DOT/FAA/AR-05/7

Office of Aviation Research
Washington, D.C. 20591

Study of Side Load Factor During Aircraft Ground Operations

March 2005

Final Report

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-05/7		

4. Title and Subtitle	5. Report Date
STUDY OF SIDE LOAD FACTOR DURING AIRCRAFT GROUND OPERATIONS	March 2005
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Todd Jones, John W. Rustenburg, Donald A. Skinn, and Daniel O. Tipps	UDR-TR-2004-00076
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
University of Dayton Research Institute Structural Integrity Division 300 College Park Dayton, OH 45469-0120	11. Contract or Grant No. Grant No.: 2001-G-005
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591	Technical Report
	14. Sponsoring Agency Code ANM-110

15. Supplementary Notes

The Federal Aviation Administration William J. Hughes Technical Center COTR was Thomas DeFiore

16. Abstract

The primary objective of this study was to support the Federal Aviation Administration (FAA) Operational Loads Monitoring Research Program by developing new and improved methods and criteria for processing and presenting commercial transport airplane ground loads usage data. The scope of activities performed involved (1) defining the service-related factors that affect the operational life of commercial aircraft; (2) designing an efficient software system to reduce, store, and process large quantities of optical quick access recorder data; and (3) reducing, analyzing, and providing processed data in statistical formats that will enable the FAA to reassess existing certification criteria. Equally important, these new data will also enable the FAA, the aircraft manufacturers, and the airlines to better understand and control those factors that influence the structural integrity of commercial transport aircraft.

The data presented in this report will provide the user with information comparing the side load factors encountered during ground maneuvers for airplane models B-747-400, B-767-200, B-737-400, CRJ100, and A320 in actual operational usage. The University of Dayton Research Institute database used for this report consisted of 95,862 flight hours for the B-747-400; 44,990 flight hours for the B-767-200; 89,269 flight hours for the B-737-400; 463 flight hours for the CRJ100; and 30,817 flight hours for the A320.

17. Key Words	18. Distribution Statement
Side/Lateral load factor, B-747-400, B-767-200, B-737-400, CRJ100, A320, Ground loads, Operational data, Statistical loads data, Taxi-out, Taxi-in, Takeoff and Landing roll, Touchdown event, Runway turnoff	This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	49	N/A

Form DOT F1700.7 (8-72) **Reproduction of completed page authorized**

PREFACE

The Flight Systems Integrity Group of the Structural Integrity Division at the University of Dayton Research Institute performed this work under Federal Aviation Administration (FAA) Grant No. 2001-G-005 entitled "Assessment of Actual Operational Usage on Large Wide Body Transport Aircraft." The program manager for the FAA was Mr. Thomas DeFiore of the FAA William J. Hughes Technical Center at Atlantic City International Airport, New Jersey, and the program technical advisor was Mr. John Howford FAA Chief Scientific and Technical Advisor for Loads/Aeroelasticity. Mr. Daniel Tipps was the principal investigator for the University of Dayton and provided overall technical direction for this effort. Mr. Donald Skinn developed the data reduction algorithms, programmed the data reduction criteria, and performed the data reduction. Mr. John Rustenburg along with Mr. Todd Jones performed the data analysis, created the graphical presentations, and assisted in preparation of the final report.

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EXECUTIVE SUMMARY

The primary objective of this study was to support the Federal Aviation Administration (FAA) Operational Loads Monitoring Research Program by developing new and improved methods and criteria for processing and presenting commercial transport airplane ground loads usage data. The scope of activities performed involved (1) defining the service-related factors that affect the operational life of commercial aircraft; (2) designing an efficient software system to reduce, store, and process large quantities of optical quick access recorder data; and (3) reducing, analyzing, and providing processed data in statistical formats that will enable the FAA to reassess existing certification criteria. Equally important, these new data will also enable the FAA, the aircraft manufacturers, and the airlines to better understand and control those factors that influence the structural integrity of commercial transport aircraft.

The data presented in this report will provide the user with information comparing the side load factors encountered during ground maneuvers for the B-747-400, B-767-200, B-737-400, CRJ100, and A320 in actual operational usage. The University of Dayton Research Institute database consisted of 95,862 flight hours for airplane models B-747-400; 44,990 flight hours for the B-767-200; 89,269 flight hours for the B-737-400; 463 flight hours for the CRJ100; and 30,817 flight hours for the A320.

1. INTRODUCTION.

Lateral acceleration certification criteria outlined by Title 14 Code of Federal Regulations (CFR) for commercial aircraft ground operations are based primarily on two ground events that are considered to be the most critical to the aircraft structure; those events being the touchdown event (14 CFR 25.485) and turning (14 CFR 25.495). Data reduced using previously accepted methods of ground phase breakdown showed that for the B-747-400 aircraft, the largest magnitudes of lateral accelerations occurred during the landing roll phase. Since there was no 14 CFR criteria specified for side load spectrum during this phase of ground maneuver, additional investigation ensued about possible causes. Further examination into the high Ny values that appeared in the landing roll revealed that the occurrences were taking place within seconds after main gear touchdown. Discussion of this fact with experienced flight loads professionals resulted in the proposal that the current touchdown phase criteria did not capture the landing event completely and should be re-evaluated.

The decision was made to extend the touchdown event to include the time period through nose gear touchdown. At the request of the Federal Aviation Administration (FAA), the University of Dayton Research Institute (UDRI) developed new criteria for the touchdown event and also performed data reduction for ground phases on a selection of available aircraft. The FAA, along with the Aviation Rulemaking Advisory Committee, displayed interest in additional criteria for 14 CFR 25.495, turning. The concern was that the current CFR's turning criterion was too stringent and could be lowered in special cases. Regulatory authorities in position to make special conditions to 14 CFR 25.495 were hesitant to do so without the appropriate technical substantiation. Initially, only the ground maneuver data generated for the B-747-400 had been updated; however, similar data was requested for additional aircraft within the UDRI database (B-737-400, B-767-200, A320, and CRJ100) for comparison purposes.

2. DATA REDUCTION CRITERIA.

The following section explains the criterion to identify the touchdown event that was used in previous reports and then describes the procedure involved in updating this criteria. After the description of the development of the new touchdown event, phase descriptions for the remaining ground maneuvers are given.

2.1 TOUCHDOWN CRITERIA DEFINED.

The criteria for reporting lateral acceleration (Ny) occurring in the touchdown event was previously 3 seconds prior to main gear squat closure until 1 second after main gear squat. Figure 1 shows the results produced with this original criteria. The maximum Ny values were observed to occur in the landing roll phase.

The main objective for redefining the touchdown criteria was to ensure that Ny occurrences associated with the landing event are grouped with the landing event and not grouped in the landing roll. In order to do this, the touchdown event was redefined to include the time period through closure of the nose gear squat switch. This was accomplished by changing the touchdown event criteria to start 3 seconds prior to main gear squat and end 1 second after nose gear squat. The updated criteria would increase the time and also the occurrences of Ny

measured during the touchdown event, therefore reducing the time Ny is measured in the new shortened landing roll. This was acceptable because it was important to group Ny events related to landing within the touchdown event and not in the landing roll phase.

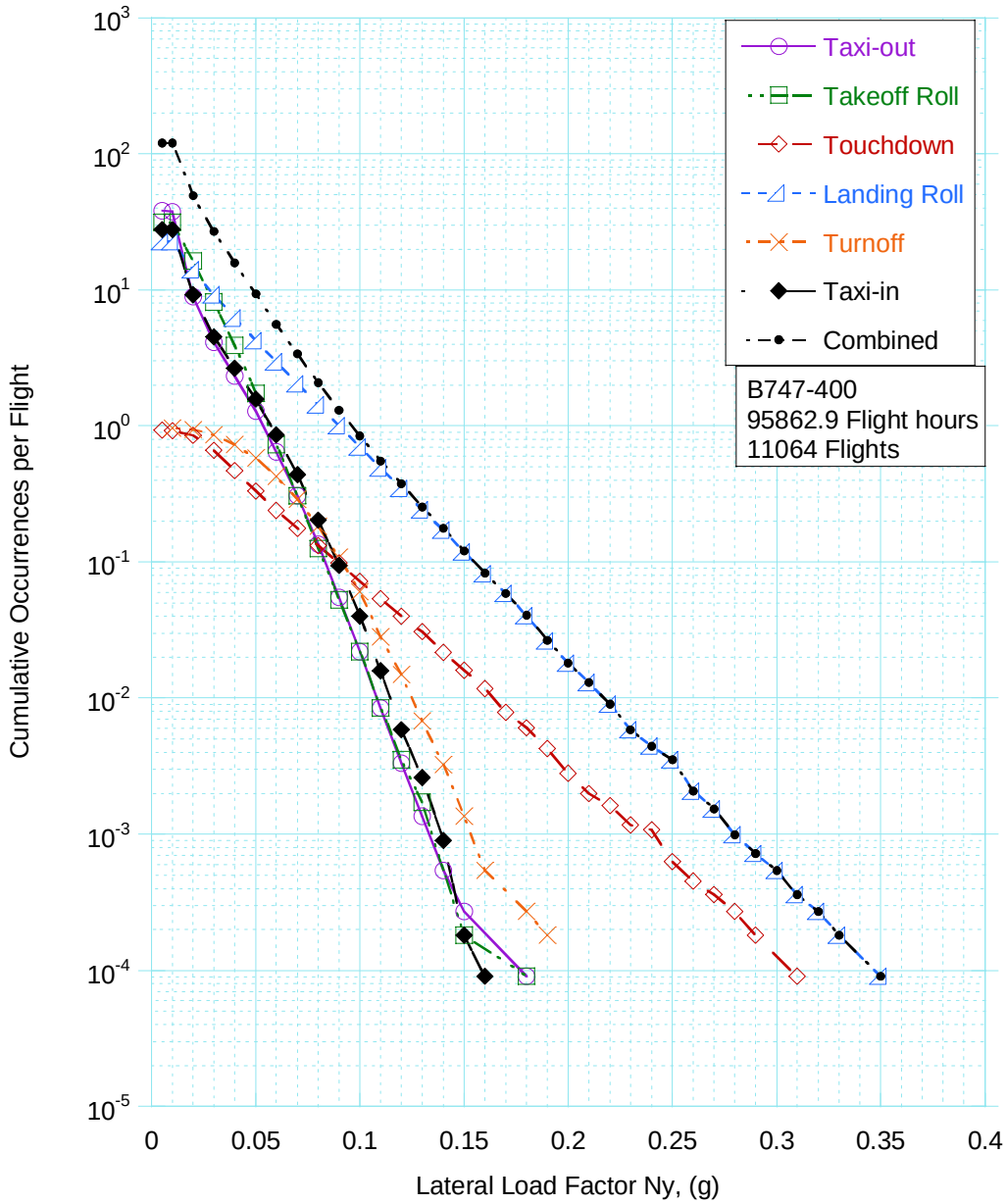

FIGURE 1. B-747-400 CUMULATIVE Ny OCCURRENCES FOUND USING ORIGINAL GROUND PHASE CRITERIA

2.2 NEW TOUCHDOWN CRITERIA DEVELOPMENT.

The new criteria for defining the landing event could simply be applied to the three aircraft in the database on which the nose gear squat switch parameter was available (B-747-400, A320, and CRJ100). The remaining two aircraft being evaluated for this study (B-767-200 and B-737-400)

did not have the nose gear squat indicator data recorded and, therefore, required an alternative method of identifying when the nose gear was down. A detailed analysis of the data from the three aircraft models, which had nose squat indications, was conducted to determine a consistent method that would accurately estimate when the nose gear was down for those models without nose squat indications. The primary candidate parameters for this supplemental nose gear study were radio altitude and pitch angle.

2.2.1 Radio Altitude Method.

The method using radio altitude involved calculating the average altitude for each flight between 15 and 30 seconds after touchdown. The average altitude would serve as the reference that the aircraft was down, then assuming the nose touched down when the aircraft crossed that average. Figure 2 shows that for the B-747, the method performed well using this approximation when compared to the nose gear squat indicator. However, the same method applied to the A320 resulted in misidentifying nose gear squat indicator early (figure 3). The radio altitude procedure was ruled out when the results between the B-747-400 and the A320 for identifying nose gear down were not comparable. The discrepancy with the radio altitude method was likely due to the difference in location of the flight recorder within the airplanes.

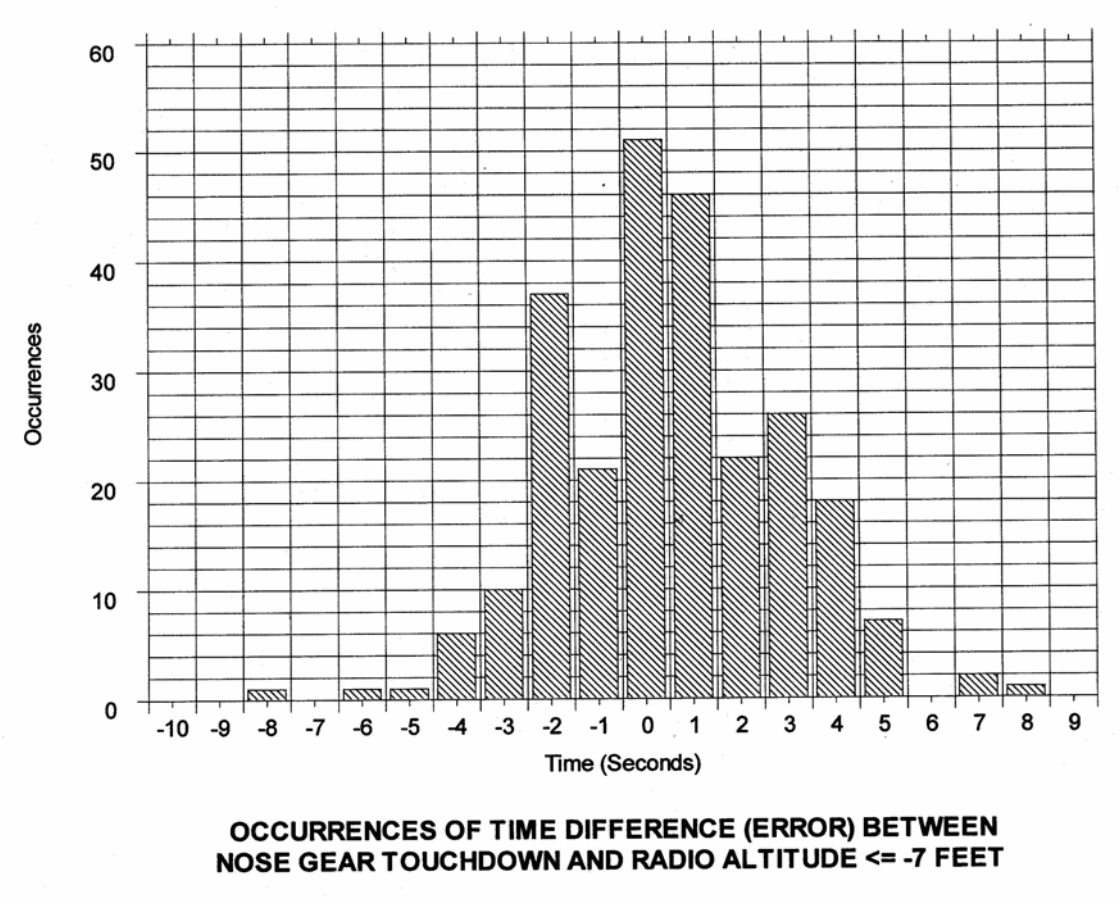

FIGURE 2. B-747 RADIO ALTITUDE METHOD ERROR

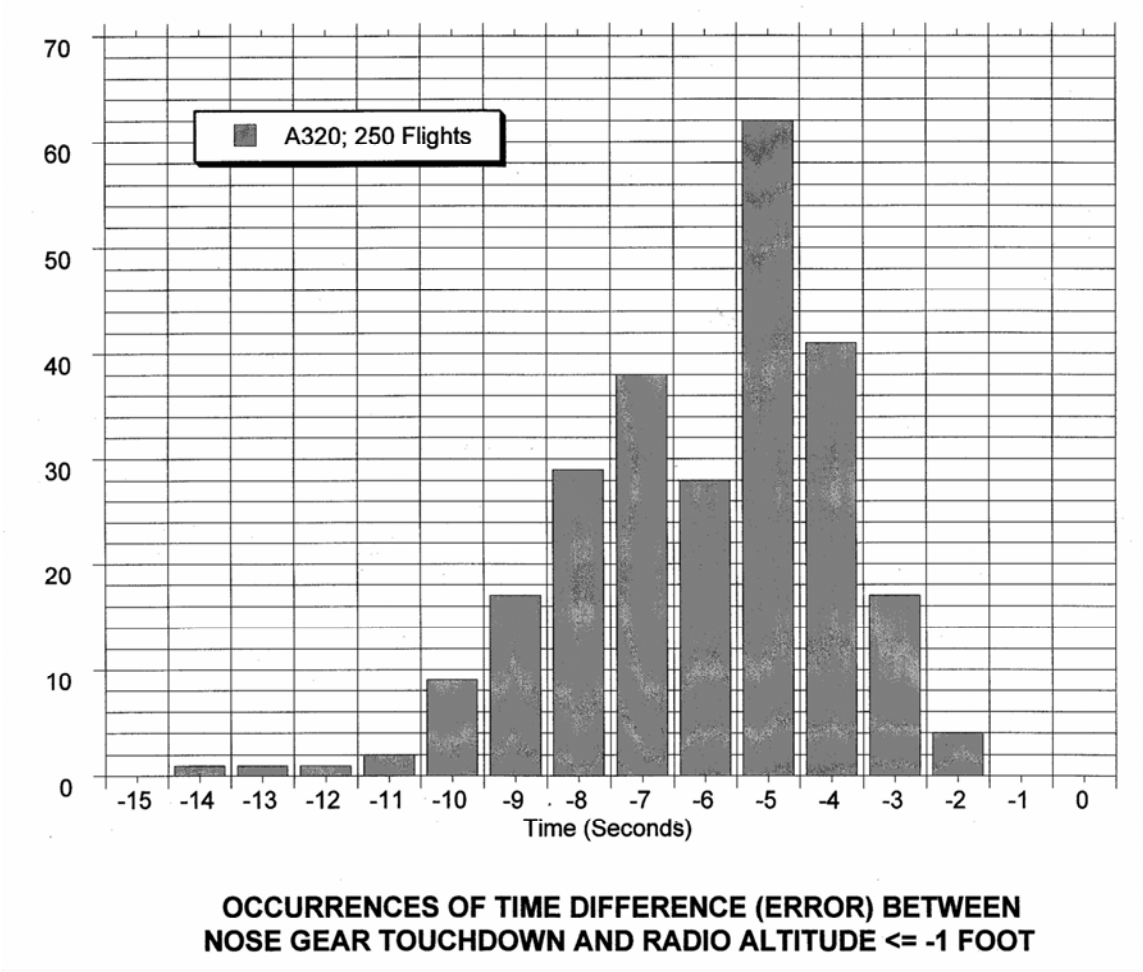

FIGURE 3. A320 RADIO ALTITUDE METHOD ERROR

2.2.2 Pitch Angle Method.

The method for determining when the nose gear was down using pitch angle was applied identically between the three aircraft used in the study (B-747-400, A320, and CRJ100). The pitch angle method, similar to the radio altitude procedure, consisted of calculating the average pitch angle of each flight between 15 and 30 seconds after main gear squat. This average was used as the initial reference line and identified when the aircraft was flat on the runway, i.e., constant pitch angle. The original reference line was then shifted half of a degree to make sure that the criteria would identify when the nose gear was down for every flight. When the aircraft's pitch angle first crossed the reference line (average pitch angle on the runway plus the half a degree), the nose gear was assumed to be down and the touchdown event concluded (figure 4). As figure 4 shows, the pitch angle method ensures that the nose squat is included within the landing event.

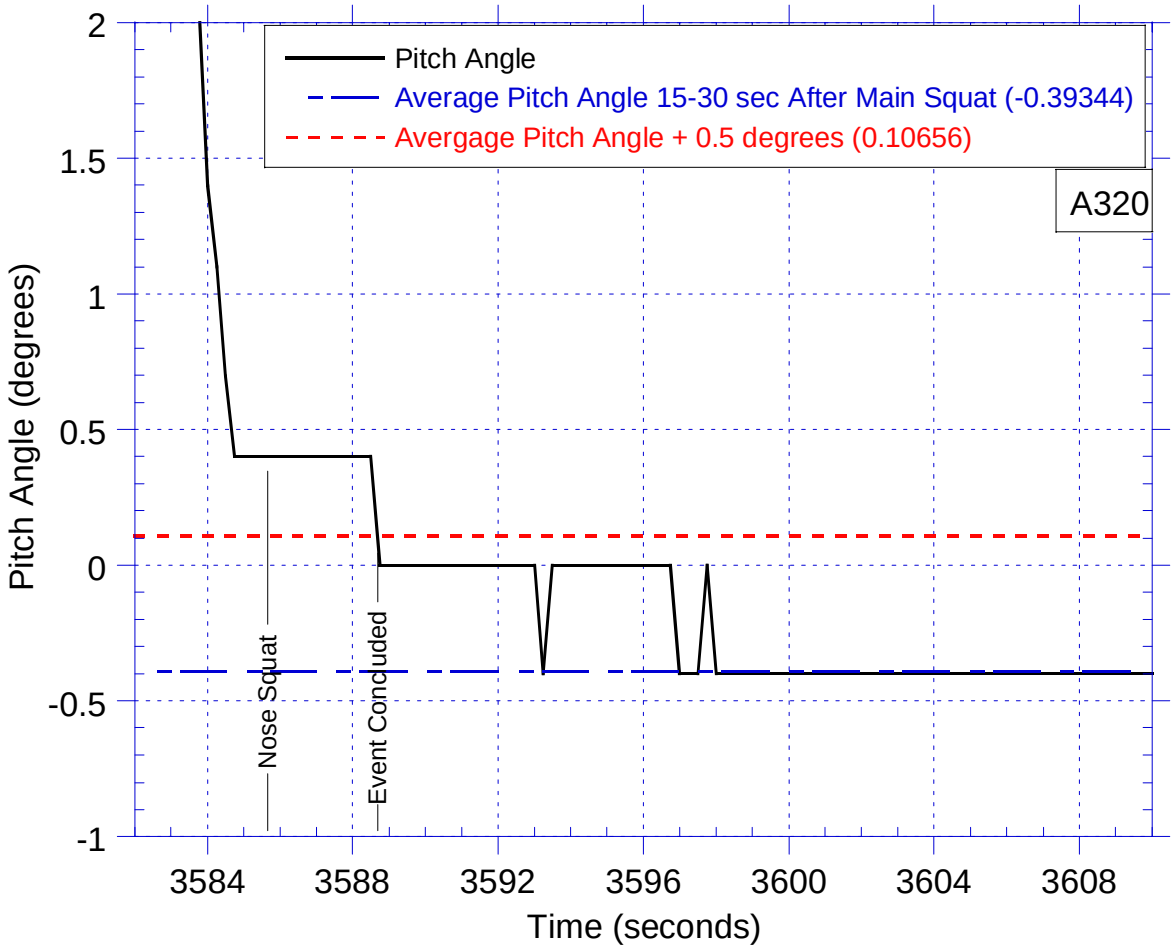

FIGURE 4. TIME HISTORY ILLUSTRATING PITCH ANGLE METHOD

Cumulative occurrences of Ny values measured in the touchdown event using the pitch angle method were checked against Ny occurrences found using the criteria of identifying the end of touchdown that uses nose squat plus a second. Figures 5 and 6 show the favorable results found between the two methods for the B-747-400 and the A320 airplanes. Figure 7 contains the results for the CRJ100. The CRJ100 in previous research was identified to land with lower pitch angles than the other aircraft in the study, with some flat landings (main and nose touching down simultaneously) occurring in the sample data set. This resulted in high Ny values being recorded in both the landing event and the landing roll. The positive results from the B-747-400, A320, and the explanation for inconsistency in the CRJ100 data confirmed that the pitch angle method would ensure that the nose gear down condition was included in the touchdown event with minimal affect on the landing roll.

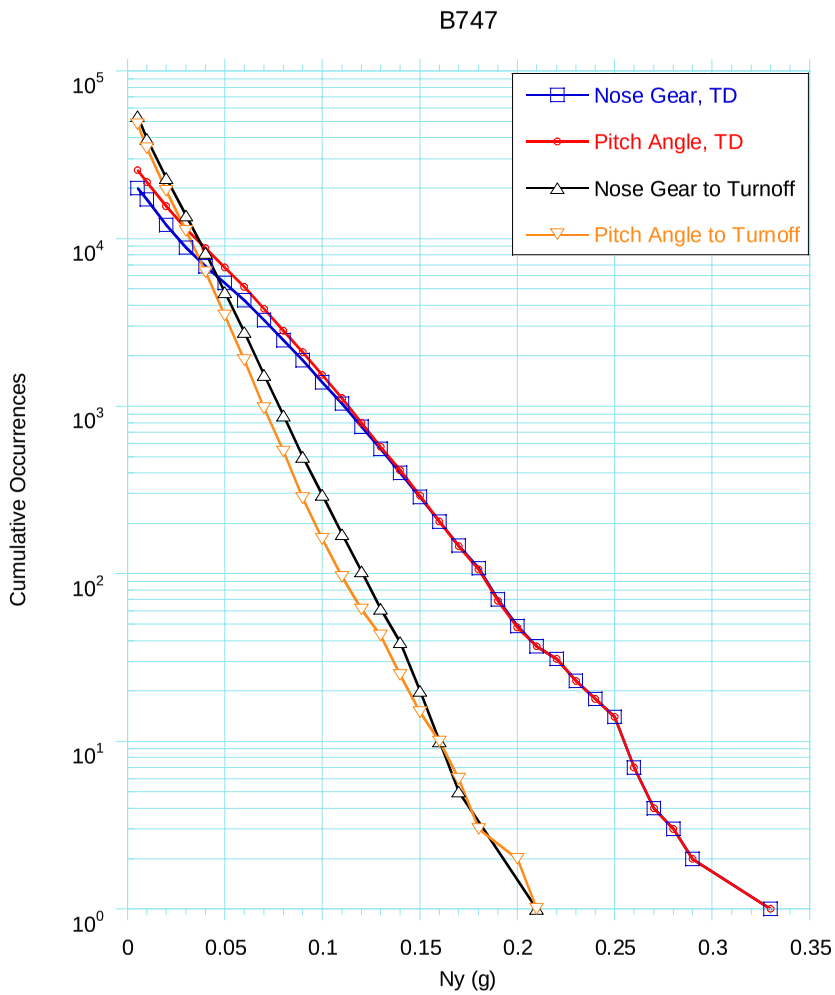

FIGURE 5. B-747 PITCH ANGLE, NOSE GEAR SQUAT COMPARISON FOR 250 FLIGHTS

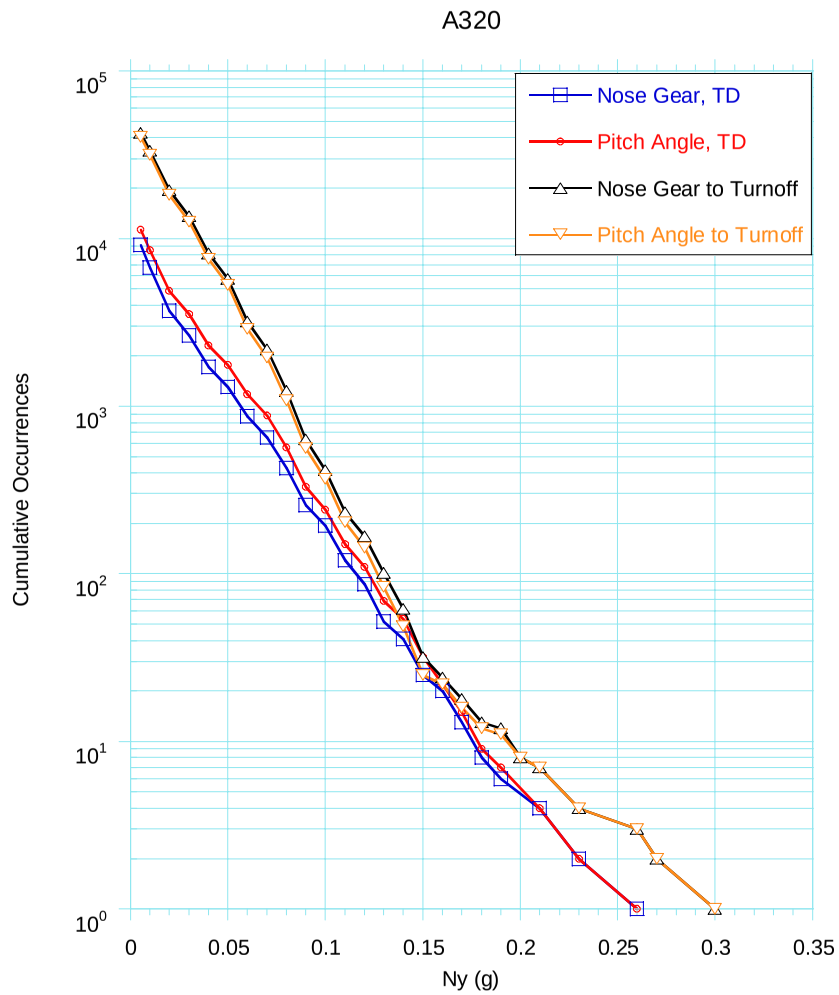

FIGURE 6. A320 PITCH ANGLE, NOSE GEAR SQUAT COMPARISON FOR 256 FLIGHTS

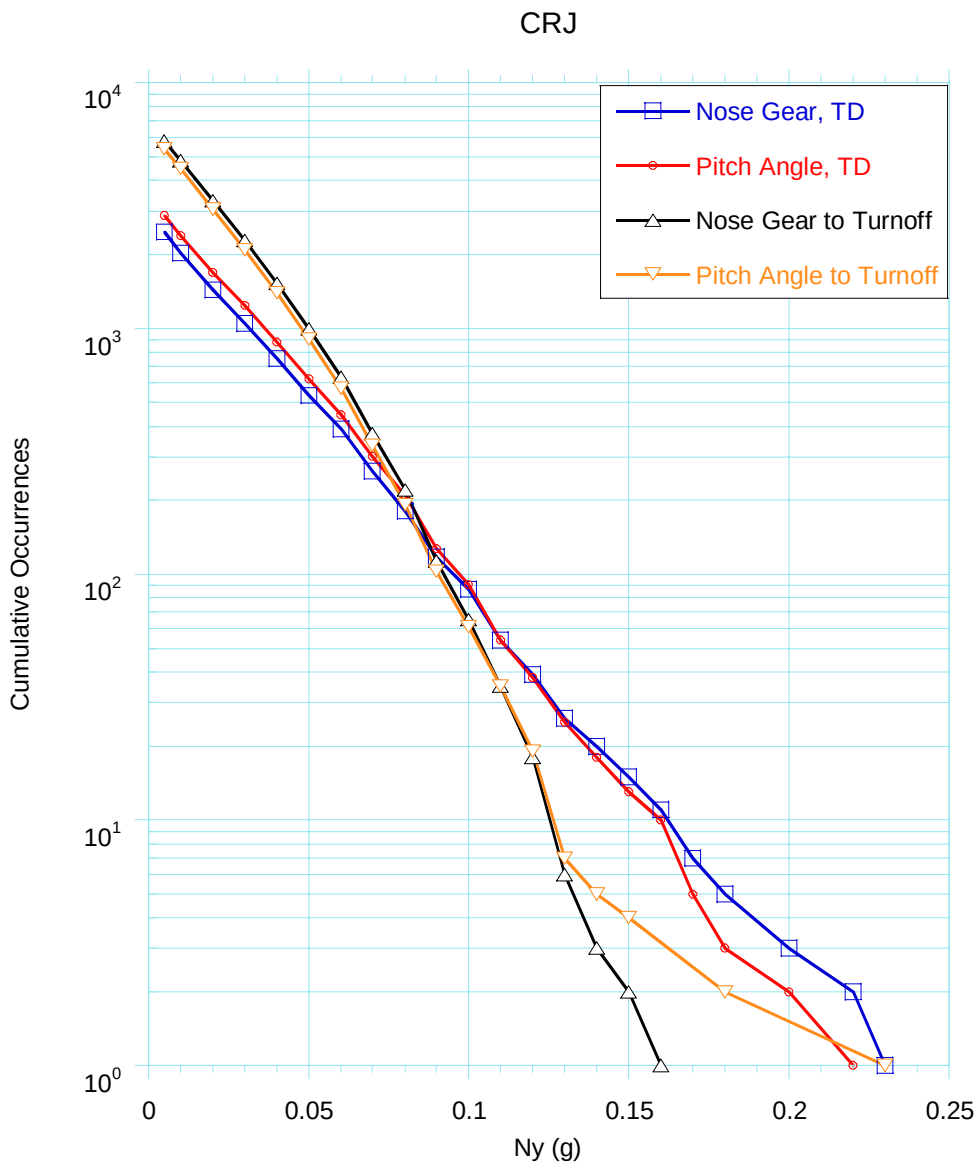

FIGURE 7. CRJ100 PITCH ANGLE, NOSE GEAR SQUAT COMPARISON FOR 359 FLIGHTS

2.3 GROUND PHASES DEFINED.

UDRI separated the ground portion of each flight from the time it departed the gate area to its return to the gate into phases called taxi-out, takeoff roll, touchdown event, landing roll, runway turnoff, and taxi-in. Specific data reduction criteria were developed by UDRI and used to identify the beginning and end of each of these phases. Figure 8 shows these phases and events.

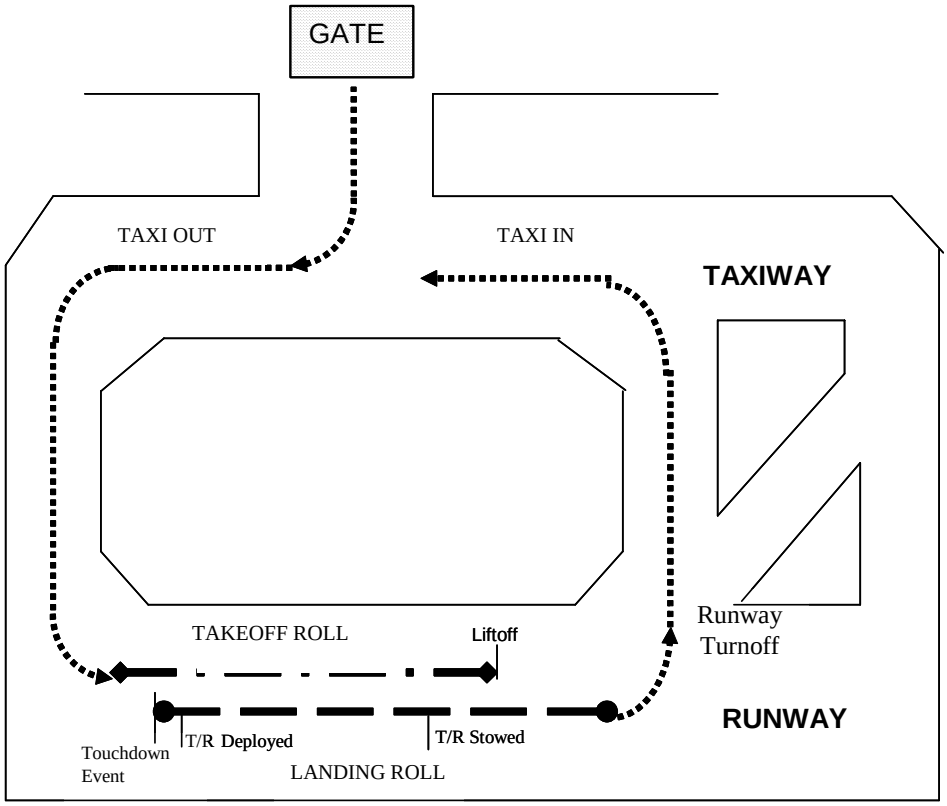

FIGURE 8. GROUND PHASE SCHEMATIC

The criteria used to define each of these phases are summarized in table 1 and discussed in more detail in the following paragraphs.

TABLE 1. FLIGHT PHASE CRITERIA

Phase/Event	Defining Conditions
Taxi-Out	From engine start to beginning of takeoff roll
Takeoff Roll	Ground acceleration > 2kts/sec for at least 20 seconds beginning with the time slice where the first ground speed rate change greater than 2 kts/sec for that sequence occurred
Touchdown Event	From 3 seconds prior to main gear squat switch on until 1 second after nose gear squat (or pitch angle method)
Landing Roll	Begins immediately following touchdown event and ends at the start of runway turnoff
Runway Turnoff	From first sequential magnetic heading change >2 degrees in the same direction from runway heading and subsequent heading changes >13.5 degrees
Taxi-In	After runway turnoff to gate or recorder shutdown

2.3.1 Taxi-Out and Taxi-In.

UDRI defined all aircraft movement from engine start-up until the aircraft begins its takeoff roll as being taxi-out. Taxi-in was defined as beginning from the point where the aircraft completed its turnoff from the active runway after its landing roll to when the aircraft was parked at the gate or the recorder was shutdown.

2.3.2 Takeoff and Landing Roll.

UDRI identified the beginning of the takeoff roll by searching for ground speeds that accelerated at rates greater than 2 kts/sec for a minimum duration of 20 seconds. Then, when these values were found, the beginning of the takeoff roll was assigned as being the time slice where the first ground speed rate change greater than 2 kts/sec for that sequence occurred. The takeoff roll ends at liftoff with the squat switch off signal.

The landing roll phase was defined as beginning immediately after the touchdown event and ending when the aircraft starts its turnoff from the active runway.

2.3.3 Runway Turnoff.

UDRI used changes in magnetic heading to identify the beginning and the end of the aircraft's turnoff from the active runway. After the aircraft touched down and was on the ground for four seconds, the subsequent average magnetic heading readings were used to define the aircraft's landing centerline. UDRI then searched for magnetic heading changes that continuously moved in the same direction away from this centerline. When the aircraft's sequential magnetic heading change exceeded 13.5 degrees from the direction of the landing centerline or the integrated distance from the centerline exceeded 100 feet, the time slice associated with the first sequential heading change greater than 2 degrees from the landing centerline in the direction of the turn was defined as the beginning of the airplane's turnoff from the runway.

UDRI developed the 100-foot deviation as an alternate method of identifying flights involving shallow turns from the runway that did not exceed the 13.5 degree turn criteria. This method used aircraft ground speed and magnetic heading to calculate the aircraft's position relative to the runway centerline. Then, as above, the time slice associated with the first aircraft movement away from the landing centerline in the direction of the turn was defined as the beginning of the aircraft's turnoff from the runway.

The end point of this turnoff from the runway was also identified using magnetic heading readings. UDRI developed an algorithm that used the changes in magnetic heading, while the aircraft was in its turn, to identify when the aircraft had either returned to taxiing in a straight line or was turning in the opposite direction. The first point that provided this indication was then defined as the end point of the turnoff from the runway. This point is also the beginning of the taxi-in phase.

3. DATA PRESENTATION.

The statistical data presented in this section provided the FAA and aircraft manufacturers with the information that was needed to assess the side load factors for each of the defined ground phases for the B-747-400, B-767-200, B-737-400, CRJ100, and A320. Table 2 reports the amount of flight hours, total number of flights, and the average flight length for each of the five aircraft used in this study. All data were checked, and any suspicious flights were analyzed and removed if the data were found to be faulty.

TABLE 2. FLIGHT STATISTICS

Aircraft	Flights	Flight Hours	Average Flight Time (Hours)
B-747-400	11,064	95,862	8.66
B-767-200	6,551	44,990	6.87
B-737-400	60,734	89,269	1.47
CRJ100	359	463	1.29
A320	10,066	30,817	3.06

Table 3 lists the statistical formats for which the data were processed. The side load factor data formats are grouped together within the table in an attempt to categorize the results by aircraft model and by individual ground phases.

TABLE 3. STATISTICAL DATA FORMATS

Data Description	Figure
LATERAL LOAD FACTOR BY AIRCRAFT MODEL	
B-747-400	
Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-1
Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-2
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight by Ground Phase	A-3
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour by Ground Phase	A-4
Summary Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-5
Summary Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-6
B-767-200	
Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-7
Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-8
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight by Ground Phase	A-9
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour by Ground Phase	A-10
Summary Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-11
Summary Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-12

TABLE 3. STATISTICAL DATA FORMATS (Continued)

Data Description	Figure
LATERAL LOAD FACTOR BY AIRCRAFT MODEL (continued)	
B-737-400	
Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-13
Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-14
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight by Ground Phase	A-15
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour by Ground Phase	A-16
Summary Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-17
Summary Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-18
CRJ100	
Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-19
Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-20
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight by Ground Phase	A-21
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour by Ground Phase	A-22
Summary Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-23
Summary Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-24
A320	
Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-25
Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-26
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight by Ground Phase	A-27
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour by Ground Phase	A-28
Summary Cumulative Occurrences of Lateral Load Factor per Flight by Ground Phase	A-29
Summary Cumulative Occurrences of Lateral Load Factor per Flight Hour by Ground Phase	A-30
LATERAL LOAD FACTOR BY GROUND PHASES	
TAXI-OUT	
Cumulative Occurrences of Lateral Load Factor per Flight During Taxi-Out by Aircraft Model	A-31
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Taxi-Out by Aircraft Model	A-32
TAKEOFF ROLL	
Cumulative Occurrences of Lateral Load Factor per Flight During Takeoff by Aircraft Model	A-33
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Takeoff by Aircraft Model	A-34
TOUCHDOWN	
Cumulative Occurrences of Lateral Load Factor per Flight During Touchdown by Aircraft Model	A-35
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Touchdown by Aircraft Model	A-36
LANDING ROLL	
Cumulative Occurrences of Lateral Load Factor per Flight During Landing Roll by Aircraft Model	A-37
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Landing Roll by Aircraft Model	A-38

TABLE 3. STATISTICAL DATA FORMATS (Continued)

Data Description	Figure
LATERAL LOAD FACTOR BY GROUND PHASES (Continued)	
RUNWAY TURNOFF	
Cumulative Occurrences of Lateral Load Factor per Flight During Runway Turnoff by Aircraft Model	A-39
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Runway Turnoff by Aircraft Model	A-40
TAXI-IN	
Cumulative Occurrences of Lateral Load Factor per Flight During Taxi-In by Aircraft Model	A-41
Cumulative Occurrences of Lateral Load Factor per Flight Hour During Taxi-In by Aircraft Model	A-42
CORRECTED LATERAL LOAD FACTOR BY GROUND PHASES	
TAXI-OUT	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Taxi-Out by Aircraft Model	A-43
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Taxi-Out by Aircraft Model	A-44
TAKEOFF ROLL	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Takeoff Roll by Aircraft Model	A-45
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Takeoff Roll by Aircraft Model	A-46
TOUCHDOWN	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Touchdown by Aircraft Model	A-47
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Touchdown by Aircraft Model	A-48
LANDING ROLL	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Landing Roll by Aircraft Model	A-49
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Landing Roll by Aircraft Model	A-50
RUNWAY TURNOFF	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Runway Turnoff by Aircraft Model	A-51
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Runway Turnoff by Aircraft Model	A-52
TAXI-IN	
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight During Taxi-In by Aircraft Model	A-53
Cumulative Occurrences of (Recorded Weight/Max Landing Weight)*Ny per Flight Hour During Taxi-In by Aircraft Model	A-54

Figures A-1 through A-54 are presented in appendix A. It should also be noted that the data presented in these figures were checked and any data found to be erroneous was removed.

Cumulative occurrence of lateral load factor plots provided in appendix A present data in two forms, by flight and by flight hours. The values of Ny presented are the absolute value with no

differentiation between left and right turns. These plots provide ground phase data grouped by aircraft model. Additionally, the data is provided for each ground phase separately for comparison between different aircraft models.

Data contained in the plots that are identified as corrected have Ny values that were adjusted to take into account weight loss that occurs in flight when fuel mass is burned off. Lateral load factors reported in these plots have been multiplied by the corresponding gross weight at touchdown and then divided by the maximum ramp or landing weight as appropriate for that aircraft model. Gross weight was not available for the CRJ100 model, so the corrected data in these plots were multiplied by the maximum landing weight and, again, divided by the maximum ramp weight. Table 4 provides the numerical values of maximum landing and ramp weights used by each model.

TABLE 4. DESIGN WEIGHT VALUES USED FOR Ny CORRECTION

	B-747-400 (lb)	B-767-200 (lb)	B-737-400 (lb)	A320 (lb)	CRJ100 (lb)
Maximum Ramp Weight	877,000	352,200	143,000	162,920	53,250
Maximum Landing Weight	652,000	278,000	121,000	142,195	47,000

The takeoff roll phase for the CRJ100 contained some high Ny values. Closer examination as to why shows that the CRJ100, because of its small size, is capable of quickly accelerating around the turn from the taxiway to the runway for takeoff. As a result, instead of the Ny appearing in the taxi-out phase as it should, the plane has met the criteria for takeoff roll based on its acceleration, even though it is still turning onto the runway.

4. CONCLUSIONS.

In support of a number of Federal Aviation Administration certification initiatives and Aviation Rulemaking Advisory Committee activities, data formats for ground phase operations that were not previously available have been included in this report. The updated ground phase criteria and the large quantity of flight data within this report make it a very complete resource for characterizing aircraft lateral load factor during ground operations. The data herein has been presented in a manner that allows for individual aircraft to be studied (plots by model) as well in a way that allows comparisons among different aircraft models to be made (plots by phase).

The figures in appendix A shows that, in general, the size of the aircraft does appear to be a significant factor of not only when high Ny values occur, but also the magnitude of Ny. Small aircraft such as the CRJ100 and B-737, for example, tend to see most of their higher Ny occurrences while turning (due to higher speeds and gear layout). Larger aircraft are prone to encounter lower values of Ny taxiing and tend to have their highest Ny occurrences found during the touchdown event and rollout.

As data for future aircraft models or increased flight hours for existing models become available, these same formats will be created and provided either in future flight load reports or in a manner similar to this report.

APPENDIX A—COMPARITIVE SIDE LOAD FACTOR DATA

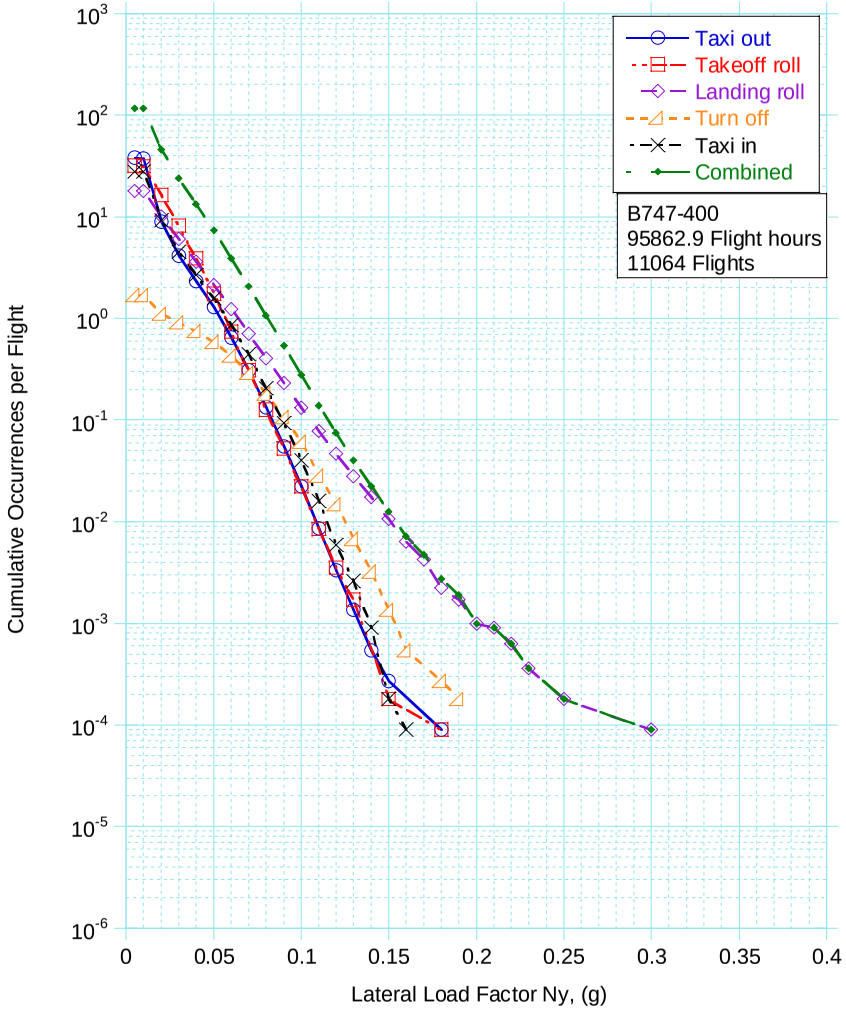

FIGURE A-1. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-747-400)

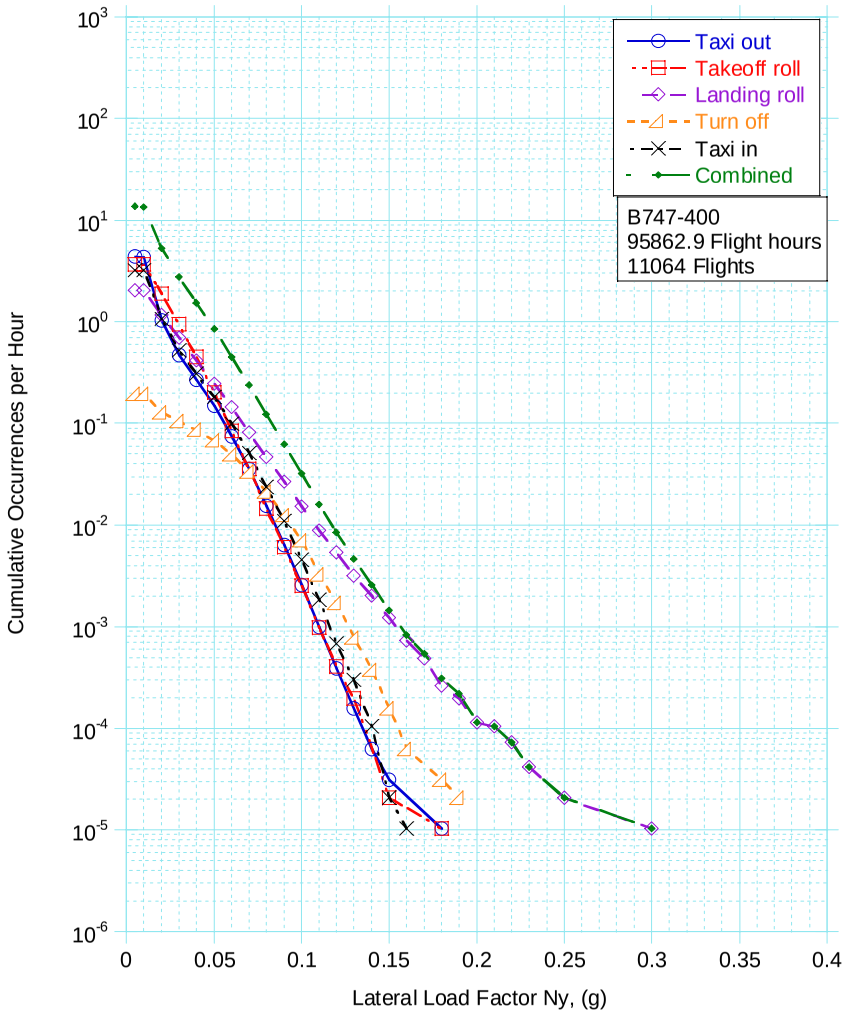

FIGURE A-2. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-747-400)

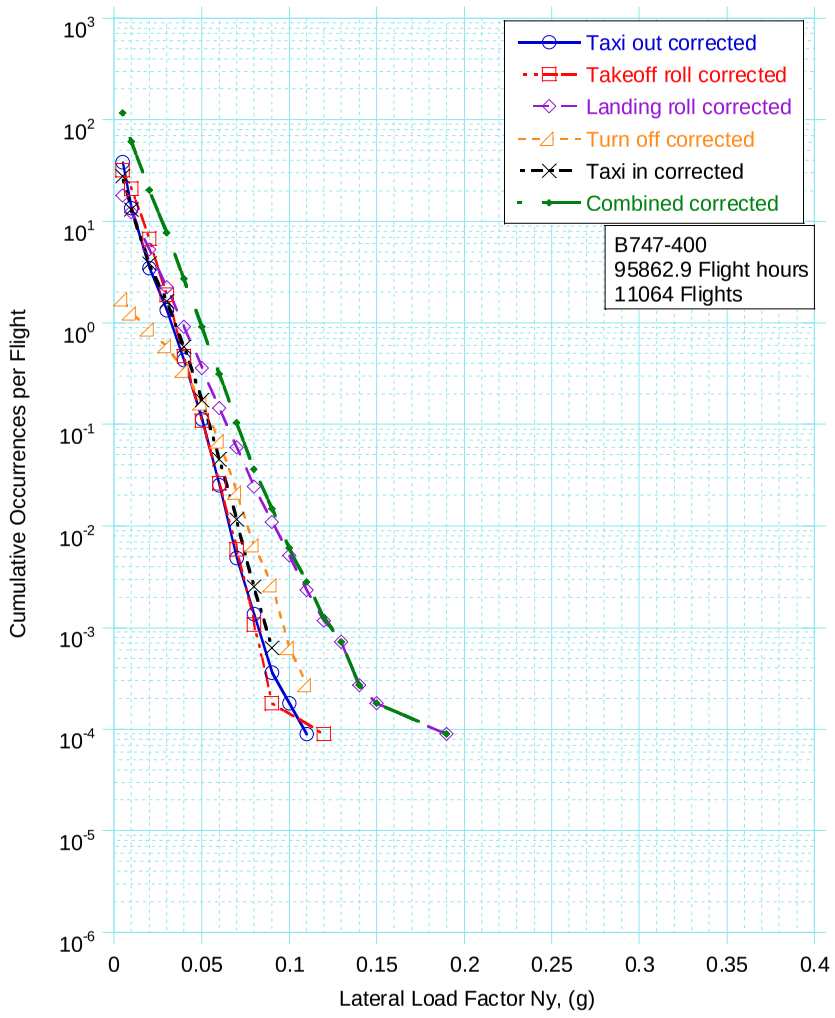

FIGURE A-3. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT BY GROUND PHASE (B-747-400)

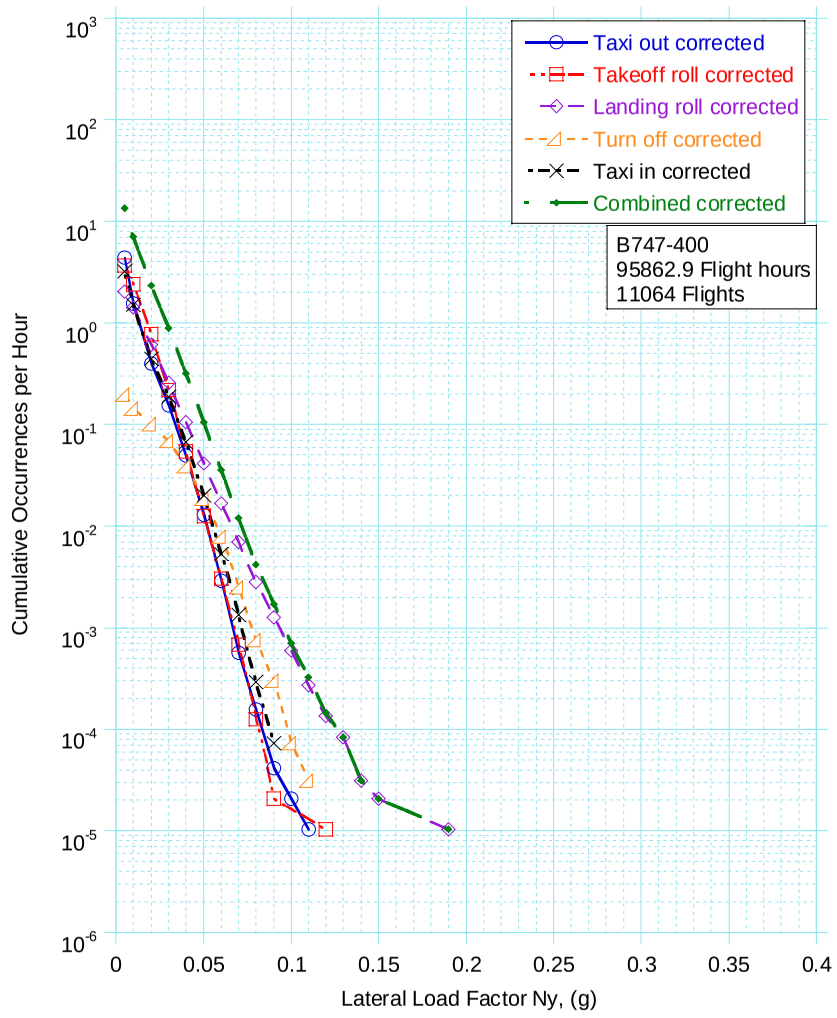

FIGURE A-4. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR BY GROUND PHASE (B-747-400)

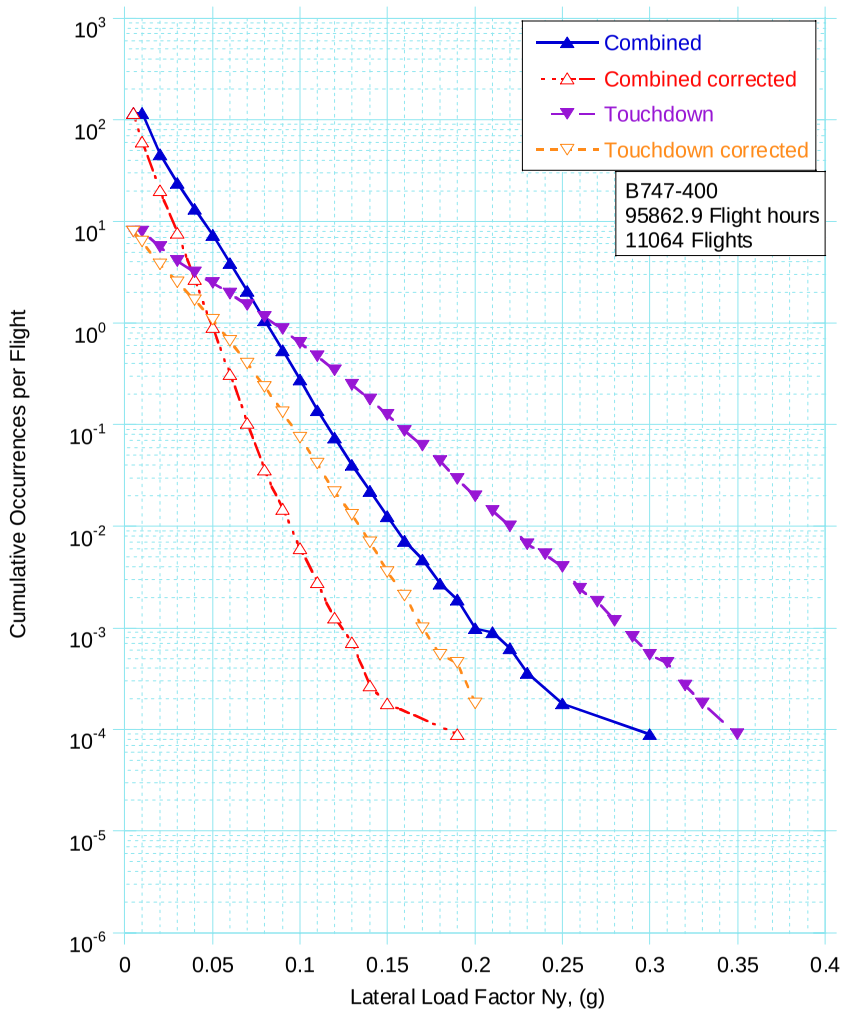

FIGURE A-5. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-747-400)

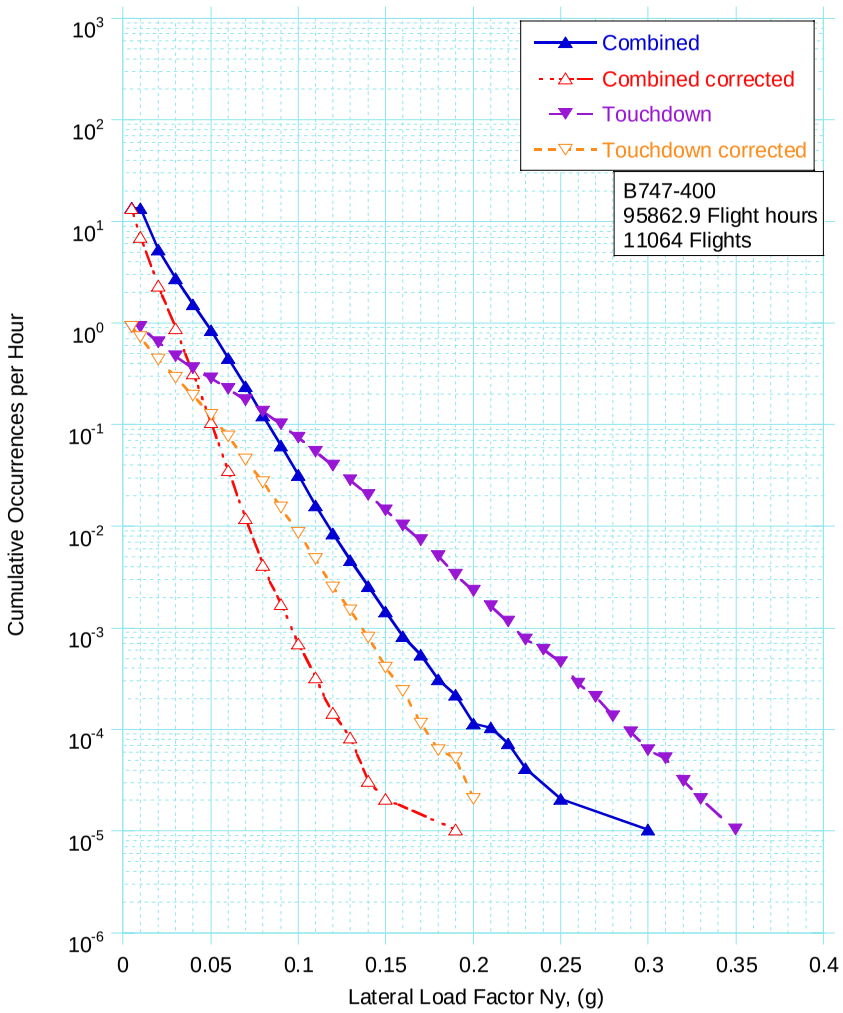

FIGURE A-6. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-747-400)

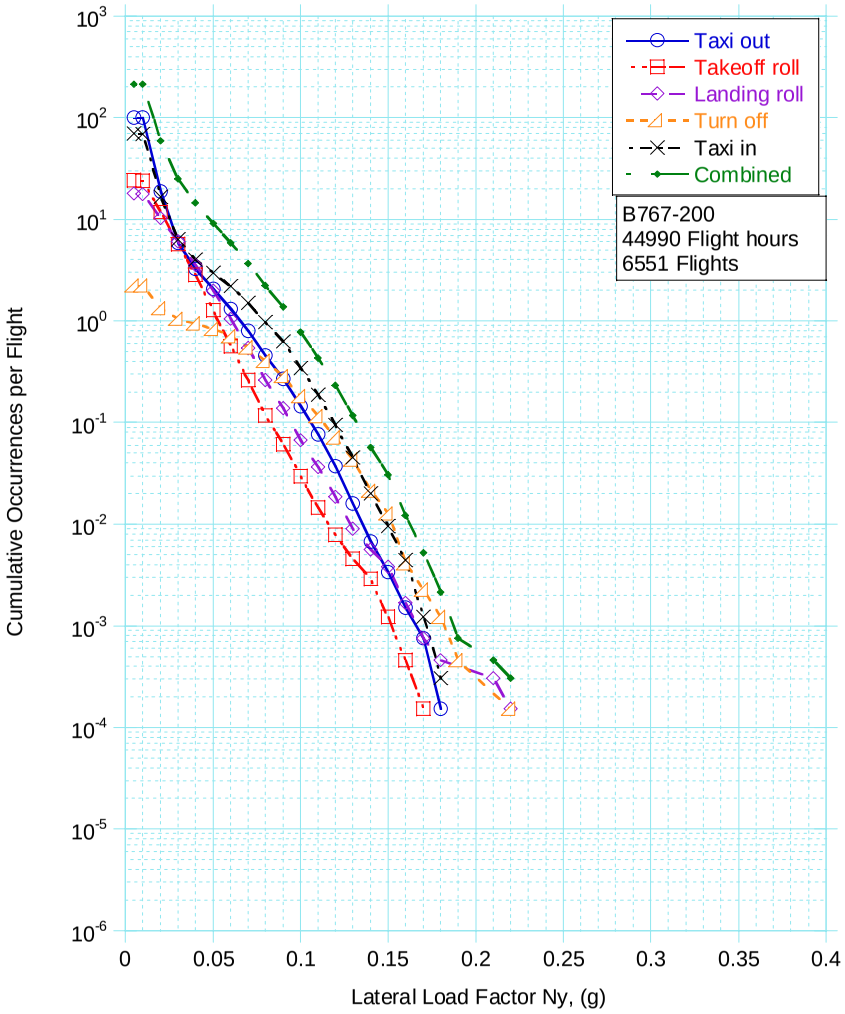

FIGURE A-7. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-767-200)

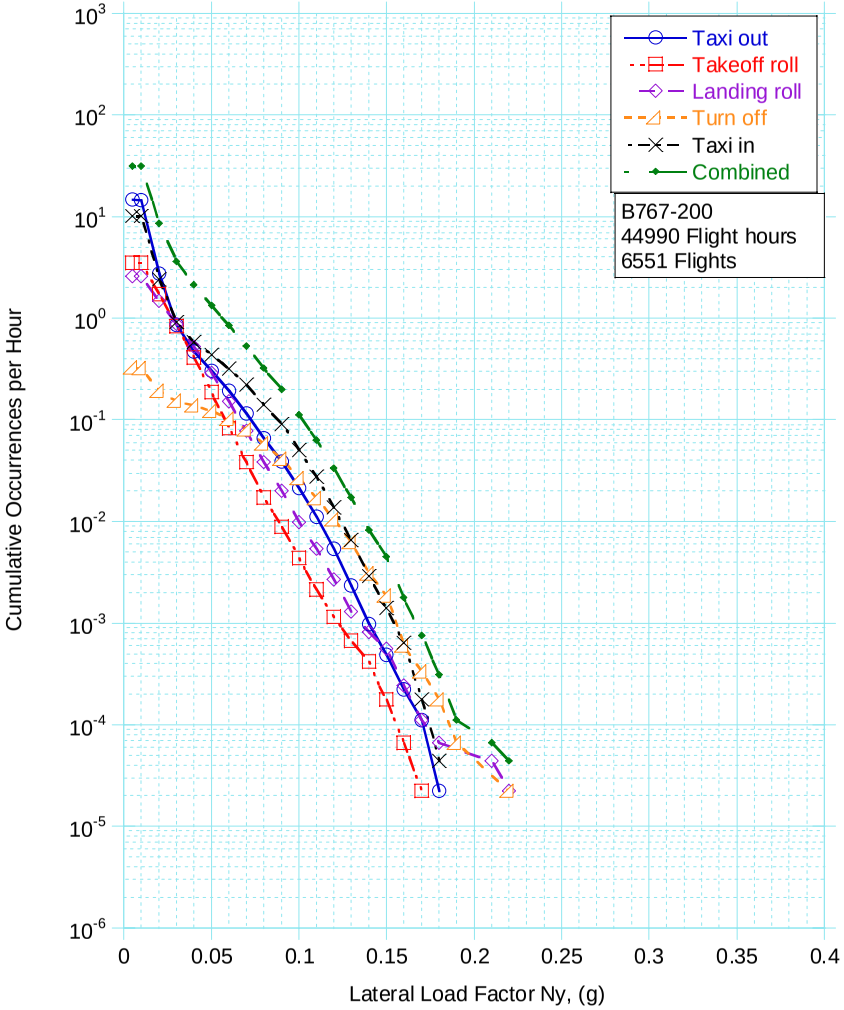

FIGURE A-8. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-767-200)

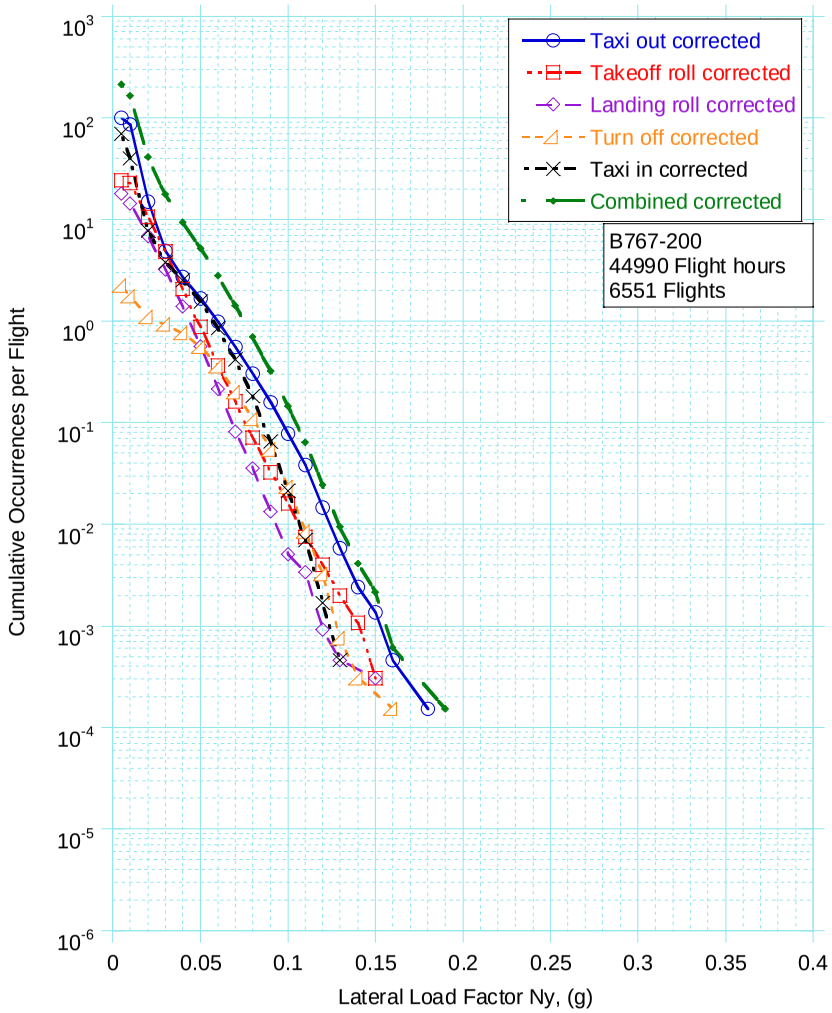

FIGURE A-9. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT BY GROUND PHASE (B-767-200)

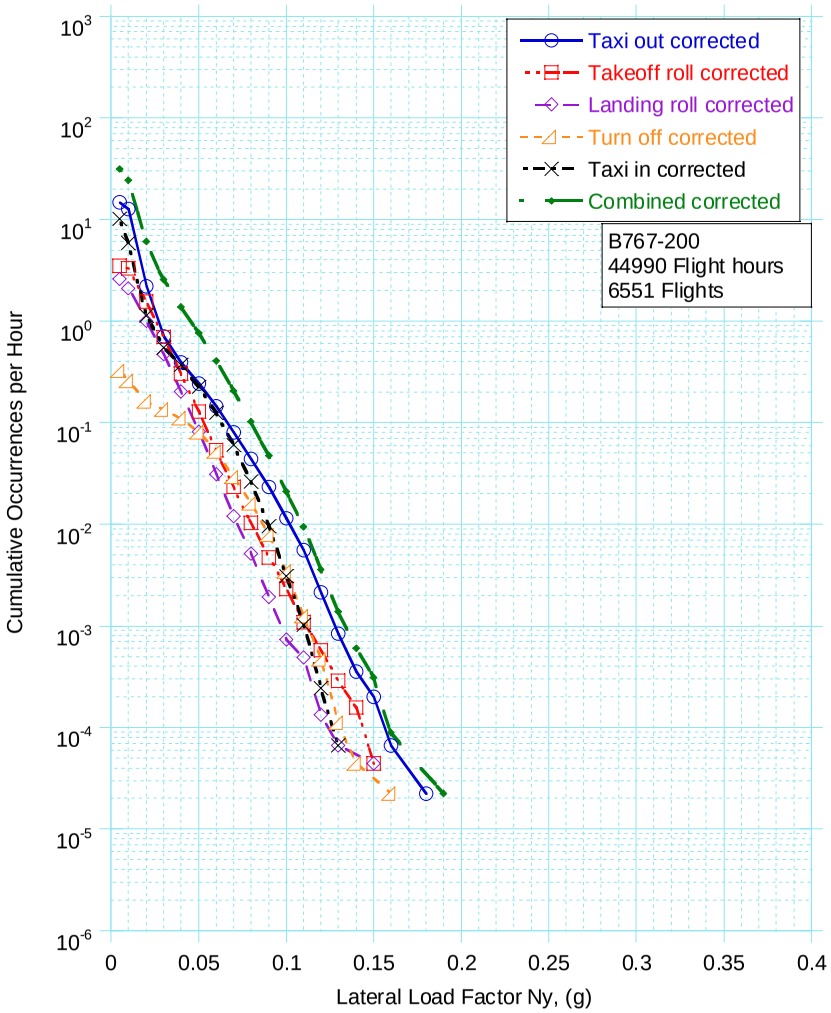

FIGURE A-10. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR BY GROUND PHASE (B-767-200)

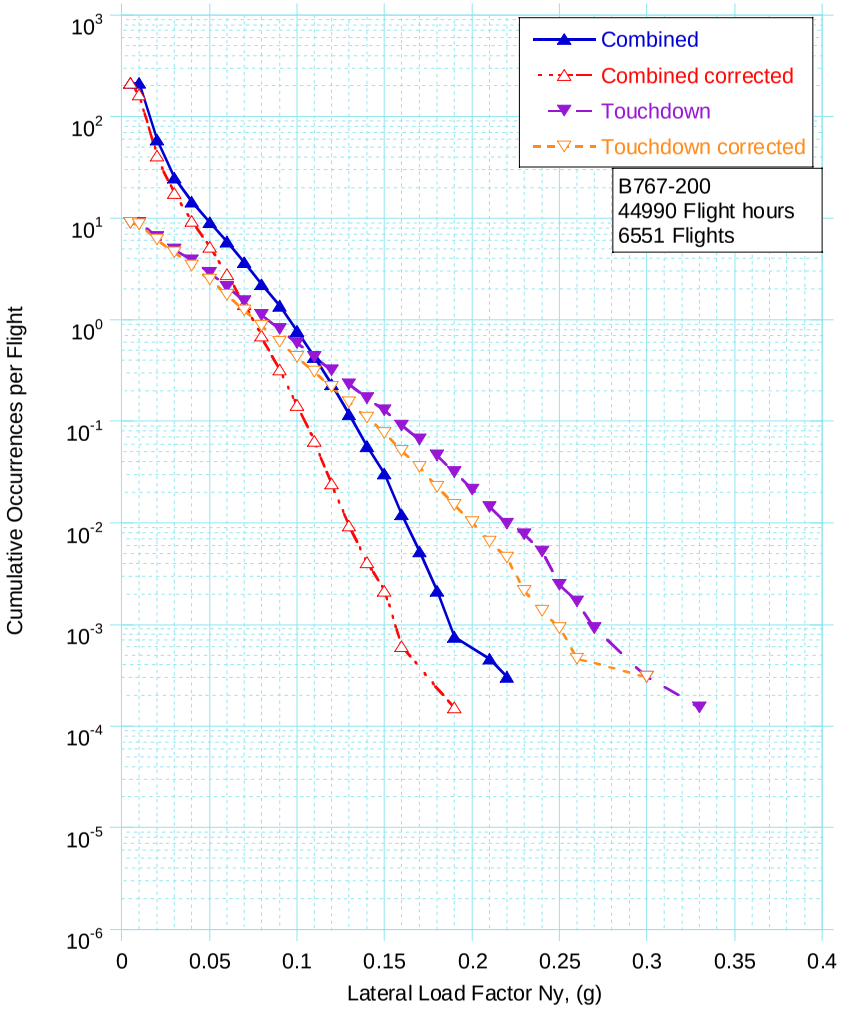

FIGURE A-11. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-767-200)

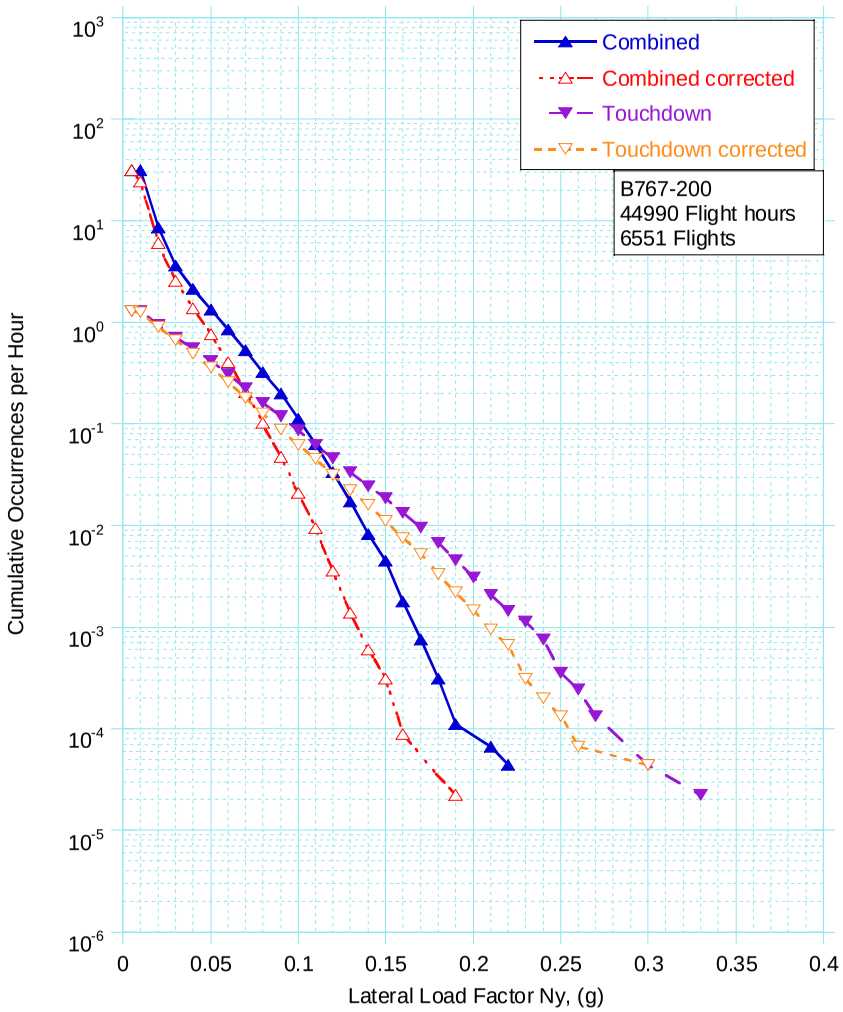

FIGURE A-12. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-767-200)

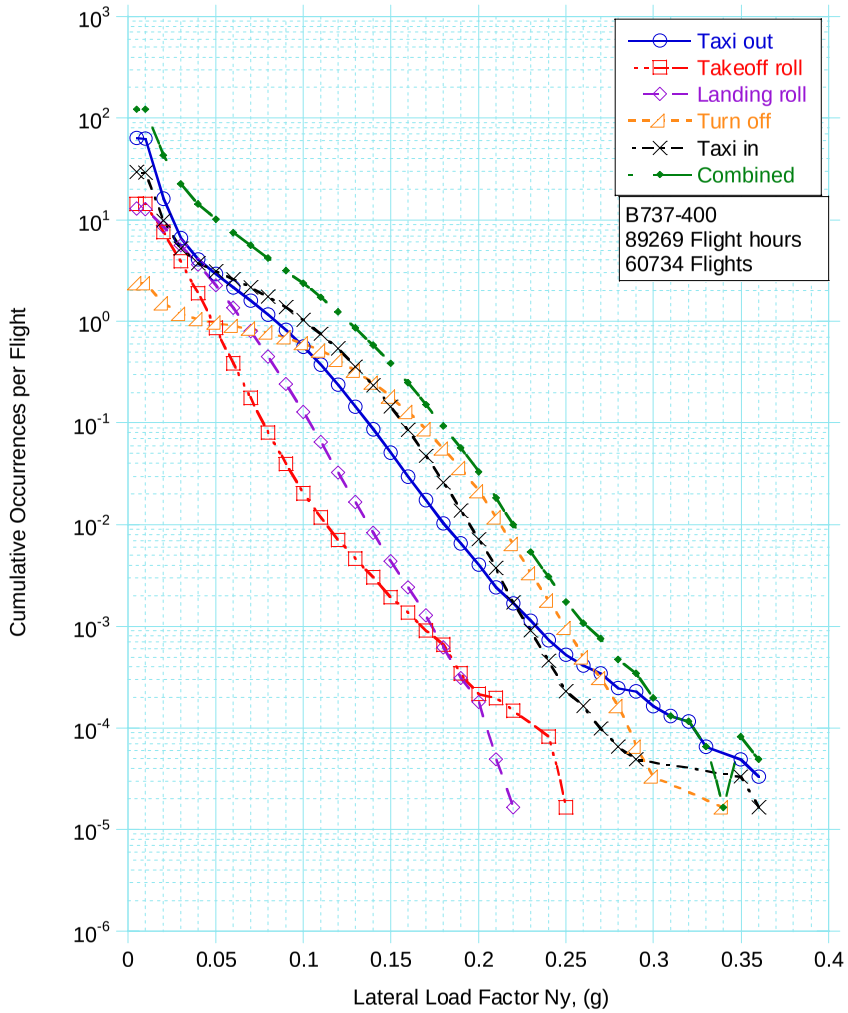

FIGURE A-13. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-737-400)

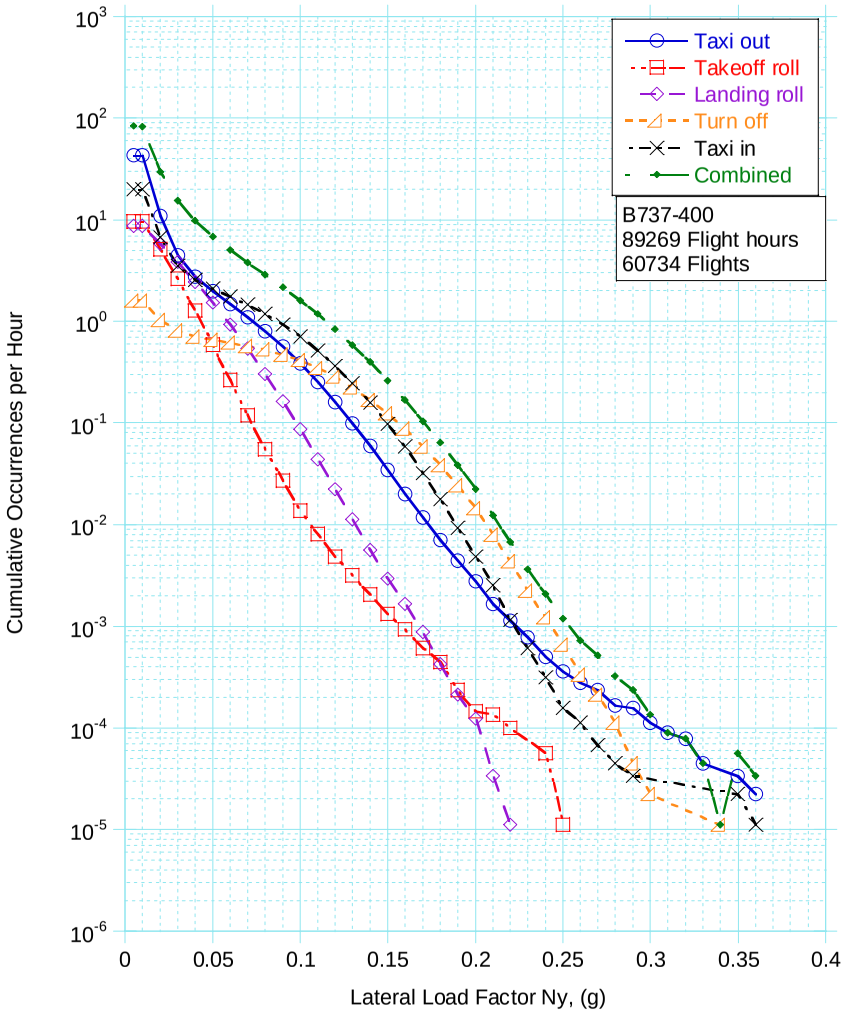

FIGURE A-14. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-737-400)

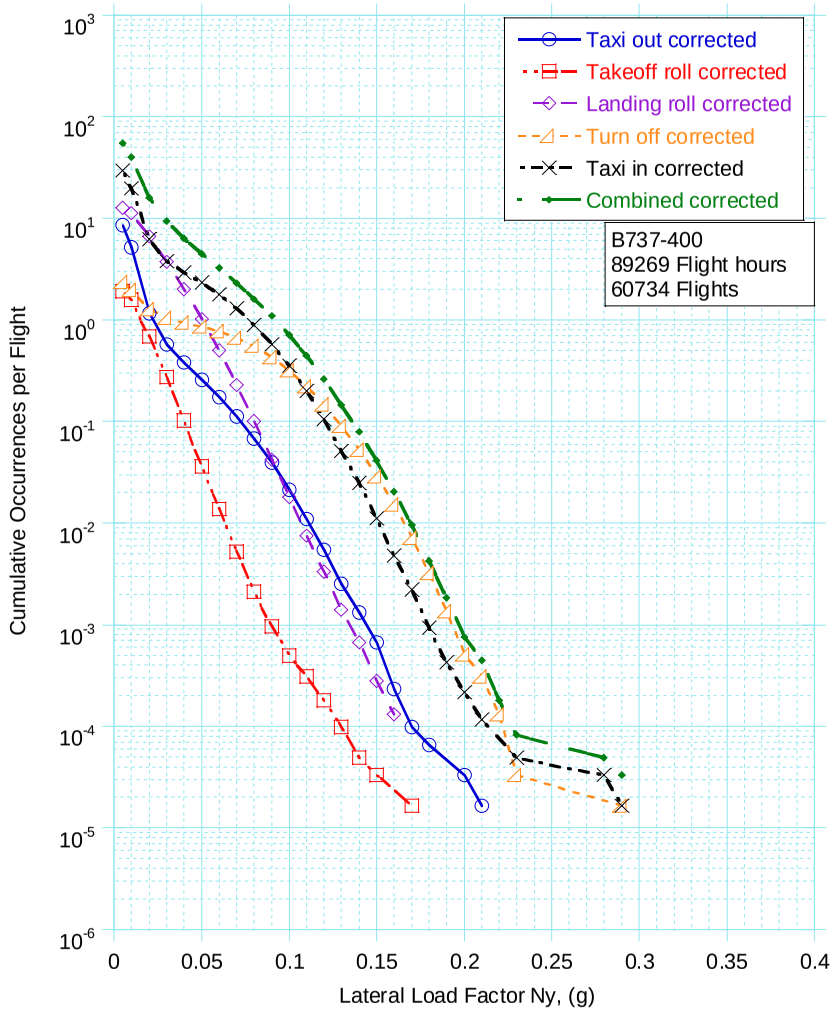

FIGURE A-15. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT BY GROUND PHASE (B-737-400)

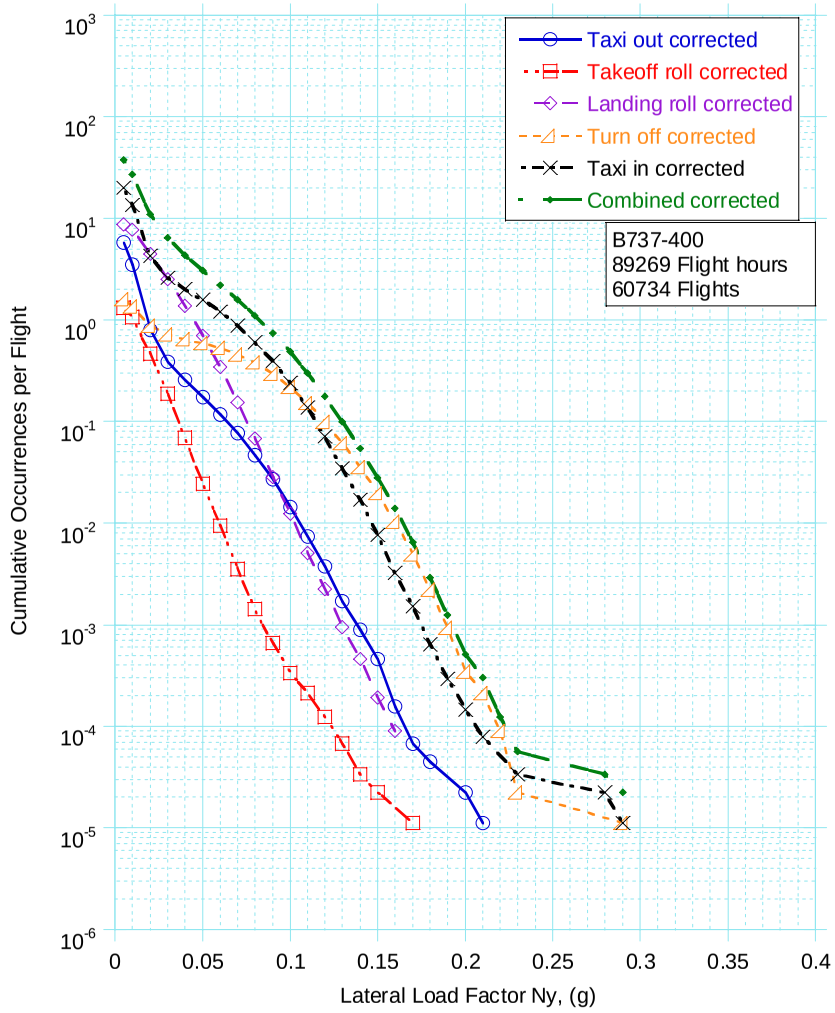

FIGURE A-16. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR BY GROUND PHASE (B-737-400)

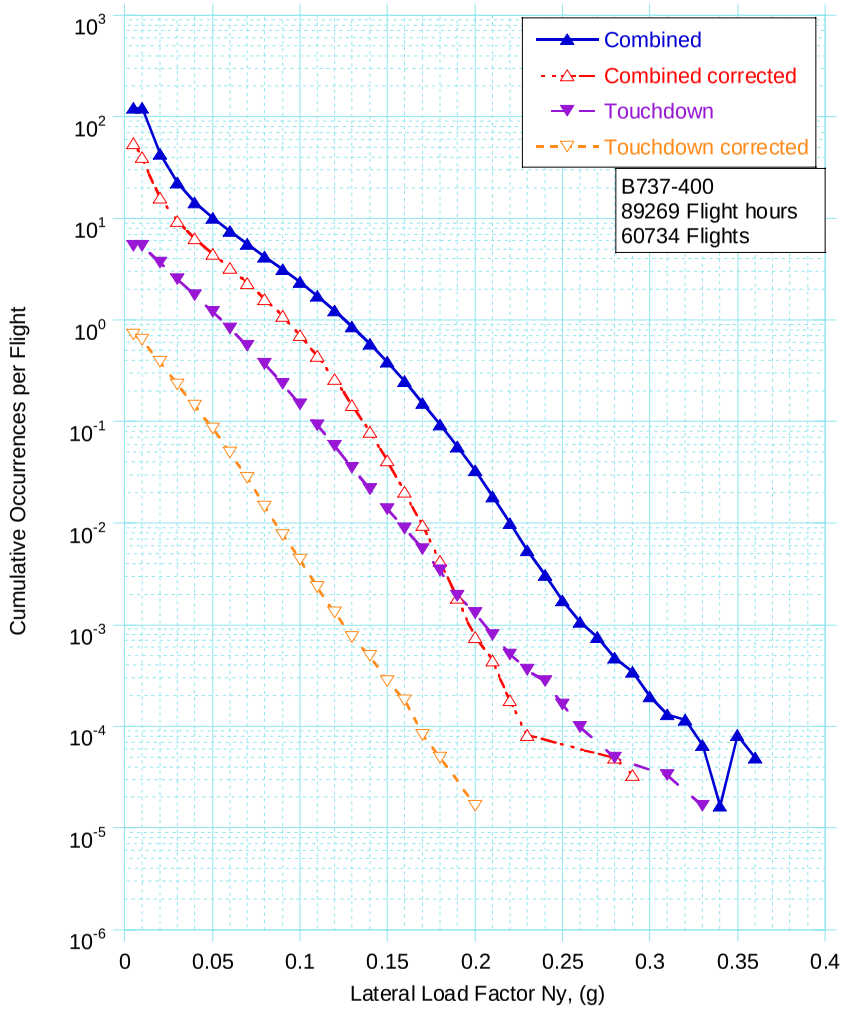

FIGURE A-17. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (B-737-400)

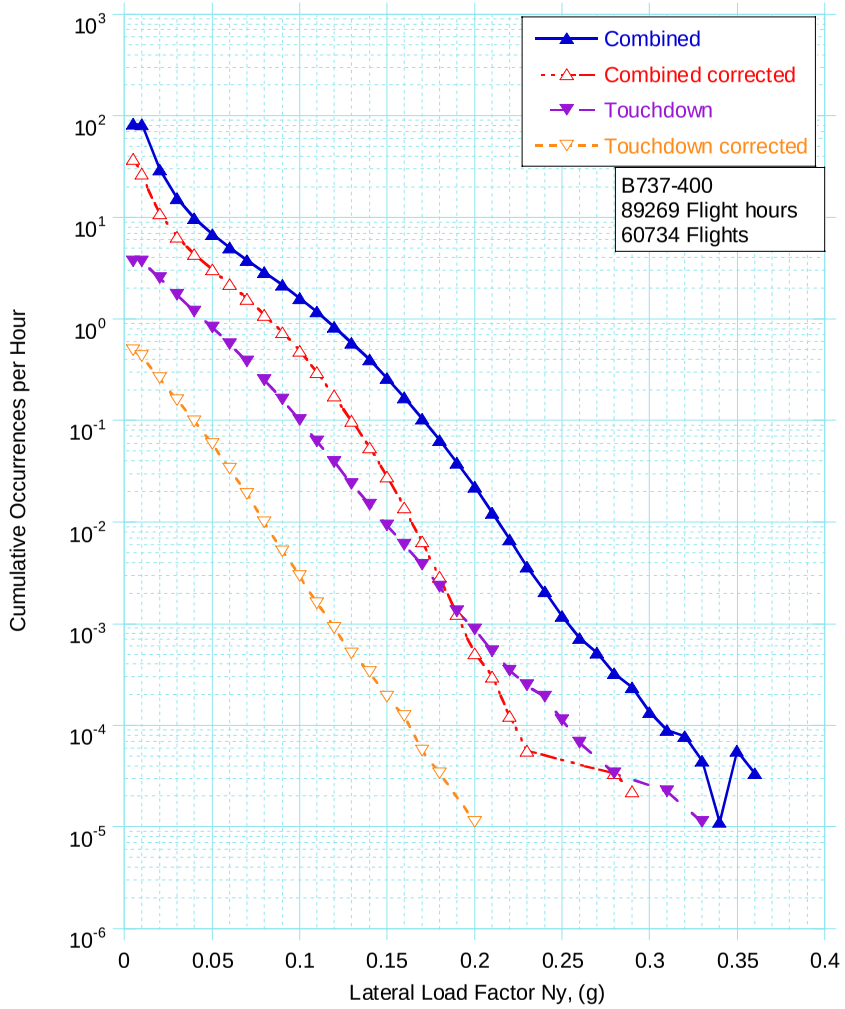

FIGURE A-18. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (B-737-400)

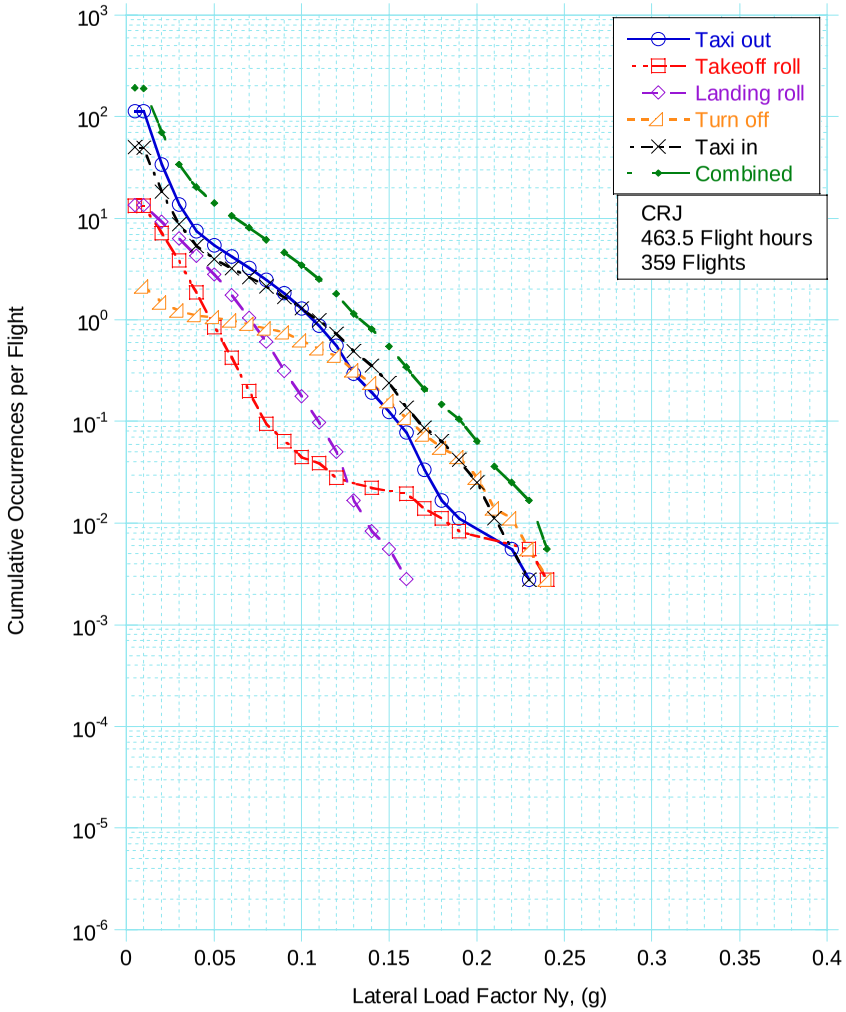

FIGURE A-19. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (CRJ100)

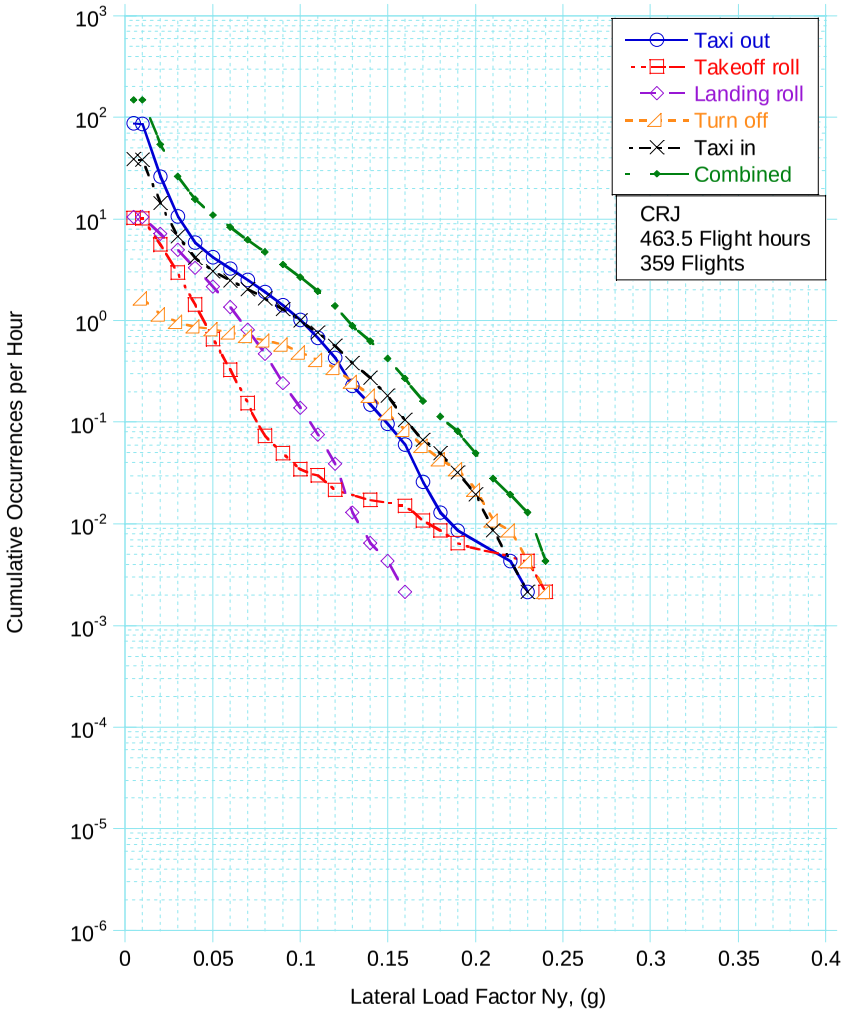

FIGURE A-20. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (CRJ100)

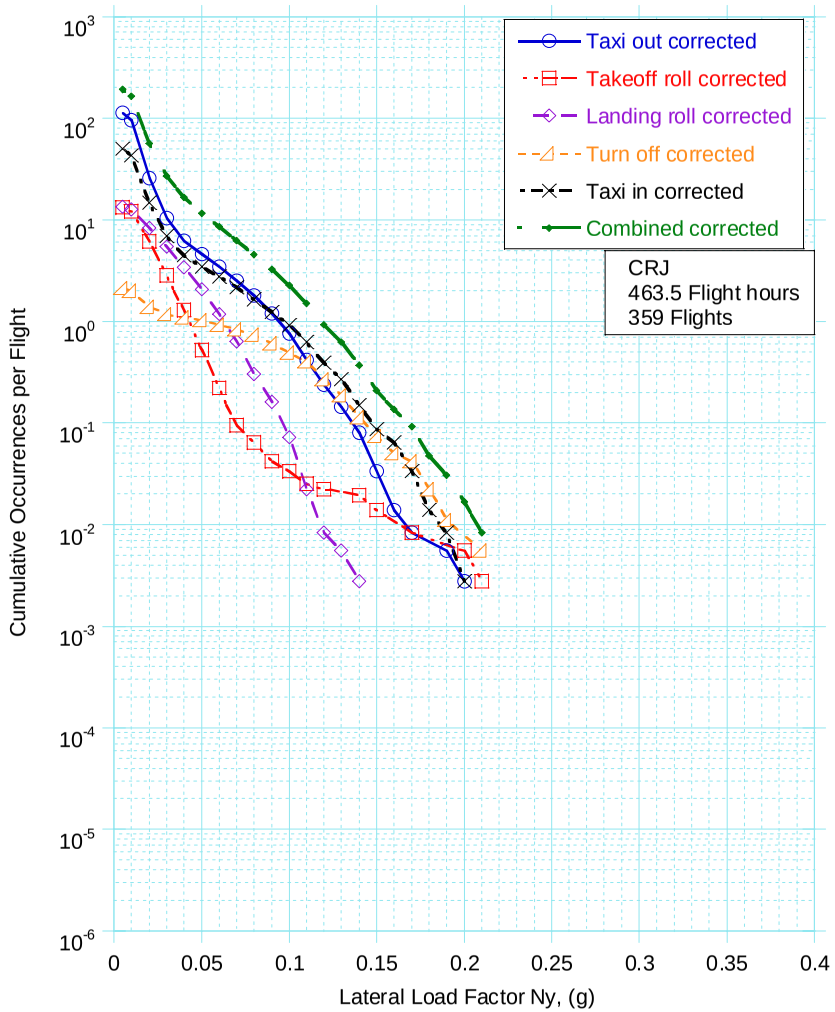

FIGURE A-21. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT BY GROUND PHASE (CRJ100)

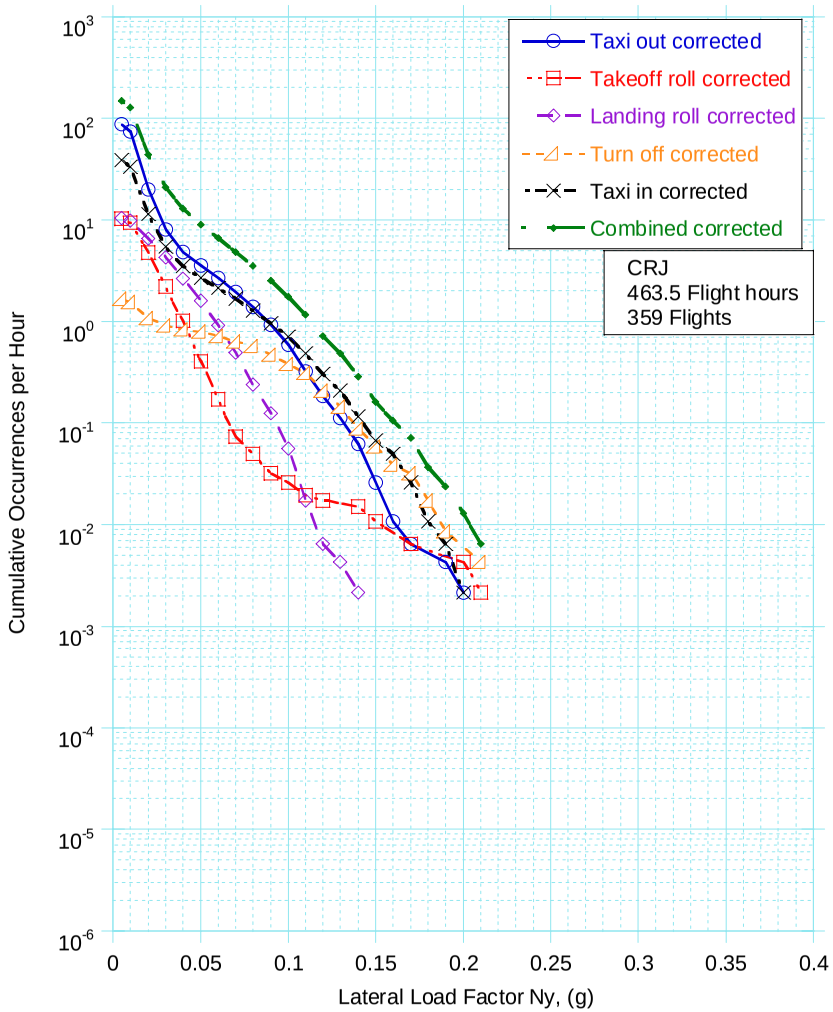

FIGURE A-22. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR BY GROUND PHASE (CRJ100)

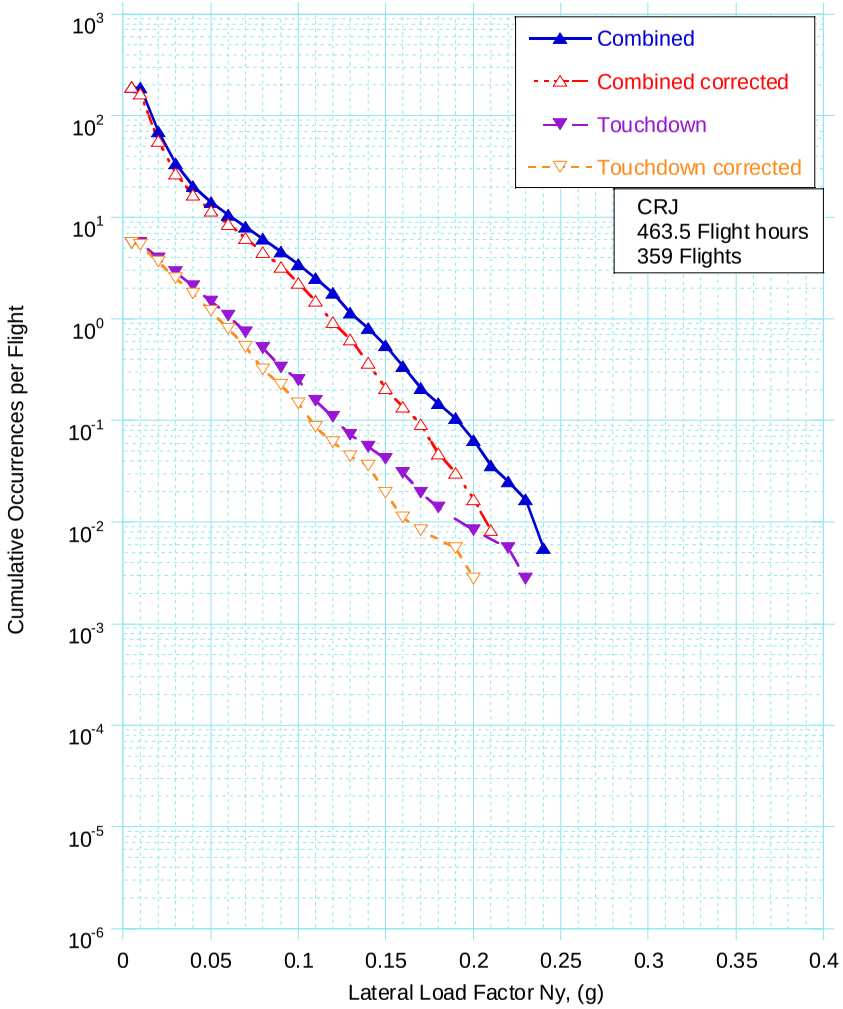

FIGURE A-23. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (CRJ100)

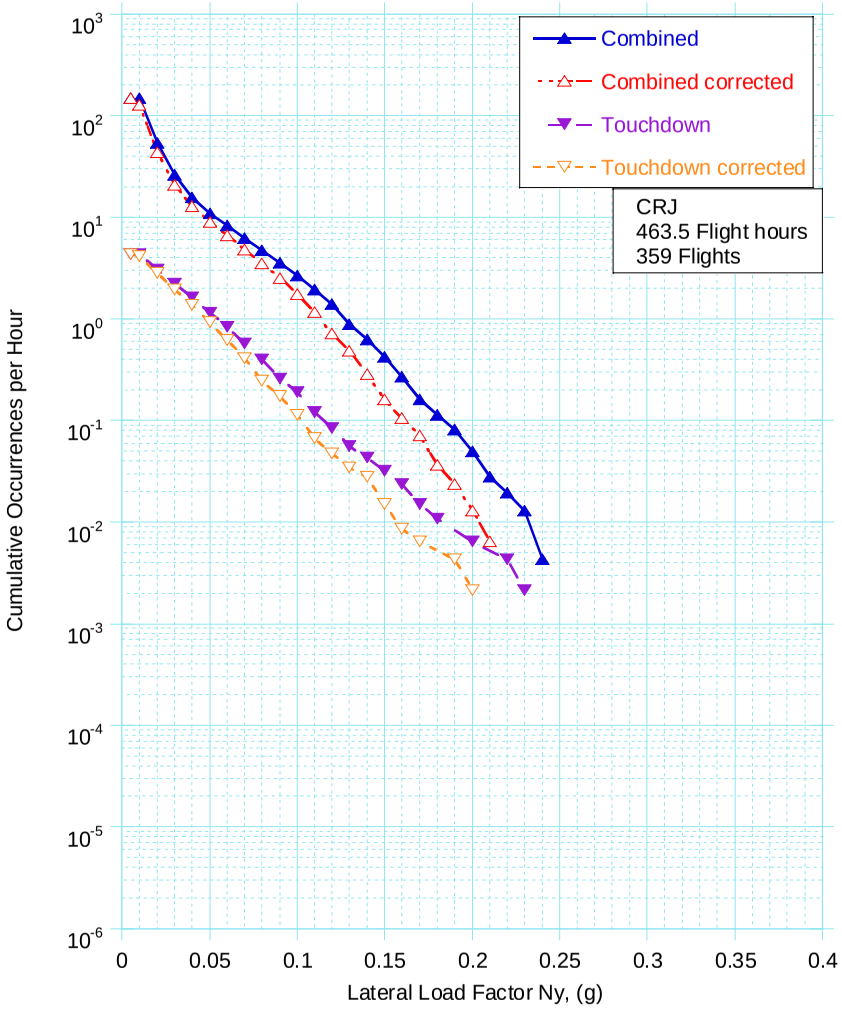

FIGURE A-24. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (CRJ100)

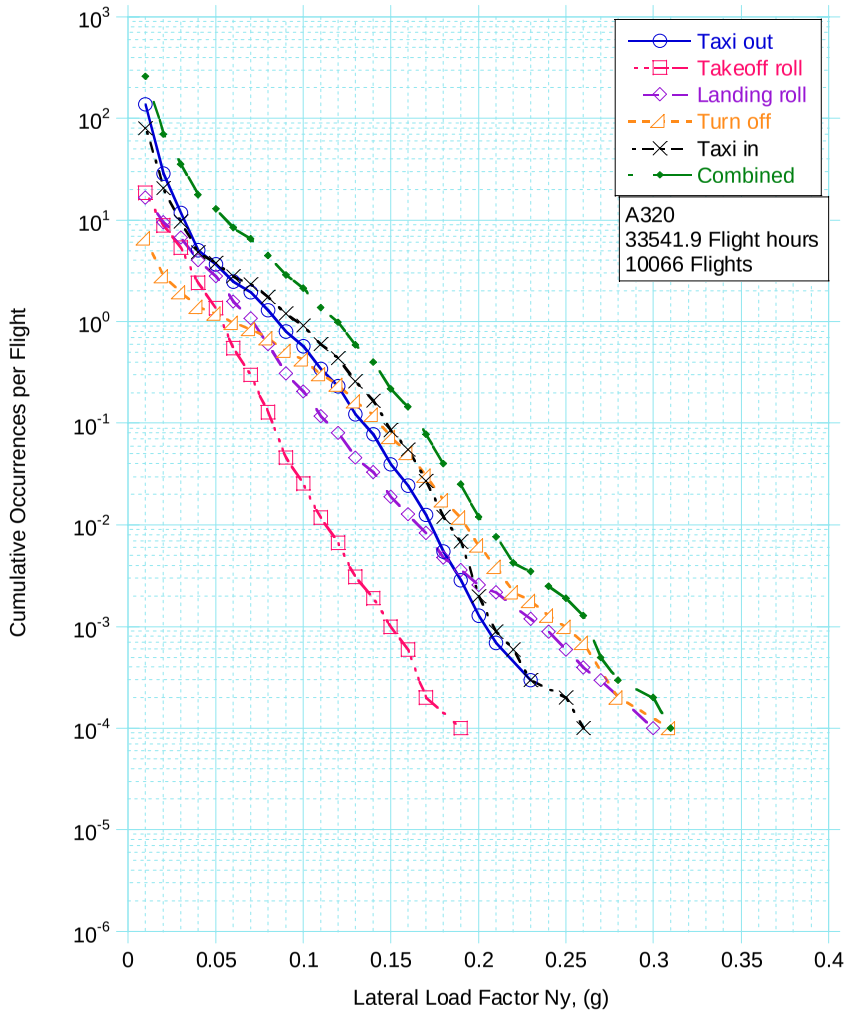

FIGURE A-25. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (A320)

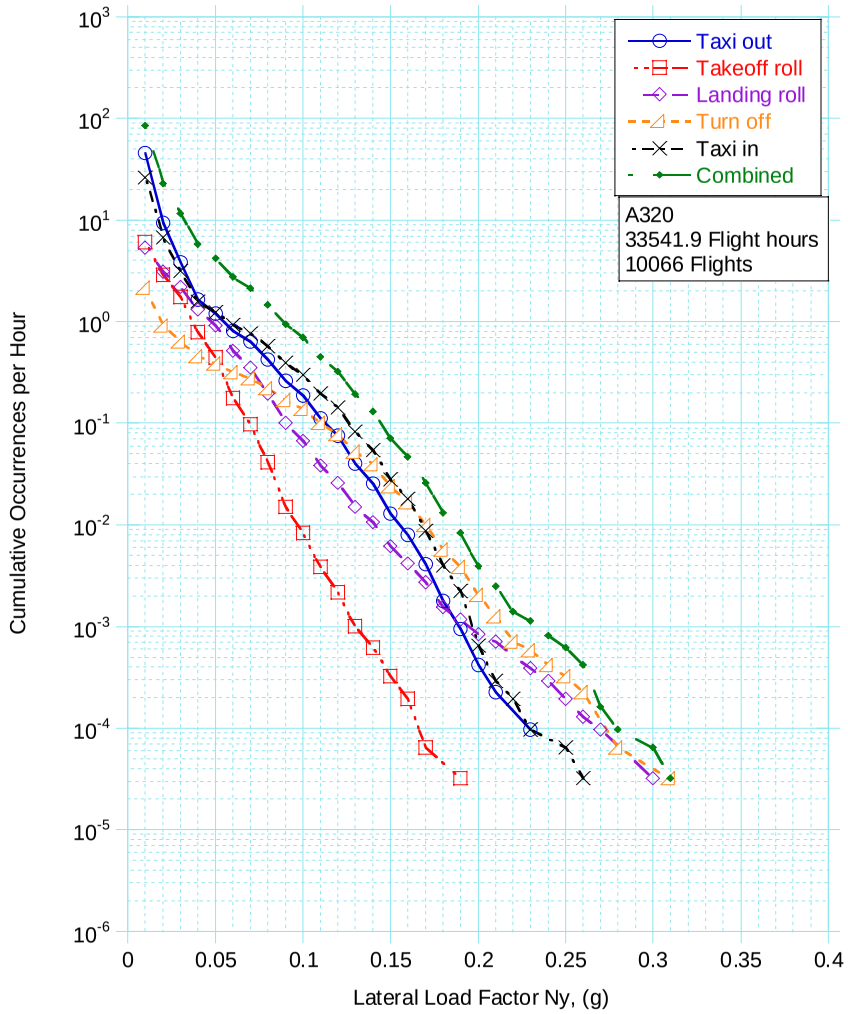

FIGURE A-26. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (A320)

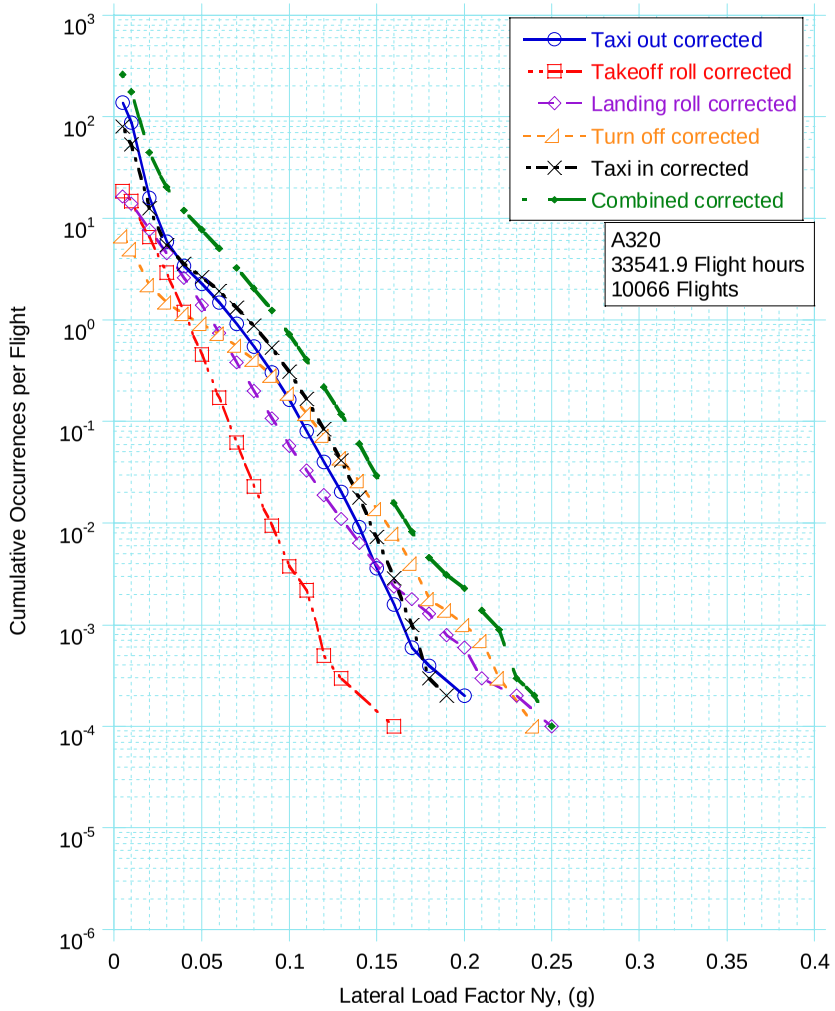

FIGURE A-27. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT BY GROUND PHASE (A320)

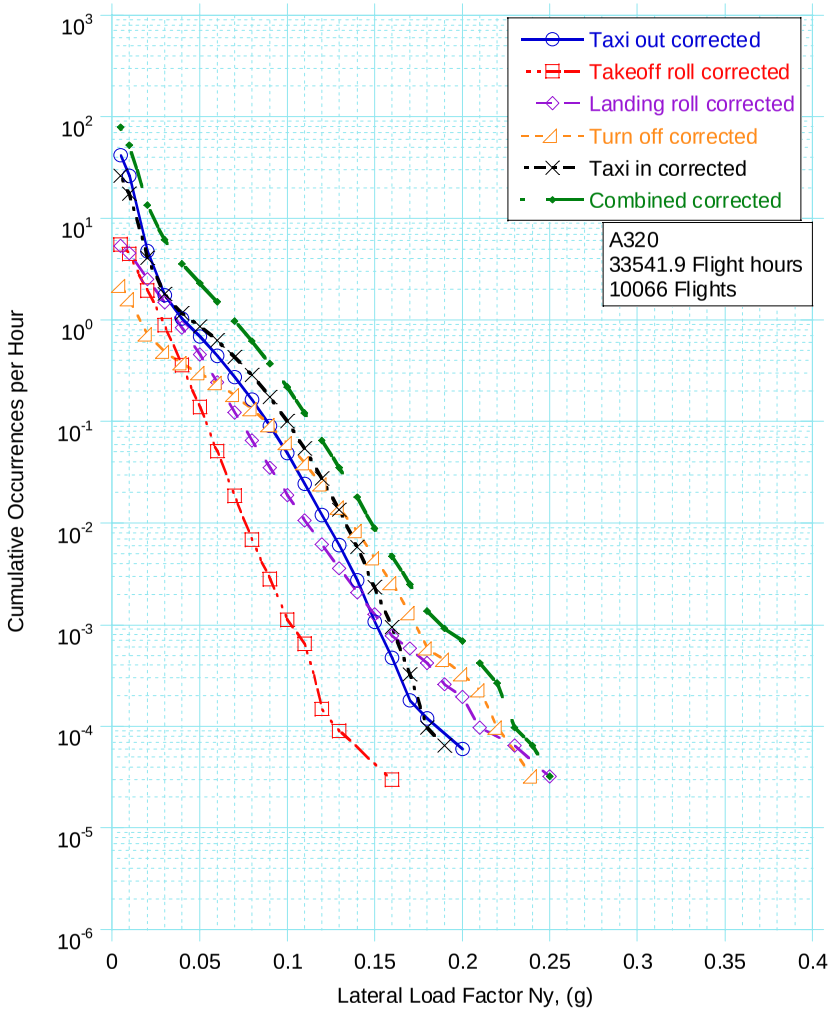

FIGURE A-28. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR BY GROUND PHASE (A320)

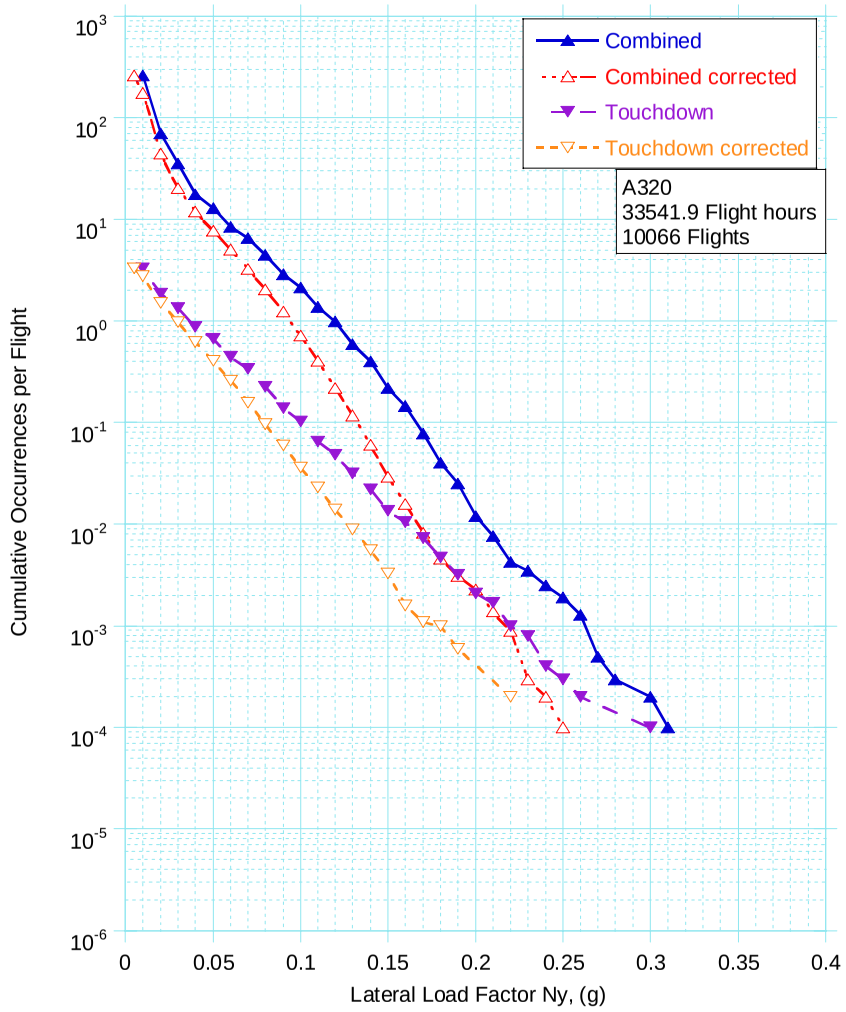

FIGURE A-29. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT BY GROUND PHASE (A320)

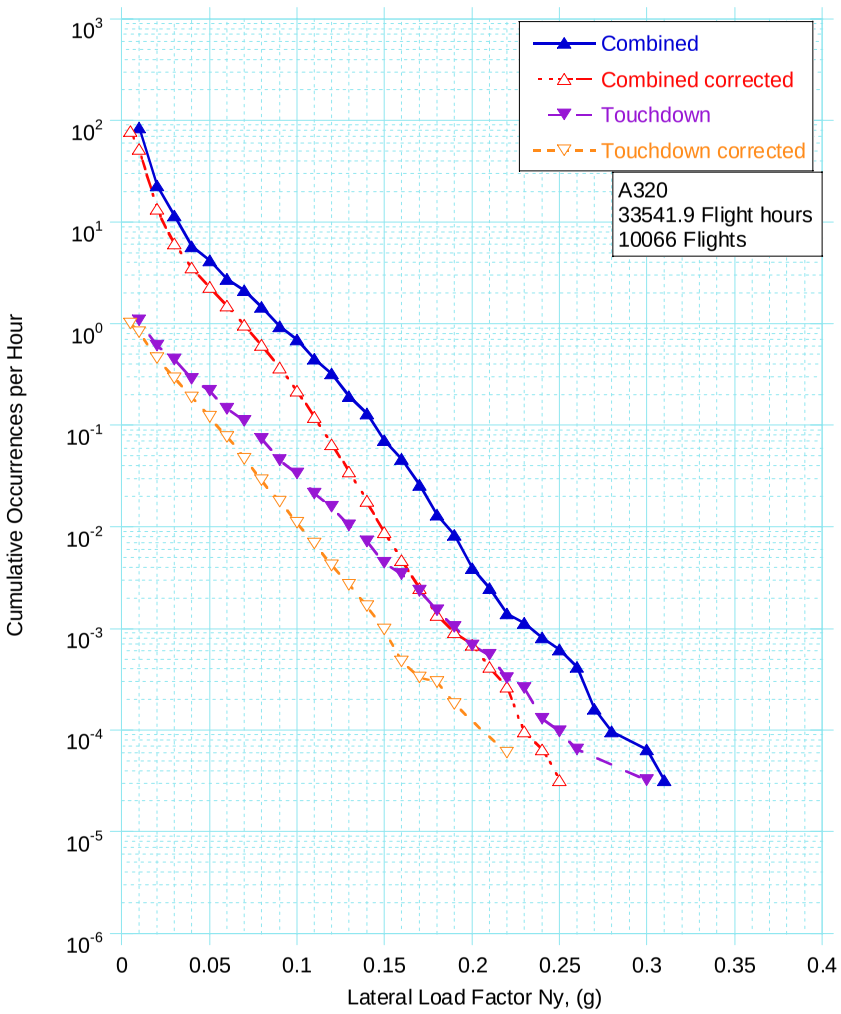

FIGURE A-30. SUMMARY CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR BY GROUND PHASE (A320)

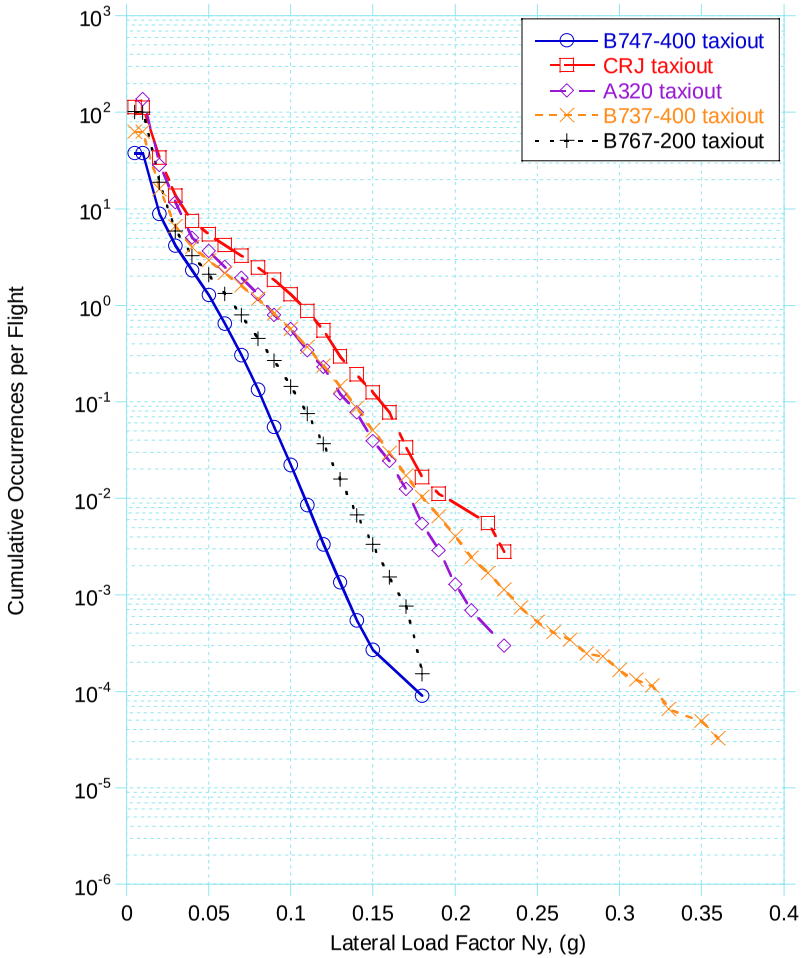

FIGURE A-31. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING TAXI-OUT BY AIRCRAFT MODEL

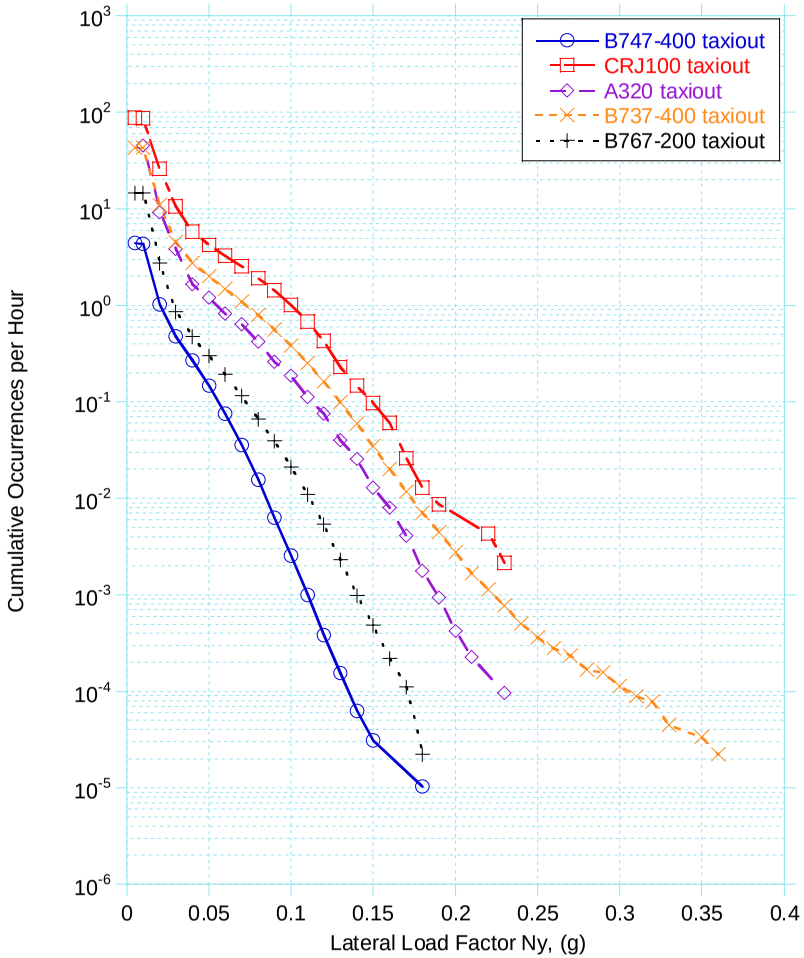

FIGURE A-32. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR DURING TAXI-OUT BY AIRCRAFT MODEL

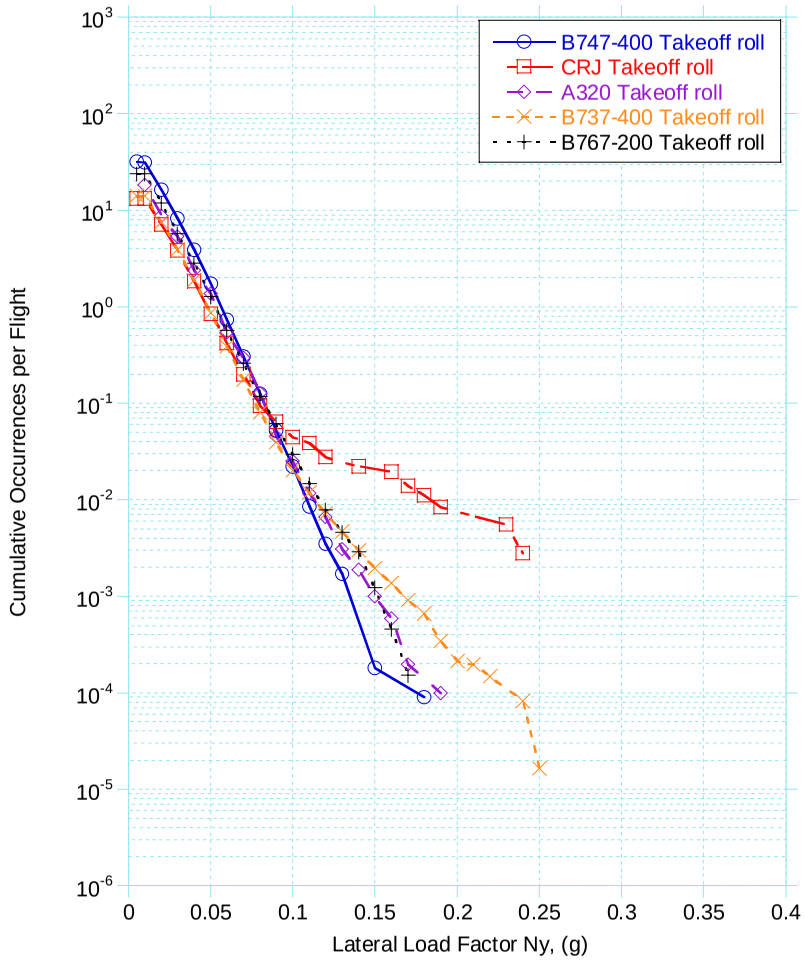

FIGURE A-33. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING TAKEOFF ROLL BY AIRCRAFT MODEL

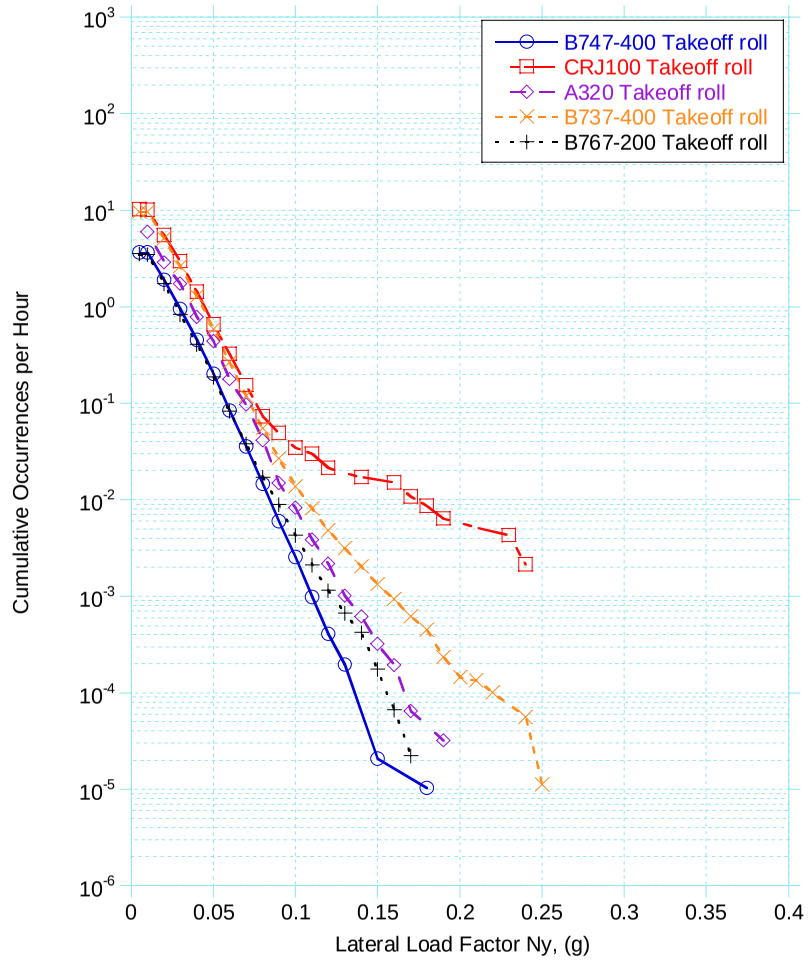

FIGURE A-34. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR DURING TAKEOFF ROLL BY AIRCRAFT MODEL

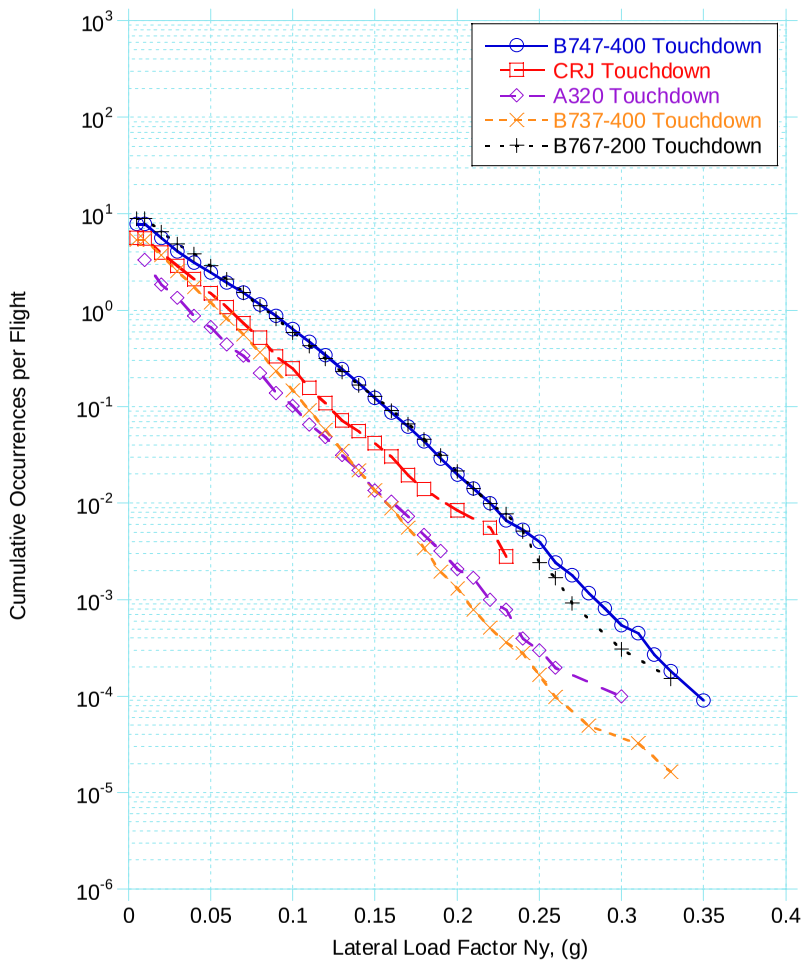

FIGURE A-35. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING TOUCHDOWN BY AIRCRAFT MODEL

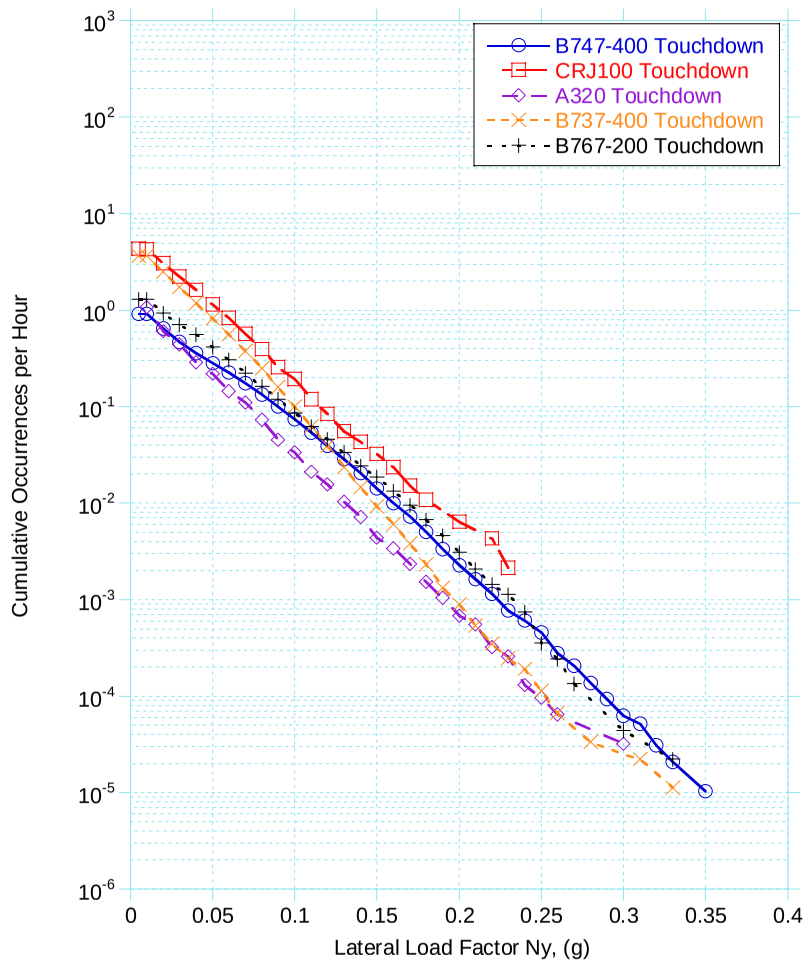

FIGURE A-36. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR DURING TOUCHDOWN BY AIRCRAFT MODEL

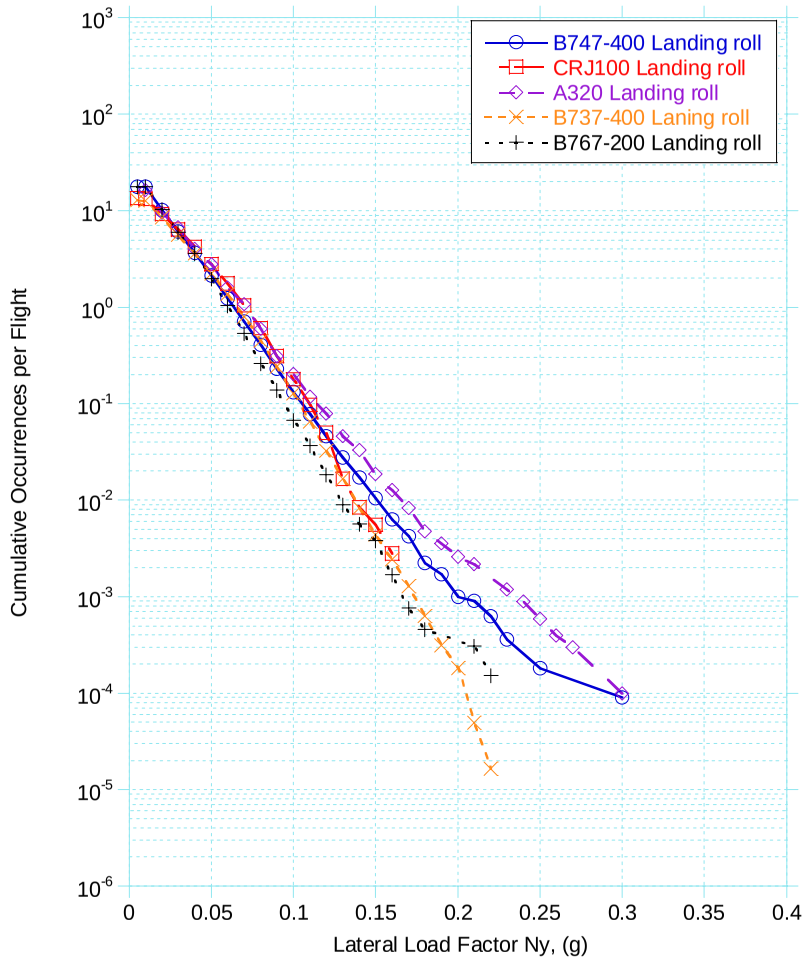

FIGURE A-37. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING LANDING ROLL BY AIRCRAFT MODEL

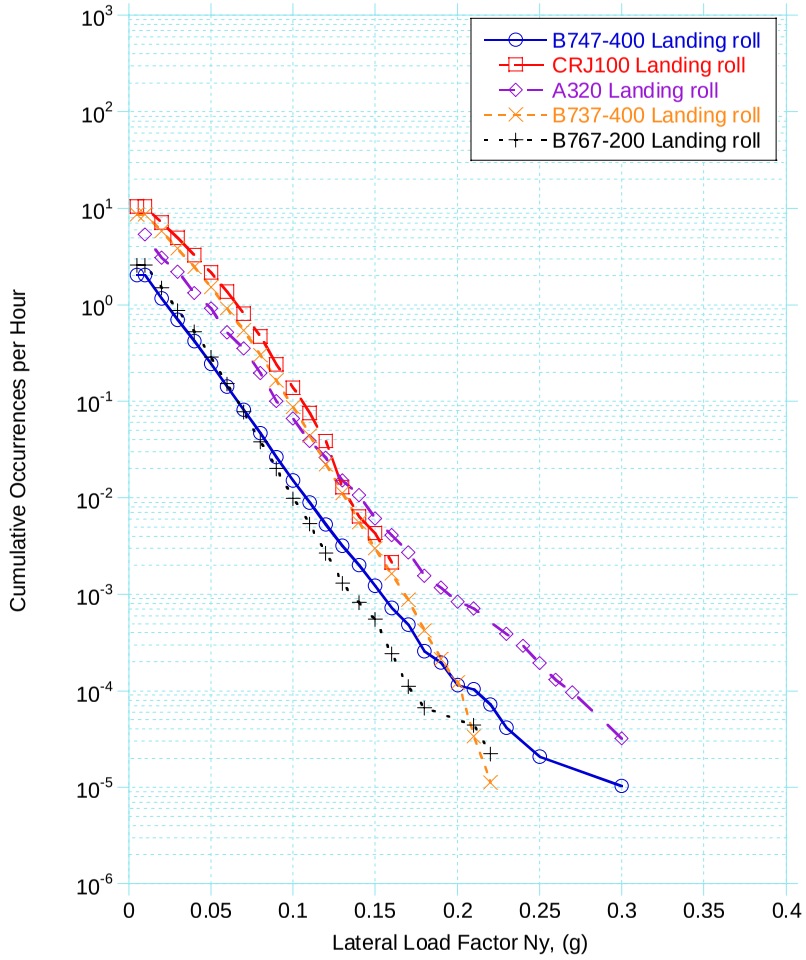

FIGURE A-38. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR DURING LANDING ROLL BY AIRCRAFT MODEL

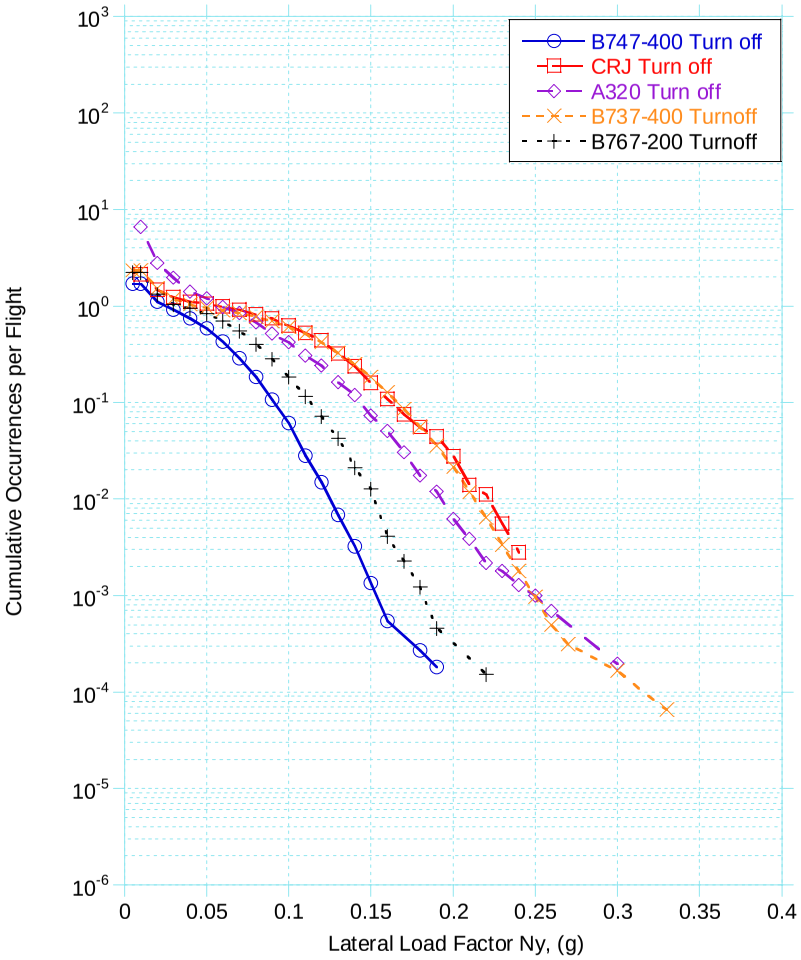

FIGURE A-39. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING RUNWAY TURNOFF BY AIRCRAFT MODEL

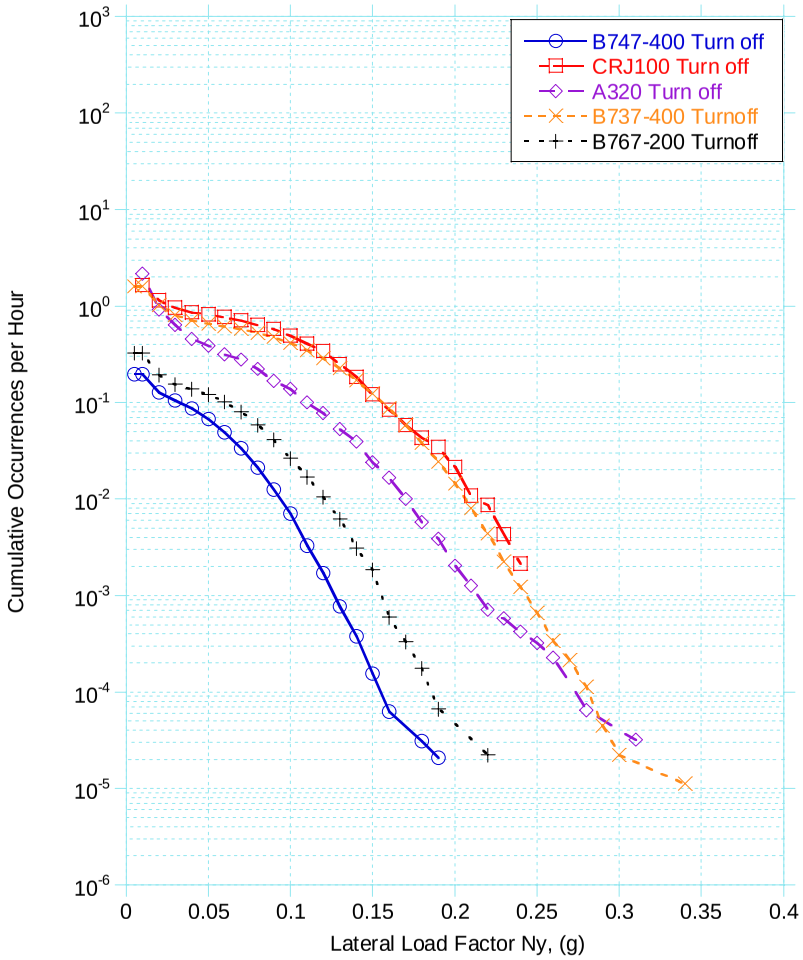

FIGURE A-40. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT HOUR DURING RUNWAY TURNOFF BY AIRCRAFT MODEL

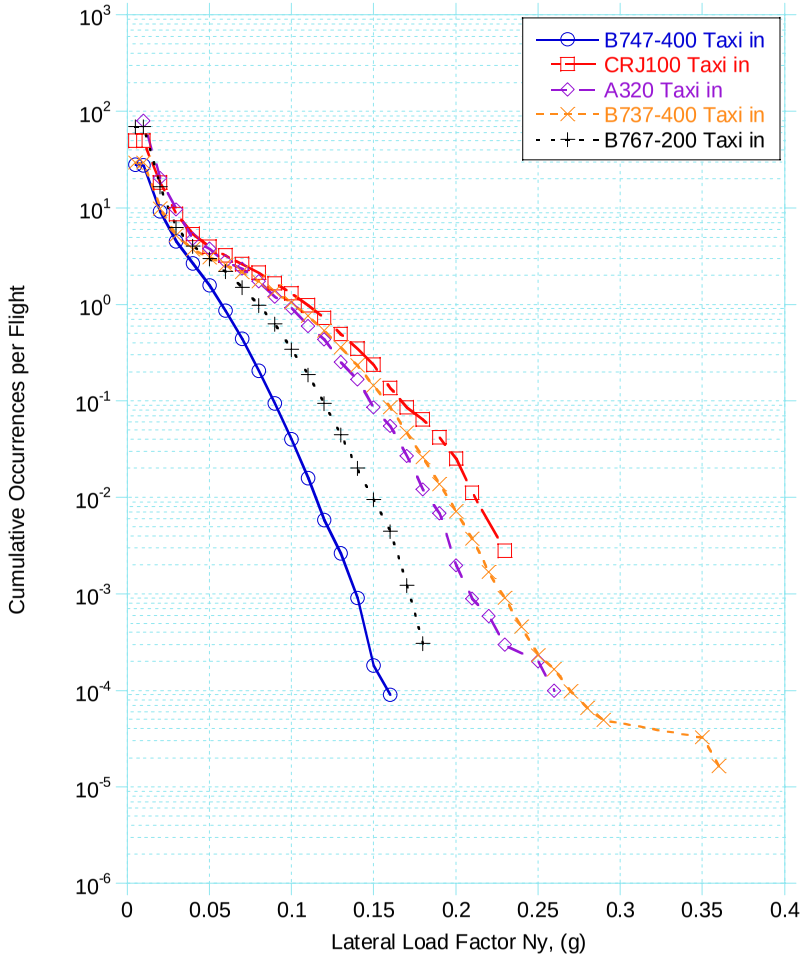

FIGURE A-41. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING TAXI-IN BY AIRCRAFT MODEL

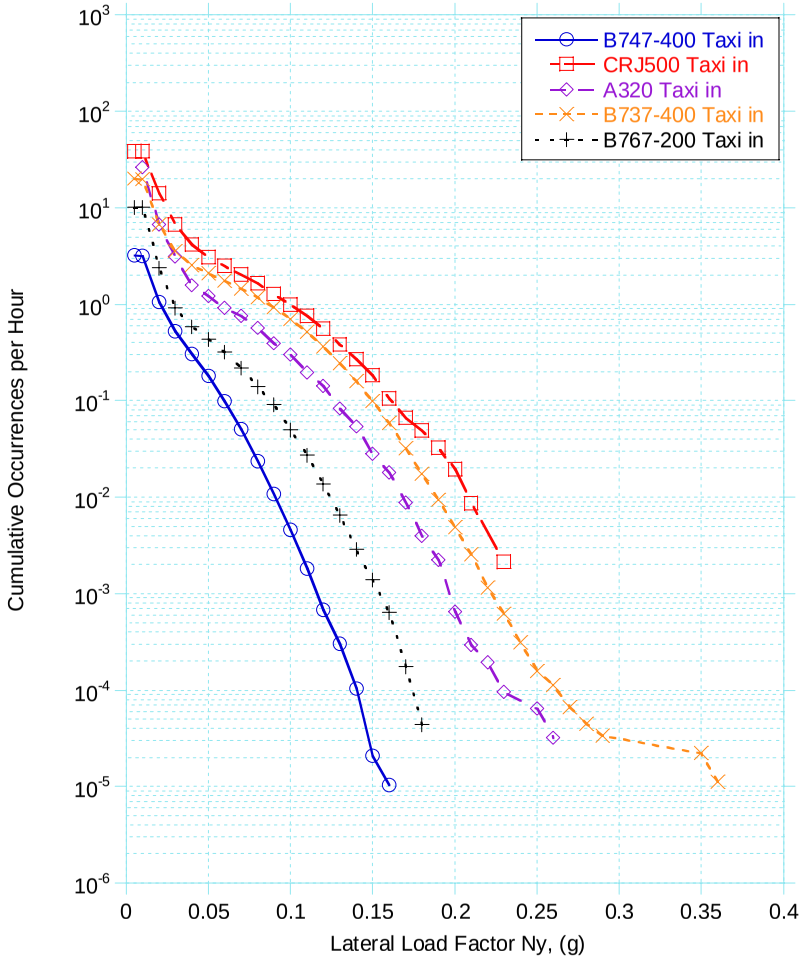

FIGURE A-42. CUMULATIVE OCCURRENCES OF LATERAL LOAD FACTOR PER FLIGHT DURING TAXI-IN BY AIRCRAFT MODEL

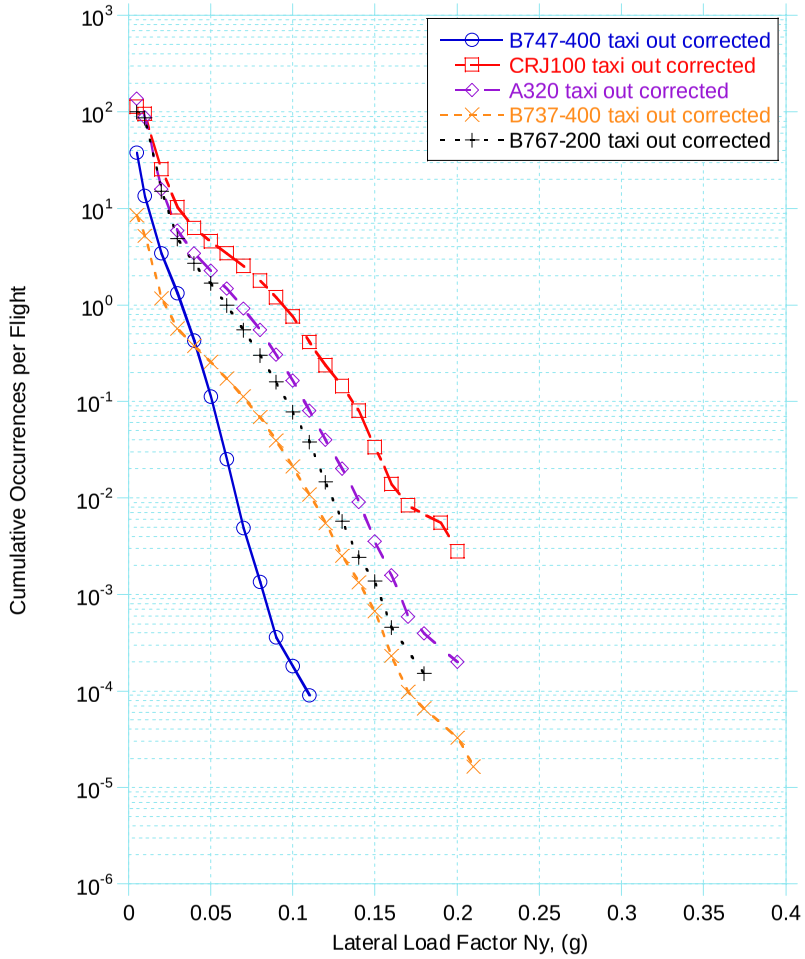

FIGURE A-43. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING TAXI-OUT BY AIRCRAFT MODEL

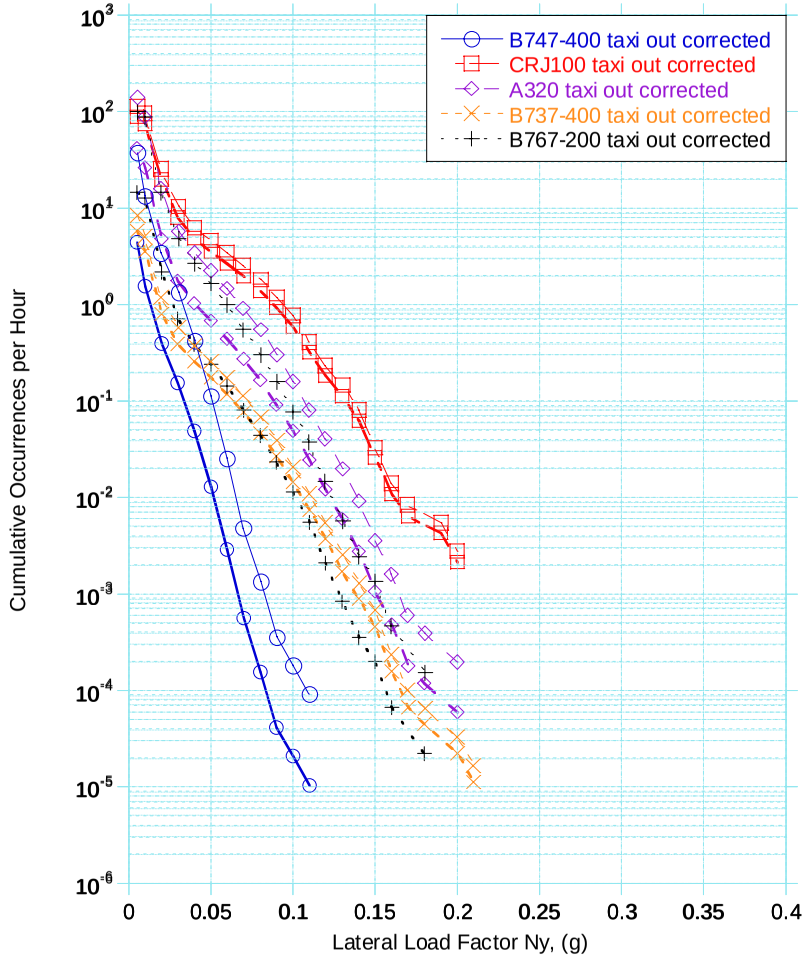

FIGURE A-44. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING TAXI-OUT BY AIRCRAFT MODEL

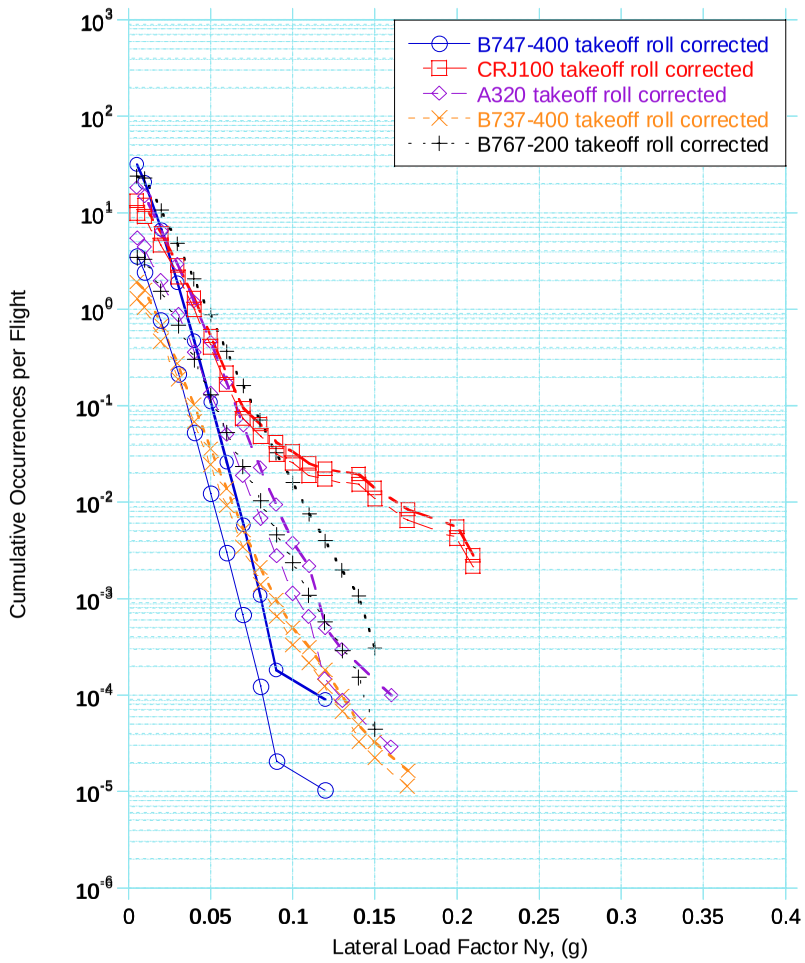

FIGURE A-45. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING TAKEOFF ROLL BY AIRCRAFT MODEL

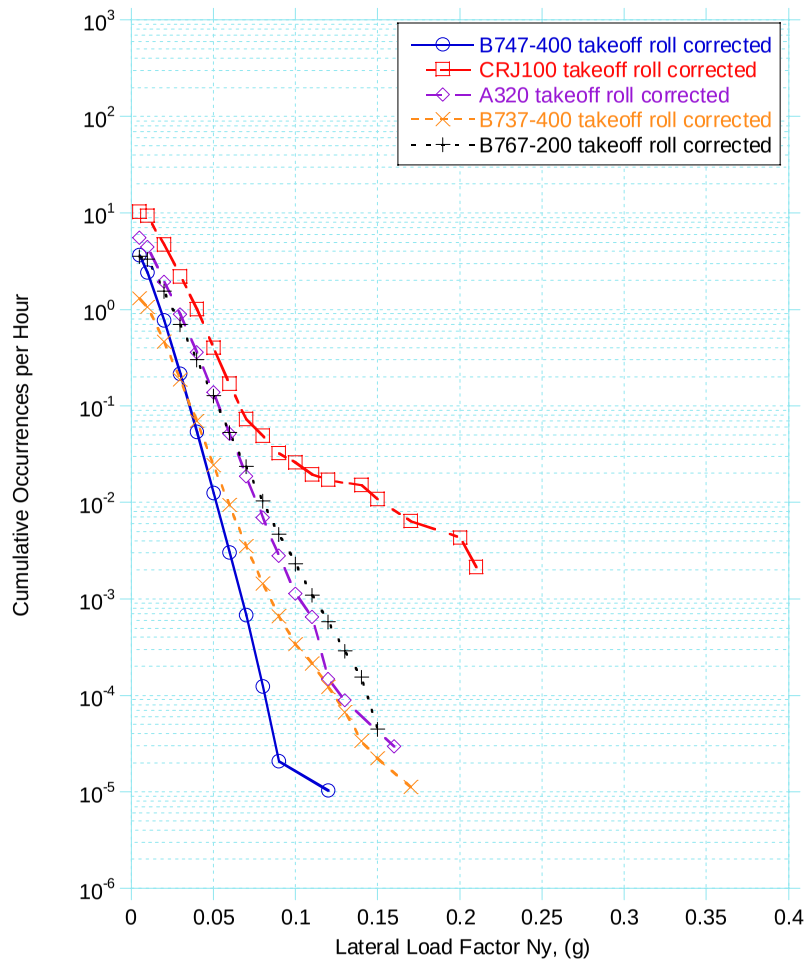

FIGURE A-46. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING TAKEOFF ROLL BY AIRCRAFT MODEL

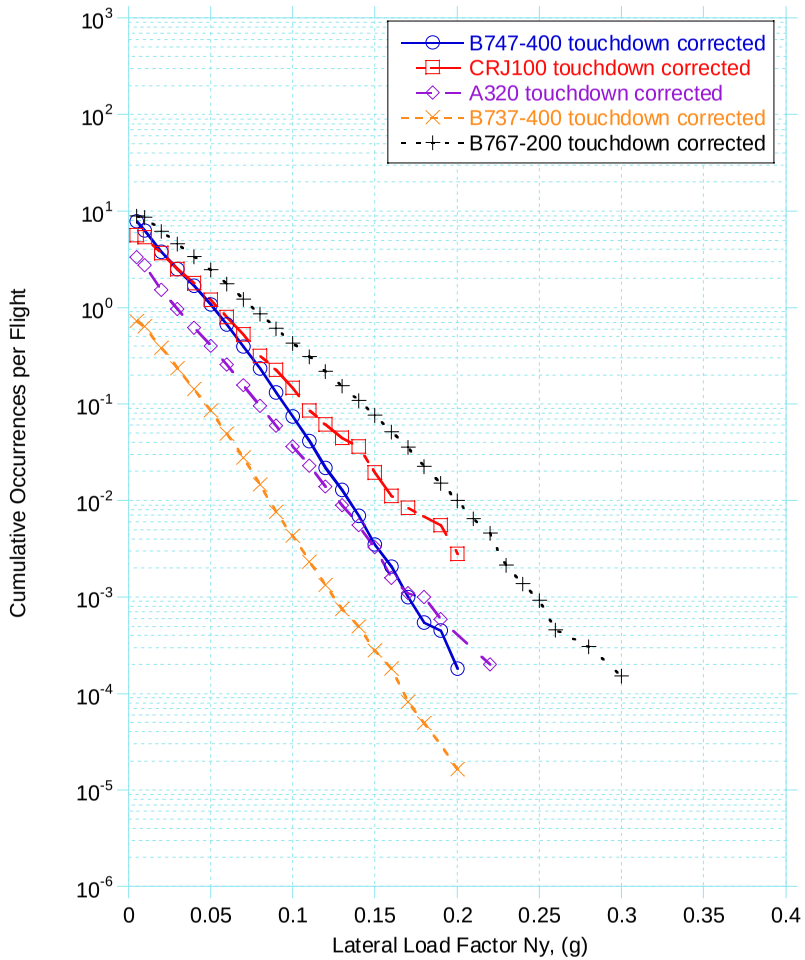

FIGURE A-47. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING TOUCHDOWN BY AIRCRAFT MODEL

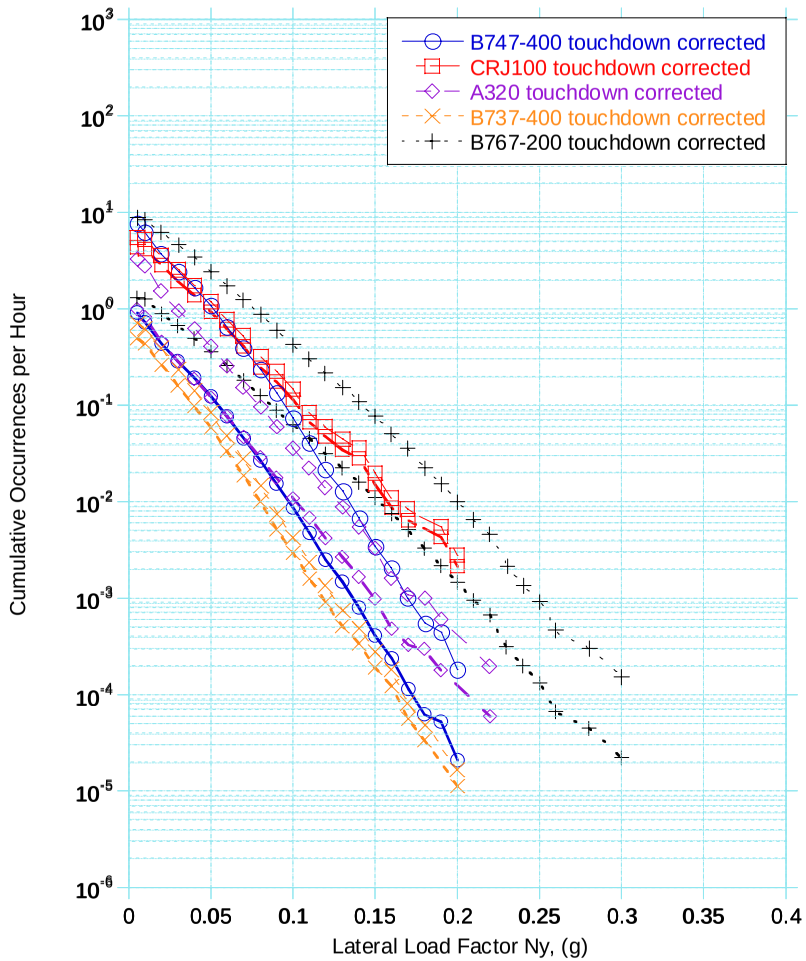

FIGURE A-48. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING TOUCHDOWN BY AIRCRAFT MODEL

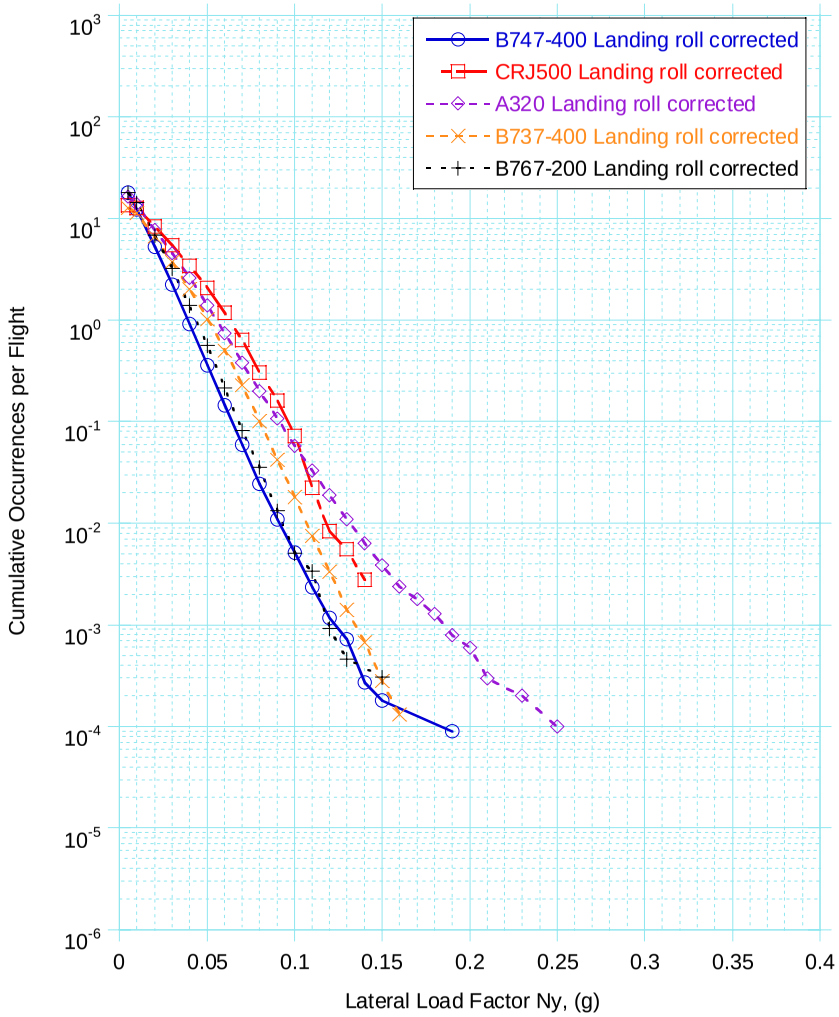

FIGURE A-49. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING LANDING ROLL BY AIRCRAFT MODEL

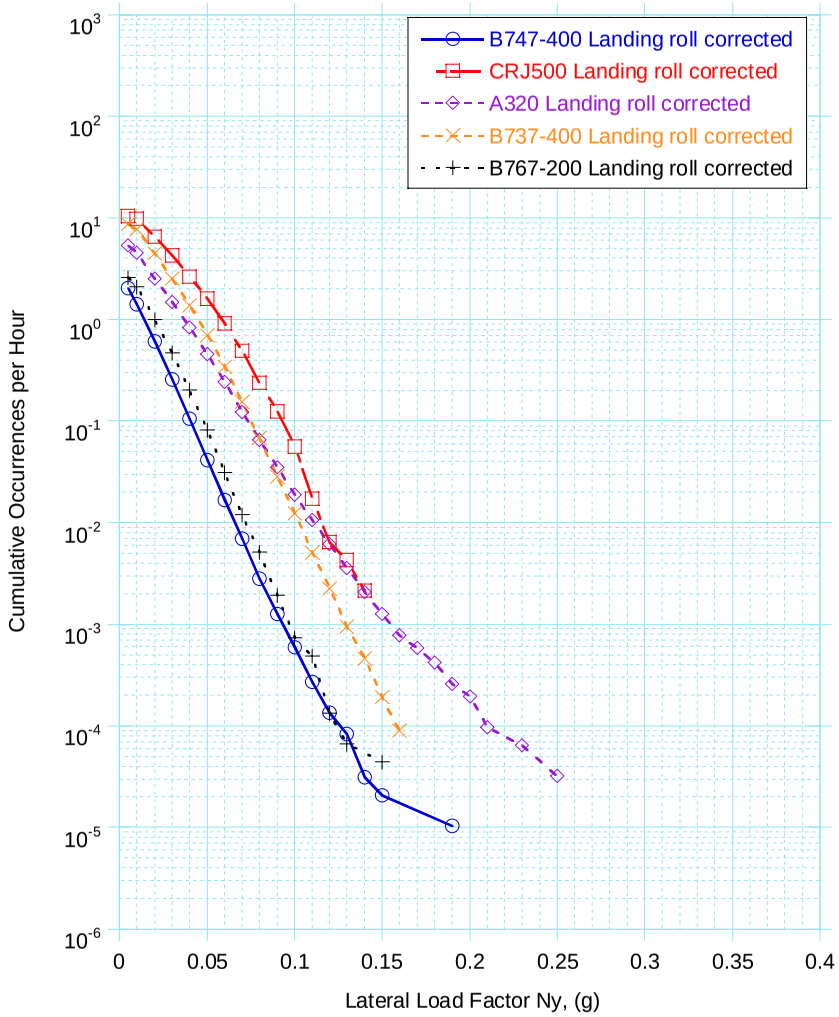

FIGURE A-50. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING LANDING ROLL BY AIRCRAFT MODEL

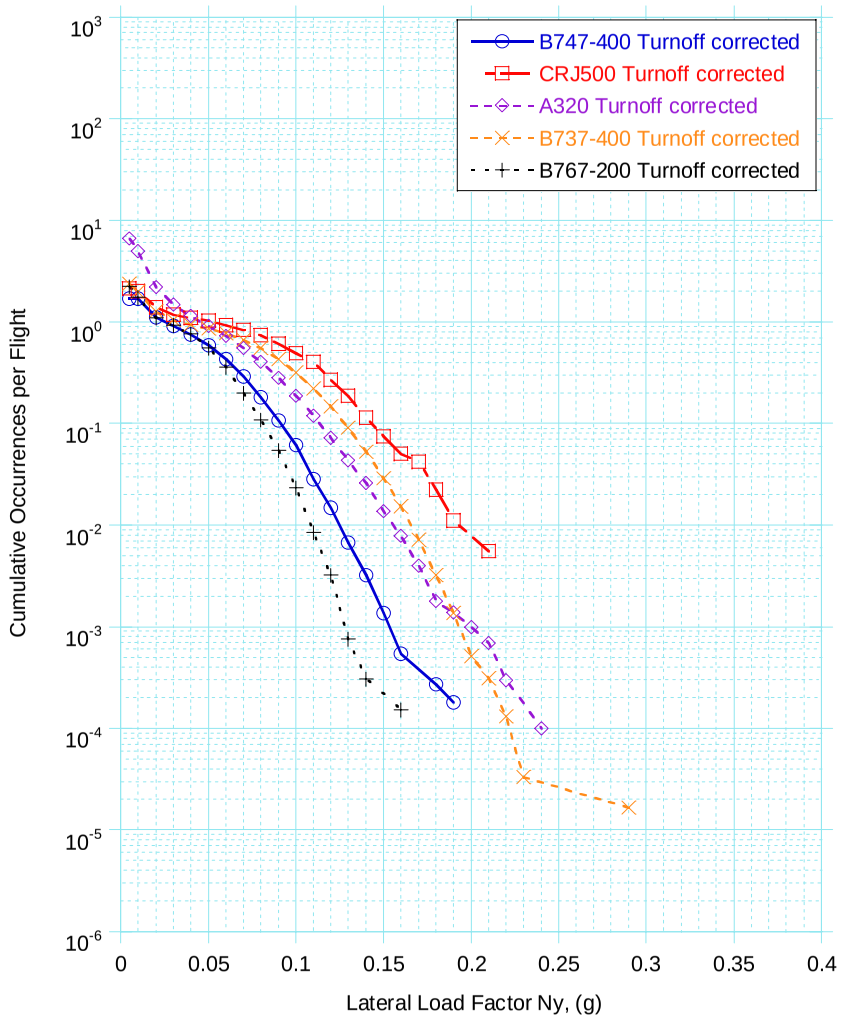

FIGURE A-51. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING RUNWAY TURNOFF BY AIRCRAFT MODEL

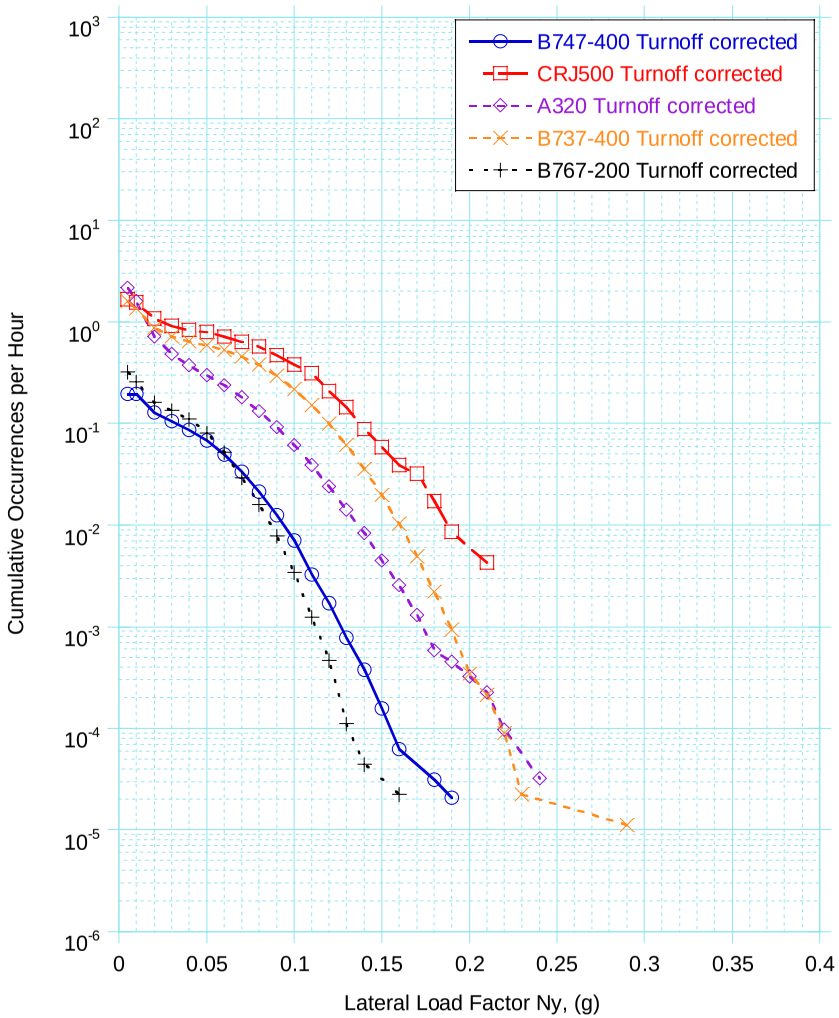

FIGURE A-52. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING RUNWAY TURNOFF BY AIRCRAFT MODEL

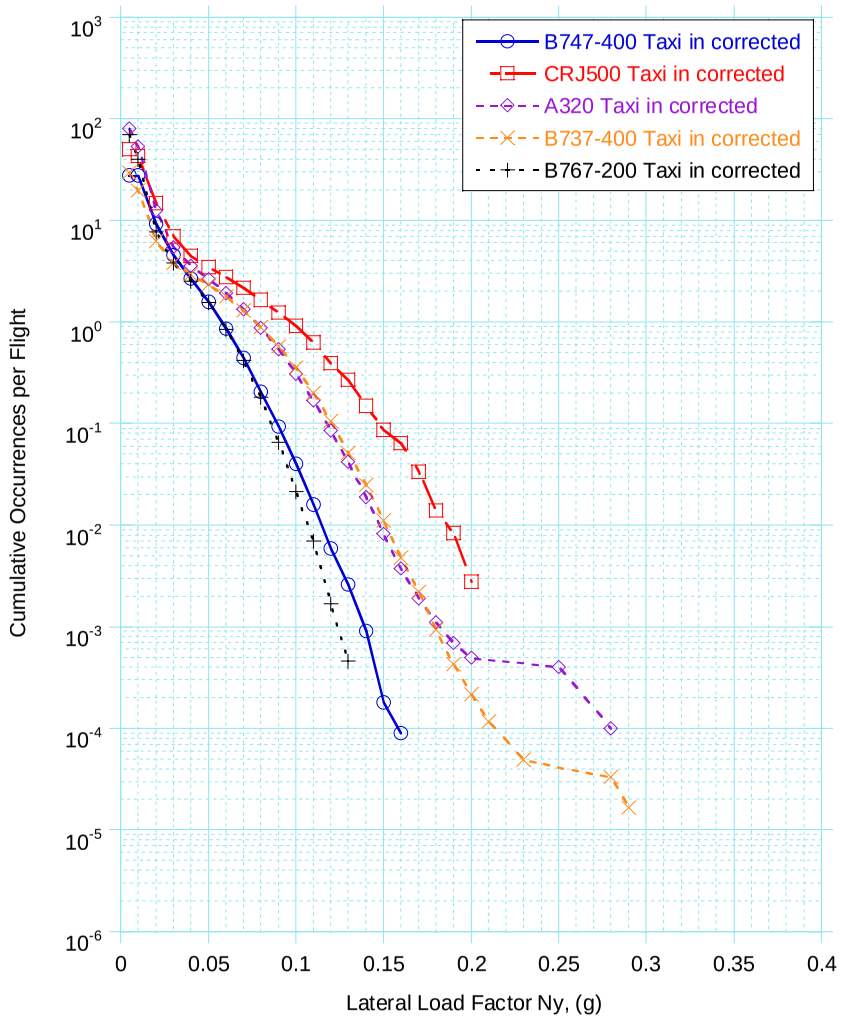

FIGURE A-53. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT DURING TAXI-IN BY AIRCRAFT MODEL

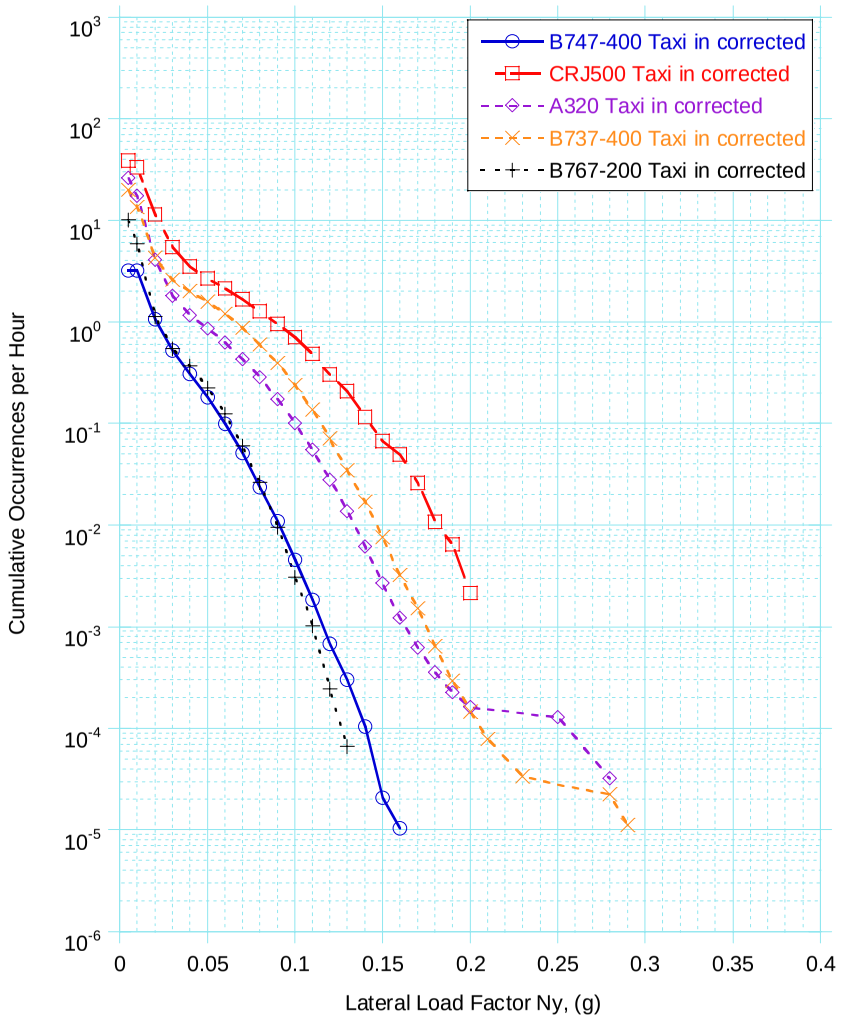

FIGURE A-54. CUMULATIVE OCCURRENCES OF (RECORDED WEIGHT/MAX LANDING WEIGHT)*Ny PER FLIGHT HOUR DURING TAXI-IN BY AIRCRAFT MODEL