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FIELD SURVEY AND ANALYSIS OF AIRCRAFT DISTRIBUTION ON AIRPORT PAVEMENTS

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FOR

U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
SOILS AND PAVEMENTS LABORATORY
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16. Abstract

The current procedure for converting aircraft operations (passes) to pavement coverages (stress and/or deflection repetitions) is based on limited observations of military aircraft operations made many years ago, prior to the advent of jet aircraft in commercial air transportation. Fundamental to the current procedure is the assumption, derived from those observations, that aircraft wheel-paths for 75% of operations are practically uniformly distributed over a particular width. New generations of civil jet aircraft, some with complex multi-wheel configurations, have since been introduced. The current pass-to-coverage (p/c) relationship may not be valid for these aircraft types, nor for operations in the present-day civil-airport environment. In this study, data for the current, most-commonly-used air carrier aircraft were collected and analyzed. The data collected at nine major civil airports, include observations of lateral wheel-path distributions on runways, runway exits, and taxiways; operating ground speeds on runways and taxiways; and the general areas of aircraft touchdown and rotation on runways. Statistical analysis of the data indicates that the actual lateral distributions of aircraft wheel-paths on runways and taxiways are more accurately represented by theoretical normal distribution functions, compared with the uniform distribution assumed in the current p/c relationship. The mean and standard deviations of the observed distributions were calculated and are presented by aircraft type. These mean and standard deviation values may be used as the basis for selecting representative normal distribution functions for use in developing more realistic p/c relationships, for either individual or groupings of aircraft types.

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PREFACE

This study was sponsored by the DOT/FAA Systems Research and Development Service (SRDS) and was performed for the U. S. Army Engineer Waterways Experiment Station (WES). It constitutes an integral part of an extensive research program being conducted by SRDS as a coordinated contractor/in-house/industry effort for upgrading airport pavement technology.

This study was performed by Howard, Needles, Tammen & Bergendoff (HNTB) of Alexandria, Virginia, under the management of Mr. Victor A. HoSang. Significant contributions were made by other HNTB personnel, including Messrs. John Duggan, Robert Holloway, Kenneth Hulbert, Alex Kuprijanow, William Scheirer, and Richard Steinmann.

The field data-collection system used in the study was furnished under a subcontract by the Cadre Corporation of Atlanta, Georgia, under the direction of Mr. Jay Queen of that firm. Other personnel of the Cadre Corporation who made significant contributions were Messrs. Gordon Anderson, Jerry Brittingham, and John Scoville.

HNTB wishes to acknowledge and express appreciation for the generous cooperation received from the many airport management representatives and FAA (Air Traffic Control Tower, Airway Facilities Sector, Air Carrier District Office) personnel at the various airports visited during the study. Their thoughtful assistance made possible and contributed significantly to the expeditious completion of the data-collection phase of the study.

The contract was monitored for WES, at the start by Mr. Donald N. Brown, then by Dr. Walter J. Horn, under the general supervision of Mr. James P. Sale, Chief of the Soils and Pavements Laboratory, WES. The Contracting Officer was initially Col. E. D. Peixotto, C. E. who was succeeded by Col. G. H. Hilt, C.E.

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[illegible] Service (SEDS) and was performed for the U. S. Army Engineer Waterways Experiment Station (WES). It constitutes an integral part of an extensive [illegible]

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LIST OF ABBREVIATIONS

Airport Identifiers

ATL	William B. Hartsfield Atlanta International Airport
BUF	Greater Buffalo International Airport
CLE	Cleveland Hopkins International Airport
DEN	Denver Stapleton International Airport
DFW	Dallas-Fort Worth Regional Airport
MIA	Miami International Airport
MSY	New Orleans International Airport
ORD	Chicago O'Hare International Airport
SEA	Seattle-Tacoma International Airport

Aircraft Types

BAC-111	British Aircraft Corporation Model 1-11, Series 400 and 475
C-580	General Dynamics Convair, Model 580
C-880	General Dynamics Convair, Model 880
DC-8-40,-50, -60	McDonnell-Douglas DC-8 Model, Series 40, 50 and 60, respectively. Also labeled as DC8-4,-5 and -6, respectively, in computer-generated tables.
DC-9-10,-20, -30,-40	McDonnell-Douglas DC-9 Model, Series 10, 20, 30 and 40, respectively. Also labeled as DC9-1,-2,-3 and -4, respectively, in computer-generated tables.
DC-10-10	McDonnell-Douglas DC-10 Model, Series 10. Also labeled as DC10 in computer-generated tables.
L-1011	Lockheed L-1011 Model
YS-11	Nihon Model YS-11-100
707	Boeing Models 707-120,-320,-320B,-320C and -420.
727-100,-200	Boeing Models 727-100 and -200 respectively. Also labeled as 727-1 and -2 in computer-generated tables.
737	Boeing Models 737-100 and -200.
747	Boeing Models 747, 747B, 747C and 747F

Other Abbreviations

bpi	Bits per inch
DOT	U. S. Department of Transportation
FAA	Federal Aviation Administration
KHz	Kilo-Hertz (10^3 Cycles per second)
MHz	Mega-Hertz (10^6 Cycles per second)
GND	General Normal Distribution
SND	Standard Normal Distribution

LIST OF SYMBOLS

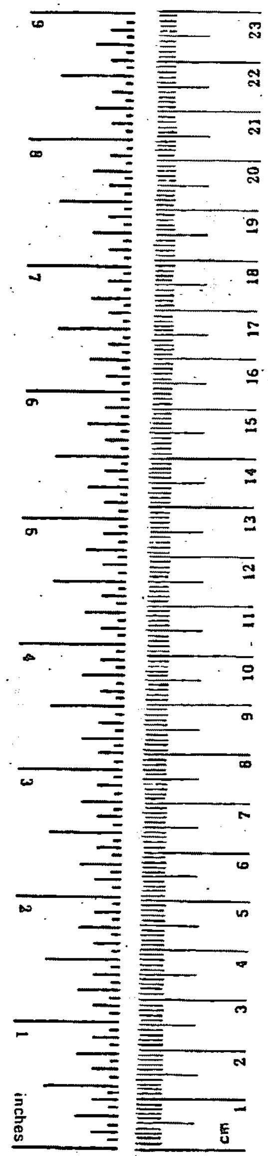
a	Acceleration
c	Coverages
C_x	Maximum ordinate of General Normal Distribution of main-gear single-wheel passes
C_z	Maximum ordinate of Standard Normal Distribution
C_{xc}	Maximum ordinate of Cumulative Distribution of passes of all main-gear wheels
e	Base (2.7183) of natural logarithms
I1,....,I4	"I"-type array designation
m_i	Number of observations in ith interval
n	Sample size
N1,....,N5	"N"-type array designation
p_i	Expected proportion of sample in ith interval
p	Aircraft passes
S	Standard deviation
V	Average velocity
$\bar{x}$, X	Mean of aircraft-centerline offsets relative to pavement centerline or guideline markings -- plus and minus values indicate right and left, respectively, of pavement centerline or guideline markings.
x	Variable in General Normal Distribution
W_t	Tire-contact width
z	Variable in Standard Normal Distribution
μ	Mean in General Normal Distribution
σ	Standard deviation in General Normal Distribution
χ^2	Chi-squared statistical value

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

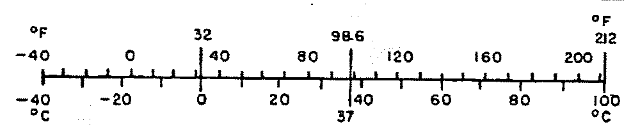
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Background

In the current FAA design criteria for runway and taxiway pavements, load repetitions are expressed in terms of coverages which represent the number of times a particular point on the pavement is expected to be stressed as a result of a given number of aircraft operations (passes).

Coverages resulting from operations of a particular aircraft type are a function of the number of aircraft passes, the number and spacing of wheels on the aircraft main landing gear, the width of the tire-contact area, and the lateral distribution of the aircraft wheel-paths relative to the pavement centerline or guideline markings. The collective influence of these factors has been conveniently expressed in terms of derived pass-to-coverage (p/c) ratios, based on observed lateral distribution patterns of aircraft wheel-paths on runways and taxiways.

Fundamental to the current procedure for converting aircraft passes to coverages is the assumption that aircraft wheel-paths for 75% of operations are practically uniformly distributed over a certain pavement width. Prior to this study, the current p/c procedure was re-examined on the *a priori* assumption that aircraft wheel-paths conform more nearly to a normal (bell-shaped) than to a uniform distribution. Theoretical normal distribution curves were fitted to the limited number of actual wheel-path distribution data available and found to be much more representative of the actual distributions than those distribution curves based upon the uniform distribution assumption. Aircraft p/c ratios based on the normal curves were calculated for both military and civil aircraft, even though no measured traffic distribution data were available to verify the procedure for civil aircraft.

Objectives

The primary purpose of this study, therefore, was to collect and analyze data relative to the lateral distribution of aircraft wheel-paths on runways, runway exits, and taxiways at civil airports. Data on the longitudinal distributions of touchdown and rotation points on runways, and aircraft ground operating speeds at the points of observed lateral distributions were also collected.

Lateral distributions of aircraft wheel-paths were determined at three generalized locations on runways: (a) soon after the point of touchdown or start of takeoff roll; (b) prior to turnoff or liftoff from the runway; and (c) an intermediate point between (a) and (b). For convenience, those runway locations have been herein referred to as First Point, Last Point, and Intermediate Point, respectively.

Aircraft types studied were those commonly used in commercial air transportation with maximum gross weights in excess of 50,000 pounds. Data were collected at nine airports selected to provide a reasonably good representation of the range of operational conditions normally encountered in day-to-day aircraft operations.

Methodology

Data-Collection System - The data-collection system used in the study consisted basically of: (a) infrared light-sensors placed at particular locations along runways, runway exits, and taxiways where aircraft distributions were to be determined; (b) a computer-based processing-and-recording system; and (c) a low-power telemetry link between the light-sensors and the processing-and-recording system.

Light sensors were grouped in arrays of either one or three beams, referred to as "I" and "N" type arrays, respectively. The beams were projected across the pavement at aircraft wheel-level height. The passage of aircraft through an array resulted in interruptions of the beams in the array and the recording of the times-of-occurrence of the interruptions.

Aircraft wheel-paths in terms of aircraft-centerline offsets relative to pavement centerline or guideline markings were determined within an accuracy of plus or minus 1 foot, or better. Information regarding the weather and runway conditions existing at the time of data collection at each airport was recorded for analysis of their possible effects on the observed distributions.

Data Analysis - A reasonably good variation in such factors as runway length, field altitude, temperature, and wind and other weather conditions was obtained at the nine airports combined in the data collection.

The mean and standard deviations of the lateral distributions and ground operating speeds were calculated for each sample--individual or combined aircraft types at individual or combined airports--and were the two primary statistical parameters used in describing and comparing samples. Frequency distributions (histograms) of the observed aircraft-centerline offsets were plotted, in terms of the proportionate occurrences in two-foot intervals on either side of the pavement centerline or guideline markings.

Data Collected

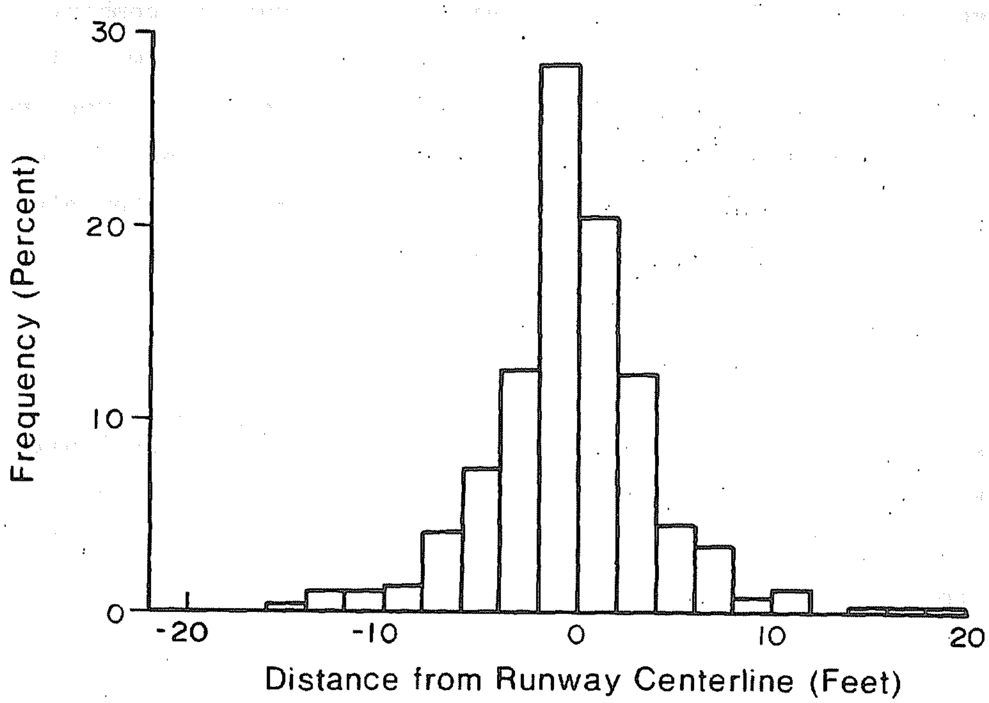
Runway Operations - One runway at each of the nine airports was instrumented such that data could be collected for both operating directions of each runway. Two of the runways were 200 feet wide; the others were 150 feet wide. A total of 4,359 takeoffs and 5,200 landings were recorded during the field survey.

High-Speed Exit Operations - Eight high-speed exits were instrumented in the study. A total of 697 operations at those exits were recorded.

Taxiway Operations - Seven locations on straight taxiways were instrumented in the study. One location was on a 100-foot-wide taxiway; the others were on 75-foot-wide taxiways. A total of 590 operations at those locations were recorded.

Analytical Results

General - It was obvious from inspection of the histograms, such as the one shown in the figure below, that the lateral distributions of aircraft traffic on runways, runway exits, and taxiways would be much more nearly represented by theoretical normal distribution functions, rather than by a modified uniform distribution function which had been assumed in the current procedure for deriving p/c ratios. This observation was also statistically verified.



TYPICAL HISTOGRAM OF LATERAL DISTRIBUTION OF AIRCRAFT TRAFFIC ON RUNWAYS DURING TAKEOFFS (Actual data from Cleveland Hopkins International Airport Runway 23L)

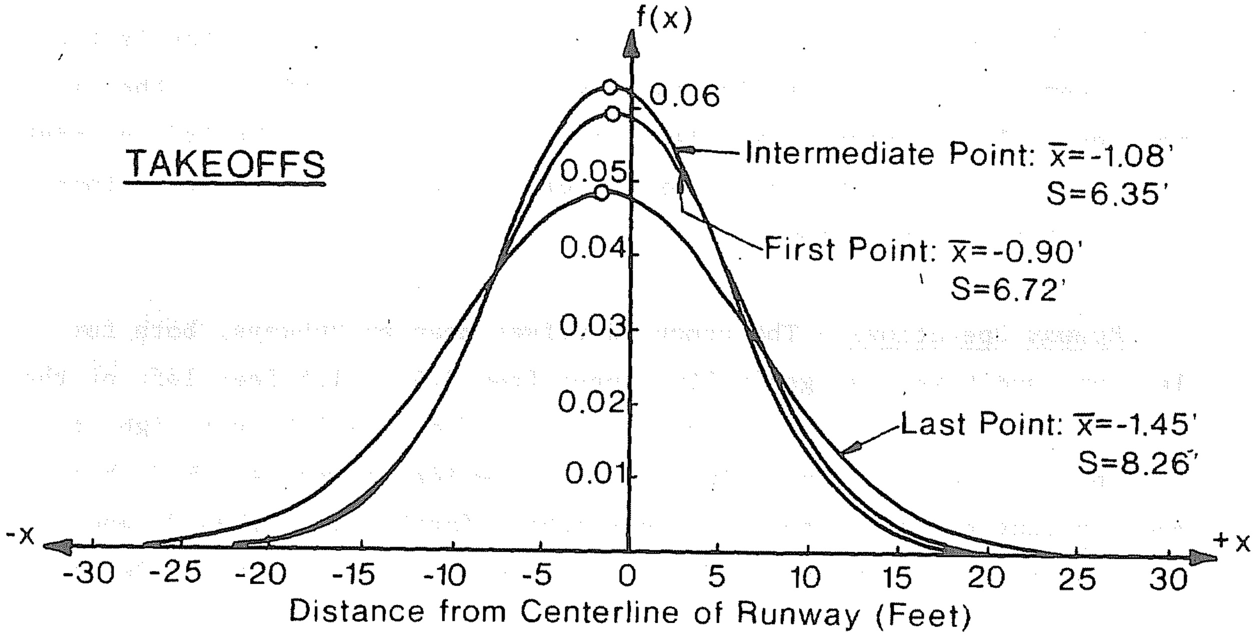
On the average, aircraft centerline offsets were (a) to the left of the pavement centerline stripe on runways; (b) to the right of the pavement centerline stripe on straight taxiways; and (c) to the left or right of the guideline on high-speed exits, depending on aircraft operational flow-pattern and exit configuration.

Runway Operations - The computed offset mean on runways, both for landings and takeoffs, generally ranged from 0.5 to 1.5 feet left of the centerline on 150-foot-wide pavements, and were from 0.8 feet right to 2.5 feet left of the centerline on 200-foot-wide pavements. Wide-body and 4-engine aircraft tended to be slightly farther left than 2- and 3-engine aircraft, but the difference was neither large nor consistent enough to make a distinction among such aircraft groupings.

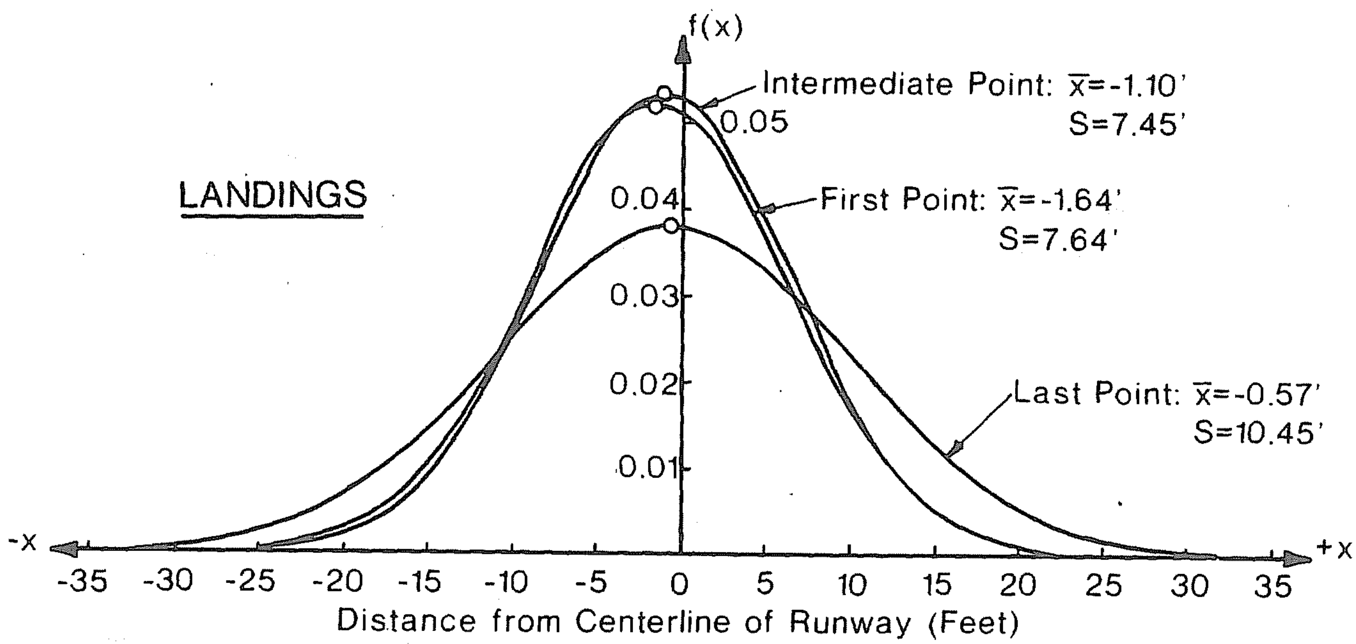
The shapes of the lateral distribution patterns for takeoffs were generally narrower than those for landings. The computed standard deviations for individual aircraft types, compared at the various airports, varied generally from 3 to 8 feet for takeoffs and from 4 to 9 feet for landings. There was no consistent correlation with respect to aircraft type or size.

The standard deviations for takeoffs, for all the airports combined, varied among individual aircraft types generally from 6 to 9 feet in the vicinity of liftoff and from 5.5 to 7 feet in earlier portions of takeoff roll. On 200-foot-wide runways, the standard deviations in the vicinity of liftoff were about the same as those in the same area on 150-foot-wide runways, but about 1.5 feet wider in earlier portions of takeoff roll. The normal distribution curves for the case of takeoff operations of all aircraft at all airports is shown on the following page.

The standard deviations for landings, for all the airports combined, varied among individual aircraft types generally from 7 to 8.5 feet, except near the end of landing rolls where, as expected, exit-influences were much in evidence. The normal distribution curves for the case of landing operations of all aircraft at all airport is also shown on the following page.



$$f(x)=\frac{1}{S\sqrt{2\pi}}e^{-(x-\bar{x})^2/2S^2}$$



SUMMARY OF LATERAL DISTRIBUTIONS ON RUNWAYS
ALL AIRCRAFT AT ALL AIRPORTS

Factors such as night operations, crosswinds, and wet pavements had an apparent effect on aircraft lateral distributions on runways; however, their overall impact was not considered significant because the effect of any one such factor was either (a) relatively small or generally not consistent, (b) infrequent in occurrence, or (c) compensated or nullified by other factors in the overall operating conditions.

In general, 90 to 95 percent of touchdowns occurred in the first 3000 feet from the threshold, 70 to 85 percent occurred in the first 2000 feet, and 15 to 25 percent occurred in the first 1000 feet. A higher percentage of 2-engine aircraft touchdowns occurred closer to the threshold in comparison with wide-body and 4- and 3-engine narrow-body aircraft.

High-Speed Exit Operations - The standard deviations of the observed lateral distributions on high-speed exits were generally wider than those on runways and were influenced by aircraft operational flow-pattern and exit configuration. The standard deviations ranged approximately from 8 to 10.5 feet, with the upper limit probably more representative of typical exit-configurations and their normal usage--two of the instrumented high-speed exits were used mostly (if not all the time) for 180-degree turns from the runway to a parallel taxiway.

Taxiway Operations - The computed offset mean of the lateral distributions on straight-taxiway sections was approximately 2 feet right of the centerline on the 75-foot-wide taxiways, and approximately 3 feet right of the centerline on the 100-foot-wide taxiway. The standard deviations were much narrower than those on runways, ranging approximately from 2.5 to 4 feet on the 75-foot-wide taxiways, and averaging about 6 feet on the 100-foot-wide taxiway. The average taxiing speeds ranged between 35 and 45 feet per second on both the 75- and 100-foot-wide taxiways.

Conclusions

The results of the analysis of the field survey data yield the following conclusions:

1. The lateral distribution of aircraft on runways, runway exits, and taxiways is much more nearly represented by theoretical normal distribution functions than by uniform distribution functions.

2. On the average the properties of the aircraft wheel-path distribution might be summarized as in the following table:

SUMMARY OF AIRCRAFT DISTRIBUTION CHARACTERISTICS

PAVEMENT TYPE	PAVEMENT WIDTH, FT.	--- DISTRIBUTION CHARACTERISTICS --- AVERAGE OFFSET, FT.[1/]	STANDARD DEVIATION, FT.
Runways			
Landings	150	0.9 - 1.5 Left	7.0 - 10.3
	200	0.8 Right - 2.3 Left	9.0 - 11.2
Takeoffs	150	0.5 - 1.2 Left	6.0 - 8.3
	200	2.3 - 2.5 Left	7.5 - 8.2
Taxiways			
(Straight Sections)	75	2.1 Right	2.5 - 4.0
	100	3.2 Right	6.0
Runway Exits			
(High-Speed)	Varies	See Note [2/]	8.0 - 10.5

1/ Aircraft-centerline offset, measured relative to pavement centerline or guideline markings.

2/ Average offset was to the left or to the right of the guideline, depending upon the aircraft operational flow-pattern and exit configuration.

3. The overall impact of such factors as night operations, cross winds, and wet pavements is not considered to be a significant influence on the distribution of aircraft traffic.

Recommendations

It is recommended that theoretical normal distribution curves be used for representing aircraft lateral distributions on runways, runway exits, and taxiways, and as the basis for deriving more realistic p/c ratios using the procedure outlined in this report.

INTRODUCTION

One of the parameters in the current FAA design criteria for runway and taxiway pavements is the number of aircraft wheel-load repetitions expected to be imposed on a pavement over its design life. In the design criteria, load repetitions are expressed in terms of coverages which represent the number of times a particular point on the pavement is expected to be stressed by a given number of aircraft operations (passes). The concept of coverages was first described in a letter entitled, "Design Curves for Less Than Capacity Operations," dated 18 April 1949.[1]

A coverage caused by a particular aircraft type is a function of the number of passes, the number and spacing of wheels on the aircraft main landing gear, the width of the tire-contact area, and the lateral distribution of the aircraft wheel-paths relative to the pavement centerline or guideline markings. The collective influence of these factors has been conveniently expressed in terms of derived pass-to-coverage (p/c) ratios based on observed lateral distribution patterns of aircraft wheel-paths.

The current FAA procedure for determining p/c ratios was derived from studies of military aircraft operations made many years ago, before the advent of jet aircraft in commercial air transportation. The background, development, and application of the current procedure were documented by D. N. Brown and O. O. Thompson,[2] but are partly reiterated in the paragraphs below in order to provide a fuller understanding herein of the purposes of this study.

Pavement test sections are used to develop relationships between load, traffic (coverages), and thickness requirements. Traffic on the test sections is programmed so that successive wheel-paths do not overlap and an accurate determination can be made of the applied coverages. The p/c ratios, therefore, provide a means for simulating the wheel-path distribution patterns that the pavement will in all likelihood experience on an actual airfield.

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[1] U.S. Army Engineer Waterways Experiment Station, CE, "Collection of Letter Reports on Flexible Pavement Design Curves," Miscellaneous Paper No. 4-61, June 1951, Vicksburg, Miss.

[2] U.S. Army Engineer Waterways Experiment Station, Soils and Pavement Laboratory, "Lateral Distribution of Aircraft Traffic," Miscellaneous Paper S-73-56, July 1973, Vicksburg, Miss.

It is assumed that the coverages to failure are the same for a test section and an airfield pavement when both are subjected to the same loadings. In design, therefore, the predicted number of aircraft passes is converted to coverages using the applicable p/c ratio; and the test-track coverages-versus-thickness relationships can be applied directly to the airfield facility.

In previous studies on lateral distribution patterns it was concluded that, for all practical purposes, the wheel-paths for 75% of the operations may be assumed uniformly distributed over a particular width. The current method for determining p/c ratios is based on this assumption.

The current p/c procedure has been reexamined by Brown and Thompson[1] on the *a priori* assumption that aircraft wheel-paths conform more nearly to a normal (bell-shaped) than a uniform distribution. Theoretical normal distribution curves were therefore fitted to the limited number of actual wheel-path distribution data available and found to be much more representative of the actual distributions than those distribution curves based upon the uniform distribution assumption. Aircraft p/c ratios based on the normal curves were calculated for both military and civil aircraft. However, no measured traffic distribution data were available to verify the procedure for civil aircraft.

The primary objective of this study, therefore, was to collect and analyze data relative to the lateral distribution of aircraft wheel-paths on runways, runway exits, and taxiways at civil airports. Data relative to the longitudinal distribution of touchdown and rotation on runways were also collected and analyzed.

This report describes the instrumentation used in the data collection, the collected data, and the results of the analysis. The mean and standard deviation of the observed aircraft-centerline offsets relative to the pavement centerlines or guidelines were calculated and are presented by aircraft type for each airport and for all nine airports where data were collected. These mean and standard deviation values may be used as the basis for selecting representative normal distribution functions from which more realistic p/c ratios can be determined.

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[1] Ibid.

SECTION I - DATA COLLECTION

Aircraft Types Observed

The aircraft types considered in this study were those commonly used in commercial air transportation with maximum gross weights in excess of 50,000 pounds.[1] They include the Boeing 747, 707, 727 and 737, McDonnell-Douglas DC-10, DC-8 and DC-9, Lockheed L-1011, General Dynamics Convair 880 and 580, British Aircraft Corporation BAC-111, and Nihon YS-11.

Airports in Data-Collection Program

The airports in the data-collection program were selected for their individual or collective potential to yield, in a reasonable amount of time, quantities of data for each of the above aircraft types sufficient to permit meaningful statistical analysis. In addition, the airports were chosen to represent a wide geographic distribution, with as much variation as was practical to obtain in meteorological and ground operating conditions. The following nine airports, in the order visited, were therefore selected for inclusion in the data-collection program:

- William B. Hartsfield Atlanta International Airport (ATL)
- Chicago O'Hare International Airport (ORD)
- Denver Stapleton International Airport (DEN)
- Seattle-Tacoma International Airport (SEA)
- Cleveland Hopkins International Airport (CLE)
- Greater Buffalo International Airport (BUF)
- Miami International Airport (MIA)
- New Orleans International Airport (MSY)
- Dallas-Fort Worth Regional Airport (DFW).

Types of Aircraft Data Collected

Data were collected on aircraft lateral distributions on runways and taxiways and on longitudinal distributions of touchdown and rotation points on runways. Aircraft ground operating speeds were also determined at the

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[1]A table of factors for converting U.S. customary units of measurements of metric (SI) units is presented on page xvi.

points of observed lateral distributions. The prevailing weather conditions during the data collection period, as well as other factors that might have influenced the observed distribution patterns, were recorded for analysis of their effects on operations.

Lateral distributions, in terms of aircraft-centerline offsets from the center of painted pavement-centerline stripes or guidelines, were determined to an accuracy of plus or minus 1 foot or better. The locations on runways where lateral distributions were observed were:

For landings:

a) Soon after the point of touchdown
b) Prior to exit from the runway
c) An intermediate point between a) and b);

For takeoffs:

a) Soon after the start of takeoff roll
b) Approximate point of rotation
c) An intermediate point between a) and b).

Lateral distributions were also determined at locations on high-speed, and right-angled runway exits and on straight segments of taxiways.

Touchdown and rotation points on runways were generally determined to within plus or minus 500 feet relative to the runway ends. In a few instances, these points were determined to greater tolerances owing either to: (a) local pavement configurations (intersecting runways and/or taxiways) that precluded placement of instruments at locations required to achieve the plus-or-minus-500-feet-or-better accuracy; or (b) a longer-than-usual runway length that necessitated placement of a limited number of available instruments at greater intervals.

Data-Collection System

General - The data-collection system used in the study consisted of two basic sub-systems: (a) a detection system, consisting of photoelectric sensors installed on the airfield at particular locations along runways, runway exits, and taxiways where aircraft distributions were to be determined;

and (b) a remote, computer-based, processing-and-recording system housed in a monitoring vehicle within line of sight of the detection system.

Data generated by the passage of an aircraft through the photoelectric sensors in the detection system were transmitted by low-power telemetry to the processing-and-recording system. A computer in the processing-and-recording system used these data to calculate the aircraft's ground speed and lateral position at the respective measuring points, its point of touchdown or rotation (if a runway operation), and its identification. A block diagram of the data-collection system is shown in Figure 1.

Detection System - The photoelectric sensors in the detection system used invisible infrared light beams that were projected across the runways and taxiways at a height of approximately one foot above the pavement center line. The light sensors were grouped in arrays of either one or three beams, referred to as "I" or "N" arrays, respectively.

"N" arrays were installed at those locations where lateral distributions were to be determined. On runways, their relative positions also enabled determination of the points of touchdown and rotation. Each "N" array was made up of three light-transmitters and three light-receivers which were placed on opposite sides of the runway or taxiway pavement, as shown in Figures 2 and 3. The parallel beams in the "N" arrays were projected normal to the pavement centerline or guideline.

"I" arrays were used on runways only, to supplement the "N" arrays in determining aircraft touchdown and rotation points. Each "I" array was made up of one light-transmitter and one light-receiver, which were placed on opposite sides of a runway so that the projected beam was normal to the pavement centerline. A typical layout of an "I" array is shown in Figure 2.

The total number of arrays used in the detection system consisted of five "N" and four "I" arrays for placement at runway locations, and two "N" arrays for placement at runway-exit and taxiway locations. At each airport, one runway and two runway-exit/taxiway locations were selected for instrumentation. One "N" array was used at each runway-exit/taxiway location.

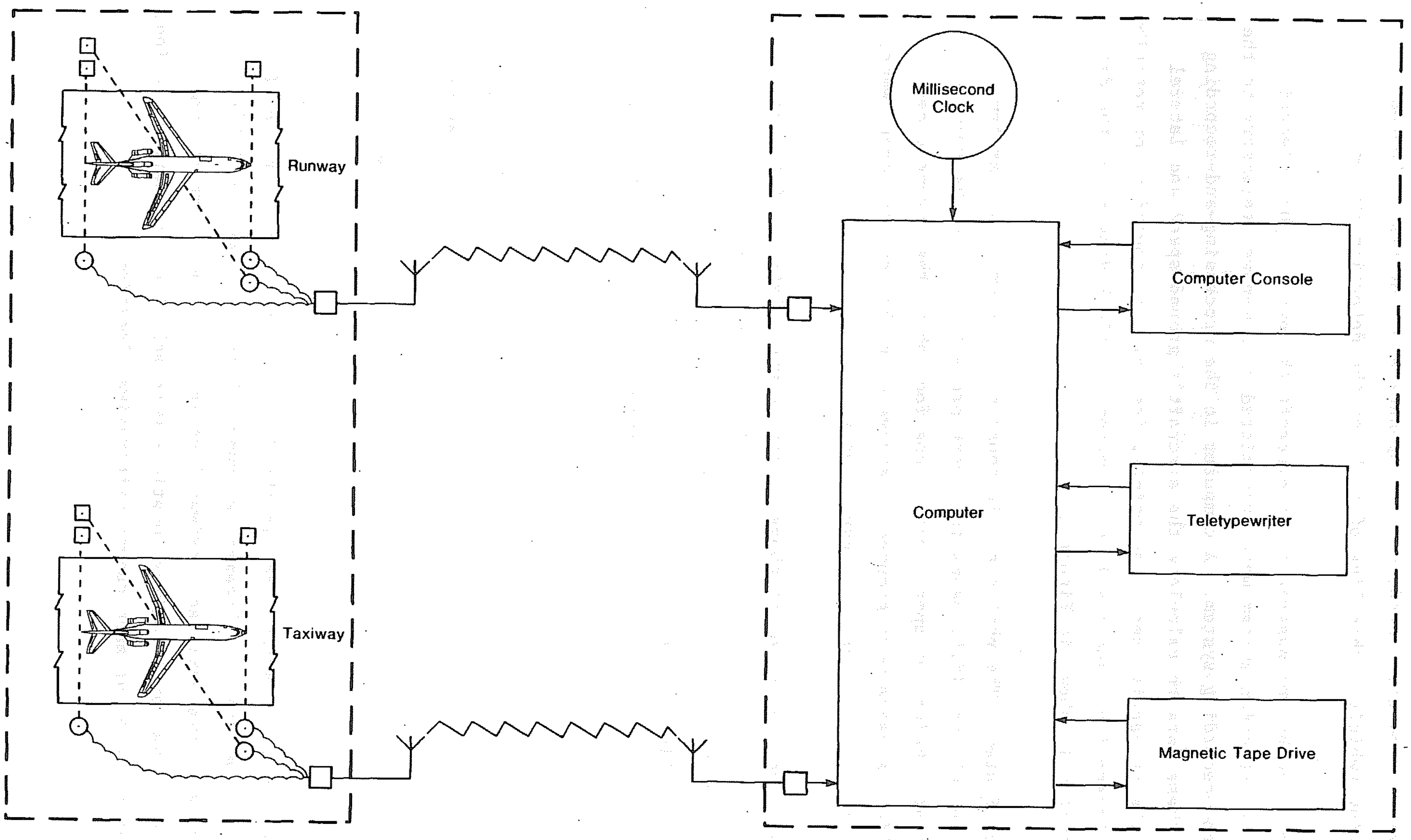
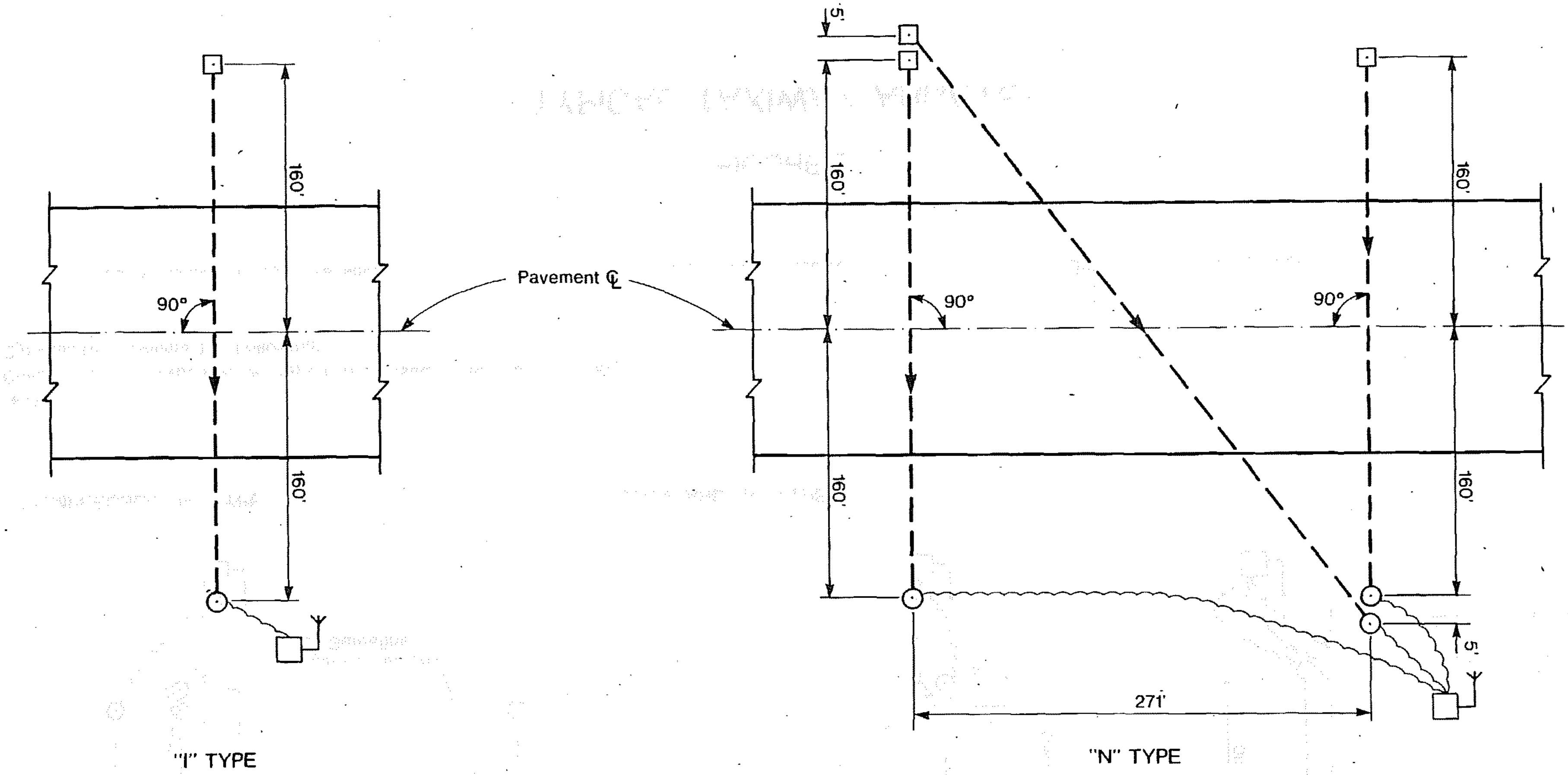


FIGURE 1

BLOCK DIAGRAM - DATA-COLLECTION SYSTEM



NOTES

Dimensions shown are typical, except as otherwise noted on Instrumentation Layout for each airport

Symbols used denote the following:

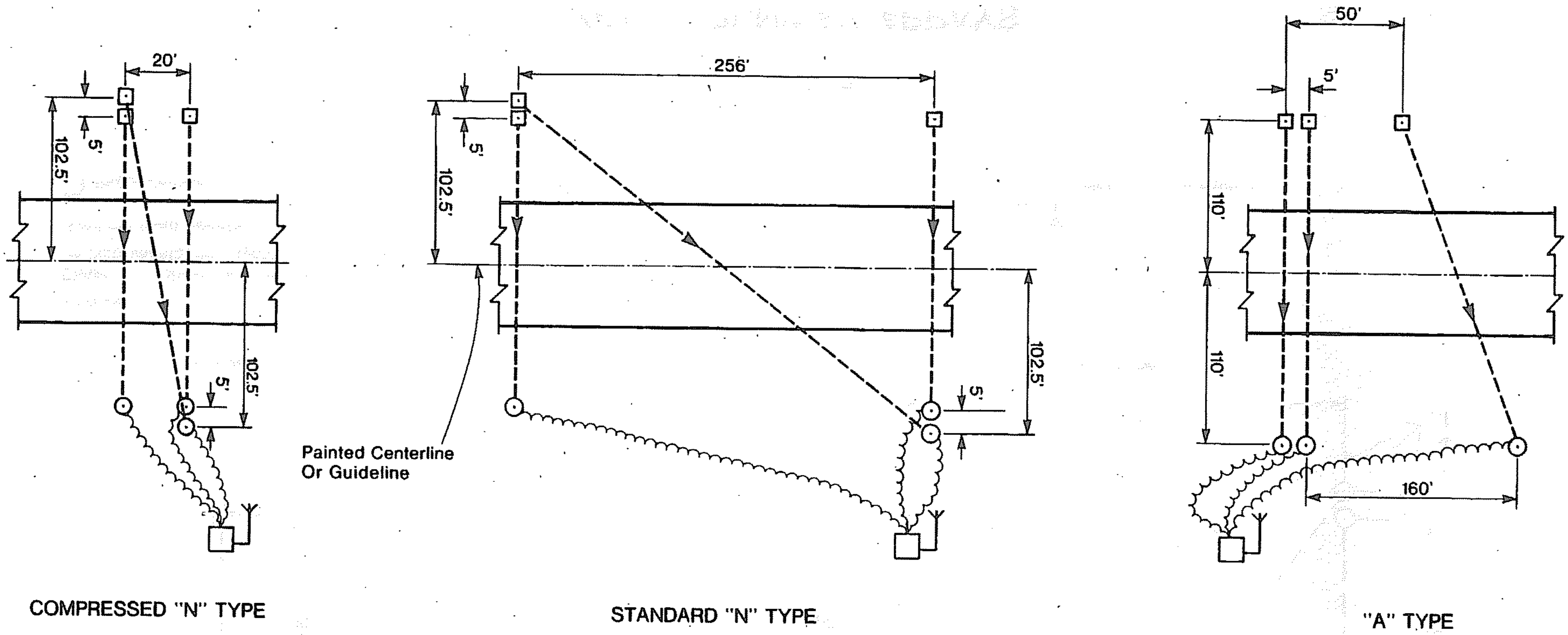
⊡ Photoelectric Transmitter

⊙ Photoelectric Receiver

□ Telemetry Transmitter

FIGURE 2

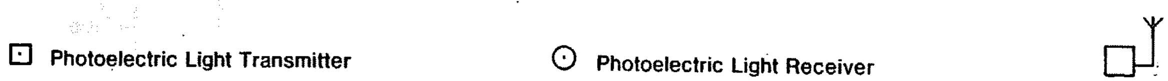
TYPICAL RUNWAY ARRAYS



NOTES

Compressed "N" Type And "A" Type Arrays Used On Runway Exits Only

Symbols Used Denote The Following:



Photoelectric Light Transmitter — Photoelectric Light Receiver — Telemetry Transmitter

FIGURE 3

TYPICAL TAXIWAY ARRAYS

Each array had one telemetry transmitter connected to it on the light-receiver side. Two frequencies were used for telemetry transmissions. One was assigned to the transmitters connected to runway arrays, the other to transmitters connected to runway-exit or taxiway arrays. Frequencies within the designated experimental band were used to minimize signal interferences originating externally of the data-collection system. The two selected frequencies were 218.5 MHz and 216.5 MHz.

Each light-transmitter, light-receiver, and telemetry transmitter unit had its own separate power source located adjacent to the units. This reduced the amount of wiring for interconnections that would have been required otherwise. The only substantial lengths of wiring in the system were those connecting the telemetry transmitter and the far light-receiver in each "N" array, as shown in Figures 2 and 3. There was no wiring between arrays. The power sources were six-volt, lantern-type batteries.

As an aircraft passed through an array (see Figure 4), each light beam in the array was broken in turn; first by the aircraft nose-wheel, then by the main-gear wheels. Each time a beam was broken, an output device in the light receiver for that beam was energized. This caused the array's telemetry transmitter to emit a uniquely-coded signal that identified the interrupted beam and the originating telemetry transmitter. The particular array through which the aircraft was passing or had just passed was identified from known pairings of arrays to coded telemetry transmitters.

Each telemetry transmitter contained an encoder/modulator. For each light-beam interruption, the encoder generated a 16-bit code. The output of the modulator was an 18-KHz (logic zero) signal supplied to the transmitter. Each time a light beam was interrupted, the transmitter was turned on to transmit the 16-bit code. Only one transmission was made for each beam-interruption.

Processing-and-Recording System - The processing-and-recording system was designed around a small (4K-word-memory) digital computer. Interfaced with this computer were two telemetry receivers (one for each telemetry

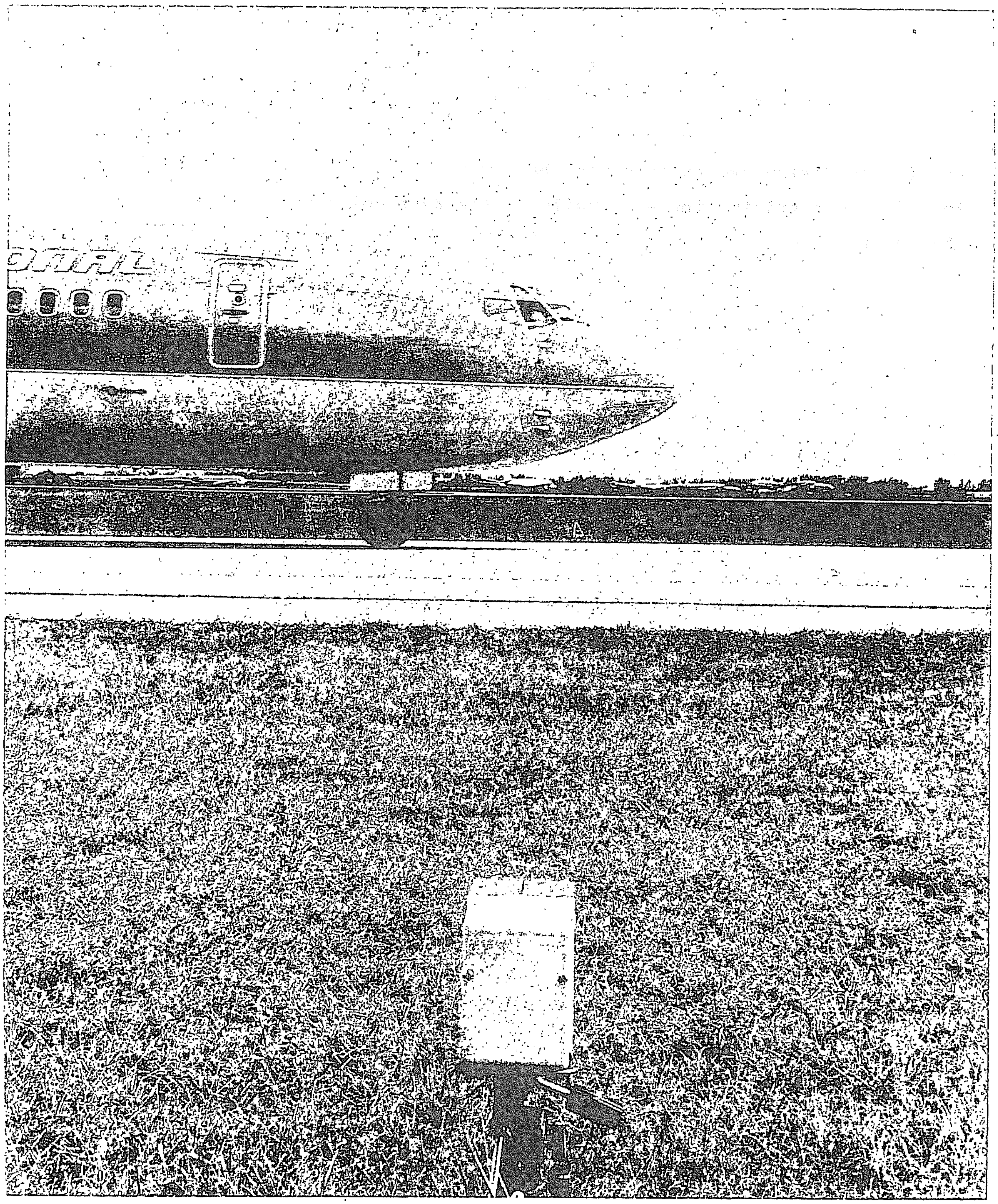


FIGURE 4

AIRCRAFT PASSING THROUGH AN ARRAY

frequency and each containing a decoder/demodulator); a one-millisecond, real-time clock; a teletypewriter; and a 9-track, 800-bpi, digital tape drive.

As each beam in each array was broken in turn, one of the telemetry channels (runway or runway-exit/taxiway) was activated; the computer obtained the time from the clock and stored it along with the address (signal code) of the interrupted beam; and a "watch-dog" timer was activated. After each telemetry input, the timer was automatically reset at a maximum anticipated time interval between successive beam interruptions. Separate timers were provided for each telemetry channel, allowing simultaneous events on the runway and taxiway to be recorded.

Expiration of the time on the "watch-dog" timer signified that no further light beams were expected to be broken by the aircraft operation that had initiated the current sequence of signals. Processing of the stored time information then began.

The computer in the processing-and-recording system was selected for its priority-interrupt feature. The operating program was designed in two distinct phases. The first phase was required only during initial activation of the system and was subsequently overlaid by data arrays in order to conserve memory capacity for the second phase.

The second phase of the program consisted of interrupt-processing, computation, and input/output processing. It was organized as asynchronous, multi-priority functions, with higher priorities assigned to real-time functions and lower priorities assigned to less critical tasks. The priority assignments, from the highest to the lowest, were as follows:

- Input, output, and command processing
- Computational level
- Teletype hardware interrupt
- Day clock
- Magnetic tape hardware interrupt
- Runway telemetry unit
- Taxiway telemetry unit
- Real-time clock.

The processing-and-recording system was installed in a vehicle (see Figure 5) that served as the monitoring center while data were being collected at each airport and as a convenient means of transporting the equipment between airports. The vehicle had its own power generator, but commercial power sources were used when available. At each airport, the vehicle was parked where it would not interfere with the normal airport traffic and where there was a line of sight to each of the field arrays. The computer, teletypewriter, and tape drive are shown in Figure 6.

Processing Method - The sequence and spacing of the arrays on the runway, the geometry of each "N" array, and the telemetry transmitter signal code associated with each array were defined to the computer. The geometry of each "N" array was defined by the distance between its parallel elements and the location of its apexes relative to the pavement centerline. The apexes were the theoretical intersections of the parallel elements and the diagonal element.

The time information generated by the passage of an aircraft through an "N" array, together with the known geometry of the "N," permitted the calculation of the aircraft's speed and lateral position at that "N," as well as determination of the aircraft's identity. The relationships used are demonstrated in simplified illustrations in Figures 7 and 8.

Aircraft paths through the "N" arrays were assumed to be practically parallel to the pavement centerline, and aircraft motions were assumed to be essentially uniform across each "N" array. An aircraft's continuous operation through a series of "N" arrays provided a speed history of that operation, which in turn was used to obtain a closer determination of the average speed across particular segments of any one "N" array in the series (i.e., between either of the two parallel elements and the diagonal element of the "N"). The speed history of the aircraft was also used to determine whether the operation was a landing or takeoff, based on increasing or decreasing speeds through consecutive "N" arrays.

An aircraft was identified from its "footprint." For each aircraft type studied there was a unique combination of wheelbase and tread-dimensions (see Figure 9) which allowed positive identification to be made. It should

FIGURE 5

MONITORING VEHICLE

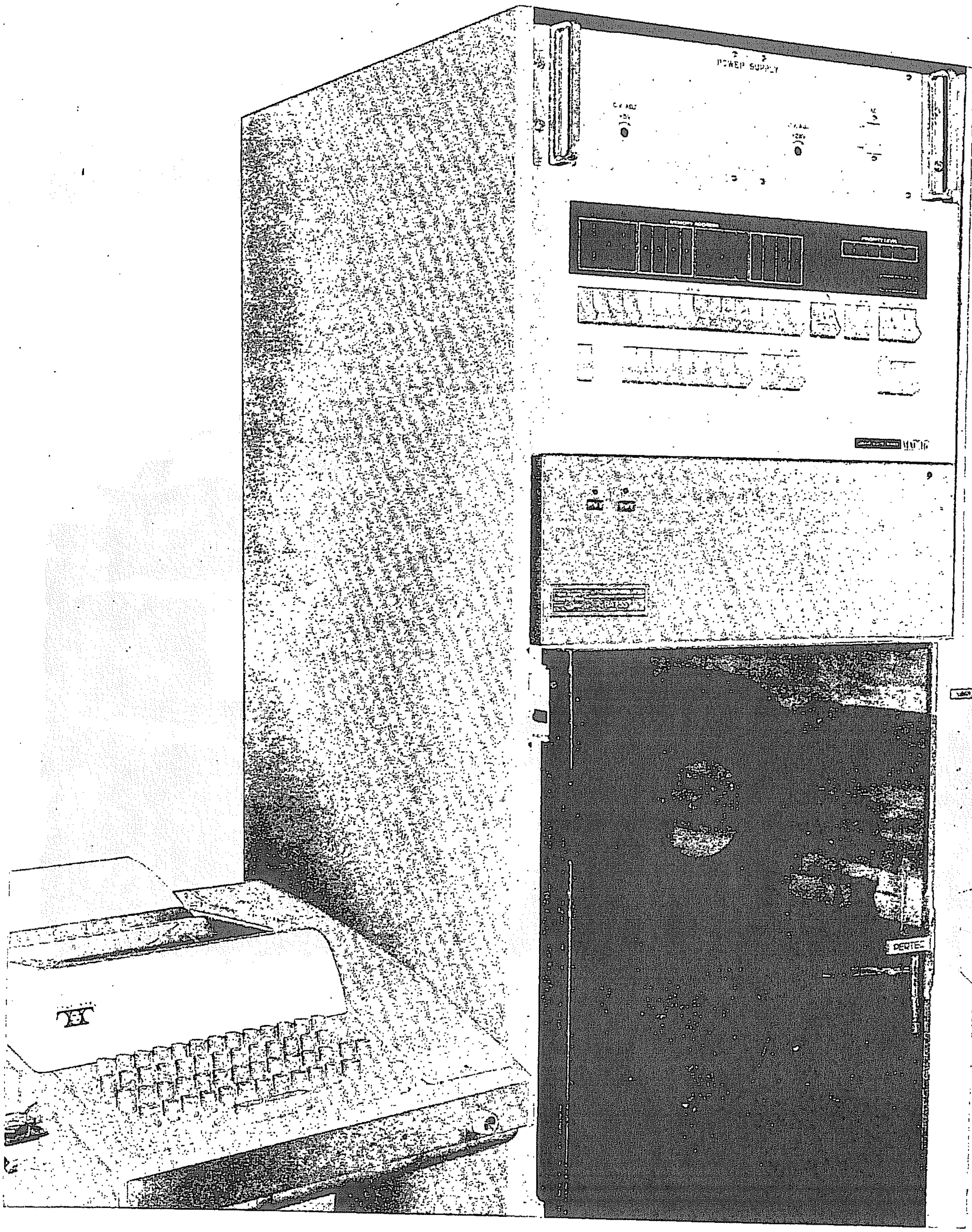
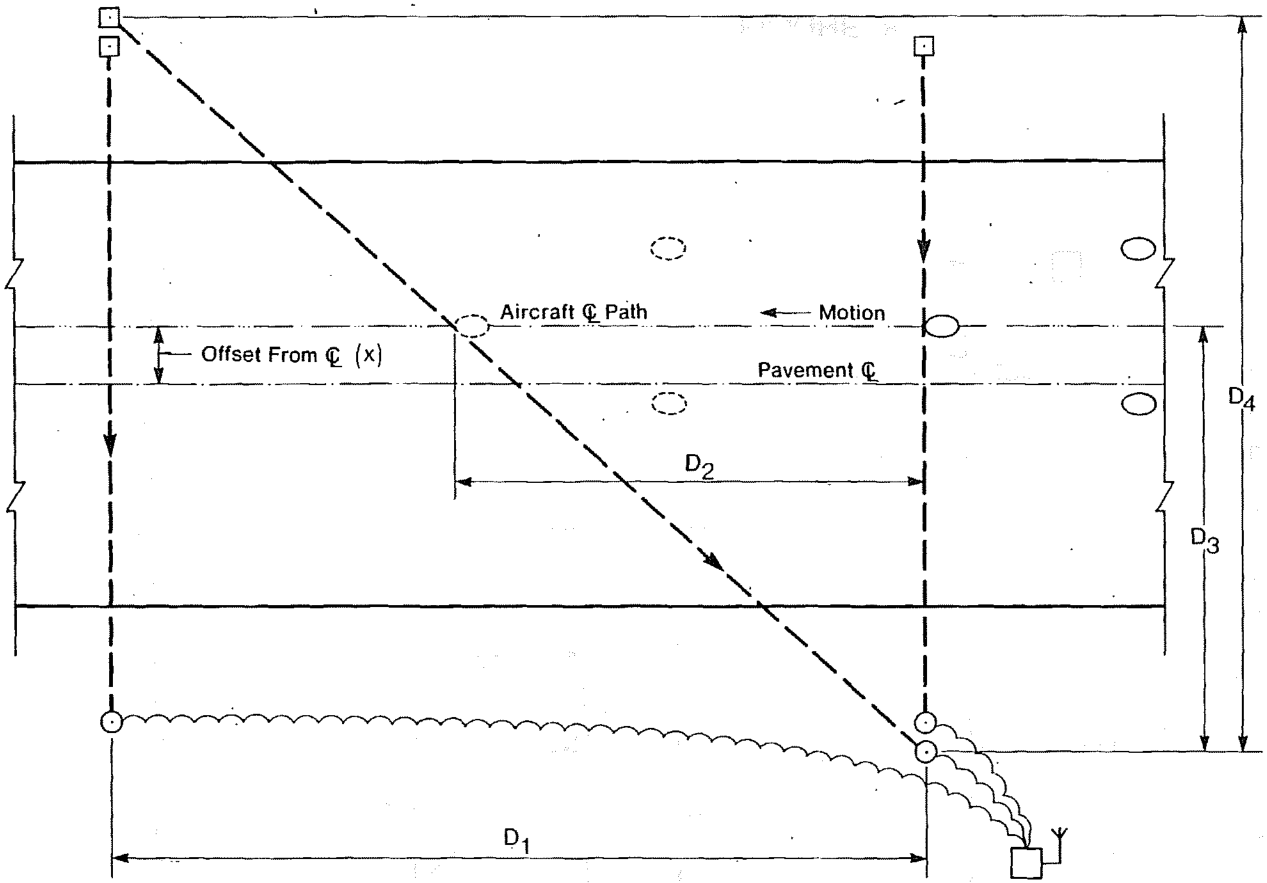


FIGURE 6

PROCESSING-AND-RECORDING SYSTEM



For aircraft nose-wheel interruption of light beams:

Let,

T_1 = Travel time over distance D_1

T_2 = Travel time over distance D_2

V_{AV} = Aircraft average speed across array

X = Aircraft offset distance from pavement centerline

Then,

$$\boxed{V_{AV} = \frac{D_1}{T_1}}$$

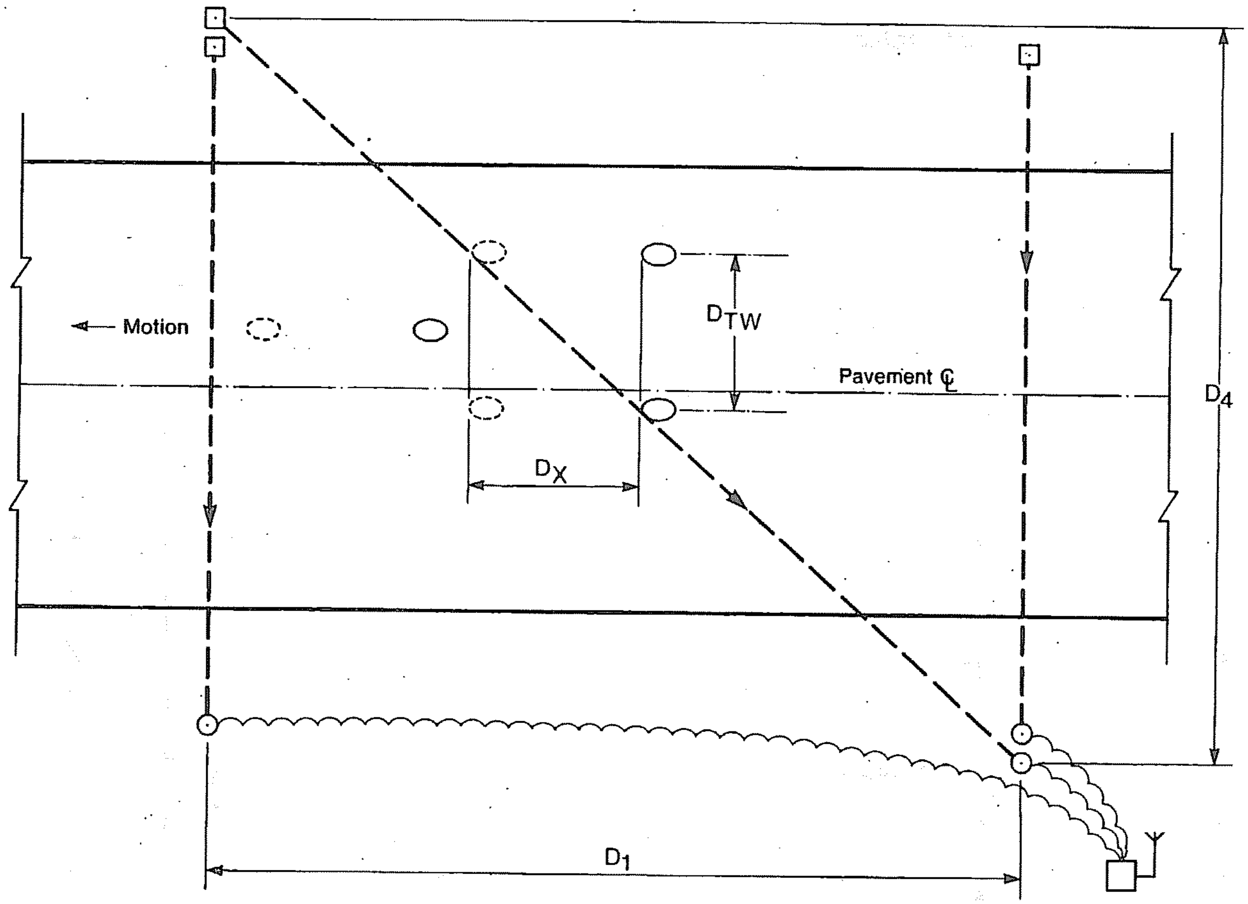
$$D_2 = V_{AV}\ T_2$$

$$D_3 = \frac{D_2\ D_4}{D_1}$$

$$\boxed{X = D_3 - \frac{D_4}{2}}$$

FIGURE 7

DETERMINATION OF AIRCRAFT SPEED AND OFFSET



Let,

T_{WB} = Time interval between nose and main-gear wheel interruptions of either of the two transverse elements

D_{WB} = Aircraft wheelbase dimension

T_1 = Travel time over distance D_1

T_X = Time interval between right and left main-gear wheel interruptions of the diagonal element

D_{TW} = Aircraft tread dimension

Then,

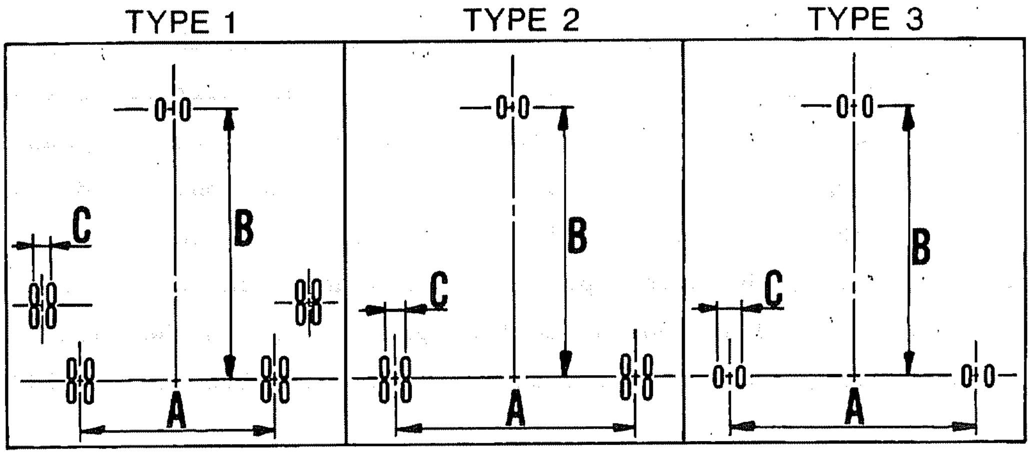
$$D_{WB} = \frac{D_1 T_{WB}}{T_1}$$

$$D_X = \frac{D_1 T_X}{T_1}$$

$$D_{TW} = \frac{D_4 D_X}{D_1}$$

FIGURE 8

DETERMINATION OF AIRCRAFT WHEELBASE AND TREAD DIMENSIONS



LANDING GEAR CONFIGURATIONS

AIRCRAFT TYPE	LANDING GEAR TYPE	WHEEL-SPACING DIMENSIONS A	B	C
737-100	3	17'-2"	34'-4"	30.5"
727-100	3	18'-9"	53'-3"	34"
727-200	3	18'-9"	63'-3"	34"
707-100	2	22'-1.2"	52'-4"	34"
707-300	2	22'-1.2"	59'-0"	34.6"
747	1	12'-6"(Rear)	89'-0.7"(Rear)	44"
		36'-2"(Front)	78'-11.5"(Front)	
DC-9-10	3	16'-5"	43'-8"	24"
DC-9-20	3	16'-5"	43'-8"	25"
DC-9-30	3	16'-5"	53'-2"	25"
DC-9-40	3	16'-5"	56'-2"	26"
DC-8-40,-50	2	20'-10"	57'-6"	30"
DC-8-61	2	20'-10"	77'-6"	30"
DC-8-63	2	20'-10"	77'-6"	32"
DC-10-10	2	35'-0"	72'-4.6"	54"
L-1011	2	36'-0"	70'-0"	52"
C-880	2	18'-11"	53'-1"	21.5"
C-580	3	25'-0"	26'-1.8"	20"
BAC-111-400	3	14'-3"	33'-1"	21"
BAC-111-475	3	14'-3"	33'-1"	24.5"
YS-11	3	28'-2.6"	31'-2.6"	20"

FIGURE 9

AIRCRAFT WHEEL-SPACING DIMENSIONS

be noted, however, that the wheelbase and tread dimensions of the Boeing 727-100 and Convair 880 differred by only two inches. This difference was too small to permit positive distinction between those two aircraft types at all times. Also, during the period of data collection, the Convair 880 was being phased out of operation but was still being operated at two (ORD and DEN) of the nine airports, where it represented only about three per cent or less of the combined 727-100 and 880 scheduled operations. In the data collected at ORD and DEN, therefore, 880 aircraft were labelled as 727-100's.

An aircraft's wheelbase and tread dimensions were calculated from the time data obtained in any one "N" array in which all its wheels interrupted all the beams in the array. (Note that only the main-gear wheels are on the pavement during the initial segment of a landing roll or the last segment of a takeoff roll.)

The calculated wheelbase and tread dimensions were compared against actual values stored in the computer to determine the aircraft type and model. If the calculated dimensions did not compare with any of the stored values, the operation was labeled as a "non-descript" (ND) and was not used in the study. Non-descripts included small aircraft, ground vehicles, or (on occasion) animals.

An aircraft's lateral position through each "N" array was calculated from the time information provided by the nose wheel. However, if the beams were interrupted by the main-gear wheels only, the lateral position was calculated from the time data provided by the main-gear wheels after identification of the aircraft had been made as described above. The tread dimension was then determined (from the aircraft's identity) and used in calculating the aircraft's lateral position.

The longitudinal distances from the landing or takeoff end of a runway to the points of touchdown or rotation were determined by noting the first light-sensor to be interrupted in the case of a landing, or the last light-sensor to be interrupted by the nose wheel in the case of a takeoff. The touchdown distance was deemed to be, and was calculated as, the distance from the landing end of the runway to the mid-point between the first interrupted sensor and the sensor that preceded it (or runway end, if there was no preceding sensor). The rotation distance was deemed to be, and was calculated as, the distance from the takeoff end of the runway to the midpoint between the last sensor interrupted by a nose wheel and the sensor that followed it.

The processing-and-storing system was activated from the teletypewriter. The activation included specification of the field array layout and the field pairings of telemetry transmitters (signal codes) to arrays. Prevailing weather and runway-condition data, as listed on the form shown in Figure 10, were are also prepared and entered at the start of data collection. Thereafter, revisions were entered whenever there was a significant change in any of those conditions.

Weather and runway-condition data were added to the field-collected, processed information for each aircraft operation, and all data were stored on magnetic tape for later statistical analysis by computer. At the conclusion of processing each aircraft operation, an abbreviated listing of the processed-and-stored information was printed at the teletypewriter. This listing (see Figure 11) provided a method for continuous checking of the data-collection system's operation.

Photoelectric Sensors - The aircraft detection technique utilized was insensitive to ambient light levels. This was accomplished by modulating the emitted infrared beam by pulses at a known frequency and using band-pass filtering at the light-receivers to cause all inputs not modulated at the known frequency to be rejected. The modulation frequency used was approximately 15 KHz.

The light source in each transmitter was a solid-state lamp commonly called a light-emitting diode (LED). Each light-receiver consisted of a photo-transistor and a transistorized pulse-detector. A light-transmitter and a light-receiver are shown in Figures 12 and 13, respectively.

Each light unit was housed in a weather-resistant enclosure mounted on a heavy-duty industrial tripod which had extendable, telescoping, tubular legs. The tripod feet were formed by a flattening of the bottom portion of the bottom section of each leg. The flattened section was bent outward to a horizontal position. A long tent-spike driven through a hole in the horizontal section anchored each leg to the ground. All light units

AIRPORT		_ _ _	Identifier
DATE		_ _ _ _ (M M D D)	M=Month, D=Date
TIME		_ _ _ _ (H H M M)	H=Hours (24-Hr. Clock), M=Minutes
CEILING	Height	_ _ _	No. 100's ft. (999 for CAVU)
	Type	_	S=Scattered, B=Broken, Ø=Overcast, X=CAVU
VISIBILITY	Distance	_ _ . _	No. miles (99.9 for CAVU)
	Obstruction	_ _	FG=Fog, HZ=Haze, SM=Smoke, FS=Smog, BS=Blowing Snow, BD=Blowing Dust, XX=None
PRECIPITATION	Type	_ _	DZ=Drizzle, RN=Rain, FR=Freezing Rain, HL=Hail, SL=Light Snow, SH=Heavy Snow, XX=None
ALTIMETER	Reading	_ _ . _ _	No. inches
TEMPERATURE		_ _	Degrees Farenheit
WIND	Speed	_ _	Knots
	Direction	_ _ _	Degrees
	State	_	L=Light, V=Variable, G=Gusts, S=Steady
RUNWAY	Number	_ _	Operating Direction
	Surface	_	D=Dry, W=Wet, I=Icy
	Lights	_	1=Off, Daylight 2=On, Daylight 3=On, Twilight/Dark 4=On, Dark

FIGURE 10

INPUT FORM - WEATHER AND RUNWAY CONDITION DATA

```
?WX
DEN,0527,1807,050,X,05.0,XX,XX,29.92,82,15,300,S,26,D,1
?GO
```

Time of Operation	Sequence Number (Total Operations)	Aircraft Type	Mode of Operation (T=Takeoff, L=Landing, N=Normal, R=Reverse)	Touchdown or Rotation Distance	Aircraft Centerline Offset (L=Left Offset) (R=Right Offset)	Aircraft Speed (Feet/Sec.)	Data Quality Index	Sequence Number (By Aircraft Type)
18:26:14	00038	7272	LN	02614.500	00009.055 R	00205.651	Q 0001	00004
18:29:00	00039	7272	LN	01494.000	00007.612 L	00181.664	Q 0001	00005
18:31:26	00040	*ND*	LN	01494.000	00010.945 L	00073.206	Q 1001	00009
18:37:13	00041	DC10	TN	05452.000	00006.974 R	00227.472	Q 0001	00004
18:40:22	00042	7200	LN	01494.000	00008.884 L	00173.023	Q 1000	00002
18:42:08	00043	7272	LN	01494.000	00001.824 L	00187.086	Q 1001	00006
18:43:41	00044	DC84	LN	01494.000	00008.762 L	00077.095	Q 1100	00001
18:45:42	00045	7370	LN	01494.000	00013.273 L	00202.654	Q 0001	00005
18:47:19	00046	DC10	LN	01494.000	00001.647 L	00178.130	Q 0000	00005
18:51:47	00047	7271	LN	01494.000	00024.882 L	00185.218	Q 0000	00007
18:55:08	00048	DC91	LN	00497.000	00000.118 L	00142.858	Q 0000	00001
18:56:50	00049	7370	LN	02614.500	00012.514 L	00206.538	Q 0000	00006

FIGURE 11

SAMPLE OF ABBREVIATED FIELD LISTINGS

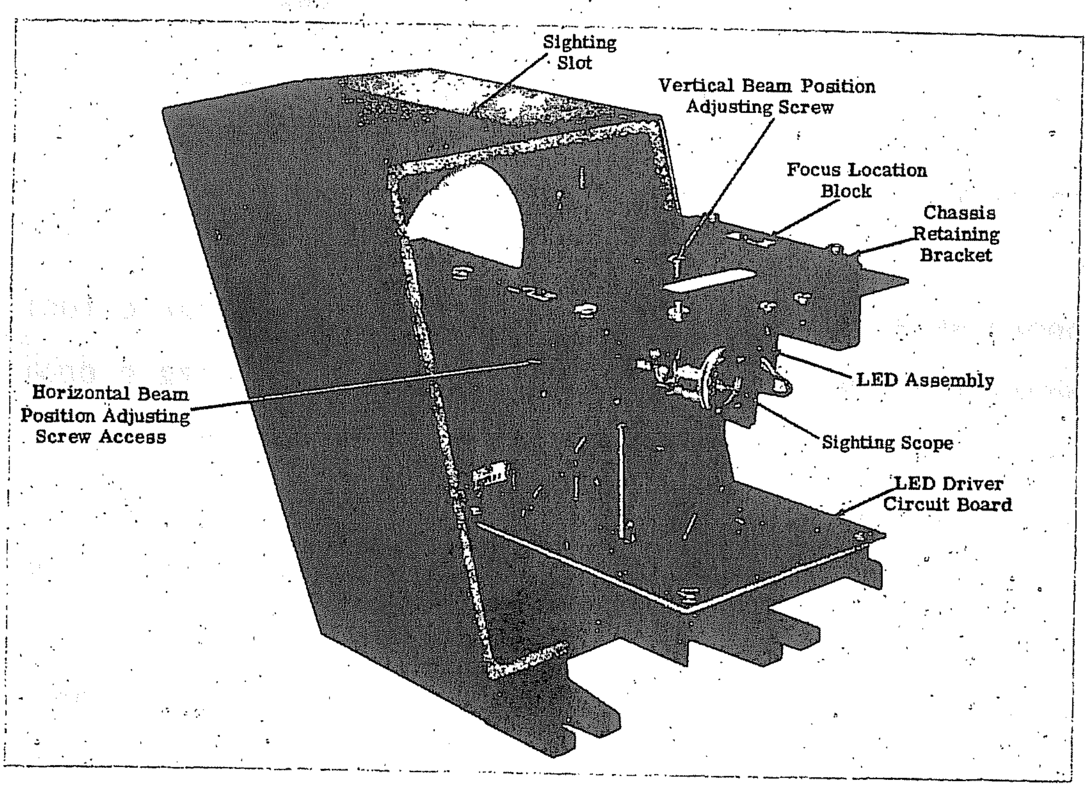


FIGURE 12
A LIGHT TRANSMITTER (REAR OF HOUSING REMOVED)

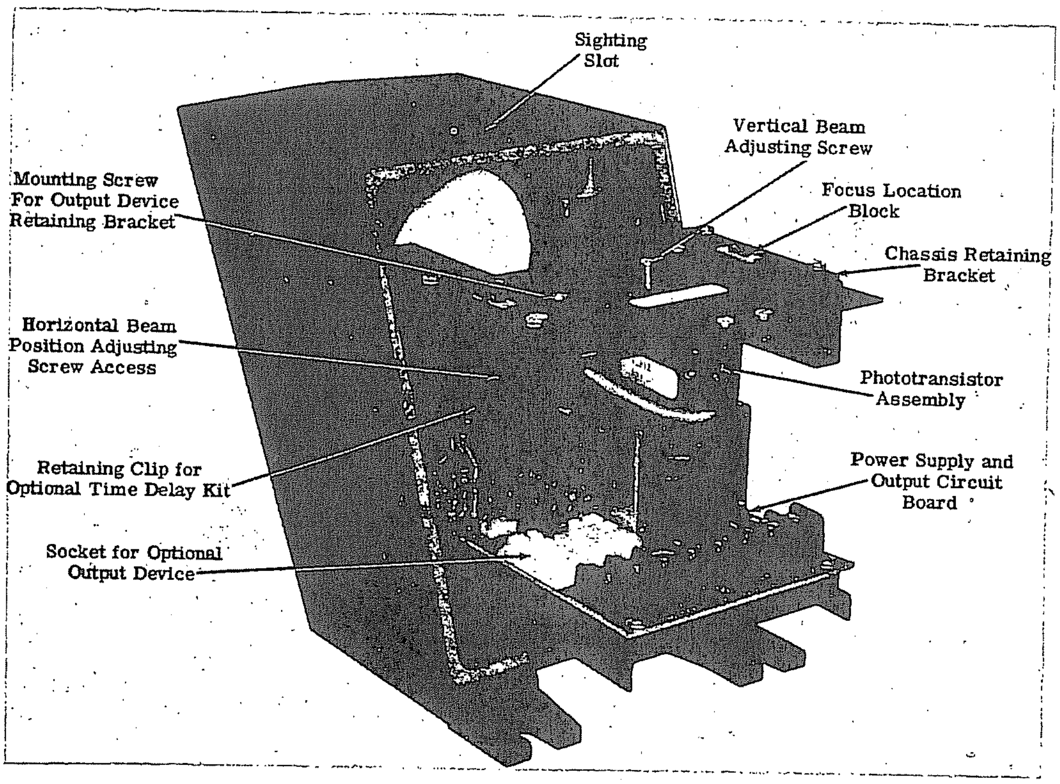


FIGURE 13
A LIGHT RECEIVER (REAR OF HOUSING REMOVED)

were located in unpaved areas to facilitate this method of anchorage.

Each tripod was also secured by a chain-and-turnbuckle arrangement, as shown in Figure 14. The turnbuckle, which was partially inserted into the bottom portion of the vertical tubular post in the tripod head, was attached to the post by a pin passed through the post and the inserted end of the turnbuckle. The chain was attached at its lower end to a corkscrew-type anchor turned into the ground directly beneath the tripod head and was hooked to the free end of the turnbuckle at its upper end. The chain was tensioned through the turnbuckle.

The tripod heads could be rotated about three axes and could be raised or lowered vertically by small amounts without adjusting the legs. These features of the tripod permitted rapid alignment of the light units.

Set-up time for the arrays was reduced by presetting the length of the tripod legs so that, when opened to their full spread at their respective locations, the projected beams from the mounted light units were at the approximately required height above the pavement.

A sighting-groove for preliminary alignment was located on the top of each light-unit housing, and a two-axis (vertical and horizontal) vernier-screw adjustment for fine alignment was located internally. Use of the internal screw adjustment, however, required removal of the rear portion of the housing, which took some time. Since the amount of set-up time permitted on an airfield at close proximity to an active pavement was generally restricted, and often required a temporary closure of the pavement to aircraft traffic, a faster alignment procedure was devised.

This procedure utilized sighting telescopes (see Figure 15) placed in the sighting grooves of the transmitter and receiver units being aligned to obtain a rough alignment. Final alignment was then made by replacing the telescope at the receiver unit with a lantern containing a specially-designed circuit, and by temporarily connecting it to the receiver (see Figure 16).

If the units were within alignment, the lantern would light up. If not, usually a small angular turn of the transmitter, in the horizontal and/or

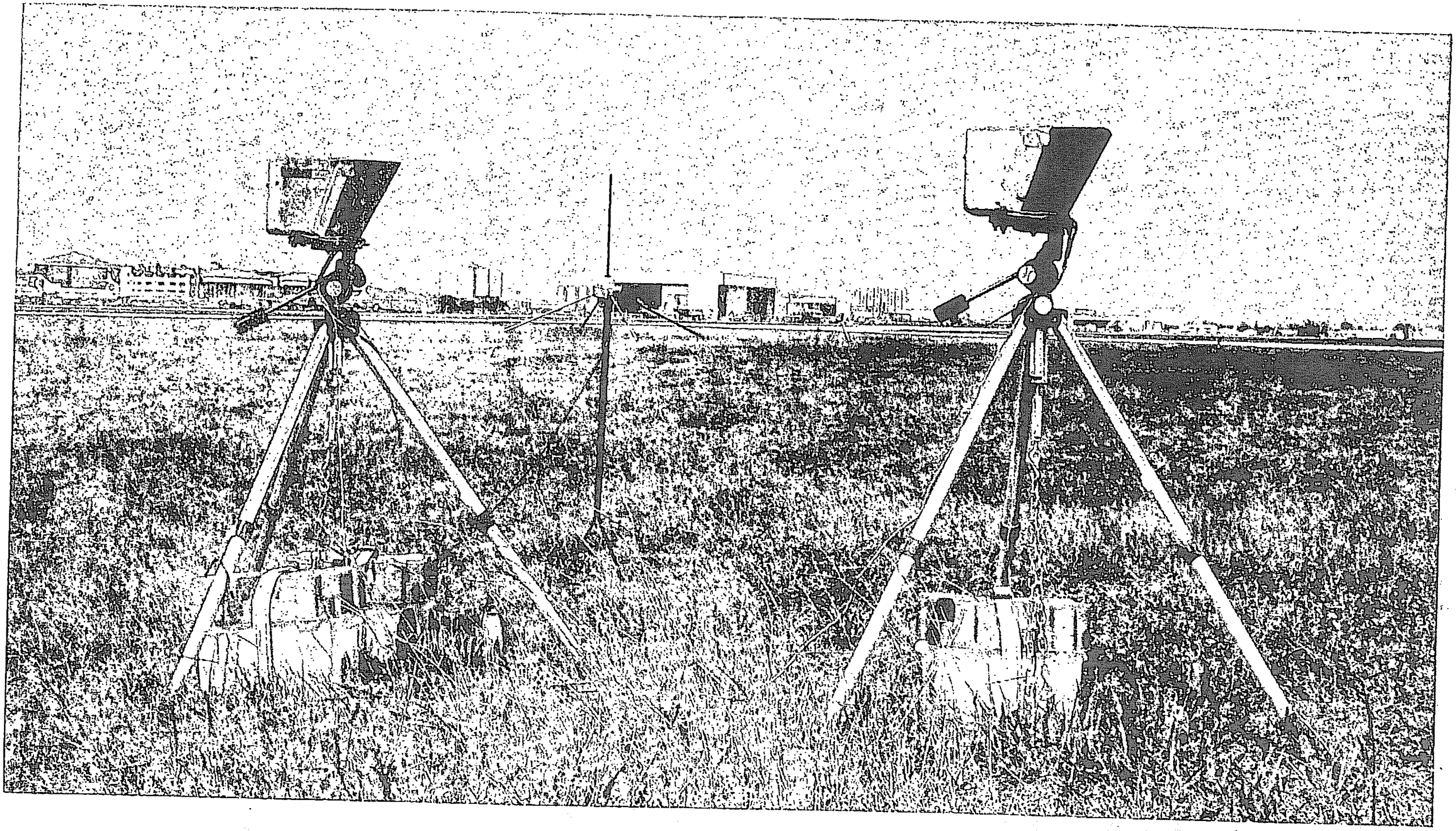


FIGURE 14

LIGHT UNITS ON TRIPOD SUPPORT

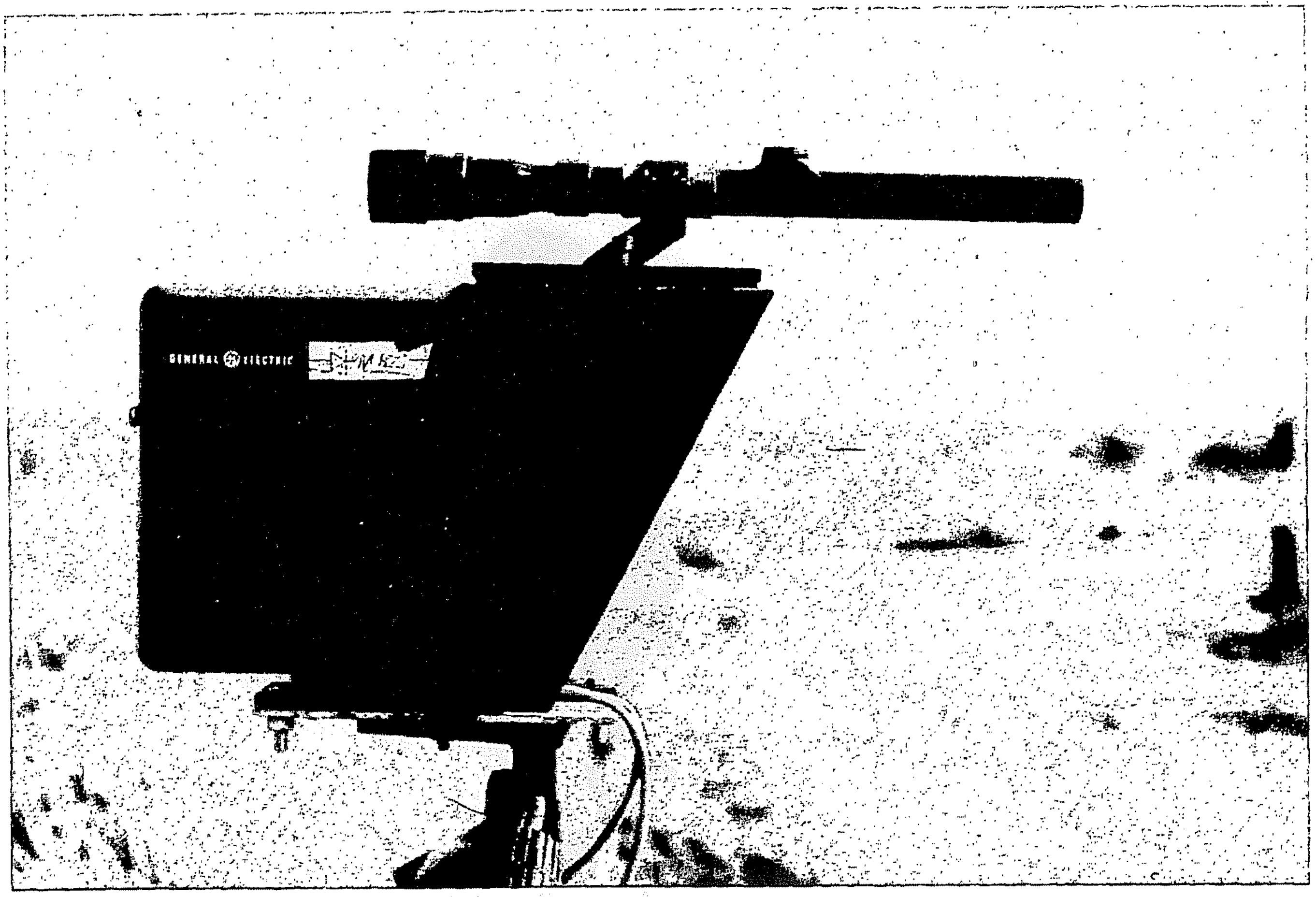


FIGURE 15

TELESCOPE FOR INITIAL ALIGNMENT

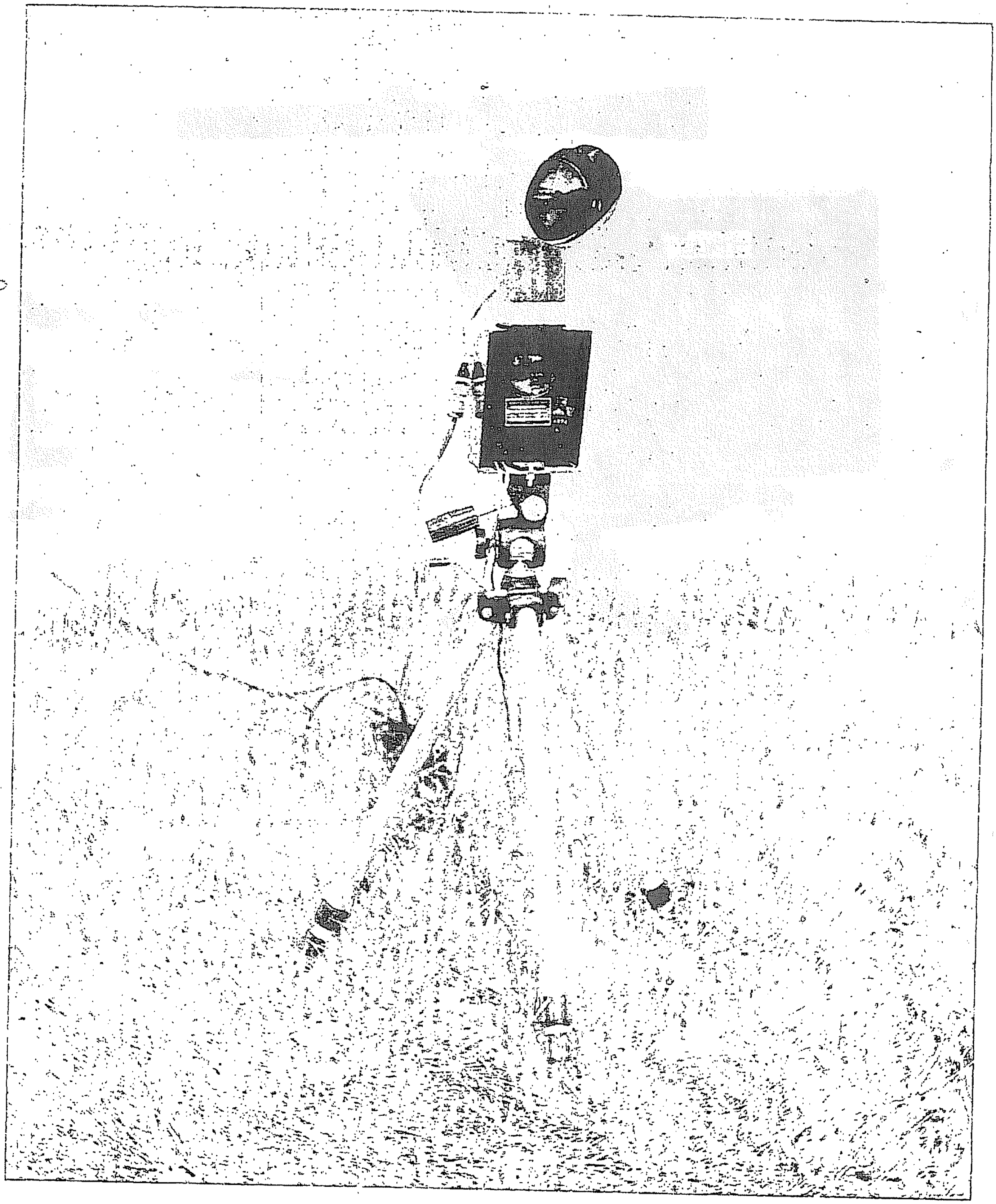


FIGURE 16

LANTERN FOR FINAL ALIGNMENT

vertical planes, would bring the units into alignment. The alignment was optimized by panning horizontally and vertically to determine the width and height of the beam spot, then by centering within those limits.

The maximum rated operating range of the light units was 1,000 feet, and less in adverse weather such as rain, snow, or fog. The rated ambient operating temperature range was -25°F to 122°F. The beam spot diameter was rated at 12.5 inches at 200 feet, 25 inches at 400 feet, and 60 inches at 1,000 feet.

The minimum pulse-duration required to energize the output device in the light receivers was 5 milliseconds. The hold time was adjustable between 0.02 and 0.5 seconds; and the reset time, after the output circuit was de-energized, was 0.01 seconds.

Array Layouts - All arrays were staked relative to the centerline of the painted pavement "centerline" stripe or guideline, which was established at each array location at the time of staking. Aircraft-centerline lateral offsets at the "N" arrays were therefore computed relative to such locally established lines.

This stake-out procedure was adopted on the premise that the painted "centerline" on runway pavements was used by aircraft as the operational reference, and on the assumption that the center of the painted line was coincident with the theoretical or true centerline of the runway pavements. Where runway "centerline" lights existed, their location relative to the painted line was determined in each case, so that if they were in use, possibly as the aircraft operational reference, their effect could be taken into account in the lateral offsets obtained for that condition.

The geometry of the "N" arrays was constrained by the operational range and the physical installation requirements of the light units, and by the functional requirements of the arrays. The functional requirements, however, were such that the light units were placed well within their operational range but far enough beyond the pavement so that they would neither obstruct aircraft traffic nor be affected by aircraft jet blast.

The angle of the diagonal beam in the "N" arrays was such that it passed between the left and right main-landing-gear assemblies of all the aircraft types of interest. In addition, the distance along the aircraft's line of travel, between either of the two parallel beams and the diagonal beam of the "N," was such that, for the various combinations of possible operational speeds and wheelbase dimens-ions, the signals generated by all the wheels (nose and main gears) of an aircraft crossing one beam of the array would arrive at the telemetry receiver before the arrival of the signal generated by the first wheel crossing the next beam in the array. This latter requirement, therefore, established the distance between the parallel elements and, consequently, the locations of the apexes of the "N."

On runways, the requirements to determine (a) the location of touchdown and rotation points to within 500 feet of actual and (b) the lateral distributions at the previously mentioned locations, combined with the known occurrence of most touchdowns within 2,000 feet from the landing end and of most rotations between 3,000 and 7,000 feet from the start of takeoff roll, led to the spacing of runway arrays at distances of no more than 1,000 feet along the full length of most runways. In order to provide the capability of recording operations in both directions of a runway (and thereby to maximize the amounts of data), the arrays were, to the extent practicable, symmetrically located relative to the runway ends.

The selection of a runway for instrumentation at each airport was based on a variety of factors, some of which were peculiar to the individual airport. The general criteria, however, included: the most frequently used runway, particularly about the time of data collection; use by both landings and takeoffs; use by as many aircraft of interest as possible, especially wide-body aircraft; accessibility for equipment installation and maintenance by field personnel, with minimal or no interference to normal aircraft operations; feasibility of temporary closure without undue disruption of airport traffic flow; and concurrence of airport management.

Taxiway- and runway-exit locations were usually selected in the general proximity of the selected runway, so that all arrays were within the telemetry line-of-sight requirement and the operational range. This practice also facilitated the installation and maintenance of the field units.

The instrumentation layouts along the selected runway and taxiway points at each airport are shown in Figures 17 to 25. Pertinent runway features are also noted in those figures. A summary of the distances from each runway end to each transverse light element is given in Figure 26.

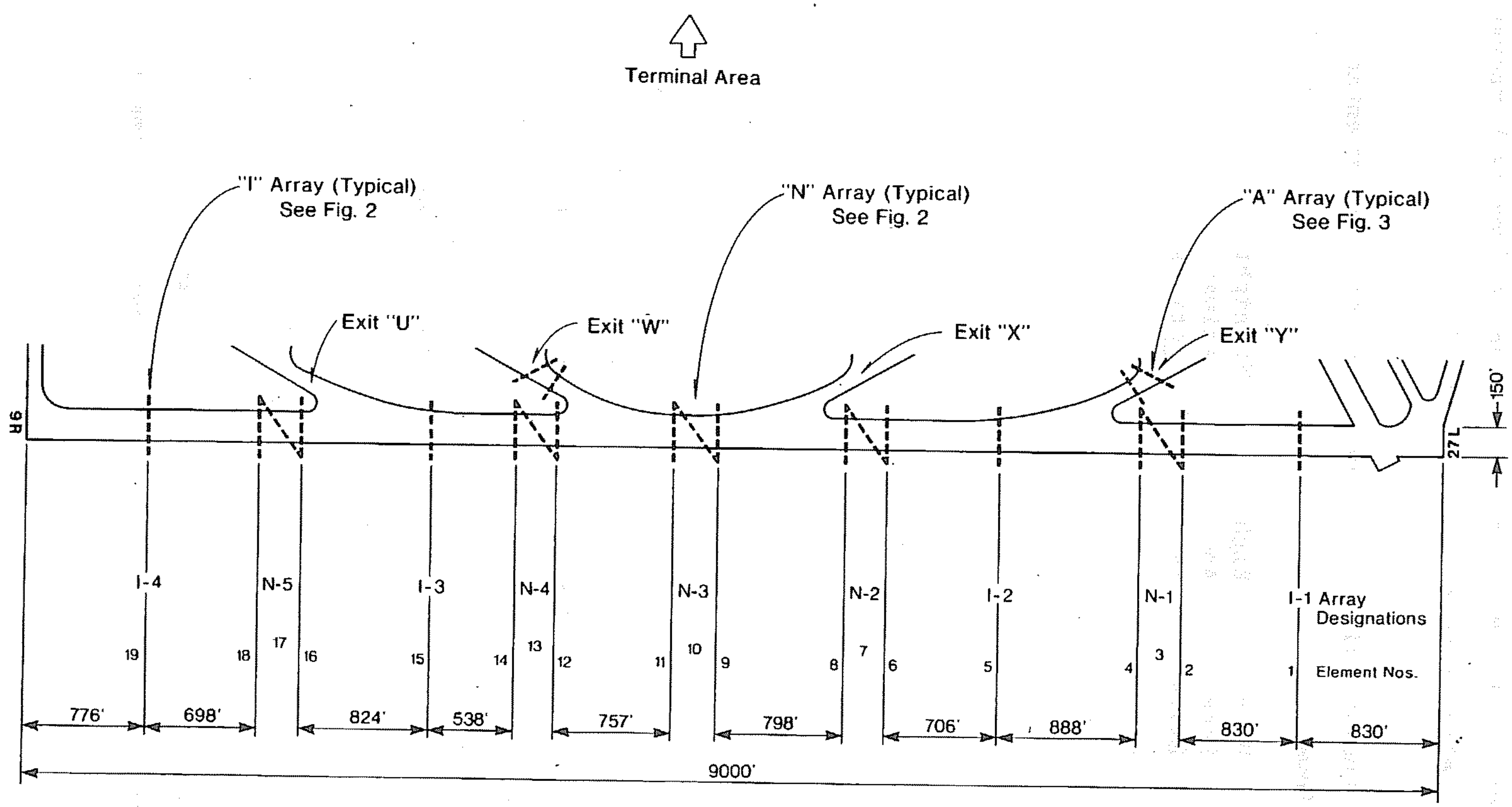
The number and types of runway-exit and taxiway locations instrumented at each airport were as follows:

Airport	High-Speed Exits	Right-Angled Exits	Straight Taxiway Sections
ATL	2	-	-
ORD	2	-	-
DEN	2	-	-
SEA	1	-	1
CLE	-	-	2
BUF	-	1	1
MIA	1	-	1
MSY	-	1	1
DFW	1	-	1

Modified "N" Arrays - ATL and ORD were the first two airports visited in the data collection program. Two high-speed exits were chosen for instrumentation at each of those airports. The exits were located between the runway and a parallel taxiway in each case (see Figures 17 and 18). The limited distance between runway and parallel taxiway, combined with the relatively flat angle of the selected exits, did not allow placement of "N" arrays as configured in Figure 3.

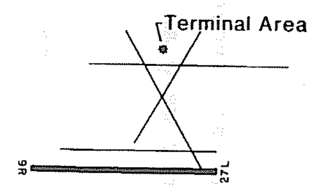
A modification, therefore, was made to the standard "N" configuration. The modification was basically a transposition of one of the transverse elements of the "N" to the opposite side of the "N," as shown in Figure 3. This modified array, designated an "A" array, was functionally the same as the standard "N" array.

Each "A" or "N" array placed at runway-exit and taxiway locations was intended to perform independently of the other arrays in the system, in that



RUNWAY NOTES.

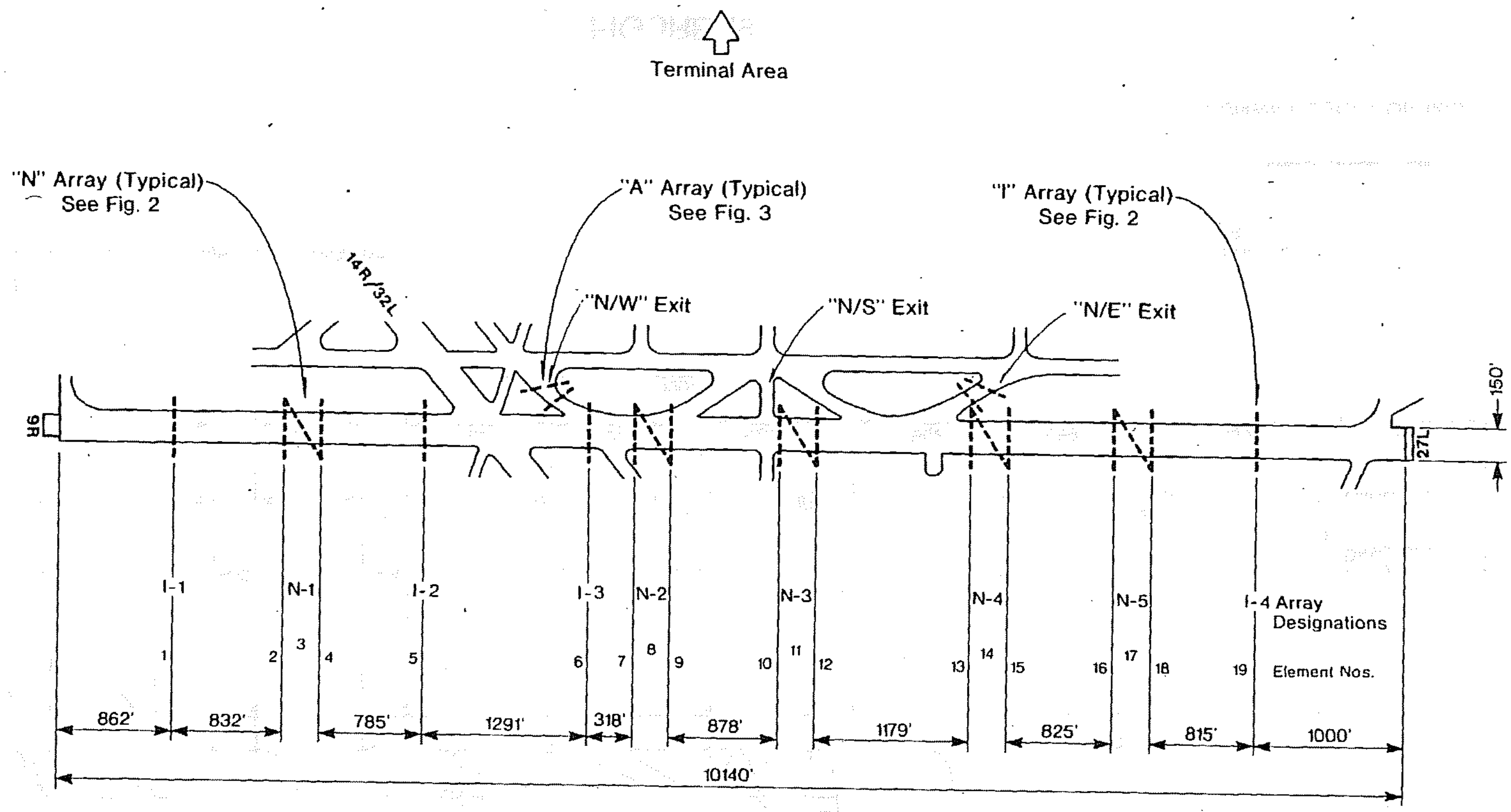
ILS 9R and 27L; Centerline Lights 2' Right of 9R Pavement Centerline; Approach Lights 9R.



RUNWAY LOCATION MAP

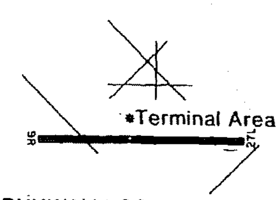
FIGURE 17

ATL INSTRUMENTATION LAYOUT



RUNWAY NOTES

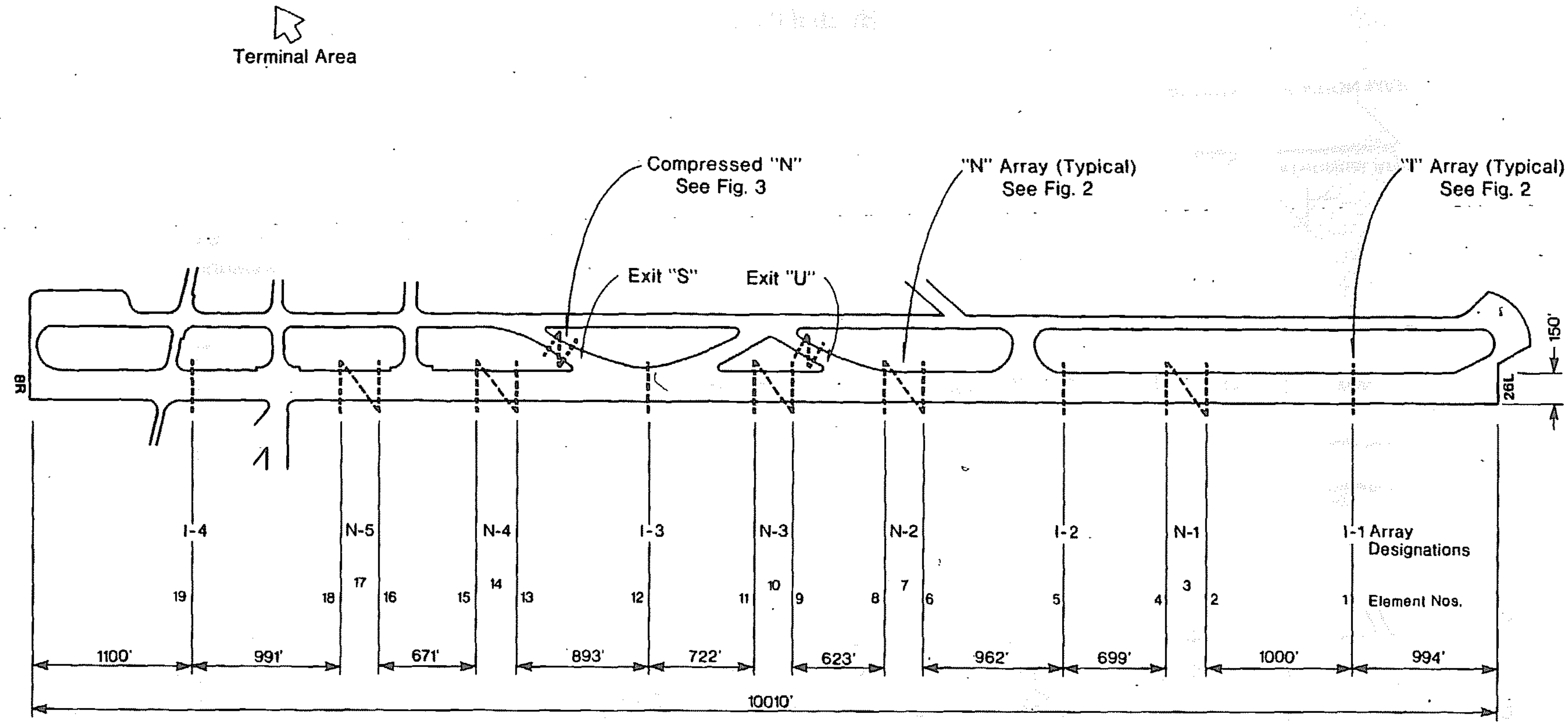
ILS, Approach Lights and VASI 9R and 27L.



RUNWAY LOCATION MAP

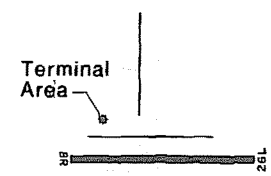
FIGURE 18

ORD INSTRUMENTATION LAYOUT



RUNWAY NOTES

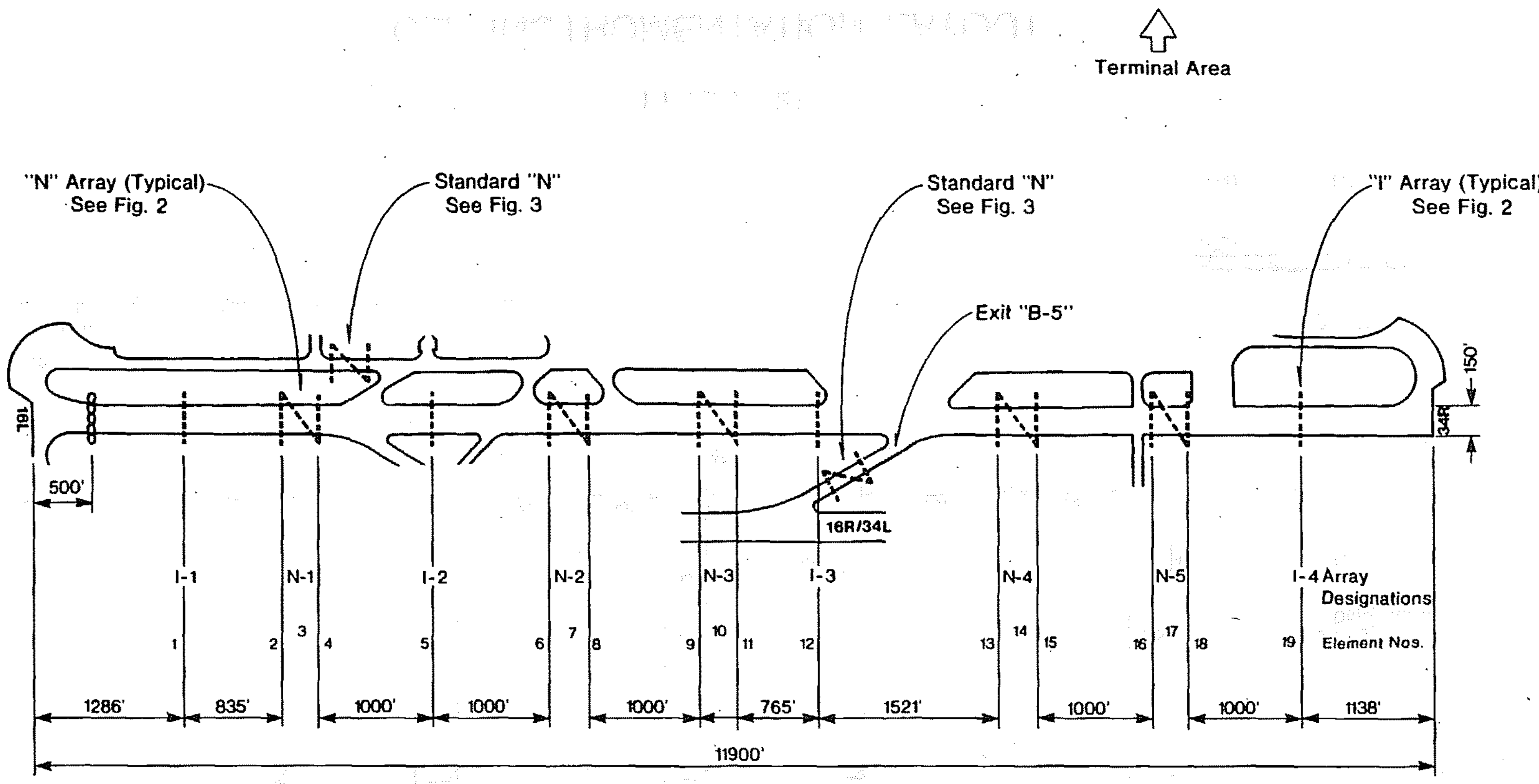
ILS 26L; Loc. BC 8R; Approach Lights 26L; VASI 8R.



RUNWAY LOCATION MAP

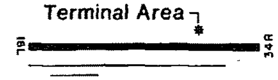
FIGURE 19

DEN INSTRUMENTATION LAYOUT



RUNWAY NOTES

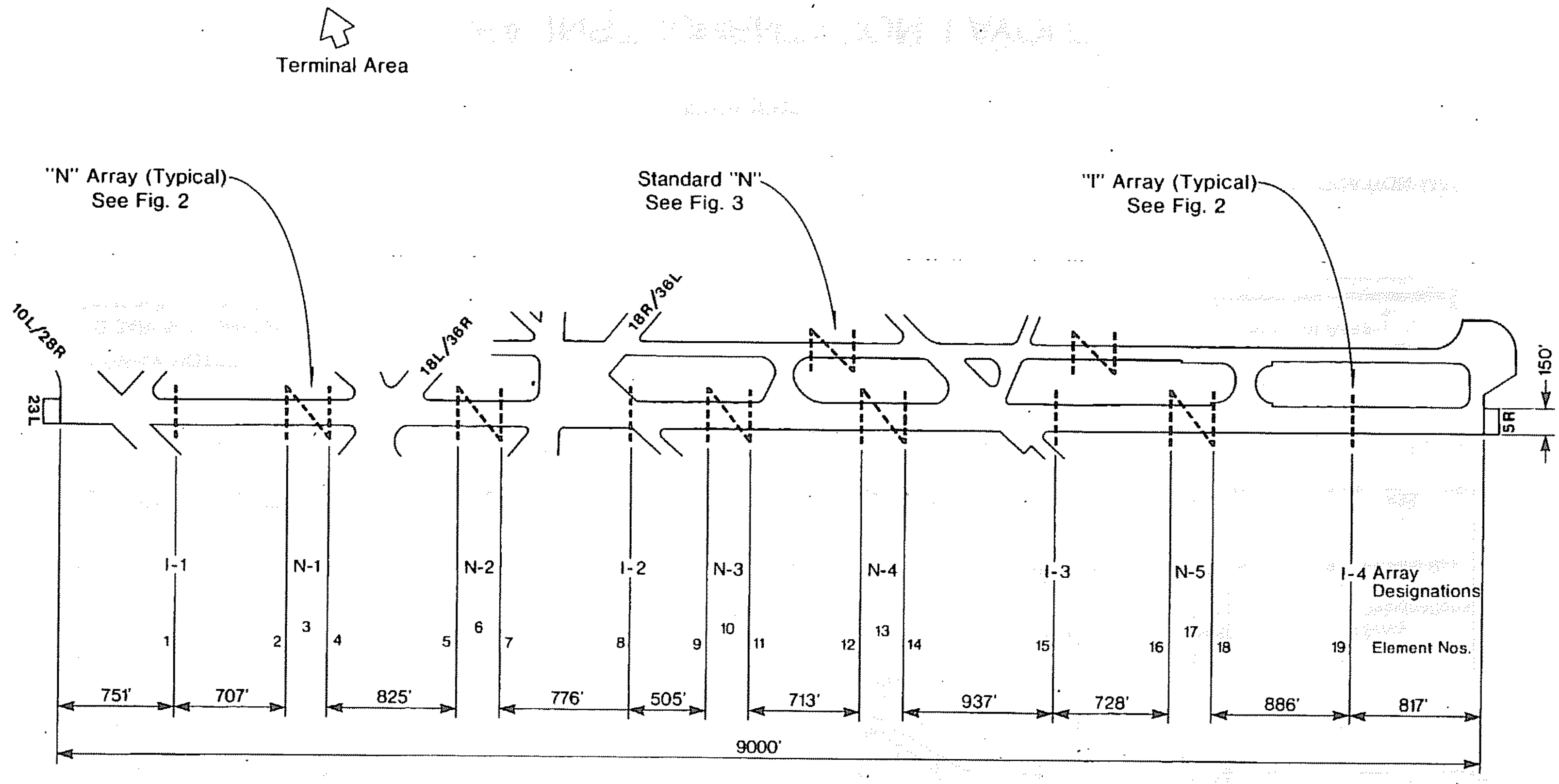
ILS 34R; 500' Displaced Threshold 16L;
Approach Lights 34R.



RUNWAY LOCATION MAP

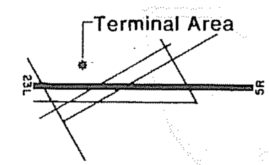
FIGURE 20

SEA INSTRUMENTATION LAYOUT



RUNWAY NOTES

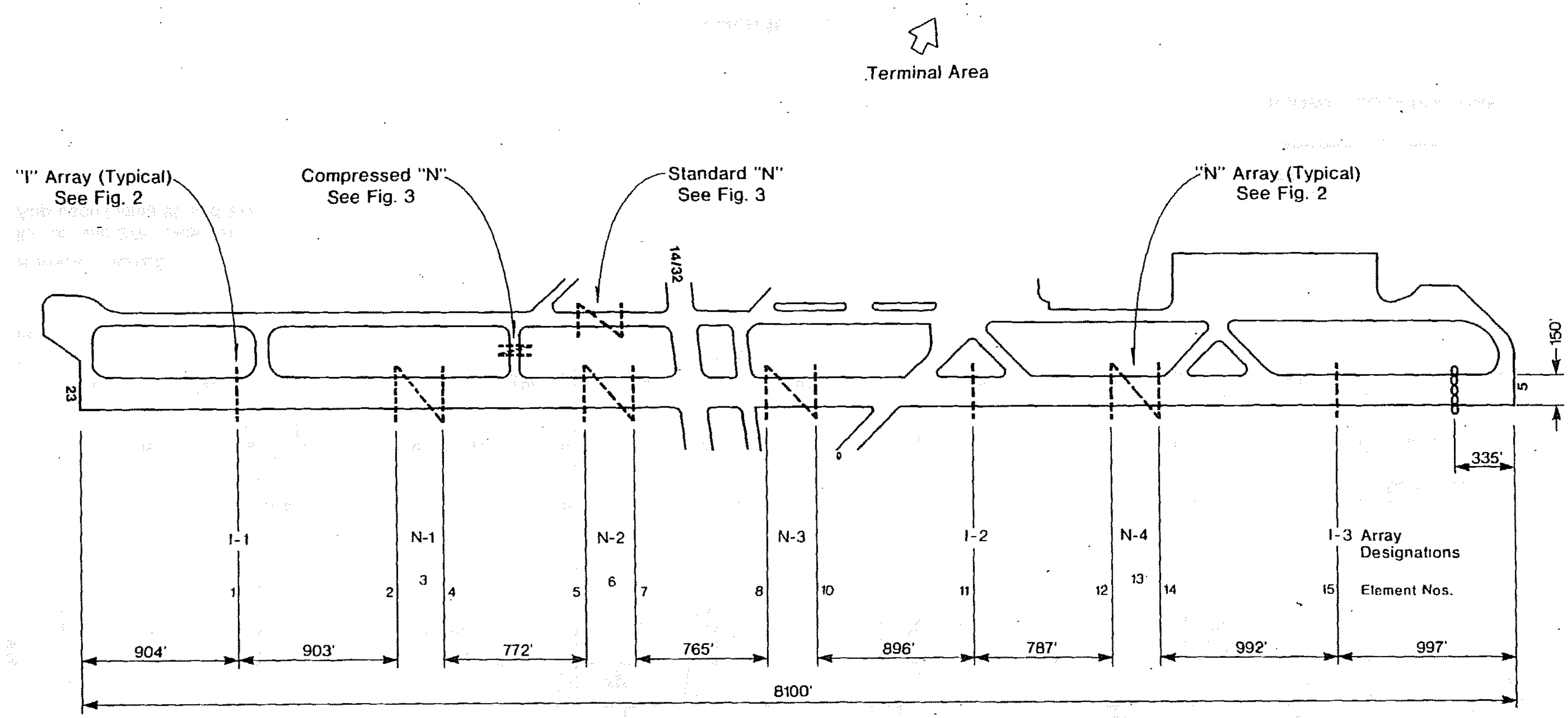
ILS 5R and 23L; VASI 23L; Approach Lights 5R;
Centerline Lights (5R Only) 2' Left of Pavement Centerline.



RUNWAY LOCATION MAP

FIGURE 21

CLE INSTRUMENTATION LAYOUT



RUNWAY NOTES

ILS 5 and 23; Approach Lights 5 and 23;
Centerline Lights 1.5' Left of Rwy. 5 Pavement
Centerline; 335' Displaced Threshold Rwy. 5

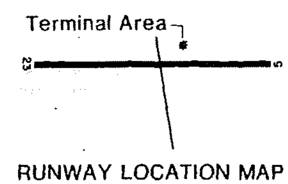
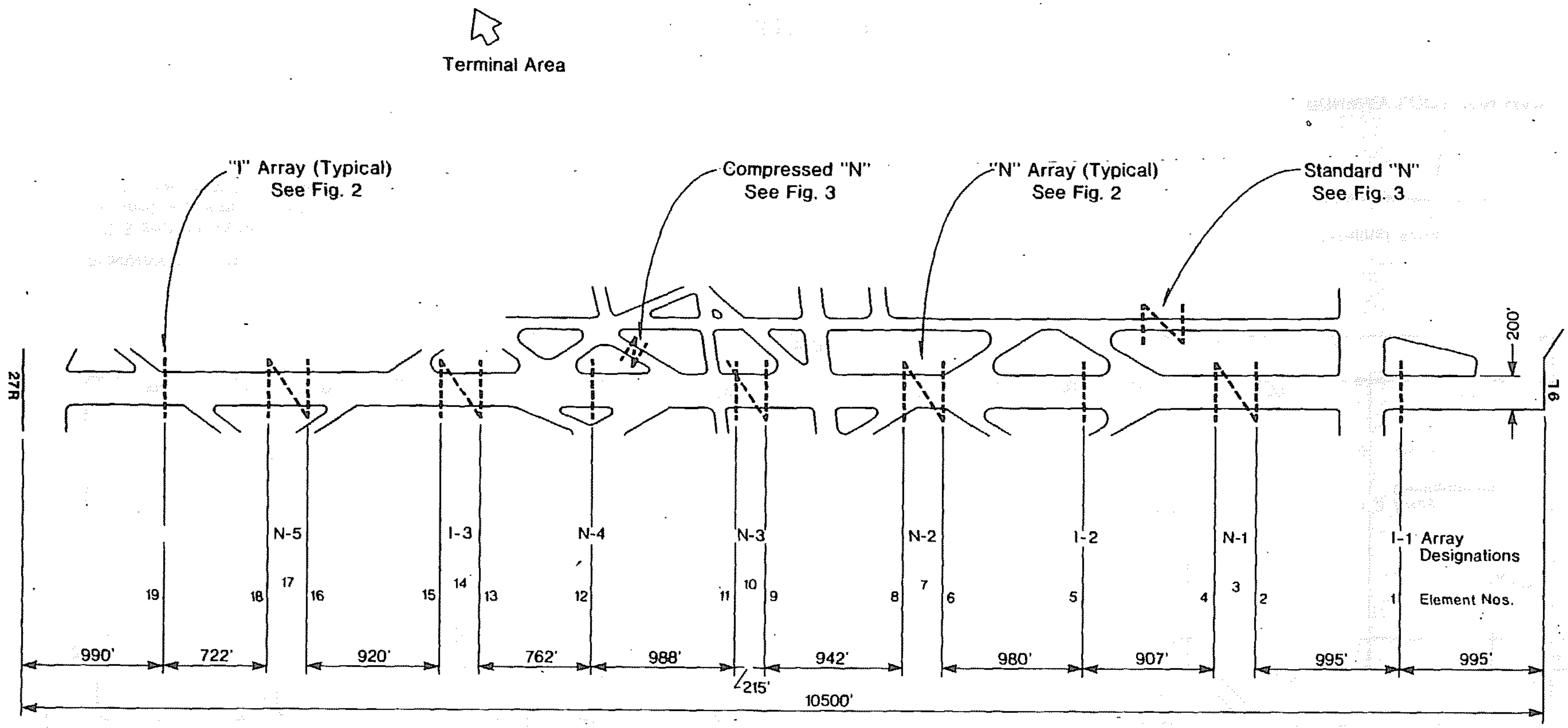


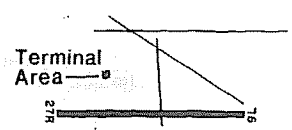
FIGURE 22

BUF INSTRUMENTATION LAYOUT



RUNWAY NOTES

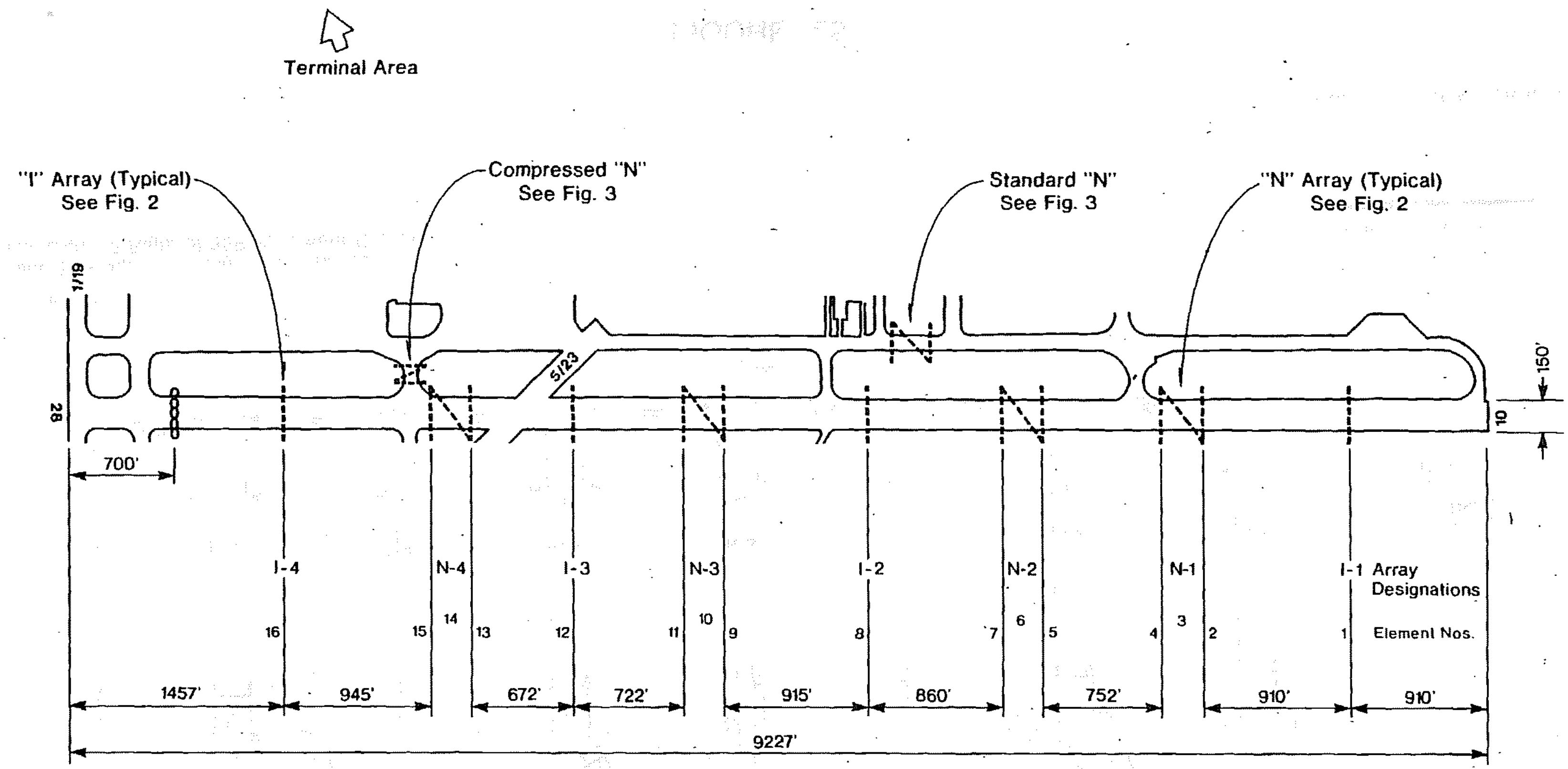
ILS 9L and 27R; VASI 27R;
Approach Lights 9L and 27R.



RUNWAY LOCATION MAP

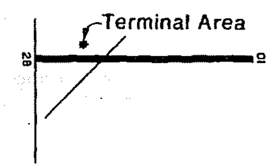
FIGURE 23

MIA INSTRUMENTATION LAYOUT



RUNWAY NOTES

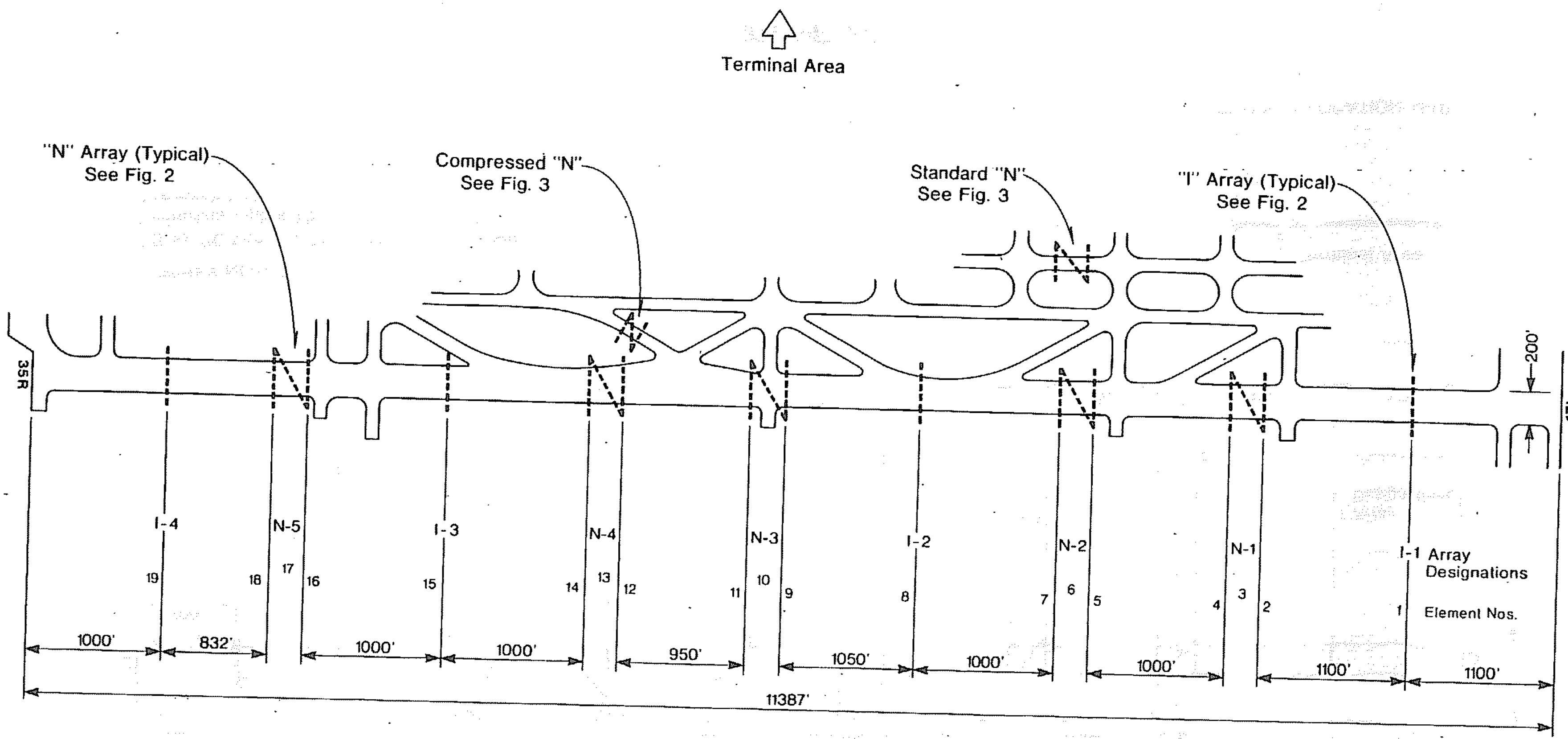
ILS 10; BC Loc. 28; 700' Displaced Threshold 28;
Centerline Lights 1.5' Left of Rwy. 10 Pavement Centerline;
Approach Lights 10.



RUNWAY LOCATION MAP

FIGURE 24

MSY INSTRUMENTATION LAYOUT



RUNWAY NOTES

ILS 17L and 35R; Approach Lights 17L and 35R;
Centerline Lights 2 Right of 35R Pavement Centerline

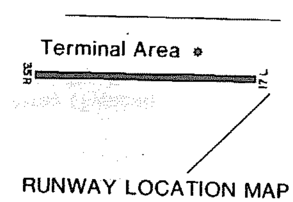


FIGURE 25

DFW INSTRUMENTATION LAYOUT

AIRPORT	RUNWAY	LIGHT ELEMENT NOS. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ATL	9R	8170	7340	N1*	7069	6181	5475	N2*	5204	4406	N3*	4135	3378	N4*	3107	2569	1745	N5*	1474	776
	27L	830	1660		1931	2819	3525		3796	4594		4865	5622		5893	6431	7255		7526	8224
ORD	9R	862	1694	N1*	1965	2750	4041	4359	N2*	4630	5508	N3*	5779	6958	N4*	7229	8054	N5*	8325	9140
	27L	9278	8446		8175	7390	6099	5781		5510	4632		4361	3182		2911	2086		1815	1000
DEN	8R	9016	8016	N1*	7745	7046	6084	N2*	5813	5190	N3*	4919	4197	3304	N4*	3033	2362	N5*	2091	1100
	26L	994	1994		2265	2964	3926		4197	4820		5091	5813	6705		6977	7648		7919	8910
SEA	16L	1286	2121	N1*	2392	3392	4392	N2*	4663	5663	N3*	5934	6699	8220	N4*	8491	9491	N5*	9762	10762
	34R	10614	9779		9508	8508	7508		7237	6237		5966	5201	3580		3409	2409		2138	1138
CLE	5R	8249	7542	N1*	7271	6446	N2*	6175	5399	4894	N3*	4623	3910	N4*	3639	2702	1974	N5*	1703	817
	23L	751	1458		1729	2554		2825	3601	4106		4377	5090		5361	6298	7026		7297	8183
BUF	5	7198	6295	N1*	6024	5252	N2*	4981	4216	N3*	3945	3049	2262	N4*	1991	999				
	23	904	1807		2078	2850		3121	3886		4157	5053	5840		6111	7103				
MIA	9L	995	1990	N1*	2261	3168	4148	N2*	4419	5361	N3*	5576	6564	7326	N4*	7597	8517	N5*	8788	9510
	27R	9505	8510		8239	7332	6352		6091	5139		4924	3936	3174		2903	1983		1712	990
MSY	10	910	1820	N1*	2091	2843	N2*	3114	3974	4889	N3*	5160	5882	6554	N4*	6825	7770			
	28	8317	7407		7136	6384		6113	5253	4338		4067	3345	2673		2402	1457			
DFW	17L	1100	2200	N1*	2471	3471	N2*	3742	4742	5792	N3*	6063	7013	N4*	7284	8284	9284	N5*	9555	10387
	35R	10287	9187		8916	7916		7645	6645	5595		5324	4374		4103	3103	2103		1832	1000

*See Figures 17 to 25

FIGURE 26
DISTANCES FROM RUNWAY ENDS TO TRANSVERSE LIGHT-ELEMENTS

the information obtained at each such array would alone be adequate to identify correctly an aircraft and calculate its lateral position and speed at that array. This objective was readily achieved on straight sections of taxiways.

At the ATL and ORD high-speed exits (with the "A" arrays), however, an occasional aircraft of interest would be incorrectly identified or it could not be identified. From visual observations at those locations, the probable causes appeared to be one or more of the following: (a) an erratic aircraft speed across the array; (b) a non-parallel or non-linear line of travel across the array; and (c) a relatively long distance along the line of travel between the transverse and diagonal elements, which aggravated the effects of the preceding two factors. The last was the only one of the three causes that could be dealt with readily. To obtain a reduction in travel distance across the array, the Compressed "N" array shown in Figure 3 was introduced.

Functionally, the Compressed "N" array differed some from the standard "N" array, in that it was used only: (a) at exits from a runway which had also been instrumented; and (b) to determine lateral offsets only. Aircraft identities were obtained from the runway arrays, based on the operational logic that only the immediately preceding landing on the instrumented runway would use the exit where a Compressed "N" array had been placed.

Mis-identified aircraft in the samples collected for the high-speed exits at ATL and ORD were isolated using the above operational logic. Each aircraft identity at the "A" arrays was compared with the aircraft identity of the immediately-preceding runway operation, which necessarily had to be a landing. If those identities were in agreement, the compared "A"-array operation was retained in the sample and the calculated lateral offset for that operation was accepted. If the identities were different, the compared "A"-array operation was eliminated from the sample, since the corresponding lateral offset would be questionable.

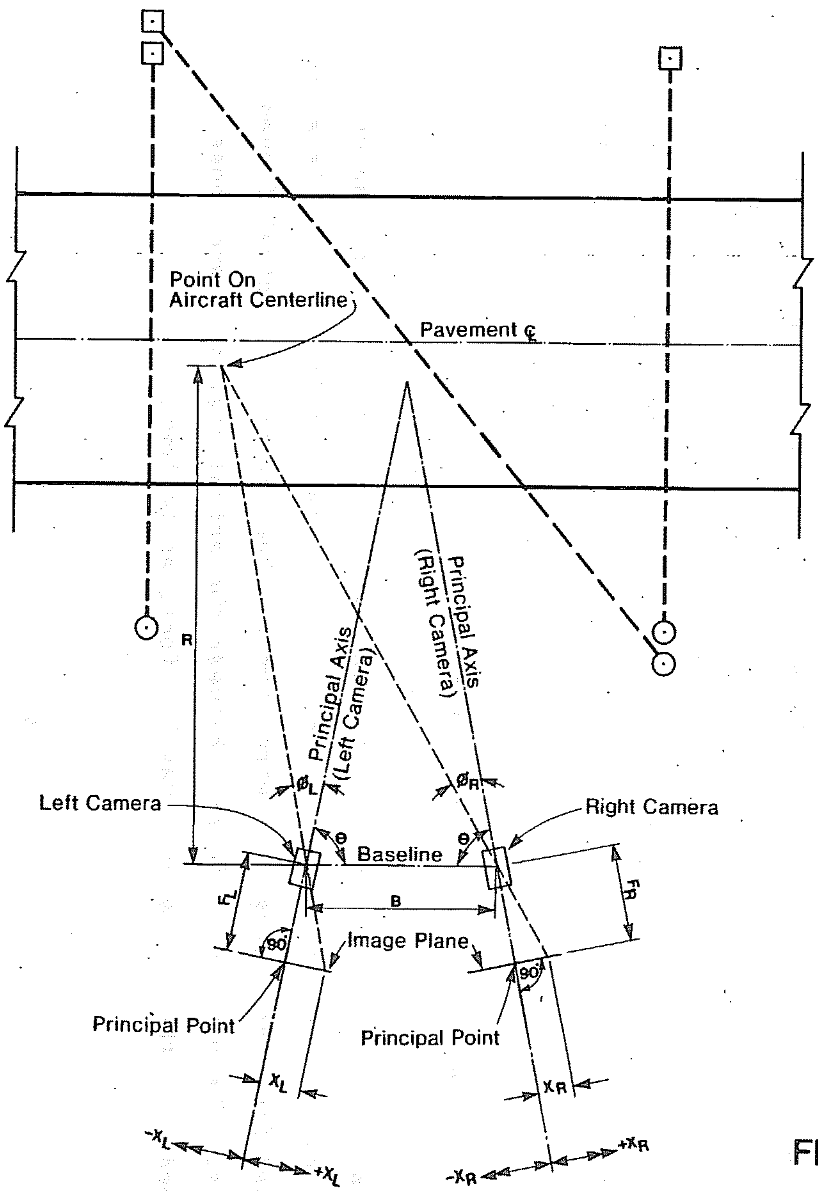
System Verification - The capability of the data-collection system to determine aircraft lateral offsets within the prescribed accuracy was verified using a photographic technique. Since the lateral offsets were based on aircraft speeds, verification of the calculated offsets implicitly verified the corresponding speeds.

The verification technique employed two synchronized 100-mm, high-speed, high-precision cameras to obtain sequenced, overlapping pairs of photographs of aircraft passing through an "N" array. The cameras were placed off to one side of the "N" array, as shown in Figure 27, and were positioned a known distance apart along a baseline that had been established at a known distance parallel to the pavement centerline. Both cameras were aimed toward the "N" array and were angled a known amount toward each other to obtain the required overlap in the respective camera images.

As an aircraft passed through the "N" array, both cameras were simultaneously activated to obtain a coordinated sequence of photographs of the aircraft. (A part of one such sequence is shown in Figure 28.) At the same time, the data-collection system detected, processed, and recorded the photographed operation.

A matching frame from each camera sequence was then selected and, using the fiducial marks along the sides of the frames, the center (principal point) of each frame was established. A point on the aircraft's centerline (the nose-gear strut, for example) was selected. The horizontal image-distance between the selected point and the established principal point was then measured very accurately in each frame. These distances, denoted by the subscripted X dimensions in Figure 27, were used in calculating the distance from the camera baseline to the selected point on the aircraft, as also illustrated in Figure 27. The pavement centerline-to-camera baseline distance was subtracted from the calculated distance to obtain the aircraft's lateral offset--which was then compared with that determined by the data-collection system.

Before using the above method to verify the accuracy of the data-collection system, the method itself was verified. This was accomplished by placing a surveyor's range-pole on the pavement at several known distances from the camera baseline and photographing it at each position. The distances determined from the photographs were then checked against the actual (taped) distances. The maximum difference between the actual distances and those determined from the photographs was 0.3 foot, as follows:



Let,

B = Distance between left and right cameras.

Θ = Angular orientation of cameras relative to baseline.

F_L, F_R = Focal length of left and right cameras, respectively.

X_L, X_R = Horizontal image-distance between the principal point and selected point on aircraft in the left and right images, respectively.

$$K_L = \frac{\tan\Theta + \tan\phi_L}{1 - \tan\Theta \tan\phi_L}, \quad \text{where} \quad \tan\phi_L = \frac{X_L}{F_L}$$

$$K_R = \frac{\tan\Theta + \tan\phi_R}{1 + \tan\Theta \tan\phi_R}, \quad \text{where} \quad \tan\phi_R = \frac{X_R}{F_R}$$

Then,

$$R = B\,\frac{K_L\, K_R}{K_L + K_R}$$

FIGURE 27

DATA-COLLECTION SYSTEM VERIFICATION

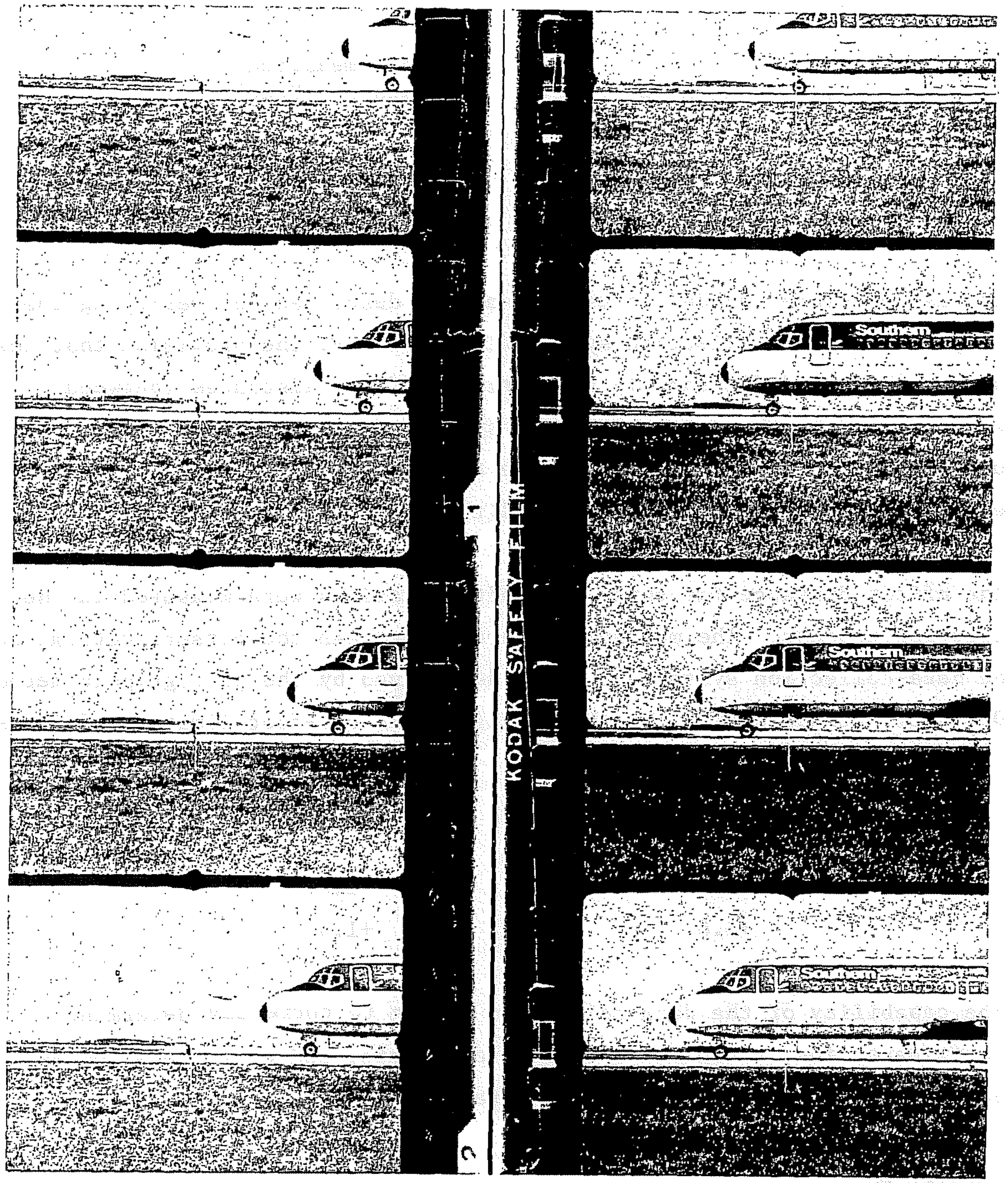


FIGURE 28

PART OF MATCHED VERIFICATION-PHOTO SEQUENCE

Taped Distance (Feet)	Photo-measured Distance (Feet)
270.5	270.2
280.5	280.4
261.5	261.6

It was therefore decided to use the method described for verifying the accuracy of the data-collection system with, however, the provision that the maximum acceptable difference in the aircraft offset distances (between those determined by the data-collection system and those determined by the photographic technique) would be no more than 0.7 foot (the difference between the required system accuracy and the above 0.3 foot).

The offset distance for three aircraft operations were measured in the verification process. The maximum difference between the offsets determined by the data-collection system and those determined by the photographic method was 0.3 foot, compared with the above-established 0.7-foot limit, as follows:

Photo-measured Offset (Feet)	System-measured Offset (Feet)
-0.4	-0.1
+1.7	+2.0
+1.6	+1.4

The capability of the data-collection system to correctly determine aircraft identities, touchdown and rotation points, and operational modes (takeoff, landing, or taxiing) was satisfactorily verified.

Data Collected

The amounts of each type of data collected at each airport for each aircraft type depended on many factors. They included the distribution of the various aircraft types in the fleet mix which used the airport and their frequency of operation on the runways and taxiways instrumented. Prevailing wind directions at the time of data collection and preferential runway usage were also factors affecting the amounts and types of data collected.

Occasional equipment malfunctions also interrupted or interfered with the data collection. At DFW, for example, an undetected malfunction of the magnetic tape unit resulted in improper recording and loss of six days' data.

At BUF and MSY, where the only two right-angled runway exits in the study were instrumented, a combination of very infrequent usage of those exits at the time of data collection and malfunctioning telemetry transmitters (including damage caused by severe lightning storms) resulted in too few observations for meaningful analysis. In addition, most of these were unusable, probably because of the stop-and-go or other erratic nature of the movement of some of the aircraft through such exits (see Figures 22 and 24).

In periods of heavy rainfall, most if not all of the operations on runways had large, extended trailing sprays of water which caused long (time) or additional interruptions of the light-beams. On such occasions, the data-collection system could not distinguish between interruptions caused by aircraft wheels and those caused by the spray. The signals generated by those interruptions were frequently merged into each other. As a result, no useful or interpretable data could be recorded for those operations.

It should therefore be noted that, where usable information for operations on wet runways appear in the recorded data, such operations should be considered to have occurred where there were small amounts of free surface water. As a result, there was probably a minimal amount of hydroplaning during those operations.

The numbers of takeoff, landing, high-speed exit,and straight-taxiway operations recorded at each airport are summarized in Figures 29 to 32.

AIRPORT	RUNWAY	707	727-100	727-200	737	747	DC-8-40 DC-8-50	DC-8-60	DC-9-10 DC-9-20	DC-9-30 DC-9-40	DC-10-10	L-1011	C-580	YS-11	BAC-111	TOTALS
		AIRCRAFT TYPE														
ATL	9R	1	34	54	17	4	5	8	13	95	4	5	3	8	0	251
	27L	8	130	183	53	7	21	22	36	324	9	22	1	18	1	835
ORD	9R	22	39	36	12	9	16	10	4	30	3	3	6	0	0	190
	27L	35	106	77	31	5	14	7	5	84	2	5	6	0	0	377
DEN	8R	16	32	31	28	0	9	3	5	6	12	2	17	0	0	161
	26L	3	16	10	13	0	0	0	1	1	51	0	4	0	0	99
SEA	16L	20	37	29	8	8	4	13	8	5	8	0	3	1	0	144
	34R	14	18	20	2	16	3	7	2	0	3	3	0	0	0	88
CLE	5R	20	53	13	41	0	10	8	2	21	2	0	14	13	23	220
	23L	25	114	33	89	0	15	13	11	36	1	0	17	8	28	390
BUF	5	8	11	3	6	0	1	0	0	14	2	3	7	0	27	82
	23	23	37	20	27	0	3	0	0	59	11	0	27	4	113	324
MIA	9L	28	102	77	3	7	15	3	3	79	2	38	5	1	3	366
	27R	25	78	54	1	2	15	1	2	63	0	17	3	0	1	262
MSY	10	3	22	20	0	0	5	5	21	34	0	0	2	0	0	112
	28	0	31	31	0	0	10	12	19	35	0	1	0	0	2	141
DFW	17L	42	41	45	11	7	12	3	49	55	11	7	29	0	0	312
	34R	0	1	3	0	1	0	0	0	0	0	0	0	0	0	5
	TOTALS	293	902	739	342	66	158	115	181	941	121	106	144	53	198	4359

FIGURE 29

SUMMARY OF RUNWAY OPERATIONS - TAKEOFFS

AIRPORT	RUNWAY	707	727-100	727-200	737	747	DC-8-40 DC-8-50	DC-8-60	DC-9-10 DC-9-20	DC-9-30 DC-9-40	DC-10-10	L-1011	C-580	YS-11	BAC-111	TOTALS
		AIRCRAFT TYPE														
ATL	9R	2	22	59	10	1	14	18	17	93	7	5	2	5	0	255
	27L	18	108	106	25	10	56	37	60	241	15	15	5	15	0	712
ORD	9R	79	128	93	36	14	33	24	7	66	20	10	10	0	0	520
	27L	10	21	23	10	2	3	6	1	29	2	2	10	0	0	119
DEN	8R	9	13	16	17	0	4	3	3	2	9	0	8	0	0	84
	26L	52	136	118	110	0	30	15	18	14	36	1	47	0	0	577
SEA	16L	13	11	10	5	6	5	9	5	3	2	0	1	0	0	70
	34R	57	132	119	25	14	31	31	23	33	31	0	10	0	0	506
CLE	5R	25	101	32	20	1	12	12	6	20	1	0	3	3	14	250
	23L	34	130	35	93	1	12	17	9	26	2	0	15	0	24	398
BUF	5	10	17	6	4	0	2	0	1	21	2	0	6	0	28	97
	23	18	46	24	13	0	2	0	3	57	13	0	21	0	123	320
MIA	9L	63	287	88	4	2	19	2	7	98	2	21	5	0	2	600
	27R	7	67	30	0	3	7	4	0	54	1	13	2	0	0	188
MSY	10	4	34	34	0	0	9	18	30	59	1	1	5	0	2	197
	28	0	17	23	0	0	8	7	11	35	1	1	3	0	1	107
DFW	17L	33	24	20	2	6	15	6	24	26	3	6	9	0	1	175
	34R	5	5	4	1	1	0	1	1	3	1	1	2	0	0	25
	TOTALS	439	1299	840	376	61	262	210	226	880	149	76	164	23	195	5200

FIGURE 30

SUMMARY OF RUNWAY OPERATIONS - LANDINGS

AIRPORT	EXIT	707	727-100	727-200	737	747	DC-8-40 DC-8-50	DC-8-60	DC-9-10 DC-9-20	DC-9-30 DC-9-40	DC-10-10	L-1011	C-580	YS-11	BAC-111	TOTALS
		AIRCRAFT TYPE														
ATL	W	1	37	40	20	0	9	1	36	169	5	2	0	11	3	334
	Y	1	9	20	3	2	4	0	9	37	1	0	0	1	1	88
ORD	NE	21	19	33	3	2	5	8	1	6	5	5	0	0	1	109
	NW	3	0	0	0	1	0	0	0	0	0	0	0	0	0	4
DEN	U	0	3	1	4	0	0	0	0	0	0	0	2	0	0	10
	S	1	40	12	29	0	0	0	6	7	3	0	14	0	0	112
SEA	B-5	0	6	3	0	0	2	0	0	0	0	0	0	0	0	11
DFW	(See Fig. 25)	6	3	9	0	0	2	0	1	5	1	2	0	0	0	29
	TOTALS	33	117	118	59	5	22	9	53	224	15	9	16	12	5	697

FIGURE 31

SUMMARY OF HIGH-SPEED-EXIT OPERATIONS

AIRPORT	707	727-100	727-200	737	747	DC-8-40 DC-8-50	DC-8-60	DC-9-10 DC-9-20	DC-9-30 DC-9-40	DC-10-10	L-1011	C-580	YS-11	BAC-111	TOTALS
	AIRCRAFT TYPE														
CLE	4	24	14	8	0	2	3	1	11	0	0	0	0	4	71
BUF	10	29	19	20	0	1	0	0	36	3	0	10	0	18	146
MIA	16	69	35	0	0	6	3	2	49	0	3	0	0	0	183
MSY	1	15	22	0	0	4	7	14	23	0	0	2	0	0	88
DFW	12	15	16	3	2	8	4	8	24	4	3	3	0	0	102
TOTALS	43	152	106	31	2	21	17	25	143	7	6	15	0	22	590

FIGURE 32

SUMMARY OF STRAIGHT-TAXIWAY OPERATIONS

General

The intent in collecting data at several airports was to obtain distribution patterns, particularly for runway operations, that were generally representative of the range of operational conditions normally encountered in day-to-day aircraft operations.

The airports at which data were collected provided a reasonably good variation in such factors as runway length, field altitude, temperature, wind, and other weather conditions. Certain factors, however, which existed or were encountered only at certain airports, at the time of data collection, could have had a unique effect on the distribution patterns found at those airports.

Therefore, in addition to the analysis of the distribution patterns for the overall conditions, an examination was made of the possible effect of particular factors on the distributions where such factors existed or were encountered in the data collection. These factors included runway or taxiway width, runway-exit type and location, nighttime operations, centerline lighting, headwinds, crosswinds, wet pavements, displaced thresholds, and reduced (meteorological) visibility.

It should be noted that there are factors affecting aircraft performance and their distributions on pavements (particularly, the longitudinal distribution of rotation points) but that, for two basic reasons, were not specifically addressed or examined in this study. Either (a) information relative to those factors was not available from the data collected; or (b) their effects on aircraft performance were already well known or predictable. Such factors include aircraft gross weights, airline operating procedures, ambient temperature, and field elevation.

The mean and standard deviations of the lateral distributions and corresponding ground operating speeds were calculated for each sample--individual or combined aircraft types at individual or combined airports--and were the two primary statistical parameters used in describing and comparing samples.

Frequency distributions (histograms) of the aircraft-centerline offsets were also plotted for each sample for which the mean and standard deviation were calculated, in terms of proportionate occurrences in two-foot intervals on either side of the pavement centerline or guideline. Because of the large number (over 1700) of such plots, however, only those for all aircraft types combined and others of particular interest were included in this report. Calculation of the mean and standard deviation values and plotting of the histograms were done by computer.

In many instances there was a substantial difference in size among samples. Such differences were especially important when such samples were being compared. Obviously, more reliance had to be placed on the larger sample sizes. This fact is reflected in confidence intervals around mean and standard deviation values, as illustrated below for a 95% level of confidence.

Using a normal approximation (of the t-distribution), valid for sample sizes of 30 or more, half of the 95% confidence interval for the <u>mean</u> of a normal population is calculated as $1.96S/n^{0.5}$, where S is the unbiased sample standard deviation and n is the sample size. Thus, given a sample size of 100 with a sample standard deviation of 6, there is a 95% probability that the actual mean is within ± 1.176 of the computed sample mean.

For sample sizes of less than 30, the normal approximation of the t-distribution is no longer valid; the t-distribution itself must be used. Half of the 95% confidence interval for the mean of a normal population is thus $tS/n^{0.5}$, where t depends upon n, as listed in Figure 33.

Using a normal approximation (of the chi-square distribution), valid for sample sizes of 100 or more, the lower and upper bounds of the 95% confidence interval for the <u>standard deviation</u> of a normal population is calculated as $S\ (2m)^{0.5}/(K \pm 1.96)$, where

$$m = n-1$$
$$K = (2n-3)^{0.5}$$

Thus, for the above example, there is a 95% probability that the actual standard deviation is between 5.278 and 6.992. For sample sizes of less than 100, the normal approximation of the chi-square distribution cannot be used; the chi-square distribution itself must be used. The lower bound of the 95%

SAMPLE SIZE, n	t
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201
13	2.179
14	2.160
15	2.145
16	2.131
17	2.120
18	2.110
19	2.101
20	2.093
21	2.086
22	2.080
23	2.074
24	2.069
25	2.064
26	2.060
27	2.056
28	2.052
29	2.048
30	2.045
31	2.042
41	2.021
61	2.000
121	1.980
∞	1.960

FIGURE 33

VALUES OF t FOR COMPUTING CONFIDENCE INTERVALS confidence interval for the standard deviation of a normal population is $S(m/X_a)^{0.5}$ and the upper bound is given by $S(m/X_b)^{0.5}$, where X_a and X_b depend upon n, as listed in Figure 34.

Runway Operations

Because of the varied locations of the "N" arrays relative to the runway ends (see Figure 26) and the variations in touchdown points and takeoff and landing-roll distances, the lateral distributions of aircraft-centerline offsets on runways were analyzed for the three generalized locations described in the preceding section. This method of analysis provided a convenient way of consolidating and presenting an otherwise voluminous amount of data in more useful form.

The generalized locations are herein referred to as First Point, Intermediate Point, and Last Point. The offset used for each aircraft operation in determining the lateral distribution at the First Point was that measured at the first "N" array encountered by the aircraft after touchdown or start of takeoff roll. That at the Last Point was the offset measured at the last "N" array encountered prior to turnoff or liftoff from the runway. At the Intermediate Point, the offset used was either that measured at the "N" array closest to the midpoint between the first and last "N" arrays encountered, or the average of the offsets measured at the center two of the "N" arrays crossed if an even number of "N" arrays was encountered by the aircraft.

Longitudinal distributions of touchdown and rotation points were analyzed in terms of the first and last light elements, respectively, interrupted by the aircraft. For reference, the light elements were numbered consecutively from one end of the runway as shown in Figures 17 to 25. The distances from both ends of each runway to each transverse light element are summarized in Figure 26.

It should be noted that there were a few occasions when a light-beam or an array was temporarily inoperative--because of low battery-power, for example. On those occasions, the passage of aircraft through such light-beam or array was not detected and therefore not recorded. Such occurrences were obvious

SAMPLE SIZE, n	X_a	X_b
3	7.378	0.051
4	9.348	0.216
5	11.143	0.484
6	12.833	0.831
7	14.449	1.237
8	16.012	1.690
9	17.535	2.180
10	19.023	2.700
11	20.483	3.247
12	21.920	3.816
13	23.337	4.404
14	24.736	5.009
15	26.119	5.629
16	27.488	6.262
17	28.845	6.908
18	30.191	7.564
19	31.526	8.231
20	32.852	8.907
21	34.170	9.591
22	35.479	10.283
23	36.781	10.982
24	38.076	11.689
25	39.364	12.400
26	40.647	13.120
27	41.923	13.844
28	43.194	14.573
29	44.461	15.308
30	45.722	16.047
31	46.979	16.791
41	59.342	24.433
51	71.420	32.357
61	83.298	40.482
71	95.023	48.758
81	106.629	57.153
91	118.136	65.647
101	129.561	74.222

FIGURE 34

VALUES OF X_a AND X_b FOR COMPUTING CONFIDENCE INTERVALS in the recorded data, when the inoperative unit was between the first and last units crossed. When, however, the inoperative unit was the first or last unit crossed, such occurrences were sometimes evident only upon closer examination of the recorded data--for example, when there was no exit on a runway following the recorded last-interrupted light-beam or array for a landing operation.

The first array from each runway end was always an "I" type located, on the average, about 900 feet from the runway end. The second array from each runway end was always an "N" type located, on the average, about 1,800 feet from the runway end. Between the first and last "N" arrays, the spacing and sequencing of "N"- and "I"-type arrays varied to suit local conditions.

Lateral and longitudinal distributions were analyzed for each aircraft type at each airport and at all airports combined, and for all aircraft types combined at each airport and at all airports combined.

Runway-Exit and Taxiway Operations

High-Speed Exits - A total of seven high-speed exits were instrumented in the study. Operations on those exits were analyzed for each aircraft type, if sufficient data existed, and for all aircraft types combined at each such exit. Operations at different exits were not combined because of the variations in exit-locations (left versus right side of runway and distance from threshold) and, in some instances, peculiar local conditions.

Arrays on high-speed exits were located approximately at the midpoint between the runway and parallel taxiway in the cases of ATL, ORD, and DEN, and approximately at the midpoint between Runways 16L and 16R at SEA (see Figure 20). In addition to the lateral distributions, the average speeds in the high-speed exits were analyzed. The average speeds at approximately the point of turnoff from the runway into these exits were also examined and compared with the average speeds in the exits.

Right-Angled Exits - As mentioned in the preceding section, there were too few operations obtained on the instrumented right-angled exits to provide any meaningful or reliable analysis.

Straight-Taxiway Sections - Seven locations on straight-taxiway sections were instrumented in the study. Lateral distributions and average speeds by aircraft types were examined at each of those locations.

Lateral Distributions

The offset mean and standard deviations of the lateral distributions at the First, Intermediate, and Last Points for takeoffs are summarized in Figures A-1 to A-18 in Appendix A, both for individual and combined aircraft types at each airport. The offset mean and standard deviations of the lateral distributions for individual and combined aircraft types at all airports combined are given in Figure 35.

Examination of Figures A-1 to A-18 reveals that the offset mean for each aircraft type at each airport was generally to the left of the runway centerline. Wide-body and 4-engine aircraft tended generally to be slightly farther left than 2- and 3-engine aircraft--the difference, however, was neither large nor consistent enough to make any specific distinction in this regard among such aircraft groupings.

As shown in Figure 35, the offset mean for all aircraft types combined was from 1 to 1.5 feet to the left of the pavement centerline. The mean was closer to the centerline nearer the start of takeoff and slightly farther away in the vicinity of liftoff.

Figures A-1 to A-18 show that the standard deviations for individual aircraft types generally varied from about 3 to 8 feet, but there was no consistent correlation with respect to aircraft type or size. Figure 35 shows the standard deviations among aircraft types for all airports combined ranged generally from 5.5 to slightly more than 7 feet at the First Point, from 5.5 to about 6.5 feet at the Intermediate Point, and from about 6 to 9 feet at the Last Point.

Histograms of the lateral distributions are shown in Figures A-19 to A-36 in Appendix A, for all aircraft combined at each airport. Inspection of these histograms clearly shows that the lateral distribution patterns are much closer to being normal (bell-shape) than uniform.

Effect of Runway Width - Takeoffs were recorded on two 200-foot-wide runways (at MIA and DFW). The other runways instrumented were 150 feet wide. The possibility of this difference in pavement widths affecting lateral distributions for takeoffs was examined.

The lateral distributions for individual and combined aircraft types are summarized in Figure 36 for each pavement width. The offset mean was generally farther left of the pavement centerline on the 200-foot runways, by approximately 1.5 feet on the average, compared with that on the 150-foot runways.

The standard deviations at the First and Intermediate Points were generally wider on the 200-foot runways--about 1.5 feet wider on the average compared with those at corresponding points on the 150-foot runways. In the area of liftoff, the standard deviations were about the same for both runway widths.

Effect of Nighttime Operations - Some of the visual references available to the pilot by day are replaced by different ones at night, or some may appear differently at night. Runway centerline lights, for example, may replace the painted centerline as the operational reference; and, when in use, could shift the offset mean toward the centerline lights--the centers of the painted centerline stripe and centerline lights are as much as 2 feet apart. The standard deviations for nighttime operations may also differ from those for daytime operations.

ATL and MIA were the only airports where any significant numbers of nighttime takeoffs were recorded. There were centerline lights on the runway instrumented at ATL (see Figure 17) but none on the runway at MIA.

Daytime and nighttime lateral distributions are compared in Figure 37 for 727-100 and DC-9-30 takeoffs on Runway 27L at ATL, and for 727-100 takeoffs on Runway 9L at MIA. There was no consistent effect on the mean of the offsets, but the standard deviations were generally narrower for nighttime operations. It should be noted, however, that sample sizes of nighttime operations used in this comparison were relatively small.

Effect of Crosswinds - ORD and DEN were the only airports where takeoffs with any significant crosswinds were recorded. Lateral distributions at the last "N" array encountered before liftoff were analyzed for takeoffs on Runway 9R at ORD and Runway 8R at DEN. The effect of crosswinds of 5 knots or more from the left and from the right, and crosswinds of less than 5 knots are examined in Figure 38.

There was no consistent effect on the offset mean, but the standard deviations in crosswinds of 5 knots or more were consistently wider than those in lesser crosswinds.

Effect of Wet Pavements - Takeoffs on wet pavements were recorded at ORD and CLE. The lateral distributions on wet and dry pavements at these airports are compared in Figures 39 and 40.

The offset mean for takeoffs on wet pavements, compared with those on dry pavements, tended to be more left at ORD and more right at CLE. The standard deviations tended to be generally wider on wet pavements, particularly near liftoff.

Longitudinal Distributions

The proportionate number of takeoffs that lifted off after each light element are summarized by aircraft type at each airport in Figures A-37 to A-45 in Appendix A.

As briefly mentioned in the preceding section, takeoff-roll distances vary according to a number of factors, including (principally) aircraft gross weight, ambient temperature, and field elevation. Consequently, there was a wide range in observed takeoff-roll distances. Figure 41 shows the cumulative distribution of takeoff-roll distances. As seen in that figure, nearly all liftoffs occurred between 3000 and 7000 feet from start of takeoff roll.

Effects of Headwinds - Headwinds shorten the lengths of takeoff ground-roll distances because of corresponding reductions in the ground speeds required to achieve rotation air-speeds.

This effect was examined for takeoffs at ORD, where there were significant variations in headwinds. Figures 42 and 43 show the cumulative percentages of takeoffs that occurred after each light element for headwinds of less than 5 knots, 5 to 10 knots, and over 10 knots. As expected, these show that takeoff rolls were consistently shorter at higher headwinds.

The average ground speed at array "N3" on Runway 27L at ORD (see Figure 18), for 727-100's that lifted off before reaching array "N2," was 228 feet per second in headwinds of less than 10 knots and 217 feet per second in headwinds of 10 knots or more.

Effect of Wet Pavements - The effect of wet pavements on takeoff ground-roll distances and acceleration rates were analyzed.

The cumulative percentages of takeoffs that occurred after each light element are plotted in Figures 44 to 46 for wet versus dry pavement operations at ORD and CLE. These figures show that takeoff-roll distances were consistently shorter on dry pavements.

Average acceleration rates are compared for operations on wet versus dry pavements in Figure 47, for 727-100's that lifted off between arrays "N3" and "N4" on Runway 23L at CLE (see Figure 21). The average acceleration rates were slightly less on the wet pavement.

AIRCRAFT TYPE	SAMPLE SIZE	----FIRST POINT---		----INT. POINT---		----LAST POINT----	
		X	S	X	S	X	S
707	293	-2.53	6.51	-2.20	6.29	-1.59	7.51
727-100	902	-1.43	6.26	-1.44	6.08	-1.19	7.08
727-200	739	-.40	6.41	-.88	6.00	-1.01	7.26
737	342	-.61	7.07	-.36	6.31	-.32	9.24
747	66	-1.72	6.46	-2.33	5.47	-3.92	5.82
DC-8-40,-50	158	-1.08	6.50	-1.09	5.59	-.72	5.79
DC-8-60	115	-1.61	5.56	-1.76	5.22	-1.60	5.94
DC-9-10,-20	181	-2.28	7.25	-2.74	7.44	-3.93	8.96
DC-9-30,-40	941	-.11	6.90	-.41	6.31	-1.56	8.84
DC-10-10	121	-.56	7.69	-1.00	5.38	-1.10	6.75
L-1011	106	-1.17	6.34	-1.85	6.88	-2.33	7.84
C-580	144	-1.17	6.69	-.71	6.21	-.81	6.48
YS-11	53	.41	9.46	2.91	8.74	-1.52	8.68
BAC-111	198	-.10	6.38	-1.52	7.66	-2.88	14.43
ALL	4359	-.90	6.72	-1.08	6.35	-1.45	8.26

X = Mean Offset (Feet)   S = Standard Deviation (Feet)

FIGURE 35

SUMMARY OF TAKEOFF LATERAL DISTRIBUTIONS - ALL RUNWAYS COMBINED

RUNWAY WIDTH	AIRCRAFT TYPE	SAMPLE SIZE	----FIRST POINT---- X	S	----INT. POINT---- X	S	----LAST POINT---- X	S
150'	707	198	-1.44	5.82	-1.11	5.55	-.34	7.20
	727-100	680	-1.25	5.86	-1.27	5.75	-1.05	6.82
	727-200	560	.10	5.92	-.47	5.36	-.61	6.90
	737	327	-.63	7.19	-.41	6.35	-.41	9.24
	747	49	-1.20	5.77	-2.00	4.65	-4.06	5.46
	DC-8-40,-50	116	-1.14	6.61	-1.09	5.43	-.57	5.68
	DC-8-60	108	-1.62	5.70	-1.78	5.30	-1.76	5.77
	DC-9-10,-20	127	-.93	5.46	-1.55	5.99	-3.22	8.64
	DC-9-30,-40	744	.25	6.64	-.05	5.87	-1.35	8.91
	DC-10-10	108	.34	7.36	-.11	5.18	-.22	6.25
	L-1011	44	-.91	5.78	-1.95	6.93	-2.78	8.01
	C-580	107	-.95	6.39	-.31	5.63	-.43	5.99
	YS-11	52	.37	9.55	2.92	8.82	-1.59	8.74
	BAC-111	194	-.07	6.36	-1.37	7.60	-2.74	14.51
	ALL	3414	-.51	6.41	-.70	5.95	-1.16	6.28
200'	707	95	-4.83	7.24	-4.47	7.09	-4.19	7.48
	727-100	222	-1.96	7.33	-1.96	6.99	-1.60	7.82
	727-200	179	-1.98	7.52	-2.19	7.51	-2.27	8.17
	737	15	-.12	3.62	.73	5.46	1.58	9.05
	747	17	-3.22	7.96	-3.30	7.24	-3.50	6.76
	DC-8-40,-50	42	-.92	6.20	-1.08	6.00	-1.12	6.05
	DC-8-60	7	-1.56	2.88	-1.45	3.81	.84	7.73
	DC-9-10,-20	54	-5.46	9.57	-5.53	9.50	-5.61	9.47
	DC-9-30,-40	197	-1.46	7.65	-1.78	7.58	-2.34	8.52
	DC-10-10	13	-8.01	6.09	-8.42	6.17	-8.49	6.19
	L-1011	62	-1.36	6.70	-1.78	6.85	-2.00	7.70
	C-580	37	-1.82	7.45	-1.87	7.53	-1.92	7.63
	YS-11	1	2.55	0.	2.55	0.	2.55	0.
	BAC-111	4	-1.81	6.92	-8.87	6.79	-9.44	7.07
	ALL	945	-2.32	7.56	-2.46	7.46	-2.48	8.14

X = Mean Offset (Feet)   S = Standard Deviation (Feet)

FIGURE 36
SUMMARY OF TAKEOFF LATERAL DISTRIBUTIONS BY RUNWAY WIDTH

AIRPORT-RUNWAY	AIRCRAFT TYPE	RUNWAY LOCATION	DAY n	DAY V	DAY X	NIGHT n	NIGHT V	NIGHT X
ATL-27L	727-100	First Pt.	112	148 (21)	-0.67 (5.79)	16	154 (6)	4.69 (3.93)
		Int. Pt.		188 (27)	-1.71 (6.55)		178 (17)	-5.01 (4.04)
		Last Pt.		213 (35)	-2.91 (8.37)		197 (30)	-4.67 (5.29)
	DC-9-30	First Pt.	204	152 (17)	0.65 (6.19)	33	152 (5)	0.48 (5.49)
		Int. Pt.		184 (16)	-0.08 (6.29)		185 (9)	0.54 (6.01)
		Last Pt.		214 (20)	-2.14 (9.42)		217 (12)	0.56 (7.21)
MIA-9L	727-100	First Pt.	83	168 (25)	0.80 (6.69)	15	178 (29)	1.30 (5.40)
		Int. Pt.		196 (25)	0.50 (6.02)		208 (21)	0.27 (4.75)
		Last Pt.		216 (32)	-0.09 (6.41)		226 (25)	1.09 (3.87)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 37

TAKEOFF LATERAL DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS

AIRPORT-RUNWAY	AIRCRAFT TYPE	CROSSWIND COMPONENTS: 5 Kts. or Greater From Right			Less than 5 Kts. Left & Right			5 Kts. or Greater From Left		
		n	V	X	n	V	X	n	V	X
DEN-8R	727-100	13	244 (9)	1.54 (5.85)	20	223 (56)	-0.59 (4.36)	-	-	-
	737	12	250 (16)	-9.43 (14.05)	17	209 (58)	-3.42 (8.43)	-	-	-
	ALL	84	239 (25)	-2.82 (10.16)	74	228 (39)	-1.06 (7.35)	5	232 (21)	1.05 (7.63)
ORD-9R	727-100	-	-	-	61	200 (20)	-1.92 (3.76)	45	194 (37)	-2.41 (6.20)
	DC-9-30	-	-	-	47	195 (12)	0.93 (5.88)	35	191 (12)	-1.18 (7.79)
	ALL	-	-	-	203	202 (23)	-0.98 (5.03)	174	198 (28)	-1.87 (6.95)

n = Sample Size   V = Average Speed (Ft./Sec.)   X = Average Offset (Feet)   ( ) Standard Deviation

FIGURE 38

TAKEOFF LATERAL DISTRIBUTIONS FOR VARIOUS CROSSWIND CONDITIONS

AIRCRAFT TYPE	RUNWAY LOCATION	DRY PAVEMENT n	V	X	WET PAVEMENT n	V	X
DC-9-30	First Pt.	65	152 (5)	0.55 (4.79)	19	150 (6)	-1.71 (4.96)
	Int. Pt.		173 (7)	0.51 (4.94)		171 (8)	-0.60 (3.31)
	Last Pt.		195 (13)	-0.10 (6.90)		192 (13)	-1.44 (10.63)
727-100	First Pt.	74	146 (20)	-0.95 (3.30)	32	151 (19)	-1.54 (4.76)
	Int. Pt.		171 (24)	-1.16 (3.27)		176 (16)	-2.48 (5.68)
	Last Pt.		195 (32)	-1.67 (3.77)		201 (20)	-3.19 (6.99)
ALL	First Pt.	279	148 (17)	-0.02 (4.69)	99	150 (15)	-1.71 (4.36)
	Int. Pt.		174 (18)	-0.63 (4.32)		176 (15)	-2.15 (5.19)
	Last Pt.		199 (26)	-1.06 (5.44)		200 (23)	-2.31 (7.33)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 39

TAKEOFF LATERAL DISTRIBUTIONS ON WET VERSUS DRY PAVEMENTS
ORD RUNWAY 9R

AIRCRAFT TYPE	RUNWAY LOCATION	DRY PAVEMENT n	V	X	WET PAVEMENT n	V	X
737	First Pt.	68	137 (23)	-1.47 (5.40)	11	135 (9)	-0.90 (3.42)
	Int. Pt.		173 (25)	-0.77 (3.75)		168 (12)	-1.00 (4.27)
	Last Pt.		209 (36)	-0.33 (5.87)		200 (22)	1.45 (12.35)
727-100	First Pt.	86	131 (21)	-1.53 (3.83)	25	132 (17)	-0.16 (4.01)
	Int. Pt.		157 (22)	-1.04 (3.07)		163 (12)	-0.23 (4.02)
	Last Pt.		183 (29)	-0.16 (4.40)		192 (20)	0.03 (3.91)
ALL	First Pt.	308	134 (21)	-1.09 (4.64)	79	139 (22)	0.13 (5.14)
	Int. Pt.		165 (23)	-0.52 (4.19)		168 (20)	0.19 (4.63)
	Last Pt.		197 (35)	0.37 (7.44)		198 (30)	0.30 (7.48)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 40

TAKEOFF LATERAL DISTRIBUTIONS ON WET VERSUS DRY PAVEMENTS

CLE RUNWAY 23L

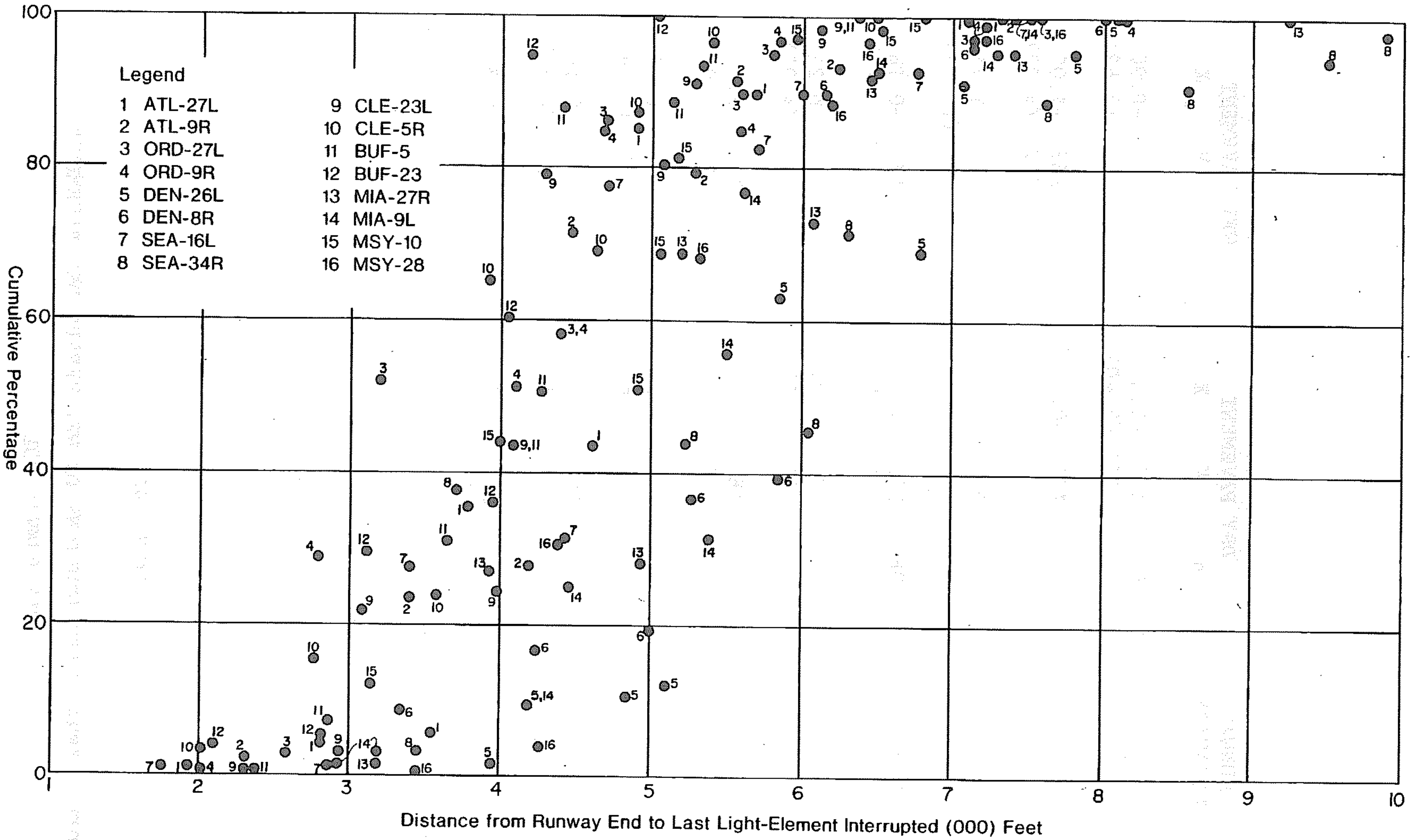


FIGURE 41

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES ALL AIRCRAFT COMBINED

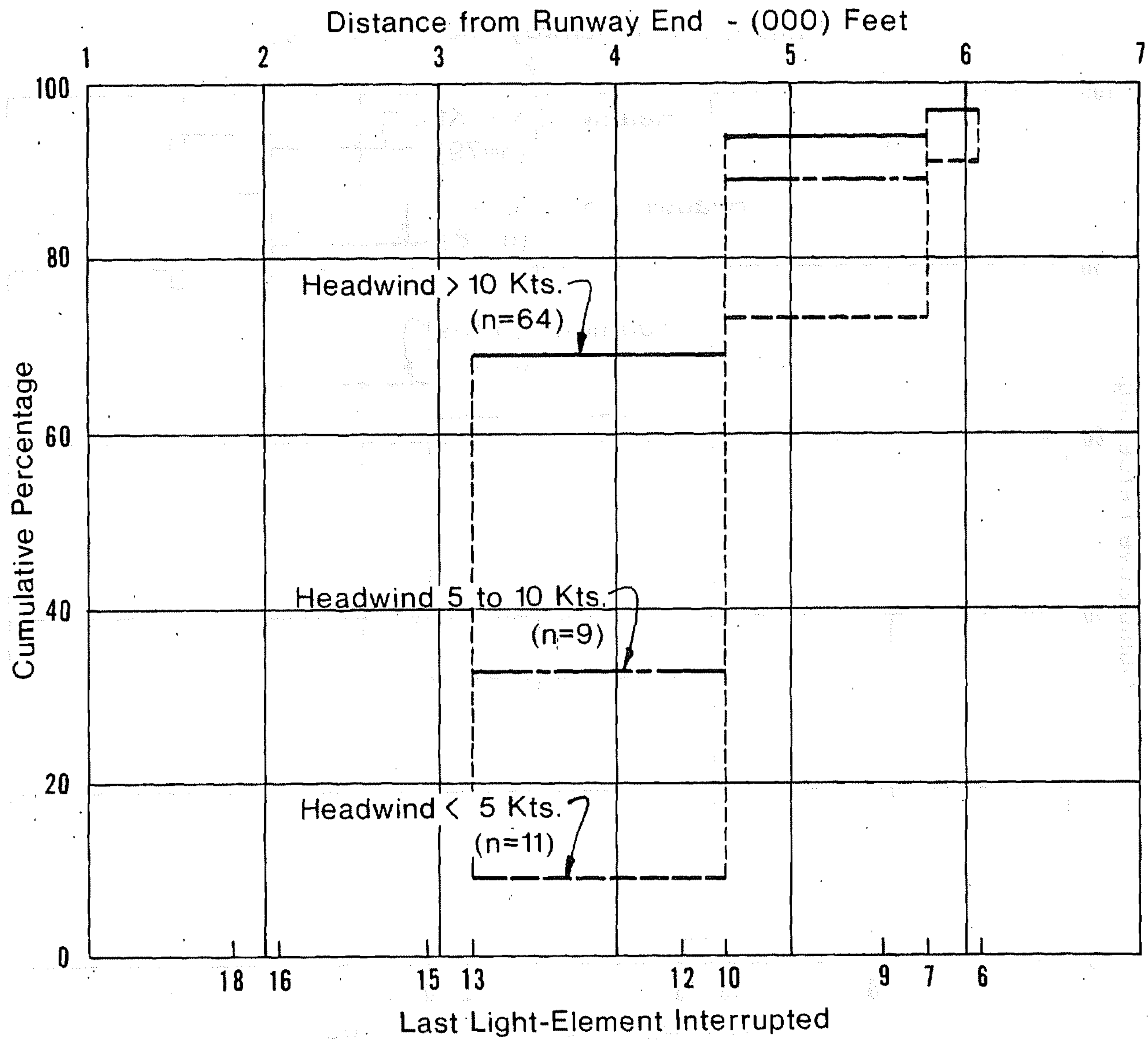


FIGURE 42

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES FOR VARIOUS HEADWIND CONDITIONS DC-9-30,-40 ON ORD RUNWAY 27L

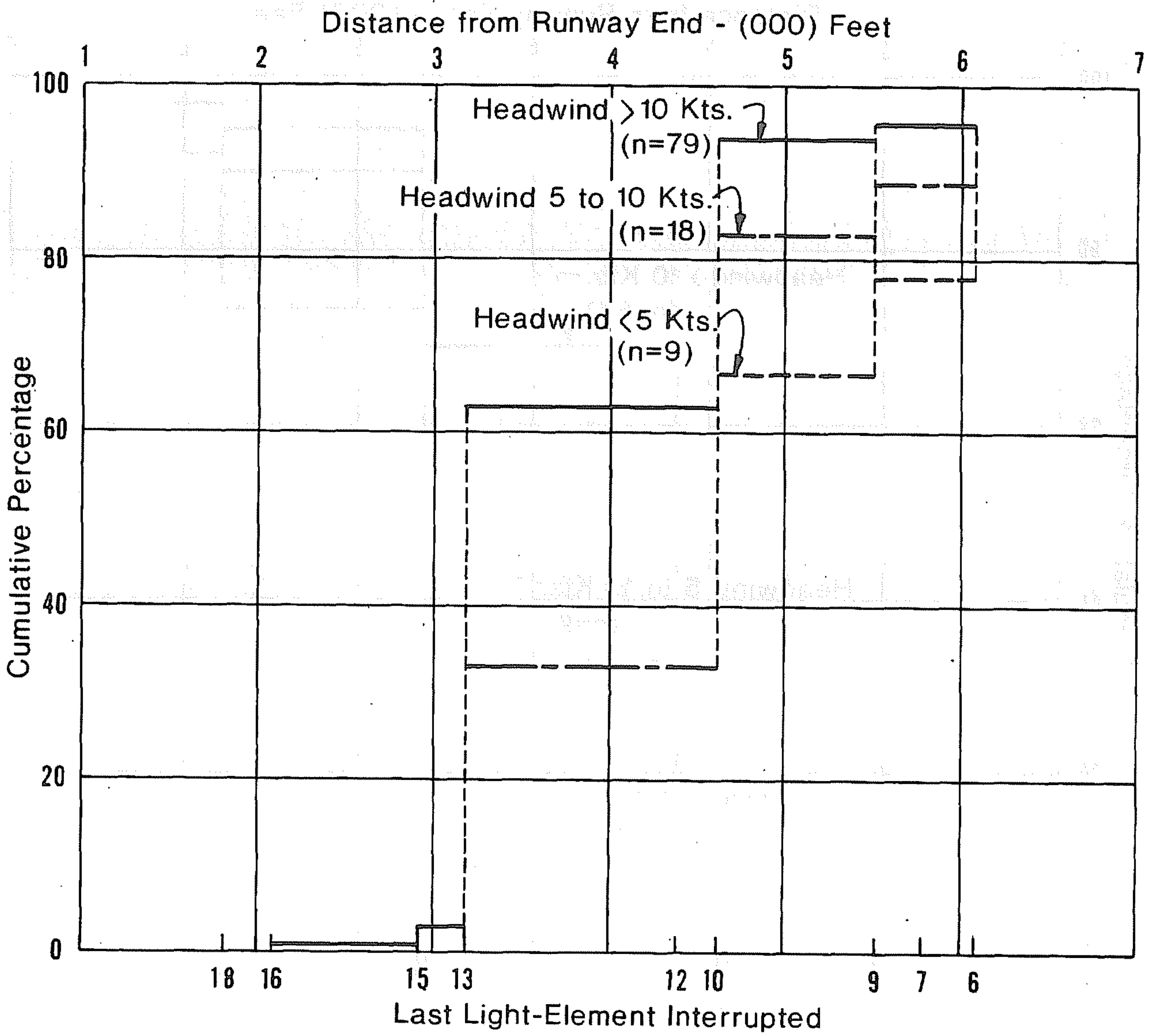


FIGURE 43

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES FOR VARIOUS HEADWIND CONDITIONS 727-100 ON ORD RUNWAY 27L

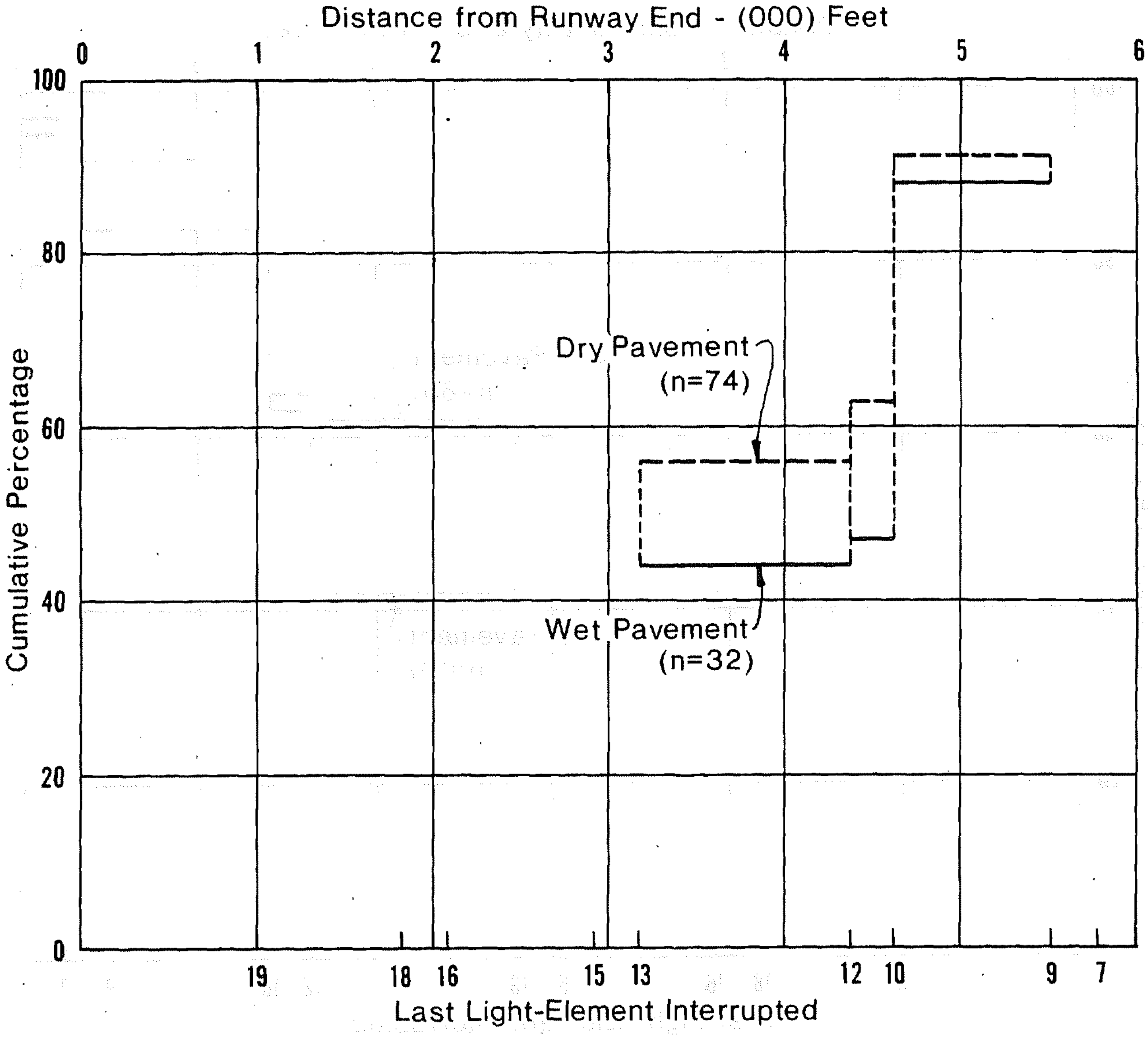


FIGURE 44

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES ON WET VERSUS DRY PAVEMENTS 727-100 ON ORD RUNWAY 27L

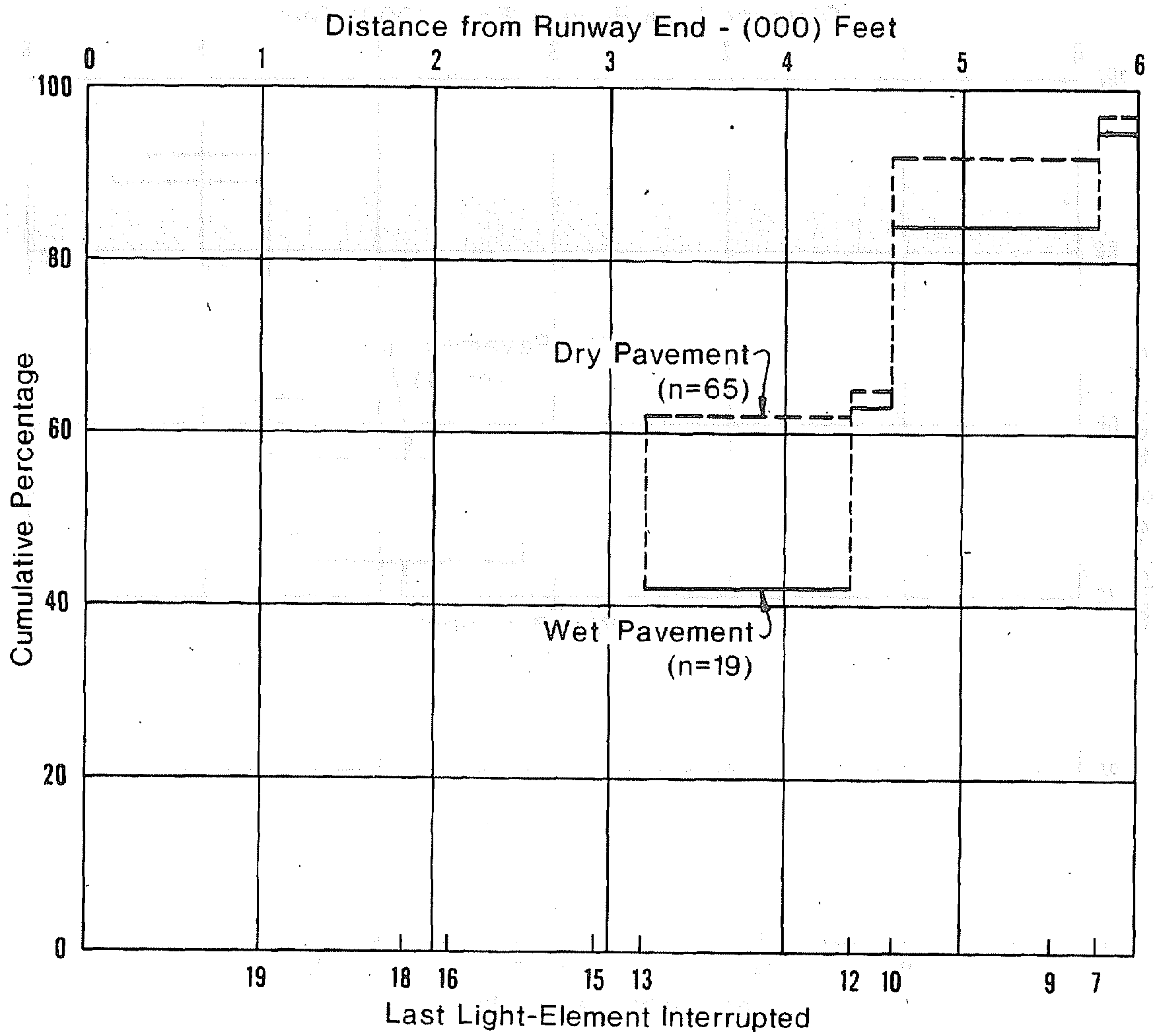


FIGURE 45

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES ON WET VERSUS DRY PAVEMENTS DC-9-30,-40 ON ORD RUNWAY 27L

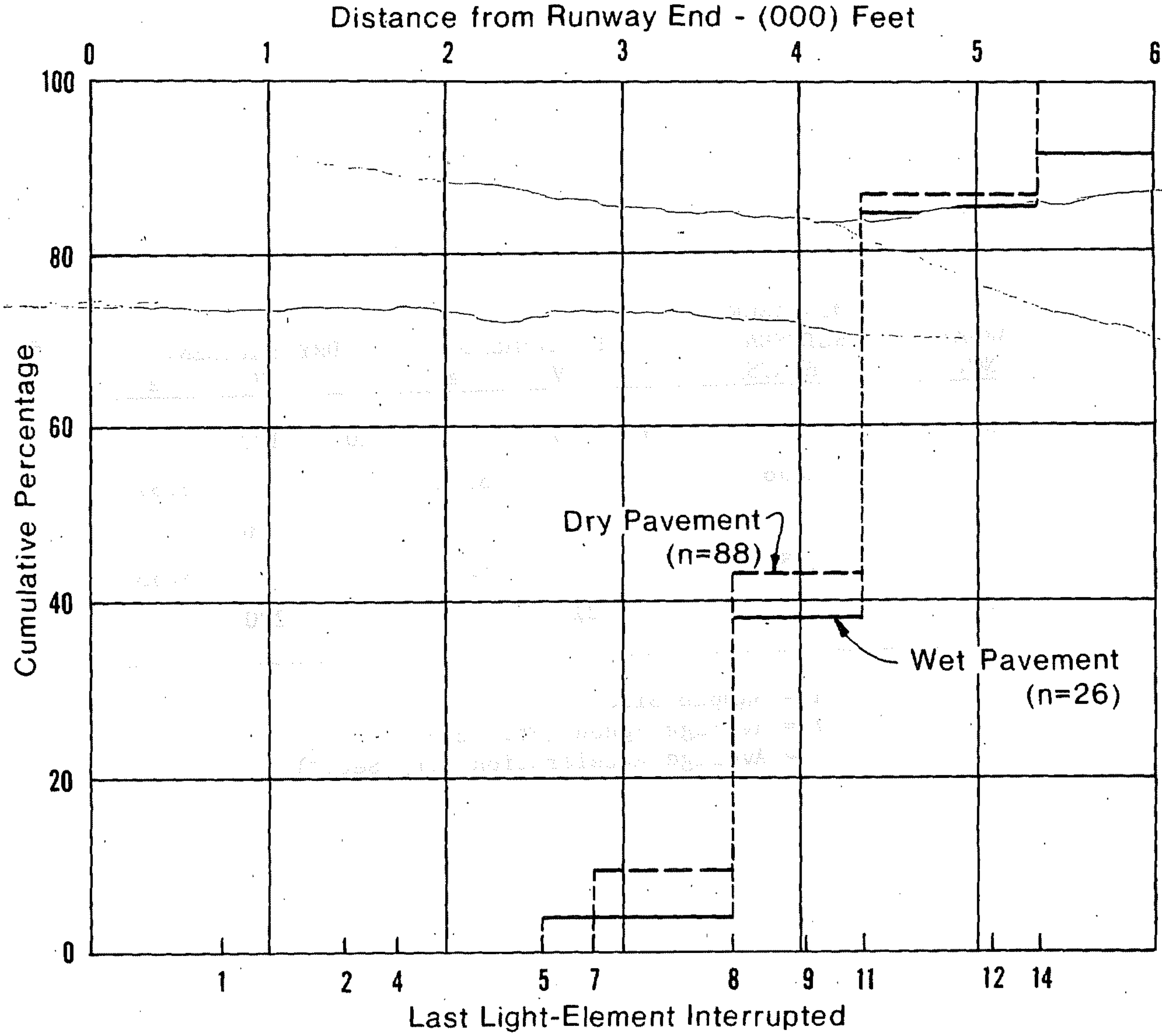


FIGURE 46

CUMULATIVE DISTRIBUTIONS OF TAKEOFF-ROLL DISTANCES ON WET VERSUS DRY PAVEMENTS 727-100 ON CLE RUNWAY 23L

ARRAY NO.	DISTANCE BETWEEN ARRAYS	WET PAVEMENT			DRY PAVEMENT		
		n	V	a	n	V	a
N1		9	125		20	127	
	1096'			6.21			6.67
N2			171			176	
	1552'			5.21			5.63
N3			213			220	

n = Sample Size
V = Average Speed (Ft./Sec)
a = Average Acceleration (Ft./Sec.^{2})

FIGURE 47

TAKEOFF ACCELERATION RATES ON WET VERSUS DRY PAVEMENT

727-100 LIFTOFFS BETWEEN ARRAYS N3 AND N4 ON CLE RUNWAY 23L

SECTION IV - LANDING OPERATIONS

Lateral Distributions

The offset mean and standard deviations of the lateral distributions at the First, Intermediate, and Last Points for landings are summarized in Figures A-46 to A-63 in Appendix A, for individual and combined aircraft types at each airport. The offset mean and standard deviations of the lateral distributions for individual and combined aircraft types at all airports combined are given in Figure 48.

Examination of Figures A-46 to A-63 reveals that the offset mean for each aircraft type at each airport was generally to the left of the runway centerline. Wide-body and 4-engine aircraft tended generally to be slightly farther left than 2- and 3-engine aircraft--however, as in the case of takeoffs, the difference was neither large nor consistent enough to make a distinction in terms of such groupings. As shown in Figure 48, the offset mean for all aircraft types combined was from approximately 0.5 to 1.5 feet left of the pavement centerline.

Figures A-46 to A-63 show that the standard deviations for individual aircraft types generally varied from about 4 to 9 feet, but there was no consistent correlation with respect to aircraft type or size. Figure 48 shows the standard deviations among aircraft types for all airports combined ranged generally between 7 and 8.5 feet at the First Point, and between 7 and 8 feet at the Intermediate Point. The standard deviations at the Last Point were much wider because of exit effects, as discussed later in this section.

Histograms of the lateral distributions for all aircraft combined at each airport are shown in Figures A-64 to A-81 in Appendix A. As in the case of takeoff operations, inspection of these histograms clearly shows that the lateral distribution patterns are much closer to being normal than uniform.

Effect of Runway Width - Landings were recorded on two 200-foot-wide runways (at MIA and DFW). The other runways instrumented were 150 feet wide. The possibility of this difference in pavement widths affecting lateral distributions for landings was examined.

The lateral distributions for individual and combined aircraft types are summarized in Figure 49 for each pavement width. The offset mean computed at the First Point was approximately 1 foot farther left on the 200-foot runways, whereas at the Intermediate Point it was approximately 0.5 foot closer to the pavement centerline than that computed for the 150-foot runways.

The standard deviations on the 200-foot runways tended to be wider--generally by 1 to 2 feet more than those on the 150-foot runways at the First and Intermediate Points. Exit effects were evident at the Last Point for both runway widths. The standard deviations were generally wider at that point.

Effect of Runway Exits - The influence of exits on the observed lateral distributions on runways was examined for high-speed exits at ATL and ORD where a significant number of the recorded landings used those exits; the effects of a runway exit at CLE, almost a right-angled exit, were similarly examined.

In Figure 50, the offset mean and standard deviations at array "N3" at ATL (see Figure 17) are shown for landings that turned off at Exits "W" and "X" (which were immediately adjacent to that array) and for landings that turned off at exits beyond Exits "W" and "X." As seen in Figure 17, array "N3" was located at about the midpoint between Exits "W" and "X", near the start of turnoff to those exits.

Figure 50 shows that the offset mean at array "N3" for those landings that used Exits "W" and "X" were well displaced toward the exit-side of the runway, compared with the offset mean of the landings that continued past those exits. The standard deviations were generally wider for aircraft that exited, compared with the standard deviations for aircraft that continued past the exits.

Histograms of the lateral distributions at array "N3," both for aircraft that turned off at Exit "W" and for aircraft that continued past Exit "W," are shown in Figure 51 for DC-9-30 landings on Runway 27L at ATL.

Figure 52 shows the offset mean and standard deviations of the lateral distributions for landings on ATL's Runway 27L at (a) array "N2" for aircraft that turned off at Exit "W" and aircraft that continued past Exit "W," and (b) array "N4" for aircraft that turned off at Exit "U." Array "N2" (see Figure 17) was located approximately 1070 feet from the start of turnoff to Exit "W," and array "N4" was located approximately 540 feet from the start of turnoff to Exit "U."

Figure 53 shows the offset mean and standard deviations of the lateral distributions for landings on ATL's Runway 9R at (a) array "N2" for aircraft that turned off at Exit "Y," and (b) array "N4" for aircraft that turned off at Exit "X." Array "N2" was located approximately 740 feet from the start of turnoff to Exit "Y," and array "N4" was located approximately 1030 feet from the start of Exit "X."

Figures 52 and 53 indicate that, for landings that turned off at high-speed exits, there was no consistent nor significant difference in the offset mean and standard deviations of the aircraft lateral distributions at distances of 500 feet or more before the start of turnoff into such exits.

Histograms of the lateral distributions at array "N2," for aircraft that turned off at Exit "W" and aircraft that continued past that exit, are shown in Figure 54 for DC-9-30 landings on Runway 27L at ATL.

Figure 55 shows the offset mean and standard deviations of the lateral distributions at array "N3" at ORD (see Figure 18) for landings on Runway 9R that turned off at Exit "NE" and those that continued past Exit "NE." That array was located approximately 300 feet prior to the start of turnoff to Exit "NE." A shift in the offset mean in the direction of the turnoff is noted for aircraft that turned off at Exit "NE." The standard deviations for aircraft that exited were approximately the same as for those that passed the exit.

Figure 56 shows the offset mean and standard deviations of the lateral distributions at array "N3" at CLE (see Figure 21), for landings on Runway 23L that turned off at the near-right-angled exit immediately past array "N3" and those that continued past that exit. As seen in Figure 56, there was a distinct shift in the offset mean toward the exit-side of the runway.

Effect of Nighttime Operations - Possible differences in the lateral distributions for nighttime landings were examined for the same reasons stated for nighttime takeoffs in the preceding section.

ATL, ORD, and MIA were the only airports where significant numbers of nighttime landings were recorded. There were centerline lights on the runway instrumented at ATL, and none on the runways instrumented at ORD and MIA.

Daytime and nighttime lateral distributions are compared in Figure 57 for landings on Runways 27L at ATL, and in Figure 58 for landings on Runways 9R and 9L at ORD and MIA, respectively.

At ATL the offset mean for nighttime landings was shifted toward the centerline lights, whereas at ORD and MIA (where there were no centerline lights) the offset mean for nighttime landings was further to the right compared with that for daytime landings. The standard deviations were generally narrower for nighttime landings at ATL and MIA, but not at ORD.

Effect of Crosswinds - Strong enough crosswinds could affect the observed lateral distributions, particularly near the point of touchdown.

ORD and DEN were the only airports where landings with any significant crosswinds were recorded. Lateral distributions at the first "N" array encountered after touchdown were analyzed for landings on Runway 9R at ORD and Runway 26L at DEN. The effect of crosswinds of 5 knots or more from the left and from the right, and crosswinds of less than 5 knots are examined in Figure 59. There was no consistent effect on the offset mean. The standard deviations in crosswinds of 5 knots or greater tended to be wider, but not consistently so.

Effect of Wet Pavements - Landings on wet pavements were recorded at ORD and CLE. Lateral distributions on wet and dry pavements at these airports are compared in Figures 60 and 61.

The offset mean on wet pavements tended to be more right at ORD and more left at CLE. This is the opposite of the tendency for takeoffs at ORD and CLE described in the preceding section. The standard deviations tended to be generally narrower on wet pavements (again the opposite of the indication obtained for takeoffs), except at the Last Point prior to turnoff (possibly because of the pilot having less control over an aircraft turning on a wet pavement).

Longitudinal Distributions

The proportionate number of landings that touched down before each light element are summarized by aircraft type at each airport in Figures A-82 to A-90 in Appendix A.

From Figures A-82 through A-90, it is seen that almost all landings touched down before the fourth transverse light element from each runway end (or the fifth light element, counting the diagonal element in the first "N" array).

For convenience, the distances from the landing threshold to the first, third, and fourth transverse light elements (or the first, fourth, and fifth light elements) on each runway are tabulated in Figure 62. Also shown in Figure 62 are the average distances from the threshold to those light elements. It is seen that these average distances were not too far from representing nominal distances of 1000, 2000, and 3000 feet, respectively, from the threshold.

In Figures 63 to 76, the cumulative percentages of the touchdowns that occurred within each of the above nominal distances from threshold are tabulated for each runway. The weighted average of these cumulative percentages is also shown for all runways combined.

The cumulative percentages of aircraft that touched down in each nominal distance from threshold are summarized by aircraft type in Figure 77 for all runways combined. It is seen from Figure 77 that, on the average, a higher percentage of 2-engine aircraft touchdowns occurred closer to the threshold in comparison with wide-body and with narrow-body 4- and 3-engine aircraft.

The proportionate number of landings that turned off the runway after each light element are summarized by aircraft type at each airport in Figures A-91 to A-99 in Appendix A.

The lengths of landing rolls to a large extent depend on, besides aircraft performance, the types of exits and their locations relative to the landing threshold. The use of an exit by an aircraft depends on its expected speed when it reaches the vicinity of the exit, and the speed at which an exit is used depends on the type of exit.

The use of exits may also be a matter of pilot choice or preference, if an aircraft has already slowed to a speed compatible with the exit types available. A pilot may also increase or decrease the rate of deceleration of an aircraft by varying the amounts of braking action, within certain limits, in order to turn off at a particular exit.

Effect of Nighttime Operations - The longidudinal distribution of touchdown points was compared for nighttime and daytime landings at ATL, ORD, and MIA.

Cumulative percentages of touchdowns that occurred before each light element are plotted in Figures 78 to 82. These show that generally a smaller percentage of touchdowns at night occurred in the first 1000 feet.

Effect of Headwinds - Strong enough headwind components can shorten the length of landing roll distances, mainly because of corresponding reductions in relative ground speeds for achieving operational landing approach air speeds.

The reduced ground speeds at touchdown require less braking to bring aircraft to a safe exit speed, or enable the pilot to reach suitable exit speeds sooner in time and distance with about the same amount of braking as in weaker or no headwinds.

ORD was the only airport where landings with significant variations in headwinds were recorded. The cumulative percentages of aircraft that turned off after each light element are plotted in Figures 83 to 85, for headwinds of greater than 10 knots and of 10 knots or less. These figures show a higher percentage utilization of earlier exits at higher headwinds.

Effect of Displaced Threshold - Three runways with displaced thresholds were instrumented in the study. They were Runway 16L at SEA with a displacement of 500 feet, Runway 5 at BUF with a displacement of 335 feet, and Runway 28 at MSY with a displacement of 700 feet.

Of the above runways, significant numbers of landings by particular aircraft types were recorded only on Runway 28 at MSY. For this reason, primarily, the recorded landings on Runway 10/28 at MSY were used to assess the effect of a displaced threshold on touchdown distributions.

At MSY, the distance from the displaced threshold on Runway 28 to the first light element was 757 feet, and the distance from the runway end (no displaced threshold) to the first light element on Runway 10 was 910 feet. These distances were relatively close, in comparison with similar distances used at SEA and BUF--another reason for selecting MSY to assess the effect of a displaced threshold.

Figure 86 shows the cumulative percentages of touchdown that occurred prior to the first and second light elements on MSY's Runways 10 and 28, for 727-200 and DC-9-30 and -40 landings. In Figure 86, the indication is that a higher percentage of touchdowns occurred closer to a displaced threshold than when a threshold was at the runway end.

This is further supported in Figure A-89 of Appendix A, in which the proportionate number of touchdowns that occurred (for the aircraft types other than the above two) before light element No. 16 (the first element on Runway 28) may be compared with those that occurred before light element No. 1 (the first element on Runway 10--see Figure 24). Generally, higher percentages of touchdowns occurred prior to light element No. 16 than prior to light element No. 1.

Effect of Reduced Visibility - It is thought that reduced meteorological visibility (less than 2 miles) may have an effect on touchdown distribution, similar to nighttime operations. This, however, could not be investigated for lack of an adequate sample size--only 11 landings in visibility of less than 2 miles were recorded at all airports studied.

AIRCRAFT TYPE	SAMPLE SIZE	----FIRST POINT--		----INT. POINT---		----LAST POINT----	
		X	S	X	S	X	S
707	439	-1.68	8.25	-1.13	7.62	-.82	9.53
727-100	1299	-1.72	7.51	-.95	7.24	-.34	10.33
727-200	840	-1.48	7.04	-1.32	7.17	-1.06	8.92
737	376	-1.15	7.22	-1.13	7.23	-1.76	12.65
747	61	-4.33	9.39	-2.01	8.08	-1.17	9.09
DC-8-40,-50	262	-2.11	8.22	-1.53	8.00	.01	10.23
DC-8-60	210	-1.34	8.09	-1.41	7.48	-1.57	8.80
DC-9-10,-20	226	-2.10	8.18	-1.29	7.89	-.73	11.38
DC-9-30,-40	880	-.88	7.48	-.83	7.58	.63	11.93
DC-10-10	149	-3.77	8.19	-1.34	7.29	-2.27	8.80
L-1011	76	-1.05	8.37	-.09	9.04	-.20	10.94
C-580	164	-1.07	7.25	-.40	7.34	.64	8.60
YS-11	23	3.26	8.31	2.69	6.70	5.05	9.45
BAC-111	195	-2.60	7.31	-1.37	6.75	-1.35	9.62
ALL	5200	-1.64	7.64	-1.10	7.45	-.57	10.45

X = Mean Offset (Feet) S = Standard Deviation (Feet)

FIGURE 48

SUMMARY OF LANDING LATERAL DISTRIBUTIONS - ALL RUNWAYS COMBINED

RUNWAY WIDTH	AIRCRAFT TYPE	SAMPLE SIZE	----FIRST POINT— X	S	-----INT. POINT— X	S	———LAST POINT---- X	S
150'	707	331	-1.02	7.72	-1.17	7.21	-1.40	9.42
	727-100	916	-1.49	6.47	-1.28	6.17	-1.04	9.52
	727-200	698	-1.42	6.78	-1.52	6.96	-1.21	8.71
	737	369	-1.14	7.25	-1.12	7.27	-1.84	12.64
	747	49	-5.47	8.49	-3.19	7.52	-2.04	8.70
	DC-8-40,-50	221	-1.93	8.10	-1.68	7.96	-.57	10.25
	DC-8-60	197	-1.06	8.07	-1.35	7.57	-1.76	8.85
	DC-9-10,-20	194	-1.84	8.12	-.91	7.46	-.40	11.49
	DC-9-30,-40	699	-.67	7.09	-.95	7.13	.45	11.98
	DC-10-10	142	-3.60	8.18	-1.27	7.32	-2.35	8.90
	L-1011	35	-1.12	8.72	2.32	9.63	.67	10.95
	C-580	146	-1.09	7.06	-.37	7.16	.77	8.59
	YS-11	23	3.26	8.31	2.69	6.70	5.05	9.45
	BAC-111	192	-2.65	7.35	-1.24	6.34	-1.86	9.65
	ALL	4212	-1.49	7.26	-1.19	7.05	-.89	10.25
200'	707	108	-3.69	9.41	-1.01	8.74	.93	10.80
	727-100	383	-2.27	9.53	-.14	9.24	1.34	11.89
	727-200	142	-1.77	8.19	-.31	8.05	-.31	9.83
	737	7	-1.68	5.22	-1.64	4.71	2.00	12.62
	747	12	.30	11.28	2.79	8.49	2.38	9.76
	DC-8-40,-50	41	-3.03	8.78	-.71	8.14	3.13	9.53
	DC-8-60	13	-5.62	7.09	-2.31	5.84	1.38	7.38
	DC-9-10,-20	32	-3.70	8.32	-3.57	9.71	-2.71	10.52
	DC-9-30,-40	181	-1.70	8.81	-.39	9.11	1.30	11.68
	DC-10-10	7	-7.29	7.66	-2.80	6.68	-.58	6.13
	L-1011	41	-.98	8.06	-2.15	7.94	-.95	10.88
	C-580	18	-.87	8.65	-.62	8.61	-.38	8.62
	YS-11	0	0.	0.	0.	0.	0.	0.
	BAC-111	3	.40	3.34	-9.56	17.81	-1.70	7.10
	ALL	988	-2.31	9.04	-.68	8.95	.76	11.20

X = Mean Offset (Feet)   S = Standard Deviation (Feet)

FIGURE 49

SUMMARY OF LANDING LATERAL DISTRIBUTIONS BY RUNWAY WIDTH

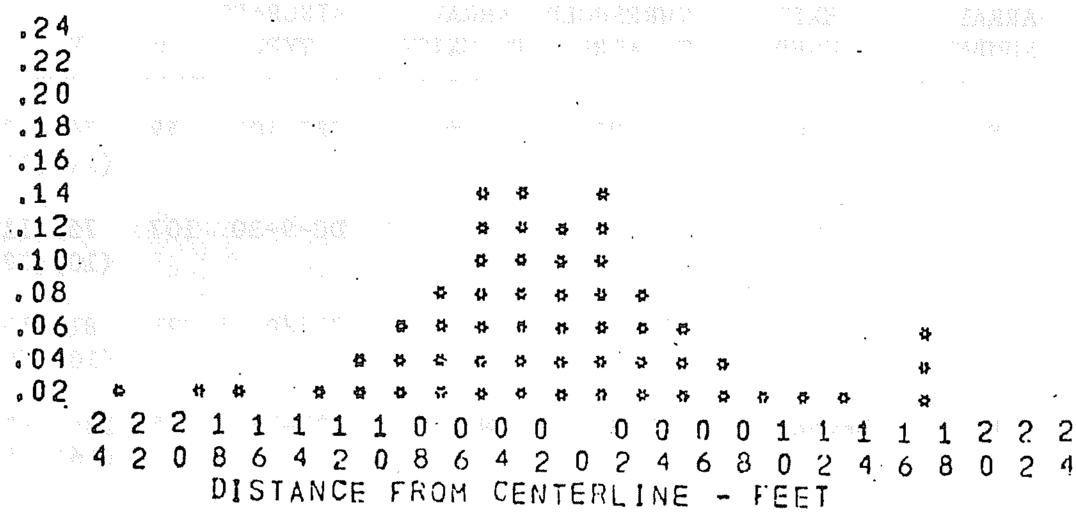
LANDING RUNWAY	ARRAY NUMBER	EXIT USED	- DISTANCES, FT. - THRESHOLD TO ARRAY	ARRAY TO EXIT*	AIRCRAFT TYPE	n	V	X
27L	N3	W	4730	0 ±	727-100	59	74 (11)	7.56 (11.93)
					DC-9-30	107	75 (10)	11.22 (12.15)
					707/DC-8	21	81 (10)	10.99 (8.37)
27L	N3	Beyond W	4730	N/A	727-100	18	134 (16)	-2.05 (5.85)
					DC-9-30	58	130 (17)	-0.87 (9.10)
9R	N3	X	4270	0 ±	DC-9-30	8	81 (8)	-15.97 (8.78)
9R	N3	Beyond X	4270	N/A	DC-9-30	57	144 (21)	2.71 (7.22)
					727-100	17	157 (24)	2.86 (7.27)

*Approximate Start of Runway Turnoff

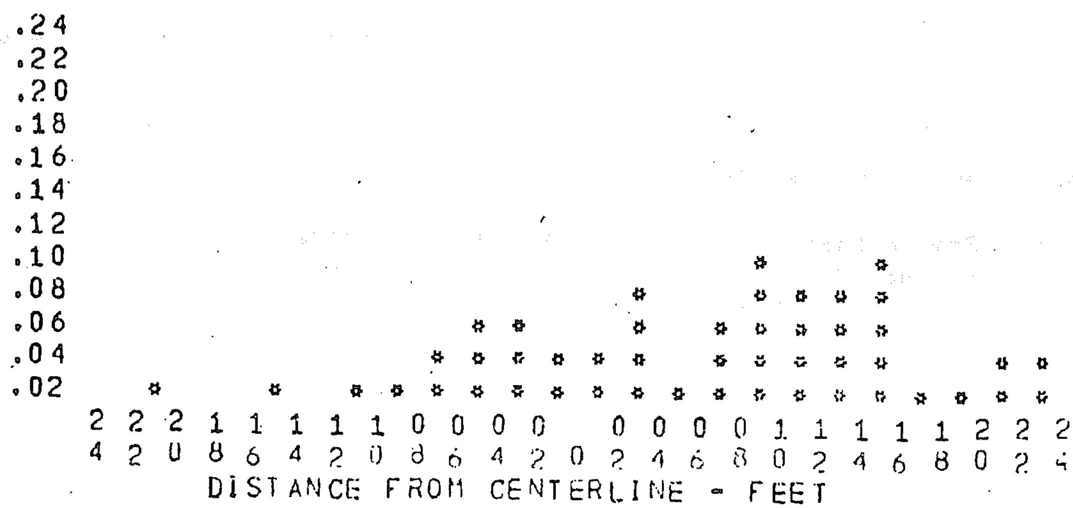
n = Sample Size
X = Average Offset (Feet)
V = Average Speed (Ft./Sec.)
( ) Standard Deviation
N/A = Not Applicable

FIGURE 50

LANDING LATERAL DISTRIBUTIONS AT RUNWAY-TURNOFFS TO HIGH-SPEED EXITS AT ATL



A. AIRCRAFT EXITING BEYOND EXIT "W"



B. AIRCRAFT EXITING AT EXIT "W"

FIGURE 51

LANDING LATERAL DISTRIBUTIONS ON ATL RUNWAY 27L

DC-9-30 AT ARRAY N3

ARRAY NUMBER	EXIT USED	--- DISTANCES, FT. --- THRESHOLD TO ARRAY	ARRAY TO EXIT*	AIRCRAFT TYPE	n	V	X
N4	U	5757	540±	727-100	7	83 (6)	-2.02 (5.35)
				DC-9-30	22	84 (4)	0.20 (11.54)
				707/DC-8	49	99 (22)	-1.90 (10.11)
				747/DC-10/ L-1011	21	102 (23)	-5.31 (8.42)
N2	W	3660	1070±	727-100	83	137 (21)	-2.81 (8.01)
				DC-9-30	174	139 (22)	-2.57 (7.60)
N2	Beyond W	3660	N/A	727-100	19	172 (14)	-2.85 (5.92)
				DC-9-30	58	166 (15)	-C.10 (9.06)

*Approximate Start of Runway Turnoff

n = Sample Size
X = Average Offset (Feet)
V = Average Speed (Ft./Sec.)
( ) Standard Deviation
N/A = Not Applicable

FIGURE 52

LANDING LATERAL DISTRIBUTIONS BEFORE RUNWAY-TURNOFFS TO HIGH-SPEED EXITS ON ATL RUNWAY 27L

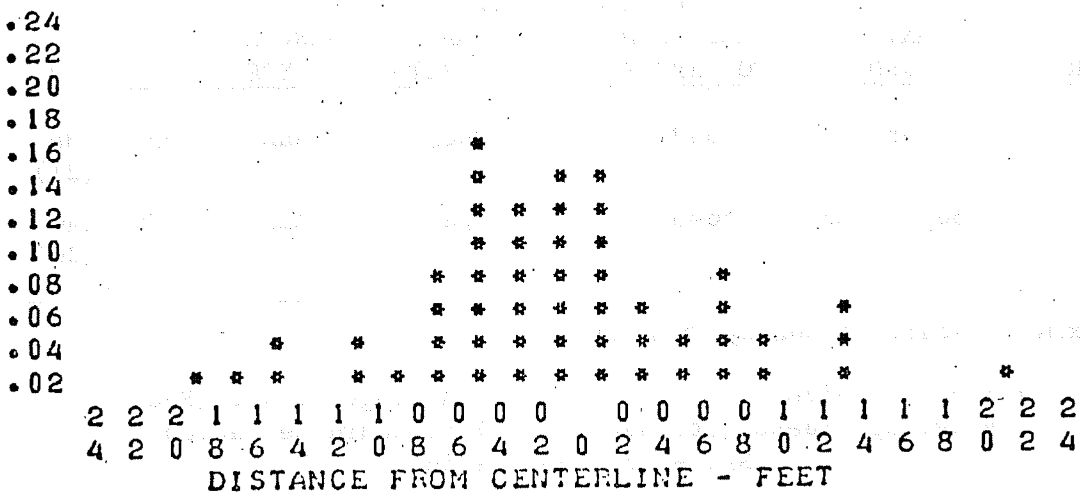
ARRAY NUMBER	EXIT USED	--- DISTANCES, FT. --- THRESHOLD TO ARRAY	ARRAY TO EXIT*	AIRCRAFT TYPE	n	V	X
N4	X	3243	1030 ±	727-100	5	157 (12)	0.88 (2.76)
				DC-9-30	25	148 (13)	0.03 (6.19)
N4	Beyond X	3243	N/A	727-100	16	193 (16)	1.64 (7.49)
				DC-9-30	28	180 (17)	2.35 (6.67)
N2	Y	5340	740 ±	727-100	16	106 (20)	1.48 (7.65)
				DC-9-30	48	104 (17)	1.97 (8.35)
				707/DC-8	20	112 (12)	4.25 (10.38)
				747/ DC-10/ L-1011	11	137 (16)	6.66 (11.82)

*Approximate Start of Runway Turnoff

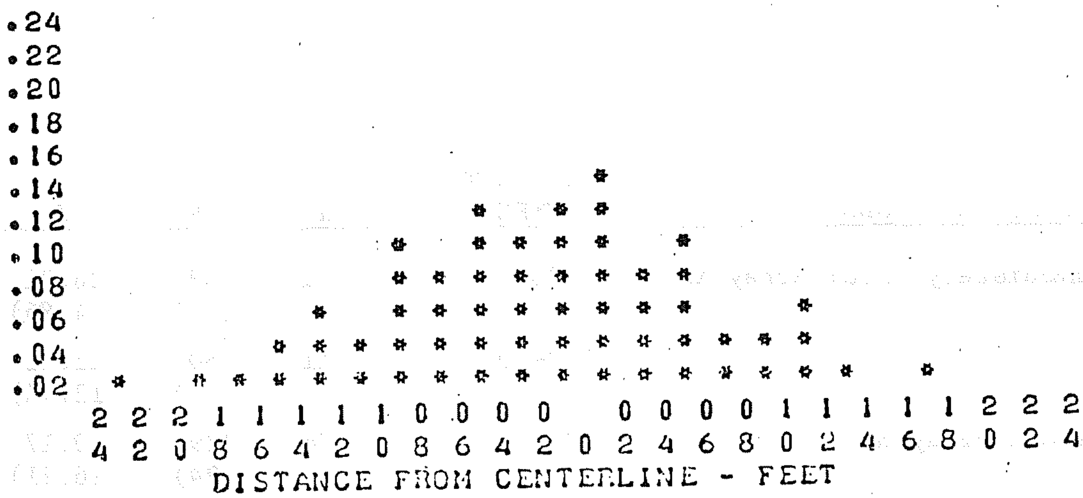
n = Sample Size X = Average Offset (Feet)
V = Average Speed (Ft./Sec.) ( ) Standard Deviation
N/A = Not Applicable

FIGURE 53

LANDING LATERAL DISTRIBUTIONS BEFORE RUNWAY-TURNOFFS TO HIGH-SPEED EXITS ON ATL RUNWAY 9R



A. AIRCRAFT EXITING BEYOND EXIT "W"



B. AIRCRAFT EXITING AT EXIT "W"

FIGURE 54

LANDING LATERAL DISTRIBUTIONS ON ATL RUNWAY 27L

DC-9-30 AT ARRAY N2

ARRAY NUMBER	EXIT USED	--- DISTANCES, FT. --- THRESHOLD TO ARRAY	ARRAY TO EXIT*	AIRCRAFT TYPE	n	V	X
N3	NE	5643	300±	ALL	337	86 (21)	-5.46 (9.13)
N3	Beyond NE	5643	N/A	ALL	39	140 (26)	-3.32 (9.69)

* Approximate Start of Runway Turnoff

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation
N/A = Not Applicable

FIGURE 55

LANDING LATERAL DISTRIBUTIONS BEFORE RUNWAY-TURNOFFS TO HIGH-SPEED EXITS ON ORD RUNWAY 9R

RUNWAY EXIT USED	AIRCRAFT TYPE	n	V	X
Immediately after Array N3	737	71	49 (21)	-26.01 (4.86)
	727-100	11	50 (9)	-11.22 (12.44)
Beyond Array N4	727-100	74	129 (24)	-0.17 (6.21)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 56

LANDING LATERAL DISTRIBUTIONS AT ARRAY N3 ON CLE RUNWAY 23L

AIRCRAFT TYPE	RUNWAY LOCATION	DAY n	DAY V	DAY X	NIGHT n	NIGHT V	NIGHT X
727-100	First Pt.	86	190 (25)	-2.24 (7.53)	20	196 (28)	-3.18 (7.81)
	Int. Pt.		137 (20)	-1.66 (7.66)		134 (24)	-4.42 (4.58)
	Last Pt.		90 (23)	6.98 (13.60)		87 (35)	-0.08 (8.31)
DC-9-30	First Pt.	289	194 (24)	1.75 (8.79)	32	192 (23)	-1.66 (5.44)
	Int. Pt.		139 (22)	-1.51 (8.21)		135 (19)	-4.16 (6.58)
	Last Pt.		95 (29)	7.27 (12.45)		90 (27)	-1.03 (8.89)
ALL	First Pt.	615	194 (28)	-2.39 (8.21)	99	194 (32)	-1.62 (7.47)
	Int. Pt.		145 (25)	-1.85 (8.09)		139 (25)	-2.93 (7.33)
	Last Pt.		101 (30)	4.69 (12.36)		93 (31)	-0.61 (9.58)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 57

LANDING LATERAL DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS ON ATL RUNWAY 27L

AIRPORT - RUNWAY	RUNWAY LOCATION	DAY n	DAY V	DAY X	NIGHT n	NIGHT V	NIGHT X
MIA-9L	First Pt.	235	156 (46)	-2.81 (10.20)	31	174 (40)	.01 (7.04)
	Int. Pt.		121 (30)	.06 (9.48)		131 (25)	2.21 (9.10)
	Last Pt.		87 (25)	1.90 (11.46)		89 (30)	6.21 (11.84)
ORD-9R	First Pt.	55	185 (35)	-3.21 (8.18)	28	183 (37)	-0.25 (9.64)
	Int. Pt.		137 (29)	-4.67 (6.40)		128 (25)	-1.37 (8.11)
	Last Pt.		99 (43)	-6.26 (7.46)		90 (29)	-1.72 (8.67)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 58

LANDING LATERAL DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS

727-100 AT MIA AND ORD

AIRPORT-RUNWAY	AIRCRAFT TYPE	CROSSWIND COMPONENTS: 5 Kts. or Greater From Right			Less than 5 Kts. Left & Right			5 Kts. or Greater From Left		
		n	V	X	n	V	X	n	V	X
DEN-26L	727-100	39	224 (20)	-3.26 (4.82)	92	218 (33)	-2.43 (6.65)	6	227 (8)	-2.56 (4.31)
	737	17	220 (11)	0.52 (8.60)	84	208 (34)	-0.43 (7.71)	7	192 (60)	5.33 (11.35)
	ALL	126	225 (24)	-3.81 (8.30)	340	220 (32)	-1.84 (7.69)	34	214 (35)	1.64 (8.65)
ORD-9R	727-100	6	153 (46)	-4.72 (2.60)	100	185 (34)	-1.43 (6.64)	22	182 (37)	-1.65 (9.04)
	DC-9-30	3	189 (13)	-0.74 (4.14	49	178 (27)	-2.90 (5.60)	13	172 (23)	-3.74 (7.21)
	ALL	31	174 (43)	-1.82 (5.56)	372	183 (31)	-2.44 (7.08)	121	187 (34)	-2.28 (7.60)

n = Sample Size   V = Average Speed (Ft./Sec.)   X = Average Offset (Feet)   ( ) Standard Deviation

FIGURE 59

LANDING LATERAL DISTRIBUTIONS FOR VARIOUS CROSSWIND CONDITIONS

AIRCRAFT TYPE	RUNWAY LOCATION	DRY PAVEMENT n	DRY PAVEMENT V	DRY PAVEMENT X	WET PAVEMENT n	WET PAVEMENT V	WET PAVEMENT X
DC-9-30	First Pt.	54	181 (25)	-3.20 (6.27)	9	158 (18)	-1.63 (3.11)
	Int. Pt.		153 (33)	-3.12 (5.81)		127 (23)	-1.67 (3.98)
	Last Pt.		132 (54)	-4.48 (7.97)		99 (33)	-2.68 (4.90)
727-100	First Pt.	99	184 (34)	-1.61 (7.46)	27	179 (39)	-1.60 (5.28)
	Int. Pt.		130 (23)	-2.91 (6.77)		127 (29)	-2.80 (5.61)
	Last Pt.		87 (31)	-5.06 (9.39)		87 (39)	-3.14 (7.76)
ALL	First Pt.	406	184 (32)	-2.78 (7.19)	117	182 (35)	-0.94 (6.73)
	Int. Pt.		138 (26)	-3.75 (6.72)		134 (26)	-2.74 (7.02)
	Last Pt.		102 (38)	-4.92 (8.52)		96 (33)	-4.39 (8.83)

n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 60

LANDING LATERAL DISTRIBUTIONS ON WET VERSUS DRY PAVEMENTS

ORD RUNWAY 9R

AIRCRAFT TYPE	RUNWAY LOCATION	DRY PAVEMENT n	DRY PAVEMENT V	DRY PAVEMENT X	WET PAVEMENT n	WET PAVEMENT V	WET PAVEMENT X
737	First Pt.	70	189 (18)	-1.70 (5.18)	18	193 (12)	-2.49 (5.41)
	Int. Pt.		169 (27)	-2.25 (5.69)		165 (24)	-3.22 (6.29)
	Last Pt.		133 (56)	-8.96 (12.81)		112 (63)	-11.40 (13.83)
727-100	First Pt.	99	200 (22)	-2.51 (6.34)	29	204 (15)	-2.67 (5.43)
	Int. Pt.		154 (28)	-0.16 (5.42)		166 (18)	-0.66 (4.54)
	Last Pt.		86 (32)	-1.09 (5.84)		101 (27)	-0.88 (11.67)
ALL	First Pt.	310	196 (25)	-1.64 (6.66)	88	199 (18)	-2.42 (5.75)
	Int. Pt.		159 (29)	-1.20 (6.20)		168 (21)	-1.34 (5.54)
	Last Pt.		104 (47)	-3.58 (9.84)		111 (45)	-4.51 (12.76)

n = Sample Size X = Average Offset (Feet)
V = Average Speed (Ft./Sec.) ( ) Standard Deviation

FIGURE 61

LANDING LATERAL DISTRIBUTIONS ON WET VERSUS DRY PAVEMENTS

CLE RUNWAY 23L

AIRPORT	RUNWAY	TRAVERSE LIGHT ELEMENT RELATIVE TO THRESHOLD First	Third	Fourth
ATL	9R	776	1745	2569
	27L	830	1931	2119
ORD	9R	862	1965	2750
	27L	1000	2086	2911
DEN	8R	1100	2362	3033
	26L	994	2265	2964
SEA	16L	786	1892	2892
	34R	1138	2409	3409
CLE	5R	817	1974	2702
	23L	751	1729	2552
BUF	5	664	1927	2714
	23	904	2078	2850
MIA	9L	995	2261	3168
	27R	990	1983	2903
MSY	10	910	2091	2843
	28	757	1973	2645
DFW	17L	1100	2471	3741
	35R	1000	2103	3103
	AVERAGE DIST.	910	1863	2905
	NOMINAL DIST.	1000	2000	3000

FIGURE 62

DISTANCES FROM LANDING THRESHOLD TO TRANSVERSE LIGHT ELEMENTS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	2	0	0	100
	27L	18	6	100	100
ORD	9R	79	6	72	96
	27L	10	40	100	100
DEN	8R	9	0	89	100
	26L	52	8	72	87
SEA	16L	13	8	76	90
	34R	57	49	95	100
CLE	5R	25	0	60	72
	23L	34	3	80	95
BUF	5	10	10	100	100
	23	18	33	89	100
MIA	9L	63	14	52	98
	27R	7	0	57	100
MSY	10	4	50	100	100
	28	0	-	-	-
DFW	17L	33	3	78	78
	35R	5	0	0	80
	WEIGHTED AVERAGES		14	75	93

FIGURE 63

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - 707 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	22	0	68	100
	27L	108	18	95	97
ORD	9R	128	9	75	98
	27L	21	19	90	95
DEN	8R	13	0	92	100
	26L	136	6	85	95
SEA	16L	11	18	91	100
	34R	132	49	96	99
CLE	5R	101	15	86	98
	23L	130	4	90	99
BUF	5	17	41	94	94
	23	46	30	98	100
MIA	9L	287	22	52	99
	27R	67	0	50	100
MSY	10	34	18	95	100
	28	17	47	88	100
DFW	17L	24	21	89	89
	35R	5	0	0	100
	WEIGHTED AVERAGES		18	78	98

FIGURE 64

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - 727-100 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	59	3	64	93
	27L	106	9	82	92
ORD	9R	93	2	68	92
	27L	23	57	92	96
DEN	8R	16	0	100	100
	26L	118	5	78	89
SEA	16L	10	40	90	90
	34R	119	37	96	100
CLE	5R	32	9	80	100
	23L	35	6	83	100
BUF	5	6	50	100	100
	23	24	54	95	100
MIA	9L	88	10	52	99
	27R	30	0	40	90
MSY	10	34	18	97	100
	28	23	57	92	96
DFW	17L	20	15	80	80
	35R	4	0	0	50
	WEIGHTED AVERAGES		16	73	90

FIGURE 65

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - 727-200 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	10	0	60	100
	27L	26	12	97	100
ORD	9R	36	36	86	94
	27L	10	60	90	90
DEN	8R	17	0	82	100
	26L	110	18	78	88
SEA	16L	5	20	80	80
	34R	25	56	92	100
CLE	5R	20	30	100	100
	23L	93	20	92	100
BUF	5	4	50	100	100
	23	13	38	91	100
MIA	9L	4	0	50	75
	27R	0	–	–	–
MSY	10	0	–	–	–
	28	0	–	–	–
DFW	17L	2	50	100	100
	35R	1	0	0	100
	WEIGHTED AVERAGES		25	87	96

FIGURE 66

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - 737 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	1	0	100	100
	27L	10	10	70	80
ORD	9R	14	0	35	85
	27L	2	0	100	100
DEN	8R	0	–	–	–
	26L	0	–	–	–
SEA	16L	6	17	50	83
	34R	14	57	100	100
CLE	5R	1	0	100	100
	23L	1	0	100	100
BUF	5	0	–	–	–
	23	0	–	–	–
MIA	9L	2	50	50	100
	27R	3	0	67	100
MSY	10	0	–	–	–
	28	0	–	–	–
DFW	17L	6	17	67	67
	35R	1	0	0	100
	WEIGHTED AVERAGES		20	67	88

FIGURE 67

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - 747 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	14	0	50	86
	27L	56	4	69	90
ORD	9R	33	9	76	100
	27L	3	33	100	100
DEN	8R	4	0	100	100
	26L	30	3	53	96
SEA	16L	5	0	80	100
	34R	31	39	97	100
CLE	5R	12	0	58	91
	23L	12	8	75	100
BUF	5	2	0	100	100
	23	2	0	50	50
MIA	9L	19	26	63	95
	27R	7	0	57	100
MSY	10	9	22	100	100
	28	8	25	88	100
DFW	17L	15	20	80	80
	35R	0	-	-	-
	WEIGHTED AVERAGES		14	75	96

FIGURE 68

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - DC-8-40,-50 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	18	0	51	90
	27L	37	5	76	81
ORD	9R	24	8	71	92
	27L	6	17	84	84
DEN	8R	3	0	67	100
	26L	15	7	54	94
SEA	16L	9	44	88	100
	34R	31	26	94	100
CLE	5R	12	17	66	100
	23L	17	0	59	88
BUF	5	0	-	-	-
	23	0	-	-	-
MIA	9L	2	0	50	100
	27R	4	0	25	100
MSY	10	18	22	84	95
	28	7	43	100	100
DFW	17L	6	0	50	50
	35R	1	0	0	100
	WEIGHTED AVERAGES		13	72	91

FIGURE 69

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - DC-8-60 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	17	0	94	100
	27L	60	7	92	99
ORD	9R	7	14	100	100
	27L	1	100	100	100
DEN	8R	3	0	100	100
	26L	18	17	88	94
SEA	16L	5	40	100	100
	34R	23	70	100	100
CLE	5R	6	17	84	100
	23L	9	22	88	100
BUF	5	1	0	100	100
	23	3	0	100	100
MIA	9L	7	0	14	85
	27R	0	-	-	-
MSY	10	30	27	100	100
	28	11	27	100	100
DFW	17L	24	21	84	84
	35R	1	0	0	100
	WEIGHTED AVERAGES		22	92	98

FIGURE 70

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - DC-9-10,-20 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	93	5	84	99
	27L	241	14	86	94
ORD	9R	66	38	84	99
	27L	29	72	100	100
DEN	8R	2	0	100	100
	26L	14	21	92	92
SEA	16L	3	67	100	100
	34R	33	55	88	88
CLE	5R	20	0	75	100
	23L	26	8	96	100
BUF	5	21	67	100	100
	23	57	33	91	100
MIA	9L	98	28	75	100
	27R	54	0	56	100
MSY	10	59	29	98	100
	28	35	40	91	100
DFW	17L	26	23	100	100
	35R	3	0	0	100
	WEIGHTED AVERAGES		24	85	98

FIGURE 71

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - DC-9-30,-40 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	7	0	43	100
	27L	15	0	74	81
ORD	9R	20	5	55	100
	27L	2	100	100	100
DEN	8R	9	0	78	78
	26L	36	17	73	95
SEA	16L	2	50	100	100
	34R	31	42	90	100
CLE	5R	1	0	100	100
	23L	2	0	50	50
BUF	5	2	0	50	50
	23	13	31	92	100
MIA	9L	2	50	100	100
	27R	1	0	100	100
MSY	10	1	0	0	0
	28	1	0	100	100
DFW	17L	3	0	0	0
	35R	1	0	0	100
	WEIGHTED AVERAGES		19	73	91

FIGURE 72

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - DC-10-10 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	5	0	20	60
	27L	15	13	73	86
ORD	9R	10	0	50	90
	27L	2	50	100	100
DEN	8R	0	-	-	-
	26L	0	-	-	-
SEA	16L	0	-	-	-
	34R	0	-	-	-
CLE	5R	0	-	-	-
	23L	0	-	-	-
BUF	5	0	-	-	-
	23	0	-	-	-
MIA	9L	21	14	28	100
	27R	13	0	31	100
MSY	10	1	0	100	100
	28	1	0	100	100
DFW	17L	6	0	33	33
	35R	1	0	0	100
	WEIGHTED AVERAGES		8	44	88

FIGURE 73

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - L-1011 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	2	0	100	100
	27L	5	20	80	100
ORD	9R	10	40	60	60
	27L	10	90	100	100
DEN	8R	8	0	100	100
	26L	47	6	74	89
SEA	16L	1	0	100	100
	34R	10	60	100	100
CLE	5R	3	33	100	100
	23L	15	27	94	94
BUF	5	6	33	83	83
	23	21	24	91	96
MIA	9L	5	40	100	100
	27R	2	0	0	100
MSY	10	5	40	100	100
	28	3	33	100	100
DFW	17L	9	89	100	100
	35R	2	0	0	100
	WEIGHTED AVERAGES		29	85	93

FIGURE 74

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - C-580 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	5	0	80	100
	27L	15	13	86	90
ORD	9R	0	–	–	–
	27L	0	–	–	–
DEN	8R	0	–	–	–
	26L	0	–	–	–
SEA	16L	0	–	–	–
	34R	0	–	–	–
CLE	5R	3	67	67	67
	23L	0	–	–	–
BUF	5	0	–	–	–
	23	0	–	–	–
MIA	9L	0	–	–	–
	27R	0	–	–	–
MSY	10	0	–	–	–
	28	0	–	–	–
DFW	17L	0	–	–	–
	35R	0	–	–	–
	WEIGHTED AVERAGES		17	82	89

FIGURE 75

CUMULATIVE TOUCHDOWN DISTRIBUTIONS – YS-11 LANDINGS

AIRPORT	RUNWAY	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
ATL	9R	0	-	-	-
	27L	0	-	-	-
ORD	9R	0	-	-	-
	27L	0	-	-	-
DEN	8R	0	-	-	-
	26L	0	-	-	-
SEA	16L	0	-	-	-
	34R	0	-	-	-
CLE	5R	15	7	94	100
	23L	25	32	96	100
BUF	5	29	41	97	100
	23	124	31	93	100
MIA	9L	2	50	100	100
	27R	0	-	-	-
MSY	10	2	0	100	100
	28	1	0	100	100
DFW	17L	1	0	100	100
	35R	0	-	-	-
	WEIGHTED AVERAGES		30	94	100

FIGURE 76

CUMULATIVE TOUCHDOWN DISTRIBUTIONS - BAC-111 LANDINGS

AIRCRAFT TYPE	SAMPLE SIZE	CUMULATIVE PERCENTAGES AT NOMINAL DISTANCES FROM THRESHOLD 1000'	2000'	3000'
747	61	20	67	88
DC-10-10	149	19	73	91
L-1011	75	8	44	88
DC-8-60	210	13	72	91
DC-8-40,-50	262	14	75	96
707	439	14	75	93
727-200	840	16	73	90
727-100	1299	18	78	98
DC-9-30,-40	880	24	85	98
DC-9-10,-20	226	22	92	98
737	376	25	87	96
BAC-111	199	30	94	100
C-580	164	29	85	93
YS-11	23	17	82	89

FIGURE 77

SUMMARY OF CUMULATIVE TOUCHDOWN DISTRIBUTIONS AT ALL AIRPORTS COMBINED

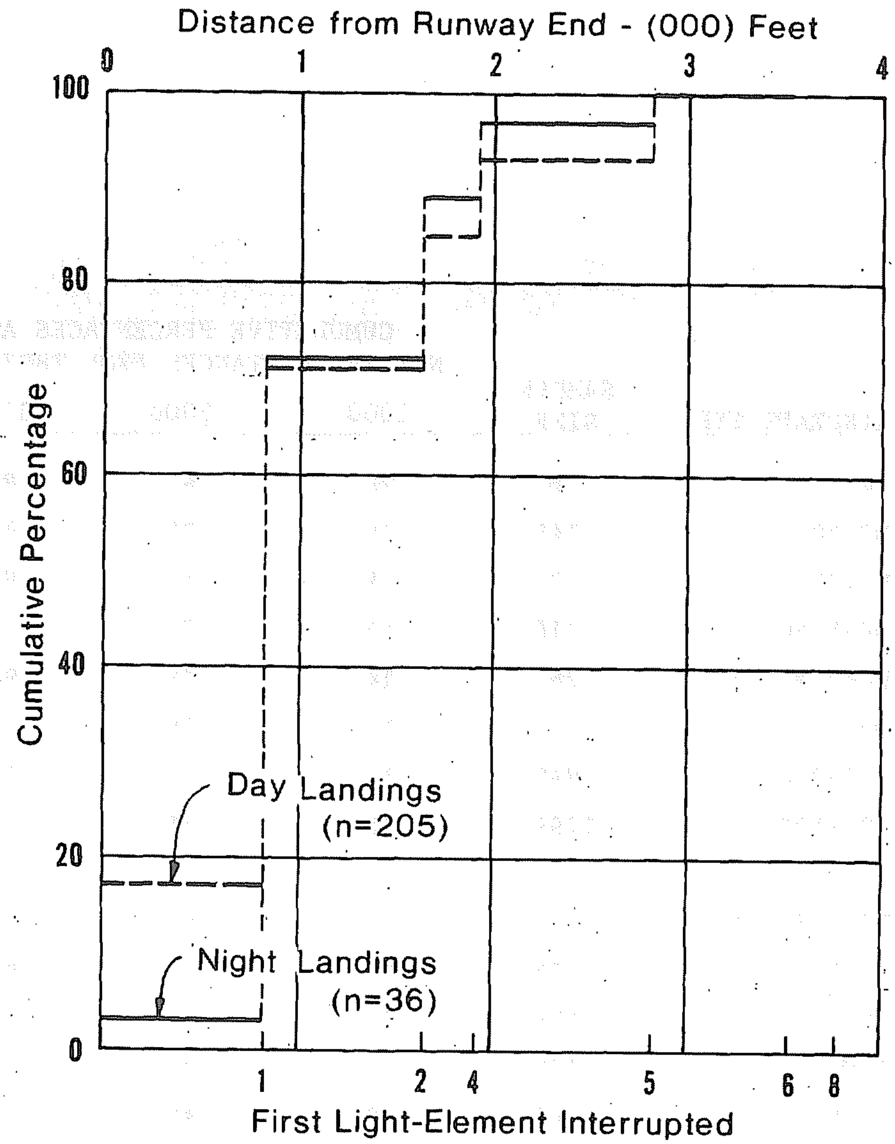


FIGURE 78

CUMULATIVE TOUCHDOWN DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS DC-9-30, -40 ON ATL RUNWAY 27 L

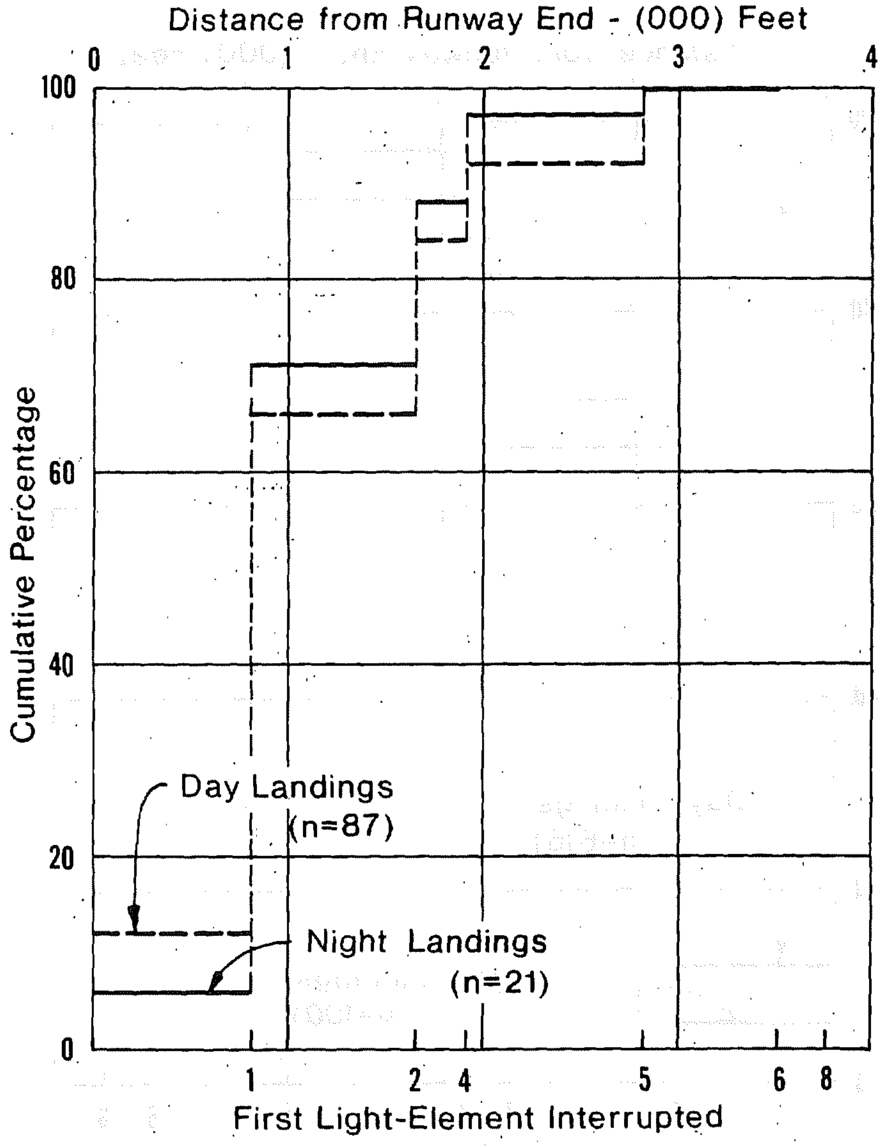


FIGURE 79

CUMULATIVE TOUCHDOWN DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS 727-100 ON ATL RUNWAY 27L

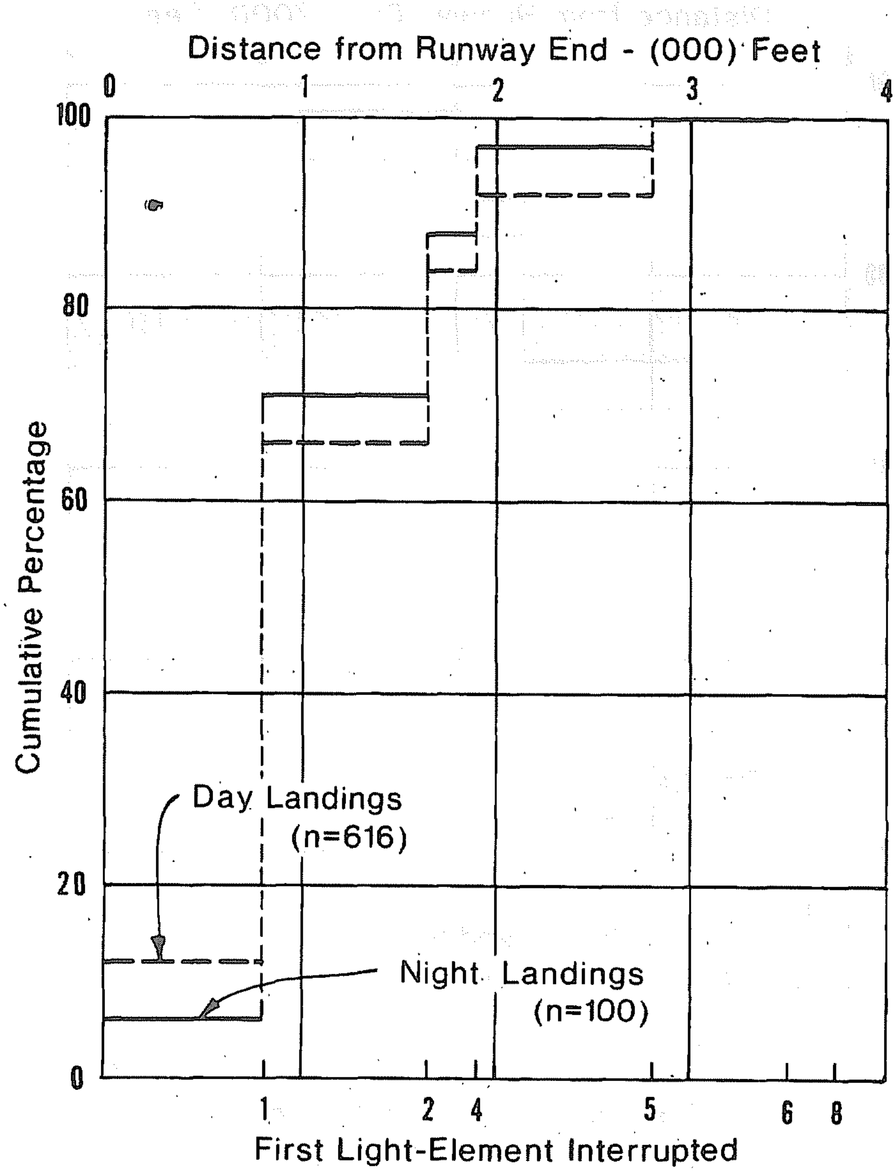


FIGURE 80

CUMULATIVE TOUCHDOWN DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS ALL AIRCRAFT ON ATL RUNWAY 27L

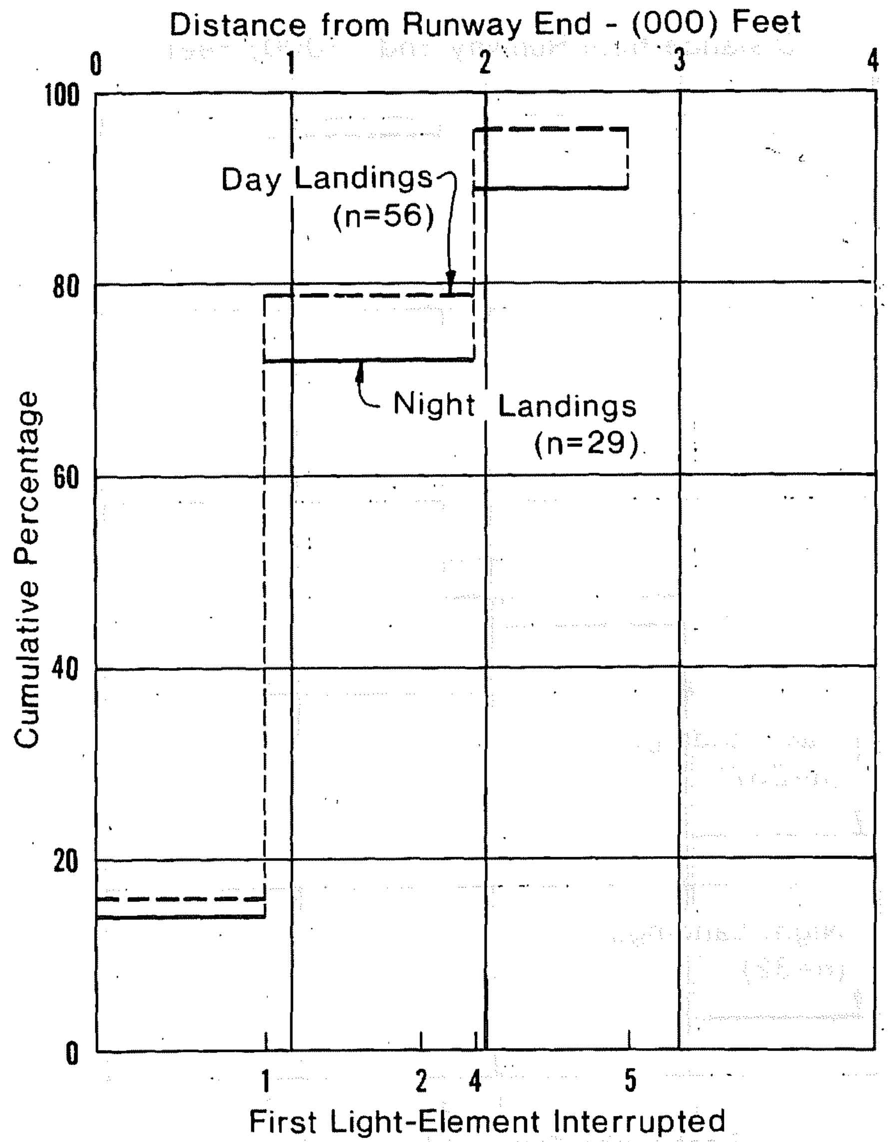


FIGURE 81

CUMULATIVE TOUCHDOWN DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS 727-100 ON ORD RUNWAY 9R

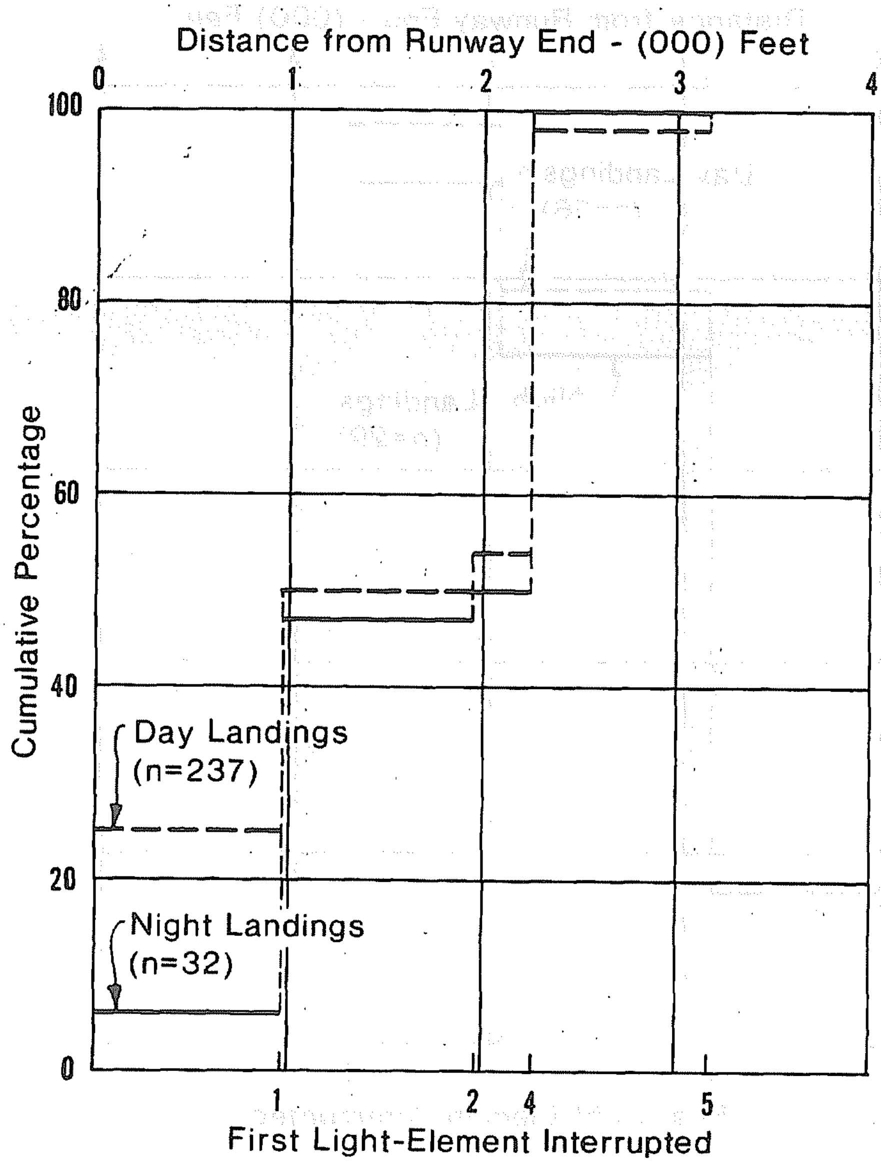


FIGURE 82

CUMULATIVE TOUCHDOWN DISTRIBUTIONS FOR DAY VERSUS NIGHT OPERATIONS 727-100 ON MIA RUNWAY 9L

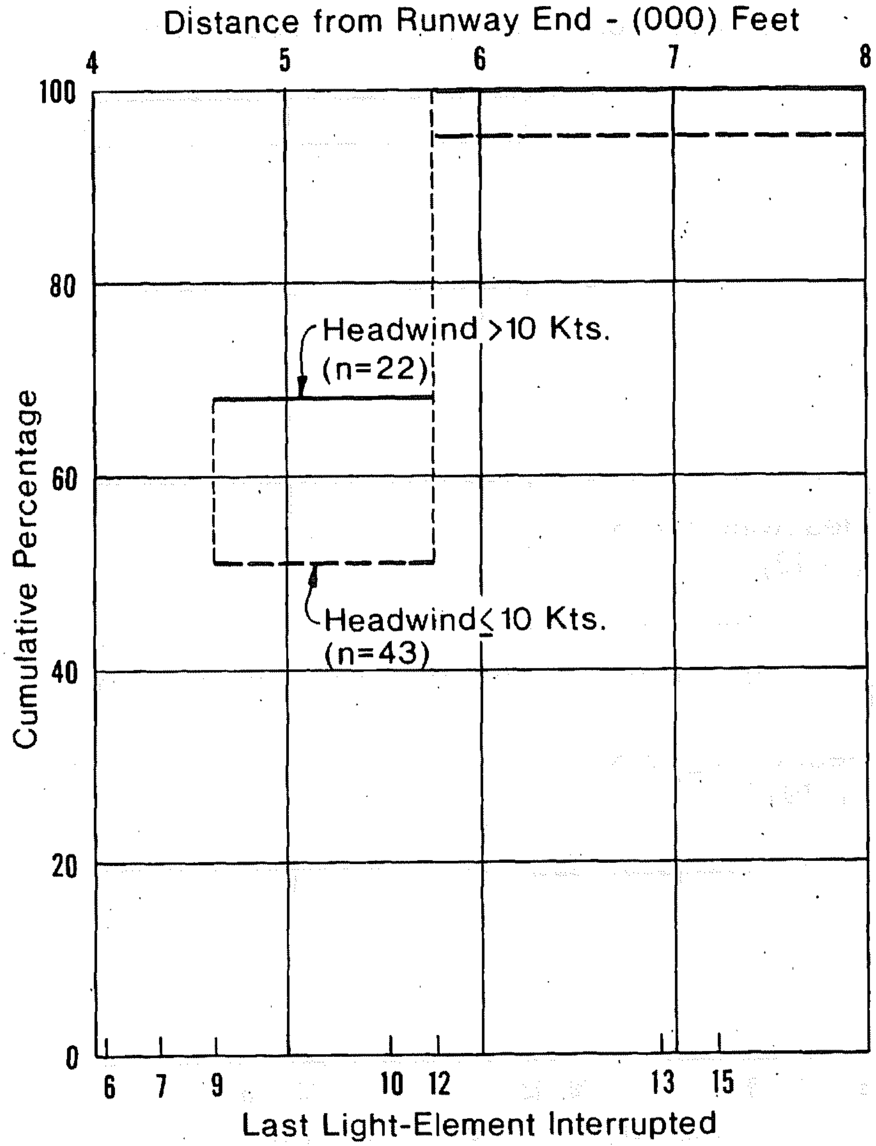


FIGURE 83

CUMULATIVE DISTRIBUTIONS OF LANDING-ROLL DISTANCES FOR VARIOUS HEADWIND CONDITIONS DC-9-30, -40 ON ORD RUNWAY 9R

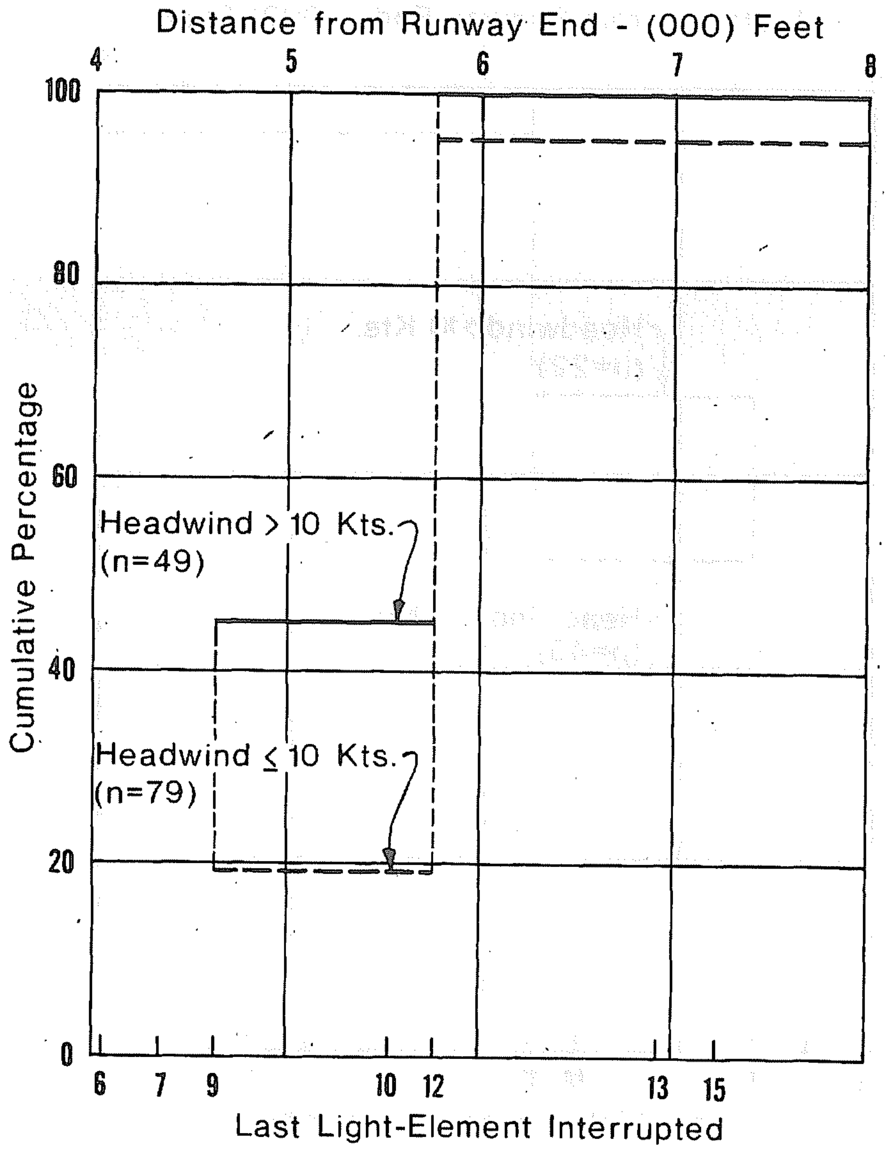


FIGURE 84

CUMULATIVE DISTRIBUTIONS OF LANDING-ROLL DISTANCES FOR VARIOUS HEADWIND CONDITIONS 727-100 ON ORD RUNWAY 9R

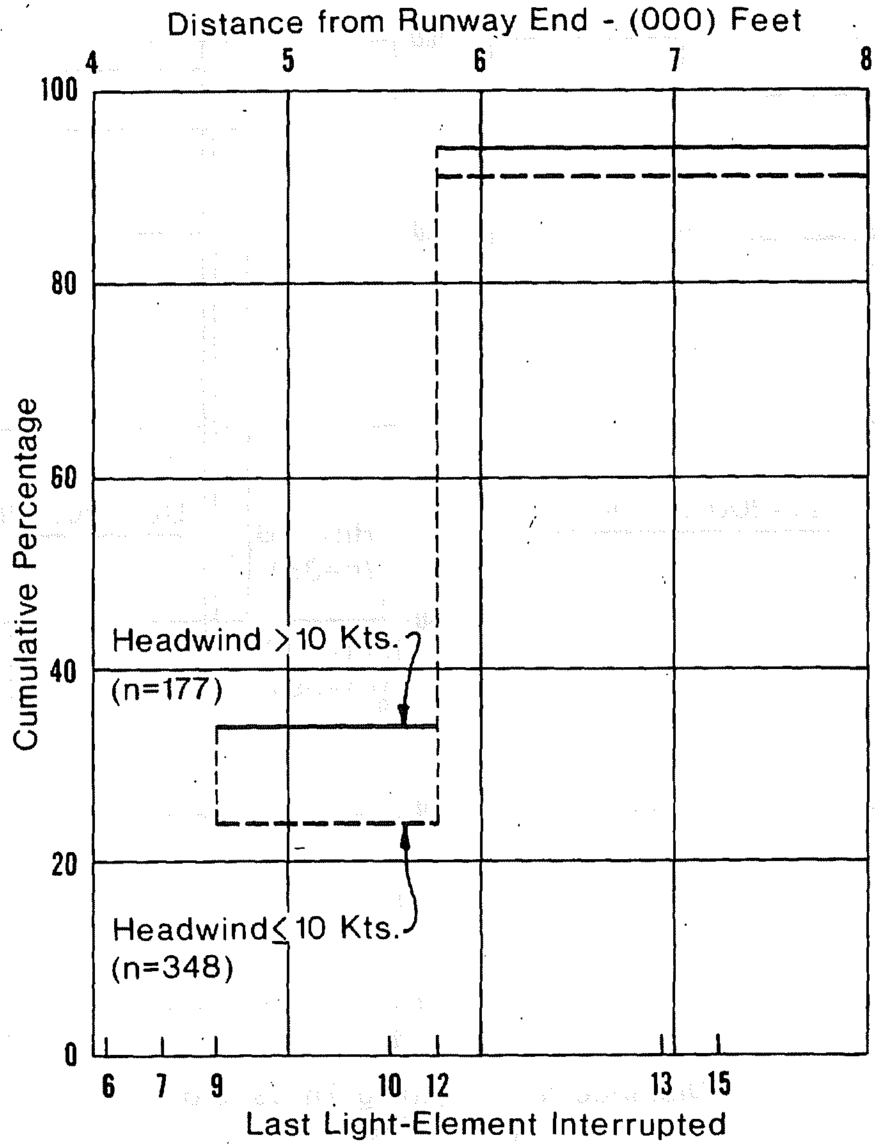


FIGURE 85

CUMULATIVE DISTRIBUTIONS OF LANDING-ROLL DISTANCES FOR VARIOUS HEADWIND CONDITIONS ALL AIRCRAFT ON ORD RUNWAY 9R

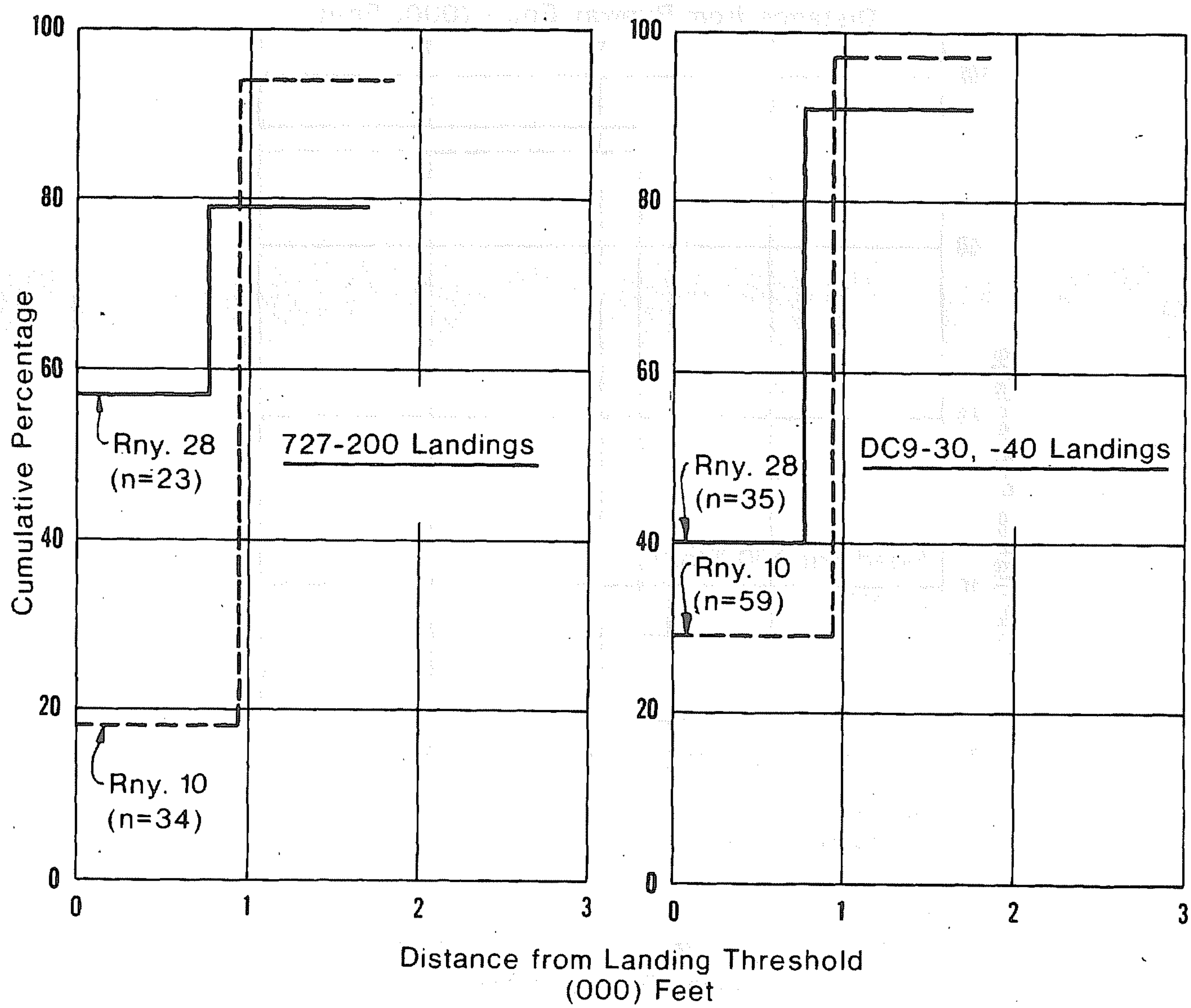


FIGURE 86

CUMULATIVE TOUCHDOWN DISTRIBUTIONS ON MSY RUNWAY 10 VERSUS RUNWAY 28

High-Speed Exit Operations

Eight high-speed exits were instrumented in the study. They were Exits "W" and "Y" at ATL, "NE" and "NW" at ORD, "U" and "S" at DEN, "B-5" at SEA, and one (unnamed--see Figure 25) at DFW.

At DEN, only one landing on Runway 26L and eight landings on Runway 8R used Exit "U." The landings on Runway 8R used Exit "U" to make 180-degree turns onto the parallel taxiway (see Figure 19) to taxi toward the terminal area. (The average speed in Exit "U" of those eight operations was 29 feet per second and the mean offset was 12.27 feet to the right of the guideline.) Exit "U" at DEN, therefore, was essentially not used for high-speed turnoffs during the period of the data collection.

At ORD, there were relatively few landings recorded on Runway 27L. Only a few of those landings turned off at Exit "NW" and of those, only four were positively identified (probably owing to the nature of the intersection at the parallel taxiway--see Figure 18).

For the above reasons, Exit "U" at DEN and Exit "NW" at ORD were not included in the analysis of high-speed exit operations which follows.

Lateral Distributions - The mean and standard deviations of the lateral distributions at each high-speed exit are summarized in Figure 87, by aircraft types for which relatively large samples were obtained, and for all aircraft combined.

At ATL, the offset mean at Exit "W" generally was to the right of the guideline (1.5 feet for all aircraft), and at Exit "Y" it generally was to the left (2.8 feet for all aircraft). In Figure 17, it is seen that Exits "W" and "Y" were entirely curved on one side--on the right side of Exit "W" and on the left side of Exit "Y." The offset mean at each of these exits occurred toward the curved side of the exit. The standard deviations of the distributions at those exits were fairly consistent, averaging about 10.5 feet.

Exit "S" at DEN was relatively straight (see Figure 19), and Exit "B-5" at SEA (see Figure 20) had a relatively long, straight section. The mean of the offsets at those two exits were about 1 foot to the left of the guideline. The standard deviation of the distributions at Exit "S" was about 8 feet (somewhat less than those observed on the exits at ATL). That at Exit "B-5" was approximately 5 feet, which probably was more akin to the standard deviations observed on straight taxiways, as described later in this section.

The offset mean at Exit "NE" at ORD was approximately 14 feet to the right of the guideline, and that at the instrumented exit at DFW was approximately 10 feet to the left of the guideline. These offsets were much farther displaced from the guidelines than those at the ATL, DEN, and SEA exits.

The standard deviation of about 8.5 feet for the lateral distributions at the ORD and the DFW exits indicated a systematic pattern to the widely displaced offsets, rather than just random occurrences. An investigation of the flow-pattern of aircraft that used those exits revealed that almost all such aircraft turned onto the parallel taxiway and taxied in the direction opposite their landing direction (see Figures 18 and 25). The tendency, therefore, was for such aircraft to track along wide-sweeping paths (away from the guidelines) in order to accomplish the 180-degree turns.

Histograms of the lateral distributions for DC-9-30 and -40 aircraft at Exit "W" at ATL, and for all aircraft combined at Exit "NE" at ORD, and Exit "S" at DEN, are shown in Figure 88. Inspection of these histograms shows that the shapes of the lateral distribution patterns are much closer to being normal than uniform.

Exit Speeds - The mean and standard deviations of the speeds in the exits are also summarized in Figure 87.

The arrays at Exits "Y" at ATL, "NE" at ORD, "B-5" at SEA, and at the exit instrumented at DFW were generally located about 7000 feet from the respective landing thresholds. The average speeds through those arrays were fairly consistent, ranging from 40 to 45 feet per second.

The array at Exit "W" at ATL was located approximately 5700 feet from the landing threshold. The average speed through that array was about 55 feet per second. The array at Exit "S" at DEN, however, was approximately 6500 feet from the landing threshold, but the average speed at that array was over 55 feet per second. This higher average speed was attributed to the generally higher touchdown ground-speeds resulting from DEN's mile-high elevation (compare speeds at First Point for landings at DEN with those at the other airports--reference Figures A-46 to A-63, in Appendix A).

Speeds at Runway Turnoffs - In Figure 89, the average speeds on runways at the approximate start of turnoff into high-speed exits are summarized and compared with the average speeds measured in the exits themselves.

It is seen in Figure 89 that the average runway-turnoff speeds ranged from about 75 to 80 feet per second. The average speeds in the exits--measured at approximately 1000 feet from the runway-turnoff points--were about 45 feet per second at the ORD and DFW high-speed exits and about 55 feet per second at ATL's Exit "W." The lower speeds at ORD and DFW were attributed to the operational flow-pattern discussed on the preceding page.

The average speeds in Exit "W" at ATL were about 75% of the runway-turnoff speeds, and those in the high-speed exits at ORD and DFW were about 57% of the runway-turnoff speeds.

Operations on Straight Taxiways

Seven locations on straight taxiways were instrumented in the study. One each was instrumented at SEA, BUF, MIA, MSY, and DFW; two were instrumented at CLE. The taxiway width at DFW was 100 feet. All the others were 75 feet.

The mean and standard deviations of the lateral distributions and speeds are summarized in Figure 90 for all 75-foot taxiways, and in Figure 91 for the 100-foot taxiway at DFW.

Lateral Distributions - The mean offsets were consistently to the right of the pavement centerline, and ranged between 1 and 5 feet from the centerline. The mean offset for all (488) recorded operations on the 75-foot taxiways was 2.09 feet, compared with 3.20 feet for all (102) recorded operations on the 100-foot taxiway at DFW.

The standard deviations on the 75-foot taxiways generally ranged between 2.5 feet and 4 feet, and those on the 100-foot taxiway were generally wider, with an overall average of about 6 feet.

Histograms of the lateral distributions on straight taxiways are shown in Figure 92 for all aircraft combined at BUF and at MIA, and in Figure 93 for all aircraft combined at DFW. Inspection of the histograms shows that the shapes of the lateral distribution patterns are much closer to being normal than uniform.

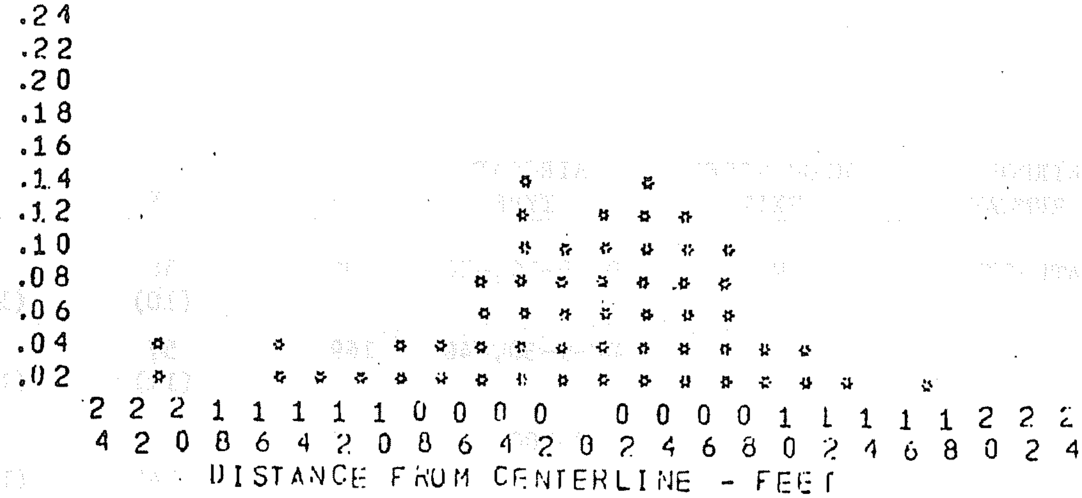
Taxiing Speeds - Average taxiing speeds ranged between 35 and 45 feet per second, on both 75- and 100-foot taxiways (see Figures 90 and 91). Larger aircraft appeared to taxi at slower speeds. For instance, the average speed of 707's at MIA and DFW was approximately 35 feet per second, while the average speed of DC-9's at BUF, MIA, MSY and DFW was aprpoximately 43 feet per second.

AIRPORT-RUNWAY	HIGH-SPEED EXIT	AIRCRAFT TYPE	n	V	X
ATL-27L	W	DC-9-10,-20	36	56 (10)	0.00 (10.19)
		DC-9-30,-40	169	57 (11)	2.69 (10.64)
		727-100	37	54 (14)	3.47 (11.21)
		727-200	40	57 (12)	-1.73 (9.28)
		ALL	334	56 (12)	1.50 (10.72)
ATL-9R	Y	DC-9-30,-40	37	42 (8)	-2.40 (10.7[illegible])
		727-200	20	42 (6)	-2.36 (9.84)
		ALL	88	43 (7)	-2.77 (10.55)
ORD-9R	NE	727-100	19	40 (8)	14.99 (8.21)
		727-200	33	40 (7)	9.95 (6.73)
		ALL	109	39 (9)	13.76 (8.24)
DEN-26L	S	727-100	40	60 (26)	-0.56 (7.82)
		737	29	56 (14)	-0.85 (8.87)
		ALL	112	57 (19)	-0.73 (8.15)
SEA-16R	B-5	ALL	11	41 (10)	-1.17 (4.93)
DFW-17L	See Fig. 25	ALL	29	44 (9)	-10.36 (8.68)

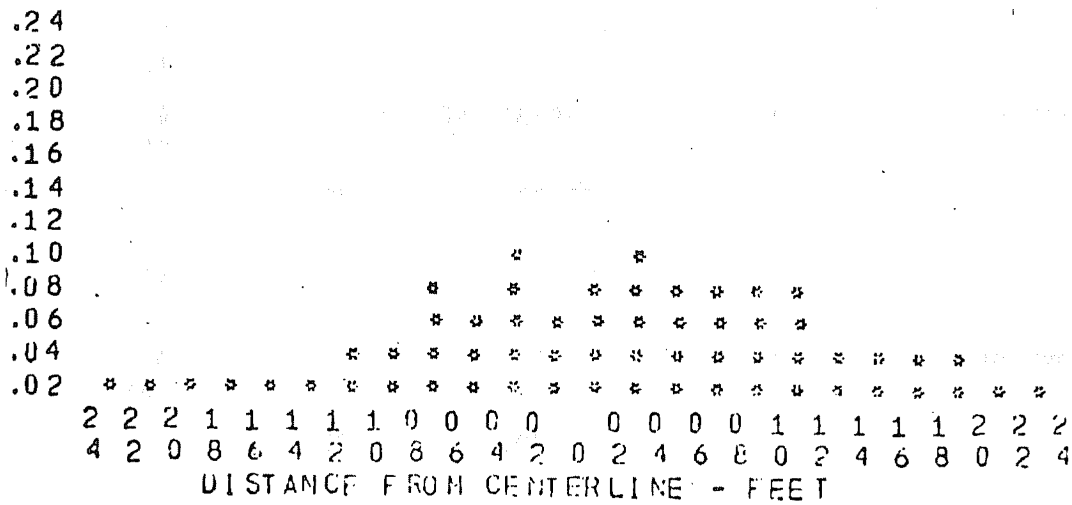
n = Sample Size
V = Average Speed (Ft./Sec.)
X = Average Offset (Feet)
( ) Standard Deviation

FIGURE 87

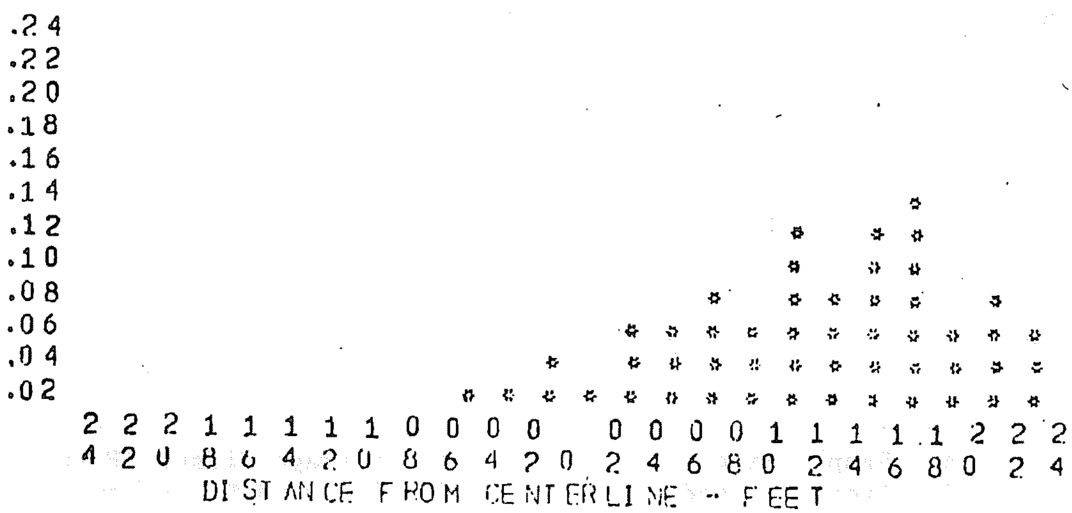
LATERAL DISTRIBUTIONS OF HIGH-SPEED-EXIT OPERATIONS



A. ALL AIRCRAFT AT DEN EXIT "S"



B. DC-9-30,-40 AIRCRAFT AT ATL EXIT "W"



C. ALL AIRCRAFT AT ORD EXIT "NE"

FIGURE 88

LATERAL DISTRIBUTION-HISTOGRAMS FOR HIGH-SPEED-EXIT OPERATIONS AT DEN, ATL AND ORD

AIRPORT-RUNWAY	EXIT	AIRCRAFT TYPE	AVERAGE SPEED, FT./SEC. AT APPROX. RNY.-TURNOFF	AT ARRAY IN EXIT	APPROX.[1] DIST.	SPEED RATIO [2]
ATL-27L	W	727-100	74 (11)	54 (11)	970'	0.73
		DC-9-30	75 (10)	57 (11)		0.76
ATL-9R	X	DC-9-30	81 (8)	-	-	-
ORD-9R	NE	ALL	77[3] (21)	43 (7)	865'	0.58
DFW-17L	See Fig. 25	ALL	78 (14)	44 (9)	970'	0.56

( ) Denotes standard deviation

1/ From runway-turnoff point to array in exit

2/ Average speed at array in exit to that at approximate runway-turnoff point.

3/ Estimated average speed. Array N3 on runway was approximately 300' prior to runway-turnoff point. Average speed at Array N3 was 86 ft./sec. Therefore, average deceleration rate between Array N3 and array in the exit was 2.38 ft./sec./sec.

FIGURE 89

AIRCRAFT AVERAGE SPEEDS AT RUNWAY-TURNOFF POINTS AND IN HIGH-SPEED EXITS

AIRPORT	AIRCRAFT TYPE	n	V	X
CLE	727-100	24	38 (6)	4.85 (3.78)
	ALL	71	39 (7)	4.88 (3.87)
BUF	727-100	29	33 (6)	3.13 (2.24)
	727-200	19	35 (10)	3.35 (2.50)
	737	20	36 (6)	1.80 (2.98)
	DC-9-30,-40	36	38 (7)	1.77 (2.97)
	BAC-111	18	45 (3)	0.10 (2.24)
	ALL	146	37 (8)	2.27 (2.98)
MIA	727-100	69	43 (9)	0.78 (2.90)
	727-200	35	43 (10)	1.37 (2.90)
	DC-9-30,-40	49	43 (8)	1.51 (4.25)
	ALL	183	43 (9)	1.06 (4.10)
MSY	727-100	15	40 (9)	2.77 (4.22)
	727-200	22	42 (6)	0.89 (2.51)
	DC-9-10,-20	14	47 (7)	1.09 (3.95)
	DC-9-30,-40	23	49 (10)	1.79 (3.35)
	ALL	88	45 (9)	1.67 (3.34)

n = Sample Size
X = Average Offset (Feet)
V = Average Speed (Ft./Sec.)
( ) Standard Deviation

FIGURE 90

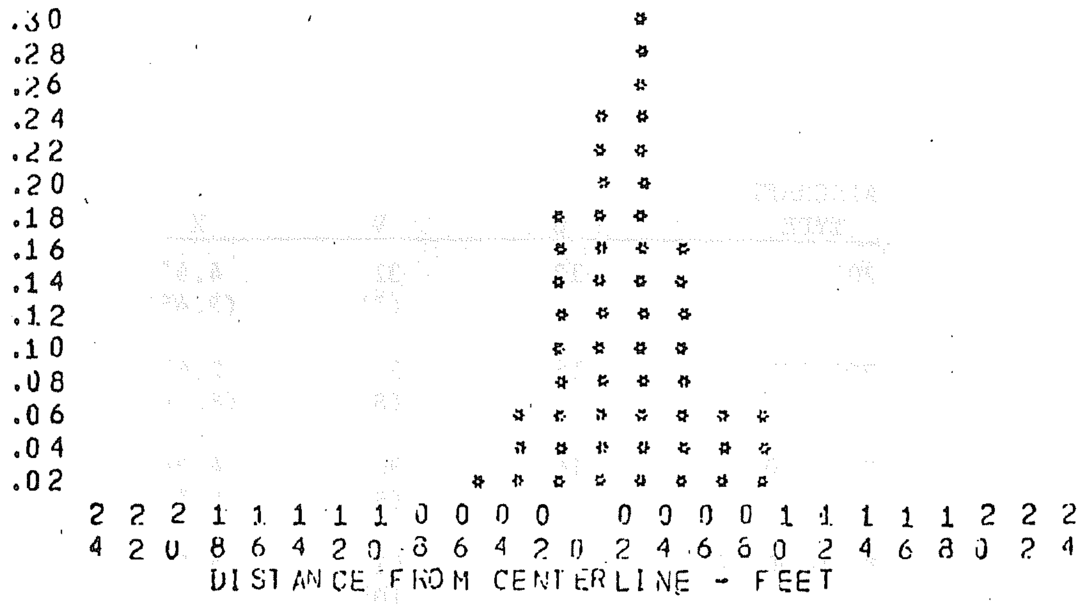
LATERAL DISTRIBUTIONS OF STRAIGHT-TAXIWAY OPERATIONS - 75-FOOT-WIDE TAXIWAYS

AIRCRAFT TYPE	n	V	X
707	12	32 (7)	4.47 (3.45)
727-100	15	35 (8)	2.65 (8.14)
727-200	16	36 (9)	4.34 (5.14)
DC-9-30,-40	24	41 (10)	4.57 (5.50)
ALL	102	40 (11)	3.20 (5.90)

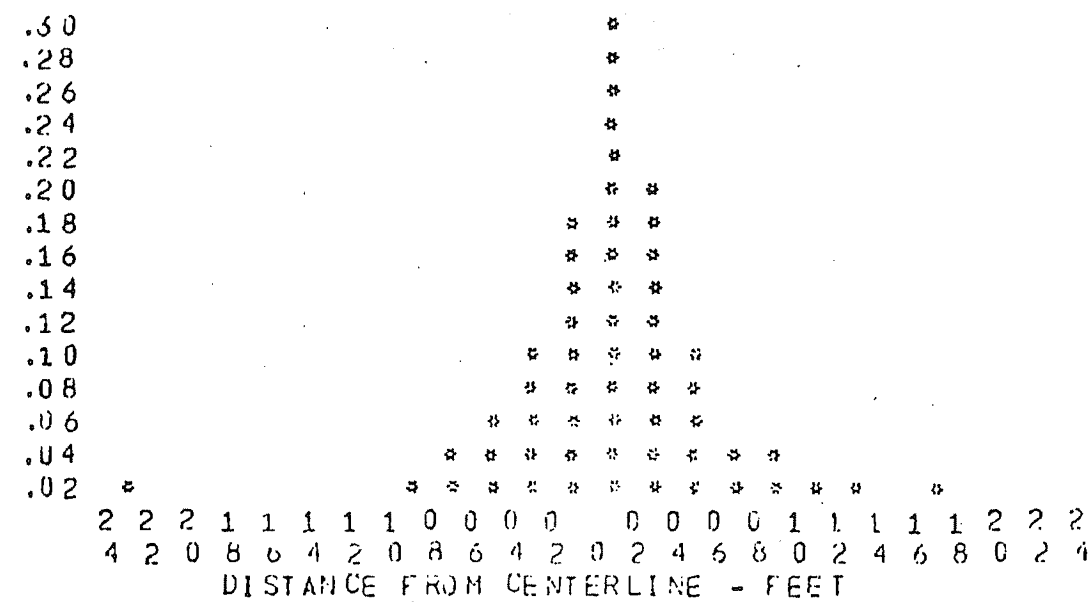
n = Sample Size
X = Average Offset (Feet)
V = Average Speed (Ft./Sec.)
( ) Standard Deviation

FIGURE 91

LATERAL DISTRIBUTIONS OF STRAIGHT-TAXIWAY OPERATIONS
100-FOOT-WIDE TAXIWAY AT DFW



A. ALL AIRCRAFT AT BUF



B. ALL AIRCRAFT AT MIA

FIGURE 92

LATERAL DISTRIBUTION-HISTOGRAMS FOR STRAIGHT-TAXIWAY OPERATIONS AT BUF AND MIA

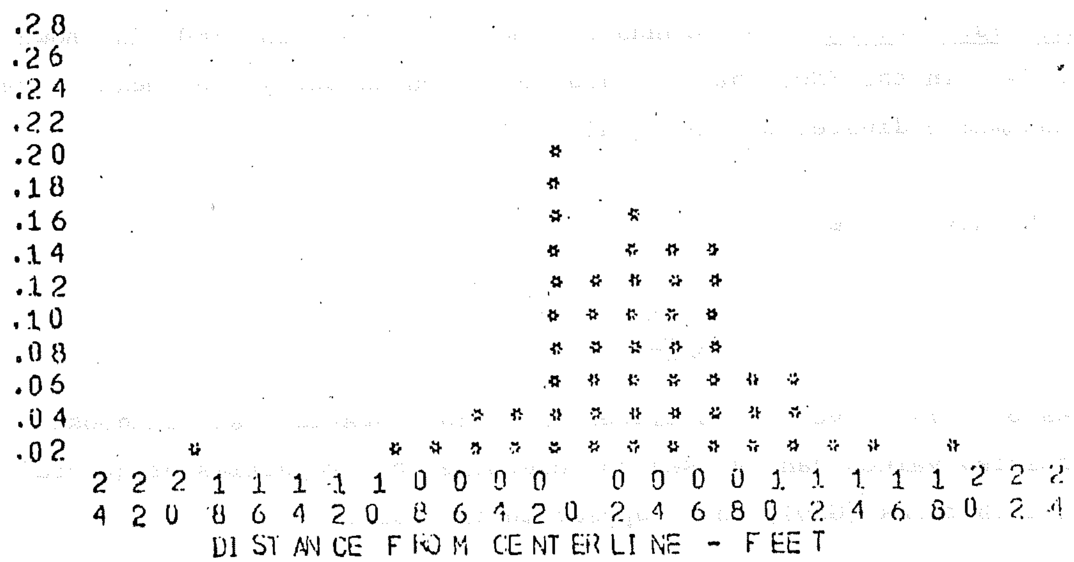


FIGURE 93

LATERAL DISTRIBUTION-HISTOGRAM FOR STRAIGHT-TAXIWAY OPERATIONS AT DFW

SECTION VI - PROPOSED PASS-TO-COVERAGE PROCEDURE

Theoretical Normal and Uniform Distributions

Inspection of the histograms referenced or presented in the preceding three sections shows that the lateral distributions of aircraft on runways, runway exits, and taxiways are consistently much more nearly normal (bell-shaped) than uniform. This observation, however, was statistically verified, as shown below, by comparing one of the field-observed distribution patterns with fitted normal and uniform distribution functions.

Normal Distribution - The standard normal distribution (SND) is shown in Figure 94. In the SND, the standard deviation is unity, the mean is zero, and the maximum ordinate, C_z, is equal to 0.399.

The SND curve is defined by the function:

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-0.5 z^2}$$

Properties of this curve are tabulated in various statistical handbooks. These tabulated values can be used to determine the properties of general normal distributions (GND), which appear in the form:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-0.5[(x-\mu)/\sigma]^2}$$

The GND is related to the SND curve using the substitution:

$$z = \frac{x - \mu}{\sigma}$$

where,

z = a variable in the SND

x = a variable in the GND

μ = mean value in the GND

σ = standard deviation in the GND.

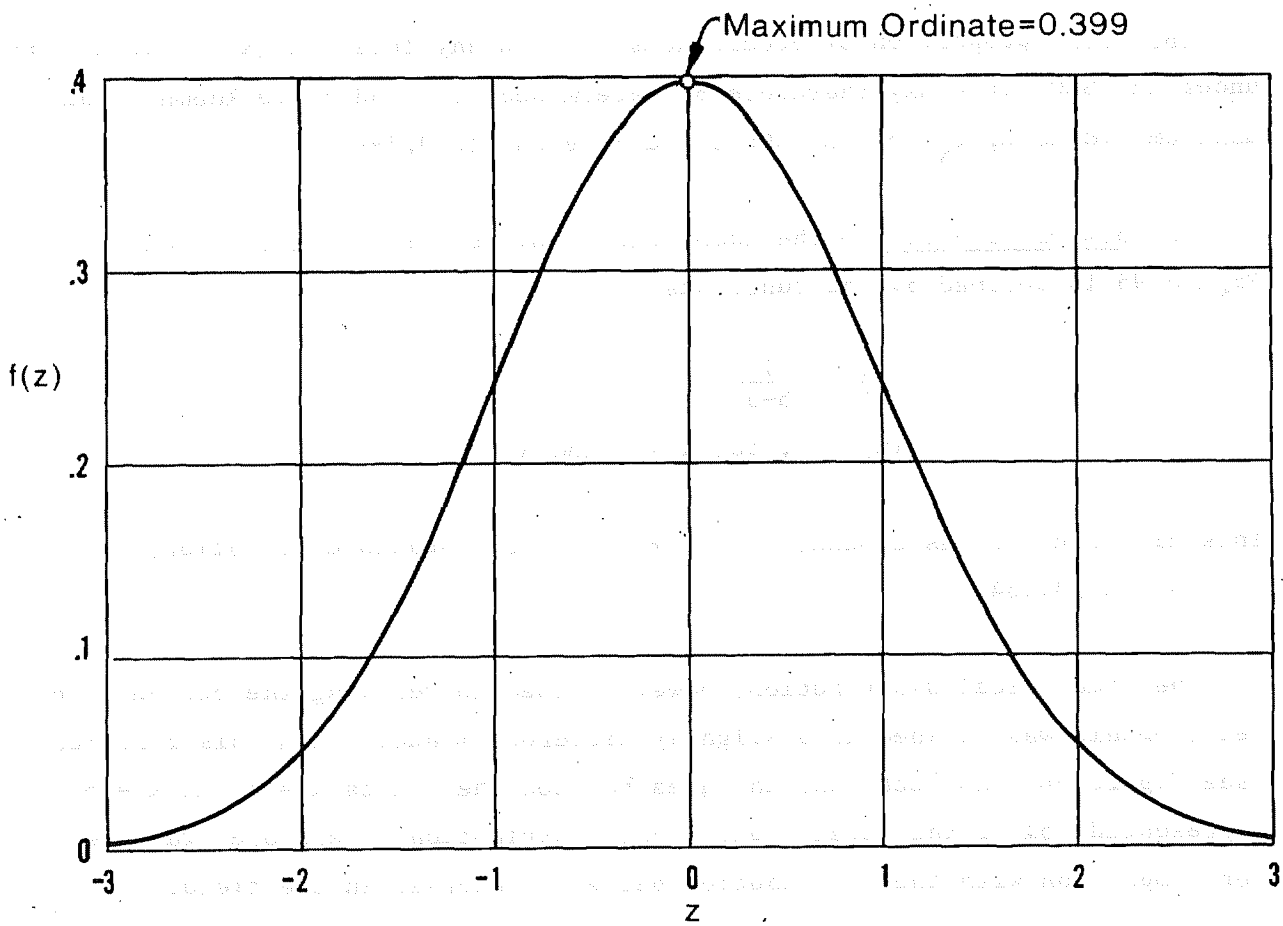


FIGURE 94

STANDARD NORMAL DISTRIBUTION CURVE

The area (proportion of occurrences) within any interval ($x = a$ to $x = b$) under the GND curve may therefore be determined if μ and σ are known. The maximum ordinate, C_x, of the GND curve is equal to $0.399/\sigma$.

<u>Uniform Distribution</u> - The theoretical uniform distribution shown in Figure 95 is defined by the functions:

$$f(x) = \frac{1}{b-a}, \text{ for } a \leq x \leq b$$

$$f(x) = 0, \text{ for } x < a \text{ and } x > b$$

This distribution has a mean, $\mu = (b + a)/2$ and a standard deviation, $\sigma = (b - a)/3.464$.

The theoretical distribution, however, used in deriving the current p/c relationship was defined in a slightly different manner. That distribution (see Figure 96) was such that the area between the limits $x = a$ and $x = b$ represented 75% of the total area. That distribution, therefore, was used for comparison with the distribution patterns observed in the field.

<u>Normal versus Uniform Distribution</u> - The distribution--normal or uniform--that more closely represents the observed distribution patterns was determined by checking the goodness-of-fit using the χ^2 test, where:

$$\chi^2 = \sum_{i=1}^{k} \frac{(m_i - np_i)^2}{np_i}, \text{ in which}$$

m_i = the actual number of observations in interval i, where $i = 1, \ldots, k$

k = number of intervals

n = total sample size

p_i = the expected proportion of the sample in interval i, given the distribution (normal or uniform) under consideration.

The intervals must be such that no fewer than 10 observations occur in each interval.

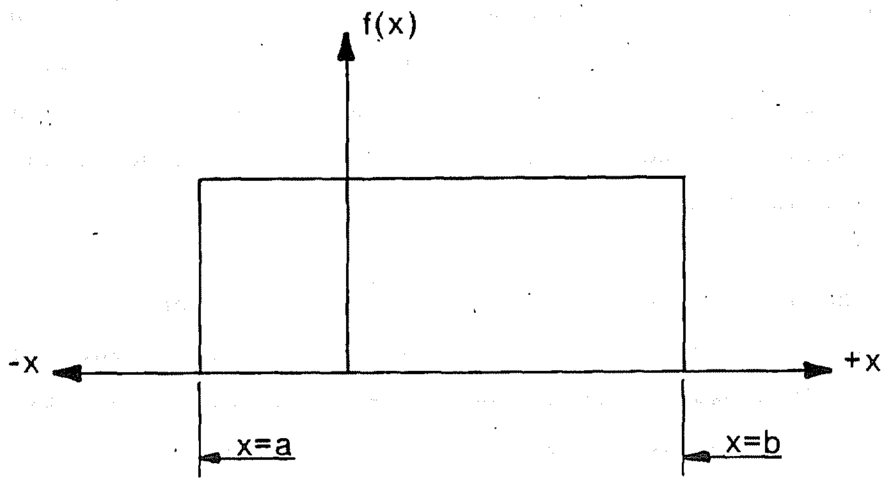


FIGURE 95

THEORETICAL UNIFORM DISTRIBUTION

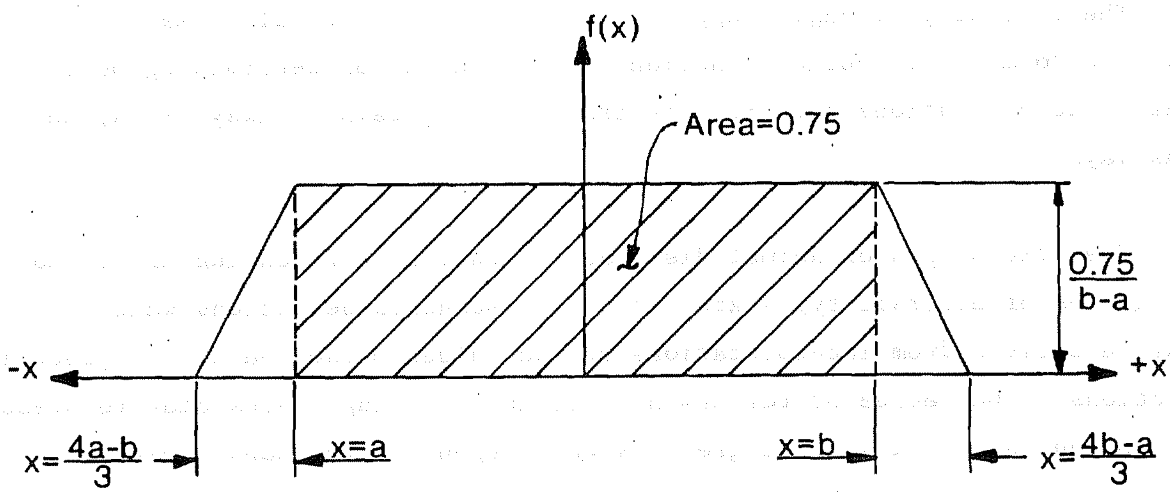


FIGURE 96

THEORETICAL DISTRIBUTION ASSUMED
IN CURRENT P/C PROCEDURE

The sample used for the comparison was the observed distribution at the First Point (see Figure A-53 of Appendix A) for all landings on Runway 34R at SEA. The mean and standard deviation of that distribution were -1.37 and 6.22 feet, respectively. The limits (x = a and x = b) within which 75% of the lateral offsets occurred were determined by centering about the interval containing the offset mean.

Figure 97 shows the calculation of the value of χ^2 for goodness-of-fit of the above sample to the distribution assumed for the current p/c relationship, and Figure 98 shows it for goodness-of-fit to the normal distribution. The calculated χ^2 values are 30.66 and 6.44, respectively.

The threshold value of χ^2 for 95% confidence level and seven degrees of freedom (number of intervals less three) is 14.07. This value is larger than the calculated χ^2 for goodness-of-fit to the normal distribution and much smaller than that for goodness-of-fit to the other distribution. The conclusion, therefore, is that the observed distribution is, by a large margin, much more accurately represented by a normal distribution function.

Derivation of p/c Ratios[1]

The preceding strongly supports the use of theoretical normal, rather than uniform, distribution functions as the basis for determining more realistic p/c rations for aircraft traffic on runways, runway exits, and taxiways.

Specific shapes of normal distribution curves representing individual or groups of aircraft types are defined by standard deviations which may be derived from interpretations of the values presented in the preceding sections. The degree of refinement used in selecting representative standard deviation values will, to a great extent, depend on the sensitivity of pavement design procedures to the p/c ratios based on these values.

[1] *Ibid*.

INTERVAL FROM	TO	ACTUAL NO. OBSERVATIONS (m_i)	FITTED NO. OBSERVATIONS (np_i)	$\frac{(m_i-np_i)^2}{np_i}$
-24	-10	35	26.0	3.12
-10	-8	32	37.6	0.83
-8	-6	40	54.1	3.67
-6	-4	59	54.1	0.44
-4	-2	76	54.1	8.87
-2	0	66	54.1	2.62
0	2	59	54.1	0.44
2	4	49	54.1	0.48
4	6	31	54.1	9.86
6	24	59	63.6	0.33
			χ^2 =	30.66

Degrees of Freedom = 7

FIGURE 97

CALCULATION FOR GOODNESS-OF-FIT TO ASSUMED DISTRIBUTION IN CURRENT p/c RELATIONSHIP

INTERVAL FROM	TO	ACTUAL NO. OBSERVATIONS (m_i)	FITTED NO. OBSERVATIONS (np_i)	$\frac{(m_i-np_i)^2}{np_i}$
-24	-10	35	41.8	1.32
-10	-8	32	30.9	.04
-8	-6	40	42.9	.20
-6	-4	59	54.4	.39
-4	-2	76	62.6	2.87
-2	0	66	64.4	.04
0	2	59	59.9	.01
2	4	49	50.8	.06
4	6	31	38.6	1.50
6	24	59	59.7	.01

$\chi^2 = 6.44$

Degrees of Freedom = 7

FIGURE 98

CALCULATION FOR GOODNESS-OF-FIT TO NORMAL DISTRIBUTION

In order to use the normal distribution as the basis for computing p/c ratios, it is necessary to revise the concept of coverage. Brown and Thompson[1] did this by redefining coverage as:

> "...the maximum number of tire prints or partial tire prints applied to the pavement surface at that point where maximum accumulation occurs."

For a single wheel, maximum accumulation occurs at the midpoint (location of the mean) of the normal distribution curve (see Figure 99). However, for a tire-contact width of W_t, accumulations will occur at the midpoint for only those wheel passes for which the wheel centerline is within $W_t/2$ distance from the midpoint. Therefore, the proportionate number of wheel passes that will accumulate at the midpoint (maximum point) of the curve will be the area under the curve within the width W_t centered about the midpoint. Referring to Figure 99, that area (which represents coverages, c) is, for practical purposes, equal to $C_x W_t$.

For an aircraft with many wheels, the maximum ordinate, C_{xc}, of the cumulative distribution of all the wheels must be determined. This is shown for a Boeing 727 main gear in Figure 100, using for an example a standard deviation of 72 inches for the aircraft-centerline lateral distribution. The resultant cumulative distribution curve for all four wheels of the main gear has a C_{xc} values of 0.0109.

C_{xc} represents the number of wheel-centerline passes per inch of width, per aircraft pass (all main-gear wheels of the aircraft considered), which accumulate at the <u>point</u> where maximum accumulation occurs. C_{xc} therefore is in units of wheel-passes per inch per aircraft pass. And, since coverage has been redefined as the maximum number of wheel passes at the point of maximum accumulation, C_{xc} may be assigned the units of coverages per inch per aircraft pass. Further, for a tire-contact width of W_t, the coverage per aircraft pass is approximated by $C_{xc}W_t$. The reciprocal of $C_{xc}W_t$ is therefore referred to as the pass-to-coverage (p/c) ratio. Thus:

$$\frac{p}{c} = \frac{1}{C_{xc}W_t}$$

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[1] Ibid.

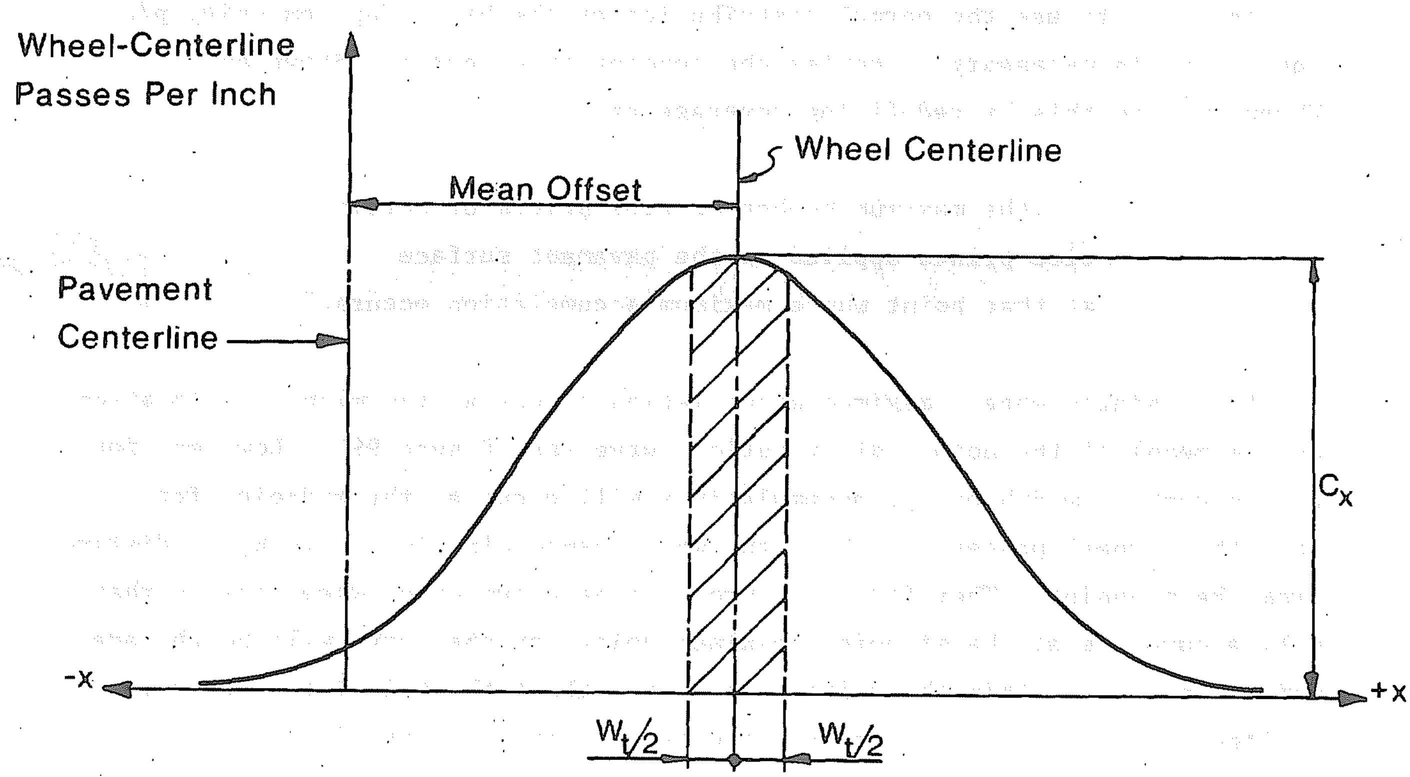


FIGURE 99
THEORETICAL NORMAL DISTRIBUTION
FOR SINGLE WHEEL

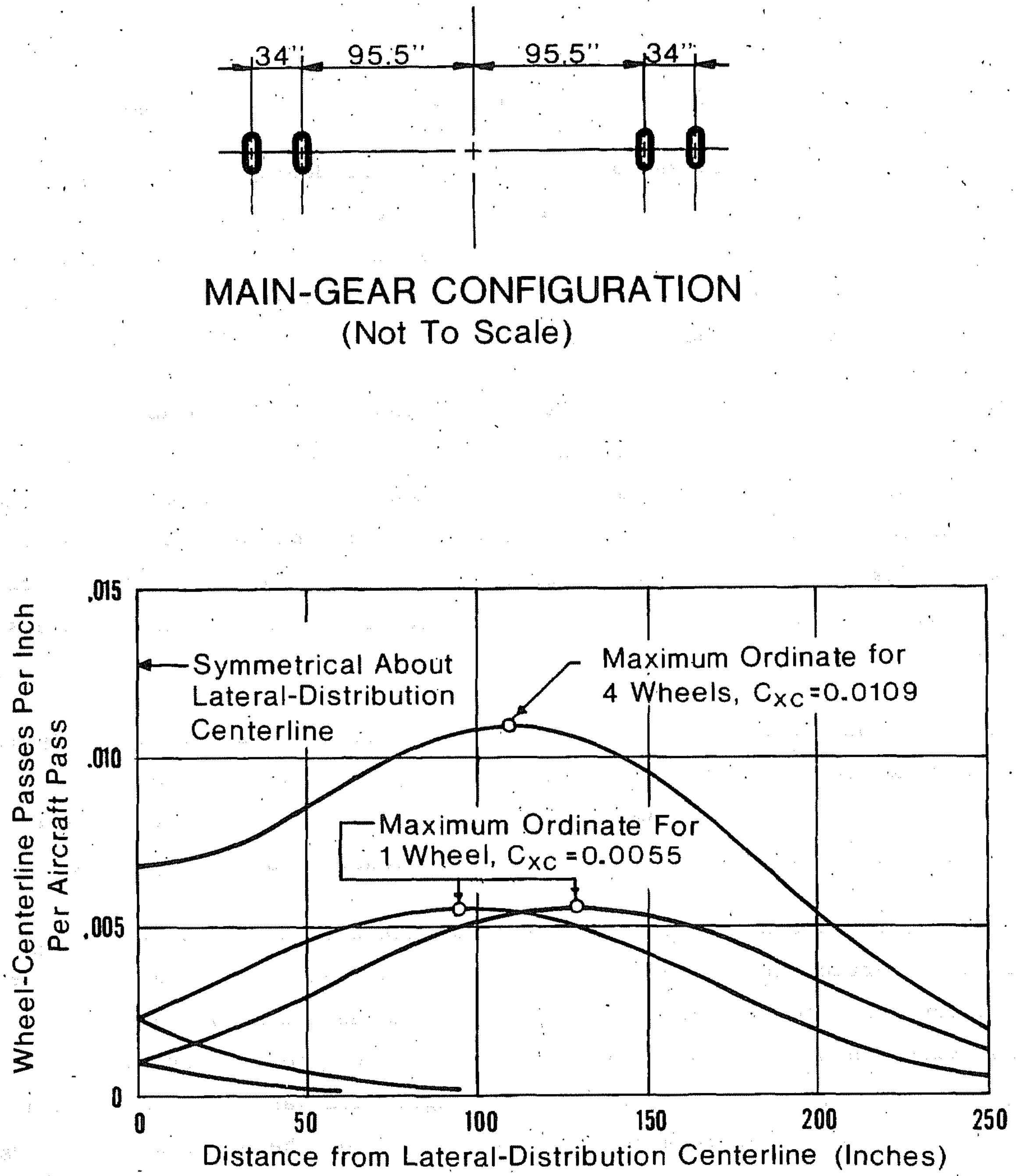


FIGURE 100

THEORETICAL NORMAL DISTRIBUTION FOR BOEING 727 MAIN-GEAR (FOR STANDARD DEVIATION OF 72 INCHES)

For the illustration given in Figure 100, the p/c ratio at W_t = 13.5 inches is equal to 1/(0.0109 x 13.5) or 6.796 aircraft passes per coverage.

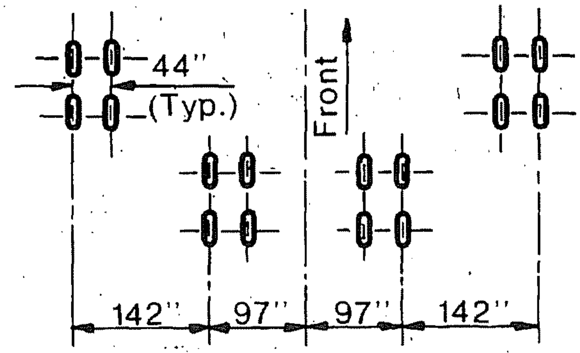
Application of the revised p/c procedure to the Boeing 747 is illustrated in Figure 101, using for an example a standard deviation of 65 inches for the aircraft centerline lateral distribution. The resultant cumulative distribution has a C_{xc} value of 0.0281. Thus, for W_t = 12.9 inches, the p/c ratio is 2.759 aircraft passes per coverage.

From the preceding discussion, it is seen that in order to determine the p/c ratio for any aircraft, based on the revised procedure, the parameters C_{xc} and W_t are required. C_{xc} is in turn dependent upon the aircraft main-gear configuration (number and spacing of wheels) and the standard deviation of the normal distribution function selected to represent the aircraft-centerline lateral distribution. W_t values are obtainable from aircraft manufacturers' specifications.

It should be noted that the p/c ratio developed in this section is applicable to flexible pavements for all aircraft types. However, special consideration of the tandem wheel-spacing is necessary when applying this procedure to rigid pavements for aircraft with tandem-gear configuration.

From Figures 100 and 101, it is seen that the determination of the C_{xc} value for a particular aircraft at a particular standard deviation would be an unwieldy exercise, if there was a need to examine the relative effects (sensitivity) on C_{xc} values of various standard deviations. For that reason, therefore, the family of curves in Figure 102 was constructed with the aid of a computer program prepared explicitly for the purpose. The program and input values used in generating Figure 102 are described in Appendix B.

Figure 102 shows, for each aircraft type, the relationship between C_{xc} and variations in standard deviation values. It is of interest to note (a) the general groupings of the curves--narrow-body 2- and 3-engine aircraft being in one such group, wide-body 3-engine aircraft in another, then narrow-body 4-engine aircraft, followed by 747; and (b) the sharp flattening of the curves generally beyond S = 60 inches for 2- and 3-engine aircraft and the 747, and beyond S = 110 inches for narrow-body 4-engine aircraft.



MAIN-GEAR CONFIGURATION
(Not To Scale)

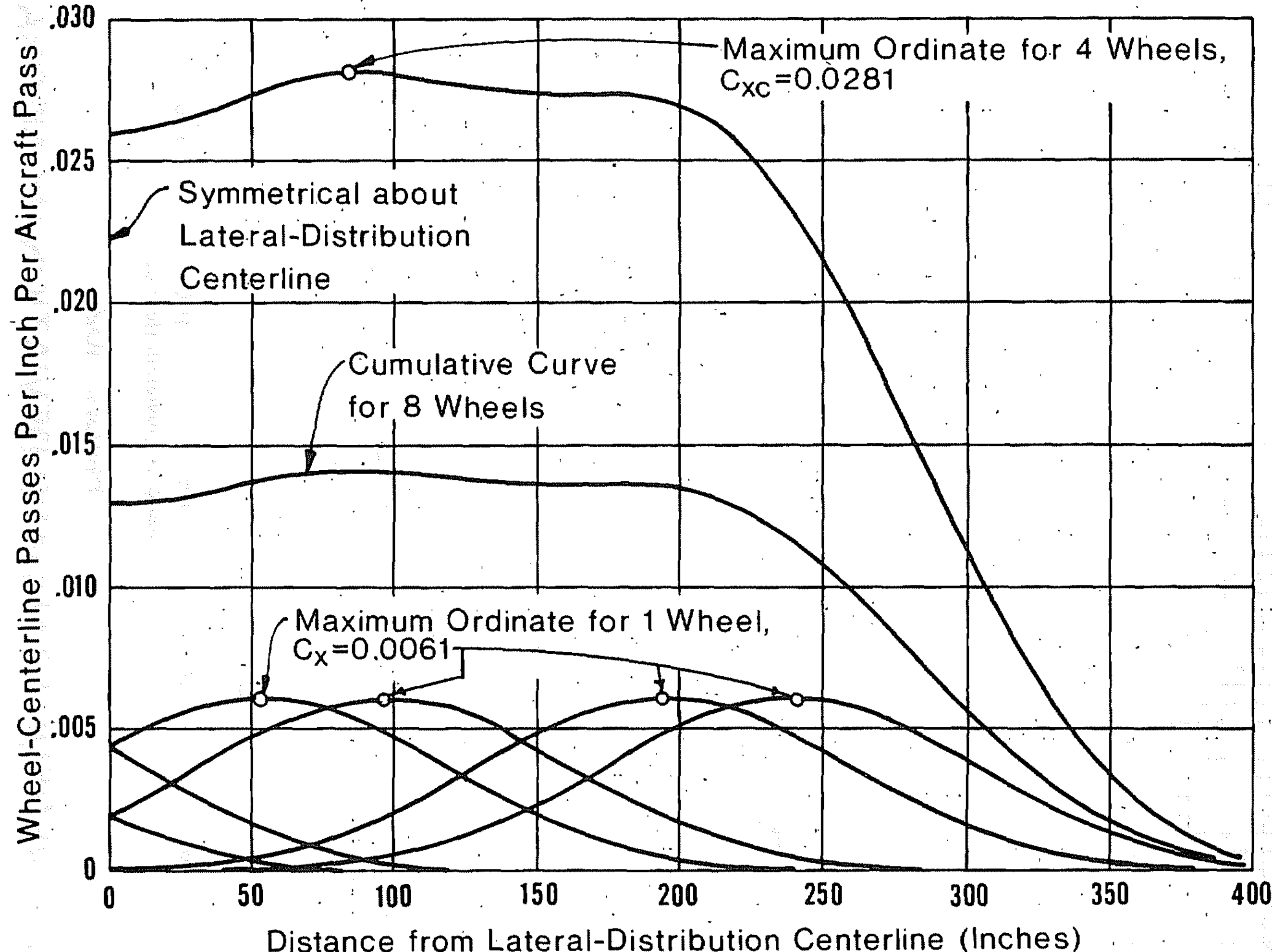


FIGURE 101

THEORETICAL NORMAL DISTRIBUTION
FOR BOEING 747 MAIN-GEAR
(FOR STANDARD DEVIATION OF 65 INCHES)

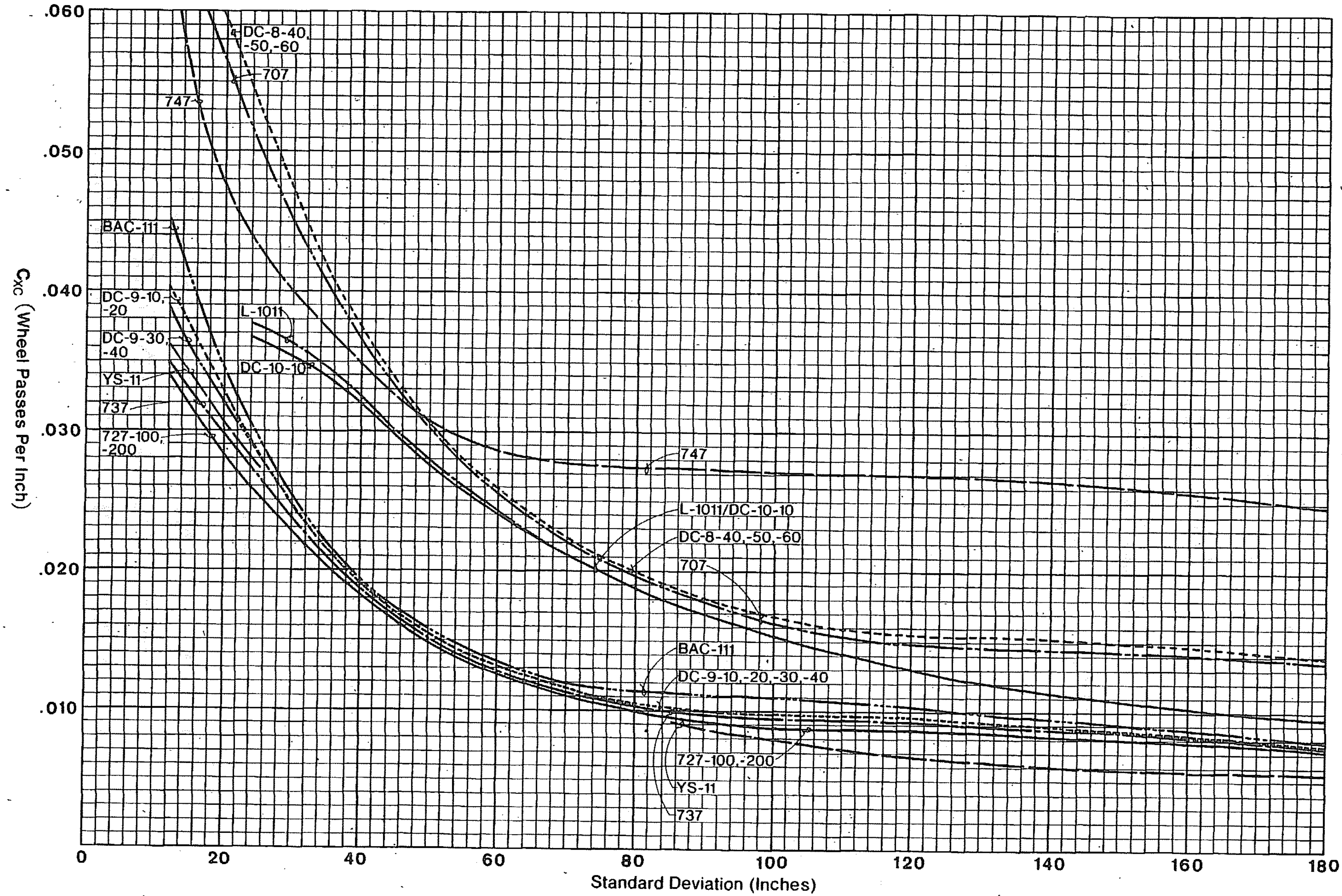


FIGURE 102

C_{xc} VERSUS STANDARD DEVIATION BY AIRCRAFT TYPE

SECTION VII - CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The most important conclusion derived from this analysis was that the lateral distributions of aircraft traffic on runways, runway exits, and taxiways are much more nearly represented by theoretical normal distribution functions, rather than a modified uniform distribution function.

On the average, the observed aircraft-centerline offsets were (a) to the left of the pavement centerline stripe on runways; (b) to the right of the pavement centerline stripe on straight taxiways; and (c) to the left or right of the guideline on high-speed turnoffs, depending on aircraft operational flow-pattern and exit configuration.

On runways and straight taxiways the offset mean may, for practical purposes, be considered as located at the pavement centerline stripe because of (a) the relatively close proximity of occurrence of mean offsets to centerline stripes; and (b) the generally two-directional operation on runways and straight taxiways.

The mean offset on runways was generally 1 to 2 feet to the left of the centerline on 150-foot-wide pavements, and 1 to 1.5 feet farther left on 200-foot-wide pavements. Wide-body and 4-engine aircraft tended to be slightly farther left than 2- and 3-engine aircraft, but the difference was neither large nor consistent enough to make a distinction among such aircraft groupings.

The mean offset on 75-foot-wide taxiways was approximately 2 feet to the right of the pavement centerline, and that on 100-foot-wide taxiways was approximately 1 foot farther to the right.

The shapes of the lateral distribution patterns for takeoffs were generally narrower than those for landings. Standard deviations for individual aircraft types, compared at the various airports, varied from

3 to 8 feet for takeoffs, and from 4 to 9 feet for landings. There was, however, no consistent correlation with respect to aircraft type or size.

The standard deviations for takeoffs, for all airports combined, varied among individual aircraft types generally from 6 to 9 feet in the vicinity of liftoff and from 5.5 to 7 feet in the earlier portion of takeoff roll. On 200-foot-wide runways, the standard deviations in the vicinity of liftoff were about the same as those in the corresponding area on 150-foot-wide runways, but about 1.5 feet wider in the earlier portion of takeoff roll.

The standard deviations for landings, for all airports combined, generally varied among individual aircraft types from 7 to 8.5 feet, except near the end of landing roll where exit-influences were much in evidence, as expected.

The standard deviations on straight taxiways were generally much narrower than those on runways. On 75-foot-wide taxiways they ranged from 2.5 to 4 feet, whereas on 100-foot-wide taxiways they averaged around 6 feet.

The standard deviations on high-speed exits were generally wider than those on runways and were influenced by aircraft flow-pattern and exit-configuration--the general range was 8 to 10.5 feet, with the upper limit probably being more typical for normal usage of such exits.

Factors such as night operations, crosswinds, and wet pavements had an effect on aircraft lateral distributions on runways, but their overall impact was not considered significant because the effect of any one such factor was either (a) relatively small or generally not consistent, (b) infrequent in occurrence, or (c) compensated for or nullified by other factors in the overall operating conditions.

Recommendations

It is recommended that theoretical normal distribution curves be used for representing aircraft lateral distributions on runways, runway exits, and taxiways, and as the basis for deriving more realistic p/c ratios using the procedure outlined in this report.

The sensitivity of airport pavement thickness requirements to aircraft coverages (p/c ratios) should be examined and used as a guide in selecting representative standard deviations (for individual or groups of aircraft) from the computed values of the field observations presented in this report.

APPENDIX A

Presented in this appendix are the computer-generated tables and histograms pertaining to runway operations, which have been referenced in the text of the report.

Figures A-1 to A-18 are tabulations of the mean offsets and speeds for takeoffs, and the corresponding standard deviations, at each of the generalized locations on runways described in the report. Takeoffs from each runway end are summarized respectively in each table, for individaul and combined aircraft types.

Figures A-19 to A-36 show histograms of aircraft-centerline offsets for takeoffs. Each figure contains a set of three histograms, one each for the generalized locations on runways described in the report. These histograms show the frequency distributions of the observed offsets in terms of proportionate occurrences in two-foot intervals on either side of the runway centerline. Takeoffs from each runway end are shown respectively in each figure, for all aircraft types combined.

Figures A-37 to A-45 are tabulations of the proportionate occurrences of aircraft liftoff after each light element on runways. Takeoffs from each runway are tabulated respectively in each figure, for individual aircraft types.

Figures A-46 to A-63 are tabulations for landings, similar to those for takeoffs in Figures A-1 to A-18 described above.

Figures A-64 to A-81 show histograms of aircraft-centerline offsets for landings, similar to those for takeoffs in Figures A-19 to A-36 described above.

Figures A-82 to A-90 are tabulations of the proportionate occurrences of aircraft touchdowns before each light element on runways. Landings on each runway are tabulated respectively in each figure, for individual aircraft types.

Figures A-91 to A-99 are similar to the preceding set of figures, except they are tabulations of the proportionate occurrences of turnoffs after each light element on runways.

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	1	-21.06	0.	214.77	0.	-21.06	0.	214.77	0.	-21.06	0.	214.77	0.
727-1	34	2.54	7.30	145.18	15.28	.51	7.18	190.53	17.97	-.22	9.09	216.71	21.78
727-2	54	2.83	4.32	141.14	9.08	1.56	5.12	200.67	11.84	1.80	6.43	230.88	13.47
737	17	3.29	6.39	156.36	22.49	.06	4.75	187.73	18.01	-2.43	8.24	212.19	20.45
747	4	1.30	5.29	132.60	5.27	.22	2.81	187.93	24.00	-3.33	3.37	222.05	22.24
DC8-4,5	5	9.69	14.62	152.01	16.47	7.38	13.10	197.26	13.52	4.61	13.72	226.78	12.03
DC8-6	8	4.34	6.90	146.04	14.80	2.80	4.52	195.31	13.46	3.36	2.69	224.85	11.84
DC9-1,2	13	3.98	5.00	157.37	18.26	2.40	5.27	184.91	19.03	-1.38	10.42	209.53	28.24
DC9-3,4	95	2.87	5.66	150.28	19.67	1.83	5.91	182.90	16.17	-1.01	10.75	212.53	18.92
DC10	4	4.64	6.50	143.99	6.67	2.15	6.02	203.86	13.17	4.03	5.23	235.20	12.20
L1011	5	-.88	3.61	144.95	6.07	-1.09	2.14	207.72	12.23	-1.40	3.13	245.77	12.83
C580	3	.71	2.37	134.65	3.48	.71	2.37	134.65	3.48	.71	2.37	134.65	3.48
YS-11	8	.26	4.39	143.62	20.00	-1.01	5.42	153.52	21.57	-2.28	6.78	163.42	29.29
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	251	2.81	6.27	147.67	17.95	1.37	6.18	188.39	19.71	-.23	9.23	216.23	24.66

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-1

LATERAL DISTRIBUTION AND VELOCITY - ATL RWY 9R TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	8	.85	3.40	155.79	35.75	.82	3.84	183.68	40.12	.67	4.61	200.93	51.99
727-1	130	-1.17	5.67	148.67	19.59	-2.10	6.30	186.33	26.14	-3.09	7.97	211.17	34.38
727-2	183	.35	6.20	149.19	21.36	-.71	5.49	201.71	16.24	-1.66	6.9	227.47	20.97
737	53	1.57	5.92	152.34	10.91	1.00	5.92	186.94	12.09	-1.75	9.12	218.23	15.98
747	7	-.43	2.36	150.49	28.11	-.48	1.33	182.01	38.15	-1.13	3.37	202.18	47.57
DC8-4,5	21	-.72	4.95	155.99	30.60	-1.51	3.72	197.99	35.11	-1.86	4.12	223.26	42.51
DC8-6	22	-1.44	3.76	153.07	14.65	-4.32	3.84	198.55	22.60	-5.51	3.99	223.50	28.95
DC9-1,2	36	-.95	5.19	161.68	15.45	-1.71	5.08	191.44	13.49	-2.46	5.41	221.20	20.45
DC9-3,4	324	.65	6.11	152.65	16.64	-.00	6.25	185.52	15.69	-1.84	9.24	214.22	18.90
DC10	9	-4.45	4.50	170.76	27.08	-5.71	4.99	209.24	19.36	-6.55	7.34	238.85	12.73
L1011	22	-.94	5.69	157.81	14.56	-2.72	7.97	222.35	8.78	-4.07	8.47	254.93	21.85
C580	1	.83	0.	133.06	0.	.83	0.	133.06	0.	.83	0.	133.06	0.
YS-11	18	-.25	4.10	144.87	7.03	-.80	4.75	149.74	10.26	-1.35	5.66	154.60	19.94
BAC-111	1	-2.60	0.	148.62	0.	-2.46	0.	185.42	0.	-2.33	0.	222.22	0.
ALL A/C	835	.02	6.01	151.89	18.99	-.85	6.11	190.06	21.86	-2.24	8.15	217.26	27.74

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-2

LATERAL DISTRIBUTION AND VELOCITY - ATL RWY 27L TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	22	-4.50	8.82	157.48	19.55	-2.88	7.01	166.81	26.38	-2.86	7.05	170.75	33.31
727-1	39	-1.87	4.95	150.65	17.78	-1.89	4.95	153.69	20.86	-1.90	4.98	156.72	27.85
727-2	36	-4.57	6.76	146.30	14.34	-4.62	6.95	161.19	25.03	-4.78	7.71	174.58	40.57
737	12	-.61	2.32	154.99	6.86	-.49	2.32	161.80	13.15	-.37	2.69	168.61	27.63
747	9	-5.22	6.26	147.93	7.33	-3.91	4.69	191.76	32.70	-5.12	5.80	216.60	48.63
DC8-4,5	16	-1.73	5.96	130.27	37.18	-1.71	5.92	135.34	41.31	-1.68	5.96	140.41	48.90
DC8-6	10	-6.35	6.39	135.71	23.64	-5.14	7.18	159.83	41.39	-4.09	8.20	178.96	57.92
DC9-1,2	4	-3.37	5.24	163.64	7.27	-3.37	5.24	163.64	7.27	-3.37	5.24	163.64	7.27
DC9-3,4	30	-2.36	5.46	155.74	5.21	-2.48	5.00	157.83	8.46	-2.61	5.10	159.91	15.55
DC10	3	-1.32	2.63	154.23	4.05	.19	3.17	171.64	20.78	1.69	4.72	189.05	45.38
L1011	3	-9.73	5.38	158.22	5.12	-8.42	6.38	187.26	36.34	-11.40	4.89	192.89	44.30
C580	6	-2.27	3.09	115.76	34.95	-2.27	3.09	115.76	34.95	-2.27	3.09	115.76	34.95
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	190	-3.23	6.27	148.41	21.06	-2.89	5.90	158.20	29.14	-2.96	6.30	165.55	40.05

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-3

LATERAL DISTRIBUTION AND VELOCITY - ORD RWY 9R TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	35	.13	5.47	152.46	24.04	-1.01	5.47	179.76	21.34	-.57	6.58	207.73	27.13
727-1	106	-1.15	3.73	147.71	19.40	-1.56	4.09	172.82	21.49	-2.13	4.90	197.15	28.56
727-2	77	.11	5.30	141.69	11.92	-.97	4.43	176.27	15.41	-1.16	4.70	205.87	24.90
737	31	-2.04	4.20	151.00	6.03	-3.18	4.84	173.98	9.81	-3.88	6.36	197.16	17.83
747	5	2.26	2.08	136.97	5.04	1.42	2.08	173.15	9.99	-1.86	4.72	205.00	18.73
DC8-4,5	14	-1.67	4.04	164.97	24.93	-2.87	3.64	185.94	20.84	-1.52	4.33	208.19	28.15
DC8-6	7	-.83	4.89	142.39	13.11	-2.08	4.43	176.93	22.84	-2.41	3.84	209.31	38.97
DC9-1,2	5	-2.02	2.82	161.10	5.32	-2.38	3.37	183.54	6.50	-2.75	4.04	205.99	7.72
DC9-3,4	84	-.08	5.00	151.67	5.21	.12	4.78	172.85	7.04	-.55	7.81	194.08	12.59
DC10	2	3.27	3.64	170.78	20.98	.75	3.83	215.90	4.81	.68	6.48	252.55	22.13
L1011	5	4.66	5.40	144.19	6.63	4.03	5.59	181.08	5.06	4.45	8.47	217.09	10.56
C580	6	1.11	1.74	140.75	3.64	1.05	1.75	143.43	7.30	.98	1.76	146.11	12.85
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	377	-.45	4.72	148.62	16.12	-1.05	4.64	174.85	17.44	-1.41	6.03	199.83	25.47

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-4

LATERAL DISTRIBUTION AND VELOCITY - ORD RWY 27L TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	16	-1.06	3.01	172.74	12.91	.27	3.79	210.71	16.89	.71	4.78	246.95	23.96
727-1	32	-2.13	5.93	162.62	9.59	-1.49	6.42	205.77	13.31	.26	5.02	238.68	16.44
727-2	31	-.96	6.49	162.19	14.33	1.67	3.78	207.90	13.79	1.14	7.44	242.24	16.29
737	28	-1.83	6.41	170.98	8.77	-2.92	8.03	199.38	11.10	-6.12	11.22	233.98	23.63
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	9	-2.79	10.48	159.56	6.27	-.50	6.27	203.25	10.41	3.36	5.30	248.82	21.60
DC8-6	3	.62	1.44	170.26	18.30	1.97	1.80	222.43	14.78	1.38	4.61	256.10	5.00
DC9-1,2	5	-8.59	9.07	172.55	3.11	-6.21	6.47	193.44	7.04	-10.81	10.22	217.97	21.07
DC9-3,4	6	-.35	2.44	167.40	1.05	-3.58	5.57	195.29	13.45	-17.17	14.06	225.81	25.71
DC10	12	-2.00	5.00	168.68	5.63	-1.19	4.07	213.12	13.29	.08	4.26	254.64	21.18
L1011	2	-.25	.08	165.89	5.55	-4.11	.30	240.72	8.79	-5.01	2.57	271.83	4.33
C580	17	-2.37	5.64	158.89	3.78	-2.21	4.84	173.51	4.53	-2.13	5.40	188.83	9.49
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	161	-1.86	6.27	165.55	11.15	-1.15	5.98	202.53	17.31	-1.77	8.76	235.48	26.38

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-5

LATERAL DISTRIBUTION AND VELOCITY - DEN RWY 8R TAKEOFFS

AIRCRAFT	NO.	FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
		X	S	V	S	X	S	V	S	X	S	V	S
707	3	.11	7.31	108.61	82.92	.17	7.36	112.59	88.52	.23	7.41	116.57	94.12
727-1	16	-2.70	7.64	176.52	56.03	-1.04	6.67	200.00	58.56	-1.19	5.35	211.65	62.93
727-2	10	1.97	9.10	139.28	54.12	.82	4.58	191.95	52.39	-.36	6.28	221.57	55.70
737	13	-.58	1.89	155.42	45.38	-.85	1.76	190.46	58.58	-1.31	2.07	206.97	66.10
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	1	.60	0.	160.70	0.	-3.25	0.	227.96	0.	-32.69	0.	251.23	0.
DC9-3,4	1	.86	0.	159.80	0.	.15	0.	190.15	0.	-.55	0.	220.50	0.
DC10	51	1.39	8.67	169.86	22.79	.94	4.75	233.05	6.98	.54	4.72	257.68	11.67
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	4	1.30	5.27	131.53	41.87	2.93	3.42	145.42	50.65	4.56	1.85	159.31	61.33
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	99	.47	7.88	162.36	43.22	.38	4.96	210.29	49.85	-.27	5.88	231.24	56.03

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-6

LATERAL DISTRIBUTION AND VELOCITY - DEN RWY 26L TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	20	.32	5.78	170.58	18.93	.66	4.27	191.86	18.31	1.19	3.79	209.12	29.53
727-1	37	1.77	4.11	160.00	27.71	1.87	4.02	181.54	33.59	1.92	4.58	201.98	44.30
727-2	29	2.34	4.38	160.28	29.44	2.34	4.78	182.46	29.13	2.69	5.56	200.88	36.18
737	8	2.98	4.97	171.98	11.23	1.32	6.67	176.41	12.82	-.34	10.14	180.84	21.85
747	8	2.50	4.76	164.16	4.36	.80	4.85	208.76	22.70	-2.23	5.46	239.51	33.57
DC8-4,5	4	-.66	2.39	176.47	3.44	-.08	1.81	185.82	17.08	.49	1.70	195.17	33.11
DC8-6	13	2.15	3.01	186.04	29.33	2.23	2.70	202.96	25.13	2.31	2.75	219.88	30.77
DC9-1,2	8	3.27	3.11	161.11	61.32	2.81	2.84	161.12	61.31	2.35	3.06	161.12	61.29
DC9-3,4	5	1.60	2.00	167.59	5.73	1.60	2.00	167.59	5.73	1.60	2.00	167.59	5.73
DC10	8	5.07	7.21	172.25	13.09	3.50	6.01	211.56	20.60	3.85	11.21	239.48	27.60
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	3	1.68	2.41	152.75	7.77	1.11	1.62	162.70	8.54	.54	.87	172.66	21.96
YS-11	1	2.34	0.	166.13	0.	2.34	0.	166.13	0.	2.34	0.	166.13	0.
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	144	2.02	4.63	166.13	28.21	1.81	4.37	185.99	31.85	1.71	5.58	202.85	41.65

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-7

LATERAL DISTRIBUTION AND VELOCITY - SEA RWY 16L TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	14	-2.63	2.84	162.31	21.09	-3.27	2.83	187.03	21.29	-3.68	3.37	208.96	24.27
727-1	18	-4.87	4.67	145.33	42.40	-3.57	6.62	166.51	44.67	-2.12	9.58	184.69	51.40
727-2	20	-2.94	3.38	167.34	18.09	-2.88	3.75	190.01	11.21	-2.30	5.29	214.40	18.55
737	2	3.77	4.76	108.03	62.86	3.77	4.76	108.03	62.86	3.77	4.76	108.03	62.86
747	16	-2.82	5.79	154.42	23.92	-4.60	4.41	195.46	33.48	-6.54	5.36	231.43	50.77
DC8-4,5	3	-3.95	1.36	179.19	24.28	-3.86	1.94	192.80	14.65	-3.77	2.59	206.41	5.04
DC8-6	7	-3.50	3.35	168.13	18.01	-2.27	1.90	200.51	12.95	-2.61	2.01	231.78	35.94
DC9-1,2	2	-3.09	2.67	189.71	8.28	-4.07	2.49	201.29	3.30	-4.25	2.30	212.87	14.89
DC9-3,4	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	3	-3.84	5.39	136.63	77.20	-3.09	6.05	154.47	90.02	-2.33	6.71	172.30	102.85
L1011	3	-2.69	2.53	165.64	10.61	-1.98	1.61	188.31	22.41	-.67	1.17	216.31	45.64
C580	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	88	-3.23	4.37	158.21	33.76	-3.24	4.59	183.77	37.49	-3.18	6.23	207.84	48.48

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-8

LATERAL DISTRIBUTION AND VELOCITY - SEA RWY 34R TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	20	-4.08	2.81	156.17	7.70	-2.52	4.12	183.86	23.22	1.99	11.15	203.23	39.08
727-1	53	-4.57	5.27	156.07	28.30	-4.08	5.67	170.78	30.89	-3.75	7.73	182.91	39.53
727-2	13	.01	4.56	147.43	3.35	-2.29	4.02	186.77	22.15	-3.02	9.51	204.98	28.57
737	41	-2.47	9.22	158.86	15.92	-.20	8.61	186.51	17.13	1.28	10.10	210.93	26.96
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	10	-3.18	3.13	164.07	23.67	-2.19	3.84	175.60	21.75	-1.20	5.16	187.13	32.35
DC8-6	8	-4.17	4.81	147.69	61.13	-3.37	4.61	180.47	71.46	-3.04	5.16	197.52	80.00
DC9-1,2	2	-3.46	2.51	157.11	1.30	-3.07	1.13	191.29	1.30	-2.68	.26	225.46	1.29
DC9-3,4	21	-4.94	3.49	161.52	20.34	-3.77	3.39	183.06	19.54	-2.60	4.04	204.60	30.37
DC10	2	-1.35	.24	117.23	117.42	-.53	.59	117.24	117.40	.54	1.66	117.29	117.36
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	14	-3.16	5.73	147.48	6.36	.04	9.59	152.67	18.47	1.11	11.52	154.36	22.47
YS-11	13	.42	12.66	175.03	32.66	10.92	5.49	218.25	8.77	-2.77	7.25	239.27	7.88
BAC-111	23	-2.49	5.62	157.69	17.06	-1.51	9.76	176.35	19.98	-2.38	16.31	193.48	31.38
ALL A/C	220	-3.18	6.66	157.06	26.89	-1.53	7.43	179.99	31.72	-1.25	10.10	196.55	41.59

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-9

LATERAL DISTRIBUTION AND VELOCITY - CLE RWY 5R TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	25	-.65	3.69	137.39	21.73	-.03	4.34	171.54	31.09	1.52	7.08	206.09	45.55
727-1	114	-1.16	3.87	131.06	19.86	-.75	3.44	158.27	20.62	.09	4.81	184.88	27.50
727-2	33	.11	2.29	133.67	19.06	.33	3.50	167.88	15.80	3.69	7.81	208.35	37.34
737	89	-.78	5.72	138.49	24.30	-.11	4.47	174.23	23.54	1.82	8.07	209.58	32.71
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	15	-3.36	5.04	139.54	25.33	-2.08	4.09	170.67	19.61	-.91	4.58	200.98	27.51
DC8-6	13	-2.47	6.70	127.86	13.17	.57	4.83	175.16	26.39	1.64	6.28	217.80	38.38
DC9-1,2	11	-3.13	2.31	141.21	14.28	-2.09	1.92	177.50	13.40	-6.44	12.10	213.17	22.07
DC9-3,4	36	.07	4.68	132.73	18.56	.13	4.33	161.08	17.99	.04	4.44	189.20	27.72
DC10	1	.09	0.	139.97	0.	-3.43	0.	188.24	0.	-8.45	0.	236.38	0.
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	17	1.12	7.41	137.42	26.36	.61	5.88	151.93	23.05	-.47	4.05	166.06	26.61
YS-11	8	-.55	5.26	147.40	28.46	.68	5.86	177.95	22.31	-1.71	5.99	201.78	15.35
BAC-111	28	-.23	3.59	133.40	14.31	-.63	4.82	160.93	15.30	-4.99	10.63	188.23	22.51
ALL A/C	390	-.83	4.76	134.86	21.40	-.37	4.28	166.04	22.60	.36	7.42	197.04	33.61

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-10

LATERAL DISTRIBUTION AND VELOCITY - CLE RWY 23L TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	8	-3.72	3.94	172.23	7.19	-3.53	3.45	199.63	14.85	-3.48	4.04	224.39	28.13
727-1	11	-3.06	3.18	165.83	7.94	-1.92	3.26	181.33	15.62	-2.32	3.64	190.65	26.61
727-2	3	-4.78	2.06	162.17	4.73	-3.95	2.20	186.54	14.50	-3.12	2.64	210.92	31.60
737	6	-12.66	6.41	160.74	1.68	-6.55	4.94	181.96	13.95	-.44	6.96	203.18	29.06
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	1	-.12	0.	166.13	0.	1.71	0.	196.34	0.	3.55	0.	226.55	0.
DC8-6	1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DC9-1,2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	14	-1.97	7.08	162.45	5.72	-3.26	5.77	175.90	13.34	-4.55	10.51	189.35	28.40
DC10	2	-5.66	2.30	180.59	3.06	-5.02	1.66	197.60	20.08	-4.39	1.03	214.62	37.10
L1011	3	-1.89	.88	176.38	3.55	-1.64	3.79	209.50	3.28	-1.39	7.35	242.62	3.22
C580	7	-3.01	3.38	154.91	3.60	-3.01	3.38	154.91	3.60	-3.01	3.38	154.91	3.60
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	27	-.31	4.79	160.01	23.05	-1.33	7.73	168.54	27.00	-2.35	13.36	177.06	35.89
ALL A/C	82	-2.74	5.77	163.37	15.02	-2.41	6.10	178.14	23.17	-2.31	10.08	191.81	36.40

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-11

LATERAL DISTRIBUTION AND VELOCITY - BUF RWY 5 TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	S	FIRST POINT VELOCITY V	S	INTERMEDIATE POINT OFFSET X	S	INTERMEDIATE POINT VELOCITY V	S	LAST POINT OFFSET X	S	LAST POINT VELOCITY V	S
707	23	.16	6.83	170.71	32.17	.33	7.32	192.30	34.30	.34	8.07	211.50	39.11
727-1	37	.39	12.45	160.51	38.06	1.71	9.95	179.73	40.80	2.16	10.00	196.64	45.95
727-2	20	2.68	10.17	149.95	50.93	1.64	8.05	166.56	56.28	1.75	7.35	183.66	63.03
737	27	-.02	11.95	179.39	20.97	1.77	8.56	194.74	16.75	3.63	11.82	208.97	21.60
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	3	3.49	2.18	164.69	2.56	3.81	1.81	171.70	12.47	4.13	1.50	178.70	22.38
DC8-6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	59	-.43	12.53	168.64	21.16	.36	6.95	186.00	14.99	.84	9.80	202.13	16.86
DC10	11	-.61	2.38	178.22	15.77	-.84	3.57	206.12	13.58	-2.09	4.33	229.93	15.52
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	27	-1.00	8.16	155.44	27.78	.18	4.98	159.77	28.15	-.09	5.04	163.39	30.98
YS-11	4	2.32	22.10	171.13	27.30	6.14	19.04	187.46	21.29	2.15	22.16	197.13	22.34
BAC-111	113	.66	7.20	166.46	18.01	-1.31	7.51	184.91	11.91	-2.04	15.06	200.09	15.49
ALL A/C	324	.33	9.98	168.32	22.61	.17	7.96	185.02	21.42	.11	11.89	200.27	26.27

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-12

LATERAL DISTRIBUTION AND VELOCITY - BUF RWY 23 TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	28	-.69	5.61	174.53	29.31	.06	4.07	197.87	32.63	.79	4.45	216.41	47.17
727-1	102	.73	6.46	169.11	25.54	.51	5.68	199.78	33.72	.24	6.19	222.07	56.51
727-2	77	.65	6.11	185.40	30.75	.28	5.98	213.82	18.00	.00	6.69	229.56	23.61
737	3	3.06	2.41	225.47	17.51	7.30	6.94	235.51	13.55	11.55	15.43	245.55	12.82
747	7	-4.58	7.66	171.07	29.51	-3.46	6.00	205.55	15.13	-3.05	4.28	239.26	19.79
DC8-4,5	15	-1.19	4.75	148.96	35.37	-1.13	4.42	160.21	43.32	-.73	4.37	168.97	53.02
DC8-6	3	.07	2.72	185.43	18.24	1.38	2.57	211.85	31.89	8.05	5.14	229.43	47.39
DC9-1,2	3	3.08	1.18	167.29	7.75	1.85	1.02	179.15	9.09	.63	2.59	191.02	25.85
DC9-3,4	79	1.02	6.98	177.45	33.15	.68	6.81	196.81	25.14	-.25	8.52	213.63	29.95
DC10	2	-1.32	0.	252.40	80.93	-1.32	0.	252.40	80.93	-1.32	0.	252.40	80.93
L1011	38	.38	5.23	192.74	34.84	.50	5.18	219.27	24.03	.48	5.34	236.55	27.78
C580	5	.84	6.05	109.23	30.60	.91	6.10	116.63	32.72	.98	6.14	124.03	40.54
YS-11	1	2.55	0.	213.87	0.	2.55	0.	213.87	0.	2.55	0.	213.87	0.
BAC-111	3	.28	6.81	177.42	28.63	-8.58	7.82	197.97	26.22	-8.77	8.05	207.16	34.28
ALL A/C	366	.48	6.27	176.83	33.88	.32	5.92	201.86	32.86	.14	6.87	219.73	44.56

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-13

LATERAL DISTRIBUTION AND VELOCITY - MIA RWY 9L TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	25	-3.91	5.98	166.90	21.39	-3.12	5.78	187.89	16.89	-2.66	6.01	209.08	17.99
727-1	78	-3.16	4.94	167.19	21.87	-2.90	4.79	193.27	17.61	-1.56	7.12	221.84	28.89
727-2	54	-3.11	5.45	166.68	21.73	-3.09	5.12	200.09	16.25	-2.73	6.21	230.51	22.03
737	1	.50	0.	229.63	0.	.50	0.	229.63	0.	.50	0.	229.63	0.
747	2	-1.53	.87	164.53	18.65	-4.39	.30	199.66	11.01	-5.84	.05	250.76	12.61
DC8-4,5	15	2.24	6.95	174.85	21.37	1.70	6.92	194.24	16.78	1.16	7.24	213.64	17.30
DC8-6	1	-1.05	0.	177.85	0.	-1.41	0.	227.15	0.	-2.54	0.	251.72	0.
DC9-1,2	2	-.80	3.48	180.54	26.25	-1.02	3.26	191.66	15.13	-1.24	3.04	202.77	4.01
DC9-3,4	63	-1.36	6.05	172.26	23.38	-1.95	6.18	185.47	13.64	-2.53	7.59	198.69	9.50
DC10	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	17	-1.81	6.03	166.87	21.85	-2.90	5.34	214.57	15.70	-3.09	6.97	252.78	18.45
C580	3	-5.20	3.10	133.60	1.04	-5.92	4.15	151.00	.62	-6.65	5.19	168.40	1.82
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	-8.09	0.	194.53	0.	-9.76	0.	217.11	0.	-11.44	0.	239.70	0.
ALL A/C	262	-2.38	5.76	168.77	22.79	-2.51	5.58	193.64	18.50	-2.21	6.96	218.05	26.46

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-14

LATERAL DISTRIBUTION AND VELOCITY - MIA RWY 27R TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	3	-1.49	1.06	109.76	77.69	-2.62	1.87	123.71	87.53	-3.74	2.68	137.66	97.37
727-1	22	-.53	4.34	150.76	40.03	-.32	4.74	166.47	44.42	-.14	5.33	184.15	54.55
727-2	20	.09	3.77	164.58	19.66	.42	4.97	189.98	20.81	.72	7.12	221.23	35.96
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	5	.55	2.57	146.35	29.09	1.32	1.63	162.78	37.03	2.09	2.01	179.22	45.10
DC8-6	5	-5.72	4.45	167.32	19.96	-6.73	5.09	186.81	8.29	-6.11	4.36	212.54	18.06
DC9-1,2	21	-2.03	3.63	166.56	14.28	-2.43	4.27	178.65	19.48	-2.82	6.25	190.75	27.84
DC9-3,4	34	-.48	4.65	163.44	6.35	-.08	4.82	182.49	30.43	-.61	7.12	202.04	60.96
DC10	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	2	2.83	3.16	151.06	16.04	-.74	.41	162.99	4.11	-4.31	3.98	174.91	7.81
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	112	-.84	4.31	159.49	27.71	-.79	4.85	177.35	35.23	-.97	6.49	197.08	52.24

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-15

LATERAL DISTRIBUTION AND VELOCITY - MSY RWY 10 TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	31	-1.67	4.16	174.13	21.64	-1.49	4.36	193.15	13.73	-1.32	4.80	212.17	12.81
727-2	31	-1.52	2.14	170.75	22.48	-1.76	2.77	192.63	17.15	-1.94	3.67	213.79	17.44
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	10	-.60	5.43	164.79	38.84	-1.48	3.85	196.50	20.06	-2.35	4.34	228.21	5.73
DC8-6	12	-1.62	4.85	170.55	24.86	-1.62	4.69	196.29	13.48	-1.70	5.13	221.15	9.89
DC9-1,2	19	-.23	4.58	170.04	7.72	-.25	4.71	190.95	10.72	-.27	5.10	211.86	24.02
DC9-3,4	35	-1.70	5.62	164.34	23.42	-.93	4.49	189.69	28.17	-.16	5.21	215.04	36.96
DC10	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	5.29	0.	165.27	0.	3.73	0.	196.11	0.	2.18	0.	226.95	0.
C580	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	-6.62	.72	166.65	4.93	-13.58	5.74	195.81	7.30	-20.54	12.19	224.98	9.67
ALL A/C	141	-1.39	4.53	169.27	23.06	-1.39	4.45	192.44	19.19	-1.38	5.47	215.38	23.52

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-16

LATERAL DISTRIBUTION AND VELOCITY - MSY RWY 28 TAKEOFFS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	42	-8.13	7.31	180.67	20.61	-8.28	7.31	182.82	22.10	-8.42	7.48	184.97	27.22
727-1	41	-6.36	10.03	169.63	14.43	-6.30	10.23	174.99	17.52	-6.23	10.47	180.35	28.63
727-2	45	-5.71	9.60	169.76	13.01	-5.99	9.92	187.53	21.08	-6.33	10.39	203.71	39.19
737	11	-1.04	3.55	186.98	7.25	-1.04	3.55	186.98	7.25	-1.04	3.55	186.98	7.25
747	7	-5.23	5.52	164.42	5.50	-5.71	5.16	184.86	19.30	-6.19	4.90	205.31	42.85
DC8-4,5	12	-4.52	4.52	176.59	5.31	-4.50	4.54	180.80	10.70	-4.47	4.57	185.01	24.31
DC8-6	3	-3.35	2.44	166.26	13.15	-4.29	3.35	182.29	11.92	-5.24	4.48	198.32	33.75
DC9-1,2	49	-6.17	9.72	184.21	29.20	-6.17	9.72	184.21	29.20	-6.17	9.72	184.21	29.20
DC9-3,4	55	-5.13	8.69	180.87	12.87	-5.13	8.69	180.87	12.87	-5.13	8.69	180.87	12.87
DC10	11	-9.63	5.85	187.44	14.22	-9.71	5.85	192.07	16.68	-9.79	5.85	196.70	27.99
L1011	7	-9.75	8.58	176.50	4.54	-11.40	8.74	195.45	19.79	-13.05	9.69	214.40	41.58
C580	29	-1.93	7.82	160.44	12.18	-1.93	7.82	160.44	12.18	-1.93	7.82	160.44	12.18
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	312	-5.72	8.74	176.06	19.04	-5.84	8.85	180.98	21.08	-5.95	9.04	185.67	29.94

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-17

LATERAL DISTRIBUTION AND VELOCITY - DFW RWY 17L TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	S	VELOCITY V	S	INTERMEDIATE POINT OFFSET X	S	VELOCITY V	S	LAST POINT OFFSET X	S	VELOCITY V	S
707	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	1	-2.04	0.	218.62	0.	-2.43	0.	231.10	0.	-2.82	0.	243.58	0.
727-2	3	6.87	3.49	219.59	2.93	7.89	3.20	232.43	3.29	8.91	3.05	245.26	3.65
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	1	16.91	0.	226.55	0.	16.91	0.	226.55	0.	16.91	0.	226.55	0.
DC8-4,5	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	5	7.10	6.58	220.79	3.69	7.63	6.61	230.99	3.42	8.16	6.73	241.18	7.87

X – Mean Offset in Feet
V – Mean Velocity in Feet Per Second
S – Standard Deviation

FIGURE A-18

LATERAL DISTRIBUTION AND VELOCITY - DFW RWY 35R TAKEOFFS

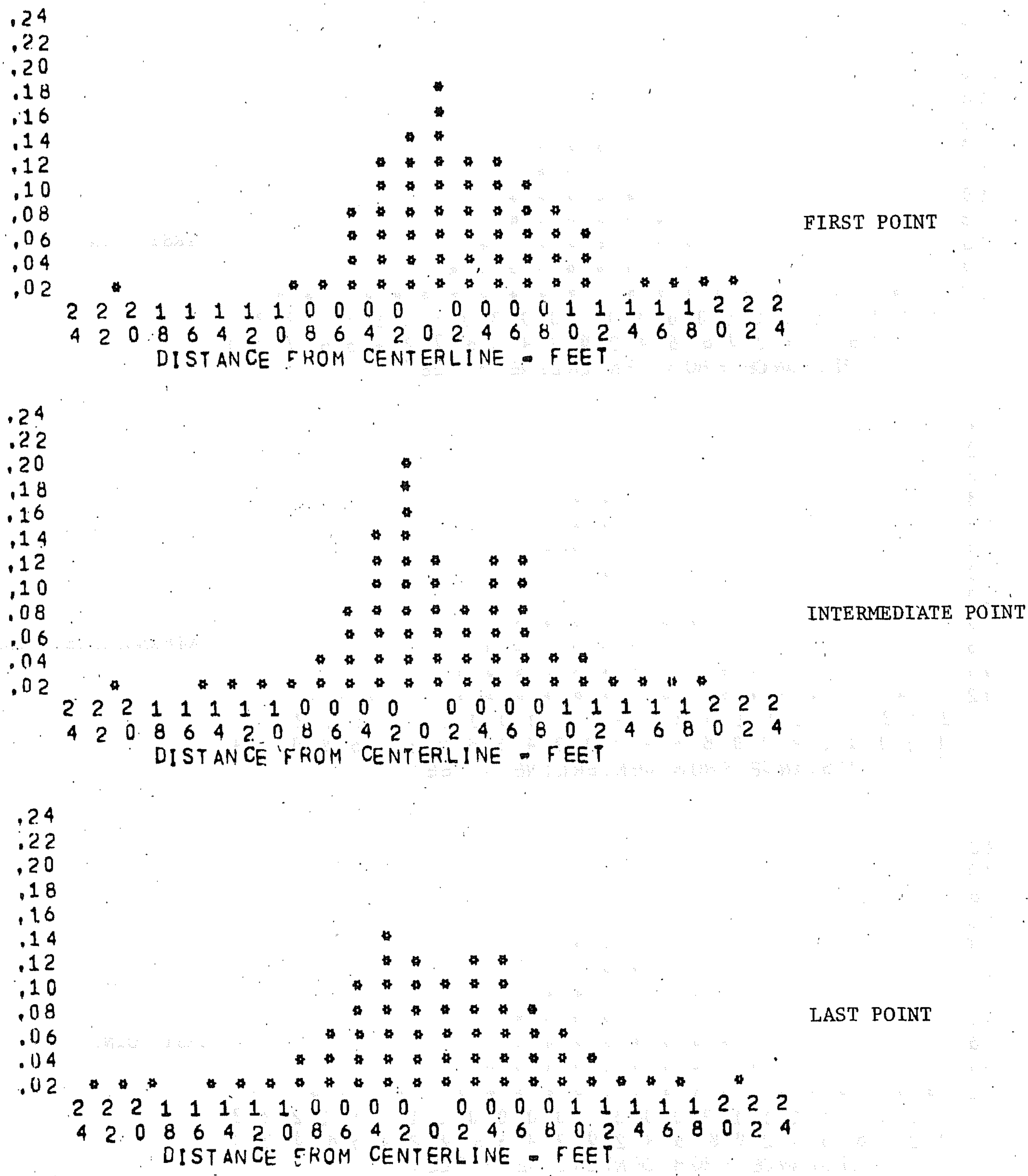


FIGURE A-19

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS ATL RWY 9R

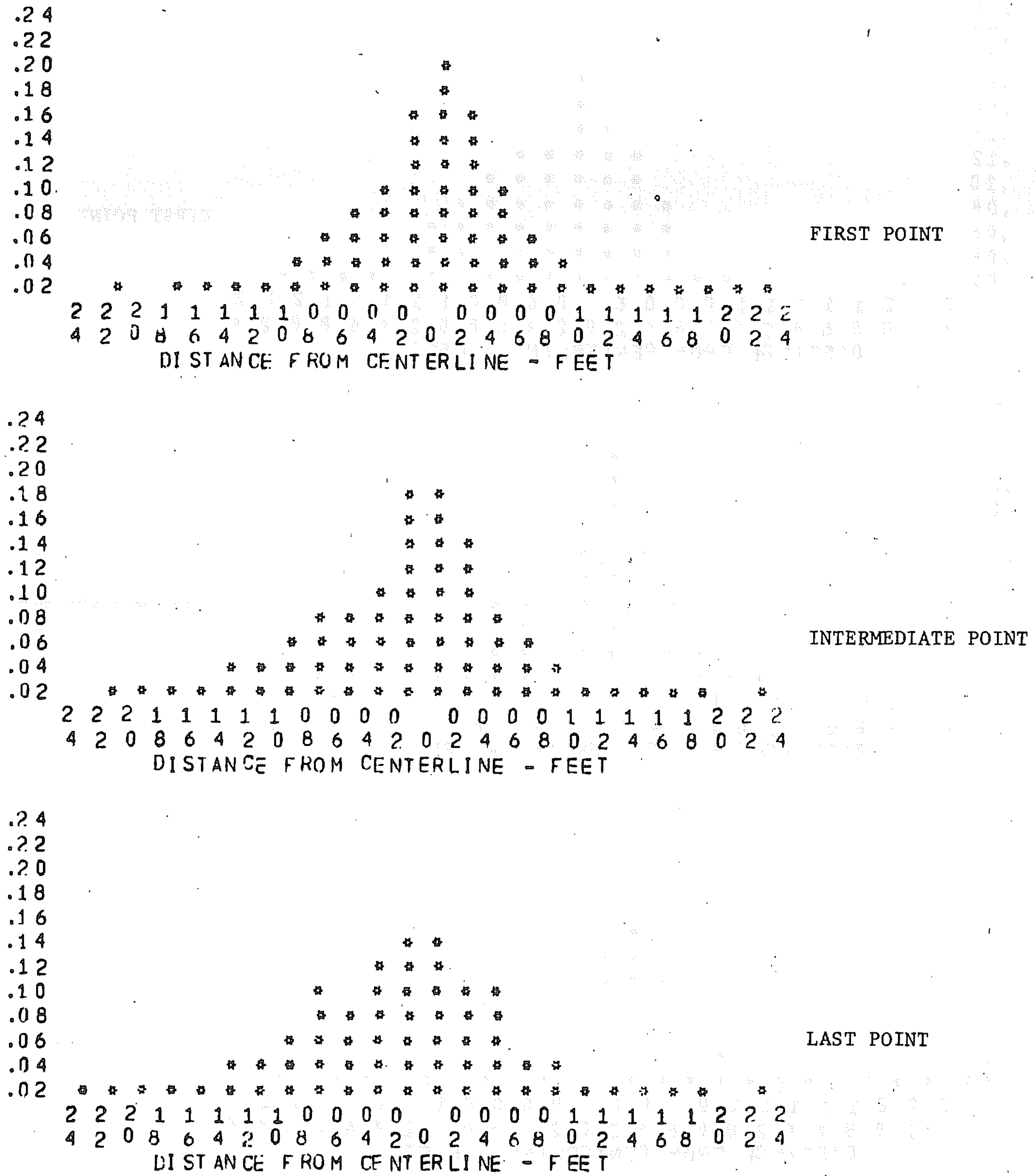


FIGURE A-20
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS ATL RWY 27L

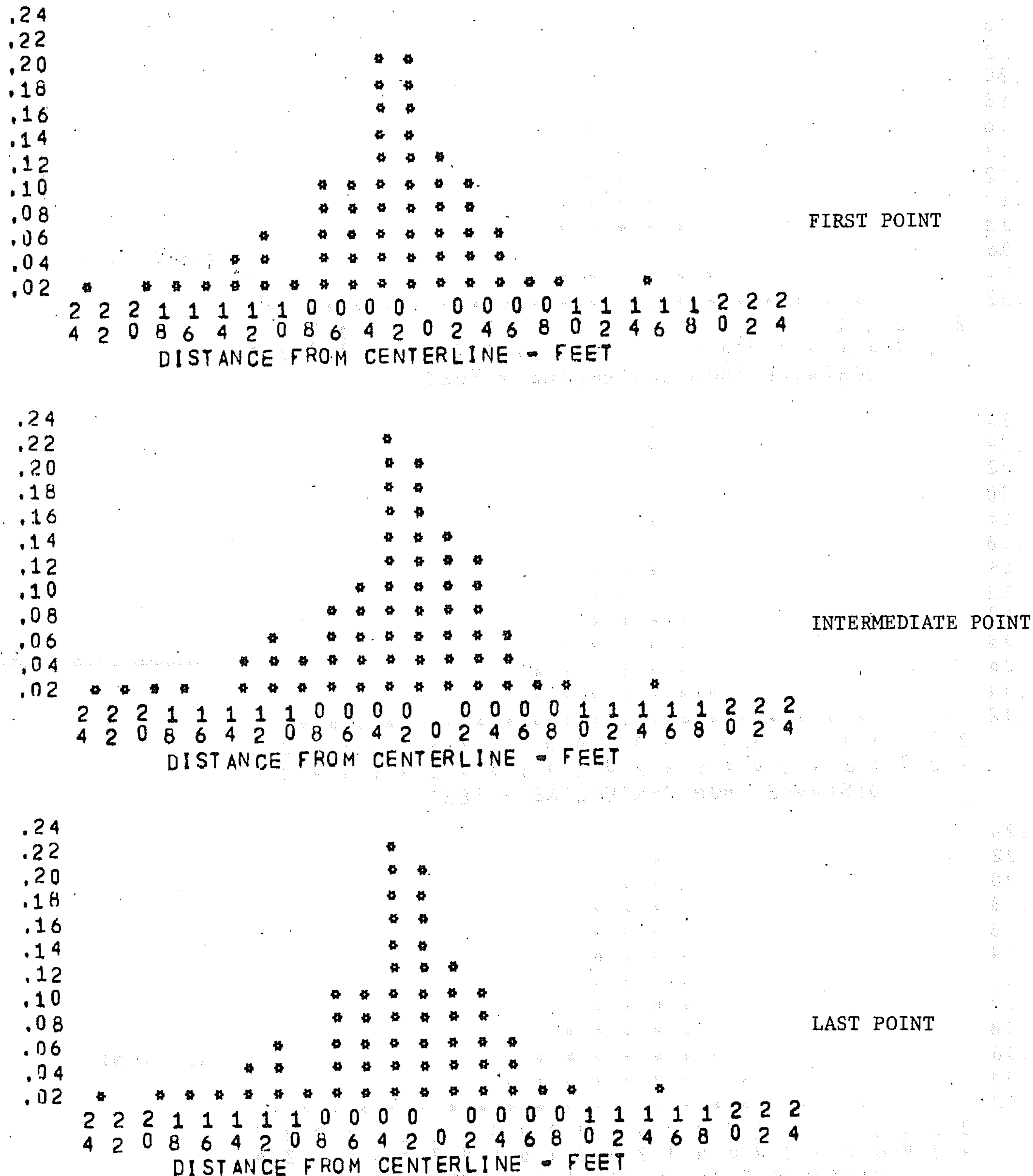


FIGURE A-21

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS ORD RWY 9R

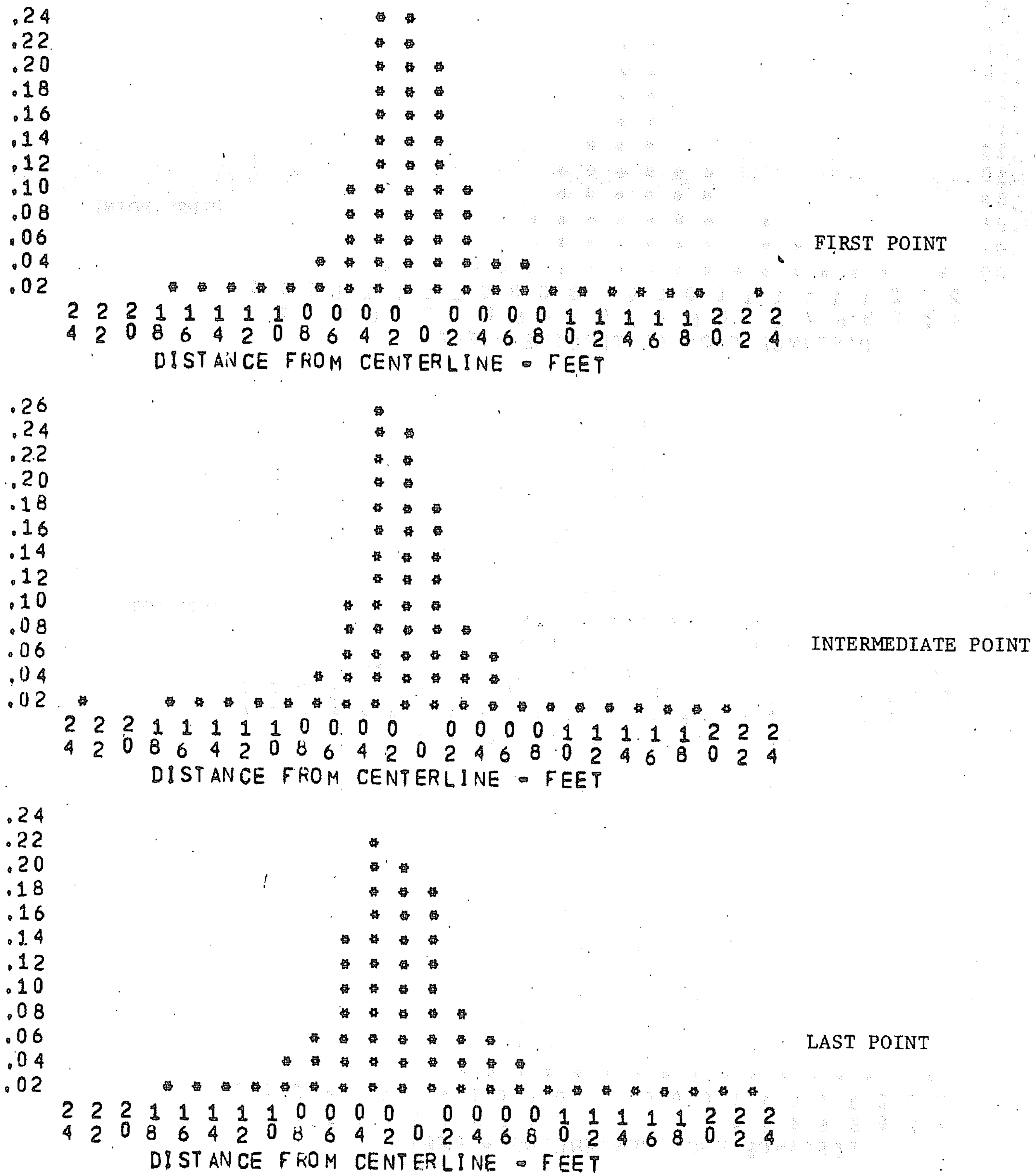


FIGURE A-22

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS ORD RWY 27L

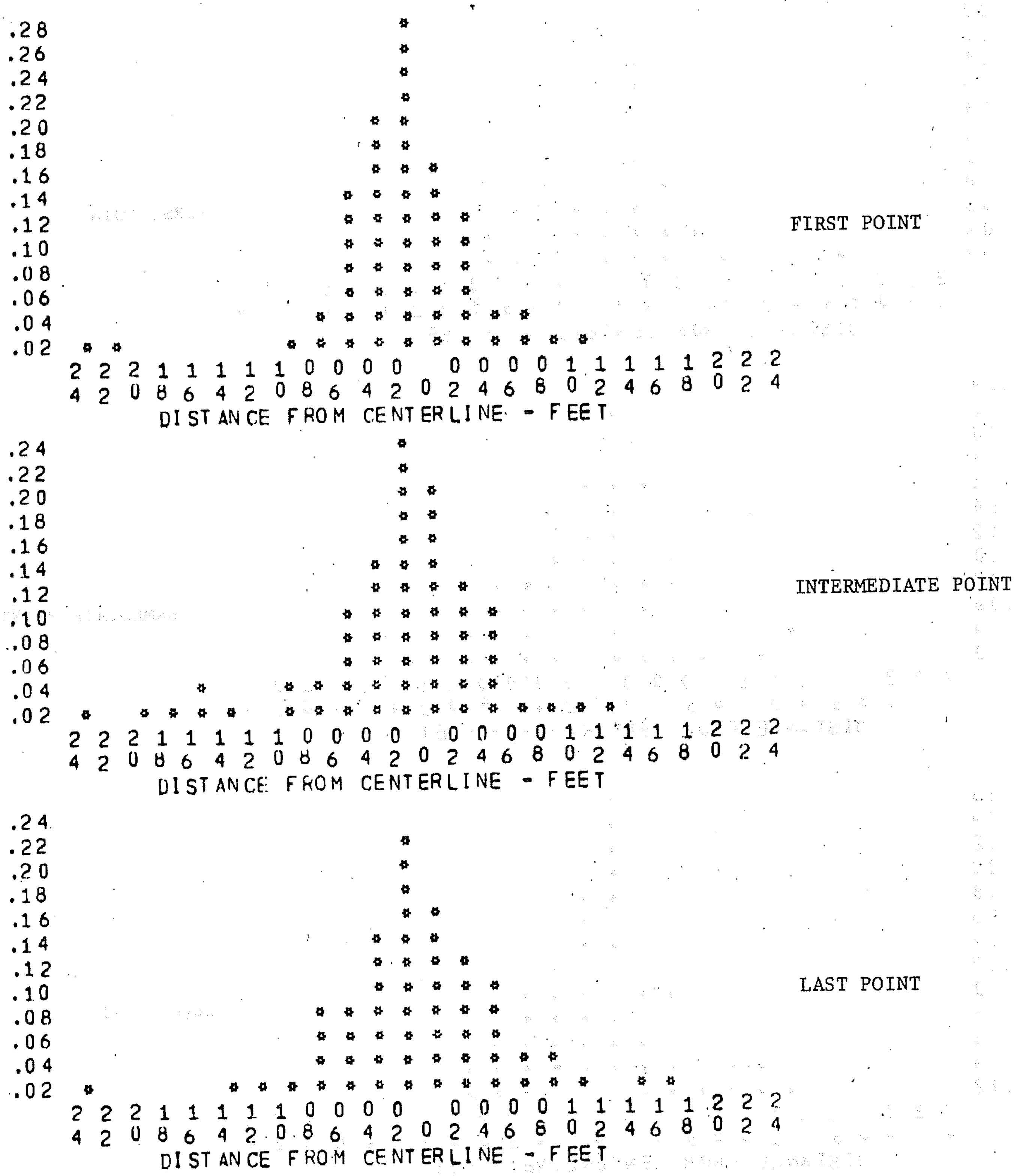
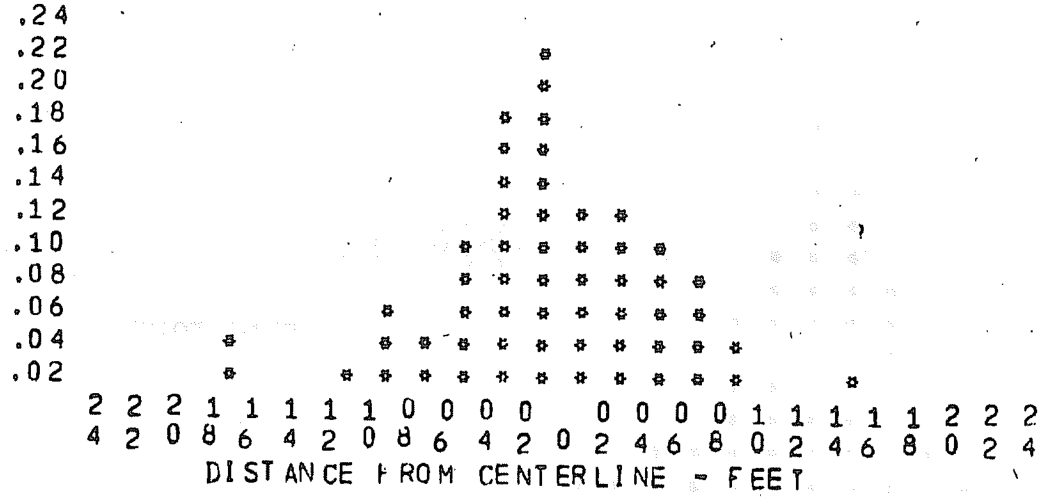
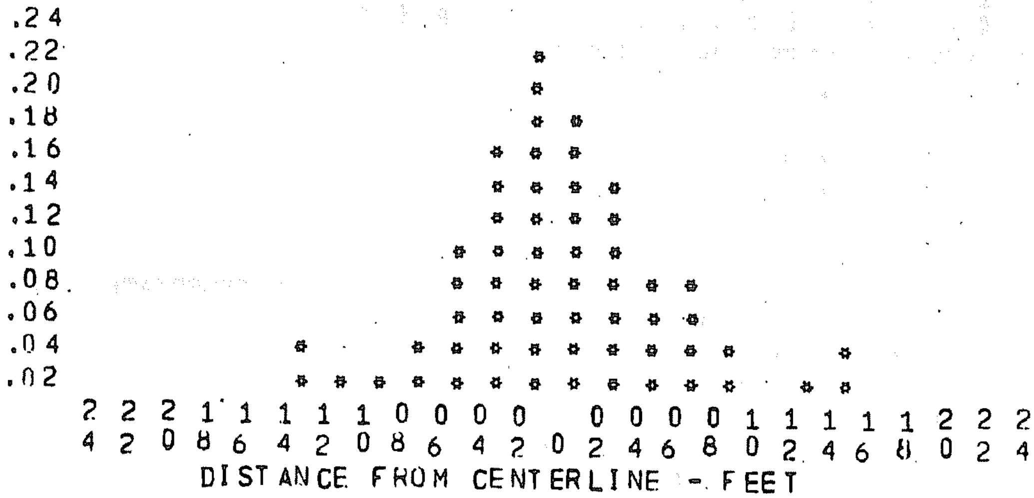


FIGURE A-23

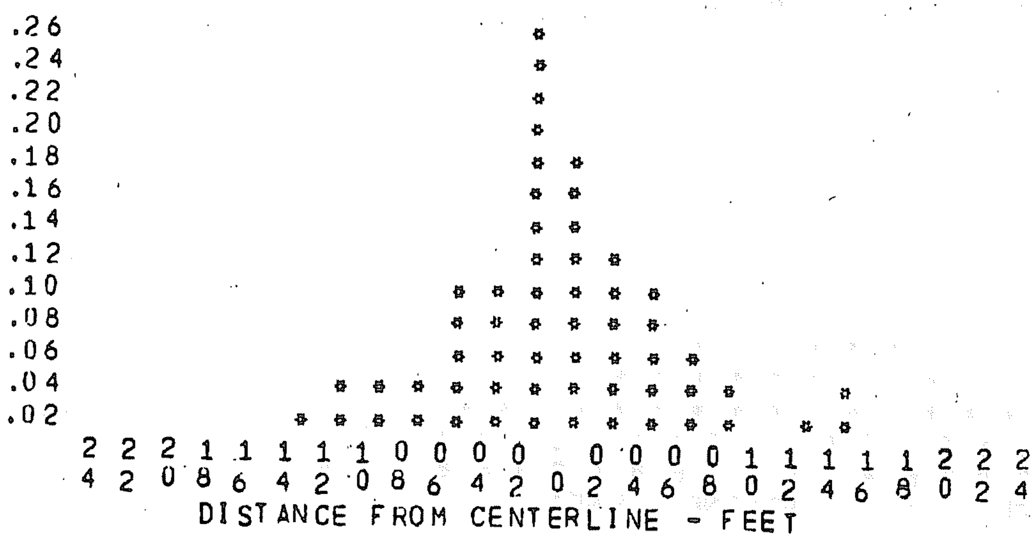
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS DEN RWY 8R



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-24
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS DEN RWY 26L

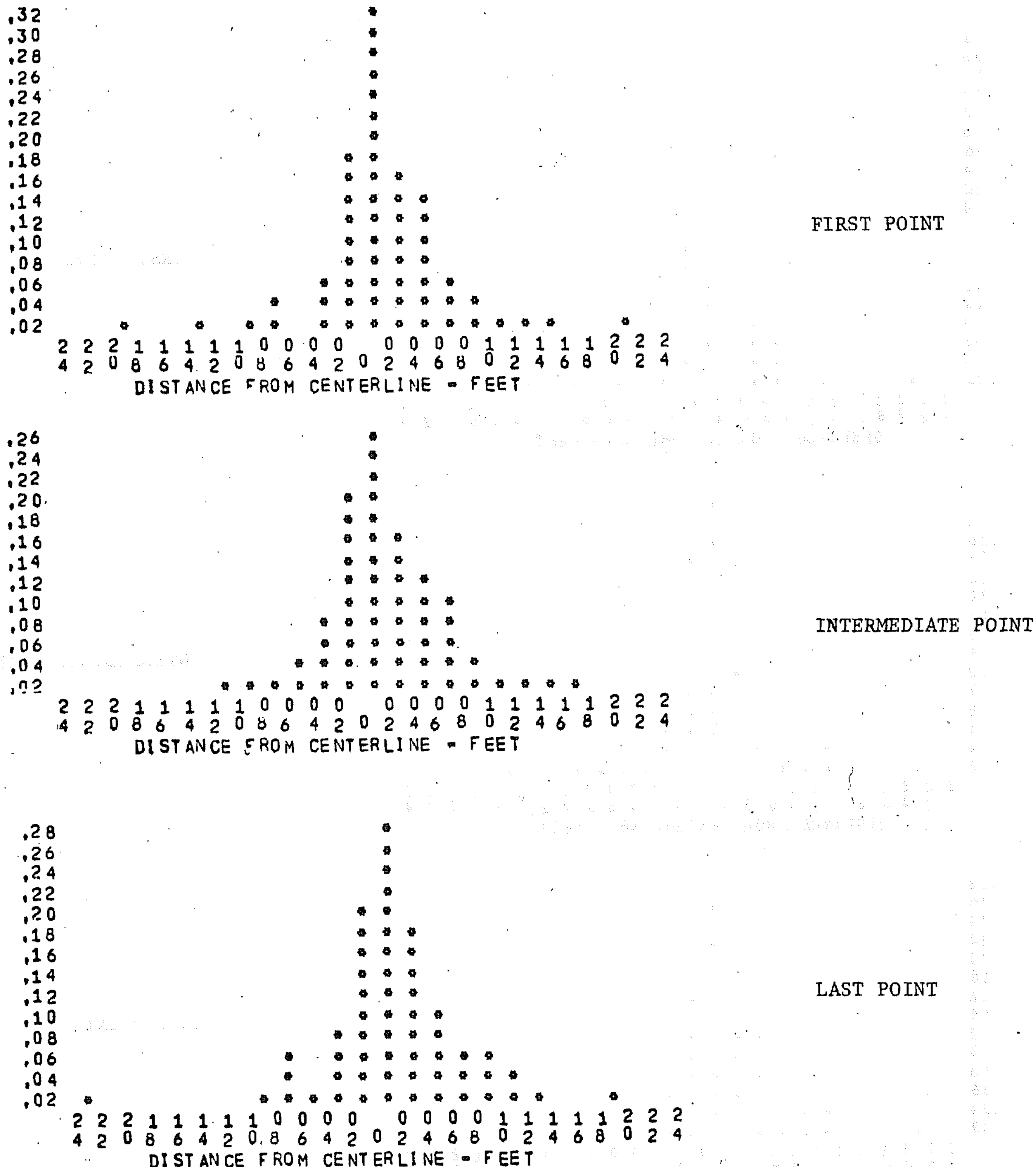
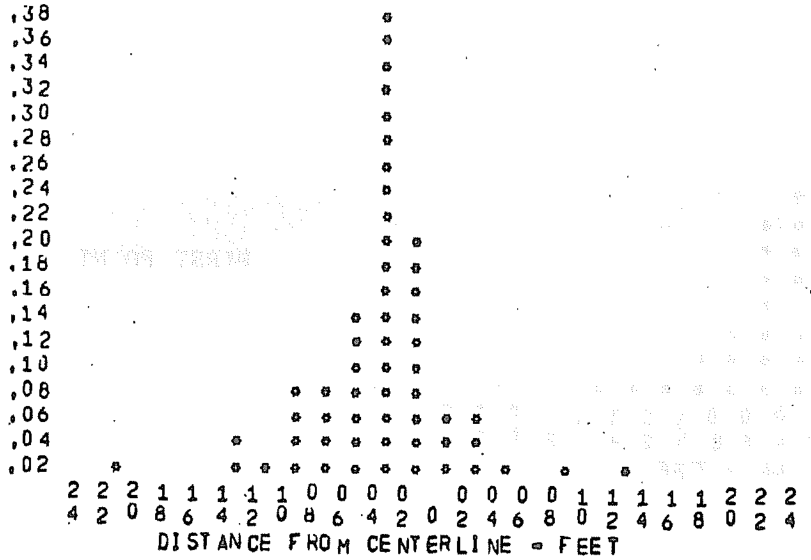
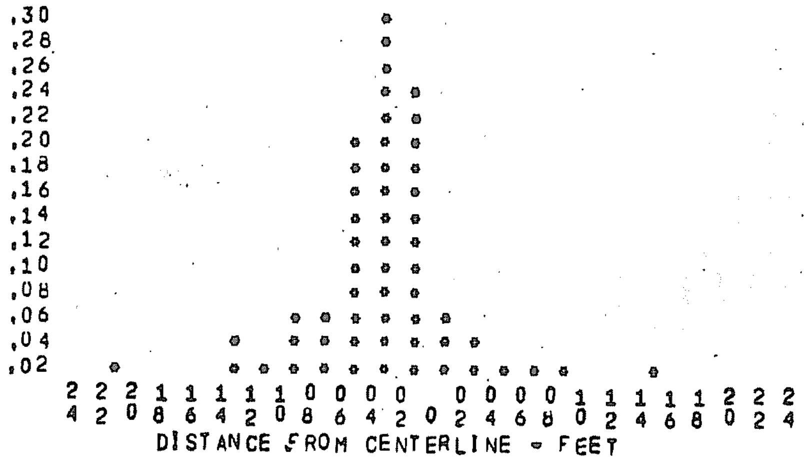


FIGURE A-25

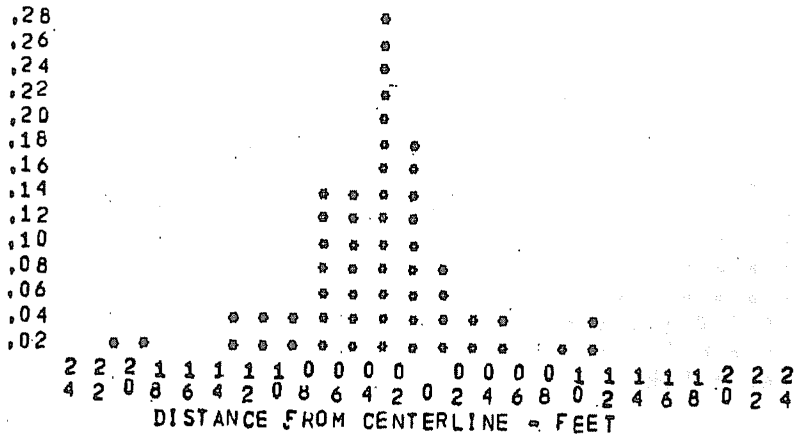
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS SEA RWY 16L



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-26

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS SEA RWY 34R

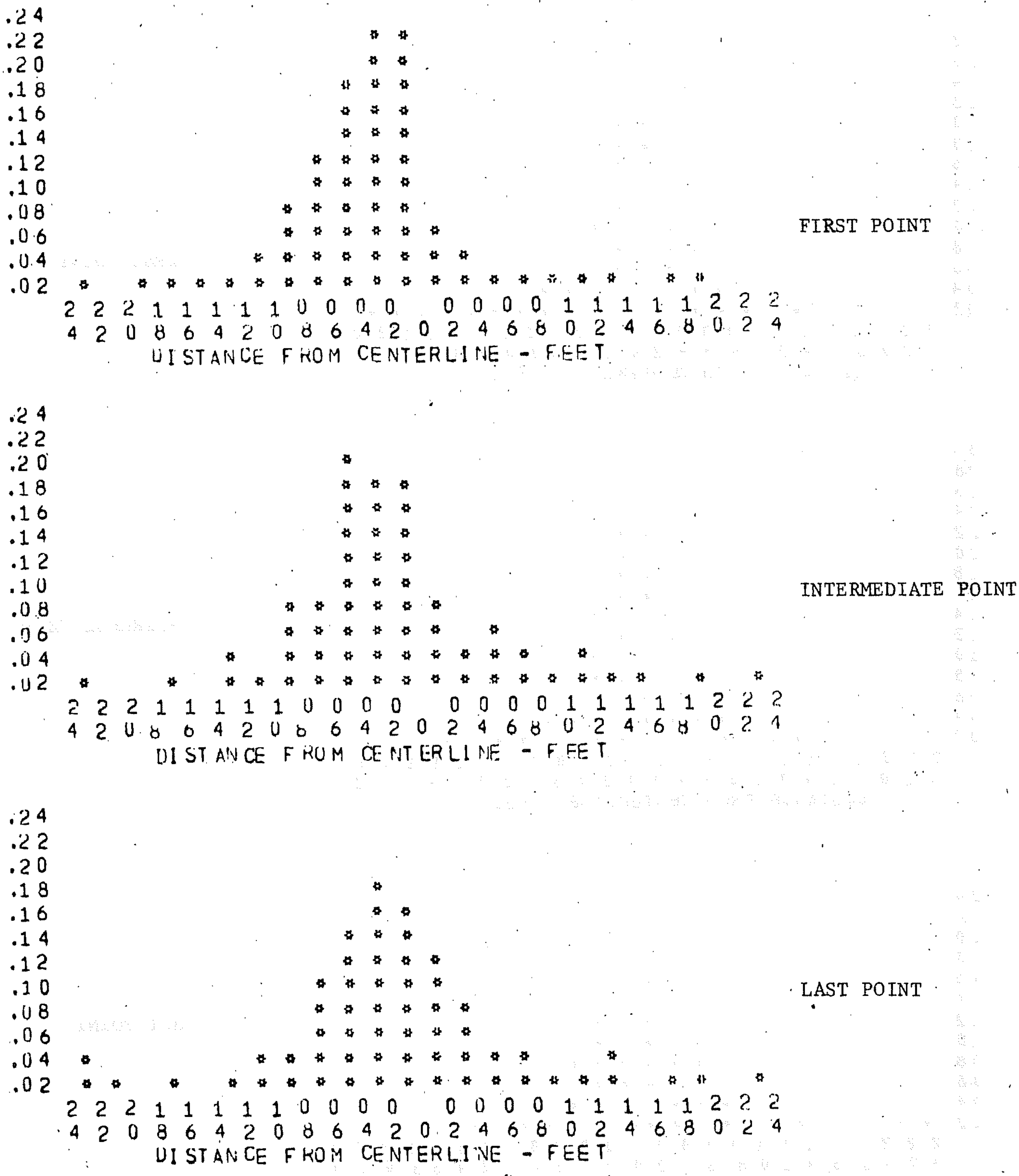
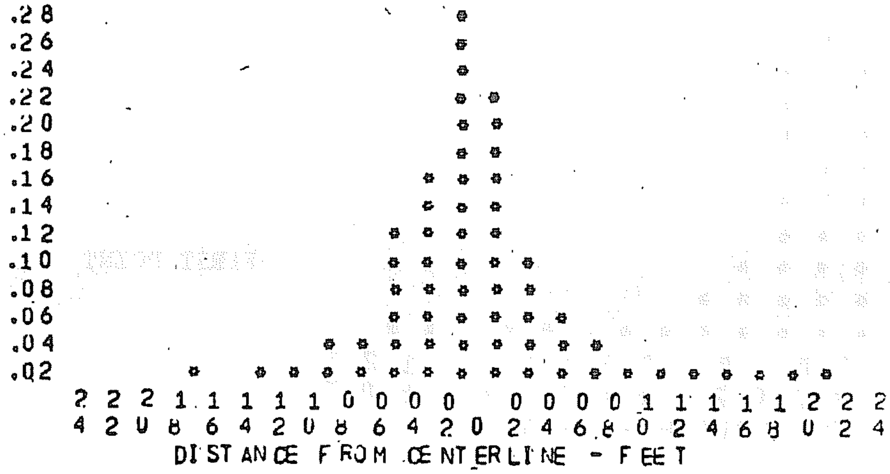
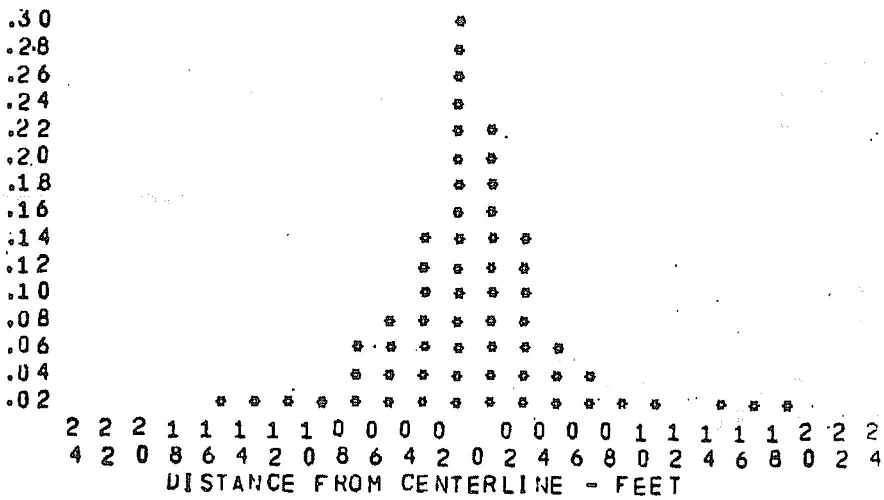


FIGURE A-27

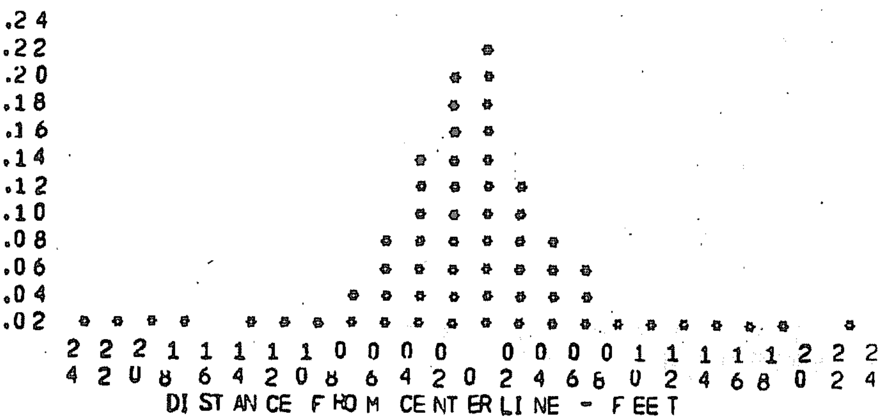
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS CLE RWY 5R



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-28

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS CLE RWY 23L

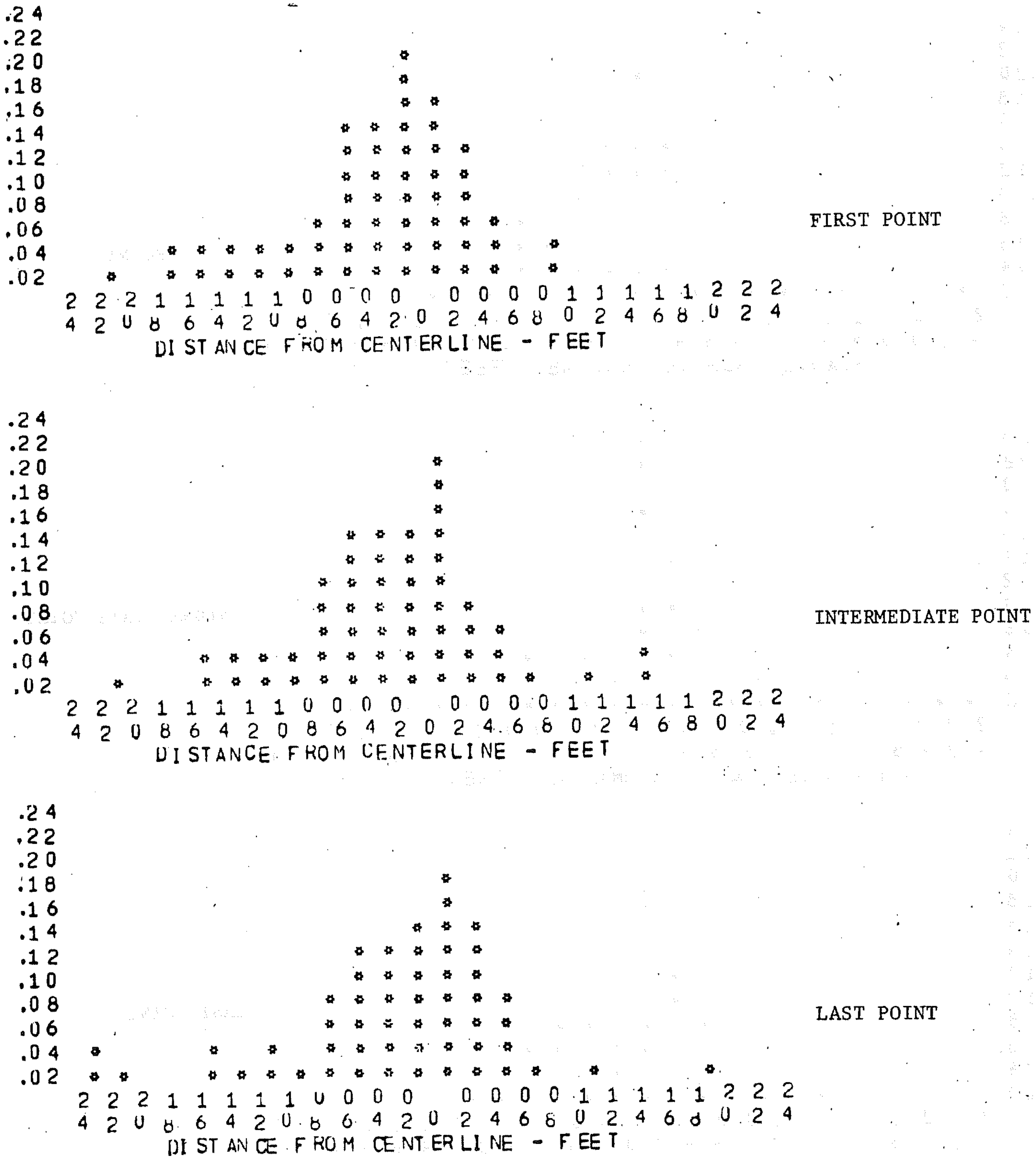
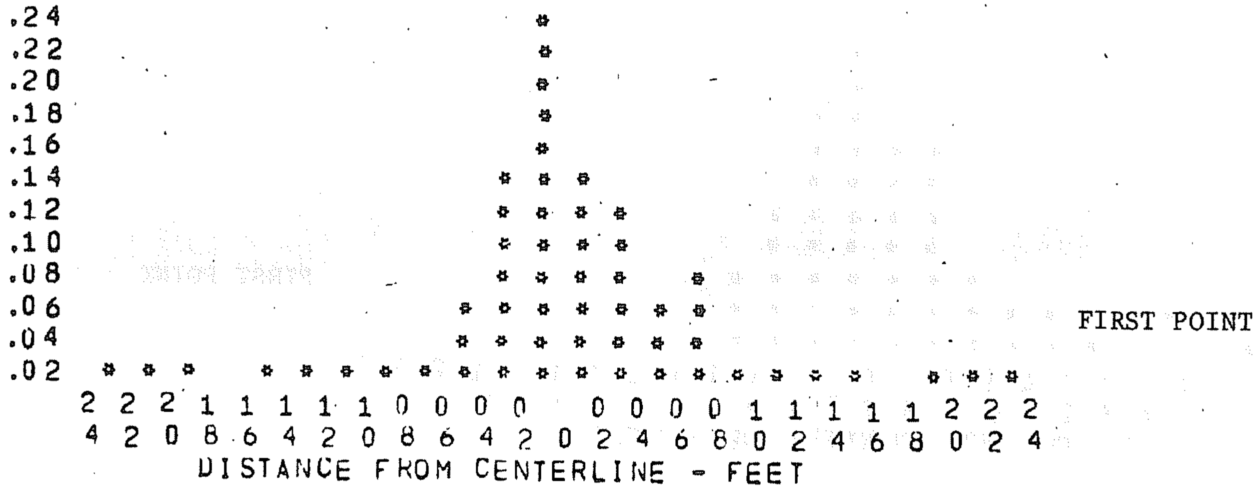
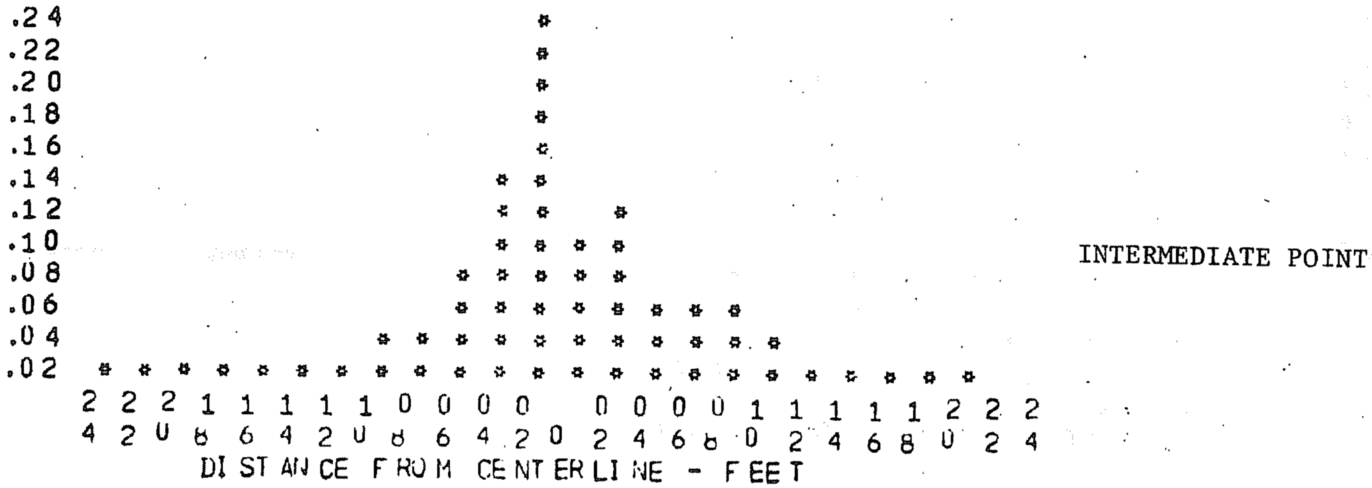


FIGURE A-29

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS BUF RWY 5





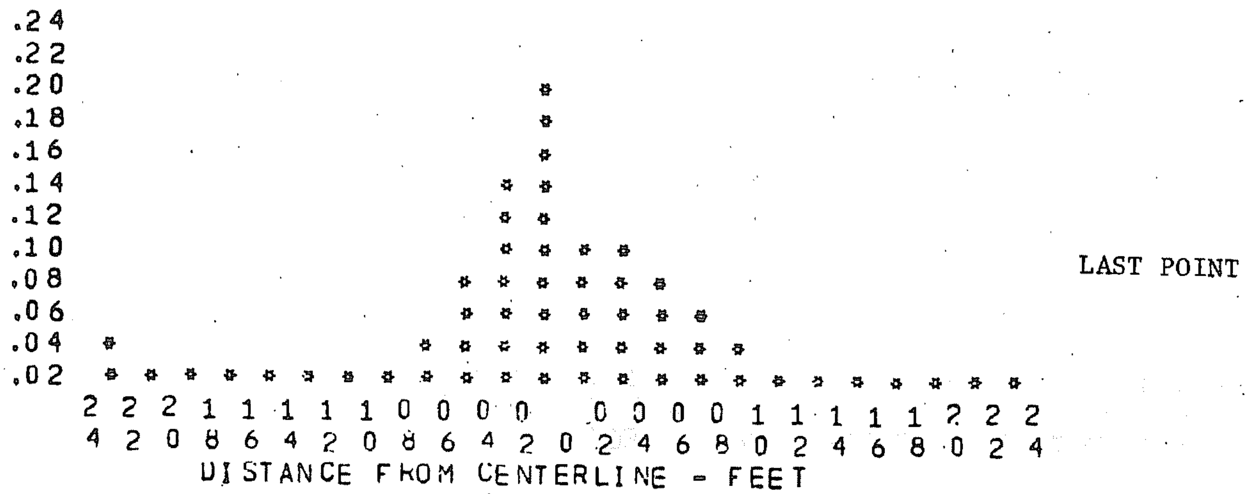
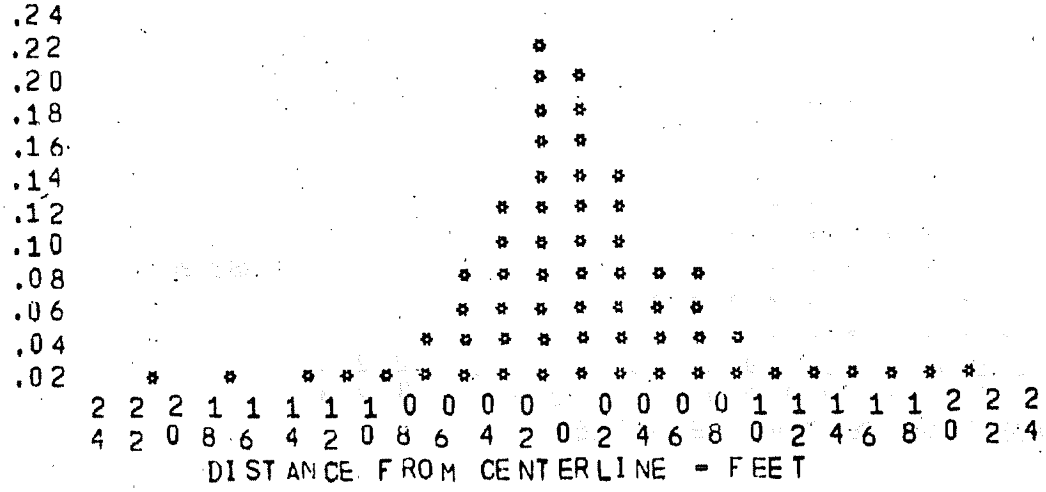
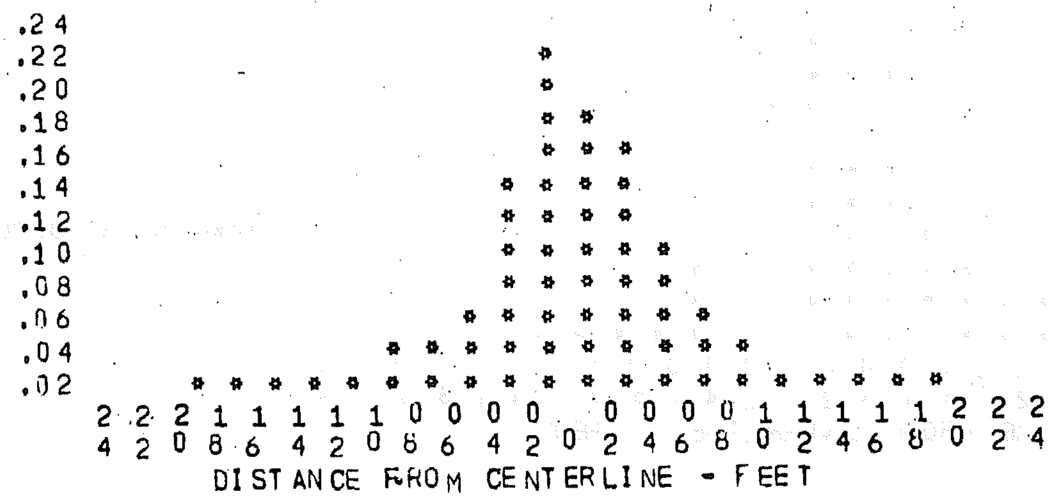


FIGURE A-30

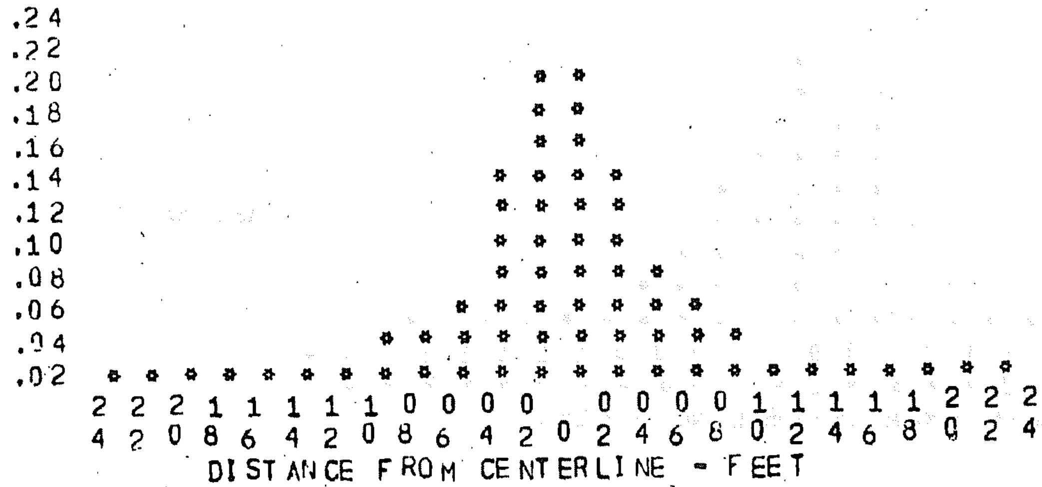
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS BUF RWY 23



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-31

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS MIA RWY 9L

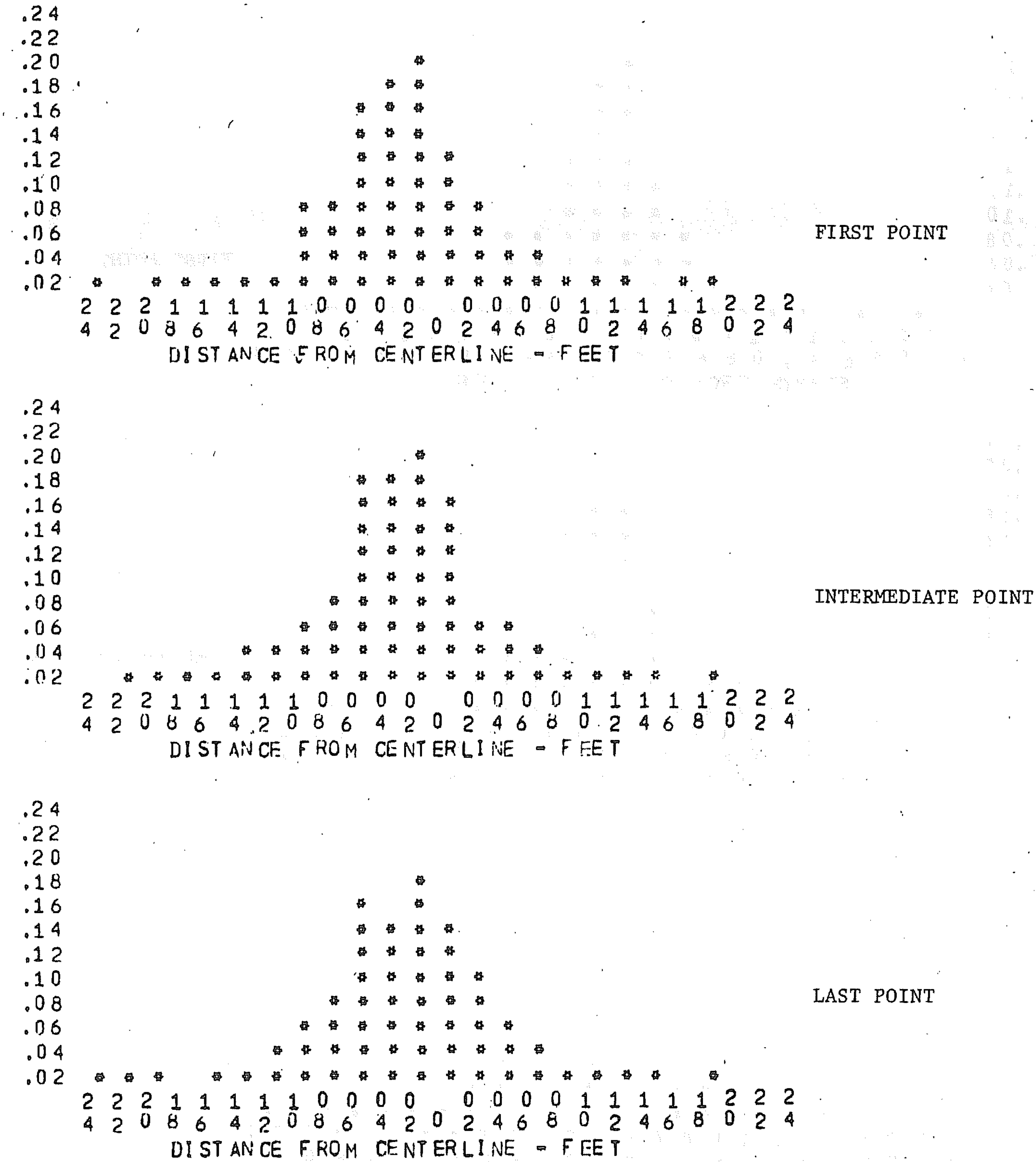


FIGURE A-32

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS MIA RWY 27R

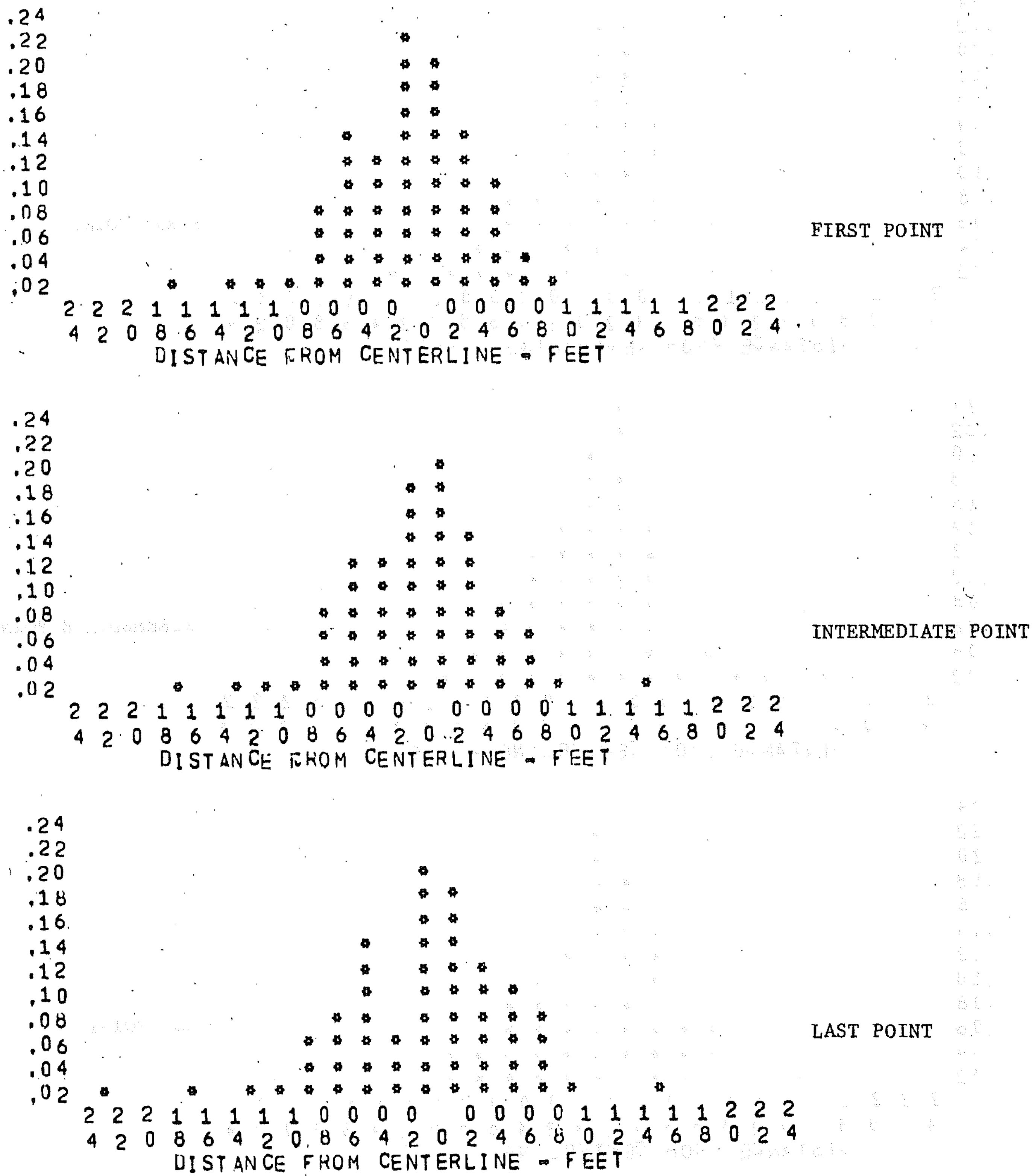


FIGURE A-33

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS MSY RWY 10

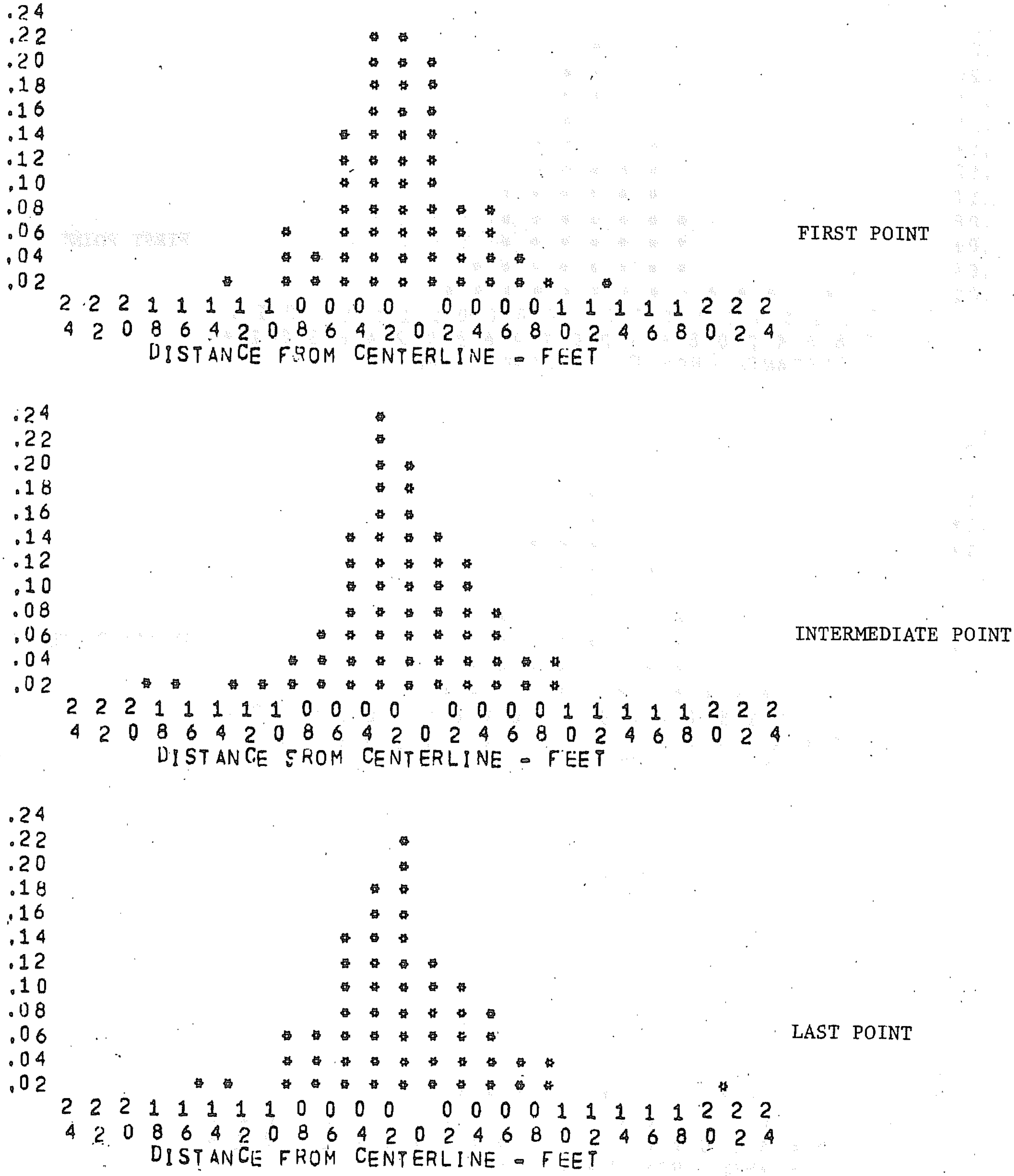
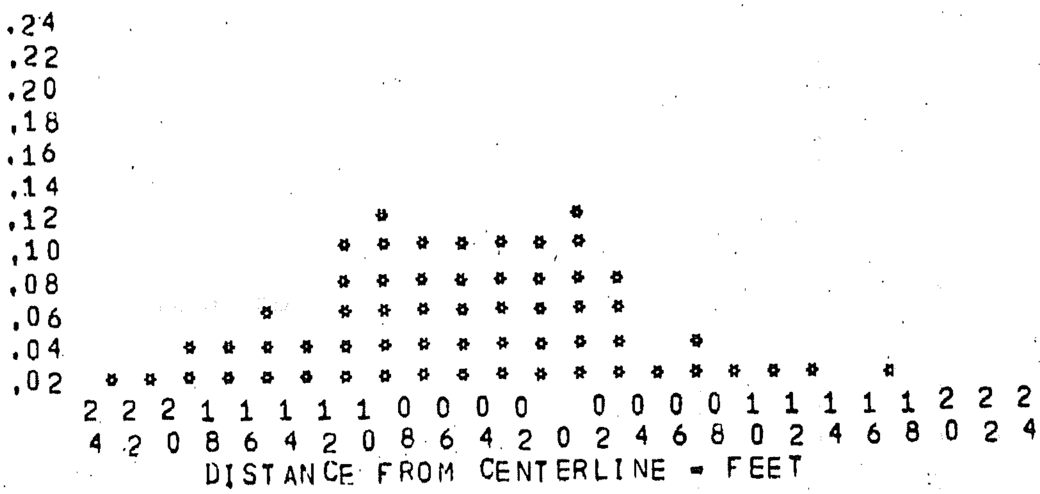
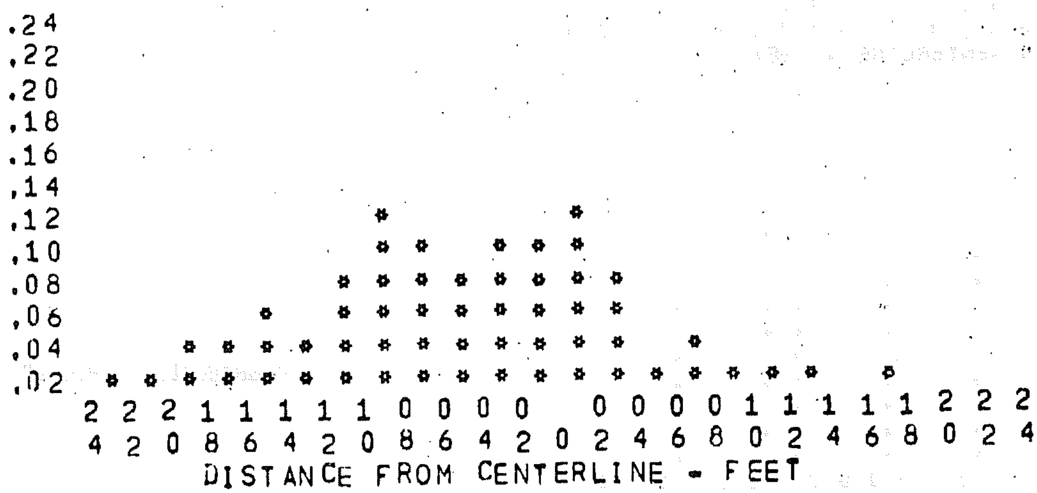


FIGURE A-34

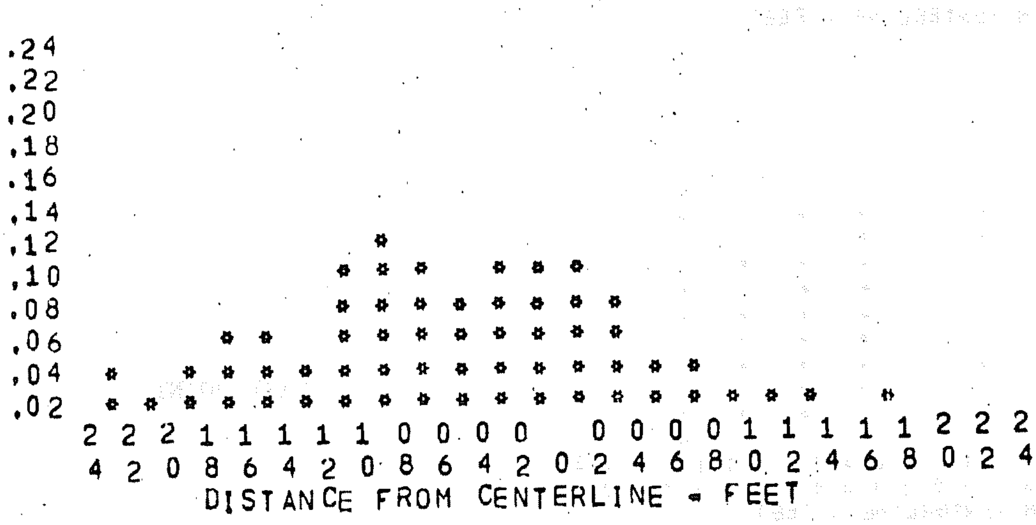
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS MSY RWY 28



FIRST POINT



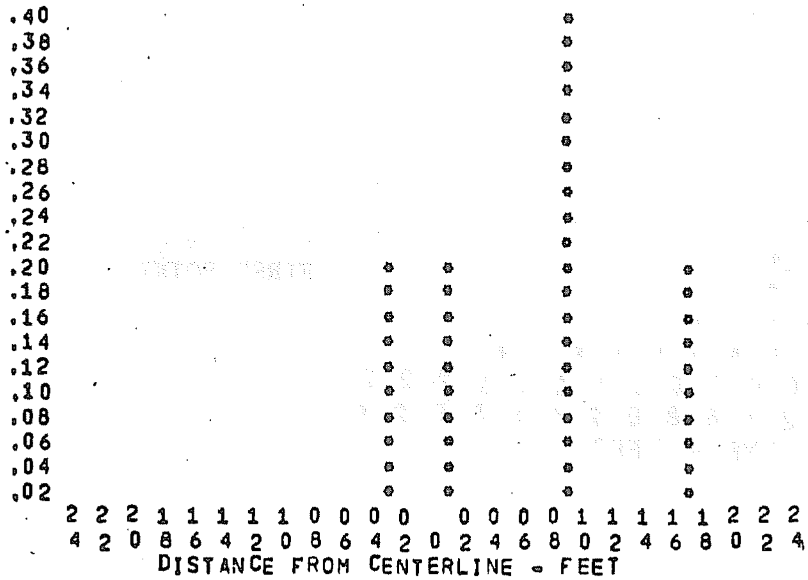
INTERMEDIATE POINT



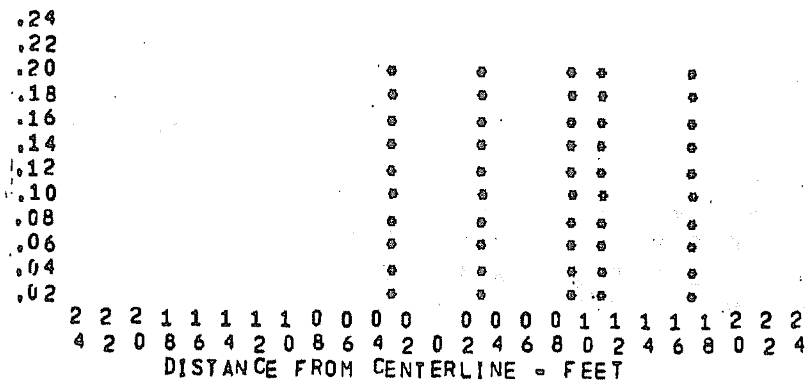
LAST POINT

FIGURE A-35

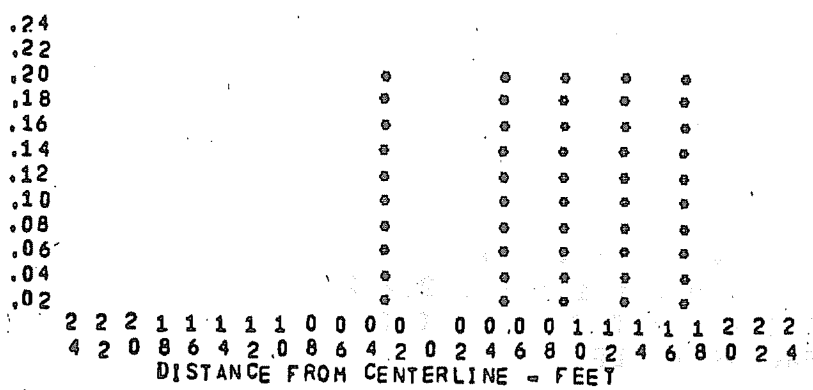
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS DFW RWY 17L



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-36

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL TAKEOFFS DFW RWY 35R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
727-1	34	.00	.09	.00	.03	.00	.00	.03	.03	.32	.18	.00	.26	.03	.03	.00	.00	.00	.00	.00
727-2	54	.00	.09	.00	.02	.04	.11	.13	.15	.33	.02	.02	.09	.00	.00	.00	.00	.00	.00	.00
737	17	.00	.12	.00	.00	.00	.00	.00	.06	.59	.06	.12	.06	.00	.00	.00	.00	.00	.00	.00
747	4	.00	.00	.00	.00	.00	.00	.00	.25	.50	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	5	.00	.00	.00	.00	.00	.00	.00	.00	.40	.20	.00	.40	.00	.00	.00	.00	.00	.00	.00
DC8-6	8	.00	.13	.00	.00	.00	.00	.00	.00	.25	.38	.25	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	13	.00	.08	.00	.00	.00	.00	.00	.00	.08	.08	.00	.54	.00	.15	.08	.00	.00	.00	.00
DC9-3,4	95	.00	.04	.00	.00	.02	.11	.05	.08	.40	.08	.06	.13	.01	.01	.00	.00	.00	.00	.00
DC10	4	.00	.00	.00	.00	.00	.00	.00	.25	.25	.25	.25	.00	.00	.00	.00	.00	.00	.00	.00
L1011	5	.00	.00	.00	.00	.00	.20	.20	.00	.40	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.33	.33	.00	.00	.00
YS-11	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.38	.13	.13	.25	.13	.00	.00	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	8	.00	.00	.00	.13	.00	.00	.13	.13	.00	.13	.13	.00	.00	.13	.25	.00	.00	.00	.00
727-1	130	.00	.00	.00	.00	.05	.02	.04	.38	.08	.06	.26	.03	.02	.05	.01	.00	.00	.00	.00
727-2	183	.00	.00	.00	.01	.01	.01	.00	.12	.03	.05	.51	.06	.05	.08	.03	.01	.01	.01	.00
737	53	.00	.00	.00	.00	.02	.00	.04	.43	.06	.06	.34	.04	.02	.00	.00	.00	.00	.00	.00
747	7	.00	.00	.00	.00	.00	.14	.00	.00	.00	.14	.14	.29	.14	.14	.00	.00	.00	.00	.00
DC8-4,5	21	.00	.00	.00	.00	.00	.00	.00	.38	.14	.10	.24	.10	.00	.00	.00	.00	.05	.00	.00
DC8-6	22	.00	.00	.00	.00	.00	.00	.00	.27	.14	.09	.36	.00	.00	.05	.00	.00	.05	.00	.05
DC9-1,2	36	.00	.00	.00	.00	.03	.00	.03	.72	.11	.08	.03	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	324	.00	.00	.00	.01	.01	.02	.02	.28	.11	.14	.31	.04	.02	.05	.01	.00	.00	.00	.00
DC10	9	.00	.00	.00	.00	.00	.00	.11	.22	.22	.11	.33	.00	.00	.00	.00	.00	.00	.00	.00
L1011	22	.00	.00	.00	.00	.00	.00	.00	.05	.05	.09	.55	.05	.00	.14	.05	.00	.00	.05	.00
C580	1	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	18	.00	.00	.00	.44	.28	.11	.00	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 27L

FIGURE A-37

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - ATL TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	22	.00	.00	.00	.00	.55	.05	.05	.09	.14	.00	.05	.05	.00	.05	.00	.00	.00	.00	.00
727-1	39	.00	.00	.00	.00	.38	.28	.15	.05	.08	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00
727-2	36	.00	.00	.00	.00	.11	.22	.06	.00	.36	.03	.08	.11	.00	.00	.00	.00	.00	.03	.00
737	12	.00	.00	.00	.00	.17	.42	.08	.08	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	9	.00	.00	.00	.00	.00	.22	.00	.22	.00	.00	.00	.22	.00	.11	.22	.00	.00	.00	.00
DC8-4,5	16	.00	.00	.00	.00	.38	.13	.00	.00	.44	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00
DC8-6	10	.00	.00	.00	.00	.10	.20	.00	.00	.30	.00	.00	.30	.00	.00	.00	.00	.00	.10	.00
DC9-1,2	4	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	30	.00	.00	.00	.00	.33	.30	.07	.10	.17	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00
DC10	3	.00	.00	.00	.00	.00	.00	.33	.33	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00
L1011	3	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.33	.33	.00	.00	.00	.00	.00	.00	.00
C580	6	.00	.00	.00	.33	.17	.00	.00	.00	.33	.00	.00	.17	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	35	.03	.00	.03	.00	.00	.03	.00	.03	.00	.11	.06	.03	.57	.09	.03	.00	.00	.00	.00
727-1	106	.00	.00	.00	.00	.00	.02	.02	.03	.04	.24	.08	.06	.51	.00	.01	.01	.00	.00	.00
727-2	77	.01	.00	.00	.00	.01	.10	.08	.00	.04	.32	.03	.06	.30	.01	.00	.03	.00	.00	.00
737	31	.00	.00	.00	.00	.00	.03	.03	.00	.03	.19	.06	.10	.52	.00	.03	.00	.00	.00	.00
747	5	.00	.00	.00	.00	.00	.00	.20	.00	.00	.60	.00	.20	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	14	.00	.00	.00	.00	.00	.07	.00	.07	.00	.14	.07	.00	.50	.07	.07	.00	.00	.00	.00
DC8-6	7	.00	.14	.00	.00	.00	.00	.14	.00	.00	.00	.14	.00	.57	.00	.00	.00	.00	.00	.00
DC9-1,2	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00
DC9-3,4	84	.00	.02	.00	.00	.00	.01	.04	.02	.00	.19	.07	.07	.51	.02	.04	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	5	.00	.00	.00	.00	.00	.20	.00	.00	.20	.40	.00	.00	.20	.00	.00	.00	.00	.00	.00
C580	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.50	.00	.00	.00

RUNWAY 27L

FIGURE A-38

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - ORD TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	16	.00	.00	.00	.00	.00	.38	.00	.13	.19	.06	.06	.19	.00	.00	.00	.00	.00	.00	.00
727-1	32	.00	.00	.00	.00	.09	.63	.06	.00	.16	.00	.00	.03	.03	.00	.00	.00	.00	.00	.00
727-2	31	.00	.16	.00	.00	.10	.61	.00	.03	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	28	.00	.00	.00	.00	.04	.39	.00	.04	.25	.07	.07	.11	.04	.00	.00	.00	.00	.00	.00
DC8-4,5	9	.00	.11	.00	.00	.11	.44	.22	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	3	.00	.00	.00	.00	.33	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	5	.00	.00	.00	.00	.00	.80	.00	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	6	.00	.00	.00	.00	.17	.83	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	12	.00	.00	.00	.08	.00	.42	.00	.00	.25	.08	.08	.08	.00	.00	.00	.00	.00	.00	.00
L1011	2	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	17	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.29	.65	.00	.00	.00	.00	.00	.00

RUNWAY 8R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.00	.33	.00	.00	.33	.00
727-1	16	.00	.00	.00	.00	.00	.00	.06	.25	.00	.06	.19	.25	.00	.00	.06	.06	.00	.06	.00
727-2	10	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00	.30	.00	.10	.40	.00	.00	.10	.00
737	13	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00	.23	.31	.00	.15	.15	.00	.00	.08	.00
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC9-3,4	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC10	51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.51	.12	.10	.12	.00	.00	.02	.00
C580	4	.00	.00	.00	.00	.00	.25	.25	.00	.25	.00	.00	.00	.00	.00	.25	.00	.00	.00	.00

RUNWAY 26L

FIGURE A-39

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - DEN TAKEOFFS

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	20	.00	.00	.00	.00	.35	.00	.00	.50	.00	.00	.05	.00	.00	.00	.10	.00	.00	.00	.00
727-1	37	.00	.00	.00	.03	.14	.00	.08	.51	.08	.05	.00	.05	.00	.00	.03	.00	.03	.00	.00
727-2	29	.00	.00	.00	.00	.34	.03	.00	.34	.03	.07	.00	.10	.00	.00	.00	.00	.00	.03	.03
737	8	.00	.00	.00	.00	.63	.00	.00	.38	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	8	.00	.00	.00	.00	.13	.00	.00	.50	.00	.13	.00	.13	.00	.00	.13	.00	.00	.00	.00
DC8-4,5	4	.00	.00	.00	.00	.50	.00	.00	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.25
DC8-6	13	.00	.00	.00	.00	.00	.15	.00	.62	.00	.15	.08	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	8	.00	.00	.00	.13	.75	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.13
DC9-3,4	5	.00	.00	.00	.00	.00	.20	.20	.60	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	8	.00	.00	.00	.00	.13	.00	.00	.25	.25	.25	.13	.00	.00	.00	.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.33	.00	.33	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 16L

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	14	.00	.00	.00	.00	.00	.07	.00	.00	.21	.07	.00	.29	.36	.00	.00	.00	.00	.00	.00
727-1	18	.00	.06	.00	.00	.00	.11	.11	.00	.17	.00	.06	.06	.44	.00	.00	.00	.00	.00	.00
727-2	20	.00	.05	.00	.00	.00	.10	.00	.00	.25	.15	.00	.05	.40	.00	.00	.00	.00	.00	.00
737	2	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00
747	16	.00	.06	.00	.19	.13	.19	.00	.00	.25	.06	.00	.00	.13	.00	.00	.00	.00	.00	.00
DC8-4,5	3	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00
DC8-6	7	.14	.00	.00	.00	.00	.14	.00	.00	.14	.14	.14	.00	.14	.00	.14	.00	.00	.00	.00
DC9-1,2	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00	.00	.00	.00
DC10	3	.00	.00	.00	.00	.00	.00	.00	.00	.67	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00
L1011	3	.00	.00	.00	.00	.00	.00	.00	.00	.67	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00

RUNWAY 34R

FIGURE A-40

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - SEA TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	20	.00	.00	.00	.00	.00	.00	.00	.00	.25	.00	.00	.30	.25	.05	.15	.00	.00	.00	.00
727-1	53	.02	.00	.00	.00	.04	.00	.02	.04	.11	.08	.06	.17	.13	.15	.17	.02	.00	.00	.00
727-2	13	.00	.00	.00	.00	.00	.00	.00	.38	.31	.00	.08	.15	.08	.00	.00	.00	.00	.00	.00
737	41	.00	.00	.00	.00	.02	.00	.00	.07	.07	.02	.02	.56	.07	.10	.05	.00	.00	.00	.00
DC8-4,5	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.30	.10	.30	.10	.20	.00	.00	.00	.00
DC8-6	8	.00	.00	.00	.00	.00	.00	.00	.38	.25	.13	.00	.00	.13	.00	.13	.00	.00	.00	.00
DC9-1,2	2	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	21	.00	.00	.00	.00	.00	.00	.00	.05	.10	.00	.05	.57	.14	.05	.05	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00
C580	14	.00	.00	.00	.00	.00	.00	.00	.07	.00	.07	.00	.00	.00	.07	.43	.36	.00	.00	.00
YS-11	13	.00	.00	.00	.00	.00	.00	.00	.15	.54	.31	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	24	.00	.00	.00	.00	.00	.00	.00	.00	.17	.04	.04	.33	.21	.04	.13	.04	.00	.00	.00

RUNWAY 5R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	25	.00	.00	.00	.00	.00	.00	.00	.48	.04	.08	.28	.00	.12	.00	.00	.00	.00	.00	.00
727-1	114	.00	.00	.00	.01	.01	.00	.07	.33	.09	.10	.26	.03	.04	.05	.02	.00	.00	.00	.00
727-2	33	.00	.00	.00	.00	.00	.00	.06	.12	.06	.03	.48	.00	.09	.12	.03	.00	.00	.00	.00
737	89	.00	.00	.00	.00	.01	.00	.03	.16	.13	.12	.48	.01	.02	.02	.00	.00	.00	.00	.00
DC8-4,5	15	.00	.00	.00	.00	.00	.00	.07	.33	.13	.00	.33	.00	.07	.00	.00	.00	.07	.00	.00
DC8-6	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.69	.00	.00	.15	.00	.00	.00	.00	.08
DC9-1,2	11	.00	.00	.00	.00	.00	.00	.00	.18	.09	.00	.64	.00	.00	.00	.00	.00	.09	.00	.00
DC9-3,4	36	.00	.00	.00	.00	.03	.00	.03	.22	.22	.06	.36	.00	.00	.08	.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
C580	17	.00	.00	.00	.00	.00	.00	.53	.24	.06	.06	.00	.00	.06	.00	.06	.00	.00	.00	.00
YS-11	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.13	.00	.38	.00	.00	.00	.00	.00
BAC-111	28	.00	.00	.00	.00	.00	.00	.00	.43	.11	.11	.29	.00	.04	.04	.00	.00	.00	.00	.00

RUNWAY 23L

FIGURE A-41

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - CLE TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	8	.00	.00	.00	.00	.00	.25	.00	.50	.13	.00	.13	.00	.00	.00	.00	.00	.00	.00	.00
727-1	11	.00	.00	.00	.18	.18	.00	.00	.09	.00	.00	.55	.00	.00	.00	.00	.00	.00	.00	.00
727-2	3	.00	.00	.00	.33	.00	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	6	.00	.00	.00	.00	.00	.00	.00	.67	.00	.17	.17	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	14	.00	.14	.00	.00	.21	.07	.00	.43	.07	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	3	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.71	.29	.00	.00	.00	.00	.00	.00	.00
BAC-111	28	.00	.00	.00	.07	.04	.00	.04	.39	.36	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 5

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	23	.00	.00	.00	.00	.00	.00	.26	.09	.35	.26	.00	.00	.00	.04	.00	.00	.00	.00	.00
727-1	37	.00	.00	.00	.00	.00	.08	.19	.14	.22	.22	.08	.00	.00	.05	.00	.00	.00	.00	.00
727-2	20	.00	.00	.00	.05	.00	.05	.40	.00	.20	.05	.15	.00	.00	.00	.00	.00	.00	.00	.00
737	27	.00	.00	.00	.04	.00	.04	.22	.11	.22	.30	.07	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	3	.00	.00	.00	.00	.33	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	59	.00	.00	.00	.00	.00	.00	.07	.02	.19	.69	.03	.00	.00	.00	.00	.00	.00	.00	.00
DC10	11	.00	.00	.00	.00	.00	.00	.27	.00	.27	.45	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	27	.00	.00	.00	.37	.07	.15	.33	.00	.04	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00
VS-11	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	114	.00	.00	.00	.01	.01	.03	.18	.08	.33	.35	.01	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 23

FIGURE A-42

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - BUF TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	28	.00	.00	.00	.00	.07	.07	.11	.11	.07	.11	.04	.29	.00	.00	.14	.00	.00	.00	.00
727-1	102	.00	.00	.00	.01	.01	.03	.04	.20	.06	.28	.23	.11	.01	.00	.01	.01	.00	.01	.00
727-2	77	.00	.00	.00	.00	.01	.03	.01	.01	.08	.29	.32	.21	.00	.03	.01	.00	.00	.00	.00
737	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.00	.33	.00	.00	.00	.00	.00	.00	.00
747	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.29	.00	.29	.00	.00	.43	.00	.00	.00	.00
DC8-4,5	15	.00	.00	.00	.00	.00	.07	.20	.07	.00	.20	.20	.27	.00	.00	.00	.00	.00	.00	.00
DC8-6	3	.00	.00	.00	.00	.00	.00	.00	.33	.00	.33	.00	.33	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	3	.00	.00	.00	.00	.00	.33	.33	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	79	.00	.00	.00	.01	.04	.09	.08	.18	.08	.16	.27	.10	.00	.00	.00	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.50	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	38	.00	.00	.00	.00	.00	.05	.00	.00	.03	.34	.08	.39	.03	.08	.00	.00	.00	.00	.00
C580	5	.00	.00	.00	.40	.40	.00	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	3	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.33	.00	.33	.00	.00	.00	.00	.00	.00

RUNWAY 9L

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	25	.00	.00	.00	.00	.00	.12	.00	.08	.08	.24	.00	.44	.04	.00	.00	.00	.00	.00	.00
727-1	78	.04	.00	.00	.00	.03	.14	.01	.00	.36	.15	.00	.26	.01	.00	.00	.00	.00	.00	.00
727-2	54	.04	.00	.00	.00	.02	.30	.06	.09	.30	.04	.04	.11	.02	.00	.00	.00	.00	.00	.00
737	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	2	.50	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	15	.00	.00	.00	.00	.07	.20	.00	.00	.07	.13	.00	.47	.07	.00	.00	.00	.00	.00	.00
DC8-6	1	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	2	.00	.00	.00	.00	.00	.50	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	63	.06	.00	.00	.00	.02	.10	.03	.03	.33	.11	.02	.30	.00	.00	.00	.00	.00	.00	.00
L1011	17	.06	.00	.00	.00	.24	.18	.00	.06	.35	.00	.00	.12	.00	.00	.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 27R

FIGURE A-43

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - MIA TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	3	.00	.00	.00	.00	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	22	.00	.00	.00	.00	.00	.00	.05	.18	.09	.27	.14	.18	.00	.00	.05	.00	.00	.00	.00
727-2	20	.00	.00	.00	.00	.00	.00	.05	.05	.05	.30	.20	.35	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	5	.00	.00	.00	.00	.00	.00	.00	.60	.00	.40	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	5	.00	.00	.00	.00	.00	.00	.00	.20	.20	.20	.20	.20	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	21	.00	.00	.00	.00	.00	.00	.29	.52	.05	.05	.10	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	34	.00	.00	.00	.03	.00	.00	.12	.29	.09	.12	.15	.15	.03	.00	.03	.00	.00	.00	.00
C580	2	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 10

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
727-1	31	.00	.00	.00	.00	.03	.03	.29	.42	.23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	31	.00	.03	.03	.00	.10	.00	.35	.42	.00	.03	.00	.00	.03	.00	.00	.00	.00	.00	.00
DC8-4,5	10	.00	.00	.00	.00	.00	.00	.10	.60	.30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	12	.00	.00	.00	.00	.17	.00	.33	.42	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	19	.00	.00	.00	.00	.00	.00	.05	.21	.58	.05	.05	.05	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	35	.00	.03	.03	.00	.11	.00	.03	.40	.37	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 28

FIGURE A-44

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - MSY TAKEOFFS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	42	.00	.00	.00	.50	.00	.00	.00	.38	.02	.02	.07	.00	.00	.00	.00	.00	.00	.00	.00
727-1	41	.00	.00	.00	.27	.00	.00	.00	.51	.07	.02	.12	.00	.00	.00	.00	.00	.00	.00	.00
727-2	45	.00	.00	.00	.29	.00	.00	.00	.27	.00	.07	.24	.00	.04	.07	.00	.02	.00	.00	.00
737	11	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	7	.00	.00	.00	.00	.00	.00	.00	.57	.00	.00	.29	.00	.00	.14	.00	.00	.00	.00	.00
DC8-4,5	12	.00	.00	.00	.25	.00	.00	.00	.67	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	3	.00	.00	.00	.00	.00	.00	.00	.33	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	49	.00	.00	.00	.63	.00	.00	.00	.33	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	55	.00	.00	.00	.45	.00	.00	.00	.42	.09	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00
DC10	11	.00	.00	.00	.36	.00	.00	.00	.55	.00	.00	.09	.00	.00	.00	.00	.00	.00	.00	.00
L1011	7	.00	.00	.00	.00	.00	.00	.00	.43	.14	.14	.29	.00	.00	.00	.00	.00	.00	.00	.00
C580	29	.00	.00	.00	.93	.00	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 17L

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
727-1	1	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	3	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	1	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 35R

FIGURE A-45

PROPORTION OF LIFTOFFS AFTER EACH LIGHT ELEMENT - DFW TAKEOFFS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	2	-.33	.73	194.01	5.29	-1.24	.98	164.93	3.82	14.49	.50	107.57	5.75
727-1	22	.33	6.22	199.34	20.60	1.50	6.80	157.44	21.74	-2.12	10.21	103.25	17.55
727-2	59	-2.53	6.60	218.38	22.52	1.15	6.78	178.78	17.80	2.17	7.84	118.77	20.78
737	10	-.46	7.97	190.65	19.60	.20	8.10	150.16	12.69	-3.99	10.02	97.18	18.90
747	1	-4.10	0.	193.35	0.	9.31	0.	174.15	0.	19.03	0.	131.28	0.
DC8-4,5	14	1.21	7.86	190.32	28.03	.59	7.59	160.69	21.37	4.29	10.30	111.51	9.54
DC8-6	18	1.56	9.58	213.50	10.81	3.51	10.00	179.21	14.88	4.72	10.20	120.04	32.23
DC9-1,2	17	1.81	5.34	205.03	11.12	-1.28	5.99	150.40	14.09	-8.12	10.18	98.10	18.64
DC9-3,4	93	1.29	6.04	199.07	18.24	1.68	6.46	152.26	19.10	-3.27	12.05	102.95	27.02
DC10	7	-2.76	7.17	211.05	12.19	-1.88	8.22	184.56	11.92	-.37	8.89	124.30	28.05
L1011	5	1.95	6.95	212.00	8.00	13.25	9.31	184.00	11.64	11.19	8.29	139.44	16.70
C580	2	-5.80	14.34	144.74	30.83	-5.65	5.02	108.83	24.42	-2.80	1.61	71.40	16.50
YS-11	5	2.61	10.96	156.56	15.64	.34	3.67	107.78	11.06	-5.06	8.67	69.14	5.01
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	255	.14	7.11	203.43	22.92	1.41	7.33	161.48	23.70	-.73	11.12	108.30	25.83

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-46

LATERAL DISTRIBUTION AND VELOCITY - ATL RWY 9R LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	18	-1.75	6.38	182.04	27.22	-1.50	4.98	128.98	16.37	8.72	9.03	81.93	12.09
727-1	108	-2.22	7.59	189.80	27.64	-2.20	7.34	135.88	21.52	5.81	12.88	89.30	25.37
727-2	106	-2.69	7.54	212.61	22.19	-1.49	7.45	162.78	20.50	1.26	10.33	112.06	28.07
737	26	-2.60	5.99	182.27	18.42	-1.95	7.33	130.64	19.70	8.41	11.98	89.42	25.13
747	10	-7.41	9.62	192.69	22.76	-5.21	5.81	157.34	23.13	-3.32	3.95	119.37	35.07
DC8-4,5	56	-3.10	9.15	184.49	36.91	-2.45	9.22	149.94	29.93	.73	10.20	112.11	32.16
DC8-6	37	-2.51	6.33	211.93	16.38	-4.38	8.31	169.20	15.23	-4.07	10.24	118.65	26.81
DC9-1,2	60	-3.09	8.79	193.89	26.10	-1.75	7.85	137.71	18.76	5.35	13.40	94.94	26.41
DC9-3,4	241	-1.71	8.36	193.00	23.92	-1.86	8.04	138.39	21.90	6.06	12.3[illegible]	94.35	28.48
DC10	15	-6.18	7.81	200.26	19.58	-5.95	8.74	168.35	19.03	-4.03	8.75	123.51	35.06
L1011	15	2.25	8.20	217.29	26.64	2.35	9.45	164.68	18.55	-2.50	12.26	107.83	25.57
C580	5	-2.60	2.78	129.93	12.32	1.24	6.42	118.39	15.38	5.53	11.44	108.71	26.39
YS-11	15	1.97	7.17	138.61	13.20	1.85	6.89	112.78	21.40	7.26	8.08	92.51	30.92
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	712	-2.27	8.11	194.12	28.63	-1.99	7.99	144.41	25.25	3.96	12.14	99.92	29.96

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-47

LATERAL DISTRIBUTION AND VELOCITY - ATL RWY 27L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	79	-1.81	7.50	191.12	34.43	-3.11	7.42	136.88	21.37	-4.88	8.05	95.45	20.48
727-1	128	-1.62	6.95	183.15	34.87	-2.89	6.44	129.91	25.08	-4.63	8.96	88.10	33.61
727-2	93	-3.00	6.82	188.18	34.07	-5.25	6.45	132.80	19.69	-7.40	8.27	90.82	20.79
737	36	-3.16	5.98	172.63	29.88	-3.89	5.39	149.36	34.99	-4.29	5.44	129.30	52.87
747	14	-4.68	6.92	168.03	25.75	-3.94	6.87	127.84	16.94	-3.82	8.42	95.17	17.02
DC8-4,5	33	-3.61	7.73	186.26	27.30	-4.32	8.48	136.15	22.62	-3.33	9.91	92.30	30.91
DC8-6	24	-1.32	9.79	200.31	24.01	-3.79	8.19	144.03	18.00	-4.66	10.16	98.80	16.42
DC9-1,2	7	-2.19	4.70	186.02	19.65	-3.56	4.63	159.31	42.78	-6.45	5.51	144.94	56.27
DC9-3,4	66	-2.91	5.77	177.39	25.31	-2.92	5.58	148.69	32.65	-4.24	7.79	126.62	51.35
DC10	20	-.33	9.25	183.25	22.75	-1.09	7.91	143.67	20.33	-.26	8.83	106.24	31.01
L1011	10	-4.17	6.64	188.64	26.43	-3.23	5.16	136.63	14.81	-2.73	6.08	98.90	18.06
C580	10	-1.02	5.42	131.66	23.44	-2.84	7.69	124.25	27.36	-4.66	12.17	116.85	33.41
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	520	-2.36	7.13	183.54	32.70	-3.52	6.80	137.15	26.22	-4.81	8.59	100.62	37.10

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-48

LATERAL DISTRIBUTION AND VELOCITY - ORD RWY 9R LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	10	-2.94	8.24	188.09	9.63	.24	10.05	152.85	12.37	.12	8.65	91.59	20.58
727-1	21	-.01	9.29	171.67	28.37	.91	8.45	139.74	23.20	4.79	10.25	84.69	26.62
727-2	23	.58	3.79	170.91	35.82	2.25	4.60	140.19	27.42	4.75	6.03	93.09	32.10
737	10	3.80	7.37	158.69	30.18	4.89	6.60	129.40	20.09	10.88	9.74	90.14	22.70
747	2	-7.02	1.98	181.25	2.42	-3.33	3.26	142.73	12.42	.56	4.31	83.00	31.70
DC8-4,5	3	-7.90	7.17	193.03	14.71	-5.60	4.05	141.69	23.79	9.33	13.35	72.59	13.05
DC8-6	6	2.26	6.58	172.27	40.54	1.84	6.62	139.73	25.66	6.04	6.22	87.57	24.29
DC9-1,2	1	-13.03	0.	159.40	0.	-8.72	0.	136.26	0.	-4.42	0.	113.12	0.
DC9-3,4	29	1.26	6.65	159.28	14.68	2.27	6.80	132.08	13.09	4.86	9.72	101.10	20.00
DC10	2	-3.18	2.48	176.34	16.14	-1.96	.50	151.47	14.76	-.75	1.49	126.59	13.37
L1011	2	-4.00	6.51	169.68	6.10	-1.65	4.21	145.28	8.56	.71	1.90	120.88	11.01
C580	10	1.05	5.66	141.89	12.30	1.97	6.30	124.41	13.83	4.68	7.35	100.94	29.60
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	119	.14	7.28	166.96	27.83	1.51	7.13	137.26	21.32	4.78	9.03	94.08	26.69

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-49

LATERAL DISTRIBUTION AND VELOCITY - ORD RWY 27L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	9	-4.99	4.64	223.06	13.29	-3.97	4.22	165.59	17.19	-3.43	5.87	90.79	15.80
727-1	13	1.27	4.93	214.33	18.39	2.22	3.83	164.46	16.28	1.89	5.92	87.84	30.48
727-2	16	-2.96	6.34	227.98	13.48	-3.66	6.49	179.02	12.97	.05	8.32	89.72	18.90
737	17	.18	7.66	208.60	19.94	.07	4.97	156.20	13.79	-1.14	6.22	90.78	18.56
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	4	-6.69	5.56	216.71	11.28	-7.03	4.77	177.11	6.53	-4.58	4.49	103.49	38.68
DC8-6	3	-4.17	5.50	213.29	3.17	-4.53	2.91	166.91	.38	-.41	2.15	90.50	6.09
DC9-1,2	3	6.98	5.36	226.79	11.98	7.10	5.47	166.38	15.96	.30	7.89	76.53	9.53
DC9-3,4	2	7.50	9.57	213.51	.07	10.15	8.11	138.40	4.23	2.88	.75	73.95	2.83
DC10	9	-.76	6.18	203.02	49.47	1.74	4.45	160.58	30.63	1.25	4.83	99.30	33.86
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	8	-2.48	4.29	171.77	9.84	-2.13	6.29	139.50	14.09	-3.16	7.79	106.11	23.83
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	84	-1.22	6.84	211.94	26.57	-.78	6.29	163.03	20.29	-.62	6.77	92.18	24.75

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-50

LATERAL DISTRIBUTION AND VELOCITY - DEN RWY 8R LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	52	-3.82	8.23	232.52	28.74	-1.13	5.41	173.85	22.64	-1.05	7.40	83.54	28.44
727-1	136	-2.69	6.07	221.38	21.95	-2.70	5.53	169.86	19.57	-2.33	7.45	101.64	36.23
727-2	118	-.98	7.51	238.61	24.80	-.91	5.97	176.83	21.19	-1.75	7.38	84.46	31.22
737	110	.04	8.24	210.27	27.89	.51	7.62	163.10	21.23	2.59	8.37	94.82	28.20
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	30	-3.39	7.74	219.94	13.05	-1.52	7.90	174.31	21.01	-.52	9.71	91.75	42.37
DC8-6	15	-.99	7.51	236.94	15.87	-1.92	6.22	180.07	15.69	-5.67	10.65	76.54	20.67
DC9-1,2	18	-4.97	12.75	211.96	26.19	-.04	6.94	162.64	13.20	-.87	8.57	93.96	29.72
DC9-3,4	14	-.63	6.83	213.96	14.61	.57	6.61	158.02	20.23	-.15	6.74	111.50	25.57
DC10	36	-6.55	10.31	234.28	27.82	1.22	5.84	172.39	13.08	-4.98	8.83	83.24	34.37
L1011	1	-8.68	0.	224.41	0.	9.45	0.	202.69	0.	2.47	0.	65.32	0.
C580	47	-1.95	8.39	182.32	14.79	-.23	8.09	143.92	17.49	1.89	8.41	106.63	25.59
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	577	-2.13	8.10	221.27	28.47	-.87	6.65	168.44	21.87	-.87	8.34	93.22	32.97

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-51

LATERAL DISTRIBUTION AND VELOCITY - DEN RWY 26L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	13	3.55	12.17	177.27	46.43	3.11	8.18	131.70	29.51	6.65	9.59	100.45	27.96
727-1	11	6.35	8.40	196.09	20.92	.94	9.13	141.51	17.67	2.18	6.14	97.12	21.57
727-2	10	.34	6.57	205.54	18.36	1.00	5.90	143.71	23.02	1.06	7.46	106.08	21.22
737	5	.31	3.46	180.89	15.90	-1.03	4.16	124.44	24.44	-6.38	5.19	93.32	11.66
747	6	2.82	8.05	183.22	36.76	6.05	5.65	148.57	31.92	7.03	6.39	99.85	22.38
DC8-4,5	5	3.03	6.55	160.71	35.09	3.83	9.19	134.77	28.80	2.16	6.02	105.89	25.45
DC8-6	9	-1.13	8.71	199.11	30.25	-1.74	4.05	144.28	22.88	.51	4.70	103.72	24.43
DC9-1,2	5	-1.26	5.46	172.36	25.97	4.52	8.92	111.60	15.43	2.82	4.59	91.16	12.63
DC9-3,4	3	3.74	2.84	170.00	10.67	1.50	3.22	116.89	9.08	1.56	2.95	77.54	21.05
DC10	2	-3.00	.75	180.16	22.52	-.17	.72	139.03	1.55	.49	.02	116.24	1.08
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	1	18.12	0.	191.08	0.	18.12	0.	191.08	0.	18.12	0.	191.08	0.
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	70	2.66	9.09	193.54	67.33	2.14	7.42	140.77	40.40	2.64	7.66	101.08	25.59

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-52

LATERAL DISTRIBUTION AND VELOCITY - SEA RWY 16L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	57	-.78	6.20	191.87	16.24	-1.04	7.54	163.78	19.64	-1.48	9.59	114.53	37.39
727-1	132	-1.09	5.20	182.88	26.35	-1.42	5.17	151.25	24.33	-2.46	7.09	100.73	30.95
727-2	119	-.92	6.38	203.50	22.44	-.92	6.45	171.32	22.44	-.66	7.90	111.48	41.47
737	25	-1.40	5.53	174.70	28.76	-.83	5.83	151.61	26.91	1.53	10.52	117.22	37.82
747	14	-7.67	8.03	199.42	27.84	-5.04	7.01	162.25	28.69	-4.32	8.89	65.36	21.84
DC8-4,5	31	-.39	6.88	186.70	16.50	-.88	6.76	157.41	19.53	-4.38	10.75	103.43	38.73
DC8-6	31	.15	7.41	209.63	17.39	-2.36	5.94	175.74	21.56	-4.49	4.22	96.74	49.74
DC9-1,2	23	-2.46	4.28	173.99	16.16	-1.69	4.61	149.58	17.71	-.32	5.72	118.00	30.93
DC9-3,4	33	-.03	5.73	164.23	45.66	.98	6.03	136.54	36.06	.70	8.51	101.55	35.36
DC10	31	-4.12	5.64	190.94	15.17	-2.22	7.19	164.71	17.19	-.83	10.60	120.52	38.40
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	10	-5.96	6.21	143.15	14.97	-5.68	6.35	141.09	14.27	-5.40	6.59	139.03	16.10
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	506	-1.37	6.22	188.76	28.01	-1.35	6.31	159.17	25.83	-1.68	8.41	107.38	38.47

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-53

LATERAL DISTRIBUTION AND VELOCITY - SEA RWY 34R LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	S	VELOCITY V	S	INTERMEDIATE POINT OFFSET X	S	VELOCITY V	S	LAST POINT OFFSET X	S	VELOCITY V	S
707	25	-.10	6.91	196.50	25.94	1.38	5.72	147.97	21.54	.19	5.12	81.36	27.15
727-1	101	-.13	5.77	191.04	23.87	1.09	4.87	140.79	20.82	1.70	6.16	97.89	31.65
727-2	32	1.67	6.71	185.43	34.48	.81	6.47	141.54	22.21	.73	8.60	88.80	27.36
737	20	1.73	7.03	181.56	10.50	2.55	7.55	175.50	15.02	3.37	9.44	169.45	25.35
747	1	-4.00	0.	56.19	0.	-4.00	0.	56.19	0.	-4.00	0.	56.19	0.
DC8-4,5	12	-.69	6.02	191.40	15.56	-1.23	6.12	154.16	12.07	-3.32	9.34	84.30	13.34
DC8-6	12	-.30	7.24	190.08	26.07	2.71	7.18	153.42	22.04	.61	6.78	106.02	33.01
DC9-1,2	6	.89	4.17	195.79	31.67	2.56	3.70	141.85	44.95	4.57	6.21	93.99	65.14
DC9-3,4	20	1.85	4.85	185.49	27.26	2.36	3.61	136.88	22.16	3.55	6.38	93.91	32.16
DC10	1	.06	0.	209.75	0.	-.96	0.	162.64	0.	1.67	0.	118.30	0.
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	3	-2.08	2.28	153.89	9.94	-1.02	3.99	125.43	17.54	.40	1.80	108.68	28.33
YS-11	3	10.82	2.34	162.65	83.75	10.82	2.34	162.65	83.75	10.82	2.34	162.65	83.75
BAC-111	14	.52	9.37	179.91	20.06	4.77	9.01	146.14	25.82	7.85	13.55	116.70	45.65
ALL A/C	250	.52	6.44	187.79	28.42	1.56	5.97	145.55	26.27	1.87	7.78	102.29	40.45

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-54

LATERAL DISTRIBUTION AND VELOCITY - CLE RWY 5R LANDINGS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	34	.50	7.13	201.93	37.95	.35	5.62	162.06	36.85	-.88	10.46	93.24	31.48
727-1	130	-2.51	6.06	201.26	20.15	-.32	5.18	156.87	26.12	-1.05	7.42	89.78	31.63
727-2	35	-.55	4.83	208.68	16.61	-.34	3.99	165.87	25.28	-.94	6.71	88.94	38.41
737	93	-1.56	5.83	189.33	18.18	-2.39	6.10	167.01	26.87	-9.30	12.91	128.40	57.09
747	1	-15.67	0.	226.66	0.	-13.34	0.	171.54	0.	-11.01	0.	116.42	0.
DC8-4,5	12	.54	9.55	196.03	16.70	1.08	4.52	155.27	23.40	.21	5.40	108.42	42.19
DC8-6	17	-3.00	8.63	216.97	19.07	1.08	5.07	179.39	14.25	2.49	5.21	112.00	38.01
DC9-1,2	9	-.24	8.52	201.40	9.29	-8.67	9.82	146.18	26.94	-15.78	14.39	74.89	23.44
DC9-3,4	26	-2.44	4.49	191.44	22.19	-3.19	7.11	149.07	27.42	-9.68	12.67	79.94	44.59
DC10	2	.46	3.91	220.24	6.70	-5.81	5.39	162.80	13.62	-8.20	10.92	88.82	.61
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	15	-1.45	3.79	144.13	40.24	-1.27	3.80	140.55	40.15	-1.09	3.85	136.96	42.15
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	24	-3.91	8.29	187.84	12.11	-2.73	6.21	171.48	19.48	-1.56	7.24	155.12	32.63
ALL A/C	399	-1.81	6.46	196.46	23.96	-1.23	6.05	161.21	27.42	-3.78	10.53	105.72	46.60

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-55

LATERAL DISTRIBUTION AND VELOCITY - CLE RWY 23L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	10	-.31	4.38	195.73	31.18	-.48	9.48	140.26	24.43	-5.66	9.20	83.12	22.57
727-1	17	-.40	6.72	176.62	38.36	-.13	7.39	162.14	34.52	-.78	7.05	147.53	48.50
727-2	6	-1.64	5.63	213.05	21.82	-.21	4.66	165.22	29.33	-.37	4.67	127.11	54.01
737	4	-16.32	1.33	174.01	15.23	-1.73	9.81	135.47	33.87	12.85	18.42	96.94	55.50
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	2	5.65	.94	200.55	9.28	-2.30	2.40	152.81	11.47	-10.11	3.99	115.64	21.63
DC8-6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	1	-17.53	0.	178.37	0.	30.62	0.	113.88	0.	-15.34	0.	74.96	0.
DC9-3,4	21	-1.81	4.61	185.55	19.18	-1.57	3.55	166.18	23.33	-1.32	3.73	146.82	51.05
DC10	2	-2.23	5.11	133.40	96.69	-3.95	6.83	94.10	57.39	-.95	3.82	59.03	22.32
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	6	.02	2.88	123.22	55.84	.02	2.88	123.22	55.84	.02	2.88	123.22	55.84
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	28	-.81	7.52	174.97	23.50	-.69	7.63	164.18	29.18	-.69	7.94	152.57	46.60
ALL A/C	99	-1.51	6.86	180.60	32.37	-.49	7.44	157.37	32.15	-1.12	8.29	135.51	51.82

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-56

LATERAL DISTRIBUTION AND VELOCITY - BUF RWY 5 LANDINGS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	18	2.40	9.21	190.88	36.39	-1.58	10.14	164.60	30.12	-5.23	11.76	101.13	49.96
727-1	46	-2.26	5.87	180.55	29.03	-3.90	6.11	156.01	29.49	-11.34	12.44	116.50	46.90
727-2	24	.29	6.02	203.73	20.25	-10.59	10.75	152.25	27.39	-8.83	10.04	55.78	34.51
737	13	-5.43	6.62	157.04	21.33	-9.81	8.00	129.48	26.21	-25.86	8.89	87.49	37.73
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	2	-6.97	2.98	180.84	20.73	-5.11	4.86	146.05	16.90	-5.28	8.78	86.48	11.71
DC8-6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	3	-4.83	4.56	171.14	12.97	-2.95	5.81	133.49	22.61	-16.99	3.26	47.71	2.48
DC9-3,4	57	-2.24	7.47	182.53	21.75	-4.97	6.69	146.02	30.58	-13.27	10.28	67.28	50.05
DC10	13	-.16	5.02	199.54	11.88	-.97	7.63	167.62	18.13	-3.60	5.62	83.43	54.48
L1011	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	21	.47	6.09	133.16	21.98	.67	6.22	131.68	20.50	.77	6.83	124.17	22.23
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	123	-3.31	6.68	177.05	18.81	-1.88	5.69	164.38	19.36	-3.41	9.26	147.27	33.60
ALL A/C	322	-2.09	6.98	178.53	26.90	-3.54	7.43	154.67	27.78	-7.59	11.50	110.84	53.37

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-57

LATERAL DISTRIBUTION AND VELOCITY - BUF RWY 23 LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	S	VELOCITY V	S	INTERMEDIATE POINT OFFSET X	S	VELOCITY V	S	LAST POINT OFFSET X	S	VELOCITY V	S
707	63	-2.56	9.34	177.33	38.68	-.93	8.60	140.48	25.73	.09	10.10	93.51	34.30
727-1	287	-2.13	10.00	158.51	46.13	.62	9.48	123.08	29.82	2.78	11.54	88.19	26.01
727-2	88	-1.72	7.95	188.51	36.67	.16	7.74	149.23	26.15	-.20	9.25	106.14	33.31
737	4	2.40	2.58	153.72	61.71	1.88	2.58	103.47	29.38	7.71	14.06	58.68	13.76
747	2	11.05	9.39	155.73	6.81	11.05	9.39	155.73	6.81	11.05	9.39	155.73	6.81
DC8-4,5	19	.14	7.35	157.42	50.61	1.98	6.60	132.06	38.18	2.43	9.04	105.30	39.15
DC8-6	2	-6.88	11.75	232.43	13.25	-6.95	9.13	206.08	.40	-2.60	10.93	166.50	27.29
DC9-1,2	7	-3.02	7.65	142.79	37.87	-1.66	7.98	119.22	22.57	-2.67	9.43	96.62	19.26
DC9-3,4	98	-2.08	9.45	177.19	35.46	-.02	9.81	128.27	27.93	3.85	11.54	85.32	33.65
DC10	2	-4.92	4.39	197.80	36.69	2.24	2.77	164.87	3.77	2.80	3.33	145.59	15.51
L1011	21	.67	9.48	175.09	34.46	.02	9.68	150.80	14.97	-.04	10.97	121.21	34.94
C580	5	-4.51	.33	115.96	32.41	-4.51	.33	115.96	32.41	-4.51	.33	115.96	32.41
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	-.88	3.43	183.95	42.36	-15.82	18.93	118.61	15.56	-4.03	7.70	77.52	13.00
ALL A/C	600	-1.96	9.39	168.03	44.15	.10	9.23	130.97	30.66	1.86	11.13	93.33	32.27

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-58

LATERAL DISTRIBUTION AND VELOCITY - MIA RWY 9L LANDINGS

		FIRST POINT				INTERMEDIATE POINT				LAST POINT			
		OFFSET		VELOCITY		OFFSET		VELOCITY		OFFSET		VELOCITY	
AIRCRAFT	NO.	X	S	V	S	X	S	V	S	X	S	V	S
707	7	-6.92	9.42	188.12	55.27	-1.63	7.18	145.12	46.64	-2.94	5.34	98.09	59.50
727-1	67	-1.22	6.37	203.46	14.99	-1.51	7.17	157.48	28.47	-3.75	12.27	85.06	48.29
727-2	30	-1.58	9.90	206.30	16.08	-1.19	9.75	159.44	24.79	-2.77	11.09	90.59	42.75
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	3	3.61	8.82	215.13	6.61	3.87	10.68	158.69	5.13	4.16	14.74	67.24	22.32
DC8-4,5	7	-1.84	3.82	203.52	16.05	-1.54	3.81	162.55	21.16	3.03	5.62	101.90	44.31
DC8-6	4	-5.26	4.51	203.86	17.25	-1.61	.27	158.98	14.74	1.10	4.24	101.77	11.13
DC9-1,2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	54	-.67	7.49	188.08	19.51	-.73	8.20	148.37	30.85	-3.58	11.01	90.40	54.02
DC10	1	-6.00	0.	220.12	0.	-2.28	0.	171.43	0.	-1.19	0.	75.01	0.
L1011	13	-1.68	5.97	200.53	37.97	-4.05	5.35	162.66	31.32	-3.42	12.06	116.95	45.43
C580	2	8.78	2.96	112.17	14.02	8.68	3.06	102.77	4.62	8.58	3.15	93.36	4.79
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	188	-1.31	7.59	198.04	24.58	-1.23	7.83	154.81	29.83	-2.86	11.34	90.90	48.97

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-59

LATERAL DISTRIBUTION AND VELOCITY - MIA RWY 27R LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	4	-1.97	3.05	188.86	55.04	-3.94	3.97	151.80	44.02	-1.12	1.06	96.31	36.72
727-1	34	-2.10	5.22	208.48	17.67	-.84	5.52	175.70	28.99	.04	6.02	116.61	42.15
727-2	34	-1.61	6.53	231.82	33.83	-.19	5.11	196.84	25.83	-.71	4.80	128.23	57.55
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	9	.29	5.93	214.06	5.93	.75	4.87	193.52	14.32	5.65	9.51	156.91	29.36
DC8-6	18	-.86	5.61	225.54	8.65	-.52	6.14	198.56	21.15	-2.73	6.39	152.49	40.71
DC9-1,2	30	-.86	6.05	203.70	26.46	.53	6.50	178.06	23.95	-.69	6.57	123.76	42.04
DC9-3,4	59	-1.75	4.54	201.62	19.07	-.58	4.70	168.69	24.94	1.88	6.42	103.48	42.52
DC10	1	-1.20	0.	180.54	0.	-3.74	0.	144.48	0.	-6.29	0.	108.43	0.
L1011	1	-23.56	0.	282.05	0.	-6.57	0.	186.85	0.	10.42	0.	91.66	0.
C580	5	6.03	6.32	163.11	7.01	6.55	6.20	141.29	19.70	8.55	7.34	83.06	37.12
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.87	.19	193.63	.31	3.05	2.37	180.36	13.58	2.31	1.63	143.43	50.51
ALL A/C	197	-1.37	5.81	210.07	27.73	-.22	5.55	179.10	28.74	.59	6.64	119.73	47.75

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-60

LATERAL DISTRIBUTION AND VELOCITY - MSY RWY 10 LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	17	1.26	5.15	198.05	16.49	2.23	5.39	162.29	26.23	2.88	7.71	121.01	49.33
727-2	23	.09	3.63	209.87	19.27	-1.05	4.39	175.60	24.19	-.22	5.30	126.10	47.69
737	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	8	-.10	5.68	200.10	13.22	1.13	6.71	165.56	21.97	3.94	9.44	106.64	40.66
DC8-6	7	-3.33	11.34	227.94	28.10	.39	4.20	170.88	24.12	2.09	5.16	100.61	28.47
DC9-1,2	11	-1.29	3.85	188.82	14.83	-.47	3.87	148.65	23.27	-.21	6.12	107.85	39.32
DC9-3,4	35	1.46	6.46	193.45	19.80	2.22	6.68	157.34	28.34	3.46	7.22	112.89	49.66
DC10	1	-3.05	0.	220.45	0.	-9.62	0.	156.94	0.	-8.45	0.	104.23	0.
L1011	1	-.85	0.	236.76	0.	12.48	0.	168.46	0.	18.06	0.	90.75	0.
C580	3	1.96	2.20	155.95	14.12	.39	2.80	125.49	21.43	6.17	11.88	75.42	3.50
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	5.63	0.	201.29	0.	5.55	0.	177.20	0.	5.48	0.	153.11	0.
ALL A/C	107	.41	5.95	199.67	22.68	1.01	5.83	162.05	27.42	2.26	7.44	114.27	46.25

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-61

LATERAL DISTRIBUTION AND VELOCITY - MSY RWY 28 LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	33	-5.55	9.62	166.98	50.34	-1.35	9.80	133.26	39.81	3.15	13.02	102.06	47.81
727-1	24	-7.18	9.97	167.12	67.69	-5.18	9.79	135.08	52.72	-1.07	11.36	119.56	59.26
727-2	20	-4.03	4.80	187.71	38.07	-2.38	5.68	152.53	30.84	1.59	10.06	128.33	45.05
737	2	-6.67	2.50	198.35	6.88	-6.67	2.50	198.35	6.88	-6.67	2.50	198.35	6.88
747	6	-4.59	10.85	173.16	34.07	-.11	5.01	129.91	29.49	-1.45	3.34	97.52	38.81
DC8-4,5	15	-7.60	10.07	165.58	44.37	-3.72	10.03	126.94	29.17	4.07	11.33	97.72	36.57
DC8-6	6	-5.38	6.97	157.73	15.83	-.87	5.97	137.06	19.22	3.64	7.23	116.38	26.41
DC9-1,2	24	-4.24	8.49	184.65	51.91	-3.99	10.27	154.20	44.49	-2.09	10.56	138.56	58.97
DC9-3,4	26	-3.14	8.32	178.75	23.53	-1.65	7.87	165.74	26.57	1.35	10.49	156.57	41.64
DC10	3	-12.41	8.04	162.97	5.54	-7.68	7.26	131.54	4.58	-2.95	8.16	100.11	4.27
L1011	6	-4.63	5.05	188.92	32.62	-5.53	2.19	139.37	13.52	1.18	7.20	107.36	21.78
C580	9	-.49	10.88	143.36	21.88	-.49	10.88	143.36	21.88	-.49	10.88	143.36	21.88
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	2.97	0.	155.22	0.	2.97	0.	155.22	0.	2.97	0.	155.22	0.
ALL A/C	175	-4.99	8.99	173.07	46.26	-2.79	8.94	144.45	38.84	.87	10.97	124.21	50.85

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-62

LATERAL DISTRIBUTION AND VELOCITY - DFW RWY 17L LANDINGS

AIRCRAFT	NO.	FIRST POINT OFFSET X	FIRST POINT OFFSET S	FIRST POINT VELOCITY V	FIRST POINT VELOCITY S	INTERMEDIATE POINT OFFSET X	INTERMEDIATE POINT OFFSET S	INTERMEDIATE POINT VELOCITY V	INTERMEDIATE POINT VELOCITY S	LAST POINT OFFSET X	LAST POINT OFFSET S	LAST POINT VELOCITY V	LAST POINT VELOCITY S
707	5	-1.20	4.12	183.16	21.05	1.03	2.80	156.76	18.23	2.24	3.52	110.24	33.08
727-1	5	-.77	8.25	164.87	20.28	-1.20	7.48	149.73	17.42	-1.63	6.94	134.59	18.29
727-2	4	6.91	6.43	143.16	35.19	6.27	5.69	127.29	21.44	5.64	5.02	111.42	13.62
737	1	-7.70	0.	119.46	0.	-5.59	0.	107.47	0.	-3.48	0.	95.49	0.
747	1	-1.84	0.	191.47	0.	.42	0.	154.39	0.	2.68	0.	117.32	0.
DC8-4,5	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	1	-5.93	0.	189.63	0.	-4.51	0.	162.26	0.	-3.10	0.	134.88	0.
DC9-1,2	1	4.40	0.	137.12	0.	-6.79	0.	116.64	0.	-17.99	0.	96.17	0.
DC9-3,4	3	4.50	8.49	144.54	8.66	4.86	8.60	124.42	7.31	5.22	9.15	104.31	7.46
DC10	1	2.04	0.	177.16	0.	1.21	0.	153.32	0.	.38	0.	129.49	0.
L1011	1	-4.83	0.	169.42	0.	-2.76	0.	144.24	0.	-.69	0.	119.07	0.
C580	2	-3.09	1.09	116.16	11.20	-.80	2.20	103.61	16.68	1.48	3.31	91.06	22.15
YS-11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ALL A/C	25	.45	7.01	158.52	30.04	.77	6.37	138.42	23.73	.88	7.11	114.29	23.63

X - Mean Offset in Feet
V - Mean Velocity in Feet Per Second
S - Standard Deviation

FIGURE A-63

LATERAL DISTRIBUTION AND VELOCITY - DFW RWY 35R LANDINGS

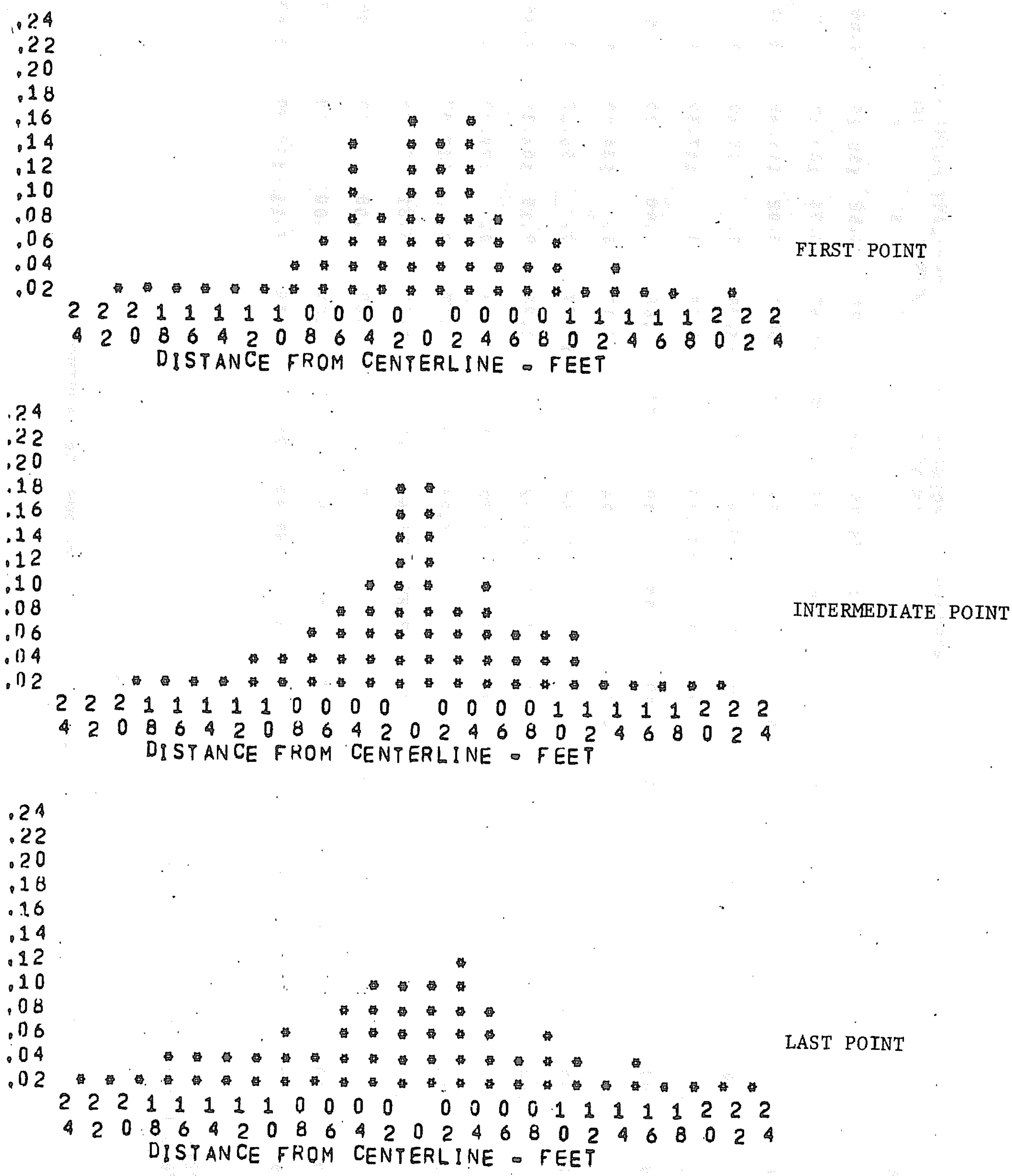
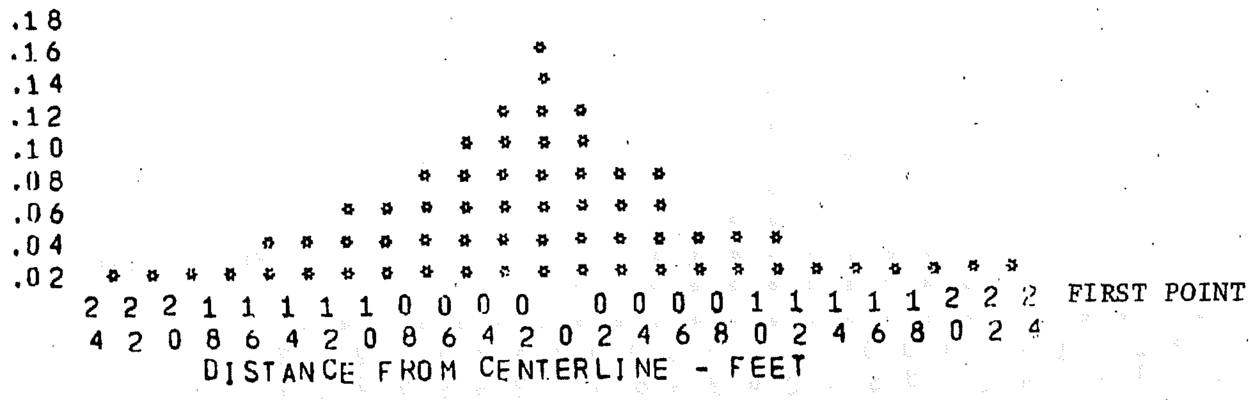
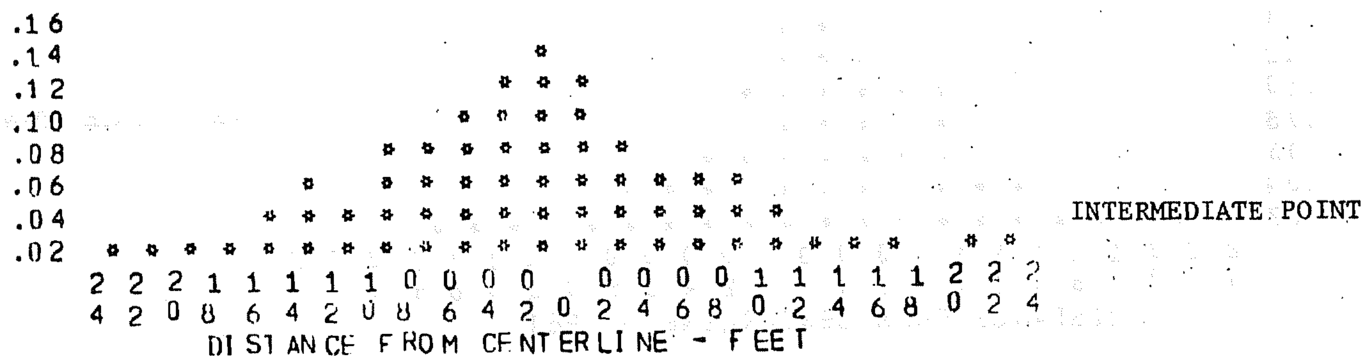


FIGURE A-64

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS ATL RWY 9R





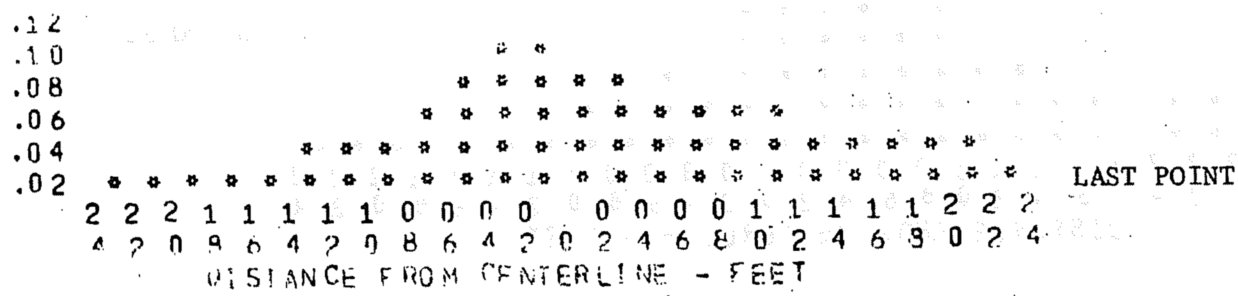


FIGURE A-65

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS ATL RWY 27L

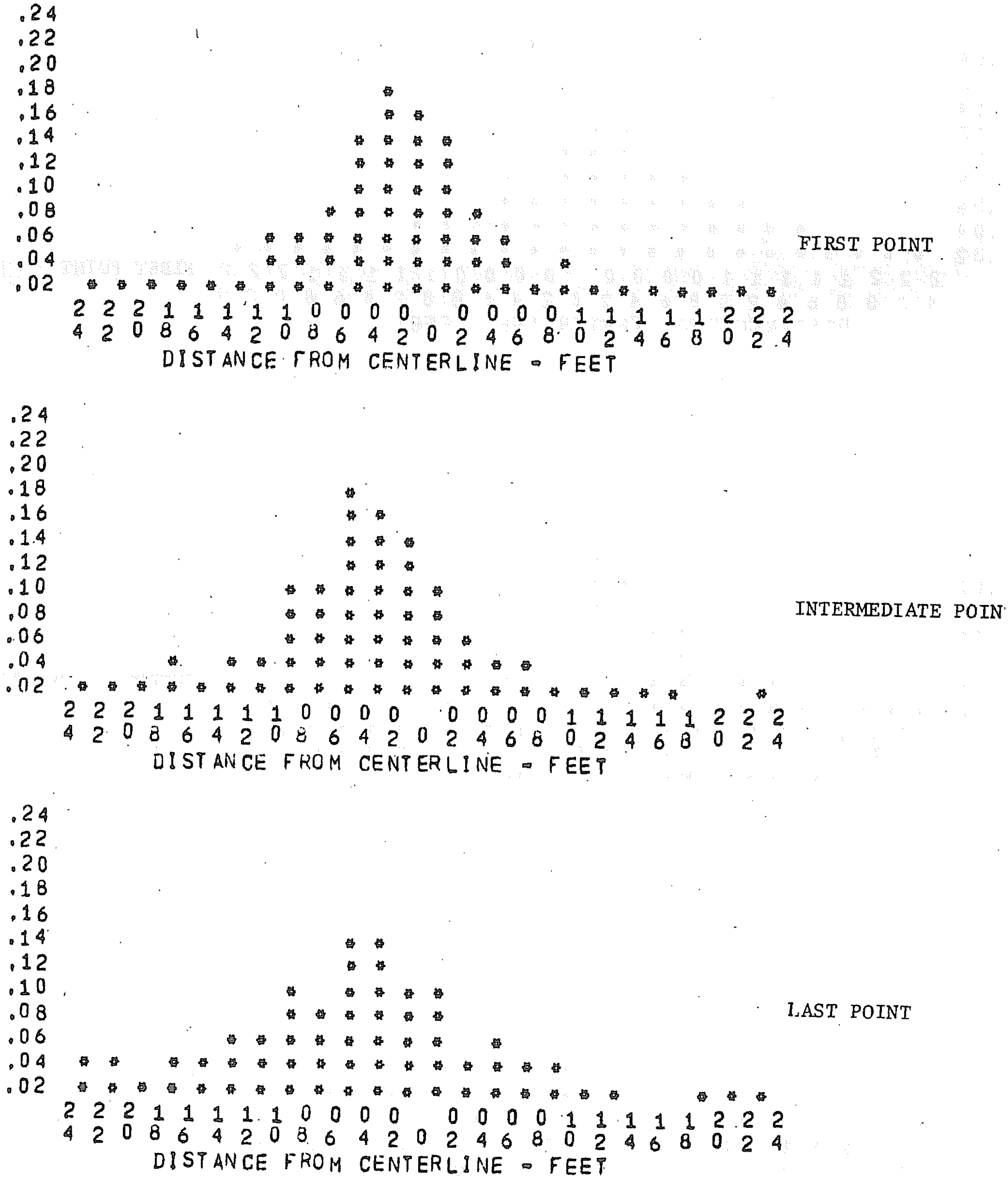


FIGURE A-66

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS ORD RWY 9R

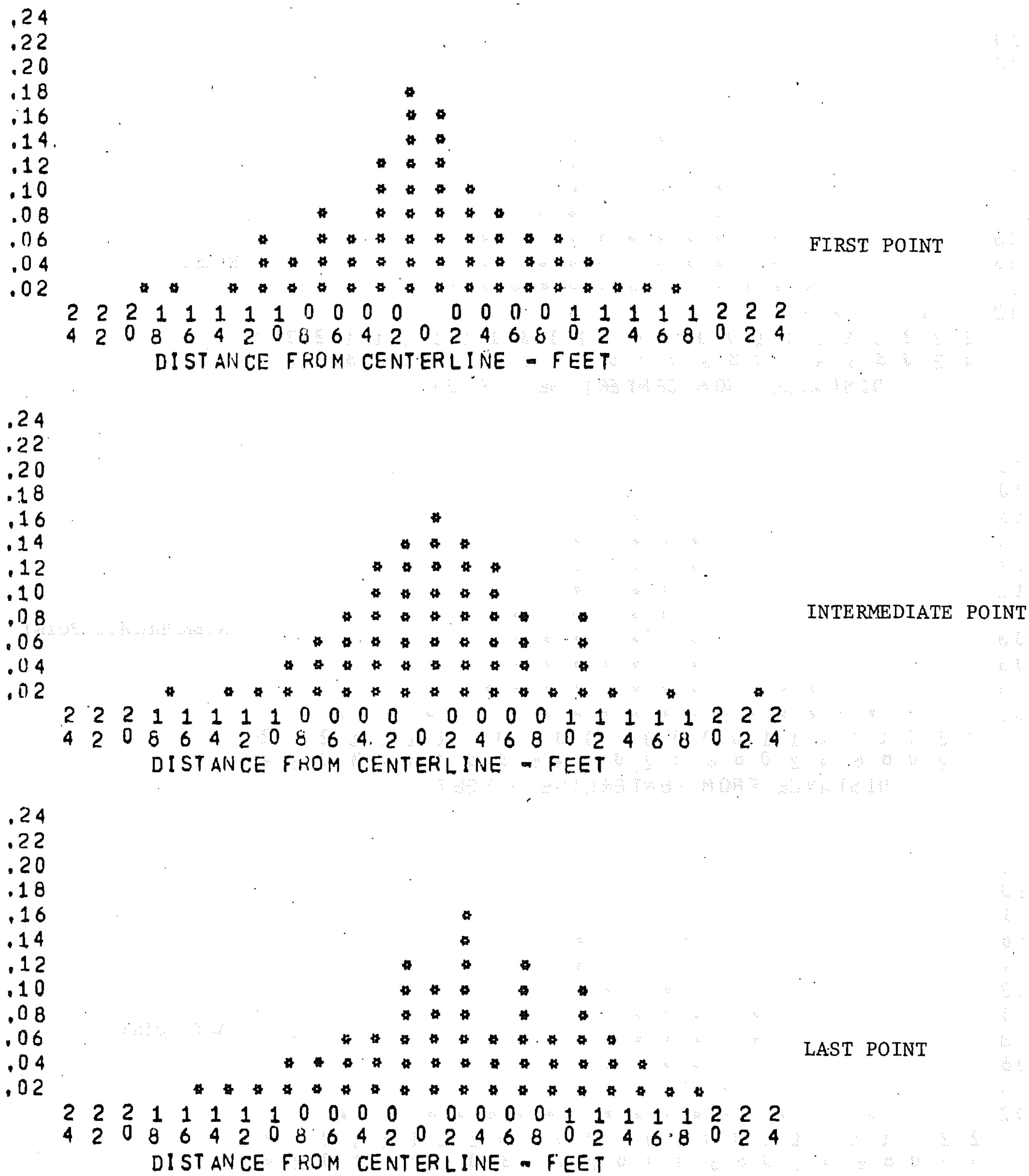
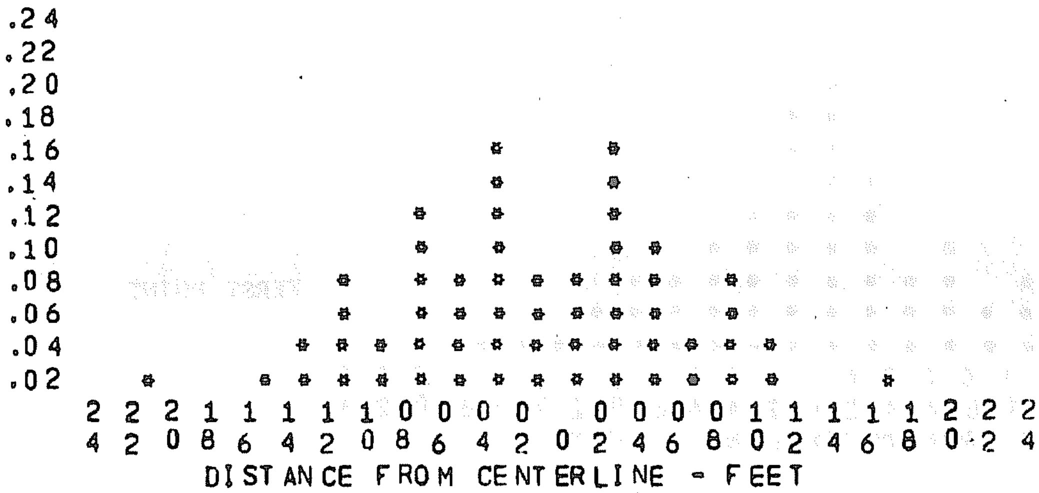
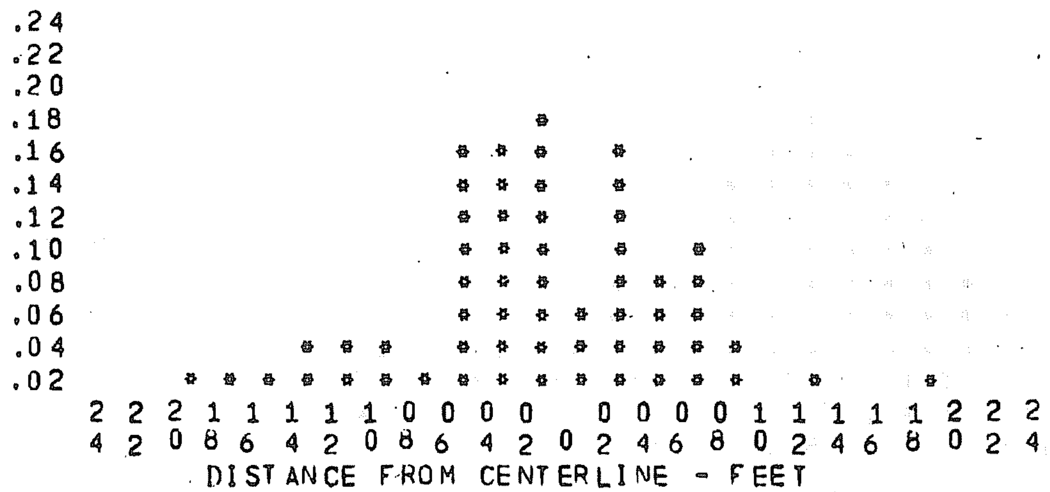


FIGURE A-67

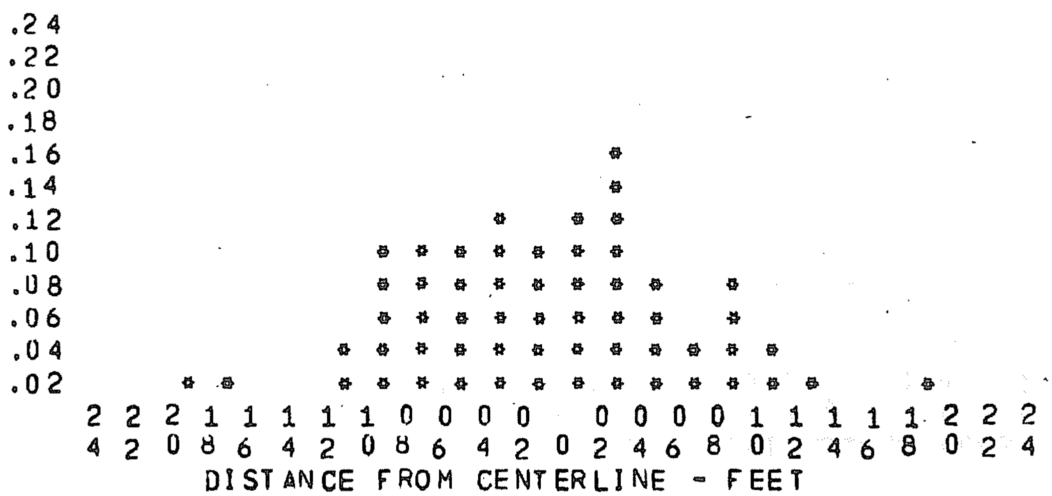
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS ORD RWY 27L



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-68

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS DEN RWY 8R

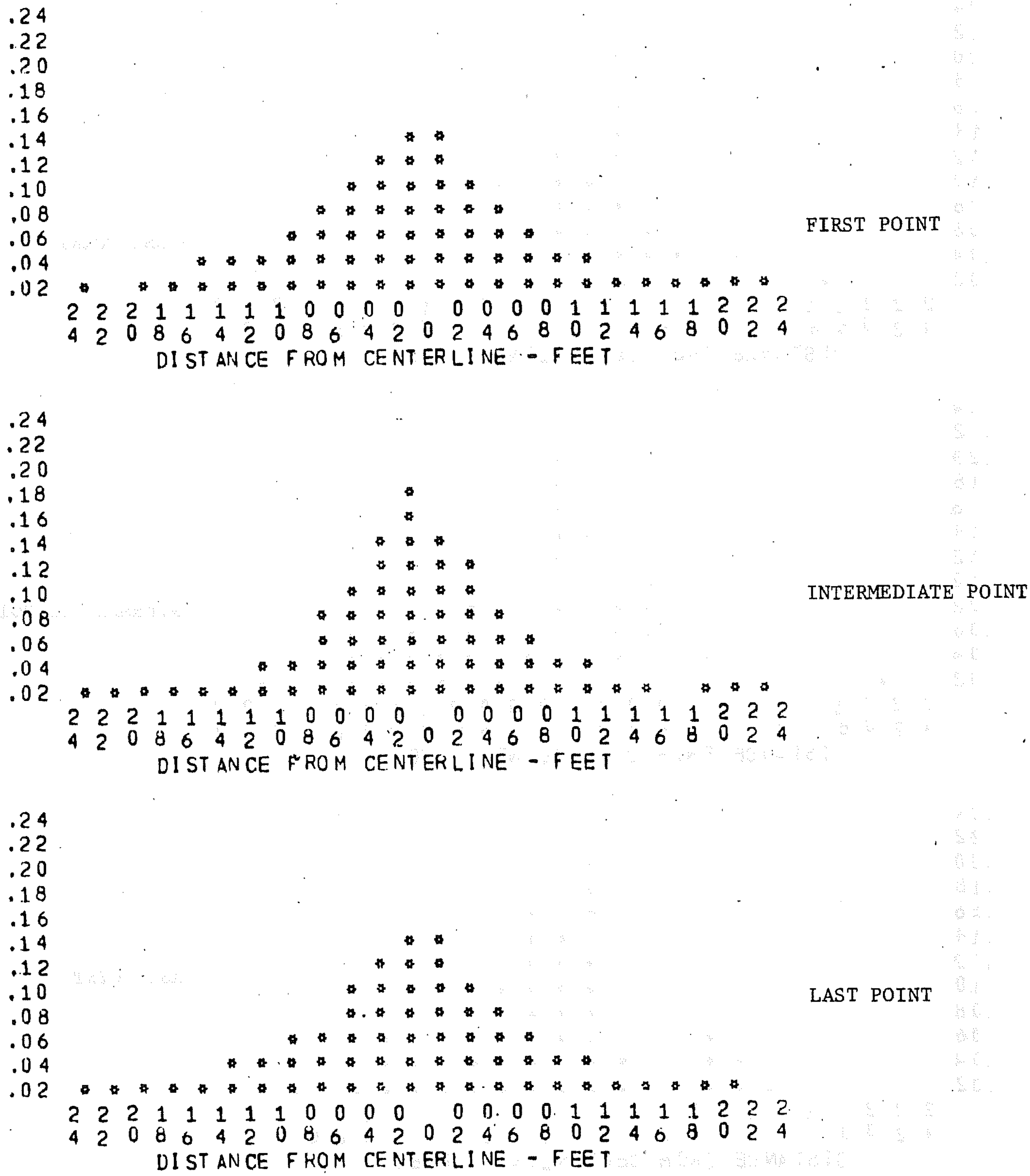


FIGURE A-69

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS DEN RWY 26L

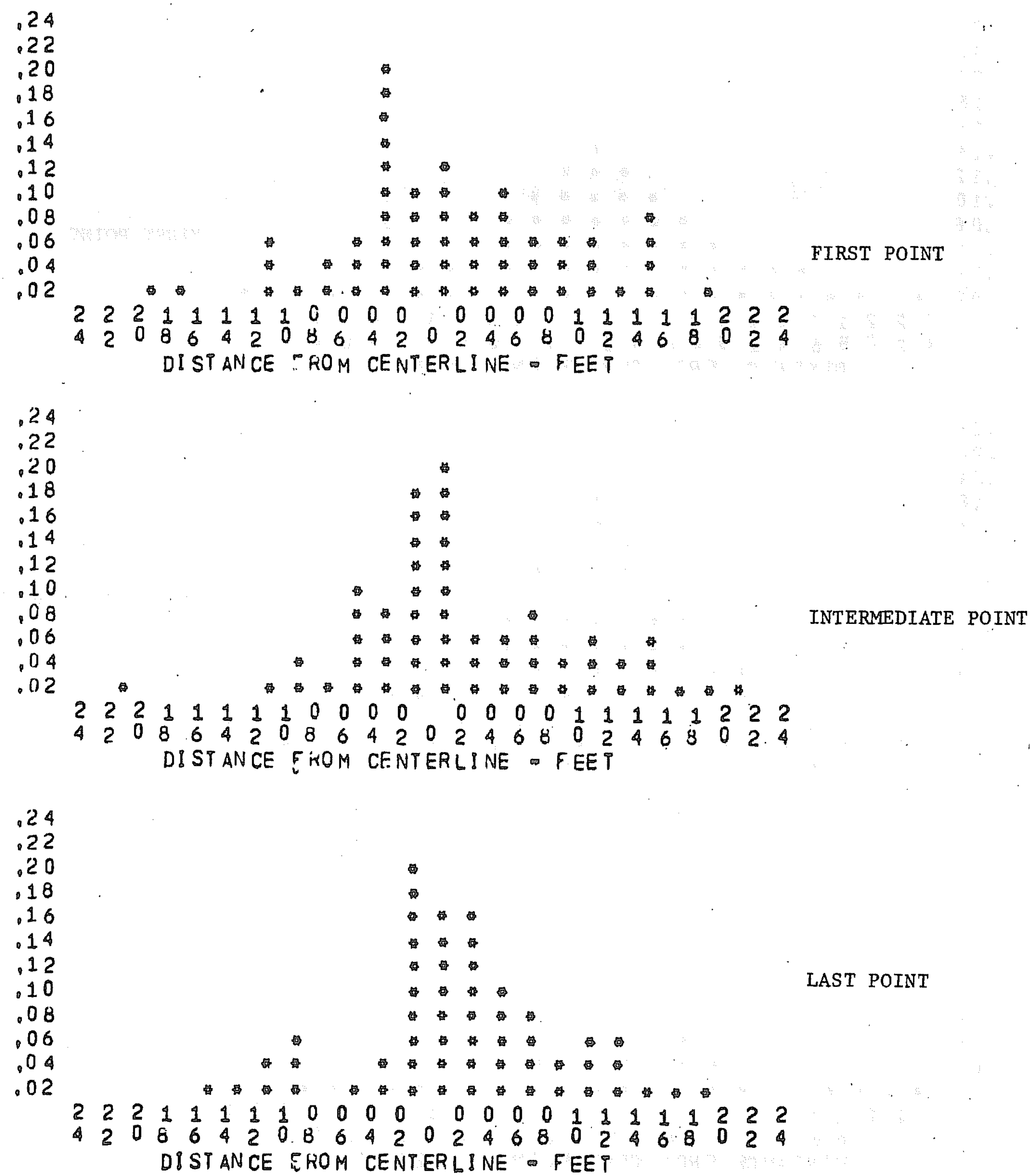
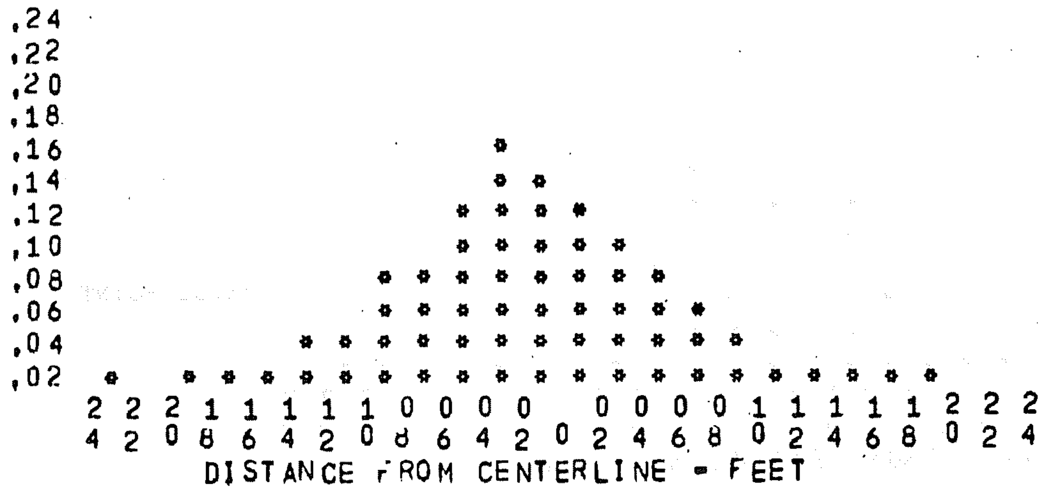
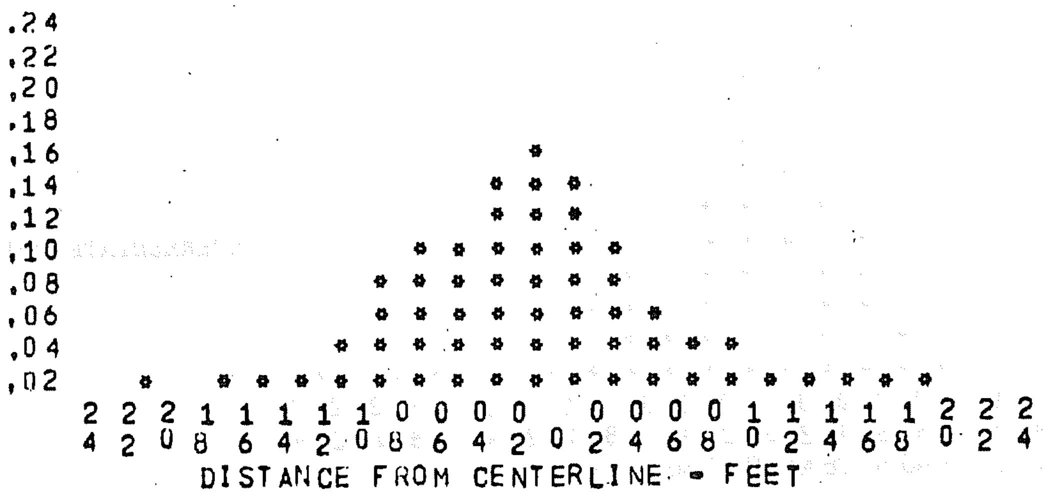


FIGURE A-70

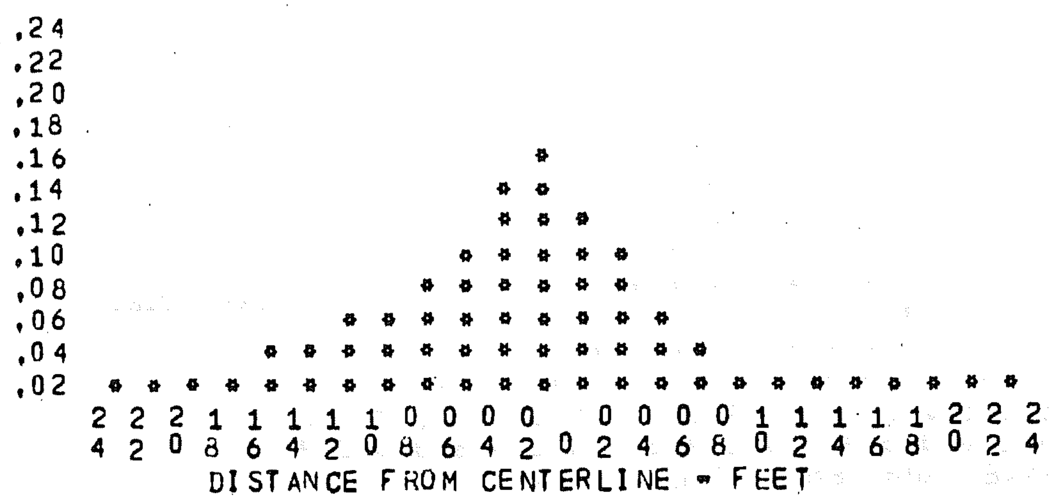
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS SEA RWY 16L



FIRST POINT



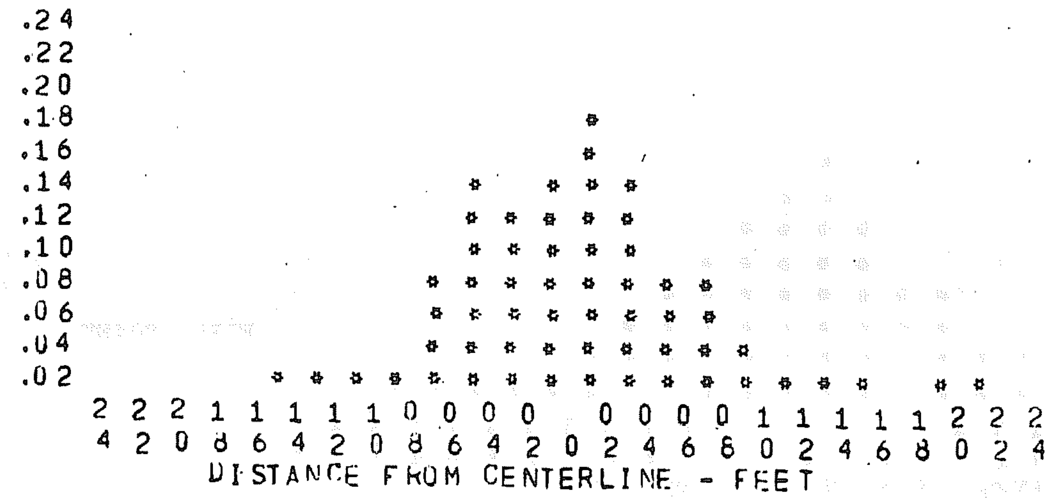
INTERMEDIATE POINT



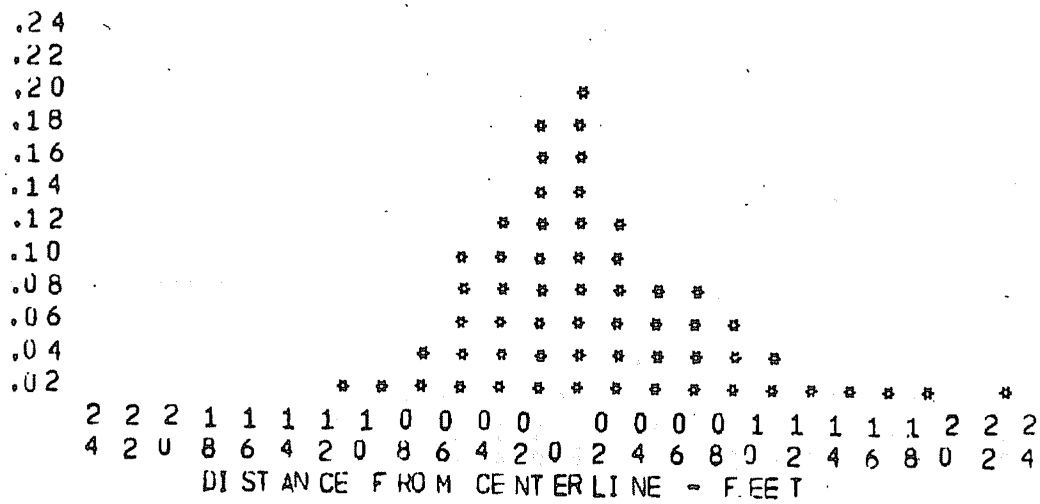
LAST POINT

FIGURE A-71

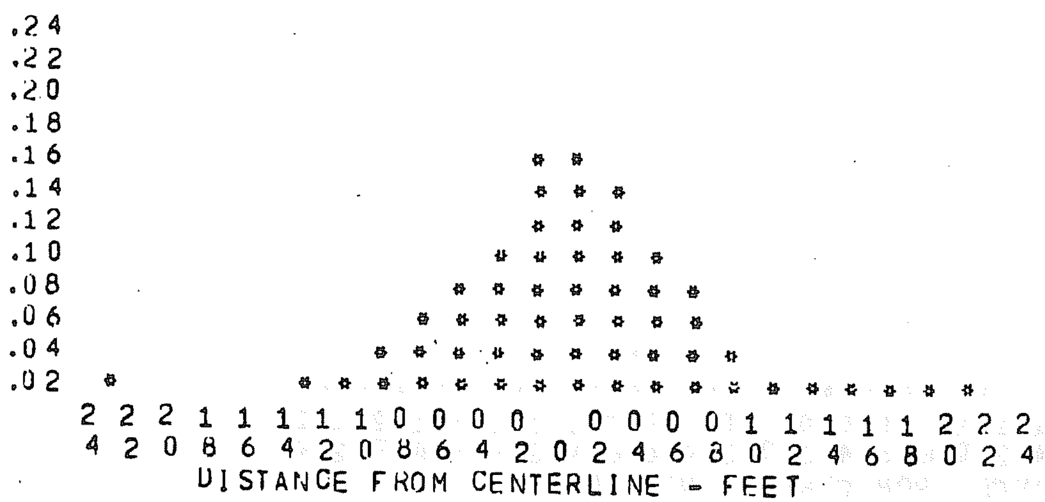
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS SEA RWY 34R



FIRST POINT



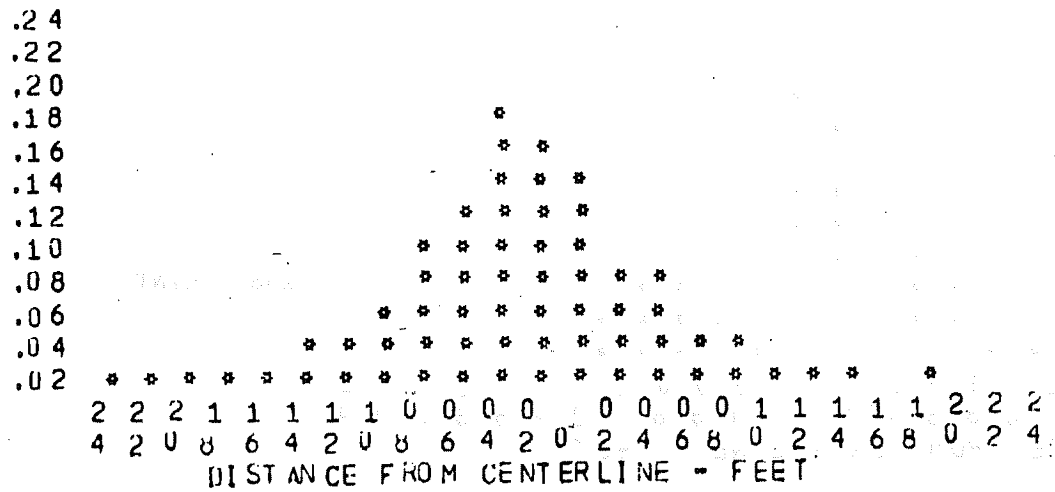
INTERMEDIATE POINT



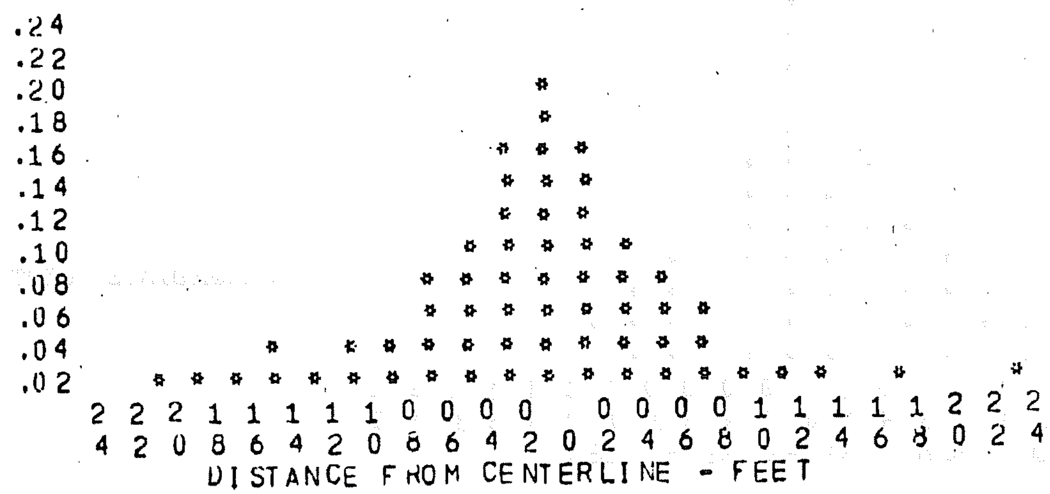
LAST POINT

FIGURE A-72

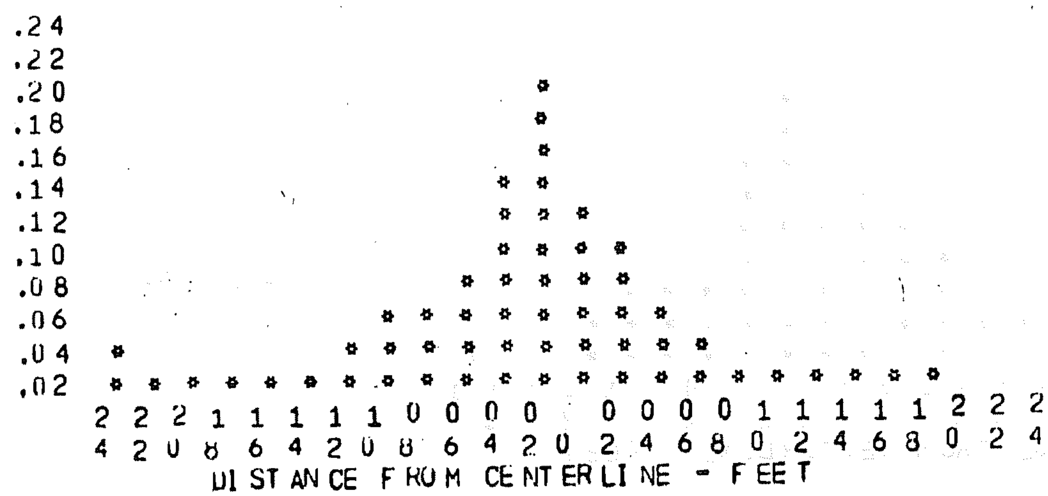
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS CLE RWY 5R



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-73

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS CLE RWY 23L

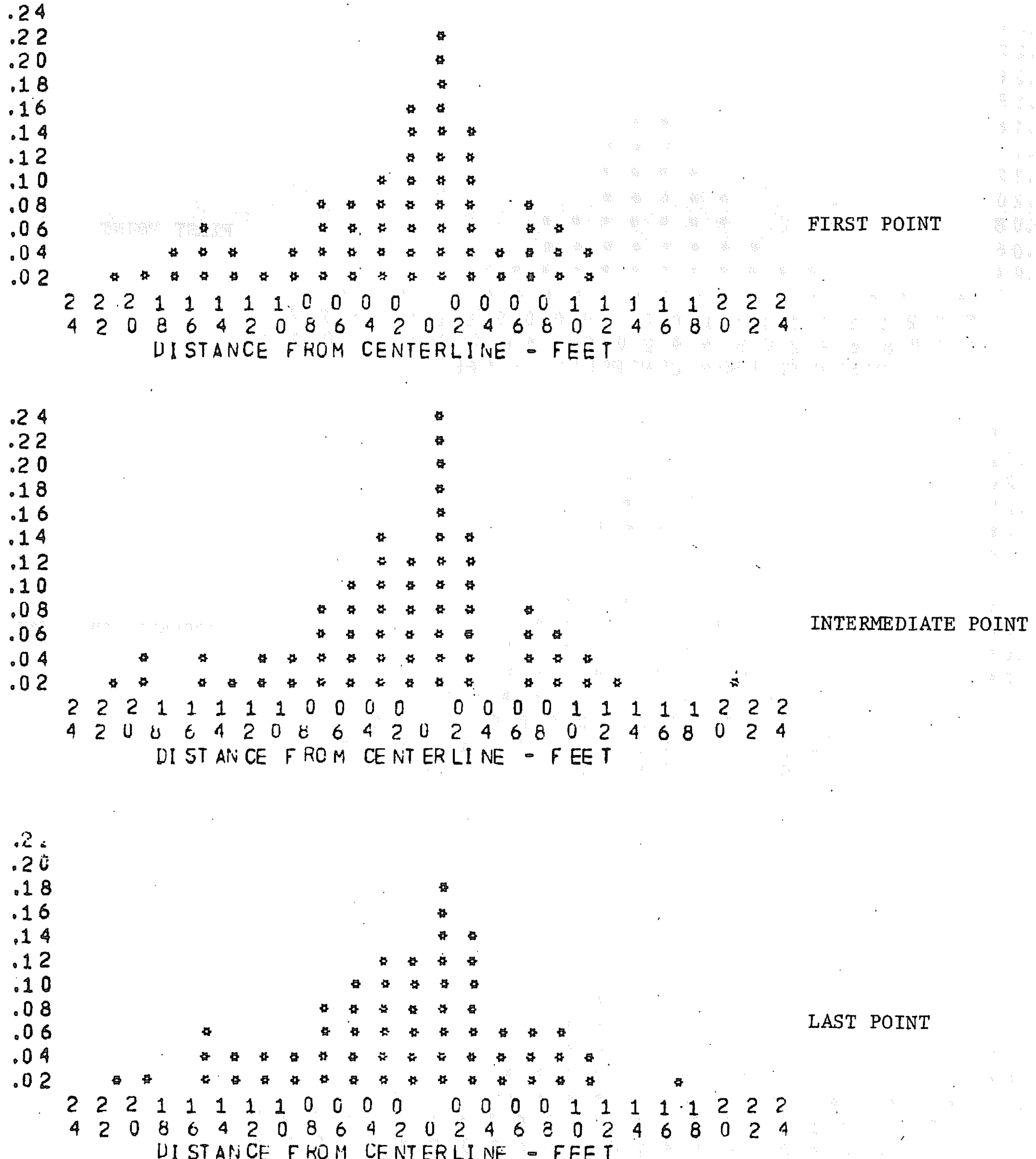
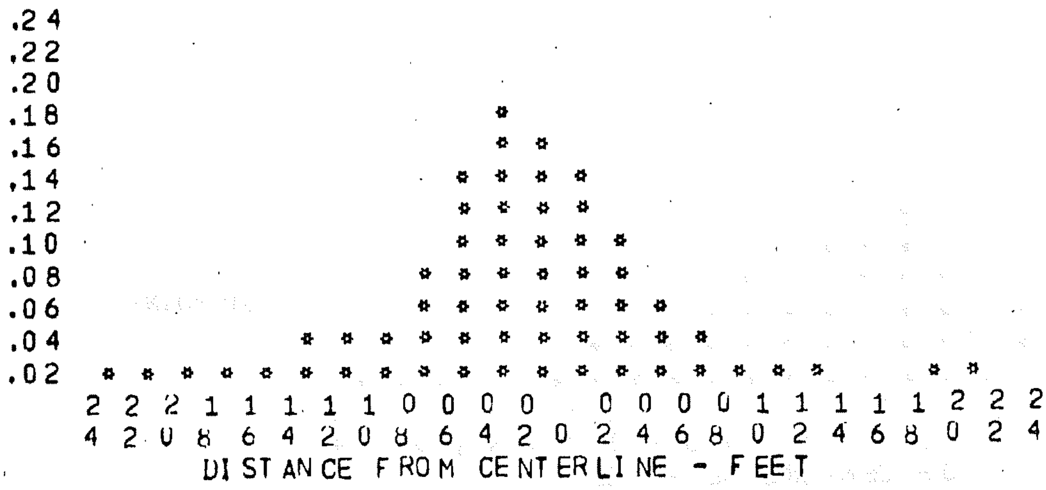
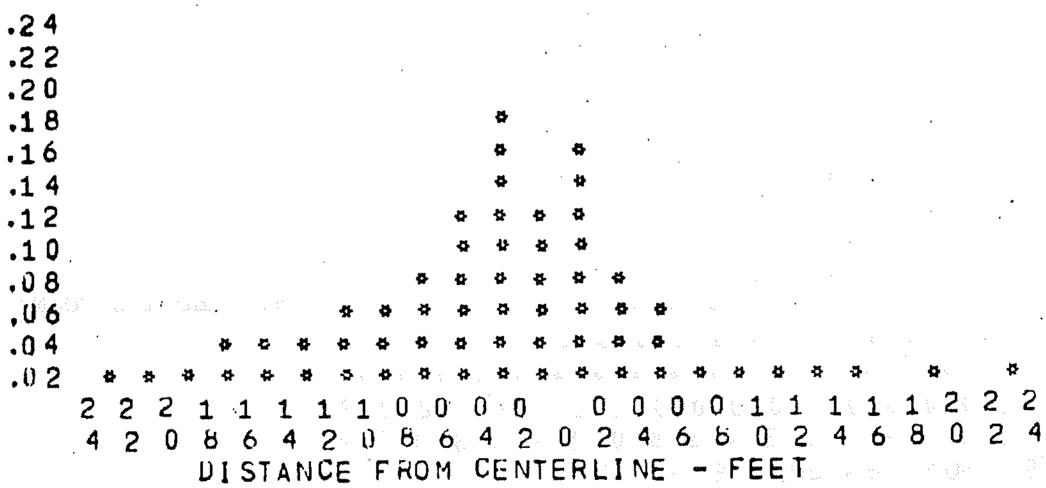


FIGURE A-74

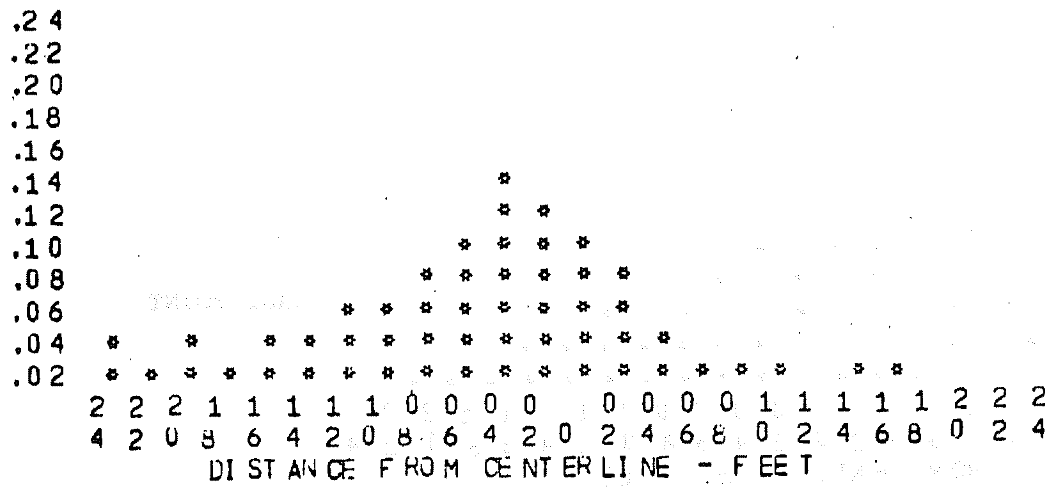
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS BUF RWY 5



FIRST POINT



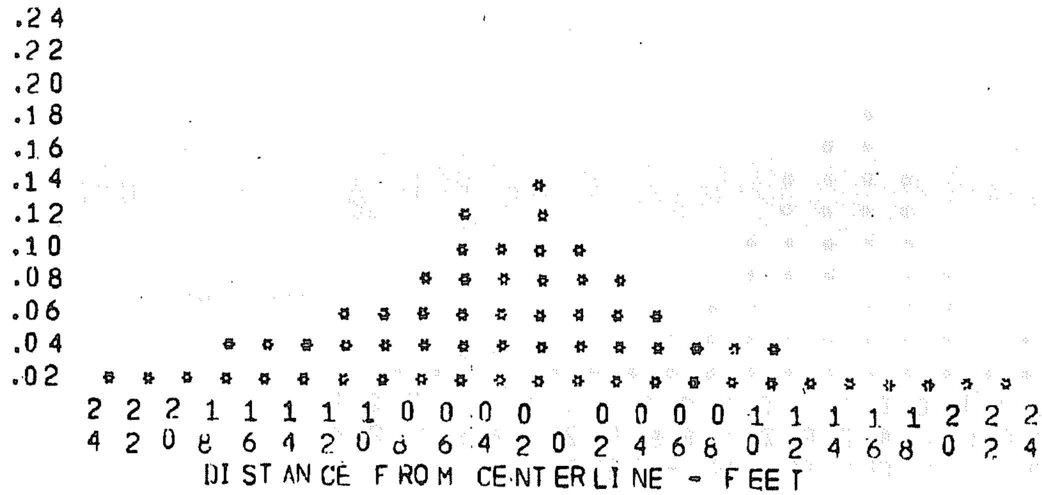
INTERMEDIATE POINT



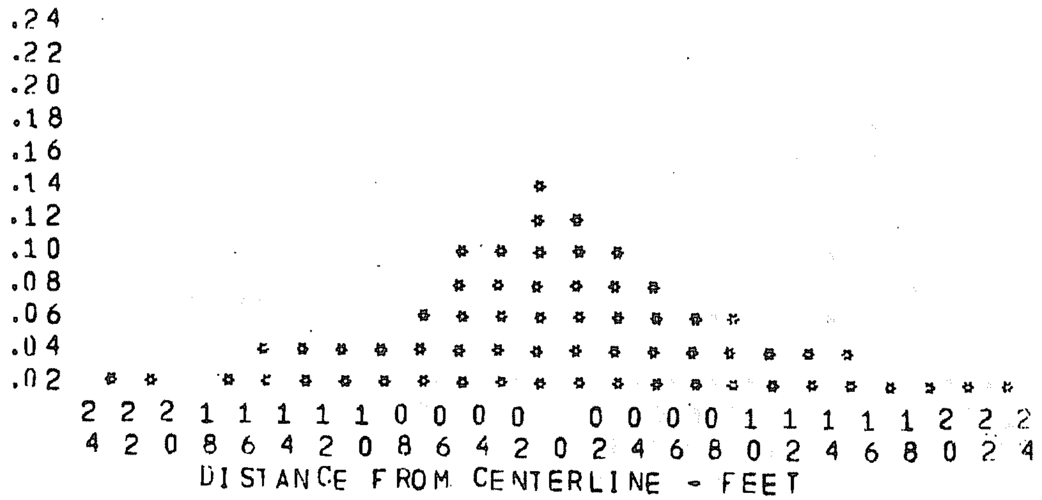
LAST POINT

FIGURE A-75

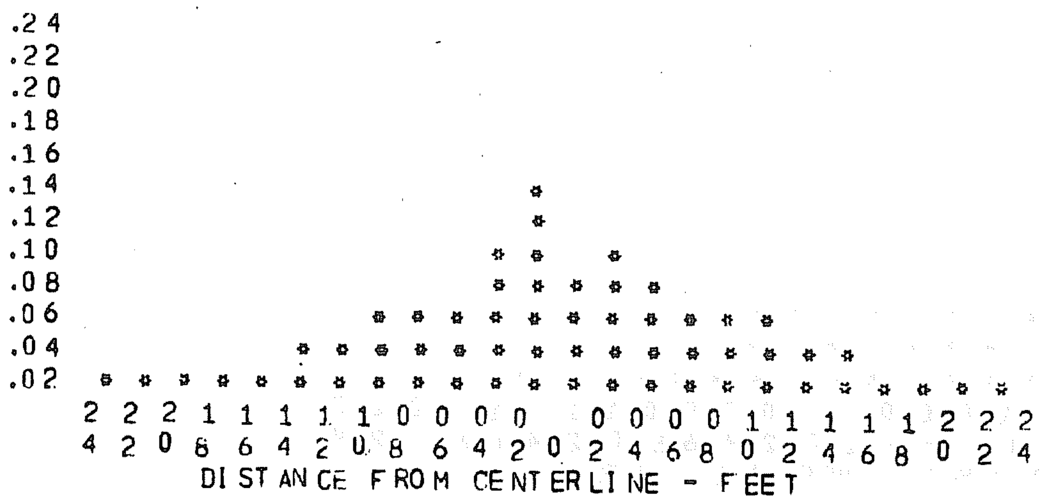
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS BUF RWY 23



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-76

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS MIA RWY 9L

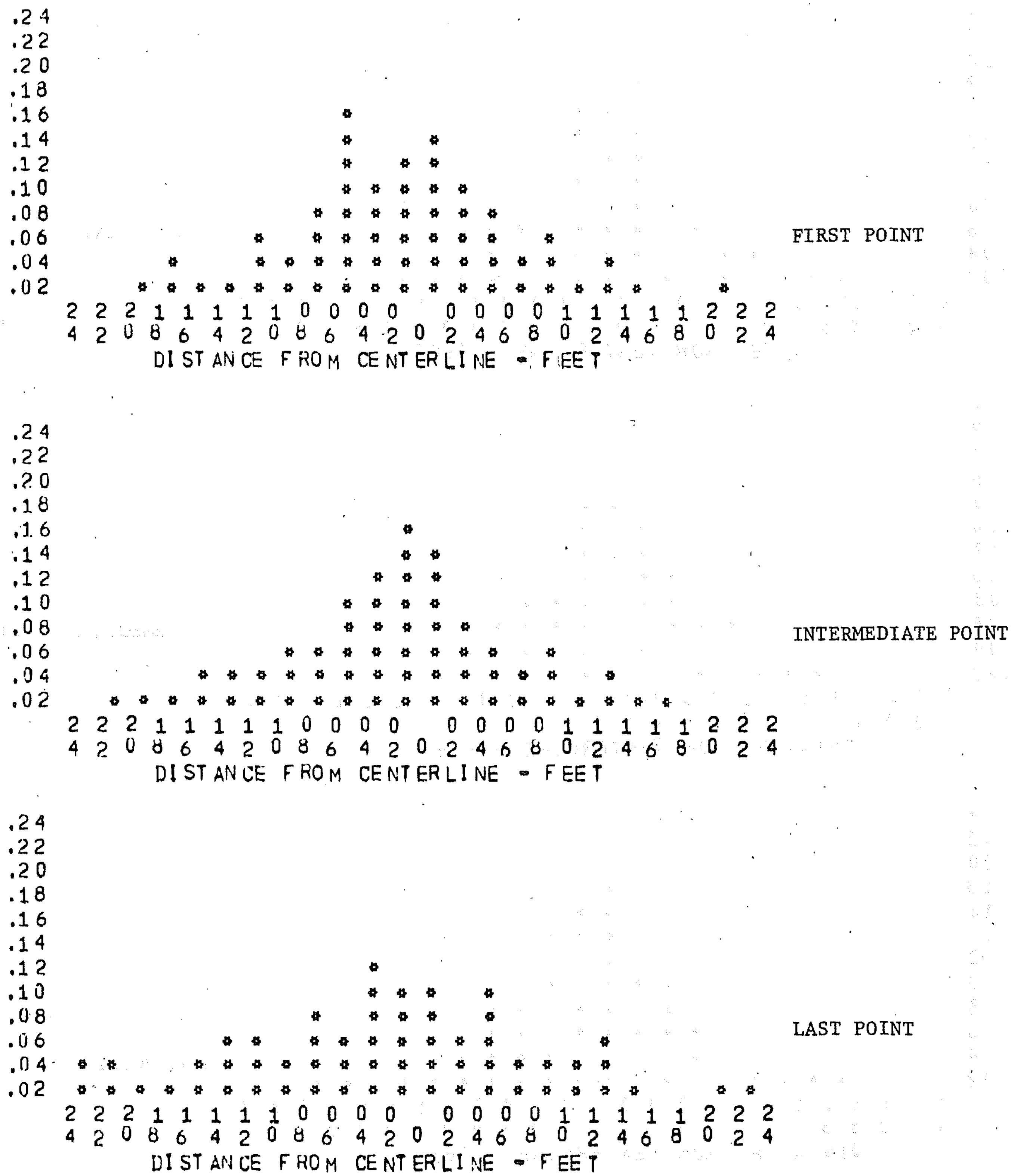
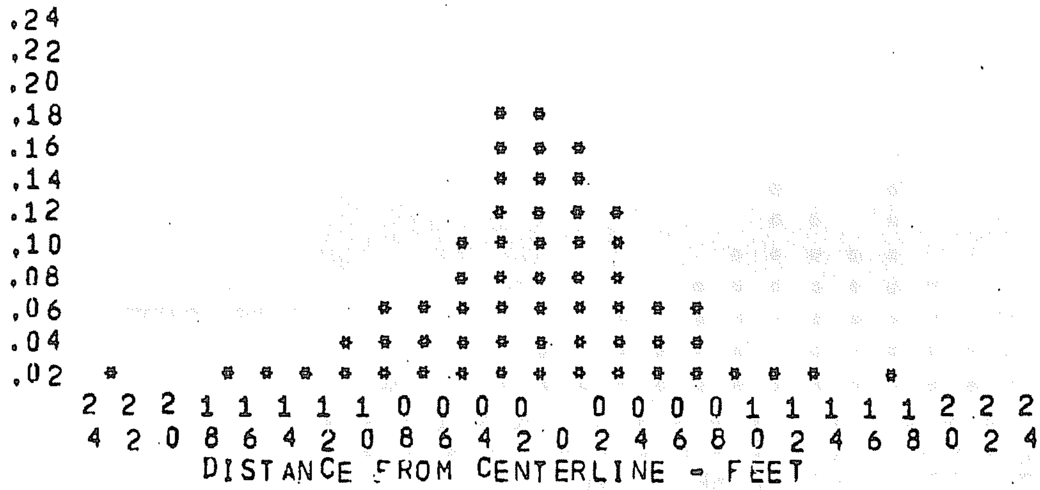
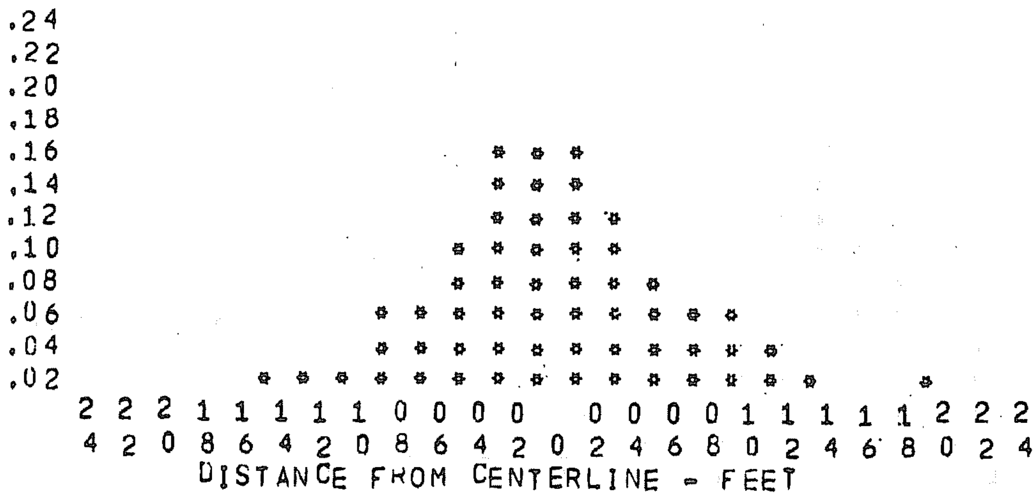


FIGURE A-77

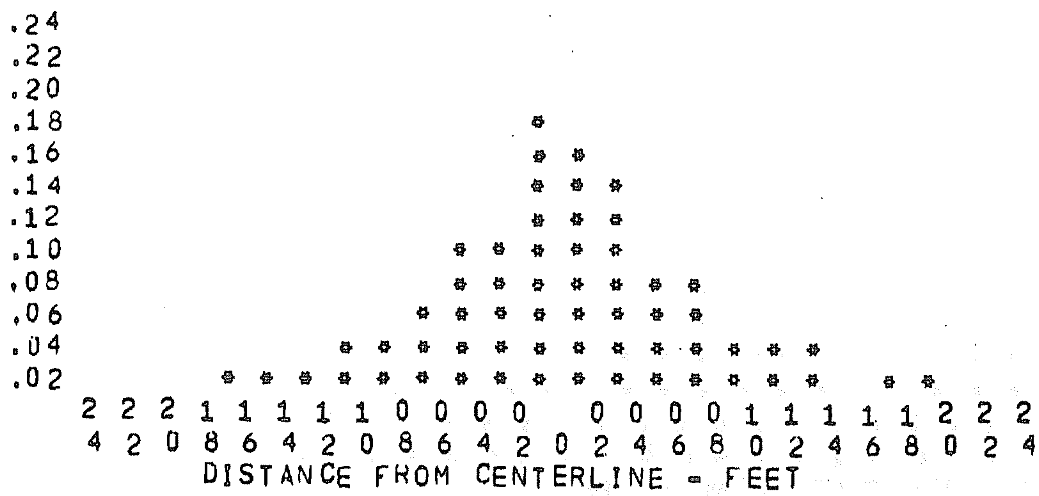
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS MIA RWY 27R



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-78

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS MSY RWY 10

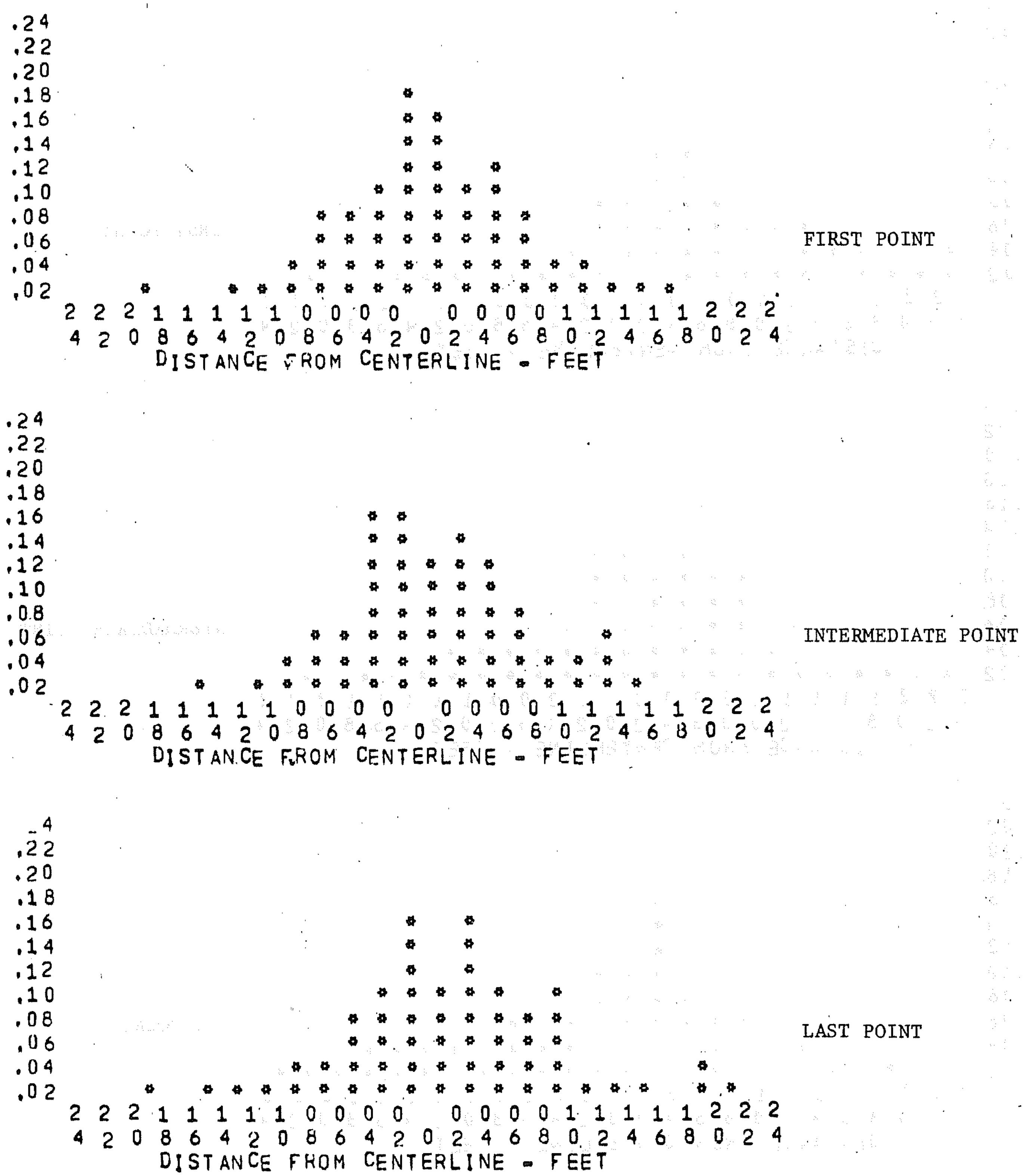
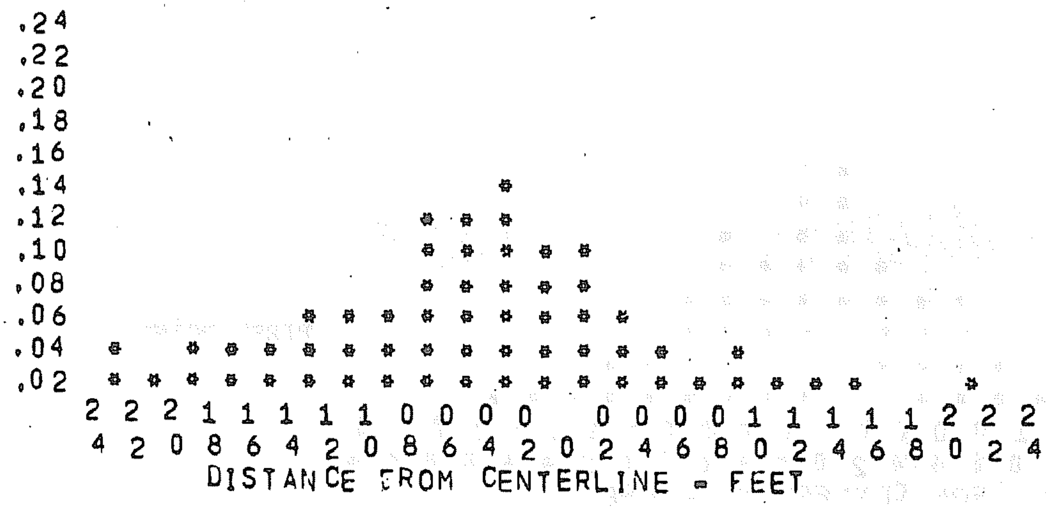
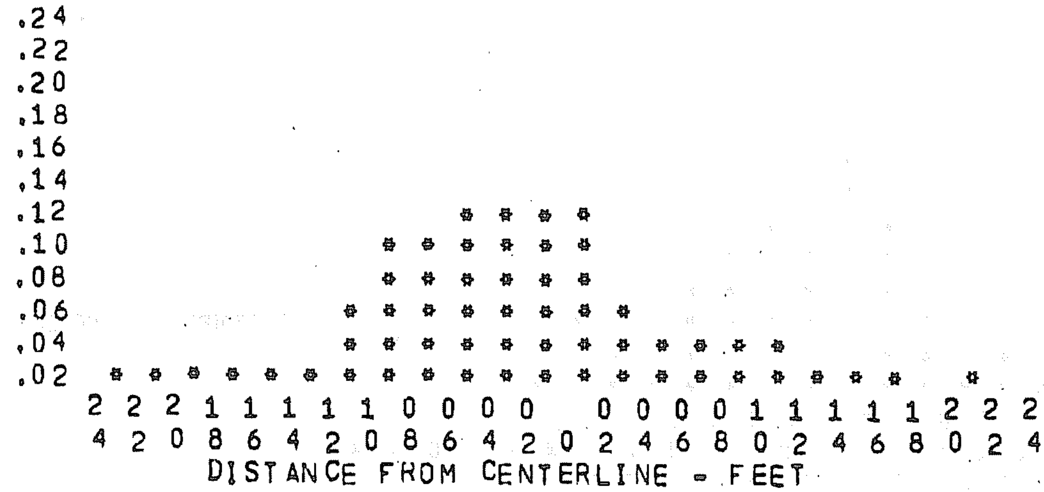


FIGURE A-79

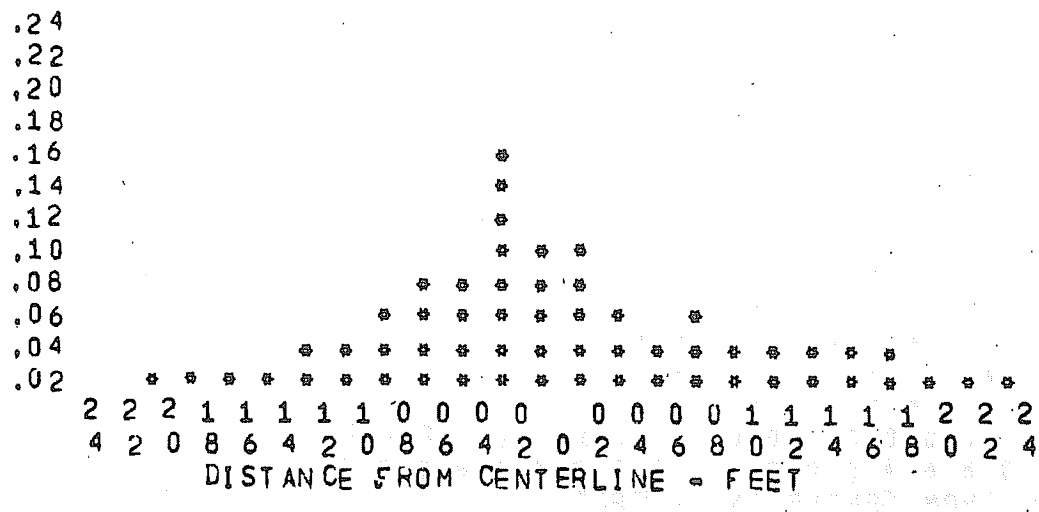
LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS MSY RWY 28



FIRST POINT



INTERMEDIATE POINT



LAST POINT

FIGURE A-80

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS DFW RWY 17L

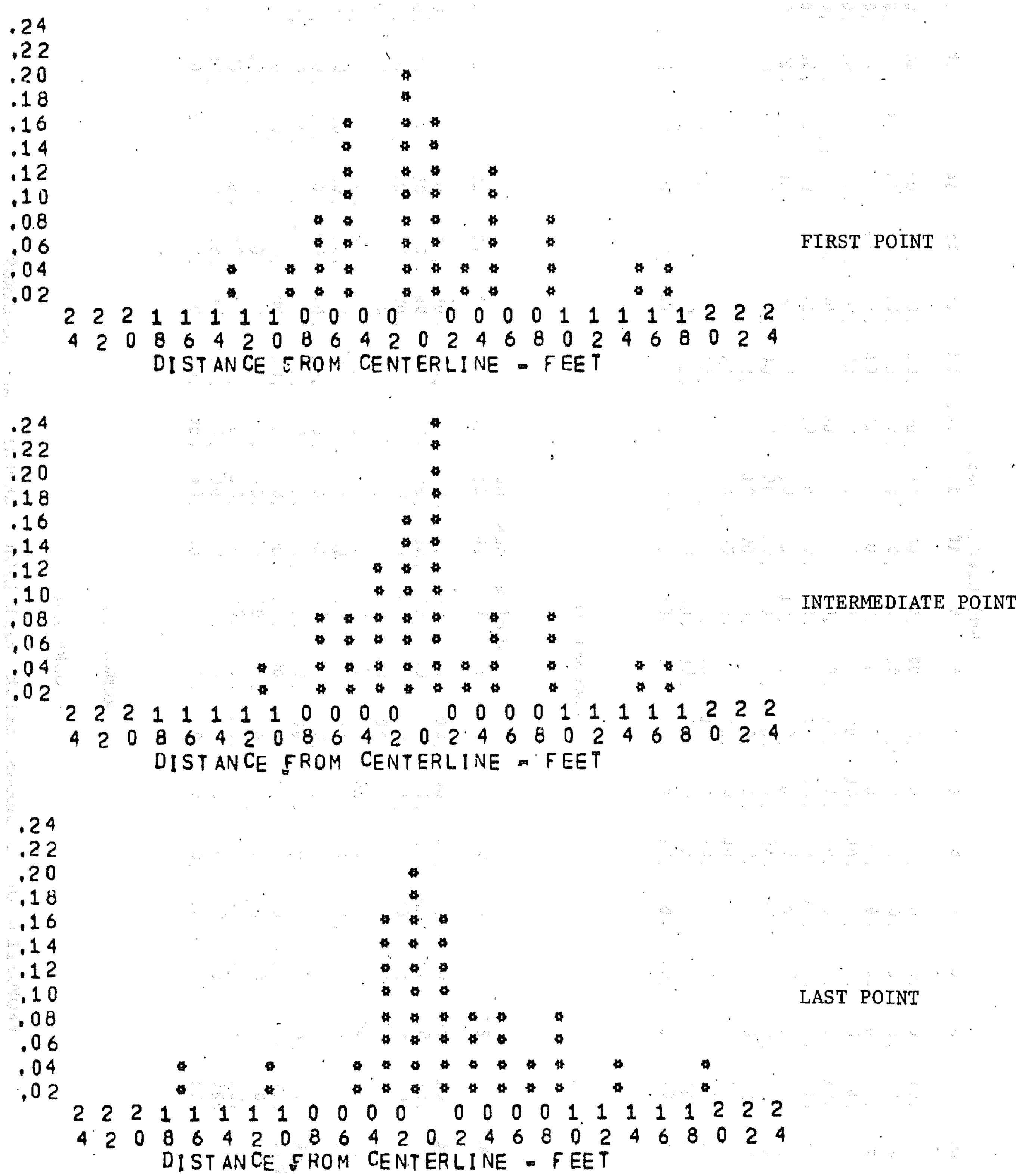


FIGURE A-81

LATERAL DISTRIBUTION OF CENTERLINE OFFSETS - ALL LANDINGS DFW RWY 35R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
727-1	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.32	.09	.14	.45	.00
727-2	59	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.02	.29	.07	.15	.42	.03
737	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.40	.00	.00	.60	.00
747	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00
DC8-4,5	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.36	.07	.07	.36	.00
DC8-6	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.06	.39	.06	.17	.28	.00
DC9-1,2	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.06	.06	.82	.00
DC9-3,4	93	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.15	.08	.12	.59	.05
DC10	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.57	.00	.43	.00	.00
L1011	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.40	.40	.00	.00	.20	.00
C580	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
YS-11	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.00	.20	.60	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	18	.06	.78	.06	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	108	.18	.54	.11	.12	.02	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	106	.09	.55	.14	.04	.10	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	26	.12	.69	.08	.08	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	10	.10	.50	.00	.10	.10	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	56	.04	.41	.13	.11	.21	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	37	.05	.49	.11	.11	.05	.19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	60	.07	.62	.15	.08	.07	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	241	.14	.57	.10	.05	.08	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	15	.00	.47	.00	.27	.07	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	15	.13	.40	.07	.13	.13	.13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	5	.20	.60	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	15	.13	.60	.13	.00	.07	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 27L

FIGURE A-82

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - ATL LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	79	.06	.54	.04	.08	.24	.03	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	128	.09	.59	.04	.03	.23	.02	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	93	.02	.55	.01	.10	.26	.03	.02	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	36	.36	.50	.00	.00	.08	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	14	.00	.21	.00	.14	.50	.07	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	33	.09	.58	.00	.09	.24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	24	.08	.63	.00	.00	.21	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	7	.14	.71	.00	.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	66	.38	.36	.05	.05	.15	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	20	.05	.40	.00	.10	.45	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	10	.00	.40	.00	.10	.40	.00	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	10	.40	.20	.00	.00	.00	.20	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.40	.40
727-1	21	.00	.00	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.05	.14	.00	.57	.19
727-2	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.04	.00	.00	.35	.57
737	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00	.00	.00	.30	.60
747	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
DC8-4,5	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.33
DC8-6	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.17	.00	.00	.00	.00	.00	.67	.17
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00
DC9-3,4	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.28	.72
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00
L1011	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50
C580	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.90

RUNWAY 27L

FIGURE A-83

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - ORD LANDINGS

AIRCRAFT	NO.	LIGHT ELEMENT NOS. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.22	.67	.00
727-1	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.92	.00
727-2	16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.06	.88	.00
737	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.18	.00	.06	.76	.00
DC8-4,5	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
DC8-6	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.67	.00
DC9-1,2	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
DC9-3,4	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00
DC10	9	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00	.00	.11	.00	.00	.00	.11	.00	.67	.00
C580	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.25	.75	.00

RUNWAY 8R

AIRCRAFT	NO.	LIGHT ELEMENT NOS. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	52	.08	.54	.06	.04	.15	.12	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00
727-1	136	.06	.67	.04	.08	.10	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	118	.05	.62	.08	.03	.11	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	110	.18	.67	.03	.00	.10	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00
DC8-4,5	30	.03	.37	.10	.03	.43	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	15	.07	.47	.00	.00	.40	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	18	.17	.61	.11	.00	.06	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	14	.21	.57	.00	.14	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	36	.17	.47	.06	.03	.22	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	47	.06	.64	.02	.02	.17	.09	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 26L

FIGURE A-84

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - DEN LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	13	.08	.69	.00	.00	.15	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00	.00
727-1	11	.18	.73	.00	.00	.09	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	10	.40	.40	.10	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	5	.20	.40	.20	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	6	.17	.33	.00	.00	.33	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	5	.00	.80	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	9	.44	.33	.00	.11	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	5	.40	.20	.20	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	3	.67	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	2	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	1	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 16L

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05	.00	.07	.39	.49
727-1	132	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.03	.00	.02	.45	.49
727-2	119	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.01	.01	.57	.37
737	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.36	.56
747	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07	.36	.57
DC8-4,5	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.58	.39
DC8-6	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.03	.65	.26
DC9-1,2	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.30	.70
DC9-3,4	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.09	.00	.00	.00	.00	.00	.33	.55
DC10	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.03	.03	.42	.42
C580	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.40	.60

RUNWAY 34R

FIGURE A-85

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - SEA LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.24	.12	.00	.08	.52	.00
727-1	101	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.12	.07	.10	.54	.15
727-2	32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.22	.13	.16	.41	.09
737	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.70	.30
747	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
DC8-4,5	12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.33	.08	.08	.42	.00
DC8-6	12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.08	.08	.33	.17
DC9-1,2	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.17	.17	.00	.50	.17
DC9-3,4	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.25	.00	.00	.75	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
C580	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.33
YS-11	3	.00	.00	.00	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67
BAC-111	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07	.00	.07	.80	.07

RUNWAY 5R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	34	.03	.56	.12	.09	.15	.00	.00	.03	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00
727-1	130	.04	.68	.10	.08	.09	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	35	.06	.63	.11	.03	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	93	.20	.65	.04	.03	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	1	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	12	.08	.67	.00	.00	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	17	.00	.41	.00	.18	.29	.12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	9	.22	.22	.33	.11	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	26	.08	.65	.19	.04	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	2	.00	.50	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	15	.27	.60	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	25	.32	.60	.00	.04	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 23L

FIGURE A-86

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - CLE LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.90	.10	.00	.00	.00	.00
727-1	17	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.12	.41	.41	.00	.00	.00	.00
727-2	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00
737	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00
DC8-4,5	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
DC9-3,4	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.67	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00
C580	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.33	.00	.00	.00	.00
BAC-111	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.03	.03	.48	.41	.00	.00	.00	.00

RUNWAY 5

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	18	.33	.39	.06	.11	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	46	.30	.59	.07	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	24	.54	.33	.00	.08	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	13	.38	.38	.00	.15	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	2	.00	.00	.50	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	3	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	57	.33	.54	.02	.02	.09	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	13	.31	.38	.15	.08	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	21	.24	.57	.05	.05	.05	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	124	.31	.49	.04	.08	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 23

FIGURE A-87

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - BUF LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	63	.14	.30	.05	.0[illegible]	.46	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	287	.22	.26	.02	.02	.47	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	88	.10	.32	.08	.02	.47	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00
737	4	.00	.50	.00	.00	.25	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	2	.50	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	19	.26	.32	.00	.05	.32	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	2	.00	.00	.00	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	7	.00	.14	.00	.00	.71	.00	.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	98	.28	.43	.01	.03	.26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	2	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	21	.14	.14	.00	.00	.71	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	5	.40	.60	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9L

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
									LIGHT ELEMENT NOS.											
707	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.43	.00	.14	.43	.00
727-1	67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.51	.01	.03	.45	.00
727-2	30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.50	.03	.03	.33	.00
747	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.67	.00
DC8-4,5	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.43	.00	.00	.57	.00
DC8-6	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.75	.00	.25	.00	.00
DC9-3,4	54	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.44	.04	.02	.50	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
L1011	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.69	.00	.00	.31	.00
C580	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00

RUNWAY 27R

FIGURE A-88

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - MIA LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	4	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	34	.18	.71	.06	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	34	.18	.76	.03	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	9	.22	.44	.11	.11	.00	.00	.00	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	18	.22	.56	.06	.00	.11	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	30	.27	.70	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	59	.29	.68	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	5	.40	.40	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 10

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
727-1	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.06	.00	.35	.47	.00	.00	.00
727-2	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.04	.09	.04	.22	.57	.00	.00	.00
DC8-4,5	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.13	.00	.13	.50	.25	.00	.00	.00
DC8-6	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.00	.43	.43	.00	.00	.00
DC9-1,2	11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.73	.27	.00	.00	.00
DC9-3,4	35	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.09	.00	.00	.51	.40	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.33	.00	.00	.00
BAC-111	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00

RUNWAY 28

FIGURE A-89

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - MSY LANDINGS

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	33	.03	.58	.06	.15	.00	.00	.00	.09	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	24	.21	.42	.13	.13	.00	.00	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	20	.15	.50	.10	.05	.00	.00	.00	.15	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	2	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	6	.17	.33	.17	.00	.00	.00	.00	.17	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	15	.20	.53	.07	.00	.00	.00	.00	.07	.13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	6	.00	.17	.00	.33	.00	.00	.00	.33	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	24	.21	.46	.13	.04	.00	.00	.00	.08	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	26	.23	.73	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	3	.00	.00	.00	.00	.00	.00	.00	.67	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	6	.00	.33	.00	.00	.00	.00	.00	.50	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	9	.89	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 17L

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.80	.00	.00	.00	.00
727-1	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
727-2	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.50	.00	.00	.00	.00
737	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
747	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC8-6	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC9-3,4	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
C580	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00

RUNWAY 35R

FIGURE A-90

PROPORTION OF TOUCHDOWNS BEFORE EACH LIGHT ELEMENT - DFW LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	2	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	22	.05	.00	.00	.00	.73	.00	.00	.00	.23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	59	.17	.00	.00	.00	.73	.05	.00	.00	.03	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00
737	10	.00	.10	.00	.00	.40	.00	.10	.00	.40	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	1	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	14	.14	.00	.00	.00	.86	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	18	.50	.06	.00	.00	.33	.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	17	.00	.00	.00	.00	.53	.00	.00	.00	.47	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	93	.02	.03	.00	.00	.54	.08	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	7	.14	.00	.00	.00	.71	.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	5	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	2	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00
YS-11	5	.00	.00	.00	.00	.20	.00	.00	.00	.80	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.94	.00	.00	.00	.06	.00	.00	.00	.00
727-1	108	.00	.00	.00	.02	.00	.01	.00	.02	.00	.00	.78	.00	.00	.01	.17	.00	.00	.00	.00
727-2	106	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.50	.00	.00	.01	.47	.00	.00	.00	.01
737	26	.00	.00	.00	.04	.04	.00	.00	.04	.00	.00	.81	.00	.00	.00	.08	.00	.00	.00	.00
747	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.10	.70	.00	.00	.00	.10
DC8-4,5	56	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.32	.00	.00	.02	.55	.00	.00	.04	.05
DC8-6	37	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.16	.00	.00	.00	.59	.00	.03	.00	.19
DC9-1,2	60	.00	.00	.00	.02	.02	.00	.00	.02	.00	.00	.75	.00	.00	.05	.13	.00	.02	.00	.00
DC9-3,4	241	.00	.00	.00	.02	.01	.00	.00	.00	.00	.00	.72	.00	.00	.01	.23	.00	.00	.00	.00
DC10	15	.00	.00	.00	.00	.00	.00	.00	.00	.07	.00	.27	.00	.00	.00	.60	.00	.00	.00	.07
L1011	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.13	.00	.00	.07	.67	.00	.00	.00	.13
C580	5	.00	.00	.00	.40	.20	.00	.00	.00	.00	.00	.40	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	15	.00	.00	.00	.13	.13	.00	.00	.07	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 27L

FIGURE A-91

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - ATL LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	79	.00	.00	.00	.00	.00	.01	.00	.00	.22	.00	.00	.59	.00	.00	.00	.00	.00	.01	.16
727-1	128	.00	.00	.00	.00	.02	.02	.00	.00	.25	.00	.00	.68	.00	.00	.00	.02	.00	.00	.02
727-2	93	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.88	.00	.00	.00	.00	.00	.00	.09
737	36	.00	.00	.00	.00	.06	.06	.00	.00	.56	.00	.00	.31	.00	.00	.03	.00	.00	.00	.00
747	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.79	.00	.00	.00	.00	.00	.00	.21
DC8-4,5	33	.00	.00	.00	.00	.00	.00	.00	.00	.21	.00	.00	.67	.00	.00	.00	.00	.00	.00	.12
DC8-6	24	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.88	.00	.00	.00	.00	.00	.00	.08
DC9-1,2	7	.00	.00	.00	.00	.00	.14	.00	.00	.43	.00	.00	.43	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	66	.00	.00	.00	.00	.06	.09	.00	.02	.41	.00	.00	.39	.00	.00	.00	.00	.02	.00	.02
DC10	20	.00	.00	.00	.00	.00	.00	.00	.00	.05	.00	.00	.90	.00	.00	.00	.00	.00	.05	.00
L1011	10	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.70	.00	.00	.00	.00	.00	.10	.10
C580	10	.00	.00	.00	.00	.20	.00	.00	.00	.40	.00	.00	.40	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9R

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	10	.00	.00	.00	.00	.00	.40	.00	.00	.00	.50	.00	.00	.10	.00	.00	.00	.00	.00	.00
727-1	21	.00	.00	.00	.00	.00	.19	.00	.00	.00	.48	.00	.00	.33	.00	.00	.00	.00	.00	.00
727-2	23	.00	.00	.00	.00	.00	.30	.00	.00	.00	.30	.00	.00	.35	.00	.00	.04	.00	.00	.00
737	10	.00	.00	.00	.00	.00	.20	.00	.00	.00	.30	.00	.00	.50	.00	.00	.00	.00	.00	.00
747	2	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	3	.00	.00	.00	.33	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	6	.00	.00	.00	.00	.00	.67	.00	.00	.00	.17	.00	.00	.17	.00	.00	.00	.00	.00	.00
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00
DC9-3,4	29	.00	.00	.00	.00	.00	.03	.00	.00	.03	.14	.03	.00	.76	.00	.00	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00
L1011	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00
C580	10	.00	.00	.00	.00	.10	.00	.00	.00	.00	.10	.00	.00	.80	.00	.00	.00	.00	.00	.00

RUNWAY 27L

FIGURE A-92

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - ORD LANDINGS

		LIGHT ELEMENT NOS.																		
AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	9	.00	.11	.00	.00	.00	.89	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	13	.00	.08	.00	.00	.00	.62	.00	.00	.23	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00
727-2	16	.13	.00	.00	.00	.00	.69	.00	.00	.19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	17	.12	.00	.00	.00	.00	.47	.00	.00	.29	.00	.00	.12	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	4	.25	.25	.00	.00	.00	.25	.00	.00	.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	3	.33	.33	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	3	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	2	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	9	.00	.33	.00	.00	.00	.56	.00	.00	.00	.00	.00	.00	.11	.00	.00	.00	.00	.00	.00
C580	8	.00	.00	.00	.00	.00	.13	.00	.00	.25	.00	.00	.38	.25	.00	.00	.00	.00	.00	.00

RUNWAY 8R

		LIGHT ELEMENT NOS.																		
AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	52	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.40	.00	.00	.56	.00
727-1	136	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.03	.38	.00	.01	.37	.00	.01	.19	.00
727-2	118	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.17	.00	.00	.40	.00	.00	.43	.00
737	110	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05	.39	.00	.00	.48	.00	.00	.08	.00
DC8-4,5	30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.07	.00	.00	.33	.00	.00	.57	.00
DC8-6	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.27	.00	.00	.73	.00
DC9-1,2	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.44	.00	.00	.56	.00	.00	.00	.00
DC9-3,4	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.64	.00	.00	.36	.00	.00	.00	.00
DC 10	36	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.00	.00	.53	.00	.00	.33	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00
C580	47	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.66	.00	.00	.21	.00	.00	.02	.00

RUNWAY 26L

FIGURE A-93

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - DEN LANDINGS

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	13	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.23	.62	.00	.00	.08	.00	.00	.00	.00
727-1	11	.00	.00	.00	.00	.00	.00	.00	.09	.00	.00	.18	.64	.00	.00	.09	.00	.00	.00	.00
727-2	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.80	.00	.00	.00	.00	.00	.00	.00
737	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.80	.00	.00	.00	.00	.00	.00	.00
747	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.17	.50	.00	.00	.33	.00	.00	.00	.00
DC8-4,5	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.80	.00	.00	.00	.00	.00	.00	.00
DC8-6	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.67	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.60	.00	.00	.20	.00	.00	.00	.00
DC9-3,4	3	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
C580	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00

RUNWAY 16L

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	57	.00	.02	.00	.00	.02	.00	.00	.00	.46	.05	.02	.00	.44	.00	.00	.00	.00	.00	.00
727-1	132	.00	.00	.00	.00	.00	.00	.00	.00	.48	.01	.01	.01	.48	.00	.00	.01	.00	.00	.00
727-2	119	.00	.01	.00	.00	.00	.03	.00	.00	.58	.00	.02	.02	.34	.00	.00	.00	.00	.00	.00
737	25	.00	.00	.00	.00	.00	.00	.00	.00	.28	.00	.04	.00	.60	.00	.04	.04	.00	.00	.00
747	14	.00	.00	.00	.00	.07	.14	.00	.00	.79	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	31	.00	.00	.00	.00	.00	.10	.00	.00	.61	.00	.00	.00	.29	.00	.00	.00	.00	.00	.00
DC8-6	31	.00	.03	.00	.00	.03	.26	.00	.00	.68	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	23	.00	.00	.00	.00	.00	.00	.00	.00	.26	.00	.00	.00	.52	.00	.00	.22	.00	.00	.00
DC9-3,4	33	.00	.00	.00	.00	.00	.00	.00	.00	.39	.00	.00	.06	.55	.00	.00	.00	.00	.00	.00
DC10	31	.00	.00	.00	.00	.03	.00	.00	.00	.71	.00	.00	.00	.26	.00	.00	.00	.00	.00	.00
C580	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00

RUNWAY 34R

FIGURE A-94

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - SEA LANDINGS

AIRCRAFT	NO.	LIGHT ELEMENT NOS. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	25	.08	.04	.00	.00	.56	.00	.00	.32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	101	.02	.00	.00	.00	.20	.01	.00	.68	.01	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00
727-2	32	.00	.00	.00	.03	.44	.00	.00	.44	.06	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00
737	20	.00	.00	.00	.00	.00	.00	.00	.90	.00	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00
747	1	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	12	.00	.08	.00	.00	.58	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	12	.17	.00	.00	.00	.42	.00	.00	.33	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00	.00
DC9-1,2	6	.00	.00	.00	.00	.67	.00	.00	.17	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	20	.00	.00	.00	.00	.30	.00	.00	.70	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.00	.33	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
YS-11	3	.00	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00
BAC-111	15	.00	.07	.00	.00	.33	.00	.00	.53	.00	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00

RUNWAY 5R

AIRCRAFT	NO.	LIGHT ELEMENT NOS. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.21	.00	.00	.44	.03	.00	.00	.12	.21
727-1	130	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.39	.02	.02	.53	.02	.00	.00	.00	.01
727-2	35	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.43	.00	.00	.40	.00	.00	.03	.00	.11
737	93	.00	.00	.00	.00	.00	.00	.04	.04	.02	.00	.46	.00	.02	.39	.01	.00	.00	.00	.01
747	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	12	.00	.00	.00	.00	.00	.00	.08	.08	.00	.00	.17	.00	.00	.50	.08	.00	.00	.00	.08
DC8-6	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.24	.00	.00	.18	.06	.00	.00	.12	.41
DC9-1,2	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.33	.00	.00	.67	.00	.00	.00	.00	.00
DC9-3,4	26	.00	.00	.00	.04	.00	.00	.00	.04	.04	.00	.46	.00	.04	.35	.00	.04	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.50
C580	15	.00	.00	.00	.00	.00	.00	.53	.00	.00	.07	.33	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	25	.00	.00	.00	.00	.00	.00	.08	.04	.00	.00	.56	.00	.00	.32	.00	.00	.00	.00	.00

RUNWAY 23L

FIGURE A-95

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - CLE LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	10	.20	.00	.00	.00	.70	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	17	.06	.06	.00	.00	.18	.00	.00	.59	.06	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00
727-2	6	.17	.17	.00	.00	.50	.00	.00	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	4	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	2	.50	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	1	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	21	.00	.00	.00	.00	.29	.00	.00	.71	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	2	.50	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	6	.00	.00	.00	.00	.00	.00	.00	.83	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	29	.50	.00	.00	.07	.24	.00	.00	.55	.00	.00	.14	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 5

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	18	.00	.00	.00	.00	.00	.00	.06	.06	.06	.06	.22	.00	.00	.56	.00	.00	.00	.00	.00
727-1	46	.00	.00	.00	.00	.00	.00	.02	.02	.00	.57	.22	.00	.00	.17	.00	.00	.00	.00	.00
727-2	24	.00	.00	.00	.00	.00	.00	.00	.04	.00	.04	.08	.00	.00	.83	.00	.00	.00	.00	.00
737	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.69	.23	.00	.00	.08	.00	.00	.00	.00	.00
DC8-4,5	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00
DC9-1,2	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
DC9-3,4	57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07	.04	.00	.00	.89	.00	.00	.00	.00	.00
DC10	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.23	.23	.00	.00	.46	.08	.00	.00	.00	.00
C580	21	.00	.00	.00	.00	.00	.00	.05	.00	.00	.24	.05	.00	.00	.67	.00	.00	.00	.00	.00
BAC-111	124	.00	.00	.00	.00	.01	.00	.03	.01	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
											.10	.01	.01		.82	.02				

RUNWAY 23

FIGURE A-96

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - BUF LANDINGS

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	63	.00	.00	.00	.00	.00	.00	.02	.05	.00	.00	.22	.48	.00	.00	.24	.00	.00	.00	.00
727-1	287	.00	.00	.00	.00	.00	.00	.00	.13	.00	.00	.44	.40	.00	.00	.01	.02	.00	.00	.00
727-2	88	.00	.00	.00	.00	.00	.00	.01	.01	.00	.01	.13	.72	.00	.00	.10	.01	.00	.01	.00
737	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00
747	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	19	.00	.00	.00	.00	.00	.00	.00	.05	.00	.00	.32	.32	.00	.00	.05	.16	.00	.11	.00
DC8-6	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00	.00	.00	.50	.00
DC9-1,2	7	.00	.00	.00	.00	.00	.00	.00	.14	.00	.00	.43	.43	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	98	.00	.00	.00	.00	.00	.01	.00	.13	.02	.00	.50	.32	.00	.00	.02	.00	.00	.00	.00
DC10	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00	.00	.00	.00	.00	.00	.00
L1011	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.76	.00	.00	.14	.00	.00	.00	.00
C580	5	.00	.00	.00	.20	.40	.00	.20	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00	.00	.00	.00

RUNWAY 9L

LIGHT ELEMENT NOS.

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
707	7	.14	.00	.00	.00	.00	.57	.00	.00	.14	.00	.00	.00	.00	.00	.00	.14	.00	.00	.00
727-1	67	.01	.00	.00	.00	.03	.33	.00	.00	.55	.00	.00	.06	.01	.00	.00	.00	.00	.00	.00
727-2	30	.03	.03	.00	.00	.17	.30	.00	.00	.40	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00
747	3	.00	.33	.00	.00	.33	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	7	.14	.14	.00	.00	.14	.14	.00	.00	.43	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	4	.00	.25	.00	.00	.25	.00	.00	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	54	.00	.00	.00	.00	.02	.22	.00	.02	.56	.00	.00	.13	.06	.00	.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	13	.08	.08	.00	.00	.08	.15	.00	.00	.46	.00	.08	.00	.08	.00	.00	.00	.00	.00	.00
C580	2	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 27R

FIGURE A-97

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - MIA LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	4	.00	.00	.00	.00	.00	.00	.00	.25	.00	.00	.00	.25	.00	.00	.25	.25	.00	.00	.00
727-1	34	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.03	.85	.00	.00	.09	.00	.00	.00	.00
727-2	34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.74	.00	.00	.21	.06	.00	.00	.00
DC8-4,5	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.78	.00	.00	.00	.22	.00	.00	.00
DC8-6	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.44	.00	.00	.06	.50	.00	.00	.00
DC9-1,2	30	.00	.00	.00	.00	.00	.00	.07	.00	.00	.00	.00	.87	.00	.00	.03	.03	.00	.00	.00
DC9-3,4	59	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.02	.73	.00	.00	.20	.03	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00
C580	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 10

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
727-1	17	.00	.00	.00	.00	.47	.00	.24	.12	.18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-2	23	.22	.00	.00	.00	.39	.00	.22	.13	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-4,5	8	.25	.00	.00	.00	.50	.13	.13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	7	.57	.00	.00	.00	.29	.00	.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	11	.00	.00	.00	.00	.27	.09	.00	.18	.36	.00	.00	.00	.09	.00	.00	.00	.00	.00	.00
DC9-3,4	35	.00	.00	.00	.00	.49	.00	.06	.31	.11	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00
DC10	1	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	3	.00	.00	.00	.00	.33	.00	.00	.00	.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 28

FIGURE A-98

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - MSY LANDINGS

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	33	.00	.00	.00	.12	.00	.00	.00	.03	.00	.03	.39	.00	.00	.36	.00	.00	.00	.03	.00
727-1	24	.00	.00	.00	.29	.00	.00	.00	.08	.04	.00	.13	.00	.00	.29	.08	.00	.00	.00	.00
727-2	20	.00	.00	.00	.25	.00	.00	.00	.05	.05	.00	.10	.00	.00	.50	.05	.00	.00	.00	.00
737	2	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00
747	6	.00	.00	.00	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.17	.00	.00	.00	.00
DC8-4,5	15	.00	.00	.00	.07	.00	.00	.00	.00	.00	.00	.33	.00	.00	.60	.00	.00	.00	.00	.00
DC8-6	6	.00	.00	.00	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.17	.00	.00	.00	.00
DC9-1,2	24	.00	.00	.00	.25	.00	.00	.00	.08	.04	.00	.25	.00	.00	.33	.04	.00	.00	.00	.00
DC9-3,4	26	.00	.00	.00	.58	.00	.00	.00	.08	.04	.04	.15	.00	.00	.12	.00	.00	.00	.00	.00
DC10	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00
L1011	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.67	.33	.00	.00	.00	.00
C580	9	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BAC-111	1	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 17L

AIRCRAFT	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		LIGHT ELEMENT NOS.																		
707	5	.00	.00	.00	.00	.20	.00	.00	.60	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
727-1	5	.00	.00	.00	.00	.00	.00	.00	.80	.00	.00	.00	.20	.00	.00	.00	.00	.00	.00	.00
727-2	4	.00	.00	.00	.00	.00	.00	.00	.50	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
737	1	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
747	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC8-6	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-1,2	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC9-3,4	3	.00	.00	.00	.00	.00	.00	.00	.67	.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DC10	1	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L1011	1	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C580	2	.00	.00	.00	.00	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

RUNWAY 35R

FIGURE A-99

PROPORTION OF TURNOFFS AFTER EACH LIGHT ELEMENT - DFW LANDINGS

APPENDIX B

The C_{xc} values at various standard deviations used in construction of the curves shown in Figure 102 were calculated with the aid of a computer program (named CXC) written explicitly for that purpose. A listing of Program CXC is provided herein, together with a brief description of its design and a tabulation of the input wheel-spacing dimensions used in generating Figure 102.

Program CXC was written in FORTRAN language and was designed for use on an interactive computer system. Actual processing was done on a CDC-6400 computer, with access from a teletype-terminal. The program, possibly with minor modifications, should be able to operate on any other system allowing interactive processing.

For a given aircraft type, Program CXC will calculate the value of C_{xc} at each of various standard deviations from 1 to 15 feet, at increments of 1 foot, when the following data are input:

a) the total number of wheel (NWHEELS) on the aircraft main landing gear
b) the spacing of wheels, X(I), in inches, relative to the aircraft centerline; where I = 1,....,NWHEELS.

The above data are entered at the terminal when requested by the program. Given a Boeing 727-100, for example, "4" would be entered when "NUMBER OF WHEELS?" is displayed at the terminal; and "-95.5, -129.5, 129.5, 95.5" would be entered when "WHEEL LOCATIONS?" is displayed. (Note--the wheel-spacing dimensions may be entered in any order).

The program output consists of 15 printed lines each containing two sets of numbers--the standard deviation (in inches), followed by the calculated C_{xc} value at that standard deviation.

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A sample program run is shown in Figure B-1, for Boeing 727-100.

A source listing of Program CXC is shown in Figure B-2, and a description of the variable names used in the program is given in Figure B-3. Two subprograms are called by Program CXC. They are SUBROUTINE CALC and FUNCTION F, for which source listings are also shown in Figure B-2. The wheel-spacing dimensions used in generating Figure 102 are shown in Figure B-5.

After initial declarative statements (Lines 100-120), the program queries the user for the number of wheels (Line 130) and wheel locations (Line 150). Responses are entered at the terminal (Lines 140 and 160).

After initializing variables L, D and U, the program enters a 15-cycle loop (Lines 200-405) in which a C_{xc} value is calculated and printed for a different standard deviation value in each cycle of the loop. Starting at a value of 1 foot, the standard deviation is increased by one-foot-increments on successive cycles.

FUNCTION F is called by SUBROUTINE CALC to calculate the ordinate, f(x), of the general normal distribution (see Section VI) at location XX (where $L \leq XX \leq U$), for a particular wheel located at XMEAN (see Figure B-4), as follows:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-0.5\ [(XX-XMEAN)/\sigma]^2}$$

where σ is the standard deviation for which C_{xc} is being calculated.

SUBROUTINE CALC is called by Program CXC to calculate the sum of the ordinates, YP, at location XX, of the general normal distributions which individually represent the respective wheels on the main landing gear of the given aircraft, as follows:

$$YP = \sum_{I=1}^{NWHEELS} f(x)_I$$

```
NUMBER OF WHEELS ? 4
WHEEL LOCATIONS ? -95.5,-129.5,129.5,95.5
 12.0   .033892
 24.0   .025866
 36.0   .019824
 48.0   .015612
 60.0   .012793
 72.0   .010887
 84.0   .009643
 96.0   .008916
108.0   .008618
120.0   .008559
132.0   .008388
144.0   .008145
156.0   .007865
168.0   .007569
180.0   .007273
STOP.
```

FIGURE B-1

PROGRAM CXC SAMPLE RUN - 727-100 AIRCRAFT

```
PROGRAM CXC(INPUT,OUTPUT,TAPE1)
DIMENSION X(100)
REAL L
PRINT,* NUMBER OF WHEELS*,
READ,NWHEELS
PRINT,* WHEEL LOCATIONS*,
READ,(X(I),I=1,NWHEELS)
L=-400.
D=1.
U=400.
DO 10 K=1,15
S=12.*K
CXC=0
I=1
XX=L
1 CONTINUE
CALL CALC(X,NWHEELS,S,XX,YP)
IF(YP.GE.CXC)CXC=YP
XX=XX+D
IF(XX.GT.U)2,1
2 CONTINUE
PRINT 5,S,CXC
5 FORMAT(1X,F5.1,F10.6)
10 CONTINUE
STOP
END
SUBROUTINE CALC(X,NWHEELS,S,XX,YP)
DIMENSION X(100)
YP=0
DO 1 I=1,NWHEELS
YP=YP+F(X(I),S,XX)
1 CONTINUE
RETURN
END
FUNCTION F(XMEAN,SD,X)
F=(1/((SQRT(2*3.14159))*SD))*EXP(-1*((X-XMEAN)**2)/(2*(SD**2)))
RETURN
END
```

FIGURE B-2

PROGRAM CXC SOURCE LISTING

X(I) = Location of Ith wheel relative to the centerline of the aircraft, where I = 1,....,NWHEELS

L = Lower limit (-400 inches) of distance XX

NWHEELS = Total number of wheels on the aircraft main landing system

D = The amount (1 inch) by which XX is incremented

U = Upper limit (400 inches) of distance XX

K = DO-Loop index

S = Standard deviation defining a general normal distribution of the aircraft centerline offsets

CXC = The maximum ordinate of the cumulative normal distribution for all wheels of the aircraft (CXC = Maximum YP)

XX = Distance to a point located between L and U (at increments D), relative to the pavement centerline, at which YP is calculated

YP = The ordinate, at the point defined by XX, of the cumulative normal distribution for all wheels of the aircraft

XMEAN)
SD) = Equivalent of X(I),S,XX, respectively, in FUNCTION F
X)

FIGURE B-3

DESCRIPTION OF VARIABLE NAMES IN PROGRAM CXC

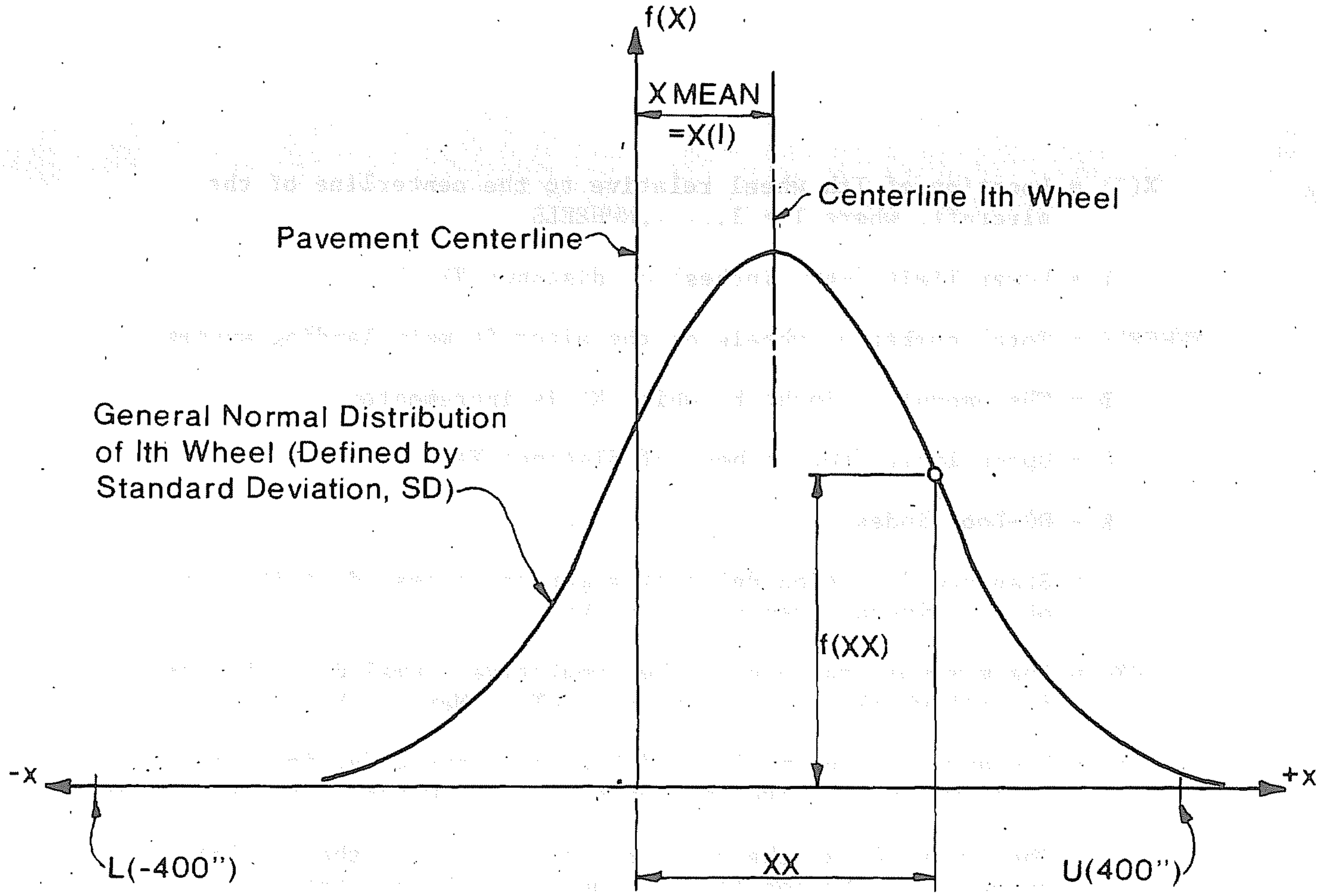

FIGURE B-4

VALUE CALCULATED IN FUNCTION F

AIRCRAFT TYPE	NUMBER WHEELS	WHEEL SPACINGS (INCHES) RELATIVE TO AIRCRAFT CENTER LINE
747	16	-239.0, -239.0, -195.0, -195.0, -97.0, -97.0, -53.0, -53.0, 53.0, 53.0, ~~97.0,~~ 97.0, 195.0, 195.0, 239.0, 239.0
DC-8-40,-50,-60	8	-140.0, -140.0, -110.0, -110.0, 110.0, 110.0, 140.0, 140.0
707	8	-149.6, -149.6, -115.6, -115.6, 115.6, 115.6, 149.6, 149.6
L-1011	8	-242.0, -242.0, -190.0, -190.0, 190.0, 190.0, 242.0, 242.0
DC-10-10	8	-236.0,-236.0, -182.0, -182.0 182.0, 182.0, 236.0, 236.0
BAC-111	4	-96.0, -75.0, 75.0, 96.0
DC-9-10,-20	4	-110.5, -86.5, 86.5, 110.5
DC-9-30,-40	4	-111.0, -86, 86, 111.0
YS-11	4	-183.3, -155.3, 155.3, 183.3
737	4	-118.25, -87.75, 87.75, 118.25
727-100,-200	4	-129.5, -95.5, 129.5, 95.5

FIGURE B-5
AIRCRAFT WHEEL-SPACING DIMENSIONS
INPUT TO PROGRAM C