DOT/FAA/AR-08/12

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

Video Landing Parameter Surveys—Cincinnati/Northern Kentucky and Atlantic City International Airports

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

August 2008

Final Report

This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof. The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the objective of this report. This document does not constitute FAA certification policy. Consult your local FAA aircraft certification office as to its use.

This report is available at the Federal Aviation Administration William J. Hughes Technical Center's Full-Text Technical Reports page: actlibrary.tc.faa.gov in Adobe Acrobat portable document format (PDF).

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-08/12		

4. Title and Subtitle	5. Report Date
VIDEO LANDING PARAMETER SURVEYS—CINCINNATI/NORTHERN KENTUCKY AND ATLANTIC CITY INTERNATIONAL AIRPORTS	August 2008
	6. Performing Organization Code
7. Author(s) Thomas DeFiore and Richard Micklos	8. Performing Organization Report No.
9. Performing Organization Name and Address 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	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTFACT-06-C-00021
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code ANM-110

15. Supplementary Notes

These video landing parameter surveys were conducted jointly by personnel from the Federal Aviation Administration William J. Hughes Technical Center and the Naval Air Warfare Center, Aircraft Division, Patuxant River, MD.

16. Abstract

A joint survey team consisting of personnel from the Federal Aviation Administration (FAA) William J. Hughes Technical Center and the Naval Air Warfare Center, Patuxent River, MD, conducted a series of video landing parameter surveys at high-activity commercial airports. The goal of this research was 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 report documents landing parameter research conducted at the Atlantic City International Airport (ACY) during 2002 and 2003 as well as a survey performed in September 2004 at Cincinnati/Northern Kentucky International Airport (CVG). These are the last research efforts planned as part of this program.

The FAA conducted a video landing parameter survey at CVG to characterize the landing load environment of regional jet airplanes. This survey was in response to recent recommendations by Transport Canada and the Aviation Rulemaking Advisory Committee (ARAC) for the FAA to acquire landing touchdown contact data at a commercial airfield where a significant number of regional jets operate. The FAA and ARAC will jointly use the data (sink speed; approach velocity; touchdown pitch, roll, and yaw, etc.) obtained from this survey to assess the validity and continued suitability of a number of landing load certification criteria. The research at ACY was an attempt to document the influence of weather conditions on aircraft landing performance.

Video cameras were installed along the northern edge of runway 13 at ACY and the eastern edge of runway 18L at CVG. Image sequences of aircraft landings on those runways were recorded. Subsequent processing and analysis of these images provided the following landing parameters: sink speed; approach speed; touchdown pitch, roll, and yaw; off-centerline 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 was only concerned with the overall statistical usage information, all data were processed and presented without regard to the airline or flight number.

17. Key Words	18. Distribution Statement
Landing parameters; Sink speed; 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	177	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

		Page
EXECUTIVE SUMMARY		ix
1.	INTRODUCTION	1
2.	SYSTEM DESCRIPTION	2
3.	CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT DISCUSSION	5
	3.1 Operations at CVG	5
	3.2 Conditions at CVG	7
4.	THE CVG SURVEY RESULTS	8
	4.1 Overall Parameter Summaries	8
	4.2 Initial Observations	9
5.	ATLANTIC CITY INTERNATIONAL AIRPORT DISCUSSION	23
	5.1 Operations at ACY	23
	5.2 The ACY Landing Discussions	26
	5.2.1 The ACY Weather Impact	31
	5.2.2 Global Positioning Systems Operations at ACY	36
6.	CONCLUSIONS	39
7.	REFERENCES	39

APPENDICES

A—Landing Parameter Statistical Summaries for Atlantic City International Airport and Cincinnati/Northern Kentucky International Airport Surveys

B—Listing of Individual Aircraft Landing Parameter Data for Atlantic City International Airport and Cincinnati/Northern Kentucky International Airport Surveys

C—Landing Parameter Survey Definitions

D—Research Program and Installation Plan and Video Landing Parameter Survey for Cincinnati/Northern Kentucky International Airport

E—Atlantic City International Airport, FAA Video Landing Survey Facility Description

F—Selected Regression Curves From the Atlantic City International Airport and Cincinnati/Northern Kentucky International Airport Landing Parameter Surveys

G—Box-and-Whisker Plots

H—Box-and-Whisker Plots Cincinnati/Northern Kentucky International Airport and Atlantic City International Airport Survey Results

I—Correlation Comparison Plots for Cincinnati/Northern Kentucky International Airport by Aircraft Model and Atlantic City International Airport by Approach Type

LIST OF FIGURES

Figure		Page
1	Video Camera in Operation During Commercial Landing Parameter Survey	3
2	The FAA Landing Loads Camera Locations, CVG Airport Survey	4
3	The CVG Airport Diagram	6
4	Approach Plate for CVG, Runway 18L	8
5	The CVG Survey Sink Speed Probability	12
6	Box-and-Whisker Plot, Touchdown to Runway Threshold Distance, CVG Survey	15
7	Box-and-Whisker Plot, Sink Speed Comparison by Aircraft Type, CVG Survey	15
8	Box-and-Whisker Plot, Geometric Glide Slope Angle Comparison, CVG Survey	16
9	Average Main Wheel Sink Speed Versus Touchdown to Runway Threshold Distance by Aircraft Category, CVG Survey	17
10	Average Main Wheel Sink Speed Versus Headwind Component, Wide-Body Aircraft, CVG Survey	18
11	Bombardier Regional Jet, Sink Speed Versus Approach Speed	20
12	Correlation Coefficient r, Instantaneous Glide Slope Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey	22
13	Correlation Coefficient r, Average Sink Speed Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey	22
14	Correlation Coefficient r, Average Sink Speed Versus Approach Speed, CVG Landing Parameter Survey	22
15	The ACY Airport Diagram	24
16	The ACY Approach Plate, ILS, Runway 13	25
17	The ACY Sink Speed Probability by Aircraft Model	28
18	Sink Speed Probability, Medium Wide-Body Aircraft, LHR Survey	28
19	The ACY Average Sink Speed Versus Touchdown Distance to Runway Threshold	29
20	DC-9 Sink Speed Rate Versus Approach Speed by Approach and Runway Condition	32

21 The ACY Average Sink Speed Versus Touchdown Distance From Runway Threshold Correlation Coefficient (r), DC-9 Landings 35

22 KC-10 ACY Touchdown Groundspeeds 37

23 KC-10 ACY Touchdown Vertical Velocities 37

24 The ACY KC-10 Average Sink Speed at Touchdown 38

25 The ACY KC-10 Average Groundspeed at Touchdown 38

LIST OF TABLES

Table		Page
1	Number of Landings and Landing Weight by Model, CVG Survey	9
2	Comparison of Primary Landing Parameters by Aircraft Model, CVG Survey	10
3	Comparison of Selected Wide-Body Aircraft Landing Parameters With Results From Previous Surveys	10
4	Comparison of Selected Narrow-Body Aircraft Landing Parameters With Results From Previous Surveys	11
5	Comparison of Primary Landing Parameters of CVG Landings by Aircraft Type	12
6	Mean Value and Standard Deviation of Selected CVG Landing Parameters by Aircraft Type	13
7	Corrected Threshold Crossing Height by Model, CVG Survey	14
8	The CVG Aircraft Type Correlation Matrix (r)	18
9	The CVG Correlation Matrix (r) by Aircraft Model	20
10	Number of Landings and Maximum Landing Weight by Model, ACY Survey	26
11	Comparison of Primary Landing Parameters by Aircraft Model, ACY Survey	27
12	Comparison of Primary Landing Parameters of ACY Landings by Aircraft Model	29
13	The ACY DC-9 Principal Landing Parameters by Weather and Runway Condition	31
14	The ACY KC-10 Principal Landing Parameters by Weather and Runway Condition	32
15	The ACY Beechcraft 1900D Correlation Matrix (r)	33
16	The ACY DC-9 Correlation Matrix (r)	34
17	The ACY KC-10 Correlation Matrix (r)	34
18	Modified Statistical Summary of KC-10 Landing Parameters Without Data From GPS Approaches at ACY for 101 Landings	36

LIST OF ACRONYMS

ACY	Atlantic City International Airport
ADO	Airport District Office
ARAC	Aviation Rulemaking Advisory Committee
CRJ	Bombardier (Canadair) regional jet
CVG	Cinncinnati/Northern Kentucky International Airport
DCA	Washington National Airport
ERJ	Embraer regional jet
FAA	Federal Aviation Administration
GPS	Global positioning system
HNL	Honolulu International Airport
ILS	Instrument landing system
IQR	Interquartile range
JFK	John F. Kennedy International Airport
LCY	London City Airport
LHR	London Heathrow Airport
MEX	Mexico City International Airport
NAALDAS	Naval Aircraft Approach and Landing Data Acquisition System
NASA	National Aeronautics and Space Administration
OAG	Official Airline Guide
PHL	Philadelphia International Airport
r	Correlation coefficients
TN	Technical note

EXECUTIVE SUMMARY

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

This report documents landing parameter research conducted at the Atlantic City International Airport (ACY) during 2002 and 2003 and a survey performed in September 2004 at the Cincinnati/Northern Kentucky International Airport (CVG). These are the last research efforts planned as part of this program.

The FAA conducted a video landing parameter survey at CVG to characterize the landing environment of regional jet airplanes. This survey was in response to recent recommendations by Transport Canada and the Aviation Rulemaking Advisory Committee (ARAC) for the FAA to acquire landing touchdown contact data at a commercial airfield with a significant number of regional jet arrivals. The FAA and ARAC will jointly use the data (sink speed; approach velocity; touchdown pitch, roll, and yaw, etc.) obtained from this survey to assess the validity and continued suitability of a number of landing load certification criteria. The research at ACY was an attempt to document the influence of weather conditions on aircraft landing performance.

Video cameras were installed along the northern edge of runway 13 at ACY and the eastern edge of runway 18L at CVG. Image sequences of aircraft landings on those runways were recorded. Subsequent processing and analysis of these images provided the following landing parameters: sink speed; approach speed; touchdown pitch, roll, and yaw angles; off-centerline distance; and the touchdown distance from the runway threshold. Wind and weather conditions were also recorded. Since this program was only concerned with overall statistical usage information, all data were processed and presented without regard to the airline or flight number.

1. INTRODUCTION.

In an effort to better understand and document the actual operational environment of commercial jet transport aircraft landing impact conditions, 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 have 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 surveys were 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 used 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 were 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 speeds at higher gross weights.

Prior to the current series of airport landing parameter surveys, FAA certification engineers relied on historical precedent and the results of NASA surveys from the 1960s. These survey results showed that the Boeing 707/DC8 jets landing descent velocities were appreciably higher than contemporary piston and turboprop powered aircraft, but no changes were made to the structural design criteria. Since that time, aircraft size has continued to grow and traffic density has increased. While complete structural failure of a landing gear assembly or support structure remain extremely unusual events, a significant number of service difficulties are being reported. Consequently, the FAA has been interested in obtaining typical operational landing data for current generation transports and current airport operating environments to evaluate the continued suitability of the 10 ft/sec maximum sink speed as a design strength requirement (Title

14 Code of Federal Regulations (CFR) 25.473) and to ensure robust fatigue and damage tolerant designs reflective of routine operations.

The 10-ft/sec certification limit of 14 CFR 25.473, "Landing Load Condition and Assumptions," represents a design limit for all 14 CFR Part 25 airplanes from the smallest, up to the new Airbus A-380, and for operations on all of the world's commercial airfields. Consequently, the regulatory authorities are concerned with the continued suitability of the 10-ft/sec certification requirement, particularly for large sized aircraft. A subcommittee of the International Aviation Rulemaking Advisory Committee (ARAC) was tasked to conduct an investigation into the sink speed issue, and the committee has recommended that an additional video landing parameter survey be conducted of other airports to further characterize touchdown contact conditions.

The first FAA commercial aircraft video landing survey 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 feet long and cannot handle aircraft larger than the Airbus A-320 and B-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-foot 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 5459-foot-long runway 17, which is restricted to commuter aircraft operation. The results from both these commuter surveys are documented [15].

The Heathrow survey [16] was conducted in response to a joint FAA, United Kingdom Civilian Aviation Authority (CAA), and ARAC requirement. The goal of the Heathrow survey was to generate sufficient quantities of reliable landing ground-impact data to assist with the certification criteria of the aviation industry's planned A-380 size aircraft. These ultra-large airplanes are expected to land with touchdown gross weights of up to 3/4 million pounds.

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, and type and wind conditions.

2. SYSTEM DESCRIPTION.

Technical advancements in video technology permits the U.S. Navy to transition its landing parameter data analysis system from using photographic film to one using video technology. The U.S. 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 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. Specific predetermined 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, yet more efficient, than the U.S. Navy's previously used 70-mm film system. The accuracy of the sink speed measurements of the video system is documented in references 9 and 10.

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 feet 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 Atlantic City International Airport (ACY). 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 were located approximately 500 feet apart, starting approximately 1600 feet from the end of the runway. Each camera was aimed at the center of a selected region of the expected touchdown area. The camera's aim was fixed and did not track the aircraft. Figure 2 shows a schematic of the multiple-camera configuration.

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

The NAALDAS data recording system was operated from a trailer placed in a safe location near the touchdown region of the survey runway. Judicious selection of this location was required to prevent any interference with airport operations. Temporary fiber-optic cabling was run from the vehicle to the cameras and the vehicle remained in the chosen location during flight operations. The system was powered entirely by 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 would require the runway be closed.

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

Figure 2. The FAA Landing Loads Camera Locations, CVG Airport Survey

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

The analysis workstation consists of a Sun® Microsystems computer 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, which 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 that was measured using an anemometer situated near the touchdown location was used to calculate the approach speed.

Supplementary data describing each landing were collected during the video survey to determine which set of geometric data to use in the analysis. An anemometer was temporarily installed near the survey site to collect wind speed and direction for each landing. An estimate of the aircraft's touchdown landing weight was provided by the aircraft operators. Each aircraft's tail number was observed and recorded to be certain that the correct geometric information is inserted into the data analysis software.

3. CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT DISCUSSION.

3.1 OPERATIONS AT CVG.

CVG is a hub airport for Delta Airlines and the primary base of operations for Comair airlines, a major user of regional jets. CVG was selected for this survey because previous surveys contained very few regional jet operations. Approximately 65 percent of the operations at CVG are regional jets. CVG handled 22.8 million passengers in 2005. At the time of the survey, CVG had three primary runways with over 1400 operations per day. Two of the airport's primary runways (18L/36R and 18R/36L) are oriented in a north-to-south direction. The third runway is an east-to-west runway (9/27). The three primary runways are at least 10,000 feet long and use a 3.0-degree glide slope. Since the survey was completed, a fourth runway was constructed, which is 12,000 ft long and oriented north to south. The new runway is designated as runway 18R/36L; the former runway 18R/36L is now designated as 18C/36C. The CVG airport diagram is shown in figure 3.

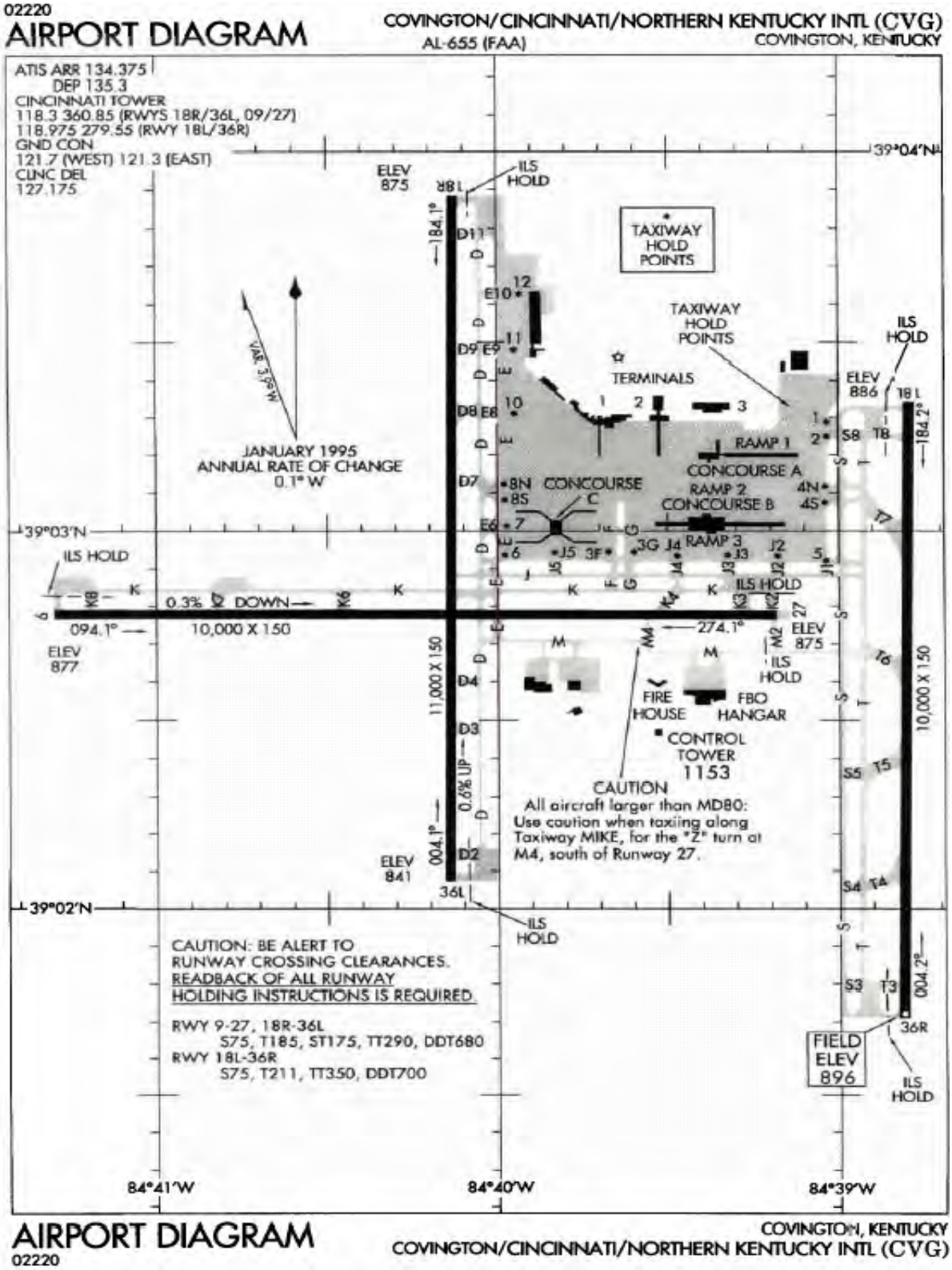


Figure 3. The CVG Airport Diagram

3.2 CONDITIONS AT CVG.

The video landing survey data acquisition equipment was installed on the east side of runway 18L, a 150-foot-wide, 10,000-foot-long runway. Runway 18L was selected after observing flight operations and reviewing expected wind conditions and historical landing runway operations data. In addition, runway 18L 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 or maintenance activity.

Since there were no operations on the opposite end of the surveyed runway, video image data was collected every day. The weather was clear, warm, and dry with light and variable winds during the entire survey. Temperatures ranged between 51° and 85°F, and winds were measured up to 8 knots, with maximum crosswinds recorded at 4 knots. The pace of landing operations was reasonable, with a steady flow of arrivals throughout the day. The approach plate describing landing procedures for runway 18L is shown in figure 4. The survey test plan is included as appendix D. From observation of the airport diagram and runway 18L's proximity to the terminals and concourses, it can easily be inferred that operators of regional jets will try to exit the runway as soon as possible after crossing runway 9-27. In addition, it was observed that frequent simultaneous departures were conducted on runways 18R and 27R, thus leaving 18L as the primary arrival runway. Even though runway 18L is 10,000 feet long, most regional jet pilots adhered to the custom of exiting 18L shortly after crossing runway 9-27. This custom, in effect, makes runway 18L an approximately 6500-foot runway. While land and hold short operations were not conducted on runway 18L, the acquisition of regional jet landing data from a runway with the custom of making short landings is highly useful.

Daylight arrivals for a typical weekday (0700 to 1900 hours) on all the runways at CVG totals 368 per day and include the following regional jet airplanes:

- Canadair Regional Jet (CRJ) 241
- Canadair Regional Jet 700 35
- Embraer Regional Jets (ERJ) 18
- Fairchild Dornier 328 Jet 71
- Others 3

The video system is usable only in daylight, and the utility of the system is limited by lighting conditions in the hours around dusk and dawn.

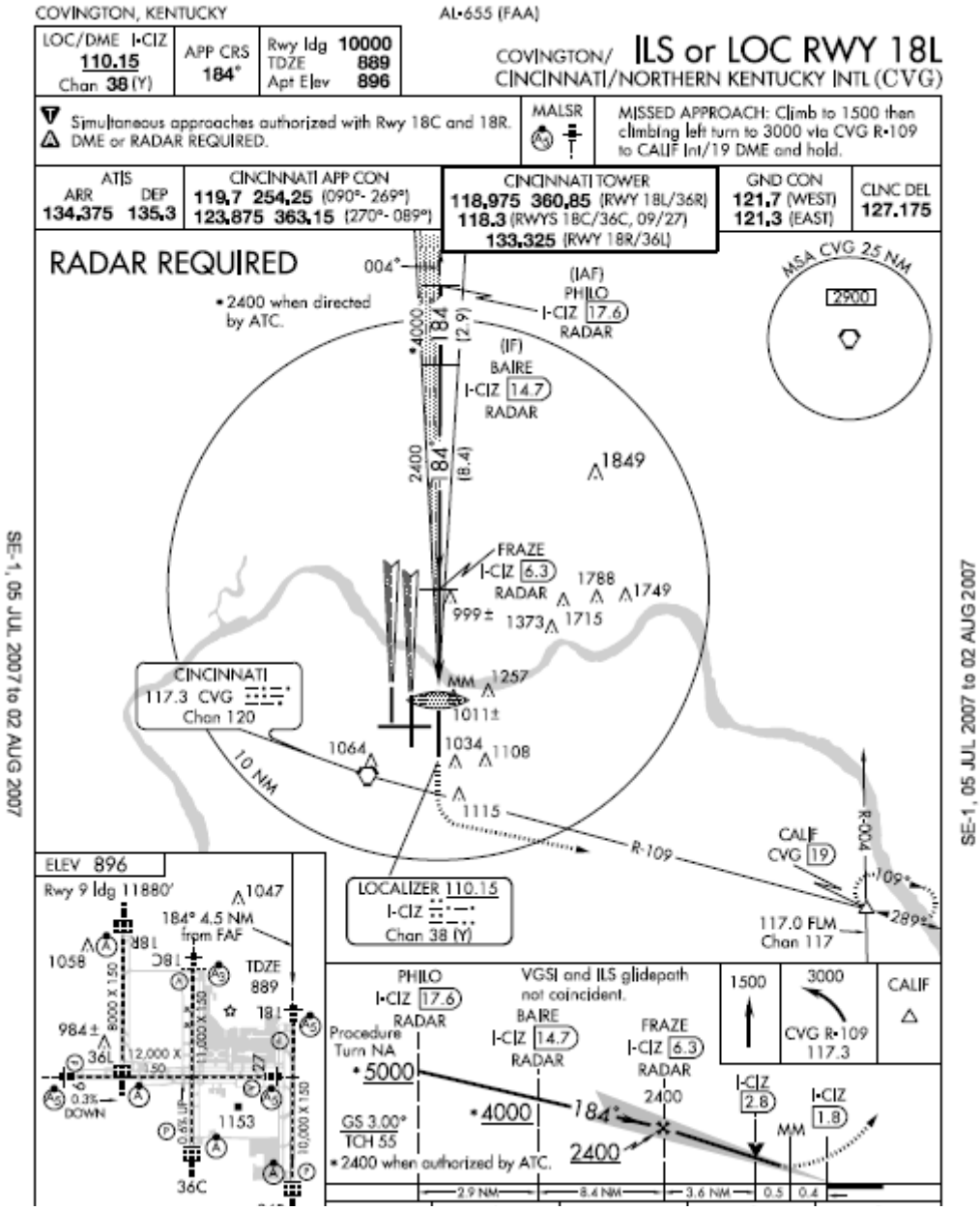


Figure 4. Approach Plate for CVG, Runway 18L

4. THE CVG SURVEY RESULTS.

4.1 OVERALL PARAMETER SUMMARIES.

After processing and reviewing the video image data, a total of 220 good-quality landings were included in this survey. Statistical summaries of the landing parameter data for each model aircraft are presented in appendix A. The landing parameter data collected for each individual landing is listed in appendix B, which has separate tables for each aircraft model 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 observed airlines. Survey terms and symbols used in this report are documented in appendix C. Table 1 list the number of landings processed for each aircraft model along with the range of maximum landing weights for each model.

Table 1. Number of Landings and Landing Weight by Model, CVG Survey

Aircraft Model	Boeing 737	Boeing 757	Boeing 767	Boeing 777	McDonnell Douglas MD-90	Bombardier CRJ	Dornier 328J	Embraer ERJ
No. of Landings	23	27	17	4	29	84	19	14
Average Landing Weight (lb)	83,000	155,000	270,000	418,000	99,500	44,000	28,000	38,000
Maximum Landing Weight (lb)	107,000	210,000/ 224,000	270,000/ 350,000	445,000/ 524,000	142,000/ 150,000	47,000	29,000	41,000/ 53,000

While not the primary goal of the survey, a total of 79 narrow-body jet aircraft were also recorded and processed. This included 50 Boeing aircraft: 27 B-757, and 23 B-737 models. In addition, 29 McDonnell Douglas MD-90 series aircraft landings were included. Given the relatively limited number of B-737 aircraft processed, the various models of B-737s were combined into one group. The B-737-100 and B-737-200 models dominated the survey, only one B-737-300/400/500 landing was recorded during the survey.

Again, in this case, the heavier landing weight of the B-757s should be considered in any direct comparison of the narrow-body aircraft. With the exception of the wide-body aircraft, landing weights for individual landings were not obtained; however, average weights by model type are provided in table 1.

4.2 INITIAL OBSERVATIONS.

Table 2 provides statistical information on the primary landing parameters collected at CVG. The statistical information is sorted by aircraft model. The data collected at CVG for the wide-body B-767 aircraft is compared to previous survey results in table 3. The table reveals that the CVG B-767 approach and closure speeds were typical of previous survey results, but the CVG average sink speeds were the lowest observed for any survey of this model aircraft. Table 3 also shows that the benign operating environment during the survey led to more consistent (lower sink speed standard deviation) landing performance. Increased visibility and the lack of crosswinds or weather complications appears to permit more consistent and effective flaring of the aircraft prior to touchdown.

Table 2. Comparison of Primary Landing Parameters by Aircraft Model, CVG Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
B-737	Mean	133	132	1.7	0.9	-0.9
	Std Dev	8.33	8.39	0.85	1.96	1.42
	Skewness	-0.033	0.060	1.678	0.069	0.241
B-757	Mean	129	128	2.0	1.3	-1.0
	Std Dev	5.30	5.98	0.97	1.77	1.83
	Skewness	0.497	0.199	1.624	0.591	0.118
B-767	Mean	145	1.44	2.1	1.3	-0.9
	Std Dev	4.58	5.40	1.05	2.00	2.02
	Skewness	0.238	-0.718	0.286	0.764	-0.277
MD-90	Mean	141	141	2.2	0.4	-0.1
	Std Dev	8.28	9.07	1.07	2.11	2.20
	Skewness	0.595	0.833	0.297	0.299	-0.433
Bombardier CRJ	Mean	126	125	1.7	1.2	-0.9
	Std Dev	13.87	13.96	0.836	1.60	2.17
	Skewness	0.059	0.029	0.815	0.627	-0.020
Dornier 328 Jet	Mean	111	111	1.3	0.1	-0.3
	Std Dev	16.33	16.07	0.57	1.20	2.33
	Skewness	0.796	0.783	0.398	-1.105	-0.308
Embraer ERJ	Mean	127	126	1.8	0.8	-0.6
	Std Dev	12.56	11.76	0.729	1.80	2.93
	Skewness	-0.823	-0.987	-0.288	-1.528	-1.047

Std Dev = Standard deviation

Table 3. 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-767		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
CVG	17	145	4.58	144	5.40	2.1	1.05
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

Table 4 shows the narrow-body B-757 sink speed at CVG is lower compared to previous landing surveys except for the JFK (2.0 ft/sec), which matches the CVG result. The sink speeds for the B-737 are lower than all surveys except for nine B-737s at JFK, where they landed with a mean

sink speed below 1 ft/sec. The CVG MD-90 also exhibited the lowest sink speeds observed for that model.

Table 4. 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	Std Dev	Mean	Std Dev	Mean	Std Dev
CVG	27	129	5.30	128	5.98	2.00	0.969
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	Std Dev	Mean	Std Dev	Mean	Std Dev
CVG	26	133	8.33	132	8.39	1.7	0.848
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
MD-80/90		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
CVG	29	141	8.28	141	9.07	2.2	1.08
LHR	36	147	11.21	140	12.37	3.3	1.43
DCA	118	139	10.14	137	10.33	2.57	1.57

Std Dev = Standard deviation

The B-757 approach speeds were the lowest recorded on any survey. The CVG value of 129 knots reflects the prevailing lower winds during this survey. The B-757 approach speeds were 132 knots at DCA and 131 knots at JFK.

Similarly, the B-737 and MD-90 approach speeds were the lowest observed to date. A comparison of the CVG approach speeds with closure shows that the differences for these two parameters at CVG values are considerably less than the same parameters from previous surveys. Consequently, these results support the proposition that the aircraft were landing under highly favorable operating conditions.

The primary purpose of the CVG landing parameter survey was to collect data on the landing performance of regional jet aircraft. This was the one aircraft type that had not been observed in any significant numbers during previous landing parameter surveys. Regional jet operations contribute to a significant portion of the operations at CVG. This survey resulted in the collection of data on 82 narrow-body, 22 wide-body, and 117 regional jet aircraft. A comparison of the primary landing parameters by aircraft type is shown in table 5.

Table 5. Comparison of Primary Landing Parameters of CVG Landings by Aircraft Type

Aircraft Type		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
Narrow-Body Jets	Mean	134	134	1.99	0.9	-0.7
	Std Dev	9.00	9.61	0.97	1.97	1.88
	Skewness	0.546	0.654	1.034	0.193	0.013
Wide-Body Jets	Mean	146	144	2.11	1.4	-0.9
	Std Dev	4.21	5.05	1.02	1.93	1.99
	Skewness	0.217	-0.67	0.156	0.809	-0.070
Regional Jets	Mean	124	123	1.67	1.0	-0.8
	Std Dev	15.18	14.97	0.80	1.61	2.29
	Skewness	-0.107	-0.098	0.740	0.253	-0.239

Std Dev = Standard deviation

The first observation that stands out in table 5 is the extremely low values of head- and crosswinds observed during this survey. They are the lowest wind values reported in any of the surveys. These wind values, combined with the straight-in approach to the runway, in excess of 15 miles (see figure 4), makes this the most benign operating environments observed to date. The values of sink speed and approach speed for the narrow- and wide-body jets compare favorably with previous reported results. The recorded sink speeds are lower than those previously reported. In fact, when a curve of sink speed probabilities was prepared (figure 5), it showed that the probability curve for all three types of aircraft was significantly lower than the military sink speed distribution for transport category aircraft. This is in contrast to the curves in previous survey reports [12, 13, and 14], which showed wide-body aircraft sink speed at or higher than the reference curve.

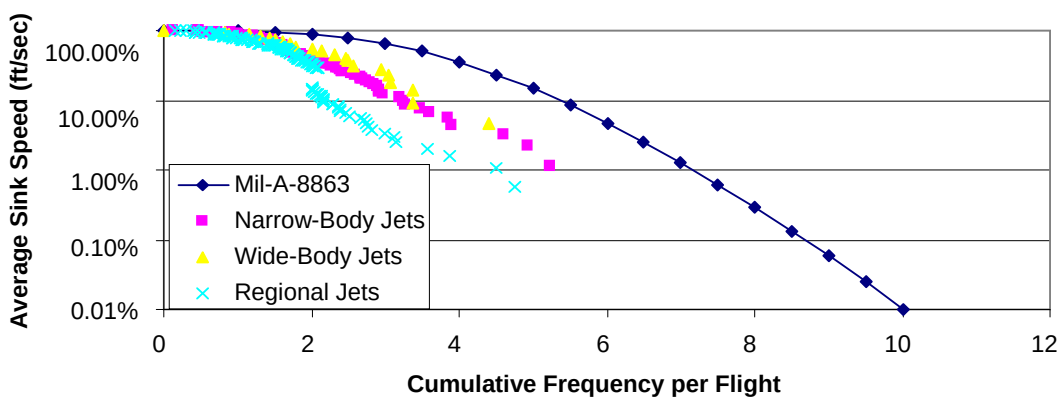


Figure 5. The CVG Survey Sink Speed Probability

There are higher standard deviations in the measurement of regional jet approach and closure speeds shown in table 5, than for the narrow- and wide-body jets. At first glance, this could be attributed to the larger range of approach speeds within this group; the Dornier 328 jets have a slower approach speed than the Bombardier or Embraer models. However, this scatter still persists when the models are evaluated individually.

The aircraft in the wide-body jet category are primarily B-767s, but four B-777 landings are also included. The narrow-body jets are almost equally divided between B-737, B-757, and MD-90 aircraft.

Additional landing parameters, grouped by aircraft type, are shown in table 6. The values of both instantaneous glide slope, which is calculated from aircraft velocities, and geometric glide slope, which is calculated from runway threshold height and touchdown distance, are consistent across aircraft types. The slightly larger variation in pitch angle results from the mix of various types of aircraft. Each aircraft has its individual recommended pitch attitude during final approach to landing. Roll angles are also very consistent across aircraft types.

Table 6. Mean Value and Standard Deviation of Selected CVG Landing Parameters by Aircraft Type

Aircraft Type		Threshold Height (feet)	Touchdown Distance to Runway Threshold (feet)	Instantaneous Glide Slope (degrees)	Geometric Glide Slope (degrees)	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)
All Wide Body	Mean	44.7	1636	0.495	1.585	4.27	-0.218
	Std Dev	6.43	411	0.235	0.352	1.375	1.225
All Narrow Body	Mean	40.9	1605	0.502	1.536	4.81	-0.382
	Std Dev	8.87	450	0.235	0.412	1.24	1.354
All Regional Jets	Mean	48.3	1993	0.465	1.418	3.29	-0.201
	Std Dev	10.11	370	0.221	0.226	1.69	1.934

Std Dev = Standard deviation

The reported values for threshold height need further clarification. The video system calculates threshold height by recording the aircraft's main landing gear wheel position as the aircraft crosses the runway threshold. An additional camera, camera C-8 shown in figure 2, was installed specifically for this measurement. The traditional measure of threshold crossing height is to the ILS receiver on the aircraft. Thus, the threshold height reported in table 6 must be corrected to account for the height difference between the landing gear wheel and the ILS receiver. Table 2-3 of reference 17 indicates that an approximate 25-foot height difference exists between the landing gear and glide path for wide-body jets. Similarly, a 20-foot difference should be used for the B-757, and 15 feet for the B-737 and MD-90. The approach plate for runway 18L (see figure 4) indicates the ILS is set for a 55-foot threshold crossing height. If the measured value of threshold crossing height (see table 6) is increased by the 15-foot allowance for the B-737 and MD-90, the mean value of threshold crossing height for narrow-body aircraft becomes 56 feet. Table 7 shows the aircrafts threshold crossing height by aircraft model before

and after the landing gear correction is applied. Since reference 15 does not include guidance for regional jets, threshold crossing heights for those aircraft were calculated using both 10- and 15-foot corrections. The tolerance on threshold crossing height is ±5 feet. All the corrected values for narrow-body jets fall within 55 ±5 ft. The B-767 landings cross the threshold outside this range. Depending on which correction is used for the regional jets, if 10 feet is used as the correction, the crossing heights are within the expected range. If 15 feet is used, the Bombardier regional jets are crossing the threshold high.

Table 6 also includes the mean value of the aircraft's touchdown distance from the runway threshold. The mean value of touchdown distance varies by only 30 feet between the wide-body and narrow-body jets observed in this survey, but for the regional jets, the mean touchdown distance is more that 350 feet further down the runway than the other two types. Part of this difference may be the result of the shorter landing gear height of the regional jets. The height difference resulting from moving 350 feet down a 3-degree glide slope is just 18 feet, so following the identical glide slope to touchdown, an aircraft with shorter main gear would land further down the runway. Table 7 indicates that the landing gear height variation between regional and narrow-body jets is between 10 and 15 feet. There does not appear to be any operational advantage for the regional jets to land further from the runway threshold.

Table 7. Corrected Threshold Crossing Height by Model, CVG Survey

Aircraft Model	Measured Crossing Height	Correction for Landing Gear Height	Corrected Threshold Crossing Height
B-737	40.1	15	55.1
B-757	39.6	20	59.6
MD-90	42.7	15	57.2
B-767	43.6	25	68.6
Bombardier CRJ	50.2	10/15	60.2/65.2
Dornier 328J	46.2	10/15	56.2/61.2
Embraer RJ	39.9	10/15	49.9/54.9

Figure 6 is a box-and-whisker plot of the variation in touchdown distance to the runway threshold for each aircraft type observed. A description of box-and-whisker plots is provided in appendix G. The figure emphasizes the difference for this parameter between the aircraft types. Clearly, the bulk of the usage data for the regional jet touchdown distances are considerably higher than those in the other categories of aircraft. The box in the center of each column indicates the 25th percentile, median value, and 75th percentile of the distribution of the observed parameter. The lines at the upper and lower ends of the column are the maximum and minimum values observed.

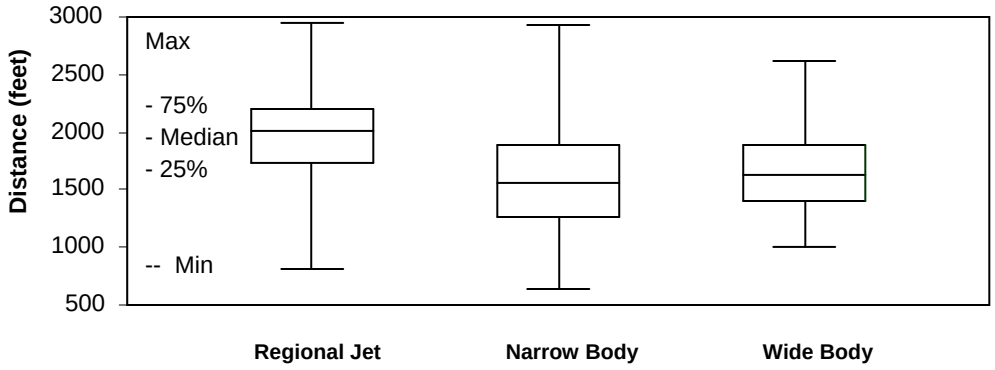
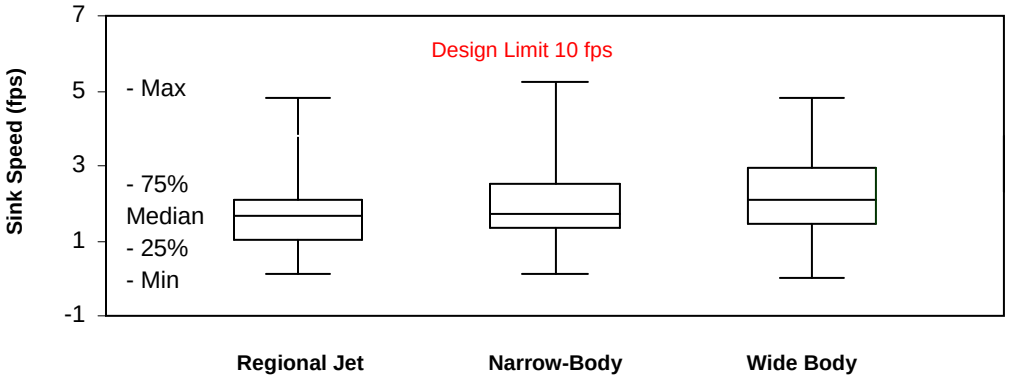


Figure 6. Box-and-Whisker Plot, Touchdown to Runway Threshold Distance, CVG Survey

Figure 7 shows that although the median values of sink speed are similar by type, the wide-body aircraft, in general, have higher sink speeds in the range between 25th to 75th percentile. While the overall sink speed levels are lower at CVG, the characteristics of the sink speed comparisons remain the same as during other surveys, i.e., heavier aircraft experience higher sink speeds.



fps = feet per second

Figure 7. Box-and-Whisker Plot, Sink Speed Comparison by Aircraft Type, CVG Survey

Figure 8 shows the variation of geometric glide slope measurements for regional, narrow- and wide-body jets. Box-and-whisker plots for the other parameters in tables 5 and 6 are included in appendix H.

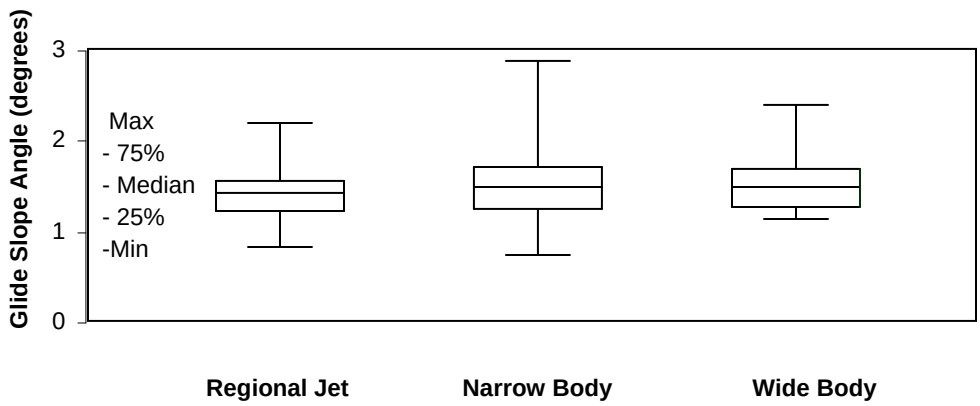
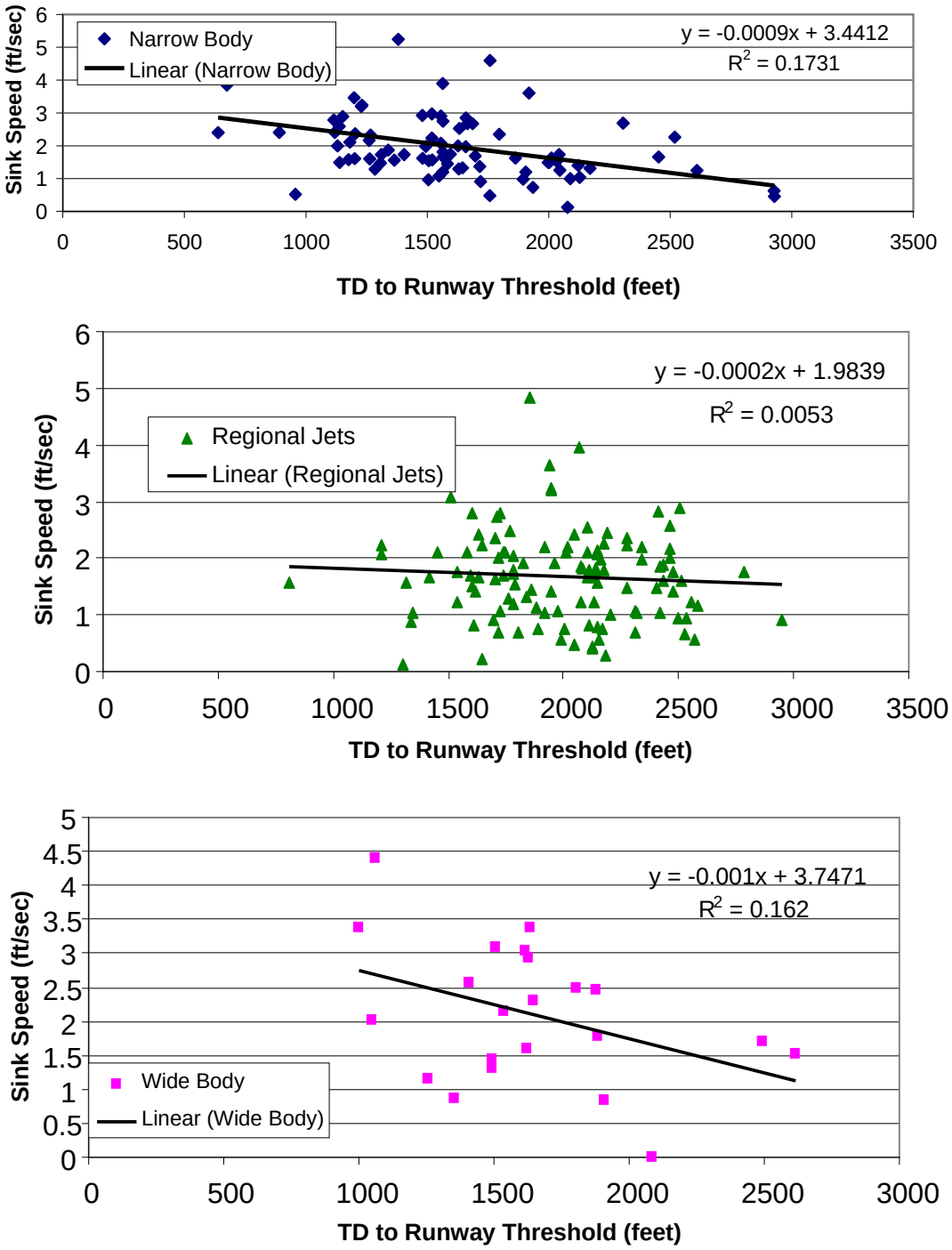


Figure 8. Box-and-Whisker Plot, Geometric Glide Slope Angle Comparison, CVG Survey

Landing parameters for these aircraft type were analyzed further by plotting regression curves between selected combinations. Figure 9 is an example of the scatter plots prepared as part of this analysis. This regression analysis also generated a correlation coefficient that indicates the degree to which two parameters may influence each other. Figure 10 shows the regression curve relating sink speed versus headwind for wide-body landings. The value of R^2 on the curve is the square of the correlation coefficient "r". This curve corresponds to the highest value of correlation listed in table 8.



TD = Touchdown

Figure 9. Average Main Wheel Sink Speed Versus Touchdown to Runway Threshold Distance by Aircraft Category, CVG Survey

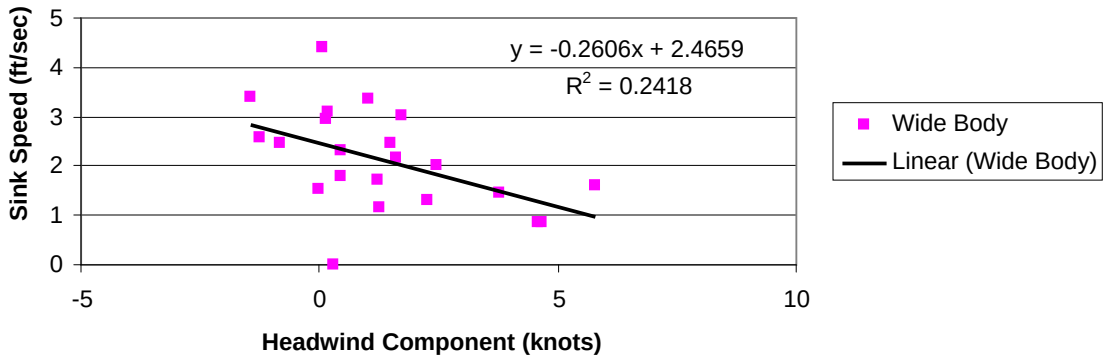


Figure 10. Average Main Wheel Sink Speed Versus Headwind Component, Wide-Body Aircraft, CVG Survey

Table 8. The CVG Aircraft Type Correlation Matrix (r)

Average Main Wheel Sink Speed vs *			
Aircraft Type	Narrow Body	Wide Body	Regional Jet
*Touchdown to runway threshold	0.416	0.402	0.073
*Geometric glide slope	0.392	0.399	0.154
*Approach speed	0.320	0.141	0.159
*Headwind	0.067	0.273	0.041
*Crosswind	0.146	0.492	0.123
Approach Speed vs **			
**Touchdown to runway threshold	0.057	0.443	0.209
**Headwind	0.211	0.256	0.177
**Crosswind	0.289	0.375	0.054
Instantaneous Glide Slope Angle vs ***			
***Touchdown to runway threshold	0.413	0.388	0.079
Touchdown to Runway Threshold Distance****			
****Headwind	0.079	0.121	0.014
****Crosswind	0.084	0.221	0.056
Number of observations	82	22	117

Note: Sink speed, approach speed with the parameters designated **, is correlated with the left-hand column parameters designated with *, instantaneous glide slope with the parameters designated ***, and touchdown distance from runway threshold with those parameters identified with ****. The second column in the table provides the regression coefficients calculated for the two parameters without regard to type of approach.

The definition of the correlation coefficient, r, is included in appendix C. 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. An r value of -1.0 implies a perfect negative relationship between the two parameters involved, while a value of 0.0 will result in a horizontal regression, indicating that no relationship exists between the parameters involved. The values of r are frequently presented as r^2, which is provided directly by Microsoft® Excel® software and used in preparing scatter plots for this report. Given the highly variable nature of landing parameter data, 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. 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, an r^2 >0.10 would imply that at least modest or meaningful correlation exists.

Table 8 shows a table of correlation coefficients (r) derived from the data from the CVG survey. This table shows that a number of data correlations, which are observed for both wide- and narrow-body aircraft, do not appear to hold true for the regional jets. The upper portion of table relates aircraft sink speed to other parameters. The first comparison is between average main landing gear wheel sink speed and the distance the aircraft touchdown from the runway threshold. In this case, the regional jet data indicates that no correlation exists, while the other aircraft types show a strong correlation between these parameters.

Geometric glide slope is a measure of the aircrafts approach path calculated from the aircrafts height crossing the runway threshold and the distance the aircraft touches down from the runway threshold. In this case, sink speed and geometric glide slope are strongly related for the narrow and wide-body jets, but to a far lesser extent for the regional jets.

The correlation between sink speed and approach speed is strong for the narrow-body jets. The degree of correlation is about the same for the wide-body and regional jets, but not very significant.

The values of head- and crosswinds correlate with sink speed for the wide-body models. The stronger correlation exists for crosswind. There is no correlation between sink speed and headwind for the narrow-body and regional jets. A weak correlation exists between sink speed and crosswind for these types. Given the rather insignificant winds observed during this survey, these correlations are hard to explain.

The central portion of table 8 relates approach speed to the variables touchdown distance, headwind, and crosswind. Approach speed shows strong correlation with touchdown distance for wide-body jets, a moderate correlation for regional jets, and no correlation for narrow-body jets. Headwind shows a moderate correlation with approach speed for all three types. Crosswind correlates with approach speed for the wide- and narrow-body types, but not with the regional jets.

Instantaneous glide slope is a measure of the aircrafts approach path calculated from the aircrafts average sink speed and aircraft closure speed at touchdown. This parameter is strongly correlated with touchdown distance for both the wide- and narrow-body jets, but not the regional jets.

The value of touchdown distance from the runway threshold shows moderate correlation with the crosswind component for wide-body aircraft. This parameter shows little correlation with headwind or crosswind in the other comparisons.

The next step in the analysis was to repeat the regression analysis for each model of aircraft observed in this survey. Figure 11 shows the relationship between sink speed and approach speed for the Bombardier regional jet. The results of this analysis are shown in table 9. Selected regression curves, those that generated r^2 values greater than 0.1, are provided in appendix F.

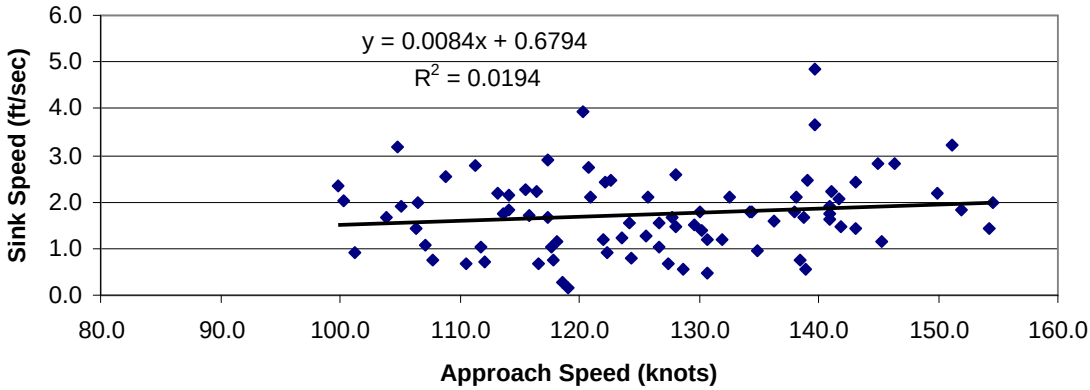


Figure 11. Bombardier Regional Jet, Sink Speed Versus Approach Speed

Table 9. The CVG Correlation Matrix (r) by Aircraft Model

Average Main Wheel Sink Speed vs *							
Aircraft Type	B-737	B-757	B-767	MD-90	CRJ	328 Jet	ERJ
*Touchdown to runway threshold	0.157	0.316	0.327	0.565	0.102	0.154	0.266
*Approach speed	0.195	0.284	0.030	0.430	0.139	0.055	0.203
*Headwind	0.033	0.030	0.468	0.077	0.049	0.000	0.267
*Crosswind	0.065	0.085	0.300	0.348	0.197	0.129	0.101
*Absolute value of crosswind	0.238	0.022	0.220	0.341	0.017	0.189	0.085
Approach Speed vs **							
**Touchdown to runway threshold	0.072	0.038	0.441	0.172	0.092	0.001	0.235
**Headwind	0.086	0.242	0.229	0.263	0.006	0.252	0.502
**Crosswind	0.244	0.079	0.350	0.347	0.117	0.083	0.014
**Absolute value of crosswind	0.062	0.137	0.254	0.316	0.071	0.176	0.003
Instantaneous Glide Slope Angle vs ***							
Aircraft Type	B-737	B-757	B-767	MD-90	CRJ	328 Jet	ERJ
***Touchdown to runway threshold	0.151	0.312	0.310	0.574	0.108	0.098	0.166

Table 9. The CVG Correlation Matrix (r) by Aircraft Model (Continued)

Touchdown to Runway Threshold Distance****							
****Headwind	0.077	0.327	0.160	0.362	0.006	0.385	0.217
****Crosswind	0.093	0.361	0.385	0.000	0.173	0.111	0.251
****Absolute value of crosswind	0.349	0.448	0.161	0.325	0.133	0.024	0.036
Number of observations	26	27	17	29	84	19	14

Note: Approach speed is correlated with the left-hand column parameters designated with **, instantaneous glide slope with the parameters designated ***, and touchdown distance from runway threshold with those parameters identified with ****. The second column in the table provides the regression coefficients calculated for the two parameters without regard to type of approach.

When reviewing table 9, the number of highly correlated parameters for the MD-90 stand in sharp contrast to the correlation coefficients calculated for the CRJ. While the MD-90 shows high correlation between sink speed and the parameters for touchdown distance, approach speed, and crosswind, the CRJ shows only a correlation with crosswind. For approach speed, the MD-90 correlates with all the parameters presented, while the CRJ shows only mild correlation with crosswind. There is a dramatic difference in the level of correlation between the parameters instantaneous glide slope and touchdown distance for these two models. Headwind has a significant correlation with touchdown distance for the MD-90 but not for the CRJ. In fact, the only significant levels of correlation involve comparison with crosswind or the absolute value of that parameter, but given the extremely low crosswind observed in this survey, that observation has little significants.

The results for the ERJ are much different than the CRJs. In nearly all cases, the ERJ shows a much stronger correlation between the parameters in table 9, than the CRJ. Given the similarity in size and configuration, this observation was unexpected. The Dornier 328 jet data shows a strong influence of headwind on approach speed and touchdown distance, but in contrast, headwind had no influence on this aircraft's sink speed.

In an attempt to simplify the interpretation of table 9, the regression coefficients between selected parameters for each aircraft model in the CVG survey are presented as bar graphs in figures 12, 13, and 14. The entire set of these plots is provided in appendix I.

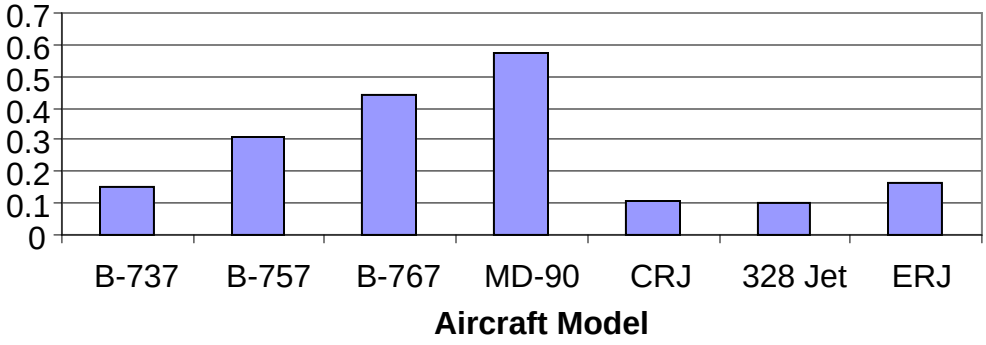


Figure 12. Correlation Coefficient r, Instantaneous Glide Slope Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey

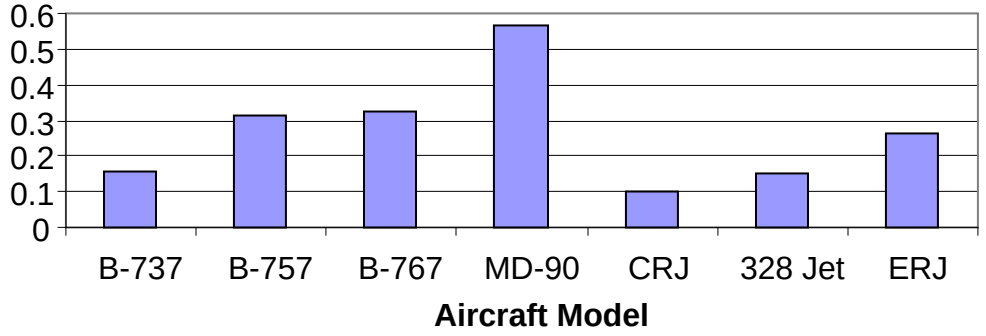


Figure 13. Correlation Coefficient r, Average Sink Speed Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey

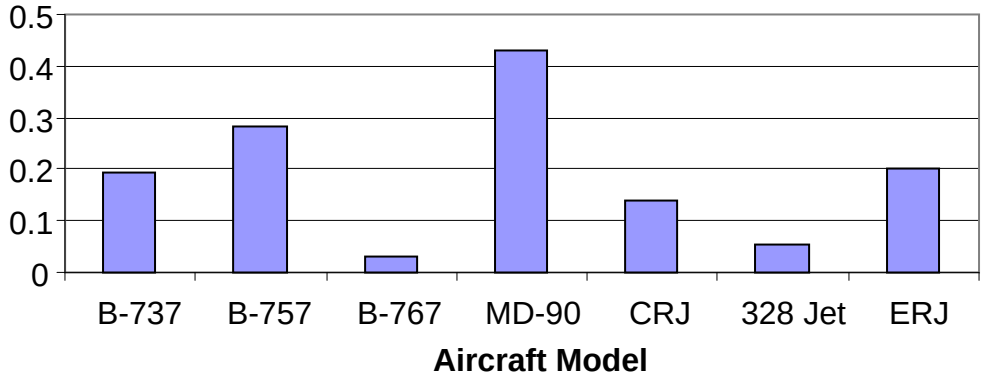


Figure 14. Correlation Coefficient r, Average Sink Speed Versus Approach Speed, CVG Landing Parameter Survey

These plots show the consistently high correlations for the MD-90 landings compared to the other aircraft models. In general, the regional jets show lower correlations between these variables, as shown in figures 11-14, than the large aircraft. While there is no clear explanation for these findings, it is possible that piloting techniques are different for individual models and perhaps even different between operators of the same model.

5. ATLANTIC CITY INTERNATIONAL AIRPORT DISCUSSION.

5.1 OPERATIONS AT ACY.

ACY, which is the home of the FAA William J. Hughes Technical Center, is a regional airport with limited commercial traffic. The airport averages less than 40 commercial aircraft operations per day. In addition, a large number of U.S. Air National Guard and U.S. Coast Guard operations are conducted at ACY. Both of these organizations have aircraft based at the airport. The FAA also has several research aircraft based at this facility, and both military and civilian training is conducted at ACY. As shown in figure 15, the airport has two runways, the 10,000-foot runway 13/31 and the 6,140-foot runway 4/22. The commercial terminal is located off of taxiway H. Thus, commercial aircraft landing on runway 13 normally slow down to turn off the runway at taxiway H, effectively reducing the length of the runway used during routine operations.

The limited commercial aircraft flight schedule provides the opportunity for use of the airport for various training operations. Large numbers of military and government aircraft use the airport for training landings. In particular, military transports and air-refueling aircraft perform touch-and-go landings at ACY. Periodically, the airport is used for training flights for commercial airlines.

During the time period that landing parameter data was collected at ACY, only runway 13 was equipped with an ILS. This restricted landing operations to this runway during poor weather conditions. The restriction was a primary consideration for selecting this location for the FAA's Video Landing Survey Facility. A more detailed description of this facility is provided in appendix E. One of the goals of this facility was to characterize the effects of weather conditions on aircraft landing performance. The airfields, on which most other video landing parameter surveys were conducted, had multiple runways with multiple ILS capability to accommodate wind and weather conditions. Only DCA [13], which only had one main runway, with an ILS serving only approaches from the south, has conditions similar to ACY.

During the survey period, the primary commercial operations at ACY were performed using McDonnell Douglas DC-9 and Beechcraft 1900D aircraft. Data on the Beechcraft 1900D landings were previously reported in reference 16. The Beechcraft 1900D data is used in this report as a comparison to the other reported data. In addition, a significant number of training operations of U.S. Air Force KC-10 aircraft were recorded. KC-10's are large tanker/transport aircraft based on the McDonnell Douglas DC-10-30CF commercial transport. These operations were primarily touch-and-go landings, not full-stop landings. Once the aircraft touched down on the runway, the aircraft accelerated and tookoff, returning to the landing pattern for another approach.

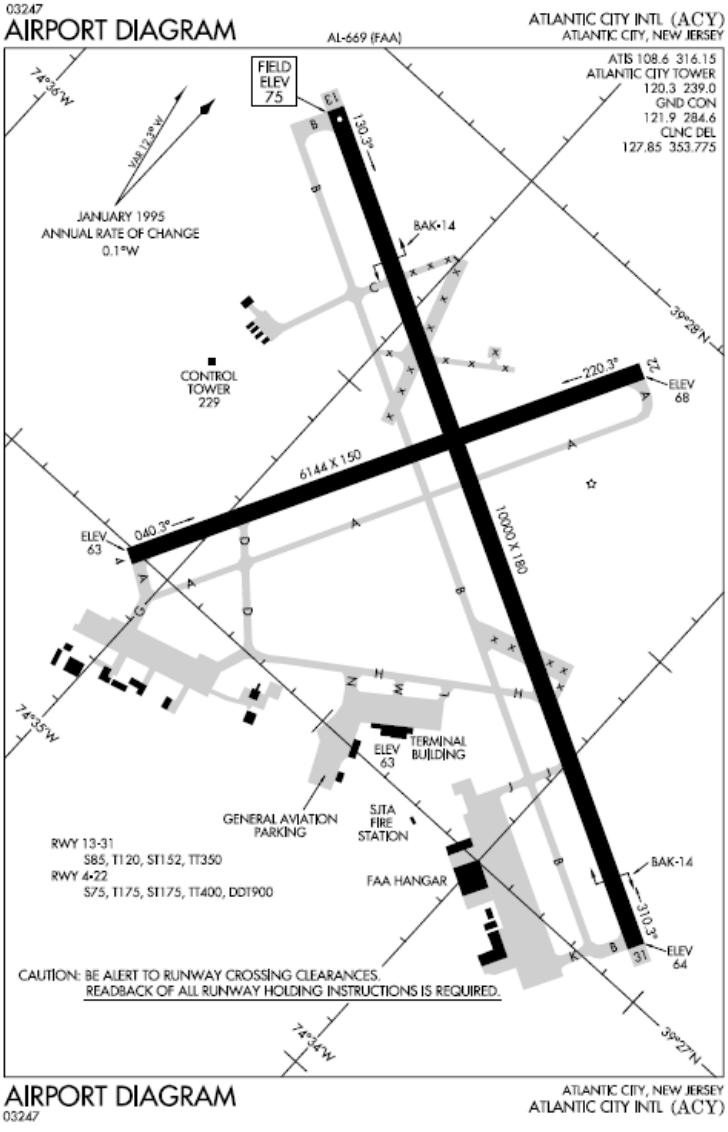


Figure 15. The ACY Airport Diagram

In addition, a series of pilot training and familiarization landings (touch-and-go landings) of Airbus A330 aircraft were recorded. The landing impact parameters recorded during these A330 training operations were not within the range of parameters observed during normal flight operations. The bulk of these A330 landings in good weather were reported to be visual (non-ILS) approaches. Subsequent discussions with the video operator indicated that the flight crews were practicing for extreme conditions and operating at reduced landing weights. It can be assumed that the KC-10 landings were also performed at reduced landing weights.

One of the unique advantages of the Video Landing Survey Facility was that with a slower pace of flight operations, there was the ability of the video operator to monitor communications between the tower and the aircraft during the final approach. This allowed the video system operator to record whether the pilots were flying an ILS or visual approach to touchdown. This allowed the landing data collected to be grouped into visual and ILS approaches, which were further subdivided into ILS landings onto dry runways or wet runways. Toward the end of the

data collection phase of the program, runway repairs were being performed at the far end of the runway, which reduced the available runway length. A limited number of landings were collected with the reduced runway length.

As indicated in figure 16, the ILS approach to ACY runway 13 is flown at a 3.0-degree glide slope, with a straight-in approach of over 10 miles. The expected threshold crossing height is 58 feet. Other than any difficulties caused by crosswinds and other weather effects, ACY runway 13 landings experience rather benign operating condition.

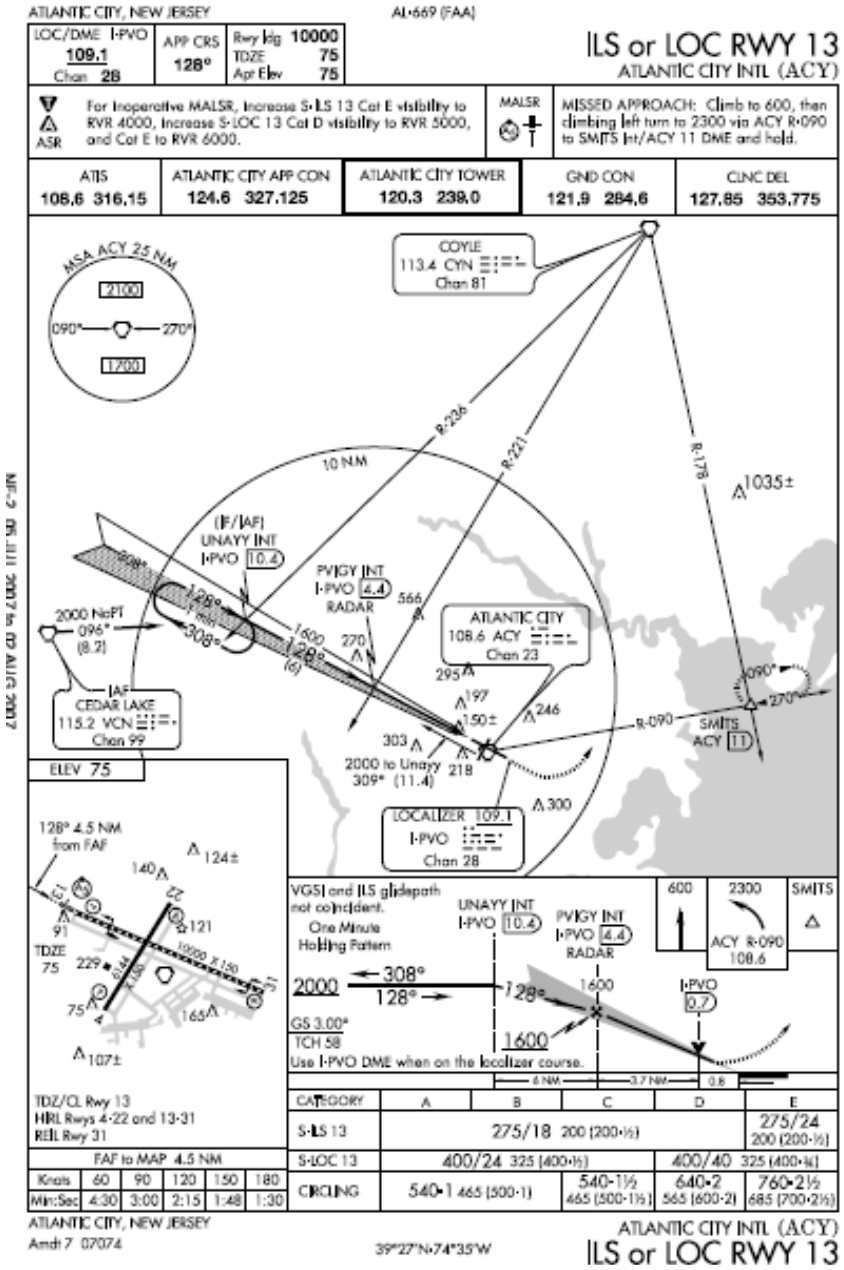


Figure 16. The ACY Approach Plate, ILS, Runway 13

5.2 THE ACY LANDING DISCUSSIONS.

The ACY data collection facility was operational for a period of over 1 year from April 1999 to September 2000. Unfortunately, this task was not a high-priority activity and the data collection facility was operated only when such activity did not interfere with other work. Given the pace of commercial flight operations and the standard workday for the personnel involved, afternoon flight operations were the most likely to be monitored, usually three or four scheduled landings around noon and other training flights as available. These constraints limited the number of landings recorded. Table 10 shows aircraft landings and landing weights by aircraft model.

Table 10. Number of Landings and Maximum Landing Weight by Model, ACY Survey

Aircraft Model	Airbus A330	McDonnell Douglas DC-9	McDonnell Douglas KC-10	Beechcraft 1990D
No. of Landings	43	199,000	106	77
Maximum Landing Weight (lb)	396,800/ 407,900	102,000/ 110,000	435,000	16,765

Table 11 provides information on the mean standard deviation and skewness values for the principle landing parameters observed at ACY. Grouped by aircraft models, appendix A provides the same statistical information for the other landing parameters collected during this survey and appendix B provides a list of the parameters observed for each individual landing.

The most striking observation in table 11 is the high mean values of sink speed observed for both the Airbus A330 and KC-10 landings. The mean sink speed value for the Airbus A330 at ACY is the highest mean value reported in any FAA landing parameter survey. The only other data on this wide-body model of Airbus was during the LHR survey, which resulted in a mean sink speed of 3.69 ft/sec, which in itself is quite high compared to other wide-body landings recorded at LHR. Just for reference, the A340, measured at LHR, produced a mean touchdown sink speed of 3.37 ft/sec. The results for the A330 training flights indicated that commercial operators who introduced new aircraft designs may have experienced sink speeds considerably higher than subsequently experienced in revenue service. In fact, three of the landings were in excess of the design limit value of 10 ft/sec. The authors recommend that, in the future, airframe manufacturers and regulatory authorities monitor the training flights of new design more closely.

Table 11. Comparison of Primary Landing Parameters by Aircraft Model, ACY Survey

Aircraft Model		Parameters				
		Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
Airbus A330	Mean	133	128	4.7	5.1	3.3
	Std Dev	7.97	7.97	2.67	4.07	9.10
	Skewness	0.041	0.447	0.717	-0.818	-0.581
McDonnell Douglas DC-9	Mean	130	126	2.3	4.6	-1.0
	Std Dev	11.11	11.37	1.18	3.88	6.58
	Skewness	0.905	0.606	0.554	0.131	0.300
McDonnell Douglas KC-10	Mean	141	136	3.7	3.9	1.2
	Std Dev	13.63	13.90	1.47	4.46	7.76
	Skewness	0.668	0.364	0.275	0.259	-0.701
Beechcraft 1990D	Mean	104	98	1.7	4.4	0.2
	Std Dev	11.46	10.68	1.06	4.35	6.11
	Skewness	0.735	0.678	1.850	0.304	-0.247

Std Dev = Standard deviation

While the sink speed reported for KC-10 appears high, the previous survey results show that the DC-10 typically had sink speeds of approximately 3.5 ft/sec. Consequently, the value of 3.7 ft/sec for these training flights was not troubling compared to the A330 findings. In contrast, the sink speed values for the ACY DC-9 is generally lower than the sink speed values reported for the DC-9 and MD-80/90 aircraft in previous survey results. These relatively low DC-9 average sink speeds suggest that the higher sink speeds observed for the KC-10 and A330 landings were not the result of system or calibration errors.

The sink speed probability distribution for the ACY landings is shown in figure 17. When this figure is compared with the results of the LHR survey shown in figure 18, the ACY A330 sink speed probability is much different than the A330/A340. Both figures include the sink speed distribution from the U.S. Military Specification (MIL)-A-8863, which is used for military transport aircraft design criteria and was used as a basis of comparison on previous surveys. The curve for the KC-10, which follows the MIL-A-8863 curve in figure 17, is similar to the sink speed distribution reported in references 12, 13, and 14.

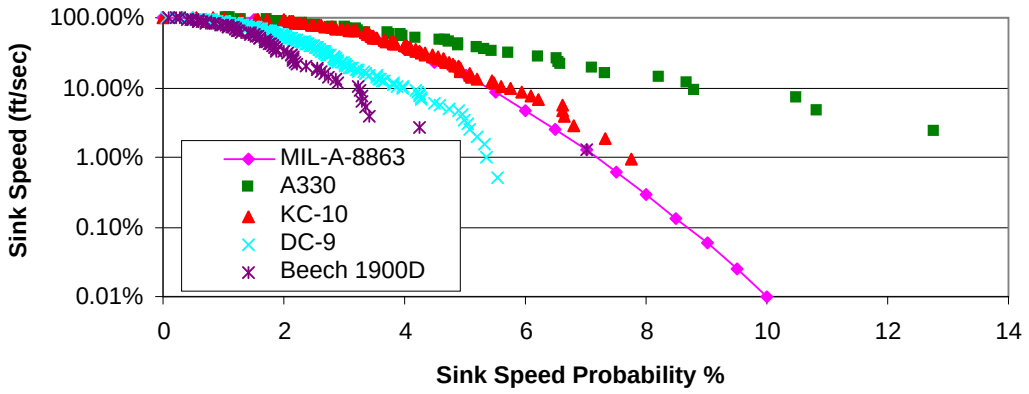


Figure 17. The ACY Sink Speed Probability by Aircraft Model

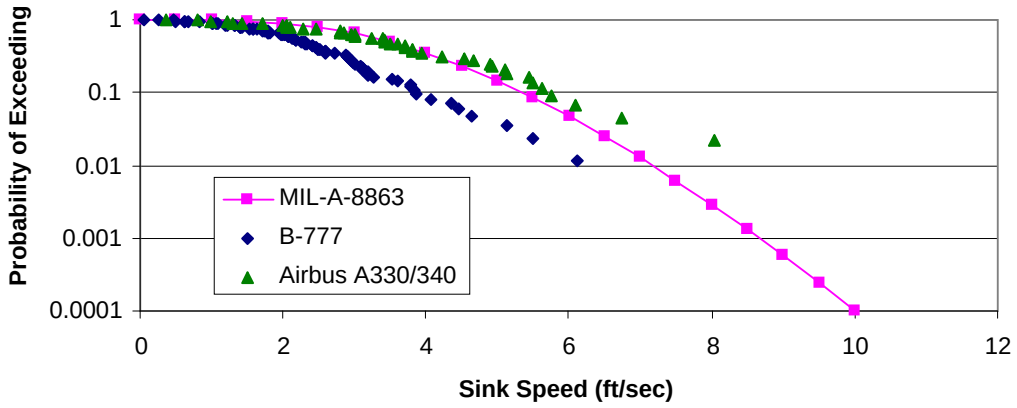


Figure 18. Sink Speed Probability, Medium Wide-Body Aircraft, LHR Survey

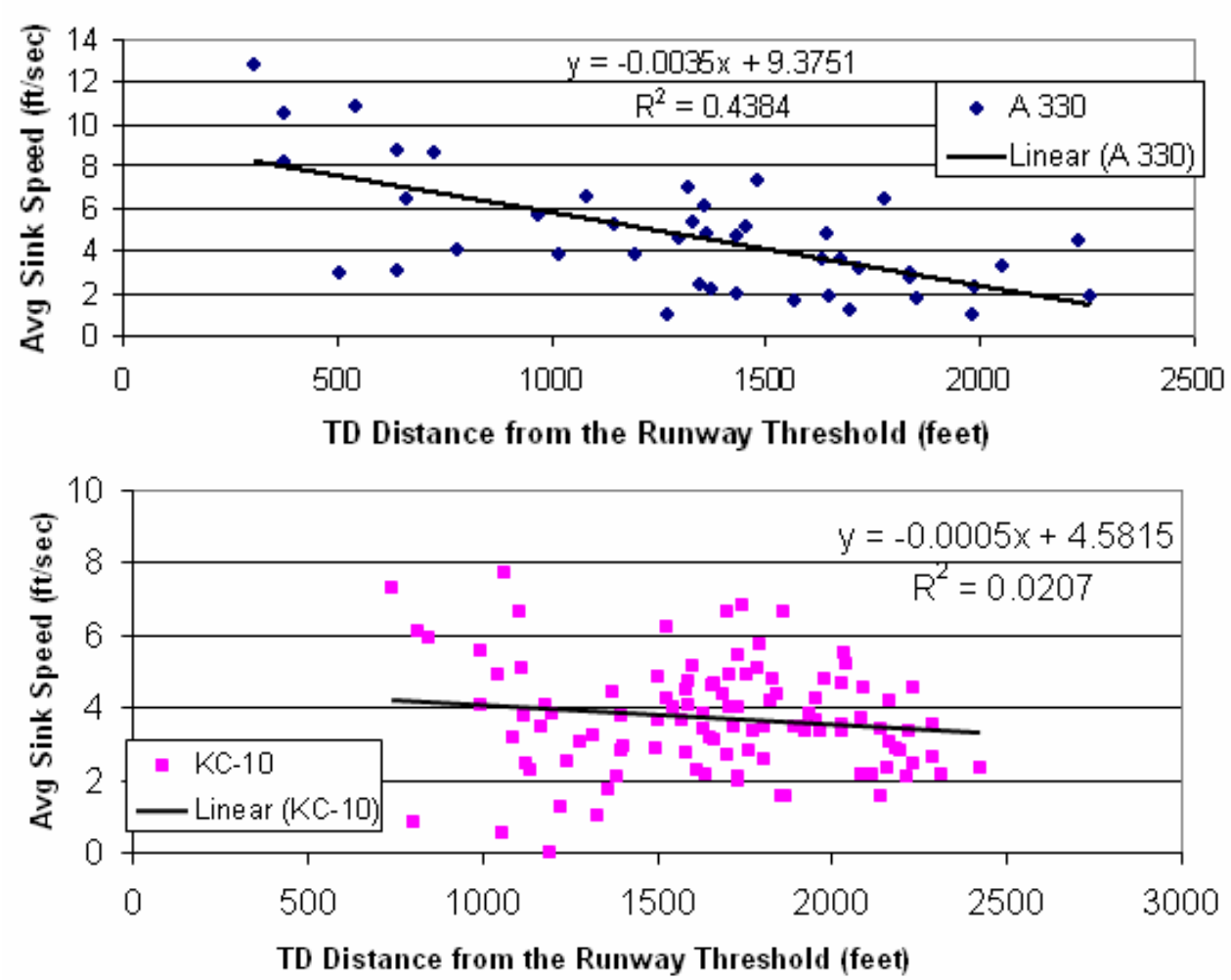
Another notable observation is the standard deviation values for crosswinds shown in table 11. For the entire ACY survey, the standard deviation of crosswind average was over 7 knots. Comparing this to the CVG crosswind average of 2 knots provides an indication that there were significant crosswinds during the ACY recording interval and the CVG survey was conducted in conditions considerably more benign than the ACY survey. This was not terribly surprising since runway 13 is the only ACY ILS runway.

As shown in table 12, two factors are revealed that contribute to the sink speed differences between the training landings (A330 and KC-10) and standard commercial flights. The first factor is the aircraft's touchdown distance from the runway threshold. The mean value of touchdown distance for the A330 is 1319 feet, and for the KC-10 it is 1662 feet. Both the DC-9 and Beechcraft 1900D touchdown over 1800 feet down the runway. The fact that the training flights are touch-and-go landings, the pilots may be trying to maximize the available runway in case a problem occurs when accelerating for takeoff. The shorter touchdown distance also reflects less of a flare of the aircraft prior to touchdown. Figure 19 emphasizes the differences in the relationship of these parameters between aircraft models.

Table 12. Comparison of Primary Landing Parameters of ACY Landings by Aircraft Model

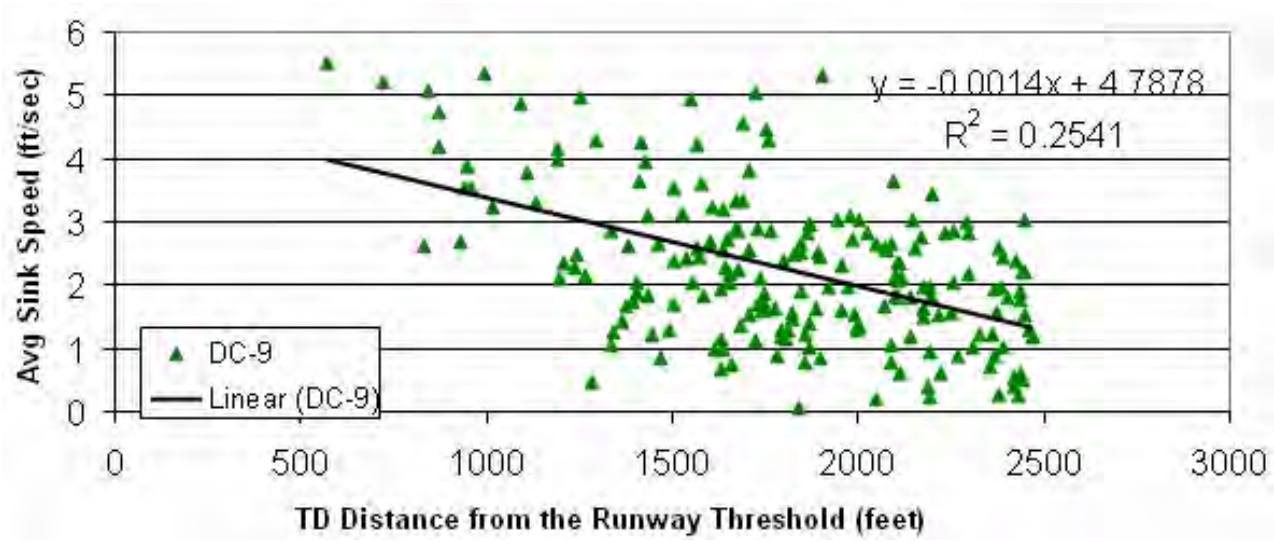
Aircraft Type		Touchdown Distance to Runway Threshold (feet)	Instantaneous Glide Slope (degrees)	Pitch Angle at Touchdown (degrees)	Roll Angle at Touchdown (degrees)	Yaw Angle at Touchdown (degrees)
Airbus A330	Mean	1319	1.27	10.3	1.35	-0.88
	Std Dev	520	0.74	2.13	1.33	5.09
McDonnell Douglas DC-9	Mean	1811	0.61	9.02	0.81	-0.44
	Std Dev	422	0.32	2.13	1.89	2.90
McDonnell Douglas KC-10	Mean	1662	0.92	10.75	0.93	0.19
	Std Dev	394	0.38	1.14	1.61	1.39
Beechcraft 1990D	Mean	1825	0.60	1.69	0.12	16.6
	Std Dev	339	0.37	2.62	2.48	2.90

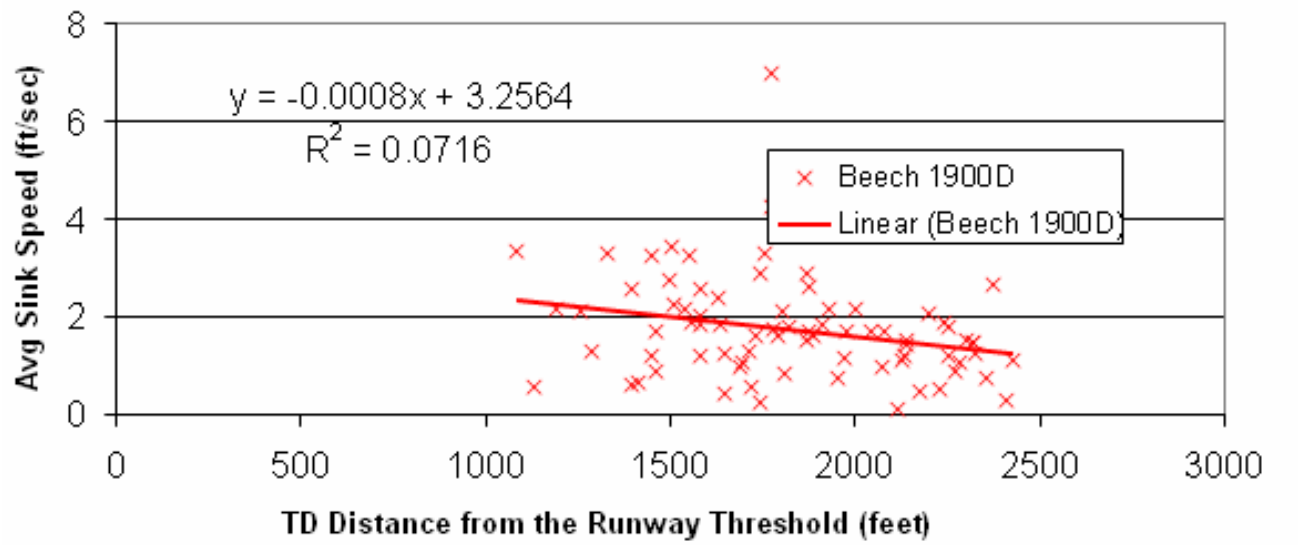
Std Dev = Standard deviation



TD = Touchdown

Figure 19. The ACY Average Sink Speed Versus Touchdown Distance to Runway Threshold





TD = Touchdown

Figure 19. The ACY Average Sink Speed Versus Touchdown Distance to Runway Threshold (Continued)

Shown in table 12, instantaneous glide slope is calculated from the aircraft's arctangent of sink speed divided by groundspeed. The lower the value, the more the pilot has flared his aircraft prior to touchdown. If there was no flare at all, the value should be the ILS glide slope setting, in this case 3.00 degrees. For the commercial landings, the value of instantaneous glide slope is 0.60 degrees. The review of previous survey results [12, 13, and 14] show that instantaneous glide slope values of 0.60 are typical and well within the range of previous findings. In contrast, the values calculated for the training landings are higher than any previously reported findings.

5.2.1 The ACY Weather Impact.

One of the key motivations for collected landing data at ACY was to evaluate the impact of weather conditions on aircraft landing performance. As a part of that effort, weather conditions as well as approach type were monitored as part of the data collection effort. Weather data was collected for the Beechcraft 1900D, McDonnell Douglas DC-9, and KC-10 landings. The landings were divided into non-ILS-approached on dry runways, ILS-approached on dry runways, ILS-approached on wet runways, and in the case of the DC-9s, landings on the shortened runway that was being repaired, as shown in table 13. Additionally, the five KC-10 landings used a global positioning system (GPS) approach, as shown in table 14. The Airbus A330 landings were not included in this weather discussion, since those landings only occurred in good weather. When these landings were divided into separate categories, the influence of weather variations on mean values of landing parameters was not apparent. Only the KC-10 GPS landings show a significant difference among the landing types.

Table 13. The ACY DC-9 Principal Landing Parameters by Weather and Runway Condition

DC-9	No. of Landings	Parameters					
			Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
Dry Runway, Non-ILS	64	Mean	131	126	2.1	5.3	-1.17
		Std Dev	12.8	12.81	1.13	4.33	7.31
		Skewness	1.517	0.850	0.612	-0.177	0.347
Dry Runway, ILS	81	Mean	129	125	2.2	4.4	-1.0
		Std Dev	9.25	9.83	1.09	3.83	6.30
		Skewness	0.006	-0.039	0.770	-0.178	0.473
Wet Runway, ILS	29	Mean	129	124	2.0	5.5	-2.6
		Std Dev	10.88	10.57	1.07	2.79	7.39
		Skewness	0.893	1.213	0.538	0.486	0.128
Runway Under Repair	25	Mean	131	129	3.1	2.2	-1.27
		Std Dev	12.94	12.72	1.33	3.13	4.26
		Skewness	0.275	0.169	0.092	0.281	0.50

Std Dev = Standard deviation

Table 14. The ACY KC-10 Principal Landing Parameters by Weather and Runway Condition

KC-10	No. of Landings	Parameters					
			Approach Speed (knots)	Closure Speed (knots)	Average Sink Speed (ft/sec)	Headwind (knots)	Crosswind (knots)
Dry Runway, Non-ILS	40	Mean	150	140	3.4	4.0	0.3
		Std Dev	11.92	12.93	1.26	4.36	7.51
		Skewness	-0.185	0.172	0.281	0.899	-1.217
Dry Runway, ILS	29	Mean	146	137	3.2	2.6	1.1
		Std Dev	14.42	13.97	1.23	3.61	5.10
		Skewness	0.741	0.583	1.100	0.104	0.204
Wet Runway, ILS	11	Mean	139	134	2.4	4.2	-2.6
		Std Dev	11.14	10.79	1.27	3.37	3.66
		Skewness	-0.190	-0.669	-0.034	0.196	-0.128
GPS Approach	5	Mean	170	156	4.16	3.8	5.0
		Std Dev	4.17	7.74	2.18	4.06	4.88
		Skewness	-1.668	-1.670	-0.511	0.380	-0.067

Std Dev = Standard deviation

The next step in the weather analysis involved plotting regression curves between selected landing parameters to identify differences in their interrelationships based on weather variations. Figure 20 shows the regression curve for DC-9 sink speed versus approach speed, which compares the approach speed and sink speed relationship for dry runway approach types.

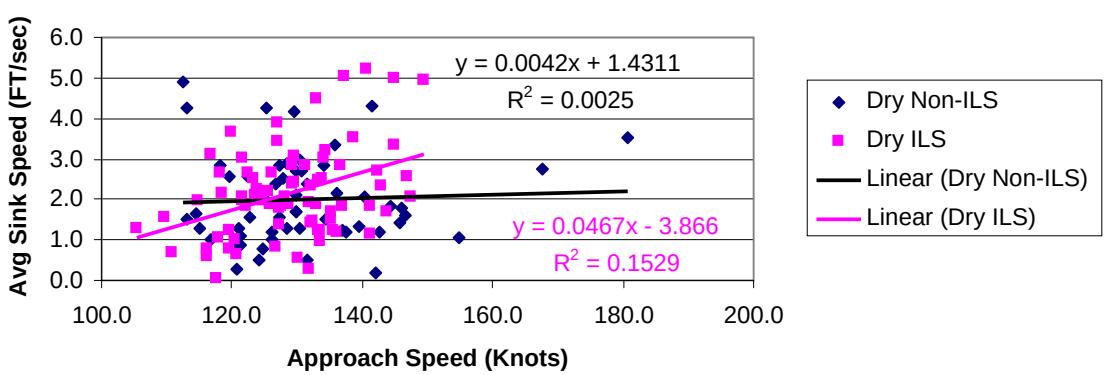


Figure 20. DC-9 Sink Speed Rate Versus Approach Speed by Approach and Runway Condition

Figure 20 shows that there is no relationship between sink speeds and approach speeds for aircraft arriving using a visual approach, but shows a strong correlation between the same parameters for aircraft on an ILS approach. The values of R^2 on the plot are the squares of the correlation coefficient r, which indicates the degree of correlation between the two variables. The definition of correlation coefficient is provided in appendix C.

The results of these regression analyses are summarized in table 15 for the Beechcraft 1900D, table 16 for the DC-9, and table 17 for the KC-10. These tables list the regression coefficients calculated for the regression curves between the landing parameters. The upper portion of these tables relates average sink speed with the parameters in the first column of the tables. Similarly, approach speed is correlated with the first column parameters designated with **, instantaneous glide slope with the parameters designated ***, and touchdown distance from runway threshold with those parameters identified with ****. The second column in the table provides the regression coefficients calculated for the two parameters without regard to type of approach.

Table 15. The ACY Beechcraft 1900D Correlation Matrix (r)

Average Main Wheel Sink Speed vs *				
Approach Type	All Landing Types Combined	Dry Non-ILS	Dry ILS	Wet ILS
*Touchdown to runway Threshold	0.268	0.182	0.387	0.378
*Closure speed	0.028	0.196	0.270	0.356
*Approach speed	0.053	0.144	0.125	0.454
*Headwind	0.085	0.074	0.422	0.045
*Crosswind	0.252	0.222	0.084	0.024
*Absolute value of crosswind	0.077	0.017	0.176	0.128
Approach Speed vs ***				
**Touchdown to runway threshold	0.022	0.195	0.475	0.099
**Headwind	0.293	0.645	0.181	0.645
**Crosswind	0.069	0.074	0.244	0.565
**Absolute value of crosswind	0.273	0.198	0.531	0.269
Instantaneous Glide Slope Angle vs ***				
***Touchdown to runway threshold	0.258	0.141	0.434	0.400
Touchdown to Runway Threshold Distance ****				
****Headwind	0.0745	0.141	0.206	0.512
****Crosswind	0.033	0.114	0.020	0.266
****Absolute value of crosswind	0.062	0.004	0.144	0.325
Number of observations	77	43	24	10

Table 16. The ACY DC-9 Correlation Matrix (r)

Average Main Wheel Sink Speed vs *					
Approach Type	All Landing Types Combined	Dry Non-ILS	Dry ILS	Wet ILS	GPS
*Touchdown to runway threshold	0.504	0.384	0.394	0.686	0.560
*Closure speed	0.123	0.096	0.327	0.057	0.368
*Approach speed	0.085	0.050	0.391	0.008	
*Headwind	0.046	0.192	0.030	0.251	
*Crosswind	0.022	0.101	0.089	0.136	
*Absolute value of crosswind	0.107	0.133	0.063	0.315	
Approach Speed vs **					
**Touchdown to runway threshold	0.062	0.091	0.123	0.120	0.046
**Headwind	0.184	0.300	0.085	0.239	
**Crosswind	0.003	0.010	0.040	0.022	
**Absolute value of crosswind	0.080	0.194	0.138	0.336	
Instantaneous Glide Slope Angle vs ***					
***Touchdown to runway threshold	0.486	0.368	0.369	0.699	0.509
Touchdown to Runway Threshold Distance****					
****Headwind	0.075	0.107	0.133	0.080	
****Crosswind	0.033	0.121	0.161	0.003	
****Absolute value of crosswind	0.062	0.064	0.115	0.138	
Number of observations	199	64	81	29	25

Table 17. The ACY KC-10 Correlation Matrix (r)

Average Main Wheel Sink Speed vs *					
Approach Type	All Landing Types Combined	Dry Non-ILS	Dry ILS	Wet ILS	GPS
*Touchdown to runway threshold	0.144	0.228	0.421	0.447	0.002
*Closure speed	0.106	0.173	0.134	0.433	0.325
*Approach speed	0.022	0.060	0.126	0.311	0.769
*Headwind	0.026	0.020	0.110	0.268	0.801
*Crosswind	0.005	0.194	0.100	0.256	0.744
*Absolute value of crosswind	0.099	0.014	0.069	0.685	0.270
Approach Speed vs **					
**Touchdown to runway threshold	0.135	0.224	0.258	0.505	0.998
**Headwind	0.017	0.211	0.054	0.026	0.744
**Crosswind	0.233	0.014	0.117	0.434	0.408
**Absolute value of crosswind	0.113	0.126	0.507	0.419	0.408

Table 17. The ACY KC-10 Correlation Matrix (r) (Continued)

Instantaneous Glide Slope Angle vs ***					
Approach Type	All Landing Types Combined	Dry Non-ILS	Dry ILS	Wet ILS	GPS
***Touchdown to runway threshold	0.181	0.178	0.480	0.409	0.024
Touchdown to Runway Threshold Distance****					
****Headwind	0.136	0.036	0.047	0.547	0.536
****Crosswind	0.326	0.036	0.344	0.108	0.825
****Absolute value of crosswind	0.005	0.146	0.169	0.618	0.469
Number of observations	106	40	29	11	5

Significant differences in correlation exist among various landing parameters for different landing types. In general, higher correlations exist for landings performed on wet runways. Graphs of correlation coefficients as a function of landing type are included in appendix I. These plots are for all the parameter combinations reported in tables 15, 16, and 17. Figure 21 is representative of the plots provided in appendix I.

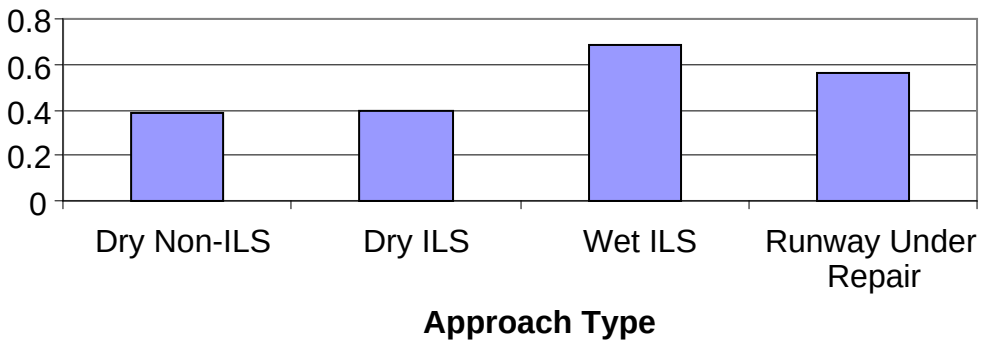


Figure 21. The ACY Average Sink Speed Versus Touchdown Distance From Runway Threshold Correlation Coefficient (r), DC-9 Landings

For all three aircraft models, the values of sink speed and instantaneous glide slope angle correlated well with touchdown distance on a wet runway. A detailed study of these numerous relationships among parameters is presented in appendix I.

It is obvious from the review of tables 15, 16, and 17 that weather conditions do have an impact on the correlation coefficients between various landing parameters. However, given the rather limited number of bad-weather landings recorded, no general conclusions can be drawn from this data.

Table 17 shows the variation in mean values of landing parameters for the KC-10 aircraft. The last column of data shows a landing category identified as GPS approach. This category comprises only five landings, but those landings have higher approach closures and sink speeds than the other KC-10s in this survey. The mean approach speed is 20 knots higher, and the sink speed is nearly 3/4 ft/sec higher. These are the only surveyed landings that were identified as

flying a GPS approach. To emphasis the impact of these landings, table A-2 of appendix A, which documents the statistical distribution of landing parameters for the KC-10, was recalculated without the GPS landings included. When table 18 is compared to table A-2, the average sink speed decreases by 0.5 ft/sec, and the average approach speed decreases by 2 knots. The values in table 18 agree well with DC-10 data collected on previous commercial surveys.

Table 18. Modified Statistical Summary of KC-10 Landing Parameters Without Data From GPS Approaches at ACY for 101 Landings

Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video sink speeds	Port wheel	3.2	1.48	0.621	ft/sec
	Starboard wheel	3.3	1.31	0.280	ft/sec
	Average of main wheels	3.2	1.26	0.478	ft/sec
Closure speed (measured to camera)		135	12.44	0.352	knots
Approach speed		139	12.02	0.220	knots
Wind speed:	Headwind	3.5	4.00	0.665	knots
	Crosswind	0.2	6.35	-0.882	knots
Pitch angle at touchdown		10.8	1.07	-0.386	degrees
Roll angle at touchdown		0.8	1.64	-0.268	degrees
Yaw angle at touchdown		0.3	2.47	0.136	degrees
Instantaneous glide slope angle		0.8	0.32	0.484	degrees
Geometric glide slope angle					degrees
Height over runway threshold					feet
Threshold to touchdown distance		1614	372	-0.198	feet
Off-centerline distance at touchdown		-0.2	10.37	-0.218	feet

5.2.2 Global Positioning Systems Operations at ACY.

One of the more notable findings from the landing data obtained from the ACY landing loads facility is the possibility of higher loads at touchdown for aircraft using the GPS for guidance. At ACY, the joint FAA and U.S. Navy video survey team collected a limited quantity of touchdown data for aircraft that used GPS for guidance. These were the military KC-10 aircraft that were conducting routine touch-and-go training exercises. The tabular results for both the GPS and non-GPS KC-10 landings are presented in table B-3 in appendix B. There were no recorded GPS operations for commercial aircraft at ACY.

During the ACY data collection phase accurate records of the type of landing were being maintained for most of the KC-10 aircraft. These records included: weather, ILS, non-ILS, wet or dry conditions, and whether a landing was using GPS.

These GPS operations were compared to the other ILS and manual touch-and-go landings for the same KC-10 aircraft. Since the Next Generation Air Transportation System commercial aircraft operations will be conducted almost entirely using the GPS, there could be some concerns that using GPS for final approach and landing has the potential to impart increased loads and fatigue on the landing gear and support structure of commercial aircraft. Figures 22 and 23 show that both the GPS touchdown groundspeeds and vertical accelerations (sink speed) are higher than their non-GPS counterparts. In either case, the median (i.e., middle 50%) of the GPS groundspeeds and vertical accelerations at touchdown are clearly higher than the corresponding non-GPS values.

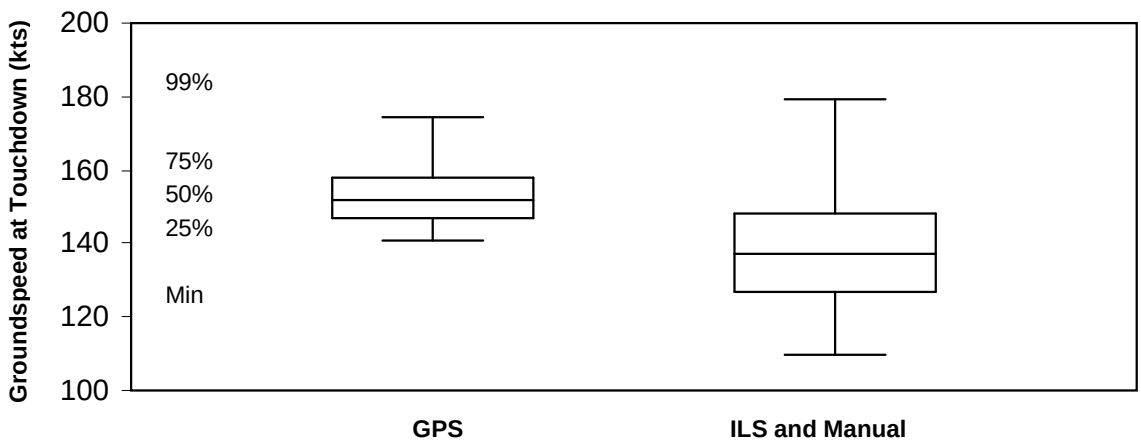


Figure 22. KC-10 ACY Touchdown Groundspeeds

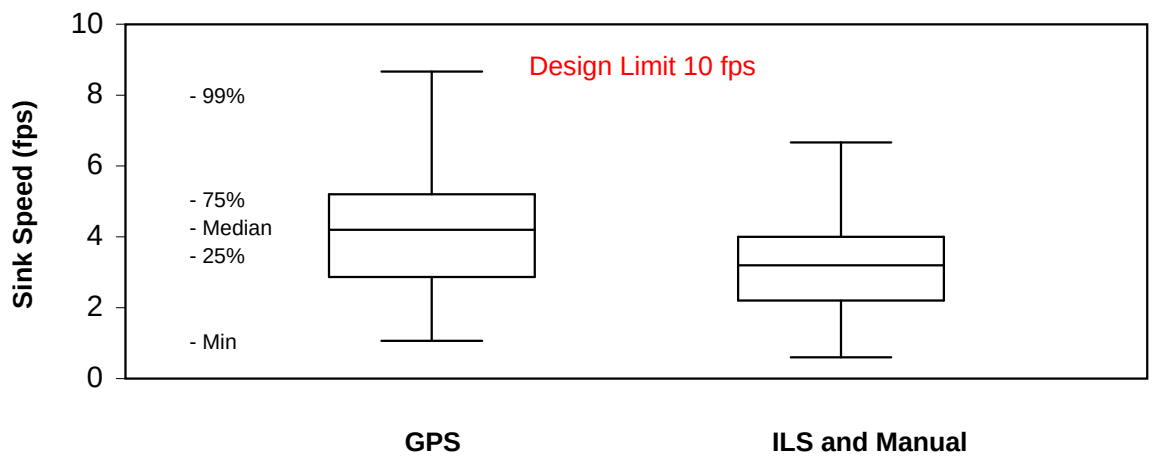


Figure 23. KC-10 ACY Touchdown Vertical Velocities

An alternative assessment of the same data provided for the calculation of the average sink speed and groundspeed for a more extensive separation of the landing data. Since weather conditions were recorded, the analysts were able to separate the landing data into the following four categories: GPS, dry non-ILS, dry ILS, and wet ILS. The average sink speed values are shown in figure 24.

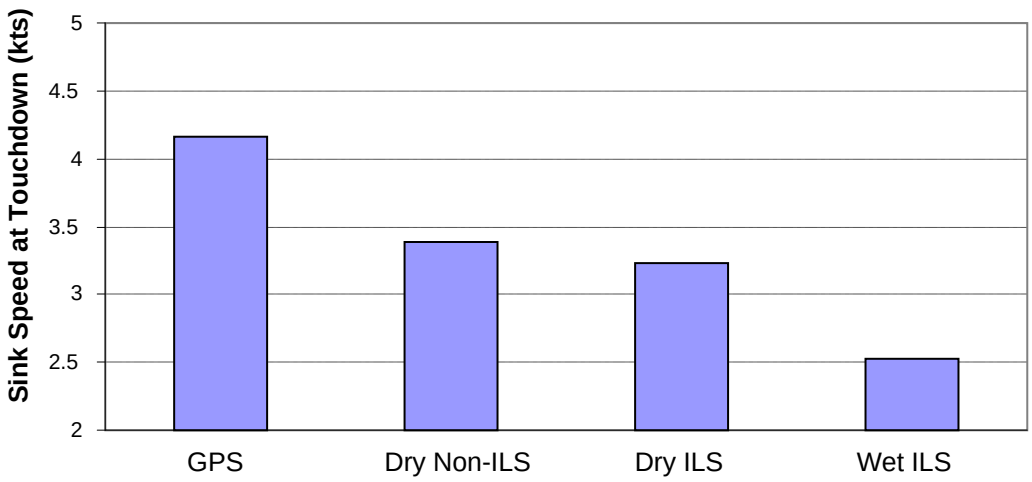


Figure 24. The ACY KC-10 Average Sink Speed at Touchdown

One can readily observe that the GPS average sink speed is greater than the averages of all the other categories. There is no explanation as to why the landings in wet ILS conditions have a lower sink speed than the landings in dry conditions. The data for groundspeeds are similarly provided in figure 25. Again, the average groundspeed for KC-10's using GPS is considerably higher than the other three categories of conditions.

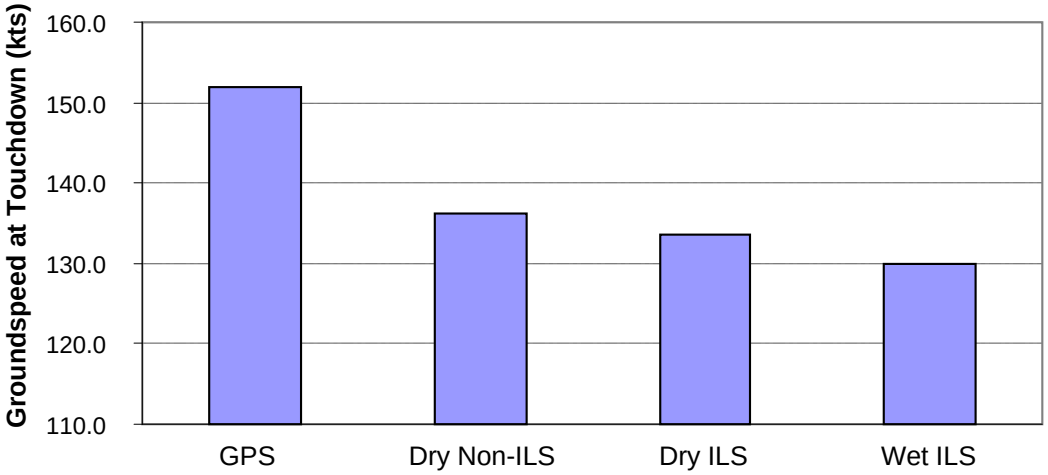


Figure 25. The ACY KC-10 Average Groundspeed at Touchdown

The authors recognize that the sample size for GPS landings is quite small; however, the results, limited as they are, should be further studied to determine if the use of GPS does actually result in higher sink speeds and ground velocities at touchdown. A procedure for accomplishing this task would be to record the touchdown vertical acceleration and groundspeeds for landing for both the GPS and non-GPS events. Since a modest correlation between vertical velocity and vertical acceleration exists, if the vertical accelerations for the GPS are significantly higher (as it

was in the ACY data), then GPS landings would be harder than non-GPS landings. The same can be done for the groundspeed parameter.

The finding described above should provide the rational for the need for future research dealing with the full implementation of GPS. The FAA should continuously access the effect of operational changes on the airframe loads and fatigue lives caused by the full GPS guidance.

6. CONCLUSIONS.

When compared to the results from previous surveys, operations at Cincinnati/Northern Kentucky International Airport generated lower values of sink speed rate and approach speed for both wide- and narrow-body jets. This is most likely attributed to the minimal wind and good weather conditions at the time of the survey.

The same characteristic exists whereby heavier aircraft land with a higher sink speed than smaller aircraft models.

Regional jet operations, in general, experienced lower sink speeds and lower sink speed variability than their larger counterparts operating within the same time frame. Regional jet landings exhibited higher scatter in approach speed than other aircraft types.

Training operations conducted by military refueling aircraft generated approach and sink speeds similar to those recorded for the civil version of the same model aircraft during previous landing parameter surveys.

Attempts to deduce the impact of weather conditions on aircraft landing performance at Atlantic City International Airport (ACY) were inconclusive. There was very little variation in usage due to weather; however, the inclement weather sample sizes were small.

Commercial aircraft training operations observed at ACY generated landings sink speeds considerably higher than those recorded during any of the previous commercial landing loads survey. Three of the recorded landings had sink speeds above the design limit of 10 ft/sec.

A small number of global positioning system (GPS) landings from military aircraft experienced significantly higher approach and sink speeds than the same model using other approach procedures. This suggests that the impact of using GPS may warrant future study to identify whether these procedures inherently generate higher sink speeds and the potential to negatively impact the fatigue lives of the landing gear and support structure.

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

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

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

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

15. DeFiore, Thomas, Jones, Todd, and Micklos, Richard, “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. DeFiore, Thomas, and Micklos, Richard, “Video Landing Parameter Survey—London Heathrow Airport,” FAA report DOT/FAA/AR-07/53, November 2007.

17. United States Department of Transportation, Federal Aviation Administration Change Order 8260.3B, United States Standard Terminal Instrument Procedures

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

APPENDIX A—LANDING PARAMETER STATISTICAL SUMMARIES FOR ATLANTIC CITY INTERNATIONAL AIRPORT AND CINCINNATI/NORTHERN KENTUCKY AIRPORT SURVEYS

Location: Atlantic City International Airport					
Aircraft Model: Airbus A330, Number of Landings—43					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	4.6	2.67	0.717	ft/sec
	Starboard Wheel	4.9	3.07	1.084	ft/sec
	Average of Main Wheels	4.7	2.76	0.984	ft/sec
Closure Speed (Measured to Camera)		128	7.92	0.448	knots
Approach Speed		133	7.98	0.041	knots
Wind Speed:	Headwind	5.1	4.07	-0.818	knots
	Crosswind	3.3	9.10	-0.581	knots
Pitch Angle at Touchdown		10.3	2.27	0.565	degrees
Roll Angle at Touchdown		1.3	1.33	0.218	degrees
Yaw Angle at Touchdown		-0.9	5.09	0.833	degrees
Instantaneous Glide Slope Angle		0.92	0.38	0.430	degrees
Geometric Glide Slope Angle					degrees
Height Over Runway Threshold					feet
Threshold to Touchdown Distance		1319	520	-0.315	feet
Off-Center Distance at Touchdown		0.0	12.6	-1.039	feet

Location: Atlantic City International Airport					
Aircraft Model: McDonnell Douglas KC-10, Number of Landings—106					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	3.6	1.64	0.42	ft/sec
	Starboard Wheel	3.7	1.52	0.23	ft/sec
	Average of Main Wheels	3.7	1.47	0.27	ft/sec
Closure Speed (Measured to Camera)		136	13.90	0.364	knots
Approach Speed		141	13.63	0.668	knots
Wind Speed:	Headwind	3.9	4.46	0.259	knots
	Crosswind	1.2	7.76	-0.701	knots
Pitch Angle at Touchdown		10.8	1.14	-1.227	degrees
Roll Angle at Touchdown		0.9	1.61	-0.381	degrees
Yaw Angle at Touchdown		0.2	2.31	0.200	degrees
Instantaneous Glide Slope Angle		1.27	0.74	0.881	degrees
Geometric Glide Slope Angle					degrees
Height Over Runway Threshold					feet
Threshold to Touchdown Distance		1662	394	-0.326	feet
Off-Center Distance at Touchdown		0.8	10.3	-0.573	feet

Location: Atlantic City International Airport					
Aircraft Model: McDonnell Douglas DC-9, Number of Landings—199					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.3	1.18	0.554	ft/sec
	Starboard Wheel	2.3	1.28	0.589	ft/sec
	Average of Main Wheels	2.3	1.17	0.641	ft/sec
Closure Speed (Measured to Camera)		126	11.37	0.607	knots
Approach Speed		130	11.11	0.905	knots
Wind Speed:	Headwind	4.6	3.88	0.131	knots
	Crosswind	-1.0	6.58	0.300	knots
Pitch Angle at Touchdown		9.0	2.13	-0.701	degrees
Roll Angle at Touchdown		0.8	1.89	-0.156	degrees
Yaw Angle at Touchdown		-0.44	2.90	-0.424	degrees
Instantaneous Glide Slope Angle		0.61	0.32	0.760	degrees
Geometric Glide Slope Angle					degrees
Height Over Runway Threshold					feet
Threshold to Touchdown Distance		1812	422	-0.465	feet
Off-Center Distance at Touchdown		1.6	7.3	-1.109	feet

Location: Atlantic City International Airport					
Aircraft Model: Beechcraft 1900D, Number of Landings—77					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	1.8	1.07	1.92	ft/sec
	Starboard Wheel	1.7	1.26	1.34	ft/sec
	Average of Main Wheels	1.7	1.06	1.85	ft/sec
Closure Speed (Measured to Camera)		98	10.68	0.678	knots
Approach Speed		104	11.46	0.734	knots
Wind Speed:	Headwind	4.4	4.35	0.304	knots
	Crosswind	5.2	3.19	-0.246	knots
Pitch Angle at Touchdown		1.7	2.63	2.63	degrees
Roll Angle at Touchdown		0.1	2.48	0.236	degrees
Yaw Angle at Touchdown		1.66	0.29	2.214	degrees
Instantaneous Glide Slope Angle		0.60	0.37	1.83	degrees
Geometric Glide Slope Angle					degrees
Height Over Runway Threshold					feet
Threshold to Touchdown Distance		1825	339	-0.034	feet
Off-Center Distance at Touchdown		1.0	5.1	-0.039	feet

Location: Cincinnati International Airport					
Aircraft Model: Boeing 737, Number of Landings—26					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.0	1.03	0.915	ft/sec
	Starboard Wheel	1.6	1.08	2.107	ft/sec
	Average of Main Wheels	1.7	0.85	1.678	ft/sec
Closure Speed (Measured to Camera)		132	8.39	0.060	knots
Approach Speed		133	8.33	-0.033	knots
Wind Speed:	Headwind	0.9	1.96	0.069	knots
	Crosswind	-0.9	1.42	0.241	knots
Pitch Angle at Touchdown		5.5	1.28	1.287	degrees
Roll Angle at Touchdown		-0.1	1.48	-0.383	degrees
Yaw Angle at Touchdown		1.3	2.38	0.299	degrees
Instantaneous Glide Slope Angle		0.4	0.20	1.278	degrees
Geometric Glide Slope Angle		1.4	0.29	0.216	degrees
Height Over Runway Threshold		40.1	7.1	-0.647	feet
Threshold to Touchdown Distance		1708	358	1.667	feet
Off-Center Distance at Touchdown		-5.0	5.4	0.373	feet

Location: Cincinnati International Airport					
Aircraft Model: Boeing 757, Number of Landings—27					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.0	0.98	1.353	ft/sec
	Starboard Wheel	2.0	1.21	1.300	ft/sec
	Average of Main Wheels	2.0	0.97	1.624	ft/sec
Closure Speed (Measured to Camera)		128	5.98	0.199	knots
Approach Speed		129	5.30	0.497	knots
Wind Speed:	Headwind	1.3	1.77	0.591	knots
	Crosswind	-1.0	1.83	0.119	knots
Pitch Angle at Touchdown		4.5	0.96	-0.024	degrees
Roll Angle at Touchdown		-0.4	1.19	0.231	degrees
Yaw Angle at Touchdown		1.0	1.90	0.823	degrees
Instantaneous Glide Slope Angle		0.5	0.25	1.533	degrees
Geometric Glide Slope Angle		1.5	0.28	0.655	degrees
Height Over Runway Threshold		39.6	6.9	0.335	feet
Threshold to Touchdown Distance		1544	350	0.869	feet
Off-Center Distance at Touchdown		-5.0	6.4	0.395	feet

Location: Cincinnati International Airport					
Aircraft Model: Boeing 767, Number of Landings—17					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.4	1.24	0.079	ft/sec
	Starboard Wheel	1.9	1.11	0.491	ft/sec
	Average of Main Wheels	2.1	1.05	0.286	ft/sec
Closure Speed (Measured to Camera)		144	5.40	-0.718	knots
Approach Speed		146	4.58	0.239	knots
Wind Speed:	Headwind	1.3	2.00	0.764	knots
	Crosswind	-0.9	2.02	-0.277	knots
Pitch Angle at Touchdown		4.4	1.23	0.325	degrees
Roll Angle at Touchdown		-0.3	1.31	-0.063	degrees
Yaw Angle at Touchdown		0.2	2.58	-0.419	degrees
Instantaneous Glide Slope Angle		0.5	0.24	0.271	degrees
Geometric Glide Slope Angle		1.6	0.38	0.645	degrees
Height Over Runway Threshold		43.6	6.8	0.682	feet
Threshold to Touchdown Distance		1585	354	0.885	feet
Off-Center Distance at Touchdown		-5.1	5.5	0.056	feet

Location: Cincinnati International Airport					
Aircraft Model: Boeing 777, Number of Landings—4					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.2	0.83	1.632	ft/sec
	Starboard Wheel	1.8	1.27	-0.844	ft/sec
	Average of Main Wheels	1.9	0.94	-0.220	ft/sec
Closure Speed (Measured to Camera)		144	4.39	0.654	knots
Approach Speed		145	2.94	1.960	knots
Wind Speed:	Headwind	1.6	2.13	1.475	knots
	Crosswind	-0.7	2.35	0.569	knots
Pitch Angle at Touchdown		4.6	0.50	-1.055	degrees
Roll Angle at Touchdown		-0.1	0.73	-1.109	degrees
Yaw Angle at Touchdown		0.2	0.39	-1.002	degrees
Instantaneous Glide Slope Angle		0.5	0.21	-0.314	degrees
Geometric Glide Slope Angle		1.4	0.20	-0.892	degrees
Height Over Runway Threshold		48.8	2.6	1.206	feet
Threshold to Touchdown Distance		2009	423	1.460	feet
Off-Center Distance at Touchdown		-3.0	5.7	-1.285	feet

Location: Cincinnati International Airport					
Aircraft Model: Bombardier CRJ-200, Number of Landings—84					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	1.8	1.02	1.231	ft/sec
	Starboard Wheel	1.7	1.06	0.952	ft/sec
	Average of Main Wheels	1.7	0.84	0.816	ft/sec
Closure Speed (Measured to Camera)		125	13.96	0.029	knots
Approach Speed		126	13.87	0.060	knots
Wind Speed:	Headwind	1.2	1.60	0.628	knots
	Crosswind	-0.9	2.18	-0.020	knots
Pitch Angle at Touchdown		2.7	1.35	1.782	degrees
Roll Angle at Touchdown		-0.1	1.97	0.504	degrees
Yaw Angle at Touchdown		0.9	2.27	-0.115	degrees
Instantaneous Glide Slope Angle		0.5	0.23	0.756	degrees
Geometric Glide Slope Angle		1.4	0.23	0.241	degrees
Height Over Runway Threshold		50.2	10.2	0.564	feet
Threshold to Touchdown Distance		2056	347	0.009	feet
Off-Center Distance at Touchdown		-1.1	5.2	0.576	feet

Location: Cincinnati International Airport					
Aircraft Model: Dornier 328 Jet, Number of Landings—19					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	1.5	0.96	0.564	ft/sec
	Starboard Wheel	1.2	0.73	0.468	ft/sec
	Average of Main Wheels	1.3	0.57	-0.398	ft/sec
Closure Speed (Measured to Camera)		111	16.07	0.783	knots
Approach Speed		111	16.33	0.796	knots
Wind Speed:	Headwind	0.1	1.20	-1.105	knots
	Crosswind	-0.3	2.33	-0.308	knots
Pitch Angle at Touchdown		4.5	1.51	-0.667	degrees
Roll Angle at Touchdown		-0.2	2.17	0.068	degrees
Yaw Angle at Touchdown		0.4	2.98	0.184	degrees
Instantaneous Glide Slope Angle		0.4	0.18	-0.120	degrees
Geometric Glide Slope Angle		1.4	0.19	0.570	degrees
Height Over Runway Threshold		46.2	6.3	0.643	feet
Threshold to Touchdown Distance		1902	308	-0.089	feet
Off-Center Distance at Touchdown		-2.4	4.3	-0.606	feet

Location: Cincinnati International Airport					
Aircraft Model: Embraer ERJ, Number of Landings—14					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.0	0.97	-0.164	ft/sec
	Starboard Wheel	1.6	0.64	0.677	ft/sec
	Average of Main Wheels	1.8	0.73	-0.288	ft/sec
Closure Speed (Measured to Camera)		126	11.76	-0.987	knots
Approach Speed		125	12.56	-0.823	knots
Wind Speed:	Headwind	0.8	1.80	-1.528	knots
	Crosswind	-0.6	2.93	-1.047	knots
Pitch Angle at Touchdown		5.3	1.30	-0.294	degrees
Roll Angle at Touchdown		-0.6	1.36	0.966	degrees
Yaw Angle at Touchdown		0.4	2.16	0.104	degrees
Instantaneous Glide Slope Angle		0.5	0.22	-0.144	degrees
Geometric Glide Slope Angle		1.4	0.26	-0.650	degrees
Height Over Runway Threshold		39.9	8.4	-0.540	feet
Threshold to Touchdown Distance		1734	462	-0.307	feet
Off-Center Distance at Touchdown		-3.3	3.4	-1.066	feet

Location: Cincinnati International Airport					
Aircraft Model: McDonnell Douglas MD-90, Number of Landings—29					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	2.4	1.11	0.052	ft/sec
	Starboard Wheel	2.1	1.23	0.756	ft/sec
	Average of Main Wheels	2.2	1.07	0.298	ft/sec
Closure Speed (Measured to Camera)		141	9.07	0.833	knots
Approach Speed		141	8.28	0.596	knots
Wind Speed:	Headwind	0.4	2.12	0.299	knots
	Crosswind	-0.1	2.20	-0.433	knots
Pitch Angle at Touchdown		4.5	1.23	-0.179	degrees
Roll Angle at Touchdown		-0.7	1.36	0.234	degrees
Yaw Angle at Touchdown		0.2	1.75	-0.328	degrees
Instantaneous Glide Slope Angle		0.5	0.25	0.286	degrees
Geometric Glide Slope Angle		1.7	0.53	0.468	degrees
Height Over Runway Threshold		42.7	11.4	-0.048	feet
Threshold to Touchdown Distance		1569	585	0.429	feet
Off-Center Distance at Touchdown		-1.8	4.5	0.089	feet

Location: Cincinnati International Airport					
Aircraft Model: SAAB SF-340B, Number of Landings—3					
Parameter		Mean Value	Standard Deviation	Skewness	Measurement Units
Video Sink Speeds	Port Wheel	1.1	0.35	1.045	ft/sec
	Starboard Wheel	1.3	1.08	-0.056	ft/sec
	Average of Main Wheels	1.2	0.68	1.513	ft/sec
Closure Speed (Measured to Camera)		122	7.40	-1.719	knots
Approach Speed		122	6.23	-1.431	knots
Wind Speed:	Headwind	-0.2	1.61	-0.575	knots
	Crosswind	0.7	2.05	0.986	knots
Pitch Angle at Touchdown		4.7	1.86	-0.555	degrees
Roll Angle at Touchdown		-0.3	3.73	0.630	degrees
Yaw Angle at Touchdown		1.1	1.29	-1.176	degrees
Instantaneous Glide Slope Angle		0.3	0.18	1.628	degrees
Geometric Glide Slope Angle		1.3	0.33	-1.698	degrees
Height Over Runway Threshold		44.8	15.5	-1.640	feet
Threshold to Touchdown Distance		1879	239	-1.536	feet
Off-Center Distance at Touchdown		-9.0	4.4	-1.630	feet

APPENDIX B—LISTING OF INDIVIDUAL AIRCRAFT LANDING PARAMETER DATA FOR ATLANTIC CITY INTERNATIONAL AIRPORT AND CINCINNATI/NORTHERN KENTUCKY AIRPORT SURVEYS

(Grouped by aircraft model, location, and landing number.)

Table B-1. Landing Data Model Airbus A330
FAA Survey Atlantic City International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)								
701		126.9	4.4	4.0	4.2	777	13	14.2	1.8	-0.6			1.12
702		124.6	3.0	7.7	5.3	1147	5	14.1	3.3	0.4			1.45
703		124.1	4.5	3.4	4.0	1194	-2	13.6	-0.5	0.6			1.08
704		132.6	7.7	3.7	5.7	966	-1	14.9	-0.3	-0.8			1.46
706		128.5	4.6	3.3	3.9	1017	-2	12.4	1.5	-1.6			1.04
711	128.2	114.2	5.6	6.8	6.2	1355	23	12.3	0.1	3.6	14.0	6.5	1.85
712	135.7	126.4	5.0	5.9	5.4	1328	7	12.2	2.5	-0.7	9.3	9.3	1.46
713	137.5	125.8	1.9	2.3	2.1	1432	13	11.9	2.7	-0.9	11.7	7.3	0.56
716	133.8	127.1	1.6	3.5	2.5	1342	2	13.3	1.8	-0.2	6.7	9.9	0.67
717	131.3	123.8	3.4	0.5	2.0	1647	14	13.3	1.5	0.6	7.5	10.4	0.54
718	135.6	127.8	8.5	8.9	8.7	728	9	14.7	3.6	0.3	7.8	10.4	2.30
720	137.7	134.6	4.0	5.2	4.6	2227	16	12.7	1.7	0.1	3.1	11.0	1.16
722	139.5	129.8	3.0	2.6	2.8	1834	3	12.5	0.9	0.9	9.7	11.6	0.73
724	132.7	128.3	5.5	7.5	6.5	1776	10	10.7	4.0	0.1	4.4	9.3	1.73
725	141.2	133.2	7.1	2.7	4.9	1359	-3	12.3	-0.2	-2.6	8.0	9.6	1.24
727	140.1	133.4	6.6	6.6	6.6	1079	1	12.7	3.3	0.5	6.7	8.9	1.67
732	149.9	145.9	0.9	1.3	1.1	1268	-31	7.6	0.9	-1.1	4.0	10.5	0.26
738	123.0	120.4	7.1	7.6	7.3	1481	10	9.8	1.3	7.0	2.6	11.1	2.07
739	126.8	125.7	1.5	2.4	1.9	2251	3	9.3	0.8	-0.9	1.1	12.5	0.52
741	122.5	117.8	2.2	1.2	1.7	1567	12	10.1	0.7	-1.3	4.7	9.7	0.49
744	130.2	127.6	1.8	1.9	1.8	1851	9	8.0	2.0	2.7	2.6	13.3	0.48
745	125.4	121.1	3.1	4.4	3.7	1671	12	8.8	1.3	1.2	4.3	14.1	1.05

Table B-1. Landing Data Model Airbus A330
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)								
748	129.7	123.7	2.5	3.5	3.0	1833	11	8.2	2.9	-1.5	6.0	11.8	0.82
749	120.9	114.4	0.8	1.8	1.3	1692	7	8.5	2.1	-2.1	6.5	11.8	0.39
752	137.9	133.5	2.6	3.9	3.2	1716	9	9.9	0.7	-3.3	4.4	12.9	0.82
786	146.8	144.0	4.4	3.0	3.7	1631	0	7.0	-1.0	-0.1	2.8	4.8	0.88
789	131.1	135.8	2.2	2.5	2.4	1983	5	8.2	0.1	-1.2	-4.7	2.6	0.59
790	120.2	120.1	3.5	5.9	4.7	1297	-3	8.2	3.0	-0.4	0.1	4.8	1.33
792	120.3	123.7	4.6	4.9	4.8	1430	-2	9.2	0.0	0.1	-3.4	4.5	1.30
793	142.3	148.1	1.2	0.9	1.1	1978	-17	7.3	1.8	-0.3	-5.8	2.4	0.24
794	128.7	129.2	3.2	3.5	3.3	2047	2	8.8	0.0	-0.7	-0.5	6.5	0.88
800	135.5	129.7	5.2	4.6	4.9	1641	2	9.2	-0.5	2.2	5.8	-8.6	1.28
801	124.4	118.5	5.4	5.0	5.2	1449	-4	8.3	0.0	0.5	5.9	-9.8	1.49
804	133.1	128.0	11.0	10.7	10.8	542	-7	8.8	2.7	4.3	5.1	-7.0	2.87
808	137.4	130.4	3.3	3.1	3.2	640	6	9.1	-0.1	2.3	7.0	-10.4	0.83
809	145.2	138.8	11.3	14.2	12.8	307	-38	8.2	2.6	12.2	6.4	-9.8	3.12
810	123.8	116.7	8.7	12.3	10.5	377	-10	9.6	3.7	4.9	7.1	-10.2	3.05
811	143.7	136.1	1.9	2.7	2.3	1372	-18	9.0	0.7	-2.3	7.6	-8.8	0.57
812	138.6	130.8	6.5	6.6	6.6	663	-18	8.7	2.2	-5.9	7.8	-8.1	1.70
816	138.5	133.0	8.1	8.4	8.2	375	-21	9.5	1.5	13.6	5.5	-10.4	2.10
818	143.3	137.3	2.6	3.5	3.1	506	-17	9.0	-0.4	10.1	6.0	-8.6	0.75
820	130.7	123.0	8.4	9.2	8.8	638	0	9.7	1.0	7.3	7.7	-10.6	2.43
825	123.5	116.1	6.9	7.3	7.1	1315	-9	8.0	0.3	-1.5	7.4	-9.5	2.08

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-2. Landing Data Model Beechcraft 1900D
FAA Survey Atlantic City International Airport

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
228	No ILS	109.6	101.6	2.3	3.0	2.7	2374	1	2.0	0.6	1.6	8.0	0.8	0.89
243	No ILS	91.4	88.2	0.4	0.9	0.6	1413	-8	4.1	0.3	2.0	3.2	3.8	0.25
245	No ILS	109.3	96.4	1.1	0.7	0.9	1466	-7	2.7	-0.1	1.7	12.9	1.6	0.30
269	Dry ILS	92.4	82.9	2.6	2.6	2.6	1584	-3	5.5	-0.5	1.5	9.5	5.5	1.05
300	No ILS	84.9	78.0	1.3	-0.8	0.2	1748	-1	3.3	-2.9	1.5	6.9	0.9	0.10
303	Dry ILS	97.3	96.9	0.2	1.0	0.6	1719	0	5.8	0.6	1.8	0.4	6.0	0.20
309	Dry ILS	93.4	90.6	2.0	1.8	1.9	2245	10	3.5	0.6	1.8	2.8	6.4	0.70
317	No ILS	103.6	101.5	1.5	1.1	1.3	1288	-12	4.5	-6.5	1.3	2.1	-11.8	0.43
323	No ILS	109.4	107.1	1.6	1.4	1.5	2319	-2	3.2	-3.1	1.5	2.3	-14.8	0.46
337	Wet ILS	104.7	104.3	2.2	1.2	1.7	1465	-6	1.2	-2.3	1.4	0.4	-4.0	0.55
344	Dry ILS	114.5	106.2	0.1	0.5	0.3	2410	-8	2.2	-1.5	1.4	8.3	-8.6	0.09
345	Dry ILS	104.9	98.5	1.2	0.5	0.8	1812	-6	3.9	-4.0	1.5	6.4	-7.7	0.29
360	No ILS	99.1	97.6	1.0	0.5	0.7	2357	11	2.7	-1.8	1.6	1.5	-2.6	0.25
362	No ILS	125.0	120.3	1.8	2.5	2.1	1262	-6	4.1	1.0	1.7	4.7	-5.2	0.60
367	No ILS	85.7	87.1	0.7	0.1	0.4	1650	-4	2.2	-1.1	1.6	-1.4	3.8	0.16
369	No ILS	105.2	103.9	1.1	0.3	0.7	1956	-6	6.1	1.4	2.0	1.3	6.9	0.24
378	No ILS	107.9	101.0	0.6	2.2	1.4	2141	4	2.8	5.1	1.8	6.9	5.8	0.47
432	Wet ILS	99.4	85.1	1.1	1.1	1.1	2427	6	2.0	-0.4	2.1	14.3	7.3	0.43
433	Wet ILS	115.4	99.8	1.8	1.4	1.6	1794	1	7.5	2.4	1.9	15.6	9.0	0.55
441	No ILS	114.4	106.6	1.4	2.9	2.2	1193	-3	1.4	3.5	1.6	7.8	7.8	0.69
454	Dry ILS	90.7	94.6	0.5	0.5	0.5	2230	-3	0.6	0.3	1.9	-3.9	0.7	0.18
464	Wet ILS	98.3	95.8	1.7	2.0	1.9	1916	-1	0.6	-1.4	1.6	2.5	-3.2	0.66

Table B-2. Landing Data Model Landing Data Model Beechcraft 1900D
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
465	Wet ILS	96.0	94.4	1.2	0.6	0.9	1692	1	1.6	0.1	1.5	1.6	-1.2	0.34
471	Wet ILS	92.9	86.9	1.3	1.1	1.2	2328	-1	2.6	-2.0	1.5	6.0	-5.2	0.48
501	No ILS	98.0	97.4	1.8	1.5	1.7	1980	1	2.4	1.1	1.8	0.6	9.0	0.59
515	No ILS	86.8	83.3	2.7	5.8	4.2	1773	4	4.4	5.4	1.8	3.5	11.5	1.73
519	Dry ILS	93.9	86.7	2.4	1.8	2.1	1803	-4	2.3	-3.2	1.3	7.2	-9.6	0.83
521	Dry ILS	105.3	97.4	1.9	1.3	1.6	1888	-8	2.2	-2.4	1.3	7.9	-7.6	0.55
535	No ILS	92.7	92.3	3.3	2.5	2.9	1871	0	3.6	-1.9	1.8	0.4	-2.0	1.07
545	Dry ILS	116.7	113.1	0.6	0.3	0.5	2178	2	5.9	1.2	1.8	3.6	7.1	0.14
548	No ILS	116.9	108.4	1.7	1.7	1.7	2081	12	1.2	2.0	1.8	8.5	5.3	0.53
550	No ILS	114.2	104.7	4.4	2.2	3.3	1087	-4	3.6	0.6	1.7	9.5	3.3	1.08
555	No ILS	101.6	97.0	1.4	1.2	1.3	1718	-1	0.5	0.1	1.6	4.6	-5.3	0.44
556	No ILS	98.7	90.7	1.4	1.8	1.6	1733	-9	2.7	-1.8	1.3	8.0	-8.9	0.60
567	Dry ILS	88.9	81.4	1.0	3.0	2.0	1586	1	3.7	6.0	1.7	7.5	-2.9	0.83
573	No ILS	107.0	98.0	0.6	3.8	2.2	1933	-1	0.8	-0.6	1.3	9.0	0.6	0.74
583	No ILS	106.5	99.5	3.6	3.0	3.3	1330	3	3.0	0.9	1.6	7.0	0.4	1.12
599	Dry ILS	124.3	116.9	1.6	1.5	1.5	2141	-1	2.3	-5.5	1.4	7.4	-11.9	0.44
614	Wet ILS	135.0	118.6	2.4	1.1	1.8	2255	0	2.2	0.1	1.1	16.4	4.4	0.51
617	Dry ILS	108.1	99.7	7.2	6.8	7.0	1778	15	1.2	3.0	1.7	8.4	7.1	2.38
631	Dry ILS		91.1	2.9	1.4	2.2	2001	0	3.6	-1.5	1.7			0.80
638	Wet ILS		83.6	2.0	1.7	1.9	1560	2	5.6	0.0	2.0			0.76
652	No ILS		94.2	1.9	1.1	1.5	2302	3	4.5	-0.5	1.7			0.54
656	No ILS		99.6	2.3	1.9	2.1	2204	1	4.4	-0.7	1.6			0.70

Table B-2. Landing Data Model Beechcraft 1900D
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
659	No ILS		93.7	0.8	0.3	0.6	1136	-7	4.2	2.0	1.4			0.21
666	No ILS		84.4	1.3	1.6	1.5	2324	6	4.4	0.2	1.5			0.58
676	No ILS		89.1	1.4	0.8	1.1	2132	0	5.5	-0.3	1.5			0.41
685	No ILS		91.2	2.6	2.5	2.5	1398	2	2.4	0.8	1.8			0.95
686	No ILS		89.3	1.8	1.7	1.7	1779	1	2.9	1.7	1.5			0.66
698	No ILS		103.1	1.6	2.1	1.9	1636	3	3.0	3.3	2.0			0.61
707	No ILS		98.1	2.3	2.1	2.2	1510	1	0.9	6.5	1.6			0.77
775	Dry ILS	89.3	84.9	3.3	3.2	3.2	1556	5	2.6	1.5	1.7	5.1	89.3	1.29
783	No ILS	113.8	118.8	3.0	3.6	3.3	1451	5	2.8	4.5	1.6	5.4	113.8	0.93
834	Wet ILS	96.9	104.1	1.7	1.9	1.7	1877	0	2.9	-1.4	1.6	-4.1	96.9	0.56
846	Dry ILS	96.6	91.7	1.5	0.7	1.1	1972	1	2.0	-2.0	1.4	-4.9	96.6	0.42
847	Dry ILS	89.0	83.0	1.4	1.0	1.2	1453	4	3.6	-0.3	1.5	-2.3	89.0	0.49
850	Dry ILS	110.1	104.2	3.1	2.3	2.7	1500	3	3.0	-2.5	2.0	-5.7	110.1	0.89
853	Dry ILS	107.7	103.7	1.8	0.4	1.2	2253	5	1.5	-3.2	1.7	4.7	107.7	0.39
854	Dry ILS	101.5	101.0	1.3	2.4	1.8	1585	8	3.3	1.0	1.8	4.5	101.5	0.61
867	No ILS	114.0	110.1	2.0	3.2	2.6	1875	6	3.3	3.8	1.8	11.3	114.0	0.80
875	Dry ILS	115.7	113.1	-0.5	0.7	0.1	2115	2	2.6	0.0	1.5	-3.4	115.7	0.03
877	Dry ILS	88.4	83.9	1.9	2.5	2.2	1543	4	3.4	0.7	1.7	-4.5	88.4	0.88
878	Dry ILS	102.6	99.0	1.6	0.5	1.1	1698	7	2.5	-2.6	1.4	-5.4	102.6	0.36
884	Wet ILS	101.7	97.5	1.0	0.1	1.0	2073	5	5.0	-1.3	1.8	-3.7	101.7	0.34
886	Dry ILS	100.8	99.8	1.0	1.4	1.2	1581	2	3.0	0.1	1.4	-3.6	100.8	0.40
887	Dry ILS	100.0	99.9	0.9	0.7	0.9	2276	3	5.3	-1.4	1.6	-1.0	100.0	0.29

Table B-2. Landing Data Model Beechcraft 1900D
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
892	No ILS	1.7	2.9	2.4	2.3	2.4	1632	10	9.9	1.0	3.0	1.7	2.9	25.93
897	No ILS	1.4	5.5	2.5	4.1	3.3	1760	5	6.0	2.0	0.9	1.4	5.5	19.52
911		3.6	6.8	2.6	3.1	2.9	1744	2	1.9	2.2	1.7	3.6	6.8	14.04
912		5.2	6.7	1.4	-0.2	0.6	1399	5	1.7	3.9	1.8	5.2	6.7	2.94
919	No ILS	4.1	8.4	0.8	1.6	1.2	1647	3	1.9	3.9	1.6	4.1	8.4	4.96
942	No ILS	1.6	-5.3	1.8	1.8	1.8	1824	2	3.9	-0.3	1.6	1.6	-5.3	-11.38
947	No ILS	1.5	-2.5	2.1	1.3	1.7	2046	2	5.0	-3.1	1.3	1.5	-2.5	-21.83
949	No ILS	0.7	-4.5	1.6	0.8	1.2	2133	2	3.3	-1.0	1.6	0.7	-4.5	-8.98
985	No ILS	2.0	2.5	1.1	1.1	1.1	2284	5	3.2	0.2	1.8	2.0	2.5	14.23
993	No ILS	0.0	0.0	3.1	3.8	3.4	1507	5	5.0	1.1	1.8	0.0	0.0	
997	No ILS	7.3	0.1	2.1	0.9	1.5	1871	-4	4.9	-2.0	1.5	7.3	0.1	83.66

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-3. Landing Data Model McDonnell Douglas KC-10
FAA Survey Atlantic City International Airport

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
25	Wet ILS	137.8	127.8	3.5	2.4	3.0	1405	-11	9.9	-1.7	-0.7	10.0	0.0	0.78
45	No ILS	140.4	128.9	3.2	2.4	2.8	1396	-14	10.2	-2.7	5.0	11.5	-19.9	0.73
46	No ILS	135.4	123.9	5.3	3.0	4.2	2164	-4	9.6	-2.5	2.5	11.5	-19.9	1.15
47	No ILS	143.3	127.2	3.4	3.3	3.3	1964	3	7.2	-0.9	1.2	16.1	-19.2	0.89
62	Dry ILS	128.9	118.1	1.1	2.0	1.6	1871	9	11.3	2.2	-1.2	10.8	-1.9	0.45
77		117.2	103.4	5.9	2.3	4.1	993	-23	5.2	-3.3	-3.2	13.8	-11.6	1.35
79		132.4	117.1	7.2	7.4	7.3	745	-27	12.2	1.0	-0.8	15.3	-12.9	2.12
98	Wet ILS	133.1	130.5	0.6	2.6	1.6	2139	-10	10.8	0.1	2.4	2.6	-3.1	0.41
99	Wet ILS	139.5	134.8	1.2	-0.1	0.6	1057	-9	11.0	-1.7	1.9	4.7	-1.7	0.14
100	Wet ILS	135.9	131.2	1.9	2.8	2.4	2423	3	9.2	0.2	3.2	4.7	-1.7	0.61
104	No ILS	147.3	137.0	2.3	4.6	3.5	1171	-15	11.4	0.4	0.9	10.3	-3.8	0.86
106	No ILS	167.0	154.8	1.9	2.3	2.1	1387	-12	10.3	-1.0	2.9	12.2	-4.4	0.46
115	Wet ILS	114.7	106.8	1.0	0.7	0.8	806	-15	11.6	-0.8	1.4	7.9	-1.4	0.27
135	Dry ILS	169.3	163.9	3.4	4.0	3.7	2083	-10	12.0	0.9	5.0	5.4	-4.5	0.77
143	Dry ILS	129.2	128.5	2.4	3.4	2.9	2184	-2	12.2	1.1	-1.5	0.7	3.9	0.76
144	Dry ILS	137.3	138.7	3.0	3.4	3.2	1650	10	11.6	-0.1	2.3	-1.4	3.8	0.78
151	Dry ILS	145.5	140.5	4.7	2.9	3.8	1118	-29	12.6	-2.2	5.6	5.0	-8.7	0.92
152	No ILS	145.4	137.7	0.6	2.0	1.3	1226	-21	11.9	-1.8	4.1	7.7	-9.2	0.32
154	Dry ILS	132.8	128.9	2.1	3.3	2.7	1701	-1	10.9	3.3	-2.1	3.9	-4.6	0.71
155	No ILS	137.0	131.2	2.2	4.5	3.4	2223	-2	11.8	1.2	2.4	5.8	-6.9	0.87
169	No ILS	128.6	126.2	4.2	3.9	4.1	1180	-16	13.0	-0.8	6.3	2.4	-6.6	1.09
170	Wet	132.0	128.0	2.2	2.2	2.2	1642	-3	12.1	0.5	5.7	4.0	-6.9	0.58

Table B-3. Landing Data Model McDonnell Douglas KC-10
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
194	No ILS	149.9	148.0	2.0	2.7	2.3	2160	-1	10.6	2.8	-0.7	1.9	-2.3	0.54
199	Dry ILS	138.2	135.2	3.4	2.8	3.1	2168	-2	9.8	-0.1	-0.3	3.0	-0.5	0.77
207	No ILS	134.1	128.0	3.9	4.5	4.2	1826	-6	9.1	2.1	1.2	6.1	-5.1	1.11
211		139.8	135.3	0.0	0.0	0.0	1192	-3	12.0	1.0	-0.7	4.5	-2.1	0.00
216	No ILS	138.2	138.5	3.4	3.4	3.4	1777	1	9.2	-0.1	-1.3	-0.3	-4.0	0.83
237	GPS	143.7	141.0	4.2	6.0	5.1	1600	7	11.1	1.9	-1.1	2.7	7.5	1.23
239	GPS	165.6	158.7	2.4	3.3	2.9	1494	-3	11.7	0.1	-0.4	6.9	5.8	0.61
246	GPS	162.3	157.5	4.8	4.9	4.8	1978	15	10.9	3.0	-0.8	4.8	13.2	1.03
247	GPS	153.7	150.6	7.1	6.2	6.6	1109	1	10.6	0.0	-2.8	3.1	8.5	1.49
249	GPS	159.4	152.2	0.9	1.2	1.0	1329	-7	10.7	1.0	-0.7	7.2	12.0	0.23
255	Wet ILS	146.4	146.4	3.4	3.4	3.4	1632	5	11.8	-0.2	0.0			0.79
256	Wet ILS	129.7	129.0	4.7	4.0	4.4	1691	-6	10.9	0.6	2.4	0.7	-7.0	1.14
258	Dry ILS	127.4	127.0	3.1	2.5	2.8	1764	-7	11.6	-3.1	4.4	0.4	-4.0	0.75
274	Dry ILS	149.4	144.5	3.3	3.8	3.5	2287	-2	11.5	2.8	0.4	4.9	12.1	0.83
275	Dry ILS	152.1	148.3	4.9	4.1	4.5	1586	4	11.3	1.3	-1.9	3.8	10.3	1.02
282	Wet ILS	150.4	144.4	3.8	3.2	3.5	2031	-17	9.9	0.4	0.6	6.0	-8.0	0.83
284	Dry ILS	138.5	133.7	1.6	2.7	2.1	1730	3	10.5	0.1	0.7	4.8	-5.1	0.54
285	Dry ILS	145.4	140.8	3.3	2.8	3.1	1281	-11	11.4	-0.1	0.1	4.6	-6.6	0.74
371	No ILS	128.1	126.2	2.9	2.2	2.6	1809	10	8.8	0.6	1.2	1.9	10.8	0.69
380	No ILS	115.0	111.2	2.8	1.4	2.1	2216	2	10.4	3.4	-0.1	3.8	10.3	0.63
381	No ILS	147.0	140.6	1.5	2.0	1.7	1358	-1	11.1	1.5	-1.2	6.4	10.2	0.41
390	Dry ILS	132.5	136.0	3.8	4.2	4.0	1546	7	9.9	1.4	-1.2	-3.5	6.1	1.00

Table B-3. Landing Data Model McDonnell Douglas KC-10
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
417	Dry ILS	154.1	158.8	3.6	3.8	3.7	1952	6	11.1	2.0	-0.2	-4.7	6.5	0.78
422		152.0	156.6	3.9	2.9	3.4	2029	2	9.5	-1.0	-3.6	-4.6	3.9	0.73
424		146.7	155.1	2.3	3.3	2.8	2195	7	10.0	2.2	-1.3	-8.4	5.4	0.61
451		132.9	135.0	1.5	2.8	2.1	2086	11	10.9	2.8	0.0	-2.1	11.8	0.54
461		130.9	132.5	2.2	2.1	2.1	2117	9	10.4	-0.7	2.8	-1.6	3.7	0.55
462	No ILS	141.1	142.2	3.1	3.8	3.5	1893	7	11.1	2.0	-4.3	-1.1	4.9	0.82
475	No ILS		143.8	3.8	4.4	4.1	1589	10	9.2	-0.7	0.2			0.97
476	No ILS		167.4	5.0	5.9	5.4	1729	20	8.6	3.9	1.5			1.10
480	No ILS	129.0	127.2	3.9	2.5	3.2	1087	4	10.9	1.1	0.7	1.8	7.8	0.85
482	No ILS	134.0	132.3	3.5	3.9	3.7	1573	4	10.6	2.9	-0.3	1.7	8.8	0.94
483	No ILS	125.0	127.5	2.1	2.5	2.3	1141	-8	9.5	0.3	0.3	-2.5	8.7	0.61
484	No ILS	150.6	148.1	3.9	3.1	3.5	1717	9	9.3	2.6	0.8	2.5	8.7	0.80
485	No ILS	128.6	124.5	7.2	6.0	6.6	1860	19	10.4	3.7	1.0	4.1	8.0	1.80
492		173.1	171.6	4.3	4.8	4.6	2236	13	9.8	1.2	0.3	1.5	4.8	0.90
493	No ILS	148.2	147.9	7.2	6.5	6.8	1742	7	10.3	2.5	0.4	0.3	5.0	1.56
494		132.4	132.1	5.3	5.1	5.2	2040	6	10.9	0.0	0.5	0.3	4.0	1.34
496	No ILS	141.2	140.7	3.8	3.9	3.8	1934	13	10.3	0.5	-1.7	0.5	5.0	0.92
497		150.7	150.4	2.8	2.4	2.6	2288	17	11.0	1.6	1.0	0.3	6.0	0.59
551	No ILS	131.2	123.9	3.9	4.9	4.4	1846	9	9.4	2.9	0.6	7.3	3.3	1.19
584	Dry ILS	130.0	124.4	4.9	4.6	4.7	1588	1	13.0	-0.1	1.2	5.6	-2.2	1.29
586	Dry ILS	122.7	116.0	4.3	5.6	4.9	1706	-9	12.8	0.8	2.2	6.7	-2.0	1.44
595	Dry ILS	126.9	122.0	4.9	2.5	3.7	1503	5	11.0	4.2	2.1	4.9	-5.0	1.02

Table B-3. Landing Data Model McDonnell Douglas KC-10
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
609		139.8	137.3	4.2	4.9	4.6	2091	6	10.8	1.0	-3.1	2.5	-4.3	1.12
610	No ILS	125.3	122.4	4.6	7.8	6.2	1525	6	12.9	1.8	-3.3	2.9	-2.8	1.72
612		132.2	128.5	4.7	6.3	5.5	2032	5	12.0	1.6	-2.8	3.7	-1.6	1.45
622	Dry ILS	120.8	117.5	5.0	4.8	4.9	1502	6	10.7	2.3	-0.8	3.3	3.7	1.41
624			135.6	2.0	2.9	2.5	2236	6	9.7	0.8	-1.5			0.62
625	Dry ILS		136.7	8.4	7.1	7.8	1065	-12	11.0	-0.6	0.0			1.92
629	Dry ILS		123.3	1.6	2.9	2.3	1615	-5	11.6	1.1	-1.3			0.62
632	Dry ILS		117.8	2.9	3.6	3.2	1317	-3	11.6	2.0	-3.6			0.92
633			124.4	4.8	4.5	4.7	2028	5	10.7	-0.3	-0.3			1.27
634			118.2	2.0	2.4	2.2	2313	9	9.8	1.9	-0.2			0.62
635	Wet ILS		121.5	4.2	3.8	4.0	1732	7	10.7	2.0	-1.0			1.12
645			141.7	3.8	3.1	3.4	2143	3	9.9	1.0	-0.5			0.82
650	No ILS		138.0	4.3	5.3	4.8	1829	9	10.8	1.6	0.5			1.19
654	Dry ILS		127.5	3.5	4.2	3.8	1197	-4	11.7	-0.4	0.1			1.01
663	Dry ILS		123.6	5.1	4.7	4.9	1044	-6	11.4	0.6	-0.9			1.35
664	No ILS		109.7	3.4	4.1	3.8	1397	0	9.6	1.2	-4.7			1.17
665	Dry ILS		121.8	2.9	2.0	2.5	1123	-9	10.0	1.3	-0.3			0.68
667	No ILS		149.5	5.8	4.4	5.1	1114	-16	10.1	1.0	2.3			1.15
671	Dry ILS		141.6	6.5	4.7	5.6	994	-21	10.8	-1.7	2.1			1.34
673	No ILS		150.1	7.4	5.9	6.7	1703	11	9.9	1.8	1.7			1.50
675	No ILS		120.5	4.3	3.4	3.9	1635	8	11.8	0.1	-0.1			1.08
678	No ILS		149.6	4.9	5.3	5.1	1788	10	10.5	1.3	1.8			1.15

Table B-3. Landing Data Model McDonnell Douglas KC-10
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
679	No ILS		128.5	3.4	3.5	3.5	1918	7	10.4	1.3	-0.9			0.91
689	No ILS		148.3	6.6	5.3	6.0	845	-8	10.4	-2.2	2.0			1.36
690	No ILS		141.2	6.3	5.9	6.1	819	-11	11.9	-0.5	1.4			1.46
691			133.2	5.4	4.5	4.9	1757	5	10.9	2.2	-4.5			1.26
693	No ILS		133.2	2.5	2.5	2.5	1243	0	11.5	0.7	0.8			0.64
694	No ILS		138.2	5.5	6.0	5.8	1793	9	12.0	1.1	-3.5			1.41
696	Dry ILS		134.1	4.0	4.9	4.5	1372	-2	10.4	0.3	-0.7			1.13
697	Dry ILS		135.7	4.0	4.0	4.0	1710	10	10.9	2.9	-0.7			1.01
721	No ILS	152.1	147.4	2.3	4.7	3.5	1808	7	11.1	2.8	-1.8	4.7	10.5	0.80
771	Dry ILS	132.2	129.8	3.5	3.2	3.4	1922	24	10.8	3.3	-3.8	2.4	6.9	0.88
860	Dry ILS	154.6	158.0	2.4	3.1	2.8	1586	14	11.1	1.9	-3.1	-3.4	9.4	0.60
861	No ILS	164.0	158.3	2.7	6.6	4.6	1656	20	10.6	1.6	-3.3	5.7	8.7	0.99
862	No ILS	131.5	129.0	4.1	4.5	4.3	1956	10	11.5	3.5	-1.0	2.5	9.4	1.13
903		156.2	150.9	4.3	5.1	4.7	1664	7	11.3	1.9	0.6	5.3	6.4	1.05
906		152.0	147.4	3.2	3.0	3.1	1664	7	11.3	1.9	0.6	4.6	6.1	0.72
909		147.5	143.8	1.9	2.1	2.0	1732	4	10.7	3.9	-1.4	3.7	7.0	0.47
913		185.9	178.7	3.4	5.1	4.2	1527	6	12.3	2.8	4.0	7.2	6.5	0.81
914		147.1	143.9	1.6	1.6	1.6	1858	4	9.6	1.0	0.0	3.2	7.2	0.37

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-4. Landing Data Model McDonnell Douglas DC-9
FAA Survey, Atlantic City International Airport

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
26	Dry ILS	135.6	123.8	1.6	0.9	1.2	1861	-1	7.3	-0.8	-0.7	11.8	2.1	0.33
27	Dry ILS	142.8	134.4	3.0	1.7	2.3	1960	9	7.0	-0.2	-2.5	8.4	7.1	0.59
28	Wet ILS	121.1	116.4	2.1	2.3	2.2	2297	8	9.4	1.5	-6.2	4.7	1.7	0.63
33	Dry ILS	136.9	132.2	1.1	2.6	1.8	2193	-8	8.5	-0.4	-1.3	4.7	-1.7	0.46
34	Dry ILS	116.2	111.5	1.3	0.3	0.8	2091	1	9.2	3.7	0.6	4.7	-1.7	0.24
37	No ILS	125.2	117.3	2.2	1.8	2.0	2367	0	8.3	1.3	-1.9	7.9	-1.4	0.57
38	Dry ILS	133.5	132.8	0.9	1.0	1.0	2197	3	8.2	-0.4	0.3	0.7	-3.9	0.24
40	Dry ILS	147.4	141.3	1.5	2.6	2.0	1655	4	8.9	2.0	-0.5	6.1	-3.5	0.49
42	Dry ILS	142.2	139.7	1.9	3.5	2.7	1985	-14	9.8	2.9	2.3	2.5	-4.3	0.66
43	Wet ILS	126.9	124.4	1.3	1.8	1.6	2451	5	9.7	-1.7	-4.9	2.5	-4.3	0.42
49	Wet ILS	135.8	129.0	0.4	0.4	0.4	2420	2	7.3	-0.6	3.3	6.8	-18.8	0.11
50	Dry ILS	128.7	131.1	1.7	2.0	1.9	1410	-5	11.0	-2.3	0.4	-2.4	-6.6	0.48
60	Dry ILS	121.6	113.7	2.2	1.8	2.0	2384	-3	9.8	1.5	-0.2	7.9	1.4	0.59
61	Dry ILS	147.0	139.1	3.2	2.0	2.6	2073	3	8.5	1.1	1.0	7.9	1.4	0.63
63	Dry ILS	133.3	127.7	2.5	2.5	2.5	2390	1	9.9	0.2	-0.7	5.6	-2.1	0.65
64	Dry ILS	123.4	117.8	1.9	2.3	2.1	1740	15	12.4	4.3	-2.6	5.6	-2.1	0.61
67	Dry ILS	123.8	118.2	2.0	1.9	2.0	1632	2	9.1	1.5	-4.0	5.6	-2.1	0.56
69	No ILS	114.5	114.5	2.0	1.3	1.6	1779	-3	8.3	0.3	-4.5	0.0	-10.0	0.49
72	No ILS	130.4	122.7	1.8	0.8	1.3	1492	-1	11.4	-1.8	0.7	7.7	-9.2	0.35
74	No ILS	127.8	114.9	3.3	1.7	2.5	1848	-5	9.3	0.6	-1.0	12.9	-15.3	0.74
75	No ILS	142.7	127.4	0.7	1.8	1.2	1798	2	7.0	-0.9	2.5	15.3	-12.9	0.32
76	Dry ILS	133.3	118.0	1.3	1.2	1.3	1343	-5	7.5	-0.5	0.6	15.3	-12.9	0.36

Table B-4. Landing Data Model McDonnell Douglas DC-9
FAA Survey, Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
80	No ILS	134.4	129.4	1.7	1.3	1.5	2221	-4	11.1	-3.1	2.4	5.0	-8.7	0.40
81	No ILS	139.5	134.5	1.8	0.9	1.3	1999	0	9.2	-0.6	-0.7	5.0	-8.7	0.34
82	No ILS	130.6	121.2	3.1	2.4	2.7	1606	5	8.6	-1.1	-0.8	9.4	-3.4	0.76
85	No ILS	146.6	137.0	1.1	2.1	1.6	1743	2	5.2	0.3	-1.8	9.6	-11.5	0.39
86	No ILS	167.6	153.5	3.1	2.4	2.8	2170	16	6.6	-5.7	8.2	14.1	-5.1	0.61
91	Dry ILS	135.3	139.9	1.5	1.4	1.5	2176	3	5.4	-1.2	3.9	-4.6	-3.9	0.36
92	Dry ILS	131.7	133.4	0.6	0.0	0.3	2432	-4	9.5	-1.1	-1.1	-1.7	-4.7	0.07
93	Dry ILS	127.2	128.9	1.9	1.7	1.8	2109	3	9.1	-1.5	-2.0	-1.7	-4.7	0.47
96	Dry ILS	133.0	133.0	2.2	1.6	1.9	2440	-2	5.9	-1.0	0.2	0.0	0.0	0.48
97	Wet ILS	130.3	127.7	2.2	3.9	3.0	1947	-3	10.4	1.3	-0.7	2.6	-3.1	0.81
101	No ILS	130.5	136.5	3.4	2.5	3.0	1872	6	8.4	1.9	-0.8	-6.0	10.4	0.74
102	Dry ILS	121.6	112.1	1.7	2.4	2.1	1407	-5	10.8	3.4	-0.4	9.5	-5.5	0.62
108	Dry ILS	130.2	116.1	0.0	1.1	0.5	2418	4	6.6	2.5	-2.2	14.1	-5.1	0.16
113	Dry ILS	134.5	127.6	3.5	2.9	3.2	1637	5	9.1	1.4	-0.3	6.9	-1.2	0.85
114	Dry ILS	143.8	137.9	0.3	3.1	1.7	2074	-3	8.8	0.8	0.7	5.9	-1.0	0.41
119	Wet ILS	117.0	114.0	1.7	1.9	1.8	2102	-3	8.9	0.3	0.1	3.0	-5.2	0.54
120	Wet ILS	132.2	126.8	1.5	2.8	2.2	2100	-3	8.5	-1.6	1.1	5.4	-4.5	0.58
121	Wet ILS	123.5	115.8	2.3	2.8	2.6	1710	6	11.5	0.6	0.7	7.7	-6.4	0.75
122	Wet ILS	135.4	125.9	0.3	0.5	0.4	2188	-5	8.4	0.8	2.7	9.5	-5.5	0.11
124	Wet ILS	127.9	118.4	2.2	1.4	1.8	2437	3	7.1	1.1	-1.5	9.5	-5.5	0.51
125	Wet ILS	123.3	119.8	2.1	2.5	2.3	1239	-18	11.3	0.1	3.4	3.5	-6.1	0.65
129	Dry ILS	129.5	121.8	1.6	3.3	2.4	1900	8	11.1	2.9	-3.6	7.7	6.4	0.68

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
130	Dry ILS	121.7	115.7	2.5	3.6	3.0	2296	4	6.9	5.1	-2.8	6.0	10.4	0.88
131	Dry ILS	120.7	116.9	0.3	0.9	0.6	2222	2	8.0	4.2	-3.3	3.8	10.3	0.18
134	Dry ILS	123.9	117.8	2.3	2.1	2.2	2449	-1	9.4	0.3	2.5	6.1	-5.1	0.64
139	Dry ILS	125.6	125.6	1.7	2.7	2.2	1654	9	7.1	2.3	-9.5	0.0	20.0	0.59
142	Dry ILS	134.1	131.5	2.5	3.6	3.0	2447	9	12.2	3.6	-10.0	2.6	14.8	0.78
148	No ILS	121.4	120.0	0.9	0.9	0.9	2368	-3	10.1	1.1	0.7	1.4	-7.9	0.25
149	No ILS	126.2	120.2	1.1	0.9	1.0	1641	0	9.1	-1.0	-3.5	6.0	-10.4	0.28
150	No ILS	128.4	122.9	1.8	0.8	1.3	1997	5	8.9	0.8	-1.5	5.5	-9.5	0.36
157	No ILS	124.1	123.1	0.1	0.9	0.5	2446	7	6.2	0.2	-2.4	1.0	-5.9	0.14
162	No ILS	131.6	124.7	2.4	2.3	2.4	2426	-2	10.1	-1.2	-1.8	6.9	-5.8	0.65
163	No ILS	120.7	117.7	0.2	0.4	0.3	2380	-7	8.1	0.1	1.9	3.0	-5.2	0.08
164	No ILS	154.8	151.0	1.7	0.4	1.1	2093	5	10.2	-1.3	5.0	3.8	-3.2	0.24
165	No ILS	125.3	119.2	4.7	3.8	4.3	1295	-11	11.0	-1.9	0.9	6.1	-3.5	1.22
172	Dry ILS	127.3	124.6	1.6	1.2	1.4	1684	-3	10.5	2.1	0.7	2.7	-7.5	0.37
175	No ILS	121.3	118.7	0.8	1.5	1.1	1724	3	9.4	2.3	-2.9	2.6	-1.5	0.32
177	No ILS	119.6	114.6	2.1	3.1	2.6	2080	-1	10.5	1.9	-6.3	5.0	0.0	0.76
179	No ILS	120.8	115.9	1.2	0.6	0.9	2273	3	9.5	0.2	-1.7	4.9	-4.9	0.26
187	No ILS	122.8	117.0	1.6	1.6	1.6	1823	-4	10.1	2.8	2.3	5.8	6.9	0.46
188	Dry ILS	123.8	119.8	2.1	2.4	2.2	2442	0	10.1	1.9	2.1	4.0	6.9	0.63
189	Wet ILS	133.5	130.0	2.3	0.9	1.6	1956	12	11.5	-1.2	-3.7	3.5	6.1	0.42
190	Wet ILS	116.9	114.8	2.0	2.0	2.0	1921	7	3.8	1.2	3.5	2.1	4.5	0.59
191	Dry ILS	135.3	133.8	1.7	1.7	1.7	1750	3	8.7	0.3	-0.2	1.5	-2.6	0.43

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
195	Dry ILS	131.9	127.3	2.1	1.8	1.9	1848	-2	8.4	-0.3	-0.9	4.6	-3.9	0.51
196	Dry ILS	132.2	130.5	1.8	2.8	2.3	2109	3	8.3	0.7	-6.5	1.7	3.6	0.61
198	Dry ILS	133.4	128.4	1.4	1.0	1.2	2331	-3	8.7	0.7	0.5	5.0	-0.4	0.32
213	No ILS	126.2	122.4	1.3	1.0	1.2	2140	-4	8.1	-0.9	-5.1	3.8	-3.2	0.33
214	Dry ILS	126.2	120.3	2.9	2.4	2.7	2089	6	7.8	2.7	-0.3	5.9	1.0	0.75
218	No ILS	136.2	129.3	2.1	2.2	2.2	1266	-5	9.1	2.6	-1.6	6.9	-5.8	0.56
219	Dry ILS	131.3	125.7	2.6	3.1	2.9	1340	2	9.9	0.1	-3.0	5.6	-2.1	0.77
220	Dry ILS	137.1	132.1	5.4	4.7	5.0	1723	7	10.8	-0.2	-1.1	5.0	0.0	1.29
221	Dry ILS	118.2	115.2	2.7	2.7	2.7	1848	7	10.2	0.2	-4.8	3.0	0.0	0.79
222	Dry ILS	127.0	123.4	3.6	3.3	3.4	2200	7	8.9	-0.4	-2.9	3.6	-1.7	0.94
226	Dry ILS	129.5	120.5	3.2	2.9	3.1	2146	3	13.8	1.7	3.4	9.0	-0.8	0.86
229	No ILS	131.5	132.4	0.6	0.4	0.5	1285	-19	8.6	-2.3	2.3	-0.9	-4.9	0.13
234	No ILS	116.7	113.7	1.4	0.6	1.0	2313	3	9.9	-0.8	1.9	3.0	-6.3	0.30
235	No ILS	129.8	127.3	1.4	2.0	1.7	1733	8	9.3	2.9	-0.6	2.5	-4.3	0.46
236	No ILS	127.4	125.7	1.5	1.6	1.6	2254	10	9.1	2.8	-4.9	1.7	4.7	0.42
240	No ILS	118.1	111.5	2.8	2.9	2.8	2299	0	10.1	-0.1	-1.1	6.6	2.4	0.86
250	No ILS	122.4	121.9	2.3	2.9	2.6	2157	4	9.7	1.4	-5.7	0.5	14.0	0.72
251	No ILS	146.1	139.6	2.1	1.4	1.8	2401	13	9.0	3.5	-0.6	6.5	11.3	0.44
253	No ILS	137.6	132.6	2.0	0.4	1.2	1635	7	5.1	-0.4	-2.7	5.0	8.7	0.30
254	No ILS	124.7	124.7	0.6	1.0	0.8	1861	0	9.9	0.8	-1.1	0.0	7.0	0.22
257	Dry ILS	127.5	127.1	2.0	1.7	1.9	1436	-7	8.5	-0.9	1.1	0.4	-5.0	0.49
261	Dry ILS	119.6	115.0	1.2	1.2	1.2	2364	0	8.3	0.6	-4.3	4.6	-3.9	0.37

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
263	Dry ILS	126.9	124.6	3.3	4.5	3.9	949	4	8.9	1.6	-0.9	2.3	-3.3	1.06
264	Dry ILS	114.8	109.6	2.5	1.5	2.0	2196	4	10.0	1.5	-2.9	5.2	-3.0	0.61
265	Dry ILS	132.0	126.8	1.5	1.3	1.4	1871	7	9.1	2.5	-0.3	5.2	3.0	0.37
271	Dry ILS	129.2	125.8	3.0	2.7	2.9	1681	3	10.1	3.0	-1.5	3.4	7.3	0.77
272	Dry ILS	136.6	124.5	2.0	3.7	2.8	2233	3	10.7	0.7	-3.3	12.1	7.0	0.77
276	Dry ILS	129.4	125.4	3.7	2.0	2.9	1764	7	10.5	0.3	-2.3	4.0	6.9	0.77
277	Dry ILS	124.6	120.4	1.7	2.3	2.0	1977	4	6.5	-0.2	-4.3	4.2	-4.2	0.56
278	Dry ILS	136.0	133.5	1.5	0.8	1.2	2473	5	7.8	0.5	-2.6	2.5	-3.2	0.30
279	Dry ILS	122.3	116.0	1.9	1.7	1.8	2143	0	9.8	3.3	-1.6	6.3	-7.8	0.53
280	No ILS	112.5	102.1	5.1	4.6	4.9	1094	-1	9.3	2.4	5.5	10.4	-6.0	1.62
281	Dry ILS	126.6	119.1	1.0	0.7	0.8	1470	-6	11.4	-1.0	4.2	7.5	-2.9	0.24
290	No ILS	115.1	108.7	1.7	0.9	1.3	2463	7	8.7	1.6	-3.9	6.4	2.8	0.40
295	No ILS	129.7	117.4	1.8	1.6	1.7	1377	-8	7.5	0.6	4.7	12.3	4.2	0.49
301	No ILS	137.0	126.2	1.3	1.1	1.2	1446	-3	10.0	-0.9	4.7	10.8	-1.9	0.33
304	Dry ILS	110.9	109.3	0.6	0.7	0.7	1634	13	9.3	1.3	-3.1	1.6	5.8	0.21
305	Dry ILS	118.6	120.3	1.9	2.4	2.1	1200	-8	10.5	-2.3	1.2	-1.7	4.7	0.60
306	Dry ILS	138.7	137.0	3.4	3.7	3.5	942	6	9.1	1.8	-3.2	1.7	4.7	0.88
318	No ILS	145.6	138.4	2.3	0.6	1.4	1367	-15	6.4	-2.9	2.0	7.2	-9.6	0.35
324	No ILS	180.7	172.0	3.2	3.9	3.5	1505	-2	11.4	-3.5	2.0	8.7	-5.0	0.70
329	Dry ILS	119.6	114.6	0.6	0.9	0.8	1661	12	10.7	-0.4	1.2	5.0	-8.7	0.23
334	Dry ILS	140.6	133.1	5.1	5.3	5.2	725	-4	6.8	-4.2	-2.8	7.5	-13.0	1.33
339	Dry ILS	144.9	143.2	5.1	4.9	5.0	1257	-3	8.8	-0.5	0.8	1.7	-4.7	1.18

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
340	Dry ILS	132.4	132.4	1.9	1.1	1.5	1825	4	9.3	-2.3	1.8	0.0	-5.0	0.38
341	Dry ILS	120.5	115.3	1.0	1.1	1.0	2389	-3	7.0	0.0	0.5	5.2	-9.7	0.30
342	Dry ILS	116.2	109.8	1.1	0.2	0.6	2439	2	3.0	-0.6	5.2	6.4	-7.7	0.19
346	Dry ILS	123.2	120.2	2.6	2.5	2.5	1895	4	8.1	2.3	2.2	3.0	-6.3	0.71
350	Wet ILS	138.6	130.6	0.9	0.9	0.9	1786	9	8.0	2.3	-1.9	8.0	8.9	0.23
352	No ILS	144.3	141.6	2.0	1.7	1.8	1584	8	9.5	3.6	2.3	2.7	7.5	0.44
358	Dry ILS	149.5	144.5	4.5	5.4	4.9	1553	4	3.6	1.6	1.0	5.0	0.7	1.16
379	Dry ILS	125.7	119.3	2.2	1.6	1.9	1750	-3	11.4	3.8	-5.3	6.4	7.7	0.54
387	Wet ILS	144.1	142.1	4.3	3.3	3.8	1113	-11	14.9	-0.8	1.5	2.0	-4.6	0.91
393	Wet ILS	113.1	110.4	0.9	0.8	0.9	1897	0	2.3	2.3	1.2	2.7	6.4	0.26
395	Wet ILS	128.1	125.0	1.3	0.7	1.0	1618	9	7.1	-0.1	1.3	3.1	8.5	0.27
399	Dry ILS	132.8	133.3	4.1	4.9	4.5	1756	6	5.2	2.6	-2.6	-0.5	9.0	1.14
401	Wet ILS	120.6	117.9	0.7	0.5	0.6	2113	13	9.3	-1.1	2.0	2.7	7.5	0.18
404	Wet ILS	113.9	106.4	2.6	2.6	2.6	1383	-6	7.6	-2.9	0.6	7.5	-13.0	0.84
409	Wet ILS	163.2	159.1	2.9	2.8	2.8	2026	3	4.8	1.2	2.0	4.1	11.3	0.60
431	Wet ILS	125.2	115.7	1.8	1.7	1.7	1394	-4	10.0	1.7	-2.5	9.5	5.5	0.51
443	Dry ILS	109.7	98.8	2.5	0.6	1.6	2373	11	10.2	3.5	-4.9	10.9	7.1	0.54
455	Dry ILS	117.8	121.7	1.1	1.0	1.1	1336	5	12.3	0.6	-5.5	-3.9	0.7	0.29
466	Wet ILS	112.6	107.7	4.2	3.8	4.0	1193	-7	7.8	0.4	-0.8	4.9	-4.9	1.25
467	Wet ILS	123.5	119.4	4.8	4.6	4.7	873	-6	9.6	1.2	1.7	4.1	-4.4	1.34
469	Wet ILS	133.9	127.6	3.0	1.5	2.3	1682	10	8.3	0.3	1.8	6.3	-6.5	0.60
473	Wet ILS	125.4	119.5	2.7	2.2	2.4	1573	8	10.1	0.5	0.6	5.9	-1.0	0.69

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
488	No ILS	141.6	140.2	4.1	4.4	4.3	1761	7	5.2	2.1	-2.7	1.4	7.9	1.04
503	No ILS	128.4	131.3	2.6	3.2	2.9	1730	3	10.1	3.1	2.2	-2.9	8.5	0.75
533	No ILS	127.1	119.2	2.6	3.1	2.8	1864	-1	8.2	2.1	1.9	7.9	1.0	0.80
542	Dry ILS	117.5	115.8	0.0	0.1	0.1	1841	8	4.7	0.1	1.2	1.7	6.8	0.02
543	Dry ILS	141.2	137.3	2.2	1.5	1.8	2202	11	7.6	0.5	3.0	3.9	7.0	0.45
549	No ILS	129.7	123.7	4.7	3.7	4.2	1193	-7	7.9	0.2	2.8	6.0	0.6	1.14
553	No ILS	135.8	129.3	3.3	3.3	3.3	1673	9	8.6	0.4	-5.6	6.5	-6.3	0.88
566	No ILS	113.0	106.0	1.6	1.5	1.5	1993	1	8.6	1.5	1.9	7.0	0.4	0.49
571	No ILS	130.0	123.4	2.9	2.5	2.7	932	-20	11.3	-3.2	1.8	6.6	-4.6	0.74
580	No ILS	113.2	106.9	4.0	4.6	4.3	1419	4	14.1	3.1	-2.6	6.3	-4.9	1.35
582	No ILS	129.7	122.8	2.2	2.0	2.1	2119	4	10.3	3.9	1.9	6.9	-1.0	0.59
590	Dry ILS	122.3	112.0	2.4	3.0	2.7	2048	8	10.3	2.4	2.2	10.3	3.8	0.81
601	Wet ILS	132.4	125.0	0.4	1.1	0.7	2360	5	6.3	1.9	1.7	7.4	-9.5	0.20
602	Wet ILS	139.9	128.6	2.9	0.4	1.6	1887	4	8.9	-3.5	0.9	11.3	-11.3	0.43
605	Wet ILS	143.7	133.4	2.2	2.6	2.4	1538	16	8.4	0.2	2.1	10.3	-12.3	0.61
616	Dry ILS	144.9	136.5	2.7	4.0	3.4	1689	4	9.1	3.8	-6.9	8.4	7.1	0.83
618	Dry ILS	129.2	119.4	2.1	2.7	2.4	1799	6	8.1	2.8	-3.4	9.8	5.0	0.67
620	Wet ILS	133.9	130.9	2.8	3.7	3.2	1610	-1	10.2	-1.5	-2.0	3.0	-6.3	0.84
626	Dry ILS		120.6	2.2	1.8	2.0	2176	9	10.2	1.2	2.2			0.55
644	No ILS		134.0	4.5	4.7	4.6	1693	8	7.4	-0.6	-4.5			1.16
647	Dry ILS		142.8	1.7	1.6	1.6	2176	4	8.5	3.6	1.7			0.39
657	No ILS		142.0	3.3	2.2	2.7	1651	1	11.3	-0.5	-1.5			0.66

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
658	No ILS		140.3	4.3	3.4	3.8	1711	1	9.8	1.2	-2.4			0.93
660	Dry ILS		113.2	3.2	2.7	3.0	1871	17	7.9	-0.4	-0.2			0.89
662	No ILS		154.6	4.3	4.2	4.2	1571	20	9.2	3.9	-2.3			0.93
684	No ILS		121.5	1.5	1.3	1.4	2004	8	9.8	4.1	1.9			0.38
687	No ILS		116.0	2.6	2.6	2.6	2383	1	9.4	-2.3	2.2			0.75
688	No ILS		125.4	1.5	2.5	2.0	2258	4	12.5	3.1	2.1			0.55
699	No ILS		138.0	2.6	2.8	2.7	1466	6	11.3	2.9	-4.5			0.66
705	No ILS		100.3	2.9	3.1	3.0	2004	5	11.2	7.0	1.7			1.03
709	No ILS	134.0	121.3	2.8	2.9	2.9	2260	3	7.9	3.0	2.2	12.7	8.3	0.80
735	No ILS	126.7	124.0	2.2	2.5	2.4	1212	-35	9.5	2.0	2.0	2.7	7.5	0.65
755	No ILS	140.4	135.9	1.6	2.6	2.1	2106	6	7.5	3.4	2.0	4.5	11.2	0.52
758	Wet ILS	133.3	126.0	2.2	1.0	1.6	1754	6	8.3	0.7	1.9	7.3	-2.4	0.44
765	Dry ILS	116.8	112.7	2.8	3.4	3.1	1983	1	11.3	2.1	1.8	4.1	5.2	0.94
776	Dry ILS	141.1	136.7	1.0	1.3	1.2	1806	4	9.5	2.5	2.3	4.4	5.1	0.29
778	Dry ILS	105.4	103.1	1.1	1.5	1.3	1810	3	0.5	2.0	1.2	2.3	6.2	0.43
780	Dry ILS	120.0	118.5	4.2	3.1	3.7	1416	-6	8.3	-2.4	1.2	1.5	-9.6	1.05
781	Dry ILS	128.2	126.6	1.9	2.2	2.1	1559	5	9.1	0.6	1.5	1.6	-9.2	0.55
782	No ILS	121.0	126.0	0.9	1.7	1.3	1796	3	4.0	0.7	1.8	-5.0	5.4	0.35
868	No ILS	142.1	136.5	0.6	-0.2	0.2	2053	-13	3.4	0.2	1.9	5.6	12.5	0.05
885	Dry ILS	133.9	132.4	2.4	2.6	2.5	1831	9	9.4	2.1	-3.7	1.5	-6.0	0.64
916	No ILS	114.0	114.9	2.2	2.5	2.3	2113	9	4.8	0.6	1.9	-0.9	2.6	0.69
917	No ILS	133.0	129.1	1.0	1.1	1.0	1869	8	10.6	1.5	2.2	3.9	5.0	0.27
920	No ILS	124.3	122.9	5.2	5.4	5.3	998	1	9.7	0.9	1.6	1.4	-3.9	1.47

Table B-5. Landing Data Model McDonnell Douglas DC-9
FAA Survey Atlantic City International Airport (Continued)

Landing No.	Landing Type	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Headwind (knots)	Crosswind (knots)	Glide Slope Angle (INST) (degree)
				Port (fps)	Stbd (fps)	Avg. (fps)								
921	No ILS	152.8	149.4	4.2	3.1	3.6	2099	-9	6.7	0.6	1.7	3.4	-4.3	0.83
922	Wet ILS	113.6	110.9	2.6	2.0	2.3	1646	4	13.8	0.3	-1.4	2.7	-3.9	0.70
923	No ILS	133.3	131.2	3.1	3.0	3.1	1436	3	10.2	0.2	1.0	2.1	-5.0	0.80
924	No ILS	132.0	131.4	2.4	2.7	2.5	1641	-2	9.1	-1.1	-2.8	0.6	-5.3	0.66
926	Wet ILS	130.6	124.6	3.6	4.8	4.2	876	-15	12.7	0.8	4.5	6.0	-7.4	1.14
928	Wet ILS	118.4	115.0	5.2	5.5	5.3	1908	12	11.1	2.4	-4.9	3.4	-5.0	1.57
936	No ILS	142.3	138.8	3.5	2.8	3.1	1529	6	11.1	1.1	-2.5	3.5	2.5	0.77
938	No ILS	132.6	133.3	3.6	3.6	3.6	1579	5	10.4	0.6	-7.8	-0.7	6.6	0.92
939	No ILS	122.3	122.1	4.5	6.5	5.5	575	-22	11.1	-0.5	-1.5	0.2	-4.7	1.54
940	No ILS	105.0	106.1	3.6	4.3	4.0	1431	8	8.8	3.0	2.1	-1.1	-4.8	1.27
945	No ILS	142.7	142.3	0.2	0.3	0.2	2193	7	9.3	-1.3	1.8	0.4	-2.0	0.05
946	No ILS	123.8	122.6	4.1	2.4	3.2	1021	-9	10.8	-0.6	-1.2	1.2	-4.5	0.89
948	No ILS	134.4	134.4	1.3	1.8	1.5	1708	5	11.7	1.1	-4.5	0.0	0.0	0.38
964	No ILS	137.7	142.6	3.4	3.7	3.6	964	-4	12.0	1.2	-1.8	-4.9	6.3	0.85
965	No ILS	139.2	139.2	2.4	2.3	2.4	1508	3	9.9	0.0	1.7	0.0	0.0	0.58
966	No ILS	127.9	127.9	2.9	3.7	3.3	1135	-10	9.3	2.3	-2.3	0.0	0.0	0.88
967	No ILS	122.1	120.1	4.9	5.3	5.1	848	-3	12.8	0.4	-2.5	2.0	1.9	1.44
976	No ILS	121.2	112.8	2.4	2.8	2.6	1568	1	9.2	0.9	-0.8	8.4	1.3	0.78
978	No ILS	128.1	119.0	2.5	3.3	2.9	1671	-2	7.6	2.4	-1.4	9.1	1.3	0.82
982	No ILS	156.5	151.0	2.5	2.8	2.6	833	-2	12.0	4.4	-2.2	5.5	3.3	0.59
988	No ILS	157.1	151.9	1.1	2.3	1.7	1504	6	8.9	3.6	1.7	5.2	-3.0	0.38
990	Wet ILS	135.9	132.1	2.2	2.8	2.5	1246	6	11.9	0.4	0.0	3.8	-8.8	0.64

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-6. Landing Data: Model Boeing 737
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
6	136.5	138.2	2.5	0.4	1.5	1998	-7		4.1	-0.2	4.0	-1.7	-2.3	0.37	
14	122.9	123.6	1.0	1.3	1.6	1863	-4	44	6.4	0.1	-0.9	-0.7	-1.4	0.45	1.35
71	131.7	128.5	4.4	2.0	3.0	1519	-14	33	5.0	-1.2	3.4	3.2	-3.3	0.78	1.23
82	121.5	120.6	3.8	2.6	2.7	2306	-8	51	4.3	-3.7	1.1	0.9	-3.1	0.76	1.27
119	126.4	123.0	1.1	0.5	0.9	1719	-9	46	4.2	-0.8	2.8	3.4	-2.6	0.25	1.52
122	133.8	128.1	1.1	2.4	1.6	2011	-6	42	4.7	2.4	2.1	5.7	-0.2	0.43	1.18
247	145.4	143.9	3.8	1.5	2.7	1665	-5	47	5.6	-0.3	-0.5	1.5	-1.7	0.63	1.63
277	126.3	123.7	1.4	1.6	1.4	1716	-10	41	5.0	-2.7	2.4	2.6	-0.8	0.38	1.37
384	144.7	145.4	3.3	5.7	4.6	1758	-6	46	5.6	2.2	6.3	-0.7	1.6	1.07	1.51
434	122.7	123.9	1.7	0.2	1.1	1548	-10	44	5.8	-0.6	4.0	-1.2	-1.5	0.30	1.61
446	123.9	126.6	1.8	1.7	1.7	1311	-4	43	4.8	-0.1	-0.9	-2.7	-0.4	0.46	1.86
487	143.4	142.6	2.8	2.8	2.8	1564	-10		5.0	1.0	0.6	0.8	-2.0	0.65	
493	124.2	121.9	1.8	1.2	1.5	2002	-4	46	6.1	-2.0	-1.7	2.3	-2.8	0.42	1.31
501	118.3	118.2	2.6	1.2	1.6	1506	-12		5.1	0.7	-1.9	0.1	-0.2	0.45	
635	134.3	137.5	1.4	0.8	1.0	1894	-3	32	5.1	2.2	0.1	-3.2	-0.4	0.24	0.97
651	125.0	123.8	1.5	1.7	1.5	1307	6	24	4.2	-1.7	-1.4	1.2	0.4	0.40	1.07
695	136.4	136.7	3.1	1.2	2.2	1519	-13	33	4.7	-0.8	4.3	-0.3	0.0	0.56	1.25
828	141.1	137.7	1.6	2.4	1.6	1364	4	46	7.1	0.9	0.7	3.4	-0.1	0.38	1.94
859	142.0	141.2	0.9	1.4	1.0	1505	-4	31	5.7	1.8	3.7	0.8	-1.7	0.23	1.17
865	140.0	139.2	1.5	0.9	1.2	1563	-5	29	8.7	-0.8	2.2	0.8	-1.5	0.29	1.05
870	127.3	126.2	2.2	1.9	2.1	1556	-10	35	8.8	-0.5	1.1	1.1	-1.8	0.56	1.29
883	140.2	139.2	1.3	1.8	1.6	1176	-1	37	6.8	0.7	4.8	1.0	-0.8	0.39	1.79

Table B-6. Landing Data: Model Boeing 737
FAA Survey, Cincinnati/Northern Kentucky International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
884	135.5	133.2	1.1	1.3	1.2	1905	1	39	6.5	0.9	0.4	2.3	0.2	0.31	1.18
890	136.8	135.7	1.2	1.5	1.3	1645	0	47	5.1	0.0	0.2	1.1	-0.1	0.33	1.65
939	127.6	126.9	1.7	1.6	1.7	1566	-1	46	4.1	-0.4	-2.0	0.7	1.6	0.44	1.68
985	143.7	142.5	0.4	0.1	0.5	2929	5	43	4.2	0.7	-2.1	1.2	2.0	0.11	0.83

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-7. Landing Data: Model Boeing 757
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
51	130.3	129.1	1.9	1.2	1.6	1520	-14	35	4.3	-1.4	6.3	1.2	-3.2	0.41	1.31
123	125.1	119.4	1.6	2.1	1.7	2042	-4	48	5.8	-1.1	-2.4	5.7	-4.8	0.49	1.34
196	121.7	118.0	2.2	1.5	1.7	2452	-2	52	4.2	-1.9	2.0	3.7	-2.2	0.48	1.21
203	127.3	127.3	1.5	1.4	1.5	1139	-13	37	2.8	-0.3	0.4	0.0	-2.1	0.40	1.87
205	142.0	140.7	1.9	0.8	1.3	2046	3	48	6.4	-0.3	0.5	1.3	-2.4	0.30	1.35
209	127.5	124.6	0.9	3.2	2.4	1796	-5	32	6.2	0.1	-1.0	2.9	-1.5	0.64	1.01
315	125.2	123.4	2.6	1.4	2.1	1181	-10	32	4.8	-1.1	1.2	1.8	2.3	0.58	1.56
383	119.6	119.6	2.2	0.5	1.3	1285	2	39	4.6	-0.9	0.7	0.0	0.0	0.37	1.73
397	125.3	125.3	1.8	1.7	1.7	1404	-2	47	4.7	-0.9	0.5	0.0	0.0	0.47	1.93
449	128.9	131.2	1.7	2.6	2.4	1203	-2	45	5.0	0.8	-0.8	-2.3	0.4	0.61	2.15
464	122.5	119.1	1.8	1.5	1.6	1263	-6	34	4.9	-0.6	-1.1	3.4	0.0	0.46	1.53
485	132.9	133.2	3.1	2.5	2.9	1152	-1	30	5.1	-0.4	-0.6	-0.3	-2.7	0.74	1.49
562	130.9	130.9	1.3	0.4	0.7	1935	-7	43	4.7	-1.7	1.3	0.0	1.6	0.19	1.27
564	132.9	133.2	4.7	5.8	5.2	1380	-14	33	2.5	0.4	3.6	-0.3	0.5	1.34	1.39
570	137.7	137.6	3.5	2.4	2.9	1556	-15	43	3.4	-2.5	0.4	0.1	-1.0	0.72	1.59
652	135.1	132.1	1.8	2.8	2.4	1119	-1	31	3.9	1.5	1.2	3.0	-0.4	0.62	1.61
684	127.0	126.6	1.9	1.6	1.8	1564	-13		4.0	-1.9	0.1	0.4	-0.9	0.49	
688	123.4	122.3	1.8	1.4	1.5	1583	-9	35	3.9	-0.4	4.6	1.1	-1.1	0.40	1.28
722	129.6	128.6	2.1	2.4	2.2	1261	-9		4.8	-0.3	1.3	1.0	-2.2	0.57	
753	128.2	127.9	0.6	2.5	1.3	2170	-4	48	4.8	0.6	2.0	0.3	-4.0	0.35	1.27
759	128.7	124.9	4.5	3.2	3.9	1563	-7	36	3.2	-0.4	2.5	3.8	-3.2	1.06	1.32
769	127.5	123.8	1.2	1.3	1.3	1630	-3	34	4.9	0.5	3.0	3.7	-1.4	0.36	1.19

Table B-7. Landing Data: Model Boeing 757
FAA Survey, Cincinnati/Northern Kentucky International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
790	135.0	134.4	2.6	4.5	2.9	1479	-11	32	3.9	3.0	2.4	0.6	-2.3	0.74	1.25
848	122.1	120.0	1.9	1.9	2.0	1130	-1	39	5.1	1.4	0.9	2.1	-0.3	0.57	2.00
888	136.1	134.5	1.9	1.7	1.8	1595	12	41	3.8	-0.4	-1.5	1.6	-0.6	0.44	1.47
925	127.2	127.0	0.8	0.2	0.5	1757	0	51	3.5	-1.4	0.3	0.2	0.8	0.13	1.67
930	131.2	131.7	1.6	1.6	1.6	1481	2	44	5.7	0.1	0.0	-0.5	2.9	0.42	1.68

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-8. Landing Data: Model Boeing 767
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
114	135.8	130.0	1.6	1.6	1.6	1624	-6	35	3.9	1.1	-1.1	5.8	-1.2	0.42	1.24
127	146.3	141.6	0.7	1.1	0.9	1356	0	39	4.3	0.0	-0.5	4.7	-4.5	0.21	1.65
143	146.7	146.5	4.2	2.0	3.1	1505	-12	46	4.0	-1.0	2.2	0.2	-2.7	0.71	1.75
144	141.5	139.9	2.7	1.2	2.2	1536	-14	52	6.4	-2.4	2.3	1.6	-2.8	0.52	1.94
260	147.3	145.0	2.1	1.2	1.3	1492	-11	39	4.9	0.1	-0.5	2.3	-0.3	0.30	1.50
425	144.6	144.5	4.5	4.2	4.4	1060	-1	42	3.8	-0.4	2.8	0.1	1.0	1.03	2.24
457	140.2	139.0	1.7	2.0	1.7	2491	-3	56	2.8	-2.0	2.5	1.2	-2.1	0.42	1.30
590	149.9	150.7	2.8	2.3	2.5	1804	-5	37	5.4	0.1	-1.1	-0.8	0.7	0.56	1.17
616	146.4	147.6	2.1	3.4	2.6	1409	-12	37	4.1	2.2	1.0	-1.2	0.4	0.59	1.50
625	145.0	144.7	0.1	0.0	0.0	2088	3	44	4.0	1.4	-0.1	0.3	-1.7	0.00	1.19
645	147.9	149.4	3.4	3.8	3.4	1634	-2	37	3.9	0.5	0.3	-1.5	-0.7	0.77	1.29
669	140.7	140.2	2.9	1.8	2.3	1649	-9	55	2.9	-1.6	5.2	0.5	-2.4	0.56	1.91
732	145.1	144.7	1.6	1.9	1.8	1885	-6		5.9	-0.4	-4.1	0.4	-4.2	0.42	
796	148.7	144.9	1.4	1.8	1.4	1493	-9	44	2.5	-2.6	1.3	3.8	0.3	0.34	1.68
847	156.7	154.2	4.0	0.5	2.0	1048	-3	44	5.9	-0.2	0.4	2.5	1.1	0.44	2.40
904	146.9	145.6	1.2	1.3	1.2	1255	5		6.5	-0.7	-5.5	1.3	1.9	0.27	
993	143.2	141.5	3.2	3.0	3.0	1617	-1	48	4.0	0.2	-1.8	1.7	2.1	0.73	1.69

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-9. Landing Data: Model Boeing 777
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
129	144.0	142.5	2.1	2.9	2.5	1881	2	47	5.0	0.5	0.6	1.5	-3.1	0.59	1.44
412	149.6	149.4	3.4	2.7	2.9	1631	-3	47	3.9	0.4	0.2	0.2	2.3	0.67	1.64
624	143.7	143.7	1.6	1.5	1.5	2616	0	52	4.9	-1.1	-0.3	0.0	0.0	0.36	1.15
817	143.4	138.8	1.6	0.2	0.8	1909	-11	49	4.5	-0.2	0.4	4.6	-2.0	0.21	1.47

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-10. Landing Data: Model Bombardier CRJ-200
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
18	141.9	141.1	1.4	1.9	1.5	2408	0	58	3.0	-1.8	1.8	0.8	-1.9	0.36	1.38
34	130.7	128.7	1.2	1.2	1.2	1780	-10	45	2.6	-1.9	3.9	2.0	-3.2	0.32	1.44
38	111.9	109.4	0.4	1.3	1.1	1920	-2	41	3.1	5.7	2.1	2.5	-5.0	0.33	1.21
62	151.2	151.2	2.8	4.6	3.2	1944	0	51	2.5	-3.4	2.9	0.0	-3.0	0.72	1.51
87	104.8	99.9	3.5	0.2	3.2	1944	0	46	4.6	-1.0	1.5	4.9	-4.6	1.08	1.36
88	145.2	140.4	1.1	1.4	1.2	2583	1	43	3.9	-0.4	0.0	4.8	-4.3	0.28	0.94
102	139.0	134.0	2.1	3.0	2.5	1768	-6	52	1.5	1.6	3.2	5.0	-1.6	0.63	1.68
104	100.4	95.4	2.0	2.3	2.0	1782	13	45	7.0	1.3	5.0	5.0	-5.7	0.73	1.43
116	118.6	112.2	0.1	0.5	0.3	2182	0	43	1.8	2.0	-2.2	6.4	-2.7	0.09	1.13
124	136.3	131.7	1.2	2.1	1.6	2515	-1	64	2.4	0.1	1.5	4.6	-0.2	0.41	1.46
170	138.2	137.0	2.3	1.6	2.1	2010	-7	42	2.7	-0.6	1.5	1.2	-5.6	0.52	1.20
173	122.6	121.9	3.7	0.2	2.5	2192	0	49	3.3	-0.6	-2.4	0.7	-2.2	0.69	1.27
177	105.1	103.1	1.9	2.1	1.9	1823	8	49	7.3	0.1	2.5	2.0	-4.7	0.63	1.55
178	143.0	141.5	1.1	1.5	1.4	2475	-7	53	3.0	-1.1	4.0	1.5	-1.8	0.34	1.22
189	117.8	116.5	0.5	1.6	0.8	2003	-6	47	1.6	-0.3	2.4	1.3	-3.2	0.22	1.34
206	122.1	120.4	1.2	1.3	1.2	2076	1	53	4.3	-0.5	1.6	1.7	-2.4	0.34	1.46
212	112.1	109.9	0.9	1.6	0.7	1806	11	38	3.5	-0.1	3.7	2.2	-3.3	0.22	1.20
219	154.6	153.8	1.7	2.1	2.0	2341	2	40	4.7	-4.3	2.9	0.8	-0.8	0.43	0.98
229	127.5	127.5	0.9	0.5	0.7	1720	-8	43	1.2	-2.0	-0.7	0.0	-1.0	0.18	1.42
230	120.7	120.7	0.7	3.2	2.7	1710	-3	47	2.3	0.1	4.3	0.0	-0.3	0.77	1.56
231	134.9	134.9	0.9	1.0	0.9	2533	1		2.9	-1.1	0.0	0.0	0.0	0.24	
232	103.9	102.9	2.3	1.4	1.7	2101	-3	56	3.5	-3.8	4.5	1.0	-0.9	0.55	1.53

Table B-10. Landing Data: Model Bombardier CRJ-200
FAA Survey, Cincinnati/Northern Kentucky International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
248	126.7	125.6	1.4	0.9	1.0	2322	-3	59	3.8	-2.9	3.1	1.1	-0.7	0.28	1.46
265	115.8	113.1	1.5	2.7	1.7	1785	-6	53	2.8	0.1	4.5	2.7	-0.9	0.52	1.71
266	128.1	126.2	3.1	0.1	1.5	2276	-4	62	3.5	-4.6	-3.8	1.9	-0.4	0.40	1.55
274	107.1	104.7	1.9	0.1	1.1	1728	11	39	7.9	-0.7	4.9	2.4	-1.3	0.35	1.29
298	124.2	122.7	1.6	1.6	1.6	1789	-3	49	3.1	-0.1	2.6	1.5	1.7	0.43	1.56
313	141.1	139.2	1.9	2.6	2.2	2019	1	58	2.9	0.9	-3.4	1.9	2.3	0.54	1.64
325	106.4	106.7	1.1	1.5	1.4	1864	14	41	6.8	-0.2	-0.8	-0.3	-0.5	0.45	1.24
331	123.6	123.8	1.2	1.5	1.2	2134	7	55	2.0	2.5	-1.0	-0.2	1.7	0.34	1.48
337	111.2	111.3	3.5	1.5	2.8	1727	-4	35	1.2	1.0	-2.2	-0.1	3.2	0.85	1.16
343	114.2	112.8	1.7	2.2	1.8	2417	-2	58	2.8	2.7	1.6	1.4	2.6	0.55	1.38
344	117.3	115.0	2.3	3.5	2.9	2503	-5		4.6	0.8	-2.9	2.3	2.8	0.86	
345	125.7	126.5	2.6	1.9	2.1	1583	-4	27	2.6	0.3	-0.1	-0.8	1.4	0.56	0.96
347	125.6	127.9	1.2	2.8	1.3	1763	-11	41	2.4	-3.5	-0.1	-2.3	2.2	0.34	1.34
357	141.0	141.7	2.0	1.6	1.8	2479	1	62	2.9	0.0	0.7	-0.7	2.2	0.42	1.43
365	122.4	123.6	1.9	0.7	0.9	2947	3	59	2.6	0.8	-0.5	-1.2	1.2	0.25	1.14
382	144.9	144.8	5.9	1.2	2.8	2413	7	51	3.3	-0.1	-2.6	0.1	2.3	0.67	1.20
386	116.6	115.3	0.5	0.9	0.7	2524	-5	57	2.2	-1.4	0.8	1.3	2.0	0.20	1.30
408	138.8	138.8	1.9	1.5	1.7	1633	-9	50	2.5	-1.0	2.5	0.0	0.0	0.41	1.75
458	117.7	117.0	1.1	0.8	1.1	2419	-1	77	2.5	-0.1	0.5	0.7	-1.4	0.30	1.82
462	127.8	126.1	0.5	2.6	1.7	2125	8	49	1.3	7.0	-1.3	1.7	-2.5	0.44	1.32
468	141.7	141.3	2.1	1.9	2.1	1213	-6	38	2.2	-0.1	1.2	0.4	-2.7	0.50	1.78
510	141.0	139.8	1.6	1.6	1.6	1701	-9	48	0.5	-1.2	0.5	1.2	-3.2	0.40	1.61

Table B-10. Landing Data: Model Bombardier CRJ-200
FAA Survey, Cincinnati/Northern Kentucky International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
513	119.0	117.8	0.2	0.1	0.1	1303	0	29	2.0	1.1	0.6	1.2	-2.4	0.04	1.29
517	129.7	129.0	1.6	1.5	1.5	1600	-10	39	2.8	0.0	1.5	0.7	-2.9	0.39	1.39
518	101.3	100.6	2.2	0.8	0.9	1699	-10	45	1.5	-2.6	-1.0	0.7	-1.5	0.31	1.51
520	122.1	121.1	2.0	2.9	2.4	1631	-6	43	2.7	-1.5	1.4	1.0	-2.7	0.68	1.51
523	146.3	144.9	4.1	2.0	2.8	1604	-10	41	1.5	-1.3	6.2	1.4	-1.3	0.66	1.45
524	138.0	136.9	1.8	1.9	1.8	1784	-2	47	2.7	1.3	3.8	1.1	-3.0	0.44	1.50
547	140.9	139.8	2.2	1.2	1.9	2432	1	45	2.9	-0.2	0.4	1.1	-1.8	0.46	1.07
551	130.2	128.2	1.5	1.4	1.4	1950	0	49	2.6	0.1	1.4	2.0	-0.6	0.37	1.44
553	106.5	105.4	1.7	2.3	2.0	2463	1	51	1.2	2.9	1.7	1.1	0.3	0.64	1.19
560	113.2	113.2	2.1	2.4	2.2	2338	-1	61	1.4	-5.0	-3.0	0.0	0.0	0.66	1.50
577	114.1	113.5	2.6	1.1	2.1	2148	-5	53	1.4	-0.7	-1.3	0.6	0.9	0.64	1.42
583	149.9	150.2	1.8	2.7	2.2	2462	4	40	1.3	-1.1	1.4	-0.3	0.7	0.49	0.93
589	116.5	119.4	1.4	2.6	2.2	1645	-1	35	1.6	0.3	1.2	-2.9	-0.1	0.63	1.23
591	99.8	101.9	2.0	4.5	2.4	2278	1		3.6	0.2	-1.1	-2.1	-0.3	0.79	
622	131.9	130.5	1.1	1.5	1.2	2556	-5	70	2.9	-0.3	-0.8	1.4	-2.9	0.31	1.56
667	151.9	149.0	2.3	1.3	1.8	2083	0	57	2.8	0.1	1.7	2.9	-4.2	0.41	1.56
670	113.6	110.8	1.6	2.0	1.8	2781	-3		2.3	2.3	3.2	2.8	-4.1	0.54	
671	130.7	129.1	1.2	0.1	0.5	2047	1	57	2.1	0.2	1.2	1.6	-0.3	0.12	1.61
700	138.4	138.8	1.0	0.7	0.8	2168	0		2.9	-0.3	-1.7	-0.4	-0.7	0.19	
704	128.0	127.0	2.7	1.6	2.6	2463	-4		1.9	-1.4	-2.6	1.0	-1.9	0.69	
706	107.7	108.1	0.9	0.5	0.7	1893	-7		2.7	0.4	0.7	-0.4	-3.2	0.23	
731	126.7	124.5	0.4	2.7	1.6	2149	3		2.6	-0.5	1.0	2.2	-1.9	0.43	

Table B-10. Landing Data: Model Bombardier CRJ-200
FAA Survey, Cincinnati/Northern Kentucky International Airport (Continued)

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
747	128.7	127.6	0.7	1.6	0.6	2155	1	60	0.9	-2.5	-0.6	1.1	-1.8	0.15	1.61
780	134.3	134.3	1.4	1.8	1.8	2114	-3	54	2.5	0.1	3.3	0.0	0.0	0.45	1.46
793	117.3	113.3	1.8	0.8	1.7	1418	-1	45	1.9	-2.1	-1.9	4.0	-3.0	0.50	1.80
797	134.4	131.1	1.6	2.0	1.8	2141	2	67	2.7	0.2	1.9	3.3	-2.3	0.46	1.80
850	108.8	108.1	1.5	4.1	2.6	2103	-3		2.5	0.3	2.2	0.7	-1.9	0.80	
869	110.6	109.5	0.2	1.4	0.7	2311	7	60	2.4	0.6	1.2	1.1	-1.8	0.21	1.48
879	120.9	120.3	1.8	2.4	2.1	1453	-1	45	1.8	-0.9	-3.2	0.6	-1.1	0.59	1.76
880	118.1	117.2	1.9	0.4	1.1	1880	-2	42	1.5	0.6	0.2	0.9	-1.0	0.33	1.28
889	139.7	138.1	4.2	3.1	4.8	1854	-1	48	2.9	0.6	2.5	1.6	0.7	1.19	1.48
892	115.5	115.5	2.6	1.9	2.3	2174	-6	84	2.2	0.6	-2.3	0.0	0.0	0.66	2.21
894	143.1	142.5	4.1	0.8	2.4	2050	-2	53	2.1	0.2	2.5	0.6	2.0	0.58	1.48
941	132.6	130.8	1.4	2.8	2.1	2102	0	43	2.5	1.9	-0.9	1.8	2.3	0.55	1.18
945	124.3	122.8	1.0	0.6	0.8	2150	2	59	0.4	0.2	-2.5	1.5	2.8	0.22	1.56
952	139.7	138.1	3.8	3.5	3.7	1943	-2	58	3.3	1.0	3.7	1.6	1.3	0.90	1.72
954	138.9	138.7	0.4	1.2	0.6	2568	1	65	0.7	-2.5	3.3	0.2	0.1	0.14	1.45
957	130.1	127.2	1.6	2.0	1.8	2173	3		2.1	2.3	0.1	2.9	0.5	0.48	
958	120.3	119.9	3.0	5.5	4.0	2067	2	53	2.3	1.5	3.1	0.4	2.7	1.12	1.46
977	154.3	152.3	1.5	1.3	1.4	1616	2		1.8	4.7	1.4	2.0	2.3	0.32	

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-11. Landing Data: Model Dornier 328 JET
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
20	106.4	106.3	1.7	0.6	1.2	1539	-4	39	5.7	-5.4	-2.1	0.1	-2.4	0.39	1.46
32	106.3	104.5	1.2	0.0	0.6	1990	-4	44	3.1	-2.3	6.3	1.8	-5.6	0.19	1.26
221	112.2	111.2	1.1	2.3	1.8	1538	-11		6.0	-0.9	-4.4	1.0	-1.7	0.53	
307	146.8	145.2	1.8	1.5	1.7	1598	-5	39	1.9	0.4	-2.0	1.6	3.4	0.40	1.42
329	91.6	91.3	0.9	0.9	0.9	1342	-4	38	3.7	-0.7	-0.9	0.3	0.9	0.33	1.64
359	95.1	98.3	0.9	1.3	1.1	2312	-3	49	5.0	-1.2	-3.8	-3.2	0.4	0.37	1.20
373	92.5	92.3	3.2	0.2	0.4	2128	0	42	5.1	1.9	4.3	0.2	1.0	0.16	1.12
381	96.9	98.4	1.3	0.8	1.1	1973	3	43	5.2	-0.9	0.5	-1.5	2.6	0.37	1.23
417	132.8	133.0	0.2	2.1	1.6	2432	2		6.6	0.8	0.0	-0.2	-1.7	0.41	
463	106.4	105.0	0.8	1.3	1.3	1842	3	44	4.3	-1.0	1.0	1.4	-1.5	0.43	1.35
550	102.9	102.9	2.4	0.7	1.7	1737	-2	53	3.9	0.1	1.6	0.0	0.0	0.56	1.76
610	119.3	120.2	2.6	1.0	1.8	2139	1	55	3.7	1.6	3.9	-0.9	-0.4	0.51	1.48
686	94.1	94.0	1.9	2.0	2.0	1716	-4		5.2	-0.9	-3.9	0.1	-0.6	0.72	
701	140.6	140.6	0.0	0.9	0.2	1643	-11		6.2	-2.2	0.7	0.0	0.0	0.06	
716	116.1	115.9	0.8	1.0	0.8	1610	-8		1.1	0.3	3.3	0.2	-3.8	0.24	
841	122.4	121.5	2.6	1.8	2.1	2149	0	59	4.9	-1.5	3.9	0.9	-1.3	0.58	1.57
881	93.1	92.2	3.4	0.4	1.9	2074	-3	50	6.6	-0.1	0.5	0.9	-1.0	0.68	1.37
967	116.7	116.0	0.8	1.1	1.0	2203	3	45	4.6	3.3	-0.8	0.7	2.8	0.29	1.17
971	112.6	114.1	0.9	2.7	2.0	2163	1	48	3.2	4.6	-0.5	-1.5	2.9	0.59	1.28

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-12. Landing Data: Model Embraer ERJ-135/145
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
22	125.7	124.0	0.8	1.4	0.8	2115	-5	46	4.7	-2.1	-1.6	1.7	-1.2	0.22	1.24
25	116.2	115.0	2.9	1.1	2.2	1916	-5	47	4.9	-2.1	-1.1	1.2	-7.7	0.65	1.41
63	137.6	135.1	2.3	2.0	2.1	1736	-11	49	5.0	-0.9	1.0	2.5	-4.1	0.53	1.61
69	130.6	130.1	3.2	3.0	3.1	1511	-8	31	3.5	0.2	-0.1	0.5	-0.4	0.80	1.19
176	139.6	137.4	2.1	1.5	1.9	1962	-2	49	6.3	-2.1	1.8	2.2	-1.5	0.48	1.44
228	96.7	97.3	2.3	2.3	2.2	2276	-3	45	6.6	-1.4	-1.8	-0.6	-0.1	0.78	1.12
234	131.3	130.6	1.7	1.4	1.6	806	0	24	3.5	-0.5	2.6	0.7	-2.2	0.41	1.70
279	148.5	145.3	2.5	1.1	1.6	1315	-2	41	6.3	-0.8	-0.6	3.2	1.6	0.37	1.79
286	131.2	129.2	1.9	2.4	2.1	1744	-7	40	7.4	-1.5	3.9	2.0	3.0	0.55	1.32
299	125.8	124.4	0.9	1.7	1.1	1349	-1	35	5.2	0.8	-0.4	1.4	2.0	0.29	1.50
338	114.3	115.1	2.3	2.1	2.2	1209	-1	31	5.1	1.2	-3.5	-0.8	2.9	0.66	1.49
587	126.9	131.0	0.3	0.7	0.4	2129	0	31	5.9	2.5	0.3	-4.1	1.3	0.11	0.84
698	133.2	132.6	0.8	1.3	0.9	2500	0		3.0	-0.5	3.8	0.6	-2.3	0.24	
923	121.5	120.8	3.6	0.9	2.4	1701	-1	48	6.4	-1.2	1.5	0.7	0.7	0.66	1.60

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-13. Landing Data: Model McDonnell Douglas MD-90
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
42	130.5	129.5	0.4	0.3	0.1	2077	-2	27	3.8	-1.5	1.4	1.0	-5.0	0.03	0.75
108	136.0	135.0	2.9	2.6	2.7	1686	-13	42	2.0	0.3	1.8	1.0	-5.2	0.67	1.41
142	149.6	143.7	3.9	3.7	3.9	675	-8	28	4.5	2.0	2.1	5.9	-0.1	0.91	2.35
171	145.6	143.3	1.1	1.0	1.0	2088	3	43	4.6	1.0	3.1	2.3	-2.2	0.24	1.19
268	136.0	133.7	0.8	0.7	1.0	2127	-7	58	3.7	-0.8	0.2	2.3	-0.6	0.26	1.56
339	142.9	143.9	4.6	5.2	4.9	742	-2	36	6.7	0.1	0.7	-1.0	1.3	1.16	2.76
393	134.8	136.3	1.1	1.5	1.3	2610	2	57	1.6	-0.7	-1.0	-1.5	1.1	0.31	1.24
433	140.4	141.7	2.0	1.8	1.9	1339	-1	54	5.0	-0.7	-1.8	-1.3	-1.4	0.45	2.29
482	131.8	130.2	1.1	1.8	1.6	1201	-3	28	5.8	-0.1	1.2	1.6	-1.8	0.42	1.34
567	130.8	132.7	1.6	1.5	1.5	2032	1	44	2.9	-1.8	-2.1	-1.9	-0.4	0.39	1.23
592	158.5	162.7	2.5	2.1	2.3	2518	3	52	4.2	-2.8	3.7	-4.2	0.4	0.47	1.17
605	154.4	154.7	2.8	3.7	3.2	1231	5	41	6.9	-0.5	-3.7	-0.3	0.1	0.71	1.92
637	132.4	133.0	3.5	2.6	2.9	1659	-8	50	4.3	-3.3	1.0	-0.6	-0.5	0.73	1.71
758	144.0	142.7	1.3	1.1	1.4	2121	-2	61	4.9	-0.8	1.9	1.3	-2.7	0.33	1.64
762	136.2	135.0	2.6	2.2	2.3	1266	10	44	4.7	-2.5	-1.0	1.2	-1.5	0.59	1.97
766	143.2	139.4	3.0	2.2	2.4	891	-3	20	4.3	-0.5	0.6	3.8	-0.3	0.59	1.28
827	127.0	123.8	1.9	1.5	1.7	1697	-6	49	4.6	-1.0	0.6	3.2	-2.4	0.46	1.65
862	134.3	133.0	0.9	0.2	0.5	957	-5	34	4.9	0.3	0.6	1.3	-1.9	0.13	2.04
899	142.7	141.7	2.4	1.6	2.0	1626	-3	45	3.3	-0.9	0.4	1.0	0.3	0.48	1.59
900	135.1	134.3	3.5	3.1	3.2	1228	0	50	6.4	-1.8	0.9	0.8	0.8	0.81	2.34
927	148.6	147.4	3.0	4.8	3.5	1199	-1	33	4.3	2.7	-0.6	1.2	1.2	0.80	1.60
928	137.3	137.5	2.3	1.8	2.0	1494	-5	41	5.6	-0.8	-2.9	-0.2	0.8	0.49	1.58

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-14. Landing Data: Model McDonnell Douglas MD-90
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
931	141.3	142.8	4.2	3.0	3.6	1918	2	65	4.7	-0.5	-2.7	-1.5	3.1	0.86	1.94
932	141.6	142.3	2.7	2.2	2.6	1138	-2	39	4.1	-2.0	0.7	-0.7	1.5	0.62	1.99
934	144.2	141.6	3.3	1.2	2.4	639	0	32	6.2	-3.0	-0.2	2.6	2.2	0.58	2.90
968	143.1	143.8	1.9	2.1	2.0	1658	-3	25	4.7	0.6	1.1	-0.7	3.1	0.47	0.87
984	137.8	137.5	1.1	0.1	0.6	2927	-3	56	3.4	0.1	-1.0	0.3	3.8	0.16	1.10
989	151.3	153.8	3.4	1.9	2.5	1632	0	43	4.0	-0.5	-1.2	-2.5	2.9	0.56	1.49
990	159.8	162.1	2.9	2.7	2.8	1115	-2	43	4.5	-0.2	1.1	-2.3	-0.2	0.58	2.20

fps = feet per second
TD = Touchdown
INST = Instantaneous

Table B-15. Landing Data: Model SAAB SF-340B
FAA Survey, Cincinnati/Northern Kentucky International Airport

Landing No.	Power Approach Airspeed (knots)	Closure Speed	Sink Speed at Touchdown			Ramp to TD Distance (ft)	Runway Off-Center	Height Over Runway Threshold (ft)	Pitch Angle TD (degree)	Roll Angle TD (degree)	Yaw Angle TD (degree)	Head-wind (knots)	Cross-wind (knots)	Glide Slope Angle (INST) (degree)	Glide Slope Angle Geometric (degree)
			Port (fps)	Stbd (fps)	Avg. (fps)										
783	126.3	126.3	1.6	2.4	2.0	1606	-14	27	4.9	-3.7	2.2	0.0	-1.1	0.54	0.96
905	114.5	113.2	0.9	0.2	0.7	1980	-7	52	2.7	-0.8	-0.3	1.3	2.9	0.22	1.50
961	123.8	125.7	1.0	1.3	1.0	2050	-6	55	6.4	3.7	1.5	-1.9	0.2	0.26	1.55

fps = feet per second
TD = Touchdown
INST = Instantaneous

APPENDIX C—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, which is still an instantaneous measure of sink speed, but 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 headwind 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 calculated from image measurements and is an instantaneous value at the touchdown point. Closure speed is reported with respect to the ground and is reported in knots.

Threshold Camera Closure Speed ($V_{C_{tc}}$)—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. $V_{C_{tc}}$ 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 is 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 ($_{td}$)—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 as the 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 are 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 parameter indicate that the aircraft landed on the port side of the runway centerline and are 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 (X_w)—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 (V_{V_A}) and closure speed (V_C) are used to define the instantaneous glide slope. These values are entered into the equation

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

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

$$\beta_{hw} = \arctan (H_w / X_w)$$

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 that 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 calculate r is as follows.

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

The values of r vary from +1.0 to -1.0. A value of +1.0 indicates perfect positive agreement, all points under consideration lie on a straight line sloping upward, while a value of -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, 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 automatically imply that a causal relationship exists.

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 D—RESEARCH PROGRAM AND INSTALLATION PLAN AND VIDEO LANDING PARAMETER SURVEY FOR CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT

DRAFT

Office of Aviation Research
Washington, D.C. 20591

Program and Installation Plan
Video Landing Parameter Survey
Cincinnati International Airport
(CVG)

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

May 21, 2004

US Department of Transportation
Federal Aviation Administration

Video Landing Parameter Survey
Cincinnati International Airport
(CVG)
20-24 September 2004

1.0 Objective: The Federal Aviation Administration (FAA) is proposing to conduct a video landing parameter survey at Cincinnati International Airport (CVG) in order to characterize the landing load environment of regional jet airplanes. This proposed survey is in response to recent recommendations by Transport Canada and the Aviation Rulemaking Advisory Committee (ARAC) for the FAA to acquire landing touchdown contact data at a commercial airfield with a significant number of Regional Jet arrivals. The FAA and ARAC will jointly use the data (sink speed, approach velocity, touchdown pitch, roll and yaw, etc.) obtained from this survey to assess the validity and continued suitability of a number of landing load certification criteria.

2.0 Background: The Federal Aviation Administration's William J. Hughes Technical Center has conducted a series of video landing parameter surveys at high-activity commercial airports. See typical video camera and image in Figure 1. The purpose of this research is to better understand and document commercial transport aircraft landing impact conditions during actual operations. By collecting, digitizing and analyzing large quantities of video image 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. This operational data collection is also a valuable resource in developing certification

Figure 1

requirements for future transport aircraft. To date, surveys have been conducted at JFK International, Washington National (Reagan), Honolulu International, London City, Philadelphia International and London Heathrow. A permanent video landing facility exists at Atlantic City International Airport (ACY), the home base of the FAA research team.

Video Landing Parameter Surveys are a joint undertaking by personnel from the FAA William J. Hughes Technical Center and the US Naval Air Warfare Center in Patuxent River and are a significant component of the FAA's research on Operational Loads Monitoring. Historically, neither agency has had the resources to accomplish this undertaking independently, consequently survey equipment and technology have been shared since 1992 when the Navy first developed the video survey system. The procedures used by the FAA and Navy to obtain ground contact parameters from video image data are presented in (1) and (2). Subject system has daylight capability only.

Prior to the current series of airport video landing parameter surveys, certification engineers relied on historical precedent and the results of NASA surveys, which were published in 1960 and 1962 (3,4). These survey results showed that the 707/DC8 jets landing descent velocities were appreciably higher than contemporary piston and turboprop powered aircraft, however no changes were made to the structural design criteria at that time. Since that time aircraft size has continued to grow, and traffic density increased. While complete structural failure of a landing gear assembly remains an extremely unusual event, a significant number of landing gear service difficulties are being reported. Consequently, the FAA has been interested in obtaining typical operational landing data for current generation transports in the current airport operating environments.

FAA surveys at JFK (5) and HNL International (6) Airports have demonstrated that heavy wide-body airplanes touch down with higher sink speeds than their narrow-body counterparts, consequently the margins of safety in the 10-ft/sec certification requirement are lower than that of narrow-body airplanes. This research has lead the FAA to re-evaluate the continued suitability of the 10 ft/sec maximum sink speed as a design strength requirement (FAR 25.473), and to confirm it is an adequate standard to ensure a robust and damage tolerant design for routine operations.

The 10-ft/sec certification limit of FAR 25.473, "Landing Load Condition and Assumptions," represent a design limit for all Part 25 airplanes from the smallest up to the new Airbus A-380 and for operations on all of the world's commercial airfields. Consequently, the regulatory authorities are concerned with the continued suitability of the 10-ft/sec certification requirement, particularly for aircraft of large size. A subcommittee of the International Aviation Rulemaking Advisory Committee (ARAC) has been tasked to conduct an investigation into the sink speed issue, and this group has recommended that the FAA conduct additional video landing parameter surveys of additional airports to further characterize touchdown contact conditions. Concurrently, the ARAC is looking at the smaller commercial jet arrivals to determine if the 10-ft/sec certification is too high a value for Regional Jet operations. It is anticipated that operations at CVG will provide highly valuable data for the ARAC to consider in the establishment of future certification requirements.

Only a minimal quantity of Regional Jet landings were recorded during prior surveys and data from these model types are expected to be compared to other commercial aircraft.

3.0 Introduction: Prior to embarking on a video landing parameter survey, FAA and Navy researchers conduct an extensive search of candidate airports, which takes into account the primary purpose of the survey and the available resources. Some prior surveys, especially international surveys have cost in excess of $300K. Figure 2 presents a typical research finding, where it shows that the Cincinnati airport has a significantly greater quantity of regional jet operations than other US airports. Because of the increase in the use of Regional Jet (RJ) Airplanes in the US Commercial Fleet, the need to collect the landing parameter data for this class of aircraft has become increasingly apparent. Given its large concentration of RJ operations, Cincinnati is an ideal airport for the FAA to conduct a Regional Jet video landing parameter survey

.

Figure 2: Commuter Jet Departures

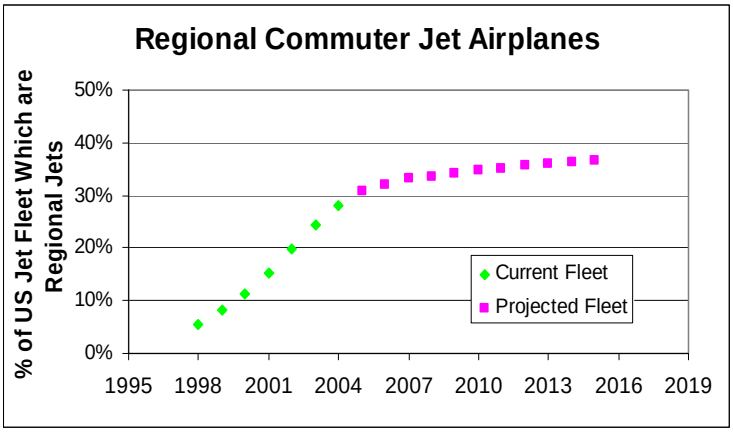


Figure 3: Percent of Total Jet Fleet

The FAA video landing parameter survey program has already collected over 2000 large jet landings and over 500 turboprop landings. Fewer than 20 Regional Jet touchdowns have been surveyed thus far. A survey at Cincinnati Airport where over 70% (See Figure 2) of the commercial operations are Regional Jets will appropriately fill in the landing survey data gap. In addition, Regional Jet airplanes are becoming an increasing percentage of the US Commercial Fleet. See Figure 3.

In 1999, Regional Jets (RJ) made up only 10% of the Commercial Fleet. In 2004, Regional Jet fleet increased to a level of 30% of the Commercial Fleet and RJ's are expected to approach 40% over the next decade. (Source: Back Aviation Solutions)

4.0 Discussion: Contingent upon approval of the Cincinnati airport management and the existence of suitable access, it is proposed that joint FAA-Navy personnel instrument the east-side apron of Runway 18L with eight video cameras and a ground data acquisition station for a five day survey period in late September 2004. Seven cameras are proposed to be placed approximately in line with the east side runway edge lights. An eighth camera would be situated at the 18L threshold, approximately 500 feet from the runway edge. Recent discussions with a Delta Commuter (Comair) representative and the Cincinnati Airport Air Traffic Control Tower Chief indicate that Runway 18L is the preferred runway for RJ arrivals. A CVG Airport Diagram is attached as Figure 4. From observation of the Airport Diagram, Runway 18L and its proximity to the Terminals and Concourses, it can easily be inferred that operators of RJ airplanes will try to exit the runway soon after crossing Runway 9-27 as possible. In addition, it was observed that frequent simultaneous take-off's are conducted on 18R and 27R, which would leave 18L as the primary arrival runway. Even though Runway 18L is 10,000 feet long, the typical landing custom of exiting soon after crossing Runway 9-27 will in effect make Runway 18L an approximately 6500 foot Runway. While 18L is not operated in Land and Hold Short Operations, the acquisition of Regional Jet landing data from a Runway with the custom of making short landings is a major goal of any survey of Regional Jet Airplanes.

Daylight arrivals for a typical week-day (0700 to 1900 hours) at Cincinnati include the following Regional Jet Airplanes:

Canadair Regional Jet	241
Canadair Regional Jet 700	35
Embraer Regional Jets	18
Fairchild Dornier 328 Jet	71
Others	3
Totals (Daily)	**368**

Assuming a worst-case scenario and we video record only 1/3 of the regional jet daylight landings during the five-day survey period, we will have captured over 500 Regional Jet arrivals. In addition, we will capture a number of narrow body arrivals for comparison with the RJ data. If the winds are unfavorable for many consecutive days, the survey could be extended an additional day or two. The anticipated CVG daylight Regional Jet arrivals sorted by time of day are as follows:

From	**To**	**Arrivals**
0700	0800	41
0800	0900	24
0900	1000	28

From	To	Arrivals
1000	1100	15
1100	1200	38
1200	1300	18
1300	1400	45
1400	1500	43
1500	1600	35
1600	1700	20
1700	1800	16
1800	1900	45
Totals		**368**

Sunrise/Sunset times for the planned survey period are as follows:

Date	Sunrise	Sunset
20 Sept	7:23AM	7:39PM
21	7:24	7:37
22	7:25	7:35
23	7:26	7:34
24	7:27	7:32
25	7:28	7:31

Since the video system has daylight only video acquisition capability, it is estimated that we will be able to collect suitable video image data from 08:30AM until approximately 06:30 PM. On a clear day these ranges could possibly be extended.

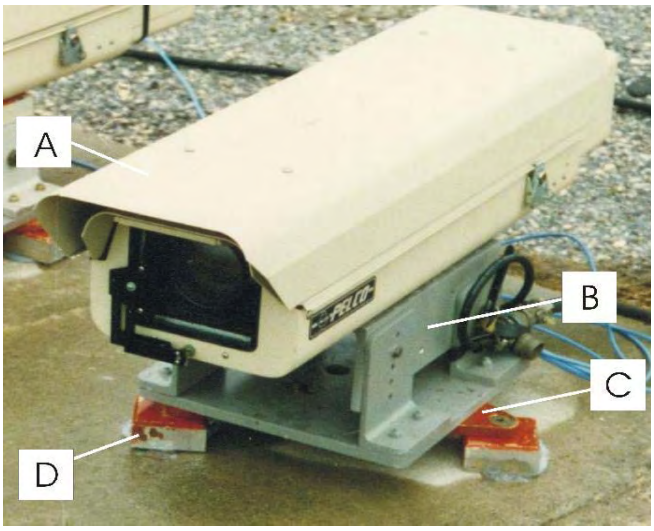


Figure 3 Video Camera

5.0 Camera Installation

A photo of an installed camera, Figure 3 is shown at left. 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 (90 cm) long, eight inches (20 cm) wide, and eight inches (20 cm) 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 13/32-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.

6.0 Landing Survey Equipment Description

The video equipment, which is planned to be involved in the video landing parameter survey at Cincinnati include:

- Eight video cameras
- Five portable generators to power the cameras: See figure 4,shown on the right
- One data acquisition station trailer or portable camper
- Considerable fiber optic cabling

The video survey team plans to position all video landing survey equipment east of runway 18L-36R The team proposed to mount the video instrumentation on Runway 18L to capture video images of arrivals and touchdown events.

Figure 4: Honda EB2500 Generator

The proposed camera number and locations at Cincinnati International are as follows.

Camera Number	Location
C1	Approximately 1400 feet from the runway threshold and 85 feet from the runway centerline
C2	Approximately 1800 feet from the runway threshold and 85 feet from the runway centerline
C3	Approximately 2200 feet from the runway threshold and 85 feet from the runway centerline

Camera Number	Location
C4	Approximately 2600 feet from the runway threshold and 85 feet from the runway centerline
C5	Approximately 3000 feet from the runway threshold and 85 feet from the runway centerline
C6	Approximately 3400 feet from the runway threshold and 85 feet from the runway centerline
C7	Approximately 3800 feet from the runway threshold and 85 feet from the runway centerline
C8	At the runway threshold, perpendicular to 18L-36R and approximately 600 feet from the centerline

Video cameras C1 through C7 will be situated on the same parallel line as the runway edge lights on the east side of Runway 18L. The proposed location of the video data acquisition station is a position 300 feet from the 18L-36R centerline and approximately 3000 feet from the threshold. The generators, which power the video system, will be positioned approximately as follows:

Generator #	Location:
G1	Will provide power for C1 and C2 and be positioned midway between C1 and C2 and 275 feet from the Runway 18L-36R centerline.
G2	Will provide power for C3 and C4 and be positioned midway between C3 and C4 and 275 feet from the Runway 18L-36R centerline.
. G3	Will provide power for C6 and C7 and be positioned midway between C6 and C7 and 275 feet from the Runway 18L-36R centerline.
G4	Will provide power C8 and will be positioned adjacent to C8
G5	Will power both the data station and camera C5 and be positioned 300 feet from the centerline and 3000 feet from the threshold

Frequently an additional larger generator is situated at the data station to provide an additional independent power source for the data acquisition equipment leaving the powering of C5 to G5 alone. All generators can run on a tank full of fuel for 6-8 hours, consequently two fuel runs are made daily. All generators will be positioned outside the 275 feet from centerline line thus ground operations will not need to be contacted for the refueling operation.

7.0 Video and Power and Power Cables: Fiber optic cables will connect C1-through C7 to the video data acquisition trailer, which will be positioned 300 feet from the centerline and 3000 feet from the 18L-36R threshold. Power cords will run from each camera to generators listed in the prior section. All fiber cable and power cord runs will be identified with red warning flags every 3 to 4 yards. The transmission of data from camera to the data acquisition station will be accomplished via a wireless connection using a DynaPix IN-2500 Wireless Video System with transmission frequency of Freq: 2.4-2.5GHz and Transmitting Power of 250mW. Please refer to the drawing on Figure 5.

8.0 Technical Support from CVG Operations

Due to the logistics of conducting a video landing parameter survey at a remote location the survey personnel routinely request a modest amount of technical support from the host organization, for this survey, CVG Operations. The FAA will reimburse CVG Operations for expenses incurred in the support of the video landing survey team. The support needed includes the following:

- Host a pre-survey visit (or two if necessary) for the survey team to inspect available runways and select, in agreement with CVG Operations and FAA Airports Regulatory personnel, appropriate locations for the survey video cameras, trailer, generators, etc.

- Accept delivery and placement of a temporary portable office (trailer or camper) for use as the survey team's data acquisition station and equipment storage area. See figure 6 with trailer specifications. Please note that the FAA-Navy camper will be shipped approximately 1-2 weeks prior to the survey. At CVG, the camper should be positioned at a location 300 feet east of 18L centerline and 3000 feet from the threshold. Camper should be positioned lengthwise with entry door facing the perimeter road, i.e., away from 18L-36R.

- Provide for a Toilet facility (i.e., Porta-Loo) or make available facilities at nearby buildings with easy walking access to video trailer location

- Issue appropriate security passes (i.e., badges) and vehicle decals for survey team members' access to the airfield.

- Arrange for access through a suitable entry gate for survey personnel to install, service, and operate equipment. Provide for appropriate CVG escort service during the survey. Provide security for FAA equipment.

9.0 Survey Schedule

The following is the proposed test schedule. The Operational Schedule is conditional on southerly winds and arrivals actually occurring on Runway 18L.

Date:	Day	Planned Activity
15 Sept	Wed	Travel, Hotel check-in, pick up rental vehicles
16 Sept	Thurs	AM: .Meet with CVG Operations & Security Obtain CVG access badges and vehicle decals PM: Move equipment from storage to 18L work site Move/setup equipment in data station, Position and fuel generators.
17 Sept	Fri	11:00pm to 6:00am: Install camera blocks and mounts. Run Camera video and power cables from the camera site Complete running video and power cables. (Limited runway access is needed)
18 Sept	Sat	11:00pm to 0600am, Mount and align cameras, connect power/video cables, operate system. Perform edge of runway alignment. Perform system calibration (Unlimited runway access is needed)
19 Sept	Sun	No scheduled work; final system check if needed
20-24 Sept	Mon/Fri	Dawn to Dusk Landing Data Collection**
25 Sept	Sat	AM to Noon: Landing Data Collection (If needed) 11:00pm to 6:00am: Second Camera Calibration, Remove all equipment from the edge of runway 18L
26 Sept	Sun	No work scheduled
27 Sept	Mon	AM/PM: Pack up trailer equipment, generators, cables Complete packing up of equipment Farewell meeting with CVG Operations Transport equipment to storage area, band skids, load truck,
28 June	Tues	Travel

** Operational schedule is contingent upon mostly southerly operations

10.0 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

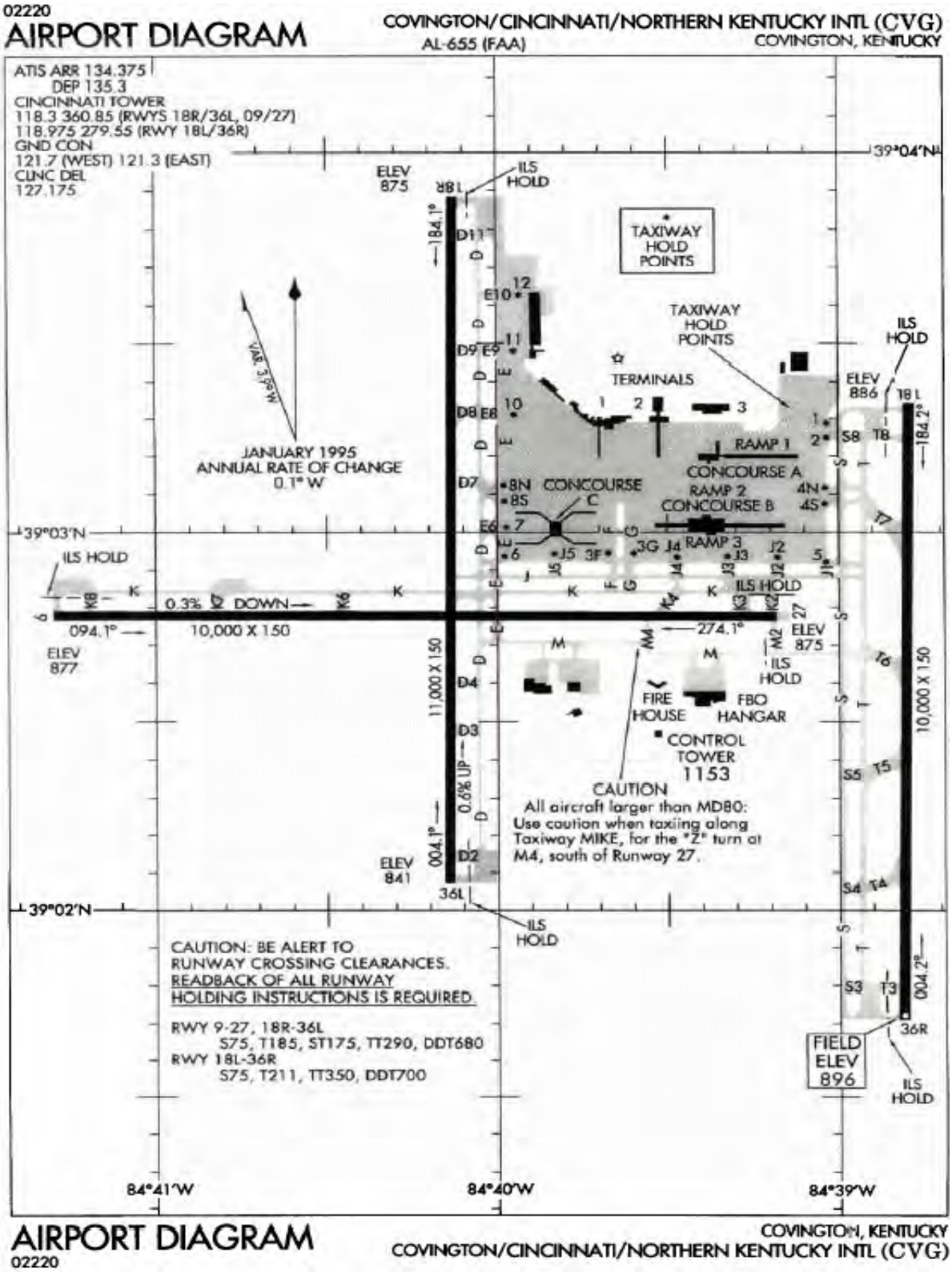

02220
AIRPORT DIAGRAM
COVINGTON/CINCINNATI/NORTHERN KENTUCKY INTL (CVG)
AL-655 (FAA)
COVINGTON, KENTUCKY
ATIS ARR 134.375
DEP 135.3
CINCINNATI TOWER
118.3 360.85 (RWYS 18R/36L, 09/27)
118.975 279.55 (RWY 18L/36R)
GND CON
121.7 (WEST) 121.3 (EAST)
CLNC DEL
127.175
39°04'N
39°03'N
39°02'N
84°41'W
84°40'W
84°39'W
ELEV 875
ILS HOLD
TAXIWAY HOLD POINTS
TERMINALS
RAMP 1
CONCOURSE A
RAMP 2
CONCOURSE B
CONCOURSE C
RAMP 3
ELEV 886
VAR 3.9°W
JANUARY 1995
ANNUAL RATE OF CHANGE
0.1° W
0.3% DOWN
094.1°
10,000 X 150
274.1°
ELEV 877
ELEV 875
11,000 X 150
0.6% UP
004.1°
ELEV 841
FIRE HOUSE
FBO HANGAR
CONTROL TOWER
1153
CAUTION
All aircraft larger than MD80:
Use caution when taxiing along
Taxiway MIKE, for the "Z" turn at
M4, south of Runway 27.
CAUTION: BE ALERT TO
RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY
HOLDING INSTRUCTIONS IS REQUIRED.
RWY 9-27, 18R-36L
S75, T185, ST175, TT290, DDT680
RWY 18L-36R
S75, T211, TT350, DDT700
FIELD ELEV 896
184.1°
184.2°
004.2°
AIRPORT DIAGRAM
02220
COVINGTON, KENTUCKY
COVINGTON/CINCINNATI/NORTHERN KENTUCKY INTL (CVG)

Figure 4

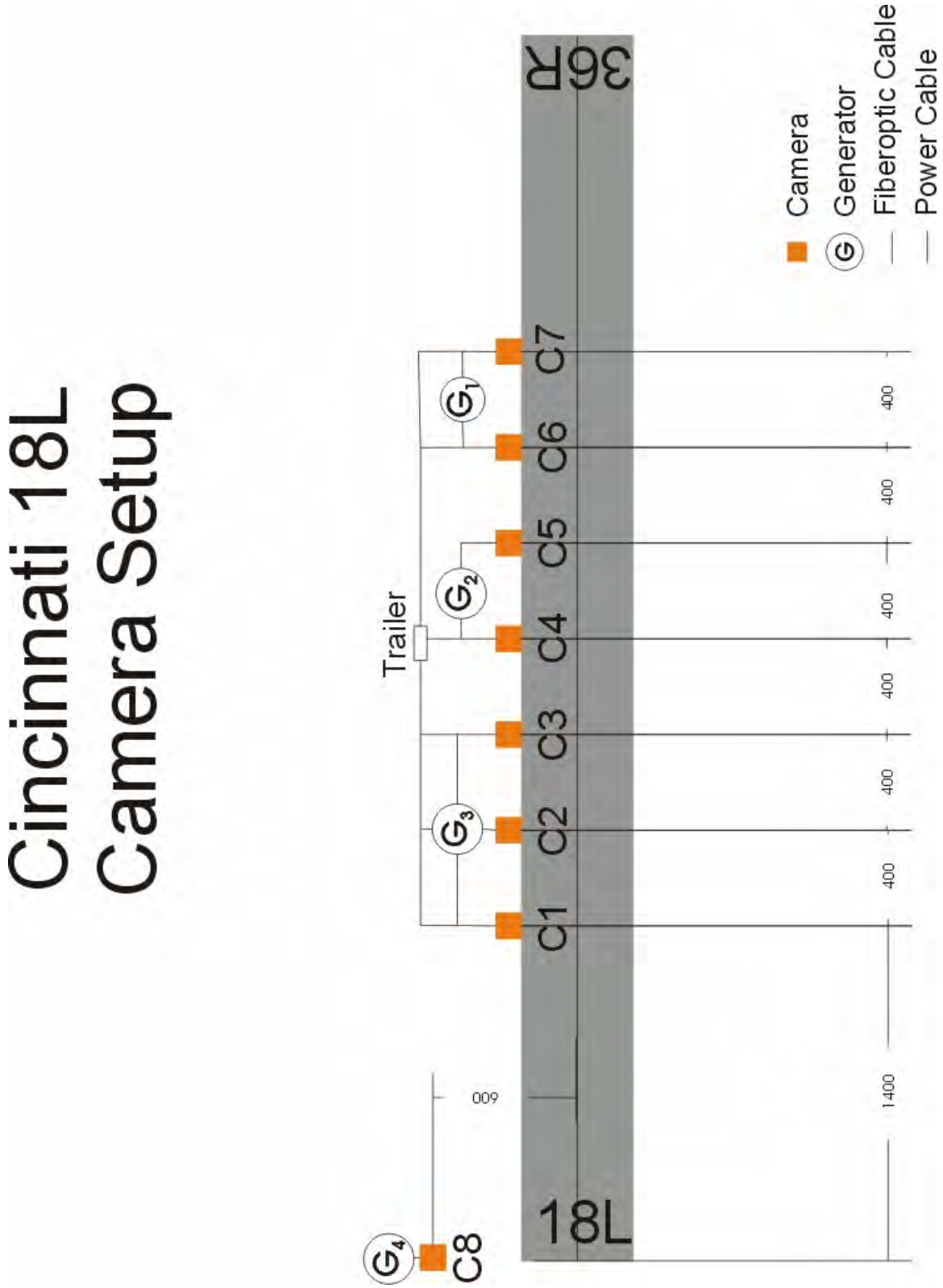

Cincinnati 18L
Camera Setup
Trailer
G4
C8
600
G3
C1
C2
C3
G2
C4
C5
G1
C6
C7
18L
36R
400
400
400
400
400
400
1400
Camera
Generator
Fiberoptic Cable
Power Cable

Figure 5

Figure 6

Trailer Specifications:

Length 28’6” + 3’ Tongue = 31' 6"
Width 106” (8’10”)
Height 10’7”
Weight 5270lbs (empty)
Weight 7000 Gross (Class 3)
Ball Required 2 5/16”

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

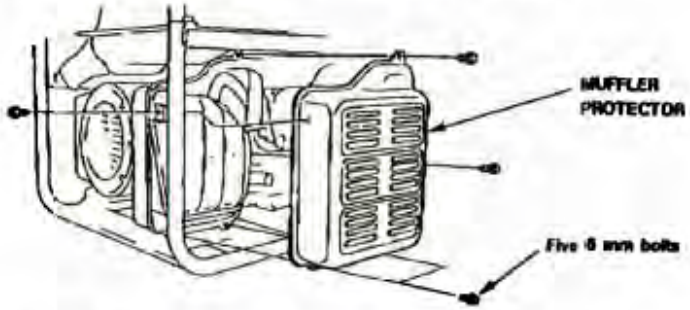
NOTE: Specifications are subject to change without notice.

Spark Arrester Maintenance

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

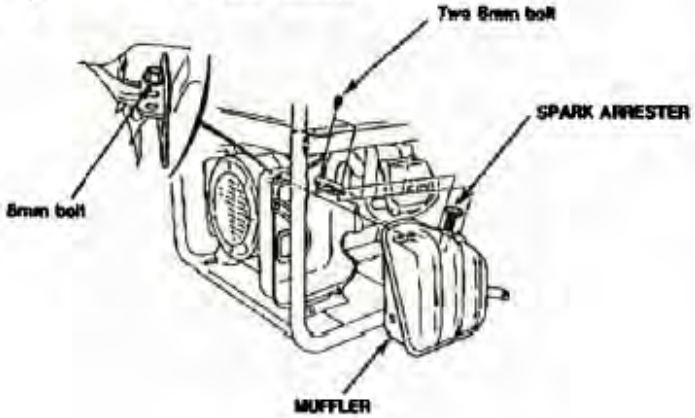
NOTICE **The spark arrester must be serviced every 100 hours to maintain its efficiency.**

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

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" THICK)

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 DEFINED 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 = 27.8 KN = 6.2 KIPS

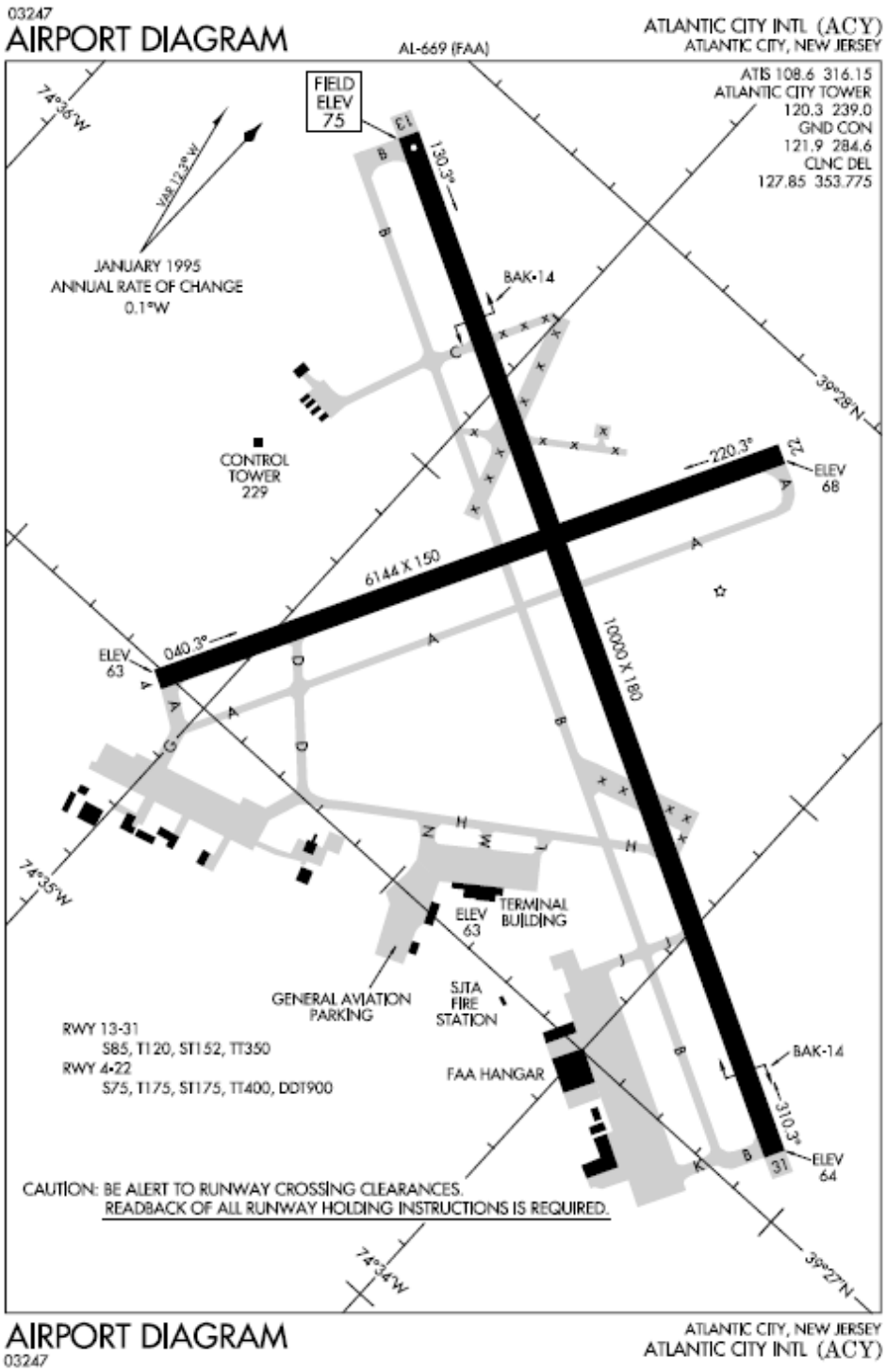
ASTM, SAE AND ISO GRADE MARKINGS AND MECHANICAL PROPERTIES FOR STEEL FASTENERS

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				

APPENDIX E—ATLANTIC CITY INTERNATIONAL AIRPORT, FAA VIDEO LANDING SURVEY FACILITY DESCRIPTION

FAA VIDEO LANDING SURVEY FACILITY:

The FAA William J. Hughes Technical Center established a Video Landing Survey Facility at Atlantic City International (ACY) Airport where aircraft landing parameter data is collected and analyzed. The airport and FAA Technical Center are collocated on the same property and share the use of the runways.



The Video Facility has three components; (1) Five Video Cameras located along the north apron of ACY Runway 13, (2) Video Data Acquisition Station in video trailer situated at a point perpendicular to Runway 13, across from Taxiway C, which is 2000 feet from the Runway 13 threshold and 600 feet north of the runway edge and (3) the video landing analysis site in Building 300 at the FAA Technical Center.

This facility enables the FAA to collect operational landing impact parameters year round under a wide variety of weather conditions. In addition to the regular commercial airplane arrivals at ACY, US Air Force KC-10's and other large aircraft frequently conduct touch-and-go training at the airport. Inclement weather data collected at this facility will be used to supplement regular survey data collected during prior 10 to 12 day surveys at commercial airports. Over 800 video images have been captured at this facility thus far.

The following functions are performed at this video landing loads facility:

- High-resolution video images are recorded of the various landing operations at Atlantic City International (ACY) Airport.

- These images are processed and analyzed to obtain landing contact parameters: i.e., sink speed, velocity, pitch, roll, yaw, ..etc.
- This facility provides typical usage data in the form of statistical information as well as individual landing results to characterize the landing load environment for a wide variety of airplane models in both good and bad weather conditions at ACY.
- The facility is utilized as a test and evaluation site for the development of landing parameter survey equipment and procedures.

Output from subject research facility forms the technical substantiation for assessing the validity of landing loads air worthiness certification standards.

APPENDIX F—SELECTED REGRESSION CURVES FROM THE ATLANTIC CITY INTERNATIONAL AIRPORT AND CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT LANDING PARAMETER SURVEYS

F.1 SELECTED REGRESSION CURVES FOR AIRBUS A330 LANDINGS AT ATLANTIC CITY INTERNATIONAL AIRPORT (ACY), ALL WEATHER CONDITION, SELECTION CRITERIA, R^2 >0.1.

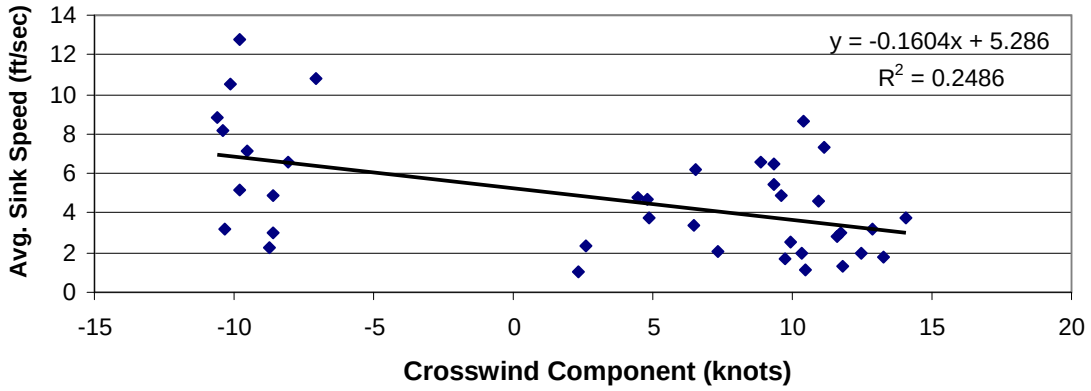


Figure F-1. A330 Average Sink Speed Versus Crosswind Component, ACY Data

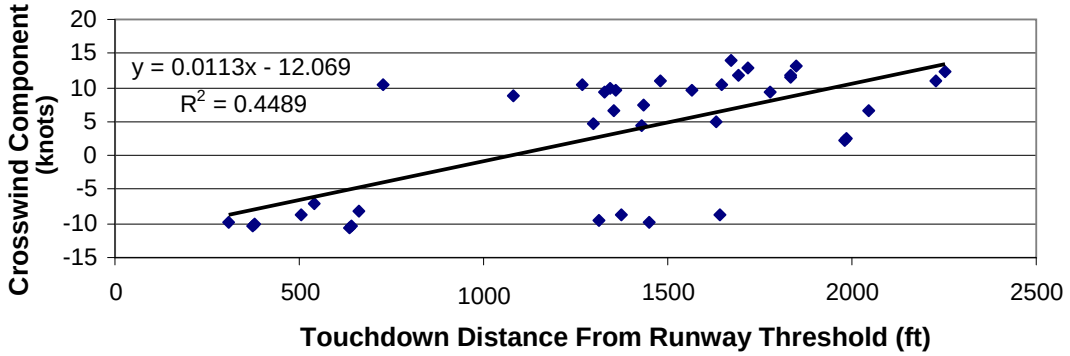


Figure F-2. A330 Touchdown Distance to Runway Threshold Versus Crosswind Component, ACY Data

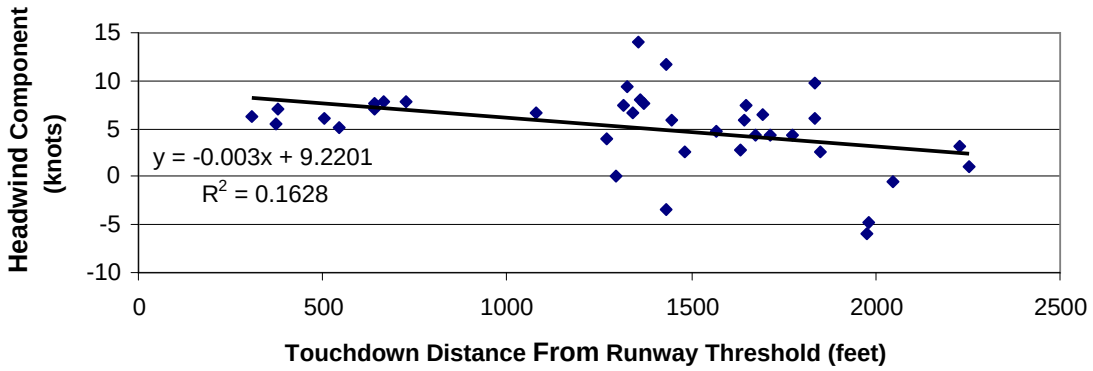


Figure F-3. A330 Touchdown Distance to Runway Threshold Versus Headwind Component, ACY Data

F.2 SELECTED REGRESSION CURVES FOR MCDONNELL DOUGLAS DC-9 LANDINGS, ALL WEATHER CONDITION, SELECTION CRITERIA, R^2 >0.1.

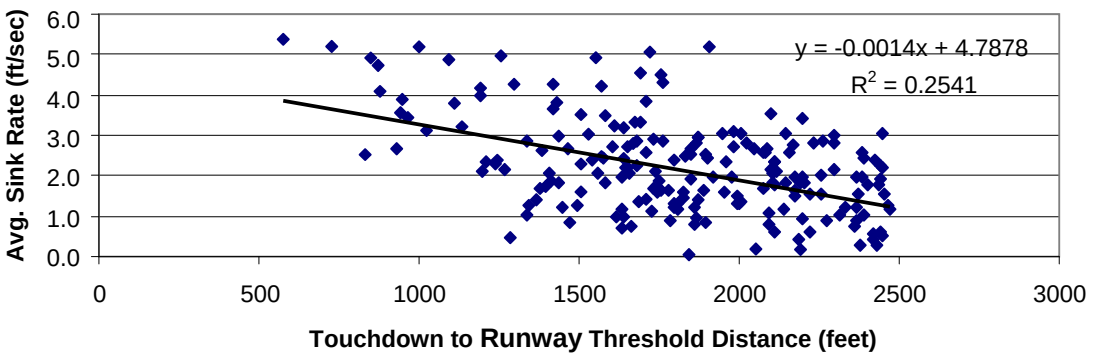


Figure F-4. DC-9 Average Sink Speed Versus Touchdown to Runway Threshold Distance, ACY Data

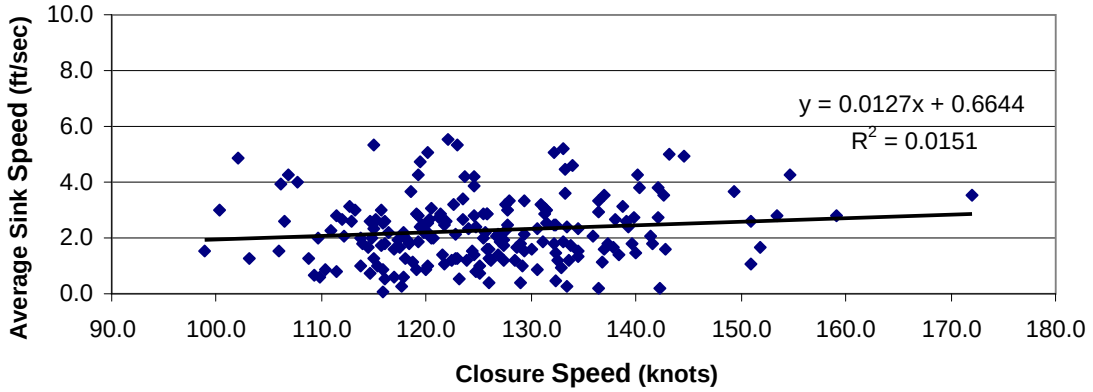


Figure F-5. DC-9 Average Sink Speed Versus Closure Speed, ACY Data

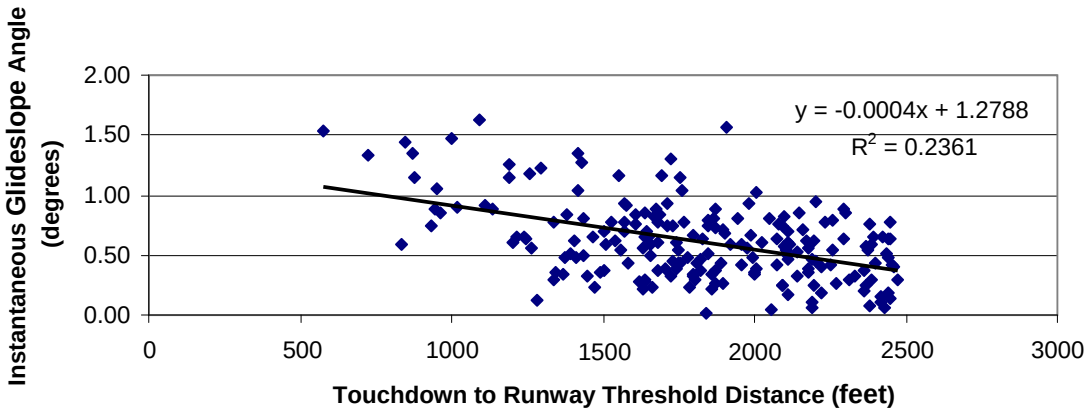


Figure F-6. DC-9 Instantaneous Glide Slope Angle Versus Touchdown to Runway Threshold Distance, ACY Data

F.3 SELECTED REGRESSION CURVES FOR MCDONNELL DOUGLAS KC-10 LANDINGS AT ACY, ALL WEATHER CONDITION, SELECTION CRITERIA, R^2 >0.1.

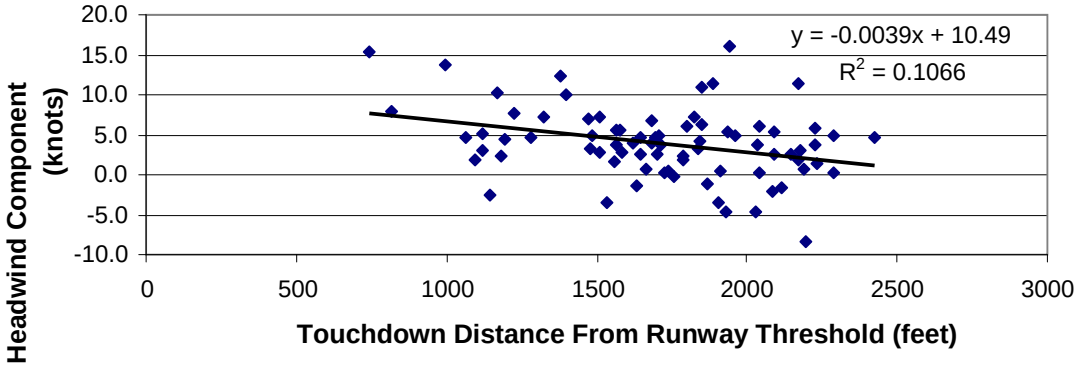


Figure F-7. KC-10 Touchdown Distance From Runway Threshold Versus Headwind Component, ACY Data

F.4 SELECTED REGRESSION CURVES FOR BEECHCRAFT 1900D LANDINGS AT ACY, GROUPED BY WEATHER CONDITIONS, SELECTION CRITERIA, R^2 >0.1.

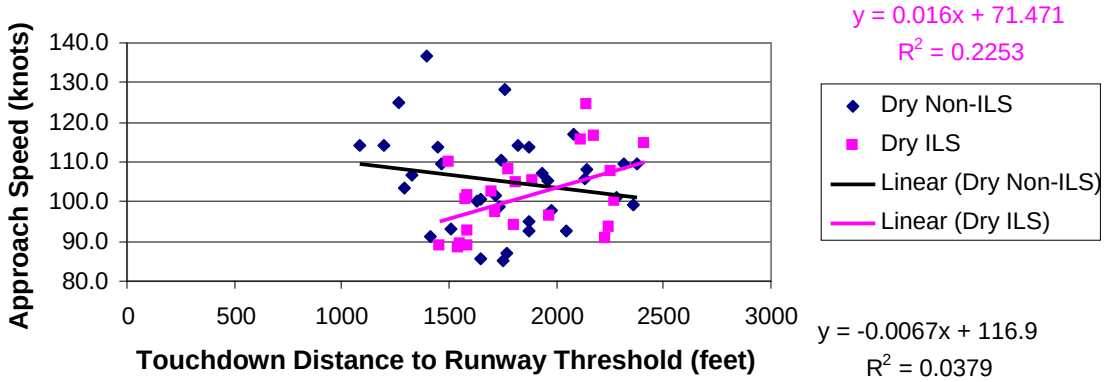


Figure F-8. ACY Beechcraft 1900D, Approach Speed Versus Touchdown to Runway Threshold Distance by Approach and Runway Conditions

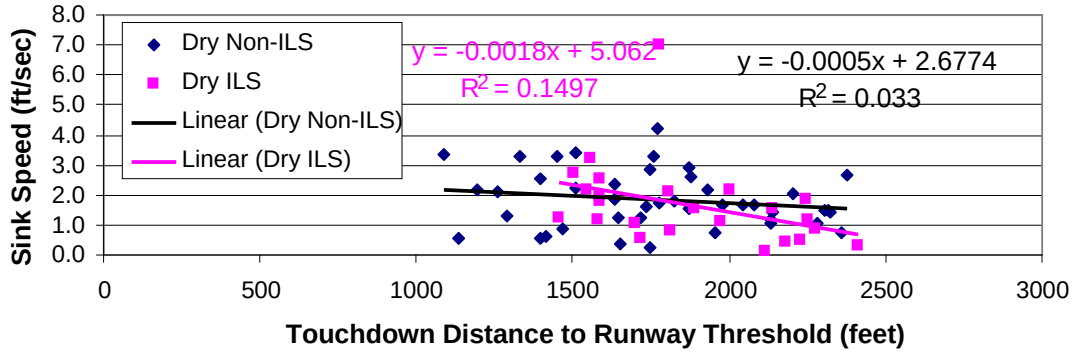


Figure F-9. ACY Beechcraft 1900D, Average Sink Speed Versus Touchdown to Runway Threshold Distance by Approach and Runway Conditions, Dry Non-ILS/Dry ILS

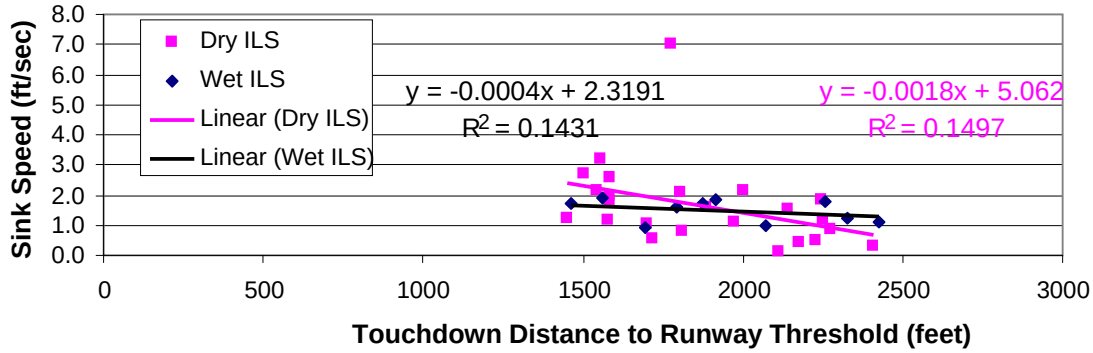


Figure F-10. ACY Beechcraft 1900D, Average Sink Speed Versus Touchdown to Runway Threshold Distance by Approach and Runway Conditions, Dry/Wet ILS

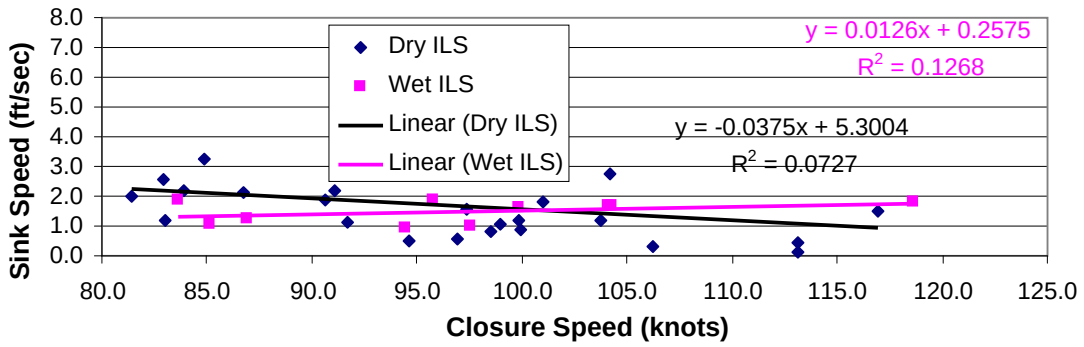


Figure F-11. ACY Beechcraft 1900D, Average Sink Speed Versus Closure Speed by Approach and Runway Conditions, Dry/Wet ILS

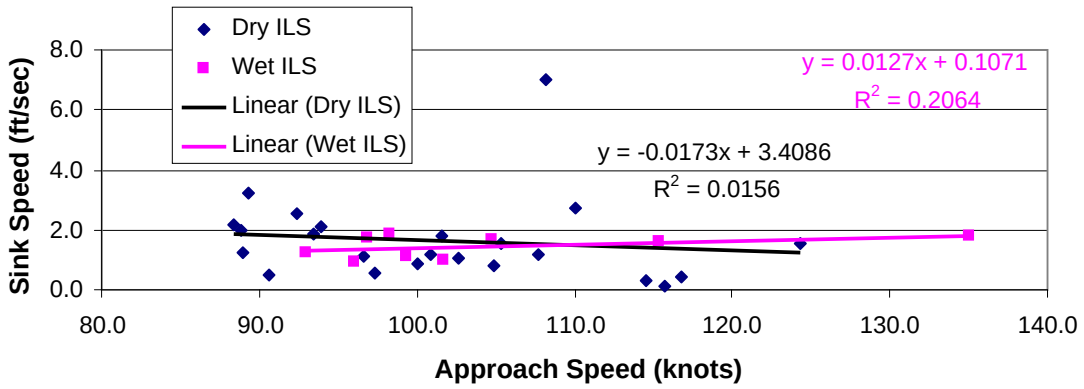


Figure F-12. ACY Beechcraft 1900D, Average Sink Speed Versus Approach Speed by Approach and Runway Conditions, Dry/Wet ILS

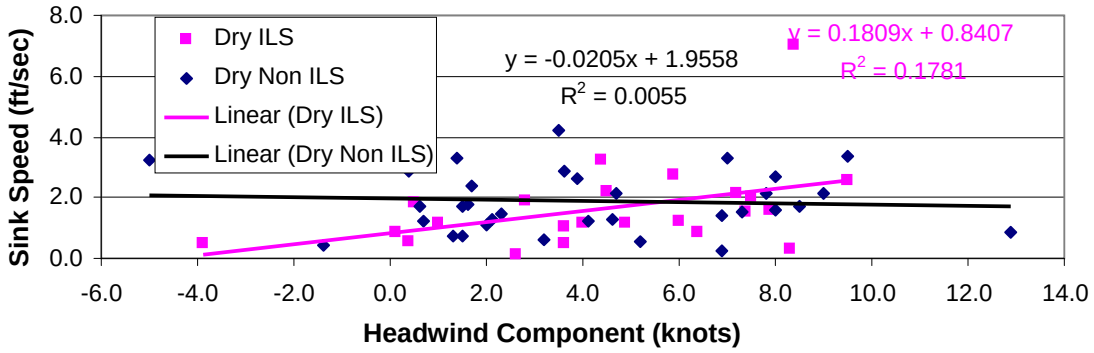


Figure F-13. ACY Beechcraft 1900D, Average Sink Speed Versus Headwind Component by Approach and Runway Conditions, Dry Non-ILS/DRY ILS

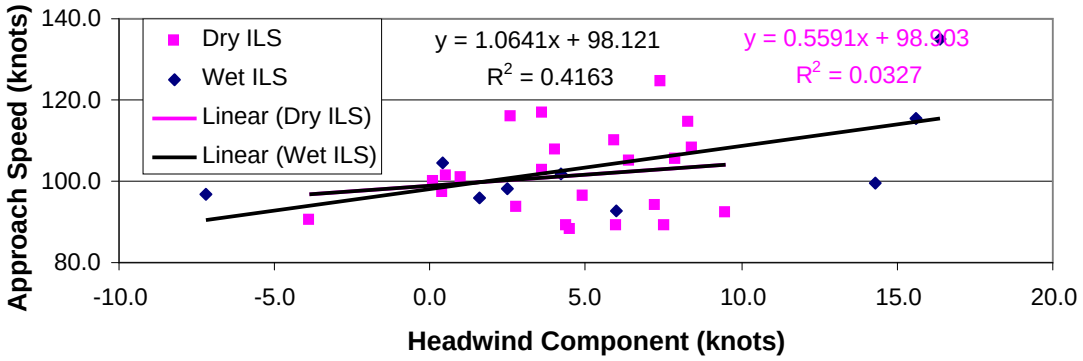


Figure F-14. ACY Beechcraft 1900D, Approach Speed Versus Headwind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

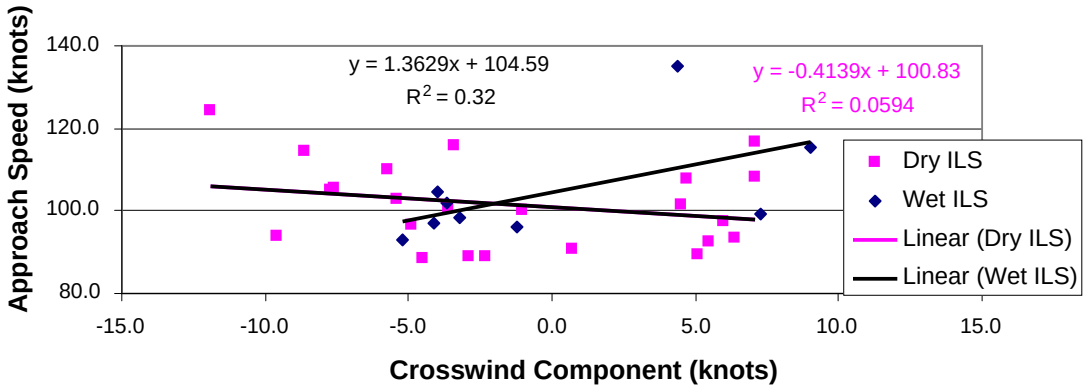


Figure F-15. ACY Beechcraft 1900D, Approach Speed Versus Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

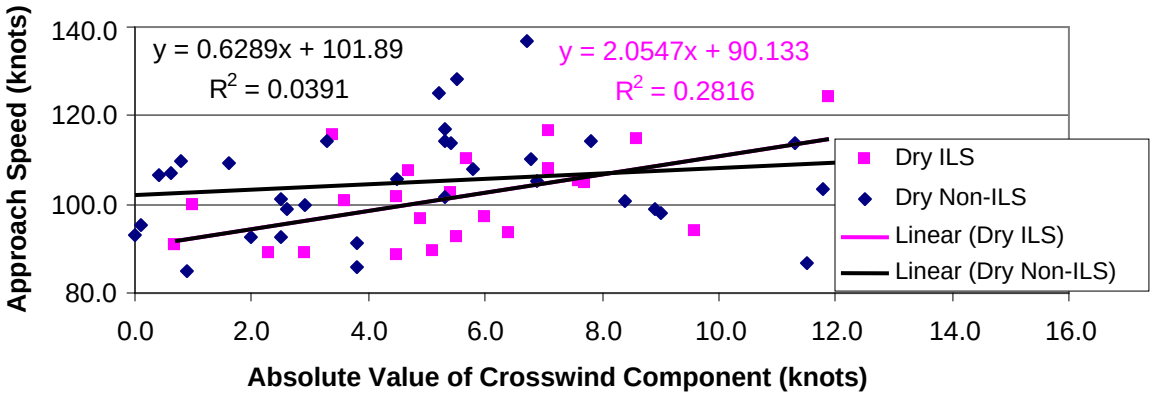


Figure F-16. ACY Beechcraft 1900D, Approach Speed Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/Dry Non-ILS

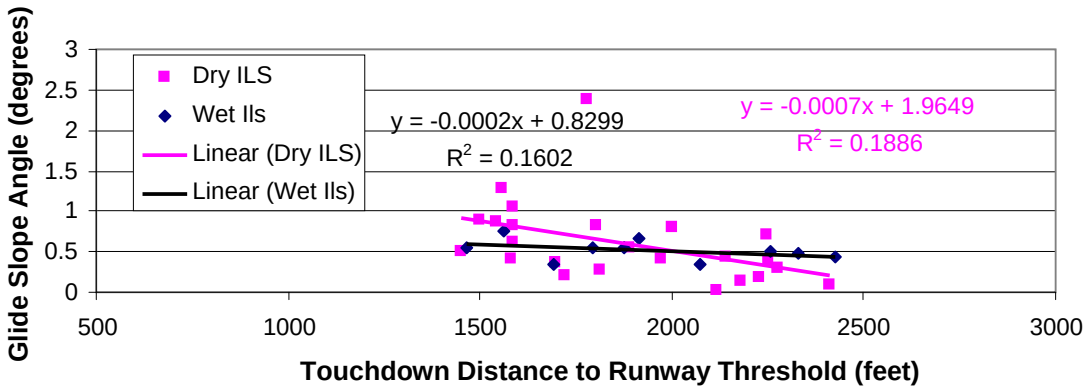


Figure F-17. ACY Beechcraft 1900D, Instantaneous Glide Slope Angle Versus Touchdown to Runway Threshold Distance by Approach and Runway Conditions

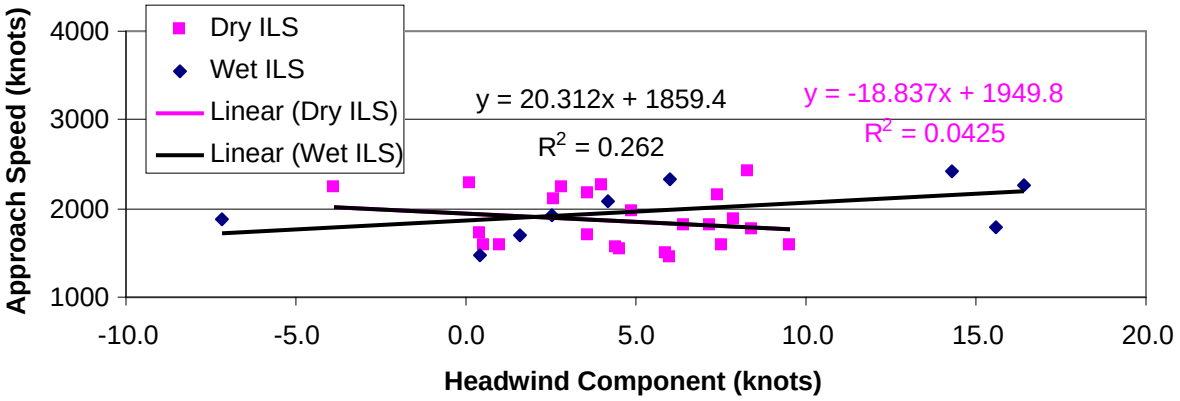


Figure F-18. ACY Beechcraft 1900D, Touchdown to Runway Threshold Distance Versus Headwind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

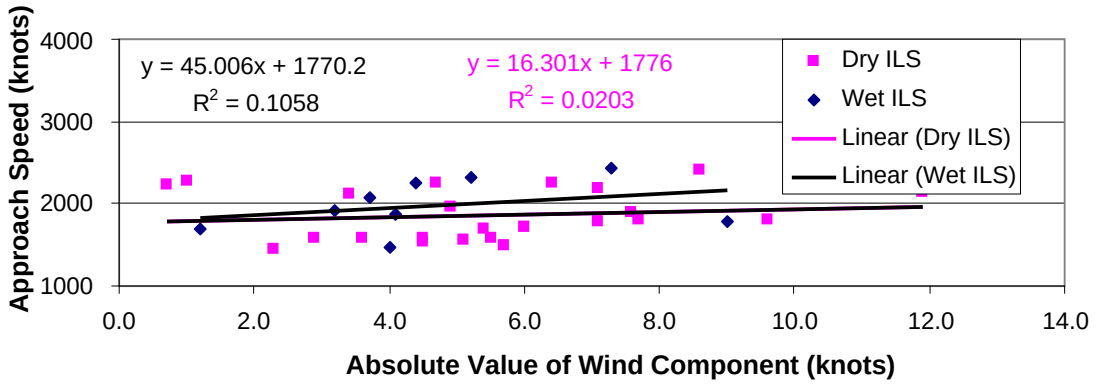


Figure F-19. ACY Beechcraft 1900D, Touchdown to Runway Threshold Distance Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

F.5 SELECTED REGRESSION CURVES FOR MCDONNELL DOUGLAS DC-9 LANDINGS AT ACY, GROUPED BY WEATHER CONDITION, SELECTION CRITERIA, R^2 >0.1.

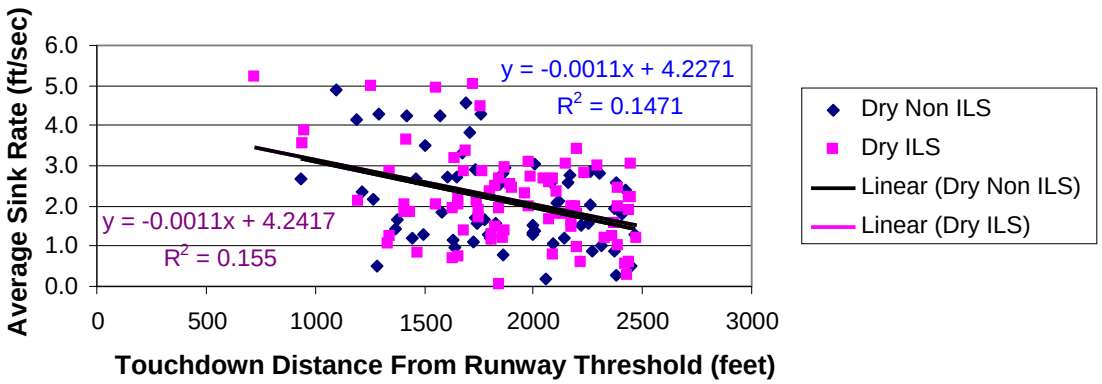


Figure F-20. ACY DC-9 Sink Rate Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry Non ILS/Dry ILS

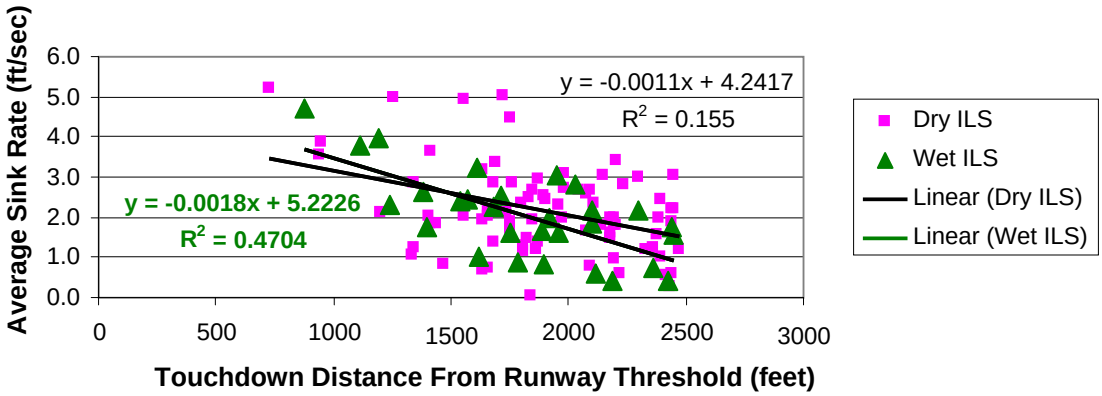


Figure F-21. ACY DC-9 Sink Rate Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Wet ILS

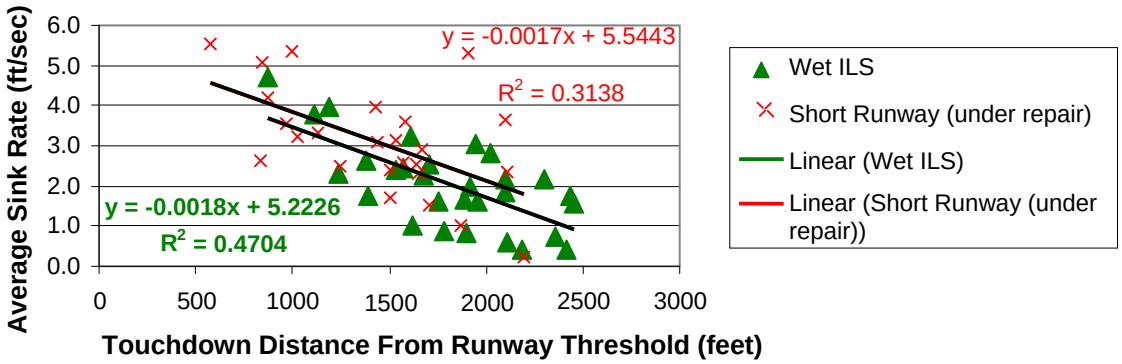


Figure F-22. ACY DC-9 Sink Rate Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Wet ILS/Short Runway

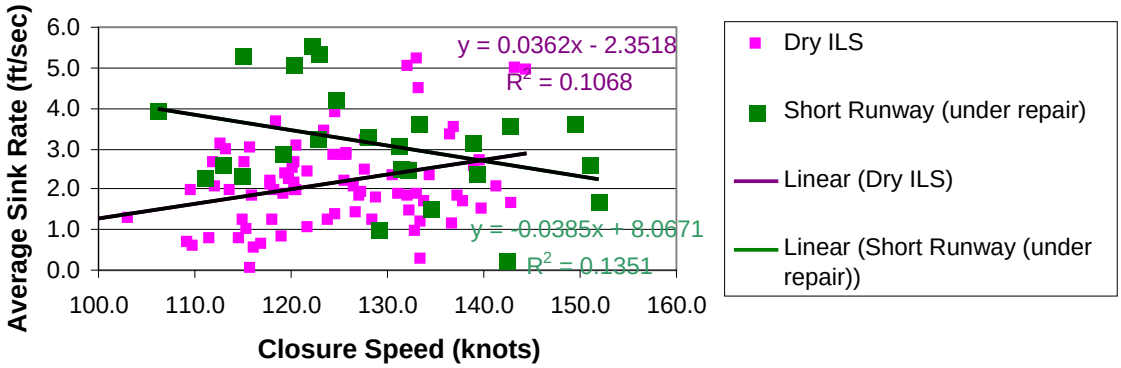


Figure F-23. ACY DC-9 Sink Rate Versus Closure Speed by Approach and Runway Conditions, Dry ILS/Short Runway

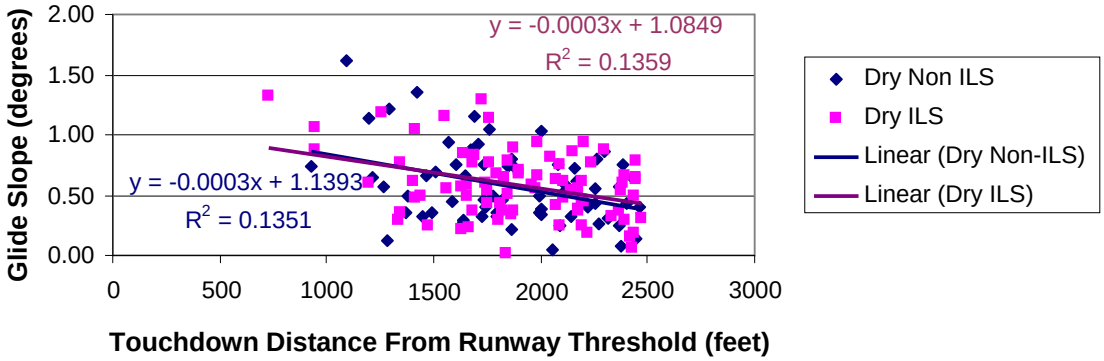


Figure F-24. ACY DC-9 Instantaneous Glide Slope Angle Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry Non-ILS/Dry ILS

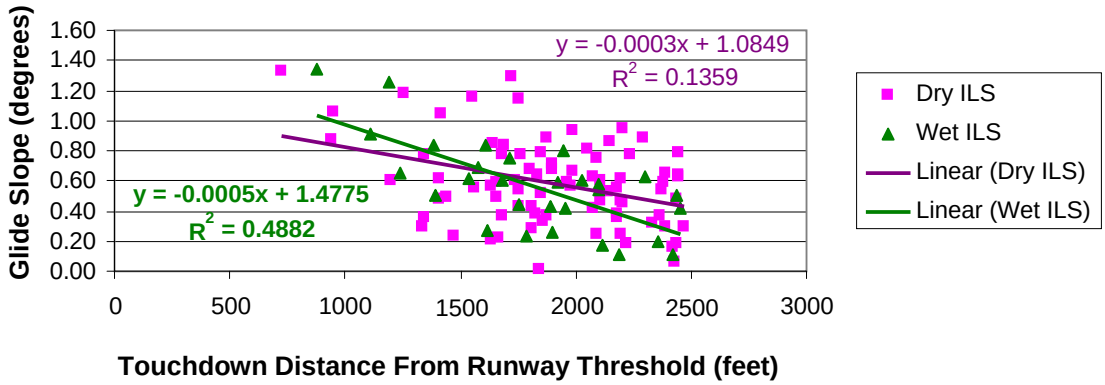


Figure F-25. ACY DC-9 Instantaneous Glide Slope Angle Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Wet ILS

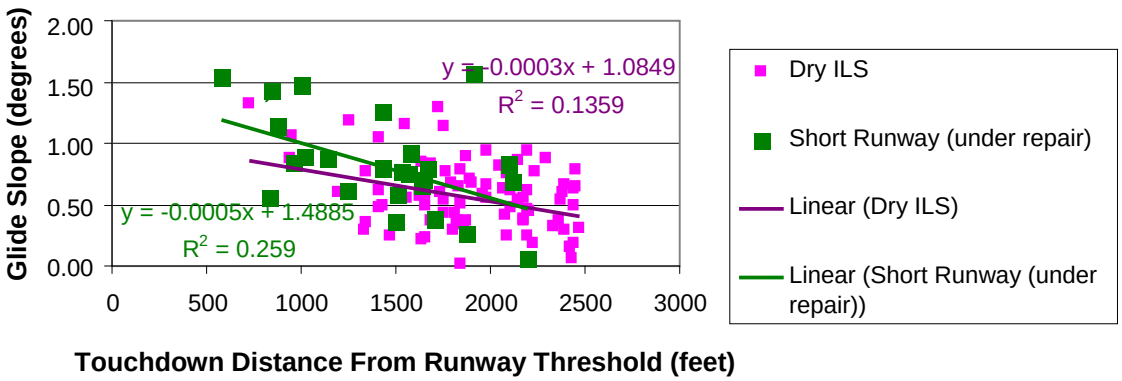


Figure F-26. ACY DC-9 Instantaneous Glide Slope Angle Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Short Runway

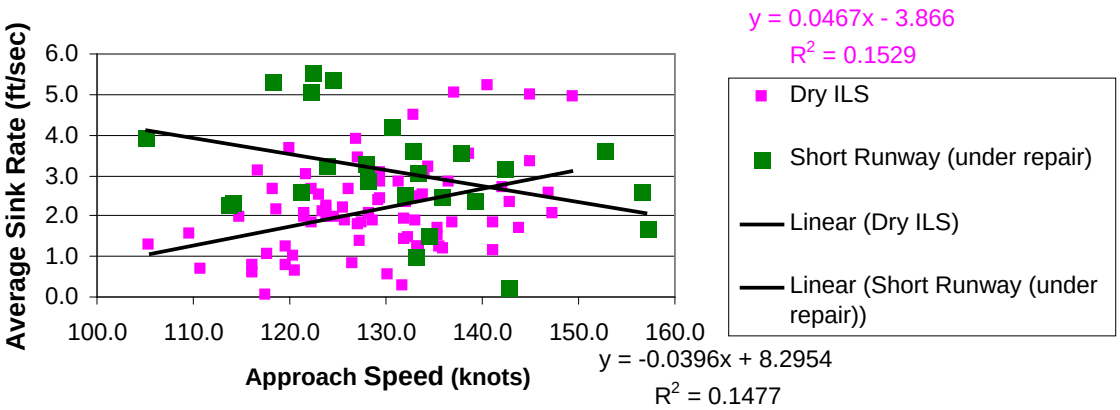


Figure F-27. ACY DC-9 Sink Rate Versus Approach Speed by Approach and Runway Conditions, Dry ILS/Short Runway

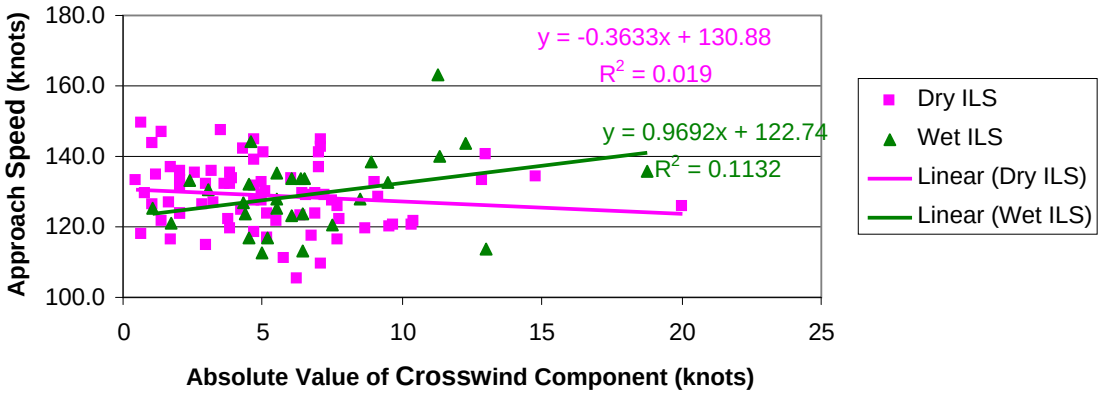


Figure F-28. ACY DC-9 Approach Speed Versus Absolute Value of Crosswind

F.6 SELECTED REGRESSION CURVES FOR MCDONNELL DOUGLAS KC-10 LANDINGS AT ACY, GROUPED BY WEATHER CONDITION, CRITERIA SELECTION, R^2 >0.1.

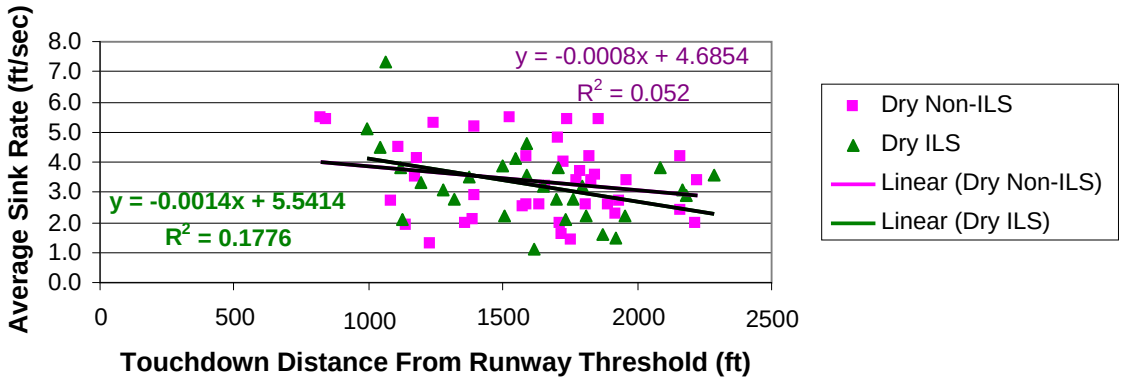


Figure F-29. ACY KC-10 Sink Rate Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry Non-ILS/Dry ILS

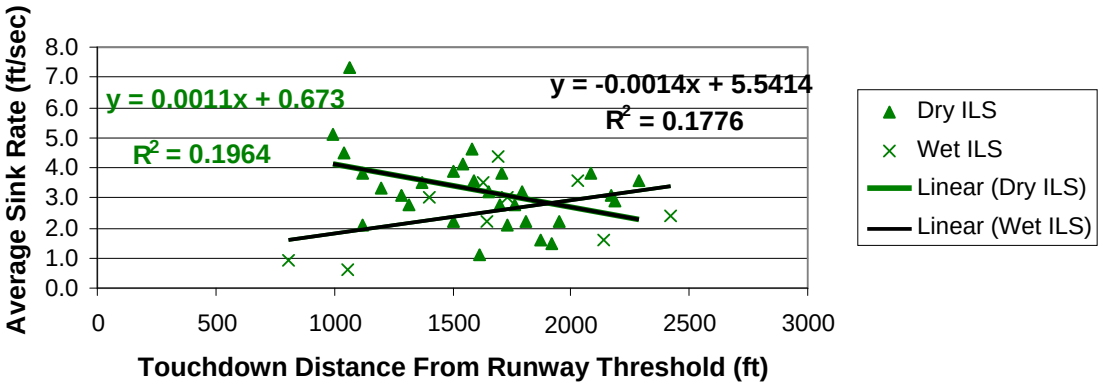


Figure F-30. ACY KC-10 Sink Rate Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Wet ILS

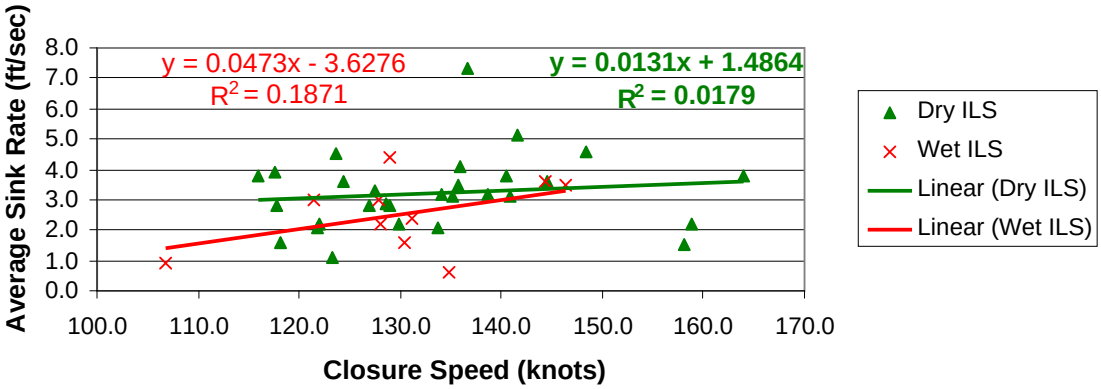


Figure F-31. ACY KC-10 Sink Rate Versus Closure Speed by Approach and Runway Conditions, Dry ILS/Wet ILS

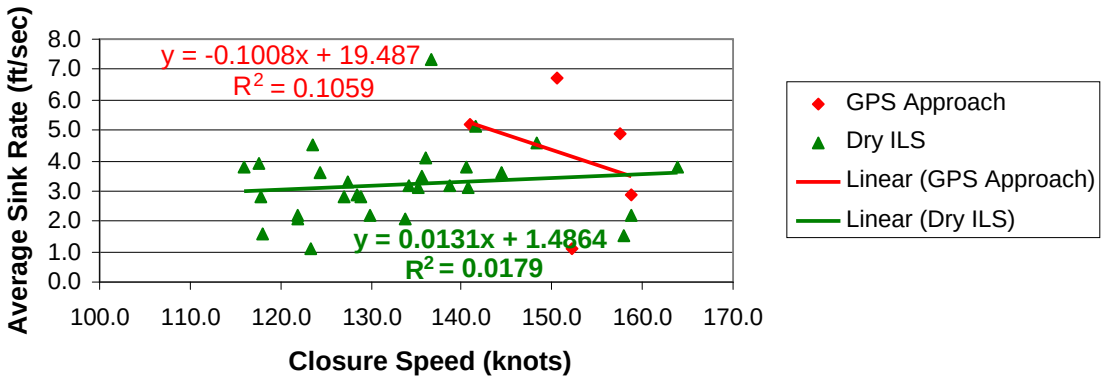


Figure F-32. ACY KC-10 Sink Rate Versus Closure Speed by Approach and Runway Conditions, Dry ILS/GPS Approach

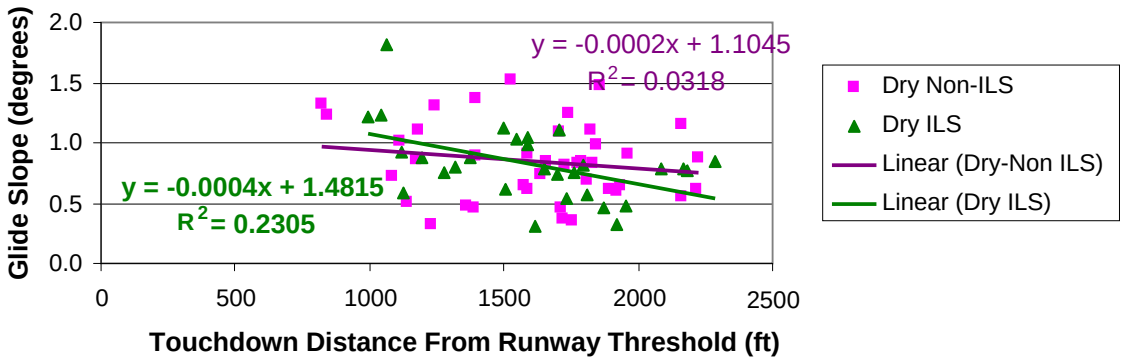


Figure F-33. ACY KC-10 Instantaneous Glide Slope Angle Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry Non-ILS/Dry ILS

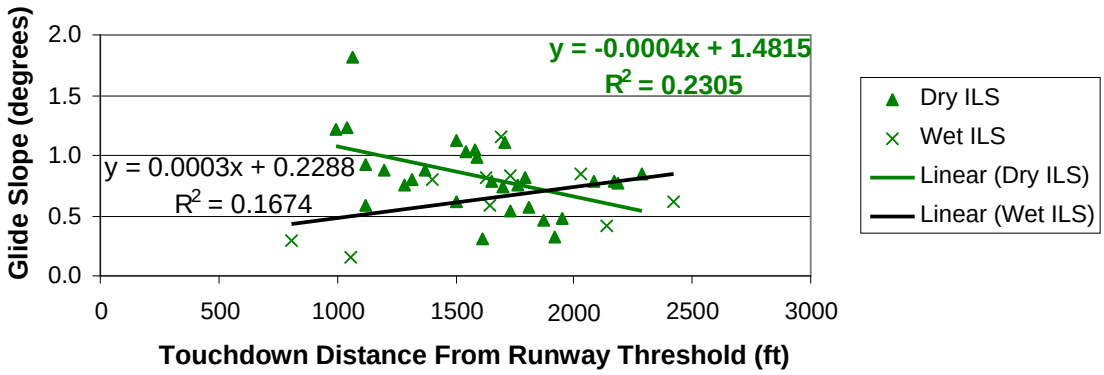


Figure F-34. ACY KC-10 Instantaneous Glide Slope Angle Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Wet ILS

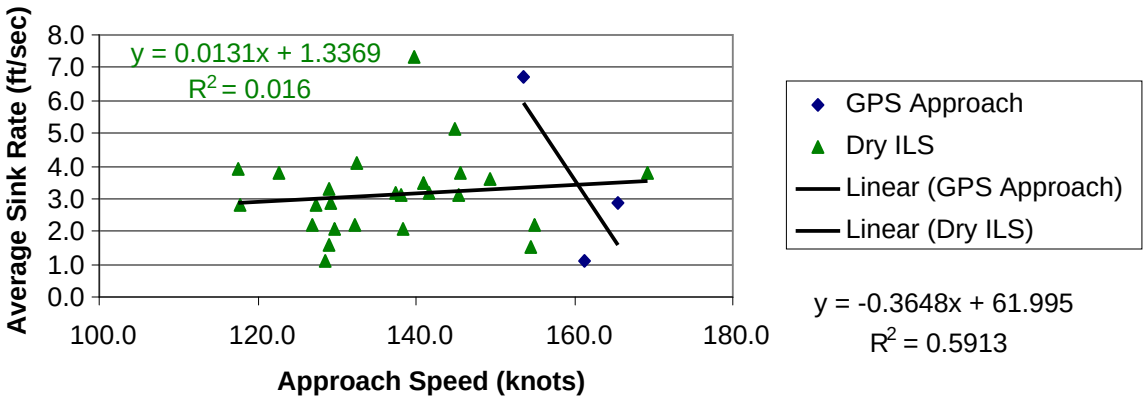


Figure F-35. ACY KC-10 Sink Rate Versus Approach Speed by Approach and Runway Conditions, Dry ILS/GPS Approach

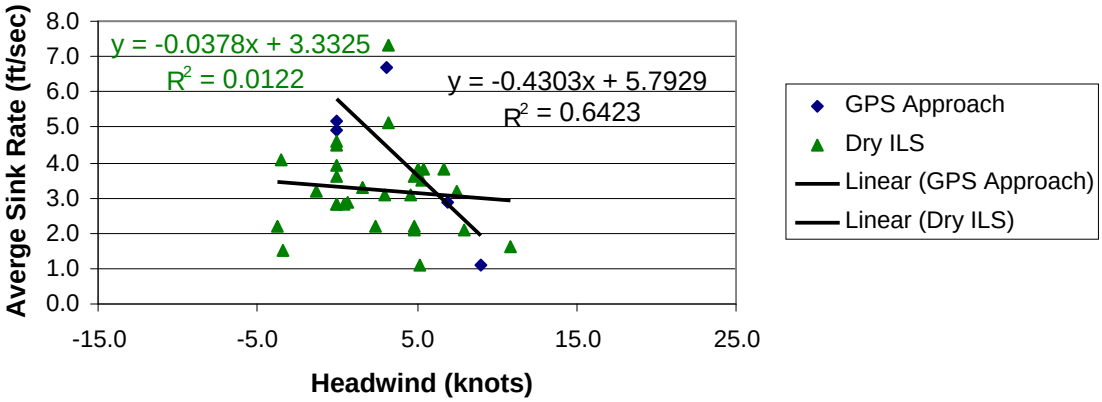


Figure F-36. ACY KC-10 Sink Rate Versus Headwind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

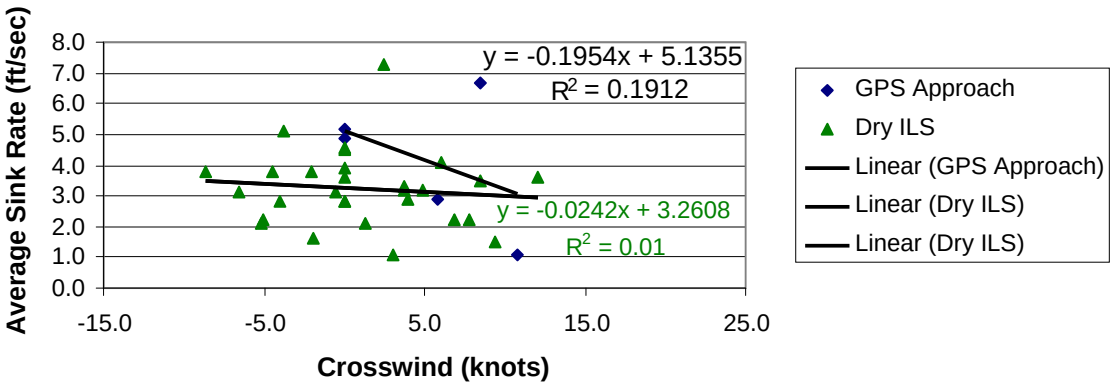


Figure F-37. ACY KC-10 Sink Rate Versus Crosswind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

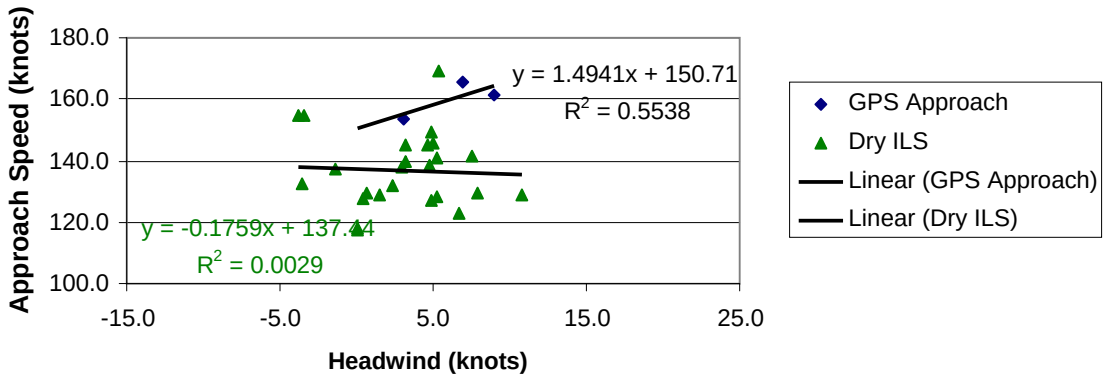


Figure F-38. ACY KC-10 Approach Speed Versus Headwind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

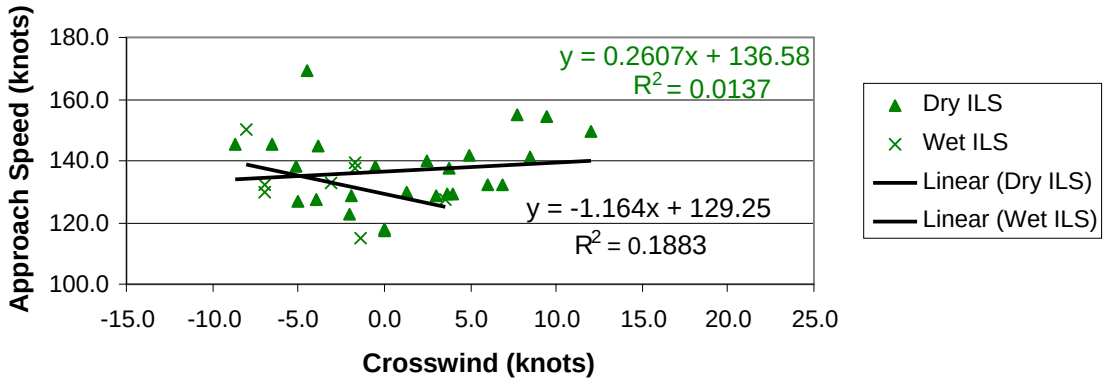


Figure F-39. ACY KC-10 Approach Speed Versus Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

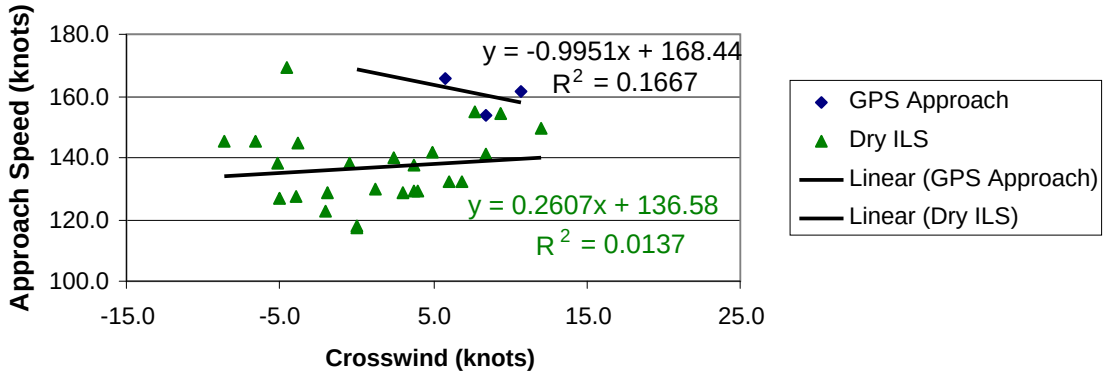


Figure F-40. ACY KC-10 Approach Speed Versus Crosswind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

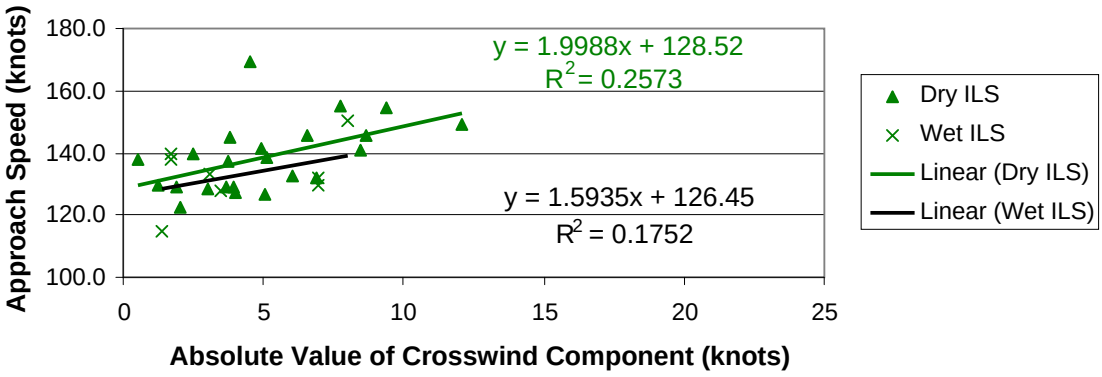


Figure F-41. ACY KC-10 Approach Speed Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

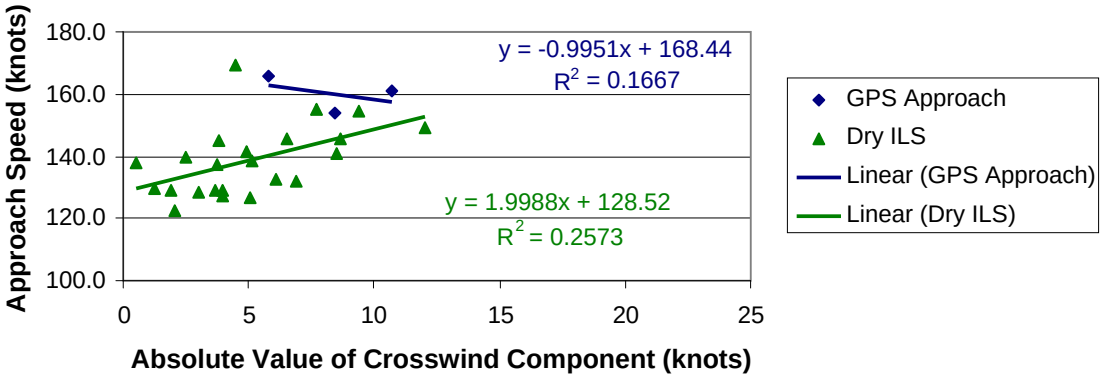


Figure F-42. ACY KC-10 Approach Speed Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

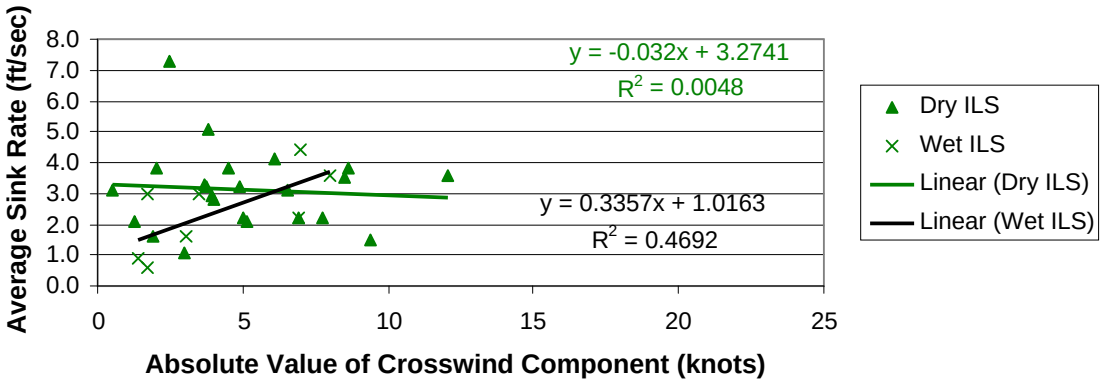


Figure F-43. ACY KC-10 Average Sink Rate Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

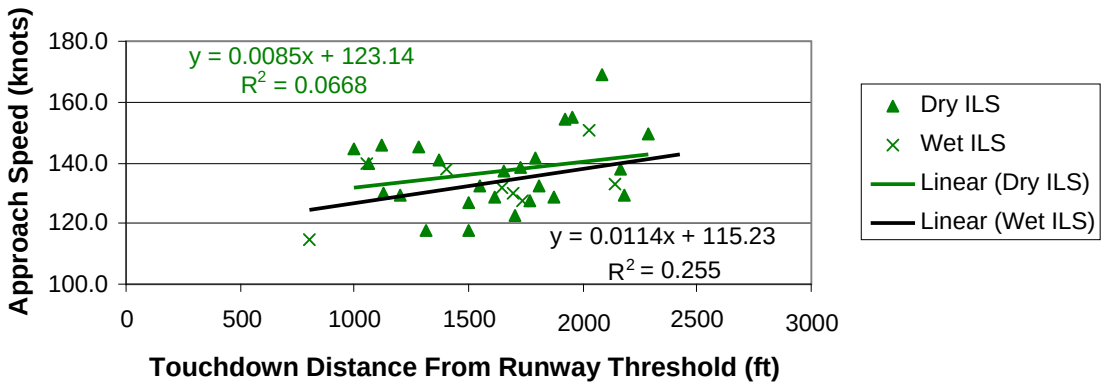


Figure F-44. ACY KC-10 Approach Speed Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/Wet ILS

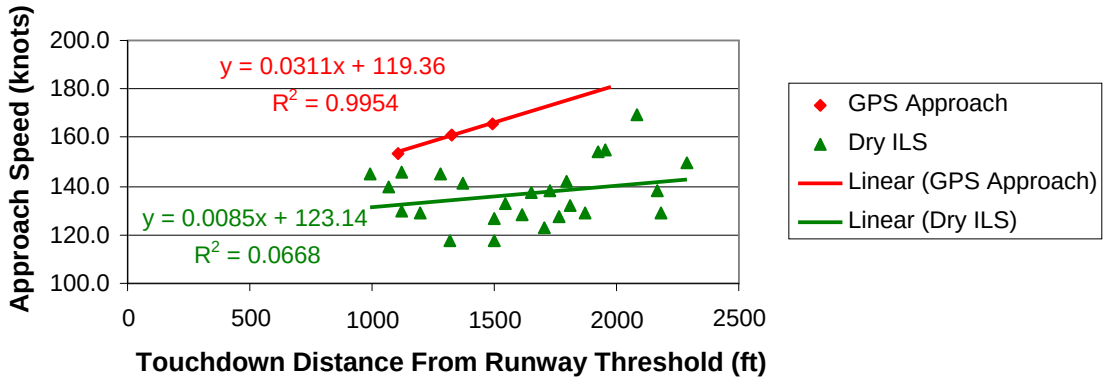


Figure F-45. ACY KC-10 Approach Speed Versus Touchdown Distance From Runway Threshold by Approach and Runway Conditions, Dry ILS/GPS Approach

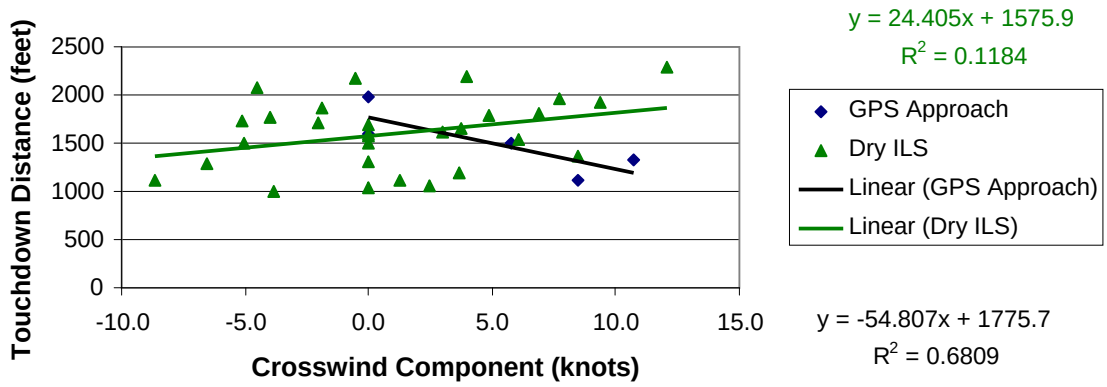


Figure F-46. ACY KC-10, Touchdown Distance From Runway Threshold Versus Crosswind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

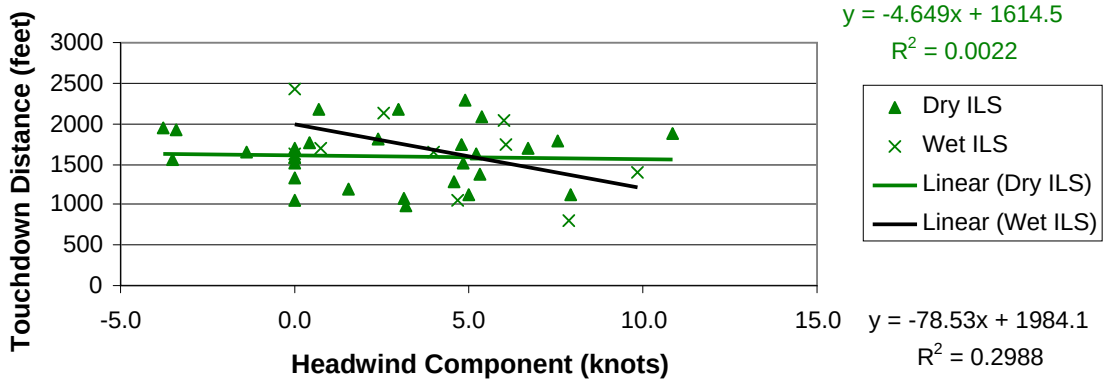


Figure F-47. ACY KC-10, Touchdown Distance From Runway Threshold Versus Headwind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

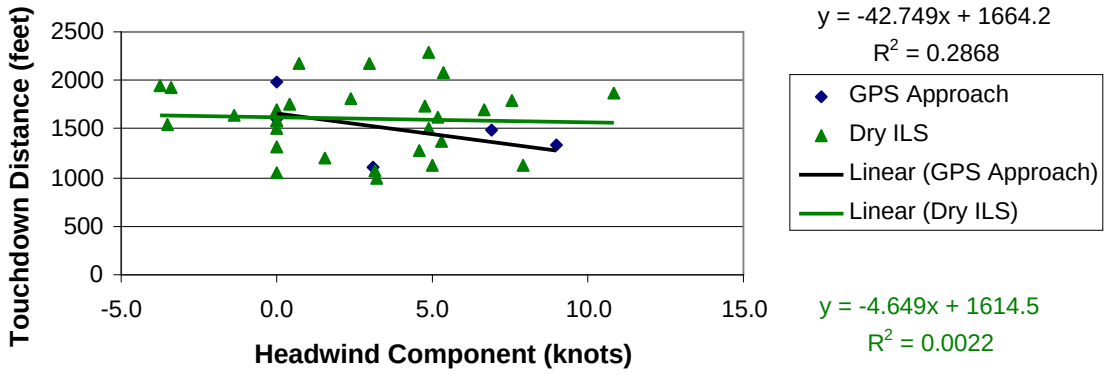


Figure F-48. ACY KC-10, Touchdown Distance From Runway Threshold Versus Headwind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

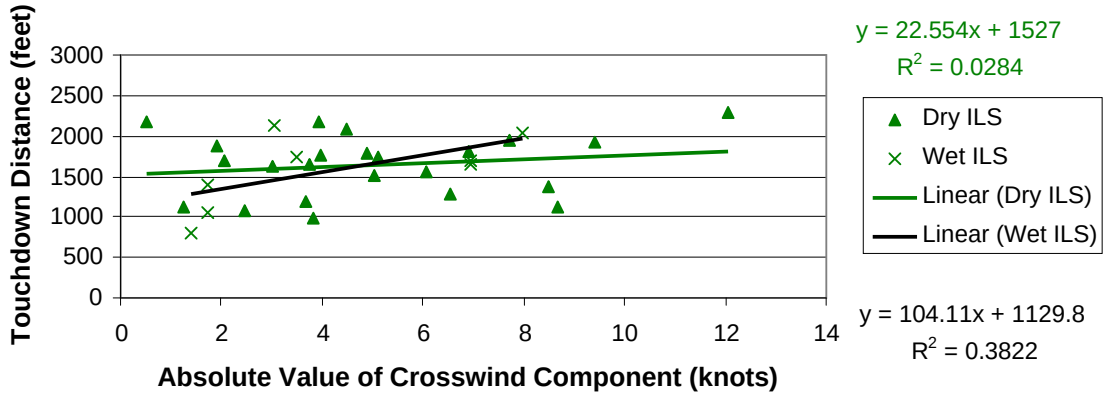


Figure F-49. ACY KC-10, Touchdown Distance From Runway Threshold Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/Wet ILS

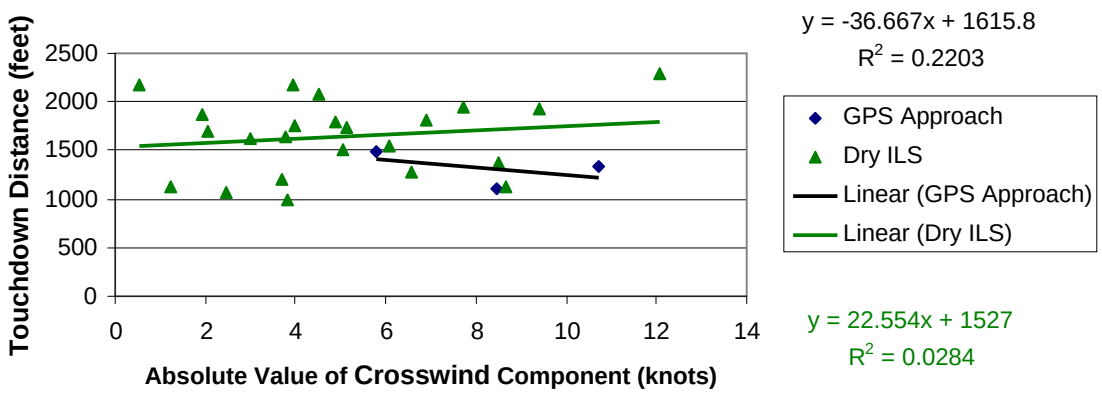


Figure F-50. ACY KC-10, Touchdown Distance From Runway Threshold Versus Absolute Value of Crosswind Component by Approach and Runway Conditions, Dry ILS/GPS Approach

F.6 SELECTED REGRESSION CURVES FOR LANDINGS AT CVG, BY AIRCRAFT TYPE. SELECTION CRITERIA, R^2 >0.1.

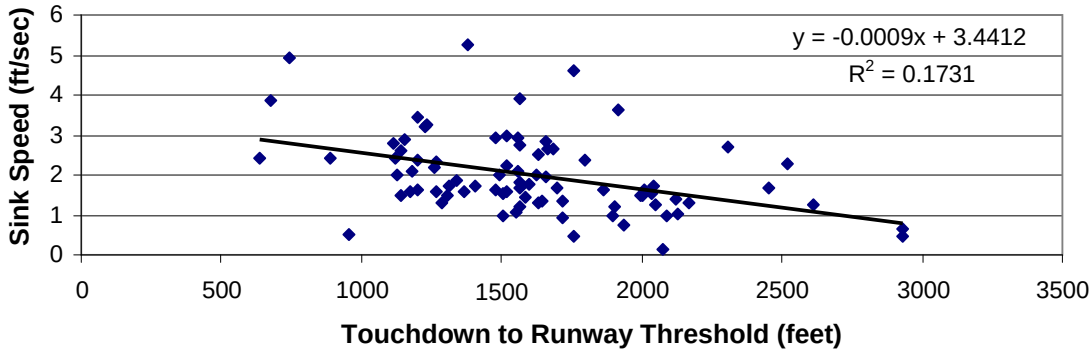


Figure F-51. Average Main Wheel Sink Speed Versus Touchdown to Runway Threshold Distance, Narrow-Body Aircraft, CVG Survey

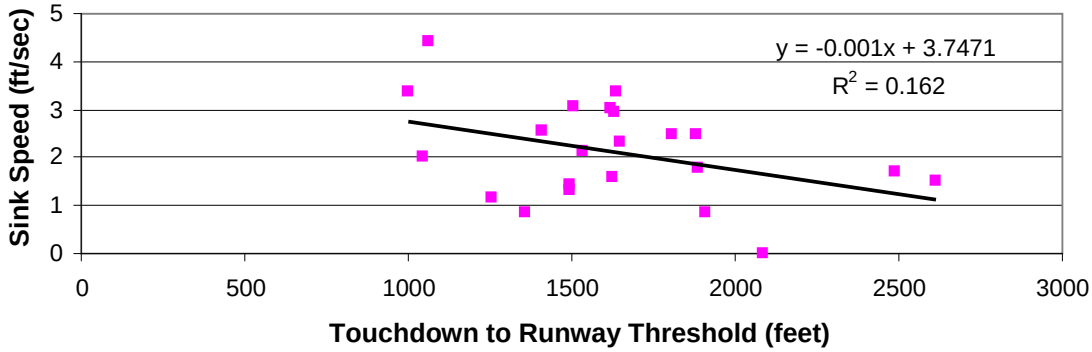


Figure F-52. Average Main Wheel Sink Speed Versus Touchdown to Runway Threshold Distance, Wide-Body Aircraft CVG Survey

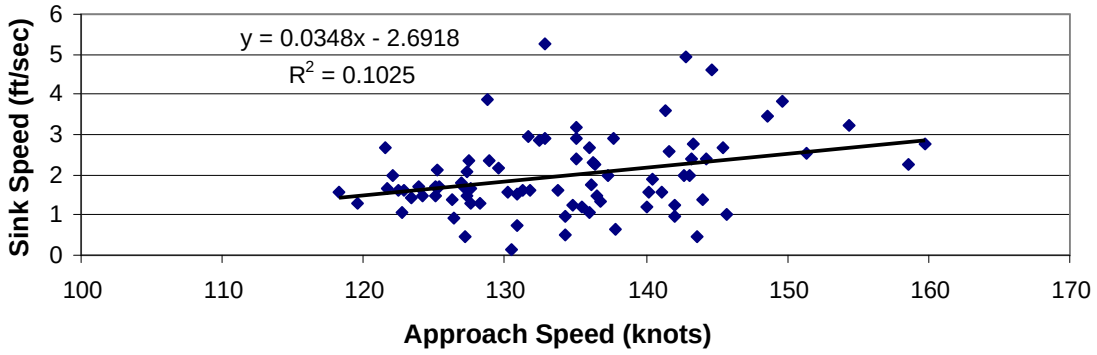


Figure F-53. Average Main Wheel Sink Speed Versus Approach Speed, Narrow-Body Aircraft, CVG Survey

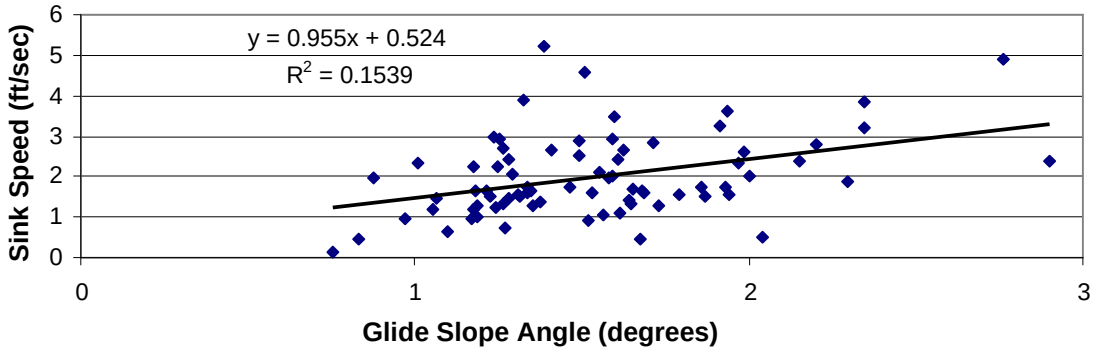


Figure F-54. Average Main Wheel Sink Speed Versus Geometric Glide Slope Angle, Narrow-Body Aircraft, CVG Survey

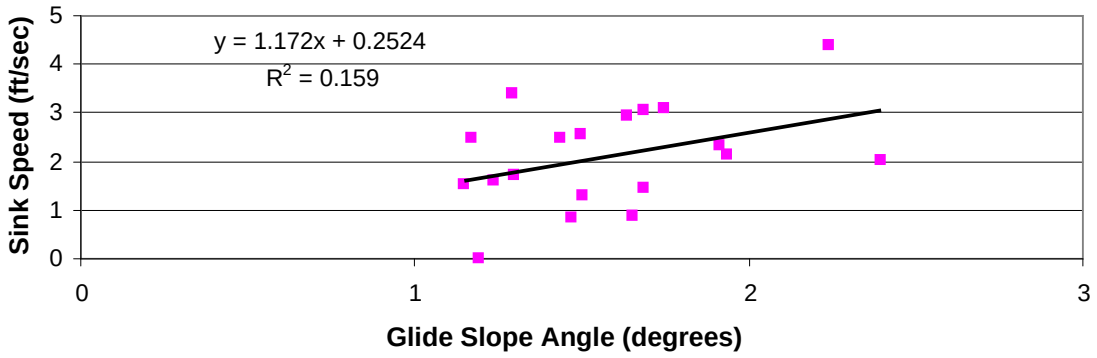


Figure F-55. Average Main Wheel Sink Speed Versus Geometric Glide Slope Angle, Wide-Body Aircraft, CVG Survey

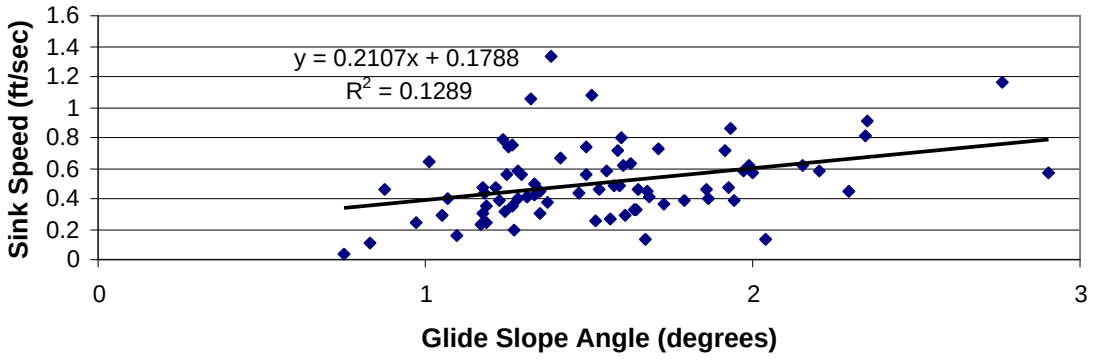


Figure F-56. Instantaneous Glide Slope Angle Versus Geometric Glide Slope Angle, Narrow-Body Aircraft, CVG Survey

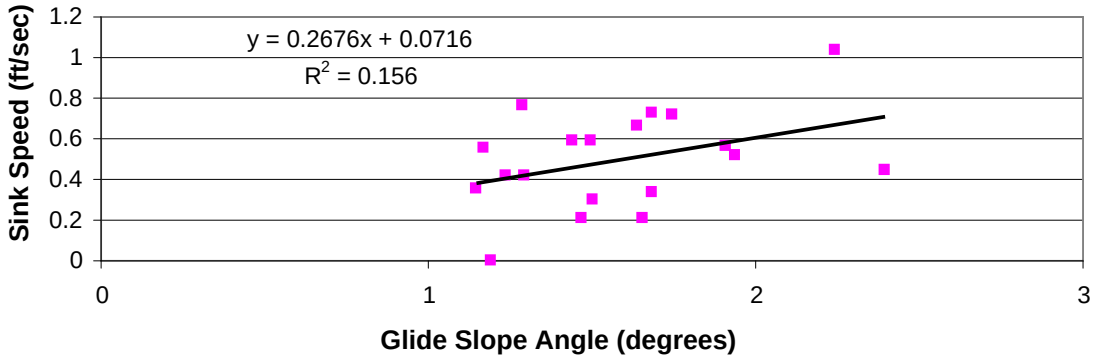


Figure F-57. Instantaneous Glide Slope Angle versus Geometric Glide Slope Angle, Wide-Body Aircraft, CVG Survey

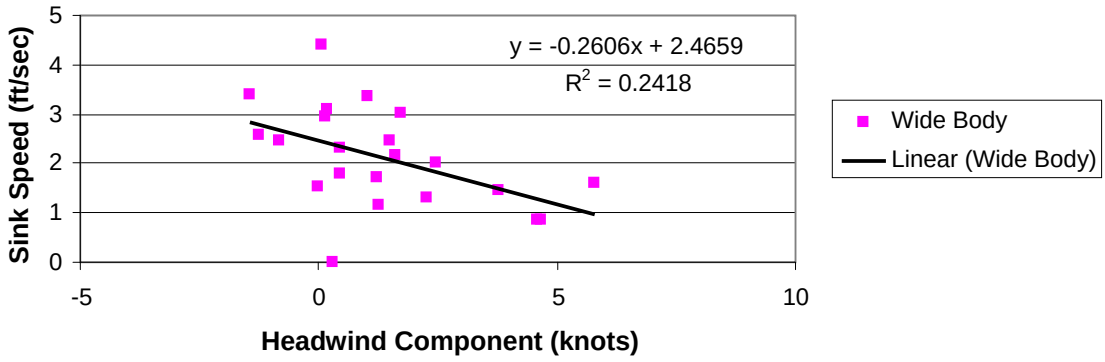


Figure F-58. Average Main Wheel Sink Speed Versus Headwind Component, Wide-Body Aircraft, CVG Survey

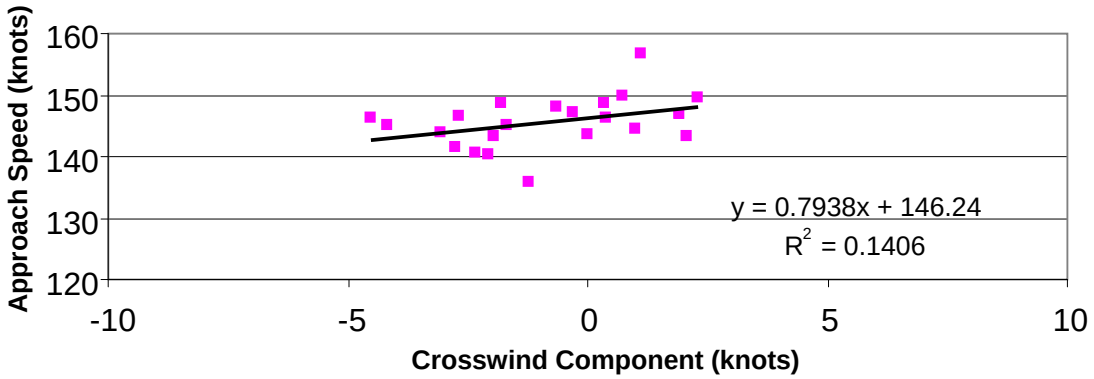


Figure F-59. Approach Speed Versus Crosswind Component, Wide-Body Aircraft, CVG Survey

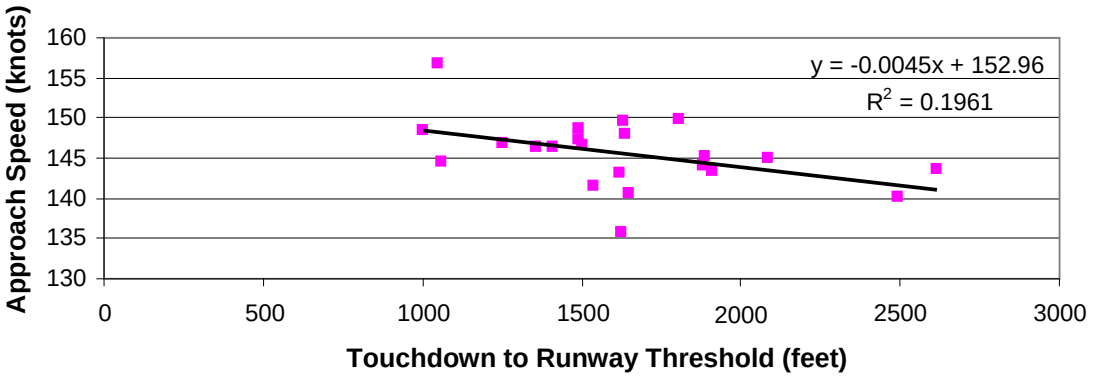


Figure F-60. Approach Speed Versus Touchdown to Runway Threshold Distance, Wide-Body Aircraft, CVG Survey

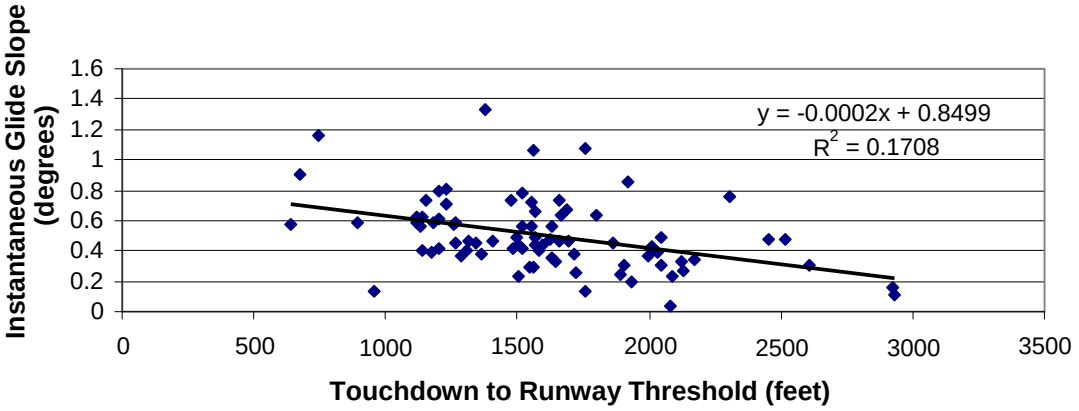


Figure F-61. Instantaneous Glide Slope Angle Versus Touchdown to Runway Threshold Distance, Narrow-Body Aircraft, CVG Survey

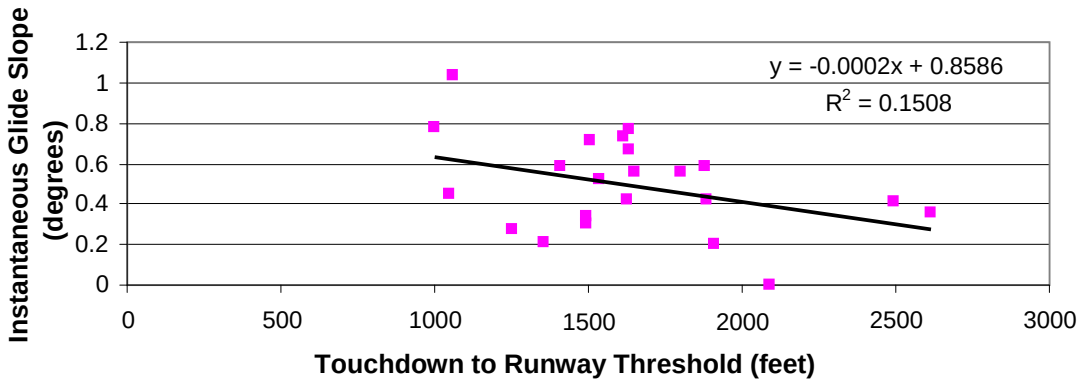


Figure F-62. Instantaneous Glide Slope Angle Versus Touchdown to Runway Threshold Distance, Wide-Body Aircraft, CVG Survey

F.7 SELECTED REGRESSION CURVES FOR LANDINGS AT CVG, BY AIRCRAFT MODEL SELECTION CRITERIA, R^2 >0.1.

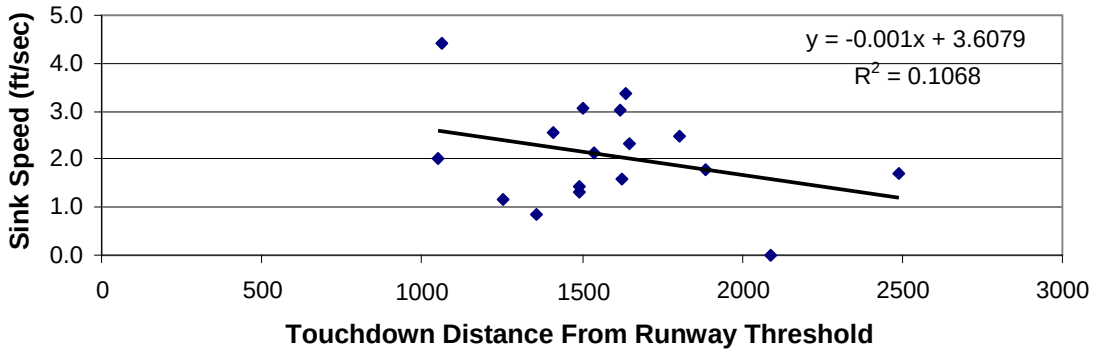


Figure F-63. Boeing 757 Average Sink Speed Versus Touchdown to Runway Threshold Distance, CVG Survey

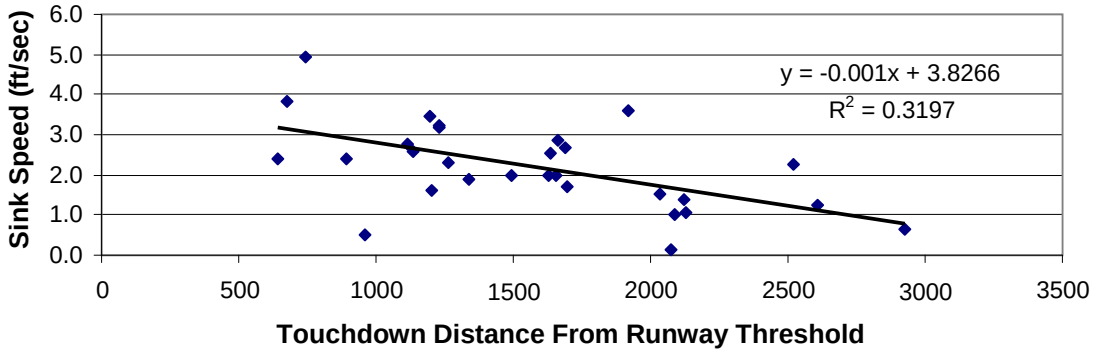


Figure F-64. McDonnell Douglas MD-90, Average Sink Speed Versus Touchdown to Runway Threshold Distance, CVG Survey

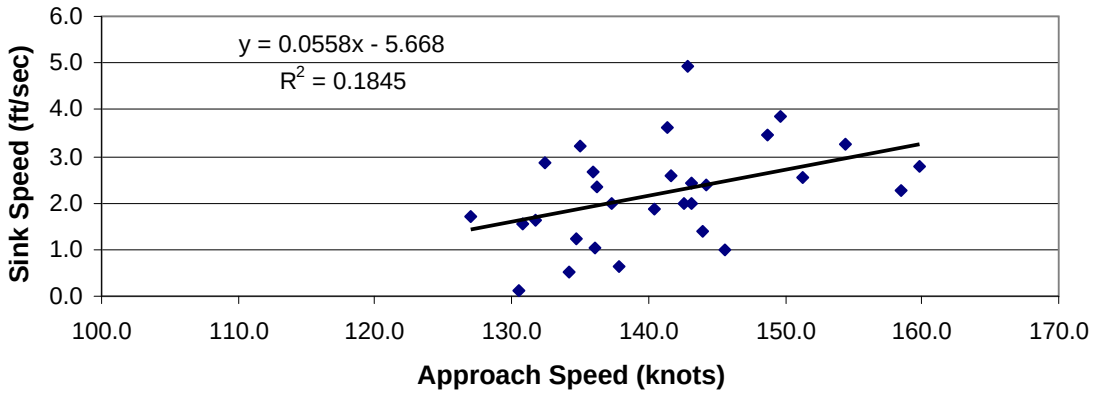


Figure F-65. McDonnell Douglas MD-90, Average Sink Speed Versus Approach Speed, CVG Survey

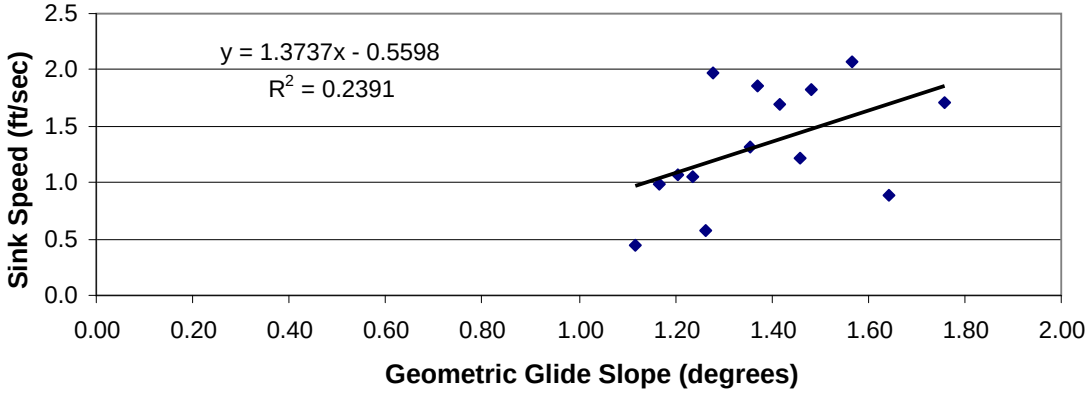


Figure F-66. Dornier 328 Jet, Average Sink Speed Versus Geometric Glide Slope Angle, CVG Survey

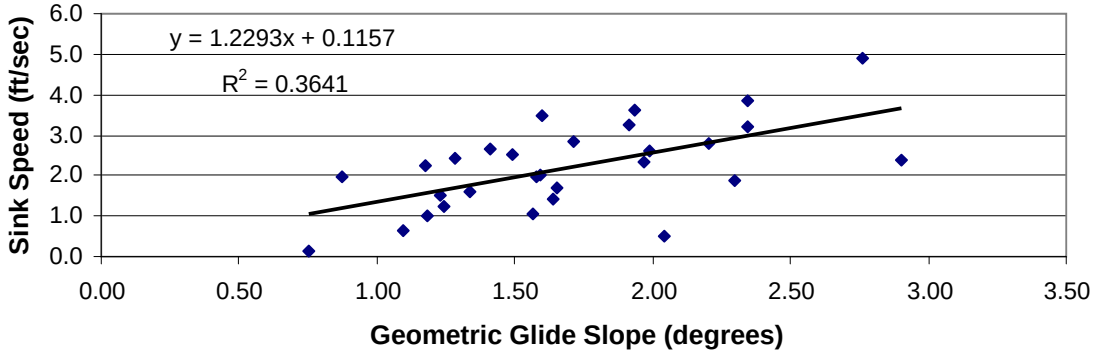


Figure F-67. McDonnell Douglas MD-90, Average Sink Speed Versus Geometric Glide Slope Angle, CVG Survey

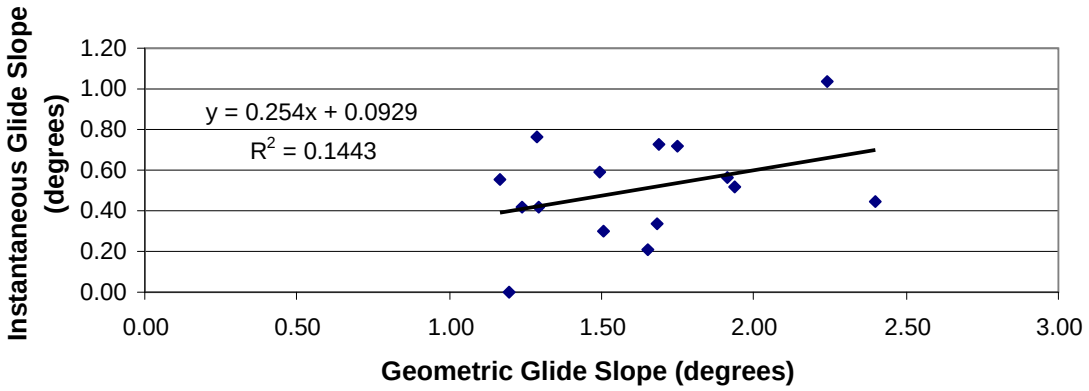


Figure F-68. Boeing 767, Instantaneous Glide Slope Angle Versus Geometric Glide Slope Angle, CVG Survey

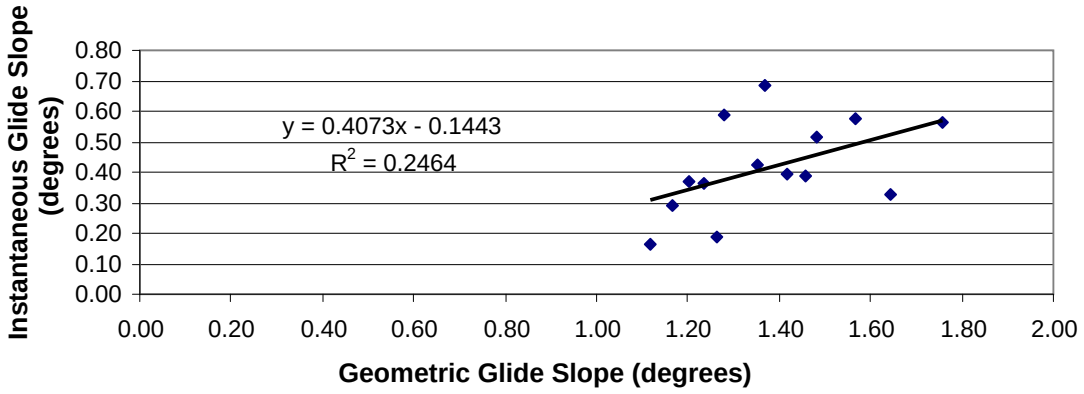


Figure F-69. Dornier 328 Jet, Instantaneous Glide Slope Angle Versus Geometric Glide Slope Angle, CVG Survey

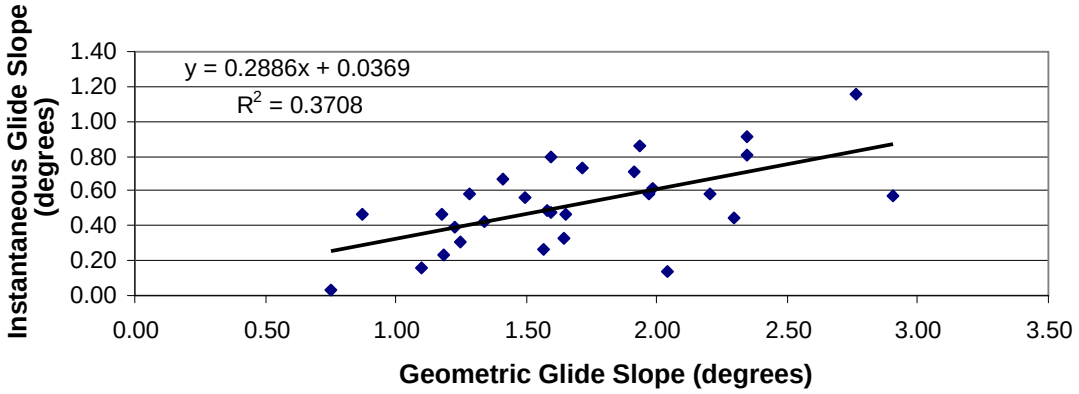


Figure F-70. McDonnell Douglas MD-90, Instantaneous Glide Slope Angle Versus Geometric Glide Slope Angle, CVG Survey

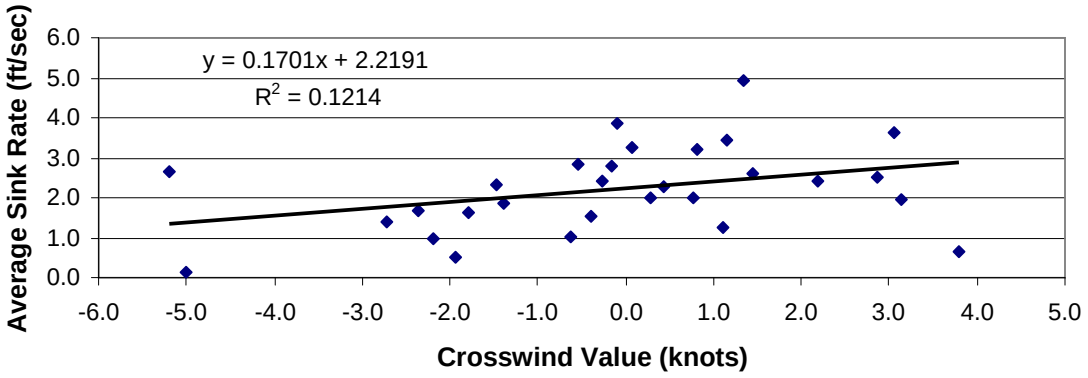


Figure F-71. McDonnell Douglas MD-90, Average Sink Speed Versus Crosswind Component, CVG Survey

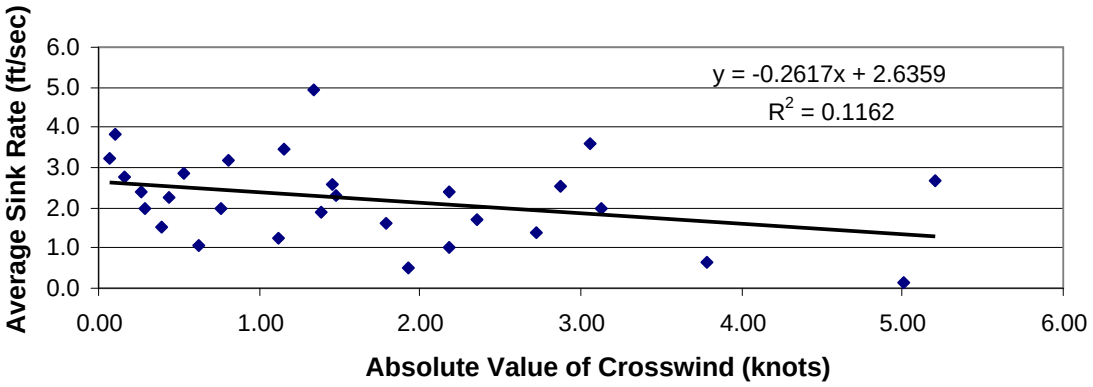


Figure F-72. McDonnell Douglas MD-90, Average Sink Speed Versus Absolute Value of Crosswind Component, CVG Survey

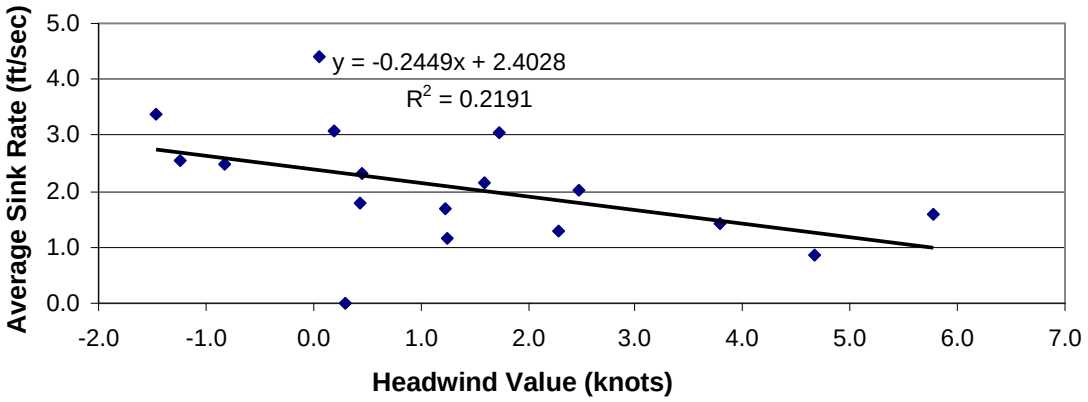


Figure F-73. Boeing 767, Average Sink Speed Versus Headwind Component, CVG Survey

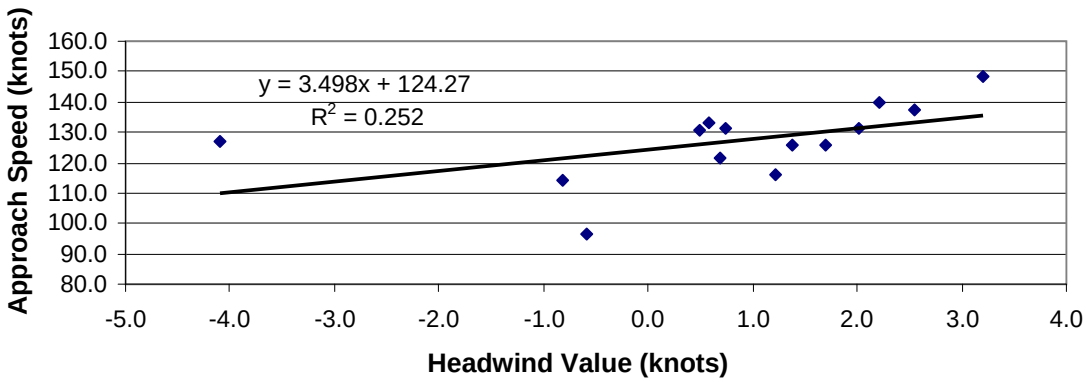


Figure F-74. Embraer Regional Jet, Average Sink Speed Versus Headwind Component, CVG Survey

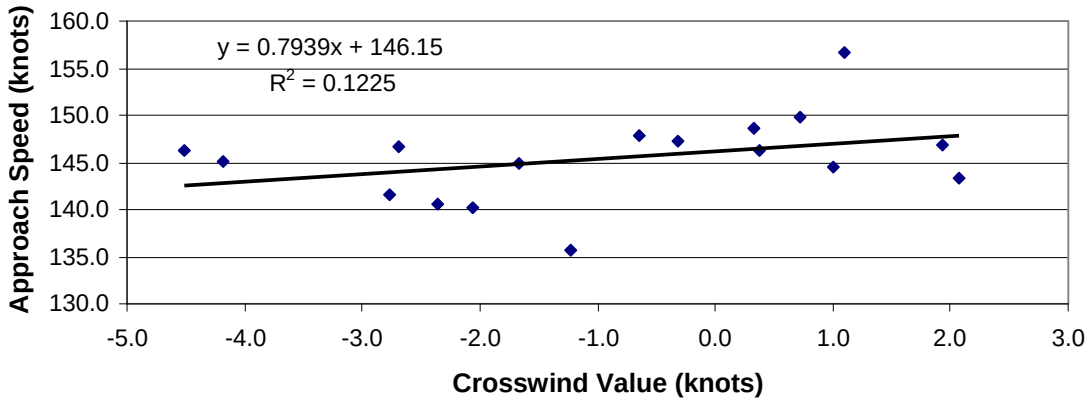


Figure F-75. Boeing 767, Approach Speed Versus Crosswind Component, CVG Survey

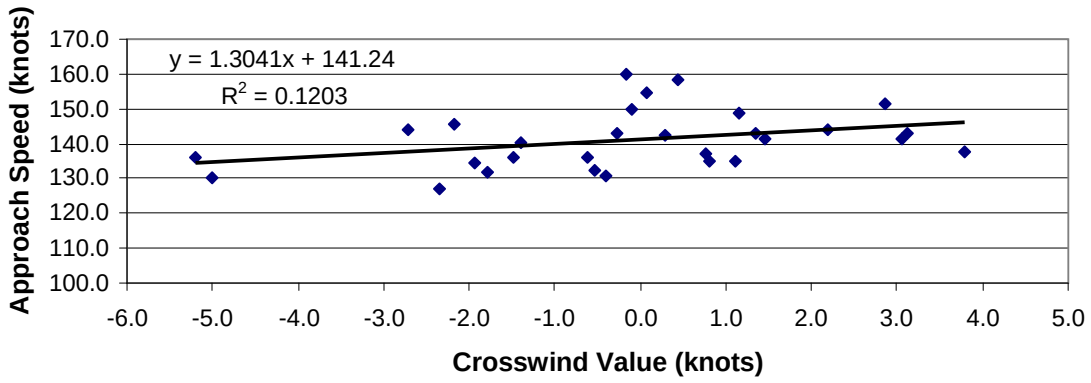


Figure F-76. McDonnell Douglas MD-90, Approach Speed Versus Crosswind Component, CVG Survey

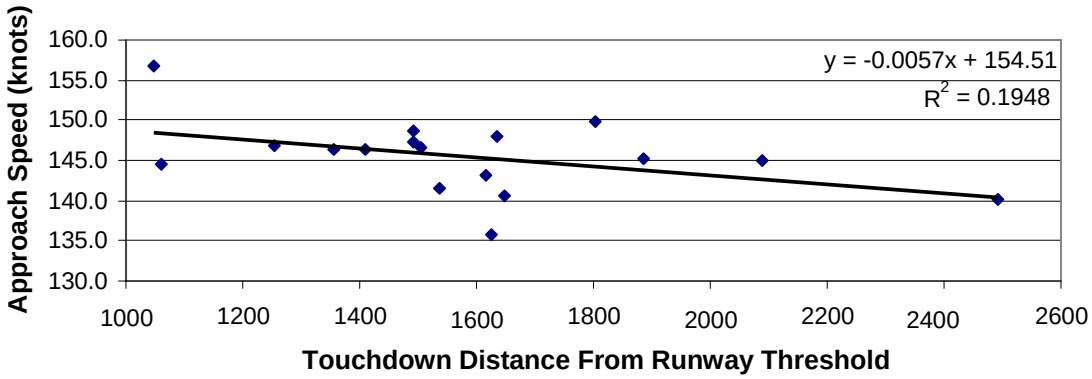


Figure F-77. Boeing 767 Approach Speed Versus Touchdown to Runway Threshold Distance, CVG Survey

APPENDIX G—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.*

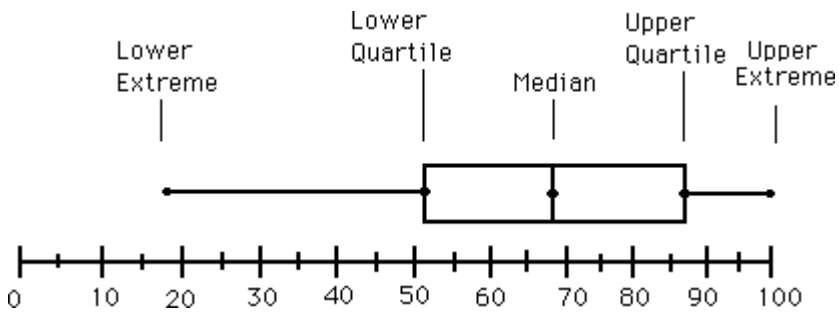
  87 is the upper quartile

  (*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 H—BOX-AND-WHISKER PLOTS, CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT AND ATLANTIC CITY INTERNATIONAL AIRPORT SURVEY RESULTS

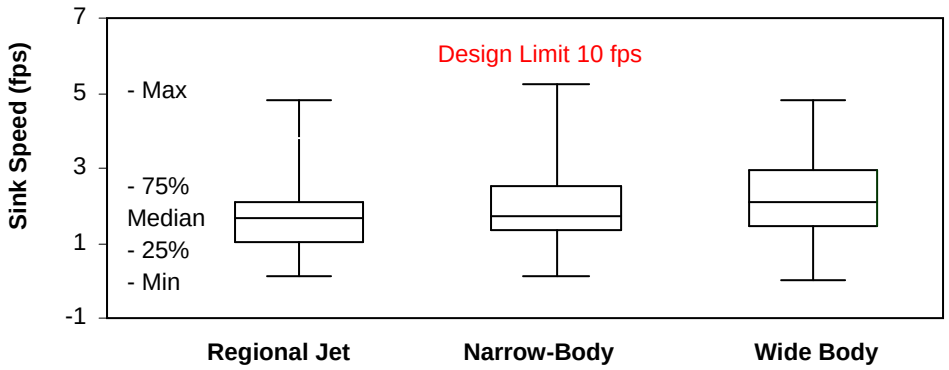


Figure H-1. Sink Speed Comparison by Aircraft Type, CVG Survey

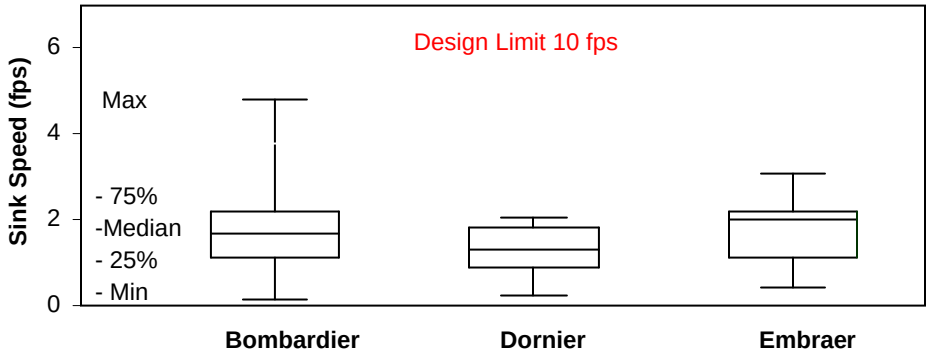


Figure H-2. Sink Speed Comparison, Cincinnati Regional Jets

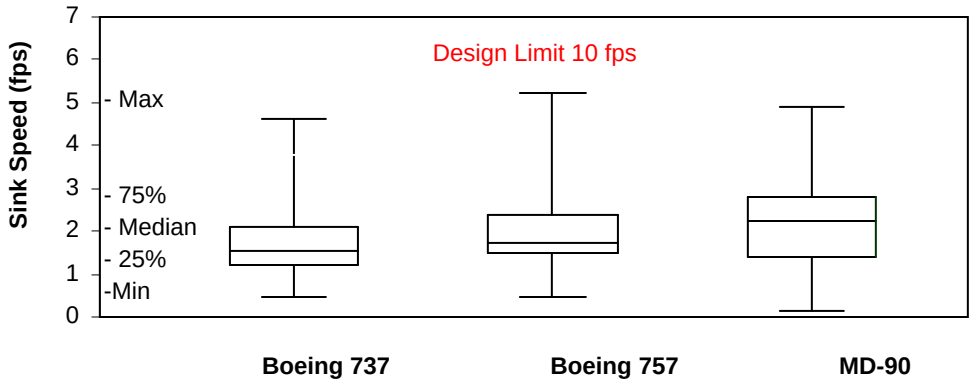


Figure H-3. Sink Speed Comparison, Narrow-Body Aircraft , CVG Survey

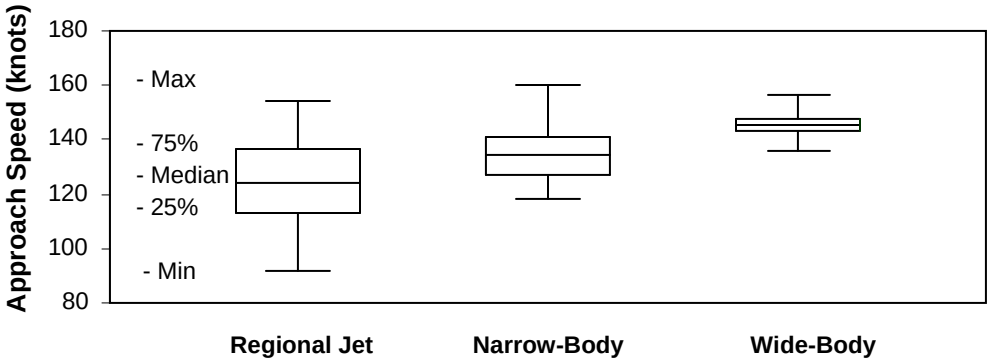


Figure H-4. Approach Speed Comparison by Aircraft Type, CVG Survey

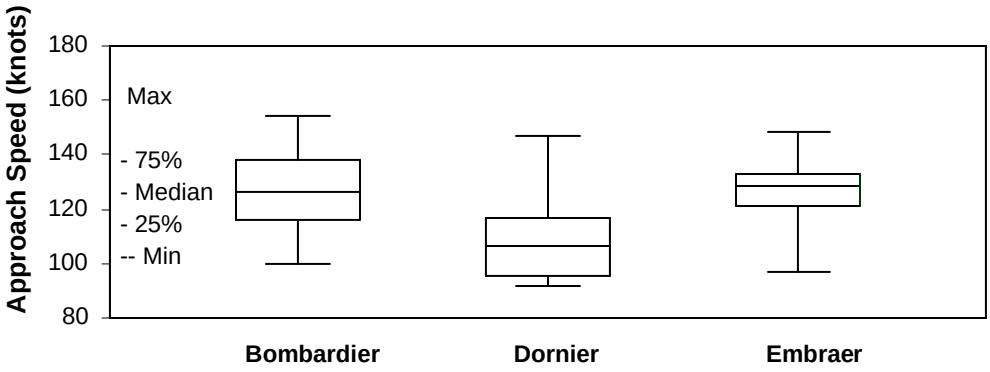


Figure H-5. Approach Speed Comparison, Cincinnati Regional Jets

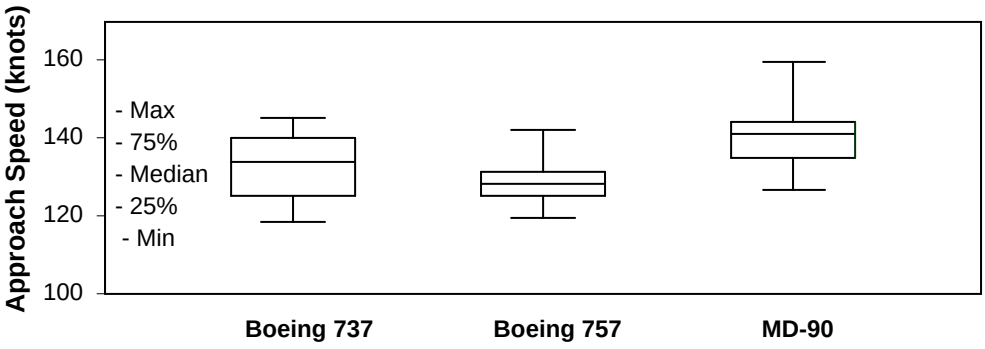


Figure H-6. Approach Speed Comparison, Narrow-Body Jets, CVG Survey

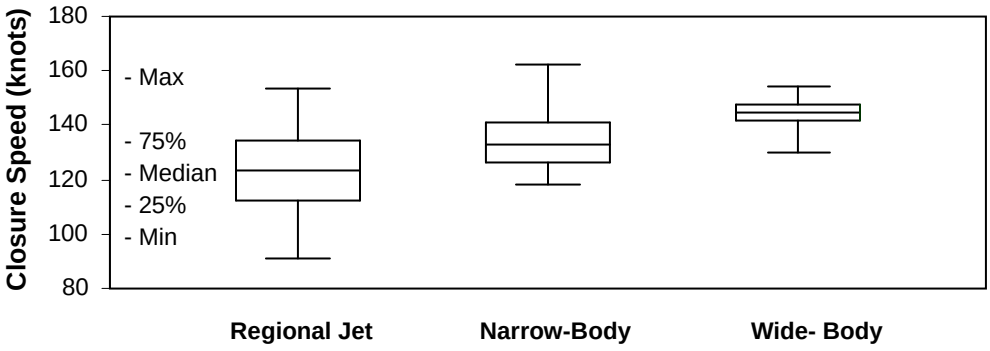


Figure H-7. Aircraft Closure Speed Comparison, CVG Survey

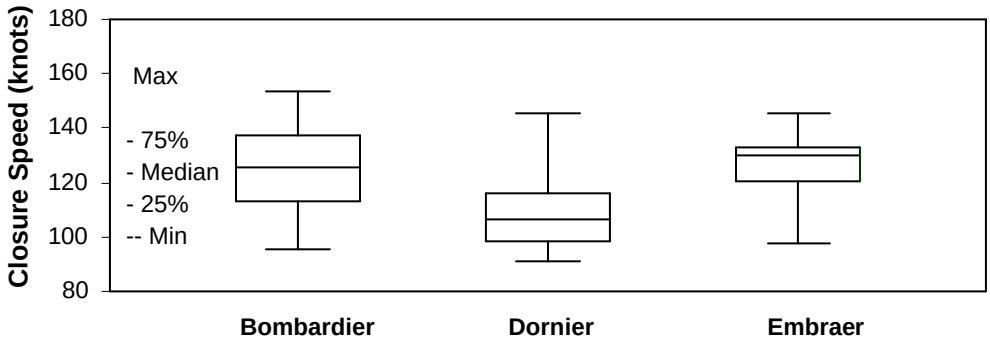


Figure H-8. Aircraft Closure Speed Comparison, Cincinnati Regional Jets

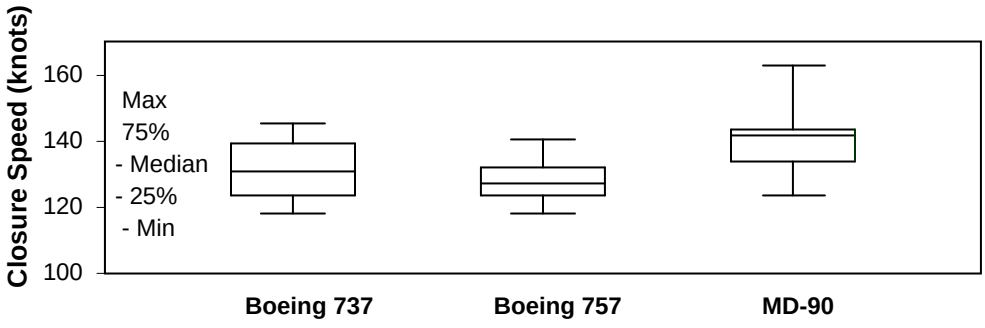


Figure H-9. Closure Speed Comparison, Narrow-Body Jets, CVG Survey

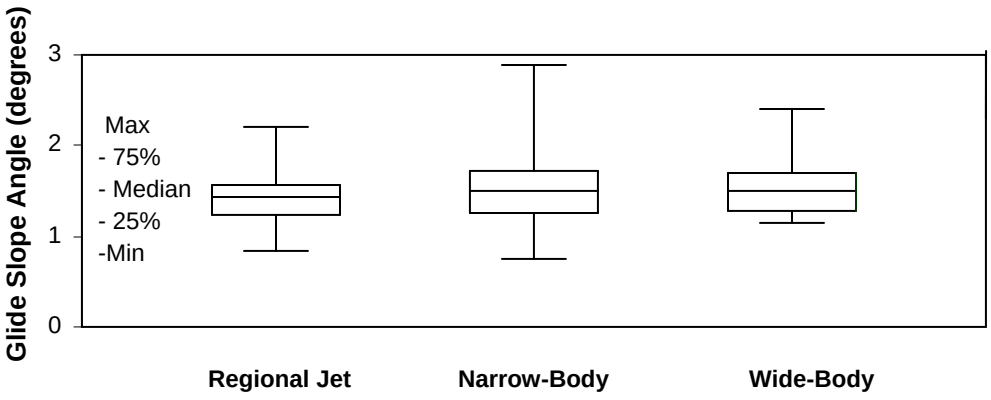


Figure H-10. Geometric Glide Slope Angle Comparison, CVG Survey

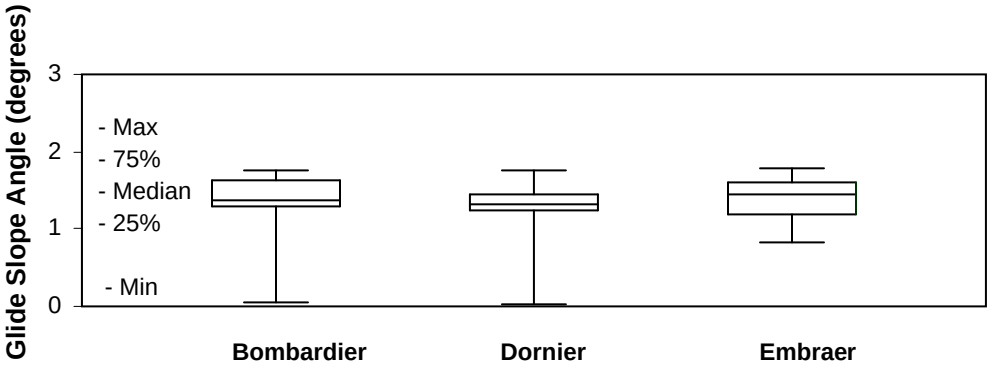


Figure H-11. Geometric Glide Slope Angle Comparison, Cincinnati Regional Jets

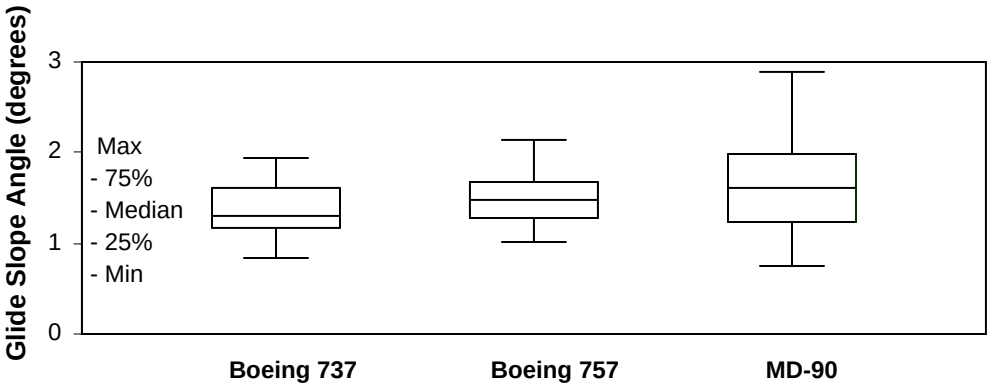


Figure H-12. Geometric Glide Slope Angle Comparison, Narrow-Body Aircraft, CVG Survey

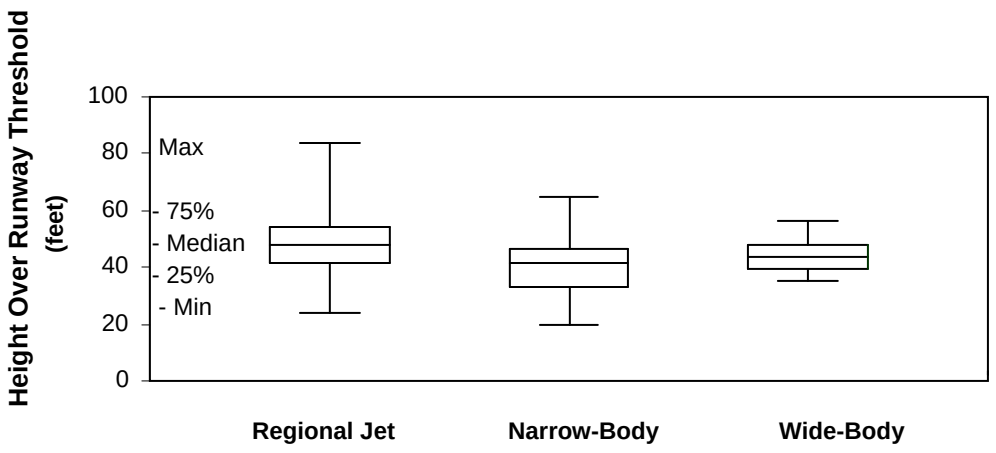


Figure H-13. Runway Threshold Crossing Height Comparison, CVG Survey

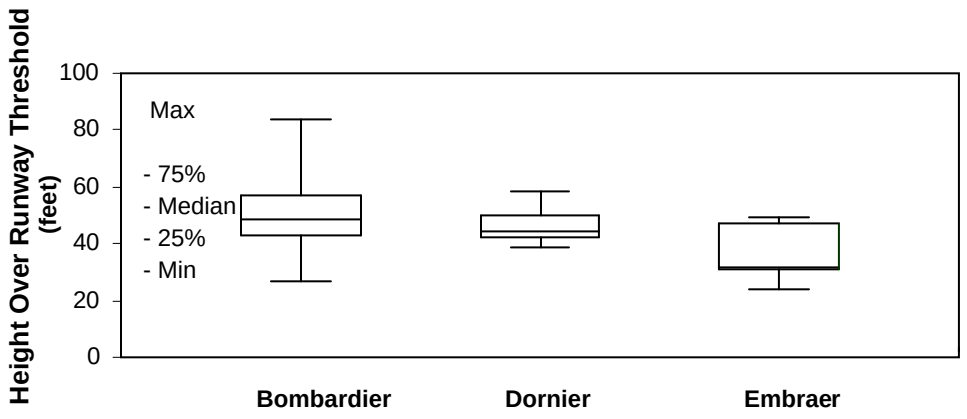


Figure H-14. Runway Threshold Crossing Height Comparison, Cincinnati Regional Jets

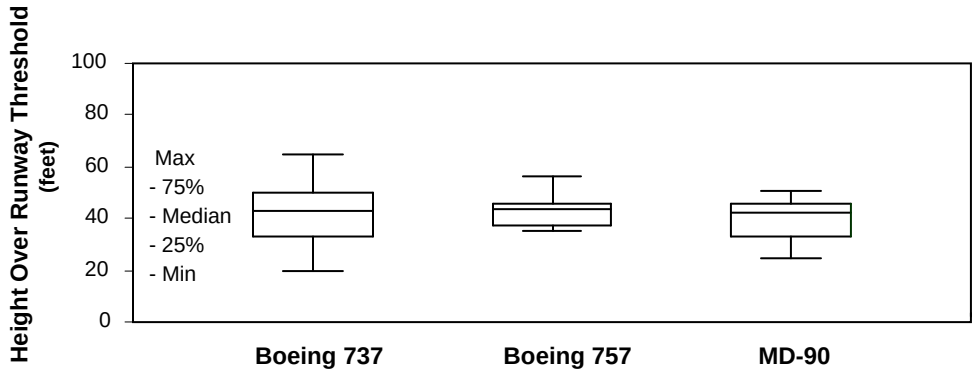


Figure H-15. Runway Threshold Crossing Height Comparison, Narrow-Body Aircraft, CVG Survey

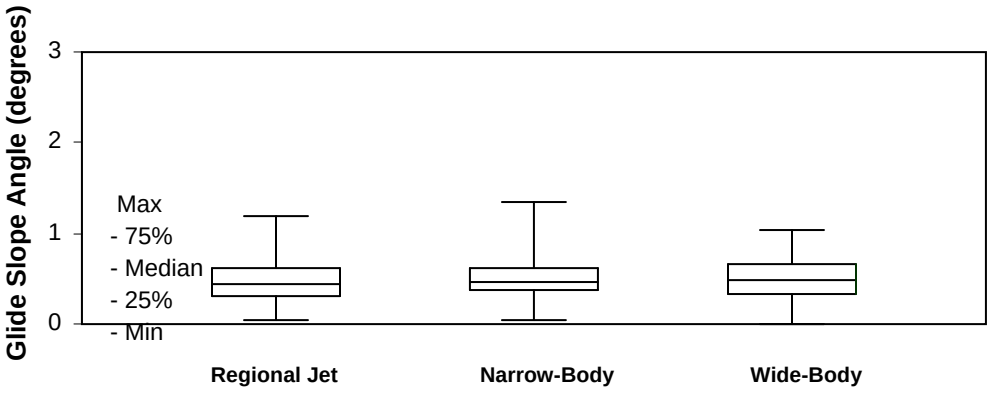


Figure H-16. Instantaneous Glide Slope Angle Comparison, CVG Survey

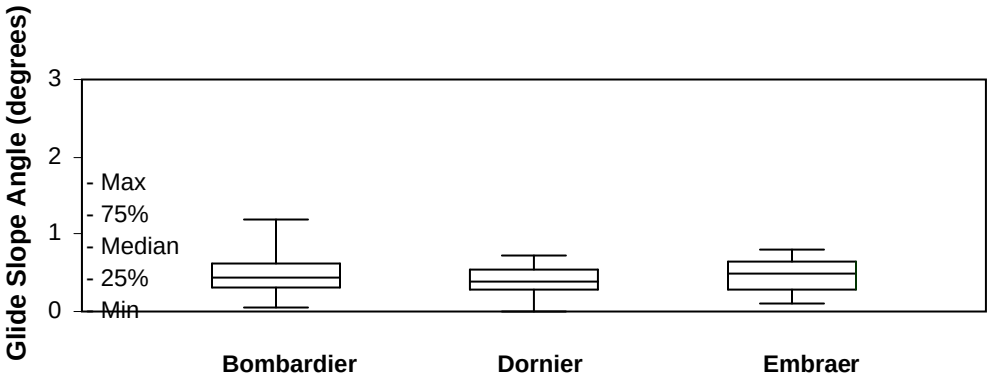


Figure H-17. Instantaneous Glide Slope Angle Comparison, Cincinnati Regional Jets

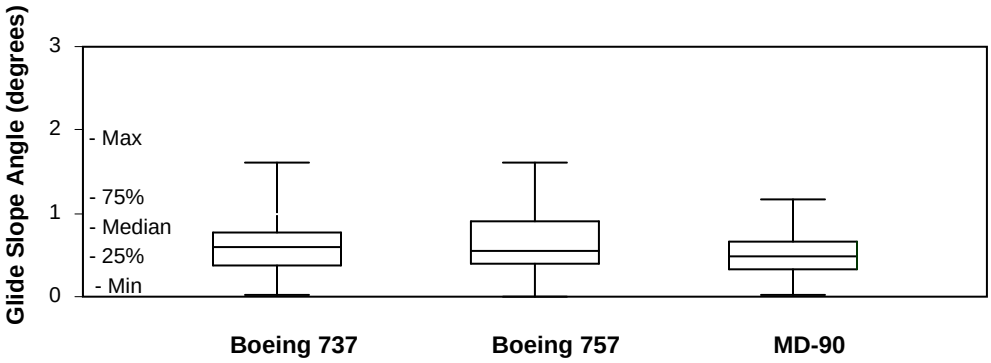


Figure H-18. Instantaneous Glide Slope Angle Comparison, Narrow-Body Jets CVG Survey

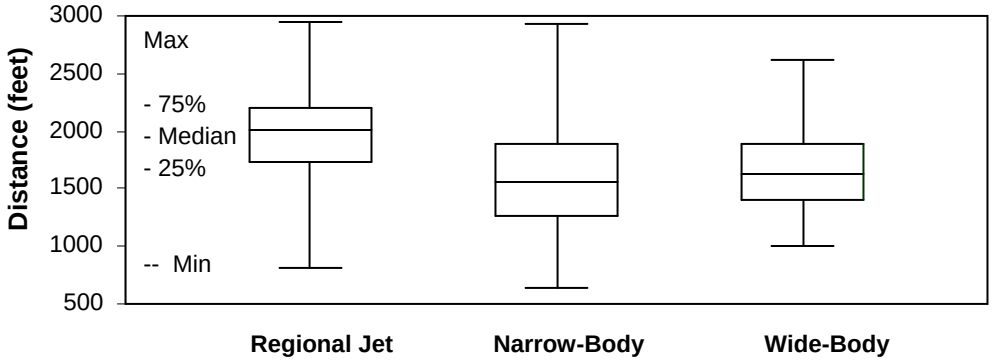


Figure H-19. Touchdown to Runway Threshold Distance Comparison, CVG Survey

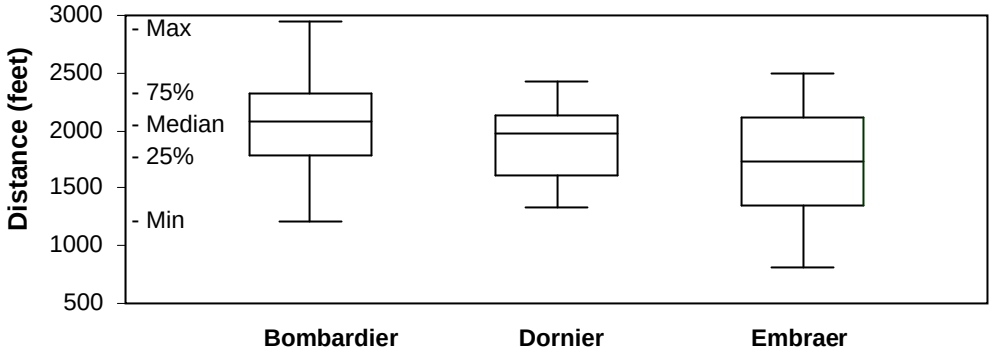


Figure H-20. Touchdown to Runway Threshold Distance Comparison, Cincinnati Regional Jets

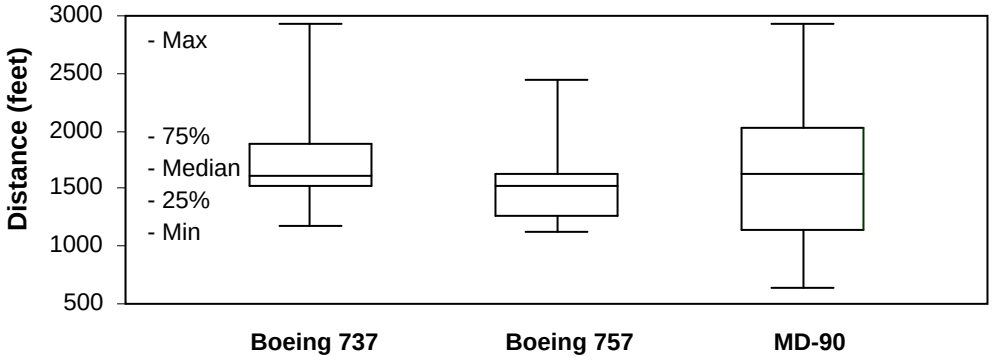


Figure H-21. Touchdown to Runway Threshold Distance Comparison, Narrow-Body Aircraft, CVG Survey

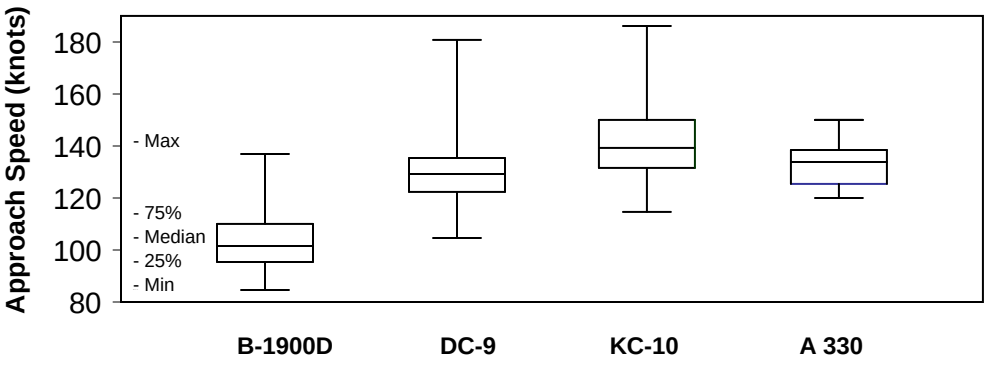


Figure H-22. Approach Speed Comparison, ACY Landings

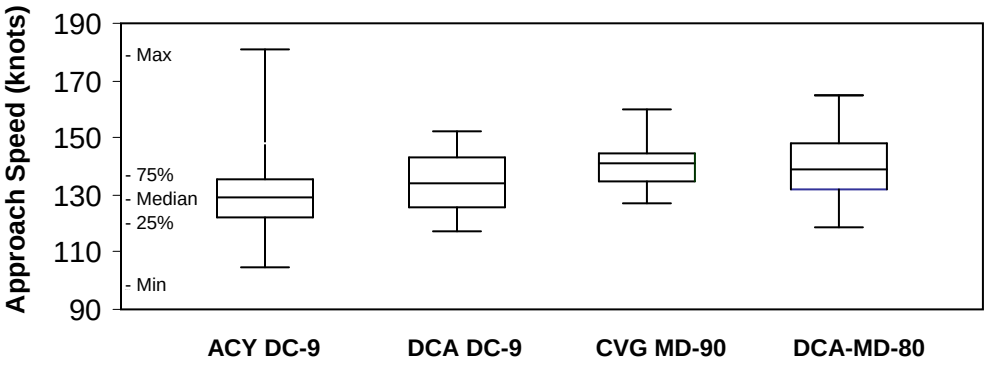


Figure H-23. Approach Speed Comparison, McDonnell Douglas Narrow-Body Jets

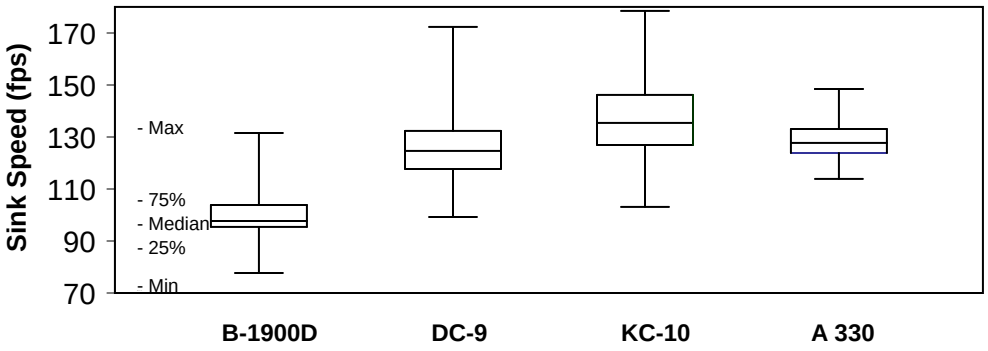


Figure H-24. Closure Speed Comparison, ACY Landings

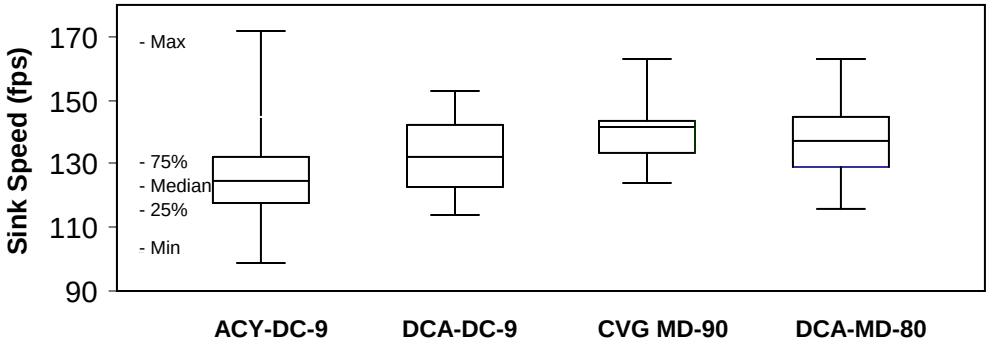


Figure H-25. Closure Speed Comparison, McDonnell Douglas Narrow-Body Jets

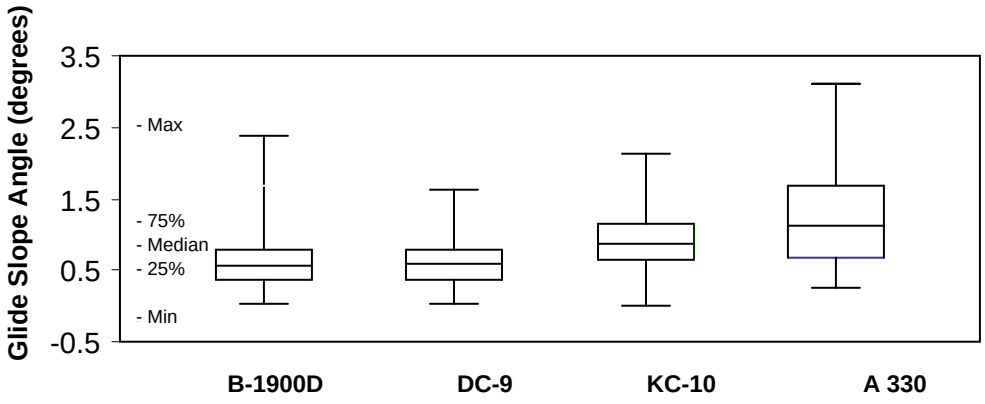


Figure H-26. Instantaneous Glide Slope Angle Comparison, ACY Landings

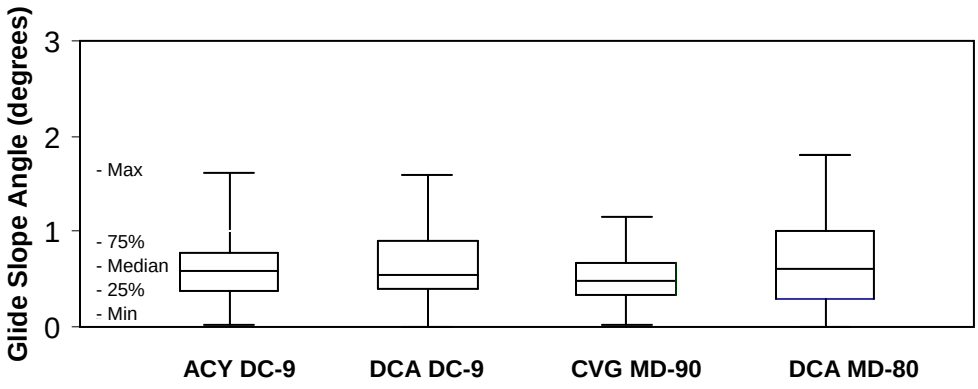


Figure H-27. Instantaneous Glide Slope Angle Comparison, McDonnell Douglas Narrow-Body Jets

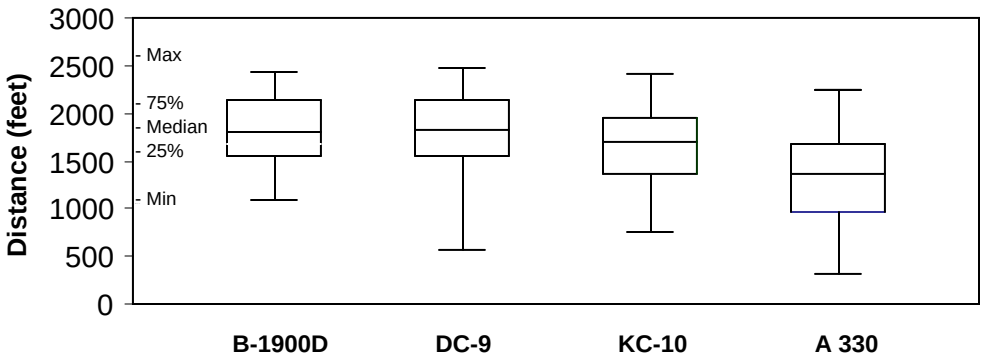


Figure H-28. Touchdown to Runway Threshold Distance Comparison, ACY Landings

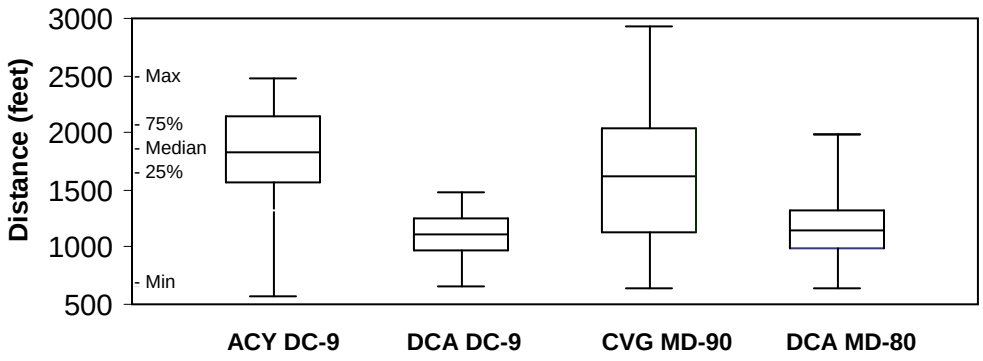


Figure H-29. Touchdown to Runway Threshold Distance Comparison, McDonnell Douglas Narrow-Body Jets

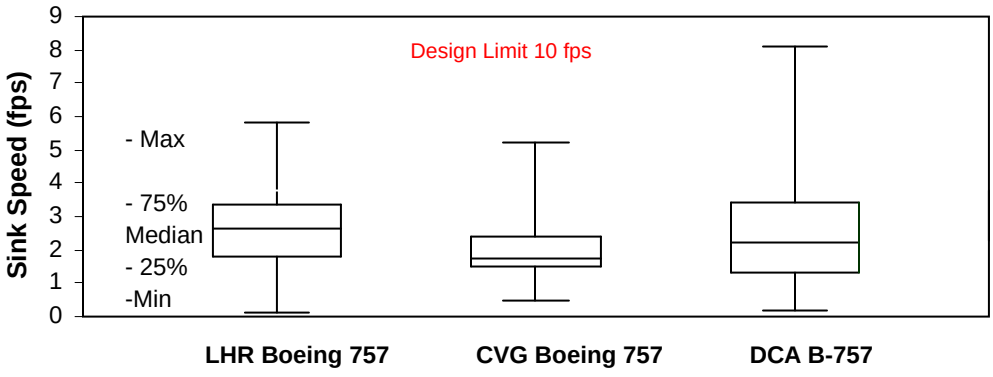


Figure H-30. Sink Speed Comparison, Boeing 757 Aircraft

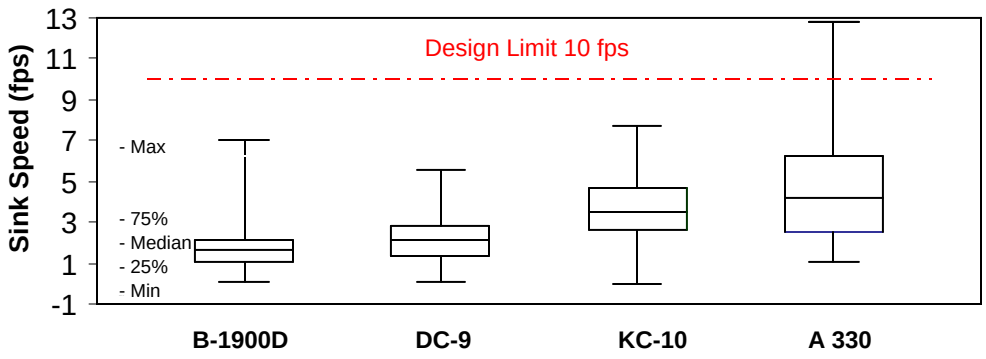


Figure H-31. Sink Speed Comparison, ACY Landings

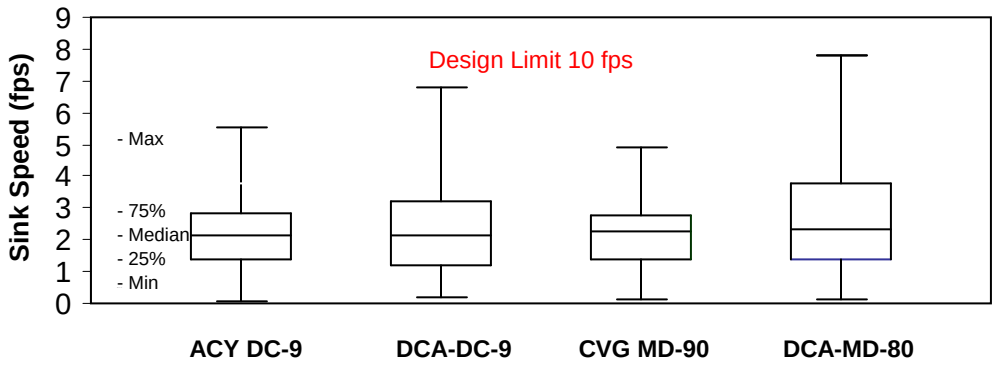


Figure H-32. Sink Speed Comparison, McDonnell Douglas Narrow-Body Jets

APPENDIX I—CORRELATION COMPARISON PLOTS FOR CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT LANDINGS BY AIRCRAFT MODEL AND FOR ATLANTIC CITY INTERNATIONAL AIRPORT LANDINGS BY APPROACH TYPE

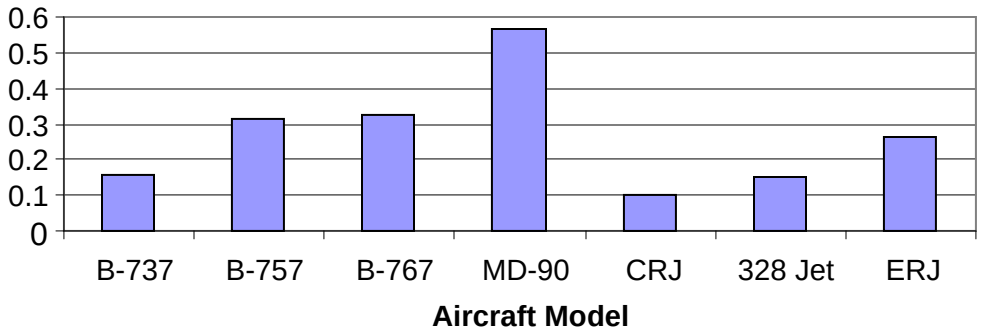


Figure I-1. Correlation Coefficient r, Average Sink Speed Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey

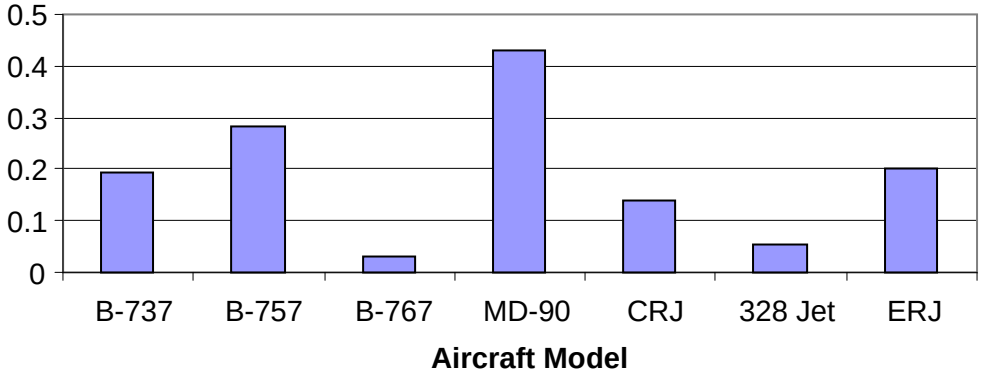


Figure I-2. Correlation Coefficient r, Average Sink Speed Versus Approach Speed, CVG Landing Parameter Survey

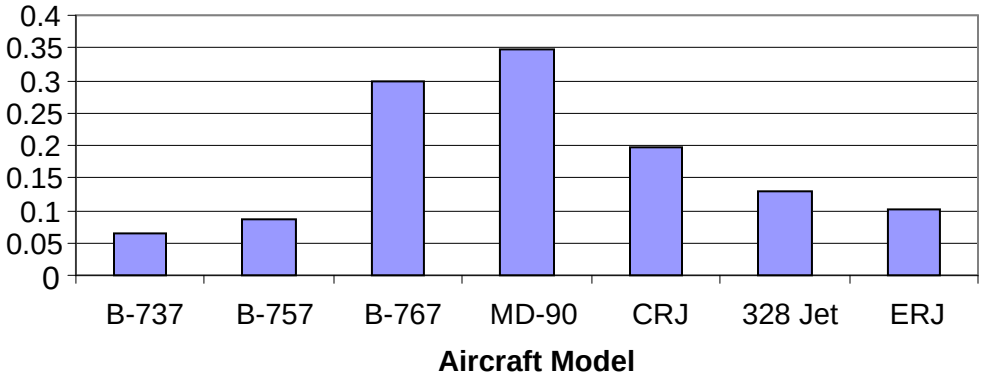


Figure I-3. Correlation Coefficient r, Average Sink Speed Versus Crosswind Component, CVG Landing Parameter Survey

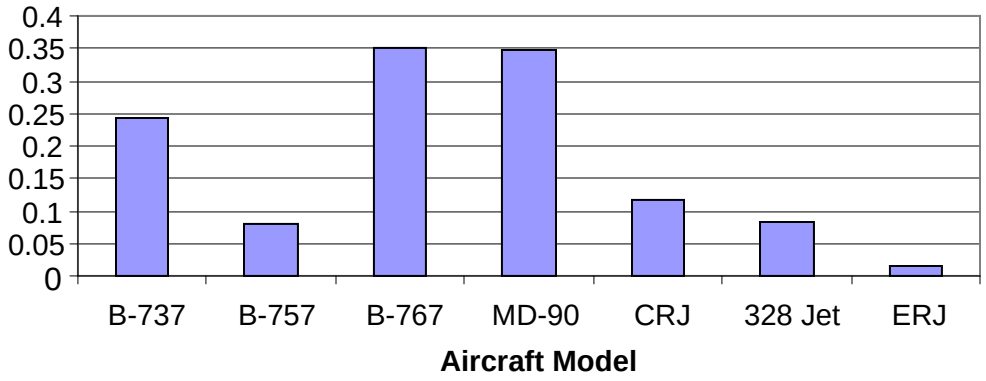


Figure I-4. Correlation Coefficient r, Approach Speed Versus Crosswind Component, CVG Landing Parameter Survey

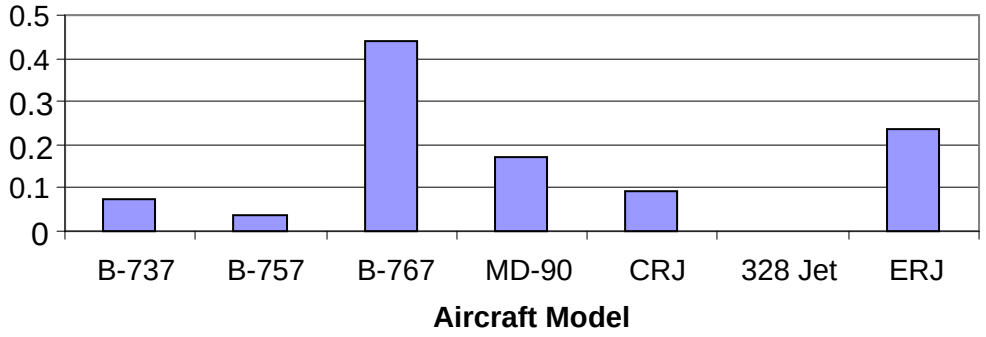


Figure I-5. Correlation Coefficient r, Approach Speed Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey

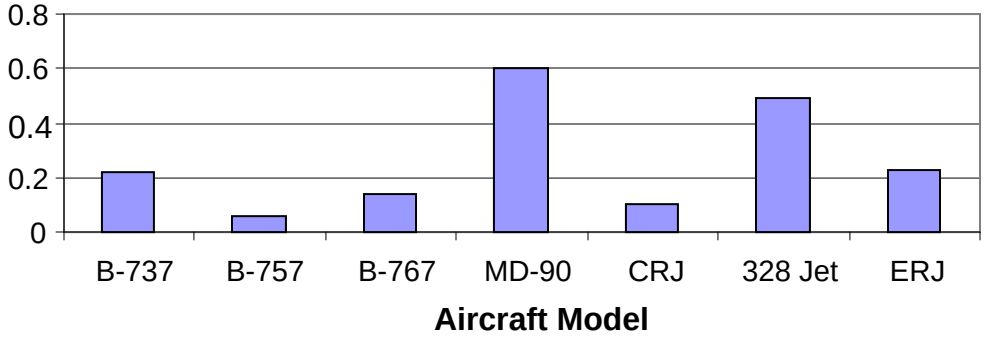


Figure I-6. Correlation Coefficient r, Average Sink Speed Versus Geometric Glide Slope Angle, CVG Landing Parameter Survey

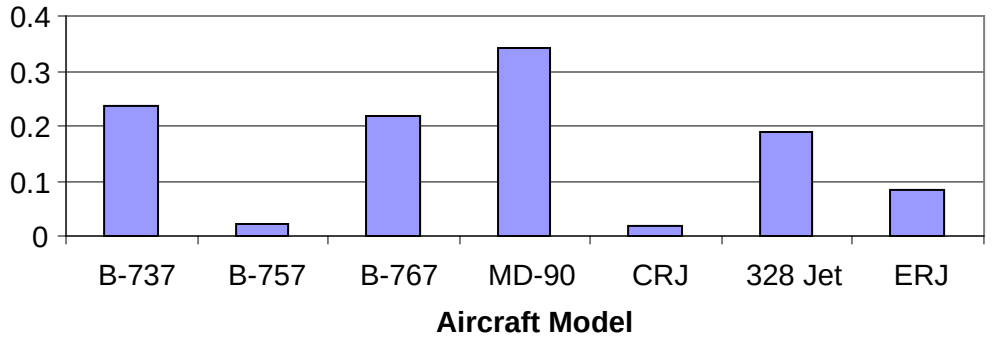


Figure I-7. Correlation Coefficient r, Average Sink Speed Versus Absolute Value of Crosswind Component, CVG Landing Parameter Survey

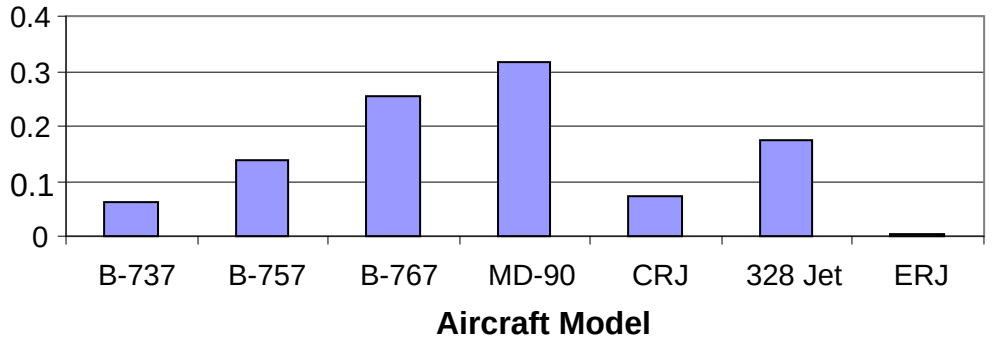


Figure I-8. Correlation Coefficient r, Approach Speed Versus Absolute Value of Crosswind Component, CVG Landing Parameter Survey

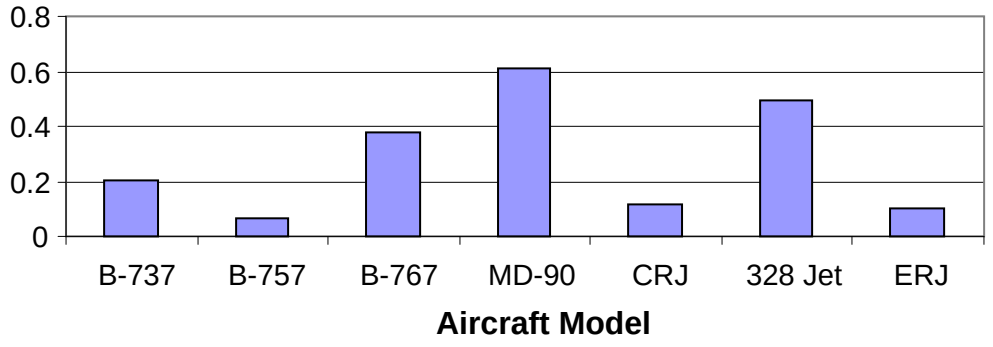


Figure I-9. Correlation Coefficient r, Instantaneous Glide Slope Angle Versus Geometric Glide Slope Angle, CVG Landing Parameter Survey

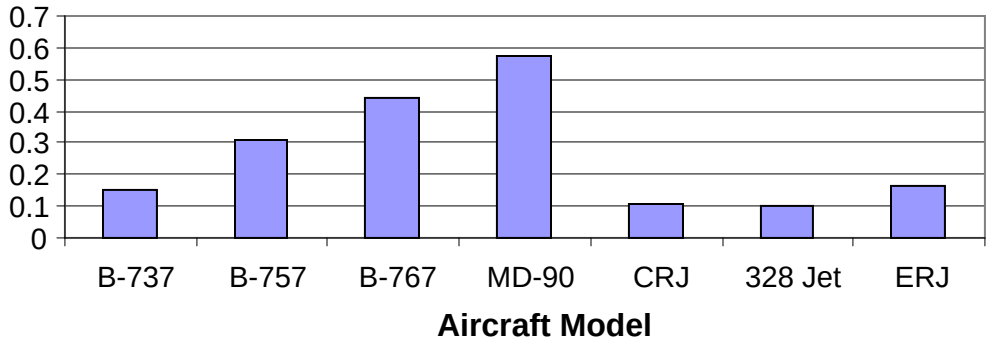


Figure I-10. Correlation Coefficient r, Instantaneous Glide Slope Angle Versus Touchdown Distance to Runway Threshold, CVG Landing Parameter Survey

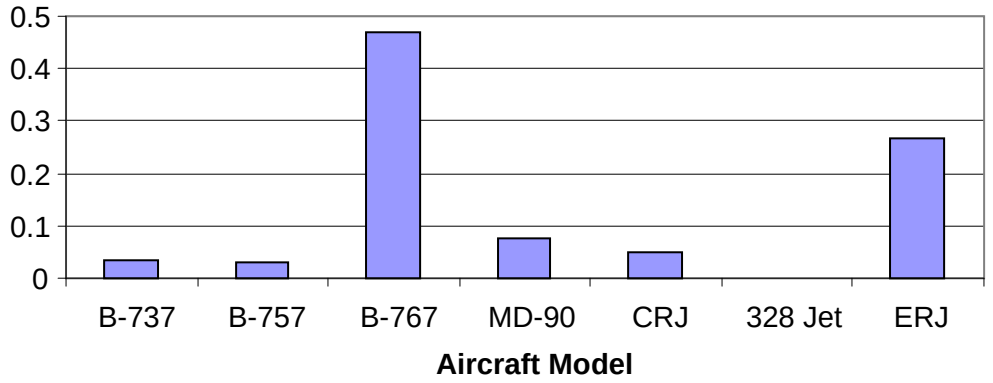


Figure I-11. Correlation Coefficient r, Average Sink Speed Versus Headwind Component, CVG Landing Parameter Survey

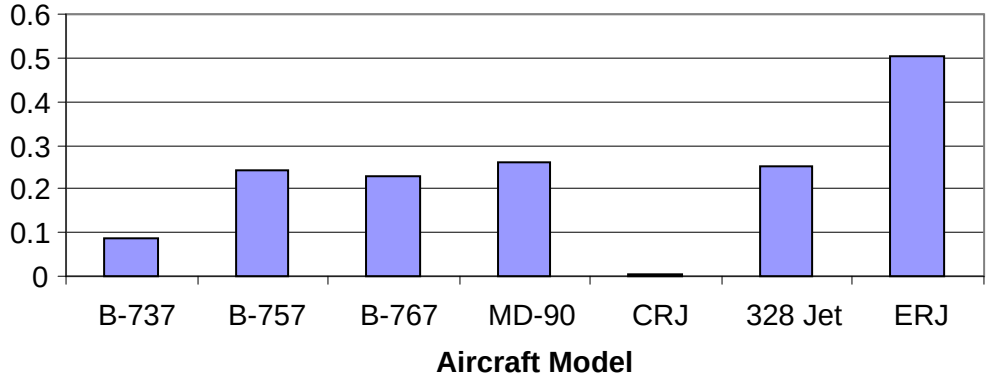


Figure I-12. Correlation Coefficient r, Approach Speed Versus Headwind Component, CVG Landing Parameter Survey

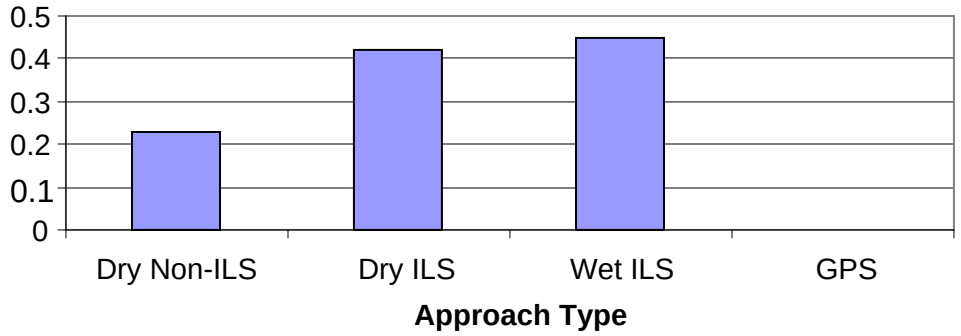


Figure I-13. ACY, Average Sink Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, KC-10 Landings

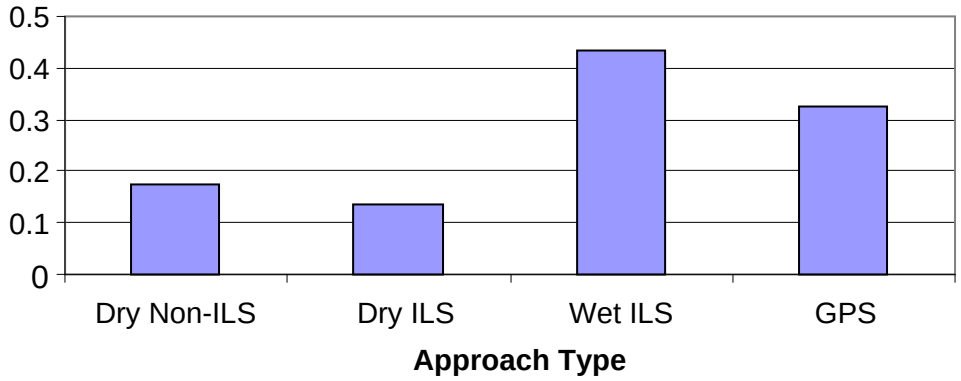


Figure I-14. ACY, Average Sink Speed Versus Closure Speed, Correlation Coefficient r, KC-10 Landings

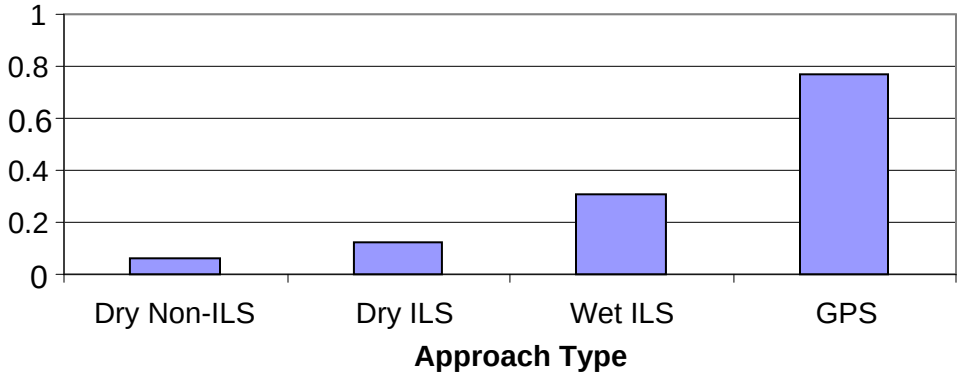


Figure I-15. ACY, Average Sink Speed Versus Approach Speed, Correlation Coefficient r, KC-10 Landings

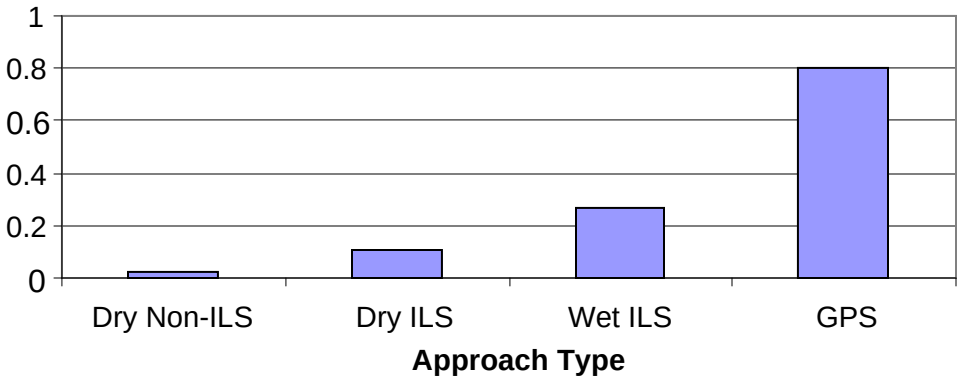


Figure I-16. ACY, Average Sink Speed Versus Headwind Component, Correlation Coefficient r, KC-10 Landings

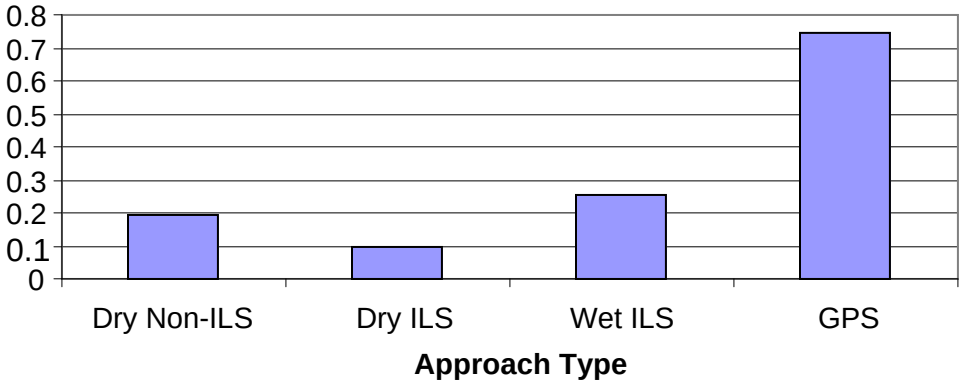


Figure I-17. ACY, Average Sink Speed Versus Crosswind Component, Correlation Coefficient r, KC-10 Landings

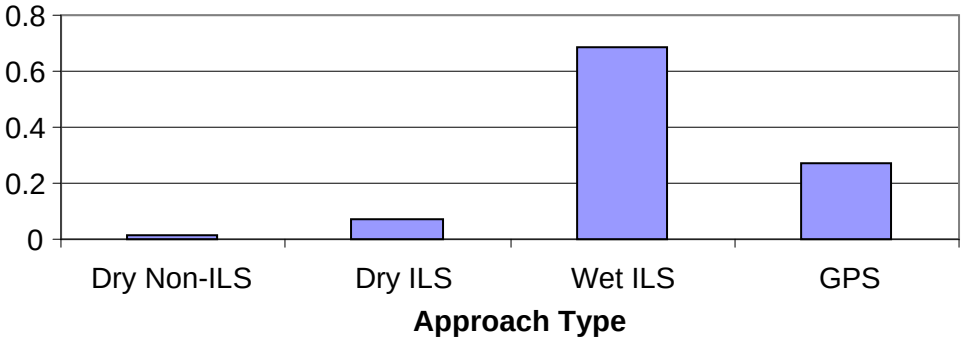


Figure I-18. ACY, Average Sink Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, KC-10 Landings

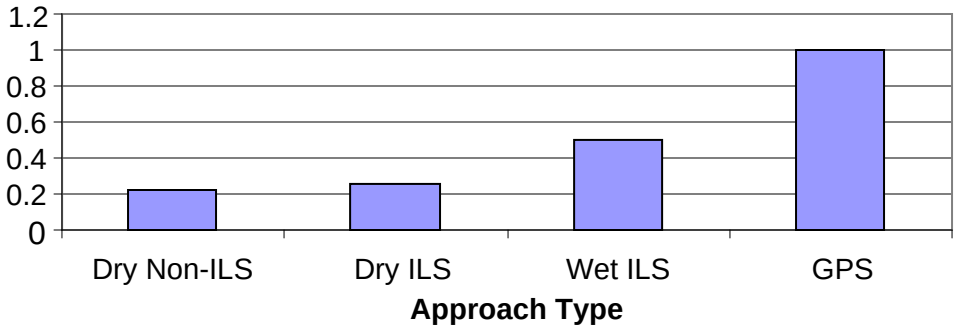


Figure I-19. ACY, Approach Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, KC-10 Landings

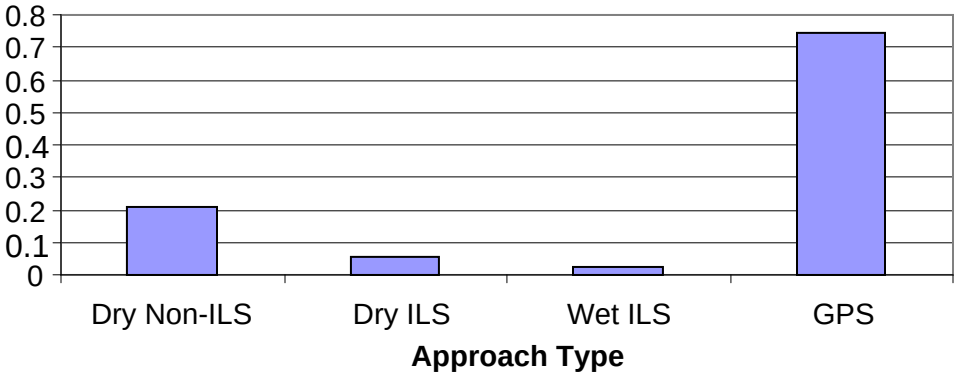


Figure I-20. ACY, Approach Speed Versus Headwind Component, Correlation Coefficient r, KC-10 Landings

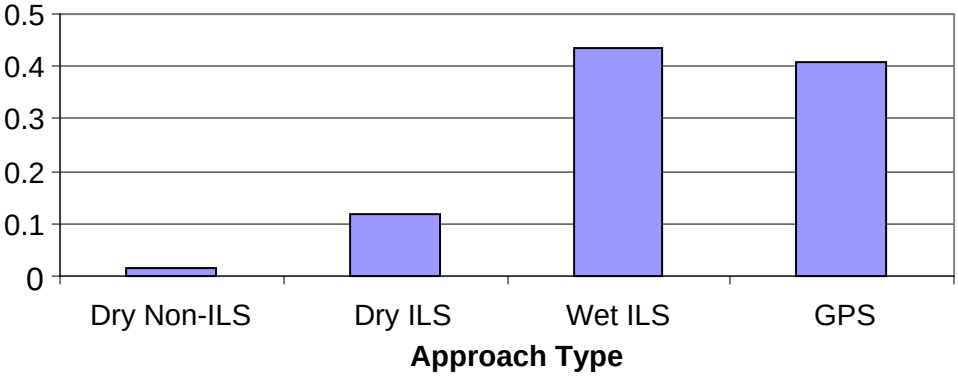


Figure I-21. ACY, Approach Speed Versus Crosswind Component, Correlation Coefficient r, KC-10 Landings

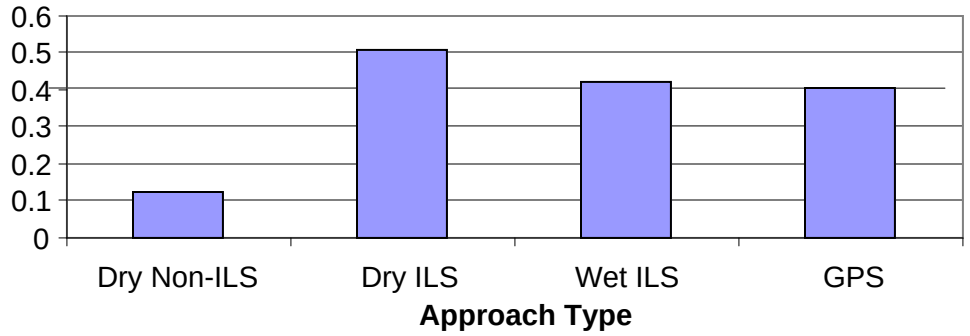


Figure I-22. ACY, Approach Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, KC-10 Landings

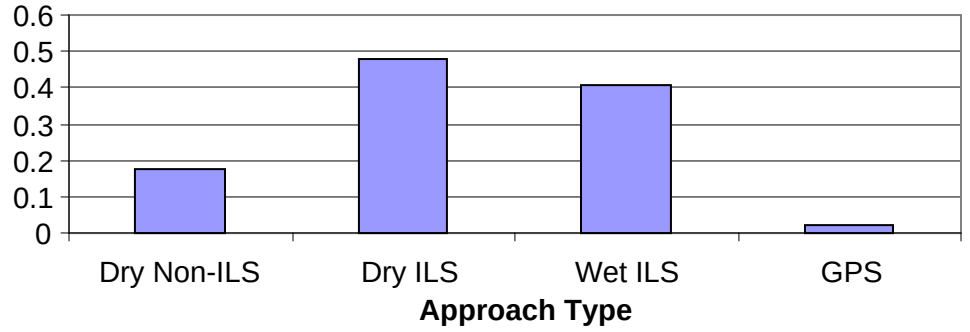


Figure I-23. ACY, Instantaneous Glide Slope Angle Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, KC-10 Landings

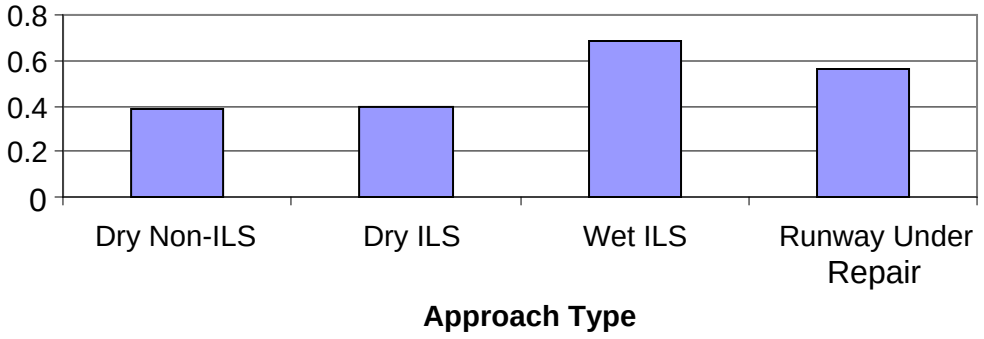


Figure I-24. ACY, Average Sink Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, DC-9 Landings

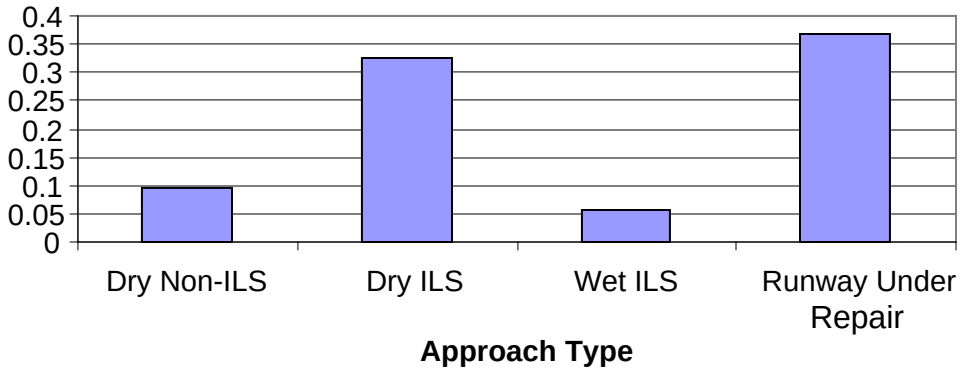


Figure I-25. ACY, Average Sink Speed Versus Closure Speed, Correlation Coefficient r, DC-9 Landings

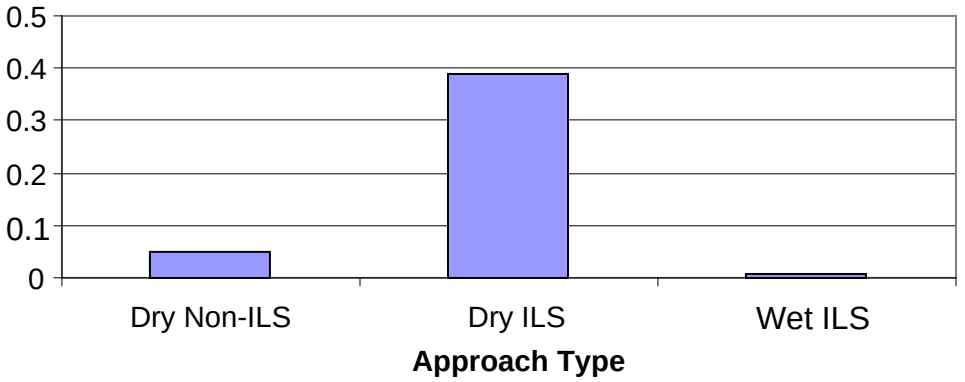


Figure I-26. ACY, Average Sink Speed Versus Approach Speed, Correlation Coefficient r, DC-9 Landings

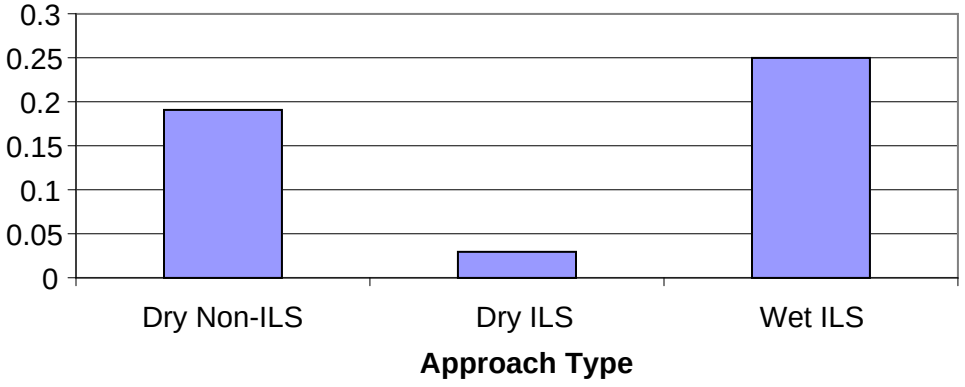


Figure I-27. ACY, Average Sink Speed Versus Headwind Component, Correlation Coefficient r, DC-9 Landings

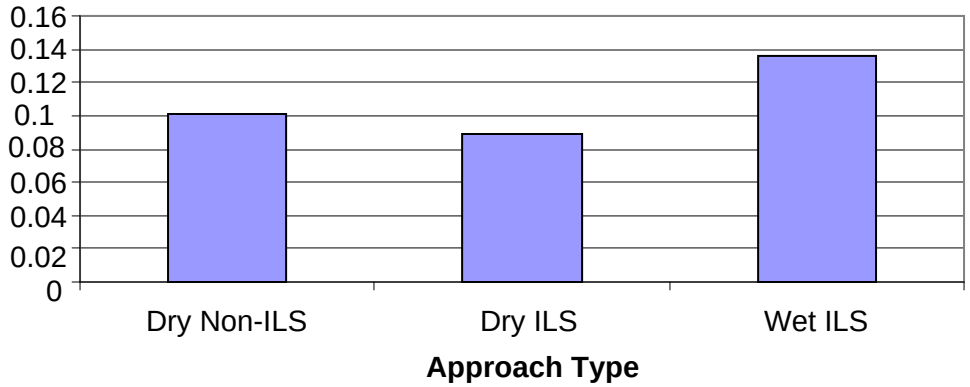


Figure I-28. ACY, Average Sink Speed Versus Crosswind Component, Correlation Coefficient r, DC-9 Landings

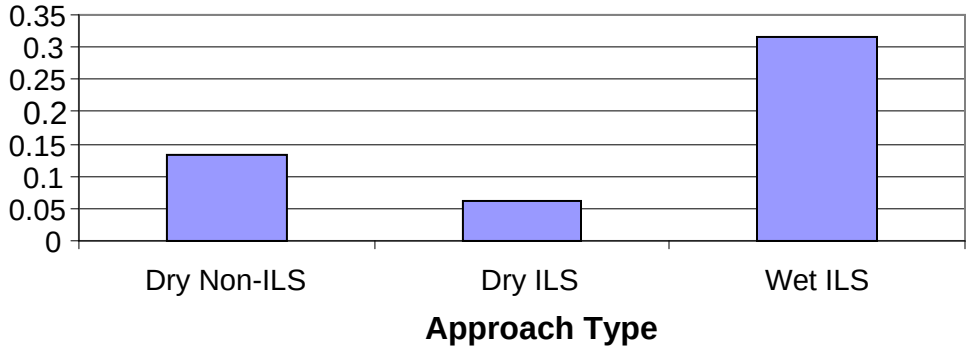


Figure I-29. ACY. Average Sink Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, DC-9 Landings

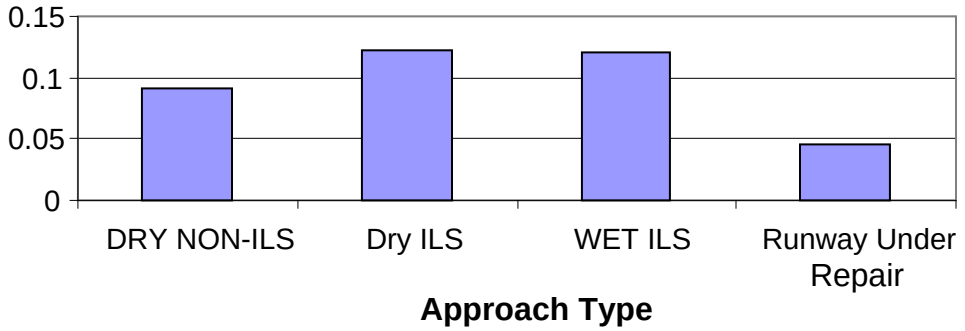


Figure I-30. ACY, Approach Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, DC-9 Landings

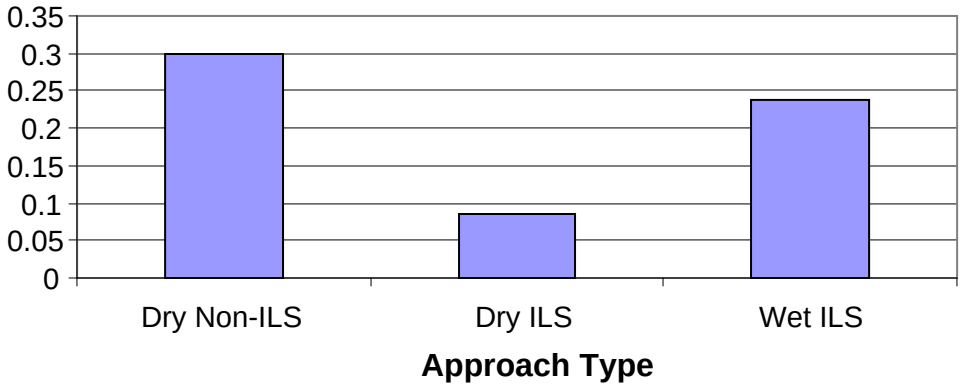


Figure I-31. ACY, Approach Speed Versus Headwind Component, Correlation Coefficient r, DC-9 Landings

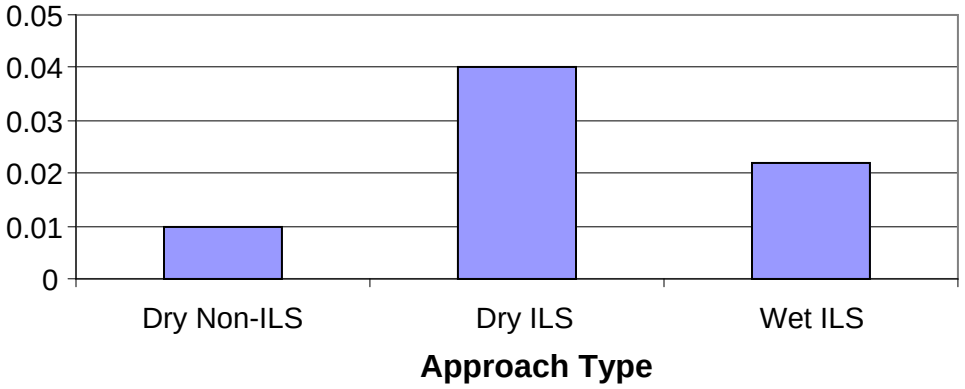


Figure I-32. ACY, Approach Speed Versus Crosswind Component, Correlation Coefficient r, DC-9 Landings

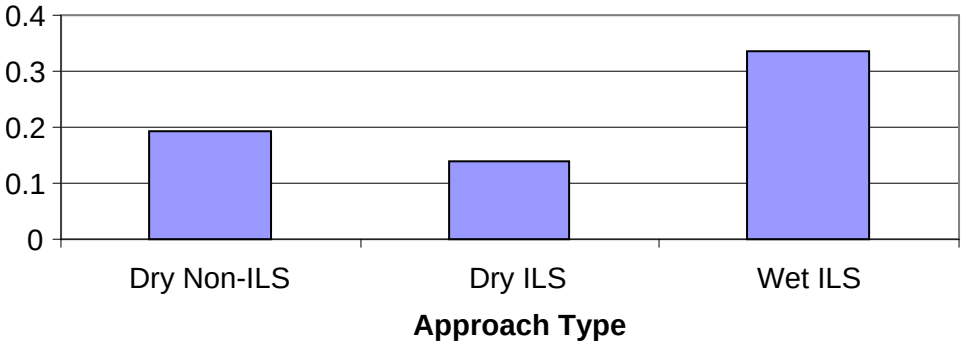


Figure I-33. ACY, Approach Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, DC-9 Landings

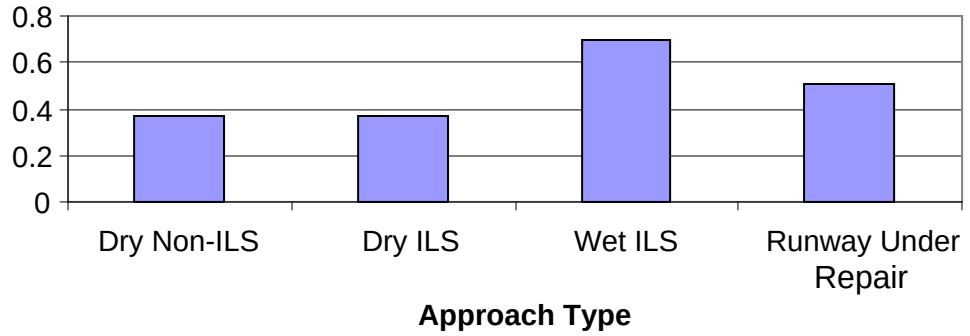


Figure I-34. ACY, Instantaneous Glide Slope Angle Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, DC-9 Landings

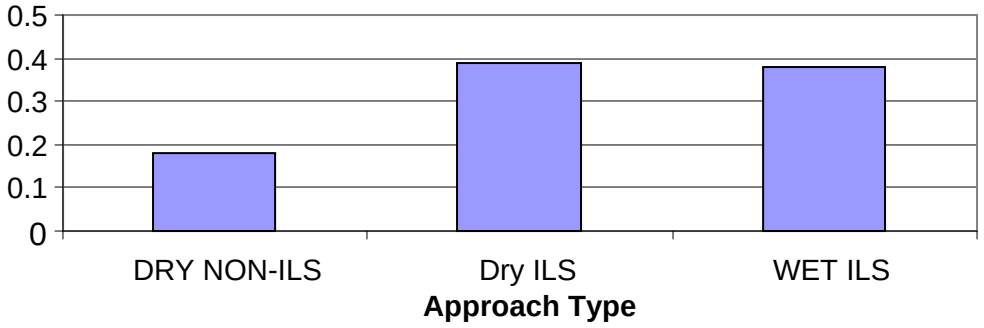


Figure I-35. ACY, Average Sink Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, Beechcraft 1900D Landings

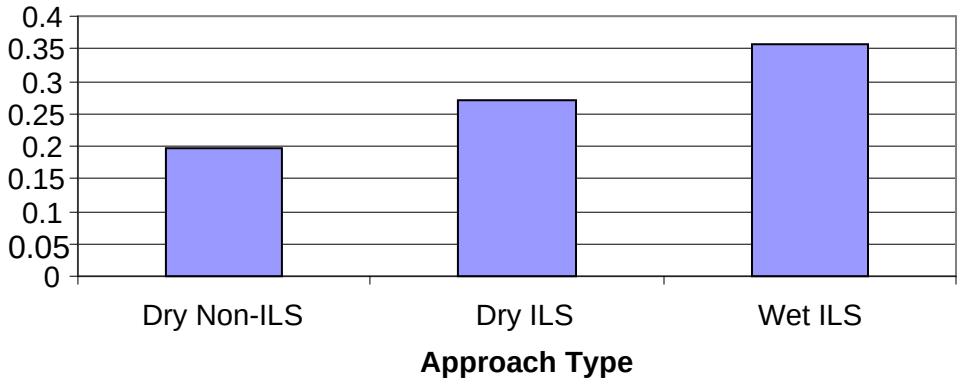


Figure I-36. ACY, Average Sink Speed Versus Closure Speed, Correlation Coefficient r, Beechcraft 1900D Landings

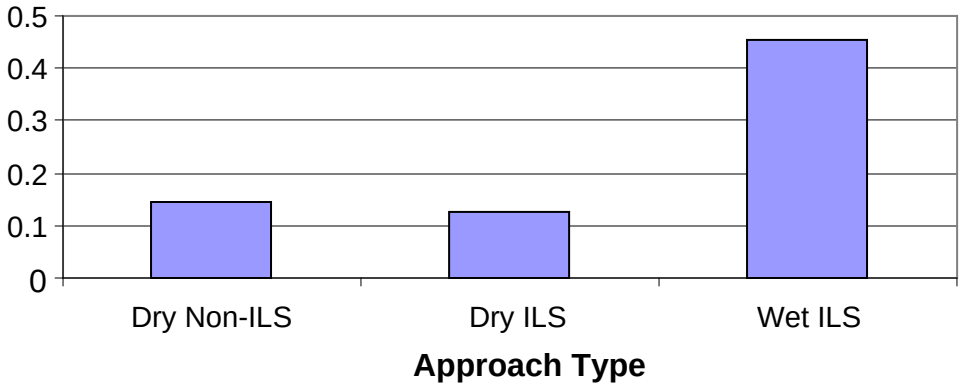


Figure I-37. ACY, Average Sink Speed Versus Approach Speed, Correlation Coefficient r, Beechcraft 1900D Landings

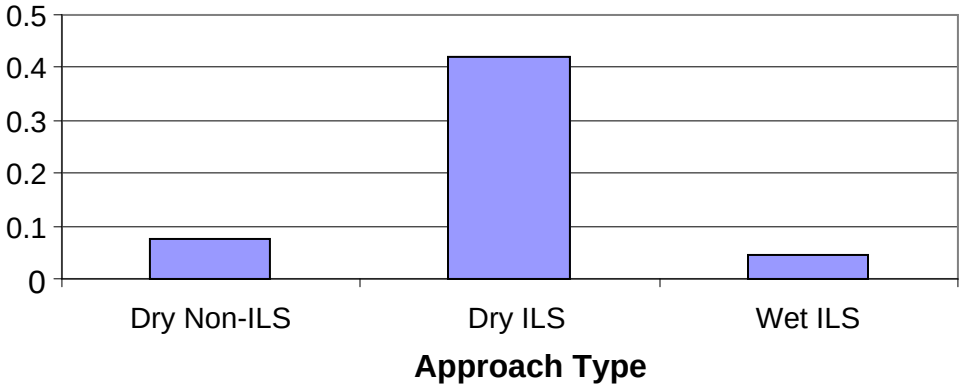


Figure I-38. ACY, Average Sink Speed Versus Headwind Component, Correlation Coefficient r, Beechcraft 1900D Landings

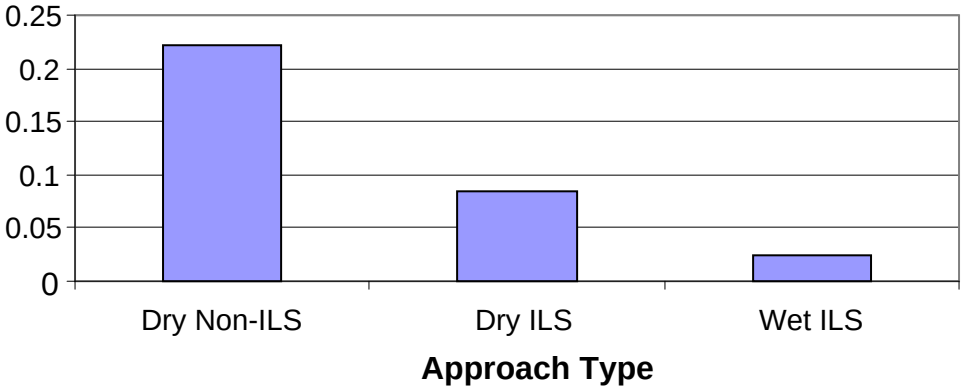


Figure I-39. ACY, Average Sink Speed Versus Crosswind Component, Correlation Coefficient r, Beechcraft 1900D Landings

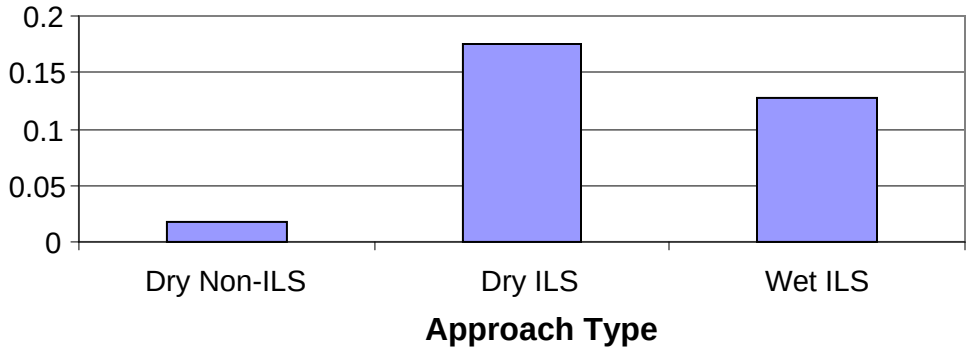


Figure I-40. ACY, Average Sink Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, Beechcraft 1900D Landings

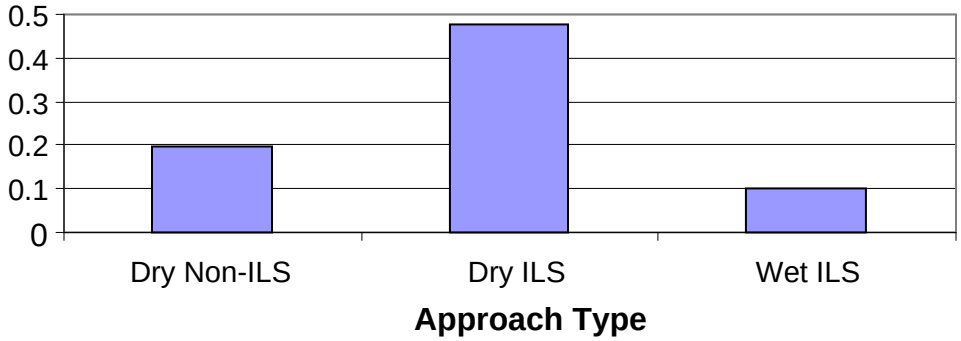


Figure I-41. ACY, Approach Speed Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, Beechcraft 1900D Landings

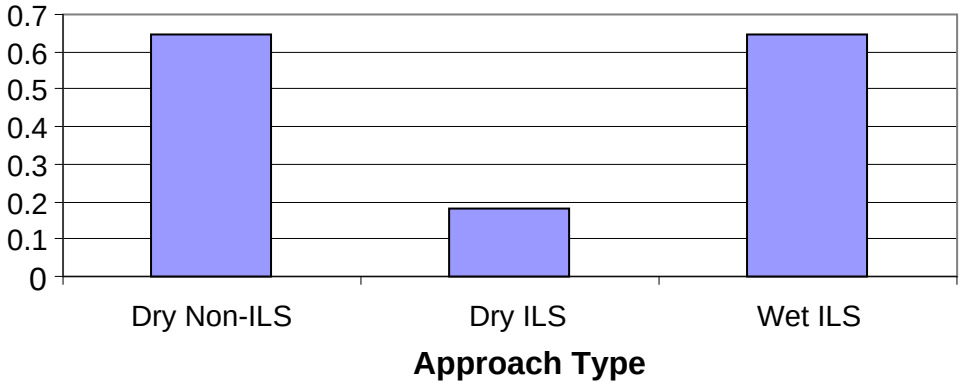


Figure I-42. ACY, Approach Speed Versus Headwind Component, Correlation Coefficient r, Beechcraft 1900D Landings

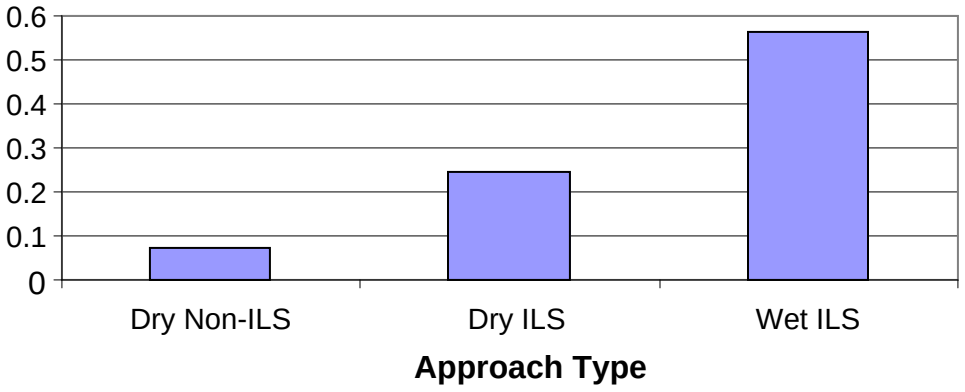


Figure I-43. ACY, Approach Speed Versus Crosswind Component, Correlation Coefficient r, Beechcraft 1900D Landings

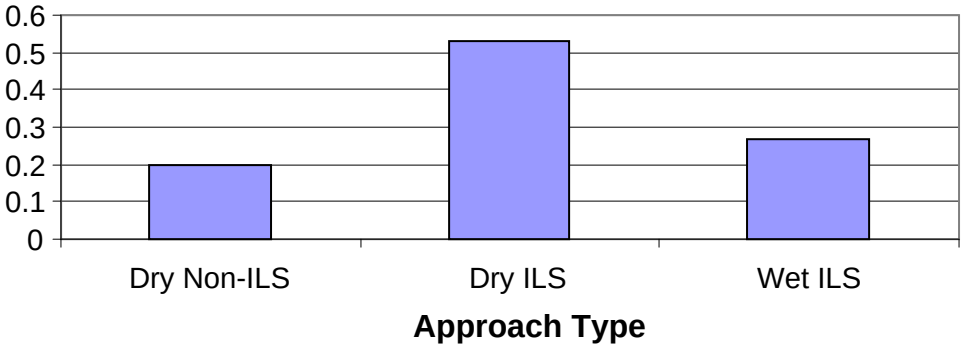


Figure I-44. ACY, Approach Speed Versus Absolute Value of Crosswind Component, Correlation Coefficient r, Beechcraft 1900D Landings

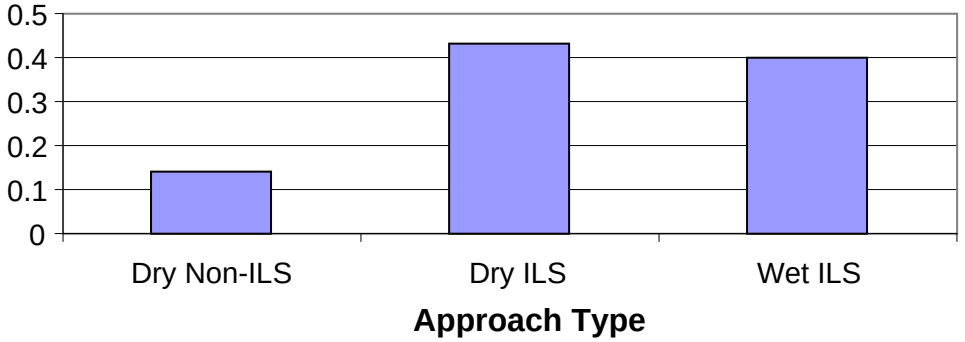


Figure I-45. ACY, Instantaneous Glide Slope Angle Versus Touchdown Distance to Runway Threshold, Correlation Coefficient r, Beechcraft 1900D Landings