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Flight Procedure Standards Branch
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LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT WAKE VORTEX STUDY FOR RUNWAYS 30L AND 30R

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12. Abstract

The Airspace Simulation and Analysis for TERPS system was used to determine the risk of a wake vortex encounter associated with simultaneous operations to runways 30L and 30R at St. Louis Lambert International Airport (STL) using the enhanced ASAT wake vortex model, version 1.2. Five sets of 100,000 ASAT runs were executed. Each set of runs was executed at a selected initial in-trail separation distance ranging from 0.5 NM to 2.5 NM at 0.5 NM increments. The runs were executed using the current aircraft fleet mix and conservative wind conditions. A sensitivity analysis was performed to determine whether a high-risk wake vortex encounter window exists and can be defined. The simulation was conducted with a ground level, direct crosswind from the right of 10 KT increasing logarithmically to 20 KT at 2,000 feet. The simulation did not detect a high-risk wake vortex encounter window. This can be attributed to the relative positions of the runways. The runway centerlines are spaced 1,300 feet apart and the thresholds are staggered 1,698 feet. Therefore, an aircraft approaching runway 30L with a 10 KT or less direct crosswind from the right that increases logarithmically to 20 KT at 2,000 feet is unlikely to encounter a wake vortex that was generated by an aircraft approaching runway 30R. The probability of an encounter is not affected by category combination or in-trail separation provided the aircraft approaching 30R leads the aircraft approaching 30L.

13. Key Words	14. Distribution Statement
ASAT SOIA Wake Vortex Wake Turbulence St. Louis	Controlled by AFS-420
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EXECUTIVE SUMMARY

The Airspace Simulation and Analysis for TERPS (ASAT) system was used to determine the risk of a wake vortex encounter associated with simultaneous operations to runways 30L and 30R at Lambert-St. Louis International Airport (STL) using the enhanced ASAT wake vortex model, version 1.2.

Five sets of 100,000 ASAT runs were executed. Each set of runs was executed at a selected initial in-trail separation distance ranging from 0.5 NM to 2.5 NM at 0.5 NM increments. The runs were executed using the current aircraft fleet mix and conservative wind conditions. A sensitivity analysis was performed to determine whether a high-risk wake vortex encounter window exists and can be defined.

The area of interest is the phase of flight where the aircraft approaching runway 30L has finished performing the Simultaneous Offset Instrument Approach (SOIA) procedure and is at the closest operational proximity to the adjacent aircraft approaching runway 30R. However, all phases of the SOIA procedure were accurately simulated using the existing SOIA capability of AFS-420's ASAT system.

The results of this simulation, using the current improved wake vortex model, are conservative because wind intensity and wind turbulence affect the decay rate of the wake. In actual atmospheric conditions, a direct cross wind from the right of 10 KT at the surface increasing to 20 KT at 2,000 feet would be coupled to some extent with ambient turbulence that would result in a faster decay of the wake than the one predicted by the model. Therefore the results presented in this report can serve as a conservative assessment of the wake vortex hazard involved in running a SOIA operation to runways 30L and 30R at STL described in section 1 of this report.

The simulation was conducted with a ground level, direct crosswind from the right of 10 KT increasing logarithmically to 20 KT at 2,000 feet. The simulation did not detect a high-risk wake vortex encounter window. This can be attributed to the relative positions of the runways. The runway centerlines are spaced 1,300 feet apart and the thresholds are staggered 1,698 feet. Therefore, an aircraft approaching runway 30L with a 10 KT or less direct crosswind from the right that increases logarithmically to 20 KT at 2,000 feet is unlikely to encounter a wake vortex that was generated by an aircraft approaching runway 30R. The probability of an encounter is not affected by category combination or in-trail separation provided the aircraft approaching 30R leads the aircraft approaching 30L.

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1.0 INTRODUCTION

The two primary runways used for approach and departure operations at Lambert-St. Louis International Airport (STL) are closely spaced, parallel runways. Independent parallel Instrument Landing System (ILS) approaches have been approved by the Federal Aviation Administration (FAA) for runways spaced at least 3,400 feet apart, but less than 4,300 feet apart when the approach surveillance radar is a Precision Runway Monitoring system. Since the runway spacing at STL is only 1,300 feet, parallel operations are not approved. In order to improve capacity at STL, Localizer-type Directional Aid (LDA) approaches with a circle maneuver for alignment with the runway were developed and commissioned approximately sixteen years ago. Although the current LDA approaches and subsequent visual lateral transition to Runways 12L and 30L do not have electronic vertical guidance, they have proven to be operationally successful.

The Flight Procedure Standards Branch (AFS-420) conducted a flight simulation to determine whether an offset LDA with electronic glideslope would actually enhance instrument operations at STL. Five LDA approaches with electronic glideslope were tested and compared to the current LDA approach. The five approaches were designed for Runway 30L using various combinations of threshold to Missed Approach Point (MAP) distances, MAP to Clear of Clouds (C/C) point distances, and MAP to the extended centerline of Runway 30R distances. Each approach incorporated a 3 degrees offset in order to increase lateral separation from traffic performing the straight-in approach to Runway 30R. The approaches can be easily adapted for Runway 12L so that all results and recommendations will extend to equivalent approaches designed for Runway 12L.

Statistical analysis of the data indicated three of the LDA approaches with glideslope were definitely superior to the current LDA approach. The three approaches were those which had MAPs farthest from the threshold of Runway 30L. One of those three LDA approaches was recommended in a report published by AFS-420 in 1999 (see Lankford, McCartor, et. al.) because of its stability qualities and because of the longer distance from C/C to the MAP.

However, the report did not address the possibility of wake vortex encounters. A report published in 1983 (see Hallock) prior to the commissioning of the current LDA approaches indicated heavy-category aircraft must be confined to the straight-in because of the threat of a wake vortex encounter. No aircraft larger than a B-727 may use the LDA approach. AFS-420 was tasked to conduct another simulation using the Airspace Simulation and Analysis for TERPS (ASAT) system to determine the risk of a wake vortex encounter associated with simultaneous operations to runways 30L and 30R at STL using the enhanced ASAT wake vortex model, version 1.2. The existence of a high-risk wake vortex encounter window was conjectured based on the Hallock report.

2.0 ASAT SCENARIO DESCRIPTION

2.1 GEODETIC SCENARIO

Figure 1 describes the geodetic configuration at STL. All measurements relate to the Airport Reference Point.

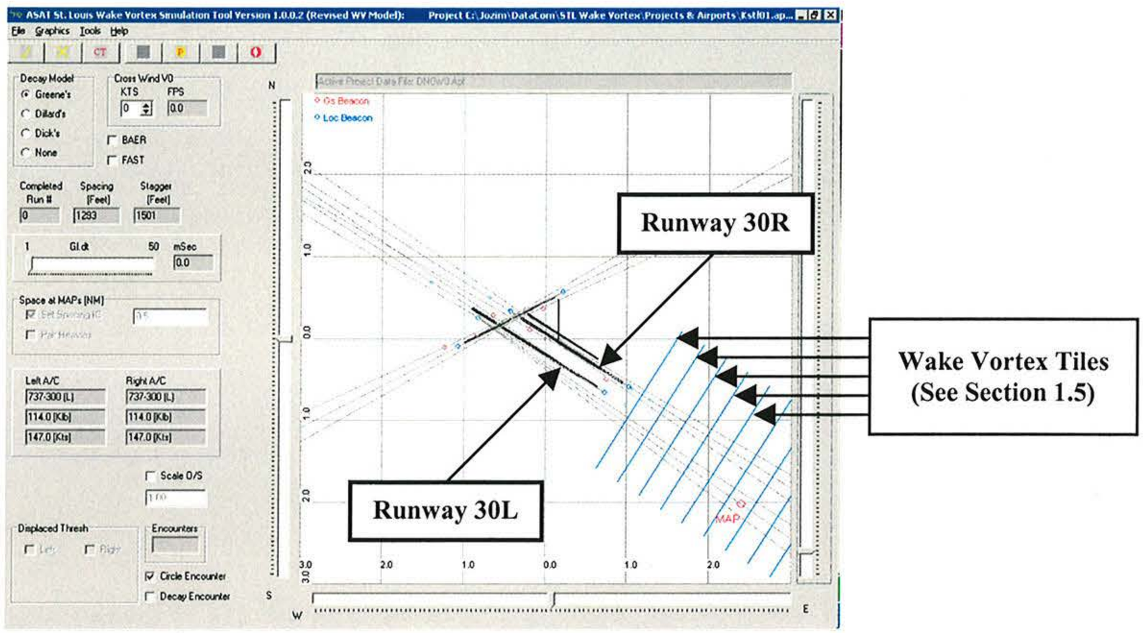

Figure 1: RUNWAY CONFIGURATION AT LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT

2.2 WIND CONDITIONS

A ground level cross wind of 10 KT increasing logarithmically to 20 KTS at 2,000 feet was set at a true direction of 212 degrees, blowing from the northeast towards southwest.

2.3 AIRCRAFT INITIAL POSITIONS AND FLIGHT CONDITIONS

(a) Aircraft approaching runway 30L was placed 1 NM prior to the runway 30L Missed Approach Point (MAP).

(b) Aircraft approaching runway 30R was placed at one of the pre-determined initial leading distances ranging from 0.5 NM to 2.5 NM relative to aircraft approaching runway 30L.

(c) Both aircraft were placed laterally and vertically using localizer and glideslope error distributions from the ICAO Collision Risk Model for ILS Operations.

(d) Aircraft types were randomly selected based upon the traffic mix at STL (see appendix A). Heavy aircraft were permitted to land on either runway.

NOTE: Even though the standard operating procedure is to segregate heavies to runway 30R, the study considered heavies approaching either runway in order to account for the B757 operations to runway 30L and to identify the widest range of wake turbulence hazard under the given wind conditions.

(e) Initial weight, approach, and final Indicated Air Speeds were assigned to each aircraft according to data associated with each type of aircraft.

At this point the simulation was in a "freeze" state and ready to execute a simulated Simultaneous Offset Instrument Approach (SOIA).

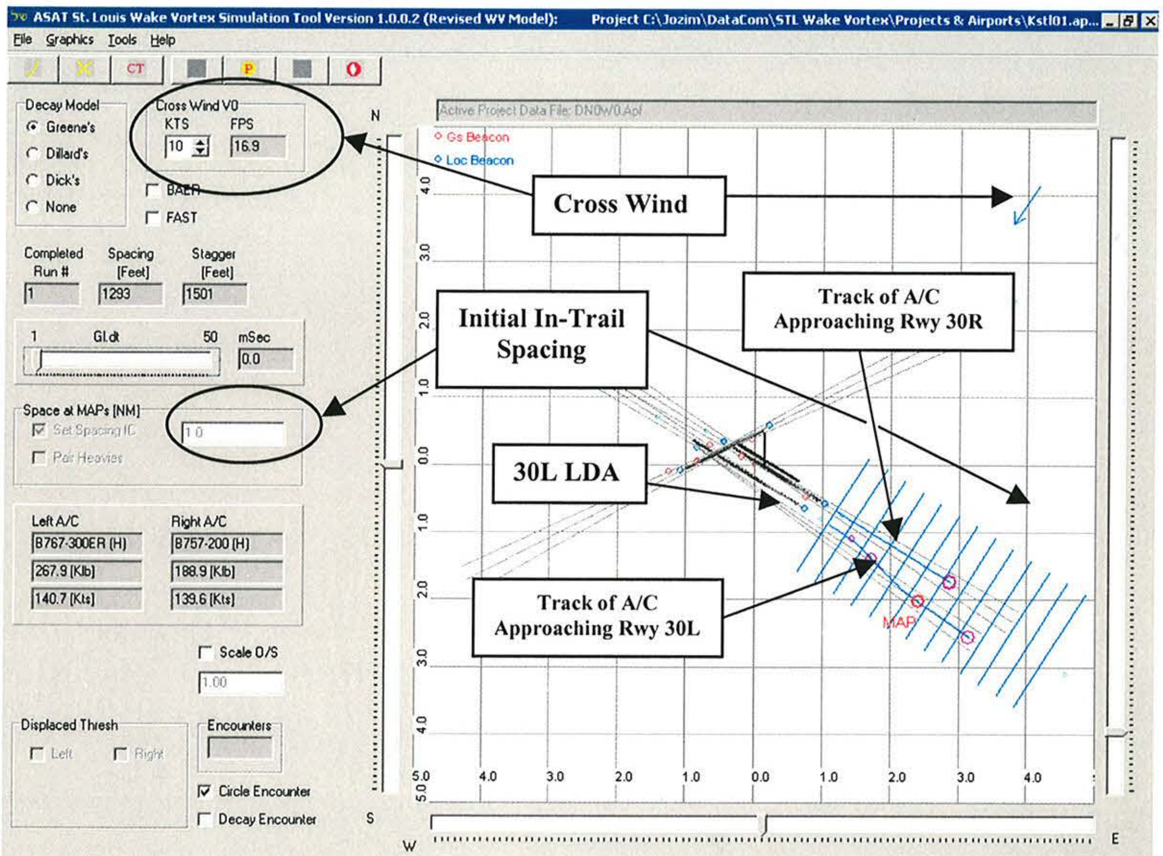

Figure 2: DESCRIPTION OF ASAT SIMULATION GRAPHIC OUTPUT (MAIN WINDOW)

2.4 SIMULATION OF THE SOIA FLIGHT PHASE

After all initial conditions were set, the simulation was "released" and both aircraft were set into flight mode.

2.4.1 AIRCRAFT APPROACHING RUNWAY 30R

Aircraft approaching runway 30R executed a straight in ILS approach to runway 30R. The aircraft are placed so that this aircraft leads the aircraft approaching 30L.

2.4.2 AIRCRAFT APPROACHING RUNWAY 30L (SOIA)

Aircraft approaching runway 30L executed a SOIA procedure. The SOIA procedure was simulated in the following manner:

a. The aircraft tracked the runway 30L LDA glidepath and localizer navigation signals.

b. At the MAP a right turn was initiated to establish a new heading that resulted in closing the lateral distance between the MAP and the extended runway 30L 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 Gaussian (normal) probability distribution was used to determine the bank angle and the bank rate used to perform the first turn. See appendix B.

c. Once the required heading was achieved, the aircraft rolled back to wings level flight. The nominal change in heading was +15 degrees (right turn). A Gaussian probability distribution of heading change was used to determine actual heading change values. See appendix B.

d. At a pre-determined point, the second turn (left bank) was initiated in order to intercept the extended runway 30L centerline. The second turn was initiated at a point and performed at conditions that resulted in a pre-determined amount of overshoot. The overshoot value was selected from a probability density function based upon data gathered during real time flight simulator tests flown by qualified and current airline pilots using a St. Louis Lambert International Airport scenario. A Gaussian probability distribution was used to determine the bank angle and the bank rate used to perform the second turn. See appendix B.

e. The aircraft navigated towards the threshold of runway 30L.

2.5 DESCRIPTION OF THE WAKE VORTICES SIMULATION

In order to determine the risk of a wake vortex encounter, the location of the trailing aircraft had to be determined relative to the location of the leading aircraft wake vortices.

ASAT handled this complex case 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 individual vertical planar surfaces located at pre-determined distances from the threshold, as illustrated in figure 1. Once the leading aircraft penetrated a "tile", a simulation of its two wing tip vortices started. Figure 3 illustrates the simulation of the vortices on two consecutive tiles. The first tile (tile # i) has been penetrated at a given time T. From that moment, the two vortices are being simulated. Some time later, T + ΔT, the aircraft penetrates the next tile, (tile # i+1). Meanwhile, the simulation that has started on tile #i at time T has developed. Figure 3 illustrates the translation of the vortices generated at time T on tile #i. The illustration depicts the position of the vortices after a period of time of ½ΔT and ΔT seconds. When the trailing aircraft penetrates a tile, the simulation of the vortices on that particular tile is terminated and ASAT computes the relative position between the trailing aircraft and the vortices of the leading aircraft. Additional computation based upon the relative position of the trailing aircraft and the leading aircraft wake vortices determines whether an encounter occurred on that particular tile.

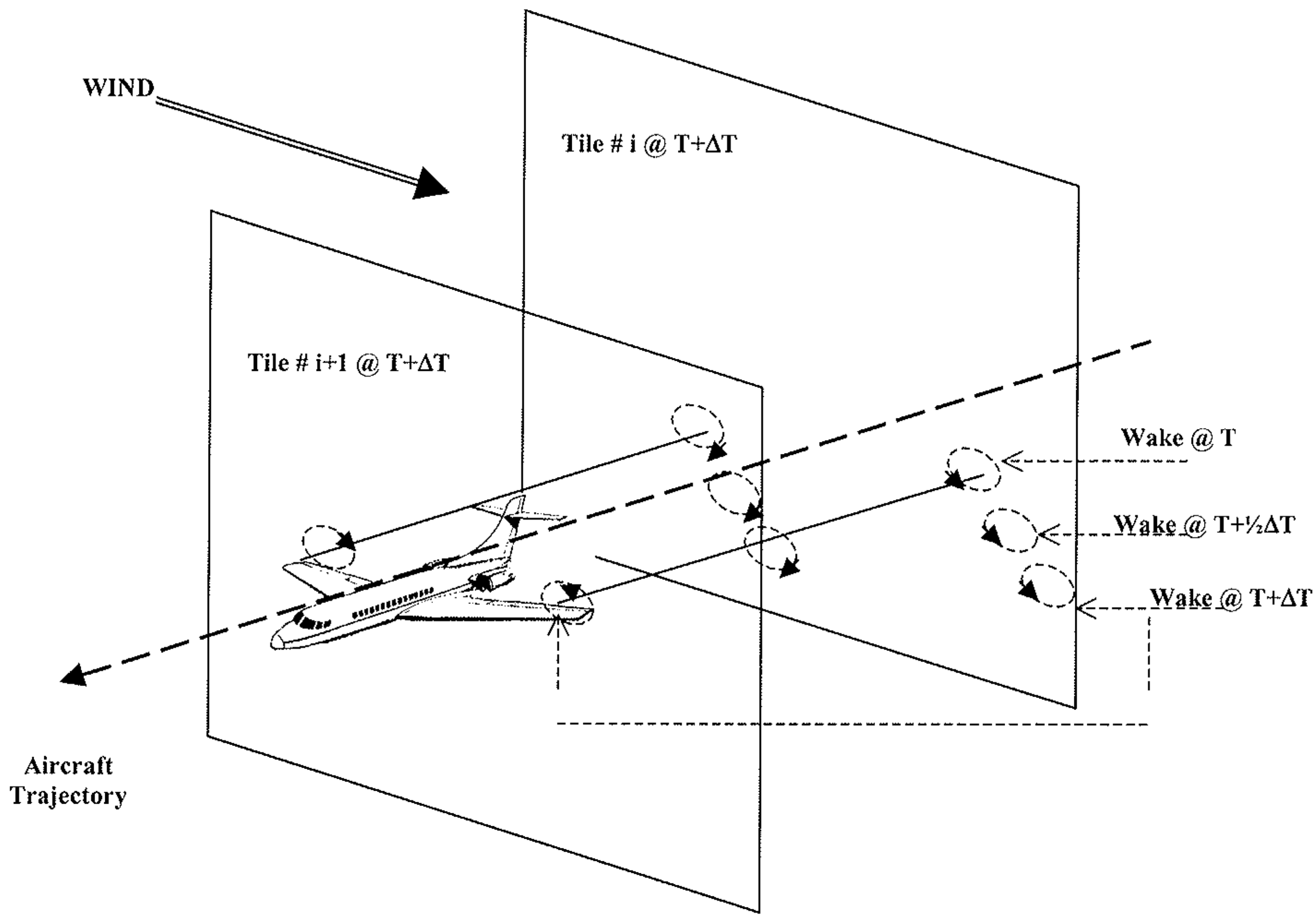

Figure 3: WAKE VORTEX "TILES" ALONG THE FLIGHT PATH OF THE AIRCRAFT

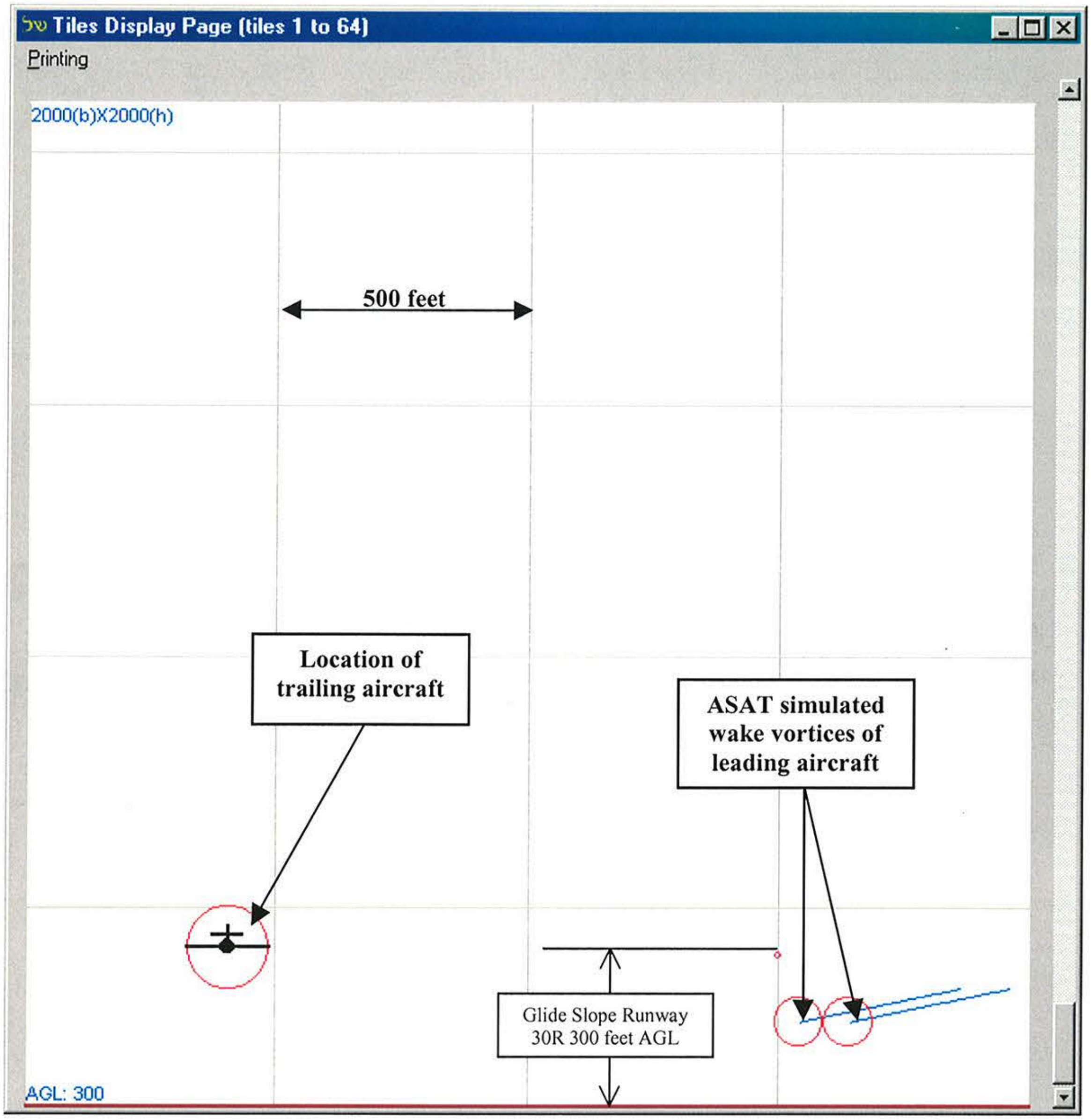

Figure 4: EXAMPLE OF ASAT WAKE VORTEX TILE AT 300 FEET AGL

3.0 RESULT OF ASAT RUNS

Five sets of 100,000 ASAT runs were executed. Each set of runs was executed at a selected initial in-trail separation distance ranging from 0.5 NM to 2.5 NM at 0.5 NM increments. The runs were executed using the current aircraft fleet mix and conservative conditions. A sensitivity analysis was performed in order to identify whether a high-risk wake vortex encounter window exists and can be defined.

The simulation did not detect the existence of a high-risk wake vortex encounter window. This can be attributed to the geometric configuration of the runways. The runway centerlines are spaced 1,300 feet apart and the thresholds are staggered 1,698 feet. Therefore, an aircraft approaching runway 30L with a 10 KT or less direct crosswind from the right that increases logarithmically to 20 KT at 2,000 feet is unlikely to encounter any hazardous wake vortex generated by an earlier aircraft approaching runway 30R. The probability of an encounter is not affected by category combination or in-trail separation, provided the aircraft approaching 30R leads the aircraft approaching 30L.

This result is not consistent with a previous study of runways 12L and 12R at STL by Hallock published in 1983. Although the Hallock report concluded "staggered thresholds mitigate the wake turbulence problem", it also recommended the following: all "heavy-category aircraft must be confined to runway 12R, all small-category aircraft must be confined to runway 12L, no aircraft larger than a B-727 may use runway 12L, and a minimum descent altitude must be established for the 3 NM DME fix on runway12L". The current simulation demonstrates the Hallock recommendation is unnecessary. Heavy aircraft were permitted on both runways and the simulation did not indicate any wake vortex encounters. Only Category C and less aircraft fly the LDA due to maneuvering. All types of aircraft fly the ILS.

Anecdotal evidence obtained from conversations with air traffic controllers at STL indicates that wake turbulence at STL has not been a problem. In fact, air traffic controllers report that in the sixteen years of operation of the current LDA approach, no reports of wake turbulence encounters have been recorded.

4.0 CONCLUSION

The simulation indicated that an aircraft approaching runway 30L at STL with a 10 KT or less direct crosswind from the right that increases logarithmically to 20 KT at 2,000 feet is unlikely to encounter any hazardous wake vortex generated by an earlier aircraft approaching runway 30R. The probability of an encounter is not affected by category combination or in-trail separation, provided the aircraft approaching 30R leads the aircraft approaching 30L.

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Lankford, David N., McCartor, Gerry, St. Louis Lambert Field Close Parallel Approaches Using 3° Offset LDA with Glideslope to Runway 30L, DOT-FAA-AFS-420-79, Flight Procedure Standards Branch, Oklahoma City, Oklahoma, 1999.

APPENDIX A

APPENDIX A

AIRCRAFT TYPES MIX

Not all aircraft operating to runways 30L and 30R at St. Louis Lambert International Airport exist in ASAT's aircraft database. Aircraft that are not currently part of the existing database were replaced with aircraft of similar category and as close as possible of similar wake vortex characteristics. Table 1 lists the various aircraft types in the real life operation (column 1), whether they were used or replaced with another type (column 2) and what percentage they comprise of the total number of aircraft (column 3).

Original Aircraft Type	Aircraft Type Used Same / Replaced with	Number of Operations for a Typical Day
MD80	Same	205
B737-300	Same	70
DC9	MD80	66
J41	ATR42	48
B717	MD83	42
ERJ	CRJ	31
B757	B757-200	29
B737S	B737-300	21
ATR42	Same	19
SF3	ATR42	19
ATR72	Same	12
CRJ	Same	11
F100	MD80	8
B737G	B737-300	8
B7375	B737-300	6
DC9-5	MD80	6
B767-300	Same	5
ARJ	CRJ	5
DC9-3	MD80	3
Metroliner	ATR42	3
B727S	B727	2
BE19	BE20	2
DC9	MD80	2
B727F	B727	1
B767	B767-300	1
CNA	CRJ	1
ER3	CRJ	1

Table A1: AIRCRAFT TYPES TRAFFIC MIX USED FOR ASAT RUNS

APPENDIX B

APPENDIX B

SIMULATION PROBABILITY DENSITY FUNCTIONS

B1 FIRST TURN BANK ANGLE

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

- **a.** Function Type : Normal
- **b.** SigmaBank1 : 3.2 degrees
- **c.** MeanBank1 : 10.6 degrees
- **d.** MaxBank1 : 15.6 degrees
- **e.** MinBank1 : 7.0 degrees

B2 SECOND TURN BANK ANGLE

The following values were used to generate the bank angle value of the second turn (left turn):

- **a.** Function Type : Normal
- **b.** SigmaBank2 : 4.4 degrees
- **c.** MeanBank2 : -14.0 degrees
- **d.** MaxBank2 : -11.0 degrees
- **e.** MinBank2 : -19.0 degrees

B3 DEFINITION OF THE RUNWAY 30L CENTERLINE OVERSHOOT

- **a.** Function Type : Normal
- **b.** SigmaOs : 78.75 feet
- **c.** MeanOs 106.50 feet
- **d.** MinOs : 0.00 feet
- **e.** MaxOs : 454.00 feet