphic below.

After passing FRNCO, the pilot is responsible for not exiting the front of the WPZ, which will occur if the LDA aircraft passes the ILS aircraft.

If practical, pilots should not allow the distance between their aircraft and the leading ILS aircraft to increase after passing FRNCO. If, after passing FRNCO, the LDA aircraft falls farther behind the ILS aircraft and exits the rear limit of WPZ, ATC will issue the following instruction:

“(AIRCRAFT/FLIGHT) #, WAKE WARNING, FLY HEADING (XXX), CLIMB AND MAINTAIN (XXXX).”

Pilot should execute the instruction, especially the commencement of the climb, as soon as practical. During WPZ operations, pilots may also use other appropriate wake mitigation strategies as defined in the AIM.

Note: The likelihood of encountering a wake of the leading ILS aircraft after passing FRNCO is very unlikely even if the LDA aircraft is operating farther behind the ILS aircraft than the rear limit of the WPZ. However, when wake separation is provided by ATC using the WPZ, the LDA aircraft must remain inside the WPZ after passing the LDA MAP unless the pilot requests and ATC approves a visual separation or visual approach clearance in which the pilot assumes responsibility for wake separation.
Figure B 6: Depiction of a WPZ

Note: The following is a depiction of the WPZ used in San Francisco data collection. The PRM monitor controller’s scope is shown in the required 4:1 aspect ratio. The LDA 28R approach course is at the top, the ILS 28L approach course at the bottom. The No Transgression Zone (NTZ) is shown in red. The WPZ is represented by the white (forward limit) and blue (rear limit) circles along the LDA course, and between the LDA MAP (located at the left end of the NTZ) and the runway threshold.