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Altitude Sensitivity Study for Simultaneous Independent Close Parallel Approaches – High Update Rate Surveillance Not Required

June 2017

Technical Report

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12. Abstract

In an effort to increase National Airspace System (NAS) capacity with better available data concerning course deviations, the Flight Technologies and Procedures Division (AFS-400) closely spaced parallel operations team worked to reduce the previous 4300 foot (ft) runway spacing standard for dual simultaneous independent approaches without high update rate surveillance and achieved a decrease to a runway spacing of 3600 ft. That study was detailed in the technical report *Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*, DOT-FAA-AFS-450-69 (AFS-450-69), which was an effort that utilized revised course deviation assumptions, modified test criterion violation volume, fast-time simulations, and human factors analysis. AFS-450-69 provided data that supported the operation at airport elevations up to 1000 ft. In response to a question from the Hartsfield-Jackson Atlanta International Airport related to eligible airport elevations greater than 1000 ft, a follow-on study supported the operation for the runway centerline spacing (RCLS) of 3600 ft up to an airport elevation of 2000 ft. This current study is intended to supplement the findings of AFS-450-69 by evaluating the effects on collision risk per approach as a function of RCLS and increased altitude on dual and triple simultaneous independent straight-in approach operations, as well as dual approach operations with one approach offset at an angle of 2.5° to 3° at airport elevations up to 6000 ft which encompasses all airports expected to conduct such operations within the NAS.

The risk of collision per approach decreases with an increase in RCLS and increases as airport elevation increases, with the results of this study indicating that the collision risk per approach is comparable to, but slightly higher than, the collision risk per approach for the same operations at lower altitudes.

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Executive Summary

The Federal Aviation Administration (FAA) has identified improvements to Closely Spaced Parallel Operations as a key enabler to increase National Airspace System (NAS) capacity and efficiency in less than visual meteorological conditions. This report supplements the analysis detailed in DOT-FAA-AFS-450-69, *Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*, September 2011, referred to hereafter as AFS-450-69.[1] That report was used as a basis to reduce the runway centerline spacing (RCLS) for simultaneous independent straight-in approach operations without high update rate (HUR) surveillance to dual parallel runways from 4300 feet (ft) to 3600 ft or greater at an airport elevation up to 1000 ft mean sea level (MSL) while maintaining current safety standards and NAS infrastructure. A follow-up analysis increased the airport elevation for simultaneous dual independent straight-in approach operations up to 2000 ft MSL.[2] This current report examines the sensitivity of collision risk as a function of runway centerline spacing to airport elevations between sea level and 6000 ft MSL, which encompasses all airports expected to conduct such operations within the NAS. Temperature was set to the ICAO Standard, with zero wind.

The operations analyzed in this study were dual simultaneous independent straight-in approach operations beginning at an RCLS at 3600 ft; dual simultaneous independent approach operations with one approach offset at an angle of 2.5° to 3° beginning at an RCLS of 3000 ft; and triple simultaneous independent straight-in approach operations beginning at an RCLS of 3900 ft. These are currently the minimum RCLS values approved for each of these operations. At each 1000 ft elevation increment, the minimum RCLS was increased by 100 ft increments and the collision risk determined for those spacings. Navigation systems approved for these operations are Instrument Landing System (ILS), Wide Area Augmentation System (WAAS) Localizer Performance with Vertical Navigation (LPV), Ground-Based Augmentation System (GBAS) Landing System (GLS), Global Positioning System (GPS)–based Area Navigation (RNAV) and Required Navigation Performance (RNP).[3] These operations were modeled with all the requirements of FAA Order JO 7110.65, *Air Traffic Control*, paragraph 5-9-7 Simultaneous Independent Approaches – Dual & Triple.[4]

The following is a summary of the results:

- Dual simultaneous independent straight-in approach operations:
  For each 1000 ft increase in elevation, the collision risk increases by an average of 4.2%.
  For each 100 ft increase in the RCLS, the collision risk decreases by an average of 7.5%.
- Dual simultaneous independent approach operations with one approach offset:
  For each 1000 ft increase in elevation, the collision risk increases by an average of 7.7%.
  For each 100 ft increase in the RCLS, the collision risk decreases by an average of 8.8%.
- Triple simultaneous independent straight-in approach operations were as follows:
  For each 1000 ft increase in elevation, the collision risk increases by an average of 4.6%.
  For each 100 ft increase in the RCLS, the collision risk decreases by an average of 7.4%.

[1] Flight Systems Laboratory, *DOT-FAA-AFS-450-69, Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required.*

[2] Flight Technologies and Procedures Division, *Altitude Limitation for Simultaneous Independent Close Parallel Approaches - High Update Radar Not Required*.

[3] Flight Technologies and Procedures Division, *Technical Memorandum on Use of Area Navigation (RNAV) or Required Navigation Performance (RNP) During Simultaneous Independent Parallel Instrument Approach (SIPIA) Operations at Runway Spacings as Low as 3600 Feet*.

[4] Air Traffic Organization, *Order JO 7110.65, Air Traffic Control*.

Even though the analysis indicates the increase in collision risk from sea level to 6000 ft MSL is significant, the resultant collision risk is still extremely improbable.

1 Introduction

Dual simultaneous independent approach operations are currently authorized for an RCLS as low as 3600 ft with airport elevations up to 2000 ft. RCLS is one of the main parameters which affects airport capacity as it determines if independent (higher throughput) or dependent (lower throughput) parallel operations may be conducted or if single runway arrival operations must be conducted.

1.1 Background

As airport elevation increases, true airspeed for a given indicated airspeed also increases, which correlates to increased aircraft closure rates. Therefore, approaches at airports of higher elevations will have an increased risk of collision due to the reduction of available reaction time to both pilots and controllers in the event that an aircraft deviates from its course toward the path of the adjacent aircraft.

In September 2013, an FAA technical memorandum was issued that increased the safe airport elevation to 2000 ft for dual simultaneous independent straight-in approach operations for the RCLS of 3600 ft. [5] The models and assumptions used in this study are consistent with those used in AFS-450-69.

1.2 Purpose

The purpose of this study was to further expand upon the work done for AFS-450-69 by utilizing the same methodology used in that report to evaluate the sensitivity of collision risk at various RCLS and airport elevations. Dual and triple simultaneous independent straight-in approach operations and dual simultaneous independent offset approach operations were analyzed up to airport elevations of 6000 ft, which encompasses all airports expected to conduct such operations within the NAS.

[5] Flight Technologies and Procedures Division, *Altitude Limitation for Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*.

2 Objective and Scope

The objective of this study was to examine the sensitivity of collision risk related to increased airport elevation and varying runway spacing while aircraft conduct dual and triple simultaneous independent parallel approach operations without HUR surveillance.

3 Methodology

3.1 Fast Time Simulation

The primary analysis tool for this safety study was the Flight Systems Laboratory (AFS-450) Airspace Simulation and Analysis Tool – Next Generation (ASAT^{ng}). ASAT^{ng} is a multifaceted fast-time simulation tool for aviation related safety assessments. ASAT^{ng} uses high fidelity models of all components of an aviation scenario to evaluate the overall risk of an operation. A wide range of parameters covering operational aspects, such as aircraft performance, atmospheric conditions, navigation system performance, air traffic control monitoring equipment, air traffic control surveillance equipment, pilot response time, and controller response time enable very efficient and realistic modeling of complex operational scenarios. ASAT^{ng} also uses official FAA databases of navigation and surveillance facilities, runways, fixes, etc. Additionally, aircraft fleet mix for the area of interest is incorporated into the simulations.

3.2 Test Design and Scenarios

The fleet mix consisted of 20% heavy aircraft, 40% large aircraft, and 40% small aircraft. Half of the heavy aircraft (i.e., 10% of the fleet mix) were represented by the Airbus 330 (A330) and half by the Boeing 747-400 (B744). The large aircraft were all represented by the Boeing 737-800 (B738) and the small aircraft were all represented by a generic Embraer regional jet. Each aircraft type in the mix has different approach speeds and dynamics in response to pilot inputs.

In each ASAT^{ng} simulation run, the closest point of approach was recorded along with the associated position of the deviating aircraft relative to the endangered aircraft. If the deviating aircraft's center of gravity penetrated the test criterion violation (TCV) volume, which is a cylinder with a radius of 265 ft and a height of 160 ft (±80 ft) centered at the endangered aircraft's center of gravity, a collision was assumed to have occurred.

The minimum RCLS values allowed by FAA Order JO 7110.65 for each operation type were used in this study. Consistent with the methodology used in AFS-450-69, the evaluation of each combination of RCLS and airport elevation involved 4 fundamental scenarios of interest, comprised of 20° and 30° course deviations that are both level and descending, as depicted in Figures 3-1 and 3-2. No determination has been made as to the prevalence of a descending or level aircraft deviation and thus, the choice was made to cover the two equally. Two controller response time distributions were utilized in this study, one for 20° deviations and one for 30° deviations. In AFS-450-69, a sensitivity analysis was performed on the probability of an accident during a closely spaced simultaneous independent parallel approach to determine compensation requirements resulting from controller learning effect experienced in a human-in-the-loop (HITL) test where deviations were simulated at an unrealistic rate. The sensitivity analysis recommended a two second shift in the mean of the controller response time probability density function to compensate for this learning effect. Therefore, the mean of the controller response time probability density function was increased by two seconds in this study. Based on previous analyses that have evaluated runway stagger, an increased runway stagger reduces collision risk.[6] The scenarios in this study were conservatively evaluated with no runway stagger.

[6] Flight Technologies and Procedures Division, *DOT-FAA-AFS-440-29, Safety Study Report on Simultaneous Parallel ILS and RNAV/RNP Approaches – Phases 1A and 2A.*

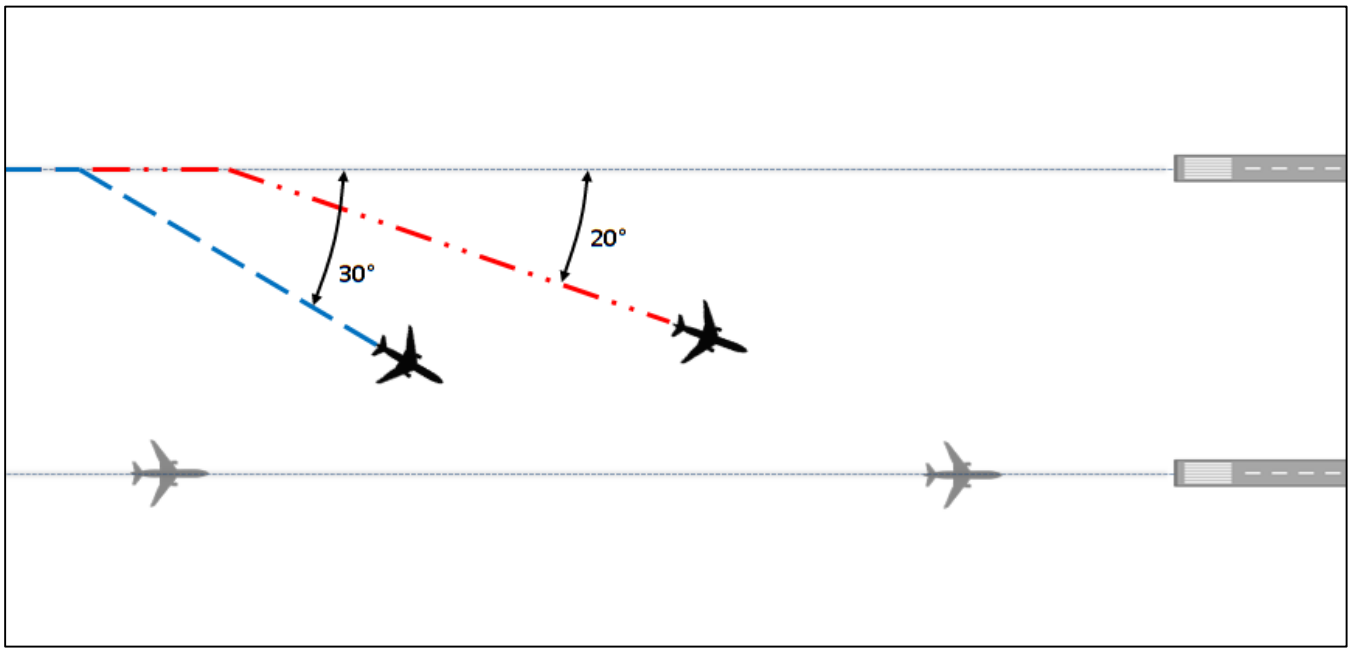

Figure 3-1: Horizontal Deviation Types – 20° and 30° Deviations

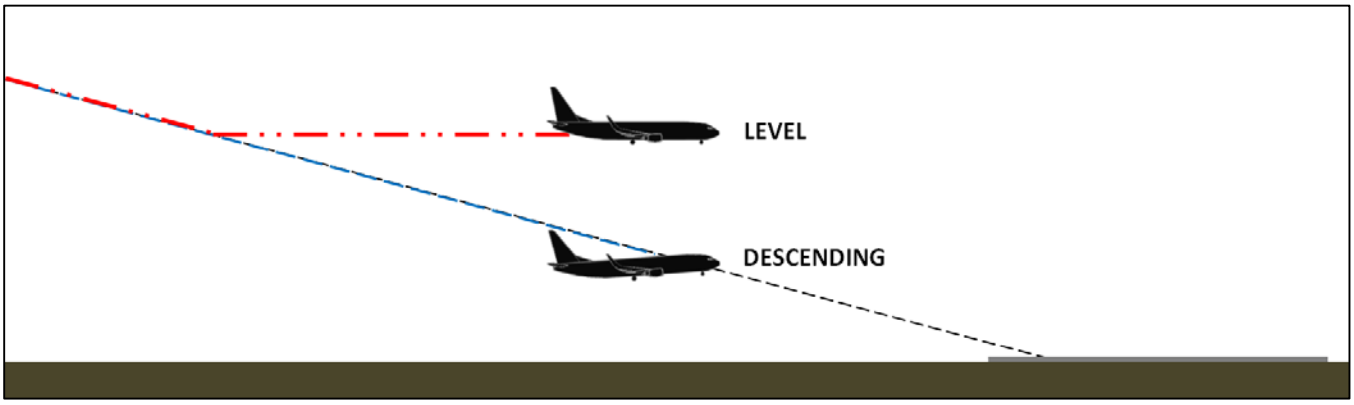

Figure 3-2: Vertical Deviation Types – Level and Descending Deviations

The dual simultaneous independent straight-in approach operations were modeled at 7 different airport elevations evaluated at RCLS values of 3600 ft, 3700 ft, and 3800 ft. There are 21 combinations of RCLS and airport elevations, and each combination was modeled by the 4 fundamental scenarios, resulting in 84 scenarios. There were 2 parallel runways with a 2000 ft wide no transgression zone (NTZ) equidistant between the extended runway centerlines, see Figure 3-3.

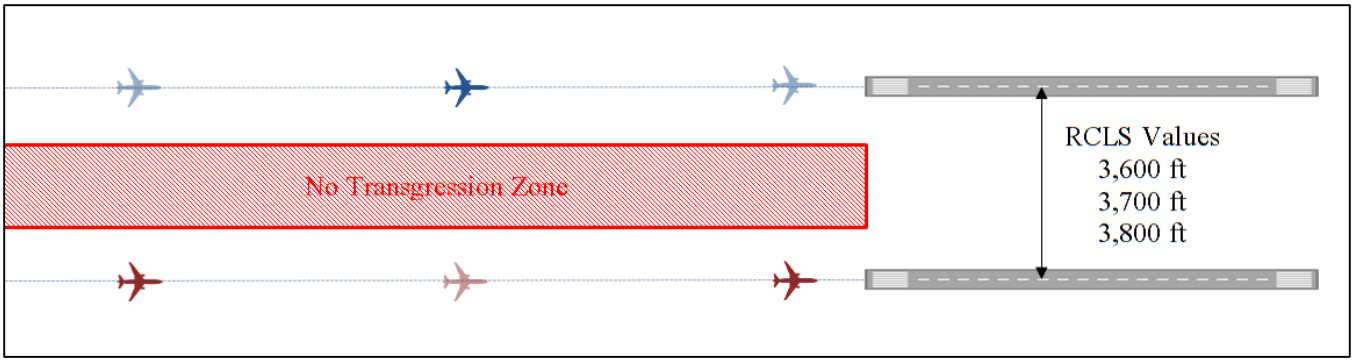

Figure 3-3: Dual Simultaneous Independent Straight-In Approach Operations

The dual operations with one offset approach were modeled with 168 scenarios, see Figure 3-4. These operations have a minimum RCLS of 3000 ft and were evaluated at RCLS 3000 ft, 3100 ft, and 3200 ft. There are 21 combinations of RCLS and airport elevations, and each combination was comprised of the 4 fundamental scenarios modeling 2 different possibilities. The two possibilities are 1) an aircraft on a straight-in approach can deviate toward the aircraft on the offset approach, or 2) an aircraft on an offset approach can deviate toward the aircraft on the straight-in approach. There were 2 parallel runways with a 2000 ft wide NTZ equidistant between the 2 approach paths. The normal operation zone, which is the distance between the approach path and the edge of the NTZ, increases as distance from the threshold increases in an offset operation. An offset results in a decrease in the collision risk as compared to the parallel approach configuration. Since the 3.0° offset has a larger normal operation zone and therefore a lower collision risk as compared to the minimum offset of 2.5°, this operation was conservatively analyzed at the minimum offset of 2.5°.

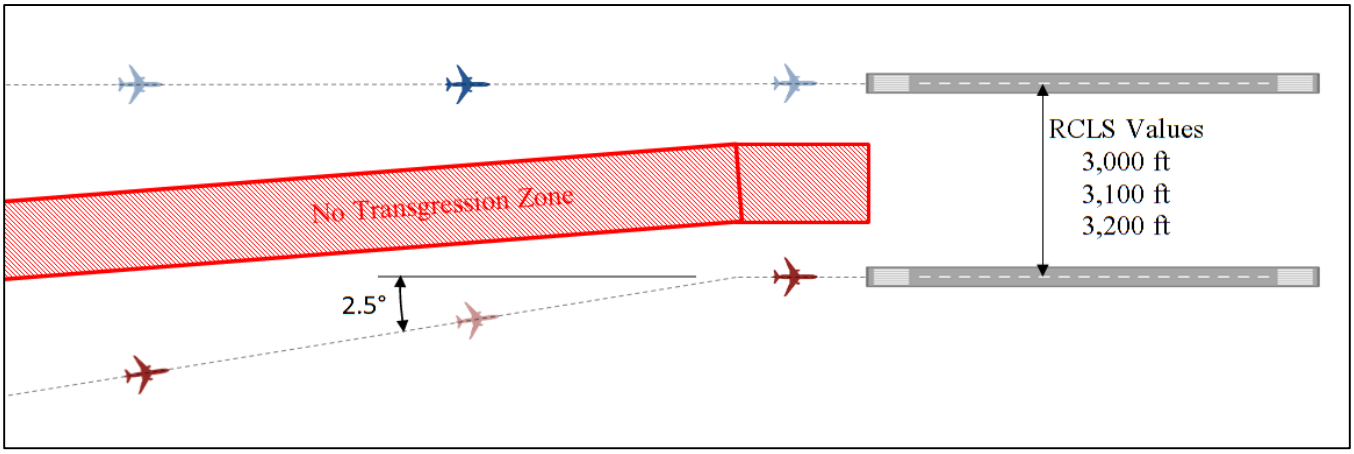

Figure 3-4: Dual Simultaneous Independent Offset Approach Operations

The triple straight-in operations were modeled with a total of 252 scenarios. These operations have a minimum RCLS of 3900 ft and were evaluated at RCLS 3900 ft, 4000 ft, and 4100 ft. There are 21 combinations of RCLS and airport elevations, and each combination was modeled by 12 scenarios. These 12 scenarios were comprised of the 4 fundamental scenarios modeling 3 different possibilities. Those three possibilities are 1) an aircraft on an outside approach can deviate toward the aircraft on the center approach, 2) an aircraft on an outside approach can deviate all the way across the center toward the aircraft on the opposite outside approach, or 3) an aircraft on the center approach can deviate toward an aircraft on an outside approach. There were 3 parallel runways with a 2000 ft wide NTZ equidistant between the extended runway centerlines of the center and the left runways and another NTZ equidistant between the extended runway centerlines of the center and the right runways, see Figure 3-5. Triple offset approaches were not analyzed and are beyond the scope of this study.

Figure 3-5: Triple Simultaneous Independent Straight-In Approach Operations

The models and assumptions used in the simulation were the same as those used in AFS-450-69. The temperature profile was a linear decrease in accordance with the International Standard Atmosphere with no wind. The release positions were distributed uniformly between 2 and 14 nautical miles (NM) prior to the threshold in such a way as to ensure that the deviating aircraft could reach the other aircraft prior to its landing. Each pair was released "at risk" for a collision in the event that the controller and/or pilot did not intervene with the aircraft deviation situation. At risk is a condition for the release of the aircraft specified within the ASAT^{ng} simulation that ensures the 2 aircraft will pass somewhere within the minimum possible lateral range which, for this study, was inside the 265 ft radius of the TCV volume.

3.3 Test Assumptions

Assumptions used in this study were consistent with AFS-450-69 and included the following:

- Aircraft were established on the final approach course pursuant to all other criteria contained in FAA Order JO 7110.65[7]
- Aircraft followed approach control directed speeds up to the point of configuring for the final approach
- Aircraft did not slow until within 2 NM prior to the final approach fix
- The surveillance source provided adequate coverage and was independent from the navigation system
- Vertical guidance was utilized
- The aircraft was flown using a flight director
- Aircraft deviations were initiated uniformly along the final approach course
- Aircraft fleet mix consisted of 20% heavy aircraft which is representative of the traffic at major airports such as Dallas Fort Worth International Airport, San Francisco International Airport, Denver International Airport, etc.

3.4 Independent Variables

A wide range of parameters were used to realistically model these complex operational scenarios. These parameters include:

- Aircraft fleet mix
- Approach type
- Pilot response time distribution
- Controller response time distribution
- Airport elevation
- Runway spacing
- Approach deviation angle and rate
- Aircraft performance
- Atmospheric conditions
- Navigation system performance
- Surveillance and monitoring equipment

3.5 Dependent Variables

The dependent variable was the TCV rate.

[7] Air Traffic Organization, *Order JO 7110.65, Air Traffic Control*.

4 Data Analysis

4.1 Collision Risk

Consistent with AFS-450-69, the NAS infrastructure incorporates and is limited to Airport Surveillance Radar (ASR-9) with a 4.8 second update rate, Standard Terminal Automation Replacement System, Final Monitor Aid with a color digital display, 4:1 aspect ratio visual and aural alerts, ILS, Wide Area Augmentation System (WAAS) Localizer Performance with Vertical Navigation (LPV), Ground-Based Augmentation System (GBAS) Landing System (GLS), Global Positioning System (GPS)-based Area Navigation (RNAV) and Required Navigation Performance (RNP). The probability of a TCV is determined by the number of TCVs that occur during a simulation, divided by the total number of approach pairs simulated. Collision risk is then calculated by multiplying the probability of a TCV by other probabilities involved, as shown in Appendix A.

4.1.1 Dual Straight-In Approach Operations

The results of the collision risk analysis for dual straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Figure 4-1. A complete collection of this data can be found in Appendix B, Table B-4.

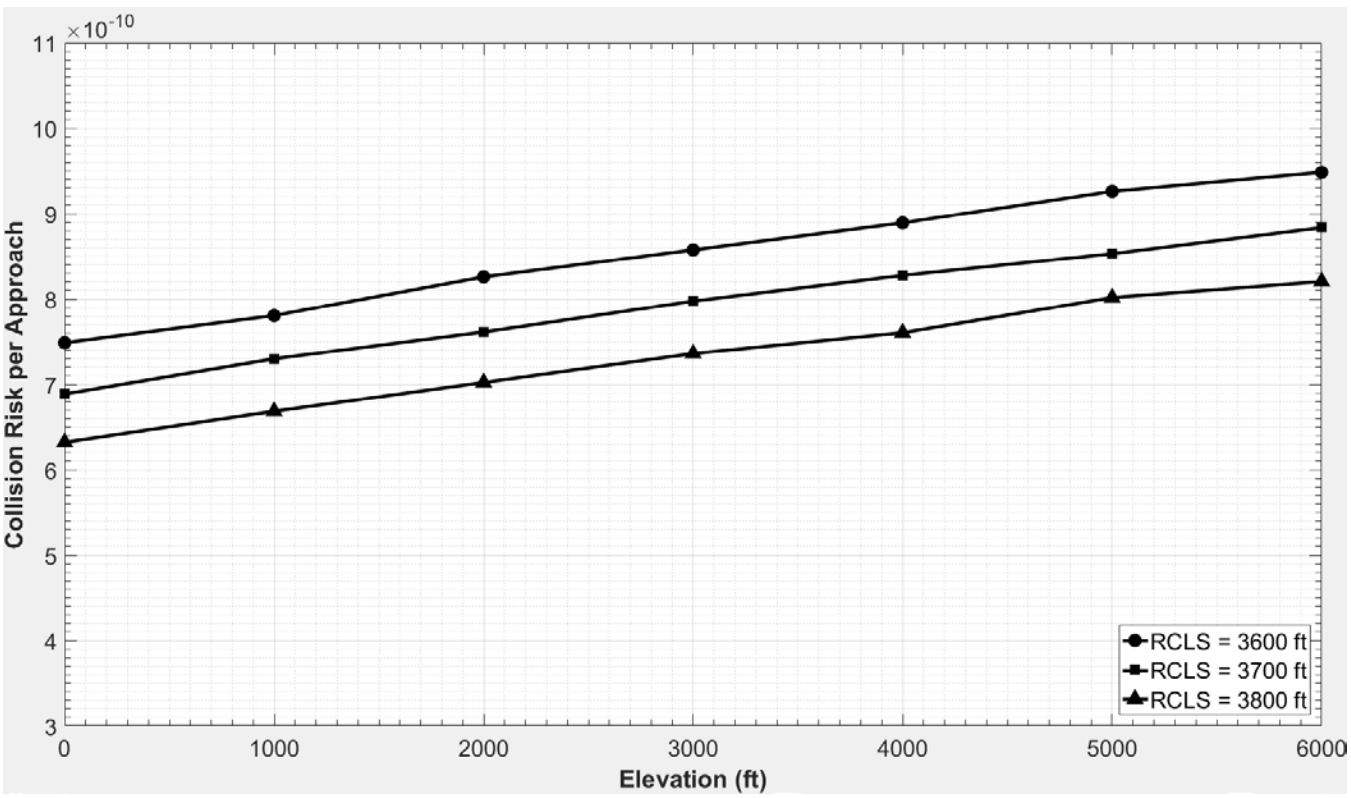

Figure 4-1: Collision Risk for Dual Straight-In Approach Operations

For each 100 ft increase in RCLS, collision risk decreases by an average of 7.5% within a range of 6.0% to 8.4%. For each 1000 ft increase in elevation, collision risk increases by an average of 4.2% within a range of 2.4% to 6.0%.

4.1.2 Dual Offset Approach Operations

The results of the collision risk analysis for dual offset approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Figure 4-2. A complete collection of this data can be found in Appendix B, Table B-5.

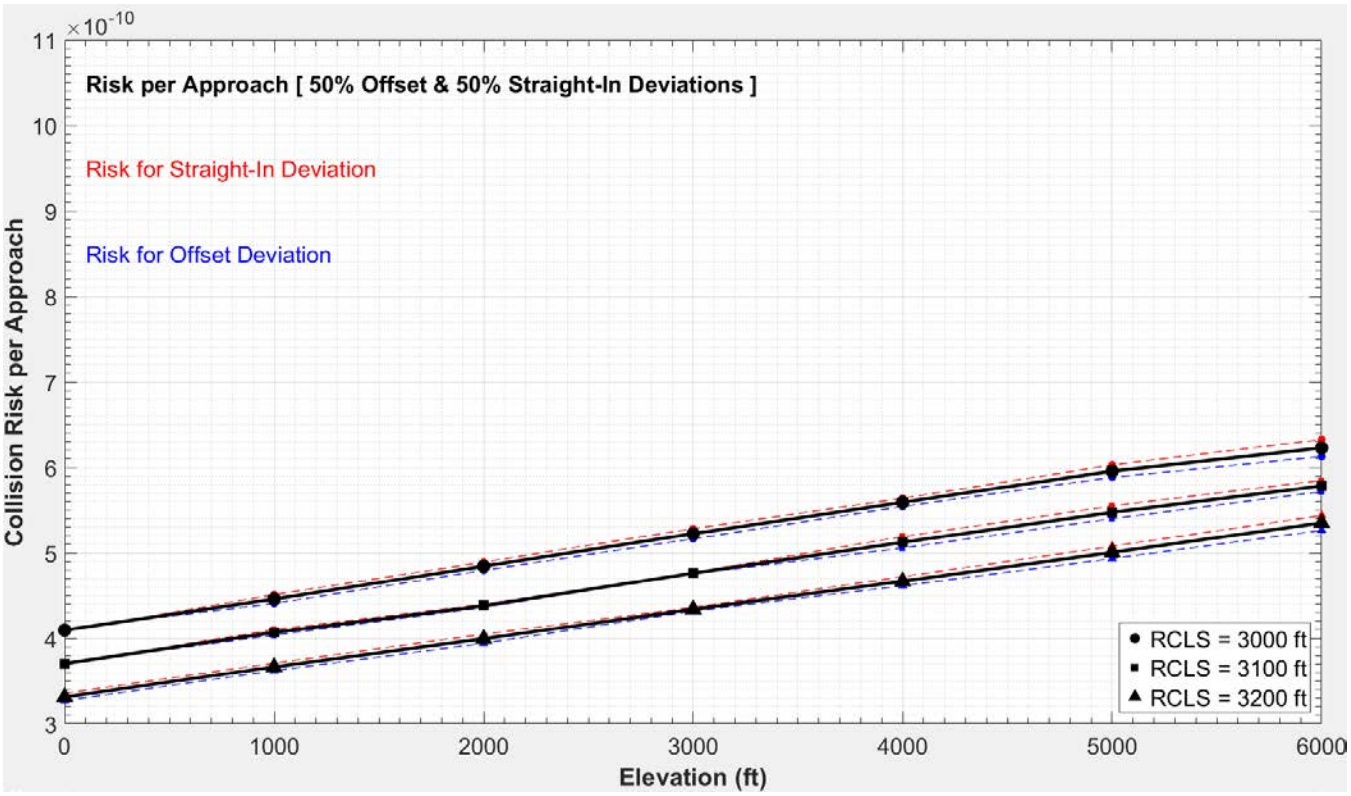

Figure 4-2: Collision Risk for Dual Offset Approach Operations

Collision risk for a deviating aircraft on the straight-in approach is shown in blue and risk for the offset approach is shown in red. Collision risk as a result of deviations from the offset is slightly higher than risk from the straight-in by an average of 2%.

Since the probability of a deviation occurring on a straight-in versus an offset approach has not been determined, an even mixture of 50% each was used in this study to align with the methodology used in previous studies. Thus, the collision risk per approach is shown in black. For each 100 ft increase in RCLS, collision risk decreases by an average of 8.8%, within a range of 7.2% to 10.8%. For each 1000 ft increase in elevation, collision risk increases by an average of 7.7%, within a range of 4.5% to 10.9%.

4.1.3 Triple Approach Operations

The results of the collision risk analysis for triple straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Figure 4-3. A complete collection of this data can be found in Appendix B, Table B-6.

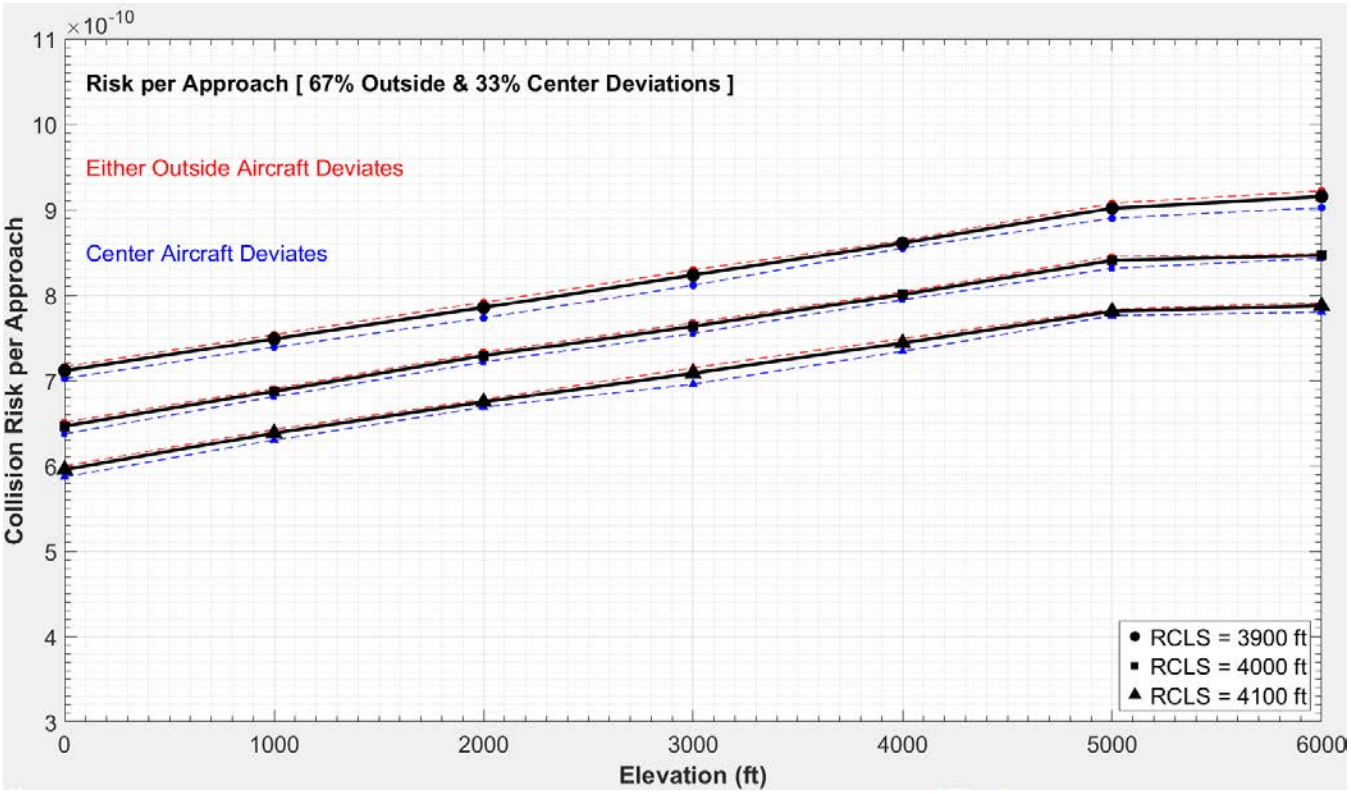

Figure 4-3: Collision Risk for Triple Straight-In Approach Operations

Collision risk for a deviating aircraft on approach to the center runway in a triple straight-in approach operation is shown in blue. Collision risk for a deviating aircraft on approach to either outside runway is shown in red, and is higher than collision risk from a deviating center aircraft by an average of 1.8%, within a range of 0.6% to 2.7%.

A deviating aircraft on approach to an outside runway can cause a TCV with either the aircraft on approach to the center runway *or* the aircraft on approach to the opposite outside runway. Therefore, the probability of either event occurring is the sum of the probabilities of both events, as shown in Table B-6.

Since the probability of a deviation occurring by an outside aircraft versus the center aircraft in triple straight-in approach operations has not been determined, an even mixture of each was used in this study as has been done in previous studies. Since the total probability of a deviation from any runway must add up to one, then a deviation by an outside aircraft can occur two-thirds of the time, while a deviation by a center aircraft can occur one-third of the time in any given scenario. Therefore, the overall risk per approach is the risk from a deviating outside aircraft, multiplied by two-thirds, *plus* the risk from the deviating center aircraft, multiplied by one-third. These results are listed in the far right column of Table B-6 and are depicted by the bold black lines in Figure 4-3.

For each 100 ft increase in RCLS for triple straight-in approach operations, collision risk decreases by an average of 7.4%, within a range of 6.8% to 9.1%. For each 1000 ft increase in elevation, from 0 ft to 5000 ft, collision risk increases by an average of 5.3%, within a range of 4.7% to 7.2%. From 5000 ft to 6000 ft elevation, collision risk increases by an average of 1.0%, within a range of 0.7% to 1.5%.

5 Conclusions

This study examined the sensitivity of collision risk as a function of RCLS and airport elevation for three types of simultaneous independent approach operations without HUR surveillance:

- Dual straight-in
- Dual with one approach offset by 2.5°
- Triple straight-in

The study evaluated these approach operations at airport elevations between sea level and 6000 ft MSL in 1000 ft increments. The minimum RCLS values used were the minimum values authorized by FAA Order JO 7110.65, Air Traffic Control, for the three operations studied, i.e., 3600 ft for dual straight-in, 3000 ft for duals with one approach offset by 2.5°, and 3900 ft for triple straight-in approaches. The RCLS values were increased in 100 ft increments.[8] Even though the analysis indicates the increase in collision risk from sea level to 6000 ft MSL is significant, the resultant collision risk is still extremely improbable.

Collision risk values per approach and trends from sea level to 6000 ft MSL were as follows:

For dual straight-in approach operations,

- 7.49×10^{-10} to 9.48×10^{-10} per approach for RCLS of 3600 ft
- For each 100 ft increase in RCLS, collision risk decreases by an average of 7.5% within a range of 6.0% to 8.4%
- For each 1000 ft increase in elevation, collision risk increases by an average of 4.2% within a range of 2.4% to 6.0%

For dual approach operations with one 2.5° offset approach,

- 4.10×10^{-10} to 6.23×10^{-10} per approach for RCLS of 3000 ft
- For each 100 ft increase in RCLS, collision risk decreases by an average of 8.8%, within a range of 7.2% to 10.8%
- For each 1000 ft increase in elevation, collision risk increases by an average of 7.7%, within a range of 4.5% to 10.9%

For triple straight-in approach operations,

- 7.11×10^{-10} to 9.16×10^{-10} per approach for RCLS of 3900 ft
- For each 100 ft increase in RCLS for triple straight-in approach operations, collision risk decreases by an average of 7.4%, within a range of 6.8% to 9.1%
- For each 1000 ft increase in elevation, from 0 ft to 5000 ft, collision risk increases by an average of 5.3%, within a range of 4.7% to 7.2%
- From 5000 ft to 6000 ft elevation, collision risk increases by an average of 1.0%, within a range of 0.7% to 1.5%
- Collision risk from deviations by either outside aircraft is higher than collision risk from deviations by center aircraft by an average of 1.8%, within a range of 0.6% to 2.7%

[8] Air Traffic Organization, *Order JO 7110.65, Air Traffic Control*.

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Appendix A: Risk Analysis - Probability of a Collision

This appendix describes the analysis methodology used in DOT-FAA-AFS-450-69, "*Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*,"[9] which limited acceptable airport elevation to 1000 ft MSL; and the follow-on memo raising the acceptable elevation to 2000 ft.[10] The purpose of this present study is to analyze the sensitivity of the previous methodology to airport elevation, see section 1.2.

Several events must occur simultaneously for a collision to occur during simultaneous instrument approaches. A deviation must occur and the deviating aircraft must be aligned with the endangered aircraft so that a TCV will occur without timely action from both the controller and the pilot of the endangered aircraft. An aligned deviation is called an at-risk deviation and is denoted in the equation. If all of the above events develop in a manner supporting a collision, a TCV occurs if the controllers and pilots fail to react in sufficient time to separate the deviating and the endangered aircraft.

A collision involves two aircraft and results in two accidents, as defined by the National Transportation Safety Board. Assuming that a TCV will result in a collision, the probability of a collision can be expressed in mathematical terms by:

$$P(\text{Collision}) = P(\text{TCV}|\text{NRD} \cap \text{ARD} \cap \text{DV})\, P(\text{NRD}|\text{ARD} \cap \text{DV})\, P(\text{ARD}|\text{DV})\, P(\text{DV}) \qquad (1)$$

Where “ARD” stands for “at-risk deviations,” “DV” stands for “deviations,” “NRD” stands for “non-responding deviations,” the symbol “∩” stands for “and,” and the symbol “ | ” stands for “given.”

Factor 1 determines the probability that a TCV occurs given that a non-responding, at-risk deviation has occurred. This is the TCV rate that is determined from the simulation. Factor 1 in equation 2 is expressed as:

$$P(\text{TCV}|\text{NRD} \cap \text{ARD} \cap \text{DV}) \qquad (2)$$

Factor 2 determines the probability that the deviating aircraft does not respond to air traffic controllers’ instructions to return to course given that an at-risk deviation has occurred. The value of this factor is 8.32×10^{-3}. Factor 2 in equation 3 is expressed as:

$$P(\text{NRD}|\text{ARD} \cap \text{DV}) \qquad (3)$$

Factor 3 is the probability that the deviation is an at-risk deviation given that a deviation has occurred. The value of this factor was estimated from simulation data using the TCV shape described in section 3.2 of this report and was found to be 3.17×10^{-2}. This value represents the likelihood that another aircraft will be at risk with the deviating aircraft. It assumes that the deviation is occurring during peak traffic times where there are aircraft separated by 3 NM in-trail on the other runway. Factor 3 in equation 4 is expressed as:

[9] Flight Systems Laboratory, *DOT-FAA-AFS-450-69, Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required.*

[10] Flight Technologies and Procedures Division, *Altitude Limitation for Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*.

$$P(ARD|DV) \quad (4)$$

Factor 4, as expressed in equation 5, is the probability of a deviation of a specified angle. Deviation data was captured from actual simultaneous approaches conducted in less than visual conditions. The probability and frequency of the occurrence of various deviation angles has been determined from the data, and binned at 10° increments up to 35° as indicated in Table A-1.[11]

$$P(DV) \quad (5)$$

Table A-1: 99% Confidence Intervals for NTZ Penetration Rates

Deviation Degrees	High Confidence Limit
$5° \leq \theta < 15°$	4.58E-5
$15° \leq \theta < 25°$	2.55E-5
$25° \leq \theta < 35°$	1.18E-5

A TCV will result in two accidents. There are two approaches in each operation. Therefore, a TCV will result in two accidents per operation, but only one accident per approach. Hence, the results of Equation 1 yield the probability of an accident per approach.

[11] Massimini, McNeil, Tene, *MP090245, Frequency and Severity of Deviations during Simultaneous Independent Approaches to Parallel Runways – A 2009 Update*, The MITRE Corp.

Appendix B: Numerical Collision Risk Results

This appendix presents the numerical results of the closely spaced simultaneous independent parallel instrument approach configurations evaluated in this study. A 6000 ft airport elevation was used to encompass all airports expected to conduct such operations within the NAS. The evaluation was conducted in a no wind condition using the ICAO standard temperature lapse rate, and based on the level of collision risk used in study DOT-FAA-AFS-450-69, *Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*.

Dual Straight-In Approach Operations – Summarized Results

A summary of the results of the collision risk analysis for dual straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-1.

Table B-1: Summarized Collision Risk per Approach for Dual Straight-In Approach Operations

Airport Elevation (ft)	RCLS 3600 ft	RCLS 3700 ft	RCLS 3800 ft
0	7.49E-10	6.89E-10	6.32E-10
1000	7.81E-10	7.30E-10	6.69E-10
2000	8.26E-10	7.61E-10	7.02E-10
3000	8.58E-10	7.98E-10	7.36E-10
4000	8.89E-10	8.28E-10	7.61E-10
5000	9.26E-10	8.53E-10	8.02E-10
6000	9.48E-10	8.84E-10	8.21E-10

Dual Offset Approach Operations – Summarized Results

A summary of the results of the collision risk analysis for dual offset approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-2.

Table B-2: Summarized Collision Risk per Approach for Dual Offset Approach Operations

Airport Elevation (ft)	RCLS 3000 ft	RCLS 3100 ft	RCLS 3200 ft
0	4.10E-10	3.71E-10	3.31E-10
1000	4.46E-10	4.07E-10	3.67E-10
2000	4.84E-10	4.38E-10	4.00E-10
3000	5.22E-10	4.76E-10	4.34E-10
4000	5.59E-10	5.12E-10	4.67E-10
5000	5.96E-10	5.47E-10	5.01E-10
6000	6.23E-10	5.78E-10	5.35E-10

Triple Straight-In Approach Operations – Summarized Results

A summary of the results of the collision risk analysis for triple straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-3.

Table B-3: Summarized Collision Risk per Approach for Triple Straight-In Approach Operations

Airport Elevation (ft)	RCLS 3900 ft	RCLS 4000 ft	RCLS 4100 ft
0	7.11E-10	6.47E-10	5.96E-10
1000	7.49E-10	6.87E-10	6.38E-10
2000	7.85E-10	7.29E-10	6.75E-10
3000	8.23E-10	7.63E-10	7.08E-10
4000	8.61E-10	8.01E-10	7.44E-10
5000	9.02E-10	8.40E-10	7.81E-10
6000	9.16E-10	8.47E-10	7.87E-10

Dual Approach Operations – Detailed Results

Detailed results of the collision risk analysis for dual straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-4.

Table B-4: Collision Risk per Approach for Dual Straight-In Approach Operations

Deviation Scenario	RCLS	Elevation	Deviation Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	Collision Risk per Approach
Straight-In	3600 ft	0 ft	20°	Level	100,000	2,350	0.02350	7.90E-11	**7.49E-10**
Straight-In	3600 ft	0 ft	20°	Descending	100,000	1,922	0.01922	6.46E-11	
Straight-In	3600 ft	0 ft	30°	Level	100,000	19,794	0.19794	3.08E-10	
Straight-In	3600 ft	0 ft	30°	Descending	100,000	19,120	0.19120	2.97E-10	
Straight-In	3600 ft	1000 ft	20°	Level	100,000	2,547	0.02547	8.56E-11	**7.81E-10**
Straight-In	3600 ft	1000 ft	20°	Descending	100,000	2,154	0.02154	7.24E-11	
Straight-In	3600 ft	1000 ft	30°	Level	100,000	19,910	0.19910	3.10E-10	
Straight-In	3600 ft	1000 ft	30°	Descending	100,000	20,123	0.20123	3.13E-10	
Straight-In	3600 ft	2000 ft	20°	Level	100,000	2,912	0.02912	9.79E-11	**8.26E-10**
Straight-In	3600 ft	2000 ft	20°	Descending	100,000	2,445	0.02445	8.22E-11	
Straight-In	3600 ft	2000 ft	30°	Level	100,000	20,142	0.20142	3.13E-10	
Straight-In	3600 ft	2000 ft	30°	Descending	100,000	21,383	0.21383	3.33E-10	
Straight-In	3600 ft	3000 ft	20°	Level	100,000	3,292	0.03292	1.11E-10	**8.58E-10**
Straight-In	3600 ft	3000 ft	20°	Descending	100,000	2,819	0.02819	9.48E-11	
Straight-In	3600 ft	3000 ft	30°	Level	100,000	19,899	0.19899	3.10E-10	
Straight-In	3600 ft	3000 ft	30°	Descending	100,000	22,026	0.22026	3.43E-10	
Straight-In	3600 ft	4000 ft	20°	Level	100,000	3,645	0.03645	1.23E-10	**8.89E-10**
Straight-In	3600 ft	4000 ft	20°	Descending	100,000	3,196	0.03196	1.07E-10	
Straight-In	3600 ft	4000 ft	30°	Level	100,000	19,571	0.19571	3.04E-10	
Straight-In	3600 ft	4000 ft	30°	Descending	100,000	22,818	0.22818	3.55E-10	
Straight-In	3600 ft	5000 ft	20°	Level	100,000	4,013	0.04013	1.35E-10	**9.26E-10**
Straight-In	3600 ft	5000 ft	20°	Descending	100,000	3,505	0.03505	1.18E-10	
Straight-In	3600 ft	5000 ft	30°	Level	100,000	19,429	0.19429	3.02E-10	
Straight-In	3600 ft	5000 ft	30°	Descending	100,000	23,863	0.23863	3.71E-10	
Straight-In	3600 ft	6000 ft	20°	Level	100,000	4,159	0.04159	1.40E-10	**9.48E-10**
Straight-In	3600 ft	6000 ft	20°	Descending	100,000	3,923	0.03923	1.32E-10	
Straight-In	3600 ft	6000 ft	30°	Level	100,000	18,985	0.18985	2.95E-10	
Straight-In	3600 ft	6000 ft	30°	Descending	100,000	24,525	0.24525	3.81E-10	
Straight-In	3700 ft	0 ft	20°	Level	100,000	1,915	0.01915	6.44E-11	**6.89E-10**
Straight-In	3700 ft	0 ft	20°	Descending	100,000	1,519	0.01519	5.11E-11	
Straight-In	3700 ft	0 ft	30°	Level	100,000	18,943	0.18943	2.95E-10	
Straight-In	3700 ft	0 ft	30°	Descending	100,000	17,920	0.17920	2.79E-10	
Straight-In	3700 ft	1000 ft	20°	Level	100,000	2,203	0.02203	7.40E-11	**7.30E-10**
Straight-In	3700 ft	1000 ft	20°	Descending	100,000	1,845	0.01845	6.20E-11	
Straight-In	3700 ft	1000 ft	30°	Level	100,000	19,303	0.19303	3.00E-10	
Straight-In	3700 ft	1000 ft	30°	Descending	100,000	18,882	0.18882	2.94E-10	
Straight-In	3700 ft	2000 ft	20°	Level	100,000	2,498	0.02498	8.40E-11	**7.61E-10**
Straight-In	3700 ft	2000 ft	20°	Descending	100,000	2,064	0.02064	6.94E-11	
Straight-In	3700 ft	2000 ft	30°	Level	100,000	19,365	0.19365	3.01E-10	
Straight-In	3700 ft	2000 ft	30°	Descending	100,000	19,730	0.19730	3.07E-10	

Deviation Scenario	RCLS	Elevation	Deviation Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	Collision Risk per Approach
Straight-In	3700 ft	3000 ft	20°	Level	100,000	2,726	0.02726	9.16E-11	**7.98E-10**
Straight-In	3700 ft	3000 ft	20°	Descending	100,000	2,377	0.02377	7.99E-11	
Straight-In	3700 ft	3000 ft	30°	Level	100,000	19,543	0.19543	3.04E-10	
Straight-In	3700 ft	3000 ft	30°	Descending	100,000	20,702	0.20702	3.22E-10	
Straight-In	3700 ft	4000 ft	20°	Level	100,000	3,046	0.03046	1.02E-10	**8.28E-10**
Straight-In	3700 ft	4000 ft	20°	Descending	100,000	2,617	0.02617	8.80E-11	
Straight-In	3700 ft	4000 ft	30°	Level	100,000	19,182	0.19182	2.98E-10	
Straight-In	3700 ft	4000 ft	30°	Descending	100,000	21,795	0.21795	3.39E-10	
Straight-In	3700 ft	5000 ft	20°	Level	100,000	3,321	0.03321	1.12E-10	**8.53E-10**
Straight-In	3700 ft	5000 ft	20°	Descending	100,000	2,920	0.02920	9.81E-11	
Straight-In	3700 ft	5000 ft	30°	Level	100,000	19,102	0.19102	2.97E-10	
Straight-In	3700 ft	5000 ft	30°	Descending	100,000	22,254	0.22254	3.46E-10	
Straight-In	3700 ft	6000 ft	20°	Level	100,000	3,526	0.03526	1.19E-10	**8.84E-10**
Straight-In	3700 ft	6000 ft	20°	Descending	100,000	3,431	0.03431	1.15E-10	
Straight-In	3700 ft	6000 ft	30°	Level	100,000	18,582	0.18582	2.89E-10	
Straight-In	3700 ft	6000 ft	30°	Descending	100,000	23,192	0.23192	3.61E-10	
Straight-In	3800 ft	0 ft	20°	Level	100,000	1,544	0.01544	5.19E-11	**6.32E-10**
Straight-In	3800 ft	0 ft	20°	Descending	100,000	1,247	0.01247	4.19E-11	
Straight-In	3800 ft	0 ft	30°	Level	100,000	18,076	0.18076	2.81E-10	
Straight-In	3800 ft	0 ft	30°	Descending	100,000	16,550	0.16550	2.57E-10	
Straight-In	3800 ft	1000 ft	20°	Level	100,000	1,859	0.01859	6.25E-11	**6.69E-10**
Straight-In	3800 ft	1000 ft	20°	Descending	100,000	1,452	0.01452	4.88E-11	
Straight-In	3800 ft	1000 ft	30°	Level	100,000	18,384	0.18384	2.86E-10	
Straight-In	3800 ft	1000 ft	30°	Descending	100,000	17,443	0.17443	2.71E-10	
Straight-In	3800 ft	2000 ft	20°	Level	100,000	2,065	0.02065	6.94E-11	**7.02E-10**
Straight-In	3800 ft	2000 ft	20°	Descending	100,000	1,747	0.01747	5.87E-11	
Straight-In	3800 ft	2000 ft	30°	Level	100,000	18,581	0.18581	2.89E-10	
Straight-In	3800 ft	2000 ft	30°	Descending	100,000	18,333	0.18333	2.85E-10	
Straight-In	3800 ft	3000 ft	20°	Level	100,000	2,367	0.02367	7.96E-11	**7.36E-10**
Straight-In	3800 ft	3000 ft	20°	Descending	100,000	1,917	0.01917	6.44E-11	
Straight-In	3800 ft	3000 ft	30°	Level	100,000	18,816	0.18816	2.93E-10	
Straight-In	3800 ft	3000 ft	30°	Descending	100,000	19,251	0.19251	2.99E-10	
Straight-In	3800 ft	4000 ft	20°	Level	100,000	2,597	0.02597	8.73E-11	**7.61E-10**
Straight-In	3800 ft	4000 ft	20°	Descending	100,000	2,151	0.02151	7.23E-11	
Straight-In	3800 ft	4000 ft	30°	Level	100,000	18,480	0.18480	2.87E-10	
Straight-In	3800 ft	4000 ft	30°	Descending	100,000	20,159	0.20159	3.14E-10	
Straight-In	3800 ft	5000 ft	20°	Level	100,000	2,887	0.02887	9.70E-11	**8.02E-10**
Straight-In	3800 ft	5000 ft	20°	Descending	100,000	2,568	0.02568	8.63E-11	
Straight-In	3800 ft	5000 ft	30°	Level	100,000	18,779	0.18779	2.92E-10	
Straight-In	3800 ft	5000 ft	30°	Descending	100,000	20,976	0.20976	3.26E-10	
Straight-In	3800 ft	6000 ft	20°	Level	100,000	3,117	0.03117	1.05E-10	**8.21E-10**
Straight-In	3800 ft	6000 ft	20°	Descending	100,000	2,898	0.02898	9.74E-11	
Straight-In	3800 ft	6000 ft	30°	Level	100,000	18,127	0.18127	2.82E-10	
Straight-In	3800 ft	6000 ft	30°	Descending	100,000	21,628	0.21628	3.36E-10	

Dual Offset Approach Operations – Detailed Results

Detailed results of the collision risk analysis for dual offset approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-5.

Table B-5: Collision Risk per Approach for Dual Offset Approach Operations

Deviation Scenario	RCLS	Elev	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	Collision Risk per Approach
Straight-In	3000 ft	0 ft	20°	Descending	100,000	167	0.0017	5.61E-12	4.08E-10	4.10E-10
Straight-In	3000 ft	0 ft	20°	Level	100,000	296	0.0030	9.95E-12		
Straight-In	3000 ft	0 ft	30°	Descending	100,000	12,178	0.1218	1.89E-10		
Straight-In	3000 ft	0 ft	30°	Level	100,000	13,076	0.1308	2.03E-10		
Offset	3000 ft	0 ft	20°	Descending	100,000	139	0.0014	4.67E-12	4.11E-10	
Offset	3000 ft	0 ft	20°	Level	100,000	307	0.0031	1.03E-11		
Offset	3000 ft	0 ft	30°	Descending	100,000	11,835	0.1184	1.84E-10		
Offset	3000 ft	0 ft	30°	Level	100,000	13,619	0.1362	2.12E-10		
Straight-In	3000 ft	1000 ft	20°	Descending	100,000	219	0.0022	7.36E-12	4.51E-10	4.46E-10
Straight-In	3000 ft	1000 ft	20°	Level	100,000	326	0.0033	1.10E-11		
Straight-In	3000 ft	1000 ft	30°	Descending	100,000	13,648	0.1365	2.12E-10		
Straight-In	3000 ft	1000 ft	30°	Level	100,000	14,175	0.1418	2.20E-10		
Offset	3000 ft	1000 ft	20°	Descending	100,000	179	0.0018	6.02E-12	4.41E-10	
Offset	3000 ft	1000 ft	20°	Level	100,000	383	0.0038	1.29E-11		
Offset	3000 ft	1000 ft	30°	Descending	100,000	12,757	0.1276	1.98E-10		
Offset	3000 ft	1000 ft	30°	Level	100,000	14,368	0.1437	2.23E-10		
Straight-In	3000 ft	2000 ft	20°	Descending	100,000	295	0.0030	9.92E-12	4.89E-10	4.84E-10
Straight-In	3000 ft	2000 ft	20°	Level	100,000	480	0.0048	1.61E-11		
Straight-In	3000 ft	2000 ft	30°	Descending	100,000	15,170	0.1517	2.36E-10		
Straight-In	3000 ft	2000 ft	30°	Level	100,000	14,609	0.1461	2.27E-10		
Offset	3000 ft	2000 ft	20°	Descending	100,000	264	0.0026	8.87E-12	4.80E-10	
Offset	3000 ft	2000 ft	20°	Level	100,000	480	0.0048	1.61E-11		
Offset	3000 ft	2000 ft	30°	Descending	100,000	14,251	0.1425	2.22E-10		
Offset	3000 ft	2000 ft	30°	Level	100,000	14,979	0.1498	2.33E-10		
Straight-In	3000 ft	3000 ft	20°	Descending	100,000	335	0.0034	1.13E-11	5.28E-10	5.22E-10
Straight-In	3000 ft	3000 ft	20°	Level	100,000	579	0.0058	1.95E-11		
Straight-In	3000 ft	3000 ft	30°	Descending	100,000	16,640	0.1664	2.59E-10		
Straight-In	3000 ft	3000 ft	30°	Level	100,000	15,353	0.1535	2.39E-10		
Offset	3000 ft	3000 ft	20°	Descending	100,000	318	0.0032	1.07E-11	5.17E-10	
Offset	3000 ft	3000 ft	20°	Level	100,000	629	0.0063	2.11E-11		
Offset	3000 ft	3000 ft	30°	Descending	100,000	15,742	0.1574	2.45E-10		
Offset	3000 ft	3000 ft	30°	Level	100,000	15,419	0.1542	2.40E-10		
Straight-In	3000 ft	4000 ft	20°	Descending	100,000	520	0.0052	1.75E-11	5.64E-10	5.59E-10
Straight-In	3000 ft	4000 ft	20°	Level	100,000	704	0.0070	2.37E-11		
Straight-In	3000 ft	4000 ft	30°	Descending	100,000	17,992	0.1799	2.80E-10		
Straight-In	3000 ft	4000 ft	30°	Level	100,000	15,610	0.1561	2.43E-10		
Offset	3000 ft	4000 ft	20°	Descending	100,000	496	0.0050	1.67E-11	5.54E-10	
Offset	3000 ft	4000 ft	20°	Level	100,000	731	0.0073	2.46E-11		
Offset	3000 ft	4000 ft	30°	Descending	100,000	17,326	0.1733	2.69E-10		
Offset	3000 ft	4000 ft	30°	Level	100,000	15,663	0.1566	2.44E-10		

Deviation Scenario	RCLS	Elev	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	Collision Risk per Approach
Straight-In	3000 ft	5000 ft	20°	Descending	100,000	621	0.0062	2.09E-11	6.03E-10	**5.96E-10**
Straight-In	3000 ft	5000 ft	20°	Level	100,000	852	0.0085	2.86E-11		
Straight-In	3000 ft	5000 ft	30°	Descending	100,000	19,631	0.1963	3.05E-10		
Straight-In	3000 ft	5000 ft	30°	Level	100,000	15,947	0.1595	2.48E-10		
Offset	3000 ft	5000 ft	20°	Descending	100,000	622	0.0062	2.09E-11	5.88E-10	
Offset	3000 ft	5000 ft	20°	Level	100,000	876	0.0088	2.94E-11		
Offset	3000 ft	5000 ft	30°	Descending	100,000	18,570	0.1857	2.89E-10		
Offset	3000 ft	5000 ft	30°	Level	100,000	16,019	0.1602	2.49E-10		
Straight-In	3000 ft	6000 ft	20°	Descending	100,000	847	0.0085	2.85E-11	6.33E-10	**6.23E-10**
Straight-In	3000 ft	6000 ft	20°	Level	100,000	999	0.0100	3.36E-11		
Straight-In	3000 ft	6000 ft	30°	Descending	100,000	21,014	0.2101	3.27E-10		
Straight-In	3000 ft	6000 ft	30°	Level	100,000	15,672	0.1567	2.44E-10		
Offset	3000 ft	6000 ft	20°	Descending	100,000	721	0.0072	2.42E-11	6.13E-10	
Offset	3000 ft	6000 ft	20°	Level	100,000	1,017	0.0102	3.42E-11		
Offset	3000 ft	6000 ft	30°	Descending	100,000	19,928	0.1993	3.10E-10		
Offset	3000 ft	6000 ft	30°	Level	100,000	15,711	0.1571	2.44E-10		
Straight-In	3100 ft	0 ft	20°	Descending	100,000	130	0.0013	4.37E-12	3.71E-10	**3.71E-10**
Straight-In	3100 ft	0 ft	20°	Level	100,000	194	0.0019	6.52E-12		
Straight-In	3100 ft	0 ft	30°	Descending	100,000	11,187	0.1119	1.74E-10		
Straight-In	3100 ft	0 ft	30°	Level	100,000	11,934	0.1193	1.86E-10		
Offset	3100 ft	0 ft	20°	Descending	100,000	97	0.0010	3.26E-12	3.71E-10	
Offset	3100 ft	0 ft	20°	Level	100,000	234	0.0023	7.87E-12		
Offset	3100 ft	0 ft	30°	Descending	100,000	10,425	0.1043	1.62E-10		
Offset	3100 ft	0 ft	30°	Level	100,000	12,687	0.1269	1.97E-10		
Straight-In	3100 ft	1000 ft	20°	Descending	100,000	198	0.0020	6.66E-12	4.10E-10	**4.07E-10**
Straight-In	3100 ft	1000 ft	20°	Level	100,000	262	0.0026	8.81E-12		
Straight-In	3100 ft	1000 ft	30°	Descending	100,000	12,413	0.1241	1.93E-10		
Straight-In	3100 ft	1000 ft	30°	Level	100,000	12,958	0.1296	2.02E-10		
Offset	3100 ft	1000 ft	20°	Descending	100,000	137	0.0014	4.60E-12	4.04E-10	
Offset	3100 ft	1000 ft	20°	Level	100,000	268	0.0027	9.01E-12		
Offset	3100 ft	1000 ft	30°	Descending	100,000	11,799	0.1180	1.84E-10		
Offset	3100 ft	1000 ft	30°	Level	100,000	13,282	0.1328	2.07E-10		
Straight-In	3100 ft	2000 ft	20°	Descending	100,000	193	0.0019	6.49E-12	4.40E-10	**4.38E-10**
Straight-In	3100 ft	2000 ft	20°	Level	100,000	324	0.0032	1.09E-11		
Straight-In	3100 ft	2000 ft	30°	Descending	100,000	13,632	0.1363	2.12E-10		
Straight-In	3100 ft	2000 ft	30°	Level	100,000	13,530	0.1353	2.10E-10		
Offset	3100 ft	2000 ft	20°	Descending	100,000	199	0.0020	6.69E-12	4.36E-10	
Offset	3100 ft	2000 ft	20°	Level	100,000	380	0.0038	1.28E-11		
Offset	3100 ft	2000 ft	30°	Descending	100,000	12,876	0.1288	2.00E-10		
Offset	3100 ft	2000 ft	30°	Level	100,000	13,919	0.1392	2.16E-10		
Straight-In	3100 ft	3000 ft	20°	Descending	100,000	287	0.0029	9.65E-12	4.77E-10	**4.76E-10**
Straight-In	3100 ft	3000 ft	20°	Level	100,000	418	0.0042	1.41E-11		
Straight-In	3100 ft	3000 ft	30°	Descending	100,000	14,950	0.1495	2.33E-10		
Straight-In	3100 ft	3000 ft	30°	Level	100,000	14,197	0.1420	2.21E-10		
Offset	3100 ft	3000 ft	20°	Descending	100,000	245	0.0025	8.24E-12	4.75E-10	
Offset	3100 ft	3000 ft	20°	Level	100,000	453	0.0045	1.52E-11		
Offset	3100 ft	3000 ft	30°	Descending	100,000	14,344	0.1434	2.23E-10		
Offset	3100 ft	3000 ft	30°	Level	100,000	14,712	0.1471	2.29E-10		

Deviation Scenario	RCLS	Elev	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	Collision Risk per Approach
Straight-In	3100 ft	4000 ft	20°	Descending	100,000	372	0.0037	1.25E-11	5.19E-10	**5.12E-10**
Straight-In	3100 ft	4000 ft	20°	Level	100,000	555	0.0056	1.87E-11		
Straight-In	3100 ft	4000 ft	30°	Descending	100,000	16,536	0.1654	2.57E-10		
Straight-In	3100 ft	4000 ft	30°	Level	100,000	14,830	0.1483	2.31E-10		
Offset	3100 ft	4000 ft	20°	Descending	100,000	346	0.0035	1.16E-11	5.06E-10	
Offset	3100 ft	4000 ft	20°	Level	100,000	585	0.0059	1.97E-11		
Offset	3100 ft	4000 ft	30°	Descending	100,000	15,491	0.1549	2.41E-10		
Offset	3100 ft	4000 ft	30°	Level	100,000	15,007	0.1501	2.33E-10		
Straight-In	3100 ft	5000 ft	20°	Descending	100,000	504	0.0050	1.69E-11	5.55E-10	**5.47E-10**
Straight-In	3100 ft	5000 ft	20°	Level	100,000	668	0.0067	2.25E-11		
Straight-In	3100 ft	5000 ft	30°	Descending	100,000	17,914	0.1791	2.79E-10		
Straight-In	3100 ft	5000 ft	30°	Level	100,000	15,227	0.1523	2.37E-10		
Offset	3100 ft	5000 ft	20°	Descending	100,000	440	0.0044	1.48E-11	5.40E-10	
Offset	3100 ft	5000 ft	20°	Level	100,000	715	0.0072	2.40E-11		
Offset	3100 ft	5000 ft	30°	Descending	100,000	16,973	0.1697	2.64E-10		
Offset	3100 ft	5000 ft	30°	Level	100,000	15,251	0.1525	2.37E-10		
Straight-In	3100 ft	6000 ft	20°	Descending	100,000	599	0.0060	2.01E-11	5.85E-10	**5.78E-10**
Straight-In	3100 ft	6000 ft	20°	Level	100,000	750	0.0075	2.52E-11		
Straight-In	3100 ft	6000 ft	30°	Descending	100,000	19,768	0.1977	3.07E-10		
Straight-In	3100 ft	6000 ft	30°	Level	100,000	14,921	0.1492	2.32E-10		
Offset	3100 ft	6000 ft	20°	Descending	100,000	560	0.0056	1.88E-11	5.72E-10	
Offset	3100 ft	6000 ft	20°	Level	100,000	866	0.0087	2.91E-11		
Offset	3100 ft	6000 ft	30°	Descending	100,000	18,518	0.1852	2.88E-10		
Offset	3100 ft	6000 ft	30°	Level	100,000	15,150	0.1515	2.36E-10		
Straight-In	3200 ft	0 ft	20°	Descending	100,000	85	0.0009	2.86E-12	3.36E-10	**3.31E-10**
Straight-In	3200 ft	0 ft	20°	Level	100,000	157	0.0016	5.28E-12		
Straight-In	3200 ft	0 ft	30°	Descending	100,000	9,903	0.0990	1.54E-10		
Straight-In	3200 ft	0 ft	30°	Level	100,000	11,158	0.1116	1.74E-10		
Offset	3200 ft	0 ft	20°	Descending	100,000	67	0.0007	2.25E-12	3.27E-10	
Offset	3200 ft	0 ft	20°	Level	100,000	172	0.0017	5.78E-12		
Offset	3200 ft	0 ft	30°	Descending	100,000	9,228	0.0923	1.44E-10		
Offset	3200 ft	0 ft	30°	Level	100,000	11,289	0.1129	1.76E-10		
Straight-In	3200 ft	1000 ft	20°	Descending	100,000	109	0.0011	3.66E-12	3.71E-10	**3.67E-10**
Straight-In	3200 ft	1000 ft	20°	Level	100,000	203	0.0020	6.82E-12		
Straight-In	3200 ft	1000 ft	30°	Descending	100,000	11,247	0.1125	1.75E-10		
Straight-In	3200 ft	1000 ft	30°	Level	100,000	11,932	0.1193	1.86E-10		
Offset	3200 ft	1000 ft	20°	Descending	100,000	115	0.0012	3.87E-12	3.62E-10	
Offset	3200 ft	1000 ft	20°	Level	100,000	218	0.0022	7.33E-12		
Offset	3200 ft	1000 ft	30°	Descending	100,000	10,303	0.1030	1.60E-10		
Offset	3200 ft	1000 ft	30°	Level	100,000	12,266	0.1227	1.91E-10		
Straight-In	3200 ft	2000 ft	20°	Descending	100,000	166	0.0017	5.58E-12	4.05E-10	**4.00E-10**
Straight-In	3200 ft	2000 ft	20°	Level	100,000	249	0.0025	8.37E-12		
Straight-In	3200 ft	2000 ft	30°	Descending	100,000	12,410	0.1241	1.93E-10		
Straight-In	3200 ft	2000 ft	30°	Level	100,000	12,724	0.1272	1.98E-10		
Offset	3200 ft	2000 ft	20°	Descending	100,000	142	0.0014	4.77E-12	3.94E-10	
Offset	3200 ft	2000 ft	20°	Level	100,000	274	0.0027	9.21E-12		
Offset	3200 ft	2000 ft	30°	Descending	100,000	11,519	0.1152	1.79E-10		
Offset	3200 ft	2000 ft	30°	Level	100,000	12,927	0.1293	2.01E-10		

Deviation Scenario	RCLS	Elev	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	Collision Risk per Approach
Straight-In	3200 ft	3000 ft	20°	Descending	100,000	201	0.0020	6.76E-12	4.36E-10	**4.34E-10**
Straight-In	3200 ft	3000 ft	20°	Level	100,000	336	0.0034	1.13E-11		
Straight-In	3200 ft	3000 ft	30°	Descending	100,000	13,629	0.1363	2.12E-10		
Straight-In	3200 ft	3000 ft	30°	Level	100,000	13,255	0.1326	2.06E-10		
Offset	3200 ft	3000 ft	20°	Descending	100,000	181	0.0018	6.08E-12	4.32E-10	
Offset	3200 ft	3000 ft	20°	Level	100,000	379	0.0038	1.27E-11		
Offset	3200 ft	3000 ft	30°	Descending	100,000	12,858	0.1286	2.00E-10		
Offset	3200 ft	3000 ft	30°	Level	100,000	13,699	0.1370	2.13E-10		
Straight-In	3200 ft	4000 ft	20°	Descending	100,000	265	0.0027	8.91E-12	4.72E-10	**4.67E-10**
Straight-In	3200 ft	4000 ft	20°	Level	100,000	411	0.0041	1.38E-11		
Straight-In	3200 ft	4000 ft	30°	Descending	100,000	14,964	0.1496	2.33E-10		
Straight-In	3200 ft	4000 ft	30°	Level	100,000	13,932	0.1393	2.17E-10		
Offset	3200 ft	4000 ft	20°	Descending	100,000	262	0.0026	8.81E-12	4.62E-10	
Offset	3200 ft	4000 ft	20°	Level	100,000	451	0.0045	1.52E-11		
Offset	3200 ft	4000 ft	30°	Descending	100,000	14,049	0.1405	2.19E-10		
Offset	3200 ft	4000 ft	30°	Level	100,000	14,084	0.1408	2.19E-10		
Straight-In	3200 ft	5000 ft	20°	Descending	100,000	374	0.0037	1.26E-11	5.08E-10	**5.01E-10**
Straight-In	3200 ft	5000 ft	20°	Level	100,000	530	0.0053	1.78E-11		
Straight-In	3200 ft	5000 ft	30°	Descending	100,000	16,406	0.1641	2.55E-10		
Straight-In	3200 ft	5000 ft	30°	Level	100,000	14,287	0.1429	2.22E-10		
Offset	3200 ft	5000 ft	20°	Descending	100,000	305	0.0031	1.03E-11	4.93E-10	
Offset	3200 ft	5000 ft	20°	Level	100,000	568	0.0057	1.91E-11		
Offset	3200 ft	5000 ft	30°	Descending	100,000	15,316	0.1532	2.38E-10		
Offset	3200 ft	5000 ft	30°	Level	100,000	14,515	0.1452	2.26E-10		
Straight-In	3200 ft	6000 ft	20°	Descending	100,000	470	0.0047	1.58E-11	5.44E-10	**5.35E-10**
Straight-In	3200 ft	6000 ft	20°	Level	100,000	683	0.0068	2.30E-11		
Straight-In	3200 ft	6000 ft	30°	Descending	100,000	17,974	0.1797	2.80E-10		
Straight-In	3200 ft	6000 ft	30°	Level	100,000	14,496	0.1450	2.25E-10		
Offset	3200 ft	6000 ft	20°	Descending	100,000	422	0.0042	1.42E-11	5.26E-10	
Offset	3200 ft	6000 ft	20°	Level	100,000	690	0.0069	2.32E-11		
Offset	3200 ft	6000 ft	30°	Descending	100,000	17,002	0.1700	2.64E-10		
Offset	3200 ft	6000 ft	30°	Level	100,000	14,436	0.1444	2.25E-10		

Triple Approach Operations – Detailed Results

Detailed results of the collision risk analysis for triple straight-in approach operations for all combinations of RCLS values and airport elevations examined in this study are included in Table B-6.

Table B-6: Collision Risk per Approach for Triple Straight-In Approach Operations

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	3900	0	20	Level	100,000	1,683	0.01683	5.66E-11	7.03E-10	7.16E-10		**7.11E-10**
1 to 2	3900	0	20	Descending	100,000	1,567	0.01567	5.27E-11				
1 to 2	3900	0	30	Level	100,000	18,551	0.18551	2.89E-10				
1 to 2	3900	0	30	Descending	100,000	19,642	0.19642	3.06E-10				
1 to 3	3900	0	20	Level	100,000	0	0.00000	0.00E+00	1.27E-11			
1 to 3	3900	0	20	Descending	100,000	60	0.00060	2.02E-12				
1 to 3	3900	0	30	Level	100,000	19	0.00019	2.96E-13				
1 to 3	3900	0	30	Descending	100,000	668	0.00668	1.04E-11				
2 to 3	3900	0	20	Level	100,000	1,813	0.01813	6.09E-11	7.02E-10		7.02E-10	
2 to 3	3900	0	20	Descending	100,000	1,549	0.01549	5.21E-11				
2 to 3	3900	0	30	Level	100,000	18,439	0.18439	2.87E-10				
2 to 3	3900	0	30	Descending	100,000	19,456	0.19456	3.03E-10				
1 to 2	3900	1000	20	Level	100,000	2,072	0.02072	6.96E-11	7.41E-10	7.54E-10		**7.49E-10**
1 to 2	3900	1000	20	Descending	100,000	1,725	0.01725	5.80E-11				
1 to 2	3900	1000	30	Level	100,000	18,796	0.18796	2.92E-10				
1 to 2	3900	1000	30	Descending	100,000	20,624	0.20624	3.21E-10				
1 to 3	3900	1000	20	Level	100,000	0	0.00000	0.00E+00	1.28E-11			
1 to 3	3900	1000	20	Descending	100,000	68	0.00068	2.29E-12				
1 to 3	3900	1000	30	Level	100,000	19	0.00019	2.96E-13				
1 to 3	3900	1000	30	Descending	100,000	660	0.00660	1.03E-11				
2 to 3	3900	1000	20	Level	100,000	2,021	0.02021	6.79E-11	7.39E-10		7.39E-10	
2 to 3	3900	1000	20	Descending	100,000	1,718	0.01718	5.77E-11				
2 to 3	3900	1000	30	Level	100,000	18,869	0.18869	2.93E-10				
2 to 3	3900	1000	30	Descending	100,000	20,559	0.20559	3.20E-10				
1 to 2	3900	2000	20	Level	100,000	2,261	0.02261	7.60E-11	7.80E-10	7.91E-10		**7.85E-10**
1 to 2	3900	2000	20	Descending	100,000	2,030	0.02030	6.82E-11				
1 to 2	3900	2000	30	Level	100,000	19,048	0.19048	2.96E-10				
1 to 2	3900	2000	30	Descending	100,000	21,837	0.21837	3.40E-10				
1 to 3	3900	2000	20	Level	100,000	0	0.00000	0.00E+00	1.13E-11			
1 to 3	3900	2000	20	Descending	100,000	59	0.00059	1.98E-12				
1 to 3	3900	2000	30	Level	100,000	17	0.00017	2.64E-13				
1 to 3	3900	2000	30	Descending	100,000	583	0.00583	9.07E-12				
2 to 3	3900	2000	20	Level	100,000	2,223	0.02223	7.47E-11	7.73E-10		7.73E-10	
2 to 3	3900	2000	20	Descending	100,000	1,978	0.01978	6.65E-11				
2 to 3	3900	2000	30	Level	100,000	18,944	0.18944	2.95E-10				
2 to 3	3900	2000	30	Descending	100,000	21,682	0.21682	3.37E-10				

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	3900	3000	20	Level	100,000	2,554	0.02554	8.58E-11	8.17E-10	8.29E-10		**8.23E-10**
1 to 2	3900	3000	20	Descending	100,000	2,314	0.02314	7.78E-11				
1 to 2	3900	3000	30	Level	100,000	19,079	0.19079	2.97E-10				
1 to 2	3900	3000	30	Descending	100,000	22,952	0.22952	3.57E-10				
1 to 3	3900	3000	20	Level	100,000	0	0.00000	0.00E+00	1.20E-11			
1 to 3	3900	3000	20	Descending	100,000	72	0.00072	2.42E-12				
1 to 3	3900	3000	30	Level	100,000	32	0.00032	4.98E-13				
1 to 3	3900	3000	30	Descending	100,000	584	0.00584	9.08E-12				
2 to 3	3900	3000	20	Level	100,000	2,488	0.02488	8.36E-11	8.12E-10		8.12E-10	
2 to 3	3900	3000	20	Descending	100,000	2,323	0.02323	7.81E-11				
2 to 3	3900	3000	30	Level	100,000	19,314	0.19314	3.00E-10				
2 to 3	3900	3000	30	Descending	100,000	22,462	0.22462	3.49E-10				
1 to 2	3900	4000	20	Level	100,000	2,770	0.02770	9.31E-11	8.52E-10	8.64E-10		**8.61E-10**
1 to 2	3900	4000	20	Descending	100,000	2,579	0.02579	8.67E-11				
1 to 2	3900	4000	30	Level	100,000	19,327	0.19327	3.01E-10				
1 to 2	3900	4000	30	Descending	100,000	23,912	0.23912	3.72E-10				
1 to 3	3900	4000	20	Level	100,000	0	0.00000	0.00E+00	1.16E-11			
1 to 3	3900	4000	20	Descending	100,000	57	0.00057	1.92E-12				
1 to 3	3900	4000	30	Level	100,000	47	0.00047	7.31E-13				
1 to 3	3900	4000	30	Descending	100,000	576	0.00576	8.96E-12				
2 to 3	3900	4000	20	Level	100,000	2,770	0.02770	9.31E-11	8.55E-10		8.55E-10	
2 to 3	3900	4000	20	Descending	100,000	2,685	0.02685	9.03E-11				
2 to 3	3900	4000	30	Level	100,000	19,316	0.19316	3.00E-10				
2 to 3	3900	4000	30	Descending	100,000	23,865	0.23865	3.71E-10				
1 to 2	3900	5000	20	Level	100,000	3,182	0.03182	1.07E-10	8.95E-10	9.08E-10		**9.02E-10**
1 to 2	3900	5000	20	Descending	100,000	2,895	0.02895	9.73E-11				
1 to 2	3900	5000	30	Level	100,000	19,301	0.19301	3.00E-10				
1 to 2	3900	5000	30	Descending	100,000	25,138	0.25138	3.91E-10				
1 to 3	3900	5000	20	Level	100,000	0	0.00000	0.00E+00	1.22E-11			
1 to 3	3900	5000	20	Descending	100,000	62	0.00062	2.08E-12				
1 to 3	3900	5000	30	Level	100,000	57	0.00057	8.87E-13				
1 to 3	3900	5000	30	Descending	100,000	591	0.00591	9.19E-12				
2 to 3	3900	5000	20	Level	100,000	3,097	0.03097	1.04E-10	8.90E-10		8.90E-10	
2 to 3	3900	5000	20	Descending	100,000	2,920	0.02920	9.81E-11				
2 to 3	3900	5000	30	Level	100,000	19,320	0.19320	3.01E-10				
2 to 3	3900	5000	30	Descending	100,000	24,882	0.24882	3.87E-10				
1 to 2	3900	6000	20	Level	100,000	2,896	0.02896	9.73E-11	9.10E-10	9.22E-10		**9.16E-10**
1 to 2	3900	6000	20	Descending	100,000	3,404	0.03404	1.14E-10				
1 to 2	3900	6000	30	Level	100,000	18,382	0.18382	2.86E-10				
1 to 2	3900	6000	30	Descending	100,000	26,540	0.26540	4.13E-10				
1 to 3	3900	6000	20	Level	100,000	0	0.00000	0.00E+00	1.16E-11			
1 to 3	3900	6000	20	Descending	100,000	55	0.00055	1.85E-12				
1 to 3	3900	6000	30	Level	100,000	49	0.00049	7.62E-13				
1 to 3	3900	6000	30	Descending	100,000	576	0.00576	8.96E-12				
2 to 3	3900	6000	20	Level	100,000	2,961	0.02961	9.95E-11	9.03E-10		9.03E-10	
2 to 3	3900	6000	20	Descending	100,000	3,246	0.03246	1.09E-10				
2 to 3	3900	6000	30	Level	100,000	18,270	0.18270	2.84E-10				
2 to 3	3900	6000	30	Descending	100,000	26,343	0.26343	4.10E-10				

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	4000	0	20	Level	100,000	1,487	0.01487	5.00E-11	6.40E-10	6.51E-10		**6.47E-10**
1 to 2	4000	0	20	Descending	100,000	1,266	0.01266	4.26E-11				
1 to 2	4000	0	30	Level	100,000	17,309	0.17309	2.69E-10				
1 to 2	4000	0	30	Descending	100,000	17,869	0.17869	2.78E-10				
1 to 3	4000	0	20	Level	100,000	0	0.00000	0.00E+00	1.14E-11			
1 to 3	4000	0	20	Descending	100,000	59	0.00059	1.98E-12				
1 to 3	4000	0	30	Level	100,000	13	0.00013	2.02E-13				
1 to 3	4000	0	30	Descending	100,000	594	0.00594	9.24E-12				
2 to 3	4000	0	20	Level	100,000	1,379	0.01379	4.64E-11	6.37E-10		6.37E-10	
2 to 3	4000	0	20	Descending	100,000	1,249	0.01249	4.20E-11				
2 to 3	4000	0	30	Level	100,000	17,261	0.17261	2.68E-10				
2 to 3	4000	0	30	Descending	100,000	18,041	0.18041	2.81E-10				
1 to 2	4000	1000	20	Level	100,000	1,660	0.01660	5.58E-11	6.79E-10	6.91E-10		**6.87E-10**
1 to 2	4000	1000	20	Descending	100,000	1,423	0.01423	4.78E-11				
1 to 2	4000	1000	30	Level	100,000	17,597	0.17597	2.74E-10				
1 to 2	4000	1000	30	Descending	100,000	19,407	0.19407	3.02E-10				
1 to 3	4000	1000	20	Level	100,000	0	0.00000	0.00E+00	1.15E-11			
1 to 3	4000	1000	20	Descending	100,000	51	0.00051	1.71E-12				
1 to 3	4000	1000	30	Level	100,000	15	0.00015	2.33E-13				
1 to 3	4000	1000	30	Descending	100,000	612	0.00612	9.52E-12				
2 to 3	4000	1000	20	Level	100,000	1,666	0.01666	5.60E-11	6.81E-10		6.81E-10	
2 to 3	4000	1000	20	Descending	100,000	1,438	0.01438	4.83E-11				
2 to 3	4000	1000	30	Level	100,000	17,733	0.17733	2.76E-10				
2 to 3	4000	1000	30	Descending	100,000	19,326	0.19326	3.01E-10				
1 to 2	4000	2000	20	Level	100,000	1,938	0.01938	6.51E-11	7.21E-10	7.33E-10		**7.29E-10**
1 to 2	4000	2000	20	Descending	100,000	1,695	0.01695	5.70E-11				
1 to 2	4000	2000	30	Level	100,000	18,306	0.18306	2.85E-10				
1 to 2	4000	2000	30	Descending	100,000	20,194	0.20194	3.14E-10				
1 to 3	4000	2000	20	Level	100,000	0	0.00000	0.00E+00	1.17E-11			
1 to 3	4000	2000	20	Descending	100,000	46	0.00046	1.55E-12				
1 to 3	4000	2000	30	Level	100,000	22	0.00022	3.42E-13				
1 to 3	4000	2000	30	Descending	100,000	634	0.00634	9.86E-12				
2 to 3	4000	2000	20	Level	100,000	2,023	0.02023	6.80E-11	7.21E-10		7.21E-10	
2 to 3	4000	2000	20	Descending	100,000	1,686	0.01686	5.67E-11				
2 to 3	4000	2000	30	Level	100,000	18,264	0.18264	2.84E-10				
2 to 3	4000	2000	30	Descending	100,000	20,100	0.20100	3.13E-10				
1 to 2	4000	3000	20	Level	100,000	2,179	0.02179	7.32E-11	7.56E-10	7.67E-10		**7.63E-10**
1 to 2	4000	3000	20	Descending	100,000	1,898	0.01898	6.38E-11				
1 to 2	4000	3000	30	Level	100,000	18,420	0.18420	2.87E-10				
1 to 2	4000	3000	30	Descending	100,000	21,358	0.21358	3.32E-10				
1 to 3	4000	3000	20	Level	100,000	0	0.00000	0.00E+00	1.17E-11			
1 to 3	4000	3000	20	Descending	100,000	55	0.00055	1.85E-12				
1 to 3	4000	3000	30	Level	100,000	17	0.00017	2.64E-13				
1 to 3	4000	3000	30	Descending	100,000	619	0.00619	9.63E-12				
2 to 3	4000	3000	20	Level	100,000	2,146	0.02146	7.21E-11	7.55E-10		7.55E-10	
2 to 3	4000	3000	20	Descending	100,000	1,933	0.01933	6.50E-11				
2 to 3	4000	3000	30	Level	100,000	18,491	0.18491	2.88E-10				
2 to 3	4000	3000	30	Descending	100,000	21,240	0.21240	3.30E-10				

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	4000	4000	20	Level	100,000	2,459	0.02459	8.27E-11	7.92E-10	8.04E-10		**8.01E-10**
1 to 2	4000	4000	20	Descending	100,000	2,173	0.02173	7.30E-11				
1 to 2	4000	4000	30	Level	100,000	18,587	0.18587	2.89E-10				
1 to 2	4000	4000	30	Descending	100,000	22,318	0.22318	3.47E-10				
1 to 3	4000	4000	20	Level	100,000	0	0.00000	0.00E+00	1.17E-11			
1 to 3	4000	4000	20	Descending	100,000	57	0.00057	1.92E-12				
1 to 3	4000	4000	30	Level	100,000	27	0.00027	4.20E-13				
1 to 3	4000	4000	30	Descending	100,000	601	0.00601	9.35E-12				
2 to 3	4000	4000	20	Level	100,000	2,427	0.02427	8.16E-11	7.95E-10		7.95E-10	
2 to 3	4000	4000	20	Descending	100,000	2,198	0.02198	7.39E-11				
2 to 3	4000	4000	30	Level	100,000	18,726	0.18726	2.91E-10				
2 to 3	4000	4000	30	Descending	100,000	22,361	0.22361	3.48E-10				
1 to 2	4000	5000	20	Level	100,000	2,782	0.02782	9.35E-11	8.34E-10	8.45E-10		**8.40E-10**
1 to 2	4000	5000	20	Descending	100,000	2,409	0.02409	8.10E-11				
1 to 2	4000	5000	30	Level	100,000	18,802	0.18802	2.92E-10				
1 to 2	4000	5000	30	Descending	100,000	23,575	0.23575	3.67E-10				
1 to 3	4000	5000	20	Level	100,000	0	0.00000	0.00E+00	1.15E-11			
1 to 3	4000	5000	20	Descending	100,000	63	0.00063	2.12E-12				
1 to 3	4000	5000	30	Level	100,000	41	0.00041	6.38E-13				
1 to 3	4000	5000	30	Descending	100,000	559	0.00559	8.69E-12				
2 to 3	4000	5000	20	Level	100,000	2,703	0.02703	9.09E-11	8.31E-10		8.31E-10	
2 to 3	4000	5000	20	Descending	100,000	2,502	0.02502	8.41E-11				
2 to 3	4000	5000	30	Level	100,000	18,716	0.18716	2.91E-10				
2 to 3	4000	5000	30	Descending	100,000	23,473	0.23473	3.65E-10				
1 to 2	4000	6000	20	Level	100,000	2,540	0.02540	8.54E-11	8.37E-10	8.48E-10		**8.47E-10**
1 to 2	4000	6000	20	Descending	100,000	2,807	0.02807	9.44E-11				
1 to 2	4000	6000	30	Level	100,000	17,375	0.17375	2.70E-10				
1 to 2	4000	6000	30	Descending	100,000	24,881	0.24881	3.87E-10				
1 to 3	4000	6000	20	Level	100,000	0	0.00000	0.00E+00	1.13E-11			
1 to 3	4000	6000	20	Descending	100,000	51	0.00051	1.71E-12				
1 to 3	4000	6000	30	Level	100,000	31	0.00031	4.82E-13				
1 to 3	4000	6000	30	Descending	100,000	587	0.00587	9.13E-12				
2 to 3	4000	6000	20	Level	100,000	2,535	0.02535	8.52E-11	8.43E-10		8.43E-10	
2 to 3	4000	6000	20	Descending	100,000	2,879	0.02879	9.68E-11				
2 to 3	4000	6000	30	Level	100,000	17,720	0.17720	2.76E-10				
2 to 3	4000	6000	30	Descending	100,000	24,773	0.24773	3.85E-10				
1 to 2	4100	0	20	Level	100,000	1,193	0.01193	4.01E-11	5.87E-10	6.00E-10		**5.96E-10**
1 to 2	4100	0	20	Descending	100,000	1,005	0.01005	3.38E-11				
1 to 2	4100	0	30	Level	100,000	16,477	0.16477	2.56E-10				
1 to 2	4100	0	30	Descending	100,000	16,533	0.16533	2.57E-10				
1 to 3	4100	0	20	Level	100,000	0	0.00000	0.00E+00	1.24E-11			
1 to 3	4100	0	20	Descending	100,000	53	0.00053	1.78E-12				
1 to 3	4100	0	30	Level	100,000	5	0.00005	7.78E-14				
1 to 3	4100	0	30	Descending	100,000	677	0.00677	1.05E-11				
2 to 3	4100	0	20	Level	100,000	1,251	0.01251	4.20E-11	5.87E-10		5.87E-10	
2 to 3	4100	0	20	Descending	100,000	1,048	0.01048	3.52E-11				
2 to 3	4100	0	30	Level	100,000	16,267	0.16267	2.53E-10				
2 to 3	4100	0	30	Descending	100,000	16,515	0.16515	2.57E-10				

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	4100	1000	20	Level	100,000	1,400	0.01400	4.71E-11	6.31E-10	6.43E-10		**6.38E-10**
1 to 2	4100	1000	20	Descending	100,000	1,182	0.01182	3.97E-11				
1 to 2	4100	1000	30	Level	100,000	17,063	0.17063	2.65E-10				
1 to 2	4100	1000	30	Descending	100,000	17,910	0.17910	2.79E-10				
1 to 3	4100	1000	20	Level	100,000	0	0.00000	0.00E+00	1.19E-11			
1 to 3	4100	1000	20	Descending	100,000	49	0.00049	1.65E-12				
1 to 3	4100	1000	30	Level	100,000	6	0.00006	9.33E-14				
1 to 3	4100	1000	30	Descending	100,000	653	0.00653	1.02E-11				
2 to 3	4100	1000	20	Level	100,000	1,444	0.01444	4.85E-11	6.30E-10		6.30E-10	
2 to 3	4100	1000	20	Descending	100,000	1,213	0.01213	4.08E-11				
2 to 3	4100	1000	30	Level	100,000	17,035	0.17035	2.65E-10				
2 to 3	4100	1000	30	Descending	100,000	17,736	0.17736	2.76E-10				
1 to 2	4100	2000	20	Level	100,000	1,602	0.01602	5.38E-11	6.66E-10	6.78E-10		**6.75E-10**
1 to 2	4100	2000	20	Descending	100,000	1,399	0.01399	4.70E-11				
1 to 2	4100	2000	30	Level	100,000	17,210	0.17210	2.68E-10				
1 to 2	4100	2000	30	Descending	100,000	19,102	0.19102	2.97E-10				
1 to 3	4100	2000	20	Level	100,000	0	0.00000	0.00E+00	1.21E-11			
1 to 3	4100	2000	20	Descending	100,000	68	0.00068	2.29E-12				
1 to 3	4100	2000	30	Level	100,000	12	0.00012	1.87E-13				
1 to 3	4100	2000	30	Descending	100,000	617	0.00617	9.60E-12				
2 to 3	4100	2000	20	Level	100,000	1,636	0.01636	5.50E-11	6.69E-10		6.69E-10	
2 to 3	4100	2000	20	Descending	100,000	1,414	0.01414	4.75E-11				
2 to 3	4100	2000	30	Level	100,000	17,414	0.17414	2.71E-10				
2 to 3	4100	2000	30	Descending	100,000	18,980	0.18980	2.95E-10				
1 to 2	4100	3000	20	Level	100,000	1,794	0.01794	6.03E-11	7.03E-10	7.15E-10		**7.08E-10**
1 to 2	4100	3000	20	Descending	100,000	1,616	0.01616	5.43E-11				
1 to 2	4100	3000	30	Level	100,000	17,685	0.17685	2.75E-10				
1 to 2	4100	3000	30	Descending	100,000	20,142	0.20142	3.13E-10				
1 to 3	4100	3000	20	Level	100,000	0	0.00000	0.00E+00	1.18E-11			
1 to 3	4100	3000	20	Descending	100,000	48	0.00048	1.61E-12				
1 to 3	4100	3000	30	Level	100,000	13	0.00013	2.02E-13				
1 to 3	4100	3000	30	Descending	100,000	640	0.00640	9.95E-12				
2 to 3	4100	3000	20	Level	100,000	1,762	0.01762	5.92E-11	6.96E-10		6.96E-10	
2 to 3	4100	3000	20	Descending	100,000	1,619	0.01619	5.44E-11				
2 to 3	4100	3000	30	Level	100,000	17,696	0.17696	2.75E-10				
2 to 3	4100	3000	30	Descending	100,000	19,729	0.19729	3.07E-10				
1 to 2	4100	4000	20	Level	100,000	2,039	0.02039	6.85E-11	7.37E-10	7.49E-10		**7.44E-10**
1 to 2	4100	4000	20	Descending	100,000	1,803	0.01803	6.06E-11				
1 to 2	4100	4000	30	Level	100,000	17,927	0.17927	2.79E-10				
1 to 2	4100	4000	30	Descending	100,000	21,148	0.21148	3.29E-10				
1 to 3	4100	4000	20	Level	100,000	0	0.00000	0.00E+00	1.21E-11			
1 to 3	4100	4000	20	Descending	100,000	67	0.00067	2.25E-12				
1 to 3	4100	4000	30	Level	100,000	21	0.00021	3.27E-13				
1 to 3	4100	4000	30	Descending	100,000	609	0.00609	9.47E-12				
2 to 3	4100	4000	20	Level	100,000	2,004	0.02004	6.74E-11	7.34E-10		7.34E-10	
2 to 3	4100	4000	20	Descending	100,000	1,825	0.01825	6.13E-11				
2 to 3	4100	4000	30	Level	100,000	17,899	0.17899	2.78E-10				
2 to 3	4100	4000	30	Descending	100,000	21,013	0.21013	3.27E-10				

Dev Scen (ILSx to ILSy)	RCLS (ft)	Elev (ft)	Dev Angle	Deviation Vertical Profile	Number of Aircraft Pairs	Number of TCVs	P(TCV|DV)	P(TCV) for Each Deviation Type	P(TCV) for 1 of 4 Deviation Types Occurring	P(TCV) for Aircraft Deviating from ILS1	P(TCV) for Aircraft Deviating from ILS2	Collision Risk per Approach
1 to 2	4100	5000	20	Level	100,000	2,299	0.02299	7.73E-11	7.72E-10	7.83E-10		**7.81E-10**
1 to 2	4100	5000	20	Descending	100,000	2,188	0.02188	7.35E-11				
1 to 2	4100	5000	30	Level	100,000	18,072	0.18072	2.81E-10				
1 to 2	4100	5000	30	Descending	100,000	21,860	0.21860	3.40E-10				
1 to 3	4100	5000	20	Level	100,000	0	0.00000	0.00E+00	1.14E-11			
1 to 3	4100	5000	20	Descending	100,000	55	0.00055	1.85E-12				
1 to 3	4100	5000	30	Level	100,000	23	0.00023	3.58E-13				
1 to 3	4100	5000	30	Descending	100,000	588	0.00588	9.15E-12				
2 to 3	4100	5000	20	Level	100,000	2,336	0.02336	7.85E-11	7.76E-10		7.76E-10	
2 to 3	4100	5000	20	Descending	100,000	2,087	0.02087	7.01E-11				
2 to 3	4100	5000	30	Level	100,000	18,171	0.18171	2.83E-10				
2 to 3	4100	5000	30	Descending	100,000	22,145	0.22145	3.44E-10				
1 to 2	4100	6000	20	Level	100,000	2,180	0.02180	7.33E-11	7.80E-10	7.91E-10		**7.87E-10**
1 to 2	4100	6000	20	Descending	100,000	2,352	0.02352	7.91E-11				
1 to 2	4100	6000	30	Level	100,000	16,983	0.16983	2.64E-10				
1 to 2	4100	6000	30	Descending	100,000	23,375	0.23375	3.64E-10				
1 to 3	4100	6000	20	Level	100,000	1	0.00001	3.36E-14	1.10E-11			
1 to 3	4100	6000	20	Descending	100,000	57	0.00057	1.92E-12				
1 to 3	4100	6000	30	Level	100,000	26	0.00026	4.04E-13				
1 to 3	4100	6000	30	Descending	100,000	557	0.00557	8.66E-12				
2 to 3	4100	6000	20	Level	100,000	2,157	0.02157	7.25E-11	7.80E-10		7.80E-10	
2 to 3	4100	6000	20	Descending	100,000	2,383	0.02383	8.01E-11				
2 to 3	4100	6000	30	Level	100,000	17,103	0.17103	2.66E-10				
2 to 3	4100	6000	30	Descending	100,000	23,228	0.23228	3.61E-10				