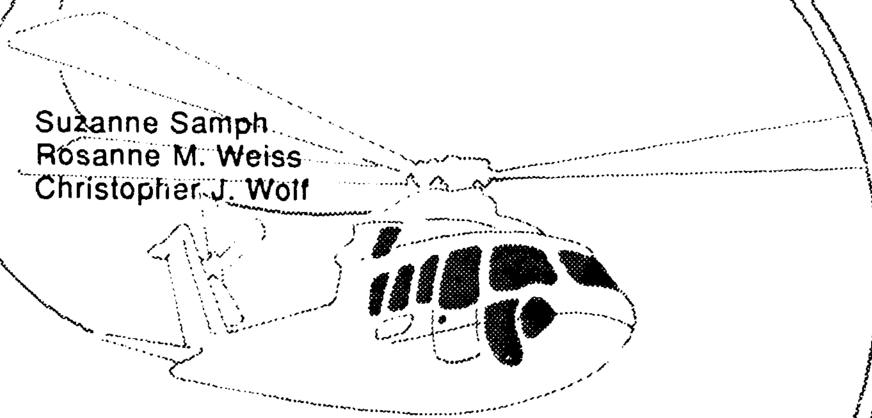
technical note technical note

AD-A226 542

Heliport Visual Approach Surface High Temperature and High Altitude Tests



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May 1990

DOT/FAA/CT-TN89/34

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U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

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16. Abstract

During the summer of 1988 flight tests were conducted at Kirkland Air Force Base, Albuquerque, New Mexico, at an auxiliary landing field. The purpose of these flights was to examine the current heliport approach/departure surface criteria under hot climate and/or high altitude conditions as defined in the Heliport Design Advisory Circular and to verify or modify these surfaces, if appropriate. Data were collected using a Bell UH-1 helicopter for 7.125°, 8.0°, and 10.0° straight-in approach surfaces. Also, straight-in departure surfaces of 7.125°, 10.0°, and 12.0° were used. In addition to these procedures, the pilots were able to choose any angle of approach and departure. All maneuvers were tracked using an onboard Global Positioning System (GPS) system.

This report documents the results of this activity. It describes the flight test and evaluation methodology and addresses technical as well as operational issues. It provides statistical and graphical analysis of pilot performance along with a discussion of pilot subjective opinions concerning the acceptability and perceived workload, safety, and control margins associated with the procedures flown.

The results of this work will be considered in the future modifications of the Federal Aviation Administration (FAA) Heliport Design Advisory Circular, AC 150/53980-2.

17. Key Words

Approach Surface Hot Climate
Departure Profiles
High Density Altitude
Final Approach Take-Off Area (FATO)

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EXECUTIVE SUMMARY

During the summer of 1988 flight tests were conducted at Kirkland Air Force Base, Albuquerque, New Mexico, at an auxiliary landing field. The purpose of these flights was to examine, under hot climate and/or high altitude conditions, the current heliport approach/departure surface criteria as defined in the Heliport Design Guide and to verify or modify these surfaces, if appropriate.

Flight activities were conducted using a Bell UH-1 helicopter. A total of 187 data runs were completed. Three different approach angles, 7.125°, 8.0° and 10.0°, and three departure angles, 7.125°, 10.0°, and 12.0°, were flown for straight-in procedures. In addition to these procedures, the pilots were able to choose any angle of approach and departure. All maneuvers were tracked by an onboard Global Positioning System (GPS) to provide accurate three-dimensional position information. Pilot opinions were also collected using both an inflight and a post-flight rating system. The inflight rating system was based on the pilot's immediate recall of what occurred during the test run. The post-flight system was based on the pilot's opinion of the flight test.

This report documents the results of this activity. The flight test profiles, pilot questionnaires, and ratings are described. Data evaluation and analysis methods are explained. The initial data analysis was accomplished by plotting radar altitude vs range, magnetic heading vs range, vertical gyro pitch vs range, and vertical gyro roll vs range for individual approaches and departures. Summary statistics were calculated and composite plots were created for in-depth analysis of pilot performance. Analysis of the pilot subjective opinions concerning the acceptability and perceived workload, and safety and control margins associated with the procedures flown were also conducted.

According to the flight data, the pilots had no difficulty maintaining consistent angles of approach and departure. However, from the subjective data, the pilots had to work harder to maintain consistent angles of departure and the steeper angles of approach. This was due to aircraft limitations.

It is recommended that part 77 surfaces for visual flight rules (VFR) heliports be revised to include an acceleration area on the order of 200 feet followed by an 8 to 1 or steeper surface.

INTRODUCTION

OBJECTIVES.

The Federal Aviation Administration (FAA) Technical Center's Heliport visual approach/departure surface testing was designed to provide data to validate the current approach/departure surface criteria as defined in the FAA Heliport Design Advisory Circular AC 150/5390-2 dated January 4, 1988. A second objective was to provide data to validate analytical studies of aircraft performance in hot/high altitudes conditions.

The flight test objectives addressed were:

1. The determination of the airspace consumed during visual approaches and departures for hot climate and/or high altitude heliport locations. For purposes of this report, hot/high altitudes are defined as density altitudes in excess of 6000 feet with temperatures in excess of 80°F.

2. The verification or modification of the current FAA Heliport Design Advisory Circular visual approach/departure path surfaces for hot climate and/or high altitude locations. Specific issues addressed are the performance of the pilot and his perception in flying fixed angle approaches and departures in hot/high altitude conditions.

BACKGROUND.

The focus of this test is the issue of airspace and obstruction protection in a hot climate and/or high altitude environment for visual approaches and departures at a heliport. AC 150/5390-2 (January 4, 1988) states:

"The approach surface is an FAR Part 77 Subpart C heliport imaginary surface which is centered on each designated approach and departure route." The approach surface also serves as a departure surface. FAR 77.29(b) defines the approach surface as follows: "the approach surface begins at each end of the heliport primary surface with the same width as the primary surface, and extends outward and upward for a horizontal distance of 4,000 feet where its width is 500 feet. The slope of the approach is 8 to 1 for civil heliports...." The transition surfaces are FAR 77 subpart C heliport imaginary surfaces which extend outward from the lateral boundaries of the primary and approach surfaces. FAR 77.29(c) defines the transitional surfaces as follows: "These surfaces extend outward and upward from the lateral boundaries of the heliport primary surface and from the approach surfaces at a slope of 2 to 1 for a distance of 250 feet measured horizontally from the centerline of the primary and approach surfaces."

The criteria for visual flight rules (VFR) heliport approach and departure surfaces has remained unchanged for a decade or more. Prior to this test, flight tests were conducted at the FAA Technical Center under mean sea level (m.s.l.) and relatively cool climate conditions. Because a helicopter's engine and rotor systems' performance deteriorate with increasing density altitude, it was necessary to conduct further flight tests under hot climate and/or high altitude conditions. Some portions of the rotorcraft industry have argued that the minimum VFR heliport approach and departure airspace is excessive. However, there has been a concern expressed that insufficient data are available to define the minimum required airspace for hot climate and high altitude.

The data collected during this study were designed to measure pilot performance and pilot perception of safety and aircraft control margins associated with various approach and departure surfaces. These tests were not designed to address operational issues such as Category A departure requirements and emergency operations protection. The specific protected airspace issues addressed were surface slope, penetrations of the slope, and the location of the slope penetrations.

METHODS

DATA COLLECTION FLIGHTS.

TEST LOCATION. The flight tests were conducted at Kirtland Air Force Base (AFB), Albuquerque, New Mexico, at an auxiliary landing field. The field is located 6 miles southeast of the Albuquerque International Airport with a field elevation of 5360 feet m.s.l. Figure 1 shows the north traffic pattern for Kirkland AFB auxillary field. This approach was made to slide B. Figure 2 shows the west traffic pattern for Kirkland AFB auxillary field. This approach was made to pad 2. Figure 3 shows the south traffic pattern for Kirkland AFB auxillary. This approach was made to pad 5. For all these patterns, the 7.125° approach was initiated 4000 feet from the helipad. The 8° approach was initiated 3557.7 feet from the helipad, and the 10° approach was initiated 2835.6 feet from the helipad. The 12° departures, for all the patterns, were concluded 470.5 feet from the helipad. The 10° departures were concluded 567.1 feet from the helipad and the 7.125° departures were concluded 711.5 feet from the helipad. The terrain at the flight test location is characterized as nearly level, which permitted the use of radar altitude data in determining the aircraft's height above the ground.

FLIGHT TEST PROCEDURES. A cross section of subject pilots from the private sector, the military, and the FAA were used during these tests. Each subject pilot was asked to fly nine approaches and nine departures, using one of three approach or departure angles.

Each approach started at a specified distance from the helipad and at an altitude of 500 feet above ground level (AGL). The distance to the helipad specified the reference approach angle to be flown (see figures 1-3). These surveyed locations resulted in constant approach angles of 7.125°, 8°, and 10°. The approach was terminated with either a low hover or a landing.

Each subject pilot flew each approach angle at least twice during a flight. In addition, the subject pilot was allowed to fly three approaches using an approach angle of his choice. This yielded a total of nine approaches. The scenarios flown did not include curved approaches due to decreased fuel loads necessitated by high density altitude. In addition, curved approach procedures were restricted because of traffic pattern at the heliport.

The departures also consisted of three different angles: 7.125°, 10°, or 12°.

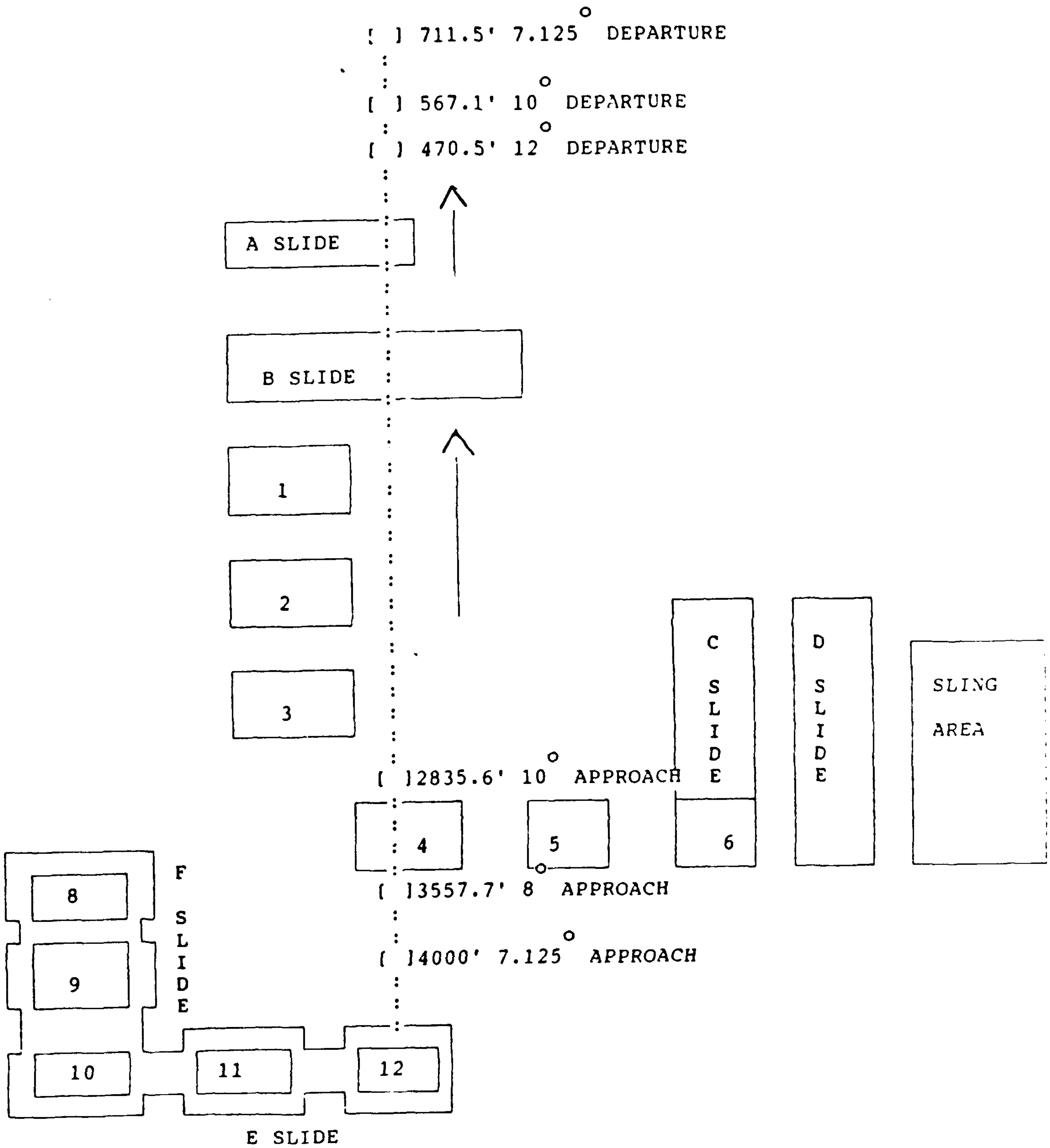


FIGURE 1. KIRKLAND AFB AUXILIARY FIELD NORTH TRAFFIC PATTERN

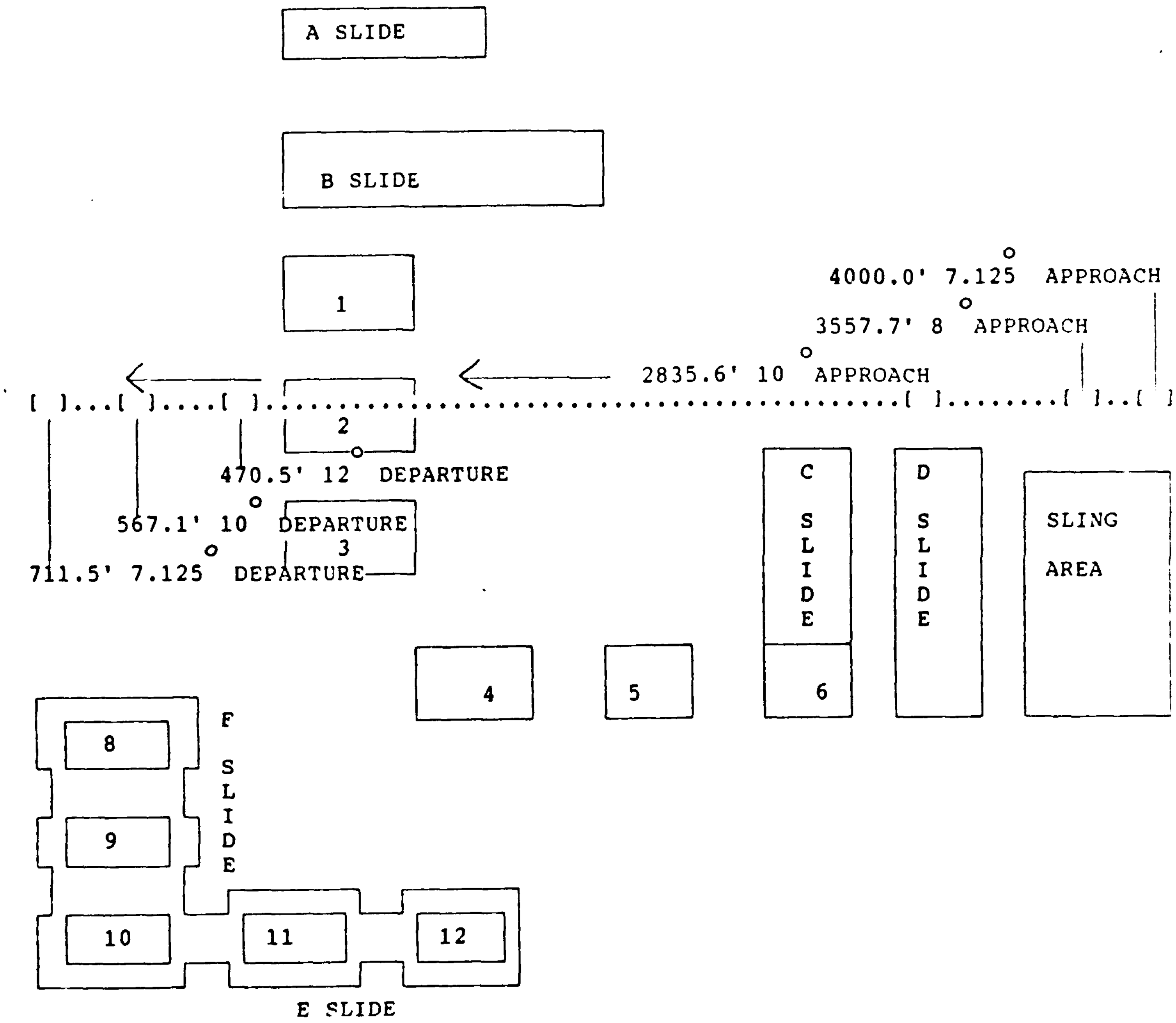


FIGURE 2. KIRKLAND AFB AUXILIARY FIELD WEST TRAFFIC PATTERN

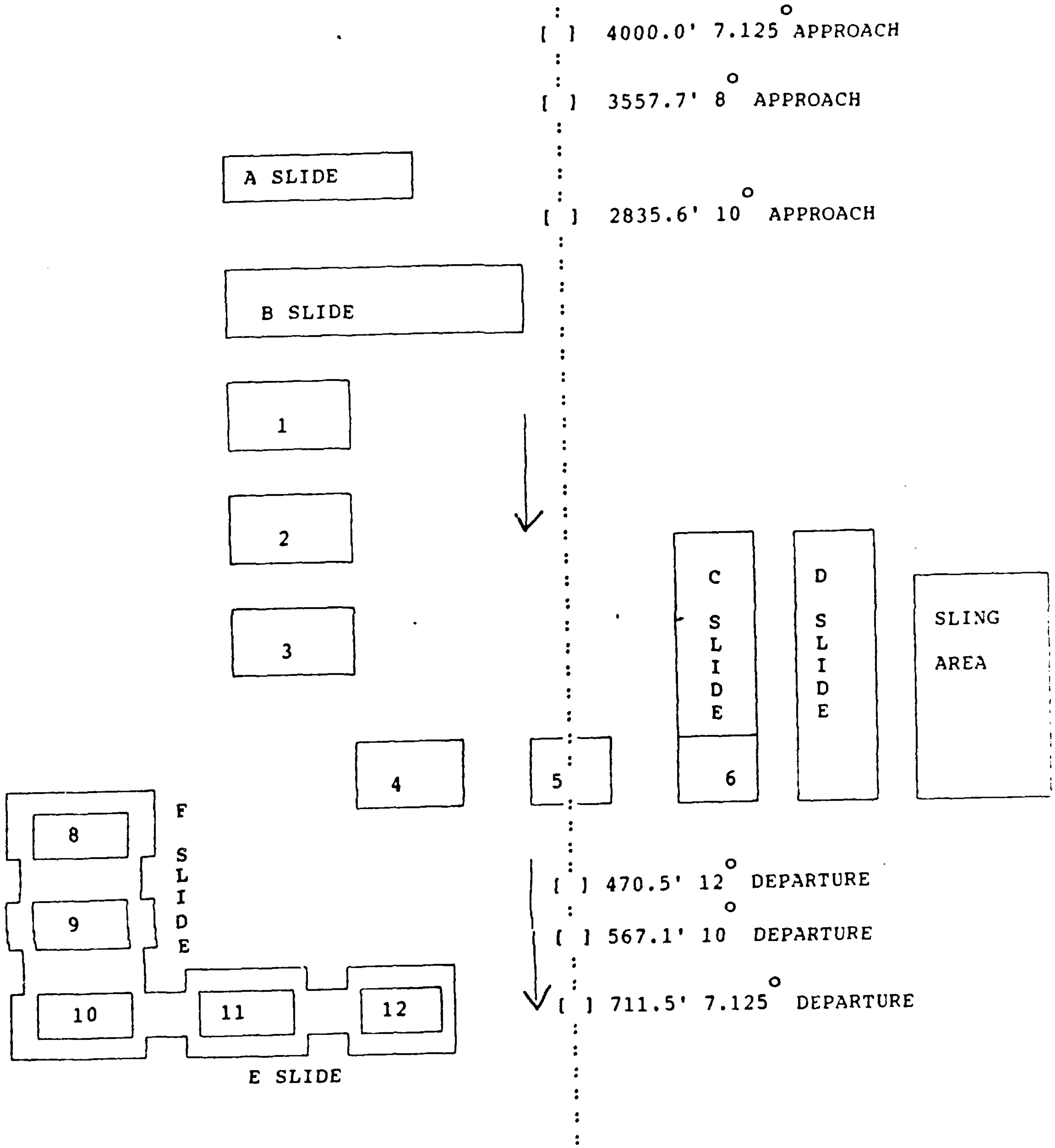


FIGURE 3. KIRKLAND AFB AUXILIARY FIELD SOUTH TRAFFIC FATTERN

The pilot was asked to fly the departure so that he would clear a simulated obstacle 100 feet AGL in height at a specified distance from the heliport (see figures 1-3). The departure began either from the ground or a low hover. As with the approaches, each departure angle was flown twice. The pilot also flew three departure angles of personal choice, yielding a total of nine departures. Curved departures were not flown for the same reasons the curved approaches were not flown. The 7.125° angles set-up approaches and departures that vertically paralleled the current approach/departure surface requirements. Test runs at this angle allowed for measurement of pilot performance against the current standard.

A safety pilot flew on each flight. Except for the pilot choice procedures, the safety pilot told the subject when to initiate the approach and which 100 feet simulated obstacle to clear during the departure. For each approach the safety pilot gave a countdown so that the subject pilot could inititate the approach as close as possible to the surveyed location. To aid in data collection the safety pilot also announced when the aircraft was above each surveyed point in the approaches and departures.

Following each maneuver the safety pilot took the controls while the subject rated the maneuver using a modified version of the Cooper-Harper Rating Scale (figure 4). Subject pilots were thoroughly briefed on the use of the Cooper-Harper Rating Scale during the subject pilot briefing sessions prior to the data collection flight.

A rating between 1 and 3 for the procedure just flown indicates the subject would routinely perform the maneuver. A characteristic rating of 4 to 6 should be interpreted as a subject being willing to only rarely conduct the maneuver. Ratings in excess of 6 indicates the subject felt the maneuver should never be attempted.

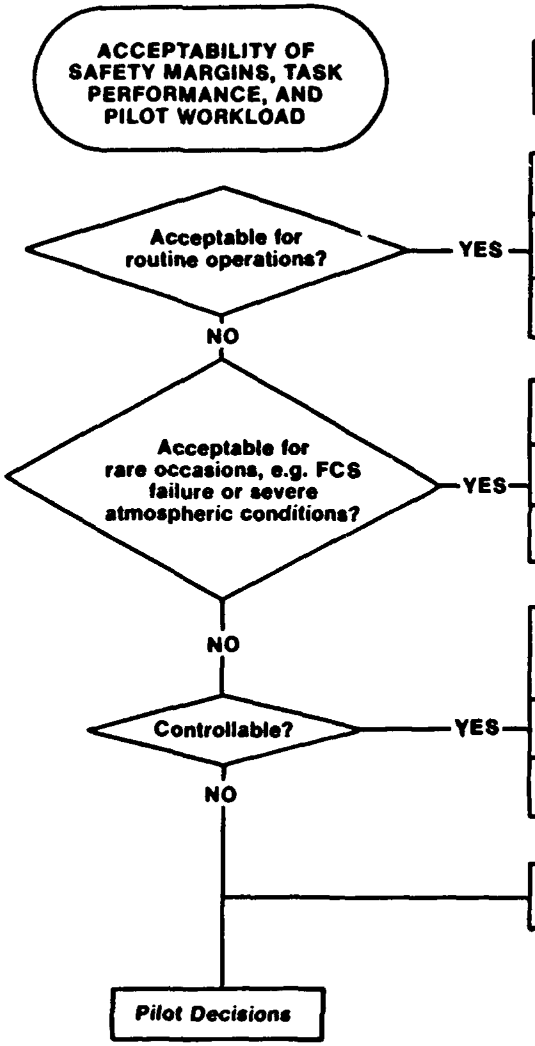
Table 1 identifies the order in which the approaches and departures were flown during a particular flight. The pilot choice maneuvers were flown both at the beginning and end of each flight in order to evaluate any change in pilot perceptions during the conducted flight.

FACILITIES AND INSTRUMENTATION.

TEST AIRCRAFT.

Bell UH-1H. The UH-1H used for this project was assigned to, and maintained by, the Department of the Army, U.S. Army Communications and Electronics Command (CECOM), Fort Monmouth, N.J., and was obtained by an Interagency Agreement. It is a single engine helicopter equipped with electromechanical displays representative of civil instrument flight rules (IFR) certified helicopters. The aircraft was designed to carry up to 14 passengers and a pilot, is capable of speeds up to 120 knots, and has a rotor diameter of 48 feet.

The aircraft was flown at maximum gross weight for in-ground effect hover capability, for the density altitude conditions which were present. Depending on the density altitude conditions present, the fuel load was varied from 8100 to 8400 pounds to obtain maximum gross weight. This test consisted of 198



GENERAL CHARACTERISTICS	SAFETY MARGINS	DEMANDS ON THE PILOT	PILOT RATING
Excellent highly Desirable	Clearly adequate	Pilot compensation not a factor for desired performance	1
Good Negligible Deficiencies	Clearly adequate	Pilot compensation not a factor for desired performance	2
Fair - Some mildly Unpleasant Deficiencies	Clearly adequate	Minimal pilot compensation required for desired performance	3
Minor but annoying deficiencies	Clearly *adequate*	Desired performance requires moderate *pilot compensation*	4
Moderately objectionable deficiencies	Adequate	Adequate performance requires considerabole pilot compension	5
Very objectionable but tolerant deficiencies	Marginal	*Adequate performance* requires extensive pilot compension	6
Major deficiencies	Inadequate	Adequate performance not attainable with maximum tolerable pilot compensation - Controllability not in question	7
Major deficiencies	Inadequate	Considerable pilot compensation is required for control	8
Major deficiencies	Inadequate	Intense pilot compensation is required to retain control	9
Major deficiencies	None	Control will be lost during some portion of required operation	10

FIGURE 4. MODIFIED COOPER-HARPER RATING SCALE

test runs and was conducted between August 9 and August 16, 1988. The environmental conditions present for each flight are presented in table 2.

TABLE 1. FLIGHT TEST APPROACH AND DEPARTURE ORDER

Run	Maneuver	Angle
1	Departure	Pilot's Choice
2	Approach	Pilot's Choice
3	Departure	Pilot's Choice
4	Approach	Pilot's Choice
5	Departure	7.125°
6	Approach	7.125°
7	Departure	7.125°
8	Approach	7.125°
9	Departure	10°
10	Approach	8°
11	Departure	10°
12	Approach	8°
13	Departure	12°
14	Approach	10°
15	Departure	12°
16	Approach	10°
17	Departure	Pilot's Choice
18	Approach	Pilot's Choice

TABLE 2. TEST ENVIRONMENTAL CONDITIONS

Flight	Wind Conditions		Density Altitude	Temperature
Number	Direction	Speed	(ft)	(°F)
1	210	8	8300	92-98
2	170	11	8150	92-98
3	190	5	8300	92-98
4	360	5	8300	92-98
5	360	5	8300	92-98
6	360	5	8100	92-98
7	230	10	8900	92-98
8	230	10	8200	92-98
9	200	15	7200	92-98
10	100	10	7400	92-98
11	Calm	--	6700	84
12	Calm	--	6700	84

AIRCRAFT TRACKING.

Global Positioning System. Precision tracking of the aircraft was accomplished by an onboard Global Positioning System (GPS) receiver. The receiver was manufactured by Collins Radio under the U.S. Air Force GPS User Equipment development contract. This receiver was provided by the GPS Joint Program Office to the U.S. Army Avionics Research and Development Activity (AVRADA), Fort Monmouth, New Jersey.

GPS accuracy was the topic of a Department of the Army Flight Test Program conducted at the FAA Technical Center in December 1986 and January 1987. The flight tests were conducted in the same UH-1H helicopter used for these tests. The GPS accuracy results are described in the AVSCOM Test Report 8412, "Report of Investigative Testing of the Global Positioning System Slant Range Accuracy." During the hot/high altitude test period, the GPS constellation had six operating satellites that provided 2- to 4- hour intervals of four-satellite coverage over selected geographical areas. For the purpose of GPS, the masking angle is the minimum angle of satellite elevation at which that satellite's signal is usable. For this test a 5° or better masking angle was needed. The four-satellite coverage period began shortly after noon at the test locations. This resulted in the best satellite coverage when the density altitude conditions were approaching their peak.

SUBJECT PILOTS.

The selection of pilots participating in this project was based primarily on the qualifications and availability of the individuals. Subjects were obtained from industry, military, and government agencies. In order to comply with the operating procedures of the Department of Army, all the pilots were required to be qualified and current in the aircraft, in accordance with provisions of Army Regulation 95-1. The affiliations of the subject pilots are listed in table 3.

Subject pilot total helicopter experience ranged from 1000 to 7800 hours with time in type over the last 6 months ranging from 20 to 130 hours. The subject pilots were questioned about the percentage of their rotorcraft flight time conducted under high density altitude conditions. A summary of the UH-1H subject pilots experience is presented in table 4.

TABLE 3. SUBJECT PILOT AFFILIATION

Affiliation	Number
FAA	3
Military	1
Industry	3

TABLE 4. SUBJECT PILOT EXPERIENCE

Total Flight Hours	Number of Pilots	Total Helicopter Hours	Number of Pilots
0-5000	2	0-2500	4
5001-10000	4	2501-5000	1
>10000	1	>5000	2

Total Time in UH-1H	Number of Pilots	Total Helicopter Hours Last 6 Months	Number of Pilots
0-1000	2	0-50	3
1001-2500	2	51-100	2
>2500	3	>100	2

Total Time in UH-1H Last 6 Months	Number of Pilots
0-50	4
51-100	2
>100	1

High Density Altitude Flight Times as a Percentage of Total Flight Time	Number of Pilots
0-10	3
11-20	2
>20	2

SUBJECT PILOT BRIEFINGS.

Each subject received a project information packet and a preflight briefing which explained the purpose of the test flight activities and the flight profiles (see appendix A for a sample of the information packet). This included a detailed description of the approaches and departures which were to be flown. In addition to the above information, the responsibilities of the subject pilot and safety pilot were defined. Local area conditions and aircraft operating information were also discussed. This included planned maximum gross weight, density altitude, and wind conditions.

In most cases, when the premission briefing was completed, an approach and departure procedure was flown to familiarize the subject pilot with test procedures and data collection activities.

DATA PROCESSING AND ANALYSIS

SOURCE OF DATA.

Test data came from four sources: in-flight pilot ratings of the procedures, observer flight logs, post-flight questionnaire and ratings, and the airborne data collection tape.

IN-FLIGHT PILOT RATINGS. The in-flight questionnaire was designed to provide immediate subject response following a particular maneuver. Each subject pilot was asked to rate each approach and departure using his perception of pilot workload, safety margin, and control margin (aircraft controllability/flyability). This rating was obtained after each procedure was flown, using a modified version of the Cooper-Harper Rating Scale (figure 4). Pilot responses were recorded on an observer log by the data technician.

OBSERVER FLIGHT LOG. The data technician was responsible for filling in the observer log during each flight. Pilot name, flight date, and start/stop times for each approach/departure available were recorded. Subject pilot comments, aircraft parameters (such as torque and maximum gross weight) and local weather and wind conditions were also noted. See appendix B for a sample obse'ver log.

POST-FLIGHT QUESTIONNAIRE. At the conclusion of the last flight, each pilot was given a post-flight questionnaire to complete (see appendix C). This questionnaire asked for the subject's opinion about issues such as the suitability of the approach/departure, control and safety margins, and workload. The post-flight questionnaire was designed to provide comparative subject pilot measures across all test profiles. Pilot background information was also collected such as the number of flight hours and aircraft experience. Other questions asked for the subject pilot input regarding the publication of maneuver and surface information and heliport factors. This information was analyzed and correlated with pilot performance.

AIRBORNE DATA COLLECTION TAPE. Airborne data were collected onboard the UH-1H helicopter. These data focused on aircraft state and control positions. The data collected are presented in table 5. The data collection system is based on a Motorola 6809 microprocessor package which is a combination of an off the shelf data package and FAA designed and built interface boards. The information is stored utilizing a Kennedy magnetic tape recorder.

TABLE 5. DATA COLLECTION PARAMETERS

Parameters	Units	Minimum Sample Rate/Second	Resolution Level
Time	Hours/minutes/seconds	5	0.001 sec
Aircraft Heading	Degrees	5	0.022 deg
Radar Altitude	Feet	5	1.732 ft
Vertical Gyro Pitch	Degrees	5	0.02? deg
Vertical Gyro Roll	Degrees	5	0.022 deg
GPS Time	Hours/minutes/seconds	1	10E-39 sec
Position (x,y,z)	Feet	1	10E-39 m
Standardized Figure of Merit	--	1	10E-39

ANALYSIS PROCEDURES.

FLIGHT DATA. Flight data were provided from two possible sources: the airborne data collection tape and the observer flight logs. The observer logs chronologically listed specific events that occurred during the various approaches and departures, along with wind information and other miscellaneous information and comments.

STATISTICS. Statistical calculations were performed on the airborne data. The arithmetic mean and the unbiased estimate of the standard deviation for the magnetic heading were calculated on a per run basis. Overall statistics were calculated for magnetic heading, vertical gyro (VG) pitch and VG roll. All plotting done for the project was accomplished using a California Computer (Calcomp) 1051 drum plotter using Calcomp 907 software for the VAX 11/750 computer. The formulas used can be found in Theory and Problems of Statistics, by Murray R. Spiegel, Ph.D, Schaun Publishing Company, New York, 1961. Examples of the types of plots compiled are described below.

FLIGHT DATA PLOTS. The plots were prepared on a per run basis in which each individual run of a particular flight was plotted separately. All plots depict the final approach take off area (FATO) as a square. Plots were generated for several parameters of interest in both the time domain and range domain. Radar altitude in feet and pitch and roll in degrees were plotted. Magnetic heading in degrees versus time in seconds were also plotted, with the dotted line representing the intended flightpath. Peak negative and positive magnetic headings for all 7.125° runs were calculated by subtracting the course heading for each run from the peak positive and negative headings for that run, then all peak positive and negative headings were averaged together. Other plots were generated for radar altitude in feet versus range in feet and VG pitch and roll attitude in degrees versus range in feet. Magnetic heading in degrees was plotted versus range in feet with the dotted line representing the intended flightpath. Examples of these plots are presented in figure 5.

Composite plots of radar altitude in feet versus range in feet for the 7.125° approaches, 8° approaches and 10° approaches were also generated along with composite pilots for the 7.125°, 10°, and 12° departures. The dashed line depicts the reference surface. These plots show how the subject pilots flew compared to the actual angle (see figures 6 through 11).

Plots of maximum undershoot and overshoot in feet versus range from the FATO for all approaches were also produced. The maximum undershoot is the largest deviation below the approach surface. These plots present the location of the maximum undershoot point for each approach. The maximum overshoot is the largest deviation above the reference surface for each approach. These plots present the location for the maximum overshoot for each run. Figures 12 through 17 present these plots.

RESULTS

Data resulting from this project will be considered in the updating of the current Heliport Design Guide Advisory Circular.

DATA PLOTS.

Plots for data cases of magnetic heading, roll, and VG pitch for all procedures can be found in division report ACD-330-90-7, "Data for Heliport Visual Approach Surface High Temperature and High Altitude Tests." Approaches

HOT/HIGH ALTITUDE TESTS USING THE UH1 PROCESSING DATE: 14-OCT-1988 13:44:29.73
7.125 DEGREE STRAIGHT IN APPROACH
FLIGHT: 02 RUN NO: 4 RUN START: 13:20:23.0 RUN STOP: 13:21:35.0
DATA PROCESSED BY FAA TECHNICAL CENTER -- ATLANTIC CITY AIRPORT NJ., 08405

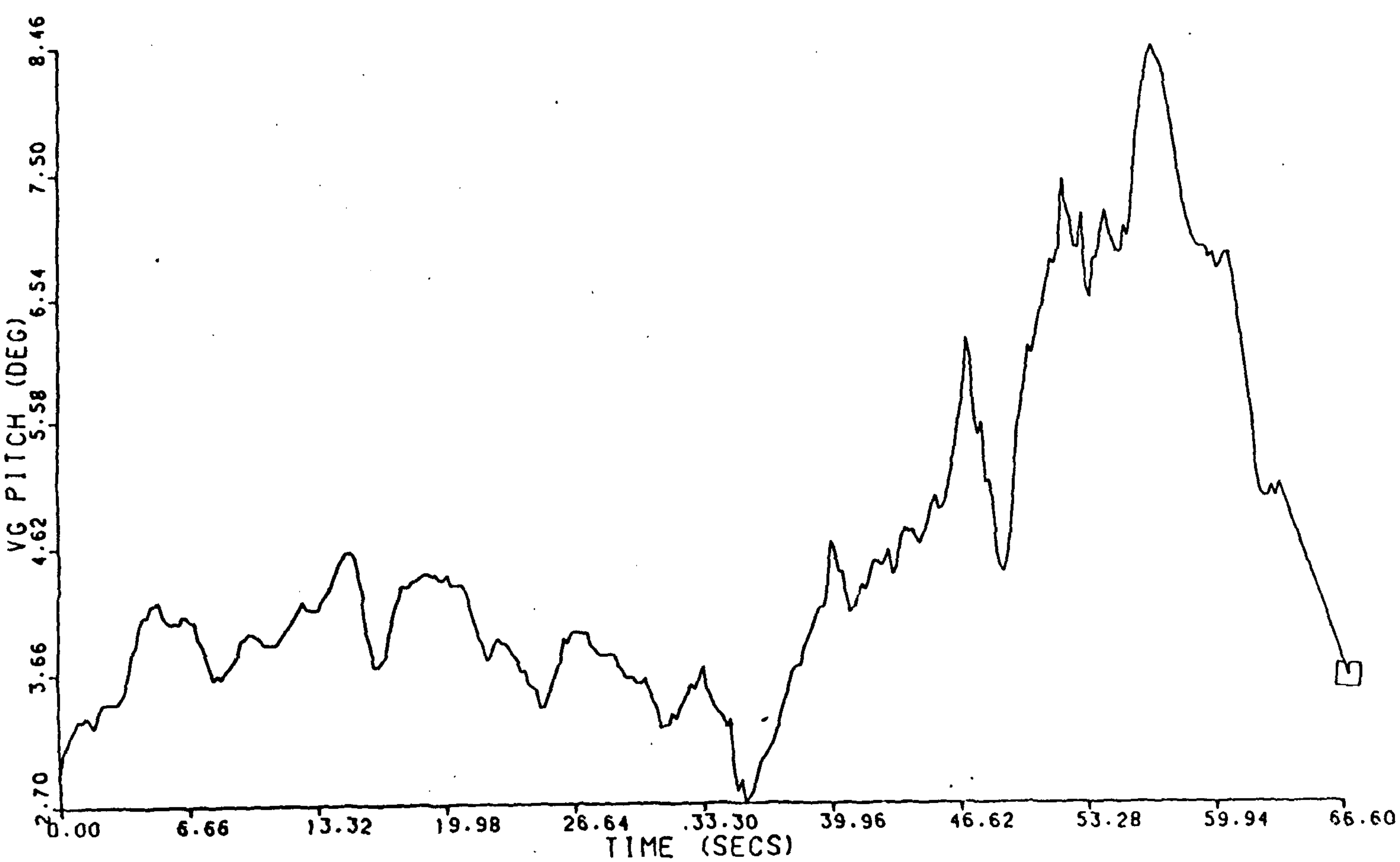


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMAT (SHEET 1 OF 7)

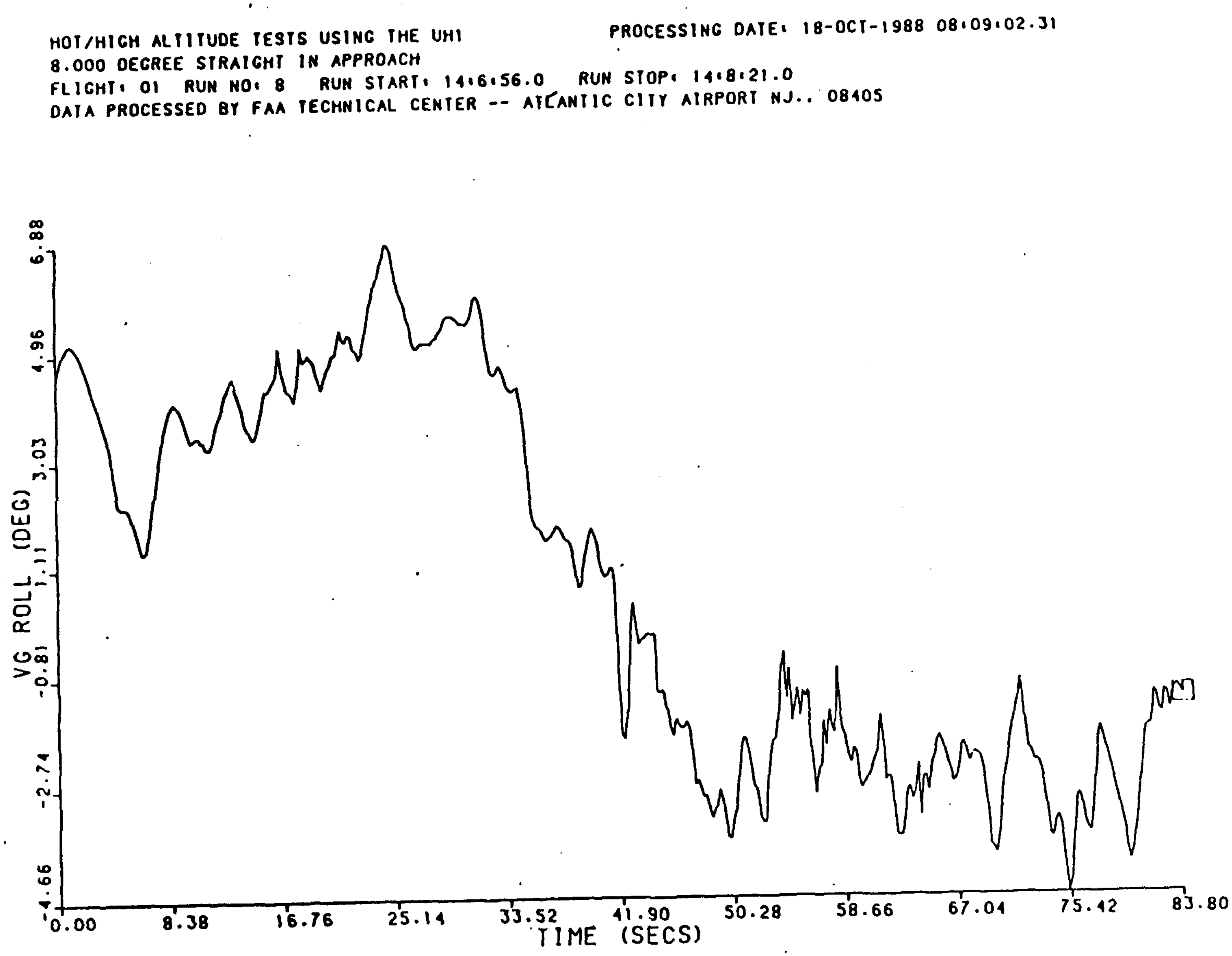


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMAT (SHEET 2 OF 7)

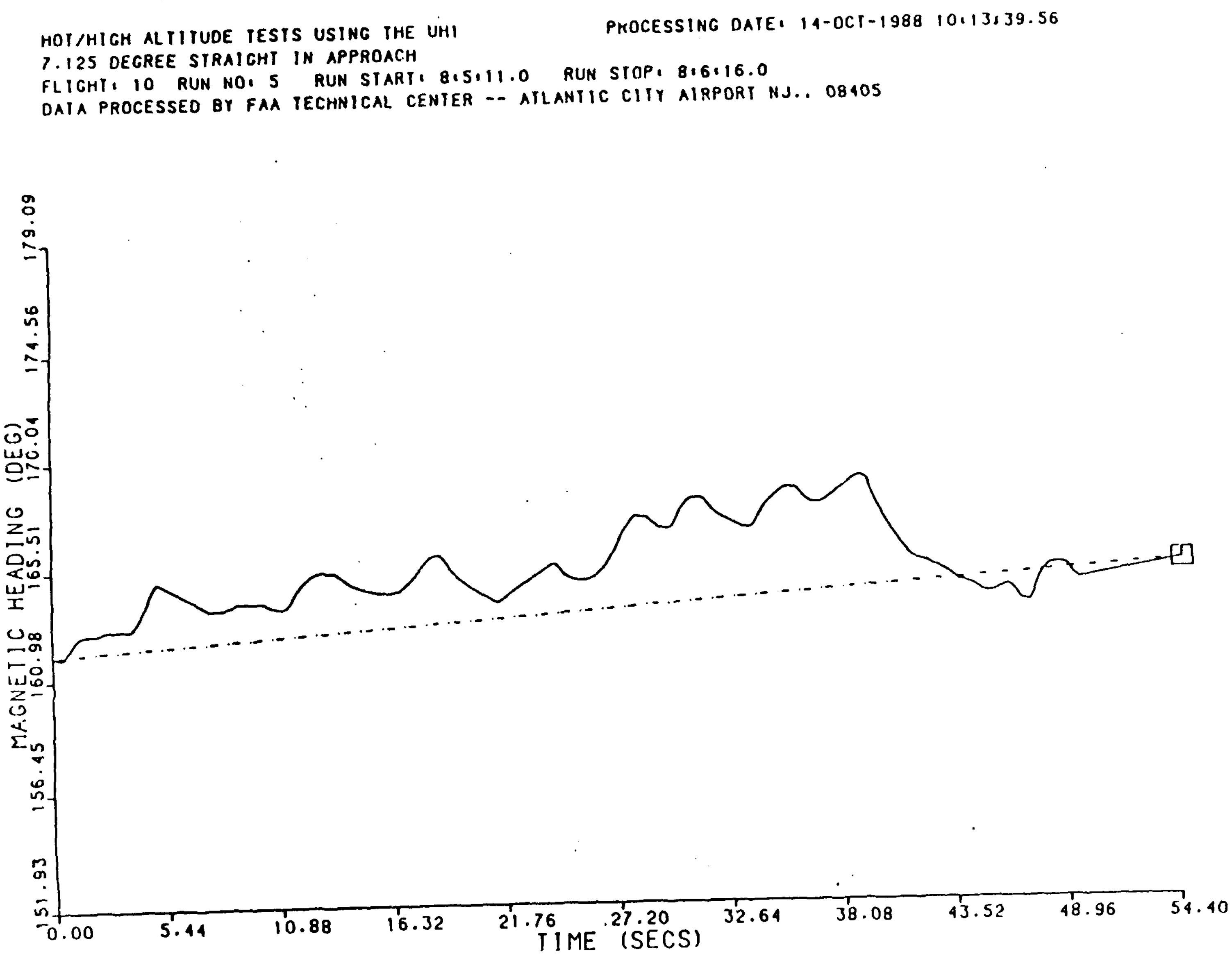


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS (SHEET 3 OF 7)

HOT/HIGH ALTITUDE TESTS USING THE UHI PROCESSING DATE: 13-OCT-1988 12:36:12.08
8.000 DEGREE STRAIGHT IN APPROACH
FLIGHT: 06 RUN NO: 12 RUN START: 13:53:1.0 RUN STOP: 13:54:10.0
DATA PROCESSED BY FAA TECHNICAL CENTER -- ATLANTIC CITY AIRPORT NJ.. 08405

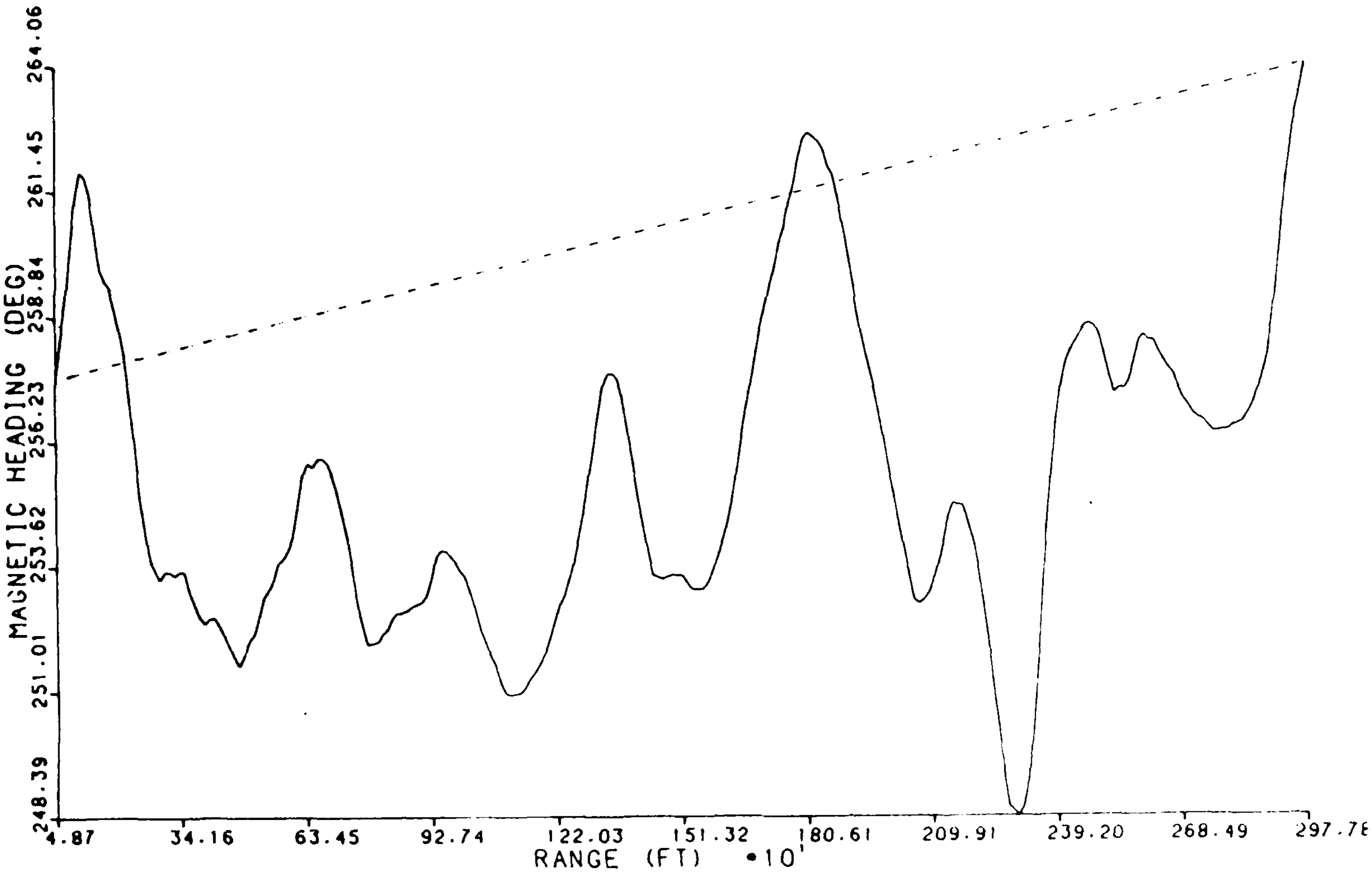


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS (SHEET 4 OF 7)

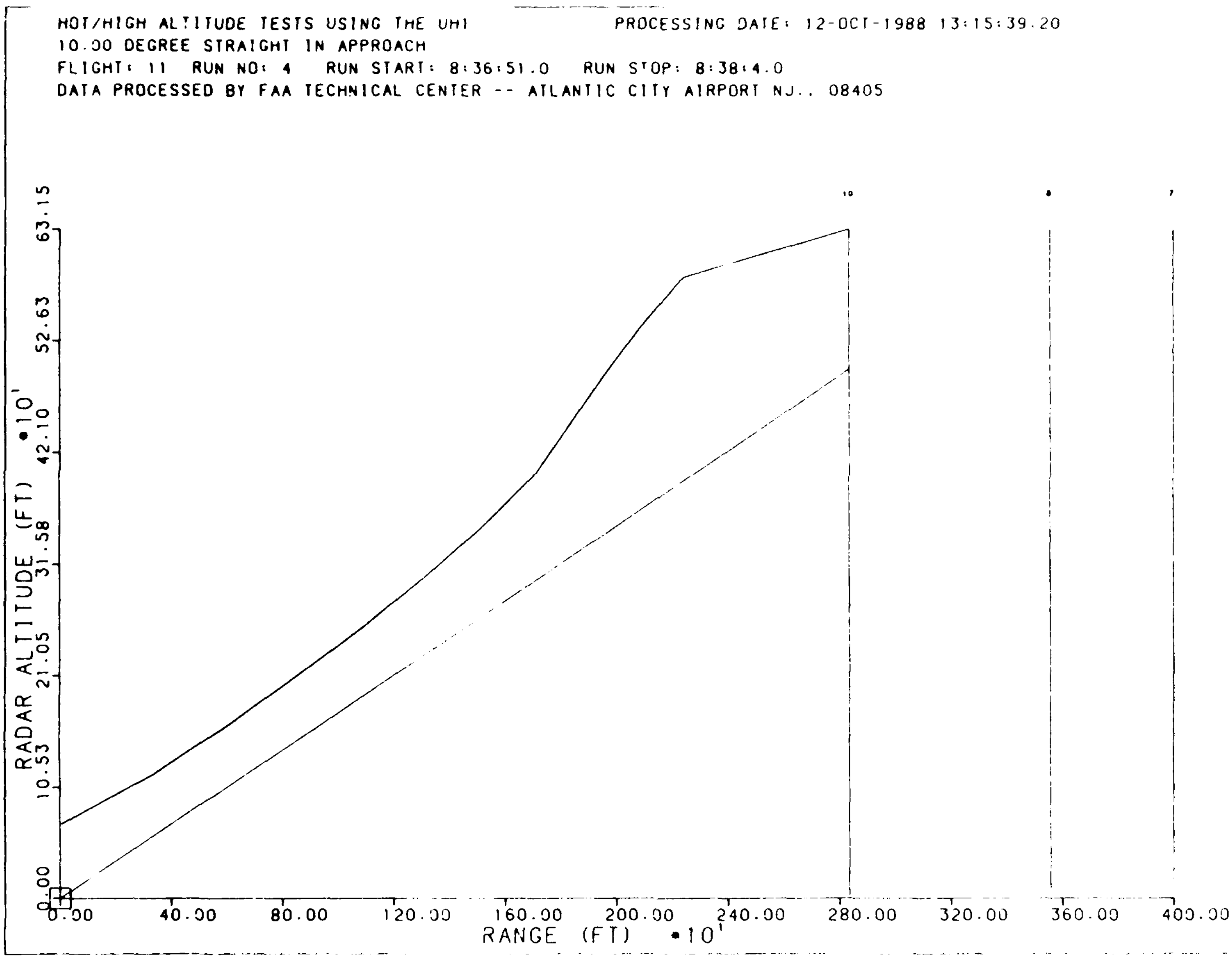


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS (SHEET 5 OF 7)

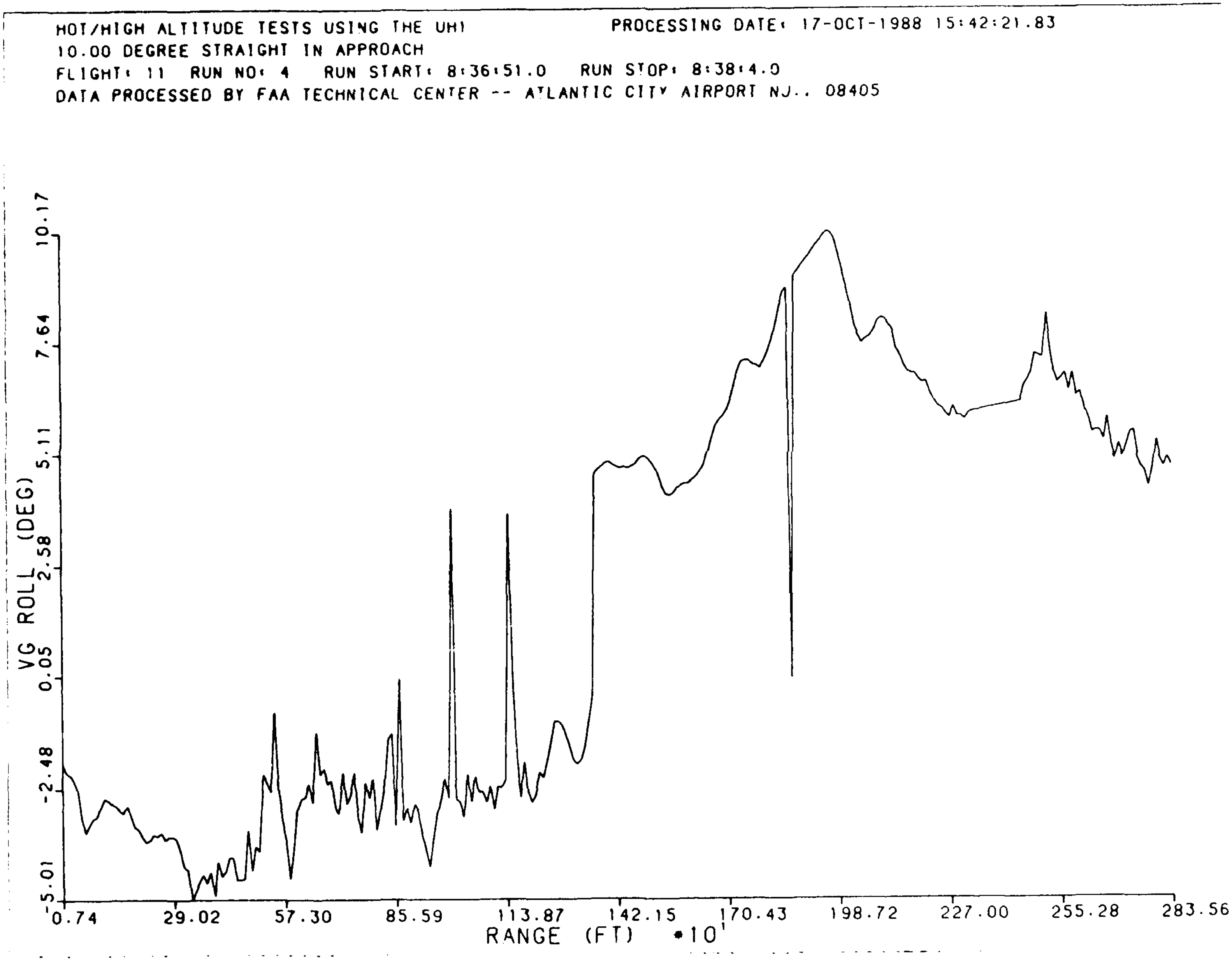


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS (SHEET 6 OF 7)

HOT/HIGH ALTITUDE TESTS USING THE UH1 PROCESSING DATE: 14-OCT-1988 13:17:54.50
10.00 DEGREE STRAIGHT IN APPROACH
FLIGHT: 11 RUN NO: 4 RUN START: 8:36:51.0 RUN STOP: 8:38:4.0
DATA PROCESSED BY FAA TECHNICAL CENTER -- ATLANTIC CITY AIRPORT NJ., 08405

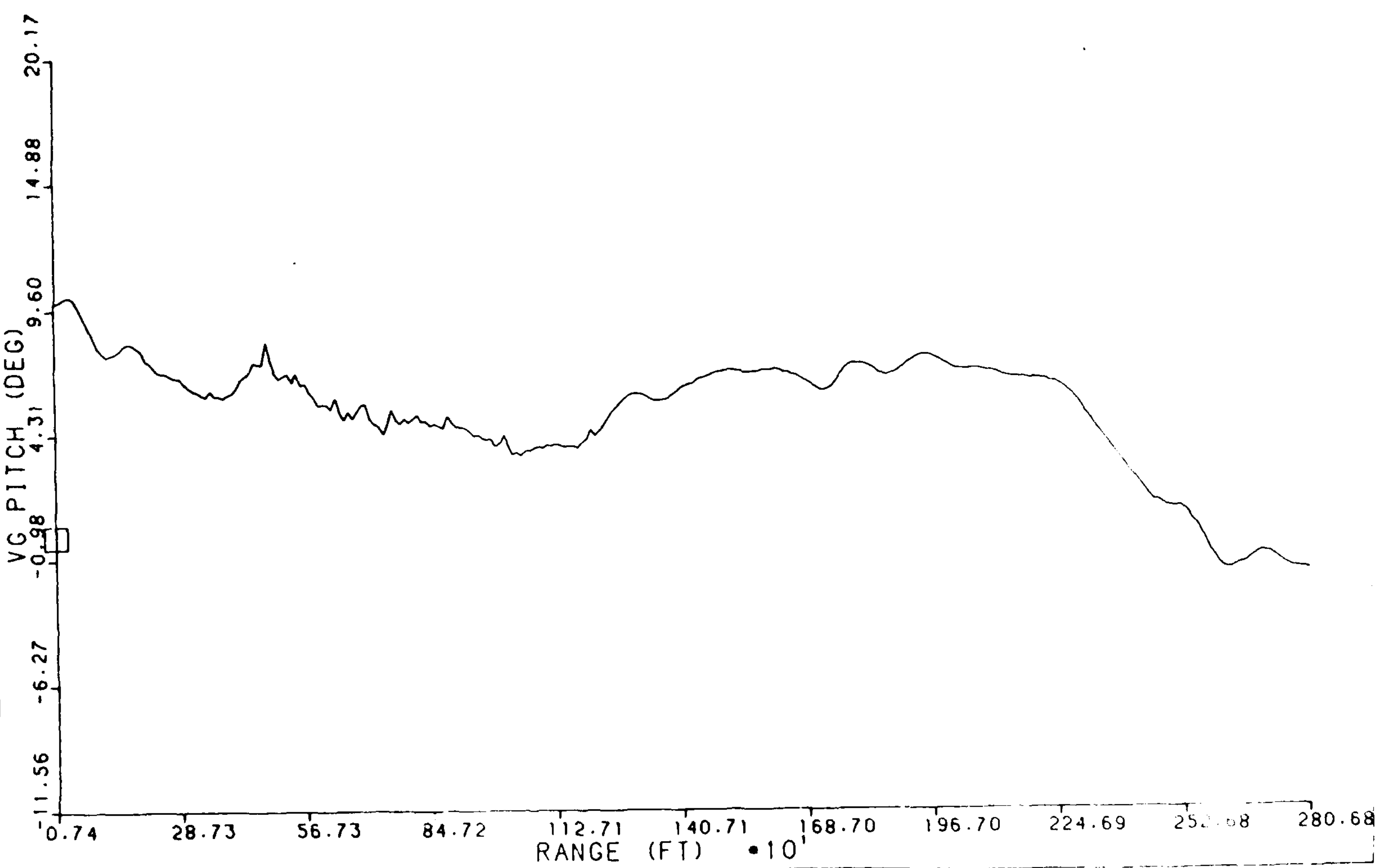


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS (SHEET 7 OF 7)

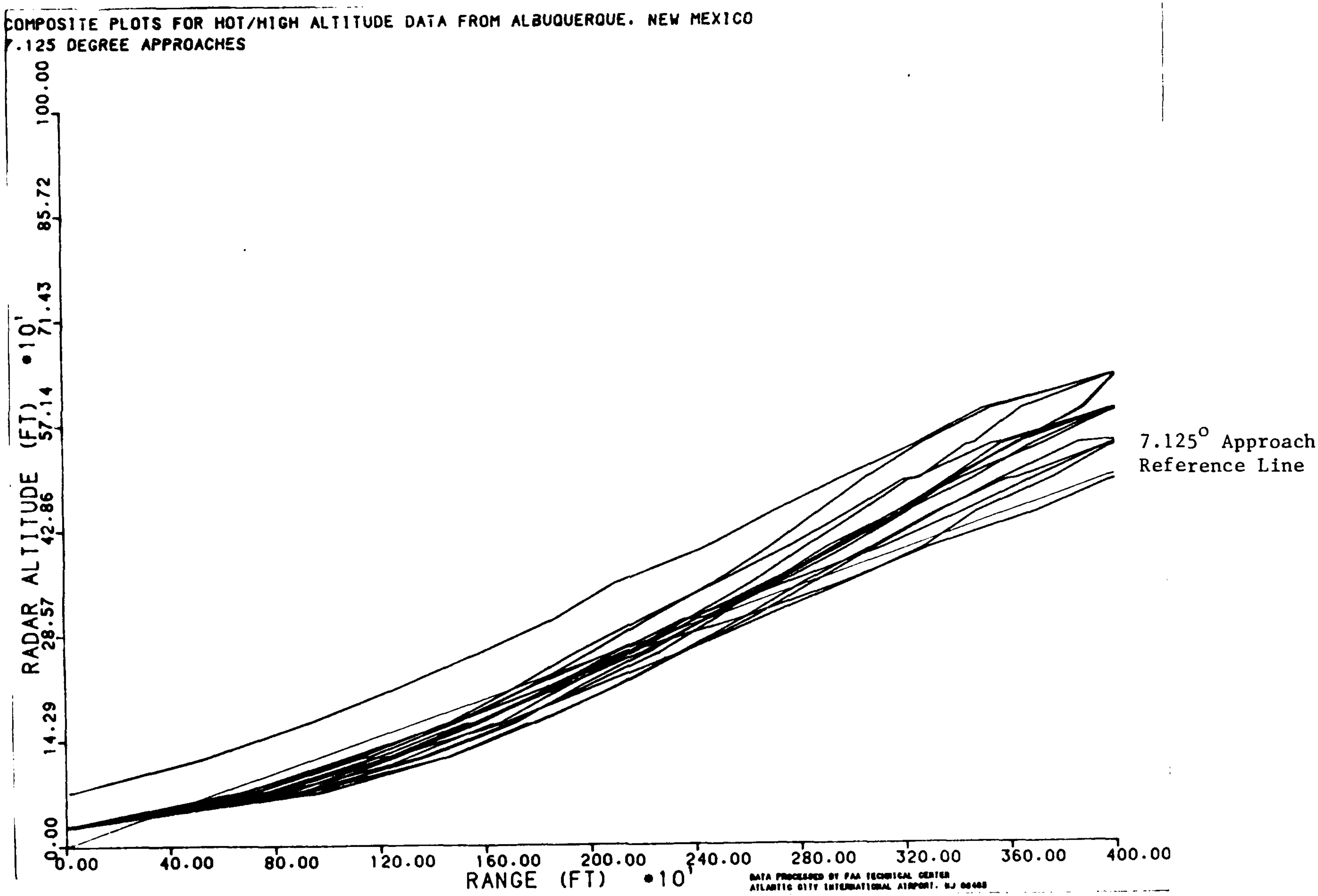


FIGURE 6. 7.125° COMPOSITE APPROACH PLOT

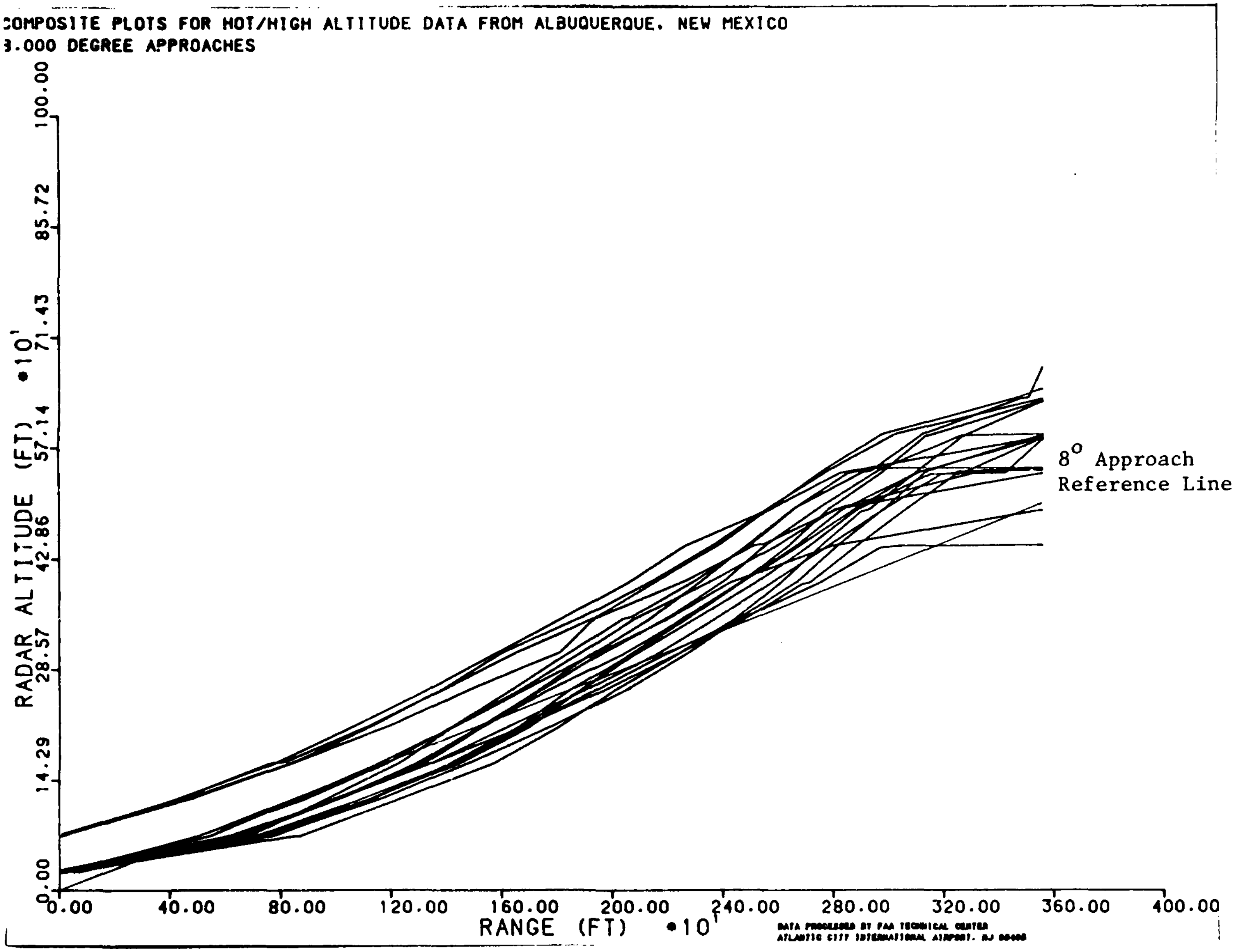


FIGURE 7. 8.0° COMPOSITE APPROACH PLOT

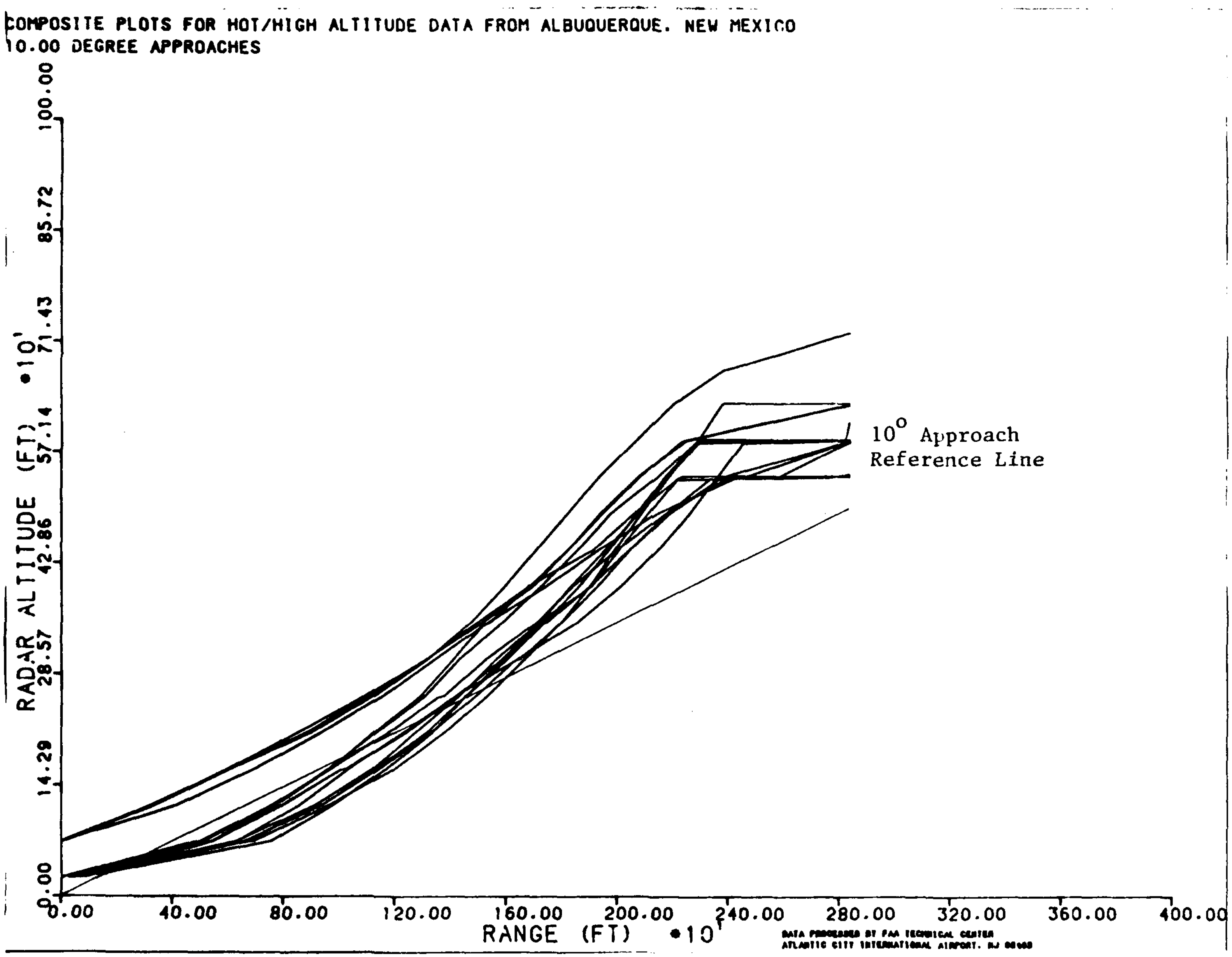


FIGURE 8. 10.0° COMPOSITE APPROACH PLOT

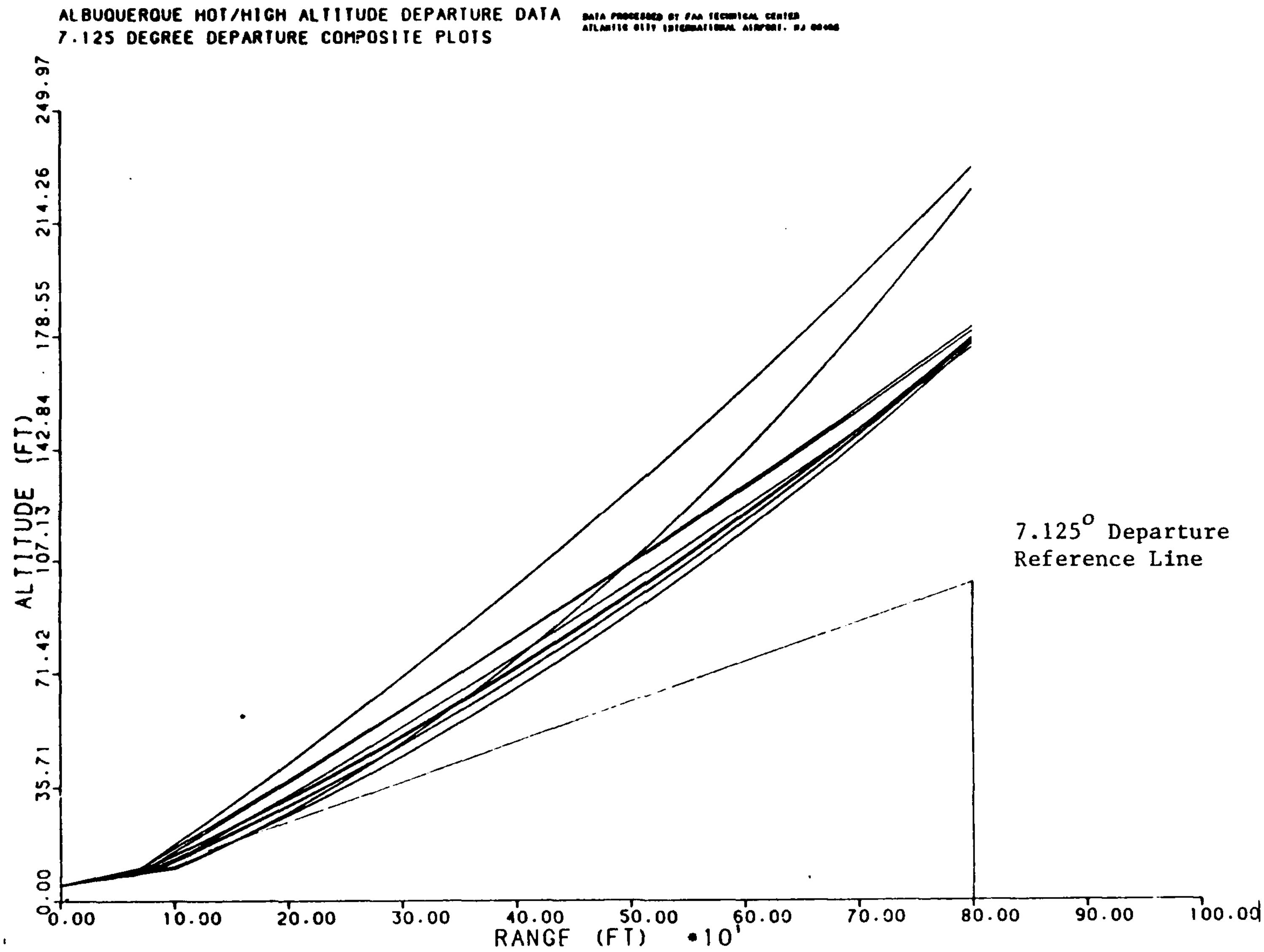


FIGURE 9. 7.125° COMPOSITE APPROACH PLOT

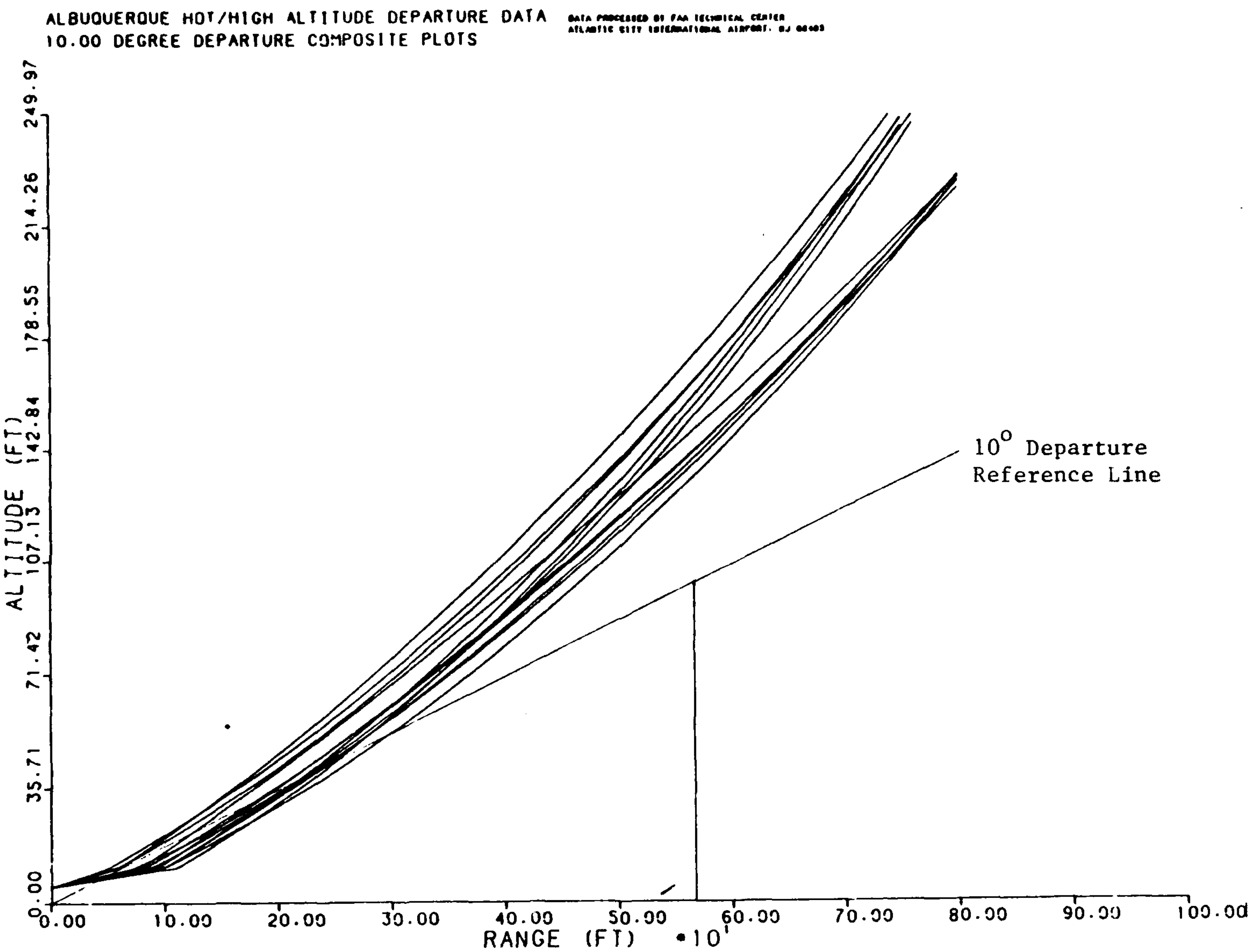


FIGURE 10. 10.0° COMPOSITE DEPARTURE PLOT

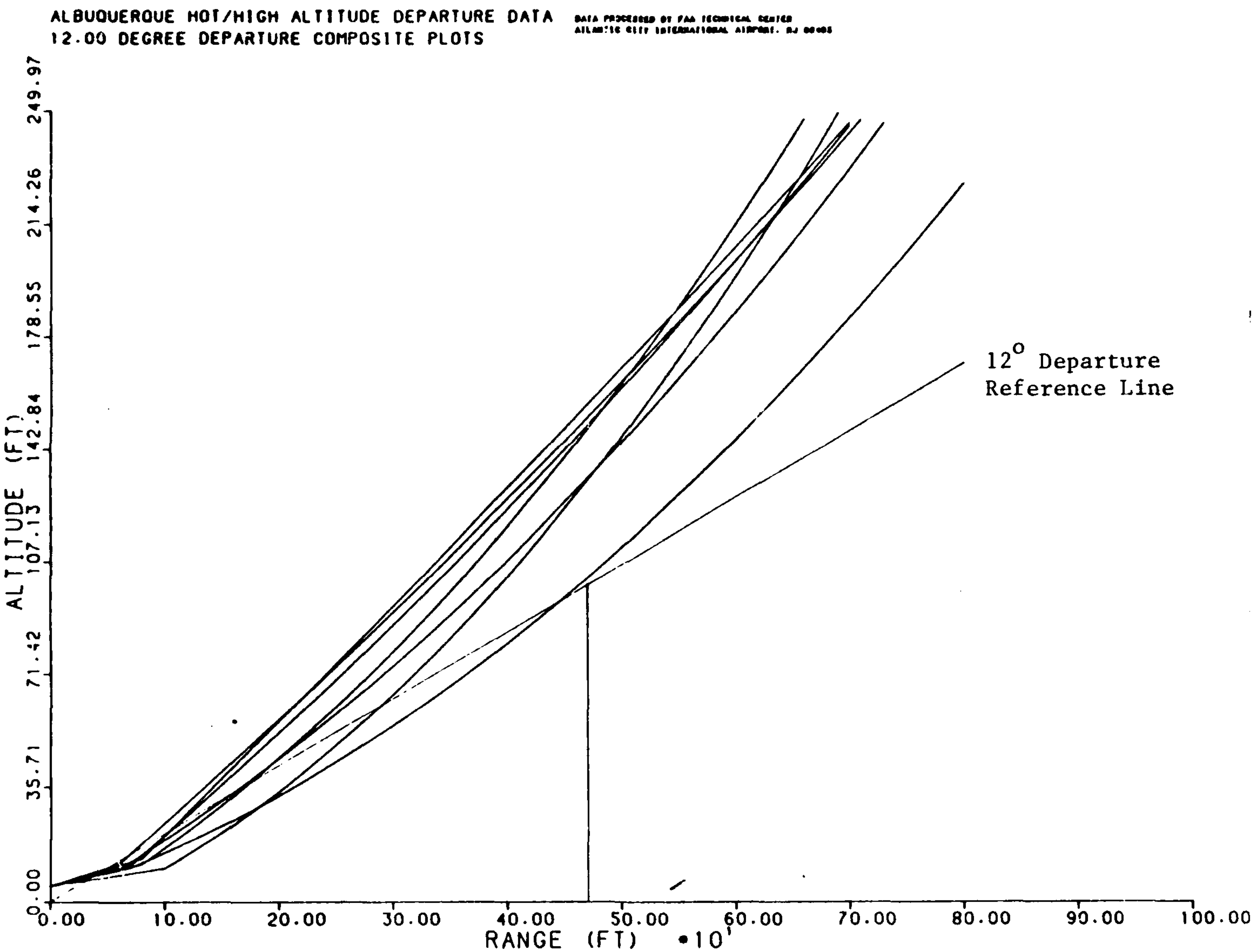


FIGURE 11. 12.0° COMPOSITE DEPARTURE PLOT

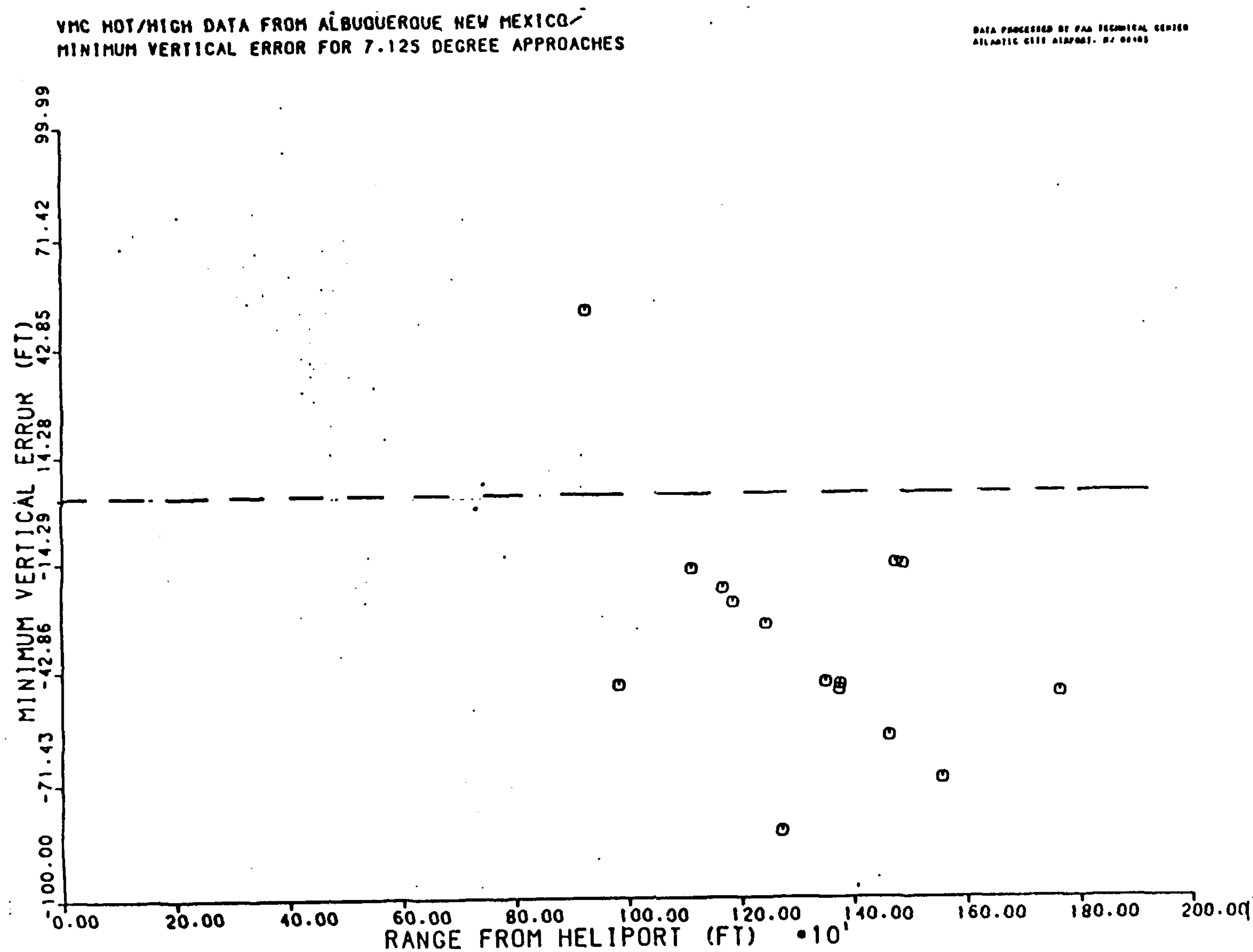


FIGURE 12. 7.125° COMPOSITE APPROACH PLOT OF MINIMUM VERTICAL ERROR (MAXIMUM UNDERSHOOT)

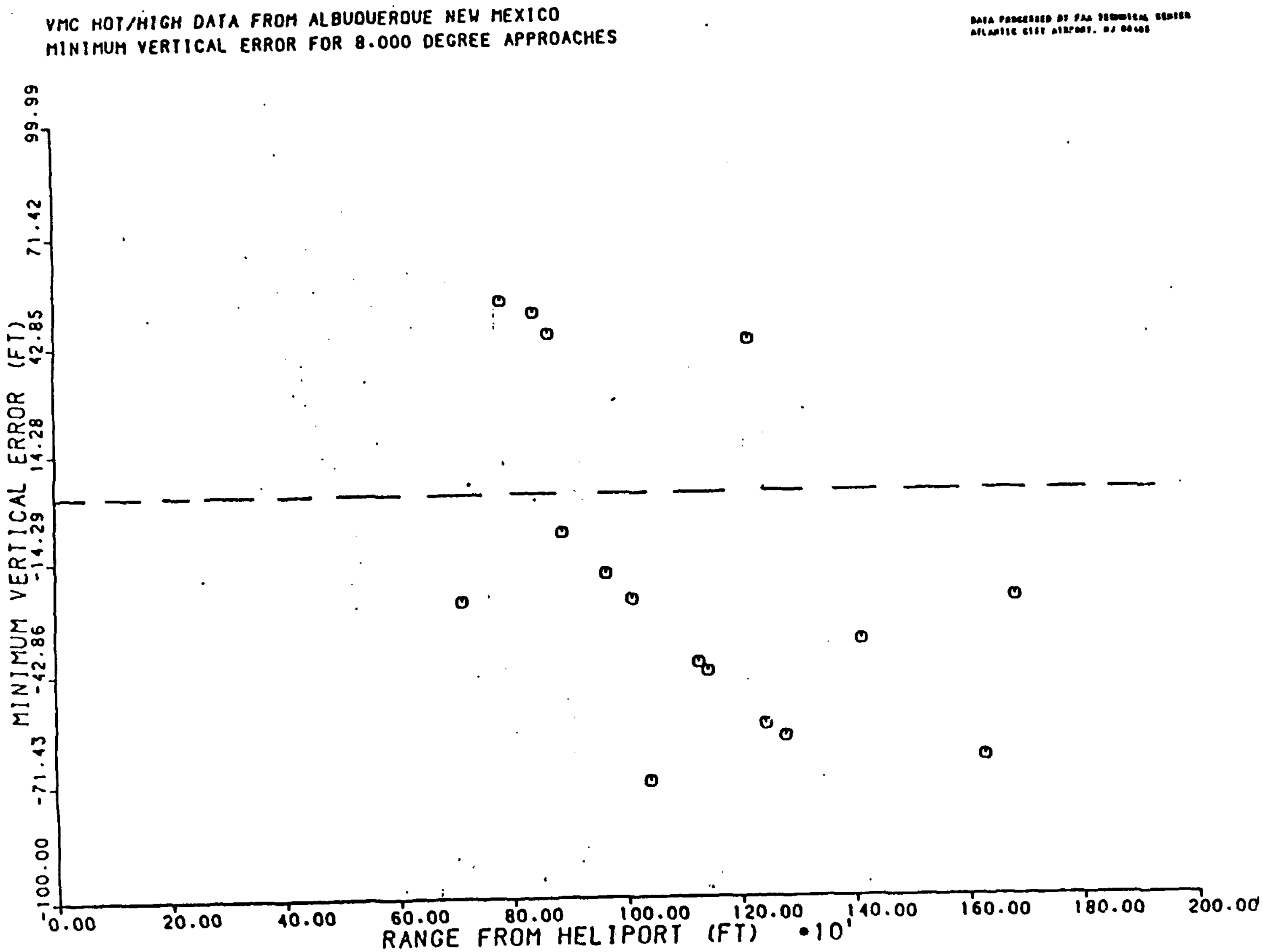


FIGURE 13. 8.0° COMPOSITE APPROACH PLOT OF MINIMUM VERTICAL ERROR (MAXIMUM UNDERSHOOT)

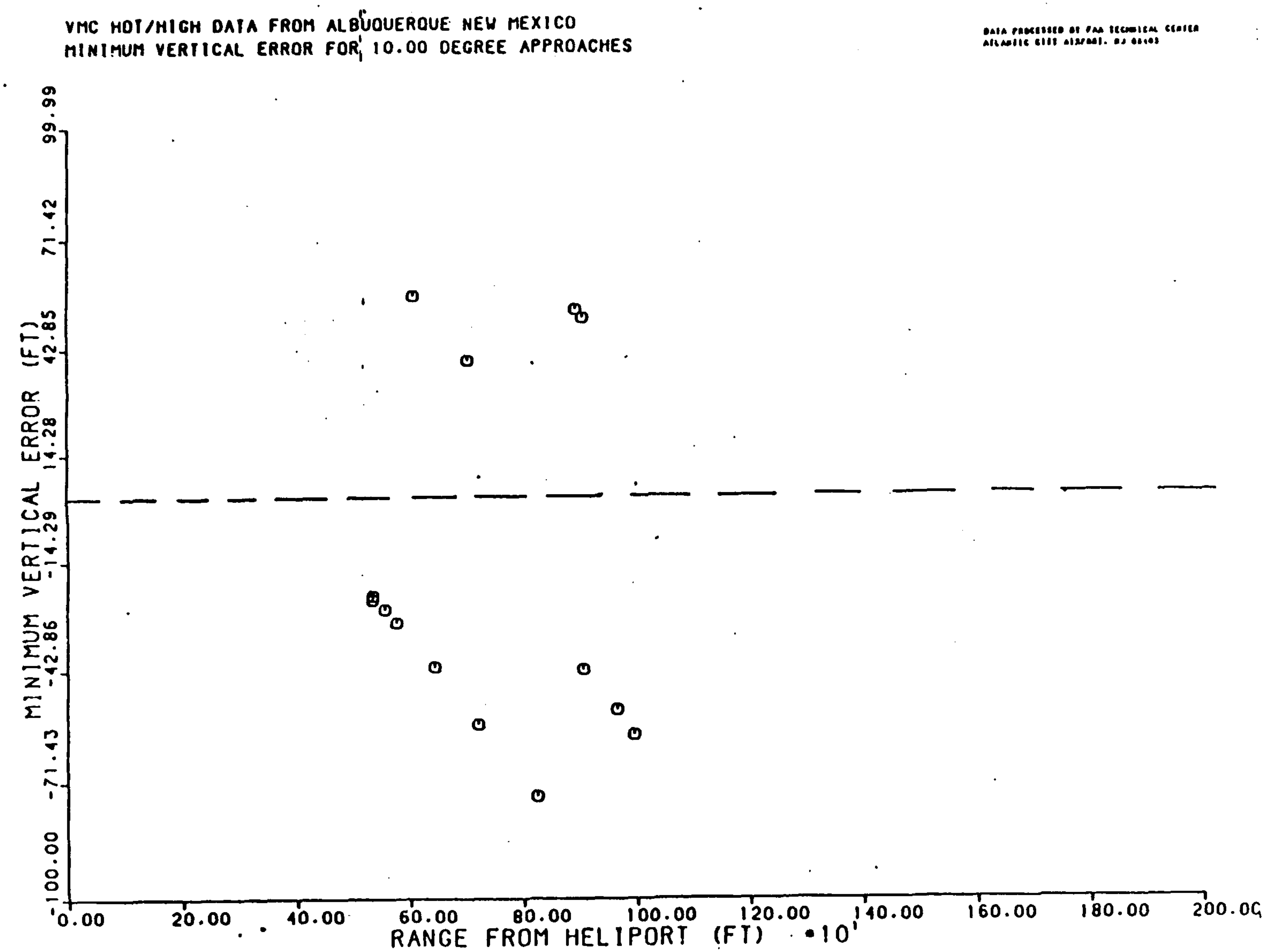


FIGURE 14. 10.0° COMPOSITE APPROACH PLOT OF MINIMUM VERTICAL ERROR (MAXIMUM UNDERSHOOT)

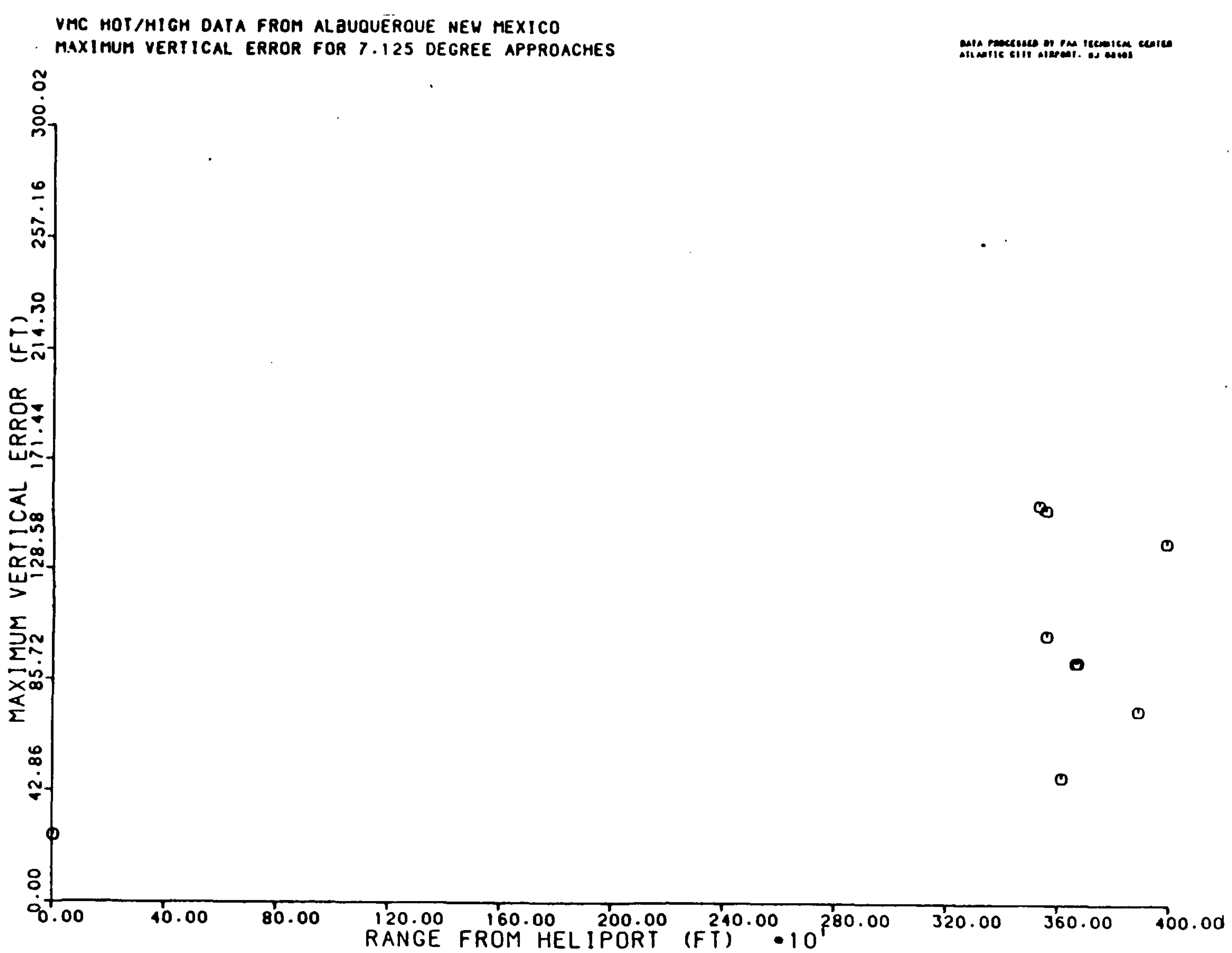


FIGURE 15. 7.125° COMPOSITE APPROACH PLOT OF MAXIMUM VERTICAL ERROR (MAXIMUM OVERSHOOT)

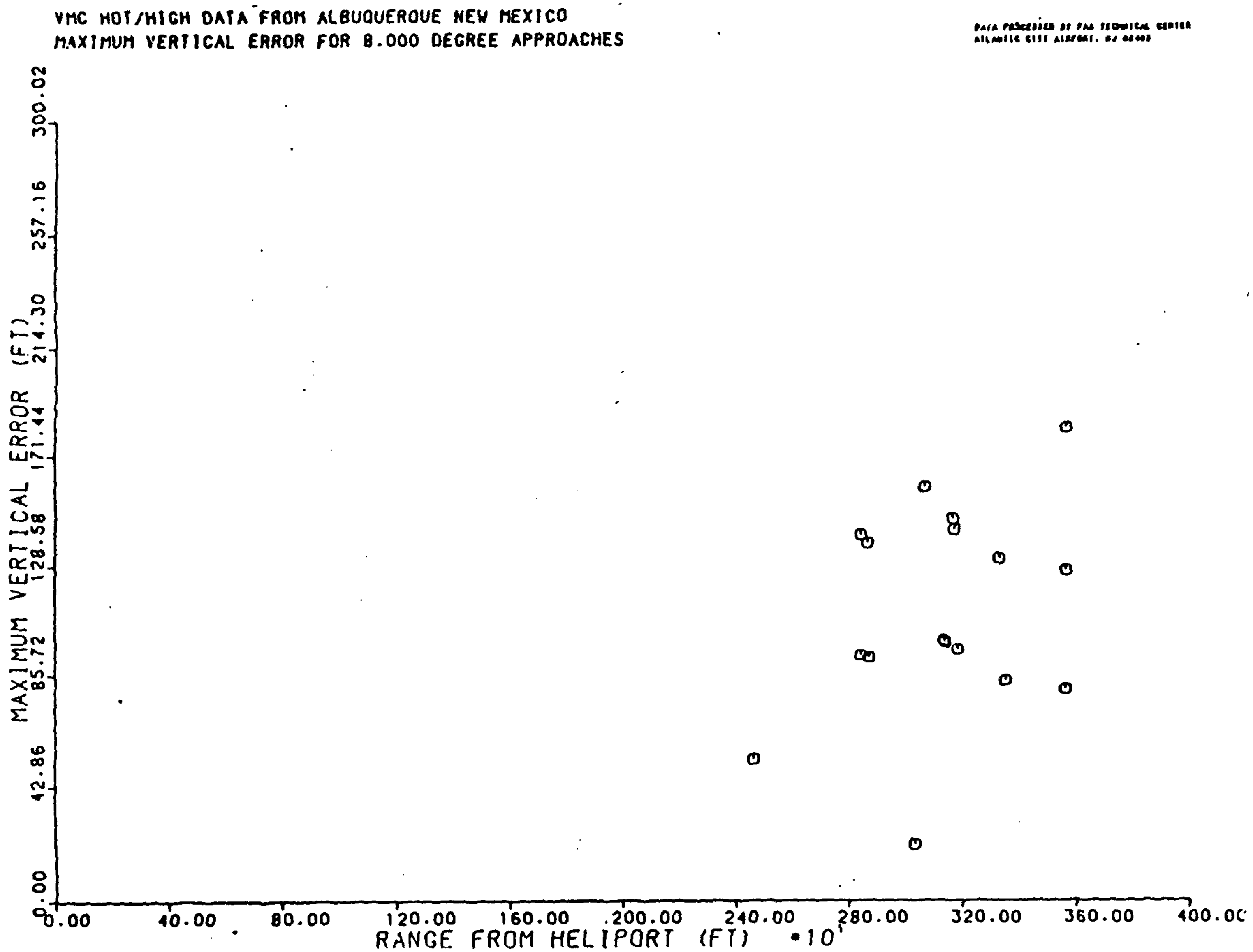


FIGURE 16. 8.0° COMPOSITE APPROACH PLOT OF MAXIMUM VERTICAL ERROR (MAXIMUM OVERSHOOT)

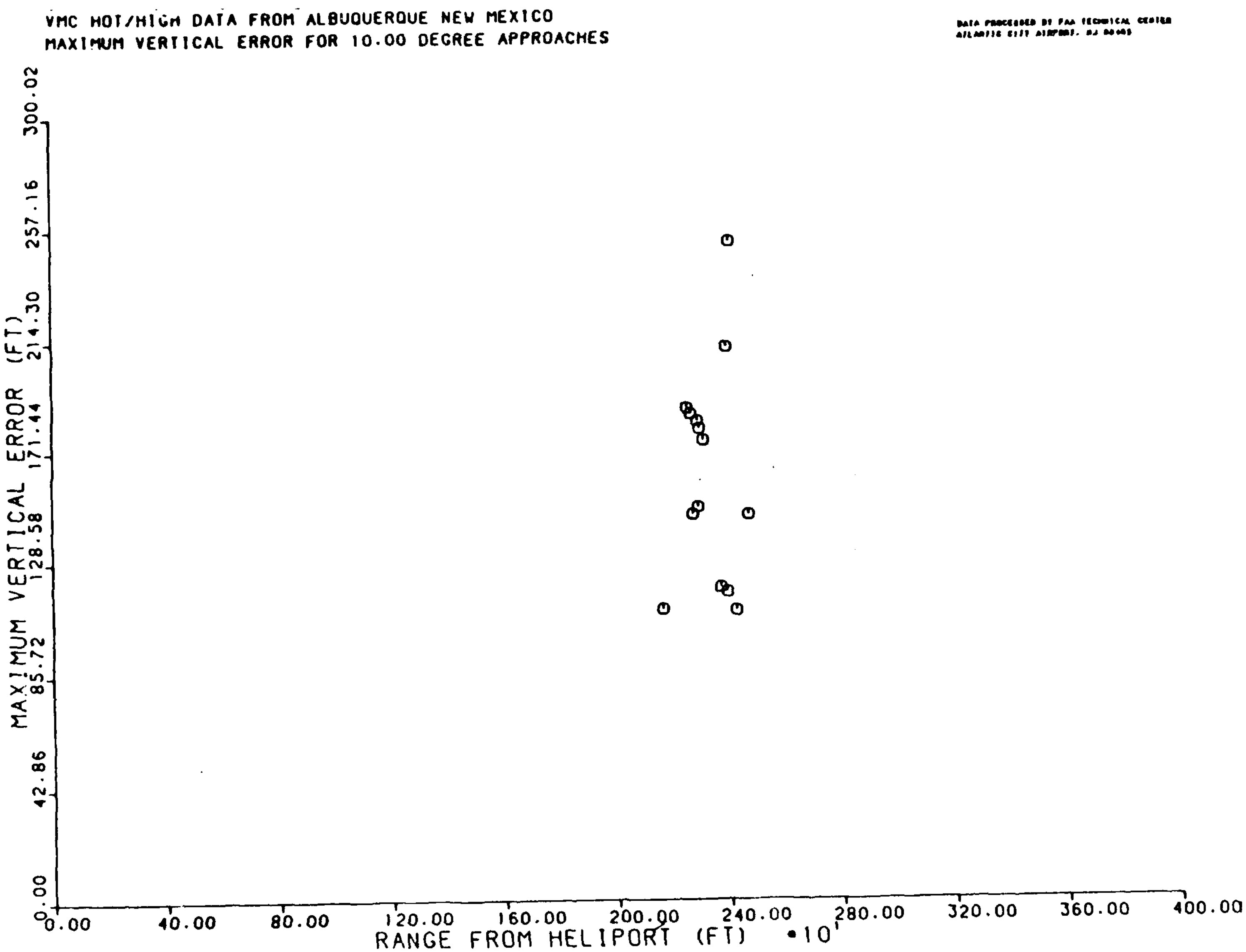


FIGURE 17. 10.0° COMPOSITE APPROACH PLOT OF MAXIMUM VERTICAL ERROR (MAXIMUM OVERSHOOT)

and departures were oriented so the pilot was always flying with a head wind. Three FATO's were used to support this orientation. The first FATO had a course headings of 160°, the second heading was 250° and the third heading was 340°. It must be remembered that for all approaches, there were no obstacles to aid in defining the desired surface. A negative number for VG pitch indicates the aircraft moved down while a positive number indicates up. A negative number for VG roll indicates the aircraft moved left and positive indicates right. Large variations in magnetic heading, VG pitch, and VG roll implies increased pilot workload. A positive undershoot indicates the pilot never operated below the reference angle.

APPROACHES.

7.125° Approaches. Figure 6 presents the composite 7.125° approach results. All but one approach were initiated above the reference surface. However, pilots did not maintain a consistent approach angle to touchdown. With the exception of one approach, all resulted in penetration of the 7.125° approach surface. The initial penetration points ranged from 1600 to 2800 feet from the FATO. The maximum penetration was 70 feet.

Figure 12 shows the plot of maximum undershoot for the 7.125° approaches. For one run, the pilot never operated below the reference surface resulting in a positive undershoot. The remaining runs had errors ranging from -15 to -83 feet. These undershoots occurred between 983 and 1760 feet from the FATO. Figure 15 shows the plot for the maximum overshoot for the 7.125° approaches. Results show a majority of maximum overshoots occurred very early in the approach between 3500 and 4000 feet from the FATO. The errors ranged from 45 to 165 feet. The one exception occurred right at the FATO (20 feet).

Tables 6, 7, and 8 show the magnetic heading, VG roll, and VG pitch data for all 7.125° approaches. Table 9 lists the mean values for these data. The standard deviation for magnetic heading for each run ranged from 1.50° to 4.68°. The large standard deviation of 4.68° occurred because the peak positive heading was 192° and the peak negative heading was 164°. The peak positive heading occurred at the beginning of the run and the event mark may have been cued before the actual start of the run. The mean peak positive magnetic heading for all 7.125° runs is 7.81° and the mean peak negative magnetic heading is -4.60°. Lateral heading changes were minimal for all 7.125° approaches. This indicates pilots had little difficulty in maintaining their course.

The 7.125° approach data for VG roll show the peak positive roll events occurring between 4.57° and 11.23°. All the peak positive VG roll angles occurred near the beginning of the runs in the range of 3114 to 2332 feet from the FATO. The mean peak positive VG roll angle for all 7.125° runs is 8°. The peak negative VG roll angle occurred between -3° and -6°. All peak negative VG roll angles occurred in the end of the runs from 40 to 1557 feet from the FATO. This is representative of a single rotor helicopter with the tail rotor below the main rotor disc. The mean peak negative VG roll angle for all 7.125° runs is -4.67°.

TABLE 6. 7.125° APPROACHES: HEADING DATA

7.125° Approaches										
		Peak Positive Heading			Peak Negative Heading			Course Heading Statistics		
Flight	Run	Value (Deg)	Alt (Ft)	Range (Ft)	Value (Deg)	Alt (Ft)	Range (Ft)	Mean (Deg)	Std Dev (Deg)	# of Points
01	4	167.20	45.55	419.89	161.00	256.15	2151.65	163.70	1.52	372
01	6	169.97	513.65	3546.91	155.29	274.15	2408.57	162.01	2.99	331
02	4	170.72	612.54	3787.26	160.61	76.49	825.80	165.58	2.10	306
02	6	167.60	551.02	3547.87	159.90	70.22	899.59	163.92	1.75	349
04	6	354.49	136.35	1229.99	341.66	57.24	456.69	346.71	1.77	366
04	8	352.13	27.63	5.90	339.83	200.31	1689.39	343.54	2.26	342
05	6	355.43	30.24	57.37	343.12	592.76	3916.69	348.87	2.54	383
05	8	353.58	34.84	296.83	343.26	66.43	897.11	347.50	2.02	401
06	7	351.08	28.07	29.02	343.12	286.69	2404.70	347.07	1.60	343
07	8	262.81	88.98	1040.94	252.11	524.33	3954.96	256.72	2.07	343
08	5	170.28	528.30	3943.59	161.44	26.46	5.65	165.03	1.50	354
08	7	168.31	51.28	403.28	160.96	524.37	3568.93	164.34	1.66	346
09	6	170.89	29.83	59.63	150.35	49.22	395.38	157.19	3.60	367
09	8	170.06	45.35	420.50	153.84	535.04	3980.31	160.28	3.09	398
11	7	192.51	628.28	3985.06	164.48	108.52	415.90	167.46	4.68	246

TABLE 7. 7.125° APPROACHES: ROLL DATA

7.125° Approaches							
		Peak Positive Roll			Peak Negative Roll		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	4	7.76	380.72	2852.72	-4.31	67.19	866.02
01	6	9.59	409.04	3114.60	-4.09	67.97	1196.46
02	4	8.46	394.50	2963.23	-4.61	53.03	416.45
02	6	9.06	372.89	2762.03	-3.93	27.08	156.60
04	6	8.46	358.44	2518.61	-5.24	53.74	403.00
04	8	8.02	388.53	2641.62	-5.43	49.14	342.67
06	7	11.23	297.25	2509.55	-4.63	44.24	261.93
07	8	9.16	293.88	2638.60	-5.05	40.95	365.84
08	5	9.64	323.40	2533.09	-4.44	41.29	219.87
08	7	7.89	390.38	2910.67	-4.00	29.21	40.02
09	6	4.57	306.78	2495.33	-6.11	47.34	362.82
09	8	4.64	325.13	2694.86	-5.78	133.89	1557.76
11	7	9.44	510.74	3084.48	-3.79	121.03	550.90

TABLE 8. 7.125° APPROACHES: PITCH DATA

7.125° Approaches							
		Peak Positive Pitch			Peak Negative Pitch		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	4	7.76	60.50	728.03	1.43	420.93	3075.79
01	6	9.59	56.72	1006.65	0.02	25.46	35.46
02	4	8.46	52.25	403.70	2.70	194.17	1747.19
02	6	9.06	53.33	608.74	1.05	627.46	3978.56
04	6	8.46	51.65	370.91	-1.85	106.64	993.62
04	8	8.02	47.63	319.53	-3.59	133.18	1248.31
05	6	6.61	57.18	578.90	0.86	580.97	3864.53
05	8	5.47	43.24	456.38	-2.04	116.04	1506.73
06	7	11.23	38.59	180.50	1.69	232.04	1962.09
07	8	9.16	42.32	388.25	1.03	125.17	1378.50
08	5	9.97	45.20	276.29	1.52	194.17	1653.07
08	7	7.89	65.76	641.54	2.94	344.90	2672.41
09	6	8.82	564.83	3902.54	0.79	242.52	2159.78
09	8	4.90	470.07	3476.15	-1.12	43.92	390.76
11	7	9.03	72.34	13.72	3.05	608.19	3759.91

The 7.125° data for VG pitch show the peak positive VG pitch angles occurred between 4° and 11°. The majority of the peak positive VG pitch angles occurred near the end of the runs in the range of 13 to 608 feet from the FATO. On flight 9, the peak positive VG pitch applications occurred early in the approach. The reason for this was the presence of a 15-knot tail wind at 500 feet AGL. The mean peak positive VG pitch angle for all 7.125° runs is 8.30°. The peak negative VG pitch angles occurred between ±3°. The majority of the peak negative VG pitch angles occurred near the beginning of the run in the range of 1248 to 3978 feet from the FATO. There were two runs, however, in which the peak negative VG pitch angles were at the end of the run between 35 and 390 feet from the FATO. The peak negative VG pitch angle for all 7.125° runs is 0.57°.

TABLE 9. 7.125° APPROACHES: PEAK POSITIVE/NEGATIVE DATA

7.125° Approaches				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (Deg)	7.81	15	-4.60	15
VG Roll (Deg)	8.00	15	-4.67	15
VG Pitch (Deg)	8.30	15	0.57	15

8° Approaches. Figure 7 presents the composite 8° approach results. This plot shows trends similar to the 7.125° composite approach plot. All but one of the approaches were initiated above the reference surface. However, pilots did not maintain a consistent approach angle to touchdown. All the approaches except one resulted in penetration of the 8° approach surface. The initial penetration point ranged from 200 to 2500 feet from FATO with penetration amounts as large as 70 feet.

Figure 13 shows the plot of maximum undershoot for the 8° approaches. This indicates four runs were flown above the surface throughout the approach. The errors ranged from 42 to 45 feet AGL occurring 800 to 1200 feet from the FATO. The maximum undershoot for the remaining runs was -71 feet. All undershoots occurred between 711 and 1700 feet from the FATO. Figure 16 presents a plot for the maximum overshoot for the 8° approaches. The overshoots ranged from 30 to 190 feet AGL and occurred 2400 to 3600 feet from the FATO very early in the approach.

Tables 10, 11, and 12 show the magnetic heading, VG roll, and VG pitch data for the 8° approaches. Table 13 presents the mean values for these data. The standard deviation of the magnetic heading ranged from 0.83° to 3.28°. The mean peak positive magnetic heading for all 8° approaches is 5.91°, and the mean peak negative magnetic heading is -4.89°. Lateral heading changes were minimal for all the 8° approaches. This indicates pilots had little difficulty in laterally tracking the FATO during the approaches.

TABLE 10. 8.0° APPROACHES: HEADING DATA

8° Approaches										
		Peak Positive Heading			Peak Negative Heading			Course Heading Statistics		
Flight	Run	Value (deg)	Alt (ft)	Range (ft)	Value (deg)	Alt (ft)	Range (ft)	Mean (deg)	Std Dev (deg)	# of Points
01	8	167.55	78.53	1063.98	158.32	303.49	2158.07	163.59	1.91	337
01	10	167.33	61.00	2728.61	157.62	199.21	1377.34	162.79	1.93	339
02	8	168.56	58.19	711.77	155.07	623.29	3537.28	164.84	2.15	333
02	10	168.08	37.70	220.76	161.84	57.88	554.49	165.51	1.37	362
03	12	257.21	528.69	3127.91	250.00	578.04	3481.20	254.32	1.53	352
04	10	343.96	557.00	3143.05	335.78	427.82	2209.74	339.65	1.85	274
04	12	354.83	52.11	396.50	331.37	87.93	835.65	335.83	2.80	369
05	10	351.14	296.41	2003.29	338.55	272.96	1868.09	346.70	2.06	366
06	9	355.72	530.94	3467.32	343.74	124.19	933.38	349.11	3.17	314
06	11	353.87	25.92	35.69	342.11	91.64	694.22	347.44	2.50	248
07	10	263.71	241.50	1626.37	255.25	185.44	1358.87	259.55	2.19	301
07	12	264.06	446.29	3026.60	248.39	322.36	2371.64	255.44	3.28	254
08	9	168.87	578.53	3548.11	158.28	337.22	2415.11	162.88	2.29	366
08	11	169.92	43.35	469.81	159.03	162.57	1448.49	163.66	2.16	347
09	10	162.67	375.29	2111.33	156.35	84.39	115.67	160.06	1.51	255
11	9	175.81	671.18	3544.33	163.33	177.93	946.55	165.25	1.89	229
11	11	167.95	629.97	3543.48	162.45	590.29	3072.82	164.07	0.83	237

TABLE 11. 8° APPROACHES: ROLL DATA

8° Approaches							
		Peak Positive Roll			Peak Negative Roll		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	8	6.86	388.16	2514.38	-3.96	39.25	606.19
01	10	5.65	424.99	2421.46	-5.24	75.11	711.86
02	8	9.21	467.35	2871.89	-4.53	35.45	291.84
02	10	7.67	377.23	2379.95	-3.81	71.61	770.34
03	12	9.12	353.66	2516.64	-4.47	99.31	1112.80
04	10	7.80	419.08	2171.01	-4.70	159.11	745.38
04	12	7.93	323.97	2153.77	-4.44	37.13	176.75
05	10	6.57	312.94	2090.22	-5.08	55.43	439.37
06	9	10.97	421.97	2494.31	-4.92	46.91	254.66
06	11	12.42	453.11	2956.47	-6.39	27.15	49.95
07	10	10.17	442.52	2450.19	-4.97	64.37	534.84
07	12	10.57	364.78	2615.76	-7.01	249.36	1983.12
08	9	13.13	435.01	2866.46	-4.63	60.82	475.51
08	11	6.61	402.83	2665.28	-4.00	161.52	1439.71
09	10	4.81	434.33	2474.07	-6.02	150.91	673.07
11	9	11.07	565.65	2901.16	-4.22	77.37	66.17
11	11	9.73	550.48	2858.94	-4.53	352.44	1903.70

TABLE 12. 8° APPROACHES: PITCH DATA

8° Approaches							
		Peak Positive Pitch			Peak Negative Pitch		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	8	6.86	57.01	818.22	-0.09	26.46	40.43
01	10	5.65	52.35	374.01	-0.92	613.85	3342.81
02	8	9.21	64.56	824.35	0.00	616.82	3496.29
02	10	7.67	49.57	417.05	2.66	355.91	2281.81
03	12	9.12	55.64	606.71	1.96	559.07	3318.92
05	10	6.57	34.82	159.35	0.46	264.59	1819.81
06	9	9.12	55.64	606.71	1.96	559.07	3318.92
06	11	12.42	30.86	93.01	1.78	476.12	3342.92
07	10	10.17	46.47	310.18	1.93	309.45	1915.19
07	12	10.57	36.74	395.68	1.56	394.81	2793.54
08	9	13.13	111.51	946.06	1.74	138.07	1147.67
08	11	6.61	83.92	901.89	-0.97	23.46	18.50
09	10	4.11	501.18	2927.54	1.52	439.05	2500.14
11	9	8.55	73.34	25.86	-1.32	620.77	3343.33
11	11	8.81	76.19	40.17	1.12	626.36	3500.59

The 8° approach data for VG roll show the peak positive VG roll angles occurred between 5.65° and 13.13°. The angles observed were slightly larger than those observed during the 7.125° approaches. All peak positive VG roll angles occurred near the start of the 10° angle mark in the range of 2901 to 2956 feet from the FATO. The mean peak positive VG roll angle for all 8° approach runs is 8.84°.

TABLE 13. 8° APPROACHES: PEAK POSITIVE/NEGATIVE DATA

8° Approaches				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (Deg)	5.91	17	-4.89	17
VG Roll (Deg)	8.84	17	-4.88	17
VG Pitch (deg)	8.46	17	0.87	17

The peak negative roll angles occurred between -3° and -7°. All but four of these angles occurred near the end of the run in the range of 49 to 770 feet from the FATO. The remaining four runs occurred 1112 to 1983 feet from the FATO. The mean peak negative VG roll angle for all 8° runs is -4.88°.

The positive VG pitch angles observed for the 8° approach data were slightly larger than for the 7.125° approaches. These peak positive VG pitch angles ranged from 4° to 13°. All of these except one occurred near the end of the run between 25 to 946 feet from the FATO. On flight 8, application of peak positive VG pitch occurred at the 10° event mark. The mean peak positive VG pitch angle is 8.46°. The peak negative VG pitch angles occurred between -0.97° and 2.66°. All the runs except two were located near the 10° angle mark in the range of 1147 to 3414 feet from the FATO. Two exceptions occurred near the end of the run. The mean peak negative VG pitch angle for all 8° approach runs is 0.87°.

<u>10° Approaches</u>. Figure 8 presents the composite 10° approach results. All the approaches were initiated above the reference surface. Pilots did not maintain a consistent approach angle to touchdown. With the exception of four approaches, all resulted in penetration of the intended 10° approach surface. The initial penetration points ranged between 200 and 1600 feet from the FATO with penetration amounts as large as 80 feet.

Figure 14 presents the plot of maximum undershoot for the 10° approaches. As with the 8° approach, four pilots remained above the surface throughout the approach. The errors ranged from 40 to 55 feet and occurred between 600 and 900 feet from the FATO. The undershoot for the remaining runs were from -23 to -75 feet and occurred between 536 and 995 feet from the FATO. The steeper angle resulted in smaller undershoot errors, closer to the FATO. Figure 17 presents the plot for the maximum overshoot for the 10° approaches. The overshoots ranged from 90 to 257 feet AGL and occurred 2100 to 2500 feet from the FATO. The largest overshoot errors were observed when the pilot initiated the approach.

Tables 14, 15, and 16 display the magnetic heading, VG roll, and VG pitch data for the 10° approaches. Table 17 lists the mean values for these data. The standard deviation of the magnetic heading ranged from 0.99° to 3.24°. The mean positive magnetic heading for all the 10° approaches is 6.71°. The mean negative magnetic heading for all 10° approaches is -3.92°. The heading analysis indicates the pilots did not experience a workload increase for the lateral tracking task with increasing approach angles.

The peak positive VG roll angles for the 10° approach data ranged from 5° to 14°. All the peak positive VG roll angles occurred near the 10° event mark, 1710 to 2216 feet from the FATO. The mean peak positive VG roll angle for all 10° approaches is 9.06°. The peak negative VG roll angles occurred between -3.76° and -8.00°. All but two of these events occurred near the end of the runs in the range of 83 to 901 feet from the FATO. The two exceptions occurred 1169 feet and 1269 feet from the FATO. The mean peak negative VG roll angle for all 10° runs is -4.80°.

The peak positive VG pitch angles observed for the 10° approach data were slightly larger than the 8° approach positive VG pitch angles. These ranged from 5° to 16° with all the peaks except one occurring near the end of the runs, 36 to 837 feet from the FATO. The exception, flight 2, occurred at 1926 feet from the FATO. The mean peak positive VG pitch angle for all 10° runs is 9.26°. The peak negative VG pitch angles occurred between -5° and +2°. The majority of the peak negative VG pitch angles occurred near the 10° event mark, 1296 to 2820 feet from the FATO. Three negative peaks occurred near the end of the runs, in the range of 22 to 68 feet from the FATO. The mean of the peak negative VG pitch events for all 10° approaches is 0.38°. The increase in peak VG pitch for the steeper approach angles was expected since a higher deceleration rate is required for increasing angles of approach if the approach entry speed is held constant.

<u>Pilot Choice Approaches</u>. For the pilot choice approaches 13 out of 27 approaches were initiated at locations resulting in approaches shallower than 7.125°. The other approaches were evenly distributed among the 7.125°, 8°, and 10° angles with only one pilot initiating an approach after 10°. See table 18 for the starting points of the pilot choice approaches.

TABLE 14. 10.0° APPROACHES: HEADING DATA

10° Approaches										
		Peak Positive Heading			Peak Negative Heading			Course Heading Statistics		
Flight	Run	Value (deg)	Alt (ft)	Range (ft)	Value (deg)	Alt (ft)	Range (ft)	Mean (deg)	Std dev (deg)	# of Points
01	12	168.56	39.09	338.60	159.95	84.13	786.17	164.05	1.86	373
01	14	168.41	480.59	2122.25	161.62	341.78	1736.88	164.89	1.73	333
02	12	166.50	189.70	1300.08	161.66	27.16	87.87	164.31	1.10	290
02	14	170.06	612.47	2772.22	162.46	30.76	117.36	164.82	1.11	308
04	14	345.52	24.14	59.15	336.36	64.84	473.82	339.92	1.69	325
04	16	340.06	36.56	209.57	330.69	64.15	545.65	335.58	1.62	277
06	13	352.40	133.97	523.64	342.88	317.11	1410.18	347.58	2.07	265
06	15	354.40	415.91	1768.68	340.54	84.79	606.67	346.19	3.24	251
08	13	165.99	46.54	317.48	157.36	576.90	2790.95	161.69	2.10	357
08	15	168.34	34.33	125.50	155.14	516.68	2304.18	161.09	2.58	366
09	14	171.38	27.81	166.94	157.36	536.69	2372.02	162.35	2.74	318
11	13	187.33	721.17	2825.31	162.81	462.47	1767.86	165.01	3.68	271
11	15	167.38	321.31	1393.79	163.03	70.34	8.50	164.82	0.99	253
12	4	173.00	629.32	2825.98	158.63	591.96	2334.18	163.00	2.27	280

TABLE 15. 10° APPROACHES: PITCH DATA

10° Approaches							
		Peak Positive Roll			Peak Negative Roll		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	12	7.52	357.50	1917.86	-4.64	40.12	351.34
01	14	14.93	480.59	2122.25	-4.92	86.89	901.92
02	12	8.68	519.69	2154.46	-3.76	157.64	1169.76
02	14	8.53	521.19	2125.20	-4.46	36.85	197.35
04	14	6.97	384.49	1710.68	-4.35	80.49	586.23
04	16	8.33	449.33	1982.37	-4.57	64.84	554.02
06	13	7.36	500.41	2216.06	-8.00	282.56	1269.11
06	15	8.81	475.78	2013.42	-4.79	49.11	326.94
08	13	6.26	384.77	1845.11	-4.00	95.17	704.89
08	15	14.30	408.43	1947.40	-4.75	73.17	565.64
09	14	5.52	398.55	1975.67	-5.52	48.54	440.84
11	13	9.38	593.28	2109.99	-4.36	99.08	202.34
11	15	10.13	553.86	2152.16	-4.19	80.93	83.28
12	4	10.17	495.69	1975.46	-4.83	117.23	337.01

TABLE 16. 10° APPROACH DATA: PITCH DATA

10° Approaches							
		Peak Positive Pitch			Peak Negative Pitch		
Flight	Run	Value (deg)	Altitude (ft)	Range (ft)	Value (deg)	Altitude (ft)	Range (ft)
01	12	7.52	63.57	639.06	0.15	23.46	22.24
01	14	14.93	73.09	837.69	-0.09	23.46	68.71
02	12	9.47	407.04	1926.56	2.22	632.35	2390.30
02	14	8.53	61.83	525.43	0.07	603.90	2437.03
04	14	6.97	48.28	305.12	-5.09	581.65	2308.04
04	16	8.33	44.15	301.96	3.49	579.87	2284.81
06	13	7.36	92.08	201.37	2.79	568.72	2775.84
06	15	8.81	42.93	265.84	1.78	261.23	1296.86
08	13	6.26	50.26	354.74	0.33	558.51	2641.81
08	15	16.27	66.95	489.84	1.16	581.56	2820.51
09	14	5.52	55.62	534.44	1.16	23.46	38.52
11	13	9.38	74.88	36.39	-1.05	716.70	2783.80
11	15	10.09	76.40	51.26	-0.44	619.00	2696.82
12	4	58.60	74.48	36.51	-1.54	627.85	2806.57

TABLE 17. 10° APPROACH DATA: PEAK POSITIVE/NEGATIVE DATA

10° Approaches				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (deg)	6.71	14	-3.92	14
VG Roll (deg)	9.06	14	-4.80	14
VG Pitch (deg)	9.26	14	0.38	14

TABLE 18. PILOT CHOICE APPROACHES

Flight Number	Run Number	Start of Run
2	2	Before 7°
2	16	Between 8° - 10°
2	18	After 10°
3	2	Between 8° - 10°
3	4	Between 7° - 8°
4	4	Before 7°
4	18	Before 7°
5	2	Before 7°
5	4	Before 7°
5	18	Before 7°
6	3	Before 7°
6	17	Between 7° - 8°
7	2	Before 7°
7	4	Before 7°
7	18	Before 7°
8	1	Between 7° - 8°
8	3	Between 7° - 8°
8	17	Between 7° - 8°
9	2	Between 8° - 10°
9	4	Between 7° - 8°
9	18	Between 8° - 10°
10	2	Between 8° - 10°
11	1	Before 7°
11	3	Between 8° - 10°
11	17	Before 7°
12	2	Before 7°
12	4	Between 7° - 8°

Tables 19, 20, and 21 show the magnetic heading, VG roll and VG pitch data for the pilot choice approaches. Table 22 gives the mean values for these data. The standard deviation of the magnetic heading ranged from 0.85° to 6.01°. The large standard deviation could have been due to the event mark for the start time being incorrectly cued with the pilot turning into the approach at

TABLE 19. PILOT CHOICE APPROACHES: HEADING DATA

Pilot Choice Approaches								
		Peak Positive Heading		Peak Negative Heading		Course Heading Statistics		
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)	Mean (deg)	Std dev (deg)	# of Points
01	2	171.55	531.15	160.51	44.28	166.31	1.89	357
01	16	169.55	251.08	158.06	174.24	163.72	2.53	409
01	18	169.13	438.68	160.43	101.95	164.42	1.54	356
02	2	167.64	169.88	160.34	22.67	165.44	1.48	326
02	16	168.43	467.65	159.86	41.54	165.12	1.41	359
02	18	169.71	180.70	162.28	55.19	165.56	1.43	336
04	2	357.37	331.37	341.50	144.00	345.51	2.36	346
04	4	358.21	71.55	342.03	554.63	345.79	2.12	401
04	18	338.55	562.65	331.92	346.63	334.25	1.40	368
05	2	356.62	25.67	341.45	486.68	345.07	2.27	414
06	3	349.67	421.54	342.11	242.64	346.12	1.96	293
06	17	351.42	33.98	342.32	370.73	345.67	2.14	307
07	2	263.62	52.49	255.49	64.92	259.03	1.96	312
08	1	170.87	43.92	161.09	579.09	166.20	1.74	412
08	3	169.92	45.78	159.82	22.75	164.75	2.03	350
09	2	169.92	40.78	143.42	91.92	152.06	6.01	412
11	1	168.25	387.04	164.56	73.55	166.72	0.85	247
12	2	167.16	62.78	160.83	30.74	164.40	1.16	331

TABLE 20. PILOT CHOICE APPROACHES: ROLL DATA

Pilot Choice Approaches					
		Peak Positive Roll		Peak Negative Roll	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	2	9.14	435.94	-4.55	74.43
01	16	12.84	227.65	-5.67	144.93
01	18	8.68	328.97	-4.92	36.54
02	2	9.03	411.29	-4.22	21.67
02	16	8.33	334.61	-3.61	99.49
02	18	8.97	582.73	-4.04	32.84
04	2	9.02	281.11	-6.98	317.07
04	4	7.27	321.15	-11.97	412.14
04	18	6.70	263.77	-4.22	113.89
05	2	6.00	246.33	-5.76	19.93
06	3	10.99	349.17	-3.48	36.42
06	17	7.27	317.34	-4.53	28.46
07	2	6.92	250.78	-4.18	33.56
08	1	7.71	332.02	-5.05	135.92
08	3	9.95	363.83	-5.34	24.39
09	2	3.89	207.37	-5.33	27.58
09	4	4.68	340.28	-6.64	21.04
11	1	7.67	461.18	-4.46	85.58
12	2	11.28	423.09	-4.70	92.71

TABLE 21. PILOT CHOICE APPROACHES: PITCH DATA

Pilot Choice Approaches					
		Peak Positive Pitch		Peak Negative Pitch	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	2	9.14	37.64	0.07	48.77
01	16	15.02	62.75	0.00	531.81
01	18	8.68	54.19	1.65	328.97
02	2	9.03	45.15	2.79	617.25
02	16	8.33	36.48	1.16	36.44
02	18	8.97	67.00	0.33	623.91
04	2	9.02	28.38	-13.50	390.96
04	4	7.27	47.70	-16.14	559.46
04	18	6.70	36.67	1.96	141.30
05	2	6.00	32.37	1.52	379.99
06	3	10.52	41.41	3.19	361.87
06	17	7.27	45.01	1.65	336.99
07	2	6.92	24.44	2.66	275.20
08	1	7.71	54.11	-0.04	568.12
08	3	9.95	46.60	0.59	40.31
09	2	4.33	27.58	0.37	66.34
09	4	4.68	41.59	-1.23	31.18
11	1	7.67	67.54	0.55	466.12
12	2	11.28	53.29	1.43	416.98

the start time recorded on the log sheet. The mean of the positive and negative magnetic heading for all the pilot choice approaches is 6.51° and -4.43°. The lateral heading changes were minimal for all pilot choice approaches.

The peak positive VG roll angles for pilot choice approaches occurred between 3° and 12° with a mean of 8.23°. The peak negative VG roll angles occurred between -3° and -11° with a mean of -5.24°.

The peak positive VG pitch angles for pilot choice approaches occurred between 4° and 15° with a mean of 8.34°. The peak negative VG pitch angles occurred between -16° and 3° with a mean of -0.58°.

DEPARTURES.

7.125° Departures. Figure 9 presents the composite 7.125° departure results. All the departures were initiated above the reference surface. However, pilots did not maintain a consistent departure angle to the 100-foot barrier. Only two pilots dropped below the surface during the initial phase of the departure. By the end of the run, all the pilots had cleared the 100-foot barrier.

TABLE 22. PILOT CHOICE APPROACHES: PEAK POSITIVE/NEGATIVE DATA

Pilot's Choice Approaches				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (deg)	6.51	19	-4.43	19
VG Roll (deg)	8.23	19	-5.24	19
VG Pitch (deg)	8.23	19	-0.58	19

Tables 23, 24, and 25 show the magnetic heading, VG roll, and VG pitch data for the the 7.125° departures. Table 26 contains summary data. The standard deviation of the magnetic heading ranged from 1.82° to 7.06°. On flight 9, the large standard deviation was due to 15-knot tail winds. The mean of the positive and negative magnetic heading for all 7.125° runs is 4.82° and -5.30°. Lateral heading changes were minimal for all the 7.125° departures. Although these means were slightly greater than the approach heading changes, the pilots appeared to have little difficulty in maintaining their course.

The peak positive VG roll angles for the 7.125° departure data occurred between 1.91° and -1.23°. All the peak positive VG roll angles occurred near the beginning of the run, 73 to 206 feet from the FATO with a mean of -0.08°. The peak negative VG roll angles occurred between -4° and -5°. As with the peak positive VG roll, the peak negative VG roll angles occurred in the beginning of the runs, 30 to 139 feet from the FATO with a mean of -4.70°.

TABLE 23. 7.125° DEPARTURES: HEADING DATA

7.125° Departures								
		Peak Positive Heading		Peak Negative Heading		Course Heading Statistics		
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)	Mean (deg)	std dev (deg)	# of Points
01	5	167.79	113.22	160.96	206.89	164.62	1.71	80
02	5	169.44	102.69	157.16	174.00	163.93	4.03	99
04	7	355.19	161.66	338.16	90.87	346.98	4.47	85
05	5	356.35	159.67	348.62	99.13	353.17	2.07	89
05	7	357.67	99.05	349.76	107.66	354.16	2.00	79
06	6	352.89	114.31	342.87	96.72	349.62	2.66	112
06	8	355.39	136.00	348.35	85.07	352.38	1.82	86
07	5	261.57	87.08	247.49	107.18	255.59	4.57	68
07	7	255.65	57.54	247.54	204.72	250.75	2.41	78
08	8	165.88	74.25	158.81	105.51	163.02	1.97	77
09	5	168.91	77.01	147.29	98.05	155.90	7.06	79
11	6	168.08	74.13	162.28	197.67	165.03	1.57	85
11	8	166.76	84.65	160.74	114.32	163.81	2.11	65

TABLE 24. 7.125° DEPARTURES: ROLL DATA

7.125° Departures					
		Peak Positive Roll		Peak Negative Roll	
Flight	Run	Value (DEG)	Altitude (ft)	Value (deg)	Altitude (ft)
01	5	1.91	206.89	-4.48	30.13
02	5	-0.92	155.59	-4.53	91.36
04	7	1.11	107.46	-5.23	93.79
05	5	0.20	75.[illegible]7	-4.92	42.56
05	7	0.55	151.[illegible]	-4.03	80.88
06	6	-0.09	87.92	-4.44	40.20
06	8	-0.48	73.04	-4.11	124.28
07	5	-0.74	101.60	-5.52	87.08
07	7	0.18	77.94	-4.61	125.52
08	8	-1.23	113.32	-4.44	139.27
09	5	-0.57	103.79	-5.93	83.70
11	6	-0.94	122.08	-4.11	86.56
11	8	0.00	163.12	-4.72	118.59

TABLE 25. 7.125° DEPARTURES: PITCH DATA

7.125° Departures					
		Peak Positive Pitch		Peak Negative Pitch	
Flight	Run	Value (Deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	5	6.26	181.86	-7.12	38.09
02	5	1.03	140.69	-3.38	86.52
04	7	0.86	164.12	-6.72	74.25
05	5	-0.24	30.41	-5.41	102.31
05	7	-2.86	120.72	-5.85	91.40
06	5	2.31	113.32	-2.48	211.00
06	7	1.30	31.27	-7.60	154.73
07	8	-0.04	39.11	-12.74	92.66
07	5	0.94	36.26	-9.45	79.21
08	6	-0.86	164.12	-6.24	93.79
09	8	-1.12	163.12	-9.71	90.39
11	6	3.76	136.74	-2.55	210.00
11	8	1.82	115.28	-4.72	79.87

The peak positive VG pitch angles occurred between -2° and 6°. All these were in the range of 113 to 181 feet from the FATO with a mean of 1.01°. The peak negative VG pitch angles occurred between -2° and -12°. All the peak negative VG pitch angles occurred near the beginning of the runs, 38 to 210 feet from the FATO with a mean of -6.46°.

<u>10° Departures</u>. Figure 10 presents the composite 10° departure results. All the departures were initiated above the reference surface. Pilots did not maintain a consistent departure angle to the 100-foot barrier. All the pilots except three dropped below the surface during the initial departure period. By the end of the run, all the pilots had cleared the 100-foot barrier.

TABLE 26. 7.125° DEPARTURES: PEAK POSITIVE/NEGATIVE DATA

7.125° Departures				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (deg)	4.82	13	-5.30	13
VG Roll (deg)	-0.08	13	-4.70	13
VG Pitch (deg)	1.01	13	-6.46	13

Tables 27, 28, 29, and 30 show the magnetic heading, VG roll, VG pitch data, and summary data for the 10° departures. The standard deviation of the magnetic heading ranged from 0.76° to 5.57°. On flight 9 the large standard deviation was due to 15-knot tail winds. The mean positive and negative magnetic heading for all the 10° runs is 5.72° and -6.17°. Lateral heading changes were minimal for all the 10° departures. However, they were slightly larger than the approach heading changes. This indicates pilots had little difficulty in maintaining their course.

The peak positive VG roll angles for the 10° data occurred between -2° and 1°. All the peak positive VG roll angles occurred near the beginning of the run, 74 to 254 feet from the FATO with a mean of -0.52°. The peak negative VG roll angles occurred between -3° and -14°. All the peak negative VG roll angles occurred under 250 feet AGL in the range of 43 to 242 feet from the FATO with a mean of 5.66°.

The peak positive VG pitch angles occurred between -2° and 5° with the exception of one run having a value of 16°. The mean of the peak positive VG pitch angles for all the 10° departures is 2.53°. The peak negative VG pitch angles occurred between -2° and -11°. All the peak negative VG pitch occurred near the beginning of the run in the range of 69 to 256 feet from the FATO with a mean of -6.65°.

<u>12° Departures</u>. Figure 11 presents the composite 12° departure results. All the departures were initiated above the reference surface. However, pilots did not maintain a consistent departure angle to the 100-foot barrier.

TABLE 27. 10.0° DEPARTURES: HEADING DATA

10° Departures									
		Peak Positive Heading		Peak Negative Heading		Course Heading Statistics		
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)	Mean (deg)	Std Dev (deg)	# of points
01	9	172.74	77.38	157.18	256.89	165.53	4.27	90
02	7	169.44	102.69	157.16	174.00	162.99	1.62	106
02	9	168.52	109.07	160.12	195.46	163.89	2.46	99
04	9	354.86	162.85	347.08	91.14	350.65	2.55	76
04	11	354.01	194.39	345.38	70.90	350.48	2.68	85
05	9	355.04	132.01	345.60	108.43	349.99	2.43	88
05	11	359.25	158.41	342.29	99.70	351.21	4.89	89
06	10	356.42	78.45	347.80	98.35	352.50	2.29	79
06	12	354.59	90.36	344.35	104.29	350.45	2.40	107
07	9	270.02	36.12	248.03	73.41	254.82	4.85	84
07	11	255.80	95.90	248.94	111.54	252.33	1.97	67
08	10	170.14	110.43	145.84	258.89	164.06	5.17	112
08	12	168.78	86.98	158.19	212.00	164.06	2.97	89
09	9	170.54	86.79	149.71	107.52	158.98	5.57	82
09	11	164.26	79.87	146.90	105.71	156.10	4.83	79
11	10	165.71	256.89	162.06	77.72	163.98	0.76	103
11	12	165.35	77.00	160.12	152.10	162.28	1.63	90

TABLE 28. 10° DEPARTURES: ROLL DATA

10° Departures					
		Peak Positive Roll		Peak Negative Roll	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	9	0.33	254.14	-4.79	76.04
02	7	-1.54	253.05	-4.97	66.59
02	9	-0.70	218.72	-4.37	87.36
04	9	0.10	85.94	-4.53	68.01
04	11	0.59	86.51	-4.04	70.90
05	9	-0.66	107.32	-5.49	83.34
05	11	0.64	129.39	-5.05	204.81
06	10	-0.13	88.39	-5.67	79.87
06	12	1.03	101.74	-5.26	78.94
07	9	-0.59	126.06	-6.64	90.36
07	11	0.13	109.29	-3.60	197.57
08	10	-1.01	113.89	-14.99	241.83
08	12	-0.09	158.11	-6.02	212.00
09	9	-2.88	74.80	-6.01	43.44
09	11	-1.38	118.98	-6.81	154.87
11	10	-1.74	89.44	-3.96	76.04
11	12	-0.91	191.98	-4.09	95.18

TABLE 29. 10° DEPARTURES: PITCH DATA

10° Departures					
		Peak Positive Pitch		Peak Negative Pitch	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	9	3.71	122.46	-7.01	232.05
02	7	2.57	137.00	-2.59	81.16
02	9	0.46	109.07	-3.12	77.06
04	9	2.66	122.72	-4.43	70.57
04	11	0.94	182.73	-4.75	69.01
05	9	-1.58	98.61	-6.06	167.71
05	11	-1.54	45.78	-5.36	87.70
06	10	2.79	180.75	-7.12	82.70
06	12	4.33	35.89	-10.00	82.73
07	9	1.14	190.68	-10.77	103.03
07	11	0.09	193.98	-11.65	93.68
08	10	2.13	132.33	-7.89	237.59
08	12	16.80	84.37	-5.52	212.00
09	9	-0.68	63.51	-7.16	88.96
09	11	-2.11	74.13	-8.83	100.93
11	10	5.60	168.33	-5.43	256.89
11	12	4.94	166.74	-5.43	85.61

TABLE 30. 10° DEPARTURES: PEAK POSITIVE/NEGATIVE DATA

10° Departures				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (deg)	5.72	17	-6.17	17
VG Roll (deg)	-0.52	17	-5.66	17
VG Pitch (deg)	2.53	17	-6.65	17

All the pilots penetrated the surface during the initial portion; yet by the end of the run, all cleared the 100-foot barrier.

Tables 31 through 34 show the magnetic heading, VG roll, VG pitch, and summary data for the 12° departures. The standard deviation for the magnetic heading ranged from 0.64° to 4.59°. The peak positive heading occurred at the beginning of the run, 41 to 262 feet from the FATO. The mean peak positive and negative magnetic heading for all the 12° departures is 4.50° and -4.85°. Lateral heading changes were minimal for all the 12° departures. This indicates pilots had little difficulty in maintaining their course.

The peak positive VG roll angles for the 12° data occurred between -2° and 1°. The peak positive VG roll angles occurred later in the run than the 7.125° and the 10° departures in the range of 57 to 259 feet from the FATO. The mean peak positive VG roll angle for all the 12° departures is -0.65°. The peak negative VG roll angles occurred between -1° and -6° with one run having a -12° error. All the peak negative VG roll angles also occurred later in the run than the 7.125° and 10° in the range of 63 to 262 feet from the FATO. The mean peak negative VG roll angle for all 12° departures is -5.16°.

The peak positive VG pitch angles occurred between -1° and 4° with the exception of one run having a value of 14°. All the peak positive VG pitch angles occurred near the beginning of the run, 42 to 288 feet from the FATO with a mean 2.82°. The peak negative VG pitch angles occurred between -0.35° and -10°. The peak negative VG pitch angles occurred later in the runs than the 7.125° departures, but about the same distance as the 10° departures in the range of 74 to 307 feet from the FATO. The mean of the peak negative VG pitch angle for all the 12° departures is -6.07°.

TABLE 31. 12.0° DEPARTURES: HEADING DATA

12° Departures								
		Peak Positive Heading		Peak Negative Heading		Course Heading Statistics		
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)	Mean (deg)	Std Dev (deg)	# of Points
01	13	168.43	127.06	162.89	100.94	166.04	1.85	87
02	11	168.08	85.16	159.99	244.15	163.98	2.45	107
02	13	167.41	102.80	161.71	251.15	164.51	1.45	105
03	13	254.90	41.37	246.35	116.07	251.00	2.47	105
04	13	357.76	254.40	344.99	132.07	350.07	4.52	91
04	15	351.69	262.89	342.48	101.61	348.20	2.65	81
06	14	360.00	216.00	344.60	115.20	350.03	2.36	99
08	14	167.33	94.40	155.38	262.89	163.54	2.97	107
09	13	164.57	84.62	146.59	151.48	157.13	4.59	85
09	15	163.64	45.57	151.77	115.89	158.44	4.26	65
11	14	167.73	185.95	162.72	82.11	165.20	1.37	93
11	16	167.68	145.28	161.57	89.92	164.46	1.72	130
12	3	168.08	105.83	164.65	259.89	166.17	0.64	78

TABLE 32. 12° DEPARTURES: ROLL DATA

12° Departures					
		Peak Positive Roll		Peak Negative Roll	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
01	13	-0.59	259.89	-4.21	198.62
02	11	-0.40	172.52	-3.87	86.25
02	13	-0.48	122.50	-4.81	99.36
03	13	0.35	157.12	-4.00	94.14
04	13	-0.83	71.68	-6.33	141.96
04	15	0.33	57.09	-4.66	262.89
06	14	-0.70	216.00	-5.05	63.62
08	14	-0.66	120.74	-12.66	239.43
09	13	-2.81	222.34	-6.55	104.73
09	15	-2.24	109.18	-6.03	100.26
11	14	-0.86	231.36	-3.19	194.97
11	16	-0.83	190.59	-3.96	79.88
12	3	1.25	255.20	-1.80	112.21

TABLE 33. 12° DEPARTURES: PITCH DATA

12° Departures					
		Peak Positive Pitch		Peak Negative Pitch	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg	Altitude (ft)
01	13	4.59	127.06	-10.90	254.97
02	11	2.61	185.86	-5.43	307.44
02	13	14.00	288.16	-3.25	81.06
03	13	0.88	145.38	-5.05	297.78
04	13	0.11	114.81	-4.11	79.05
04	15	-0.48	51.90	-5.89	74.79
06	14	4.15	42.78	-9.76	91.76
08	14	-0.70	101.72	-7.56	253.87
09	13	-1.12	84.62	-8.53	253.60
09	15	-0.86	45.57	-8.22	109.18
11	14	4.50	142.67	-2.64	207.60
11	16	4.81	127.91	-7.30	258.21
12	3	4.11	148.92	-0.35	215.34

TABLE 34. 12° DEPARTURES: PEAK POSITIVE/NEGATIVE DATA

12° Departures				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (deg)	4.50	13	-4.85	13
VG Roll (deg)	-0.65	13	-5.16	13
VG Pitch (deg)	2.82	13	-6.07	13

Pilot Choice. Figure 18 presents the composite plots for the pilot choice departures results. All the departures were initiated above the reference surface. Only one pilot dropped below the 7.125° angle. The others stayed between the 7.125° and the 10° surface, although they did not maintain a consistent departure angle to the 100-foot barrier. All the pilots had cleared the 100-foot barrier by the end of the run.

Tables 35 through 38 show the magnetic heading, VG roll, VG pitch, and summary data for the pilot choice departures. The standard deviation of the magnetic heading ranged from 0.93° to 5.83°. The large standard deviation could have been because the event mark occurred before the actual start of the run. The mean peak positive and negative magnetic heading for all pilot choice departures is -4.74° and 5.75°.

The peak positive VG roll angles of the pilot choice departure data occurred between -0.3° and -1.3° with a mean of -0.70°. The peak negative VG roll angles occurred between -3° and -5° with a mean of -4.58°.

The peak positive VG pitch angles occurred between -1° and 4° with a mean of 0.58°. The peak negative VG pitch angles occurred between -8° and -2° with a mean of -5.16°.

PILOT QUESTIONNAIRES.

IN-FLIGHT QUESTIONNAIRE. The Cooper-Harper Modified Pilot Rating Scale used for the In-flight Questionnaire employs a 1 to 10 scale, where 1 is fully acceptable. Ratings between 3 and 4 indicate mild to minor unpleasant deficiencies, but the maneuver is still considered adequate from a safety standpoint. Ratings of 7 and above indicate major deficiencies with clearly "inadequate" to "no" safety margin. Overall, there were about 20 maneuvers of each type performed.

Table 39 contains a breakdown of these ratings. As the angle of approach increased, the acceptability rating decreased from the safety standpoint. For the departures, the variation in ratings were larger than t approaches. As the angle of departure increased, the acceptability ratings decreased from the safety standpoint. The pilots felt more comfortable with the shallower angles of approach and departure than the steeper angles.

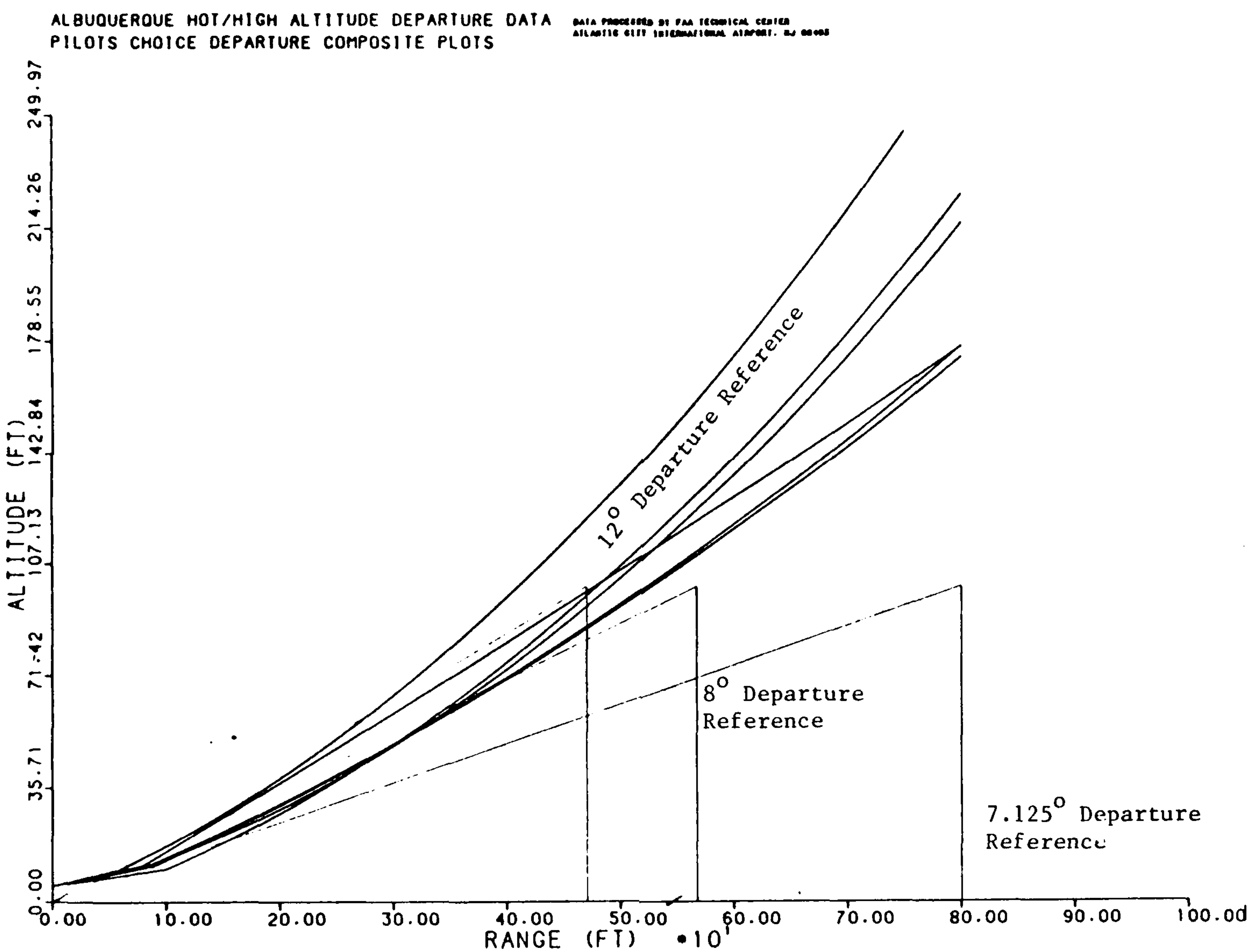


FIGURE 18. PILOT CHOICE COMPOSITE DEPARTURE PLOT

TABLE 35. PILOT CHOICE DEPARTURES: HEADING DATA

Pilot Choice Departures								
		Peak Positive Heading		Peak negative Heading		Course Heading Statistics		
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)	Mean (deg)	Std Dev (deg)	# of Points
02	1	171.90	72.43	157.93	193.60	163.48	3.74	105
02	3	170.73	94.87	161.53	175.14	166.03	2.57	124
02	15	168.87	97.31	159.16	231.11	164.09	2.76	98
02	17	167.20	99.76	159.33	208.14	163.23	2.72	107
04	1	346.68	21.58	335.52	80.70	342.23	2.67	71
04	3	346.77	29.50	337.66	51.27	342.31	2.34	67
05	1	352.74	106.25	343.83	91.29	348.41	2.61	67
08	16	164.74	73.42	161.05	153.47	162.61	0.93	80
09	1	163.29	40.78	151.20	109.87	156.02	3.65	75
09	3	170.89	39.43	147.78	160.12	155.23	5.83	85
12	1	167.46	73.75	159.20	160.12	163.71	2.48	77
12	5	166.98	97.13	158.28	114.26	161.94	2.49	91

TABLE 36. PILOT CHOICE DEPARTURES: ROLL DATA

Pilot Choice Departures					
		Peak Positive Roll		Peak Negative Roll	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
02	1	-0.51	148.41	-5.01	52.40
02	3	-0.62	106.08	-4.71	52.57
02	15	-0.26	227.77	-4.04	59.97
02	17	-0.57	238.14	-3.60	84.14
04	1	-0.68	77.84	-4.86	103.66
04	3	-0.75	100.15	-4.09	105.60
05	1	-0.59	85.31	-4.92	24.13
08	16	-1.27	85.72	-4.42	104.17
09	1	-1.10	86.43	-5.25	118.42
09	3	-0.94	78.68	-5.70	143.80
12	1	-0.48	153.09	-4.66	78.68
12	5	-0.60	185.75	-3.74	88.95

TABLE 37. PILOTS CHOICE DEPARTURES: PITCH DATA

Pilot Choice Departures					
		Peak Positive Pitch		Peak Negative Pitch	
Flight	Run	Value (deg)	Altitude (ft)	Value (deg)	Altitude (ft)
02	1	1.56	117.12	-2.11	73.30
02	3	4.50	160.12	-2.37	80.60
02	15	-0.15	114.90	-2.97	257.89
02	17	1.96	171.95	-2.88	91.48
04	1	2.00	23.70	-7.30	102.71
04	3	-1.39	27.83	-6.77	71.80
05	1	0.73	21.79	-8.13	100.27
08	16	-2.11	159.83	-6.20	93.40
09	1	-0.44	152.29	-7.69	77.51
09	3	-0.86	151.96	-8.09	81.16
12	1	0.46	67.16	-5.93	79.50
12	5	1.25	192.97	-6.86	89.69

TABLE 38. PILOT CHOICE DEPARTURES: PEAK POSITIVE/NEGATIVE DATA

Pilot Choice Departures				
	Peak Positive Data		Peak Negative Data	
	Value		Value	
Parameter	Mean	Count	Mean	Count
Heading (Deg)	5.75	12	-4.74	12
VG Roll (Deg)	-0.70	12	-4.58	12
VG Pitch (Deg)	0.58	12	-5.61	12

TABLE 39. COOPER-HARPER IN-FLIGHT QUESTIONNAIRE RATINGS

Cooper Harper In-Flight Ratings						
Procedure	1	2	3	4	5	>=6
	Number of Responses					
7.125 Degree Approaches	6	12	1	1		
8.0 Degree Approaches	4	10	3	2	1	
10.0 Degree Approaches	0	5	7	3	3	3
7.125 Degree Departures	4	10	4	1		
10.0 Degree Departures	2	6	7	2	1	2
12.0 Degree Departures	1	1	10	3	1	4

POST-FLIGHT QUESTIONNAIRE. The scale used for the Post-Flight Questionnaire was exactly opposite of the Cooper-Harper Scale. A 5 indicates an adequate safety or control margin while a 1 indicates an inadequate rating. For example, with workload, a 5 indicates a decreased workload, while a 1 indicates an increase. There were seven pilots who rated the procedures following the flights.

SAFETY MARGIN. As the angle of approach increased, the pilots felt their safety margin decreased. The departures had a wider variation in the ratings than the approaches. As the angle of departure increased, the pilots felt their safety margin decreased. The pilots felt the shallower approach and departure angles had a higher safety margin than the steeper angles. Table 40 shows the ratings of the safety margin for seven pilots who rated the procedures.

WORKLOAD. The workload ratings for the approaches showed a much wider range than the safety margin ratings. As the angle of approach increased, the pilots felt their workload increased. The departures had a wider variation in the ratings than the approaches. The pilots felt the workload was greatest for the 10° and 12° departures, and the steeper the approach and departure angles the greater the workload. A summary of these ratings is presented in table 41.

CONTROL MARGIN. All three approach angles showed a similar spread in ratings as the safety margin ratings. The 7.125° and the 8° approaches were both given ratings of one 4 and six 5's while the 10° approach received ratings of four 4's and three 5's. The control margin for all the approaches did not increase with increasing angles. The pilots felt the control margins for the departures increased with increasing angles. Table 42 shows the ratings of the control margin for the seven pilots who rated the procedures.

TABLE 40. POST-FLIGHT RATINGS FOR SAETY MARGIN

Post-Flight Ratings for Safety Margin					
Procedure	5	4	3	2	1
	Number of Responses				
7.125 Degree Approaches	6	1			
8.0 Degree Approaches	5	2			
10.0 Degree Approaches	1	3	3		
7.125 Degree Departures	5	2			
10.0 Degree Departures	0	3	3	1	
12.0 Degree Departures	0	1	2	3	1

TABLE 41. POST-FLIGHT RATINGS FOR WORKLOAD

Post-Flight Ratings for Workload					
Procedure	5	4	3	2	1
	Number of Responses				
7.125 Degree Approaches	3	2	2		
8.0 Degree Approaches	2	2	2	1	
10.0 Degree Approaches	0	1	3	3	
7.125 Degree Departures	2	1	4		
10.0 Degree Departures	0	0	4	3	
12.0 Degree Departures	0	0	1	5	1

TABLE 42. POST-FLIGHT RATINGS FOR CONTROL MARGIN

Post-Flight Ratings for Control Margin					
Procedure	5	4	3	2	1
	Number of Responses				
7.125 Degree Approaches	6	1			
8.0 Degree Approaches	6	1			
10.0 Degree Approaches	3	4			
7.125 Degree Departures	5	2			
10.0 Degree Departures	1	5	1		
12.0 Degree Departures	0	3	3	1	

CONCLUSIONS

Table 43 presents a summary of important parameters for the approach and departure data.

1. The amount of surface penetration increased with increasing angle of departure.

2. The amount of surface penetration increased with increasing angle of approach.

3. On departure, the aircraft operated above the 7.125° surface by 150 feet from the final approach take off area (FATO).

4. On the approaches, the steeper the angle the closer the initial point of penetration was to the FATO.

5. Using the Cooper-Harper Rating Scale, the pilots rated the 10° approach angle unacceptable.

6. Using the Cooper-Harper Rating Scale, the pilots rated the 10° and 12° departure angles unacceptable.

7. Based on the flight data, the pilots had no difficulty maintaining consistent angles of approach and departure. However, from the subjective data,the pilots had to work harder to maintain consistent angles of departure and the steeper angles of approach. This was due to aircraft limitations.

RECOMMENDATIONS

Part 77 surfaces for visual flight rules (VFR) Heliports be revised to include an acceleration area on the order of 200 feet followed by an 8 to 1 surface or steeper.

Table 43. SUMMARY TABLE

Approaches			
	7.125°	8.0°	10.0°
Point of Initial Penetration (Feet from FATO)	1600 - 2800	200 - 2500	200 - 1600
Maximum Depth of Penetration	70 ft	70 ft	80 ft
Range of Peak Pos VG Roll Range occurred from FATO	5° to 11° 2332 - 3114 ft	6° to 13° 2901 - 2956 ft	5° to 14° 1710 - 2216 ft
Range of Peak Neg VG Roll Range Occurred from FATO	-3° to -6° 40 - 1557 ft	-3° to 7° 49 - 770 ft	-8° to -3.70° 83 - 1269 ft
Range of Peak Pos VG Pitch Range Occurred From FATO	4° to 11° 13 - 1608 ft	4° to 13° 25 - 946 ft	5° to 16° 36 - 837 ft
Range of Peak Neg VG Pitch Range Occurred from FATO	-3° to 3° 35 - 3978 ft	-.97° to 2.66° 1147 - 3414 ft	-5° to 2° 22 - 2820 ft
Departures			
	7.125°	10.0°	12.0°
Range of Peak Pos VG Roll Range Occurred from FATO	-1.23° to 1.91° 70 - 206 ft	-2° to 1° 74 - 254 ft	-2° to 1° 57 - 259 ft
Range of Peak Neg VG Roll Range Occurred from FATO	-5° to -4° 30 - 139 ft	-14° to -3° 43 - 242 ft	-6° to -1° 63 - 262 ft
Range of Peak Pos VG Pitch Range Occurred from FATO	-2° to 6° 113 - 181 ft	-2° to 5° 45 - 193 ft	-1° to 4° 42 - 288 ft
Range of Peak Neg VG Pitch Range Occurred from FATO	-12° to -2° 38 - 210 ft	-11° to -2° 69 - 256 ft	-10° to -.35° 24 - 307 ft

APPENDIX A

PROJECT INFORMATION PACKET

VMC APPROACHES AND DEPARTURES

Flt #: .VMC Date: Aircraft: GPS Tracker Used:

Subject Pilot: Safety Pilot: Crew:

Data Period GPS Antenna Ground Position Cal. Offset
Initial: X = ;Y = ;Z =
Final : X = ;Y = ;Z =

[1] Liftoff	[2] Start curve	[3] End curve	Sync clock to Radio and Tracker
[4] Touchdown	[5] 500' Rad Alt	[6] Start Descent	Depart Hdg. - 180 Deg

RUN #	WINDS	EVENTS	RATE	REMARKS

How do you rate the approach/departure?

HELICOPTER VISUAL METEOROLOGICAL CONDITIONS (VMC)
SURFACE TEST QUESTIONNAIRE

AIRCRAFT TYPE: ____________________

OPERATIONAL PILOT QUALIFICATIONS

NAME: ____

AFFILIATION: ____

ADDRESS: ____

CITY: ____________________ STATE: __________ ZIP CODE: __________

PHONE (optional): ____

FAA HELICOPTER RATINGS (Private, Comm, ATP, Helicopter Inst):

____

____

____

____

TOTAL FLIGHT HOURS: ____

TOTAL HELICOPTER HOURS: ____

TOTAL TIME IN TYPE: ____

TOTAL HELICOPTER HOURS LAST 6 MONTHS: ______________________________

TIME IN TYPE LAST 6 MONTHS: ______________________________

PERIOD OF FAA FLIGHT TEST (week of): ______________________________

QUESTIONS

1. a. The 7° approach angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why? ____

____

____

____

____

CONTINUE ON BACK

b. With a 7° approach angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 7° approach angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 7° approach angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

2. a. The 8° approach angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why? ____

____

____

____

____

CONTINUE ON BACK

b. With a 8° approach angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 8° approach angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 8° approach angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

3. a. The 10° approach angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why?____
____
____
____
____

CONTINUE ON BACK

b. With a 10° approach angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 10° approach angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 10° approach angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

4. a. The 7° departure angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why?____
____
____
____
____

CONTINUE ON BACK

b. With a 7° departure angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 7° departure angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 7° departure angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

5. a. The 10° departure angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why?____

____

____

____

____

CONTINUE ON BACK

b. With a 10° departure angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 10° departure angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 10° departure angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

6. a. The 12° departure angle was:

_____ Acceptable _____ Unacceptable

If unacceptable why?____

____

____

____

____

CONTINUE ON BACK

b. With a 12° departure angle the safety margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

c. With a 12° departure angle the workload was:

1	2	3	4	5
Increased		Normal		Decreased

d. With a 12° departure angle the control margin was:

1	2	3	4	5
Inadequate		Marginal		Adequate

7. What percentage of your routine operations are conducted into and out of heliports or helistops? ______________________________

8. Do you feel the turning approach/departure maneuver should have an appropriate surface published in a design guide?

_____ YES _____ NO

WHY? ______________________________
____
____
____
____

CONTINUE ON BACK

9. Do you feel heliports should be delineated by capability?

_____ YES _____ NO

If yes should it classed by:

Heliport size	_____ YES	_____ NO
Rotor Configuration (single vs dual)	_____ YES	_____ NO
Aircraft Max Gross Weight	_____ YES	_____ NO

Other ______________________________
____

CONTINUE ON BACK

10. What improvements would you like to see added to a heliport to increase safety while performing approaches/departures (i.e. visual approach slope indicator)?

____
____
____
____
____
____

CONTINUE ON BACK

11. Should the approach surface ratio be published for the primary approach into a facility ?

_____ YES _____ NO

If yes how would you like it to be indicated? ______________________________
____