DOT/FAA/AR-07/53

Air Traffic Organization
Operations Planning
Office of Aviation Research
and Development
Washington, DC 20591

Video Landing Parameter Survey—London Heathrow Airport

Thomas DeFiore
Richard Micklos

Federal Aviation Administration
William J. Hughes Technical Center
Airport and Aircraft Safety
Research and Development Division
Atlantic City International Airport, NJ 08405

November 2007

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-07/53		

4. Title and Subtitle	5. Report Date
VIDEO LANDING PARAMETER SURVEY—LONDON HEATHROW AIRPORT	November 2007
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Thomas DeFiore and Richard Micklos	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety Research and Development Division Airworthiness Assurance Research and Development Branch Atlantic City International Airport, NJ 08405	RPD-510
	11. Contract or Grant No. DTFACT-06-C-00021

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591	Final Report
	14. Sponsoring Agency Code ANM-110

15. Supplementary Notes

This video landing parameter survey was conducted jointly by personnel from the FAA William J. Hughes Technical Center and the Naval Air Warfare Center, Aircraft Division, Patuxant River, MD.

16. Abstract

Researchers from the Federal Aviation Administration (FAA) William J. Hughes Technical Center have been conducting a series of video landing parameter surveys at high-activity commercial airports to acquire a better understanding of typical landing contact conditions for a wide variety of aircraft and airports as they relate to current aircraft design criteria and practices.

This is the sixth of a series of landing parameter surveys. This report documents the results from a survey at London Heathrow Airport (LHR) performed in July 2001. Previous surveys were conducted first at John F. Kennedy International Airport (JFK) in June 1994 and later at Washington National Airport (DCA) performed in June 1995. Additional surveys were performed at Honolulu International (HNL), April 1996, London City Airport in July 1997, and Philadelphia International Airport in July 1999. At LHR, six video cameras were temporarily installed along the north side of runway 27R. Video images of 495 wide-body and 468 narrow-body transports were captured and analyzed, and the results are presented herein. Landing parameters presented include sink rate; approach speed; touchdown pitch, roll, and yaw angles and rates; off-center distance; and the touchdown distance from the runway threshold. Wind and weather conditions were also recorded, and landing weights were available for most landings. Since this program is only concerned with overall statistical usage information, all data were processed and are presented without regard to the airline or flight number.

This survey has reinforced the findings from the JFK and HNL surveys concerning the landing impact parameters of heavy, wide-body aircraft. The results from the LHR survey and the prior FAA video landing parameter surveys at JFK, HNL, and DCA differ substantially from aircraft sink speeds reported 45 years ago during landing parameter surveys conducted by the National Aeronautics and Space Administration (NASA). No other efforts to collect operational landing data were performed by either the FAA or NASA in the interim. The authors recommend that aircraft manufacturers use the landing parameter data contained in the recent FAA reports in lieu of the data in the older NASA reports.

17. Key Words	18. Distribution Statement
Landing parameters; Sink rate; Approach velocity; Pitch, roll, and raw angles; Heavy wide-body civil transports	This document is available to the U.S. 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	220	

ACKNOWLEDGMENT

The authors would like to recognize the other survey team members who worked long hours in making this Heathrow Video Landing Parameter Survey the most successful to date. The team members included: Gerry Walter and Jim Newcomb from the FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ, and John Daly, Lee Rosenstadt, Rick Kreuzberg, Melvin Arache, and David Elby from the Naval Air Systems Command, Patuxant River, MD.

The authors would also like to recognize David Wright and Andrew Goudie of the United Kingdom's Civil Aviation Authority Safety Regulation Group for assisting in making the arrangements for this survey and British Airways for providing critical scheduling and landing weight data. Finally, the authors would like to recognize the entire staff of Heathrow Airport Limited Operations, in particular, George Cook, General Manager, Airside, for permitting access to their airfield and providing considerable technical support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ARAC	Aviation Rulemaking Advisory Committee
DCA	Washington National Airport
FAA	Federal Aviation Administration
HNL	Honolulu International Airport
ILS	Instrument Landing System
JFK	John F. Kennedy International Airport
LCY	London City Airport
LHR	London Heathrow Airport
MIL-SPEC	U.S. Military Specification (Procurement Specification)
NAALDAS	Naval Aircraft Approach and Landing Data Acquisition System
NASA	National Aeronautical and Space Administration
PHL	Philadelphia International Airport
SF	Scale factor

EXECUTIVE SUMMARY

A joint survey team from the Federal Aviation Administration (FAA) William J. Hughes Technical Center and the Naval Air Warfare Center, Patuxent River, MD, has conducted a series of video landing parameter surveys at high-activity commercial airports. The goal of this research is to acquire a better understanding of typical landing contact conditions for a wide variety of aircraft and airports as they relate to current aircraft design criteria and practices.

This is the sixth in that series of landing parameter surveys. This report documents the results from a survey at London Heathrow International Airport (LHR) performed in July 2001. The initial landing parameter survey was performed at John F. Kennedy International Airport (JFK) in June 1994. A second survey was performed at Washington National Airport (DCA) in June 1995. Additional surveys were performed at Honolulu International Airport (HNL), April 1996, London City Airport (LCY) in July 1997, and Philadelphia International Airport (PHL) in July 1999. Subsequent to the LHR survey, additional landing parameter research was conducted at the Atlantic City International Airport, NJ, during 2002 and 2003 and a final survey performed in September 2004 in Cincinnati, OH.

Six video cameras were installed along the north edge of runway 27R at LHR and image sequences of aircraft landings were recorded. Subsequent processing and analysis of these images provided the following landing parameters: sink rate; approach speed; touchdown pitch, roll, and yaw angles; off-center distance; and the touchdown distance from the runway threshold. Wind and weather conditions were also recorded, and landing weights were collected for a limited number of wide-body aircraft. Since this program is only concerned with overall statistical usage information, all data were processed and are presented without regard to the airline or flight number.

This survey supports the findings from the earlier JFK and HNL surveys regarding the higher mean sink rates of heavy, wide-body aircraft. This survey was also the first opportunity to collect landing parameter data for an Airbus wide-body aircraft in commercial service and has identified some unique landing characteristics of that aircraft. The results from this research effort, as well as the prior landing parameter surveys at JFK and HNL, differ substantially from aircraft sink speeds reported 45 years ago during the National Aeronautics and Space Administration (NASA) surveys. The NASA research found that mean jet aircraft sink rates were 1.6 ft/sec. In contrast, the current series of FAA surveys have found mean sink rates in the order of 2.0 to 3.5 ft/sec, depending on aircraft type. Even more importantly, the NASA data observed a maximum sink rate of 4.2 ft/sec during its survey of 106 jet transports, while current FAA surveys have observed maximum sink rates of 8.0 ft/sec or more. No other efforts to collect operational landing data were performed by either the FAA or NASA in the interim. The authors recommend that aircraft manufacturers use the landing parameter data contained in the recent FAA reports in lieu of the data in the older NASA reports.

1. INTRODUCTION.

In an effort to better understand and document the actual landing impact conditions in the operational environment of commercial jet transport aircraft, the Federal Aviation Administration (FAA) William J. Hughes Technical Center initiated a series of aircraft video landing parameter surveys at high-activity commercial airports. By collecting and analyzing large quantities of video data for a wide variety of aircraft, the original design criteria and fatigue-life estimates for aircraft landing gear and support structures can be assessed and verified. The operational data will also aid in developing certification and design requirements for future jet transports.

The use of image data to evaluate the landing performance of aircraft has been used since jet aircraft were introduced to military and, later, to commercial service. In 1947 [1], the U.S. Navy first developed a system to characterize the typical carrier landing environment and implemented procedures to make carrier arrested landings safer. The Navy system acquired aircraft landing and approach data from the tracking and analysis of recorded 16-mm film images of the arrestment. In 1954, the National Aeronautics and Space Administration (NASA) developed a similar system using a 35-mm camera and conducted a number of surveys of commercial airplanes, the last ones in 1959 [2-7]. The difference between the two systems was that the Navy photographed from a head-on aspect along the runway apron, while NASA's camera was positioned perpendicular to the runway, approximately 900 feet from the runway centerline.

In 1967, the Navy enhanced its system by replacing the 16-mm cameras with 70-mm cameras to provide considerably greater image resolution and consequently greater accuracy [8]. Using the enhanced system, the Navy conducted over 40 landing parameter surveys. However, the data reduction phase of the research was labor intensive and limited the number of surveys that could be conducted. The search for a new improved system was concluded in 1992 when the Navy successfully developed and implemented a system that uses adaptive video imaging and tracking technology for their surveys. The performance and accuracy of this system is documented in references 9 and 10. Shortly thereafter, the FAA and the Navy transitioned the newly developed video technology to commercial operations [11].

The objectives of the FAA landing parameter survey program are to acquire large amounts of typical transport operational data to (1) replace NASA TN D 4529, which was derived from usage data measured during the 1950s, (2) provide detailed characterization of typical transport airplane landing velocities and angular displacements, and (3) determine if there is a trend towards higher sink rates at higher gross weights.

The first of the FAA's commercial aircraft video landing surveys was conducted in 1994 at John F. Kennedy International Airport (JFK), runway 13L, to collect large quantities of wide-body jet aircraft data [12]. The second survey was performed in 1995 at Washington National Airport (DCA), which collected landing parameters for narrow-body aircraft operations on a shorter runway [13]. The primary arrival runway (runway 36) at DCA is 7000 ft long and cannot handle aircraft larger than the Airbus A320 and Boeing 757.

The next survey, conducted at Honolulu International Airport (HNL) in 1996, focused on wide-body aircraft [14]. This survey confirmed preliminary findings from the JFK survey concerning

the apparent increase of aircraft sink speed with increasing aircraft landing weight. The next two surveys, London City Airport (LCY) and Philadelphia International Airport (PHL), collected data on commuter aircraft operations. LCY has a single 3800-ft runway and uses a 5.5 degree glide slope. This is a severe operating environment, and the survey documented the sink speeds resulting from these operations. The survey at PHL recorded operations of commuter aircraft on the 5459-ft-long runway 17, which is restricted to commuter aircraft operation. The results from both these commuter surveys are documented in reference 15.

The London Heathrow Airport (LHR) survey was conducted in response to a joint FAA, United Kingdom Civilian Aviation Authority, and Aviation Rulemaking Advisory Committee (ARAC) requirement. The goal of the LHR survey was to generate reliable landing ground impact certification data for use in evaluating industry's planned A380 size aircraft. These ultralarge airplanes are expected to land with touchdown gross weights of up to 3/4 million pounds. LHR was recommended by ARAC because it has only two main runways and accepts nearly 100 heavy wide-body arrivals daily. A copy of the LHR Survey Test Plan is included as appendix A. LHR also provided an opportunity to compare the landing performance of Boeing and Airbus wide-body airplanes. Previous surveys collected only minimal data on Airbus wide-body aircraft landings (A300/310 only).

Video images of aircraft landing on LHR's runway 27R were recorded by a series of six cameras temporarily installed on the edge of the runway. Runway 27R was selected for the easy access it provided the survey team to get to the runway site. It also offered the most practical location for survey equipment installation. The survey data was collected over a 2-week period in June and July 2001. These video images were stored on an optical disk recorder, processed, and analyzed at the Naval Air Warfare Center, and the resulting landing parameter information was forwarded to the William J. Hughes Technical Center for final analysis and publication.

Since the primary goal of the survey was to collect statistical information on actual operations, the identity of individual aircraft, airlines, flight numbers, and dates are purposefully omitted from the report. Aircraft landing performance was analyzed only on the basis of aircraft category, model, type, and wind conditions.

2. SYSTEM DESCRIPTION.

Significant developments in video technology permitted the Navy to transition its landing parameter data analysis system from using photographic film to one using video technology. The Navy video system is known as the Naval Aircraft Approach and Landing Data Acquisition System (NAALDAS). The system consists of a high-resolution frame grab video camera, a laser disk recorder, and a computer control unit. The key to the NAALDAS system is a highly modified video camera. The camera's enhanced vertical resolution (double that of standard video formats) permits highly accurate measurement and tracking of aircraft position data. The camera is supported by an image analysis system using image processing technology. Particular image features (landing gear wheels, wing tips, flaps, or engine inlets) are tracked in successive images, and this information is used to determine the relative motion of the aircraft. The combination of camera resolution and image processing technology permits the location of image features to be determined within 0.1 pixel. The technique is as accurate as the Navy's

previously used 70-mm film system, yet more efficient. The accuracy of the sink speed measurements of the video system are documented in appendix B.

NAALDAS was designed to cover the restricted touchdown area on an aircraft carrier using a single camera. To support use at commercial airports, the FAA funded the design and development of a modified, multiple-camera configuration of NAALDAS, using four video cameras located along the edge of the runway. The images from these cameras are recorded sequentially as the aircraft passes through their field of view. The use of four cameras expands the system coverage area to approximately 2000 ft along the anticipated touchdown region of the runway. Fiber-optic signal cables are used to eliminate interference and line losses between the cameras and the recording station. The modified configuration of NAALDAS was successfully tested in February 1994 at the William J. Hughes Technical Center, Atlantic City International Airport, NJ. Figure 1 shows a camera in operation on a commercial runway.

Figure 1. Video Camera in Operation During Commercial Landing Parameter Survey

The video cameras were installed on the edge of the runway, facing the approaching aircraft. The cameras are located approximately 500 feet apart, starting 1600 feet from the end of the runway. Each camera is aimed at the center of a selected region of the expected touchdown area. The camera's aim is fixed and does not track the aircraft.

The NAALDAS video cameras have a fixed field of view. Each camera is aligned and calibrated against temporary alignment targets, which are placed on the runway for that purpose. These targets are placed in surveyed locations, and the target images are recorded as a calibration sequence. This sequence is processed to generate a transformation matrix to relate image measurements to the runway.

The NAALDAS data recording system is operated from a trailer placed in a safe location near the touchdown region of the survey runway. Judicious selection of this location is required to prevent any interference with airport operations. Temporary fiber-optic cabling is run from the vehicle to the cameras and the vehicle remains in the chosen location during flight operations. The system is powered entirely with portable electrical generators. Currently, NAALDAS is limited to coverage of one end of a runway and cannot be relocated to accommodate runway changes. This restriction exists since the cameras must be precisely aimed and recalibrated if

they are relocated, which requires the runway to be closed. Figure 2 shows the multiple camera configuration.

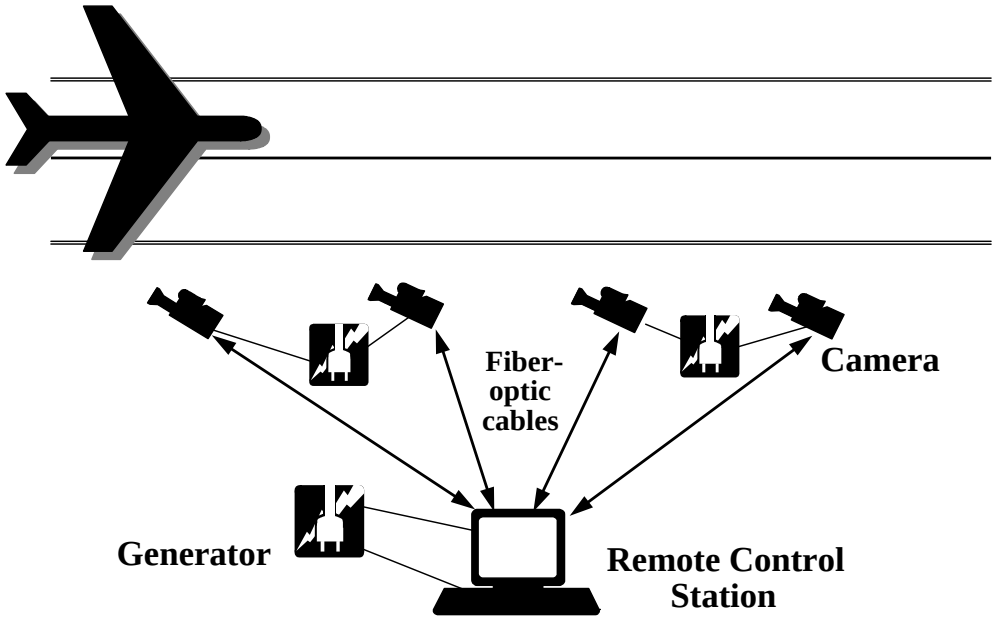


Figure 2. The FAA Landing Loads Camera Setup

The aircraft image is captured on an optical laser disk recorder for subsequent analysis on the NAALDAS analysis system workstation. Approximately 60 landings can be stored on a disk. An identity number is assigned to the disk, and event numbers are assigned to each video sequence. The use of video disks eliminates film processing cost and time.

Image enhancement and automatic data point tracking are performed using the analysis workstation. This provides position time information of image features on the aircraft. Each individual airplane landing is identified by model type and serial number so that the necessary physical dimensions and geometric locations can be correlated with the time-tracked video images. The data reduction system software then derives the landing impact parameters, i.e., sinking speed, horizontal velocity, bank angle, crab angle, etc.

The analysis station consists of a Sun® Microsystems computer workstation with an image processing board, laser disk player, computer monitor, high-resolution monitor, and associated power regulator and cables. The station operator automatically tracks the video image features during the landing sequence. By positioning windows over the desired image feature, the operator prepares the system to track that feature through the entire sequence. Multiple-image features can be tracked simultaneously using multiple windows. The operator has the capability to select image threshold levels, image enhancement formats, and algorithms. The operator can also select the type of tracking (edge or centroid) to be used to allow the system to automatically track the image, eliminating the errors in data reduction that were inherent in the manual tracking

procedures used with the 70-mm film system. The centroid tracking algorithm enables the system to locate image features with subpixel accuracy.

Once the image sequence is tracked, the pixel information is transformed, digitized, and entered into the landing parameter analysis software. The software takes image position information, determines the change in image feature position of successive frames at a rate of 30 frames per second, and generates position time curves for the feature.

The analysis of image data provides the aircraft's closure speed with respect to the camera. The reported value of approach speed is the sum of closure speed and the component of wind parallel to the centerline of the runway. The wind speed and direction information was measured using an anemometer situated near the touchdown location and was used to calculate the approach speed.

In addition to the video images, from which the ground contact parameters are derived, other data describing each landing are collected during the video survey to determine which set of geometric data to use in the analysis. An estimate of the aircraft's touchdown landing weight was provided by the aircraft operators.

3. DISCUSSION.

3.1 OPERATIONS AT LHR.

LHR is a primary hub for international flight operations out of the United Kingdom, as well as for transatlantic service between Europe and North America. In fact, it is the busiest international hub airport in the world. Over 90 major airlines from around the world operate from this airport, serving over 180 destinations. LHR has two primary runways, with over 1000 aircraft movements per day. The primary runways are oriented in an east to west direction. Review of LHR prior operational usage data showed that approximately 70% of all landings and departures were from Runway 27L or 27R, i.e., east to west. Both primary runways are over 12,000 feet long and use a 3.0-degree glide slope. In an effort to control aircraft noise and environmental impact, takeoffs and landings are scheduled to switch between the runways at 3:00 p.m. local time. At that time, the runway used for takeoffs switches to landing operations, while the opposite switch is made on the other runway. Also, from week to week, the runway accepting landings in the morning is switched. As a result of these procedures, the survey team was able to record landings during morning and early afternoon the first week of the survey and landings in the late afternoon and early evening during the second week. The video system can only record daylight operations.

3.2 LONDON HEATHROW AIRPORT CONDITIONS.

The video landing survey data acquisition equipment was installed on the north side of runway 27R, a 164-foot-wide, 12,802-foot-long runway. Runway 27R was selected after observing flight operations and reviewing expected wind conditions and historical landing runway operations data. In addition, runway 27R offered suitable unintrusive video camera positions. Normally, once the survey cameras are installed and calibrated, they cannot easily be moved to adjust to changes in operation caused by wind shifts.

During the survey period, winds were primarily from the west, and only 3 days of data collection were lost because of operations using the opposite end of the surveyed runway. Weather was clear, warm, and dry during the entire survey period. Temperatures ranged between 59° and 77°F, winds were measured up to 26 knots. The maximum crosswind recorded was 15.6 knots. The approach plate describing landing procedures for runway 27R is shown as figure 3. The survey test plan is included as appendix A.

An additional consideration for the survey team was that runway 27R-9L was being resurfaced concurrently with the conduct of the survey. Each night (midnight to 6 a.m.) approximately 200-300 feet of the runway was resurfaced, starting at 27R in the direction of 9L. In addition, with LHR being a slot-limited airfield, there was no opportunity to do any work on or near the runway in daylight. All of the camera installations, calibration, and teardown had to be done during the overnight shift concurrently with the runway-resurfacing event.

In spite of these abnormal conditions, the video survey was successfully conducted and has provided reliable results.

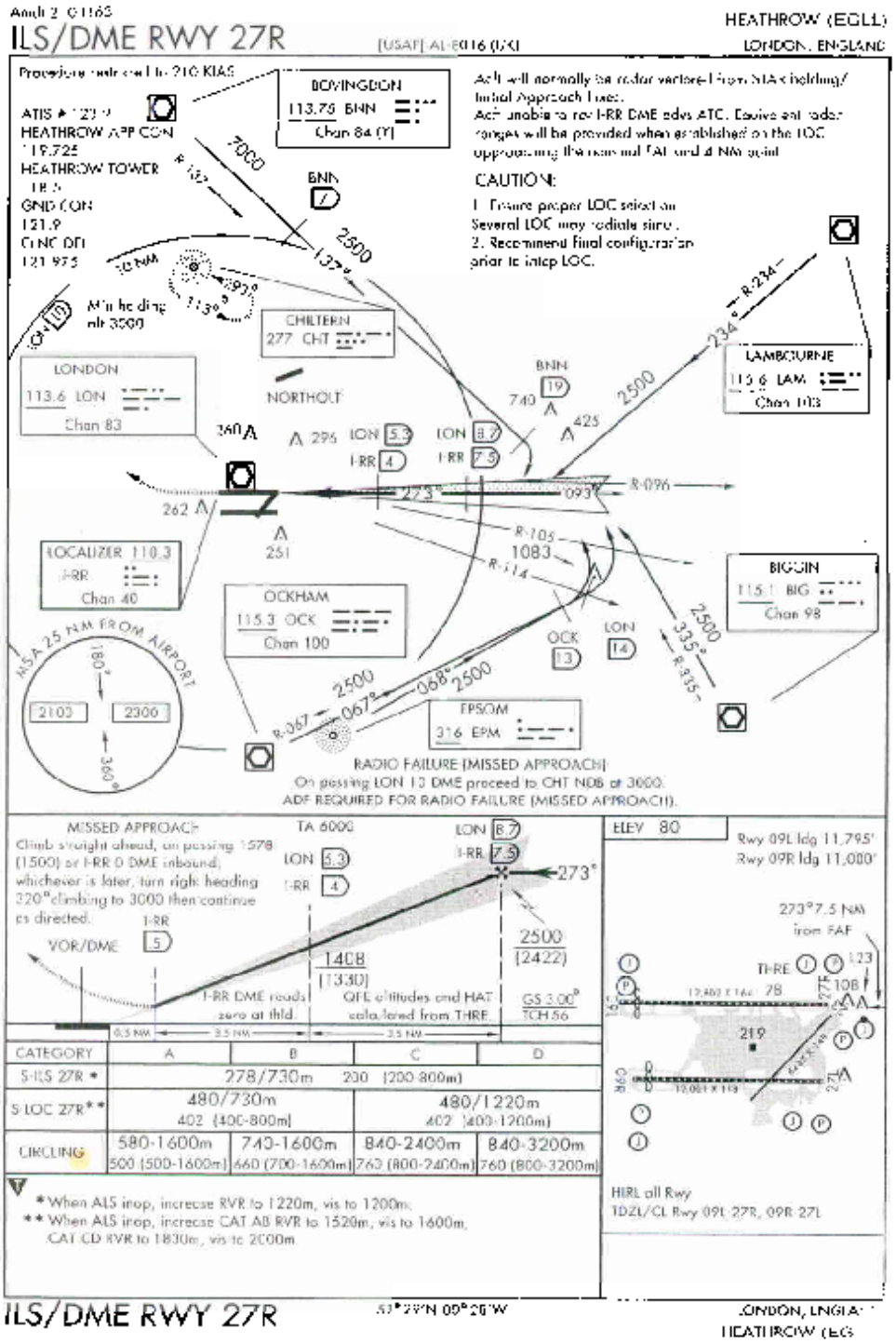


Figure 3. Approach Plate for LHR, Runway 27R

4. COMPARISON OF BOEING AND AIRBUS AIRCRAFT LANDING PERFORMANCE.

4.1 OVERALL PARAMETER SUMMARIES.

After processing and reviewing the video image data, a total of 495 good quality wide-body landings were included in this survey. Statistical summaries of the landing parameter data for each model aircraft are presented in appendix C. The landing parameter data collected for each individual landing is listed in appendix D, which has separate tables for each model aircraft listed by event number. The event number is a sequential number assigned to each landing as it is recorded, and that number is used to maintain the confidentiality of the airlines observed. Survey terms and symbols used in this report are documented in appendix E.

Of that total wide-body aircraft surveyed, 379 were manufactured by Boeing, 114 by Airbus, 8 by McDonnell Douglas, and 4 by Lockheed. The Lockheed aircraft are listed in the appendix D, but did not enter into any of the statistical analysis. Given the small sample size, the McDonnell Douglas DC-10 and MD-11 were considered one group. The Boeing wide-body aircraft consisted of B-747, B-767, and B-777 models. The Airbus models included the A300, A310, A330, and A340. In this report, landing parameter data is also analyzed by aircraft class and by manufacturer. Given the large number of landings involved, the B-747 and B-767 landings were split into "classic" and later generation groups (B-747-400 and B-767-300) for some of the analysis. Conversely, given the relatively small number of Airbus wide-body aircraft landings observed, the A300 and A310 were combined for some of the analysis, as were the A330 and A340. Table 1 lists the number of landings for each wide-body aircraft model, with the maximum landing weight for that model.

Given the wide range of landing weights included in the database of wide-body aircraft category of this survey, direct comparison between the manufacturers must be done with consideration of these substantial weight differences. Because of that concern, comparisons are included between the individual models of each manufacturer as well as among models of similar weight models for each manufacturer. For the wide-body aircraft, this involves comparisons of the B-767 with the Airbus A300/310 and between the B-777 and the Airbus A330/340.

Table 1. Number of Landings and Maximum Landing Weight by Model: Wide-Body Aircraft, LHR Survey

Aircraft Model	B-747	B-767	B-777	A300	A 310	A330	A340	DC10/ MD-11
Number of landings	193	101	85	48	21	19	25	8
Maximum landing weight	564/652 K lb	270/350 K lb	445/524 K lb	281/315 K lb	273 K lb	401/412 K lb	407/542 K lb	363/481 K lb

While not the primary goal of the survey, a total of 468 narrow-body jet aircraft were also recorded and processed. This includes 203 Boeing aircraft, primarily B-757 aircraft, along with some B-737 models. A total of 229 Airbus aircraft were observed, divided among A319, A320, and A321 aircraft. In addition, a total of 36 McDonnell Douglas MD-80 and MD-90 series aircraft landings were included. Given the relatively limited number of B-737 aircraft processed,

the various models of the B-737 were combined into one group for some of the analysis. However, in general, the B-737-100 and 737-200 were processed together and the B-737-300/400/500 were processed together. In some of the data presentations, the B-737-300/400/500 group was labeled as the B-737-300/500 group. Table 2 presents the number of narrow-body aircraft analyzed, along with the maximum landing weight for those models.

Table 2. Number of Landings and Maximum Landing Weight by Model: Narrow-Body Aircraft, LHR Survey

Aircraft Model	B-757	B-737-100/200	B-737-300/500	A319	A 320	A321	MD-80/ MD-90
Number of landings	151	15	37	62	97	70	36
Maximum landing weight	210/224 K lb	107 K lb	114/124 K lb	138 K lb	145.5 K lb	162/172 K lb	128/150 K lb

As shown for the wide-body aircraft, landing parameter summary data is presented by manufacturer, as well as for the individual models involved. The narrow-body aircraft landing impact data provided the unique opportunity to study the impact of the original equipment manufacturer "stretching" the length, a basic design on that aircraft's landing parameters. Airbus models A319, A320, and A321 are used for this study. Landing weight data was not obtained for any of the narrow-body aircraft.

Again, in this case, the heavier landing weight of the B-757s should be considered in any direct comparison of the manufacturers. Unfortunately, actual landing weight data is not available for any of the narrow-body aircraft landings.

4.2 INITIAL OBSERVATIONS.

4.2.1 Wide-Body Aircraft.

When examining the statistical summary of wide-body aircraft landing parameters presented in table 3, the initial observation is that the Boeing aircraft have higher approach and closure speeds, while the Airbus models have a higher average sink speed. Approach speed is the sum of the aircraft's closure speed and the headwind component of the measured wind at aircraft touchdown. Closure speed is the aircraft's closure rate when it enters camera range, which is also the aircraft's ground speed at touchdown. Given the large number of higher weight B-747s included in the summary, the higher approach and closure speeds for Boeing are not surprising. When the B-767 is compared to the A300 and A310 and the B-777 is compared to the A330 and A340, the Boeing models show higher approach and closure speeds. See table 4 and the tables in appendix C.

Table 3. Comparison of Primary Landing Parameters by Manufacturer: Wide-Body Aircraft, LHR Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
All Boeing wide body	Mean	153	148	2.76	5.0	0.22
	Standard deviation	10.36	11.06	1.18	6.64	4.55
	Skewness	0.09	0.03	0.39	0.95	-1.24
All Airbus wide body	Mean	145	138	2.90	7.09	-0.76
	Standard deviation	8.86	10.37	1.51	7.50	5.49
	Skewness	0.02	-0.09	0.46	0.55	-0.88
McDonnell Douglas wide body	Mean	164	156	3.50	7.86	0.61
	Standard deviation	7.44	11.33	0.89	5.72	4.09
	Skewness	-1.01	-0.14	-0.20	0.2	-1.43

Table 4. Comparison of Primary Landing Parameters by Aircraft Model: Wide-Body Aircraft, LHR Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
B-747	Mean	157	152	2.93	5.32	-0.06
	Standard deviation	10.16	11.21	1.16	6.72	4.98
	Skewness	-0.08	-0.19	0.26	0.93	-1.09
B-767	Mean	152	146	2.78	6.16	-0.24
	Standard deviation	9.71	11.06	1.16	6.97	4.65
	Skewness	-0.20	-0.11	0.55	0.74	-1.05
B-777	Mean	146	143	2.36	3.04	1.42
	Standard deviation	7.34	7.63	1.17	5.62	2.95
	Skewness	0.00	-0.12	0.66	1.31	-1.59
A300	Mean	145	138	2.77	6.65	-0.47
	Standard deviation	8.80	9.82	1.50	7.42	5.18
	Skewness	0.01	0.00	0.49	0.62	-0.95
A310	Mean	143	137	2.71	5.88	-1.00
	Standard deviation	10.34	9.3	1.50	5.21	5.59
	Skewness	-0.14	0.46	-0.13	-0.23	-1.02
A330	Mean	143	134	3.79	8.39	-0.76
	Standard deviation	7.96	8.62	1.87	8.93	5.93
	Skewness	0.50	0.28	0.33	0.68	-1.09

Table 4. Comparison of Primary Landing Parameters by Aircraft Model: Wide-Body Aircraft, LHR Survey (Continued)

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
A340	Mean	146	138	3.41	8.24	-1.68
	Standard deviation	9.54	12.25	1.45	7.93	6.43
	Skewness	0.00	-0.21	0.49	0.35	-0.69

When average sink rate is reviewed, the Airbus wide-body models show the higher sink rates. If the B-747 was not included in the Boeing wide-body data set, the sink rate difference would be more pronounced. As shown in table 4, the B-767 sink rate is similar to the A300 and A310, but the B-777 sink rate (2.36 ft/sec) is significantly lower than for the A330 or A340 landings. In fact, the average sink rate of 3.79 ft/sec for the A330 is the highest mean sink rate ever observed for any model in any prior survey. The previous high value was 3.76 for 11 B-767 aircraft landing in HNL. Table 5 compares selected wide-body landing parameters with the results from previous landing parameter surveys. The value of 3.41 ft/sec for the A340 is comparable to the sink rates for DC-10 (3.44 ft/sec) and MD-11 (3.42 ft/sec) landings at HNL and MD-11 (3.45 ft/sec) landings at JFK in New York. Another notable observation is that there is considerably less scatter in the sink rates at LHR than at either of the other two airfields. Refer to the average sink speed standard deviation values on table 5.

Table 5. Comparison of Selected Wide-Body Aircraft Landing Parameters With Results From Previous Surveys

Aircraft Type/Survey Location	Number of Landings	Approach Speed		Closure Speed		Average Sink Speed	
B-747		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	193	157	10.16	152	11.21	2.9	1.16
JFK	51	146	9.25	141	10.78	3.24	1.99
HNL	125	146	9.25	139	10	2.99	1.71
B-767		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	101	152	9.71	146	11.06	2.8	1.16
JFK	99	136	7.55	130	8.53	2.44	1.68
HNL	11	147	9.2	138	11.7	3.76	0.93
MD-11		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	5	163.0	8.03	155	12.97	3.5	0.69
JFK	12	150	13.35	145	12.99	3.45	1.81
HNL	9	157	10.4	155	11.5	3.4	2.12

Table 5. Comparison of Selected Wide-Body Aircraft Landing Parameters With Results From Previous Surveys (Continued)

Aircraft Type/Survey Location	Number of Landings	Approach Speed		Closure Speed		Average Sink Speed	
A300		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	48	145.0	8.87	138	10.26	2.7	1.35
JFK	35	134	8.26	131	7.99	2.23	1.26

4.2.2 Narrow-Body Aircraft.

Review of the statistical summaries for the recorded narrow-body aircraft landings show that the Airbus models have higher values of approach speed, closure speed, and sink rate than the Boeing aircraft, as shown in table 6. The sink rate for the McDonnell Douglas narrow-body aircraft is higher than either the Airbus or the Boeing models. The McDonnell Douglas approach speed and closure speed is comparable to the Airbus results for those parameters. The B-757, with the highest landing weight in this group, has the slowest approach speed and a lower sink rate than any Airbus or McDonnell aircraft. This information is summarized in table 7 and appendix C. The approach and closure speeds for the Airbus narrow-body aircraft show increasing values with an increase in aircraft size and landing weight. This increase in size and weight is not reflected in the average sink rate for the Airbus models. The Airbus narrow-body sink rate is virtually constant. The B-737 models show an increase in approach speed and sink rate with increased size. These models cannot be directly compared with the B-757, which is significantly different aerodynamically.

Table 6. Comparison of Primary Landing Parameters by Manufacturer: Narrow-Body Aircraft, LHR Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
All Boeing narrow body	Mean	141	135	2.6	5.5	0.0
	Standard deviation	10.31	12.12	1.11	7.58	4.93
	Skewness	0.45	-0.04	0.19	0.86	-1.01
All Airbus narrow body	Mean	146	139	2.8	7.2	-1.0
	Standard deviation	10.31	10.81	1.29	8.09	5.29
	Skewness	0.09	-0.07	0.04	0.59	-0.80
McDonnell Douglas narrow body	Mean	147	140	3.3	6.5	-1.4
	Standard deviation	11.21	12.37	1.43	8.14	5.61
	Skewness	0.13	-0.04	-0.13	0.70	-0.71

Table 7. Comparison of Primary Landing Parameters by Aircraft Model: Narrow-Body Aircraft, LHR Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
B-757	Mean	138	132	2.6	5.7	-0.4
	Standard deviation	8.62	10.86	1.09	7.50	5.18
	Skewness	0.33	-0.26	0.08	0.81	-0.86
B-737-100/200	Mean	145	141	2.5	3.7	1.9
	Standard deviation	10.30	12.68	1.01	7.54	2.96
	Skewness	0.84	0.72	0.43	1.49	-1.19
B-737-300/500	Mean	151	145	2.7	5.3	0.8
	Standard deviation	10.43	10.87	1.22	8.04	4.26
	Skewness	0.84	-0.57	0.42	1.03	-1.44
A319	Mean	141	132	2.8	8.3	-0.9
	Standard deviation	9.75	10.05	1.35	7.93	5.23
	Skewness	0.72	0.28	0.49	0.21	-0.83
A320	Mean	146	140	2.8	6.2	-0.7
	Standard deviation	9.52	9.31	1.28	7.82	5.34
	Skewness	0.31	-0.20	-0.29	0.81	-0.95
A321	Mean	152	144	2.7	7.6	-1.5
	Standard deviation	9.13	10.44	1.26	8.55	5.31
	Skewness	-0.54	-0.17	0.04	0.63	-0.62

When compared with the results of previous landing surveys (table 8), the B-757 sink rate at LHR is higher than that observed at JFK (2.0 ft/sec) and comparable to the value on the shorter runway at DCA (2.6 ft/sec). The B-757 approach speeds from the previous surveys were 132 knots at DCA and 131 at JFK.

The limited number of B-737 landings at JFK averaged 0.9-ft/sec sink speed. The B-737-100/200 at DCA averaged 2.2 ft/sec and 143-knots approach speed, while the limited sample of 737-300/500 averaged 2.82 ft/sec and 143-knots approach speed.

The only previous landing parameter data collected on Airbus narrow-body aircraft were 26 A320 landings at DCA. The average sink rate for those landings was 3.1 ft/sec with a 137-knot approach speed. The smaller length of the runway at DCA (7000 ft) must be considered when comparing these results with those from LHR.

Table 8. Comparison of Selected Narrow-Body Aircraft Landing Parameters With Results From Previous Surveys

Aircraft Type/Survey Location	Number of Landings	Approach Speed		Closure Speed		Average Sink Speed	
B-757		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	151	138	8.62	132	7.48	2.6	1.08
JFK	80	131	8.12	126	8.7	2.02	1.45
DCA	60	132	7.48	129	8.16	2.56	1.82
B-737-100/200		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	15	145.0	10.3	141	12.68	2.5	1.01
JFK	9	139	4.51	135	7.02	0.89	1.3
DCA	120	140	10.12	137	10.34	2.2	1.54
B-737-300/400/500		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	37	151	10.43	145	10.87	2.7	1.22
DCA	8	143	12.4	141	12.2	2.82	1.59
A320		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	97	146	9.52	140	12.37	3.3	1.43
DCA	26	139	10.14	137	10.33	2.57	1.57
MD-80/90		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
LHR	36	147	11.21	140	12.37	3.3	1.43
DCA	118	139	10.14	137	10.33	2.57	1.57

4.3 SINK SPEED COMPARISONS.

The sink rate of commercial aircraft is determined by two factors: the speed at which the aircraft flies down the glide slope and the flare that occurs prior to touchdown.

Aircraft approaching touchdown are guided by an instrument landing system (ILS), which provides information on how accurately an aircraft is flying down the glide slope to touchdown. The ILS establishes an electronic guide path at a 3-degree angle to the horizontal and extends from the runway centerline at approximately 1000 feet from the threshold out to a distance of 7.5 nautical miles. All commercial aircraft follow this glide slope to touchdown. There is a tolerance on the glide slope since some variability in the aircraft's glide slope can be expected.

If the aircraft followed the glide slope throughout the final approach to touchdown, the sink rate would be determined only by the aircraft's recommended approach speed. The recommended approach speed is determined by the aircraft manufacturer and is a complex evaluation involving aircraft aerodynamics and handling characteristics. Once established, recommended approach speed information is provided as a function of aircraft landing weight. The heavier the aircraft, the higher the recommended approach speed. Other factors that modify the recommended approach speed include wind conditions, particularly the presence of gusts, and weather conditions, particularly microbursts associated with strong thunderstorms.

As demonstrated in table 9, if an aircraft were to maintain its flight path all the way to touchdown, the resulting sink speeds would be much higher than observed in practice and most landings would exceed the design limit sink speed of 10 ft/sec, a once-per-airframe lifetime event [16]. Closure speed is the aircraft's approach speed minus the value of any headwind, thus approach and closure speed are identical for a landing with no headwind. To reduce structural loads and increase passenger comfort, pilots routinely flare their aircraft prior to touchdown. This maneuver involves raising the aircraft's nose (increasing pitch attitude), which increases the aircraft's lift, thus reducing the sink rate. This maneuver is dependent on pilot skill, but can be limited by conditions such as crosswinds and wet runways, which can reduce the pilot's opportunity to flare the aircraft. In this survey, the highest sink rate landing observed (8.0 ft/sec) occurred in a 13-knot crosswind.

Table 9. Sink Speed Calculated From Closure Speed Without Flare, on a 3.0-Degree Glide Slope

Closure Speed		Sink Speed
knots	ft/sec	ft/sec
100	168.8	8.8
110	185.7	9.7
120	202.5	10.6
130	219.4	11.5
140	236.3	12.4
150	253.2	13.3
160	270.0	14.2
170	286.9	15.0
180	303.8	15.9
190	320.7	16.8
200	337.6	17.7

As a first step in the review of aircraft sink rates, box and whisker plots of sink rate were generated for both wide- and narrow-body aircraft. Box and whisker figures are a nonparametric comparison among various measured parameters and are very useful in presenting multiple comparisons. A description and example of box and whisker plots are provided in appendix F. These plots are included in appendix G. For wide-body aircraft, the Airbus and Boeing wide bodies were plotted separately.

From the Airbus wide-body box and whisker plot (see figure G-2 of appendix G), it is readily apparent that the A330 aircraft landings produced a much higher maximum sink speed value, 75% value, mean value, and 25% value than the other three Airbus models. The A330 also shows a much wider range of values. The A340 is second highest, but with a range of values more representative of the A300 and A310.

When the sink rates of the A330 and A340 are compared to the B-747 and B-777 (see figure G-5 of appendix G), the results for the A330 are significantly higher than for either of the Boeing models. The sink rates for the A340 are comparable to the much larger and heavier B-747s. Box and whisker plots (see figure G-6 of appendix G) of the B-777 and B-767 compared to the

combined A300/310 and A330/340 landings, again, show the larger Airbus aircraft have the highest sink rates, while the A300, A310, and B-767 are similar.

This trend is made more apparent when sink speed probability plots are generated. These plots include the Military (MIL)-A-8863 sink speed probability curve from the U.S. Military Specification (MIL-SPEC). There is no comparable specification in the commercial arena, thus this curve has been used in evaluating previous landing load surveys sink speed results.

The sink speed probability curve, figure 4, shows it is likely that the sink speed for all wide-body aircraft in this survey is lower than the values in the MIL-SPEC. This is in contrast with the findings from the previous JFK and HNL surveys, which showed that the sink rate probability exceeded that of the MIL-SPEC curve. However, if the wide-body aircraft are separated by manufacturer, figure 5, the Airbus aircraft curve crosses the MIL-SPEC curve at higher sink rates. If the groups are further broken down by aircraft model, as shown in the medium wide-body curve, figure 6, the A330/340 aircraft exceed the MIL-SPEC curve above the 3-ft/sec point.

The question remains whether there are any differences inherent in the A330 and A340 design that could produce the higher sink rates observed in this survey.

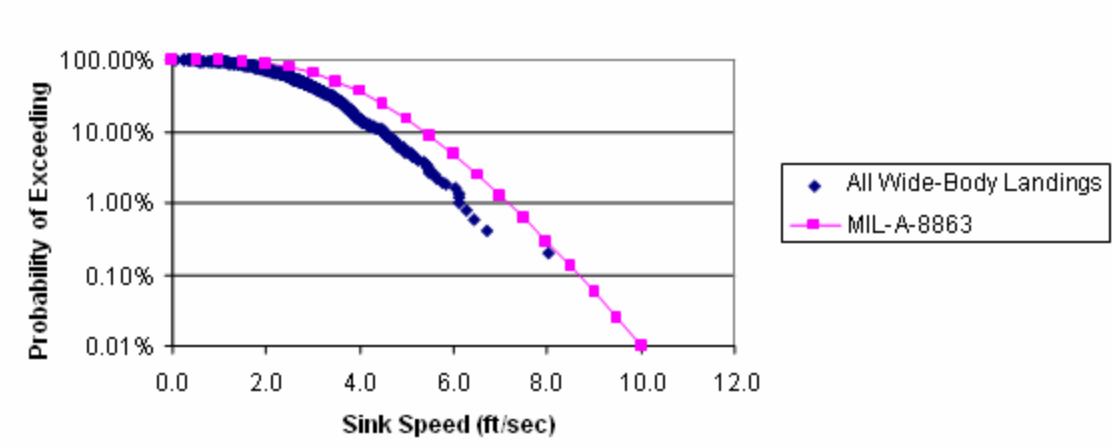


Figure 4. Sink Speed Probability, All Wide-Body Aircraft, LHR

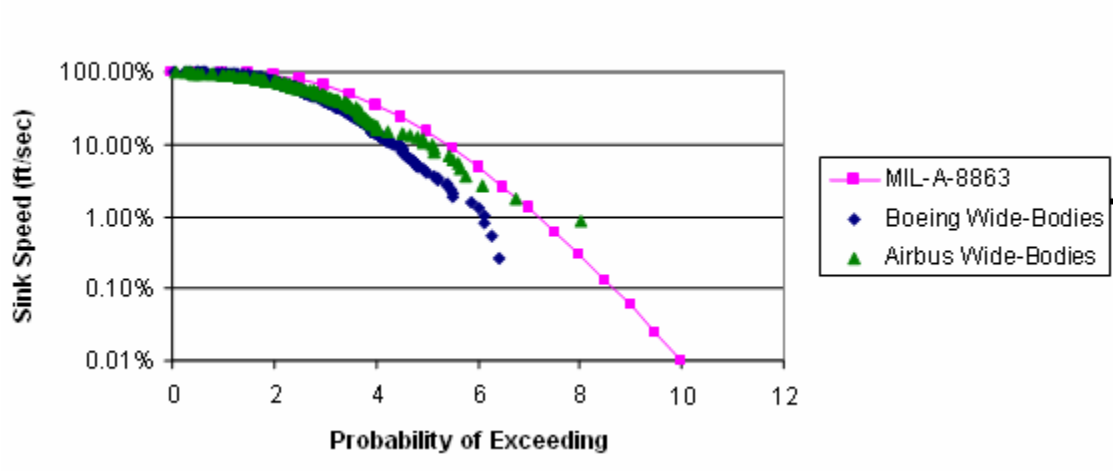


Figure 5. Sink Speed Probability, Wide-Body Aircraft by Manufacturer, LHR

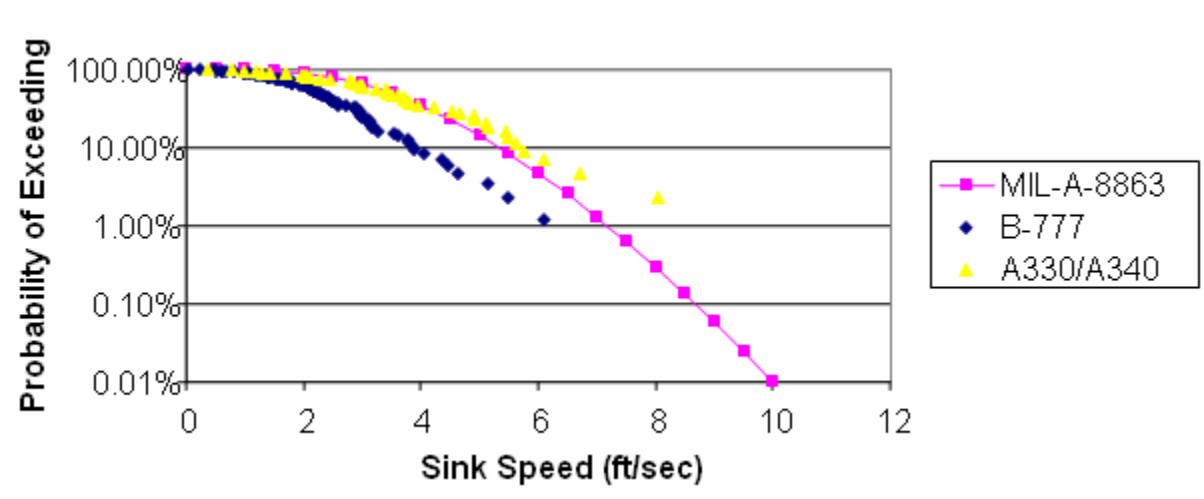


Figure 6. Sink Speed Probability, Medium Wide-Body Aircraft, LHR

As an additional comparison to the sink speeds observed in this survey, figure 7 shows the sink speed probability plot developed from the HNL Survey results [14]. What is interesting about this figure is that it includes design data for the DC-10 and B-747. It should also be noted that the probability curves for the B-747 and DC-10 data show higher sink speeds in comparison to the MIL-A-8863 curve than any of the probability curves generated from the LHR data in figures 4, 5, or 6.

These higher HNL sink speeds could have been caused by an operational requirement in effect at the time of the survey. The operational requirement stated that due to the ill-maintained condition of the initial 4000 feet of runway 8L, pilots were not to touchdown the nose gear in this first 4000 feet.

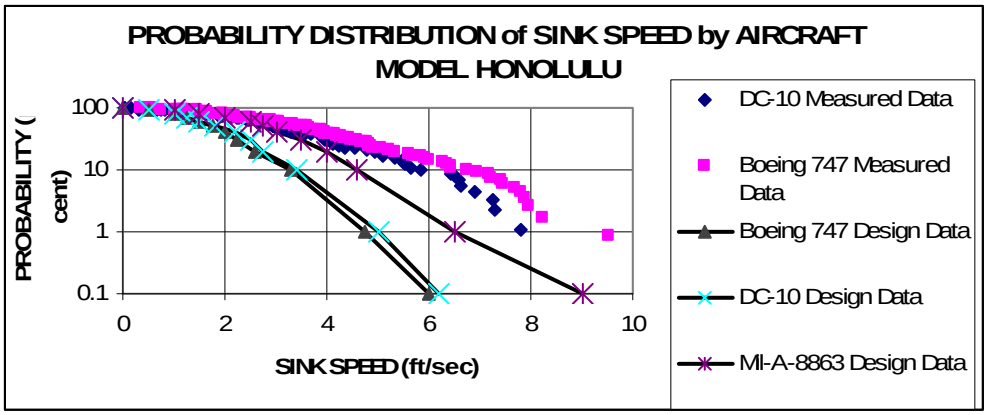


Figure 7. Probability Distribution of Sink Speed by Aircraft Model, HNL

Another sink speed comparison done from previous surveys involved plots of sink weight versus landing weight. The plot of these parameters from the JFK survey [12] led to the conclusion that aircraft sink rate increased as a function of aircraft landing weight. A plot of those parameters from LHR, figure 8, does not show a similar trend.

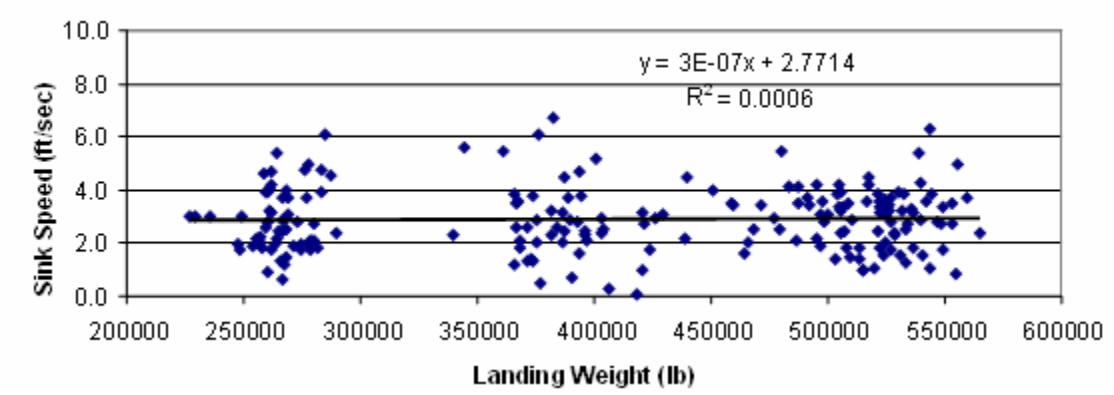


Figure 8. Average Sink Speed vs Landing Weight, All Wide-Body Landings, LHR

4.4 COMPARISON OF SINK SPEED MEASUREMENTS BETWEEN VIDEO SYSTEM AND RUNWAY THRESHOLD CAMERA.

For the first time during an FAA landing parameter survey, an additional video camera was installed at the runway threshold (approximately 300 feet from the runway centerline) in an attempt to collect data on an aircraft's height as it crossed the runway threshold. This height information, along with the time stamp on the video frame, permits a second calculation of aircraft sink rate. The result of this calculation is an average sink rate covering the time period between the aircraft's crossing the runway threshold and its final touchdown location on the runway. This is typically a 7-second interval. In contrast, the standard sink rate values reported by the video camera covers no more than the last second of aircraft travel prior to touchdown. Thus, the video camera provides an instantaneous velocity, since it is derived from the aircraft's flight path in this last instance of flight. The video system records aircraft wheel positions during the last second of flight and fits that data to a position time curve. The reported video

sink rate is the derivative (slope) of that position time curve evaluated at touchdown. Given that most aircraft flare prior to touchdown, which reduces the aircraft's sink rate, the threshold camera sink rate should be higher than the value reported by the video system. Review of appendices C and D shows this to be the case. Since both of these sources of sink rate information were available, scatter plots contrasting these two measurements were generated. Figures 9 and 10 are typical scatter plots comparing these measurements of aircraft sink rate. For the Boeing wide-body aircraft, an insignificant correlation exists between the two sink rate measurements, for Airbus wide bodies, this correlation is much more pronounced.

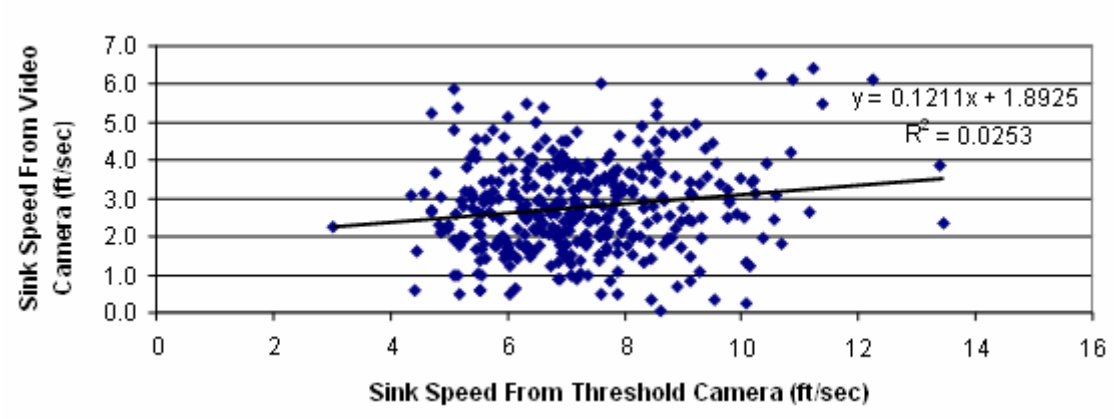


Figure 9. Video Sink Rate Measurement vs Threshold Camera Sink Speed Measurement, All Boeing Wide-Body Landings

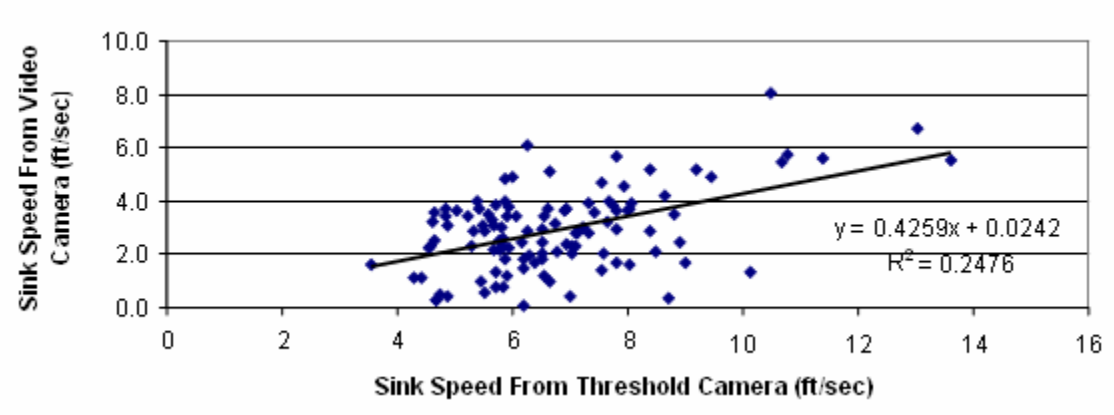


Figure 10. Video Sink Rate Measurement vs Threshold Camera Sink Speed Measurement, All Airbus Wide-Body Landings

The definition of the correlation coefficient, R, is included in appendix E. Briefly, the value of R varies from -1.0 to 1.0. A value of 1.0 implies a perfect positive linear relationship between the two parameters involved. A value of -1.0 implies a perfect negative relationship between the two parameters involved, while a value of 0.0 implies no relationship between the parameters involved. The values of R are frequently presented as R^2, which is provided directly by the Microsoft® Excel® software used in preparing scatter plots for this report. Values of R^2 in excess of 0.25, that is an R of 0.5, are considered to be a strong level of correlation considering the

highly variable nature of landing parameter data. An R^2 of 0.10 (R = .31), is not a high value in absolute terms, however, for measured data with the quantity of scatter that exists in the report data, an $R^2 > 0.10$ would imply that at least modest or meaningful correlation exists.

However, for the Airbus wide bodies, a very strong correlation exists between the two parameters. In fact, when the A310, A330, and A340 aircraft are plotted individually, they result in R^2 = 0.4254, 0.2648, and 0.2615, respectively. This is in contrast with the narrow-body aircraft, which generated R^2 = 0.0004 for the Boeing models and R^2 = 0.0188 for the Airbus aircraft. A complete listing of the correlation coefficients generated by this comparison is shown in table 10. This suggests that the Airbus wide-body aircraft have a more controlled flare, but may be less effective in reducing sink speed than the other aircraft observed in this survey.

Table 10. Correlation Comparison: Video Sink Speed vs Threshold Camera Sink Speed

Wide-Body Aircraft			Narrow-Body Aircraft		
Aircraft Model	R^2	Correlation Coefficient R	Aircraft Model	R^2	Correlation Coefficient R
All Wide Body	0.0641	0.2532	All Narrow Body	0.0092	0.0959
All Airbus	0.2476	0.4976	All Airbus	0.0188	0.1371
All Boeing	0.0253	0.1591	All Boeing	0.0004	0.02
A300	0.0000	0.0014	A319	0.0761	0.2758
A310	0.4254	0.6522	A320	0.0187	0.1367
A330	0.2648	0.5146	A321	0.0003	0.0173
A340	0.2615	0.5114	B-737-100	0.0195	0.1396
B-747	0.0501	0.2238	B-737-300	0.0000	0.0024
B-767	0.0094	0.0970	B-757	0.0000	0.0024
B-777	0.0112	0.1058	MD-80/90	0.0099	0.0995
DC-10/MD-11	0.0000	0.0001			

4.5 APPROACH SPEED COMPARISON.

In a similar manner to the sink speed analysis, the measured approach speeds from this survey were presented in a series of box and whiskey diagrams. These box and whisker plots are presented in appendix G. The results of the variation in approach speed for Airbus wide-body aircraft is shown in figure G-8, and Boeing wide-body data is shown in figure G-10 of appendix G.

The highest observed approach speed was 180 knots for a B-747, which also showed the greatest range of approach speeds, 50 knots. The smallest range of approach speeds was 25 knots for the Airbus A330s.

Approach speed should be dependent on the aircraft's landing weight. For this survey, landing weight data was collected for a limited number of wide-body aircraft. Statistical summaries for the A340, B-747, B-767, and B-777 are included in appendix C. The weights for individual landings were listed for the same models in appendix D. This permitted approach speed vs

landing weight curves to be generated. For the B-747, the plot in figure 11 indicates an increase of 1 knot in approach speed for every 10,000 lb increase in landing weight. For the B-767, figure 12 shows the increase in approach speed is roughly 3 knots for each 10,000 lb increase in landing weight.

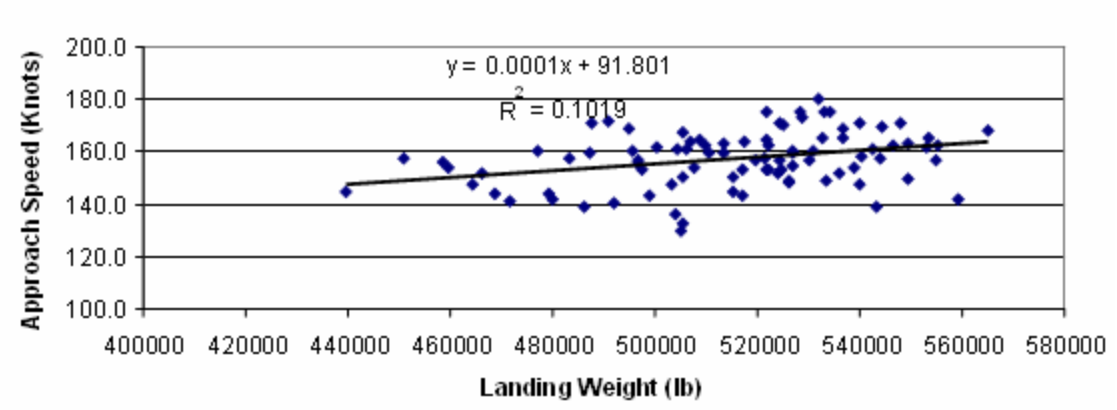


Figure 11. Approach Speed vs Landing Weight, All B-747 Landings, LHR

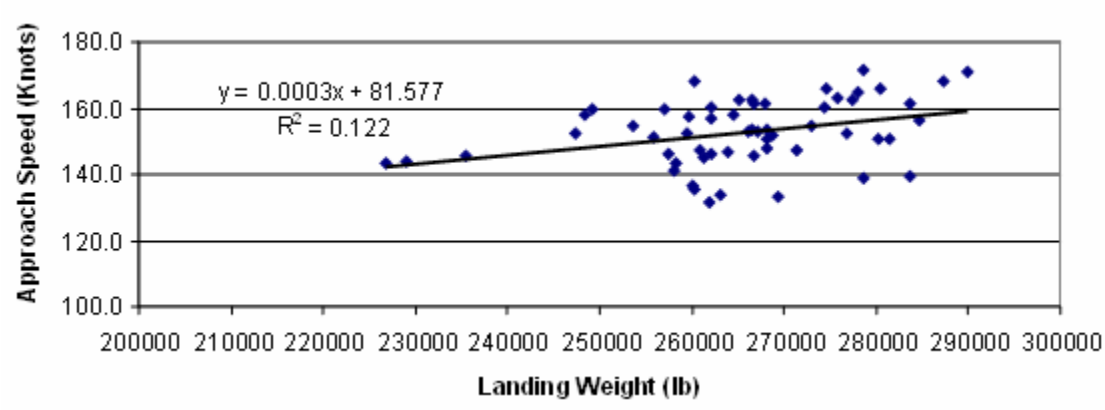


Figure 12. Approach Speed vs Landing Weight, All B-767 Landings, LHR

For the B-777, figure 13 shows the same increase in approach speed with landing weight as the B-747. All three plots show some degree of correlation between these variables with a correlation factor $R > 0.3$. For the A340, figure 14, however, shows no increase in approach speed with landing weight and no correlation between the two variables. The A340 correlation factor is about $R = 0.07$. This is the first occasion where an aircraft model did not generate an increase of approach speed with landing weight. This may be influenced by the small number of A340 landings with reported landing weights (only 19 landings), but it is certainly a result that points to something unusual with the landing performance of the A340. Landing weight for a useful number of A330 landings was not available.

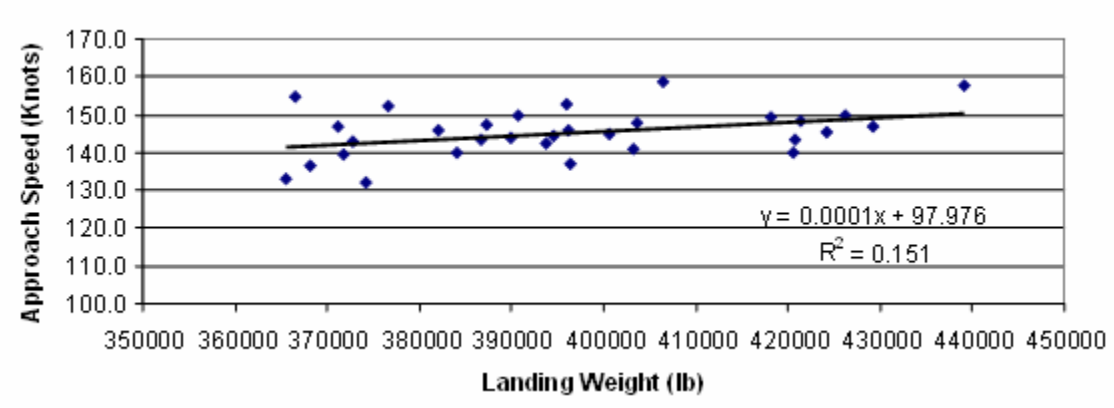


Figure 13. Approach Speed vs Landing Weight, All B-777 Landings, LHR

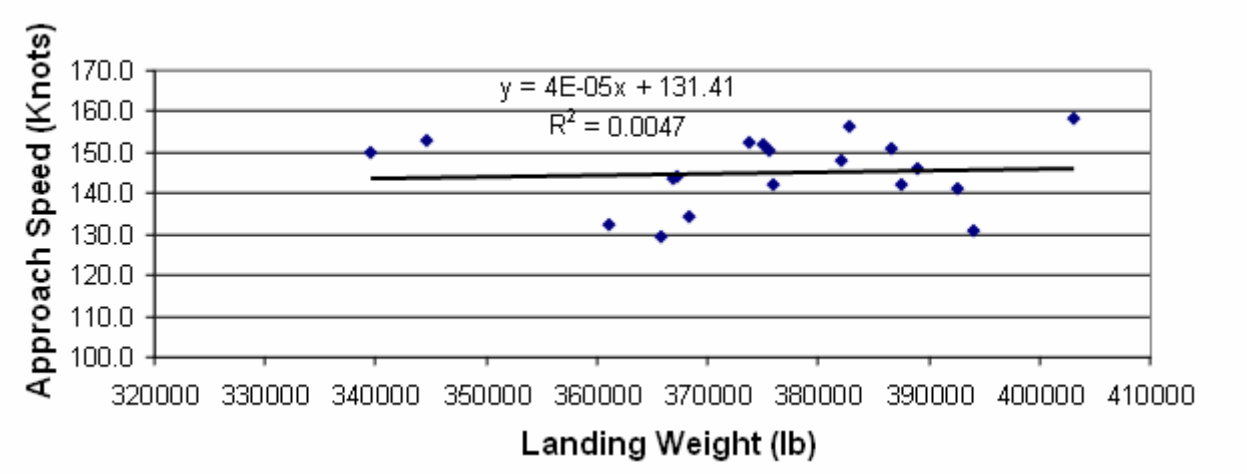


Figure 14. Approach Speed vs Landing Weight, All Airbus A340 Landings, LHR

Landing weight data was not available for the narrow-body aircraft observed during this survey. However, box and whisker plots of approach speed were generated for these aircraft and are presented in appendix G. The box and whisker plot for the Airbus narrow-body aircraft (figure G-7 of appendix G) shows an increase in the median, 25% and 75% values of approach speed with increasing aircraft size and weight. The A319 shows the lowest maximum and minimum values of approach speed. This is exactly the trend one would expect for these aircraft, which use the same wing but with varying fuselage lengths and gross weights.

The Boeing narrow-body box and whisker plot (figure G-9 of appendix G) shows an increase in approach speed between the B-737-100/200 and 737-300/500 aircraft. This was expected since the later versions of the B-737 are larger and heavier aircraft. The B-757 data shows lower minimum, 25%, median, and 75% values of approach speed than the B-737s. Figure G-9 shows that the approach speed for the B-757s is considerably lower than that of the B-737s and MD-80s. Part of this variation is caused by the much larger sample size of the B-757s compared to the other Boeing models. However, the B-757 is a much different design than the B-737, which may help to explain the observed difference.

4.6 GLIDE SLOPE COMPARISON.

After looking at the primary landing parameters individually, the next analysis uses the combination of two primary landing parameters taken together as a measure of the aircraft's glide slope. Since the aircraft is attempting to follow an established glide slope to touchdown, the glide slope measured by the video system is influenced primarily by the aircraft's flare prior to touchdown.

Using the results of the video systems measurement of sink rate and camera closure speed, a value of instantaneous glide slope was calculated. The reported value is the inverse tangent of the quantity, average sink rate divided by closure speed. Glide slope angle is reported in degrees. For each model surveyed, the mean, standard deviation, and skewness of the distribution of instantaneous glide slope measurements are reported in appendix C. In addition, the instantaneous glide slope determined for each landing is reported in appendix D.

The use of the threshold camera in this survey provides another measure of glide slope angle to add to the analysis. In this case, the measured height as the aircraft flies over the runway threshold, along with the distance between the runway threshold and touchdown point, are used to calculate a geometric glide slope. Again, the statistic information on this parameter is included in appendix C, and the value for the each landing is found in appendix D.

As shown in figure 15, the instantaneous glide slope is the tangent to aircraft's flight path at the instant of aircraft touchdown. The flight path is defined by the position time data collected in the last second of flight prior to touchdown. The instantaneous glide slope is the slope of the flight path curve evaluated at touchdown. As shown in the schematic, this can be very different from the geometric glide slope that is defined by the height over the runway threshold and runway threshold to touchdown distance. For this survey, the glide slope measurements are summarized in the table 11.

The entry labeled Runway Glide Slope in table 11 is the glide slope angle identified on the approach plate for runway 27R for LHR. This is the angle established by the runway's ILS. The FAA Advisory Circular 120-29A indicates that the tolerance on an ILS glide slope is $\pm$0.7 degrees.

This table shows the relationship between the values of instantaneous and geometric glide slope observed during this survey. Overall, the narrow- and wide-body aircraft perform similarly. In general, the aircraft begin their flare maneuver prior to crossing the runway threshold and the flare continues until touchdown. This explains why the instantaneous glide slope values are less than half of the geometric glide slope values.

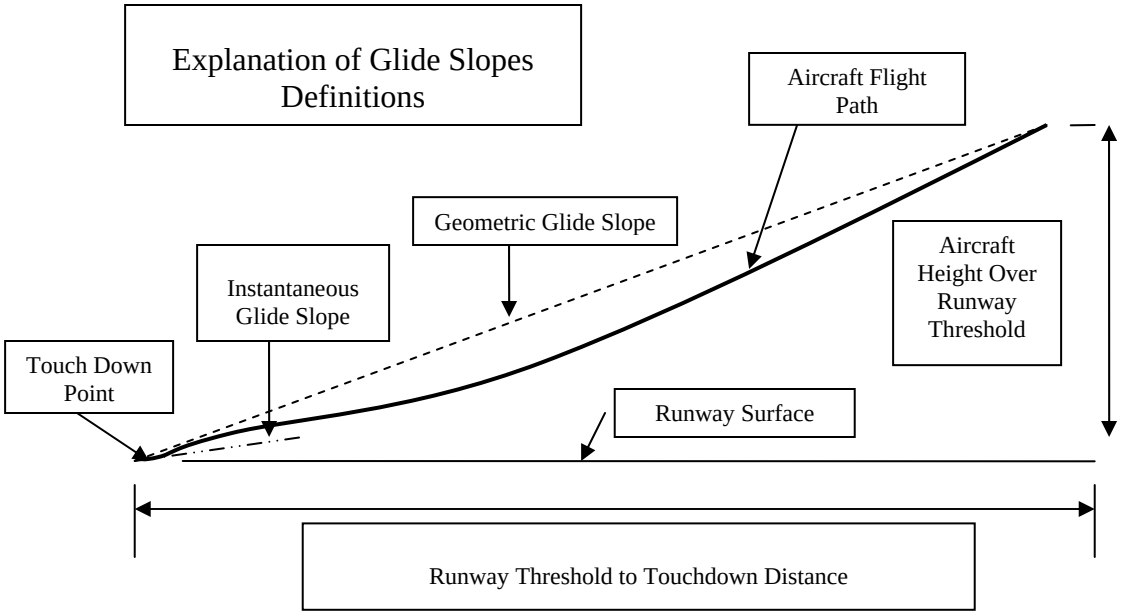


Figure 15. Explanation of Glide Slope Definitions

Table 11. Glide Slope Comparison

Narrow-Body Landings			
	Mean	Standard Deviation	Skewness
Instantaneous glide slope	0.657	0.306	0.701
Geometric glide slope	1.749	0.404	1.017
Wide-Body Landings			
Instantaneous glide slope	0.687	0.306	0.268
Geometric glide slope	1.771	0.331	0.771
Runway Glide Slope			
	3.0		

For the wide-body aircraft, the number of Boeing landings dominates the category. There are 379 Boeing landings out of 504 surveyed events. The situation is more evenly split in the narrow-body category. For the narrow-body aircraft, there are 203 Boeing landings and 229 Airbus events. Comparing the wide-body landings by manufacturer, as shown in table 12, there appears to be a difference between these groups. While the geometric glide slope is the same, the instantaneous glide slope values are different. Scatter plots were generated to explore this observation. As shown in figure 16, a plot comparing the two measures of wide-body aircraft glide slope angles shows no correlation between these variables. This changes when the same data is plotted by manufacturer. The Boeing landings, figure 17, show no correlation between the glide slope measurements, the Airbus plots, figure 18, show strong correlation.

Table 12. Wide-Body Glide Slope Comparison by Manufacturer

Airbus Wide-Body Landings			
	Mean	Standard Deviation	Skewness
Instantaneous glide slope	0.722	0.383	0.655
Geometric glide slope	1.749	0.475	1.44
Boeing Wide-Body Landings			
Instantaneous glide slope	0.638	0.279	0.548
Geometric glide slope	1.751	0.383	0.763
Runway Glide Slope			
	3.0		

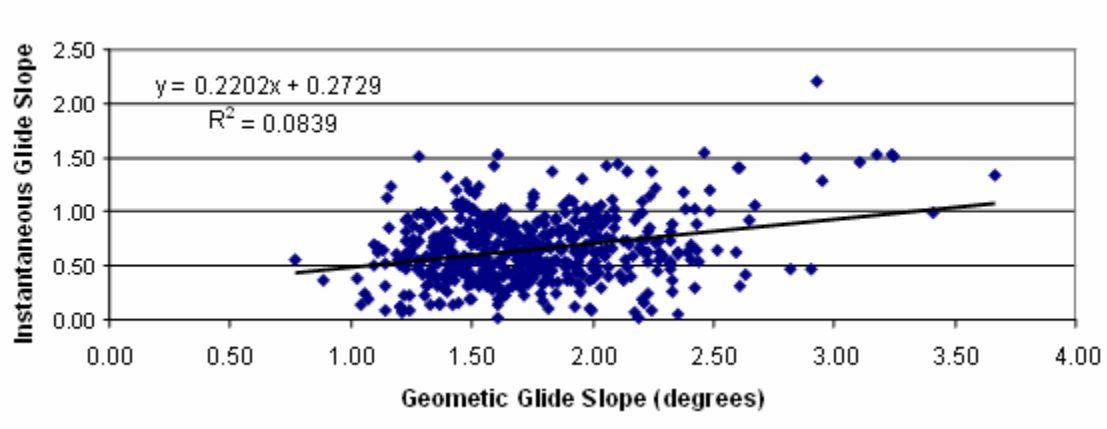


Figure 16. Instantaneous Glide Slope vs Geometric Glide Slope, All Wide-Body Landings, LHR

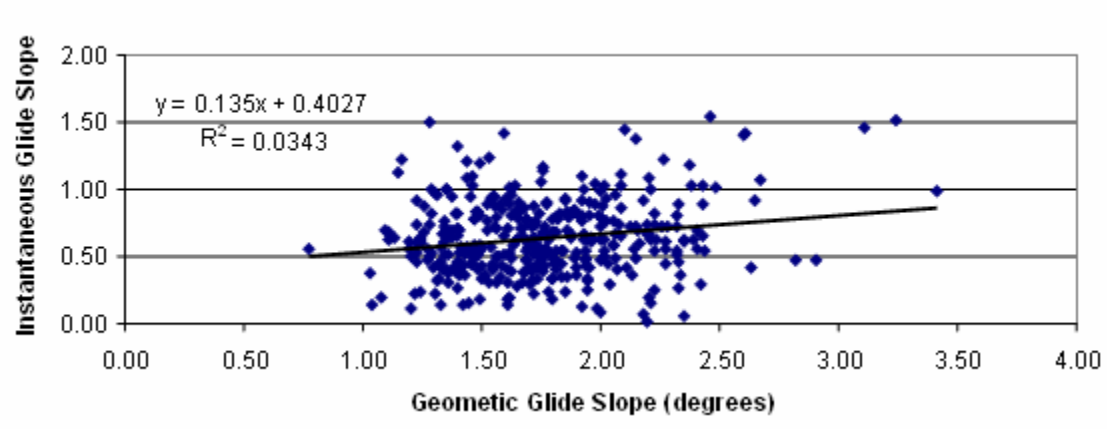


Figure 17. Instantaneous Glide Slope vs Geometric Glide Slope, All Boeing Wide-Body Landings, LHR

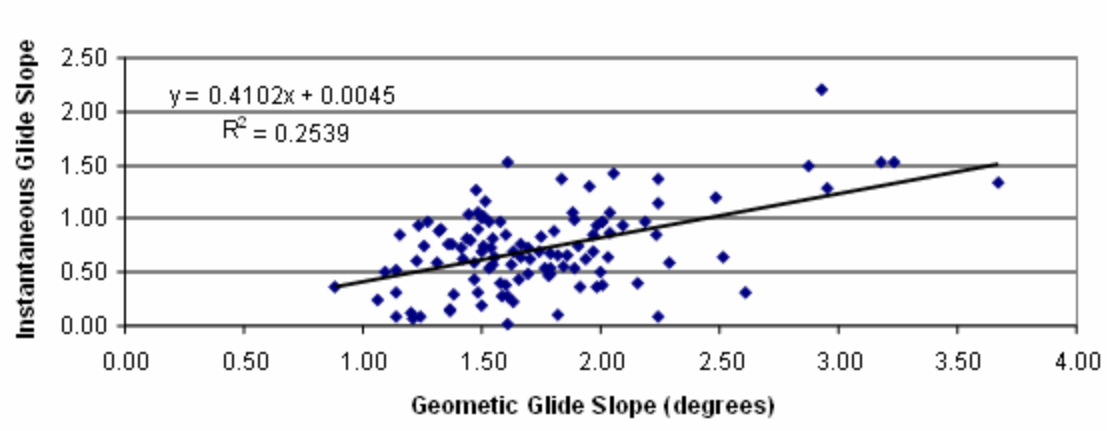


Figure 18. Instantaneous Glide Slope vs Geometric Glide Slope, All Airbus Wide-Body Landings, LHR

The R^2 value of 0.2538 in the Airbus plot, figure 18, identifies these variables as strongly correlated. While this is dramatic, even higher correlations are found between these variables if the A310, A330, and A340 are plotted separately. The R^2 value found for these models are 0.3783, 0.2787, and 0.2085, respectively. Of all the other models surveyed, only the A319 has a value of greater than 0.10. The glide slope values and the correlation coefficient calculated from the regression analysis of the scatter plots for these models are summarized in table 13. In reviewing this table, not only do the A330 and A340 have high correlation coefficients, they also have the highest mean value of geometric and instantaneous glide slope reported for this survey. The lowest value of instantaneous glide slope was recorded for the B-777, and the lowest value of geometric glide slope was from the A300. The B-777 also shows the largest difference between the mean values of glide slope angle. The A310 has the smallest difference in glide slope values along with the highest correlation coefficient.

Table 13. Mean Value of Glide Slope by Model

Aircraft Model	Instantaneous Glide Slope	Geometric Glide Slope	Correlation Coefficient R
A300	0.60	1.56	0.05
A310	0.68	1.57	0.615
A319	0.73	1.83	0.356
A320	0.70	1.72	0.153
A321	0.65	1.68	0.111
A330	0.94	2.06	0.615
A340	0.84	2.01	0.528
B-737-100/200	0.60	1.85	0.002
B-737-300/500	0.65	1.69	0.002
B-747	0.67	1.73	0.277
B-757	0.67	1.83	0.077

Table 13. Mean Value of Glide Slope by Model (Continued)

Aircraft Model	Instantaneous Glide Slope	Geometric Glide Slope	Correlation Coefficient R
B-767	0.65	1.70	0.146
B-777	0.56	1.77	0.044
DC-10/MD-11	0.77	1.77	0.096
MD-80/90	0.81	1.77	0.053

In an attempt to find an explanation for this observed difference, various scatter plots relating glide slope angle with other parameters were generated. One such analysis was a comparison of glide slope angle with observed crosswind. A plot of glide slope angle versus crosswind for all wide-body aircraft combined, figure 19, shows no correlation between these parameters.

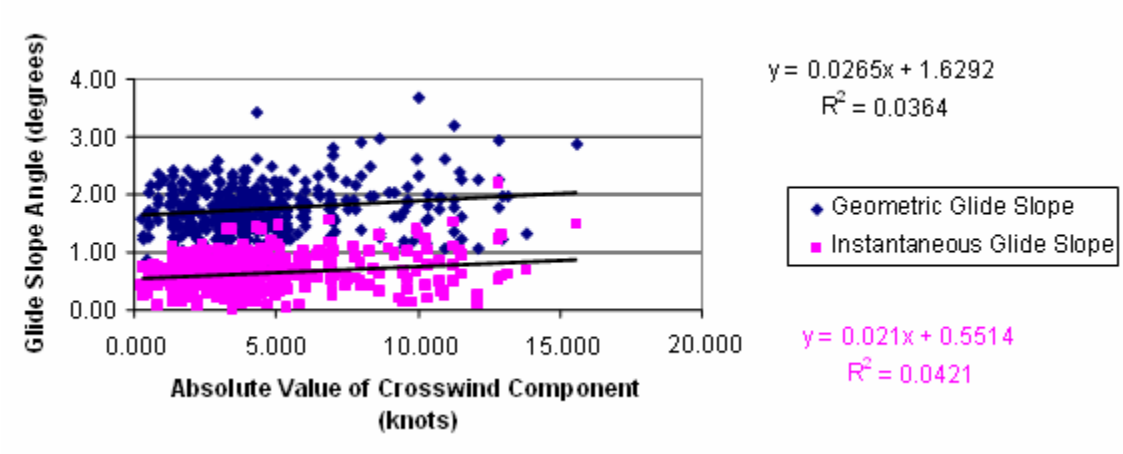


Figure 19. Glide Slope Angle vs Crosswind, All Wide-Body Aircraft, LHR

However, when these comparisons are done with the Airbus A330, figure 20, and A340 figure 21, the results are much different. The values of geometric glide slope show extremely high correlation with crosswind for these aircraft. When the overall level of scatter inherent in measured operational is considered, even the results for instantaneous glide slope show moderate correlation.

When this comparison process was extended to narrow-body aircraft, the only reasonable correlation found was for the instantaneous glide slope of the A319, as shown in figure 22.

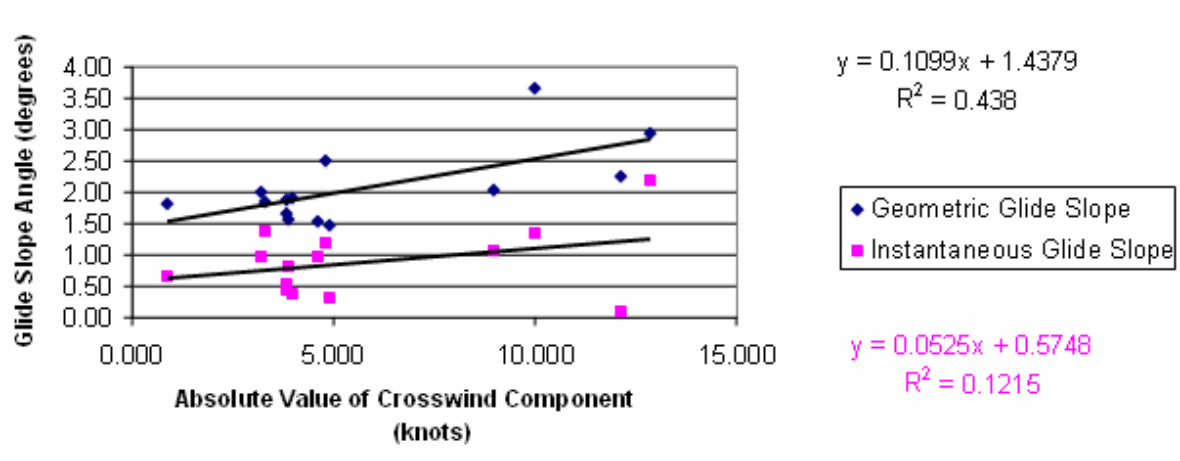


Figure 20. Glide Slope Angle vs Crosswind, All A330 Aircraft, LHR

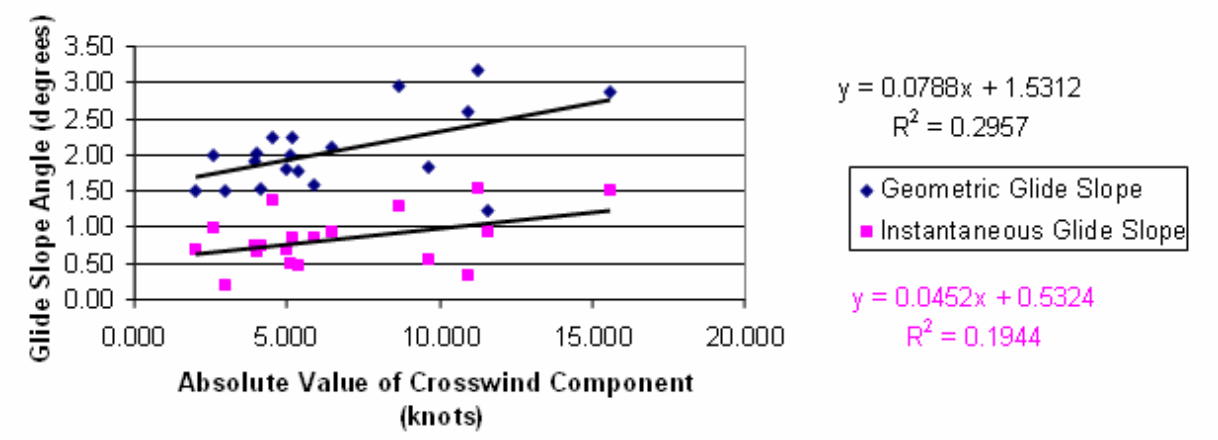


Figure 21. Glide Slope Angle vs Crosswind, All A340 Aircraft, LHR

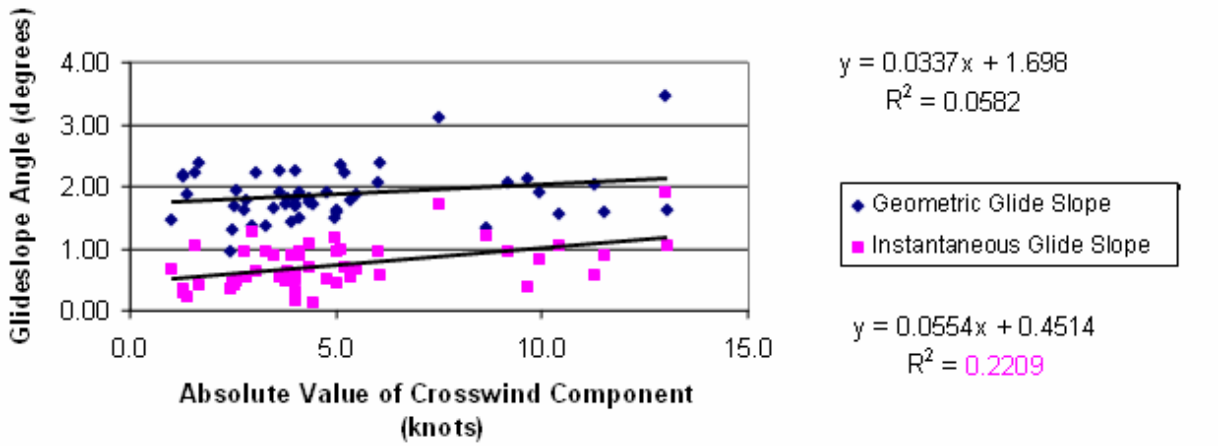


Figure 22. Glide Slope Angle vs Crosswind Component, A319 Aircraft, LHR

Overall, it appears that the glide slope angles collected for the Airbus wide-body aircraft represent a difference in landing performance compared to Boeing wide-body aircraft. This closer agreement between the two paired Airbus glide slope measurements, reflected in the higher correlation values, indicates higher sink rates for those models.

4.7 CLOSURE SPEED COMPARISON.

The statistical summaries in appendix C contain entries for closure speed and average sink speed measured by both the video camera and the threshold camera. As discussed in section 4.4, the average sink rate reported by the video touchdown camera is consistently smaller than that reported for the threshold camera. The closure speeds are consistently higher for the video camera than for the threshold camera. For the wide-body aircraft in this survey, these observations are summarized in table 14. For narrow-body aircraft, the same information is contained in table 15.

The values reported from the video camera are essentially instantaneous values of those parameters at the instance of aircraft touchdown. The values from the threshold camera are average values for the time increment that each aircraft travels from the runway threshold to its touchdown point.

Table 14. Wide-Body Aircraft, Instantaneous vs Average Parameter Comparison

Aircraft Model	Measurement Source	Closure Speed (knots)	Average Sink Speed (ft/sec)
A300	Video camera (instantaneous value)	138	2.8
	Threshold camera (average value)	132	6.1
A310	Video camera	137	2.7
	Threshold camera	131	6.1
A330	Video camera	132	2.8
	Threshold camera	126	6.8
A340	Video camera	138	3.4
	Threshold camera	131	7.7
B-747	Video camera	152	2.9
	Threshold camera	145	7.4
B-767	Video camera	146	2.8
	Threshold camera	137	6.8
B-777	Video camera	143	2.4
	Threshold camera	135	7.4
DC-10/MD-11	Video camera	156	3.5
	Threshold camera	145	7.5

Table 15. Narrow-Body Aircraft, Instantaneous vs Average Parameter Comparison

Aircraft Model	Measurement Source	Closure Speed (knots)	Average Sink Speed (ft/sec)
A319	Video camera (instantaneous value)	132	2.8
	Threshold camera (average value)	126	6.8
A320	Video camera	140	2.8
	Threshold camera	133	6.7
A321	Video camera	144	2.7
	Threshold camera	138	6.8
B-737-100	Video camera	141	2.5
	Threshold camera	129	7.0
B-737-300	Video camera	145	2.7
	Threshold camera	138	7.0
B-757	Video camera	132	2.6
	Threshold camera	126	6.8
MD-80/90	Video camera	140	3.3
	Threshold camera	135	7.0

In an effort to compare the differences in these parameter measured at different times, (i.e., at the threshold and at touchdown), values of total velocity were calculated at each time. The vector sum of sink speed and closure speed were calculated for the video camera and threshold camera separately. These values were then plotted and correlation coefficients calculated. Figure 23 is typical of the resulting plots. The value for $R^2 = 0.707$, shows excellent correlation between these two velocity values.

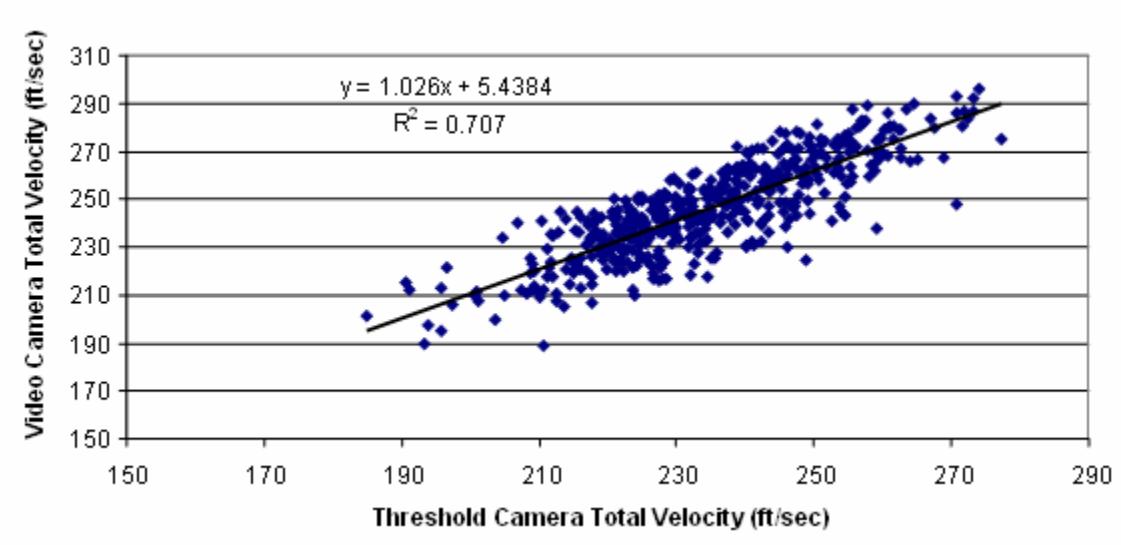


Figure 23. Total Velocity Comparison, Video Camera to Threshold Camera, All Wide-Body Aircraft, LHR

Even though excellent correlation exists, there is an apparent difference in the total velocity calculated from the instantaneous and average values of sink speed and closure speed from this survey. These differences were used to calculate the acceleration necessary to produce these observed variations. The time frame used to determine the acceleration was one-half the elapsed time between the threshold crossing and touchdown. Half the interval was used since the total velocity calculated for the threshold camera data is an average value for the entire time interval. The assumption is that those parameters occurred in the middle of the time increment, thus the change from the average to instantaneous values occurred over half the time interval. Values of Total Velocity, Velocity Difference, Apparent Acceleration, and Correlation Coefficient are listed in tables 16 for wide-body aircraft and table 17 for narrow-body aircraft.

As shown in tables 16 and 17, the amount of acceleration required to produce the observed velocity difference between the instantaneous and average velocity measures is very small, in the order of 0.1 g. Given these acceleration values, along with the high degree of correlation between the two velocity measurements, the reported variation in engaging speed measurements is considered to be reasonable.

Table 16. Wide-Body Aircraft Total Velocity, Acceleration and Correlation Comparison

Aircraft Model	Measurement Source	Total Velocity (ft/sec)	Velocity Difference (ft/sec)	Apparent Acceleration (g's)	Correlation Coefficient R (Total Velocity)
A300	Video camera (instantaneous value)	232.9302	10.06	0.089264	0.849
	Threshold camera (average value)	222.8702			
A310	Video camera	231.2413	10.0583	0.069415	0.656
	Threshold camera	221.183			
A330	Video camera	222.8043	10.03557	0.087793	0.699
	Threshold camera	212.7687			
A340	Video camera	232.9381	11.70522	0.103862	0.865
	Threshold camera	221.2329			
B-747	Video camera	256.5586	11.71898	0.097052	0.814
	Threshold camera	244.8396			
B-767	Video camera	246.4315	15.10594	0.117282	0.794
	Threshold camera	231.3255			
B-777	Video camera	241.3642	13.39402	0.109464	0.774
	Threshold camera	227.9701			
DC-10/ MD-11	Video camera	263.3166	18.47392	0.15098	0.933
	Threshold camera	244.8427			

Table 17. Narrow-Body Aircraft Total Velocity, Acceleration and Correlation Comparison

Aircraft Model	Measurement Source	Total Velocity (ft/sec)	Velocity Difference (ft/sec)	Estimated Acceleration (g's)	Correlation Coefficient R (Total Velocity)
A319	Video camera (instantaneous value)	222.8043	10.03557	0.070833	0.715
	Threshold camera (average value)	212.7687			
A320	Video camera	236.3055	11.73107	0.085722	0.655
	Threshold camera	224.5744			
A321	Video camera	243.055	10.04242	0.073383	0.722
	Threshold camera	233.0126			
B-737-100	Video camera	237.9898	20.15397	0.152658	0.784
	Threshold camera	217.8358			
B-737-300	Video camera	244.7427	11.72417	0.09336	0.486
	Threshold camera	233.0185			
B-757	Video camera	222.8018	10.03315	0.074188	0.782
	Threshold camera	212.7687			
MD-80/90	Video camera	236.3119	8.35443	0.070123	0.712
	Threshold camera	227.9575			

This conclusion also considers the inherent measurement capability of the video system, the effect of crosswinds, and the impact of the aircraft's flare maneuver on the aircraft's closure speed. The measurement accuracy for closure speed is +2.0 knots and 0.5 ft/sec for sink speed. Range measurements, which impact the average closure speed calculation, are accurate to ±2.4 ft at 250 ft from the camera.

4.8 THRESHOLD HEIGHT EVALUATION.

For LHR Operations to conduct a realistic noise assessment concurrent with the video landing survey, LHR's management asked to measure height over the threshold for each landing. After some research, the survey team decided that this measurement could be added. Future FAA landing parameter surveys plan to include the measurement of aircraft height over the runway as the aircraft crosses the runway threshold as a new parameter. For the most part, the procedure to measure height over the threshold is based on established practices and techniques used to determine landing parameters.

The basic premise of the measurement is that an object of known size, at a known distance, can be related to pixel dimensions in a video image. This relationship is known as a scale factor (SF). The SF is the ratio of the quantity (image size divided by camera focal length) to the quantity (image feature size divided by the distance from the object to the camera). Knowing these quantities, a SF can be calculated. The values of image size can be measured by the video analysis system to subpixel accuracy. The focal length of the lens/camera system is established by the overall calibration of the video system. It can also be establish by laboratory testing. The

principle uncertainties in the process are the real-world distance of the airplane from the camera and the reference dimension on the aircraft.

Uncertainties are inherent in any measurement process. The threshold camera was installed at a convenient location perpendicular to the runway centerline at the runway threshold. The camera was aimed to the estimated typical height of aircraft passing over the threshold so that the aircraft images can be recorded as they pass through the camera's field of view. A measurement of the camera's distance from the runway centerline is made to use as an input for aircraft range. A series of aircraft landings are recorded and processed using the video system to relate aircraft image features with known dimension to video system pixel measurements. For each of the recorded images, the ratio to determine the SF is

$$SF = \frac{((X_1 - X_2)/F)}{(\text{aircraft dimension})/(\text{range to camera})}$$

where the quantity X_1-X_2 is the pixel dimension of the aircraft feature being tracked in the video image. F is the camera lens system focal length. The aircraft dimension is the actual dimension of the aircraft feature being tracked (fuselage length, vertical tail height, wheel span, etc.), in the video image. Range to camera is the distance measured from the camera lens to the runway centerline.

The SFs resulting from the processing of a series of video images are tabulated, and a best estimate of an overall scale factor is calculated. This average procedure is necessary since the actual range of the aircraft to the camera varies if the aircraft does not fly precisely over the runway centerline as it crosses the runway threshold. In addition, the length of the aircraft image feature (gear, wheel, etc.) being evaluated (even of known dimension) varies if the aircraft attitude (pitch, roll, or yaw) distorts the two-dimensional view of that feature to the camera. Thus, the result is an estimated SF that is used in subsequent calculations. The actual threshold height calculation uses the calculated SF and the pixel height of the aircraft's main wheel above the ground to determine the aircraft's threshold height.

If the target aircraft is not exactly over the runway centerline when the image is recorded, the accuracy of the height calculation is influenced. The accuracy of the measurement is influenced by additional factors that need to be accounted for. A camera's field of view must be established to ensure that the aircraft image passes through the field of view as it flies over the runway threshold. This is accomplished by selecting an appropriate camera lens and positioning the camera at a suitable distance from the runway centerline. The lens/distance combination establishes the size of the image feature in the video image (i.e., number of pixels). This number of pixels for a given measurement length determines the measuring resolution of the system. The field of view and image size requirements work against one another and a trade-off between the two is needed for optimized measurement results. Optical distortions can occur if the measured image is too near the edges of the lens, and this can also adversely affect measurement performance.

4.8.1 Review of Threshold Height Data.

The threshold height is the measurement from the bottom of the main gear wheels to the ground at the runway threshold. The analysis of the threshold height camera data has led to the following observations.

For wide-body aircraft, the mean value of threshold height was 53 ft. The threshold height values ranged from a maximum of 85 ft to a minimum of 30 ft. The mean threshold height for the Boeing wide bodies was 53.3 ft, for Airbus, it was 51.8 ft (table 18). The range of threshold heights recorded went from 85 to 35 ft for the Boeing aircraft and from 81 to 30 ft for the Airbus models. Refer to box and whisker plots in figures G-16 and G-18 of appendix G.

Table 18. Mean Value of Selected Landing Parameters by Aircraft Type

Aircraft Type	Threshold Height	Runway Threshold to Touchdown Distance	Approach Speed	Closure Speed	Average Sink Rate	Pitch Angle at Touchdown
All wide body	52.8	1808	151.6	146.0	2.81	7.5
Airbus wide body	51.8	1791	145.0	137.9	2.90	10.1
Boeing wide body	53.3	1814	153.2	148.2	2.77	6.7
All narrow body	55.5	1844	144.0	137.6	2.8	5.7
Airbus narrow body	56.2	1904	146.4	139.2	2.8	5.6
Boeing narrow body	55.3	1802	140.8	135.3	2.6	5.8

The mean value of touchdown distance from runway threshold is 1814 ft for the Boeing aircraft and 1792 ft for the Airbus. The difference between the maximum and minimum values of runway threshold to touchdown distance was 2913 ft for the Boeing and 2977 ft for the Airbus wide-body landings. See figures G-12 and G-14 in appendix G.

Scatter plots were generated comparing the aircraft's measured height crossing the runway threshold to the distance the aircraft traveled down the runway to touchdown. Figure 24 is typical of these plots.

The values of R^2 in figure 24 indicate that a correlation does exist between these two variables. This holds true for nearly all the models in this survey. These results are summarized in table 19.

For wide-body aircraft, the Airbus types show a higher degree of correlation than the Boeing models. The narrow-body aircraft show essentially the same level of correlation when compared as a group. The A321 shows the highest correlation between these variables of any narrow-body model. To investigate the impact of the aircrafts height over the runway threshold on other landing parameters, the landings were subdivided into groups on the basis of threshold height.

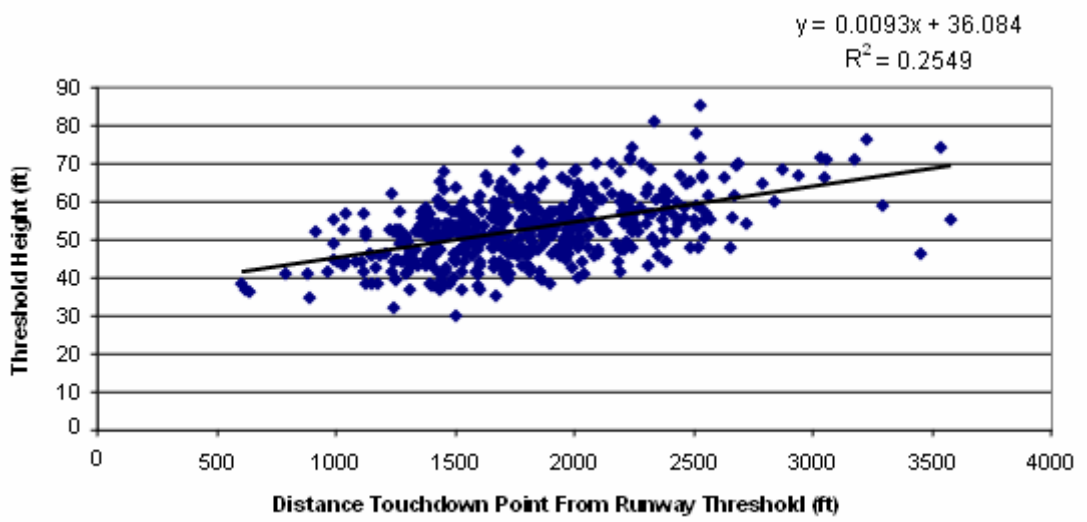


Figure 24. Height Over Runway Threshold vs Distance From Runway Threshold, All Wide-Body Landings, LHR

Table 19. Correlation Comparison: Threshold Height vs Threshold to Touchdown Distance

Wide-Body Aircraft			Narrow-Body Aircraft		
Aircraft Model	R^2	Correlation Coefficient R	Aircraft Model	R^2	Correlation Coefficient R
All wide body	0.2549	0.5049	All narrow body	0.257	0.5070
All Airbus	0.2982	0.5461	All Airbus	0.2452	0.4952
All Boeing	0.2351	0.4849	All Boeing	0.2753	0.5247
A300	0.3895	0.6241	A319	0.2563	0.5063
A310	0.2555	0.5055	A320	0.2258	0.4752
A330	0.591	0.7688	A321	0.3785	0.6152
A340	0.1802	0.4245	B-737-100	0.1476	0.3842
B-747	0.2652	0.5150	B-737-300	0.1512	0.3888
B-767	0.1855	0.4307	B-757	0.3574	0.5978
B-777	0.2909	0.5394	MD-80/90	0.1508	0.3883
DC-10/MD-11	0.2601	0.5158			

4.8.2 Discussion of Landing Parameter Variation as a Function of Threshold Height Groups.

The LHR landing parameter data was divided into three runway threshold height groups. Two groups contained the upper and lower 25% of the observed landings. The remaining landings were included in the central group. Statistical summaries for approach speed, closure speed, average sink speed, pitch angle, roll angle, off-center distance, and runway threshold to touchdown distance were calculated for three subsets of threshold height for each model aircraft. These results are documented in appendix H. When the cutoff between groups fell among a number of landings with the same threshold height, all the landings at that height were placed in the same group. Statistical information was then computed for selected landing parameters in each grouping. For example, selected landing parameters for all wide-body aircraft varied by

group are shown in table H-1 in appendix H. The same parameters are presented in table H-4 for Airbus wide-body aircraft and table H-3 for the Boeing models.

4.8.3 Wide-Body Aircraft Ramp Height Analysis.

Statistical summaries of the primary landing parameters for each model aircraft in this survey, grouped by threshold crossing height, are presented in appendix H.

Only 48 Airbus A300 and 21 A310 aircraft were available for analysis. So a study of each model individually as a function of threshold height was not possible. The landing parameter analysis for the combined models is presented in table H-10.

A similar situation exists with the Airbus A330 and A340 aircraft. Only 19 A330s and 25 A340s were available for analysis. So these models were combined for the analysis of landing parameters as grouped by threshold height. The results of this analysis are presented in table H-11.

An attempt was made to find a correlation between the aircraft's height over runway threshold and the values of headwind and crosswinds reported for each landing. This was done for each aircraft model. Only one plot, shown in figure 25, showed even a mild correlation (R = 0.47) between these variables.

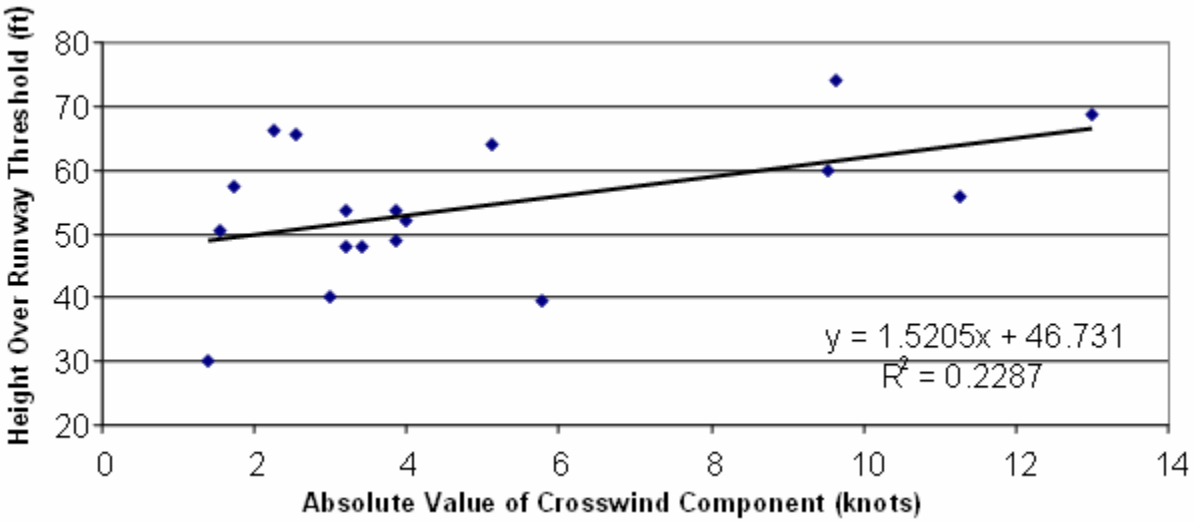


Figure 25. A310 Height Over Runway Threshold

In addition, plots of sink speed versus touchdown distance to runway threshold were generated, with the data subdivided into groups by threshold height. Plots for B-767 sink speed versus touchdown distance (figure 26) as well as the sink rate versus touchdown distance plot for the combined A330/340 (figure 27) show that the maximum sink rate landings occur near to the runway threshold.

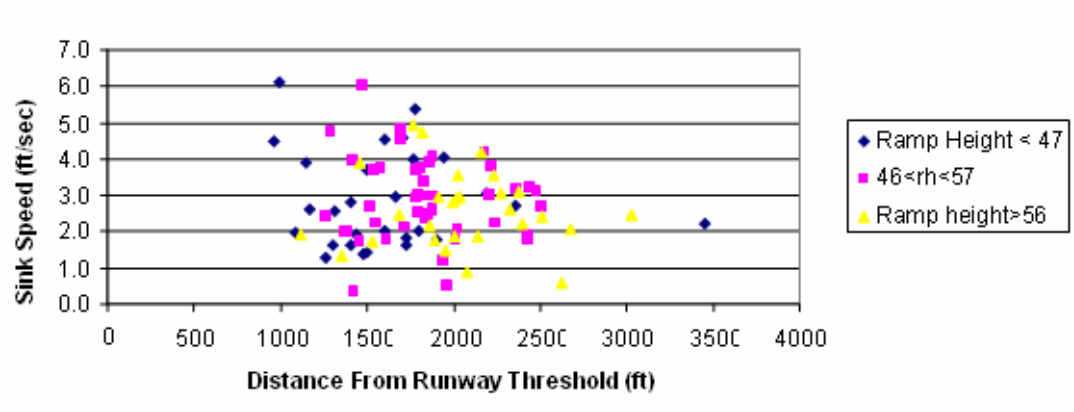


Figure 26. B-767 Sink Speed vs Touchdown Distance From Runway Threshold, Grouped by Height Over Runway Threshold

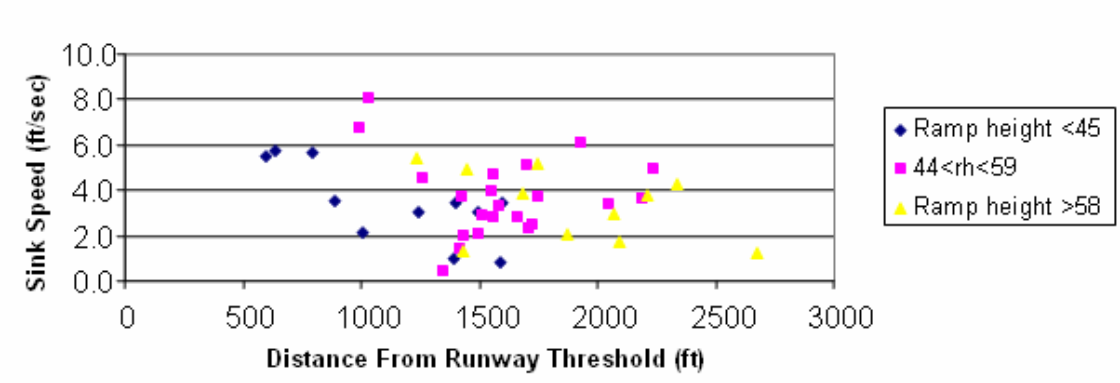


Figure 27. A330/340 Sink Speed vs Touchdown Distance From Runway Threshold, Grouped by Height Over Runway Threshold

Graphs of sink speeds versus touchdown distance from runway threshold for the B-747, B-777, and A300/310 show higher sink rate landings occurring in the mid and upper threshold height groups and were distributed down the runway. Figure 28 is an example of these results.

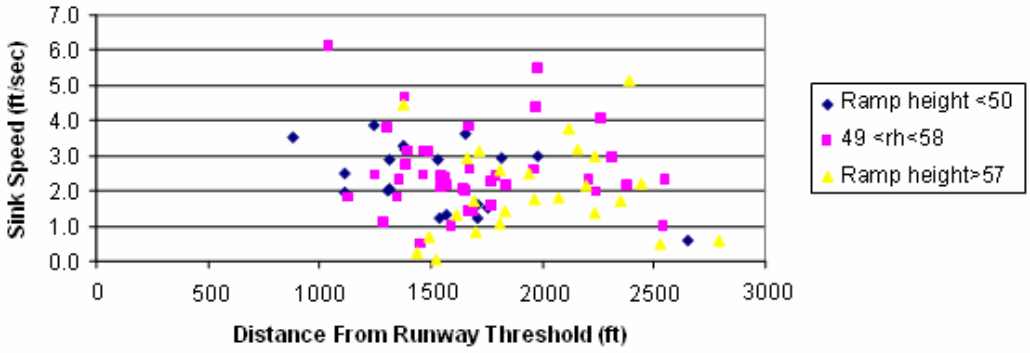


Figure 28. B-777 Sink Speed vs Touchdown Distance From Runway Threshold, Grouped by Height Over Runway Threshold

4.8.4 Narrow-Body Aircraft Ramp Height Analysis.

The scatter of threshold height measurements is significantly different for the Boeing and Airbus narrow-body models. The range of maximum to minimum values of threshold heights is 37.5 ft for the Boeing model, figure G-15 in appendix G, and 54 ft for the Airbus models, figure G-17 in appendix G. The fact that the Airbus aircraft, the A319, A320, and A321 are very similar, while the B-737-100/200, 737-300/400/500, and B-757 are more varied aerodynamically, makes this a surprising observation.

In addition, the range of touchdown distances for the Airbus models is larger than the touchdown range for the Boeings. For the three Boeing models, the maximum variation in mean touchdown distance is 51 ft, figure G-11 in appendix G. For the Airbus aircraft, the maximum variation in mean touchdown distance is 95 ft, figure G-13 in appendix G.

When looking at the Airbus models individually, the collected data show that the A320 landed with the maximum variation in threshold height of 54 ft, but with the minimum range of touchdown points at 1875 ft. The A319 and A321 show a variation of 41.5 and 41 ft, respectively, in threshold height; however, the range of touchdown distances for those aircraft is 2611 and 2552 ft, respectively. Since these aircraft have very similar flight control systems and software, these findings need additional study.

As with the wide-body landing data, the narrow-body landing parameters for each manufacturer and then each aircraft model were separated into subgroups by the threshold height. Statistical summaries for approach speed, closure speed, average sink speed, pitch angle, roll angle, off-center distance, and runway threshold to touchdown distance were calculated for three subsets of threshold height for each model aircraft. These results are documented in appendix H. The groups were separated according to the highest threshold height (roughly top 25%), lowest threshold height (lowest 25%), and the central 50%. Given the relatively small data sets involved, the B-737-100/200 and B-737-300/400/500 aircraft were grouped together for this analysis.

Review of the statistical summaries by manufacturer revealed that the aircraft's approach speed decreased as the threshold height increased for the Boeing aircraft. There was no significant variation in approach speed with threshold height for the Airbus models. There was only an increase in sink rate for the Boeing aircraft at the highest threshold height, see table H-5 in appendix H. For the Airbus aircraft, table H-6, the variation was similar but smaller. The Boeing aircraft showed more variation in pitch angle than the Airbus models.

To review individual landings, plots of average sink speed versus touchdown distance to runway threshold were generated for each model aircraft in the survey. The landings in each threshold height subgroup were plotted separately on the curves. The highest sink rate landings for the Boeing aircraft were in the lower threshold height group. As shown in figure 29, the highest sink speed B-757 landings were also the closest to the runway threshold.

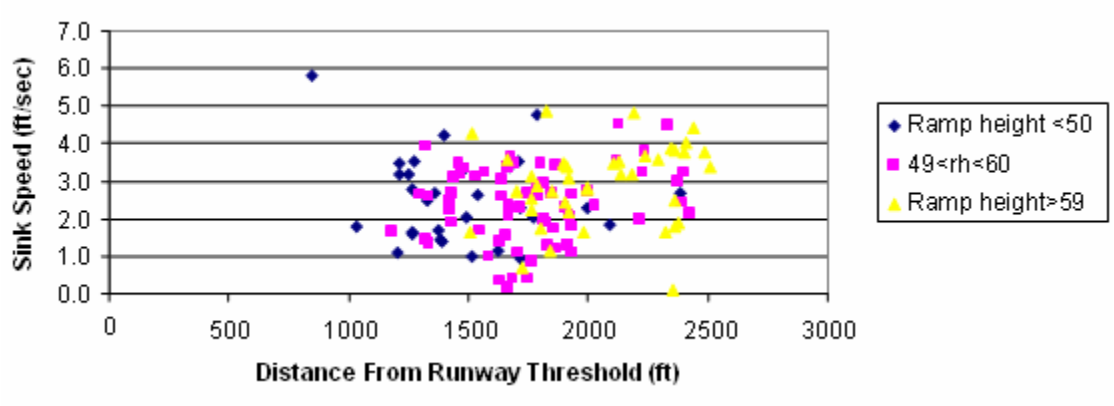


Figure 29. B-757 Sink Speed vs Touchdown Distance From Runway Threshold, Grouped by Height Over Runway Threshold

The Airbus aircraft did not indicate any clear trend. The A319 plot in figure 30 shows that although the two maximum sink speed landings occurred close to the runway threshold, one of these landings was in the highest and the other was in the lowest threshold height group.

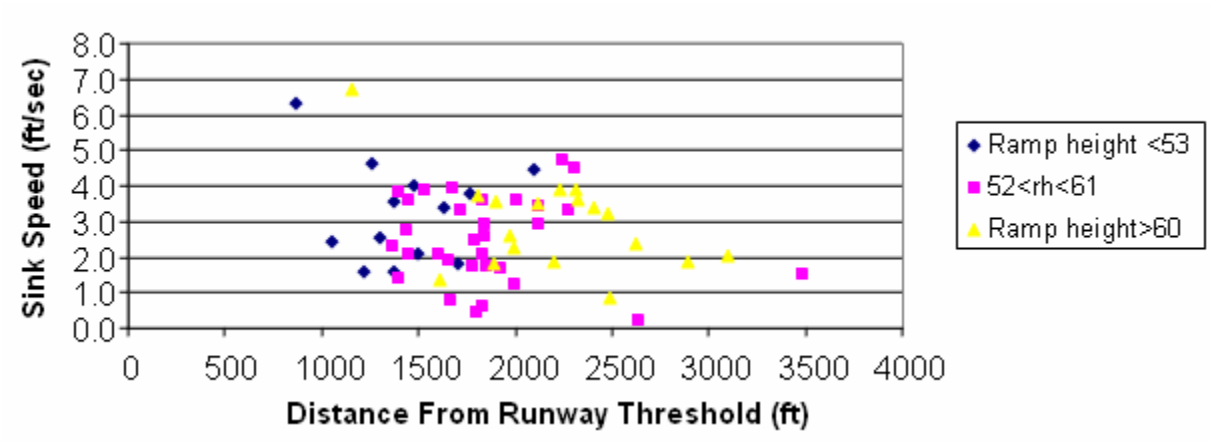


Figure 30. Airbus A319 Sink Speed vs Touchdown Distance From Runway Threshold, Grouped by Height Over Runway Threshold

For the A320, most of the landings in the lowest threshold height group occurred between 1000 and 1500 feet from the runway threshold. The bulk of the landings with sink rate greater than 4 ft/sec occurred in the midrange threshold height group. The A321 landings showed the maximum sink rate for the midrange threshold height group. Two A321 landings in the highest group landed over 3000 ft from the runway threshold.

5. CONCLUSIONS.

The sink speed frequency distribution for the Airbus A330 and A340 aircraft exceed the design distribution specified in Military (MIL)-A-8863. For Boeing heavy wide-body aircraft, London Heathrow Airport (LHR) results are similar to the results from the John F. Kennedy International Airport (JFK) and Honolulu International Airport surveys. The LHR sink speed frequency

distribution for Boeing wide-body aircraft do not exceed the MIL-A-8863 distribution. The A300 and A310 aircraft also do not exceed the MIL-A-8863 distribution. The narrow-body aircraft of both manufacturers show a lower sink speed frequency distribution than the U.S. Military Specification (procurement specification) (MIL-SPEC) curve. The frequency plots for the MD-80 and Airbus A321 do appear to approach the MIL-SPEC values.

The relationship between approach speed and landing weight show increasing approach speeds with increasing landing weight for the general wide-body population. However, for Airbus wide-body aircraft alone, there is no correlation for these parameters.

There is a substantial difference in the landing performance of Airbus and Boeing wide-body aircraft. This is apparent from a number of usage data comparisons: sink speeds, glide slope angles, sink speed versus threshold to touchdown distance, and sink speeds measured by video camera and threshold camera. Airbus wide-body aircraft appear to flare much less than the Boeing aircraft in the time between crossing the runway threshold and final touchdown. This results in higher sink rates for the Airbus aircraft.

For the most part, at LHR, an increase in landing weight did not result in an increase in sink speed. This is in contrast to the increase in sink speed with landing weight observed for wide-body aircraft during the JFK survey.

The addition of the threshold camera has provided important new data, which were not recorded during previous Federal Aviation Administration landing parameter surveys. Not only is aircraft height over the runway threshold recorded, geometric glide slope, an additional sink speed calculation, and an additional closure speed measurement were derived.

For Airbus wide-body aircraft, the comparison of instantaneous and geometric glide slope correlate. This is no evidence of this correlation for the Airbus narrow body or for any of the Boeing aircraft.

For the wide-body aircraft, the average height over threshold was nearly identical, 52 ft for the Airbus wide bodies and 53 ft for Boeing. However, there was a significant difference in the scatter of height over runway threshold between Airbus and Boeing narrow-body aircraft. The Airbus narrow-body aircraft maximum to minimum height crossing the threshold was 54 ft, while the Boeing aircraft variation was 38 ft.

6. REFERENCES.

1. Naval Air Development Center Technical Report, ASL NAM-DE-210.1, “The Standard NAES Photographic Method for Determining Airplane Behavior and Piloting Technique During Landing,” 26 September 1947.

2. NACA-TN-3050, “A Photographic Method for Determining Vertical Velocities of Aircraft Immediately Prior to Landing,” January 1954.

3. NASA Rep. 1214, “Statistical Measurement of Contact Conditions of 478 Transport-Airplane Landings During Routine Daytime Operations,” 1955.

4. NASA, Jewel and Stickle, “Landing Contact Conditions for Turbine-Powered Aircraft,” 1958.

5. NASA TN D-527, “An Investigation of Landing Contact Conditions for a Large Turbojet Transport During Routine Daylight Operations,” October 1960.

6. NASA TN-D-899, “An Investigation of Landing-Contact Conditions for Two Large Turbojet Transports and a Turboprop Transport During Routine Daylight Operations,” May 1961.

7. FAA Flight Standards Service, “Statistical Presentation of Operational Landing Parameters for Jet Transport Airplanes,” June 1962.

8. Naval Air Development Center technical report, NADC-ST-6706, “The Standard ASD Photographic Method for Determining Airplane Behavior and Piloting Technique During Field or Carrier Landings,” January 27, 1968.

9. Naval Air Warfare Center Aircraft Division technical report 941034-60, “Naval Aircraft Approach and Landing Data Acquisition System NAALDAS Video Landing System Shipboard Performance Evaluation,” Warminster, PA, 4 September 1994.

10. Naval Air Warfare Center Aircraft Division technical report 93004-60, “Naval Aircraft Approach and Landing Data Acquisition System NAALDAS Video Landing System Land Based Evaluation,” Warminster, PA, 15 April 1993.

11. Micklos, R. and DeFiore, T., “Methods for Experimentally Determining Commercial Jet Aircraft Landing Parameters From Video Image Data,” FAA report DOT/FAA/CT-93/7, August 1993.

12. DeFiore, T. and Micklos, R., “Video Landing Parameter Survey—John F. Kennedy International Airport,” FAA report DOT/FAA/AR-96/125, July 1997.

13. Barnes, T., DeFiore, T., and Micklos, R., “Video Landing Parameter Survey—Washington National Airport,” FAA report DOT/FAA/AR-97/106, June 1999.

14. Barnes, T., DeFiore, T., and Micklos, R., “Video Landing Parameter Survey—Honolulu International Airport,” FAA report DOT/FAA/AR-00/72, April 2001.

15. DeFiore, T., Jones, T., and Micklos, R., “Commuter Aircraft Video Landing Parameter Surveys, Summary Report—London City Airport, Philadelphia International Airport and Atlantic City International Airport,” FAA report DOT/FAA/AR-04/47, December 2004.

16. Title 14 Code of Federal Regulations Part 25, Aeronautics and Space, Airworthiness Standards: Transport Category Airplanes.

APPENDIX A—TEST PLAN FAA LONDON HEATHROW LANDING PARAMETER SURVEY

Office of Aviation Research
Washington, D.C. 20591

Video Landing Parameter Survey London Heathrow Airport

Thomas DeFiore

Federal Aviation Administration
William J. Hughes Technical Center
Airport and Aircraft Safety
Research and Development Division
Atlantic City International Airport, NJ 08405

April 12,2001

Program Plan

U.S. Department of Transportation
Federal Aviation Administration

Research Program and Installation Plan

Video Landing Parameter Survey London Heathrow Int'l Airport

2-14 July 2001

1.0 OBJECTIVE:

The Federal Aviation Administration (FAA) has a research program, which has the objective of acquiring operational airplane sink speed data. This is accomplished by conducting video landing parameter surveys at high activity commercial airports. These data are used to verify or update existing certification requirements. The Civil Aviation Authority (CAA), Safety Regulation Group, in conjunction with BAA Heathrow – Airside has agreed to host a Video Landing Parameter Survey of heavy wide-body airplane arrivals at Heathrow on Runway 27R from approximately June 30 to July 15.

This survey is a joint FAA, CAA, Aviation Rulemaking Advisory Committee (ARAC) requirement, to generate reliable certification data for landing ground impact for industry's planned A380 size aircraft. These ultra-large airplanes are expected to land with touchdown gross weights of up to ¾ million pounds. London's Heathrow Airport was recommended by ARAC because it has only two main runways and accepts nearly 100 heavy wide-body arrivals daily. Heathrow also provides a better distribution of Boeing/Airbus wide-body airplanes than existed at previous survey locations. BAA Heathrow Airside Management has agreed to host subject survey

The survey team plans to complement the measured touchdown parameters with the airplane landing weight. Consequently, the operators of heavy wide-body airplanes (B-747, B-777, A340, A330, MD-11, DC-10, L-1011) will be contacted by a member of the FAA's survey team to determine the most expeditious means of acquiring this important weight data.

A group of researchers from a joint FAA - US Navy team plan to temporarily install six video cameras on concrete pads along the grass edge of Runway 27R to capture video images of Heathrow arrivals. These video images will be digitized and analyzed to estimate each landing's touchdown contact parameters such as sink speed, forward velocity, pitch, roll and yaw, etc, (1,2)

2.0 BACKGROUND

Prior to the current series of airport landing parameter surveys, certification engineers relied on the results of NASA surveys that were published in 1960 and 1962 (3,4). These survey results showed that the 707/DC8 jet's landing descent velocities were appreciably higher than the turboprops, but the design criteria were not changed. Since that time, the FAA has been interested in obtaining typical operational landing data for the current transports to help manufacturers improve designs, assist with service problems, and evaluate the continued suitability of the 10 ft/sec certification requirement (FAR 25.473) for increasingly heavy wide-body airplanes.

Video Landing Parameter Surveys are a significant component of the FAA's research on Operational Loads Monitoring, RPD-510. Prior FAA surveys at JFK (5) and HNL International (6) Airports have demonstrated that heavy wide-body airplanes touchdown with higher sink

speeds than their narrow-body counterparts, consequently the margins of safety in the 10-ft/sec certification requirement are lower. However, during the JFK and HNL surveys, there were no Airbus heavy wide-body airplane arrivals.

Airbus is now in the process of originating the design of a yet heavier wide-body airplane. The respective regulatory authorities are concerned with the continued applicability of the 10-ft/sec certification requirement for this new design. Concurrently, Boeing is considering higher gross weight versions of their B-747 airplane. A subcommittee of the International Aviation Rulemaking Advisory Committee (ARAC) has been tasked to conduct an investigation into the sink speed issue. The recommendation is to conduct additional video landing parameter surveys of airports with significant heavy wide-body operations.

A statistical studies conducted by both the FAA and ARAC subcommittee members has determined that an acceptable distribution of the various heavy wide-body airplane landings could be obtained by conducting a two-week survey at BAA Heathrow (LHR). LHR's alternating runway operating procedures will enable the survey team to capture a significant quantity of heavy-body landings during a short period of time. Furthermore, an adequate quantity of Airbus heavy wide-body airplanes would be involved.

3.0 TECHNICAL SUPPORT FROM BAA HEATHROW

Due to the logistics of conducting subject survey across the ocean from its home base, the survey team requires a modest amount of technical support from the host organization, BAA Heathrow. **The Federal Aviation Administration will reimburse BAA Heathrow for all expenses involved in supporting the video landing survey team.** Included in this support are the following:

- Installation of six two-foot by two-foot concrete camera pads (6 to 8 inches thick) on the grass adjacent to the apron edge, with a steel reinforcing bar (re-bar) at each corner of the pad. Request is for the bars to be ¾ inch diameter, cogged and driven approximately 3/4 meter into the ground. Pads are to be mounted flush to the runway surface. These concrete pads will be removed when the survey is completed.

- Installation of temporary pads for six portable generators (perhaps these could be little more than two-foot by two-foot pallets)

- Loan of Light Weight Fluorescent vests for survey team members (8-9);

- Delivery and placement of a temporary portable office near the fence, approximately 30+ meters east of resurfacing contractor's temporary office(s).

-
    - Toilet facility is needed (i.e., Porta-Loo)
    - Office chairs, 6-8, preferably high back as opposed to folding chairs
    - Two office tables, minimum three-foot by five-foot for data acquisition equipment

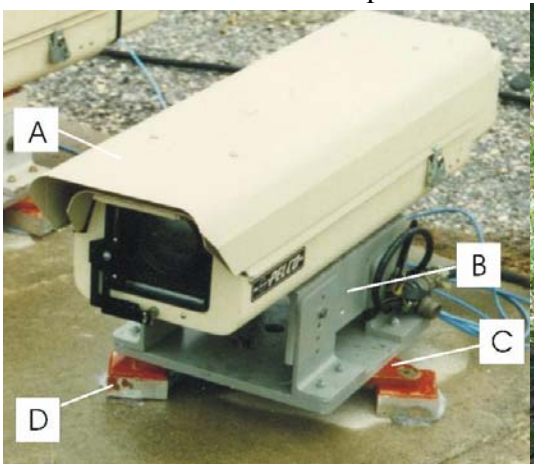
- Issuance of security passes (i.e., badges) for survey team (CAA sponsor will actually submit clearance requests)

- Arrange for access through Gate 3 for the survey team to install, service, and operate equipment. Provide for appropriate BAA escort service during the survey. Provide security for FAA equipment

4.0 CAMERA INSTALLATION

Photos of an installed camera and a generator are shown below. This camera configuration was used on all prior surveys. The camera casing is similar to many security video camera casings and is approximately 3 feet long and eight inches wide and eight inches in height. The cameras are powered by portable generators, which have spark arrestors on the exhaust. See attachment 1. Cameras (A) are mounted in a double frangible manner to the ground as follows:

Three 3 inch by 3 inch solid aluminum blocks (D) are epoxy bonded to the concrete pads using a plastic steel liquid adhesive (MMM-A-1754, MIL SPEC). See attachment 2. A camera mounting plate (C) is bolted to a hole in each aluminum block with a .41 inch bolt. The calculated frangible load for each camera mount is 6,252 pounds. See attachment 3. An aluminum camera frame (B) is mounted to the flat camera plate (C) and the camera itself is mounted to the frame. The frame is adjustable up to 15 degrees, which is necessary to horizontally align the camera to its theoretic touchdown reference. The camera plate is located less than two inches above the ground. The top of the camera's protective casing is approximately 20 inches above the ground. Power cords are run to the generators and fiber optic cables are run to the data acquisition station.



5.0 LANDING SURVEY EQUIPMENT LOCATION DESCRIPTION

The camera and generator locations are identified using the runway diagrams in figure1 and figure 2. The key locations are camera C4 and Generator G3 as described below.

Camera Number	**Location**
C4 (concrete pad)	20 meters west of the west edge of the white hold line of the abandoned taxiway between blocks 3b and 4.
C5 (concrete pad)	152.4 meters **West** of C4 at the edge of the runway apron.
C6 (concrete pad)	152.4 meters **West** of C5 at the edge of the runway apron.
C3 (concrete pad)	152.4 meters **East** of C4 at the edge of the runway apron.
C2 (concrete pad)	152.4 meters **East** of C3 at the edge of the runway apron.
C1 (concrete pad)	152.4 meters **East** of C2 at the edge of the runway apron.
C7 (stake mounted)	(Threshold camera) The camera will be positioned perpendicular to the runway at the threshold in the area between the red pegs and the north fence. C7 is used to measure the airplane's height above the runway threshold.
Generator #	**Location:**
G3	Straight back from C4 and perpendicular to the runway, positioned 15 meters **North** of the Clear & Graded Area, 58 meters **West** of the taxiway edge (construction vehicle access taxiway) as per the figure 2 drawing.
G4	15 meters **North** of the Clear and Graded Area and 228 meters **West** of G3.
G2	15 meters **North** of the Clear and Graded Area and 228 meters **East** of G3.
G1	15 meters **North** of the Clear and Graded Area and 228 meters **East** of G2.
G5	Located between the red pegs and the north fence approximately 15 meters **West** of C7.

6.0 VIDEO AND POWER AND POWER CABLES (All cable runs will be perpendicular to 29R and identified with red warning flags every 3 to 4 meters)

- The fiberoptic video cables from cameras C1 to C3 will run perpendicular to the runway from each camera to 15 meters beyond the Clear and Graded Area. C3 and C2 cables will parallel the Clear and Graded Area until joining with C1 cable. At this point the cables will run back to the video trailer. The video trailer is located along the north fence east of the construction trailer site.

- The video cables from cameras C4 to C6 will run perpendicular to the runway from each camera to 15 meters north of the Clear and Graded Area. C6 and C5 cables will parallel the Clear and Graded Area until joining with C4 cable. The cables then run back to the north fence. The cables will run within a 1 meter area between the fence and the construction vehicles, paralleling the fence to the video trailer

- The video cable from camera C7 will run from the camera to the video trailer. The cable will remain well north of the Clear and Graded Area.

- The power cable from camera C1 will run from the camera to 15 meters beyond the Clear and Graded Area to generator G1 position

- The power cables from cameras C2 and C3 will run from the cameras to 15 meters beyond the Clear and Graded Area to generator G2 position.

- The power cable from camera C4 will run from the camera to 15 meters beyond the Clear and Graded Area to generator G3 position.

- The power cables from cameras C5 and C6 will run from the cameras to 15 meters beyond the Clear and Graded Area to generator G4 position.

- The power cable from camera C7 will run from the camera to generator G5 position in the area between the red pegs and the north fence.

7.0 TEST SCHEDULE:

The following is the proposed test schedule. The Operational Schedule is conditional on westerly winds and arrivals actually occurring on Runway 27R.

Date:	Day	Planned Activity
25 June	Mon	Travel
26 June	Tue	AM: Travel, Hotel check-in, Meet with CAA/ BAA contacts Pick up car and truck rental
27 June	Wed	AM: Meet with CAA/ BAA security Move equipment from storage to 27R work site PM: Move/setup equipment in trailer, Position and fuel generators. (All work will be north of the Clear & Graded Area) 11:00pm to 6:00am: Install camera blocks and mounts. Run Camera video and power cables from the camera site to 10 meters north of the Clear & Graded Area
28 June	Thurs	PM Complete running video and power cables. (All work will be north of the Clear & Graded Area) 11:00pm to 0600am, Mount and align cameras, connect power/video cables, operate system. Perform edge of runway alignment.
29 June	Fri	No Work/Back up day
30 June	Sat	11:00pm to 0600am, Perform system calibration Note: If runway is clear of construction equipment and Personnel, calibration could be performed on 29 June from 11:00 PM to 6:00 AM
1 July	Sun	No Work
1-8 July	Mon to Sun:	6:00 AM to 3:00 PM, Video System Operation*
9-14 July	Mon to Sun:	3:00 PM to Dusk, Video System Operation *

* Operational schedule is contingent upon mostly westerly operations

Date:	Day	Planned Activity
14 July	Sat	11:00pm to 6:00am, Perform Second System Calibration Note: If runway is clear of construction equipment and personnel, calibration could be performed on 13 July from 1100PM to 0600AM
15 July	Sun-	11:00pm to 6:00am, Remove all equipment from the runway area.
16 July	Mon -	PM: Pack up trailer equipment, generators, cables
17 July	Tue -	AM/PM: Complete packing up of equipment
18 July	Wed -	AM: Transport equipment to temporary CAA storage area, band skids, return truck, prepare shipping papers. PM: Farewell meeting with BAA/CAA
19 July	Thru-	Travel

8.0 REFERENCES:

(1) NADC-ST-6706, "The Standard ASD Photographic Method for Determining Airplane Behavior and Piloting Technique During Field or Carrier Landings," Jan 1968

(2) Report DOT/FAA/CT-93/7, Methods for Experimentally Determining Commercial Jet Aircraft Landing Parameters From Video Image Data - Final Report, August 1993

(3) NASA TN D-527, An Investigation of Contact Conditions for a Large Turbojet Transport During Routine Daylight Operations, October 1960

(4) FAA Flight Standards Service, "Statistical Presentation Of Operational Landing Parameters for Jet Transport Airplanes, June 1962

(5) Report DOT/FAA/AR-96/125, Video Landing Parameter Survey - John F Kennedy International Airport, Final Report, July 1997

(6) Report DOT/FAA/AR-00/72, "Video Landing Parameter Survey - Honolulu International Airport," April 2001

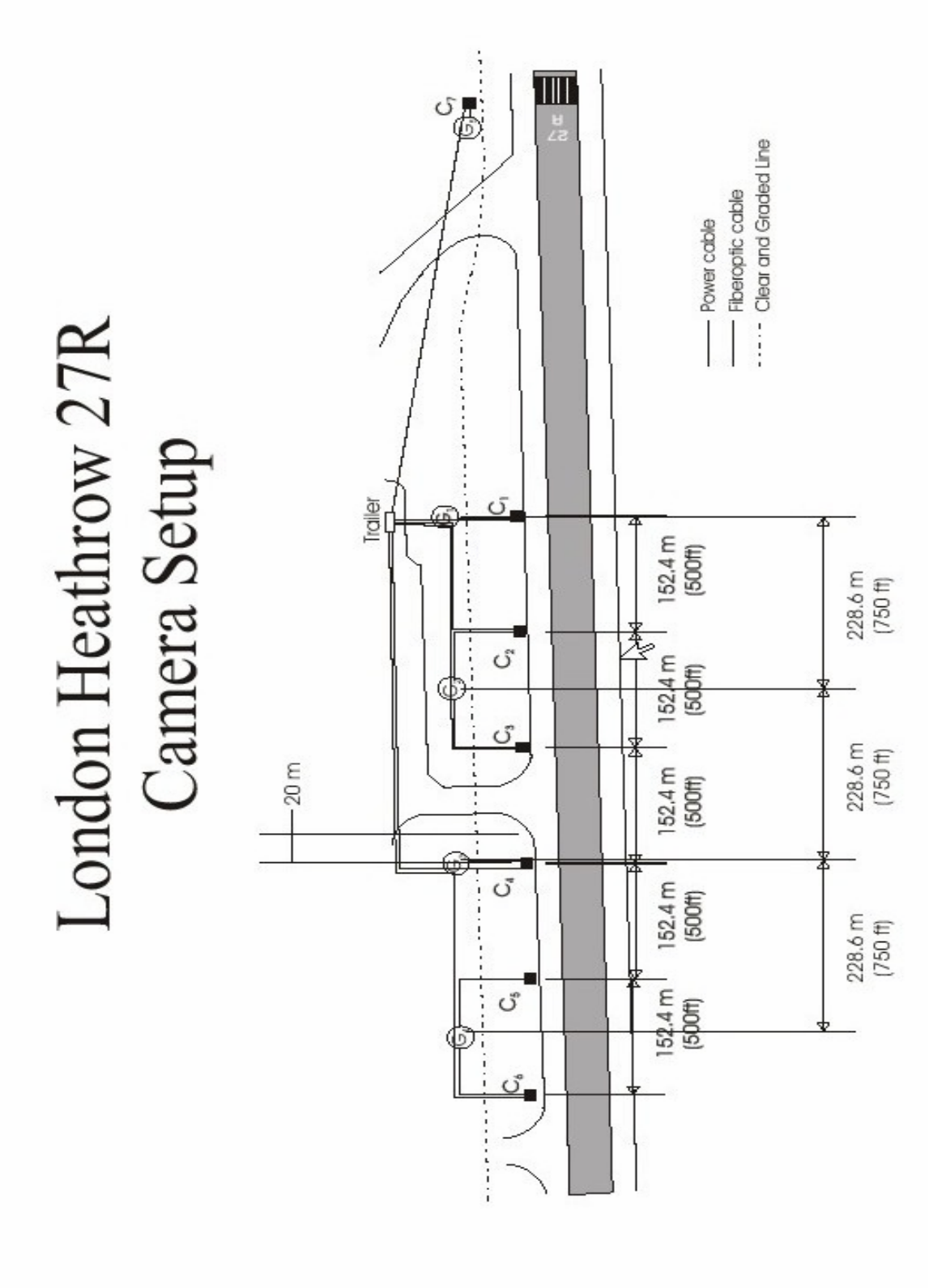

London Heathrow 27R
Camera Setup
Power cable
Fiberoptic cable
Clear and Graded Line
Trailer
20 m
C1
C2
C3
C4
C5
C6
C7
152.4 m (500ft)
228.6 m (750 ft)

Figure 1


London Heathrow 27R
Camera Setup
Trailer
27R
C1
C2
C3
C4
C5
C6
C7

Figure 2

SPECIFICATIONS

Dimensions

Model	EB2500X
Power equipment description code	EZCP
Length x Width x Height	505 x 420 x 420 mm (19.9 x 16.5 x 16.5 in)
Dry weight	44.5kg (91.8lb)

Engine

Model	GX 160 K1
Engine type	4-stroke, overhead valve, single cylinder
Displacement (Bore x Stroke)	163cc (9.9cu in) (68 x 45 mm (2.7in x 1.8in))
Compression ratio	8.5:1
Engine speed	3,600 r.p.m
Cooling system	Forced air
Ignition system	Transistorized magneto
Oil capacity	0.6 ℓ (0.63US qt, 0.52Imp qt)
Fuel tank capacity	11.0 ℓ (2.9US gal, 2.4Imp gal)
Spark plug	BPR6ES (NGK), W20EPR-U (NIPPONDENSO)

Generator

Model		EB2500X
Type		AG
AC output	Rated voltage	120V
	Rated frequency	60HZ
	Rated ampere	19.2A
	Rated output	2,300VA
	Maximum output	2,500VA

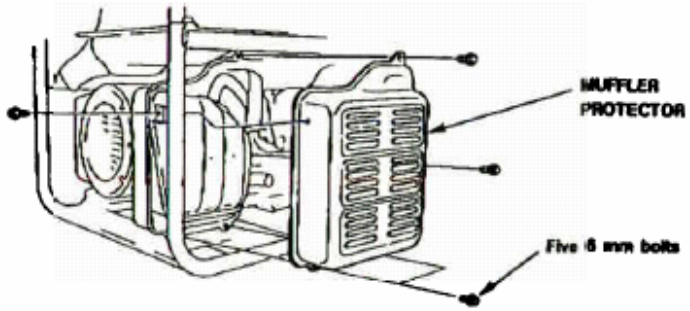
NOTE: Specifications are subject to change without notice.

Spark Arrester Maintenance

If the generator has been running,the muffler will be very hot. Allow it to cool before proceeding.

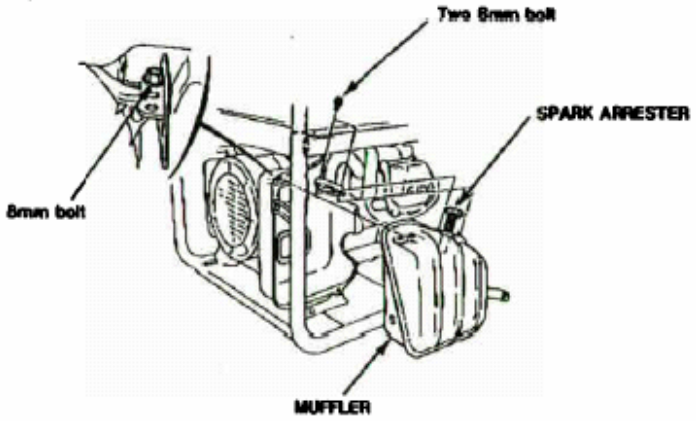
NOTICE **The spark arrester must be serviced every 100 hours to maintain its efficiency.**

1. Loosen the five 6 mm bolts to remove the muffler protector.

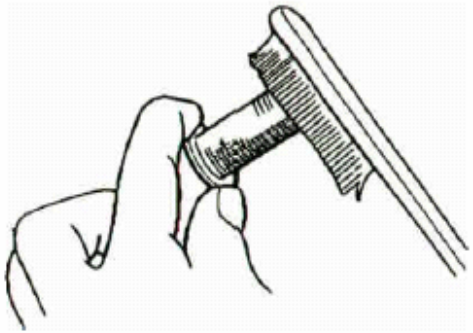


2. Remove the two 8 mm bolts at the exhaust pipe and the 8 mm bolt at the muffler stay.

Remove the muffler and the spark arrester.



3. Use a brush to remove carbon deposits from the spark arrester s
   Inspect the spark arrester screen for holes or tears. Replace if
   sary.



4. Check the exhaust pipe gasket and replace if damaged. Reins
   muffler and the protector.

Attachment 2

Devcon®

PLASTIC STEEL® LIQUID B

PRODUCT DESCRIPTION

A steel-filled, liquid epoxy for general maintenance and repairs. For tooling, mold-making and leveling equipment.

FEATURES/BENEFITS

- Low viscosity for easy pouring
- Can be cast over models for accurate detail reproduction.
- Can be machined to close tolerances.
- Low shrinkage

RECOMMENDED APPLICATIONS

- Holding fixtures for intricate parts.
- Filling and leveling equipment.
- Repairing hard-to-reach areas where a flowable epoxy is needed.
- Duplicating or tracing masters.
- Short run dies and molds

Typical Physical Properties: Cured 7 days @ 75°F.

Color	Dark grey
Mixed Viscosity	20,000 cps
% Solids by Volume	100
Cured Density	2.1 gm/cc
Cured Shrinkage ASTM D2566	0.0006 in/in
Specific Volume	13.1 in.³/lb
Potlife @ 75°F (1 lb. mass)	45 minutes
Compressive Strength ASTM D695	10,200 psi
Adhesive Tensile Shear ASTM D1002	2,800 psi
Cured Hardness Shore D ASTM D2240	85D
Dielectric Strength, volts/mil, ASTM D149	30 volts/mil
Coverage	.52 sq.in./lb. @ 1/4"
Temperature Resistance: Wet	120°F
Dry	250°F

Chemical Resistance: 7 days room temperature cure (30 days immersion @ 75°F)

Kerosene	VG	Methanol	U
10% Hydrochloric Acid	VG	Toluene	F
Chlorinated Solvent	VG	Ammonia	VG
10% Sulfuric Acid	VG	10% Sodium Hydroxide	E

KEY: E = Excellent VG = Very Good F= Fai r U= Unsatisfactory

Epoxies are very good in water, saturated salt solution, leaded gasoline, mineral spirits, ASTM #3 oil and propylene glycol. Epoxies are generally not recommended for long-term exposure to concentrated acids and organic solvents.

PLEASE CONSULT FACTORY FOR OTHER CHEMICALS.

ITW Devcon, 30 Endicott St., Danvers, MA 01923

Directions for Use:

Proper surface preparation is essential to the success of any epoxy application. In all cases the surface should be clean, dry, free from oils, and rough.

1. Remove all oils, dirt and grease by means of a strong cleaner/degreaser (Devcon Cleaner Blend 300 is suitable for this process.)
2. Roughen the surface by grit blasting (8-40 mesh grit) or grinding. A 3-5 mil profile is desired for most applications.
3. All abrasive preparation should be followed by another cleaning to remove any remnants from that process.
4. Ideal application temperature is 55 - 90°F. Under cold conditions, heating the repair area to 100 - 110°F is recommended.
5. Add hardener to resin and mix thoroughly with a screwdriver or putty knife until a uniform, streak-free consistency is obtained, (about 4 minutes).

MixRa tio:R esintoH ardener:We ight.9 :1,V olume3: 1

6. Spread mixed material over the repair area and work firmly into the substrate to ensure maximum surface contact.
7. To bridge large gaps or holes, use fiberglass tape, expanded metal or mechanical fasteners.

Directions for Casting Epoxy:

1. Brush a thin coat of epoxy onto substrate to be duplicated.
2. Pour epoxy in a fine stream to avoid entrapping air.
3. Do not pour epoxy in sections greater than 1" at a time. Allow material to set up and cool before pouring additional thicknesses.

CURE:

- Working time is 45 minutes @ 75°F
- Functional (75%) cure is achieved in 16 hours @ 75°F
- For maximum physical properties, heat cure for 4 hours at 200°F after curing at room temperature for 2-1/2 hours.

MACHINING:

Allow material to cure for at least 4 hours before machining.

- Lathe Speed: 150 ft./minute
- Cut: Dry
- Tools: Carbide Top Rake 6° (+/- 2°)- Side/Front 8° (+/- 2°)
- FeedRate (rough): Trave l speed.02 0 Roug hc ut.020 - .000
- Feed Rate (finishing): Travel speed .010 Finish cut .010
- Polishing: Use 400 to 650 emery paper wet. Material should polish to a 25-50 micro inch

PRECAUTION:

Use in accordance with Material Safety Data Sheet.

Warranty: Devcon will replace any material found to be defective. Because the storage, handling and application of this material is beyond our control, we can accept no liability for the results obtained.

Warning: For Industrial Use Only.

ORDERING INFORMATION:

Stock No.	Unit Size
10210	1 lb
10220	4 lb
10230	25 lb*

* Packaged with slow hardener. Pot life is 90 minutes.

9/26/00

Directions for Use:

Proper surface preparation is essential to the success of any epoxy application. In all cases the surface should be clean, dry, free from oils, and rough.

1. Remove all oils, dirt and grease by means of a strong cleaner/degreaser (Devcon Cleaner Blend 300 is suitable for this process.)
2. Roughen the surface by grit blasting (8-40 mesh grit) or grinding. A 3-5 mil profile is desired for most applications.
3. All abrasive preparation should be followed by another cleaning to remove any remnants from that process.
4. Ideal application temperature is 55 - 90°F. Under cold conditions, heating the repair area to 100 - 110°F is recommended.
5. Add hardener to resin and mix thoroughly with a screwdriver or putty knife until a uniform, streak-free consistency is obtained, (about 4 minutes).

MixRa tio:R esintoH ardener:We ight.9 :1,V olume3: 1

6. Spread mixed material over the repair area and work firmly into the substrate to ensure maximum surface contact.
7. To bridge large gaps or holes, use fiberglass tape, expanded metal or mechanical fasteners.

Directions for Casting Epoxy:

1. Brush a thin coat of epoxy onto substrate to be duplicated.
2. Pour epoxy in a fine stream to avoid entrapping air.
3. Do not pour epoxy in sections greater than 1" at a time. Allow material to set up and cool before pouring additional thicknesses.

CURE:

- Working time is 45 minutes @ 75°F
- Functional (75%) cure is achieved in 16 hours @ 75°F
- For maximum physical properties, heat cure for 4 hours at 200°F after curing at room temperature for 2-1/2 hours.

MACHINING:

Allow material to cure for at least 4 hours before machining.

- Lathe Speed: 150 ft./minute
- Cut: Dry
- Tools: Carbide Top Rake 6° (+/- 2°)- Side/Front 8° (+/- 2°)
- FeedRate (rough): Trave l speed.02 0 Roug hc ut.020 - .000
- Feed Rate (finishing): Travel speed .010 Finish cut .010
- Polishing: Use 400 to 650 emery paper wet. Material should polish to a 25-50 micro inch

PRECAUTION:

Use in accordance with Material Safety Data Sheet.

Warranty: Devcon will replace any material found to be defective. Because the storage, handling and application of this material is beyond our control, we can accept no liability for the results obtained.

Warning: For Industrial Use Only.

ORDERING INFORMATION:

Stock No.	Unit Size
10210	1 lb
10220	4 lb
10230	25 lb*

* Packaged with slow hardener. Pot life is 90 minutes.

9/26/00

Attachment 3

Emil Finn & Associates

JOB NO. EFA-991028 CLIENT FAA DATE 11 APR 2001
SUBJECT VIDEO CAMERA FRANGIBILITY BY EHF SHEET 1/1

① ATTACHMENT OF CAMERA SUPPORT TO RUNWAY VERGE

3 PADS PER CAMERA: EACH 3"×3" (1.25" THKC)

ADHESIVE: DEVCON PLASTIC STEEL LIQUID B
(ATTACHED 2 PG DATA SHEETS)

SHEAR (TENSILE) CAPACITY 2,800 psi

ASSUME 80% EFFICIENCY FOR 3 PAD CONFIGURATION

NOMINAL ULTIMATE SHEAR CAPACITY IS THEN

$V_{ULT} \simeq 3(3\times3)\times0.8(2800) = 60,480$ LB
$= 269$ KN

② SHEAR CAPACITY OF BOLTS CONNECTING TO ALUMINIUM 3"×3"×1.25" BLOCKS/PADS

BOLTS ARE ½"Ø DEEMED TO BE GRADE 2
(ATTACHED ROCKFORD DATA SHEET)

MIN TENSILE STRENGTH = 74,000 psi

LIKELY TENSILE STRENGTH = 1.2 × 74,000 = 88,800 psi

PROJECTED ULTIMATE SHEAR CAPACITY ≃ 59,200 psi

THREAD SCF ≃ 3.0

THREAD ROOT DIAMETER = 0.41"

LOAD SHARING FACTOR FOR 3 BOLTS = 0.8

$$V_{ULT} = \frac{\frac{\pi(0.41)^2}{4} \times 3 \times 59{,}200 \times 0.8}{3.0} = 6,252 \text{ LB}$$
$= 27.8$ KN

CONTROLLING FRANGIBILITY = 27.8KN = 6.2 KIPS

ASTM, SAE AND ISO GRADE MARKINGS AND MECHANICAL PROPERTIES FOR STEEL FASTENERS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	Yield Strength Min (psi)	Tensile Strength Min (psi)
 No Grade Mark	SAE J429 Grade 1	Bolts, Screws, Studs	Low or Medium Carbon Steel	1/4 thru 1-1/2	33,000	36,000	60,000
	ASTM A307 Grades A&B		Low Carbon Steel	1/4 thru 4	–	–	
	SAE J429 Grade 2		Low or Medium Carbon Steel	1/4 thru 3/4 Over 3/4 to 1-1/2	55,000 33,000	57,000 36,000	74,000 60,000
 No Grade Mark	SAE J429 Grade 4	Studs	Medium Carbon Cold Drawn Steel	1/4 thru 1-1/2	–	100,000	115,000
 B5	ASTM A193 Grade B5		AISI 501	1/4 Thru 4	–	80,000	100,000
 B6	ASTM A193 Grade B6		AISI 410			85,000	110,000
 B7	ASTM A193 Grade B7		AISI 4140, 4142, OR 4105	1/4 thru 2-1/2 Over 2-1/2 thru 4 Over 4 thru 7	– – –	105,000 95,000 75,000	125,000 115,000 100,000
 B16	ASTM A193 Grade B16		CrMoVa Alloy Steel			105,000 95,000 85,000	125,000 115,000 100,000
 B8	ASTM A193 Grade B8		AISI 304	1/4 and larger	–	30,000	75,000
 B8C	ASTM A193 Grade B8C		AISI 347				
	ASTM A193		AISI 316				

Frangibility Measurement from Joining the Camera Frame Plate with the Camera Mounting Plate

The plate supporting the camera frame (B) is fastened to the triangular camera mounting plate (C) using four ¼ inch bolts, which are not visible in the photo below. The top of the ¼ inch bolts is approximately 2.5 inches above the ground. Both plates are made of aluminum. The coefficient of friction between the two aluminum plates in dry condition is 1.05 (AIAA Aerospace Design Engineers Guide). The assembly and computation of frangibility is as follows:

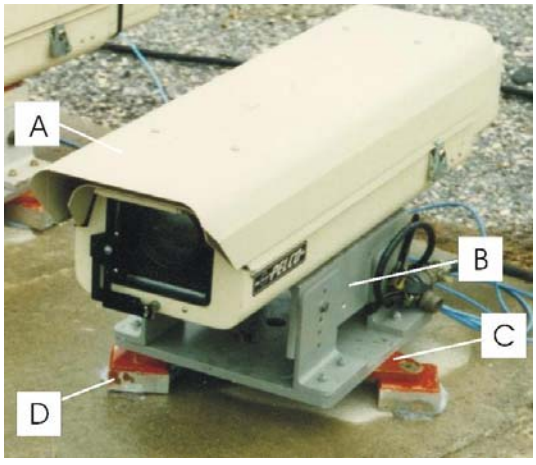
Four ¼ inch Bolts in Tension
Grade 2 Bolts: Min Tensile Strength of 74 KSI
Likely Tensile Strength of 1.2 x 74 or 88 KSI
Bolt thread Stress Concentration Factor (SCF) is approximately 3.0
Bolt thread root diameter is 0.20 inches

$$\text{Maximum Tensile Force} = \frac{(\text{Tensile Stress} \times \text{Cross Sectional Area})}{\text{SCF}}$$

$$\text{Maximum Tensile Force} = \frac{88{,}000 \times \frac{4\pi(0.20)^2}{4}}{3.0} = 3686 \text{ lb}$$

Maximum Shear Force Due to Friction is 1.05 x 3686 = 3870 lb

The ultimate shear capacity of the four bolts is actually less than 2000 lbs. At ultimate tensile load, however, the bolts have no residual shear capacity, thus the frangible load is **3870** lb.



APPENDIX B—COMPARISON OF FAA VIDEO LANDING SURVEY SYSTEM WITH THE BOEING MD-90 FLIGHT TEST INS SYSTEM

COMPARISON OF FAA VIDEO LANDING SURVEY SYSTEM WITH THE BOEING MD-90 FLIGHT TEST INS SYSTEM

Research Objective: To provide a verification of the accuracy of the vertical velocity results from the FAA Video Landing Parameter Surveys

Background: The FAA and US Navy have been jointly conducting a number of video landing parameter surveys at high capacity commercial airports. To date surveys have been conducted at John F. Kennedy (JFK) International, Washington National (DCA) (now Reagan), Honolulu (HNL) International, and London City (LCY) Airports, and plans are in place for additional surveys. After receiving published data from the JFK survey and preliminary data from DCA, the Boeing Aerospace Corporation has many concerns regarding the accuracy of the results from these Joint FAA/Navy Surveys. Specific concerns include:

- FAA/Navy Video Landing Parameter Survey Results were grossly overestimating vertical velocity.
- Due to measurement errors, FAA/Navy frequency distributions were not representative of the distribution Boeing assumes.
- Higher vertical velocity measurement errors exist at higher vertical velocities.

Approach: The FAA and Boeing Douglas Products Division (DoD) agreed to conduct a Fly-off Comparison Survey at Atlantic City International (ACY) Airport during the spring of 1998. Boeing ferried its MD-90 airplane equipped with a INS Flight Test System and flight test team to ACY while the FAA/Navy setup a temporary video landing facility on runway 13.

Accomplishment Description: Over 70 complete stop landings were flown during a 1-week period. These landings were simultaneously recorded on the Boeing flight test system and the FAA/Navy video landing parameter system. The resultant data were subsequently processed at Boeing DPD and the FAA/Navy facilities. Figure C-1 shows a good correlation of results from the respective systems. While there were some individual landing differences, overall survey vertical velocities were within FAA/Navy and Boeing assumed one half ft/sec tolerance. The frequency distribution of FAA/Navy Vertical Velocity Data closely matches similar data from the Boeing DPD (see figure C-2).

Significance: Due to the Boeing concerns regarding the accuracy of the FAA/Navy video survey results, the FAA

- Performed quasi-static calibration of FAA/Navy video system at NAWC Warminster
- Delayed Publication of DCA Report
- Stopped Data Processing of HNL and LCY Data
- Provided a complete FAA/Navy requested System Description and Representative Technical Data to Boeing to conduct a comprehensive review of Navy Data Reduction Algorithms and Procedures
- Agreed to Fly-off Comparison in April 98

Expected Results: Continuation of the publication of reports and the conduct of additional surveys to collect new data from which updated sink speed and other landing parameter certification requirements can be developed.

Reference: Barnes, T., DeFiore, T., and Micklos, R., "Video Landing Survey – John F. Kennedy International Airport," DOT/FAA/AR-96/125, July 1997

Point of Contact: Mr. Thomas DeFiore, AAR-433, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ 08405, Phone: (609) 485-5009, FAX (609) 485-4569,
e-mail: Thomas.DeFiore@tc.faa.gov

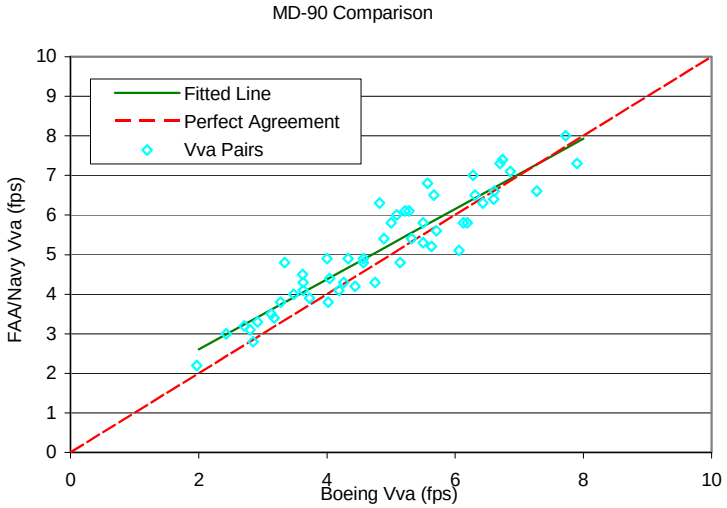


FIGURE B-1. INDIVIDUAL LANDING CORRELATION (r = 0.93)

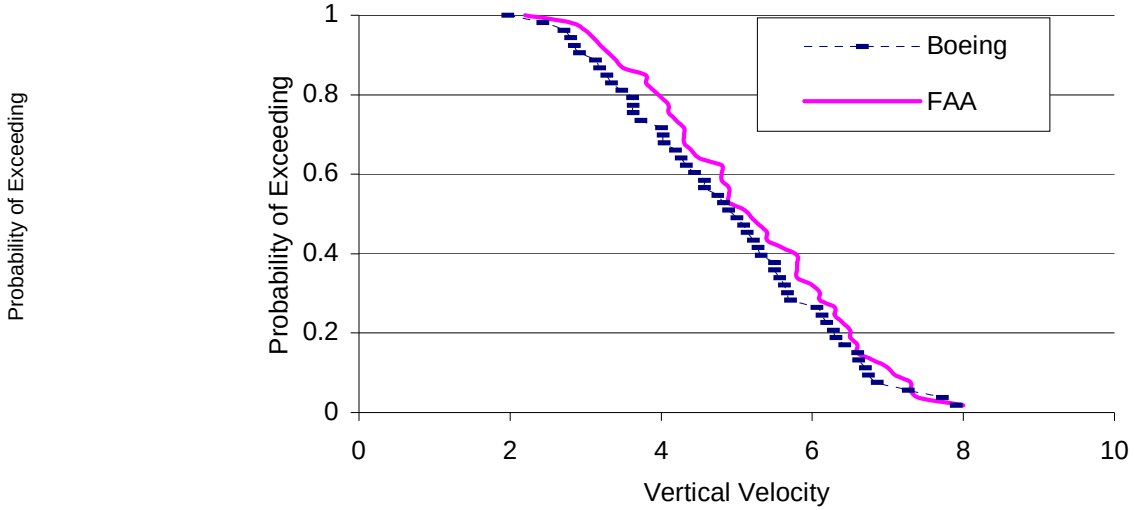


FIGURE B-2. VERTICAL VELOCITY FREQUENCY DISTRIBUTIONS

APPENDIX C—STATISTICAL SUMMARY OF PRIMARY AIRCRAFT LANDING PARAMETERS BY AIRCRAFT MODEL

Table C-1. Aircraft Model: A300, Number of Landings-48

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.0	1.73	0.53	ft/sec
Video sink speeds	Starboard wheel	2.7	1.35	0.03	ft/sec
	Average of main wheels	2.8	1.50	0.49	ft/sec
Threshold camera sink speed		6.1	1.13	0.49	ft/sec
Video closure speed (measured to camera)		138.0	9.82	0.00	knots
Threshold camera closure speed		132.0	7.37	-0.35	knots
Approach speed		145.0	8.80	0.01	knots
Wind speed:	Headwind	6.65	7.42	0.62	knots
	Crosswind	-0.47	5.18	-0.95	knots
Pitch angle at touchdown		9.32	2.73	0.74	degrees
Roll angle at touchdown		-0.43	1.50	0.33	degrees
Yaw angle at touchdown		-1.86	5.42	-0.45	degrees
Instantaneous glide slope angle		0.60	0.28	-0.13	degrees
Geometric glide slope angle		1.56	0.28	0.20	degrees
Height over runway threshold		52.0	10.10	0.43	feet
Threshold to touchdown distance		1858.0	515	0.65	feet
Off-center distance at touchdown		-1.4	7.36	-0.33	feet

Table C-2. Aircraft Model: A310, Number of Landings-21

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.0	1.64	0.19	ft/sec
Video sink speeds	Starboard wheel	2.6	1.56	0.05	ft/sec
	Average of main wheels	2.7	1.50	-0.13	ft/sec
Threshold camera sink speed		6.1	1.41	0.61	ft/sec
Video closure speed (measured to camera)		137.0	9.30	0.46	knots
Threshold camera closure speed		131.0	5.91	-0.46	knots
Approach speed		143.0	10.34	-0.14	knots
Wind speed:	Headwind	5.88	5.21	-0.23	knots
	Crosswind	-1.00	5.59	-1.02	knots
Pitch angle at touchdown		8.28	1.96	0.11	degrees
Roll angle at touchdown		-0.40	1.59	0.52	degrees
Yaw angle at touchdown		-3.46	6.04	0.10	degrees
Instantaneous glide slope angle		0.68	0.35	-0.27	degrees
Geometric glide slope angle		1.57	0.36	0.40	degrees
Height over runway threshold		53.0	11.17	-0.14	feet
Threshold to touchdown distance		1998.0	464	0.66	feet
Off-center distance at touchdown		-3.4	7.40	-0.13	feet

Table C-3. Aircraft Model: A300/A310, Combined Number of Landings-70

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.8	1.44	0.17	ft/sec
Video sink speeds	Starboard wheel	2.5	1.32	0.05	ft/sec
	Average of main wheels	2.5	1.21	-0.02	ft/sec
Threshold camera sink speed		6.1	1.21	1.01	ft/sec
Video closure speed (measured to camera)		139.0	9.99	-0.13	knots
Threshold camera closure speed		133.0	7.00	-0.24	knots
Approach speed		145.0	8.87	-0.11	knots
Wind speed:	Headwind	6.3	6.92	0.49	knots
	Crosswind	-0.4	5.02	-0.87	knots
Pitch angle at touchdown		8.2	1.77	-0.17	degrees
Roll angle at touchdown		-0.5	1.48	0.37	degrees
Yaw angle at touchdown		-2.35	5.59	-0.34	degrees
Instantaneous glide slope angle		0.62	0.304	-0.11	degrees
Geometric glide slope angle		1.57	0.305	0.31	degrees
Height over runway threshold		52.0	9.74	0.33	feet
Threshold to touchdown distance		1940.0	483.0	1.10	feet
Off-center distance at touchdown		-2.0	7.00	-0.34	feet

Table C-4. Aircraft Model: A319, Number of Landings-62

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.0	1.60	0.19	ft/sec
Video sink speeds	Starboard wheel	2.6	1.33	0.39	ft/sec
	Average of main wheels	2.8	1.35	0.49	ft/sec
Threshold camera sink speed		6.8	1.45	0.80	ft/sec
Video closure speed (measured to camera)		132.0	10.05	0.28	knots
Threshold camera closure speed		126.0	6.30	0.45	knots
Approach speed		141.0	9.75	0.72	knots
Wind speed:	Headwind	8.3	7.93	0.21	knots
	Crosswind	-0.9	5.23	-0.83	knots
Pitch angle at touchdown		5.8	1.27	0.07	degrees
Roll angle at touchdown		-0.5	1.74	-0.10	degrees
Yaw angle at touchdown		-2.0	5.98	-0.43	degrees
Instantaneous glide slope angle		0.73	0.36	0.68	degrees
Geometric glide slope angle		1.83	0.42	1.23	degrees
Height over runway threshold		57.0	7.24	0.92	feet
Threshold to touchdown distance		1870.0	491.0	0.79	feet
Off-center distance at touchdown		-1.5	7.14	0.31	feet

Table C-5. Aircraft Model: A320, Number of Landings-97

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.9	1.61	0.24	ft/sec
Video sink speeds	Starboard wheel	2.9	1.37	0.02	ft/sec
	Average of main wheels	2.8	1.28	-0.29	ft/sec
Threshold camera sink speed		6.7	1.2	0.56	ft/sec
Video closure speed (measured to camera)		140.0	9.31	-0.20	knots
Threshold camera closure speed		133.0	6.38	0.15	knots
Approach speed		146.0	9.52	0.31	knots
Wind speed:	Headwind	6.2	7.82	0.81	knots
	Crosswind	-0.7	5.34	-0.95	knots
Pitch angle at touchdown		5.8	1.19	-0.41	degrees
Roll angle at touchdown		-0.6	1.49	-0.58	degrees
Yaw angle at touchdown		-1.9	4.88	-0.31	degrees
Instantaneous glide slope angle		0.70	0.31	-0.17	degrees
Geometric glide slope angle		1.72	0.32	0.55	degrees
Height over runway threshold		56.0	9.40	0.29	feet
Threshold to touchdown distance		1881.0	359.0	-0.39	feet
Off-center distance at touchdown		-0.8	5.52	-0.66	feet

Table C-6. Aircraft Model: A321, Number of Landings-70

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.8	1.59	0.18	ft/sec
Video sink speeds	Starboard wheel	2.9	1.23	0.09	ft/sec
	Average of main wheels	2.7	1.26	0.04	ft/sec
Threshold camera sink speed		6.8	1.30	0.84	ft/sec
Video closure speed (measured to camera)		144.0	10.44	-0.17	knots
Threshold camera closure speed		138.0	7.67	-0.49	knots
Approach speed		152.0	9.13	-0.54	knots
Wind speed:	Headwind	7.6	8.55	0.63	knots
	Crosswind	-1.5	5.31	-0.62	knots
Pitch angle at touchdown		5.3	1.39	0.44	degrees
Roll angle at touchdown		-0.6	1.34	0.13	degrees
Yaw angle at touchdown		-3.2	4.83	0.38	degrees
Instantaneous glide slope angle		0.65	0.28	0.12	degrees
Geometric glide slope angle		1.68	0.31	0.95	degrees
Height over runway threshold		56.0	7.07	-0.16	feet
Threshold to touchdown distance		1966.0	434.0	0.60	feet
Off-center distance at touchdown		-1.4	6.13	-0.24	feet

Table C-7: Aircraft Model: A330, Number of Landings-19

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.9	1.89	0.13	ft/sec
Video sink speeds	Starboard wheel	3.4	1.32	-.05	ft/sec
	Average of main wheels	3.8	1.87	0.33	ft/sec
Threshold camera sink speed		7.8	2.12	1.32	ft/sec
Video closure speed (measured to camera)		134.0	8.62	0.26	knots
Threshold camera closure speed		130.0	8.49	-0.37	knots
Approach speed		143.0	10.34	-0.14	knots
Wind speed:	Headwind	8.39	8.93	0.68	knots
	Crosswind	-0.76	5.93	-1.09	knots
Pitch angle at touchdown		13.02	2.15	1.12	degrees
Roll angle at touchdown		-0.24	1.60	0.24	degrees
Yaw angle at touchdown		-0.27	4.72	-0.72	degrees
Instantaneous glide slope angle		0.94	0.50	0.58	degrees
Geometric glide slope angle		2.06	0.63	1.37	degrees
Height over runway threshold		52.0	11.88	0.74	feet
Threshold to touchdown distance		1568.0	547.0	0.22	feet
Off-center distance at touchdown		0.7	8.55	-0.55	feet

Table C-8. Aircraft Model: A340, Number of Landings-25

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.9	1.89	-0.13	ft/sec
Video sink speeds	Starboard wheel	3.3	1.33	0.07	ft/sec
	Average of main wheels	3.4	1.45	0.49	ft/sec
Threshold camera sink speed		7.7	1.94	1.07	ft/sec
Video closure speed (measured to camera)		138.0	12.25	-0.21	knots
Threshold camera closure speed		131.0	7.19	0.03	knots
Approach speed		146.0	9.54	0.00	knots
Wind speed:	Headwind	8.24	7.93	0.35	knots
	Crosswind	-1.68	6.43	-0.69	knots
Pitch angle at touchdown		12.97	1.27	-0.83	degrees
Roll angle at touchdown		0.07	1.50	-0.43	degrees
Yaw angle at touchdown		-3.04	8.30	0.54	degrees
Instantaneous glide slope angle		0.84	0.40	0.48	degrees
Geometric glide slope angle		2.01	0,50	0.90	degrees
Height over runway threshold		52.0	8.96	-0.05	feet
Threshold to touchdown distance		1552.0	361	-0.45	feet
Off-center distance at touchdown		-2.4	9.65	0.40	feet
Aircraft landing weight (Note: 19 landings)		3753740	15725	-0.60	pounds

Table C-9. Aircraft Model: A330/A340, Combined Number of Landings-44

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.9	2.08	0.05	ft/sec
Video sink speeds	Starboard wheel	3.3	1.31	0.01	ft/sec
	Average of main wheels	3.5	1.69	0.38	ft/sec
Threshold camera sink speed		7.8	1.99	1.15	ft/sec
Video closure speed (measured to camera)		136.0	10.84	0.04	knots
Threshold camera closure speed		130.0	7.71	-0.23	knots
Approach speed		145.0	8.92	0.23	knots
Wind speed:	Headwind	8.3	8.27	0.50	knots
	Crosswind	-1.3	6.17	-0.82	knots
Pitch angle at touchdown		13.0	1.68	0.75	degrees
Roll angle at touchdown		-0.07	1.53	-0.13	degrees
Yaw angle at touchdown		-1.81	7.02	0.10	degrees
Instantaneous glide slope angle		0.88	0.44	0.59	degrees
Geometric glide slope angle		2.02	0.54	1.19	degrees
Height over runway threshold		52.0	10.10	0.43	feet
Threshold to touchdown distance		1559.0	445.0	0.06	feet
Off-center distance at touchdown		-1.05	9.21	0.01	feet

Table C-10. Aircraft Model: B-737-100/200, Combined Number of Landings-15

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.2	1.37	0.45	ft/sec
Video sink speeds	Starboard wheel	2.7	1.06	-0.18	ft/sec
	Average of main wheels	2.5	1.01	0.43	ft/sec
Threshold camera sink speed		7.0	1.19	0.29	ft/sec
Video closure speed (measured to camera)		141.0	12.66	0.72	knots
Threshold camera closure speed		129.0	8.24	-0.57	knots
Approach speed		145.0	10.30	0.84	knots
Wind speed:	Headwind	3.7	7.54	1.49	knots
	Crosswind	1.9	2.96	-1.19	knots
Pitch angle at touchdown		5.3	1.63	1.21	degrees
Roll angle at touchdown		-0.8	1.60	0.57	degrees
Yaw angle at touchdown		-5.1	6.01	-0.05	degrees
Instantaneous glide slope angle		0.60	0.23	0.23	degrees
Geometric glide slope angle		1.85	0.30	-0.17	degrees
Height over runway threshold		57.0	6.51	0.11	feet
Threshold to touchdown distance		1793.0	317.0	1.30	feet
Off-center distance at touchdown		1.2	7.20	-0.39	feet

Table C-11. Aircraft Model: B-737-300/400/500, Combined Number of Landings-37

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.9	1.37	0.19	ft/sec
Video sink speeds	Starboard wheel	2.7	1.38	0.31	ft/sec
	Average of main wheels	2.7	1.22	0.42	ft/sec
Threshold camera sink speed		7.0	1.18	-0.81	ft/sec
Video closure speed (measured to camera)		145.0	10.87	-0.57	knots
Threshold camera closure speed		138.0	6.35	-0.55	knots
Approach speed		151.0	10.43	-0.37	knots
Wind speed:	Headwind	5.3	8.04	1.03	knots
	Crosswind	0.8	4.26	-1.44	knots
Pitch angle at touchdown		4.9	1.34	0.77	degrees
Roll angle at touchdown		-0.1	1.37	-0.47	degrees
Yaw angle at touchdown		-4.6	4.66	0.58	degrees
Instantaneous glide slope angle		0.65	0.30	0.45	degrees
Geometric glide slope angle		1.69	0.29	-0.96	degrees
Height over runway threshold		53.0	7.13	1.44	feet
Threshold to touchdown distance		1844.0	463.0	1.48	feet
Off-center distance at touchdown		1.2	7.02	-0.67	feet

Table C-12. Aircraft Model: All B-747 Combined Number of Landings-193

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.4	1.45	0.22	ft/sec
Video sink speeds	Starboard wheel	2.6	1.20	0.32	ft/sec
	Average of main wheels	2.9	1.16	0.26	ft/sec
Threshold camera sink speed		7.4	1.63	0.83	ft/sec
Video closure speed (measured to camera)		152.0	11.21	-0.19	knots
Threshold camera closure speed		145.0	8.53	-0.57	knots
Approach speed		157.0	10.16	-0.08	knots
Wind speed:	Headwind	5.32	6.72	0.93	knots
	Crosswind	-0.08	4.98	-1.09	knots
Pitch angle at touchdown		7.19	1.34	-0.12	degrees
Roll angle at touchdown		-0.48	1.18	0.05	degrees
Yaw angle at touchdown		-2.36	5.93	-0.28	degrees
Instantaneous glide slope angle		0.67	0.28	0.53	degrees
Geometric glide slope angle		1.73	0.39	0.99	degrees
Height over runway threshold		53.0	7.73	0.24	feet
Threshold to touchdown distance		1835.0	441.0	0.62	feet
Off-center distance at touchdown		-4.6	1.18	-0.43	feet
Aircraft landing weight (Note: 91 landings)		515190	26269	-0.60	pounds

Table C-13. Aircraft Model: B-747 Classic, Number of Landings-50

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.6	1.19	-0.06	ft/sec
Video sink speeds	Starboard wheel	2.7	1.26	-0.36	ft/sec
	Average of main wheels	3.2	0.96	0.01	ft/sec
Threshold camera sink speed		7.4	1.74	0.88	ft/sec
Video closure speed (measured to camera)		149.0	12.09	-0.02	knots
Threshold camera closure speed		142.0	9.68	-0.57	knots
Approach speed		154.0	11.25	0.06	knots
Wind speed:	Headwind	4.8	6.60	1.04	knots
	Crosswind	0.4	4.74	-1.26	knots
Pitch angle at touchdown		7.8	1.29	-0.71	degrees
Roll angle at touchdown		-0.4	0.99	0.01	degrees
Yaw angle at touchdown		-2.9	6.58	-0.12	degrees
Instantaneous glide slope angle		0.73	0.24	0.32	degrees
Geometric glide slope angle		1.75	0.52	0.33	degrees
Height over runway threshold		52.0	8.36	0.47	feet
Threshold to touchdown distance		1769.0	475.0	0.72	feet
Off-center distance at touchdown		-6.1	8.94	-0.17	feet
Aircraft landing weight (Note: 30 landings)		507035	28872	-0.01	pounds

Table C-14. Aircraft Model: B-747-400, Number of Landings-141

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.4	1.53	0.29	ft/sec
Video sink speeds	Starboard wheel	2.6	1.18	0.59	ft/sec
	Average of main wheels	2.9	1.21	0.40	ft/sec
Threshold camera sink speed		7.4	1.60	0.80	ft/sec
Video closure speed (measured to camera)		153.0	10.66	-0.18	knots
Threshold camera closure speed		147.0	7.62	-0.35	knots
Approach speed		158.0	9.56	-0.02	knots
Wind speed:	Headwind	5.4	6.67	0.90	knots
	Crosswind	-0.1	4.99	-1.05	knots
Pitch angle at touchdown		7.0	1.30	0.06	degrees
Roll angle at touchdown		-0.5	1.24	0.10	degrees
Yaw angle at touchdown		-2.0	5.64	-0.35	degrees
Instantaneous glide slope angle		0.64	0.29	0.65	degrees
Geometric glide slope angle		1.69	0.42	-0.41	degrees
Height over runway threshold		53.4	7.41	0.14	feet
Threshold to touchdown distance		1856.0	431.0	0.63	feet
Off-center distance at touchdown		-4.0	6.45	-0.45	feet
Aircraft landing weight (Note: 61 landings)		519201	24374	-0.94	pounds

Table C-15. Aircraft Model: B-757, Number of Landings—151

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.8	1.34	0.17	ft/sec
Video sink speeds	Starboard wheel	2.5	1.21	0.40	ft/sec
	Average of main wheels	2.6	1.09	0.08	ft/sec
Threshold camera sink speed		6.8	1.06	0.70	ft/sec
Video closure speed (measured to camera)		132.0	10.86	-0.26	knots
Threshold camera closure speed		126.0	7.46	-0.58	knots
Approach speed		138.0	8.62	0.33	knots
Wind speed:	Headwind	5.7	7.50	0.81	knots
	Crosswind	-0.4	5.18	-0.86	knots
Pitch angle at touchdown		6.0	1.63	2.3	degrees
Roll angle at touchdown		-0.3	1.42	0.18	degrees
Yaw angle at touchdown		-2.5	4.76	0.02	degrees
Instantaneous glide slope angle		0.67	0.29	0.99	degrees
Geometric glide slope angle		1.83	0.30	0.72	degrees
Height over runway threshold		56.0	7.02	0.12	feet
Threshold to touchdown distance		1793.0	352.0	0.09	feet
Off-center distance at touchdown		-1.3	4.29	-0.19	feet

Table C-16. Aircraft Model: All B-767, Combined Number of Landings—101

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.1	1.51	0.56	ft/sec
Video sink speeds	Starboard wheel	2.5	1.16	0.02	ft/sec
	Average of main wheels	2.8	1.16	0.55	ft/sec
Threshold camera sink speed		6.8	1.43	0.57	ft/sec
Video closure speed (measured to camera)		146.0	11.06	-0.11	knots
Threshold camera closure speed		137.0	8.29	0.10	knots
Approach speed		152.0	9.71	-0.20	knots
Wind speed:	Headwind	6.16	6.97	0.74	knots
	Crosswind	-0.24	4.65	-1.05	knots
Pitch angle at touchdown		5.87	1.27	0.48	degrees
Roll angle at touchdown		-0.52	1.41	0.03	degrees
Yaw angle at touchdown		-3.2	5.51	-0.26	degrees
Instantaneous glide slope angle		0.65	0.27	0.59	degrees
Geometric glide slope angle		1.70	0.37	0.68	degrees
Height over runway threshold		53.0	8.12	0.58	feet
Threshold to touchdown distance		1843.0	439.0	0.61	feet
Off-center distance at touchdown		-1.5	7.36	1.73	feet
Aircraft landing weight (Note: 57 landings)		265682	12791	-0.79	pounds

Table C-17. Aircraft Model: Boeing 767 Classic, Number of Landings-32

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.6	1.18	0.01	ft/sec
Video sink speeds	Starboard wheel	2.6	1.04	-0.32	ft/sec
	Average of main wheels	2.6	0.85	-0.03	ft/sec
Threshold camera sink speed		6.5	1.43	0.35	ft/sec
Video closure speed (measured to camera)		146.0	10.91	0.18	knots
Threshold camera closure speed		138.0	8.01	0.89	knots
Approach speed		150.0	10.09	-0.02	knots
Wind speed:	Headwind	3.7	6.21	1.75	knots
	Crosswind	1.9	2.25	-0.11	knots
Pitch angle at touchdown		6.4	1.54	-0.10	degrees
Roll angle at touchdown		-0.2	1.18	0.28	degrees
Yaw angle at touchdown		-3.7	6.39	-0.12	degrees
Instantaneous glide slope angle		0.60	0.20	-0.25	degrees
Geometric glide slope angle		1.58	0.33	0.17	degrees
Height over runway threshold		54.0	8.37	0.84	feet
Threshold to touchdown distance		2012.0	472.0	0.97	feet
Off-center distance at touchdown		-2.3	5.73	-0.07	feet
Aircraft landing weight (Note: 13 landings)		258136	18005	-0.61	pounds

Table C-18. Aircraft Model: B-767-300, Number of Landings-69

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.4	1.60	0.50	ft/sec
Video sink speeds	Starboard wheel	2.6	1.22	0.13	ft/sec
	Average of main wheels	3.0	1.27	0.48	ft/sec
Threshold camera sink speed		7.1	1.41	0.74	ft/sec
Video closure speed (measured to camera)		142.0	11.20	-0.23	knots
Threshold camera closure speed		133.0	8.41	-0.20	knots
Approach speed		153.0	9.47	-0.28	knots
Wind speed:	Headwind	12.5	6.55	0.18	knots
	Crosswind	-2.3	5.14	-0.70	knots
Pitch angle at touchdown		5.5	1.04	0.46	degrees
Roll angle at touchdown		-0.9	1.49	0.11	degrees
Yaw angle at touchdown		-3.7	6.39	-0.12	degrees
Instantaneous glide slope angle		0.71	0.30	0.55	degrees
Geometric glide slope angle		1.83	0.38	0.79	degrees
Height over runway threshold		52.0	8.02	0.46	feet
Threshold to touchdown distance		1678.0	402.0	0.25	feet
Off-center distance at touchdown		-1.8	8.02	1.93	feet
Aircraft landing weight (Note: 44 landings)		267912	10203	0.18	pounds

Table C-19. Aircraft Model: B-777, Number of Landings-85

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	2.7	1.33	0.79	ft/sec
Video sink speeds	Starboard wheel	2.1	1.20	0.56	ft/sec
	Average of main wheels	2.4	1.17	0.66	ft/sec
Threshold camera sink speed		7.4	1.44	0.53	ft/sec
Video closure speed (Measured to camera)		143.0	7.63	-0.12	knots
Threshold camera closure speed		135.0	5.86	-0.13	knots
Approach speed		146.0	7.34	0.00	knots
Wind speed:	Headwind	3.04	5.62	1.31	knots
	Crosswind	1.42	2.95	-1.59	knots
Pitch angle at touchdown		6.56	1.12	1.47	degrees
Roll angle at touchdown		-0.02	1.36	0.66	degrees
Yaw angle at touchdown		-1.24	4.96	-0.60	degrees
Instantaneous glide slope angle		0.56	0.28	0.70	degrees
Geometric glide slope angle		1.86	0.36	0.45	degrees
Height over runway threshold		54.0	7.31	1.02	feet
Threshold to touchdown distance		1732.0	410.0	0.52	feet
Off-center distance at touchdown		0.1	6.17	-0.36	feet
Aircraft landing weight (Note: 31 Landings)		396060	20817	0.327	pounds

Table C-20. Aircraft Model: DC-10/MD-11, Combined Number of Landings-8

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.4	1.10	0.18	ft/sec
Video sink speeds	Starboard wheel	3.6	1.16	-0.66	ft/sec
	Average of main wheels	3.5	0.89	-0.20	ft/sec
Threshold camera sink speed		7.5	1.67	0.41	ft/sec
Video closure speed (measured to camera)		156.0	11.33	-0.14	knots
Threshold camera closure speed		145.0	9.56	-0.23	knots
Approach speed		164.0	7.44	-1.01	knots
Wind speed:	Headwind	7.86	5.72	0.20	knots
	Crosswind	0.61	4.09	-1.43	knots
Pitch angle at touchdown		8.29	1.52	1.50	degrees
Roll angle at touchdown		-0.40	0.97	-0.23	degrees
Yaw angle at touchdown		-2.67	3.65	-0.07	degrees
Instantaneous glide slope angle		0.77	0.22	-0.12	degrees
Geometric glide slope angle		1.77	0.43	0.80	degrees
Height over runway threshold		55.0	7.92	-0.82	feet
Threshold to touchdown distance		1871.0	515.0	-0.01	feet
Off-center distance at touchdown		-1.5	7.56	-0.57	feet

Table C-21. Aircraft Model: MD-80/90, Combined Number of Landings-36

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
	Port wheel	3.4	1.59	0.03	ft/sec
Video sink speeds	Starboard wheel	3.4	1.46	-0.12	ft/sec
	Average of main wheels	3.3	1.43	-0.13	ft/sec
Threshold camera sink speed		7.0	1.37	0.98	ft/sec
Video closure speed (measured to camera)		140.0	12.37	-0.48	knots
Threshold camera closure speed		135.0	7.24	0.20	knots
Approach speed		147.0	11.21	0.13	knots
Wind speed:	Headwind	6.5	8.14	0.70	knots
	Crosswind	-1.4	5.61	-0.71	knots
Pitch angle at touchdown		6.1	1.22	0.72	degrees
Roll angle at touchdown		0.0	1.48	0.31	degrees
Yaw angle at touchdown		-2.1	4.87	-0.21	degrees
Instantaneous glide slope angle		0.81	0.33	0.06	degrees
Geometric glide slope angle		1.77	0.34	0.68	degrees
Height over runway threshold		52.0	8.45	-0.25	feet
Threshold to touchdown distance		1703.0	294.0	0.18	feet
Off-center distance at touchdown		1703.0	294.0	0.18	feet

APPENDIX D—LISTING OF INDIVIDUAL AIRCRAFT LANDING PARAMETERS BY AIRCRAFT MODEL (LISTING BY EVENT NUMBER)

Table D-1. Landing Data, A300 FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
66	142	146		2.6	2.7	2.7		1848	4
136	157	161	151	3.9	3.3	3.6	7.4	1466	4
180	143	148	136	2.0		1.6	3.5	3579	-16
214	143	147	138	0.7	1.4	1.0	6.6	1463	3
273	148	151	137	1.6	1.2	1.6	8.0	1500	0
316	149	152	140	1.2		1.3	5.7	1963	-4
351	137	142	141	1.9		1.7	9.0	1693	-4
405	139	140	138	2.7	2.4	2.6	5.8	2220	1
452	147	150	140	2.7	1.3	1.8	6.5	1917	-12
465	137	137	142	3.7	3.5	3.5	4.8	2184	-2
527	151	149	135	2.3	4.0	3.2	6.8	1600	0
576	148	145	139	3.9	2.7	3.3	5.6	1708	4
581	145	145	137	2.0	1.2	1.2	6.5	1315	7
592	146	144	137	0.3	1.0	0.6	5.5	2870	-3
594	146	142	131	2.6		3.1	4.9	2080	-22
675	163	159	145	0.6	0.9	0.8	5.8	2014	-2
721	148	139	129	2.5	3.5	2.5	4.7	2246	0
753	149	140	130	2.7	3.2	2.9	6.3	1959	-2
799	140	130	124	2.9	1.7	2.2	5.9	1694	0
815	141	131	132	0.4	4.1	1.5	6.2	2200	-1
945	127	117	115	3.9	3.2	3.7	5.0	1247	1
1008	145	138	137	3.1	2.6	3.1	5.5	3225	-5
1040	157	148	134	5.1	2.5	3.6	6.9	1779	1
1050	153	140	131	4.8	4.8	4.8	5.9	2534	-10

Table D-1. Landing Data, A300 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
66	0.63			9.5	0.6	-1.5	-3.8	1.4
136	0.76	1.66	43	8.8	0.3	-3.9	-3.9	0.7
180	0.37	0.88	55	9.6	-1.3		-5.0	0.4
214	0.23	1.64	42	8.2	0.3	-6.0	-3.8	3.2
273	0.36	1.99	52	10.2	-0.3	-5.7	-2.5	-5.4
316	0.30	1.38	47	9.6	-0.7	-9.0	-3.1	2.6
351	0.40	2.16	64	8.1	-1.8	3.1	-4.8	1.3
405	0.62	1.42	55	7.7	-2.0	1.2	-0.7	3.9
452	0.40	1.58	53	7.8	-1.2	-4.1	-3.0	0.3
465	0.86	1.16	44	6.9	-1.3	4.2	0.0	3.0
527	0.72	1.69	47	9.3	1.7		1.9	2.3
576	0.77	1.37	41	9.0	0.2	1.9	3.0	5.2
581	0.28	1.61	37	6.9	-1.1	1.6	0.0	7.0
592	0.13	1.37	69	8.5	3.6	-3.6	2.5	4.3
594	0.74	1.26	46	10.2	-0.9		4.5	5.4
675	0.16	1.37	48	6.9	1.5	-9.2	3.8	3.2
721	0.61	1.23	48	6.5	-1.9	-0.7	9.5	5.5
753	0.69	1.64	56	7.6	0.0	-8.0	9.4	3.4
799	0.58	1.63	48	10.3	-0.4	2.8	10.3	3.8
815	0.38	1.60	61	5.1	-1.4	-6.7	10.0	0.0
945	1.06	1.48	32	12.1	0.7	4.2	10.0	0.0
1008	0.76	1.36	76	9.6	-0.1	3.4	6.5	-11.3
1040	0.83	1.75	54	8.2	-1.3	-4.7	9.0	-10.7
1050	1.16	1.51	67	10.3	1.5	-16.4	12.1	-7.0

Table D-1. Landing Data, A300 FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1193	168	155	141	2.4		1.1	4.4	2388	-7
1229	151	144	135	4.4	2.9	3.0	7.8	1855	-6
1251	153	143	129	2.8	0.9	2.8	7.1	1381	-8
1252	159	149	133	2.0		2.4	6.9	1506	6
1343	150	130	124	3.4	2.4	2.9	5.5	1823	2
1391	147	125		5.8	1.8	3.0		1616	4
1414	147	125	123	1.9	2.1	2.0	6.5	1665	16
1423	140	116	116	2.4	3.2	2.2	5.7	1683	-2
1548	139	126	124	1.8	2.4	1.8	6.2	1839	0
1551	146	131	127	4.5	4.0	4.0	5.4	2252	1
1576	161	145	131	0.0		0.5	7.0	1390	-4
1582	144	124	119	3.0		3.2	4.6	2533	-12
1602	144	137	129	3.3	2.2	2.2	5.8	1417	4
1652	150	143	136	1.6	2.2	1.8	5.9	1815	-3
1677	151	147	135		3.9	3.7	7.8	1515	10
1695	144	135	133	2.9	4.0	4.0	5.9	2201	5
1698	138	134	135	3.2	0.1	2.3	5.8	1599	3
1713	146	140	127	3.2	2.1	2.6	5.8	2001	-8
1730	134	129	129	4.7	3.7	3.7	4.8	2097	6
1833	139	139	132	4.1	1.1	2.4	8.9	1636	8
1868	154	153	145	0.1	0.5	0.4	4.9	2726	-8
1903	150	145	135	2.6	2.5	2.5	6.2	1780	-4
1910	143	138	131	1.3		0.1	6.2	1711	-5
1947	129	126	132	3.2	4.9	3.9	7.3	1177	-6

Table D-1. Landing Data, A300 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1193	0.24	1.06	44	4.2	1.5	-8.0	13.0	-10.9
1229	0.69	1.97	64	5.7	-2.6	-2.6	7.1	-8.4
1251	0.67	1.86	45	10.6	-1.4	-3.4	10.4	-6.0
1252	0.54	1.77	46	8.7	-0.7	-12.2	10.4	-6.0
1343	0.75	1.51	48	6.1	-0.1	-1.9	20.0	0.0
1391	0.82			7.9	-2.2	4.0	22.7	-4.0
1414	0.54	1.79	52	5.0	-1.8	0.2	22.0	0.0
1423	0.65	1.66	49	7.7	-2.2	0.5	24.0	0.0
1548	0.49	1.69	54	7.8	-0.5	-1.2	13.8	-2.4
1551	1.04	1.44	57	8.6	-1.9	-1.2	15.0	0.0
1576	0.11	1.82	44	7.1	-3.3	-1.2	16.0	-5.8
1582	0.88	1.32	58	9.3	-3.3	-12.6	20.0	0.0
1602	0.55	1.53	38	8.0	-3.1	1.3	7.5	2.7
1652	0.43	1.47	46	8.5	0.7	-2.7	6.9	-4.0
1677	0.85	1.97	52	9.9	1.5	-6.3	3.9	4.6
1695	1.01	1.50	58	8.6	0.0	3.0	9.4	3.4
1698	0.59	1.47	41	4.8	0.9	6.8	4.5	5.4
1713	0.63	1.56	54	11.0	-0.5	-7.8	5.4	4.5
1730	0.97	1.27	46	8.7	-0.4	2.0	4.6	3.9
1833	0.59	2.29	65	8.1	0.2	5.8	0.0	0.0
1868	0.09	1.14	54	9.3	1.3	3.0	1.7	4.7
1903	0.58	1.55	48	8.1	-0.2	-1.8	4.3	-2.5
1910	0.02	1.61	48	8.7	-0.8	0.9	4.5	-5.4
1947	1.06	1.88	39	5.8	-1.9	7.7	3.0	-5.2

Table D-2. Landing Data, A310 FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
187	122	127	129	3.8	4.1	3.9	5.7	2487	0
286	145	145	132	2.1	1.5	1.7	7.8	1486	-1
349	145	145	135	2.5	1.4	2.2	4.5	2013	-9
561	135	132	133	3.1	2.9	3.1	5.7	2115	9
756	133	124	124	2.6	2.2	2.3	7.1	1421	-1
775	134	126	128	1.1	1.2	1.1	4.3	1505	-9
802	152	143	132	2.6	4.1	3.5	5.6	2014	-7
811	137	127	124	3.2	4.0	3.6	8.0	1506	5
1035	156	148	135	6.8	5.0	5.6	7.8	2008	-15
1171	144	139	133	0.8	0.5	0.5	4.7	2844	-8
1178	147	143	129	2.7		2.1	6.8	1794	-5
1225	148	137	138	3.9	4.2	4.0	7.7	2244	7
1303	143	130	127	0.4	0.3	0.3	4.7	3051	-16
1567	145	131	116	3.3	4.2	3.7	5.4	1605	4
1571	158	144	131	5.0		3.7	6.9	2029	-15
1700	143	136	137	4.2	1.4	2.3	5.3	1723	-7
1704	160	156	143	3.2	1.4	2.3	4.6	2523	-9
1728	138	134	128	3.3	2.4	2.8	5.3	1980	2
1816	128	128	135	3.8	3.0	3.4	5.9	2366	-3
1880	130	130	131	0.2	0.5	0.3	4.7	1866	4
1914	157	153	139	5.6	4.6	5.1	9.2	1370	2

Table D-2. Landing Data, A310 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
187	1.03	1.51	65	9.4	-2.3	-7.5	-5.4	2.5
286	0.39	2.00	52	8.1	-0.2	-5.6	0.0	4.0
349	0.52	1.14	40	10.3	-0.1	-10.4	-0.3	3.0
561	0.80	1.45	54	6.7	-1.6	6.5	3.8	3.2
756	0.63	1.94	48	6.5	0.9	5.8	9.4	3.4
775	0.30	1.14	30	9.1	0.0	2.6	7.9	1.4
802	0.82	1.43	50	7.8	1.3	-10.4	8.9	1.6
811	0.97	2.19	58	8.1	0.2	-3.3	9.8	1.7
1035	1.29	1.96	69	7.1	-1.3	-9.7	7.5	-13.0
1171	0.12	1.21	60	10.2	-0.4	-1.5	5.5	-9.5
1178	0.49	1.79	56	11.5	-2.5	-4.0	4.1	-11.3
1225	0.99	1.89	74	4.2	-2.8	1.2	11.5	-9.6
1303	0.08	1.24	66	9.8	3.9		12.8	-2.3
1567	0.97	1.57	44	11.8	0.2		14.0	0.0
1571	0.88	1.80	64	6.6	-2.9	-13.4	14.1	-5.1
1700	0.58	1.31	39	5.8	-1.8	5.1	6.9	5.8
1704	0.51	1.09	48	7.6	0.1	-10.9	3.8	3.2
1728	0.72	1.41	49	7.5	0.5	-6.5	4.6	3.9
1816	0.90	1.49	61	7.4	-0.3	-0.7	0.0	0.0
1880	0.07	1.21	39	10.9	0.3	-1.1	0.0	0.0
1914	1.14	2.24	54	7.4	0.4	-1.9	4.6	-3.9

Table D-2. Landing Data, A310 FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
73	128	131	132	0.7	2.2	1.6	9.2	1215	-4
74	136	142	132	1.7	2.1	1.7	6.6	1779	2
80	135	140	134	1.3	1.4	1.4	8.7	1395	4
105	130	129	137	3.3	3.4	3.4	5.8	2406	-10
111	144	147	135	0.4	3.1	2.1	7.8	1501	3
118	145	148	133	2.9	2.9	2.9	5.7	2117	-15
123	151	154	134	0.5		1.4	8.5	1611	-4
243	139	139	127	2.7	0.9	1.8	6.0	2206	-2
245	135	135	132	0.8	1.6	0.6	7.0	1830	-2
309	160	162	145	2.9	2.3	2.6	8.1	1971	-7
381	143	144	131	1.4	3.4	2.3	6.9	1996	-6
413	138	139	128	5.1	4.5	4.7	5.6	2243	0
464	137	137	131	4.9	3.6	3.9	6.1	2237	-1
564	144	142	133	2.6	3.7	2.9	6.8	1837	5
577	136	133	131	2.5	4.1	2.8	8.5	1440	4
625	127	125	127	5.4	3.1	4.0	6.7	1677	-2
639	141	137	126	2.6	2.3	2.3	8.8	1362	1
667	135	131	128	1.9	2.2	2.1	6.7	1832	2
724	137	130	122	1.3	1.5	1.2	6.0	1991	-4
731	139	128	118	1.3	2.4	1.7	6.0	1846	-6
790	130	121	125	0.7	2.9	2.0	4.2	3103	13
858	139	132	124	3.3	2.2	2.4	6.3	2626	-1
871	147	135	122	5.8	1.8	3.6	6.8	1373	1
874	138	127	121	3.6	1.9	3.6	5.3	2322	2

Table D-2. Landing Data, A310 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
73	0.41	2.37	50	8.1	0.0	4.2	-3.6	1.7
74	0.42	1.69	53	6.8	0.1	1.3	-5.4	2.5
80	0.34	2.19	53	6.5	-1.0	-0.4	-4.8	1.3
105	0.89	1.44	61	6.4	0.1	-5.7	0.7	3.9
111	0.48	1.95	51	6.8	-0.4	-8.7	-3.1	2.6
118	0.67	1.45	53	6.7	0.9	-20.3	-2.8	1.0
123	0.30	2.15	61	7.1	-2.3	-13.5	-2.7	1.3
243	0.45	1.62	62	8.3	-2.7	1.6	0.0	5.0
245	0.15	1.80	57	5.1	-0.8	-1.8	0.0	4.0
309	0.55	1.90	65	3.1	-2.6	-10.6	-1.7	3.6
381	0.53	1.79	62	5.6	2.1	-10.5	-1.0	2.8
413	1.16	1.49	58	6.2	-1.0	-1.0	-0.4	5.0
464	0.96	1.57	61	6.4	-1.5	5.6	0.0	5.0
564	0.70	1.74	56	4.2	-2.0	0.4	2.5	4.3
577	0.71	2.22	56	6.0	3.0	2.0	3.0	5.2
625	1.08	1.80	53	5.8	-2.4	7.1	2.5	4.3
639	0.57	2.38	57	6.7	-0.7	-1.1	3.5	6.1
667	0.54	1.77	57	6.0	0.4	-1.8	4.5	5.4
724	0.32	1.67	58	5.8	1.2	-7.3	6.9	4.0
731	0.46	1.71	55	5.1	-1.0	-0.3	10.3	3.8
790	0.56	1.15	62	6.2	0.2	2.6	9.0	0.0
858	0.61	1.72	79	4.7	1.7	4.4	6.9	4.0
871	0.89	1.90	45	4.5	-1.0	-0.8	11.3	4.1
874	0.96	1.50	61	4.0	1.3	-1.3	11.3	4.1

Table D-3. Landing Data, A319 FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
909	126	117	120	4.2	3.0	3.6	7.8	1447	10
910	141	133	117	3.2	1.6	2.5	7.7	1302	3
935	153	141	123	3.3	4.2	3.9	7.5	1533	2
950	131	126	127	5.2	3.1	4.5	5.0	2303	4
1022	121	114	120	2.2	1.8	1.9	7.2	1654	-9
1052	139	129	127	4.7	2.8	3.6	7.7	1901	-7
1068	141	133	121	4.9	3.1	3.7	7.3	1804	-8
1088	127	119	113	5.0	6.9	6.7	11.6	1161	-12
1106	138	130	123	3.3	2.5	3.2	7.0	2482	-5
1128	140	130	117	3.5	4.4	3.4	5.5	1629	-15
1146	134	128	125	3.9	3.9	3.9	5.7	2312	11
1207	136	125	120	3.8	4.2	3.8	5.7	1765	10
1212	152	140	124	1.7	1.5	1.6	7.8	1370	-5
1245	163	150	136	2.7	0.4	1.5	3.8	3479	-3
1273	132	119	118	0.5	2.3	1.8	6.6	1892	-2
1277	143	131	120	0.5	2.2	0.5	6.0	1795	0
1286	147	132	119	3.2	3.0	2.6	6.5	1835	-1
1299	148	134	119	5.3	2.8	3.8	8.3	1391	-1
1306	159	137	126	5.3	2.1	2.1	8.3	1443	-2
1339	157	134	129	1.0	0.6	0.8	5.3	2495	-9
1340	139	118	116	1.7	0.2	1.7	5.7	1926	-13
1378	137	114	119	5.2	4.6	4.6	7.9	1261	-2
1405	161	141	129	3.6	3.3	3.6	6.4	2001	-11
1434	162	142	124	2.2	2.8	2.4	8.2	1058	-2

Table D-3. Landing Data, A319 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
909	1.05	2.21	56	6.5	-0.5	-2.5	8.9	1.6
910	0.65	2.21	50	6.9	-0.2	4.1	8.5	3.1
935	0.93	2.09	56	5.9	1.3	-6.8	12.0	0.0
950	1.22	1.33	53	4.3	-3.5	-4.9	5.0	-8.7
1022	0.57	2.02	58	6.8	-0.1	-4.2	6.5	-11.3
1052	0.94	2.07	69	6.6	-1.3	-5.5	10.4	-6.0
1068	0.95	2.05	65	6.0	-3.4	-2.1	7.7	-9.2
1088	1.90	3.46	70	9.0	-2.8	3.5	7.5	-13.0
1106	0.83	1.91	83	6.2	1.7	-10.4	8.4	-10.0
1128	0.88	1.60	45	7.8	-0.6	0.8	9.6	-11.5
1146	1.04	1.54	62	5.7	2.6	-2.1	6.0	-10.4
1207	1.03	1.60	49	4.0	2.6	0.5	10.9	-13.0
1212	0.38	2.13	51	4.3	0.1	-2.6	11.5	-9.6
1245	0.35	0.96	58	6.1	2.1	-13.5	13.8	-2.4
1273	0.52	1.91	63	5.2	1.2	-4.6	13.2	-4.8
1277	0.12	1.71	53	4.1	-1.0	-2.7	12.2	-4.4
1286	0.67	1.87	60	3.5	-1.9	-3.7	15.0	-5.5
1299	0.97	2.36	57	5.4	-2.9	-4.6	14.1	-5.1
1306	0.52	2.25	57	6.4	-4.2	0.6	22.7	-4.0
1339	0.21	1.39	61	4.5	-0.2	-8.0	23.0	0.0
1340	0.49	1.66	56	4.9	0.8	-9.2	21.0	0.0
1378	1.37	2.25	49	4.9	-2.8	-0.3	23.0	0.0
1405	0.87	1.69	59	5.6	-2.5	-12.4	20.0	0.0
1434	0.58	2.24	41	7.3	-3.1	11.1	20.7	-3.6

Table D-3. Landing Data, A319 FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1455	146	127	120	2.3	1.8	1.8	5.5	1705	1
1460	134	112	120	3.6	2.1	2.1	7.6	1600	9
1480	151	131	131	3.6	3.4	3.5	6.4	2120	2
1500	136	119	127	5.3	1.9	4.4	5.1	2097	2
1525	163	146	127	1.3	0.2	0.2	4.7	2635	0
1533	136	120	115	1.8	5.5	3.4	5.5	2116	22
1539	137	118	118	4.8	2.1	3.3	4.8	2270	-18
1642	138	125	120	6.8	3.6	6.3	10.9	868	-4
1772	137	134	125	3.8	0.3	2.5	6.7	1791	-14
1801	133	129	126	1.2	0.4	0.8	7.0	1669	-4
1807	132	127	121	2.6	4.4	3.6	6.3	1834	-1
1817	143	143	126	3.0	3.5	3.4	7.0	1715	2
1846	131	131	128	4.5	3.5	4.0	6.9	1481	3
1891	145	141	134	2.2	1.3	1.9	5.1	2898	-2

Table D-3. Landing Data, A319 FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle At Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1455	0.48	1.55	46	6.4	1.0	-0.4	19.0	0.0
1460	0.64	2.14	60	4.7	-0.4	10.6	22.0	0.0
1480	0.90	1.66	61	3.4	1.9	-5.1	19.7	-3.5
1500	1.26	1.35	49	3.9	-2.0	4.1	16.7	-3.0
1525	0.05	1.25	57	5.2	0.7	4.9	17.0	0.0
1533	0.97	1.62	60	4.4	-0.1	1.4	15.8	-2.8
1539	0.95	1.37	54	4.4	-2.2	-2.2	18.7	-3.3
1642	1.70	3.10	47	7.3	-3.1	-10.1	13.0	-7.5
1772	0.63	1.81	57	7.7	-0.5	1.2	3.2	3.8
1801	0.21	1.89	55	5.4	0.4	7.6	3.8	1.4
1807	0.97	1.77	57	6.5	-0.7	1.5	5.0	0.0
1817	0.80	1.89	57	5.7	1.4	0.6	0.0	0.0
1846	1.04	1.82	47	6.1	0.3	-1.8	0.0	0.0
1891	0.45	1.29	65	6.3	1.2	-3.9	4.3	2.5

Table D-4. Landing Data, A320, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
46	145	149	147	2.2	2.1	2.2	6.8	2314	2
51	139	143	143	2.0	3.0	2.0	7.1	1819	1
56	144	147	141	1.2	1.7	1.5	4.1	1897	1
60	136	139	138	2.1	5.0	4.0	9.4	1330	7
94	156	156	143	0.9		0.3	6.3	1917	-2
114	150	153	143	2.2	4.0	3.5	6.0	1565	-4
125	157	160		3.8	3.9	3.8		2026	-10
137	147	151	145	1.0	0.6	0.8	6.1	2089	-9
189	142	147	131	3.9	1.8	2.9	6.5	2017	-6
200	142	142	133	1.4	1.2	1.2	5.2	1915	2
216	140	146	135	3.6	3.2	3.3	6.4	2003	-5
226	131	131	123	1.4	0.6	1.0	7.4	1870	-4
242	145	145	136	4.4	3.9	4.0	8.8	1825	-1
306	150	151	134	2.8	0.8	2.0	9.2	1387	0
322	154	154	140	2.6	2.2	2.2	7.8	1499	-4
337	143	143	135	4.4	4.9	4.5	6.9	1205	-4
348	149	149	148	4.7	2.7	2.7	5.7	2156	-4
354	136	136	139	3.7	1.9	2.6	6.6	1791	2
369	150	151		0.8	2.6	1.0		1373	-1
378	141	142	138	0.7	0.9	0.9	6.1	2383	-5
380	143	143	137	0.3	0.9	0.3	6.3	2432	-4
392	143	143	137	4.6	2.8	4.6	6.5	2193	6
393	146	148	135	1.8	5.2	3.1	6.0	2146	2
396	133	135	132	5.5	2.4	4.2	8.0	2189	-2

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
46	0.50	1.58	64	5.6	-0.3	-1.6	-3.8	1.4
51	0.47	1.68	53	5.2	-1.9	-2.0	-3.5	2.0
56	0.34	0.99	33	8.2	0.7	-7.2	-2.6	1.5
60	0.97	2.30	53	7.9	1.8	3.3	-2.8	1.0
94	0.07	1.50	50	7.4	-3.7	-2.7	0.0	0.0
114	0.77	1.43	39	6.8	0.0	-9.0	-2.6	1.5
125	0.81			6.5	-0.3	-10.6	-3.5	3.5
137	0.18	1.42	52	5.8	0.5	-15.2	-4.2	4.2
189	0.67	1.68	59	6.8	1.0	-11.1	-4.6	3.9
200	0.29	1.34	45	6.5	0.3	-5.5	0.0	4.0
216	0.76	1.60	56	7.0	-2.0	-6.7	-5.4	4.5
226	0.25	2.03	66	6.0	-1.8	-0.8	0.0	0.0
242	0.93	2.20	70	6.2	1.5	-3.6	0.0	5.0
306	0.46	2.34	57	6.5	-2.3	-2.4	-1.2	6.9
322	0.49	1.89	49	4.4	-0.7	-3.8	0.0	4.0
337	1.08	1.74	37	7.0	0.6	3.1	0.0	4.0
348	0.62	1.31	49	2.8	1.3	-1.5	0.0	0.0
354	0.65	1.61	50	4.7	0.8	3.5	0.0	0.0
369	0.23			6.5	-1.8	-2.2	-0.3	3.0
378	0.21	1.50	62	7.0	1.2	-3.6	-1.3	2.7
380	0.07	1.56	66	4.8	-1.7	-6.5	-0.3	3.0
392	1.09	1.60	61	5.5	0.3	-0.1	0.0	0.0
393	0.72	1.51	57	4.7	-0.9	5.6	-1.4	1.4
396	1.06	2.04	78	7.5	-1.1	5.6	-2.0	-0.2

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
407	141	141	130	4.1	2.7	3.6	7.3	1797	0
408	155	156	138	3.0	3.8	3.2	8.3	1804	-1
421	133	134	142	3.6	4.2	3.6	5.7	2413	2
432	136	136	132	4.9	3.8	3.9	6.1	1755	3
439	139	138	138	6.3	3.7	4.6	4.5	2244	4
466	147	147	136	3.9	3.2	3.5	5.1	2314	-1
467	157	159	148	2.6	2.0	2.3	9.2	1379	-2
526	139	136	131	0.2	3.3	2.0	6.5	1864	-18
546	142	139	138	2.6	3.2	2.9	5.5	2423	-2
547	147	145	136	4.1	4.1	3.5	7.2	1529	0
604	143	140	130	3.7	3.8	3.8	6.1	1855	7
605	140	137	133	3.8	3.7	3.7	7.7	1750	10
624	142	140	131	4.1	3.2	3.3	7.4	1478	6
632	144	141	132	2.6	1.3	1.9	10.0	1297	6
670	131	124		2.4	2.9	2.4		1471	1
693	147	144	134	1.5	2.4	1.9	6.5	1952	5
696	156	153	145	0.6	1.0	1.0	7.6	1741	-5
701	144	142	134	2.9	3.1	2.9	7.1	1758	5
712	134	134	139	1.6	3.3	2.2	4.8	2254	2
742	131	121	122	0.4	0.4	0.4	6.1	1839	4
748	151	141	129	5.8	5.6	5.6	5.8	1955	-6
749	142	131	128	1.1	1.1	1.1	7.5	1729	3
772	132	124	124	1.5	0.6	0.6	6.5	1656	3
778	129	122		5.8	0.5	3.8		1662	2

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
407	0.86	1.91	60	6.9	0.9	-1.0	0.0	0.0
408	0.69	2.05	65	4.9	0.0	-0.2	-0.8	2.9
421	0.91	1.36	57	5.3	0.5	-6.2	-0.8	2.9
432	0.98	1.56	48	6.2	-0.6	0.3	0.0	3.0
439	1.14	1.12	44	6.0	-3.8	5.4	1.4	-3.8
466	0.80	1.28	52	5.0	-2.7	-2.1	0.0	4.0
467	0.49	2.12	51	4.6	1.1	0.3	-1.1	1.6
526	0.49	1.69	55	5.8	0.6	0.2	3.0	5.2
546	0.70	1.36	57	6.3	-0.2	-1.8	2.5	4.3
547	0.83	1.79	48	7.0	-0.6	-5.3	2.5	4.3
604	0.92	1.58	51	6.4	0.5	-1.7	3.5	6.1
605	0.92	1.96	60	6.6	1.8	3.7	3.5	6.1
624	0.81	1.92	49	5.3	-1.1	-2.8	2.5	4.3
632	0.45	2.57	58	7.1	-0.5	4.2	3.0	5.2
670	0.67			5.7	0.6	-1.3	6.9	4.0
693	0.44	1.64	56	6.3	1.2	-6.3	3.9	4.6
696	0.22	1.78	54	4.8	-1.4	3.9	3.2	3.8
701	0.69	1.79	55	5.1	-0.1	4.1	1.4	3.8
712	0.55	1.18	46	5.9	1.0	1.2	0.0	7.0
742	0.11	1.69	54	4.8	0.5	-2.8	9.8	1.7
748	1.35	1.52	52	5.5	1.2	-5.0	9.4	3.4
749	0.28	2.01	61	4.8	-1.1	1.6	10.8	1.9
772	0.16	1.77	51	5.6	0.8	4.3	7.9	1.4
778	1.05			4.4	0.2	2.0	7.9	1.4

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
836	133	125	131	1.8	0.7	0.7	6.0	2314	0
855	160	152	133	3.6	3.5	3.6	7.0	2480	-2
861	148	139	131	5.1	3.4	4.4	7.5	1691	1
863	149	143	134	4.1	4.1	4.1	6.9	2179	7
878	152	141	129	0.8	3.4	2.2	6.5	2091	2
927	153	141	130	3.8	5.1	4.6	6.4	2019	-9
928	147	135	129	3.2	2.2	2.4	6.5	1881	-4
936	167	155	137	0.7	0.8	0.8	4.7	2024	-3
942	150	140	135	4.4	3.5	3.7	8.3	1338	2
943	153	143	132	2.0	3.9	3.0	6.7	1968	-3
1017	153	145	142	1.4	3.8	2.1	6.2	2425	-12
1044	138	126	125	2.4	2.3	2.3	5.9	2263	1
1055	144	137	130	1.7	3.9	2.8	7.5	1920	5
1061	144	137	119	4.0	3.5	4.0	9.9	1774	-9
1075	151	143	129	4.7	2.8	4.4	5.6	2256	-15
1093	149	143	129	2.8	4.0	3.6	7.5	2198	4
1103	145	137	129	3.4	3.9	3.5	7.1	2103	-4
1112	152	144	135	3.6	2.9	3.2	6.4	2009	-12
1148	131	125	137	6.1	3.0	4.8	7.3	1081	-7
1158	135	128	129	2.6	1.1	2.2	7.1	1695	-4
1160	156	149	134	5.1	3.1	3.2	5.8	2201	-4
1183	144	140		0.0	3.7	2.4		2331	2
1184	155	151		4.1	2.0	2.4		1842	-14
1194	155	148	131	1.4	6.2	3.3	5.4	2178	5

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
836	0.19	1.54	62	6.2	-1.7	2.2	7.9	1.4
855	0.80	1.79	77	5.5	1.1	-10.0	7.9	1.4
861	1.06	1.94	57	5.8	0.4	-0.5	8.9	1.6
863	0.98	1.76	67	5.8	-1.7	4.2	6.1	3.5
878	0.53	1.70	62	5.1	-3.4	-3.9	11.8	2.1
927	1.10	1.65	58	6.0	2.4	-8.1	11.8	2.1
928	0.60	1.72	57	4.2	-1.7	-4.1	12.0	0.0
936	0.18	1.17	41	5.5	-0.4	-13.1	12.0	0.0
942	0.90	2.08	49	3.9	-0.6	-1.8	10.0	0.0
943	0.70	1.74	60	5.2	1.3	-9.1	10.0	0.0
1017	0.50	1.49	63	5.1	1.3	-10.3	8.4	-10.0
1044	0.62	1.59	63	5.8	-4.0	3.1	12.3	-10.3
1055	0.70	1.95	65	7.5	0.0	-8.9	7.7	-9.2
1061	0.99	2.81	87	6.3	-2.7	1.7	7.7	-9.2
1075	1.04	1.46	57	5.1	-4.1	-5.8	7.7	-9.2
1093	0.85	1.97	76	8.1	-1.1	1.8	6.0	-10.4
1103	0.87	1.87	69	6.9	0.1	5.1	7.7	-9.2
1112	0.76	1.61	57	6.6	0.6	-11.1	7.5	-13.0
1148	1.31	1.82	34	6.3	-1.7	0.9	6.0	-10.4
1158	0.57	1.86	55	5.6	-0.6	1.0	6.5	-11.3
1160	0.72	1.47	57	3.5	-3.7	-3.9	6.5	-11.3
1183	0.59			4.2	-1.9	-4.0	4.1	-11.3
1184	0.54			5.4	-1.0	-2.0	4.1	-11.3
1194	0.76	1.38	53	5.9	-3.6	-1.1	7.5	-13.0

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1208	162	151	132	0.9	2.0	1.7	7.1	1861	-7
1234	163	148	142	3.2	4.4	3.9	9.3	1497	8
1261	165	154	138	4.1	1.4	2.8	8.2	1406	3
1295	144	131	124	2.1	4.8	3.6	5.9	1952	-8
1307	157	135	126	1.8	2.2	2.0	7.3	1440	1
1329	159	136	123	2.5	1.2	2.0	6.3	2173	4
1345	157	137	133	6.9	3.1	4.9	7.4	1540	-2
1369	140	117	130	3.6	4.2	3.6	6.5	1287	-1
1374	171	148	131	1.1	2.1	0.1	5.1	2655	4
1388	159	137	125	4.3	3.9	4.1	7.3	1809	0
1403	171	146	132	3.6	3.5	3.5	6.3	1447	2
1424	149	125	123	4.3	5.6	5.4	4.9	2373	6
1439	158	140	132	2.9	3.7	3.4	5.3	1788	5
1449	152	134	122	6.1	2.7	4.8	7.1	1290	-1
1461	153	131	124	0.9	5.1	3.4	5.8	2211	6
1462	148	128	120	3.3	1.7	2.8	6.2	1772	-10
1507	143	123	125	5.7	1.7	3.0	5.4	2111	-3
1532	142	127		3.9	1.6	3.2		2126	8
1618	145	139		1.5	3.0	2.1		1878	-8
1632	135	128		3.5	2.3	3.3		780	-3
1786	134	130	130	1.3	4.3	2.9	6.9	1796	4
1839	136	136	132	1.1	5.0	3.1	6.3	2305	-2
1840	130	130	130	0.9	2.2	1.5	4.9	2150	2
1882	133	136	135	1.9	2.8	2.4	8.3	1398	5
1918	156	152	140	4.1	5.5	4.8	7.0	1845	-4

Table D-4. Landing Data, A320, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1208	0.39	1.82	59	6.2	0.4	-6.8	10.7	-9.0
1234	0.88	2.23	58	6.6	-0.4	-8.1	15.6	-9.0
1261	0.63	2.01	49	7.3	-1.4	-3.6	11.3	-6.5
1295	0.92	1.61	55	5.7	0.9	-8.6	13.8	-2.4
1307	0.49	1.97	49	4.6	0.2	-2.6	22.7	-4.0
1329	0.50	1.74	66	4.2	-0.6	6.2	23.0	0.0
1345	1.21	1.90	51	4.9	-0.2	3.5	20.0	0.0
1369	1.04	1.70	38	5.2	-2.6	3.1	23.0	0.0
1374	0.01	1.31	61	2.9	-0.7	3.1	23.0	0.0
1388	1.02	1.99	63	3.6	-3.4	-5.3	22.7	-4.0
1403	0.82	1.61	41	6.4	-2.3	1.1	25.0	0.0
1424	1.46	1.37	57	4.4	-0.6	-6.4	24.0	0.0
1439	0.82	1.35	42	4.6	0.6	1.7	18.0	0.0
1449	1.23	1.98	45	7.5	-1.3	-1.7	18.0	0.0
1461	0.88	1.57	61	2.3	-0.3	0.5	22.0	0.0
1462	0.75	1.75	54	7.1	-0.5	-2.0	20.0	0.0
1507	0.84	1.47	54	3.7	-2.2	9.4	19.7	-3.5
1532	0.85			7.2	-1.1	0.3	15.8	-2.8
1618	0.51			5.1	-0.8	-6.0	5.5	-9.5
1632	0.87			7.1	-0.9	-5.7	7.0	-12.1
1786	0.77	1.81	57	6.1	0.0	0.6	3.8	1.4
1839	0.77	1.61	65	6.6	-0.2	-1.1	0.0	0.0
1840	0.39	1.28	48	7.4	-3.0	6.7	0.0	0.0
1882	0.61	2.09	51	6.6	0.5	0.2	-2.6	-1.5
1918	1.07	1.71	55	5.9	0.8	-1.1	4.0	-6.9

Table D-5. Landing Data, A321, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
39	157	157	148	1.1	2.8	2.2	8.1	1816	-2
72	153	156	149	1.1		0.9	7.7	1476	11
83	141	145	145	6.0	4.1	5.1	10.2	1284	10
93	149	153	145	4.6	4.3	4.6	6.1	1727	-1
116	153	156	146	3.9	1.6	1.6	6.3	2156	-6
228	146	146	138	4.3	2.8	3.0	8.0	1766	0
231	140	140	142	0.9	1.3	1.2	7.0	1756	10
234	151	153	141	3.5	2.3	2.3	5.1	2273	-1
252	158	158	148	0.6	3.2	2.4	6.3	1959	-5
268	153	153	139	3.2	1.5	2.4	6.6	1726	-10
290	158	162	147	1.8	2.8	2.3	7.4	2037	-12
308	156	156	142	5.4	2.1	3.9	7.4	1834	-4
401	146	147	140	6.4	5.4	6.1	5.7	2268	2
403	154	155	145	4.4	4.3	4.4	6.0	1952	-2
410	163	163	148	4.2	4.0	4.1	9.5	1599	-1
427	160	161	146	2.5	2.7	3.2	9.0	1437	4
442	152	154	147	4.5	4.4	4.4	4.5	3405	-2
529	148	145	140	2.8	2.1	2.5	5.8	2410	1
579	153	150	141		5.8	4.3	5.5	2511	-4
603	159	156	141	4.5	2.7	3.6	7.7	1450	4
631	128	125	135	3.4	4.5	4.2	5.8	2177	6
638	154	151	147	2.8	2.8	2.8	6.6	2329	-2
666	147	143	147	0.2	2.5	1.9	5.9	2277	7
713	161	161	151	3.0	2.1	2.6	6.8	2485	0

Table D-5. Landing Data, A321, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
39	0.48	1.86	59	6.3	0.0	-1.5	0.0	0.0
72	0.20	1.76	45	6.9	1.2	-6.7	-2.7	1.3
83	1.20	2.38	53	6.5	-0.2	2.6	-3.9	0.7
93	1.01	1.43	43	5.8	0.2	2.5	-4.7	1.7
116	0.35	1.46	55	10.5	-1.4	3.7	-2.9	0.8
228	0.70	1.97	61	5.7	-1.0	-0.9	0.0	0.0
231	0.30	1.67	51	5.4	0.4	0.3	0.2	2.0
234	0.51	1.23	49	6.3	1.1	-2.9	-2.1	4.5
252	0.51	1.45	49	5.2	0.2	-6.8	0.0	5.0
268	0.54	1.61	49	6.7	-1.1	0.0	0.0	6.0
290	0.48	1.70	61	4.7	-0.2	-14.3	-3.8	-1.4
308	0.86	1.77	57	5.7	-1.5	-3.1	-0.7	3.9
401	1.41	1.39	55	6.3	-0.9	-0.4	-0.5	3.0
403	0.96	1.40	48	6.2	0.2	-5.7	-0.8	2.9
410	0.86	2.17	61	7.7	-0.9	-12.3	0.0	0.0
427	0.67	2.10	53	4.2	-0.1	-2.2	-0.5	3.0
442	0.97	1.05	62	5.3	-1.3	-7.4	-1.7	4.7
529	0.58	1.42	60	4.9	-0.8	-1.7	2.5	4.3
579	0.98	1.33	58	6.5	-1.2	-8.9	3.0	5.2
603	0.77	1.86	47	4.9	-0.4	-1.6	3.5	6.1
631	1.13	1.45	55	7.1	-1.1	4.2	2.5	4.3
638	0.62	1.53	62	4.2	-2.2	-3.6	3.0	5.2
666	0.45	1.36	54	2.7	-0.7	-1.6	3.9	4.6
713	0.55	1.53	66	4.2	-0.5	-7.4	0.0	7.0

Table D-5. Landing Data, A321, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
765	144	134	133	1.1	2.4	2.2	8.0	1666	6
882	154	143	132	4.3	3.6	3.6	5.5	2260	5
893	169	161	141	3.0	1.5	2.3	7.3	1715	-1
904	163	153		2.9	3.3	2.9		2052	-9
941	149	138	137	0.2	1.3	0.7	6.8	1957	-6
994	155	151	141	3.6	2.0	3.0	7.1	1763	-11
995	132	131	131	2.9	2.7	2.4	6.6	1754	-5
1014	133	124	133	3.1	4.1	3.6	5.6	2350	-4
1036	153	148	136	6.0	3.9	5.0	6.3	2148	2
1065	159	151	144	1.6	5.4	2.9	8.1	1926	-5
1124	152	142	141	3.0	1.7	1.9	6.6	1654	3
1154	150	144	149	2.6	3.7	3.4	6.7	2367	-7
1162	139	134	140	4.8	3.4	3.7	7.0	2462	2
1181	146	143	136	2.1	1.3	1.3	7.0	1869	-8
1203	146	133	126	1.3	2.2	2.2	4.9	3222	-2
1205	155	144	134	0.4	0.6	0.4	7.5	1862	3
1221	146	136	127	4.5	3.4	4.0	10.1	1393	-17
1268	150	139	132	5.4	2.9	4.2	5.3	2251	-1
1270	157	146	134	4.7	2.3	3.2	8.6	1389	8
1314	154	132		0.7	1.5	1.2		1469	2
1332	157	141	130	2.7	4.4	2.7	6.6	2014	0
1347	156	134	129	0.0	4.6	2.5	5.9	2426	-2
1357	155	131	118	1.7	1.6	1.7	5.8	1733	7
1380	162	140	134	3.1	4.0	4.0	6.4	1919	0

Table D-5. Landing Data, A321, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
765	0.56	2.03	59	7.0	1.3	5.6	10.8	1.9
882	0.85	1.42	56	4.2	-0.6	3.9	11.3	4.1
893	0.49	1.76	53	4.5	-0.9	0.7	7.9	1.4
904	0.64			6.4	1.6	-11.8	10.0	0.0
941	0.17	1.68	57	5.1	-1.1	-5.7	11.3	-4.1
994	0.67	1.71	53	7.1	-0.7	-4.5	3.5	-6.1
995	0.62	1.72	53	4.6	-4.5	-2.6	1.7	-9.8
1014	0.99	1.44	59	4.0	-0.4	-5.7	8.4	-10.0
1036	1.13	1.57	59	5.4	-0.3	-2.3	4.5	-7.8
1065	0.66	1.92	65	3.4	-1.4	-7.8	7.7	-9.2
1124	0.45	1.57	45	5.1	3.5	1.7	10.0	-8.4
1154	0.81	1.52	63	2.6	-1.0	-9.7	6.5	-11.3
1162	0.94	1.69	73	4.8	-1.5	-7.3	5.0	-8.7
1181	0.31	1.76	57	5.8	-1.4	-3.5	3.4	-9.4
1203	0.56	1.32	74	5.1	-1.2	-1.8	13.0	-10.9
1205	0.09	1.89	61	3.7	-0.1	-4.9	10.9	-13.0
1221	1.00	2.69	65	6.4	-0.9	-3.6	9.6	-11.5
1268	1.02	1.36	53	6.1	-2.6	-0.2	11.3	-6.5
1270	0.75	2.17	53	6.4	-1.3	-1.3	11.3	-6.5
1314	0.31			4.4	-0.5	-0.9	22.0	0.0
1332	0.65	1.72	61	2.0	-3.6	15.1	16.0	0.0
1347	0.63	1.54	65	5.7	-0.1	-3.4	21.7	-12.5
1357	0.44	1.66	50	4.0	-0.5	-2.1	24.0	0.0
1380	0.97	1.62	54	4.8	0.6	-9.1	21.7	-3.8

Table D-5. Landing Data, A321, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1426	169	143	129	2.2	3.3	2.2	5.9	2432	-19
1442	160	136	128	2.9	5.2	4.6	6.1	2296	10
1443	164	139	125	0.9	3.6	2.7	7.5	1552	-2
1452	161	138	128	2.7	3.5	3.4	5.2	2360	-4
1473	162	142	137	3.7	2.3	3.1	5.0	2826	-5
1490	137	117	133	0.3	1.7	1.7	6.8	1577	-2
1497	152	132	122	1.5	2.9	1.5	5.0	1888	-7
1512	154	134	130	3.0	2.1	3.0	5.7	1949	-8
1524	163	147	143	3.2	4.4	3.9	6.5	2357	8
1529	155	138		1.7	3.4	3.1		2139	-2
1543	144	127	122	1.8	0.5	1.7	5.8	1796	-1
1606	158	151	138		1.0	1.3	7.2	2070	-7
1635	170	161		0.2	2.7	0.6		1474	-7
1639	145	133		1.4	3.2	2.1		1837	7
1770	151	147	142	4.2	3.3	3.2	10.5	1275	-3
1792	130	127	134	0.4	1.4	0.2	8.9	853	-11
1799	146	142	147	2.3	3.6	2.8	6.7	2280	-2
1803	151	147	144	2.4	3.1	2.5	7.0	1831	-1
1818	131	131	137	2.6	2.8	2.7	7.8	1457	4
1829	144	144	147	4.2	3.7	3.9	8.0	1900	-3
1845	150	150	139	1.9	0.4	0.8	6.1	2001	-1
1895	143	139	139	2.9	3.9	2.3	7.2	1734	-2

Table D-5. Landing Data, A321, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1426	0.53	1.54	65	4.3	-2.7	-4.3	26.0	0.0
1442	1.15	1.61	65	3.5	-0.4	-3.1	23.6	-4.2
1443	0.65	2.03	55	5.1	-1.5	-9.6	24.6	-4.3
1452	0.83	1.37	57	2.6	-0.6	-3.7	23.6	-4.2
1473	0.73	1.24	61	5.2	1.5	-2.9	20.0	0.0
1490	0.49	1.74	48	4.4	0.2	-1.3	20.0	0.0
1497	0.39	1.40	46	4.2	-2.5	-4.1	20.0	0.0
1512	0.76	1.48	50	6.8	-1.1	-9.9	20.0	0.0
1524	0.90	1.53	63	3.9	-0.6	-3.1	16.0	-5.8
1529	0.76			4.2	-0.8	-3.0	17.0	0.0
1543	0.45	1.63	51	4.7	0.2	-0.1	17.7	-3.1
1606	0.30	1.77	64	5.9	1.2	-14.5	7.0	0.0
1635	0.12	2.17	56	6.5	-3.0	-7.5	9.6	-11.5
1639	0.52			4.8	-1.4	-1.8	12.1	-7.0
1770	0.73	2.51	56	6.1	2.3	0.7	4.0	0.0
1792	0.06	2.25	33	6.8	2.0	-4.9	3.0	0.5
1799	0.68	1.54	61	4.1	-1.3	1.2	3.8	1.4
1803	0.58	1.65	53	5.6	1.6	-2.5	3.8	1.4
1818	0.70	1.94	49	6.1	-1.2	-3.2	0.0	0.0
1829	0.91	1.85	61	5.0	0.2	-2.9	0.0	0.0
1845	0.17	1.48	52	7.7	0.1	-8.6	0.0	0.0
1895	0.56	1.77	53	5.7	-2.2	3.1	4.7	1.7

Table D-6. Landing Data, A330, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
26	153	153	147	4.6	3.9	4.2	8.6	2340	-6
166	133	133	134	0.7	2.9	1.4	7.5	1415	1
174	132	132	138	4.9	5.9	4.9	6.0	2233	-14
491	141	142	133	4.3	2.9	3.4	6.1	1400	9
504	137	139	129	5.3	4.7	4.9	9.5	1452	14
1227	157	140	126	5.5	3.8	5.5	13.6	602	-14
1232	140	124	121	9.0	4.4	8.0	10.5	1031	-2
1408	151	127	113	7.2	3.5	5.8	10.8	641	7
1422	142	118	121	3.1	2.9	3.0	7.2	1241	-3
1585	147	126	113	2.3	1.7	2.0	6.3	1433	6
1586	144	126	123	6.5	5.1	5.1	6.6	1699	3
1625	157	146	132	4.4	4.7	4.5	7.9	1262	1
1629	143	136	132	0.3	1.0	0.4	8.7	1347	-15
1703	138	134	131	0.3	1.7	1.7	6.4	2098	11
1707	137	133	131	3.8	3.8	3.8	5.9	2210	6
1718	134	133	135	1.5	1.3	1.2	5.9	2677	7
1735	142	138	136	4.9	3.0	4.0	8.1	1550	-7
1748	133	128	134	3.7	2.9	3.4	5.2	1602	7
1753	149	145	133	2.2	3.4	2.8	7.1	1560	2

Table D-6. Landing Data, A330, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
26	0.94	1.99	81	13.1	-1.4	-1.8	0.0	0.0	
166	0.37	1.91	47	11.5	1.2	4.8	0.0	4.0	
174	1.26	1.48	58	14.2	-1.8	-1.9	0.0	0.0	367,286
491	0.82	1.55	38	14.5	1.4	-3.0	-1.0	3.9	381,616
504	1.20	2.49	63	11.8	-0.6	-5.3	-1.3	4.8	
1227	1.33	3.67	39	13.1	-1.2	-4.1	17.3	-10.0	
1232	2.20	2.93	53	13.8	-2.4	1.7	15.3	-12.9	
1408	1.53	3.24	36	13.6	-2.6	-3.2	24.0	0.0	
1422	0.86	2.04	44	11.3	0.2	2.4	24.0	0.0	
1585	0.54	1.89	47	12.6	-0.6	-6.1	21.7	-3.8	
1586	1.38	1.83	54	11.2	2.4	2.6	18.7	3.3	
1625	1.05	2.04	45	14.5	1.1	-0.9	10.7	-9.0	
1629	0.09	2.24	53	9.0	-1.3	0.4	7.0	-12.1	
1703	0.43	1.66	61	13.8	0.2	6.3	4.6	3.9	
1707	0.97	1.53	59	12.9	-2.5	2.1	3.9	4.6	
1718	0.31	1.48	69	11.1	2.8	5.6	0.9	4.9	
1735	0.97	2.01	54	11.4	-0.5	5.4	3.8	3.2	
1748	0.91	1.32	37	19.4	0.9	1.9	5.0	0.0	
1753	0.66	1.82	50	14.6	0.1	-12.1	4.9	0.9	

Table D-7. Landing Data, A340, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
138	163	167	148		3.6	3.4	6.6	2045	-8
158	141	141	139	2.8	2.0	2.8	7.3	1663	-7
204	129	132	131	4.8	2.9	3.8	7.7	1685	2
334	151	151	140	3.5		2.9	8.4	1510	1
502	148	149	136	2.9	3.6	3.3	7.7	1585	1
515	140	141	129	0.8	0.8	0.8	5.7	1592	-14
711	148	147	140	4.4	3.3	3.7	6.6	1751	11
939	142	133	130	3.5	2.5	2.5	6.5	1725	4
951	153	148	131	6.1	4.5	5.6	11.4	794	-11
1132	150	139	129	3.2		2.3	7.0	1712	-8
1192	152	139	131	1.6	1.3	1.3	10.1	1435	2
1197	144	131	127	6.2	3.7	3.6	4.6	2192	2
1218	132	123	126	5.6	4.4	5.4	10.7	1238	-15
1250	146	135	130	4.3	3.7	3.7	8.0	1422	9
1289	152	138	129	1.0	2.4	2.1	7.6	1876	-2
1330	134	112	115	2.1	4.4	2.1	8.5	1005	-8
1392	163	140	128	4.8	1.2	3.0	5.8	1495	1
1477	142	122	117		2.7	1.0	5.5	1395	24
1498	131	112	125	5.1	3.7	4.7	7.6	1558	0
1550	158	143	127	1.6	4.3	3.0	6.5	2068	-16
1603	142	135	132	6.7	6.1	6.1	6.2	1933	-3
1630	156	150	139	6.3	5.7	6.7	13.0	993	-22
1678	151	146	134	1.7	2.4	2.0	7.0	1497	2
1701	144	141	134	4.9	3.5	3.5	8.8	888	-5
1727	132	127	127	6.7	3.6	5.1	8.4	1751	1

Table D-7. Landing Data, A340, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
138	0.69	1.50	54	14.3	0.5	-15.8	-3.5	2.0	
158	0.67	1.79	52	10.5	-0.9	0.9	0.0	5.0	392,675
204	0.98	2.01	59	13.6	0.4	-0.2	-3.1	2.6	365,743
334	0.64	2.03	54	14.0	-1.1	-7.1	0.0	4.0	375,635
502	0.74	1.91	53	14.6	0.7		-0.7	3.9	382,057
515	0.19	1.50	42	13.1	0.3	17.1	-0.5	3.0	
711	0.85	1.60	49	12.5	0.1	2.1	1.0	5.9	
939	0.62	1.70	51	10.6	2.8	-0.1	9.0	0.0	387,582
951	1.29	2.95	41	13.9	0.7	-7.8	5.0	-8.7	344,667
1132	0.56	1.85	55	12.2	-0.3	-5.7	11.5	-9.6	339,524
1192	0.32	2.61	65	12.1	-1.3	-5.1	13.0	-10.9	373,794
1197	0.94	1.24	47	11.1	2.2	-4.7	13.8	-11.6	367,315
1218	1.50	2.88	62	13.5	-4.2	2.8	9.0	-15.6	361,034
1250	0.93	2.09	52	14.2	-1.4	-3.2	11.3	-6.5	389,074
1289	0.51	2.00	65	13.7	0.2	-7.6	14.1	-5.1	375,003
1330	0.63	2.51	44	10.4	-1.4	11.8	22.0	0.0	368,389
1392	0.73	1.54	40	12.1	-0.7	-9.9	23.6	-4.2	
1477	0.28	1.59	39	14.0	2.8	-0.3	20.0	0.0	
1498	1.42	2.06	56	12.9	-0.6	9.1	19.0	0.0	393,995
1550	0.70	1.75	63	14.3	-0.3	-16.2	15.0	0.0	403,155
1603	1.53	1.61	54	13.1	1.7	-8.4	7.0	0.0	375,915
1630	1.53	3.18	55	14.1	-0.7	-16.1	6.5	-11.3	382,915
1678	0.47	1.78	46	13.5	0.3	-4.7	4.5	5.4	386,687
1701	0.85	2.24	35	13.6	1.5	-6.9	3.0	5.2	366,956
1727	1.37	2.24	69	12.3	0.4	3.1	5.4	4.5	

Table D-8. Landing Data, B-737-100/200, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
45	133	137	131	0.5	1.4	1.0	7.9	1839	6
53	146	149	138	1.4	4.4	4.3	5.6	2329	-1
68	137	137	136	3.2	2.3	2.3	7.2	1735	0
230	137	139	125	4.6	3.1	3.8	6.4	1465	10
258	153	153	139	1.2	1.8	1.5	5.6	2039	-12
310	141	141	130	3.2	2.1	2.7	7.9	1538	0
461	171	171		0.9	4.0	2.3		1853	-7
479	155	157	140	4.5	3.8	4.1	8.8	1616	-2
727	145	139	123	0.8	3.8	2.5	6.1	1738	9
795	134	124	118	2.6	0.6	1.5	6.4	1669	4
1430	148	129	112	0.8	3.1	1.3	6.4	1602	9
1437	148	127	124	2.1	2.0	2.1	5.4	2563	-5
1762	130	126	128	2.6	3.2	2.8	9.1	1445	9
1776	149	147	131	1.2	2.4	2.0	7.9	1541	7
1943	145	142	130	3.7	2.5	3.1	7.6	1923	-9

Table D-8. Landing Data, B-737-100/200, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
45	0.24	2.04	65	9.7	0.7	-2.9	-3.9	1.0
53	0.97	1.37	56	4.5	1.5	-0.4	-2.8	1.0
68	0.57	1.79	54	6.6	-2.4	2.0	0.0	0.0
230	0.93	1.75	45	5.5	0.1	-5.1	-2.1	2.1
258	0.33	1.37	49	4.8	-1.3	-10.8	0.0	5.0
310	0.66	2.05	55	5.2	-1.5	-9.2	0.4	5.0
461	0.45			6.7	-0.5	-8.9	0.0	6.0
479	0.90	2.12	60	5.3	-2.8	-9.5	-2.0	3.5
727	0.61	1.68	51	3.4	0.5	-0.4	6.1	3.5
795	0.41	1.83	53	4.4	-2.0	5.9	9.8	1.7
1430	0.35	1.94	54	2.9	-2.5	-0.5	19.0	0.0
1437	0.57	1.48	66	3.8	-0.1	-16.9	21.0	0.0
1762	0.75	2.40	61	5.6	-1.8	-2.3	3.8	1.4
1776	0.47	2.05	55	6.2	2.4	-10.4	2.5	4.3
1943	0.74	1.97	66	5.1	-2.3	-7.6	3.5	-6.1

Table D-9. Landing Data, B-737-300/400/500, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
82	152	155	142	2.5	2.7	2.6	6.9	1543	1
98	159	162	143	0.4	1.4	1.0	7.5	1438	7
102	139	142	144	3.2	0.2	2.4	7.2	1723	9
177	165	165	148	1.1	0.7	0.9	6.3	1934	-3
190	145	149	133	3.9	2.9	3.3	7.3	1510	7
199	157	159	144	1.3		0.5	7.4	1987	-7
201	137	141	132		2.1	1.8	7.1	1481	9
222	138	138	134	2.2	2.6	2.2	8.0	1398	8
250	151	151	138	3.8	0.9	2.5	7.2	1817	3
292	148	153	141	2.3	2.6	2.8	7.7	1805	0
362	152	152	144	3.0	2.7	2.7	7.3	1953	-5
372	153	153	139	4.6	2.5	3.8	8.3	1785	5
376	124	126	143	2.3	0.3	1.9	3.7	3246	-15
484	157	157	139	3.6	3.6	3.6	6.4	1577	4
565	146	143	146	3.4	2.3	2.9	6.3	1803	-6
586	148	148	141	2.3	1.2	1.6	5.7	1978	8
630	139	136	127	4.3	4.1	4.3	7.3	1517	11
650	149	144	136	1.4	0.7	0.9	8.5	1507	4
655	131	126	135	4.1	3.6	3.8	7.5	1792	3
664	149	145		4.5	6.0	5.2	9.4	1733	-17
685	158	152	138	2.2	3.6	2.9	6.9	1971	-5
698	155	152	142	1.5	2.0	1.8	8.5	1458	9
703	157	153	146	3.3	3.8	3.5	6.0	2217	1
737	169	160	145	2.1	2.5	2.1	5.6	2396	0

Table D-9. Landing Data, B-737-300/400/500, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
82	0.57	1.66	45	5.3	-0.7	-6.3	-2.8	1.0
98	0.20	1.78	45	5.3	-0.7	-5.3	-2.3	3.3
102	0.56	1.70	51	9.6	1.3	0.0	-2.9	0.8
177	0.19	1.44	49	5.2	0.2	-6.5	0.0	4.0
190	0.74	1.88	49	5.8	1.0	-10.5	-3.9	-1.0
199	0.11	1.75	61	5.5	-1.5	-12.2	-1.9	-2.3
201	0.43	1.82	47	5.9	0.8	-6.3	-3.9	4.6
222	0.54	2.03	49	6.4	-1.8	0.4	0.0	0.0
250	0.57	1.76	56	5.7	-2.1	-1.6	0.0	3.0
292	0.61	1.85	58	5.3	-1.0	-4.7	-4.7	1.7
362	0.59	1.73	59	5.0	-1.7	-6.3	-0.3	4.0
372	0.84	2.02	63	3.8	-1.8	-3.1	0.0	5.0
376	0.52	0.87	49	6.2	-3.4	2.3	-1.7	3.6
484	0.78	1.56	43	4.6	1.1	-9.9	0.0	0.0
565	0.68	1.47	46	4.2	-1.3	-1.1	2.5	4.3
586	0.36	1.39	48	4.9	0.4	-7.4	0.9	4.9
630	1.07	1.96	52	5.1	1.0	-2.9	2.5	4.3
650	0.21	2.12	56	6.6	-0.8	-3.8	5.4	4.5
655	1.01	1.89	59	4.9	0.7	-2.8	5.2	3.0
664	1.22	1.63	49	5.6	1.5	3.1	3.8	3.2
685	0.64	1.69	58	4.6	1.0	-5.5	6.1	3.5
698	0.41	2.04	52	5.0	1.1	-7.0	3.2	3.8
703	0.78	1.38	53	3.4	0.5	2.9	3.5	6.1
737	0.45	1.30	54	2.6	0.0	-4.6	8.9	1.6

Table D-9. Landing Data, B-737-300/400/500, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
831	144	134	127	1.2	2.3	1.8	7.6	1490	13
1058	139	131	139	1.8	3.5	2.6	7.2	2524	-6
1096	155	145	133	5.3	1.5	4.0	7.5	1333	-6
1265	164	153		4.6	3.6	3.9		1436	-7
1320	161	136		1.0	3.6	2.3		1501	4
1324	139	117		3.8	4.3	3.8		3142	7
1334	164	149	132	4.6	3.0	3.5	6.6	1688	6
1409	163	141	123	5.7	4.8	5.3	6.9	1314	1
1485	166	146	131	4.9	5.5	5.5	4.2	2507	-5
1538	149	130		1.7	2.3	2.2		1932	-5
1634	144	137		3.1	1.6	2.1		1968	2
1653	159	153		2.1	3.0	2.5		1429	7
1778	146	144	136	1.9	1.5	1.5	5.6	2390	3

Table D-9. Landing Data, B-737-300/400/500, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
831	0.44	2.02	53	4.8	0.7	-7.4	9.8	1.7
1058	0.67	1.76	77	2.8	-1.4	-12.5	7.7	-9.2
1096	0.93	1.92	45	5.2	-0.7	-10.7	10.0	-8.4
1265	0.86			4.6	-1.9	-5.0	11.3	-6.5
1320	0.56			3.1	1.0	-7.2	25.0	0.0
1324	1.09			2.4	2.0	8.7	22.0	0.0
1334	0.80	1.70	50	3.4	1.4	-1.7	15.0	0.0
1409	1.28	1.91	44	6.2	1.1	-2.3	22.0	0.0
1485	1.28	1.09	48	3.6	-2.4	-11.2	20.0	0.0
1538	0.59			5.4	0.7	-9.3	18.7	-3.3
1634	0.52			4.3	2.0	-8.2	7.0	-12.1
1653	0.56			3.7	-0.4	-1.6	6.9	-4.0
1778	0.36	1.40	58	5.6	0.2	-4.2	2.0	3.5

Table D-10. Landing Data, B-747 Classic, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
27	149	149	151	3.9	2.5	3.2	9.8	1212	-7
139	171	175	162	3.6	4.6	4.2	7.8	2528	-6
151	143	143	138	2.8	1.4	2.8	7.6	1541	-5
153	145	145	142	3.1	2.0	2.5	8.6	1562	2
157	153	151	144	3.4		3.1	10.2	1032	-20
162	156	156	148	3.7	1.8	2.8	5.4	1859	-7
211	161	166	154	1.8		1.5	7.1	1998	-29
212	139	141	136	2.5	3.8	2.7	5.5	1808	-14
261	130	130	134	4.4	2.2	3.3	7.9	1752	-5
284	167	167	152	3.8	2.4	3.3	7.1	1902	-14
352	168	168	161	4.1	0.9	2.4	9.0	1625	21
374	162	162	148	3.1		3.1	5.4	2034	0
423	150	153	144	5.0	4.3	4.6	8.9	1731	-8
437	141	141	137	5.0	1.0	3.5	7.5	1721	-5
489	158	158	148	2.4	2.5	2.4	6.3	1954	-5
494	142	142	133	3.9	3.4	3.7	6.0	1988	-7
505	148	148	139	2.1		2.3	5.0	2509	-11
599	145	143	136	4.0	3.8	3.9	7.4	1342	4
600	158	153	144	4.8	3.2	4.0	6.9	1985	-2
606	171	166	155	3.7		2.9	7.8	1996	-12
651	153	148		5.0	4.1	4.5		1743	-5
755	165	155	141	3.5		3.5	6.3	2073	-19
807	165	155	144	3.5	4.1	3.9	7.0	2053	-14
810	153	144	139	3.7	2.7	3.1	9.1	1380	4
813	145	135	133	2.7	4.6	3.7	4.8	2431	-2

Table D-10. Landing Data, B-747 Classic, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
27	0.73	2.20	46	9.4	0.4	9.2	0.0	0.0	526,247
139	0.80	1.62	72	8.1	-0.8	-13.3	-4.1	2.9	487,611
151	0.66	1.87	50	6.8	0.3	4.1	-0.3	4.0	498,749
153	0.59	2.05	56	6.1	-1.5	1.2	0.0	0.0	
157	0.70	2.40	43	7.5	0.1	-13.5	2.1	-5.6	
162	0.60	1.24	40	9.6	-1.4	-4.2	-0.3	4.0	
211	0.31	1.56	54	7.3	-1.8	-9.0	-4.9	3.4	530,780
212	0.64	1.37	43	6.7	-1.5	-2.4	-2.1	4.5	
261	0.87	2.01	61	9.0	-0.2	-1.8	0.0	3.0	505,133
284	0.66	1.59	53	7.6	0.2	-8.5	0.0	6.0	505,471
352	0.49	1.89	54	8.5	-0.8	1.3	-0.2	2.0	565,138
374	0.64	1.24	44	10.0	-0.8	-13.8	-0.3	3.0	500,365
423	1.03	2.09	63	7.3	1.8	-2.4	-3.1	2.6	
437	0.83	1.86	56	7.3	-0.5	-1.3	0.0	4.0	471,751
489	0.52	1.46	50	8.1	1.2	-6.6	-0.3	2.0	521,276
494	0.88	1.52	53	8.0	-0.3	-6.1	-0.3	2.0	559,164
505	0.53	1.22	54	8.6	-1.8	-8.4	-0.8	2.9	
599	0.92	1.85	43	6.0	-1.0	-0.8	1.7	4.7	
600	0.89	1.61	56	7.8	-0.3	-8.1	4.5	5.4	450,770
606	0.59	1.72	60	8.2	-0.8	-8.1	4.5	5.4	539,856
651	1.04			6.5	0.5	1.1	5.2	3.0	
755	0.77	1.52	55	8.7	-1.5		9.4	3.4	508,601
807	0.84	1.65	59	8.4	0.2	-10.9	9.8	1.7	532,753
810	0.74	2.22	54	9.3	0.3	1.2	9.8	1.7	521,928
813	0.92	1.23	52	6.6	-0.4	-5.7	9.4	3.4	

Table D-10. Landing Data, B-747 Classic, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
876	152	140	133	1.9	1.3	1.5	9.1	1141	0
877	159	148	143	1.8	1.7	1.8	7.4	1685	-4
931	149	137	136	1.6	1.3	1.4	5.6	1925	-2
973	147	143	139	4.8	1.9	3.4	9.1	1337	-5
1021	176	169	160	0.5	2.5	1.0	5.1	2311	3
1117	157	150	141	4.1	3.7	4.1	8.4	1340	-3
1198	157	143	150	4.9	3.6	3.9	7.1	2055	-11
1279	154	140	129	4.2	3.2	3.5	5.6	1439	6
1337	164	144	137	2.6	0.0	2.1	4.9	3534	-21
1364	172	150	137	2.5		3.2	6.9	2085	-19
1398	140	119	110	2.6	2.8	2.6	5.6	1547	-1
1578	142	123	119	5.9	5.0	5.5	11.4	917	-5
1608	168	159	148	3.1	0.0	2.0	6.9	2311	-9
1626	174	170	151	5.2		5.5	8.6	2094	-28
1658	156	152	144	3.5	3.8	3.5	7.0	1878	-2
1659	139	135	138	2.3	0.1	2.1	7.7	1686	-9
1709	136	134	133	5.9	2.4	3.9	13.4	621	4
1720	146	145	141	4.1	3.9	4.0	7.7	1414	-5
1725	160	156	144	3.0	2.4	2.9	8.3	1586	-12
1746	132	132	131	3.1	3.6	3.5	7.7	1278	3
1750	163	158	147	3.4	3.2	3.4	9.3	1534	-13
1765	144	140	144	5.7	3.3	4.2	6.2	1980	6
1858	150	150	144	2.3	3.0	2.4	5.5	1858	-1
1920	152	152	147	4.8	2.4	3.5	7.8	1381	-4
1928	153	153	144	4.5	1.8	3.6	8.1	1768	-7

Table D-10. Landing Data, B-747 Classic, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
876	0.36	2.33	52	8.5	0.0	9.8	11.8	2.1	
877	0.41	1.74	43	3.3	-1.8	1.8	11.8	2.1	513,306
931	0.36	1.41	47	9.1	-0.5	-7.2	12.0	0.0	
973	0.81	2.23	58	7.0	-1.5	-0.4	3.5	-6.1	
1021	0.19	1.07	37	7.0	-0.8	-1.9	7.0	-12.1	
1117	0.93	2.02	62	6.5	-0.3	1.3	7.7	-9.2	483,220
1198	0.93	1.60	46	7.8	-0.3	1.7	13.8	-11.6	530,094
1279	0.84	1.47	52	8.6	0.0	-6.4	14.1	-5.1	459,772
1337	0.50	1.20	43	3.3	-1.8	-15.7	20.0	0.0	
1364	0.72	1.71	70	6.0	-0.5		22.0	0.0	
1398	0.73	1.72	54	7.1	-1.5	-8.4	20.7	3.6	
1578	1.51	3.25	56	7.8	-0.1	-6.6	19.0	0.0	480,069
1608	0.43	1.58	47	9.1	-0.5	-1.3	8.5	-3.1	
1626	1.10	1.92	37	9.5	0.1	-18.0	4.1	-11.3	
1658	0.78	1.66	46	8.1	0.1	-3.5	4.6	-3.9	458,603
1659	0.53	1.90	54	5.7	0.4	6.0	4.0	-6.9	486,227
1709	0.98	3.41	44	7.1	0.1	2.0	2.5	4.3	503,833
1720	0.93	1.85	58	9.4	1.2	-1.6	1.2	6.9	
1725	0.64	1.96	50	7.8	-2.2	7.5	3.9	4.6	476,998
1746	0.89	1.98	42	8.6	1.0	6.8	0.0	0.0	
1750	0.73	2.15	43	7.7	-0.2	-7.1	4.9	0.9	549,472
1765	1.03	1.46	59	9.2	-0.7	8.6	3.8	1.4	517,155
1858	0.53	1.29	74	8.5	-1.3	-1.9	0.0	0.0	505,330
1920	0.78	1.80	64	6.3	-3.1	-0.7	0.0	-7.0	523,954
1928	0.80	1.91	52	8.5	0.0	0.7	0.0	0.0	497,435

Table D-11. Landing Data, B-747-400, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
28	141	141	154	3.4	2.3	3.4	5.8	2099	-3
43	169	169		3.1	0.9	1.8		1880	-8
49	156	159		3.9		2.2		1394	5
50	152	155	150		3.7	3.3	7.8	2021	-5
62	169	173	162	2.3	2.8	2.6	7.5	1529	5
63	162	165	156	1.4	1.6	1.5	7.0	1890	-7
95	158	158	159	1.3	2.3	2.1	6.6	2429	-6
129	159	164		5.4	2.9	3.5		1366	3
152	163	166	158	4.0	3.9	3.8	7.9	1819	-12
167	162	162	154	1.6		1.5	6.1	2462	-5
168	162	163	150	2.6	2.9	2.7	6.2	1950	-6
170	156	156	151	1.8	1.5	1.7	6.4	1956	-9
173	146	146	146	5.8	2.6	4.1	5.9	2232	-9
182	156	163	154	3.7		2.9	9.8	1375	-1
197	164	165	154	5.1	4.1	4.5	7.0	1908	-3
205	164	165	155	2.7	1.8	2.6	11.2	1425	-21
206	152	154	146	6.8	5.3	6.4	11.2	1123	-10
209	162	162	151	1.5	2.3	1.8	6.2	1967	-13
213	144	144	147	1.2	1.6	1.6	4.4	3291	1
218	157	162	149	1.9	2.0	1.9	5.9	2057	-19
219	154	154	150	5.8	5.0	5.4	6.6	2235	-10
229	144	147	146	0.8	1.7	1.0	7.4	1684	0
232	164	164	151	3.3	3.4	3.4	6.1	2566	-23
233	151	154	148	2.8	3.2	3.2	6.1	2129	0
283	169	170	154	1.8		2.2	6.5	2059	-12

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
28	0.83	1.29	47	10.5	-1.8	3.8	0.0	0.0	492,071
43	0.36			6.8	0.4	-3.7	0.0	0.0	536,822
49	0.48	1.81	44	7.2	-0.8	-1.0	-2.7	1.3	
50	0.72	1.76	62	8.8	0.6	-8.3	-3.6	1.7	535,993
62	0.50	1.56	42	7.1	0.2	-9.7	-3.8	1.4	
63	0.31	1.53	50	8.7	-0.2	-2.7	-3.0	0.5	509,920
95	0.45	1.41	60	7.2	-0.8	-4.9	0.0	0.0	
129	0.72	2.28	54	8.9	1.5	-1.0	-4.6	3.9	487,144
152	0.77	1.69	54	7.1	-0.8	-2.1	-2.8	2.8	
167	0.31	1.36	58	7.9	-1.4	-9.2	-0.7	3.9	
168	0.57	1.41	48	7.8	0.9	-8.8	-0.7	3.9	
170	0.37	1.43	49	6.6	0.3	-7.6	-0.3	2.0	
173	0.94	1.38	54	6.9	-2.5	-0.1	0.0	3.0	
182	0.60	2.17	52	9.1	-1.5	-0.1	-7.0	0.6	
197	0.93	1.54	51	7.4	0.6	-7.5	-1.7	-3.6	517,296
205	0.54	2.44	61	9.1	-1.2	-2.3	-1.0	2.8	
206	1.41	2.61	51	8.0	-0.9	7.3	-2.5	4.3	
209	0.38	1.40	48	8.2	0.3	-8.6	0.0	4.0	522,049
213	0.38	1.03	59	10.9	-0.6	-0.8	0.0	3.0	
218	0.40	1.34	48	9.1	1.3		-4.5	-2.1	
219	1.19	1.49	58	5.0	0.0	-2.7	0.0	0.0	538,932
229	0.23	1.72	50	6.0	-0.8	-3.0	-2.6	3.1	515,193
232	0.70	1.37	61	7.4	0.1	-14.3	0.0	0.0	521,904
233	0.71	1.40	52	6.9	-0.2	-0.9	-2.5	-5.4	
283	0.43	1.43	51	9.1	-0.5	-15.7	-0.9	4.9	495,050

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
313	162	162	151		3.1	2.6	9.9	1538	5
315	162	163	151	3.0	2.0	2.8	7.3	1906	-7
317	158	160	153	3.1	3.9	3.2	8.1	1624	0
325	155	155	153	7.1	2.0	3.7	6.3	2131	-6
333	156	158	154	2.5		1.1	5.5	1670	2
336	144	144	151	3.1	1.5	1.9	5.9	3061	7
350	145	145	137	5.3	1.0	4.5	7.0	1653	-7
360	157	158	157	2.7	3.6	3.6	7.8	2322	4
364	173	174	160	2.3	2.3	2.3	6.6	2383	2
365	166	166	152	3.3	3.1	3.2	7.8	2036	-9
371	165	170	161	3.5	3.7	3.5	10.2	1865	1
395	160	161	152	4.2	4.2	4.2	10.9	1040	-5
499	157	157	156	1.6	0.1	0.9	6.9	2691	0
550	148	143	146	4.7	3.1	3.3	6.3	2208	0
571	158	157	150	1.4	1.8	1.5	7.6	1949	-10
572	155	154	153	3.9	3.0	3.1	6.1	2305	-8
589	153	152	151	4.8	2.3	3.6	8.9	1290	1
590	149	147	146	4.6	4.5	4.5	8.5	1713	2
591	162	160	154	4.7	2.2	3.4	9.7	1464	0
610	162	158	156	3.2	2.7	2.7	6.7	1846	-4
615	148	146	141	4.9	3.8	4.3	6.8	1806	-1
620	154	152	147	1.8		1.8	7.9	1394	9
621	153	150	141	2.7	0.4	1.6	7.9	1688	-4
622	148	145	145	2.8	2.6	2.6	5.1	2348	-7
633	161	158	149	6.0	2.1	4.2	8.6	1661	-3

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
313	0.54	2.23	60	9.2	2.2	-10.2	0.0	3.0	
315	0.58	1.63	54	6.0	-0.6	-6.3	-0.3	2.0	546,553
317	0.68	1.81	51	5.9	-0.4	3.6	-2.5	4.3	
325	0.81	1.40	52	6.0	-1.5	4.6	-0.4	5.0	
333	0.23	1.22	35	7.1	-0.2	2.5	-2.0	-0.3	5,199,673
336	0.45	1.33	71	6.9	-0.2	2.0	0.0	0.0	
350	1.05	1.75	50	6.0	-0.4	1.6	0.0	3.0	439,674
360	0.77	1.69	69	6.0	-1.1	-1.2	-0.3	4.0	
364	0.46	1.40	58	8.1	-1.9	-5.6	-0.3	3.0	528,663
365	0.65	1.75	62	7.1	0.3	-13.8	-0.4	5.0	536,873
371	0.70	2.15	70	7.2	1.5	-2.3	-4.5	2.1	553,489
395	0.89	2.43	44	6.4	0.7	7.5	-0.7	1.9	495,471
499	0.19	1.49	70	7.8	2.9	2.3	-0.3	2.0	554,920
550	0.78	1.47	57	7.2	-2.9	3.2	4.6	3.9	
571	0.33	1.71	58	6.1	0.4	-3.8	0.9	4.9	540,348
572	0.68	1.35	54	7.3	-0.3	-1.2	1.4	3.8	496,546
589	0.80	1.99	45	8.7	-0.1	7.0	1.2	6.9	516,979
590	1.04	1.98	59	6.2	-1.1	3.2	2.4	6.6	
591	0.72	2.13	54	6.9	-0.3	-2.2	2.5	4.3	
610	0.58	1.47	47	7.1	0.0	-2.7	3.5	6.1	553,165
615	0.99	1.62	51	6.9	-1.5	-0.2	1.7	4.7	539,946
620	0.41	1.81	44	7.7	0.1	-0.5	2.0	3.5	507,741
621	0.36	1.90	56	7.6	-0.9	4.6	3.0	5.2	
622	0.61	1.19	49	6.7	-2.2	-2.2	2.5	4.3	
633	0.90	1.96	57	6.9	0.1	3.9	2.5	4.3	504,472

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
652	171	166	155	3.2	2.2	2.7	6.8	2026	-7
658	162	157	153	6.2	2.5	5.0	6.5	1700	3
695	163	160	151	1.7		1.4	7.6	1938	-9
714	170	170	162	2.3	2.4	2.4	13.4	991	-14
720	154	144	144	4.3	3.7	3.7	6.6	1744	6
763	152	142	139	2.2	2.0	2.0	5.2	2374	1
767	144	134	135	3.0	2.3	2.5	7.7	1696	1
768	148	140	135	3.9	1.2	2.6	6.6	1667	2
774	158	149	133	1.8	0.4	1.1	7.3	1706	0
781	153	143	142	2.0	1.8	2.0	7.6	1578	2
782	138	129	135	2.0	1.8	1.9	5.1	2219	-4
786	153	143	138	4.1	3.4	3.6	7.7	1836	-1
814	161	153	140	4.2	2.9	3.5	8.3	1438	-7
819	167	160	149	4.9	1.9	3.4	10.2	1381	3
827	150	142	143	3.9	0.6	1.8	6.3	1687	-4
828	164	156	146	3.3	3.2	3.2	6.7	1821	-1
842	163	156	147	0.7		0.6	6.1	1938	-2
912	161	153	149	2.5	2.9	2.4	7.1	1813	-15
930	149	137	143	2.5	2.5	2.5	10.1	1246	2
953	173	168	153	3.6		3.0	5.6	2429	-16
974	163	159	142	5.2		4.6	5.5	2459	-9
993	148	146	146	1.4	0.5	0.5	5.2	2665	0
999	150	144	140	5.6	2.5	3.4	6.5	2192	-10
1031	160	155	147	3.6	2.1	2.8	8.5	1773	-11
1086	157	150		1.1	3.3	1.1		1547	-4

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
652	0.56	1.49	53	7.8	0.0	-10.3	5.2	3.0	548,050
658	1.08	1.43	43	7.8	-1.5	3.1	5.4	4.5	555,453
695	0.29	1.70	58	7.9	-0.7	-5.1	3.2	3.8	513,392
714	0.47	2.82	49	7.7	1.2	-10.2	0.0	7.0	
720	0.87	1.55	47	6.5	-0.6	0.8	10.3	3.8	526,877
763	0.48	1.27	53	3.9	-0.2	-4.0	9.4	3.4	466,222
767	0.63	1.94	58	7.1	-1.7	1.9	10.3	3.8	479,393
768	0.62	1.65	48	7.3	1.2	4.8	8.5	3.1	
774	0.24	1.85	55	5.7	0.5	2.4	8.9	1.6	543,994
781	0.48	1.80	50	8.0	0.2	5.2	10.8	1.9	524,798
782	0.50	1.28	50	6.7	-0.7	2.8	9.8	1.7	
786	0.85	1.89	61	6.0	0.2	-1.9	10.8	1.9	522,023
814	0.78	2.01	50	7.2	0.9	-3.7	7.9	1.4	542,393
819	0.73	2.32	56	7.4	0.1	-1.8	7.9	1.4	
827	0.42	1.50	44	8.2	-0.4	2.5	7.9	1.4	549,353
828	0.71	1.56	50	5.3	-0.1	-1.9	7.9	1.4	
842	0.14	1.42	48	7.9	-0.3	-3.5	7.9	1.4	
912	0.53	1.62	51	5.9	-1.3	0.3	7.9	1.4	
930	0.62	2.39	52	8.3	1.8	3.1	12.0	0.0	533,343
953	0.61	1.25	53	5.9	-3.0	-8.6	5.0	-8.7	
974	0.97	1.30	56	6.4	-2.1	-10.5	4.0	-6.9	
993	0.12	1.20	56	6.8	1.6	1.1	1.7	-9.8	
999	0.79	1.56	60	6.1	-4.1	-0.5	6.0	-10.4	
1031	0.61	1.96	61	8.8	-0.8	-2.5	4.8	-13.2	527,049
1086	0.26			3.8	0.2	5.6	7.0	-12.1	

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1190	157	145	137	4.5	5.3	5.2	4.7	1898	10
1195	175	166	161	2.6	1.1	2.4	9.2	1656	-4
1210	174	161	150	1.8	2.8	2.0	6.8	1901	-12
1222	151	142	133	4.5	3.4	4.3	9.4	1268	-2
1224	175	160	153	2.7		2.4	8.1	1794	-11
1228	157	139	125	3.2	4.0	3.7	8.6	1453	-10
1231	153	139	131	3.0	2.2	2.5	8.8	1151	-4
1263	171	161	143	2.0	2.9	2.0	8.3	1523	-3
1266	176	164	147	3.2		3.0	8.7	1578	-5
1304	158	143	138	3.7	1.7	1.7	6.3	2302	-8
1309	175	150	140	3.0	4.7	3.8	6.9	1988	-6
1338	161	141	146	0.9	4.4	2.6	5.8	2252	-4
1366	163	143	138	4.4	3.3	3.4	7.6	1310	-5
1402	160	135	135	2.1	1.8	1.8	5.8	1667	-1
1459	157	137	131	3.8	2.3	2.8	6.8	2287	-11
1468	153	129	139	3.7	3.1	3.4	7.3	1524	3
1479	172	152	142	5.7	2.3	3.7	7.8	1441	1
1528	161	144	138	4.6	1.7	3.3	7.4	1842	-8
1549	148	135	140	5.2		2.5	9.1	1265	-6
1552	170	156	142	3.6		3.1	9.2	1604	-8
1553	154	146	132	4.4		2.8	5.3	1972	-18
1560	171	157	145	2.8		1.9	5.9	1530	1
1561	165	151	137	4.9	1.7	3.6	9.4	1398	-1
1565	154	141	132	2.4	1.3	1.8	7.4	1785	-11
1566	168	155	141	4.4		4.6	5.6	1600	-7

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1190	1.23	1.17	39	7.6	-0.5	5.3	12.3	-10.3	
1195	0.49	1.94	56	5.1	-1.1	-0.1	9.0	-10.7	
1210	0.41	1.54	51	7.0	-0.8	-8.2	12.3	-10.3	
1222	1.03	2.38	53	6.3	-1.5	0.9	9.6	-11.5	
1224	0.51	1.79	56	6.5	-1.7	-1.7	15.3	-12.9	528,269
1228	0.89	2.33	59	9.1	-3.1	-4.7	17.3	-10.0	524,362
1231	0.62	2.27	46	7.0	0.7	6.3	13.8	-11.6	
1263	0.42	1.96	52	4.5	1.2	-10.0	10.0	-8.4	
1266	0.63	2.00	55	5.1	-0.6		11.3	-6.5	
1304	0.40	1.55	62	5.2	-1.8	-0.7	15.0	0.0	
1309	0.86	1.68	58	6.7	1.1	-11.6	25.0	0.0	521,798
1338	0.61	1.34	53	5.1	-1.8	0.4	20.0	0.0	
1366	0.81	1.86	43	3.6	-1.4	0.5	19.7	-3.5	
1402	0.44	1.46	43	6.4	1.9	-0.1	25.0	0.0	527,001
1459	0.68	1.76	70	6.0	-1.6	-2.7	20.0	0.0	
1468	0.90	1.78	47	6.4	-0.5	4.9	24.6	-4.3	
1479	0.83	1.88	47	6.4	-1.9	-4.4	19.7	-3.5	490,892
1528	0.79	1.81	58	7.9	-0.5	-4.8	17.0	0.0	506,242
1549	0.62	2.21	49	7.2	-3.1	4.0	13.0	-7.5	
1552	0.66	2.19	61	8.3	-0.3		14.1	-5.1	524,995
1553	0.65	1.35	46	6.5	-1.7	-9.6	8.4	-10.0	
1560	0.42	1.39	37	8.7	-2.1	-8.0	13.9	-8.0	
1561	0.81	2.32	57	8.5	-1.0	-2.3	13.9	-8.0	
1565	0.42	1.90	59	7.8	0.5	-4.1	13.0	-7.5	
1566	0.99	1.35	38	7.4	-1.6		12.8	-2.3	

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1581	151	132	128	5.6	3.8	4.8	5.8	1739	0
1587	148	132	135	6.7	5.3	5.9	5.1	3178	1
1588	166	145	137	1.5		1.5	6.4	2026	-18
1601	165	160	148	3.1	5.0	3.1	10.6	1505	-2
1605	165	159	154	2.2	1.2	2.2	7.7	1955	-2
1610	180	171	153	4.9	2.6	2.6	7.2	1726	-8
1616	171	166	155	1.6		1.6	6.0	1965	-10
1621	167	161	147	0.1	1.7	0.9	7.8	1609	-20
1644	175	163	148	2.0	1.2	1.2	10.1	1454	7
1655	135	129	135	5.3	2.1	5.2	8.6	1599	4
1670	164	161	152	3.0	2.1	2.5	7.7	1903	-16
1675	158	154	147	2.7	1.1	2.6	6.4	1962	-6
1681	175	171	156	2.8	2.7	2.7	8.3	2019	-6
1685	173	168	158	2.9	3.5	3.2	5.3	2545	-8
1686	170	163	155	4.5	3.3	3.8	6.8	2536	-7
1689	153	147	160	6.3	3.3	4.9	8.3	2057	8
1693	161	155	144	4.1	2.8	3.5	5.7	2414	-3
1694	152	145	150	4.8	5.4	4.8	5.1	2040	6
1696	141	136	146	3.7	3.9	3.8	6.7	2231	3
1699	157	152	151	4.4	2.0	3.0	9.8	1353	1
1714	157	156	147	2.4	3.0	2.6	6.5	2471	-5
1731	148	143	142	1.4	2.2	1.4	5.5	1816	2
1752	153	148	148	3.2	1.9	1.9	8.4	1328	4
1758	146	142	140	1.0	2.3	1.7	5.6	1938	-2
1766	148	145	148	2.9	3.9	3.4	8.5	1130	-3

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1581	1.24	1.53	46	6.6	-2.4	1.3	19.0	0.0	
1587	1.50	1.28	71	5.4	-1.5	-0.5	16.0	0.0	
1588	0.35	1.58	56	5.4	-0.3	-13.8	20.7	-3.6	
1601	0.65	2.43	64	4.7	-1.8	-6.0	4.6	3.9	
1605	0.47	1.69	58	6.8	-0.2	-6.8	6.0	0.0	
1610	0.51	1.60	48	6.4	-0.6	-0.9	8.5	-3.1	
1616	0.32	1.31	45	7.5	-2.2	-8.7	5.0	-8.7	524,197
1621	0.18	1.80	50	6.5	0.6	-15.9	6.0	-10.4	
1644	0.26	2.33	59	8.2	0.8	-7.2	12.1	-7.0	533,052
1655	1.38	2.14	60	4.6	0.5	1.6	6.1	-3.5	
1670	0.52	1.73	58	7.2	-0.6	-7.4	2.7	-7.5	507,087
1675	0.57	1.47	50	6.5	0.7	-7.0	3.9	4.6	
1681	0.55	1.81	64	6.6	-0.8	-9.2	4.6	3.9	534,027
1685	0.64	1.14	50	5.6	-1.3	-12.0	4.6	3.9	
1686	0.80	1.50	66	6.0	-1.8	-11.6	6.6	2.4	544,481
1689	1.14	1.76	63	5.7	-3.6	9.2	6.1	5.1	
1693	0.76	1.35	57	6.2	-1.5	-5.6	5.6	2.1	
1694	1.12	1.15	41	3.9	-1.2	7.4	6.6	2.4	
1696	0.95	1.56	61	6.5	-1.6	1.7	4.6	3.9	
1699	0.67	2.20	52	6.0	0.4	1.2	4.5	5.4	
1714	0.57	1.50	65	6.5	-1.7	-6.5	0.9	4.9	
1731	0.33	1.32	42	8.9	-1.3	0.7	4.6	3.9	503,354
1752	0.43	1.94	45	6.6	-1.0	3.9	4.9	0.9	
1758	0.40	1.35	46	7.6	0.8	-8.1	3.5	2.0	
1766	0.81	1.96	39	7.1	0.1	7.4	3.8	1.4	526,194

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1767	153	147	150	4.6	2.6	4.1	6.4	2113	0
1768	156	153	145	6.6	2.7	4.5	8.2	1239	2
1783	158	154	147	3.5	2.1	2.8	7.1	1861	-5
1795	160	157	153	2.9	2.9	2.9	5.6	2325	-4
1815	142	142	143	0.6	1.0	0.3	8.5	1671	2
1822	157	153	145	2.9	1.8	1.9	7.3	1830	-3
1867	161	160	149	2.4	3.3	2.7	6.3	2107	-4
1873	147	147	146	1.6	1.8	1.6	6.0	2246	0
1881	133	133	147	5.9	1.8	3.9	9.6	1185	8
1889	150	147	144	1.5	0.5	1.0	5.6	2938	-16
1898	154	149	140	5.4	3.8	4.8	9.1	1351	-2
1904	170	164	151	4.9		3.9	8.5	1552	-8
1905	144	140	141	2.8	1.8	2.5	9.8	1630	-7
1919	139	138	143	6.1	6.7	6.3	10.4	1228	-5
1923	154	154	151	0.9	2.2	0.9	7.2	2070	-6
1945	180	175		3.8	2.6	3.2		1548	-1

Table D-11. Landing Data, B-747-400, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1767	0.94	1.45	54	6.3	-1.1	5.3	6.6	2.4	
1768	1.00	1.93	42	5.9	0.4	3.4	3.2	3.8	
1783	0.62	1.65	54	6.7	-0.5	-2.9	3.8	1.4	
1795	0.63	1.24	50	7.5	-0.8	-2.1	3.0	0.5	510,387
1815	0.08	2.00	58	8.9	0.6	4.9	0.0	0.0	
1822	0.42	1.70	54	9.2	-0.1	-1.5	3.5	2.0	496,809
1867	0.57	1.44	53	5.0	0.9	4.6	1.7	4.7	
1873	0.37	1.41	55	6.0	-0.6	-0.3	0.0	3.0	464,223
1881	1.00	2.21	46	8.0	0.2	5.0	0.0	0.0	505,627
1889	0.23	1.31	67	7.5	3.7	-3.6	3.8	3.2	515,193
1898	1.09	2.20	52	6.2	-1.2	0.2	5.0	0.0	
1904	0.81	1.92	52	6.9	-0.3	-11.2	6.1	-3.5	
1905	0.60	2.35	67	9.3	-1.0	5.0	4.3	-2.5	468,559
1919	1.55	2.46	53	7.0	1.1	5.6	1.2	-6.9	543,352
1923	0.20	1.61	58	5.7	0.6	2.7	0.0	0.0	
1945	0.94	1.45	48	7.5	-1.8	-9.3	5.0	0.0	531,944

Table D-12. Landing Data, B-757, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
32	146	146	133	2.9	2.3	2.6	6.7	1539	2
34	152	152	135		1.3	1.0	7.8	1585	2
57	140	143	137	4.4	1.0	3.6	8.8	1661	0
58	129	133	137	2.5	2.3	2.4	5.6	2391	-2
100	123	125	135	3.2	1.8	1.0	6.4	1719	-2
106	141	143	131	2.1	2.3	2.3	5.5	1999	-8
109	138	142	135	0.1	0.4	0.4	7.6	1750	-7
110	150	154	138	2.6		2.4	5.8	2027	-3
121	144	149	141		0.9	1.8	5.6	2093	-10
135	138	144		2.3		2.3		1949	-5
144	142	147	135	5.7	0.5	3.5	6.2	2119	-1
146	149	154	135	1.5	1.0	1.3	9.2	1339	0
175	131	131	127	3.3	2.0	2.7	4.4	2387	-3
207	141	146	129	3.6	2.0	2.7	7.7	1430	2
208	142	142	128	2.1	3.4	2.6	6.0	1936	-3
217	134	139	130	4.8		4.3	9.9	1513	-1
247	129	131	129	4.3	4.5	4.5	5.9	2126	-3
262	144	144	131	2.7	4.1	3.0	5.4	2378	0
267	140	140	130	3.1	2.2	2.6	8.5	1339	-4
272	139	139	130	1.7	2.2	1.6	7.2	1979	-2
277	135	135	129	3.8	2.9	3.3	7.4	1486	4
279	135	135	130	2.5	1.9	2.0	6.2	1815	2
291	132	136	127	3.7	2.0	3.0	7.2	1639	-7
296	129	131	128	2.3	1.3	1.8	6.1	2364	1

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
32	0.61	1.69	45	7.1	-0.3	-8.4	0.0	0.0
34	0.22	1.96	54	6.3	0.7	-11.7	0.0	0.0
57	0.85	2.17	63	7.2	-1.8	3.1	-2.8	1.0
58	0.62	1.38	57	6.7	-1.1	-4.8	-3.9	0.7
100	0.26	1.62	49	5.3	-2.8	3.8	-1.1	1.6
106	0.54	1.42	49	14.5	0.2	-8.8	-2.3	1.9
109	0.10	1.91	58	6.6	-2.0	-0.2	-3.8	3.2
110	0.52	1.42	50	13.4	-2.4	-9.8	-4.1	2.9
121	0.42	1.35	49	5.7	-0.6	-12.3	-5.2	3.0
135	0.54			7.0	-0.7	-9.4	-6.0	0.5
144	0.81	1.55	57	7.5	-0.3	10.6	-4.5	2.1
146	0.30	2.32	54	7.3	-2.0	-1.9	-5.4	4.5
175	0.69	1.17	49	14.7	-1.4	-4.0	-0.2	2.0
207	0.62	2.01	50	6.8	-0.1	-4.9	-4.7	1.7
208	0.63	1.60	54	7.7	0.9	-7.4	0.0	5.0
217	1.04	2.60	69	7.4	-2.9	-7.7	-5.2	-3.0
247	1.17	1.55	57	4.7	-1.9	4.1	-2.1	4.5
262	0.70	1.38	57	6.4	0.2	-7.0	0.0	5.0
267	0.62	2.22	52	7.8	-2.8	-1.2	0.0	3.0
272	0.39	1.87	65	7.1	1.6	-9.1	0.0	5.0
277	0.84	1.94	50	6.8	0.4	-5.9	-0.4	5.0
279	0.50	1.64	52	5.9	-0.3	-3.3	0.0	0.0
291	0.76	1.92	55	5.9	-0.2	2.0	-3.8	1.4
296	0.46	1.60	66	6.7	-1.7	-3.7	-1.8	6.8

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
304	122	122	129	1.0	1.5	1.1	8.0	1840	-2
305	133	133	136	3.5	3.3	3.4	6.0	2510	-3
311	122	125	122	3.5	3.5	3.5	6.7	1805	1
312	135	135	123	2.5	1.6	2.1	7.2	1672	0
319	133	136	126	3.6	3.0	3.5	7.2	1902	2
323	149	149	141	4.0	3.5	3.8	6.2	2485	-8
343	145	147		0.4	1.9	0.4		1430	0
345	128	129	126	2.7	2.3	2.6	6.5	1795	2
367	150	150	141	1.3	2.1	1.3	6.9	1837	-3
370	142	142	134	2.8	1.8	2.1	6.8	1920	-4
383	127	128	130	3.5	3.3	3.3	4.7	2400	-11
384	143	146		3.6	2.5	2.8		1499	3
386	140	140	132	1.8	5.8	3.8	6.0	2242	1
387	123	126	128	2.0	1.9	1.9	5.7	2381	5
404	139	140	132	2.6	3.7	3.1	7.0	1919	-3
416	144	145	133	2.5	3.2	2.9	6.5	1821	0
448	122	124	133	3.3	5.5	3.9	5.9	2346	3
451	138	138	135	3.2	5.0	3.5	6.4	1707	-5
455	138	138	130	2.7	4.0	3.2	6.1	2140	-1
462	133	133	131	1.4	0.8	1.1	5.9	1938	-9
478	144	144	135	4.5	3.1	3.4	8.0	1909	-5
524	131	128	128	4.0	4.8	4.8	7.2	2188	3
557	137	136	130	1.5	1.1	1.3	5.8	1917	-7
560	139	135	128	2.3	2.6	2.5	8.3	1424	-1

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
304	0.31	2.11	68	6.1	-3.5	-3.1	-0.3	3.0
305	0.86	1.49	65	4.8	-1.2	-10.6	0.0	0.0
311	0.95	1.87	59	6.3	0.6	-4.2	-3.1	2.6
312	0.53	1.99	58	8.3	-0.4	2.8	0.0	3.0
319	0.86	1.95	65	6.3	1.1	-4.2	-2.1	2.1
323	0.85	1.51	65	4.7	-0.7	-11.1	-0.5	6.0
343	0.10			5.0	-2.3	-1.4	-1.9	2.3
345	0.68	1.76	55	4.6	0.3	-0.8	-1.3	1.5
367	0.29	1.67	53	4.2	-1.1	-5.4	-0.3	4.0
370	0.50	1.71	57	5.9	2.4	-7.4	0.0	4.0
383	0.86	1.24	52	6.6	0.7	-6.8	-1.4	3.8
384	0.65			5.5	-2.1	-6.0	-2.5	4.3
386	0.91	1.53	60	6.7	-0.2	1.2	0.0	0.0
387	0.51	1.52	63	4.4	1.8	-3.2	-3.4	4.9
404	0.75	1.79	60	5.9	1.3	-5.4	-1.0	3.9
416	0.69	1.66	53	6.6	-0.3	-3.6	-0.8	2.9
448	1.07	1.50	61	5.1	0.7	1.3	-1.0	3.9
451	0.87	1.61	48	4.1	-0.3	3.2	0.0	5.0
455	0.78	1.60	60	6.3	2.4	-2.2	0.0	4.0
462	0.28	1.53	52	5.5	0.4	-6.7	0.0	6.0
478	0.79	2.01	67	4.4	1.6	-7.0	0.3	4.0
524	1.27	1.92	73	4.9	-1.2	4.8	2.5	4.3
557	0.32	1.53	51	5.8	0.4	-7.1	0.9	4.9
560	0.62	2.18	54	7.6	0.6	-0.2	4.3	2.5

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
570	128	127	128	1.4	1.2	1.2	6.4	1864	0
573	139	138	132	3.3	3.2	3.3	7.3	1477	9
588	120	120	130	4.1	2.5	3.2	7.6	1250	3
608	137	133	132	2.1	2.6	2.1	6.4	1931	-2
617	134	133	131	3.0	4.1	3.7	5.9	2236	1
619	137	136	131	5.0	3.9	4.5	5.4	2331	-3
627	134	132	129	2.8	2.5	2.5	5.5	2360	-7
637	139	136	129	1.7	1.9	1.7	7.3	1379	4
644	123	120	126	3.3	3.3	3.2	7.1	1213	-8
662	142	138	131	3.6	3.2	3.2	7.5	1469	5
668	136	132	126	1.9	2.0	1.9	6.1	1827	-4
673	143	137	128	3.5	4.3	3.5	8.0	1463	2
697	140	137	129	3.5	1.7	2.3	6.4	1907	-4
704	142	139	133	1.2	1.5	1.3	6.4	1909	1
705	138	136	132	1.7	0.7	1.4	8.6	1320	3
706	131	128	127	2.1	2.5	2.1	6.0	1774	5
716	150	153	136	0.6	1.7	1.0	7.1	1519	4
735	130	122	122	1.7	0.2	0.4	7.0	1636	2
740	131	123	119	1.1	2.2	2.2	7.1	1419	-1
745	132	122	121	4.1	2.8	3.4	6.0	1866	-2
752	130	123	118	2.9	1.9	2.3	6.8	1720	-3
762	129	120	117	3.1	2.9	2.9	7.2	1790	4
776	137	128	119	3.2	0.4	1.7	7.6	1801	-7
783	128	119	114	1.9	1.1	1.1	5.1	1621	1

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
570	0.32	1.69	55	5.5	0.0	-0.2	0.9	4.9
573	0.81	1.89	49	6.4	0.9	-2.7	1.4	3.8
588	0.90	1.97	43	6.7	1.7	3.8	0.9	4.9
608	0.52	1.66	56	5.9	-0.9	-5.1	3.5	6.1
617	0.93	1.53	60	7.0	-1.7	0.6	0.9	4.9
619	1.12	1.39	57	5.0	-0.5	-1.5	0.9	4.9
627	0.64	1.45	60	6.4	-2.6	-1.2	2.5	4.3
637	0.42	1.92	46	7.1	2.4	-1.8	3.0	5.2
644	0.91	1.92	41	6.4	0.6	7.6	3.5	6.1
662	0.79	1.96	50	5.2	1.3	-3.6	4.5	5.4
668	0.49	1.65	53	6.3	0.5	-3.7	3.9	4.6
673	0.87	2.12	54	6.6	-1.3	-5.1	6.1	5.1
697	0.56	1.68	56	7.2	1.6	-4.7	3.2	3.8
704	0.32	1.63	54	6.3	1.5	-3.4	2.5	4.3
705	0.36	2.21	51	6.3	-0.5	4.9	2.5	4.3
706	0.54	1.60	49	4.0	0.3	2.4	2.5	4.3
716	0.22	1.77	47	6.7	-0.2	-5.2	-3.0	5.2
735	0.10	1.95	56	6.4	2.8	4.1	8.5	3.1
740	0.62	2.03	50	5.4	0.3	5.9	8.5	3.1
745	0.96	1.69	55	5.5	0.6	-3.0	10.8	1.9
752	0.63	1.97	59	7.1	-1.2	1.7	7.5	2.7
762	0.81	2.09	65	5.6	1.9	0.6	9.4	3.4
776	0.46	2.16	68	6.7	0.4	-4.2	8.9	1.6
783	0.32	1.52	43	6.0	0.6	2.6	8.9	1.6

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
796	137	126		1.8	2.0	2.0		1997	-9
800	122	113	122	1.7	2.3	1.7	6.2	2325	2
823	140	130	121	2.4	2.1	2.3	5.3	1714	-1
830	139	131	122	1.7	4.8	3.2	5.4	2227	1
833	139	131	124	1.8	2.5	2.1	4.7	2421	-6
841	134	127	123	2.3	1.3	1.8	6.2	1855	-2
875	125	115	115	1.3	3.7	1.7	6.9	1546	-2
883	133	120	117	1.1	0.9	0.9	6.2	1763	1
924	140	128	118	3.7	3.0	3.2	7.9	1764	2
944	145	135	123	3.6	2.5	3.1	7.6	1434	1
966	123	120	124	3.4	3.7	3.6	5.5	2293	2
978	138	134	129	2.2	3.1	2.4	7.5	1905	-7
997	135	130		5.1	3.6	4.3		2095	4
1034	151	144		2.9	2.6	2.7		1741	-5
1053	130	122	120	5.5	6.1	5.8	11.2	849	-9
1059	140	132	125	0.2	2.8	1.6	8.3	1508	1
1067	142	134	127	2.7	0.0	1.5	7.0	1659	0
1071	144	135	133	0.1	0.1	0.1	6.0	2356	-3
1074	137	126	123	5.1	2.6	3.5	6.1	2129	2
1079	144	136	123	1.1	0.7	1.1	6.9	1201	-5
1082	152	142	130	4.5	4.7	4.4	5.7	2443	-4
1108	135	126	122	3.5	3.1	3.5	7.0	1692	-1
1109	131	124	117	4.2	2.3	3.2	7.4	1571	-3
1115	149	140	130	4.3	3.1	3.8	5.9	2362	-7

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
796	0.54			3.0	-0.7	-3.4	10.8	1.9
800	0.50	1.71	69	6.0	-1.9	-3.8	9.4	3.4
823	0.59	1.49	45	7.3	-0.5	1.0	9.8	1.7
830	0.83	1.50	58	6.3	-0.2	2.4	7.9	1.4
833	0.55	1.28	54	5.9	0.6	-10.4	7.9	1.4
841	0.47	1.72	56	6.3	0.0	-2.3	7.9	1.4
875	0.50	2.04	55	5.5	-2.4	-7.6	9.8	1.7
883	0.24	1.79	55	7.1	0.4	-0.2	12.8	2.3
924	0.83	2.25	69	5.8	-0.5	-0.6	11.8	2.1
944	0.77	2.10	53	7.4	-1.4	-0.4	10.0	0.0
966	1.01	1.51	61	5.1	-0.4	-0.7	3.5	-6.1
978	0.62	1.97	65	4.0	0.4	-6.8	4.0	-6.9
997	1.13			5.8	-1.9	4.9	5.0	-8.7
1034	0.64			5.2	2.3	-10.7	6.5	-11.3
1053	1.61	3.17	47	6.9	2.0	-7.8	7.7	-9.2
1059	0.42	2.27	60	6.9	1.1	-3.9	7.7	-9.2
1067	0.39	1.87	54	6.0	-1.5	5.2	7.7	-9.2
1071	0.03	1.53	63	5.4	-1.1	-6.0	9.6	-11.5
1074	0.95	1.70	63	4.0	-3.1	-2.4	10.4	-6.0
1079	0.27	1.90	40	7.1	-1.5	7.6	7.7	-9.2
1082	1.06	1.50	64	3.6	1.4	-9.7	9.6	-11.5
1108	0.95	1.94	57	5.9	0.0	-2.8	9.0	-10.7
1109	0.88	2.15	59	4.7	-0.9	3.7	7.0	-12.1
1115	0.93	1.55	64	5.3	-1.1	-11.0	9.0	-10.7

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1122	170	159		3.2	4.0	3.2		2086	1
1126	141	131	115	2.2	2.5	2.2	6.2	1916	0
1138	128	122	125	2.4	3.2	3.1	8.1	1534	-6
1152	158	151		5.8	4.5	4.9		2262	-8
1155	149	142	125	2.5	0.6	1.1	6.9	1709	4
1164	133	128	128	3.6	2.0	2.3	7.4	1671	-2
1176	126	119	122	2.8	0.6	2.7	7.7	1700	-3
1187	143	138		3.3	1.5	2.0		1809	-6
1214	152	137	123	5.1	3.5	4.2	7.2	1400	-1
1215	143	132	117	3.0	2.7	2.7	6.4	1362	6
1230	154	142	124	4.3	3.9	3.9	8.3	1323	4
1236	154	141	129	1.4	2.8	1.9	8.1	1432	7
1237	159	146	127	3.8	2.0	2.2	7.4	1762	-2
1248	140	128	116	3.5	2.4	2.5	6.7	1762	3
1254	133	122	121	1.8	1.6	1.6	7.7	1267	-4
1255	134	124	123	0.6	1.8	1.7	9.5	1182	-9
1276	143	130	119	4.0	3.1	3.5	7.3	1275	3
1322	148	123		4.4	0.9	3.4		1696	0
1342	136	116	109	2.1	3.0	2.7	7.1	1296	8
1348	140	115	120	3.1	5.6	4.0	6.0	2410	-1
1354	132	110	110	4.5	2.0	2.0	4.5	2215	9
1361	154	135	120	1.5	1.5	1.5	7.1	1380	-2
1376	120	96	107	1.5	1.8	1.8	7.7	1037	-6
1384	135	112	110	0.1	3.8	1.8	5.2	1937	-1

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1122	0.68			5.4	0.3	-4.9	10.7	-9.0
1126	0.57	1.84	61	5.1	2.5	-10.0	10.7	-9.0
1138	0.86	2.20	59	5.5	-1.0	4.2	5.5	-9.5
1152	1.11			4.8	-2.0	-5.0	6.5	-11.3
1155	0.26	1.87	56	6.8	-0.8	-4.5	6.5	-11.3
1164	0.62	1.97	57	6.3	1.1	1.6	5.0	-8.7
1176	0.78	2.12	63	4.9	-1.5	-1.7	6.4	-7.7
1187	0.50			6.7	-1.5	-3.2	5.5	-9.5
1214	1.05	1.99	49	6.9	-0.7	-4.1	15.3	-12.9
1215	0.70	1.84	44	5.3	-2.4	1.2	11.5	-9.6
1230	0.94	2.28	53	6.4	-2.5	-0.6	12.3	-10.3
1236	0.46	2.14	53	4.6	-1.1	-4.3	13.0	-7.5
1237	0.52	1.97	61	3.8	-1.3	-1.3	13.0	-7.5
1248	0.67	1.94	60	5.1	-0.7	-2.2	12.1	-7.0
1254	0.44	2.16	48	5.3	-0.9	-1.3	11.3	-6.5
1255	0.45	2.63	54	5.5	1.4	1.6	10.4	-6.0
1276	0.92	2.08	46	7.4	0.4	1.1	13.2	-4.8
1322	0.95			4.5	-1.7	-5.0	25.0	0.0
1342	0.78	2.22	50	5.7	0.5	3.1	20.0	0.0
1348	1.19	1.71	72	2.4	-1.5	-5.6	25.0	0.0
1354	0.62	1.40	54	2.9	3.8	5.7	22.0	0.0
1361	0.37	2.02	49	4.5	1.0	-6.0	19.7	-3.5
1376	0.64	2.42	44	6.9	-3.0	9.5	24.0	0.0
1384	0.54	1.60	54	6.6	-2.3	-3.0	22.7	-4.0

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1390	135	112	103	3.8	3.4	3.5	6.7	1209	1
1406	144	124	115	6.9	4.5	4.9	6.8	1824	1
1415	130	110	110	2.7	2.5	2.5	6.2	1326	-3
1458	135	115		4.3	2.9	3.0		1343	4
1463	135	114		5.8	1.8	3.7		1640	3
1464	138	116	116	3.6	1.3	3.4	5.4	1670	0
1465	137	115	112	3.2	2.2	3.2	5.2	2181	1
1476	152	132	119	2.7	2.6	2.6	7.3	1640	-5
1501	133	116	107	3.9	3.3	3.6	6.0	1679	1
1506	131	111	115	4.4	3.3	3.5	5.7	2103	2
1531	145	129	122	3.0	2.6	2.8	7.7	1847	-12
1641	146	135	120	1.0		1.4	7.2	1632	-6
1646	132	122	118	2.7	2.9	2.8	7.3	1263	-2
1648	145	138	126	2.9	2.6	2.8	6.1	1996	-7
1649	138	132	124	2.4	2.8	2.7	6.7	1847	-5
1654	150	143	129	1.5	2.5	2.1	7.1	1490	0
1729	139	135	126	4.2	1.8	2.9	6.8	1784	0
1780	133	130	125	1.5	1.3	1.4	7.3	1394	5
1789	123	118	123	1.2	2.0	1.6	7.3	1267	0
1826	135	135	136	3.3	4.5	3.8	6.0	2402	-1
1830	144	144	131	0.5	0.9	0.7	8.1	1727	8
1842	146	146	133	1.7	4.1	2.8	7.4	2001	-4
1843	145	145	131	0.2	3.3	0.4	6.9	1684	-5
1849	144	144	132	5.5	2.0	4.8	6.2	1786	-13

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1390	1.05	2.19	46	5.1	-1.6	-0.1	22.7	-4.0
1406	1.34	2.00	64	4.6	-2.5	-2.9	20.0	0.0
1415	0.76	1.93	45	5.3	-0.9	2.9	20.0	0.0
1458	0.89			6.0	2.9	-0.1	20.0	0.0
1463	1.10			4.6	2.1	-0.1	21.0	0.0
1464	0.99	1.59	46	4.7	1.2	0.3	22.0	0.0
1465	0.94	1.57	60	2.9	-0.9	0.2	22.0	0.0
1476	0.67	2.06	59	3.4	-0.8	-3.5	20.0	0.0
1501	1.06	1.90	56	6.3	0.2	-0.1	16.7	-3.0
1506	1.06	1.67	61	4.0	0.0	-0.7	20.0	0.0
1531	0.72	2.15	69	5.0	1.0	-4.0	15.8	-2.8
1641	0.35	2.04	58	7.3	-1.5	-15.7	11.3	-6.5
1646	0.78	2.10	46	5.5	-1.6	1.6	10.4	-6.0
1648	0.67	1.65	57	5.1	0.7	-8.4	6.9	-5.8
1649	0.69	1.83	59	6.2	-0.2	-5.6	6.1	-5.1
1654	0.49	1.87	49	5.9	-2.1	-7.1	6.9	-4.0
1729	0.72	1.82	57	7.9	-1.2	-0.3	3.8	3.2
1780	0.37	1.97	48	6.6	-0.6	-1.1	3.5	2.0
1789	0.47	2.02	45	6.5	-0.2	3.2	4.7	1.7
1826	0.96	1.48	62	4.9	0.2	-6.6	0.0	0.0
1830	0.17	2.09	63	6.4	1.1	3.0	0.0	0.0
1842	0.66	1.89	66	5.9	1.1	-12.0	0.0	0.0
1843	0.09	1.79	53	5.0	0.6	-2.5	0.0	0.0
1849	1.13	1.59	49	5.9	-0.6	-3.4	0.0	0.0

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1871	134	134		1.5	3.9	2.8		2266	0
1876	150	148	130	0.1	1.8	0.2	6.6	1663	-1
1896	129	129	126	4.6	2.5	3.4	7.1	1666	-4
1900	140	134		3.2	2.9	3.0		1774	-2
1912	141	136	130	3.1	2.0	2.7	6.5	1746	1
1922	131	131	133	3.8	2.8	3.5	7.1	1899	-1
1941	143	137	126	2.8	2.0	2.8	6.8	1994	-8

Table D-12. Landing Data, B-757, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1871	0.70			6.3	-2.0	-1.2	0.0	3.0
1876	0.03	1.73	50	6.2	-0.8	0.9	2.5	4.3
1896	0.88	1.92	56	7.0	1.1	1.9	0.0	0.0
1900	0.77			6.9	-0.3	-1.1	6.1	-3.5
1912	0.67	1.70	52	6.9	1.0	-2.4	5.1	-6.1
1922	0.90	1.80	60	5.7	-0.7	-4.6	0.0	0.0
1941	0.68	1.83	64	8.6	-1.1	-9.9	6.0	0.0

Table D-13. Landing Data, B-767 Classic, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
30	165	165	147	1.4		1.9	7.4	2004	-13
37	135	138	144	2.7	1.8	1.9	5.2	2431	0
96	160	162	150	0.8	3.6	2.2	8.9	1554	0
154	143	143	144	4.5	4.2	4.2	5.4	2177	1
256	144	148	143	3.8	3.8	3.8	5.3	2224	-1
282	163	163	164	1.5	3.4	2.5	6.6	3030	-14
314	154	154	143	2.6	2.4	2.5	7.1	1845	0
425	153	153	141	1.5	0.7	1.3	10.1	1359	-5
430	140	140	138	3.6	2.3	2.9	6.5	1889	-9
453	132	132	135	3.2		2.6	7.0	2516	-10
457	160	163	145	2.0	4.0	3.0	7.2	2041	-6
485	136	137	133	2.5	1.9	2.2	3.0	3453	-6
500	147	147	136	1.8	0.3	1.8	6.9	1895	-8
535	138	135	130	1.7	3.5	2.6	8.0	1169	-5
543	168	164	146	4.6		4.5	6.6	1606	-5
601	144	140	135	2.2	3.7	3.0	4.9	2211	5
682	146	140	132	3.2	2.8	3.0	6.5	1801	10
733	162	153	136	4.0	2.6	2.9	6.9	1785	-2
758	135	126	125	1.0	2.1	1.4	6.2	1503	4
794	155	146	135	2.5	2.8	2.8	6.7	1994	-5
798	152	142	136	4.3	3.5	3.7	7.1	1579	0
897	144	133	125	4.0	2.2	3.0	5.4	2279	5
1310	158	133	127	2.0		2.7	4.7	2508	-9
1526	162	144	130	4.2	1.6	2.9	6.9	2015	6
1744	141	136	132	2.3	1.4	1.8	6.0	1723	-1

Table D-13. Landing Data, B-767 Classic, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
30	0.39	1.71	60	6.4	-0.8	-12.9	0.0	0.0	
37	0.46	1.23	52	8.6	-0.1	-3.4	-2.6	1.5	
96	0.47	2.00	54	5.9	1.0		-1.5	1.3	
154	1.00	1.29	49	5.3	-2.5	6.5	0.0	0.0	
256	0.87	1.26	49	6.4	0.0	-2.1	-3.8	1.4	
282	0.51	1.36	72	6.5	-1.3	-14.9	0.0	4.0	265,081
314	0.55	1.69	54	6.0	0.2	-8.3	0.0	0.0	266,627
425	0.29	2.42	58	6.2	0.6	-2.7	0.0	4.0	266,045
430	0.71	1.61	53	8.0	1.0	-0.7	0.0	5.0	
453	0.67	1.78	78	6.4	-1.7	-9.5	0.3	4.0	
457	0.62	1.68	60	8.4	0.4	-13.5	-3.0	-0.5	249,120
485	0.55	0.77	46	7.7	-0.1	-8.0	-0.9	4.9	
500	0.41	1.71	57	8.2	-0.3	-8.1	0.0	0.0	
535	0.65	2.08	43	6.6	0.8	7.6	3.9	4.6	
543	0.94	1.55	43	6.6	-2.2		3.9	4.6	287,288
601	0.74	1.23	47	7.2	-0.2	0.3	4.5	5.4	229,058
682	0.73	1.68	53	7.0	0.2	-2.1	5.4	4.5	235,451
733	0.64	1.72	54	4.2	0.2	-2.6	9.4	3.4	266,497
758	0.38	1.68	44	4.8	0.0	5.0	9.8	1.7	
794	0.65	1.68	58	7.1	0.3	-10.5	8.9	1.6	272,934
798	0.89	1.77	49	4.8	3.3	2.0	10.3	3.8	268,836
897	0.78	1.47	58	9.5	-2.5	3.7	10.8	1.9	226,853
1310	0.68	1.26	55	3.6	0.1	-16.2	25.0	0.0	
1526	0.69	1.81	64	2.9	0.5	6.6	18.0	0.0	
1744	0.45	1.55	46	5.4	0.0	-1.8	4.9	0.9	258,000

Table D-13. Landing Data, B-767 Classic, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1790	159	156	141	3.6	2.4	2.9	7.2	1917	-8
1796	157	154	138	2.1	2.0	2.0	5.9	1797	0
1805	142	137	138	1.6	3.7	2.6	5.7	2325	2
1827	163	163	149	0.1		0.4	9.5	1430	0
1887	147	147	141	3.0	2.2	2.2	6.2	2398	0
1908	153	150	135	4.1	3.4	3.1	4.4	2192	5
1938	147	147	137	2.0	1.2	1.6	5.5	1731	-5

Table D-13. Landing Data, B-767 Classic, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1790	0.64	1.72	58	6.9	-0.7	-7.4	3.0	0.5	
1796	0.44	1.46	46	5.1	-0.2	-4.1	3.0	0.5	
1805	0.65	1.40	57	9.1	-0.3	-1.5	5.0	0.0	
1827	0.07	2.18	54	7.7	-0.9	-4.5	0.0	0.0	
1887	0.51	1.49	62	5.3	1.7	-7.0	0.0	5.0	263981
1908	0.70	1.09	42	5.8	-1.4	-0.6	3.2	-3.8	
1938	0.38	1.36	41	5.8	-0.8	-1.0	0.0	0.0	

Table D-14. Landing Data, B-767-300, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
24	157	157	143	6.4	3.5	4.2	6.9	2157	3
76	151	155	150	4.3	3.2	3.8	7.3	1811	4
172	165	162	150	2.4		2.0	9.3	1390	-4
224	151	150	145	6.0	2.5	4.5	6.9	1700	-2
238	159	161	148		2.3	2.4	5.9	2513	-7
249	161	161	144	2.9	2.2	2.5	6.3	1876	-3
302	153	153	144	3.5	3.7	3.7	7.4	1786	-4
329	162	162	146	5.6	3.8	4.0	6.4	1763	11
332	145	149	142	3.2	3.5	3.2	5.4	2437	-6
335	163	163	149	4.9	3.5	4.0	7.0	1878	1
379	166	166	152	1.4	2.7	2.1	6.3	2024	-9
388	158	158	146	3.5	1.0	2.4	7.4	1836	-1
419	150	150	144	3.8	0.4	2.5	9.1	1689	4
422	153	154	144	3.9	2.9	3.4	7.4	1828	-5
434	160	160	142	3.7	0.6	2.1	5.5	2674	-2
436	155	155	145	5.5	2.9	3.6	7.8	2235	5
497	140	141	134	2.8	3.2	3.0	6.5	1848	1
498	146	146	143	2.4	2.9	2.5	6.3	1801	2
541	153	150		0.8	1.5	1.2		1939	6
554	143	143	138	4.5	4.6	4.6	5.9	1702	-2
609	148	144	131	4.9	2.9	3.7	6.6	1495	4
680	147	142	135	1.8		1.8	5.2	2434	-1
681	151	145	131	3.4	1.5	3.0	5.9	1663	1
699	146	143	135	0.3	2.5	1.4	5.9	1477	10

Table D-14. Landing Data, B-767-300, FAA Survey-LHR

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
24	0.90	1.65	62	4.7	-2.0	3.0	0.0	0.0	262,153
76	0.82	1.64	52	5.4	-0.3	-0.9	-3.8	1.4	
172	0.41	2.11	51	5.1	-1.6	-2.5	3.3	-2.3	277,930
224	1.02	1.62	48	5.8	-2.0	0.3	0.5	6.0	
238	0.51	1.35	59	5.5	-0.5	-12.0	-2.6	3.1	
249	0.54	1.49	49	6.4	-0.6	-5.3	0.0	2.0	
302	0.82	1.74	54	4.8	-1.1	-3.0	0.0	0.0	276,904
329	0.84	1.49	46	3.9	2.8	-3.3	0.0	0.0	267,859
332	0.73	1.28	54	6.2	-2.5	-6.2	-4.0	0.3	261,358
335	0.84	1.59	52	4.6	-0.2	-5.3	0.0	0.0	
379	0.42	1.41	50	4.7	0.0	-12.4	0.0	0.0	280,476
388	0.51	1.72	55	5.2	-1.1	-2.6	0.0	0.0	
419	0.55	2.14	63	4.6	-0.2	1.0	0.0	0.0	
422	0.74	1.73	55	4.5	0.2	-2.9	-1.0	2.8	
434	0.44	1.32	61	5.8	1.8	3.1	0.0	0.0	257,056
436	0.78	1.82	71	4.4	-4.3	-0.9	0.0	0.0	
497	0.72	1.66	54	5.2	0.3	-3.1	-0.2	2.0	
498	0.58	1.49	47	5.2	-0.8	-1.3	0.0	0.0	
541	0.26	1.40	47	7.0	0.9	-7.7	3.2	3.8	267,198
554	1.09	1.46	43	5.6	2.2	-1.5	0.9	4.9	258,342
609	0.87	1.72	45	8.4	-1.9	-4.1	3.5	6.1	
680	0.42	1.30	55	5.9	-1.1	-5.3	5.2	3.0	
681	0.70	1.52	44	6.6	-0.6	3.1	6.1	3.5	268,216
699	0.33	1.50	39	6.6	-0.2	-3.0	2.5	4.3	

Table D-14. Landing Data, B-767-300, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
757	145	136	130	0.6	0.8	0.6	5.5	2627	1
764	151	140	136	1.6	2.2	1.8	5.6	1906	-3
766	136	126	124	1.8	2.8	2.8	6.3	1410	13
792	132	122	126	2.6	1.4	1.8	6.6	1615	2
885	162	150	138	5.3	3.5	3.9	6.4	1862	2
900	153	144	128	2.1		2.0	5.5	1599	1
906	154	144	131	2.6		2.7	7.8	1520	1
919	171	158		2.5	2.6	2.4		1265	-2
952	139	134	140	3.7	1.1	2.1	7.6	1711	-8
1049	137	125	133	3.9	0.8	3.9	10.4	1454	-2
1175	160	155	140	3.9	1.9	3.1	4.6	2484	-10
1211	168	160	146	3.2	3.3	3.2	5.7	2369	-8
1216	172	160	143	2.0		1.7	9.0	1526	-6
1220	146	131	132	5.8	4.2	4.7	8.8	1296	1
1238	153	139	121	1.5	2.4	1.9	10.4	1117	-7
1258	147	139	137	4.7		4.1	5.5	1941	0
1267	134	122	129	2.8	0.2	2.0	8.8	1088	-18
1290	146	132	128	1.8	3.1	2.2	5.0	2240	1
1291	156	142	122	6.7	5.4	6.0	7.6	1481	0
1302	160	150		5.1		4.5		963	-5
1372	155	132	124	2.7	1.9	1.9	5.9	1441	3
1382	166	145	128	3.2	2.0	2.0	8.7	1378	5
1410	158	136	125	5.0		3.9	7.4	1421	-7
1495	163	143	132	5.8	3.9	5.0	9.2	1766	-1

Table D-14. Landing Data, B-767-300, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
757	0.15	1.44	66	5.7	2.3	3.2	9.4	3.4	266,832
764	0.43	1.40	46	5.8	0.5	-3.8	10.8	1.9	281,543
766	0.76	1.73	43	5.7	1.7	6.6	9.8	1.7	260,363
792	0.49	1.76	50	6.3	-0.7	1.3	9.8	1.7	261,907
885	0.88	1.58	51	4.7	-0.9	-2.1	11.3	4.1	283,642
900	0.48	1.47	41	7.3	-1.0		8.9	1.6	
906	0.63	2.02	54	4.8	-2.3	-8.5	10.0	0.0	
919	0.51	2.32	51	6.7	0.2	3.7	12.8	2.3	289,905
952	0.54	1.85	55	4.2	0.1	-2.1	5.1	-6.1	278,664
1049	1.06	2.67	68	6.8	-1.1	-1.7	12.1	-7.0	260,028
1175	0.69	1.11	48	7.2	-1.8	-10.5	5.5	-9.5	262,127
1211	0.67	1.33	55	4.3	-2.0	-4.6	8.0	-13.9	
1216	0.37	2.13	57	6.0	-2.3	-9.6	11.5	-9.6	278,692
1220	1.22	2.26	51	6.0	0.0	0.9	15.3	-12.9	262,004
1238	0.47	2.91	57	7.7	0.9	2.0	13.9	-8.0	247,218
1258	0.99	1.35	46	5.9	-0.5	-6.0	8.4	-7.1	260,804
1267	0.55	2.32	44	6.4	-4.4	8.0	11.3	-6.5	263,101
1290	0.57	1.33	52	5.6	-1.5	-1.8	14.1	-5.1	257,504
1291	1.44	2.10	54	4.8	0.4	-11.5	14.1	-5.1	
1302	1.02	2.48	42	6.7	-2.3	-11.4	10.0	-8.4	
1372	0.49	1.63	41	5.1	0.0	-3.9	22.7	4.0	253,677
1382	0.46	2.32	56	4.8	-2.2	-2.2	21.0	0.0	274,663
1410	0.98	2.00	50	4.3	-1.3	-8.0	22.0	0.0	259,768
1495	1.18	2.38	73	5.1	-0.4	-0.2	20.0	0.0	277,398

,

Table D-14. Landing Data, B-767-300, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1504	148	131	125	2.6	2.5	2.6	7.1	1310	0
1527	149	131	128	1.0		0.5	6.0	1968	-13
1535	141	125	119	2.4	1.1	1.6	6.3	1298	-1
1541	164	147		3.1	4.5	3.5		2021	41
1545	151	134	124	1.9	2.5	2.2	6.5	1857	-7
1555	156	148	142	7.5		6.1	10.9	988	-14
1568	161	145	131	4.1	3.3	3.7	8.1	1535	0
1575	161	145	126	2.8		3.9	7.2	1150	-9
1580	158	139	126	6.9	3.4	5.4	5.2	1780	9
1617	152	147	134	2.6	2.5	2.6	6.7	1884	-7
1619	163	157	146	4.7	2.9	4.7	8.7	1817	-13
1645	158	148	132	1.6	2.6	1.7	8.0	1461	3
1665	153	151	142	1.5	1.6	1.5	8.1	1949	-7
1666	168	165	145	2.3		0.9	6.9	2073	-17
1674	137	134	134	2.2	1.2	1.3	7.1	1256	4
1712	160	155	142	2.8	0.8	1.8	5.8	2015	-5
1722	140	138	139	4.1	5.5	4.8	7.2	1695	4
1724	151	147	143	3.9	2.7	2.7	4.7	2352	0
1733	147	144	141	3.2	0.3	1.9	7.2	2138	1
1739	133	129	137	3.1	3.0	3.1	5.6	2374	-7
1939	156	156	141	2.5	1.8	1.6	7.7	1408	-1

Table D-14. Landing Data, B-767-300, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1504	0.66	1.93	44	4.6	-0.8	1.4	16.7	-3.0	268,051
1527	0.13	1.61	55	7.5	-2.5	-4.6	18.0	0.0	
1535	0.44	1.81	41	6.4	-0.1	2.4	15.8	-2.8	
1541	0.82	1.83	65	7.2	-2.1	2.2	17.7	-3.1	
1545	0.56	1.77	58	5.5	-1.0	-4.7	17.7	-3.1	255,806
1555	1.40	2.60	45	6.6	-3.5	-13.0	8.4	-10.0	284,651
1568	0.86	2.09	56	4.8	-0.1	-9.4	16.0	0.0	266,638
1575	0.92	1.92	39	6.0	2.8	1.9	16.0	-5.8	
1580	1.31	1.39	43	5.5	0.0	-1.9	19.0	0.0	264,446
1617	0.60	1.70	56	7.5	-1.3	-5.2	5.5	-9.5	259,530
1619	1.02	2.01	64	4.8	-2.3	-2.7	6.0	-10.4	275,809
1645	0.40	2.07	53	5.0	-0.5	-7.1	10.4	-6.0	248,403
1665	0.34	1.95	66	7.2	-1.6	-4.4	1.9	-10.8	268,101
1666	0.19	1.61	58	4.8	-2.2	-16.4	3.4	-9.4	260,200
1674	0.33	1.80	39	4.4	-1.7	5.9	3.0	5.2	
1712	0.39	1.39	49	5.6	0.9	-12.1	5.4	4.5	274,340
1722	1.17	1.76	52	6.1	0.8	2.2	1.2	6.9	283,717
1724	0.62	1.11	46	4.4	0.0	-2.4	3.9	4.6	280,326
1733	0.44	1.73	65	5.1	-1.7	4.3	3.8	3.2	271,272
1739	0.81	1.39	58	4.9	-0.1	-3.3	3.8	3.2	269,288
1939	0.35	1.86	46	3.5	1.7	-4.5	0.0	0.0	

Table D-15. Landing Data, B-777, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
35	148	148	141	3.0	1.4	2.2	6.5	2445	-3
36	150	150	141	0.9	0.3	0.6	5.5	2790	2
42	155	155	138	2.0	2.8	2.6	6.3	1964	-9
75	143	147	145	0.3	1.6	0.6	4.4	2654	15
79	147	150	139	1.3	1.9	1.3	8.3	1616	5
87	148	151	144	1.3	3.4	2.5	7.2	1941	-4
90	145	145	142	4.3	6.0	5.1	6.0	2390	-7
104	151	156	146	3.3	2.3	3.2	8.0	2156	-5
107	159	161	145	0.9	0.2	0.3	10.1	1440	2
155	148	148	141	1.1	1.0	1.0	5.1	2547	11
156	144	145	137	3.6	3.1	3.6	6.7	1653	4
159	137	140	135	3.0	3.8	3.0	6.2	2236	-6
161	153	153	148	2.4	0.2	1.4	8.5	1668	-5
163	150	148	139	1.6	1.7	1.3	6.9	1569	-6
181	133	139	134	1.6	1.8	1.4	7.2	2236	0
196	140	140	134	0.1	0.5	0.5	7.6	2532	-6
198	133	138	139	3.8	3.9	3.9	8.4	1248	-2
202	143	145	134	2.1	2.2	2.1	8.2	1312	-1
203	147	147	140	0.7	1.3	0.8	9.1	1698	-4
210	143	145	138	1.4	0.2	1.4	7.0	1695	5
223	150	152	136	2.0		0.7	8.9	1489	1
225	141	144	139	3.4	4.9	4.1	5.4	2269	6
239	143	147	137	3.6	2.0	3.1	9.1	1399	-1
240	143	143	133	2.5	1.5	3.1	8.2	1715	0

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
35	0.50	1.57	67	7.0	-0.1	-8.7	0.0	0.0	
36	0.14	1.33	65	7.6	3.3	-2.6	0.0	0.0	
42	0.57	1.54	53	6.8	1.4	-8.8	0.0	0.0	366,475
75	0.14	1.04	48	9.3	3.6	2.5	-3.6	1.7	
79	0.30	2.04	58	5.9	-0.5	2.0	-3.0	0.5	371,153
87	0.57	1.70	58	6.7	1.5	-8.4	-3.0	0.5	403,607
90	1.20	1.44	60	5.6	-0.3	-6.4	0.0	0.0	400,624
104	0.69	1.86	70	10.4	-2.1	2.6	-4.8	1.3	
107	0.05	2.35	59	6.6	-0.4	-2.4	-1.8	0.8	406,383
155	0.23	1.24	55	7.2	3.9	-0.8	0.0	4.0	
156	0.84	1.67	48	7.4	-0.9	-1.4	-1.0	2.8	
159	0.73	1.55	61	6.2	-2.9	-0.5	-3.1	-2.6	
161	0.32	1.95	57	7.6	0.1	-0.4	0.0	2.0	
163	0.30	1.67	46	5.8	-0.8	1.9	2.0	-3.5	
181	0.34	1.84	72	7.4	0.3	-1.5	-5.4	4.5	
196	0.12	1.93	85	6.6	1.0	1.2	0.0	4.0	
198	0.95	2.06	45	6.7	-2.1	1.8	-4.7	1.7	
202	0.49	2.06	47	6.3	-1.8	1.4	-2.3	3.3	
203	0.19	2.21	65	6.2	0.4	0.0	0.3	3.0	
210	0.33	1.73	51	6.7	0.1	1.7	-1.4	3.8	
223	0.15	2.21	58	6.9	-1.0	-6.9	-1.9	2.3	390,772
225	0.96	1.31	52	6.9	-1.4	-2.7	-3.2	3.8	
239	0.72	2.26	55	6.4	-0.5	-4.5	-3.9	1.0	420,856
240	0.74	2.08	62	7.1	0.1	-0.8	0.4	5.0	386,608

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
255	143	144	133	1.4	1.4	1.4	7.0	1836	-6
260	150	150	141	2.4	1.1	1.1	9.3	1295	1
285	161	161	141	3.1	1.6	2.3	8.4	1568	-18
301	148	148	138	3.3		1.8	10.7	1130	-6
420	154	155	141	2.0		1.8	7.0	1966	-6
490	147	147	134	3.7	2.6	3.1	7.9	1467	-1
501	134	135	130	2.5	1.1	2.1	7.0	1576	-4
506	147	148	133	5.5	4.0	4.5	9.5	1376	13
507	133	133	127	1.0	1.6	1.2	6.0	1711	2
511	144	145	129	2.9	2.9	2.9	6.8	1533	8
512	137	138	130	1.7	2.7	2.1	6.7	1644	-2
513	139	140	136	1.6	1.4	1.6	6.5	1708	1
514	143	143	135	1.2	2.0	1.5	6.0	1759	8
540	152	149	135	1.1	0.0	0.5	7.9	1455	5
542	158	155	142	2.1	2.4	2.2	7.1	1843	6
595	145	140	134	2.5	0.1	1.6	6.9	1773	9
623	159	156	149	3.8	4.2	3.8	8.3	1670	6
656	150	145	138	3.3	2.8	3.0	5.7	2312	-3
657	151	146	139	1.4		1.2	6.8	1535	8
678	138	133	132	2.4	1.6	2.2	6.9	2197	3
689	148	144	138	2.2	1.2	1.7	6.0	2347	4
709	151	150	143	2.7	3.1	2.9	8.7	1665	10
725	132	125	126	4.6	3.0	3.8	6.1	2117	3
746	142	131	130	2.6	2.3	2.4	7.4	1545	10

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
255	0.33	1.79	58	6.1	-0.8	-5.1	-0.5	3.0	372,807
260	0.25	2.23	50	6.3	-0.7	2.1	0.0	5.0	
285	0.49	2.01	55	6.0	0.5	-11.4	0.0	2.0	
301	0.42	2.64	52	7.3	-2.4	5.5	0.0	0.0	
420	0.39	1.68	58	7.1	-1.6	-10.0	-1.0	3.9	
490	0.72	2.00	51	6.7	-0.8	-4.3	-0.5	3.0	429,196
501	0.54	1.83	50	7.0	0.3	4.0	-0.5	3.0	
506	1.02	2.43	58	5.4	-1.0	-4.2	-0.5	3.0	387,293
507	0.31	1.61	48	6.4	0.8	-0.8	-0.5	1.9	365,602
511	0.68	1.80	48	7.4	0.3	-10.4	-0.5	3.0	389,906
512	0.51	1.76	50	6.0	-0.7	5.7	-1.0	3.9	396,466
513	0.40	1.61	48	7.3	0.3	0.7	-0.9	4.9	
514	0.37	1.51	46	5.6	0.9	-2.0	-0.3	2.0	
540	0.11	1.99	50	5.5	1.0	-3.5	3.2	3.8	376,610
542	0.48	1.69	54	5.6	0.4	-3.2	3.2	3.8	439,183
595	0.38	1.76	54	7.5	-0.2	-1.2	4.5	5.4	
623	0.83	1.89	55	6.2	1.7	-0.8	2.5	4.3	
656	0.70	1.41	57	5.8	-0.4	-1.9	5.2	3.0	426,202
657	0.28	1.65	44	7.8	-0.3	-7.6	5.4	4.5	
678	0.55	1.77	68	5.3	-0.1	1.4	5.2	3.0	
689	0.41	1.48	61	5.5	-0.4	-3.3	4.6	3.9	
709	0.66	2.06	60	5.1	0.7	3.3	0.7	3.9	
725	1.03	1.64	61	4.9	-1.4	4.8	6.9	4.0	374,198
746	0.63	1.93	52	5.2	0.5	5.6	11.8	2.1	

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
747	138	129	125	2.0	2.0	2.0	5.3	2239	6
769	143	136	129	2.8	3.5	3.1	7.8	1492	-6
787	145	134	129	2.2	1.2	1.7	7.7	1690	-2
797	153	143	125	3.1	1.7	2.5	7.5	1472	2
818	150	142	129	6.0	3.0	4.6	7.9	1387	2
851	157	150	149	2.3	1.7	2.5	10.6	1256	-3
865	156	144	137	1.9	1.5	1.1	7.9	1807	-1
872	141	129	126	4.2	1.2	2.9	7.5	1314	6
884	156	144	135	2.9	1.9	2.0	7.7	1657	6
1054	161	153	136		3.6	4.4	6.5	1975	-6
1411	161	139	132	4.4	0.0	3.0	5.2	1815	-6
1450	151	131	128	2.9	3.6	3.5	10.0	885	-10
1510	146	126	116	2.1	2.5	2.3	8.0	1363	-2
1569	152	137	129	2.2	1.8	2.0	8.1	1114	2
1589	156	142	134	6.6		6.1	12.2	1044	-20
1657	156	152	140	2.7	1.3	2.0	7.6	1304	1
1660	145	140	133	4.2	3.4	3.8	8.6	1306	2
1662	142	137	133	2.9	2.3	2.3	6.8	1772	-2
1692	146	141	132	4.1	2.1	3.2	7.5	1385	2
1706	157	151	139	2.5	2.4	2.5	9.3	1110	-3
1736	150	146	136	2.8	4.1	3.0	5.4	1976	-13
1740	146	142	129	2.6	1.7	2.3	4.8	2555	3
1747	144	144	135	4.4	1.8	1.8	7.0	2075	5
1756	151	148	133	1.7	3.7	2.3	5.5	2212	4

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
747	0.52	1.43	56	6.9	-0.3	-0.1	9.4	3.4	
769	0.77	2.06	54	7.4	0.4	2.7	6.6	2.4	
787	0.44	2.03	60	7.1	0.5	0.8	11.3	4.1	424,147
797	0.59	2.05	53	5.8	0.3	3.4	10.3	3.8	396,034
818	1.11	2.08	50	7.7	-0.1	-0.7	7.9	1.4	
851	0.56	2.41	53	6.8	1.0	2.8	7.9	1.4	
865	0.25	1.95	61	5.4	-0.3	-2.7	11.8	2.1	
872	0.76	2.03	46	7.1	-1.7	5.2	11.8	2.1	
884	0.47	1.93	56	7.2	0.5	3.7	11.3	4.1	
1054	0.96	1.62	56	5.8	3.6	-15.4	7.7	-9.2	
1411	0.72	1.34	43	6.5	-1.1	-6.7	22.0	0.0	
1450	0.92	2.65	41	8.0	-0.8	-10.1	20.0	0.0	
1510	0.62	2.35	56	6.8	-2.2	-1.3	19.7	-3.5	396,193
1569	0.48	2.15	42	5.9	0.0	10.1	15.0	0.0	
1589	1.46	3.11	57	6.6	-1.5	-14.9	14.0	0.0	
1657	0.45	1.83	42	5.4	1.1	-0.8	4.6	-3.9	
1660	0.92	2.18	50	6.0	-1.0	1.9	4.5	-7.8	394,511
1662	0.56	1.73	54	6.5	-2.1	-4.0	4.5	-7.8	
1692	0.77	1.92	46	5.1	-0.4	-2.1	5.6	2.1	
1706	0.56	2.28	44	6.4	2.2	7.1	6.1	3.5	
1736	0.69	1.35	46	8.2	2.3	-10.9	3.8	3.2	
1740	0.55	1.27	57	5.7	2.4	3.9	3.8	3.2	381,967
1747	0.43	1.76	64	6.8	1.2	8.5	0.0	0.0	
1756	0.52	1.41	54	6.0	-1.3	-0.3	3.5	2.0	

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1774	135	132	134	1.8	2.2	2.1	8.0	1545	12
1782	140	136	131	2.9	2.1	2.6	7.2	1808	-3
1784	144	140	131	3.6	2.7	3.3	7.2	1378	1
1806	142	137	134	2.0	1.5	1.6	6.4	1774	-1
1814	137	137	130	1.8	1.8	1.8	8.7	1352	4
1821	140	136	131	2.7	2.5	2.6	6.8	1676	0
1832	141	141	136	3.4	1.5	2.4	7.0	1792	-3
1836	131	131	135	6.7	4.2	5.5	6.3	1980	3
1860	133	133	139	2.3	2.1	2.2	4.9	2380	-2
1886	140	140	135	1.0	0.8	1.0	7.1	1595	3
1909	149	143	133	0.5	0.6	0.0	8.6	1522	-6
1946	148	148	137	3.7		2.7	9.0	1395	-2
1948	148	145		5.3	0.5	2.9		1118	-5

Table D-15. Landing Data, B-777, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)	Reported Landing Weight (lb)
1774	0.55	2.02	54	8.0	1.8	2.1	3.1	2.6	
1782	0.65	1.87	59	5.5	0.6	-3.5	3.8	1.4	384,105
1784	0.79	1.87	45	5.2	-1.4	-2.0	3.8	1.4	
1806	0.39	1.63	50	4.9	0.4	-1.2	5.0	0.0	393,669
1814	0.45	2.27	54	5.6	0.5	-2.8	0.0	0.0	368,215
1821	0.65	1.78	52	5.0	-0.3	1.6	3.5	2.0	371,806
1832	0.58	1.74	54	5.6	-0.5	-1.0	0.0	0.0	403,168
1836	1.42	1.60	55	11.4	0.0	2.4	0.0	0.0	
1860	0.55	1.19	50	5.1	-0.2	-3.9	0.0	0.0	
1886	0.24	1.78	50	6.2	-0.4	2.1	0.0	0.0	420,602
1909	0.01	2.19	58	6.1	-0.5	1.3	6.1	-3.5	418,113
1946	0.63	2.23	54	7.8	-2.1	-4.9	0.9	-4.9	421,385
1948	0.68		54	7.5	0.5	2.2	3.0	-5.2	

Table D-16. Landing Data, DC-10, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
566	170	168	152	2.0	1.8	2.0	7.6	1840	3
920	168	156	143	3.0	4.5	3.7	5.2	2575	-15
1556	156	147	139	4.5	5.1	4.8	7.8	1972	-3

Table D-16. Landing Data, DC-10, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
566	0.41	1.69	54	7.3	1.0	-4.7	2.5	4.3
920	0.82	1.23	55	8.4	0.2		12.8	2.3
1556	1.10	1.90	65	11.6	0.2	-6.7	9.2	-7.7

Table D-17. Landing Data, L-1011, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
320	163	163	154	2.4	1.7	1.6	6.8	1453	1
551	154	149	147	2.4	2.0	2.0	6.2	1726	-10
754	146	136	142	1.4	1.6	1.4	6.5	1449	-4
1257	163	155	144	2.5	3.0	2.6	6.6	1822	-4

Table D-17. Landing Data, L-1011, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
320	0.34	1.49	38	8.6	-1.0	-2.4	0.0	3.0
551	0.46	1.44	43	7.4	-0.6	2.3	4.6	3.9
754	0.35	1.56	39	9.0	0.1	6.0	9.4	3.4
1257	0.57	1.56	50	7.9	-2.0	-3.1	8.4	-7.1

Table D-18. Landing Data, MD-11, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
444	172	172	157	3.5	3.7	3.6	7.0	2380	-7
679	163	158	150	2.4	3.7	2.8	6.0	2258	8
925	150	138	132	5.0	2.0	3.9	7.0	1250	1
1505	164	147	134	2.7	3.6	2.7	10.3	1270	-5
1684	165	161	155	4.4	4.4	4.4	9.4	1426	6

Table D-18. Landing Data, MD-11, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
444	0.71	1.52	63	8.2	0.2	0.5	0.0	0.0
679	0.61	1.36	54	6.3	-0.8	1.9	5.2	3.0
925	0.95	1.81	39	8.3	-1.4	0.2	11.8	2.1
1505	0.63	2.59	58	8.3	-1.9	-2.7	16.7	-3.0
1684	0.92	2.06	51	7.9	-0.7	0.5	4.6	3.9

Table D-19. Landing Data, MD-80/87, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
61	145	149	140	2.3	4.2	3.6	7.2	1781	6
130	134	139	146	0.8	2.5	0.8	7.5	1376	9
235	134	137	133	6.2	4.5	4.8	5.8	2157	7
294	128	130	127	2.8	3.1	2.6	5.3	2044	-15
318	136	137	135	2.8	0.6	1.9	7.3	1666	1
431	142	142	144	6.1	6.4	6.1	6.4	2205	14
539	135	133	132	2.2	1.8	1.9	6.3	1907	-4
596	138	134	137	2.6	2.7	2.6	6.5	1747	13
612	144	143	134	3.1	3.0	3.1	8.8	1504	11
635	149	146	134	6.1	4.8	5.4	7.3	1242	6
817	161	153	134		3.1	2.5	5.7	2072	-6
822	128	118	125	1.5	2.7	2.1	7.1	1891	-1
829	135	127	128	3.8	1.1	2.4	5.0	1706	-2
867	148	136	130	5.1	3.9	4.6	8.4	1442	14
938	137	127	124	2.9	3.1	3.1	6.3	1463	4
956	149	144	130	4.0	5.9	4.9	8.1	1546	-2
1029	167	159	141	3.3	2.8	3.2	11.4	1314	-4
1105	145	138	130	3.1	3.9	3.1	8.1	1829	1
1123	136	130	127	0.4	0.3	0.4	5.9	1478	4
1166	138	133	130	4.5	3.8	4.2	7.5	1490	4
1173	161	155		3.4	3.2	3.2		1421	2
1371	147	124		5.6	5.1	5.4		1413	9
1413	160	140	126	1.1	1.8	1.5	6.3	1436	1
1431	149	129		1.3	3.0	1.8		1683	-7

Table D-19. Landing Data, MD-80/87, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
61	0.81	1.74	54	6.2	0.2	-0.3	-3.8	1.4
130	0.20	1.76	42	4.8	3.1	1.5	-4.9	0.9
235	1.19	1.48	56	7.3	-3.1	5.1	-3.5	2.0
294	0.69	1.41	50	6.0	-1.8	-11.6	-2.0	3.5
318	0.48	1.84	53	5.7	0.3	2.9	-1.3	2.7
431	1.45	1.51	58	6.2	2.2	-1.4	0.0	3.0
539	0.48	1.63	54	6.5	-0.4	-1.2	2.5	4.3
596	0.66	1.60	49	6.1	1.7	3.1	4.5	5.4
612	0.74	2.22	58	6.8	0.8	-7.2	1.2	6.9
635	1.26	1.84	40	9.7	-0.2	-0.7	3.0	5.2
817	0.56	1.43	52	6.4	1.4	-14.3	7.9	1.4
822	0.61	1.91	63	6.8	0.9	-5.0	9.8	1.7
829	0.65	1.34	40	6.2	-0.5	0.4	7.9	1.4
867	1.16	2.19	55	6.6	-0.2	-4.1	11.8	2.1
938	0.84	1.72	44	6.9	1.8	-4.4	10.0	0.0
956	1.17	2.13	57	5.6	0.9	2.4	5.0	-8.7
1029	0.69	2.75	63	8.8	3.8	-6.1	7.5	-13.0
1105	0.76	2.12	68	7.4	-0.7	-4.7	7.0	-12.1
1123	0.10	1.58	41	5.3	-1.4	9.8	6.5	-11.3
1166	1.08	1.96	51	5.3	-0.5	-9.2	5.0	-8.7
1173	0.71			6.6	-1.4	-1.7	5.5	-9.5
1371	1.47			5.4	-0.6	-5.8	23.0	0.0
1413	0.37	1.69	42	8.0	1.0	-5.9	20.7	-3.6
1431	0.48			4.7	-0.2	2.8	19.7	-7.2

Table D-19. Landing Data, MD-80/87, FAA Survey-LHR (Continued)

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
1492	170	150	137	4.3	4.5	4.4	7.2	1852	-5
1518	156	136		4.4	2.8	3.1		1740	-5
1676	155	151	133	3.9	4.9	4.9	5.5	2230	1
1844	161	161	142	0.9	4.8	3.4	8.0	1809	1
1925	159	159	140	4.1	4.7	4.4	9.5	1363	9

Table D-19. Landing Data, MD-80/87, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
1492	1.00	1.80	58	4.2	0.8	-3.7	20.0	0.0
1518	0.76			5.9	-0.9	-0.7	20.0	0.0
1676	1.09	1.41	55	5.2	-1.5	2.8	3.9	4.6
1844	0.71	1.92	61	5.9	0.0	-2.2	0.0	0.0
1925	0.94	2.31	55	7.0	0.7	-1.2	0.0	0.0

Table D-20. Landing Data, MD-90, FAA Survey-LHR

Event No.	Power Approach Airspeed (knots)	Video Closure Speed (knots)	Threshold Camera Closure Speed (knots)	Video Sink Speed at Touchdown (ft/sec)			Threshold Camera Average Sink Speed (ft/sec)	Ramp to Touchdown Distance (ft)	Runway Off-Center Distance (ft)
				Port Wheel	Starboard Wheel	Average Main Wheel			
84	142	145	147	2.4	2.5	2.5	5.6	1439	9
115	153	159	150	4.9	4.9	4.9	6.7	1974	-9
734	143	135	141	4.6	4.1	4.3	7.8	2075	2
996	155	150	144	5.8	5.8	5.8	4.9	2163	1
1051	154	144	137	2.8	1.7	1.7	6.5	1751	-3
1066	153	145	136	2.5	4.1	3.2	7.0	1899	-3
1444	129	104	121	4.1	2.1	2.9	8.0	1199	2

Table D-20. Landing Data, MD-90, FAA Survey-LHR (Continued)

Event No.	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Height Over Runway Threshold	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)	Headwind (knots)	Crosswind (knots)
84	0.58	1.30	33	6.2	-0.1	-6.0	-2.8	1.0
115	1.04	1.53	53	4.9	-0.1	-9.0	-5.4	2.5
734	1.09	1.87	68	3.5	0.0	1.8	8.5	3.1
996	1.31	1.16	44	4.8	-1.5	0.8	5.0	-8.7
1051	0.40	1.62	49	5.2	-2.6	-3.5	10.4	-6.0
1066	0.74	1.76	58	5.3	-2.0	-2.4	7.7	-9.2
1444	0.96	2.25	47	6.1	0.8	1.6	24.6	-4.3

APPENDIX E—LANDING PARAMETER SURVEY DEFINITIONS

Sink Speed V_V —The instantaneous sink speed of the aircraft landing gear wheel just prior to touchdown. Sink speed is reported for the port, and starboard, wheels just prior to runway contact. In addition, the average sink speed of the aircraft main landing gear is calculated just prior to touchdown of the first main landing gear wheel. This is an average value of the port and starboard landing gear sink speeds, but still an instantaneous measure of sink speed, not the same as the Threshold Camera Sink Speed described below. Instantaneous sink speed is determined from video image data processing. The symbols used to identify aircraft sink speed are as follows:

V_{V_A} - average sink speed
V_{V_S} - sink speed of the starboard main wheel
V_{V_P} - sink speed of the port main wheel

The values of aircraft sink speed are reported in feet per second (ft/sec).

Threshold Camera Sink Speed Vv_{tc} — The threshold camera sink speed is an average sink speed for the aircraft during the time interval the aircraft flies from the runway threshold to its touchdown point on the runway. It is calculated from the measured value of threshold height Hw divided by the elapsed time between threshold crossing and touchdown.

The value of threshold camera sink speed is reported in feet per second (ft/sec).

Wind Speed V_W —Wind Speed is the wind velocity measured by the survey team's instrumentation. A head wind is defined as the positive direction for the parallel component of wind speed. The perpendicular component of wind speed and the crosswind is also reported. Wind speed is reported in knots.

Closure Speed V_C —The closure speed is the speed determined by the change in the aircraft's range from the camera. It is reported parallel to the runway centerline. Closure speed is reported with respect to the ground and is reported in knots. Closure speed is calculated from image measurements and is an instantaneous value at the touchdown point.

Threshold Camera Closure Speed Vc_{tc} — Another measure of aircraft ground speed. This quantity is calculated by dividing the Runway Threshold to Touchdown Distance X_W, by the elapsed time it takes for the aircraft to fly that distance. The elapsed time is established from the threshold camera. X_W is derived from video camera images and survey information collected during camera calibration and alignment. This is an average value of Closure Speed for the time interval involved. Vc_{tc} is reported in Knots.

Approach Speed $V_{P'AF}$ —The value of approach speed reported is the algebraic sum of closure speed and component of wind speed parallel to the runway centerline. The value of approach speed is the aircraft forward velocity with respect to the air mass and is reported in knots.

Aircraft Pitch Angle θ_p—The aircraft pitch angle is measured between the aircraft reference line and a line parallel to the runway. Positive values of pitch angle are reported for an aircraft with a nose up attitude. Pitch angle is determined from image data and is reported in degrees.

Aircraft Roll Angle θ_r—The aircraft roll angle measured between the aircraft reference line and a line parallel to the runway. Positive values of roll angle are reported for an aircraft whose starboard wing is down. Roll angle is determined from image data and is reported in degrees.

Aircraft Yaw Angle Yaw_{td}—The yaw angle is the angle between the aircraft centerline and the aircraft flight path at the point of first main wheel touchdown. Positive yaw angle is defined to be that orientation where a clockwise rotation of the flight path vector causes the vector to coincide with the aircraft centerline using a minimum angular rotation. Yaw angle is determined from image data and is reported in degrees.

Aircraft Off-Centerline Distance Y—The aircraft off-centerline distance is the perpendicular distance measured between the aircraft centerline and the centerline of the runway. This value is calculated from image data just prior to first main wheel touchdown. Positive values of this quantity indicate that the aircraft landed on the port side of the runway centerline and is reported in feet.

Threshold Height H_w — The average height of the aircraft main landing gear wheels as the aircraft flies over the runway threshold. This information is determined by the threshold camera, which is located at the runway threshold and aimed perpendicular to the runway centerline. The values of H_w are reported in feet.

Runway Threshold to Touchdown Distance XW—The distance between the runway threshold and the point of first main wheel touchdown is determined from image data and is reported in feet.

Aircraft Instantaneous Glideslope Angle β_{V_V}—This angle is determined just prior to first main wheel touchdown and is reported in degrees. The value of average sink speed (VVA) and closure speed (Vc) are used to define the instantaneous glide slope. These values are entered into the equation

$$\beta_{v_v} = \arctan\left(\frac{V_{V_A}}{Vc}\right)$$

Note: A consistent set of units (ft/sec) must be used in this equation.

Aircraft Geometric Glide Slope Angle β_{hw} — This angle is determined from the aircraft's height as it crosses the runway threshold, and the distance traveled from the runway threshold to touchdown point. These values are entered into the equation

$$\beta_{hw} = \arctan\,(Hw/XW)$$

Landing Weight W—The landing weight reported in the survey is an estimate provided by the aircraft operators. The value of this quantity is reported in pounds

Correlation Coefficient r — The correlation coefficient is a measure of the extent to which two variables are linearly related. The value of r is calculated by comparing the difference between the x and y values associated with each data point in a scatter point with the average x and y values for all the points included in the plot. The equation used to calculated using the equation

$$r = (\Sigma(x-\bar{x})\,(y-\bar{y}))/\,(\Sigma\sqrt{(x-\bar{x})^2}\,\Sigma\sqrt{(y-\bar{y})^2})$$

The values of vary from + 1.0 to -1.0. 1.0 indicates perfect positive agreement, all points under consideration lie on a straight line sloping upward. -1.0 indicates perfect negative agreement, all points lie on a straight line sloping downward. A value of 0.0 indicates the variables are not linearly related. For data with the type of scatter found in landing survey results, n r > 0.3 is considered significant, r>0.5 is highly significant and r >0.6 is extremely significant. It should be noted that finding correlation does not imply caustion.

List of Subscripts:

P	-	Port
S	-	Starboard
N	-	Nose wheel
A	-	Average
r	-	Roll
p	-	Pitch

STATISTICAL SYMBOLS

N= Number of observations (Data Points)

X = Mean Value of a parameter

P = Probability

σ = Standard Deviation of sample distribution

r = Correlation Coefficient

r^2 = Coefficient of Determination, the square of the correlation coefficient generated as part of a regression analysis

APPENDIX F—BOX AND WHISKER PLOTS

A box-and-whisker plot can be useful for handling many data values. They allow people to explore data and to make informal observations when two or more variables are present. Box and whisker plots are a contemporary tool, which provides pictorial representations for making informal comparisons/conclusions of the range and location of multiple data sets. It shows only certain statistics rather than all the data. *Five-number summary* is another name for the visual representations of the box-and-whisker plot. The five-number summary consists of the median, the quartiles, and the smallest and greatest values in the distribution. Immediate visuals of a box-and-whisker plot are the center, the spread, and the overall range of distribution.

The first step in constructing a box-and-whisker plot is to first find the *median*, the *lower quartile* and the *upper quartile* of a given set of data. Example: The following set of numbers is the amount of marbles fifteen different boys own (they are arranged from least to greatest).

18 27 34 52 54 59 61 68 78 82 85 87 91 93 100

- First find the *median.* The *median* is the value exactly in the middle of an ordered set of numbers.

68 is the median

- Next, we consider only the values to the left of the median: 18 27 34 52 54 59 61. We now find the median of this set of numbers. Remember, the median is the value exactly in the middle of an ordered set of numbers. Thus 52 is the median of the scores, which are less than the median of all scores, and therefore is the *lower quartile.*

52 is the lower quartile

- Now consider only the values to the right of the median: 78 82 85 87 91 93 100. We now find the median of this set of numbers. The median 87 is therefore called the *upper quartile.*

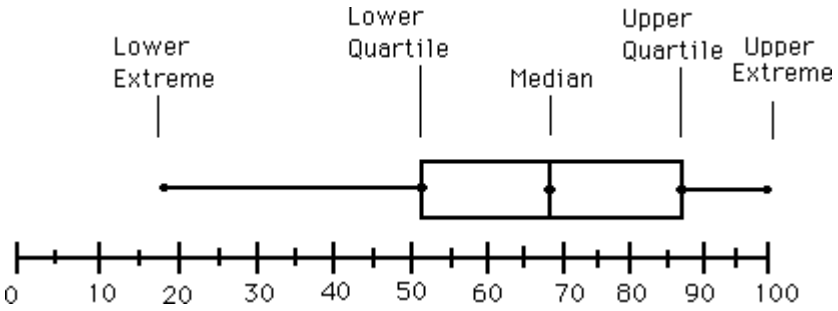
87 is the upper quartile

(*If you're finding the median in an ordered set with an even number of values, you must take the average of the two middle numbers. For example: 3, 5, 7, and 10. Add the two middle numbers. 5 + 7 = 12. Divided 12 by 2 to get the average. 12 / 2 = 6. Therefore 6 is the *median* for the ordered set of 3, 5, 7, and 10.)

- One is now ready to find the *inter-quartile range (IQR).* The inter-quartile range is the difference between the upper quartile and the lower quartile. In our case the *IQR* = 87 - 52 = 35. The *IQR* is a very useful measurement. It is useful because it is less influenced by extreme values; it limits the range to the middle 50% of the values.

35 is the inter-quartile range

Now we begin to draw our graph:



Box and Whicker plots are also very useful in identifying outliers or potential outliers in data sets. The upper and lower quartiles are frequently referred to as hinges.

Let D = the inter-quartile range.

When one draw the whiskers, extend the whiskers only 1.5*D in both directions away from the box. **Mild outliers** are data points above the upper hinge (i.e., quartile) by 1.5D to 3D or below the lower hinge by 1.5D to 3D. **Extreme outliers** are data elements, which are above the upper hinge by more than 3D or below the lower hinge by more than 3D.

References:

http://ellerbruch.nmu.edu/cs255/jnord/boxplot.html
Northern Michigan University (nmu)

http://www.math.uncc.edu/~droyster/courses/spring00/maed3103/Box_Plots.htm
University of North Carolina at Charlotte (uncc)

APPENDIX G—SELECTED BOX AND WHISKER PLOTS

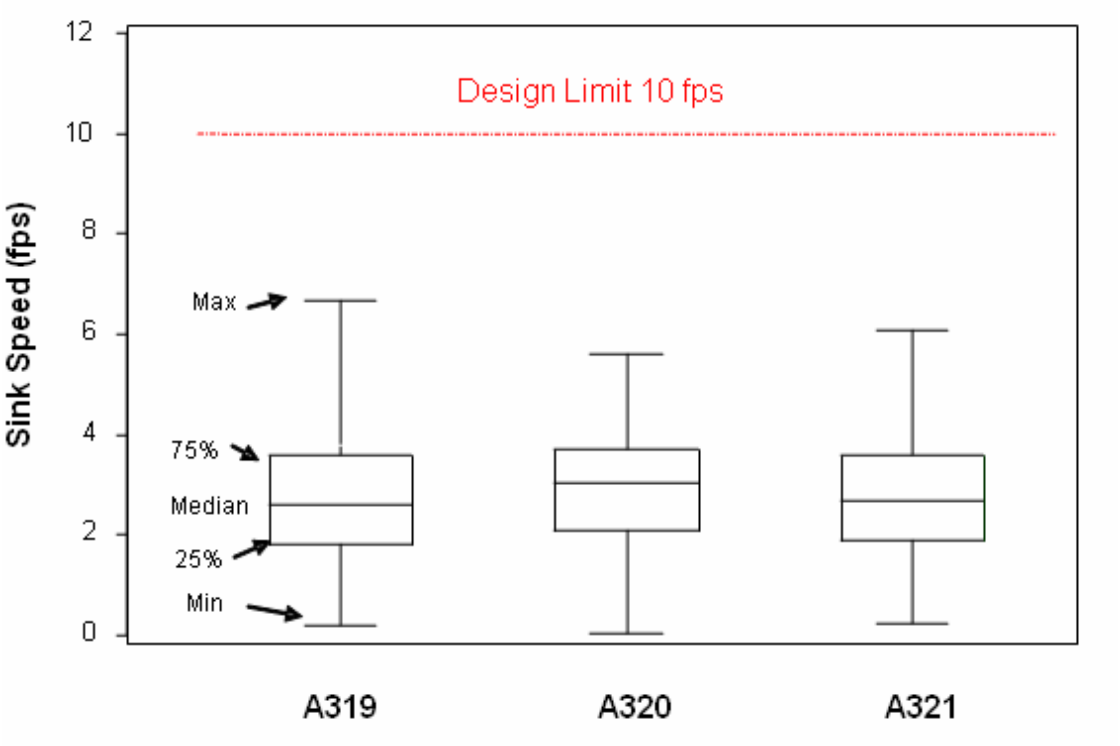


Figure G-1. Sink Speeds—Airbus Narrow-Body Aircraft, LHR

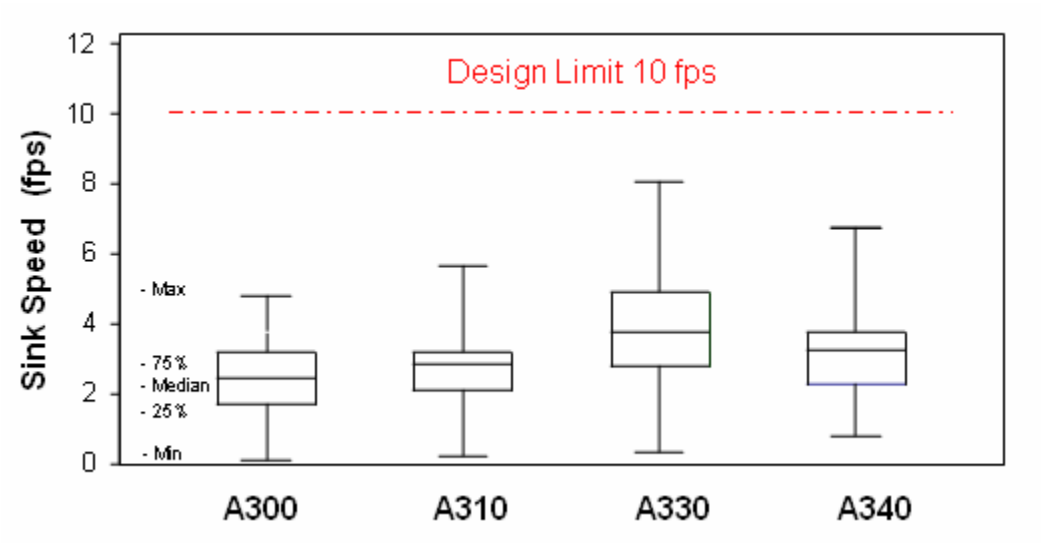


Figure G-2. Sink Speeds—Airbus Wide-Body Aircraft, LHR

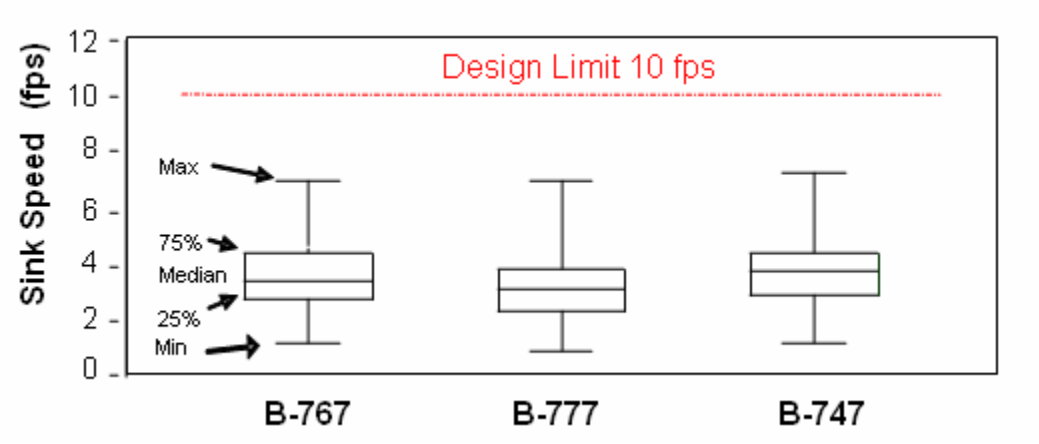


Figure G-3. Sink Speeds-Boeing Wide—Body Aircraft, LHR

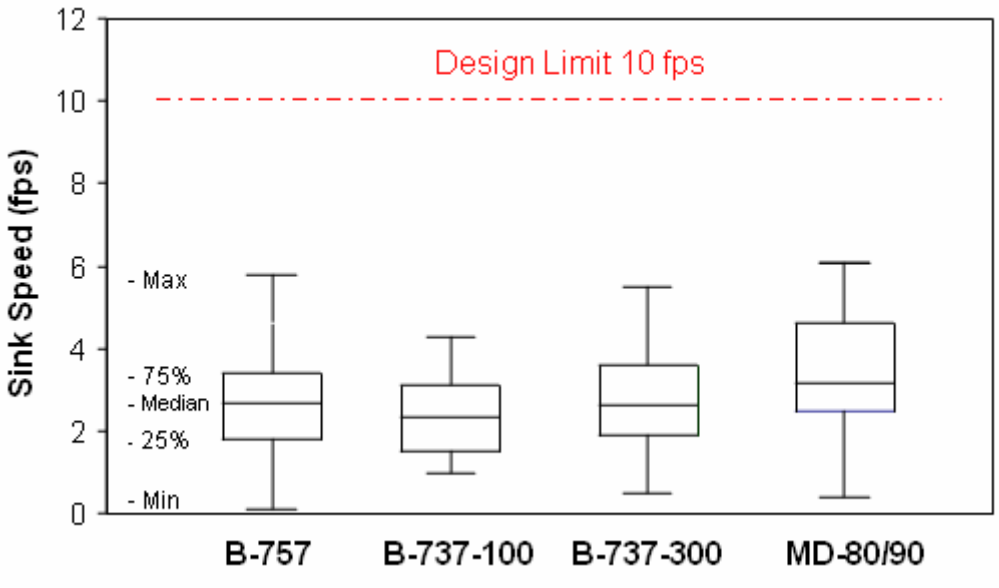


Figure G-4. Sink Speeds—Boeing Narrow-Body Aircraft, LHR

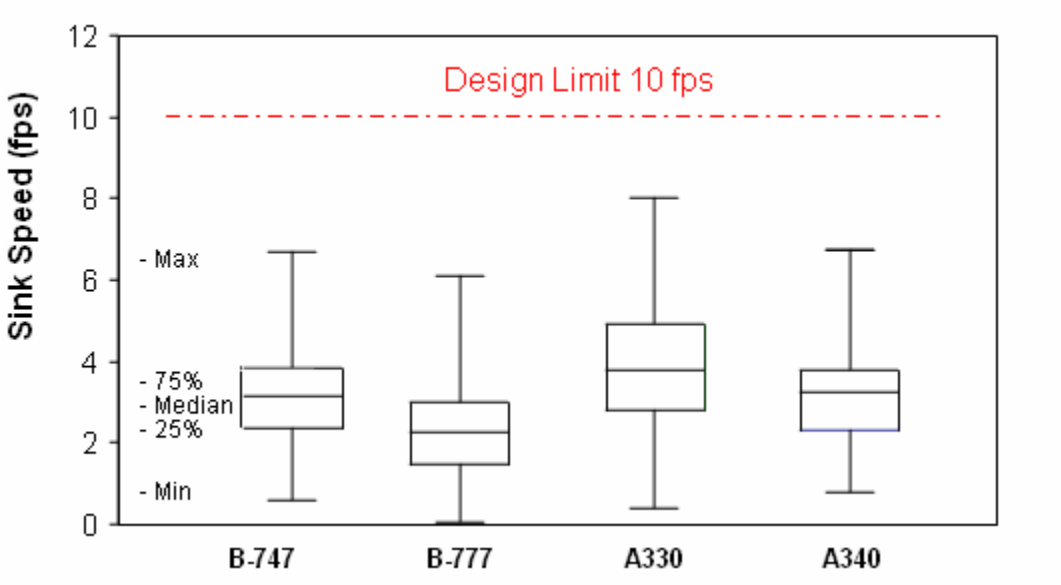


Figure G-5. Sink Speed—Wide-Body Comparison, LHR

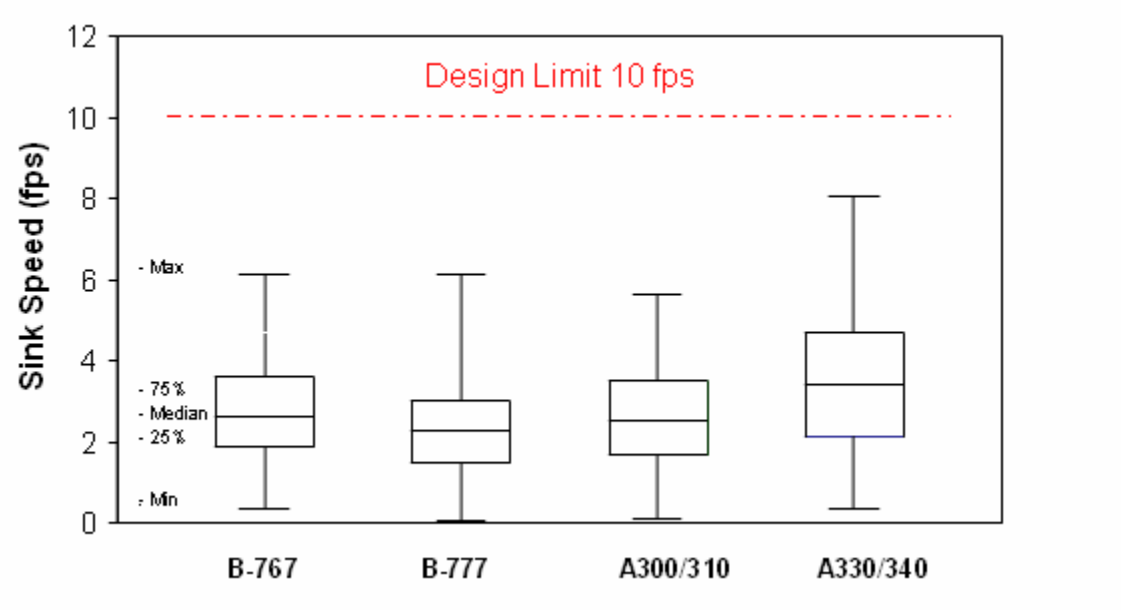


Figure G-6. Sink Speed—Medium Wide-Body Comparison, LHR

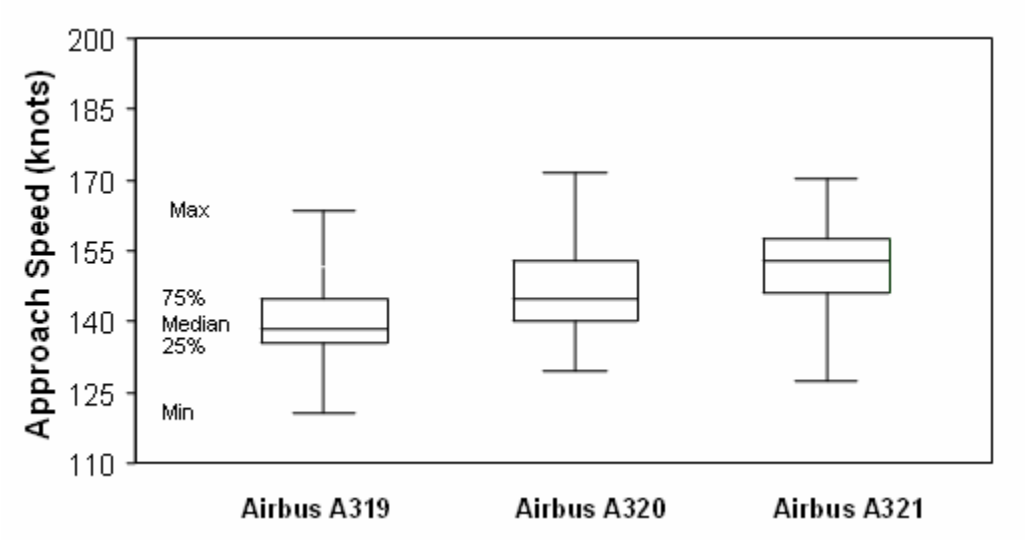


Figure G-7. Approach Speeds—Airbus Narrow-Body Aircraft, LHR

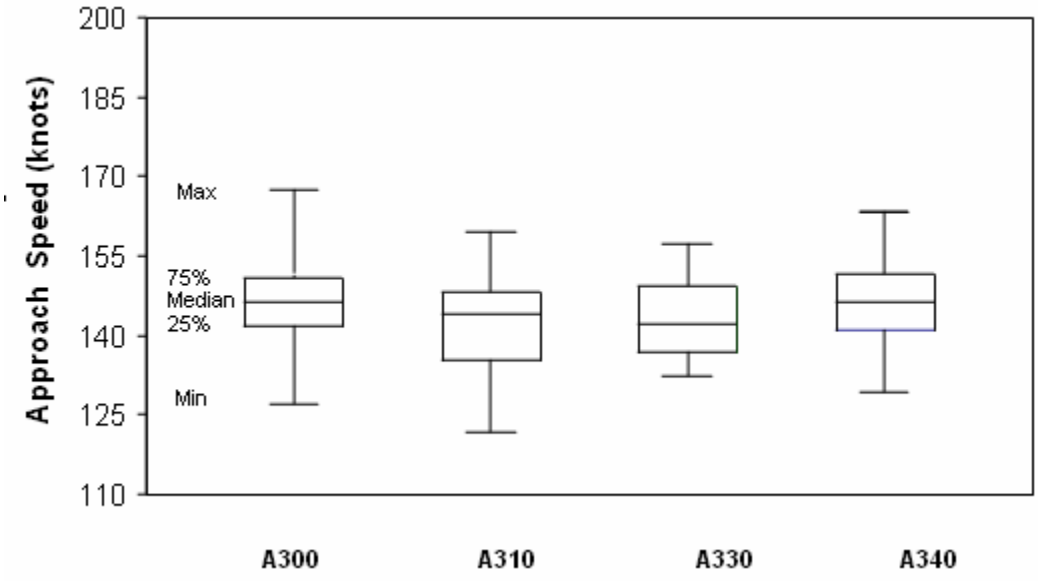


Figure G-8. Approach Speeds—Airbus Wide-Body Aircraft, LHR

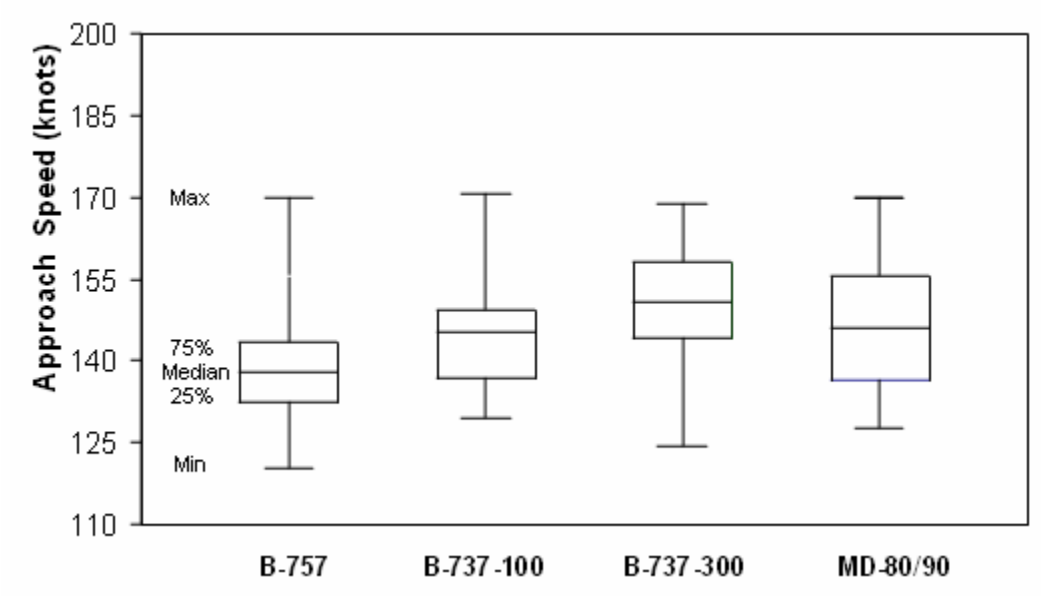


Figure G-9. Approach Speeds—Boeing Narrow-Body Aircraft, LHR

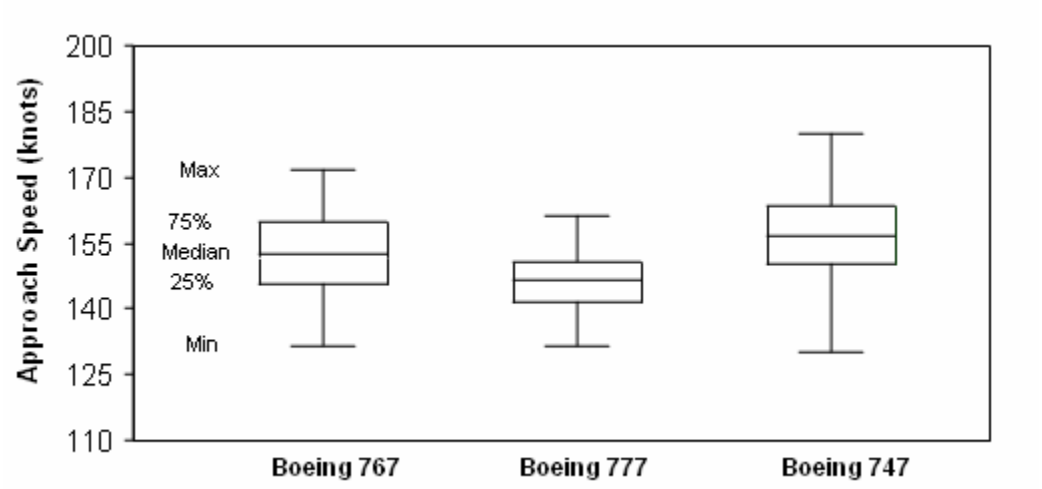


Figure G-10. Approach Speeds—Boeing Wide-Body Aircraft, LHR

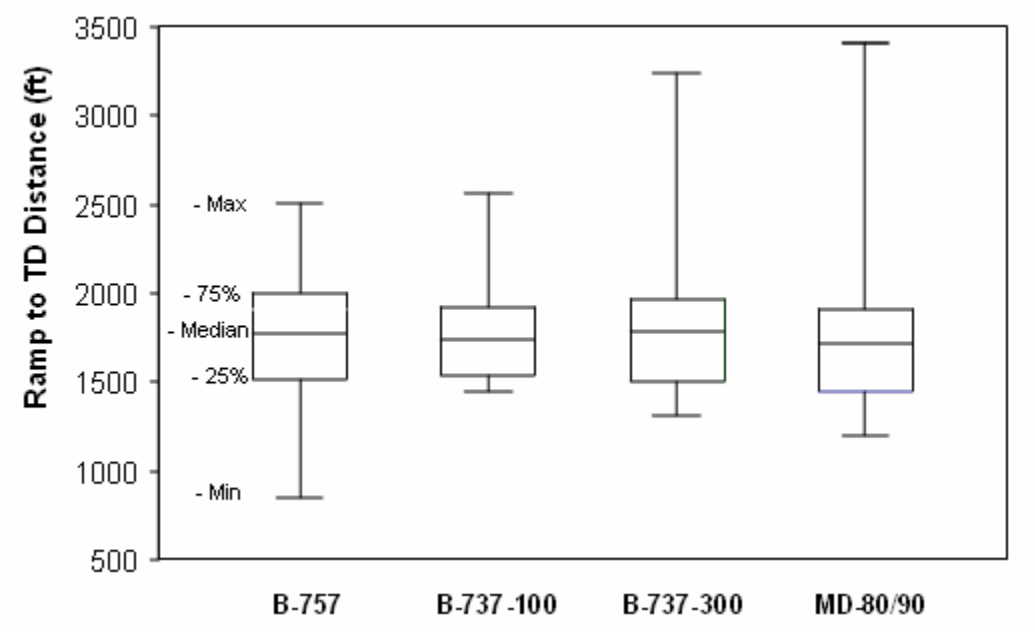


Figure G-11. Ramp to Touchdown Distance—Boeing Narrow-Body Aircraft, LHR

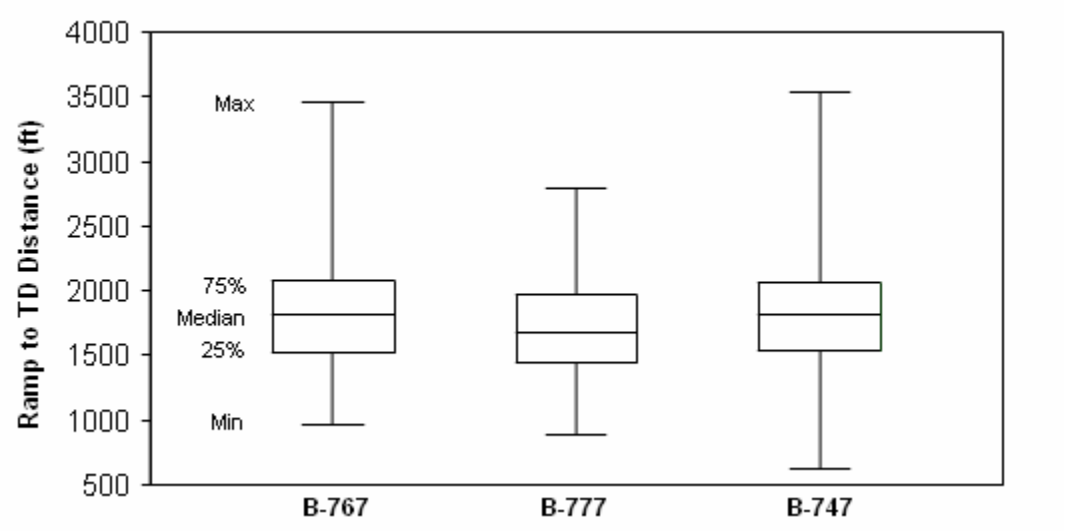


Figure G-12. Ramp to Touchdown Distance—Boeing Wide-Body Aircraft, LHR

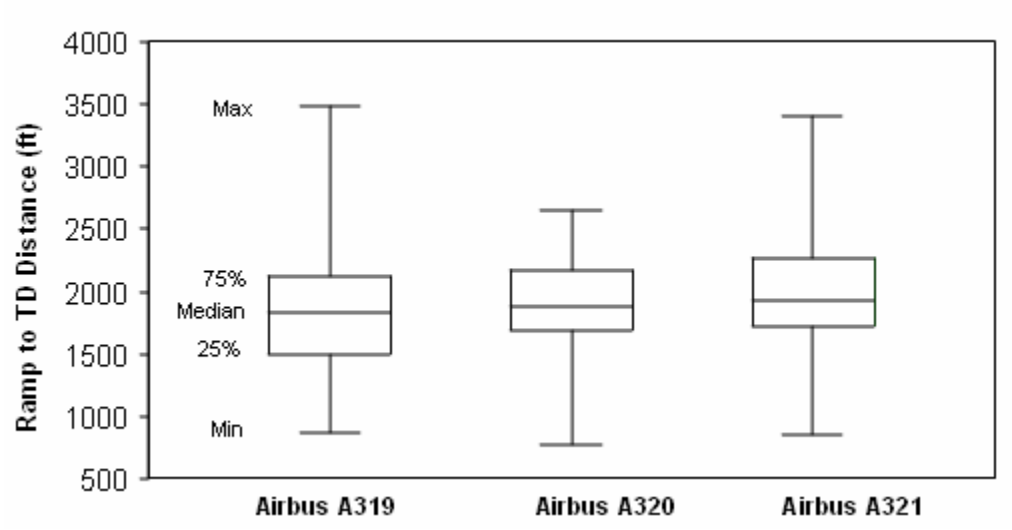


Figure G-13. Ramp to Touchdown Distance—Airbus Narrow-Body Aircraft, LHR

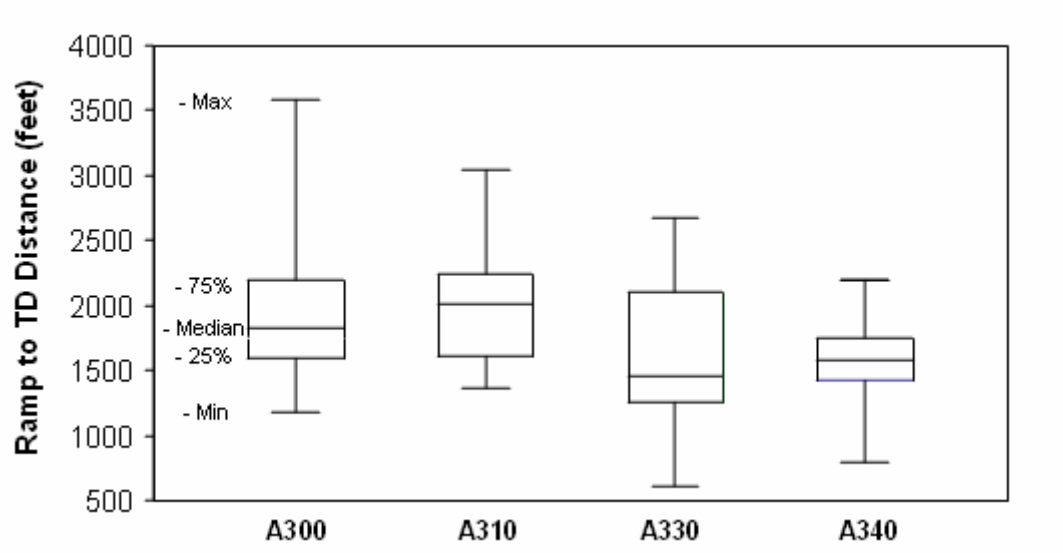


Figure G-14. Ramp to Touchdown Distance—Airbus Wide-Body Aircraft, LHR

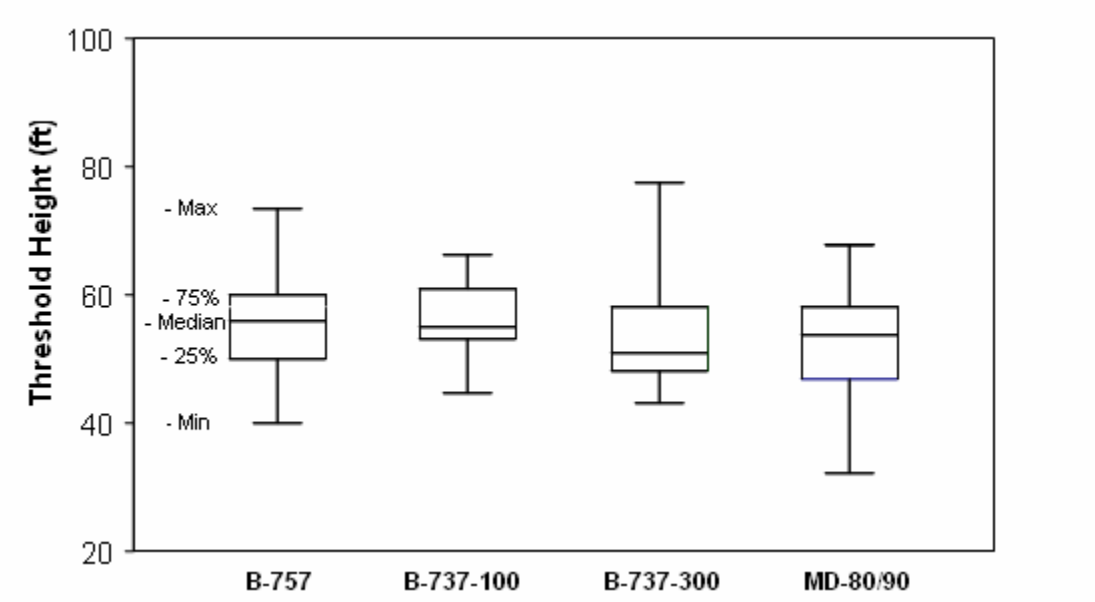


Figure G-15. Threshold Height—Boeing Narrow-Body Aircraft, LHR

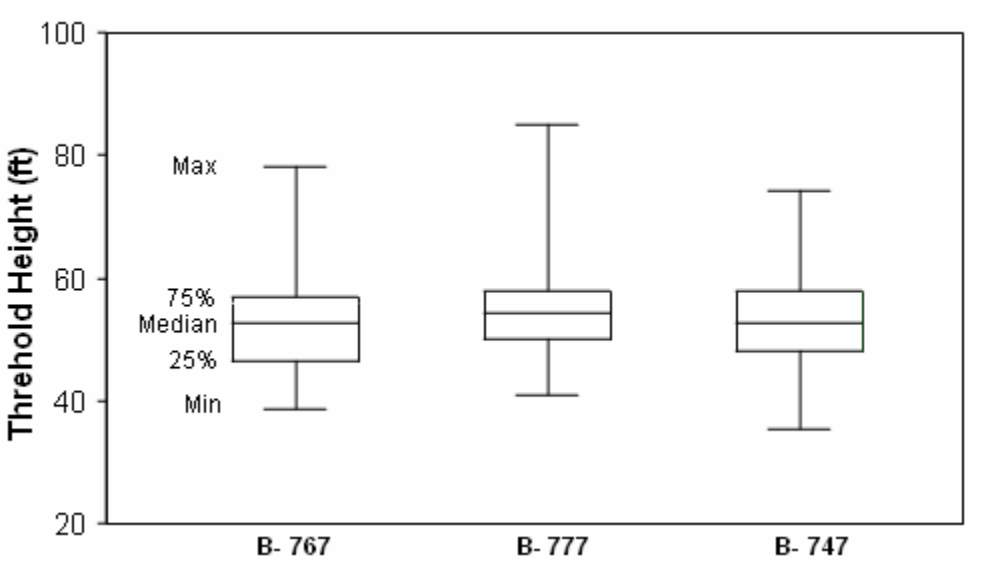


Figure G-16. Threshold Height—Boeing Wide-Body Aircraft, LHR

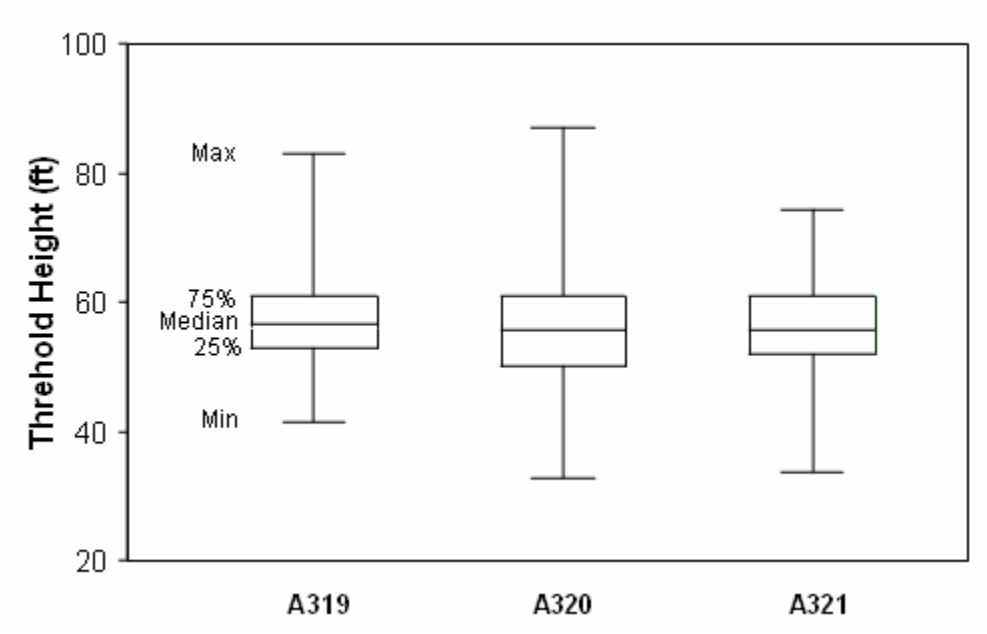


Figure G-17. Threshold Height—Airbus Narrow-Body Aircraft, LHR

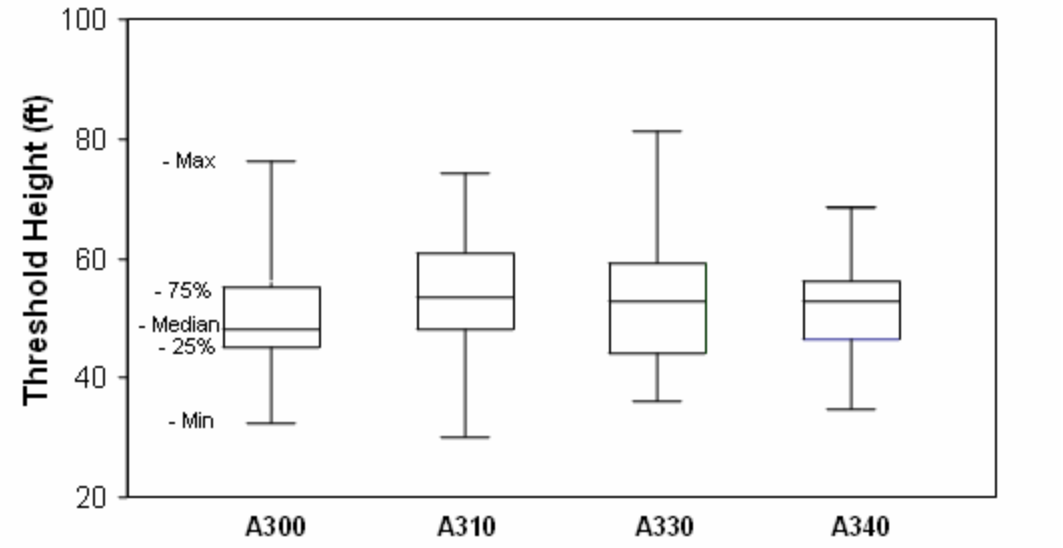


Figure G-18. Threshold Height—Airbus Wide-Body Aircraft, LHR

APPENDIX H—STATISTICAL ANALYSIS OF SURVEY AIRCRAFT BY THRESHOLD HEIGHT GROUP

Table H-1. Statistical Analysis of All Wide-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
All Wide-Body Aircraft Threshold Height <47 ft	Mean	149.6	142.7	42.5	2.82	7.81	-0.35	-1.09	1523
	Standard error	0.92	1.03	0.31	0.11	0.25	0.12	0.67	36.6
	Median	150.53	143.20	43.34	2.75	7.20	-0.20	0.00	1495.0
	Standard dev.	10.02	11.29	3.34	1.24	2.72	1.32	7.35	399.5
	Sample var.	100.42	127.40	11.18	1.55	7.42	1.75	54.08	1.60E+05
	Kurtosis	-0.24	0.22	1.01	-0.35	2.43	0.44	1.03	3.82
	Skewness	0.04	-0.02	-0.99	0.39	1.30	-0.05	-0.31	0.88
	Range	49.3	60.7	16.5	5.86	16.10	7.20	46.00	2851
	Minimum	127.1	112.4	29.9	0.25	3.30	-4.40	-22.00	602
	Maximum	176.4	173.1	46.5	6.11	19.40	2.80	24.00	3453
	Count	119	119	119	119	119	119	119	119
All Wide-Body Aircraft Threshold Height 46 ft <TH <59 ft	Mean	152.4	147.2	52.9	2.77	7.32	-0.36	-2.68	1811
	Standard error	0.63	0.70	0.20	0.07	0.12	0.07	0.41	22.8
	Median	151.63	147.20	52.80	2.62	7.00	-0.30	-2.00	1794.0
	Standard dev.	10.40	11.54	3.26	1.23	2.06	1.22	6.80	377.8
	Sample var.	108.23	133.07	10.60	1.52	4.25	1.49	46.29	1.43E+05
	Kurtosis	-0.51	-0.31	-1.05	1.40	2.56	0.67	1.19	1.00
	Skewness	0.24	-0.13	-0.12	0.66	1.42	0.38	-0.25	0.53
	Range	49.0	63.0	11.3	8.00	11.00	7.20	50.00	2662
	Minimum	130.9	111.9	47.0	0.04	3.60	-3.30	-29.00	917
	Maximum	179.9	174.9	58.3	8.04	14.60	3.90	21.00	3579
	Count	274	274	274	274	274	274	274	274
All Wide-Body Aircraft Threshold Height >58 ft	Mean	151.5	146.6	64.6	2.88	7.61	-0.47	-3.55	2136
	Standard error	1.16	1.19	0.50	0.13	0.24	0.16	0.88	45.6
	Median	151.77	144.10	63.83	2.92	7.10	-0.40	-3.00	2075.0
	Standard dev.	11.93	12.19	5.10	1.33	2.44	1.64	8.98	467.6
	Sample var.	142.29	148.61	26.05	1.78	5.96	2.69	80.60	2.19E+05
	Kurtosis	-0.54	-0.67	2.35	-0.55	0.54	0.58	5.05	0.17
	Skewness	-0.11	0.25	1.37	0.10	0.98	0.29	0.82	0.62
	Range	53.9	52.2	26.0	5.61	11.40	8.20	69.00	2296
	Minimum	121.6	123.1	59.1	0.25	2.90	-4.30	-28.00	1238
	Maximum	175.4	175.3	85.1	5.86	14.30	3.90	41.00	3534
	Count	105	105	105	105	105	105	105	105

TD = Touchdown
TH = Threshold height

Table H-2. Statistical Analysis of All Narrow-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
All Narrow-Body Aircraft Threshold Height <51 ft	Mean	143.5	136.9	46.2	2.75	6.09	-0.36	-0.17	1599
	Standard error	1.06	1.22	0.38	0.12	0.17	0.14	0.56	34.1
	Median	142.70	137.50	47.06	2.63	6.00	-0.30	1.00	1504.5
	Standard dev.	11.34	13.06	4.01	1.32	1.77	1.49	5.98	364.3
	Sample var.	128.60	170.68	16.11	1.73	3.15	2.21	35.73	1.33E+05
	Kurtosis	-0.61	-0.06	2.06	-0.17	10.15	-0.16	0.30	2.84
	Skewness	0.14	-0.36	-1.43	0.40	2.47	-0.12	-0.50	1.02
	Range	50.3	68.6	17.5	6.15	11.90	7.30	30.00	2397
	Minimum	120.2	96.2	32.7	0.15	2.80	-3.80	-17.00	849
	Maximum	170.5	164.8	50.2	6.30	14.70	3.50	13.00	3246
	Count	114	114	114	114	114	114	114	114
All Narrow-Body Aircraft Threshold Height 50 ft <TH <60 ft	Mean	143.9	138.2	56.2	2.72	5.67	-0.33	-0.51	1868
	Standard error	0.68	0.72	0.19	0.08	0.08	0.09	0.38	21.8
	Median	143.00	138.65	55.83	2.74	5.80	-0.20	-0.50	1833.0
	Standard dev.	10.39	10.96	2.98	1.21	1.24	1.43	5.84	333.2
	Sample var.	108.04	120.22	8.86	1.46	1.54	2.04	34.12	1.11E+05
	Kurtosis	-0.41	-0.23	-1.04	-0.29	1.06	0.16	1.03	1.48
	Skewness	0.28	-0.11	0.02	0.10	-0.14	-0.24	0.06	0.68
	Range	50.7	52.9	10.4	6.04	8.50	8.30	40.00	2297
	Minimum	120.7	110.0	51.0	0.05	2.00	-4.50	-18.00	1182
	Maximum	171.4	162.9	61.4	6.09	10.50	3.80	22.00	3479
	Count	234	234	234	234	234	234	234	234
All Narrow-Body Aircraft Threshold Height 61 ft <TH	Mean	143.2	136.7	66.6	2.89	5.56	-0.58	-1.84	2142
	Standard error	1.17	1.17	0.55	0.13	0.17	0.18	0.63	42.7
	Median	143.45	136.35	65.40	2.91	5.60	-0.70	-2.00	2151.0
	Standard dev.	10.58	10.63	4.96	1.18	1.50	1.66	5.72	386.9
	Sample var.	111.91	113.08	24.61	1.38	2.25	2.74	32.68	1.50E+05
	Kurtosis	-0.34	-0.14	4.20	0.44	0.10	-0.56	0.92	1.36
	Skewness	0.20	0.10	1.98	0.00	0.32	0.13	-0.14	0.49
	Range	47.0	49.1	24.7	6.59	7.30	7.80	32.00	2244
	Minimum	121.5	112.6	62.2	0.10	2.40	-4.00	-19.00	1161
	Maximum	168.5	161.7	86.9	6.69	9.70	3.80	13.00	3405
	Count	82	82	82	82	82	82	82	82

TD = Touchdown
TH = Threshold height

Table H-3. Statistical Analysis of All Boeing Wide-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
Boeing Wide-Body Aircraft Threshold Height <48 ft	Mean	151.3	144.7	43.7	2.87	6.76	-0.42	-0.78	1568
	Standard error	0.99	1.09	0.30	0.12	0.16	0.13	0.69	41.3
	Median	151.70	144.50	44.13	2.77	6.60	-0.35	0.00	1529.5
	Standard dev.	9.50	10.46	2.85	1.14	1.49	1.29	6.66	396.5
	Sample var.	90.27	109.40	8.13	1.31	2.22	1.67	44.34	1.57E+05
	Kurtosis	-0.02	0.14	0.11	-0.44	0.18	0.74	0.90	4.46
	Skewness	0.13	0.12	-0.81	0.43	0.08	0.08	-0.75	1.12
	Range	44.2	53.9	11.8	5.14	7.20	7.20	33.00	2832
	Minimum	132.2	119.2	35.5	0.97	3.30	-4.40	-20.00	621
	Maximum	176.4	173.1	47.3	6.11	10.50	2.80	13.00	3453
	Count	92	92	92	92	92	92	92	92
Boeing Wide-Body Aircraft Threshold Height 47 ft <TH <59 ft	Mean	153.7	149.2	53.4	2.72	6.66	-0.35	-3.16	1809
	Standard error	0.73	0.75	0.21	0.08	0.09	0.08	0.47	25.5
	Median	153.43	148.40	53.58	2.60	6.70	-0.30	-3.00	1806.0
	Standard dev.	10.46	10.78	3.02	1.17	1.29	1.21	6.73	365.2
	Sample var.	109.47	116.23	9.14	1.37	1.66	1.46	45.26	1.33E+05
	Kurtosis	-0.52	-0.56	-1.05	0.56	0.15	1.04	1.52	-0.49
	Skewness	0.13	-0.02	-0.09	0.48	0.28	0.43	-0.20	0.19
	Range	48.6	53.2	10.2	6.38	7.80	7.00	50.00	1748
	Minimum	131.3	121.7	48.1	0.04	3.60	-3.10	-29.00	917
	Maximum	179.9	174.9	58.3	6.42	11.40	3.90	21.00	2665
	Count	205	205	205	205	205	205	205	205
Boeing Wide-Body Aircraft Threshold Height >58 ft	Mean	154.0	149.4	64.3	2.80	6.75	-0.47	-3.79	2129
	Standard error	1.26	1.33	0.57	0.14	0.17	0.17	1.04	51.9
	Median	153.91	147.45	62.65	2.77	6.55	-0.45	-4.50	2066.0
	Standard dev.	11.11	11.76	5.08	1.24	1.51	1.54	9.20	458.0
	Sample var.	123.48	138.33	25.76	1.53	2.28	2.39	84.62	2.10E+05
	Kurtosis	-0.57	-0.68	2.66	-0.21	0.04	0.65	6.59	0.51
	Skewness	-0.15	-0.02	1.42	0.20	0.35	0.16	1.03	0.76
	Range	45.5	50.8	26.0	5.61	8.00	8.00	69.00	2109
	Minimum	129.9	124.5	59.1	0.25	2.90	-4.30	-28.00	1425
	Maximum	175.4	175.3	85.1	5.86	10.90	3.70	41.00	3534
	Count	78	78	78	78	78	78	78	78

TD = Touchdown
TH = Threshold height

Table H-4. Statistical Analysis of All Airbus Wide-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
Airbus Wide-Body Aircraft Threshold Height <46 ft	Mean	145.0	136.7	40.1	2.77	10.48	-0.23	-0.84	1426
	Standard error	1.95	2.11	0.70	0.28	0.65	0.27	1.52	75.9
	Median	143.60	139.80	40.19	3.00	10.60	0.20	0.50	1417.0
	Standard dev.	10.51	11.36	3.79	1.52	3.52	1.46	8.18	408.6
	Sample var.	110.37	129.05	14.37	2.32	12.42	2.14	66.95	1.67E+05
	Kurtosis	-0.47	-0.14	0.54	-0.54	-0.04	-0.20	1.52	0.59
	Skewness	0.33	-0.25	-0.80	0.22	0.20	-0.38	0.72	0.07
	Range	40.4	48.6	15.0	5.50	15.20	6.10	38.00	1786
	Minimum	127.1	112.4	29.9	0.25	4.20	-3.30	-14.00	602
	Maximum	167.5	161.0	44.9	5.75	19.40	2.80	24.00	2388
	Count	29	29	29	29	29	29	29	29
Airbus Wide-Body Aircraft Threshold Height 45 ft <TH <59 ft	Mean	146.1	139.0	51.7	2.93	9.95	-0.28	-1.76	1820
	Standard error	0.98	1.46	0.48	0.20	0.34	0.17	1.00	55.7
	Median	146.40	139.70	52.01	2.79	9.30	-0.40	0.00	1751.0
	Standard dev.	7.43	11.03	3.59	1.47	2.55	1.30	7.54	420.4
	Sample var.	55.19	121.75	12.86	2.17	6.52	1.70	56.92	1.77E+05
	Kurtosis	0.03	-0.15	-1.28	2.20	-0.91	-0.15	0.81	4.51
	Skewness	0.14	-0.09	-0.01	0.99	0.36	0.20	-0.55	1.39
	Range	32.44	54.90	12.61	7.95	9.60	6.10	38.00	2586
	Minimum	130.90	111.90	45.70	0.09	5.00	-3.30	-22.00	993
	Maximum	163.34	166.80	58.31	8.04	14.60	2.80	16.00	3579
	Count	57	57	57	57	57	57	57	57
Airbus Wide-Body Aircraft Threshold Height >58 ft	Mean	142.6	137.0	65.7	3.00	10.09	-0.52	-2.68	2155
	Standard error	2.00	1.44	1.07	0.32	0.60	0.40	1.75	104.0
	Median	142.50	138.40	65.40	3.10	10.20	-0.40	-3.00	2098.0
	Standard dev.	9.98	7.20	5.33	1.61	3.01	1.99	8.74	519.9
	Sample var.	99.55	51.89	28.46	2.59	9.03	3.97	76.31	2.70E+05
	Kurtosis	-0.79	-0.20	2.00	-1.09	-1.01	0.32	-0.79	-0.50
	Skewness	-0.18	0.09	1.33	-0.10	-0.32	0.58	0.01	0.30
	Range	36.6	30.1	22.1	5.34	10.10	8.10	30.00	1987
	Minimum	121.6	123.1	59.1	0.30	4.20	-4.20	-16.00	1238
	Maximum	158.2	153.2	81.2	5.64	14.30	3.90	14.00	3225
	Count	25	25	25	25	25	25	25	25

TD = Touchdown
TH = Threshold height

Table H-5. Statistical Analysis of All Boeing Narrow-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
Boeing Narrow-Body Aircraft Threshold Height <51 ft	Mean	141.4	135.6	46.4	2.65	6.22	-0.24	0.02	1582
	Standard error	1.41	1.70	0.43	0.16	0.25	0.17	0.81	45.9
	Median	140.47	137.50	47.06	2.60	5.90	-0.20	1.00	1479.5
	Standard dev.	11.44	13.80	3.46	1.31	2.05	1.40	6.59	372.9
	Sample var.	130.77	190.38	11.95	1.72	4.22	1.96	43.43	1.39E+05
	Kurtosis	-0.57	0.09	2.47	0.17	9.09	-0.38	0.03	5.38
	Skewness	0.22	-0.43	-1.29	0.63	2.74	-0.10	-0.55	1.73
	Range	45.9	68.6	17.5	5.65	11.30	6.50	30.00	2397
	Minimum	120.2	96.2	32.7	0.15	3.40	-3.40	-17.00	849
	Maximum	166.1	164.8	50.2	5.80	14.70	3.10	13.00	3246
	Count	66	66	66	66	66	66	66	66
Boeing Narrow-Body Aircraft Threshold Height 50 ft <TH <64 ft	Mean	141.0	136.6	56.6	2.66	5.81	-0.18	0.17	1832
	Standard error	0.92	1.04	0.31	0.10	0.11	0.13	0.46	27.4
	Median	139.61	135.80	55.83	2.63	5.90	-0.10	0.00	1805.0
	Standard dev.	10.10	11.45	3.36	1.14	1.24	1.43	5.04	301.2
	Sample var.	102.10	131.02	11.29	1.31	1.53	2.04	25.36	9.07E+04
	Kurtosis	0.03	-0.37	-0.87	-0.15	0.50	-0.08	0.33	-0.65
	Skewness	0.52	0.02	0.24	0.13	-0.16	0.18	0.56	0.29
	Range	47.7	50.5	12.0	5.97	7.00	6.90	25.00	1239
	Minimum	121.9	110.0	51.0	0.10	2.60	-3.10	-11.00	1182
	Maximum	169.6	160.5	63.0	6.07	9.60	3.80	14.00	2421
	Count	121	121	121	121	121	121	121	121
Boeing Narrow-Body Aircraft Threshold Height 63 ft <TH	Mean	139.0	132.8	67.2	3.00	5.49	-0.49	-2.48	2071
	Standard error	1.54	1.76	0.61	0.21	0.33	0.29	0.89	56.9
	Median	140.00	133.60	66.20	3.10	5.30	-0.70	-2.00	1979.0
	Standard dev.	8.03	9.14	3.16	1.09	1.70	1.49	4.60	295.6
	Sample var.	64.40	83.46	10.00	1.19	2.89	2.23	21.18	8.74E+04
	Kurtosis	-0.28	-0.16	3.14	-0.73	0.31	-0.89	-0.87	-1.13
	Skewness	-0.56	-0.43	1.59	-0.11	0.45	-0.13	-0.13	0.32
	Range	30.4	36.7	13.6	3.94	7.30	5.40	18.00	1050
	Minimum	121.5	112.6	63.8	0.95	2.40	-3.50	-12.00	1513
	Maximum	151.9	149.3	77.4	4.89	9.70	1.90	6.00	2563
	Count	27	27	27	27	27	27	27	27

TD = Touchdown
TH = Threshold height

Table H-6. Statistical Analysis of All Airbus Narrow-Body Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
Airbus Narrow-Body Aircraft Threshold Height <52 ft	Mean	146.0	138.7	46.6	2.79	5.84	-0.39	-0.04	1616
	Standard error	1.38	1.53	0.62	0.18	0.17	0.20	0.67	44.1
	Median	146.00	137.60	47.85	2.61	6.10	-0.20	1.00	1577.0
	Standard dev.	10.42	11.57	4.70	1.33	1.25	1.51	5.08	332.97
	Sample var.	108.57	133.78	22.13	1.77	1.56	2.27	25.78	1.11E+05
	Kurtosis	-0.69	-0.80	1.60	-0.43	-0.78	0.29	0.73	-0.27
	Skewness	0.17	-0.02	-1.47	0.21	-0.18	-0.29	-0.36	-0.03
	Range	42.8	44.3	18.3	6.08	5.40	7.30	26.00	1420
	Minimum	127.7	114.3	32.7	0.22	2.80	-3.80	-15.00	853
	Maximum	170.5	158.6	51.0	6.30	8.20	3.50	11.00	2273
	Count	57	57	57	57	57	57	57	57
Airbus Narrow-Body Aircraft Threshold Height 51 ft <TH <62 ft	Mean	146.5	139.5	56.7	2.81	5.54	-0.53	-1.32	1934
	Standard error	0.97	0.99	0.26	0.12	0.12	0.14	0.60	33.64
	Median	146.36	140.95	56.63	2.94	5.70	-0.50	-1.00	1866.50
	Standard dev.	10.39	10.62	2.78	1.27	1.29	1.51	6.45	359.13
	Sample var.	108.05	112.79	7.72	1.60	1.66	2.28	41.55	1.29E+05
	Kurtosis	-0.43	-0.09	-1.05	-0.28	1.52	0.06	1.04	2.04
	Skewness	0.08	-0.22	0.06	-0.09	-0.02	-0.34	-0.04	0.74
	Range	50.7	50.8	9.6	6.04	8.50	7.50	40.00	2204
	Minimum	120.7	112.1	51.8	0.05	2.00	-4.50	-18.00	1275
	Maximum	171.4	162.9	61.4	6.09	10.5	3	22	3479
	Count	114	114	114	114	114	114	114	114
Airbus Narrow-Body Aircraft Threshold Height 61 ft <TH	Mean	146.5	139.2	67.0	2.89	5.58	-0.74	-2.04	2231
	Standard error	1.54	1.52	0.89	0.18	0.21	0.25	0.97	62.45
	Median	144.93	136.90	65.40	2.83	5.70	-0.90	-2.00	2263.00
	Standard dev.	10.32	10.20	5.99	1.21	1.38	1.66	6.51	418.90
	Sample var.	106.45	103.95	35.92	1.45	1.91	2.77	42.41	1.75E+05
	Kurtosis	-0.87	-0.15	2.51	1.06	0.12	-0.77	0.88	1.63
	Skewness	0.11	0.15	1.74	0.31	0.14	0.05	-0.10	0.42
	Range	41.8	42.7	24.7	6.39	6.40	6.60	32.00	2244
	Minimum	126.7	119.0	62.2	0.30	2.60	-4.00	-19.00	1161
	Maximum	168.5	161.7	86.9	6.69	9.00	2.60	13.00	3405
	Count	45	45	45	45	45	45	45	45

TD = Touchdown
TH = Threshold height

Table H-7. Statistical Analysis of Boeing 767 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
B-767 Threshold Height <47 ft	Mean	148.8	141.5	43.3	2.86	5.83	-0.33	-0.36	1613
	Standard error	1.74	2.01	0.45	0.25	0.21	0.32	1.31	93.1
	Median	149.24	143.00	43.73	2.57	5.80	-0.15	0.00	1551.0
	Standard dev.	9.22	10.63	2.39	1.32	1.12	1.69	6.95	492.8
	Sample var.	84.97	112.99	5.70	1.75	1.26	2.87	48.31	2.43E+05
	Kurtosis	-0.81	-0.25	-0.74	-0.22	0.12	0.49	0.79	6.4
	Skewness	0.02	0.15	-0.48	0.82	0.02	-0.21	-0.36	2.0
	Range	34.4	41.8	7.9	4.82	4.90	7.20	31.00	2490
	Minimum	133.6	122.3	38.6	1.29	3.50	-4.40	-18.00	963
	Maximum	168.0	164.1	46.5	6.11	8.40	2.80	13.00	3453
	Count	28	28	28	28	28	28	28	28
B-767 Threshold Height 46 ft <TH <57 ft	Mean	153.0	147.2	52.2	2.87	5.70	-0.51	-1.52	1846
	Standard error	1.43	1.56	0.42	0.17	0.18	0.18	0.74	51.3
	Median	153.29	147.20	52.40	2.79	5.50	-0.25	0.00	1832.0
	Standard dev.	9.47	10.37	2.76	1.13	1.17	1.18	4.88	340.2
	Sample var.	89.72	107.60	7.63	1.28	1.38	1.39	23.79	1.16E+05
	Kurtosis	-0.67	-0.53	-1.16	0.59	-0.40	1.15	-0.13	-0.6
	Skewness	-0.23	-0.19	-0.37	0.26	0.56	0.40	-0.27	0.4
	Range	39.6	44.2	8.9	5.68	5.00	5.80	23.00	1243
	Minimum	131.5	121.7	47.0	0.35	3.60	-2.50	-13.00	1265
	Maximum	171.1	165.9	55.9	6.03	8.60	3.30	10.00	2508
	Count	44	44	44	44	44	44	44	44
B-767 Threshold Height 56 ft <TH	Mean	154.5	148.7	61.9	2.59	6.15	-0.69	-2.39	2044
	Standard error	1.77	2.16	0.92	0.20	0.29	0.28	1.98	78.4
	Median	154.83	148.70	60.68	2.46	5.90	-0.60	-5.00	2018.0
	Standard dev.	9.38	11.41	4.87	1.06	1.53	1.49	10.48	414.7
	Sample var.	87.96	130.15	23.71	1.12	2.35	2.21	109.80	1.72E+05
	Kurtosis	-0.24	-0.81	-0.10	0.05	-0.02	0.17	10.65	0.5
	Skewness	-0.41	-0.37	0.87	0.43	0.37	-0.08	2.62	0.0
	Range	38.4	40.4	16.5	4.35	6.60	6.60	58.00	1913
	Minimum	133.2	124.5	56.7	0.60	2.90	-4.30	-17.00	1117
	Maximum	171.6	164.9	73.3	4.95	9.50	2.30	41.00	3030
	Count	28	28	28	28	28	28	28	28

TD = Touchdown
TH = Threshold height

Table H-8. Statistical Analysis of Boeing 777 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
B-777 Threshold Height <51 ft	Mean	145.2	141.4	47.0	2.29	6.52	-0.04	0.63	1549
	Standard error	1.42	1.17	0.56	0.20	0.20	0.24	1.07	69.3
	Median	144.18	140.40	47.67	2.11	6.35	-0.25	0.75	1534.0
	Standard dev.	7.49	6.17	2.96	1.07	1.08	1.30	5.65	366.9
	Sample var.	56.16	38.07	8.75	1.16	1.18	1.68	31.90	1.35E+05
	Kurtosis	-0.59	-0.70	-0.72	-0.69	0.02	1.19	1.32	2.5
	Skewness	0.04	-0.14	-0.55	0.25	0.60	0.94	-0.04	1.2
	Range	27.7	22.6	9.5	4.17	4.40	5.70	28.00	1769
	Minimum	132.8	129.0	41.0	0.47	4.90	-2.10	-13.00	885
	Maximum	160.5	151.6	50.4	4.64	9.30	3.60	15.00	2654
	Count	28	28	28	28	28	28	28	28
B-777 Threshold Height 50 ft <TH <58 ft	Mean	147.5	143.4	54.3	2.66	6.67	0.10	0.29	1730
	Standard error	1.42	1.55	0.31	0.20	0.21	0.28	1.33	69.8
	Median	146.68	144.30	54.37	2.41	6.70	0.10	0.00	1670.0
	Standard dev.	7.92	8.61	1.70	1.12	1.18	1.54	7.41	388.4
	Sample var.	62.70	74.21	2.89	1.25	1.38	2.37	54.88	1.51E+05
	Kurtosis	-0.78	-0.47	-1.00	2.74	7.90	0.57	1.21	-0.2
	Skewness	0.03	-0.14	-0.23	1.54	2.12	0.60	-0.89	0.5
	Range	29.8	34.9	5.5	5.11	6.40	6.30	32.00	1511
	Minimum	131.3	126.2	51.2	1.00	5.00	-2.40	-20.00	1044
	Maximum	161.1	161.1	56.7	6.11	11.40	3.90	12.00	2555
	Count	31	31	31	31	31	31	31	31
B-777 Threshold Height 57 ft <TH	Mean	145.7	144.7	62.5	2.01	6.42	-0.15	-0.50	1964
	Standard error	1.32	1.58	1.25	0.26	0.23	0.25	1.04	74.9
	Median	146.76	144.10	60.68	1.78	6.20	-0.30	-1.00	1941.0
	Standard dev.	6.60	7.88	6.23	1.30	1.13	1.25	5.20	374.4
	Sample var.	43.52	62.12	38.75	1.70	1.28	1.56	27.06	1.40E+05
	Kurtosis	0.01	0.63	6.40	0.07	5.34	1.78	0.27	-0.6
	Skewness	-0.31	-0.39	2.26	0.64	1.73	0.38	0.83	0.3
	Range	26.9	35.6	27.6	5.10	5.50	6.20	19.50	1414
	Minimum	131.8	124.9	57.5	0.04	4.90	-2.90	-7.00	1376
	Maximum	158.7	160.5	85.1	5.14	10.40	3.30	12.50	2790
	Count	25	25	25	25	25	25	25	25

TD = Touchdown
TH = Threshold height

Table H-9. Statistical Analysis of Boeing 747 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
B-747 Threshold Height <49 ft	Mean	155.4	149.2	44.1	2.91	7.46	-0.45	-2.00	1597
	Standard error	1.45	1.61	0.46	0.15	0.20	0.14	0.96	46.7
	Median	153.98	149.30	44.13	2.77	7.50	-0.35	-1.00	1633.5
	Standard dev.	10.65	11.82	3.38	1.11	1.44	1.02	7.04	343.0
	Sample var.	113.35	139.78	11.42	1.23	2.08	1.04	49.62	1.18E+05
	Kurtosis	0.26	-0.11	-0.06	-0.65	1.54	-0.75	0.69	-0.2
	Skewness	0.19	0.05	-0.82	0.06	-0.55	0.00	-0.91	-0.3
	Range	47.7	55.7	12.6	4.59	7.20	4.30	30.00	1690
	Minimum	132.2	119.2	35.5	0.64	3.30	-2.40	-20.00	621
	Maximum	179.9	174.9	48.1	5.23	10.50	1.90	10.00	2311
	Count	54	54	54	54	54	54	54	54
B-747 Threshold Height 48 ft <TH <59 ft	Mean	157.4	152.7	53.6	2.91	7.01	-0.48	-5.27	1841
	Standard error	0.99	1.06	0.29	0.12	0.12	0.11	0.68	38.7
	Median	157.73	153.80	53.58	2.89	6.95	-0.40	-5.00	1869.5
	Standard dev.	9.62	10.24	2.78	1.16	1.17	1.07	6.55	374.8
	Sample var.	92.61	104.78	7.70	1.35	1.37	1.15	42.84	1.40E+05
	Kurtosis	-0.74	-0.27	-1.08	0.65	-0.35	-0.28	3.32	-0.4
	Skewness	-0.05	-0.34	0.15	0.40	-0.06	-0.16	-0.11	-0.1
	Range	37.2	50.6	9.5	6.08	5.50	4.90	50.00	1748
	Minimum	138.3	122.9	48.9	0.34	3.90	-3.10	-29.00	917
	Maximum	175.6	173.5	58.3	6.42	9.40	1.80	21.00	2665
	Count	94	94	94	94	94	94	94	94
B-747 Threshold Height 58 ft <TH	Mean	157.8	151.9	63.7	3.09	7.32	-0.57	-6.50	2135
	Standard error	1.68	1.90	0.68	0.18	0.22	0.24	1.31	80.5
	Median	157.20	154.25	62.25	3.12	7.25	-0.80	-7.00	2044.5
	Standard dev.	10.88	12.32	4.39	1.16	1.43	1.57	8.50	521.8
	Sample var.	118.29	151.74	19.31	1.36	2.06	2.48	72.30	2.72E+05
	Kurtosis	-0.10	-0.86	-0.69	-0.01	-0.48	1.04	-0.03	0.4
	Skewness	-0.41	-0.14	0.77	0.30	0.15	0.36	-0.39	0.9
	Range	45.5	46.8	15.0	5.00	6.30	7.80	36.00	2109
	Minimum	129.9	128.5	59.1	0.86	4.60	-4.10	-28.00	1425
	Maximum	175.4	175.3	74.1	5.86	10.90	3.70	8.00	3534
	Count	42	42	42	42	42	42	42	42

TD = Touchdown
TH = Threshold height

Table H-10. Statistical Analysis of Airbus A300/310 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
A300/310 Threshold Height <46 ft	Mean	143.9	138.7	40.1	2.27	8.25	-0.56	-1.06	1615
	Standard error	2.73	2.67	1.01	0.30	0.58	0.34	1.37	81.0
	Median	144.22	136.80	40.98	2.31	8.20	0.00	1.00	1505.0
	Standard dev.	11.24	11.02	4.18	1.23	2.39	1.39	5.64	333.8
	Sample var.	126.30	121.39	17.50	1.51	5.69	1.92	31.81	1.11E+05
	Kurtosis	-0.11	0.06	1.18	-1.36	-0.94	-0.40	-1.72	0.5
	Skewness	0.45	0.04	-1.17	-0.20	0.00	-0.67	-0.23	1.0
	Range	40.4	43.9	15.0	3.67	7.90	4.80	16.00	1211
	Minimum	127.1	117.1	29.9	0.25	4.20	-3.30	-9.00	1177
	Maximum	167.5	161.0	44.9	3.92	12.10	1.50	7.00	2388
	Count	17	17	17	17	17	17	17	17
A300/310 Threshold Height 45 ft <TH <59 ft	Mean	146.7	139.8	51.4	2.52	8.36	-0.46	-1.58	1942
	Standard Error	1.22	1.78	0.64	0.18	0.23	0.20	1.22	71.6
	Median	146.70	141.10	52.01	2.49	8.15	-0.40	-0.50	1878.0
	Standard Dev.	7.30	10.67	3.82	1.06	1.40	1.22	7.32	429.6
	Sample Var.	53.26	113.91	14.59	1.11	1.97	1.49	53.56	1.85E+05
	Kurtosis	-0.23	-0.76	-1.37	0.42	0.11	-0.38	1.28	4.9
	Skewness	0.17	-0.29	0.20	-0.07	0.05	-0.16	-0.40	1.7
	Range	29.7	43.4	12.6	5.05	6.50	5.00	38.00	2209
	Minimum	133.2	115.7	45.7	0.09	5.00	-3.30	-22.00	1370
	Maximum	162.9	159.1	58.3	5.14	11.50	1.70	16.00	3579
	Count	36	36	36	36	36	36	36	36
A300/310 Threshold Height 58 ft <TH	Mean	143.5	137.9	66.1	2.75	7.86	-0.48	-5.07	2360
	Standard Error	2.67	1.77	1.24	0.44	0.52	0.59	1.99	133.9
	Median	144.50	139.00	65.40	3.03	8.10	-0.85	-4.50	2305.0
	Standard Dev.	10.00	6.61	4.65	1.65	1.94	2.20	7.44	501.0
	Sample Var.	100.04	43.64	21.63	2.74	3.78	4.82	55.30	2.51E+05
	Kurtosis	0.58	-0.98	0.83	-0.89	-0.78	0.15	-0.41	-1.0
	Skewness	-0.78	-0.43	1.01	-0.04	-0.48	0.97	0.17	0.2
	Range	36.1	21.0	16.5	5.34	6.10	6.80	24.00	1589
	Minimum	121.6	127.0	59.9	0.30	4.20	-2.90	-16.00	1636
	Maximum	157.7	148.0	76.4	5.64	10.30	3.90	8.00	3225
	Count	14	14	14	14	14	14	14	14

TD = Touchdown
TH = Threshold height

Table H-11. Statistical Analysis of Airbus A330/340 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
A330/340 Threshold Height <46 ft	Mean	146.6	133.8	39.9	3.47	13.63	0.25	-0.54	1160
	Standard error	2.78	3.37	0.96	0.48	0.64	0.43	3.21	104.3
	Median	142.90	139.95	39.40	3.43	13.60	0.50	-1.25	1251.5
	Standard dev.	9.63	11.67	3.33	1.67	2.21	1.50	11.13	361.4
	Sample var.	92.81	136.30	11.10	2.79	4.89	2.24	123.98	1.31E+05
	Kurtosis	-1.02	-0.92	-1.10	-0.82	4.25	-0.07	0.67	-1.4
	Skewness	0.35	-0.63	0.14	-0.13	1.45	-0.34	0.79	-0.4
	Range	30.0	35.7	10.2	4.95	9.00	5.40	38.00	1000
	Minimum	133.4	112.4	34.7	0.80	10.40	-2.60	-14.00	602
	Maximum	163.4	148.1	44.9	5.75	19.40	2.80	24.00	1602
	Count	12	12	12	12	12	12	12	12
A330/340 Threshold Height 45 ft <TH <60 ft	Mean	143.9	137.3	52.7	3.64	12.71	-0.07	-1.54	1641
	Standard error	1.71	2.36	0.76	0.36	0.32	0.30	1.65	68.0
	Median	144.29	135.00	52.80	3.60	12.90	-0.30	1.00	1585.0
	Standard dev.	8.18	11.34	3.64	1.74	1.54	1.45	7.93	326.1
	Sample var.	66.98	128.50	13.26	3.02	2.36	2.10	62.95	1.06E+05
	Kurtosis	0.32	1.37	-0.57	0.94	-0.23	-0.39	0.73	0.2
	Skewness	0.14	0.36	-0.12	0.71	-0.71	0.34	-0.91	0.1
	Range	34.0	54.9	12.6	7.67	5.60	5.30	33.00	1240
	Minimum	129.3	111.9	46.5	0.37	9.00	-2.50	-22.00	993
	Maximum	163.3	166.8	59.1	8.04	14.60	2.80	11.00	2233
	Count	23	23	23	23	23	23	23	23
A330/340 Threshold Height 59 ft <TH	Mean	143.3	136.5	66.5	3.22	12.86	-0.47	-0.44	1882
	Standard error	3.46	2.95	2.06	0.58	0.36	0.62	3.52	155.4
	Median	138.10	137.60	65.40	2.96	13.10	-0.30	1.00	1876.0
	Standard dev.	10.38	8.86	6.18	1.73	1.07	1.87	10.55	466.3
	Sample var.	107.82	78.50	38.21	3.00	1.16	3.48	111.28	2.17E+05
	Kurtosis	-2.04	0.67	4.17	-2.06	-1.16	2.28	-0.93	-0.6
	Skewness	0.26	0.36	1.90	0.12	-0.32	-0.43	-0.28	0.3
	Range	26.1	30.1	20.5	4.23	3.20	7.00	30.00	1439
	Minimum	-8.7	-9.4	0.2	1.24	-2.31	4.78	-16.00	1238
	Maximum	-22.5	-22.5	-5.5	1.13	-3.66	5.45	14.00	2677
	Count	9	9	9	9	9	9	9	9

TD = Touchdown
TH = Threshold height

Table H-12. Statistical Analysis of Boeing 757 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
B-757 Threshold Height <50 ft	Mean	136.6	129.3	46.4	2.53	6.59	-0.36	-1.30	1486
	Standard error	1.74	2.32	0.47	0.21	0.43	0.25	0.95	58.7
	Median	137.65	130.10	46.66	2.39	6.40	-0.40	-1.00	1397.0
	Standard dev.	9.51	12.69	2.59	1.16	2.38	1.35	5.20	321.2
	Sample var.	90.52	161.05	6.73	1.35	5.64	1.83	27.04	1.03E+05
	Kurtosis	-0.82	0.23	0.21	0.80	7.80	-0.29	-0.28	1.1
	Skewness	-0.06	-0.35	-0.86	0.86	2.66	0.01	-0.28	0.8
	Range	34.0	56.6	9.6	4.84	10.70	5.40	22.00	1538
	Minimum	120.2	96.2	39.9	0.96	4.00	-3.00	-13.00	849
	Maximum	154.2	152.8	49.4	5.80	14.70	2.40	9.00	2387
	Count	30	30	30	30	30	30	30	30
B-757 Threshold Height 49 ft <TH <60 ft	Mean	138.1	133.6	54.8	2.34	6.26	-0.16	-1.29	1767
	Standard error	0.92	1.21	0.34	0.12	0.17	0.16	0.49	36.3
	Median	138.06	134.95	55.03	2.39	6.30	-0.15	-1.00	1748.0
	Standard dev.	7.50	9.85	2.76	1.00	1.36	1.28	3.99	294.9
	Sample var.	56.28	96.95	7.63	0.99	1.84	1.64	15.90	8.70E+04
	Kurtosis	-0.48	-0.14	-0.99	-0.41	11.29	0.65	0.27	-0.2
	Skewness	0.24	-0.19	-0.10	-0.14	1.89	0.28	0.09	0.4
	Range	32.4	44.1	9.6	4.35	10.50	6.60	20.00	1239
	Minimum	121.9	110.0	50.2	0.15	2.90	-2.80	-11.00	1182
	Maximum	154.3	154.1	59.8	4.50	13.40	3.80	9.00	2421
	Count	66	66	66	66	66	66	66	66
B-757 Threshold Height 59 ft <TH	Mean	137.0	131.3	64.1	2.92	5.42	-0.34	-1.20	2047
	Standard error	1.34	1.51	0.55	0.17	0.20	0.25	0.64	44.3
	Median	137.60	131.90	63.80	3.15	5.30	-0.70	-1.00	1994.0
	Standard dev.	8.56	9.65	3.55	1.07	1.28	1.59	4.12	283.7
	Sample var.	73.30	93.03	12.61	1.14	1.64	2.52	17.01	8.05E+04
	Kurtosis	0.05	-0.57	-0.06	0.16	0.15	-0.92	0.16	-1.17
	Skewness	0.06	-0.25	0.70	-0.53	-0.02	-0.03	-0.44	-0.02
	Range	37.5	38.0	13.6	4.79	6.20	6.00	20.00	1002
	Minimum	121.5	111.3	59.8	0.10	2.40	-3.50	-12.00	1508
	Maximum	159.0	149.3	73.4	4.89	8.60	2.50	8.00	2510
	Count	41	41	41	41	41	41	41	41

TD = Touchdown
TH = Threshold height

Table H-13. Statistical Analysis of Boeing 737 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
B-737 Threshold Height <49 ft	Mean	152.0	147.6	45.5	3.20	5.07	-0.23	2.30	1644
	Standard error	3.14	2.39	0.53	0.48	0.25	0.36	1.99	115.61
	Median	153.52	145.65	44.66	3.24	5.25	-0.30	2.50	1512.00
	Standard dev.	9.94	7.57	1.68	1.53	0.78	1.14	6.29	365.60
	Sample var.	98.76	57.23	2.83	2.33	0.60	1.29	39.57	1.34E+05
	Kurtosis	-0.89	-0.57	-1.25	-0.96	0.10	-0.26	-1.63	2.90
	Skewness	-0.33	0.80	0.36	0.14	-0.54	-0.54	-0.27	1.70
	Range	29.1	22.4	4.8	4.52	2.60	3.50	16.00	1193
	Minimum	137.0	139.1	43.1	0.97	3.60	-2.40	-6.00	1314
	Maximum	166.1	161.5	47.9	5.49	6.20	1.10	10.00	2507
	Count	10	10	10	10	10	10	10	10
B-737 Threshold Height 48 ft <TH <58 ft	Mean	147.3	143.7	52.3	2.47	5.15	-0.21	2.36	1810
	Standard error	2.26	2.22	0.54	0.24	0.33	0.35	1.74	90.9
	Median	147.24	144.10	52.24	2.26	5.15	0.35	4.00	1705.5
	Standard dev.	10.59	10.42	2.52	1.12	1.55	1.65	8.16	426.5
	Sample var.	112.16	108.53	6.34	1.26	2.41	2.71	66.62	1.82E+05
	Kurtosis	0.21	-0.22	-1.49	0.29	1.97	-1.14	0.85	5.3
	Skewness	0.14	-0.08	-0.03	0.84	0.75	-0.37	-1.18	2.1
	Range	44.4	41.0	7.2	4.30	7.00	5.80	30.00	1848
	Minimum	124.3	123.8	48.7	0.89	2.60	-3.40	-17.00	1398
	Maximum	168.7	164.8	55.8	5.19	9.60	2.40	13.00	3246
	Count	22	22	22	22	22	22	22	22
B-737 Threshold Height 57 ft <TH	Mean	145.8	143.0	62.5	2.58	5.15	-0.91	-1.00	1969
	Standard error	2.72	3.43	1.50	0.30	0.44	0.35	1.59	93.0
	Median	148.10	144.20	60.61	2.75	5.10	-1.40	-2.00	1923.0
	Standard dev.	9.80	12.38	5.40	1.08	1.60	1.26	5.72	335.3
	Sample var.	95.99	153.18	29.19	1.16	2.57	1.59	32.67	1.12E+05
	Kurtosis	-0.97	-1.56	4.35	-0.17	5.78	-1.35	-1.21	-0.2
	Skewness	-0.55	-0.30	1.94	-0.56	1.82	0.27	0.34	0.7
	Range	28.5	33.8	19.1	3.62	6.90	3.80	18.00	1118
	Minimum	129.6	125.6	58.2	0.51	2.80	-2.80	-9.00	1445
	Maximum	158.1	159.4	77.4	4.13	9.70	1.00	9.00	2563
	Count	13	13	13	13	13	13	13	13

TD = Touchdown
TH = Threshold height

Table H-14. Statistical Analysis of Airbus A319 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
A319 Threshold Height <53 ft	Mean	141.3	130.7	48.0	3.24	6.02	-0.71	-0.69	1433
	Standard error	2.52	2.50	0.78	0.39	0.42	0.47	1.63	88.9
	Median	139.54	130.70	49.45	3.37	6.40	-0.40	1.00	1373.0
	Standard dev.	9.08	9.00	2.82	1.41	1.51	1.68	5.89	320.4
	Sample var.	82.49	81.08	7.93	1.98	2.28	2.83	34.73	1.03E+05
	Kurtosis	1.26	-0.08	0.72	0.16	-1.61	-0.19	2.50	0.5
	Skewness	0.85	0.02	-0.98	0.69	-0.23	0.09	-0.81	0.3
	Range	34.6	32.6	9.6	4.71	4.20	5.70	25.00	1229
	Minimum	127.7	114.3	41.5	1.59	3.90	-3.10	-15.00	868
	Maximum	162.3	146.9	51.0	6.30	8.10	2.60	10.00	2097
	Count	13	13	13	13	13	13	13	13
A319 Threshold Height 52 ft <TH <61 ft	Mean	140.3	132.1	56.3	2.50	5.63	-0.55	-1.26	1864
	Standard error	1.90	1.80	0.38	0.22	0.18	0.29	1.43	76.5
	Median	137.01	132.50	56.63	2.48	5.80	-0.50	-1.00	1830.0
	Standard dev.	10.57	10.01	2.10	1.20	0.98	1.64	7.99	425.7
	Sample var.	111.72	100.30	4.40	1.45	0.97	2.68	63.80	1.81E+05
	Kurtosis	0.34	-0.66	-0.74	-0.79	-0.47	-0.03	1.65	6.0
	Skewness	0.77	-0.30	-0.11	-0.10	-0.23	-0.15	0.24	2.0
	Range	42.7	37.5	7.2	4.53	4.20	7.20	40.00	2117
	Minimum	120.7	112.1	52.6	0.20	3.50	-4.20	-18.00	1362
	Maximum	163.4	149.6	59.8	4.73	7.70	3.00	22.00	3479
	Count	31	31	31	31	31	31	31	31
A319 Threshold Height 60 ft <TH	Mean	140.6	133.8	65.2	2.91	5.82	-0.16	-2.67	2197
	Standard error	2.18	2.63	1.51	0.31	0.36	0.47	1.56	108.3
	Median	139.26	131.80	62.21	2.90	6.10	0.15	-3.00	2221.5
	Standard dev.	9.24	11.14	6.39	1.33	1.53	1.99	6.63	459.5
	Sample var.	85.44	124.08	40.84	1.78	2.34	3.97	44.00	2.11E+05
	Kurtosis	-0.07	1.28	3.37	2.65	0.20	-1.48	1.14	0.7
	Skewness	0.67	1.04	1.97	1.11	0.12	-0.30	1.08	-0.1
	Range	33.3	42.7	22.3	5.86	5.90	6.00	25.00	1942
	Minimum	126.7	119.0	60.6	0.83	3.10	-3.40	-12.00	1161
	Maximum	160.0	161.7	82.9	6.69	9.00	2.60	13.00	3103
	Count	18	18	18	18	18	18	18	18

TD = Touchdown
TH = Threshold height

Table H-15. Statistical Analysis of Airbus A320 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
A320 Threshold Height <50 ft	Mean	147.6	140.6	44.0	3.05	5.94	-0.73	0.24	1655
	Standard error	2.50	2.14	1.17	0.27	0.29	0.30	0.76	79.0
	Median	147.40	140.20	44.66	3.37	6.20	-0.60	1.00	1529.0
	Standard dev.	11.46	9.81	5.35	1.21	1.35	1.37	3.46	362.2
	Sample var.	131.29	96.18	28.66	1.48	1.82	1.89	11.99	1.31E+05
	Kurtosis	-0.46	0.25	-0.58	-0.92	-0.02	-0.22	-0.63	-1.1
	Skewness	0.39	-0.53	-0.74	-0.26	-0.56	-0.61	-0.40	0.3
	Range	40.5	37.9	16.7	4.02	5.40	5.10	13.00	1173
	Minimum	130.0	117.2	32.7	0.80	2.80	-3.80	-7.00	1081
	Maximum	170.5	155.1	49.4	4.82	8.20	1.30	6.00	2254
	Count	21	21	21	21	21	21	21	21
A320 Threshold Height 49 ft <TH <61 ft	Mean	146.0	140.6	55.2	2.94	5.75	-0.30	-1.35	1873
	Standard error	1.28	1.38	0.43	0.19	0.15	0.25	0.97	43.7
	Median	146.70	141.30	55.03	2.95	5.80	0.40	-2.00	1861.0
	Standard dev.	8.41	9.06	2.85	1.27	1.00	1.62	6.36	286.5
	Sample var.	70.76	82.04	8.13	1.61	0.99	2.63	40.47	8.21E+04
	Kurtosis	-0.79	-0.37	-1.02	-0.09	-0.36	-0.02	-0.04	-0.2
	Skewness	0.03	-0.31	-0.19	-0.13	-0.15	-0.86	-0.48	-0.1
	Range	32.2	37.4	9.6	5.33	4.40	6.50	28.00	1126
	Minimum	131.0	121.2	50.2	0.31	3.50	-4.10	-18.00	1297
	Maximum	163.3	158.6	59.8	5.64	7.90	2.40	10.00	2423
	Count	43	43	43	43	43	43	43	43
A320 Threshold Height 60 ft <TH	Mean	146.8	139.4	66.7	2.62	5.59	-0.85	-0.08	2152
	Standard error	2.00	1.59	1.35	0.28	0.29	0.31	0.97	51.6
	Median	144.56	138.70	64.60	2.95	5.70	-0.65	0.00	2191.0
	Standard dev.	9.81	7.77	6.64	1.37	1.41	1.51	4.77	253.0
	Sample var.	96.29	60.33	44.02	1.87	2.00	2.28	22.78	6.40E+04
	Kurtosis	0.30	-0.26	2.77	-1.04	0.31	-0.34	0.34	-0.8
	Skewness	0.51	0.12	1.72	-0.44	-0.51	-0.43	-0.67	-0.1
	Range	40.4	30.8	26.3	4.55	5.80	5.50	19.00	926
	Minimum	131.0	124.9	60.6	0.05	2.30	-4.00	-12.00	1729
	Maximum	171.4	155.7	86.9	4.60	8.10	1.50	7.00	2655
	Count	24	24	24	24	24	24	24	24

TD = Touchdown
TH = Threshold height

Table H-16. Statistical Analysis of Airbus A321 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
A321 Threshold Height <52 ft	Mean	148.2	141.5	47.2	2.26	5.59	0.15	-0.56	1702
	Standard error	2.26	3.32	1.07	0.29	0.25	0.35	1.68	78.5
	Median	152.13	141.15	48.25	2.09	5.60	0.20	-1.00	1730.0
	Standard dev.	9.03	13.28	4.28	1.18	0.99	1.40	6.71	313.8
	Sample var.	81.63	176.23	18.34	1.38	0.98	1.96	45.06	9.85E+04
	Kurtosis	-0.01	-1.44	7.04	0.09	-1.37	1.41	-0.78	3.0
	Skewness	-1.04	-0.23	-2.39	0.53	-0.15	0.57	0.16	-1.0
	Range	29.5	40.2	17.5	4.35	2.90	6.00	22.00	1420
	Minimum	129.7	117.4	33.5	0.22	4.00	-2.50	-11.00	853
	Maximum	159.2	157.6	51.0	4.57	6.90	3.50	11.00	2273
	Count	16	16	16	16	16	16	16	16
A321 Threshold Height 51 ft <TH <61 ft	Mean	151.1	144.9	55.4	2.96	5.69	-0.80	-0.72	1912
	Standard error	1.85	1.81	0.45	0.25	0.29	0.25	0.95	65.8
	Median	151.30	145.10	55.03	2.98	5.70	-0.80	-1.00	1869.0
	Standard dev.	9.98	9.73	2.43	1.34	1.55	1.34	5.14	354.2
	Sample var.	99.70	94.73	5.89	1.80	2.39	1.81	26.42	1.25E+05
	Kurtosis	0.44	-0.19	-1.14	-0.09	2.51	1.76	-0.42	-1.0
	Skewness	-0.37	-0.21	0.34	0.19	0.60	-0.22	0.30	-0.2
	Range	42.8	36.4	8.0	5.52	7.90	6.80	21.00	1236
	Minimum	127.6	124.4	51.8	0.57	2.60	-4.50	-11.00	1275
	Maximum	170.4	160.8	59.8	6.09	10.50	2.30	10.00	2511
	Count	29	29	29	29	29	29	29	29
A321 Threshold Height 60 ft <TH	Mean	154.4	145.6	63.8	2.99	4.64	-0.86	-3.00	2260
	Standard error	1.69	1.98	0.80	0.22	0.28	0.25	1.51	105.9
	Median	155.85	144.20	63.01	2.94	4.70	-0.90	-2.00	2296.0
	Standard dev.	7.73	9.06	3.67	1.03	1.30	1.16	6.93	485.3
	Sample var.	59.68	82.03	13.45	1.06	1.68	1.34	48.00	2.36E+05
	Kurtosis	-0.67	-0.47	3.15	0.76	0.65	1.08	1.08	0.8
	Skewness	-0.28	0.49	1.78	-0.65	0.19	-0.20	-0.62	0.7
	Range	29.7	30.4	13.6	4.24	5.70	5.10	29.00	2012
	Minimum	138.8	132.5	60.6	0.38	2.00	-3.60	-19.00	1393
	Maximum	168.5	162.9	74.2	4.62	7.70	1.50	10.00	3405
	Count	21	21	21	21	21	21	21	21

TD = Touchdown
TH = Threshold height

Table H-17 Statistical Analysis of McDonnell Douglas MD-80/90 Aircraft by Threshold Height Group

Ramp Height Range		Power Approach Airspeed (knots)	Closure Speed (knots)	Threshold Height (ft)	Vertical Velocity at Touchdown (ft/sec)	Pitch Angle at TD	Roll Angle at TD	Off-Center Distance (ft)	Threshold to TD Distance (ft)
MD-80/90 Threshold Height <47 ft	Mean	143.6	137.9	40.7	2.75	6.49	0.28	4.00	1538
	Standard error	3.61	3.27	1.27	0.70	0.60	0.56	1.39	100.2
	Median	139.39	139.15	41.47	2.47	6.20	-0.15	4.00	1451.0
	Standard dev.	10.21	9.24	3.59	1.99	1.69	1.59	3.93	283.4
	Sample var.	104.16	85.46	12.90	3.94	2.86	2.54	15.43	8.03E+04
	Kurtosis	-1.16	-1.72	3.89	-0.82	0.53	-0.23	-0.98	3.7
	Skewness	0.74	-0.10	-1.79	0.62	1.00	0.73	-0.04	1.8
	Range	26.5	23.9	11.2	5.40	4.90	4.60	11.00	921
	Minimum	133.8	126.5	32.7	0.40	4.80	-1.50	-2.00	1242
	Maximum	160.3	150.4	43.9	5.80	9.70	3.10	9.00	2163
	Count	8	8	8	8	8	8	8	8
MD-80/90 Threshold Height 46 ft <TH <58 ft	Mean	144.1	140.1	52.7	3.50	6.01	-0.28	1.20	1758
	Standard error	2.81	3.56	0.76	0.32	0.18	0.37	2.07	79.4
	Median	145.14	137.40	53.44	3.57	6.10	-0.10	1.00	1751.0
	Standard dev.	10.89	13.80	2.95	1.23	0.69	1.42	8.03	307.7
	Sample var.	118.53	190.40	8.71	1.52	0.48	2.00	64.46	9.47E+04
	Kurtosis	-1.37	2.17	-0.65	-1.76	-0.64	-0.28	-0.19	-0.9
	Skewness	0.02	-0.97	-0.43	-0.15	0.17	-0.69	-0.22	-0.2
	Range	33.1	54.6	10.4	3.23	2.40	4.80	29.00	1031
	Minimum	127.5	104.3	47.1	1.70	4.90	-3.10	-15.00	1199
	Maximum	160.6	158.9	57.4	4.93	7.30	1.70	14.00	2230
	Count	15	15	15	15	15	15	15	15
MD-80/90 Threshold Height 57 ft <TH	Mean	150.1	143.2	61.7	3.65	6.10	0.64	1.78	1820
	Standard error	4.47	4.31	1.33	0.38	0.54	0.55	2.19	89.9
	Median	144.60	142.80	60.61	3.23	6.20	0.80	1.00	1852.0
	Standard dev.	13.42	12.94	3.99	1.13	1.62	1.66	6.57	269.6
	Sample var.	180.05	167.55	15.90	1.29	2.63	2.77	43.19	7.27E+04
	Kurtosis	-0.55	0.88	-1.00	1.96	-0.09	0.95	0.22	0.6
	Skewness	0.04	-0.58	0.75	1.18	-0.09	0.48	1.12	-0.7
	Range	41.9	42.6	9.6	3.95	5.30	5.80	19.00	891
	Minimum	127.7	117.9	58.2	2.12	3.50	-2.00	-5.00	1314
	Maximum	169.6	160.5	67.8	6.07	8.80	3.80	14.00	2205
	Count	9	9	9	9	9	9	9	9

TD = Touchdown
TH = Threshold height