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Flight Operations Simulation and Analysis Branch
Flight Technologies and Procedures Division
Flight Standards Service

Wake Vortex Safety Study for Opposite Direction Departures at Anchorage International Airport (PANC)

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12. Abstract

The Ted Stevens Anchorage International Airport (PANC) typically operates with a large percentage of aircraft in the Heavy class. While Runway 14/32 is primarily used to handle Heavy aircraft traffic, some scenarios require the use of Runway 25L. During these situations, departure operations from Runway 7L/25R are impacted by the wake turbulence criteria specified in FAA Order 7110.65, Air Traffic Control, (Reference 1) paragraph 3-9-7a.2. This provision, as it pertains to PANC, requires a 3-minute wake turbulence separation interval to be applied for any aircraft taking off (same or opposite direction) from an intersection on the same runway or parallel runways separated by less than 2,500 feet, with runway threshold offset by 500 feet or more following the take-off of a Heavy aircraft/B757. AFS-440 has been tasked to conduct a study evaluating the proposal, which is intended to increase airport capacity and meet the Federal Aviation Administration's (FAA) established Target Level of Safety (TLS).

The study found that the PANC ATC proposal to waive the three-minute wake turbulence separation standard for opposite direction intersection take offs using Runways 7L and 25L at PANC does not increase the likelihood of wake vortex encounters beyond the TLS provided mitigating factors are employed. The mitigating factors, which support this result, are as follows:

a. A maximum crosswind component limitation of 15 knots is observed from the south and perpendicular to the parallel runways.
b. The Heavy aircraft/B757 uses Runway 25L for departure. This aircraft must lift off abeam or past the corresponding Runway 7L departure point. If this cannot be assured, the three-minute separation provision must be enforced.
c. Weather conditions must allow visual determination of the Heavy aircraft/B757 lift off point.

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Executive Summary

The Ted Stevens Anchorage International Airport (PANC) typically operates with a large percentage of aircraft in the Heavy wake turbulence classification. While Runway 14/32 is primarily used to handle Heavy aircraft traffic, some scenarios require the use of Runway 25L. During these situations, departure operations from Runway 7L/25R are impacted by the wake turbulence criteria specified in FAA Order 7110.65, Air Traffic Control, (Reference 1) paragraph 3-9-7a.2. This provision, as it pertains to PANC, requires a 3-minute wake turbulence separation interval to be applied for any aircraft taking off (same or opposite direction) from an intersection on the same runway or parallel runways separated by less than 2,500 feet with runway threshold offset by 500 feet or more following the takeoff of a Heavy aircraft/B757. At PANC, Runways 7L/25R and 7R/25L intersect Runway 14/32. Runways 7L/25R and 7R/25L are separated by approximately 700 feet, and their thresholds are offset approximately 4,300 feet. Because application of the three-minute separation requirement has an adverse effect on airport capacity, the PANC Air Traffic Control (ATC) organization has proposed a waiver for both opposite and same direction departures involving Runway 25L and Runway 7L/25R when a Heavy aircraft/B757 is departing Runway 25L. The proposal is intended to increase airport capacity and meet the Federal Aviation Administration's (FAA) established Target Level of Safety (TLS).

This study utilized a computer simulation to determine whether application of the procedures in the waiver request increased the likelihood of a wake turbulence encounter beyond the TLS. The Flight Operations Simulation and Analysis Branch (AFS-440) modified its Airspace Simulation and Analysis Tool (ASAT) computer modeling system in order to evaluate the proposed operations at PANC. Parameters, such as initial position of aircraft, were individually and separately changed for each set of simulation trials in order to find those parameters that posed the greatest risk to operational safety.

Based on the analysis presented here, the PANC ATC proposal to waive the 3-minute wake turbulence separation standard for opposite direction takeoffs using Runways 7L and 25L at PANC does not increase the likelihood of wake vortex encounters beyond the TLS provided mitigating factors are employed. The mitigating factors that support this result are as follows:

a. A maximum crosswind component limitation of 15 knots is observed from the south and perpendicular to the parallel runways.

b. The Heavy aircraft/B757 uses Runway 25L for departure. This aircraft must lift off abeam or past the corresponding Runway 7L departure point. If this cannot be assured, the 3-minute separation provision must be enforced.

c. Weather conditions must allow visual determination of the Heavy aircraft/B757 liftoff point.

Table of Contents

List of Illustrations

Tables

Figures

1.0. Introduction

The Ted Stevens Anchorage International Airport (PANC) typically operates with a large percentage of aircraft in the Heavy wake turbulence classification. While Runway 14/32 is primarily used to handle Heavy aircraft traffic, some scenarios require the use of Runway 25L. During these situations, departure operations from Runway 7L/25R are impacted by the wake turbulence criteria specified in FAA Order 7110.65, Air Traffic Control, (Reference 1) paragraph 3-9-7a.2. This provision, as it pertains to PANC, requires a 3-minute wake turbulence separation interval to be applied for any aircraft taking off (same or opposite direction) from an intersection on the same runway or parallel runways separated by less than 2,500 feet with runway thresholds offset by 500 feet or more following the takeoff of a Heavy aircraft/B757. At PANC, Runways 7L/25R and 7R/25L intersect Runway 14/32. Runways 7L/25R and 7R/25L are separated by approximately 700 feet, and their thresholds are offset approximately 4,300 feet. Because application of the 3-minute separation requirement has an adverse effect on airport capacity, the PANC Air Traffic Control (ATC) organization has proposed a waiver for both opposite and same direction departures involving Runway 25L and runway 7L/25R when a Heavy aircraft/B757 is departing Runway 25L. The proposal is intended to increase airport capacity and meet the Federal Aviation Administration's (FAA) established Target Level of Safety (TLS). This report presents the results of a safety evaluation of the PANC ATC opposite direction takeoff proposal by the FAA, Flight Operations Simulation and Analysis Branch (AFS-440). (Results of the safety study of the PANC ATC same direction takeoff proposal are presented in a separate report.)

This study utilized a computer simulation to determine whether application of the procedures in the waiver request increased the likelihood of a wake turbulence encounter beyond the TLS. AFS-440 modified its Airspace Simulation and Analysis Tool (ASAT) computer modeling system in order to evaluate the proposed operations at PANC. Parameters, such as initial position of aircraft, were individually and separately changed for each set of simulation trials in order to find those parameters that posed the greatest risk to operational safety.

2.0. Description of Proposal and Model Approach

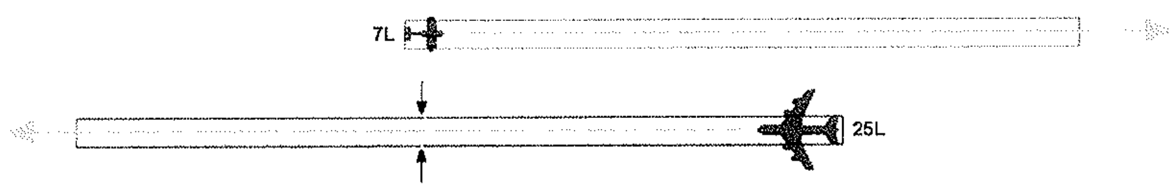

Figure 1: Proposal Diagram

The opposite direction departure proposal involves a Heavy aircraft/B757 departing Runway 25L and the succeeding aircraft departing Runway 7L. The waiver request proposes that the 3-minute interval mandated by Reference 1 for the succeeding aircraft, departing runway 7L, be waived in instances where the Heavy aircraft/B757 departing on Runway 25L lifts off abeam or southwest of (past) the aircraft departing Runway 7L. Runways 7L/25R and 7R/25L at PANC are approximately the same length but have staggered thresholds on both ends. The distance from the arrival threshold of Runway 25L (point where the takeoff begins) to the arrival threshold of Runway 7L (point where the opposite direction take off roll begins) is 6,276 feet. The waiver request makes the point that Heavy aircraft/B757 departing Runway 25L typically have a takeoff roll longer than this 6,276 feet and thus, are seldom airborne until past a position abeam the Runway 7L arrival threshold. In cases where the Heavy aircraft/B757 lifts off prior to the departure point for Runway 7L, the succeeding aircraft will not be cleared for takeoff until the 3-minute separation standard has been applied.

For purposes of this report, the beginning of the departure on Runway 25L is the arrival threshold Runway 25L. The beginning of the departure on Runway 7L is the arrival threshold of Runway 7L or a point farther down Runway 7L, which allows PANC ATC to use intersection departures on Runway 7L that meet the waiver criteria. The liftoff point is the point at which the Runway 25L aircraft first becomes airborne. (The results reported here are predicated on the liftoff point and not the point of aircraft rotation. While vortex generation begins at rotation, measurements have shown that vortices generated near the ground decay very quickly and would not be a concern for this proposal. Using the liftoff point provides a conservative initial point for evaluation of the wake hazard for this proposal.)

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 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, 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 NASA 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., B757 and Heavy. 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), aircraft positions on the runway, position of the succeeding aircraft relative to the Heavy aircraft/B757, wake turbulence generated by the Heavy aircraft/B757, and the movement of the wake turbulence as the result of crosswind. Ultimately, the outcome of the ASAT simulation was to determine whether the succeeding aircraft under the proposed opposite direction scenario encountered a wake vortex generated by the Heavy aircraft/B757.

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 2.)

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 departures from PANC encounter wake turbulence.

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 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.

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 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 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.

2.3. Wake Turbulence Aircraft Classes

Wake turbulence separation minima for Air Traffic Control (ATC) purposes are given in Reference 1. For wake turbulence purposes, Reference 1 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 regardless of whether they are operating at this weight during a particular phase of flight.

b. Large - Aircraft of more than 41,000 pounds, up to a maximum certificated takeoff weight of 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.

* B-757 has its own weight classification. However, in this study, a B757-300 was used, which is in the Heavy weight classification. The results of the study are valid for any model B757, whether in the Heavy classification or its own weight classification.

2.4. PANC Runway Configuration

The runway configuration evaluated at PANC is shown in Figure 1:

Runways 7L and 25L: The positions of the Runway 7L and Runway 25L thresholds are shown in Figure 1. Runways 7L and 25L are separated by 700 feet, and the threshold-to-threshold distance is approximately 6,276 feet.

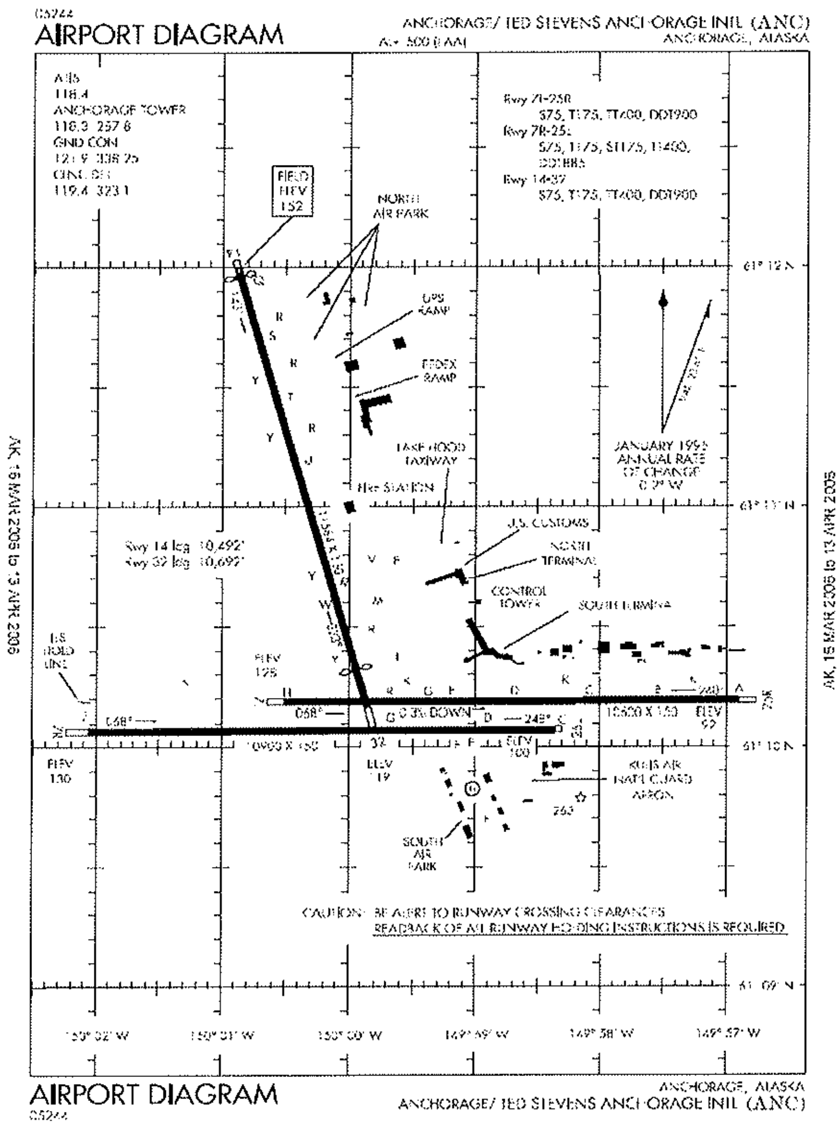

Figure 2: PANC Airport Diagram

2.5. ASAT Graphic Depiction of Proposed Opposite Direction Take-off Operation

Figure 2 is an ASAT screen capture showing the major components of the study from a top-down geographic perspective. Figure 2 shows the proposed opposite direction operation for Runways 7L and 25L.

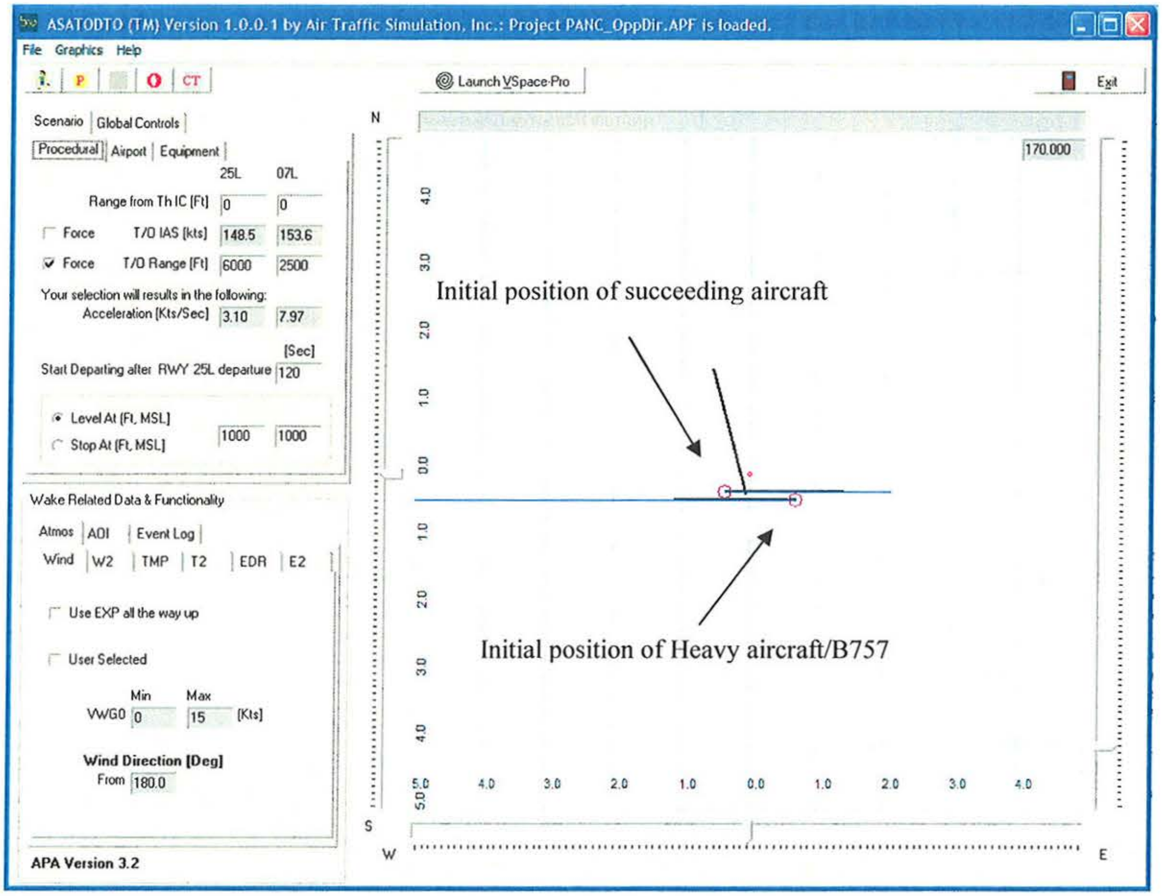

Figure 3: ASAT Graphic Depiction of Opposite Direction Departures at PANC

2.6. Initial ASAT Simulation Conditions

A crosswind randomly varying up to 15 knots was set perpendicular to the runways, blowing from the south towards the north, i.e., from the Heavy aircraft/B757 Runway, 25L, to the succeeding aircraft runway, 7L/25R. This represents the worst case scenario for a wake encounter that can currently be modeled. The initial position of the Heavy aircraft/B757 is at the threshold of Runway 25L in all scenarios. The initial position of the succeeding aircraft was varied in relation to the takeoff position of the Heavy aircraft/B757. The simulation concluded when either aircraft reached an altitude of 1,000 feet with straight-out departures for both aircraft.

The study was performed using both a B757 with a gross weight of 270,000 lbs., and a B777 with a gross weight of 460,000 lbs., as the aircraft taking off on Runway 25L. (A B777 was selected versus a B747 due to a typically earlier liftoff point.) The wake turbulence class of the succeeding aircraft, using Runway 7L for takeoff, was not significant to the test. The only aircraft-specific factor, (takeoff distance) that would have an effect on the results was statistically varied during the study.

2.7. 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 Heavy aircraft/B757 wake vortices. This complex task was accomplished by simulating the location of each of the two aircraft vortices at discrete locations along the departure path of the Heavy aircraft/B757. 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 4. Once the Heavy aircraft/B757 penetrated a "tile," a simulation of its two wing-tip vortices began. Figure 4 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 + ΔT, 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, expand, and decay.

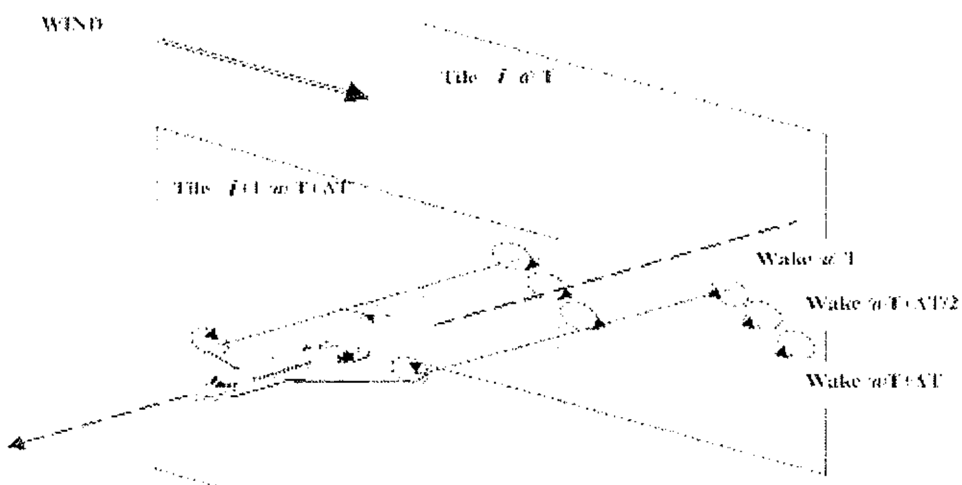

Figure 4: Wake Vortex Evaluation "Tiles"

The APA described in paragraph 2.2 was used to model the transport and decay characteristics of the simulated wakes. Figure 4 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 $\Delta T/2$ and ΔT 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 Heavy aircraft/B757. Additional ASAT analysis took place to determine if the wake strength was sufficiently strong to count as a wake encounter on that particular tile (see section 2.8).

2.8. 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 succeeding aircraft (the aircraft departing in the opposite direction from the wake generator). The radius of the AOI for this study was an absolute value of 330 feet. This value is a default value defining an area on a two-dimensional plane oriented perpendicular to the aircraft direction.

3.0. Summary of Data Analysis

(The analysis reported in this section was based on a maximum crosswind component of 15 knots from the south and perpendicular to the parallel runways.)

The results of 10,000 ASAT simulation runs showed no wake encounters for opposite direction operations on Runways 7L and 25L at PANC when the Heavy aircraft/B757 lifted off abeam or past the departure point of the succeeding aircraft using Runway 7L. The distance between the succeeding aircraft and the wake turbulence generated by the Heavy aircraft/B757 is shown in Table 1. These data resulted from an additional 1,000 ASAT simulation runs, which were aimed at finding the distance between the generated wake and the succeeding aircraft. As Table 1 indicates, no wake turbulence came within a distance of 150 feet of the succeeding aircraft. It should also be noted that the significant stagger between the runway thresholds aids in ensuring this relationship between the first aircraft's rotation point and the second aircraft's initial position for takeoff roll.

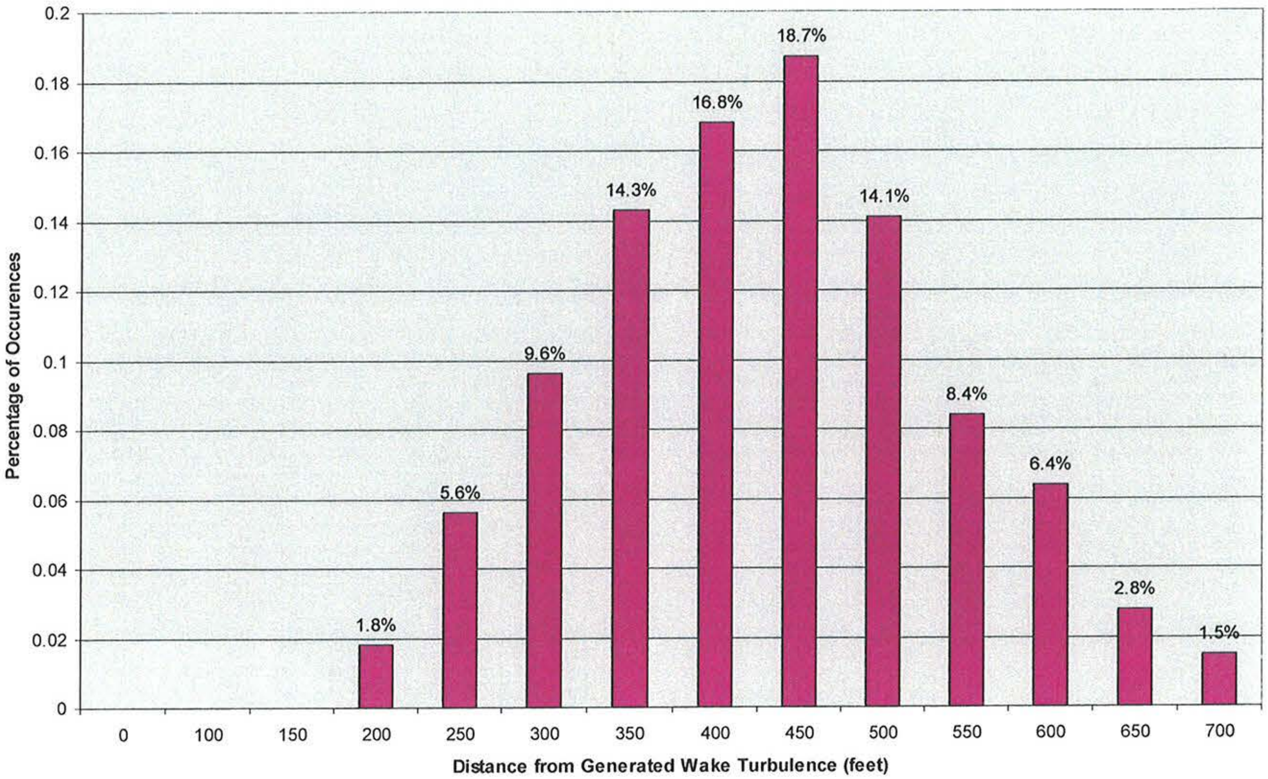

Table 1: Distance between Encounter Aircraft and Generated Wake Turbulence

4.0. Results and Conclusions

1. Based on the analysis presented here, the PANC ATC proposal to waive the 3-minute wake turbulence separation standard for opposite direction takeoffs using Runways 7L and 25L at PANC does not increase the likelihood of wake vortex encounters beyond the TLS provided mitigating factors are employed. The mitigating factors that support this result are as follows:

a. A maximum crosswind component limitation of 15 knots is observed from the south and perpendicular to the parallel runways.

b. The Heavy aircraft/B757 uses Runway 25L for departure. This aircraft must lift off abeam or past the corresponding Runway 7L departure point. If this cannot be assured, the 3-minute separation provision must be enforced.

c. Weather conditions must allow visual determination of the Heavy aircraft/B757 liftoff point.

2. This analysis did not address operational issues, such as how air traffic controllers and participating pilots are to be trained/familiarized with these operations. The waiver approval process should address these and any other operational issues.

Figure 5: View from behind Runway 7L Threshold Prior to Departure of B777 on Runway 25L

Figure 6: B777 Lifts Off Abeam the Aircraft Awaiting Departure on Runway 7L

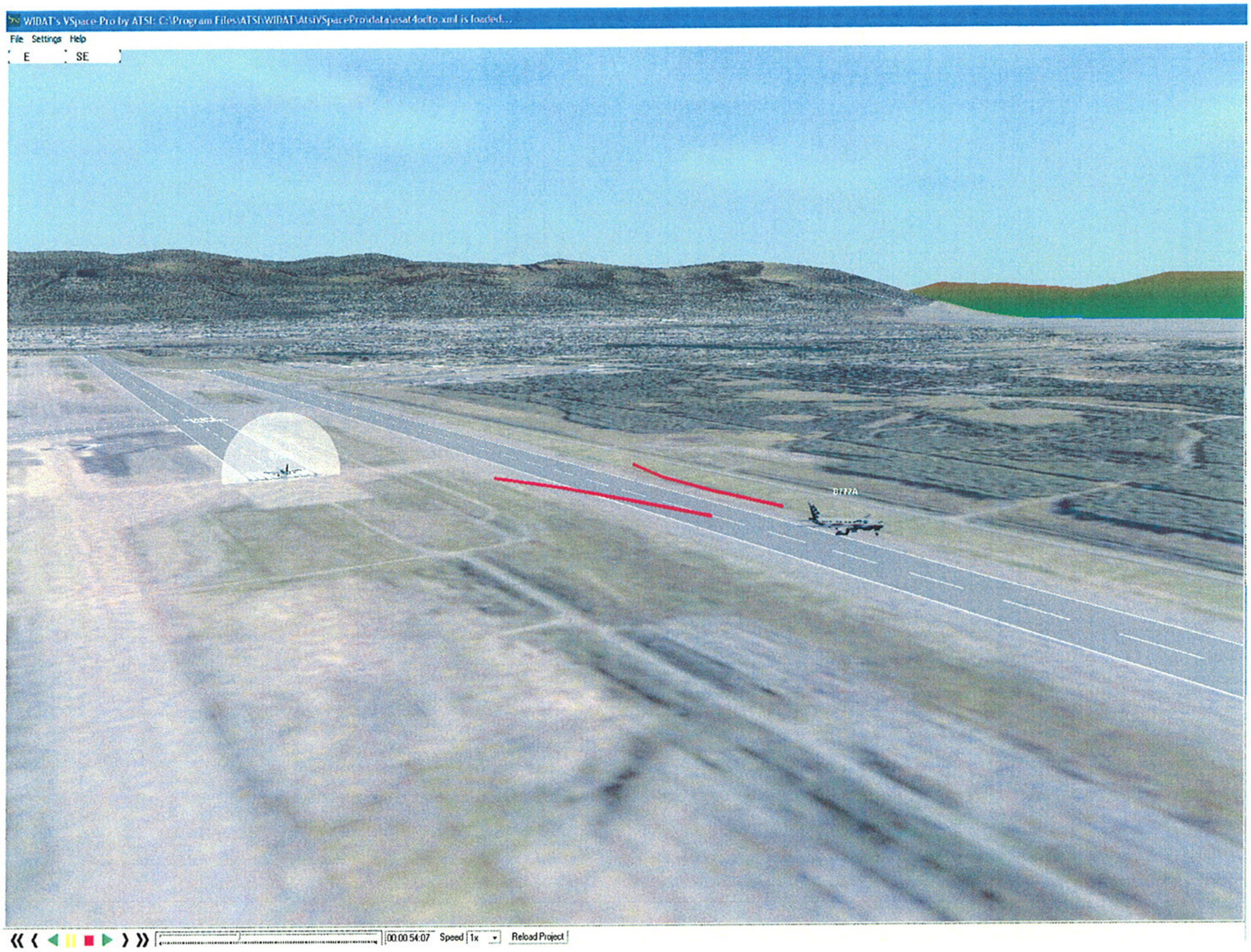

Figure 7: Wake Turbulence Is Generated by the B777 As It Lifts Off

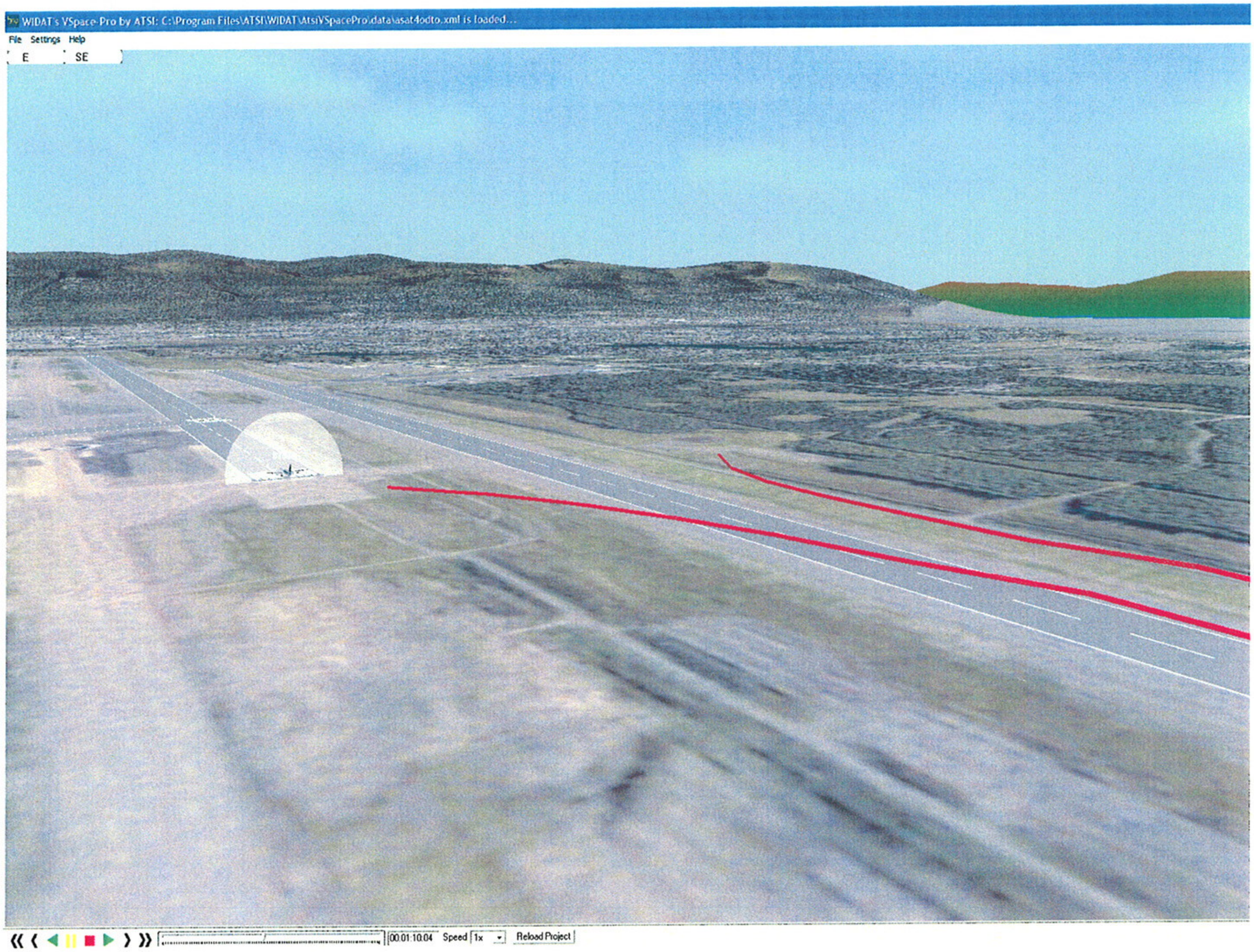

Figure 8: Wake Turbulence Approaches the Aircraft on Runway 7L

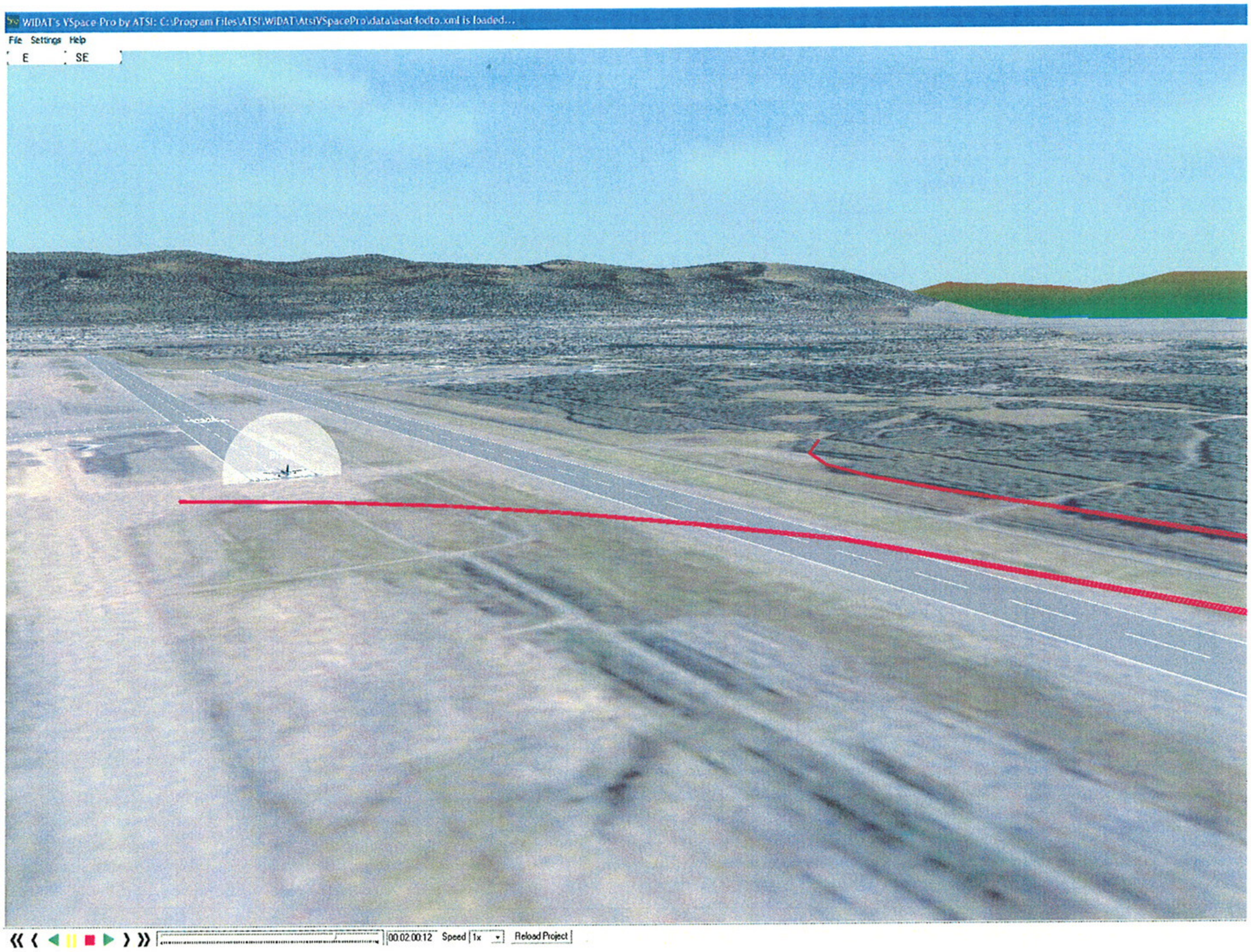

Figure 9: Wake Turbulence in Relation to Succeeding Aircraft at Two Minutes

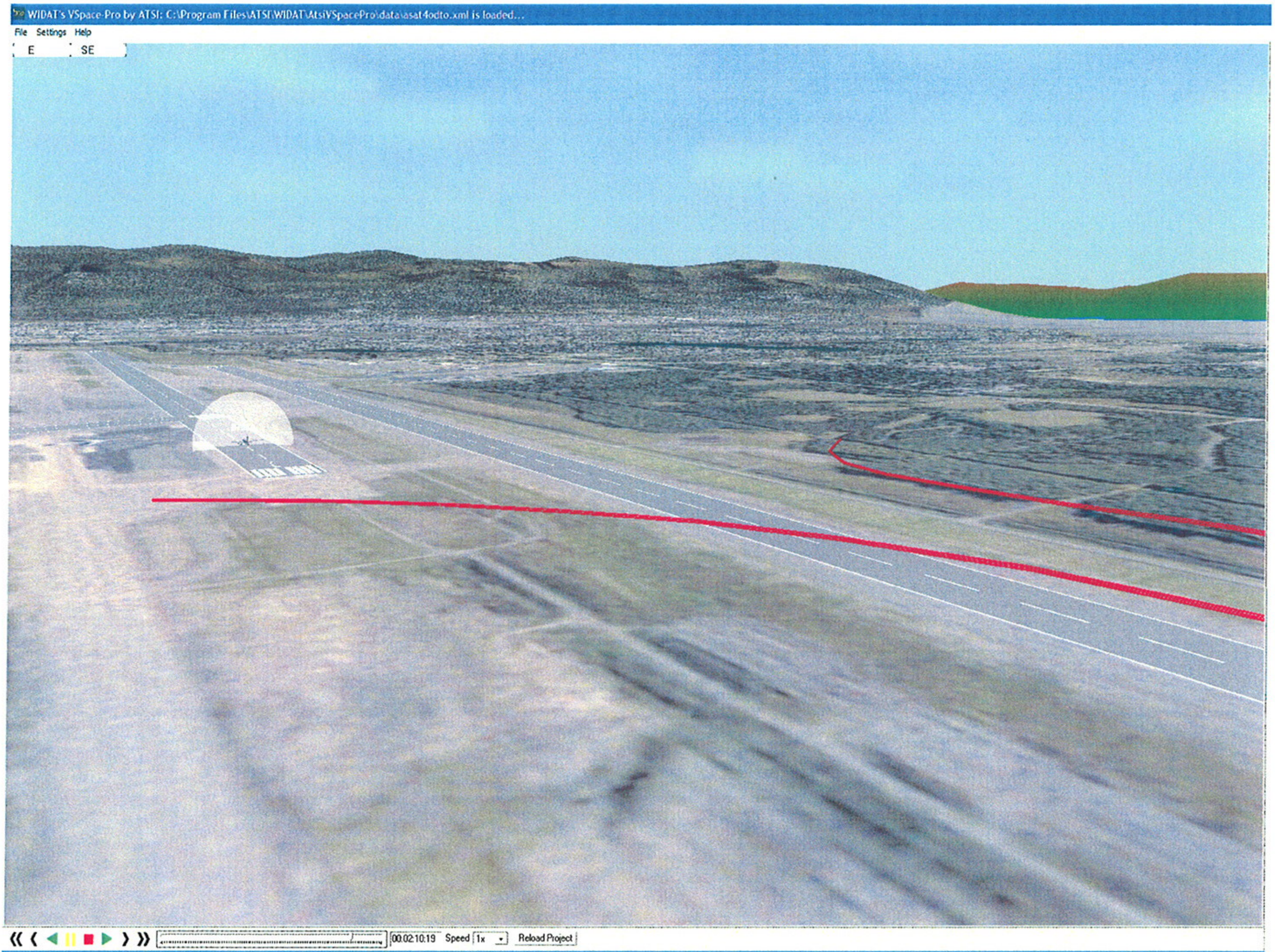

Figure 10: Aircraft on Runway 7L begins Departure after Two Minutes with No Wake Turbulence

5.0. References

I. FAA Order 71 I0.65R, Air Traffic Control, 2/16/2006.

2. Hinton, D.A.: "An Aircraft Vortex Spacing System (AVOSS) for Dynamical Wake Vortex Spacing Criteria," AGARD 78'h 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.