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Heliport Visual Approach and Departure Airspace Tests

VOL I Summary

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16. Abstract

During the winter and spring of 1987 flight tests were conducted at the Federal Aviation Administration (FAA) Technical Center's Concepts Development and Demonstration Heliport at the Atlantic City International Airport, N.J. The purpose of these flights was to examine and validate the current heliport approach/departure surfaces criteria as defined in the Heliport Design Guide and to recommend modifications to these surfaces, if appropriate. The flight activities were conducted using aircraft representative of those in the civilian world. Data were collected using approach surfaces of 7.125°, 8.00°, and 10.00° for straight as well as curved path procedures. Also, departure surfaces of 7.125°, 10.00°, and 12.00° for straight and curved path procedures were used. All maneuvers were tracked by ground based tracking systems.

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 FAA Heliport Design Advisory Circular, AC 150/5390-2.

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EXECUTIVE SUMMARY

During the winter and spring of 1987 flight tests were conducted at the Federal Aviation Administration Technical Center's Concepts Development and Demonstration Heliport at the Atlantic City International Airport, N.J. The purpose of these flights was to examine and validate the current heliport approach/departure surface criteria as defined in the Heliport Design Guide and to recommend modifications to these surfaces, if appropriate.

Flight activities were conducted using a Sikorsky S-76, a Bell UH-1, and a Hughes OH-6. A total of 1217 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 as well as curved path procedures. All manuevers were tracked by ground based tracking systems 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 pilots immediate recall of what occurred during the test run. The post-flight system was based on the pilots opinion of the test in general.

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 each approach and departure individually. 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, safety, and control margins associated with the procedures flown were also conducted.

Steeper approaches and departures can be safely flown when sufficient aircraft power reserve is available. Sufficient reserve would not be available for all aircraft.

Discussion with the subject pilots and with industry has indicated that there is a tremendous interest in curved approaches and departures. This test was not structured to define all aspects of the airspace requirements for curved approaches and departures. Additional testing is required to define the minimum airspace requirements for such procedures. Of particular interest is the minimum length of the final straight segment in a curved approach to (or departure from) a heliport and the lateral dispersion throughout the procedure.

INTRODUCTION

PURPOSE.

The Federal Aviation Administration (FAA) Technical Center's Heliport visual approach/departure surface testing was designed to provide data to validate the Heliport Design Guide's current approach/departure surface criteria.

The following flight test objectives were addressed:

1. Determine the airspace consumed during visual approaches to a heliport.

2. Verify the dimensions for the current Heliport Design Guide's visual approach path surfaces and/or determine possible modifications to these surfaces.

3. Determine the airspace consumed during visual departures.

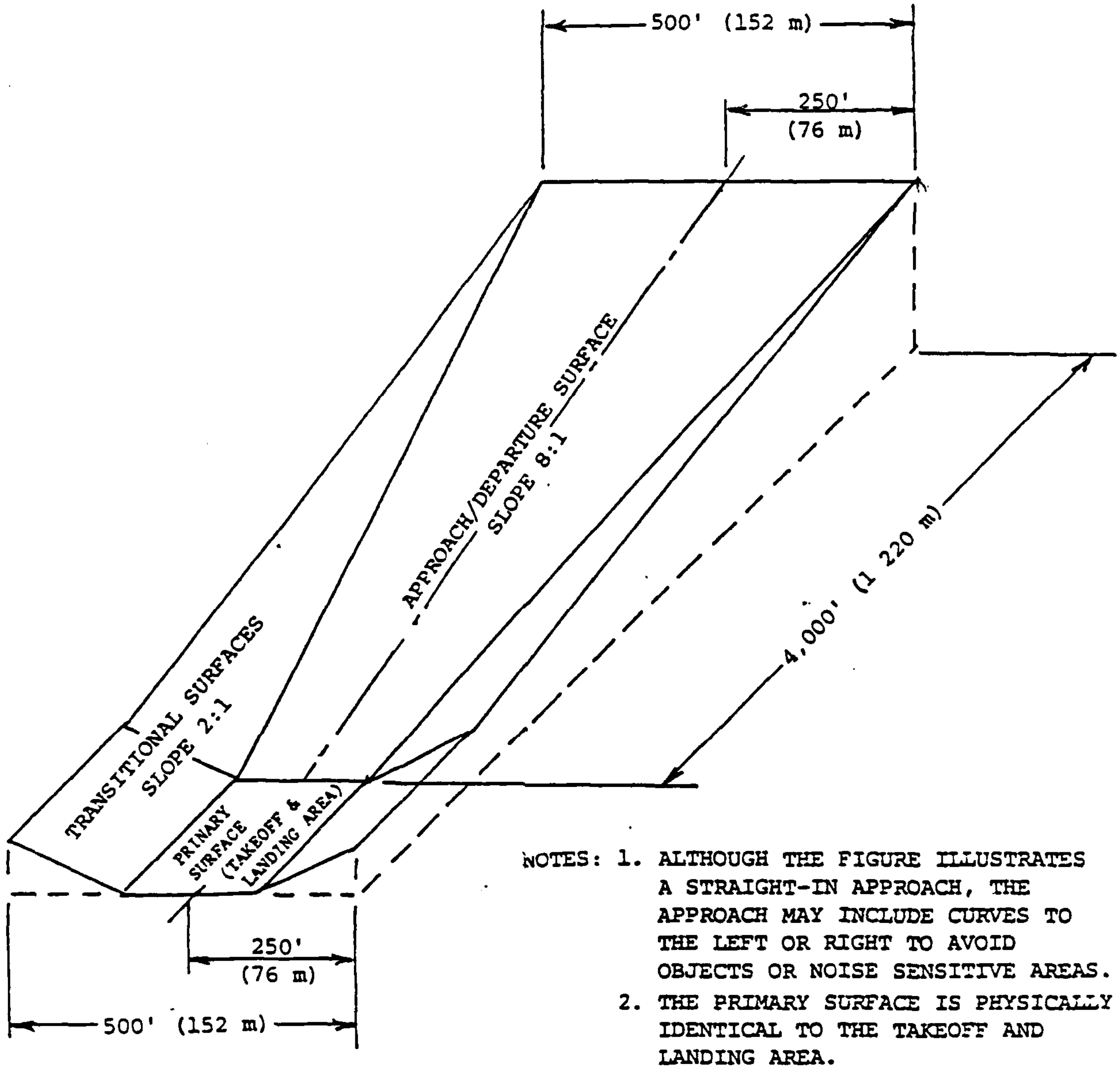
4. Verify the dimensions for the current Heliport Design Guide's visual departure path surfaces and/or determine possible modifications to these surfaces. Specific issues to be considered are the angle of approach/departure surface, width of the surface, surface length, and alignment of the surface.

BACKGROUND.

The focus of this test was on the issue of airspace and obstruction protection requirements for visual approaches and departures at a heliport. The current FAA Heliport Design Advisory Circular AC 150/5390-2, January 4, 1988, states:

"The approach surface is a 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 surface 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." (This criteria is depicted in figure 1, taken from AC 150/5390-2.)

The criteria for visual flight rules (VFR) heliport approach and departure surfaces has remained unchanged for several decades. It was developed on the basis of experience and engineering judgement. Prior to this test effort, very little data were available to validate the criteria. Since before the publication of the Heliport Design Guide in 1977, these surfaces have been the topic of discussion between the FAA and industry. Some in industry have argued that the minimum VFR heliport approach and departure airspace is excessive. Some in the FAA have expressed a concern that insufficient data has been available to



NOTES: 1. ALTHOUGH THE FIGURE ILLUSTRATES A STRAIGHT-IN APPROACH, THE APPROACH MAY INCLUDE CURVES TO THE LEFT OR RIGHT TO AVOID OBJECTS OR NOISE SENSITIVE AREAS.
2. THE PRIMARY SURFACE IS PHYSICALLY IDENTICAL TO THE TAKEOFF AND LANDING AREA.

FIGURE 1. VISUAL APPROACH SURFACE

show that the minimum required airspace is sufficient. This test is intended to provide the data to resolve this difference of opinion.

The data collected during this study was designed to measure pilot performance and pilot perception of safety and aircraft control margin associated with various approach and departure surfaces. Tests were not designed to address operational issues such as Category A departure requirements and emergency operations protection. Specific protected airspace issues addressed were surface slope, width, length, and shape (i.e, approach course alignment).

METHODS

DATA COLLECTION FLIGHTS.

TEST LOCATION. The flight tests were conducted at the FAA Technical Center's National Concepts Development and Demonstration Heliport in Atlantic City, New Jersey. This facility is located within the coverage of extensive and accurate instumented flight tracking systems.

FLIGHT TEST PROCEDURES. A cross section of subject pilots from the private sector, military, and FAA were used during these tests. Each subject pilot was asked to fly 15 approaches and departures, using one of three approach or departure angles. Each approach started at an altitude of 500 feet above ground level (AGL) over one of six surveyed locations marked on the ground, and terminated with either a low hover or an actual landing. These surveyed locations resulted in constant approach angles of 7°, 8° or 10°. Each subject pilot flew each approach angle at least three times during a flight. In addition, the subject pilot was allowed to fly six approaches using an approach angle of his choice. This yielded a total of fifteen approaches, of which five were curved path. The desired curved approach flightpaths are shown in figure 2. For these approaches the pilot was instructed to initiate the approach on base at a distance determined by the radius of the turn based on no wind, 70-knot standard turn rate (3° per/second) conditions. The turn had to be completed at least 200 feet AGL. The three segments shown in figure 2 represent the radial and downwind distances at the start of the curve and the final segment distance.

The departures also consisted of three different angles: 7°, 10°, and 12°. The three different positions from which each departure was initiated yielded one of the departure angles that would clear fixed barriers controlling the departure surface. As with the approaches, each departure angle was flown three times. The pilot also flew six departure angles of choice, thus, yielding a total of fifteen departures, five of which were curved path. Departure procedures began at liftoff and ended at 500 feet AGL. 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 begin the approach and from which point to start the departure. For straight-in approaches the safety pilot gave the subject a countdown prior to the starting point. For curved path approaches the safety pilot announced when the subject should begin the turn. For data collection purposes the safety pilot announced when the subject rolled out on centerline. Following each maneuver the safety pilot took the controls while the

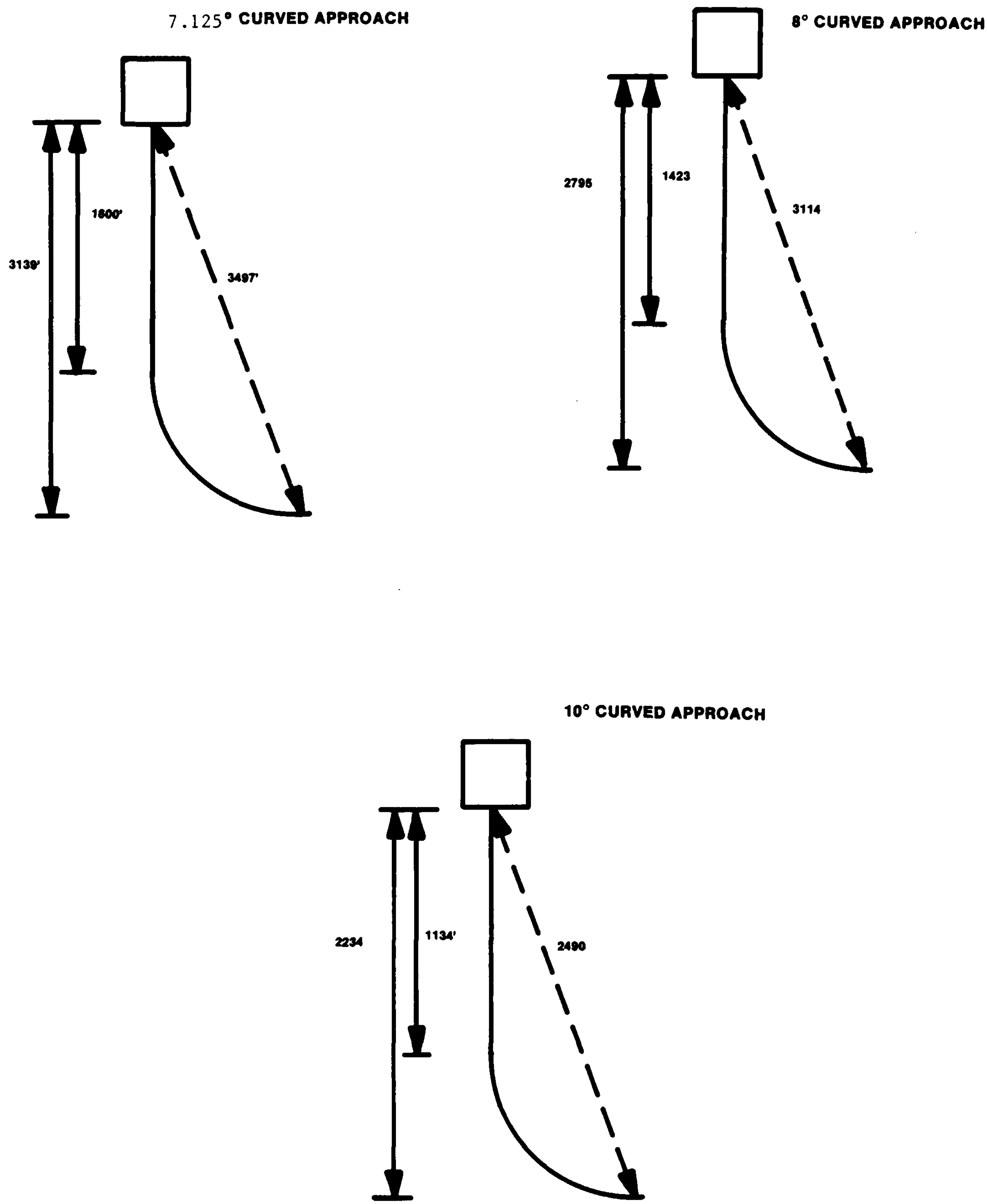


FIGURE 2. CURVED APPROACH PROFILES

subject pilot rated the maneuver using a modified version of the Cooper Harper rating scale. Using figure 3, subject pilots were thoroughly briefed on the use of the Cooper-Harper rating scale during the subject pilot briefing sessions prior to flight data collection.

Table 1 identifies the order in which the approaches and departures were flown during a particular flight. All pilot choice procedures were flown first to prevent data contamination.

FACILITIES AND INSTRUMENTATION.

TEST AIRCRAFT. The helicopters used were either owned or leased, and operated by the FAA.

Sikorsky S-76. The S-76 used was certified for single pilot Instrument Flight Rules (IFR) operations, as well as for operations with two pilots. It is designed to carry up to 13 passengers and a pilot. The S-76 is a helicopter that has a twin turbine engine, a single main rotor with a rotor diameter of 44 feet, and is capable of speeds up to 155 knots. For this test the aircraft was operated between 300 to 1300 pounds below its maximum gross weight of 10300 pounds. The S-76 data flights, consisting of 468 runs, were conducted between February 2 and February 17, 1987, and during the week of March 23, 1987.

Bell UH-1H. The UH-1H used for this project is 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 through an Interagency Agreement. It is a single engine helicopter equipped with electromechanical displays representative of civil IFR's 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. During the flights the aircraft was flown at weights between 500 and 1000 pounds less than its maximum gross weight of 9500 pounds. UH-1H flights, consisting of 510 test runs, were conducted between March 6 and May 14, 1987.

Hughes OH-6. The OH-6 used for this project was a single turbine engine, single main rotor, standard Visual Flight Rules (VFR) configured aircraft obtained through an Interagency Agreement with the New Jersey Department of Defense. It is assigned to and operated by the N.J. Army National Guard, Trenton, N.J. This helicopter is designed to carry up to three passengers and a pilot, is capable of speeds up to 124 knots, and has a rotor diameter of 24 feet, 4 inches. For this project the OH-6 was flown at weights between 2150 and 2300 pounds, which is 100 to 250 pounds less than its maximum gross weight of 2400 pounds. OH-6 flights, consisting of 239 test runs, were conducted during April and May 1987.

GROUND TRACKING. Two different tracking systems were used simultaneously during the approach and departure testing. These two systems were the NIKE/Hercules radar and the GTE Sylvania Laser Optical Tracking System. Use of both systems assured a higher degree of continuous tracking coverage.

The NIKE/Hercules radar system contains two X-band radar systems, a target tracking radar (TTR) and a missile tracking radar (MTR). They have been modified to output digital range, azimuth (AZ), and elevation (EL) data. The maximum

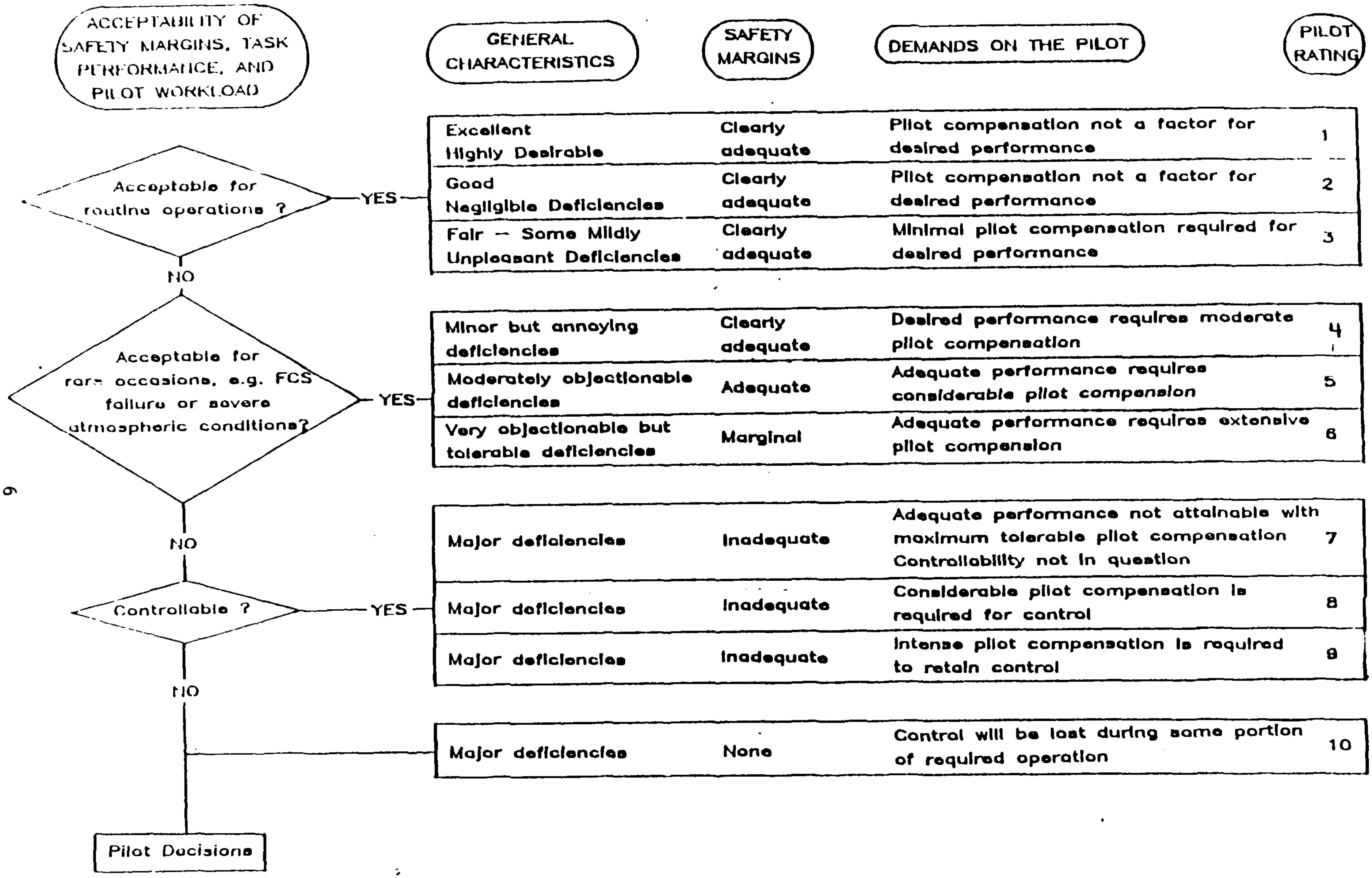


FIGURE 3. MODIFIED COOPER-HARPER PILOT RATING SCALE

TABLE 1. FLIGHT PROFILES

Run	Maneuver	Angle
1	Departure	Pilot Choice
2	Curved Approach	Pilot Choice
3	Curved Departure	Pilot Choice
4	Approach	Pilot Choice
5	Departure	Pilot Choice
6	Approach	Pilot Choice
7	Departure	Pilot Choice
8	Approach	Pilot Choice
9	Curved Departure	Pilot Choice
10	Approach	Pilot Choice
11	Departure	Pilot Choice
12	Curved Approach	Pilot Choice
13	Departure	7°
14	Approach	8°
15	Departure	10°
16	Approach	10°
17	Departure	12°
18	Approach	7°
19	Departure	7°
20	Approach	10°
21	Departure	12°
22	Curved Approach	8°
23	Departure	10°
24	Approach	7°
25	Curved Departure	10°
26	Approach	8°
27	Departure	7°
28	Approach	7°
29	Curved Departure	12°
30	Curved Approach	10°

range for coverage is 200 nautical miles (nmi) with an accuracy of 0.01 milliradians (mrads) in AZ and EL and 3 meters in range.

The laser is a mobile laser tracking and ranging system. It measures AZ, EL, and range automatically by transmitting a laser pulse to a target and measuring the angle of return and the round trip time. These data are recorded on a Digital Equipment Corporation (DEC) PDP 11/34 system. It has a maximum reliable range of 25 nmi with an accuracy of 1 foot for target ranges up to 5 nmi, 2 feet for target ranges from 5 to 10 nmi, and 5 feet for target ranges at 25 nmi. The laser can track an aircraft from takeoff through touchdown. Coverage for AZ is 540°, while EL coverage is from -5° to 85° with an accuracy of 20 arc seconds at all ranges for both AZ and EL.

SUBJECT PILOTS.

The selection of pilots participating in this project was based primarily on the qualifications and availability of the individual. Subject pilots were obtained from industry and military as well as government agencies. In addition, in order to comply with the operating procedures of the Department of the Army, all UH-1H subject pilots were required to be qualified and current in the aircraft in accordance with provisions of Army Regulation 95-1. All OH-6 subject pilots were current N.J. Army National Guard pilots and are or had been corporate helicopter pilots. A total of 27 pilots were used. The source of the subject pilots by aircraft is presented in table 2.

TABLE 2. SUBJECT PILOT SOURCE

Aircraft	Source	Number
S-76	FAA	4
	Military	2
	Industry	3
UH-1H	FAA	5
	Military	5
	Industry	3
OH-6	Military	2
	Industry	3

S-76 pilot experience ranged from 181 to 7300 total helicopter hours and from 15 to 215 recent hours (last 6 months) in type. A further breakdown of S-76 pilot experience is presented in table 3.

UH-1H pilot total helicopter experience ranged from 400 to 7300 hours with time in type over the last 6 months ranging from 5 to 100 hours. Additional UH-1H pilot experience information is given in table 3.

OH-6 pilot experience ranged from 1200 to 3200 total helicopter hours with time in type over the last 6 months ranging from 10 to 250 hours. See table 3 for further pilot experience information.

TABLE 3. SUBJECT PILOT EXPERIENCE

S-76 Subjects

Total Flight Hours	Number of Pilots
0-500	0
501-1500	0
>1500	9

Total Time in Type	Number of Pilots
0-50	1
51-200	4
>200	4

Total Helicopter Hours Last 6 Months	Number of Pilots
<10	0
10-50	4
>50	5

UH-1H Subjects

Total Flight Hours	Number of Pilots
0-500	1
501-1500	0
>1500	11

Total Time in Type	Number of Pilots
0-50	0
51-200	1
>200	11

Total Helicopter Hours Last 6 Months	Number of Pilots
<10	0
10-50	4
>50	8

OH-6 Subjects

Total Flight Hours	Number of Pilots
0-500	0
501-1500	1
>1500	4

Total Time in Type	Number of Pilots
0-50	0
51-200	0
>200	5

Total Helicopter Hours Last 6 Months	Number of Pilots
<10	0
10-50	1
>50	4

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). In addition, the responsibilities of the subject pilot and safety pilot were defined. The approach and departure test procedures were described in detail. The subject was able to ask questions relating to the maneuvers. Local area conditions and aircraft information was also discussed during the preflight briefing. When the premission briefing was completed, the subject pilot was familiarized with the heliport approach and departure routes. After the first departure, the safety pilot flew the subject pilot around the test area. The first approach was initiated after the safety pilot showed the subject the reference landmarks.

DATA PROCESSING AND ANALYSIS

SOURCE OF DATA.

Test data came from five sources: inflight pilot ratings of the procedures, observer logs, post-flight pilot questionnaire and ratings, and laser and NIKE tracking tapes.

INFLIGHT QUESTIONNAIRE. Subject pilots were asked to rate each approach or departure procedure on their preception of pilot workload, safety margin, and control margin (aircraft controllability/flyability). This rating was obtained after the procedure was flown, using a modified version of the Cooper-Harper Rating Scale. Pilot responses were recorded in a written log by the flight observer immediately following the procedure. The rating system is depicted in figure 3.

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

POST-FLIGHT QUESTIONNAIRE. At the conclusion of the second flight (or the first if only one was conducted) the subject pilot was given a post-flight questionnaire to complete (see appendix C). This questionnaire asked for the subject's opinion about issues such as suitability of the approach/departure, control and safety margins, and workload. The inflight questionnaire was designed to provide immediate subject response following a particular manuever. The post-flight questionnaire was designed to provide comparative subject pilot measures across all test profiles. Pilot background information was also collected such as number of flight hours and aircraft experience. Other questions asked for subject pilot input about publication of maneuver and surface information and heliport factors. This information was analyzed and correlated with pilot performance. Appendix C contains a sample Post-Flight Questionnaire.

TRACKER DATA. The NIKE and laser tracker tapes contained data that had been converted from slant range, azimuth, and elevation to X, Y, and Z coordinates (using the Technical Center Tracker Coordinate System) by the Technical Center's Honeywell 66/60 facility. The tapes were then converted from Honeywell format to VAX/VMS format. The origin of the tracker data was translated to the center of the heliport with the X and Y axis runing through the centerline. The X-axis is positive on the approach side and negative beyond with the Y-axis perpendicular to the X-axis within the heliport plane, positive to the right of the inbound course and negative to the left. The Z-axis is drawn perpendicular to the X-Y plane at the ground point of intercept, positive above and negative below the heliport plane (see figure 4).

Ground tracking data were used to generate plots depicting both plan and profile views of each procedure relating to the desired course. Tracking was begun prior to the aircraft reaching the approach initiation point and continued through touchdown and from departure until the aircraft had climbed to at least 500 feet AGL.

ANALYSIS PROCEDURES.

FLIGHT DATA. Flight data were provided from three possible sources: a laser tracker tape, a NIKE/Hercules tape, and observer flight logs. Both the laser and NIKE tapes contain data recorded at the tracker site. The Observer Logs chronologically ordered specific events that occurred during the various approaches and departures, along with wind information and other miscellaneous information and comments.

MERGE.

UH-1. For the purpose of data reduction and analysis, the two data tapes had to be merged into one file. When recorded, each record on each tape had been synchronized by using each tape's time tag. Thus, it was possible to merge the data from the different tapes into the one data file. The two tracking tapes were time merged using the laser as the master. Tracking data were considered invalid only if there were no data with the proper time tag.

DATA PARTITIONING. In order to perform the required statistical analysis, it was necessary to partition, or bin, the data. Binning was done in three different ways: horizontally along the inbound axis, vertically with reference to the axis perpendicular to the helipad surface, and in three dimensions along a three-dimensional reference path for the procedure being flown. All binning was begun with the center of the helipad as the first bin or bin zero.

Bin ranges for other bins were calculated as follows:

For horizontal and three-dimensional binning;

$$BRn = BRo + 100 * BNn$$

and for vertical binning;

$$BRn = BRo + 25 * BNn$$

where BRn is the nth bin range, BRo is the bin range for bin zero, 100 and 25 are the partition intervals (in feet), and BNn is the nth bin number.

STATISTICS. Statistical calculations were performed on the binned data. For each bin, the parameters of interest were the number of data points (N), the arithmetic mean, the unbiased estimate of standard deviation, skewness, and kurtosis. The first four moments about zero were calculated to aid in

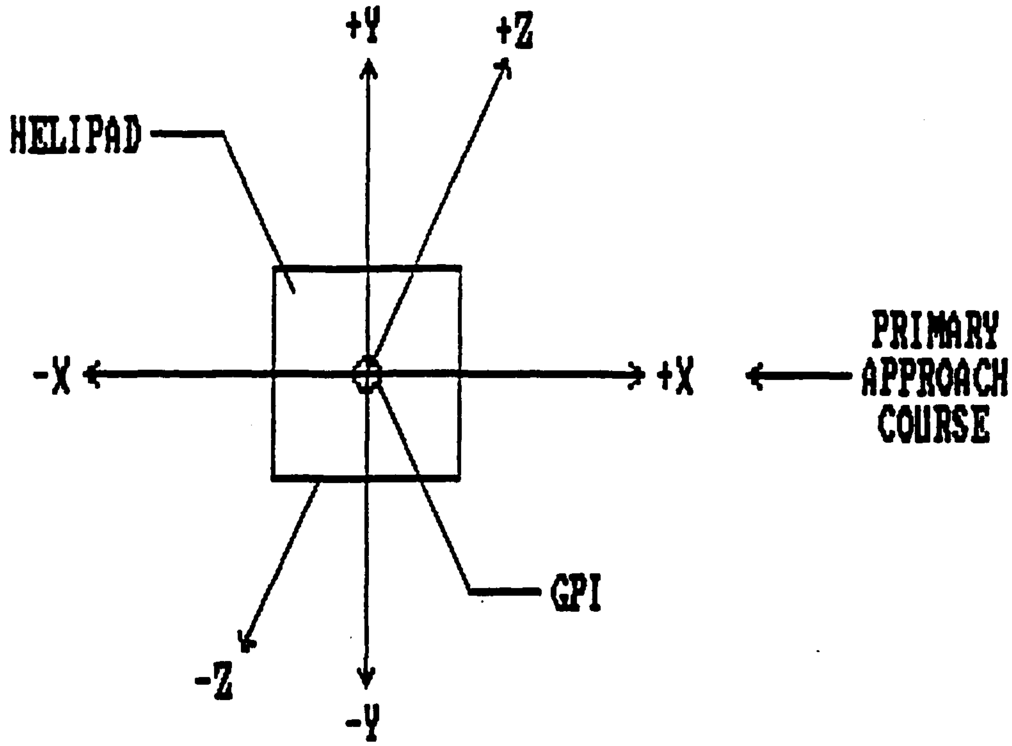


FIGURE 4. RECTANGULAR COORDINATE REFERENCE SYSTEM

calculations for skewness and kurtosis. The formulas used can be found in Theory and Problems of Statistics by Murray R. Spiegel, Ph.D, Schaun Publishing Company, New York, 1961.

PLOTTING. All plotting done for the VMC project was accomplished using a California Computer's Calcomp 1051 drum plotter using Calcomp 907 software for the VAX 11/750 computer. The plots that were generated were divided into two categories, flight data and statistical data.

FLIGHT DATA PLOTS. Two classes of flight data plots were prepared from the merged data. The first class graphically depicted lateral deviations versus range from the center of the heliport. The second class depicted vertical deviations versus range. These plots were prepared in two ways, individual and composite. The individual plots were prepared on a per run basis, in which each individual run of a particular flight was plotted separately. Individual X-Y plots were generated for crosstrack in feet versus range in feet and Z-Y plots were generated for altitude in feet versus range in feet. Other individual plots include plots of velocities in all three directions in feet per minute (fpm) versus range in feet, along with ground speed and along-path speed in knots vs range in feet. Large variations in crosstrack or along-track velocities imply increased pilot workload. The individual plots were used primarily to determine if, during a particular approach/departure, there were any problems with the ground or in the onboard data collection system. These plots also showed how well a pilot performed a particular procedure.

STATISTICAL PLOTS. A graphical presentation of the results of the statistical analysis was performed using six sigma isoprobability contours. These plots, produced for crosstrack deviation, altitude, crosstrack velocity, along track velocity, vertical velocity, along-path speed, angular error, and altitude error, were of the mean value surrounded by the envelope created by plotting the mean plus and minus six standard deviation values. All points were plotted against their associated bin ranges. Composite statistics plots were also produced for the same parameters vs. bin range, comparing all three approach and departure angles on one plot.

RESULTS

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

DATA PLOTS

INDIVIDUAL. Figure 5 shows the individual plot formats for the approaches. The dotted lines represent the reference surface the pilot would fly assuming a zero error. The heliport is at 0-foot range. Although performance for the steeper angle were not as good as the shallow angle approaches, the majority were able to stay above the desired surface and were well within the requested speed profiles.

Figure 6 shows the individual plot formats for departures. A barrier was located off the departure end of the heliport, at 155 feet from the 12° starting point, 187 feet from the 10° point, and 264 feet from the 7.125° point. Because of the large number of individual plots that resulted, only a sample is presented in

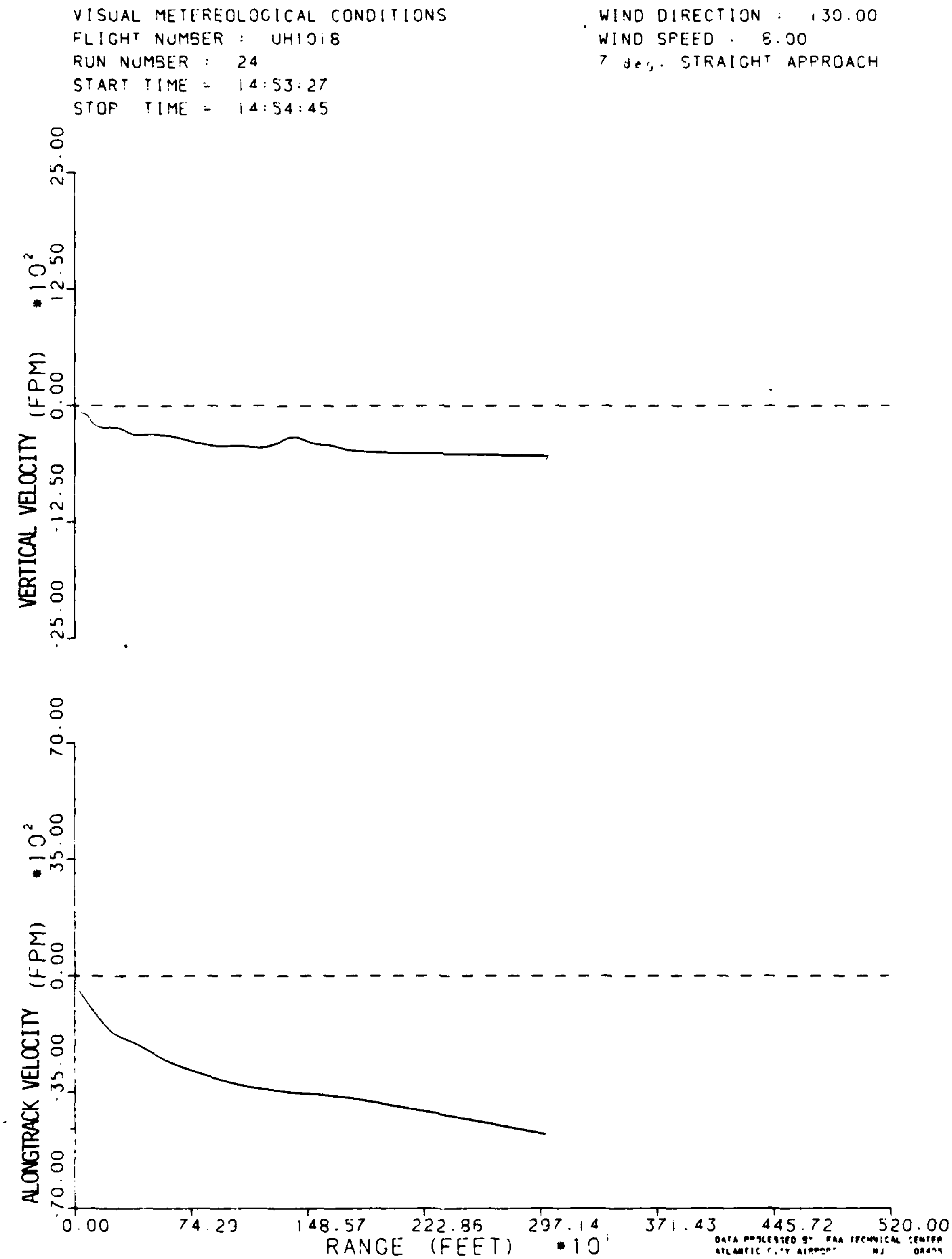


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS FOR APPROACHES (SHEET 1 OF 4)

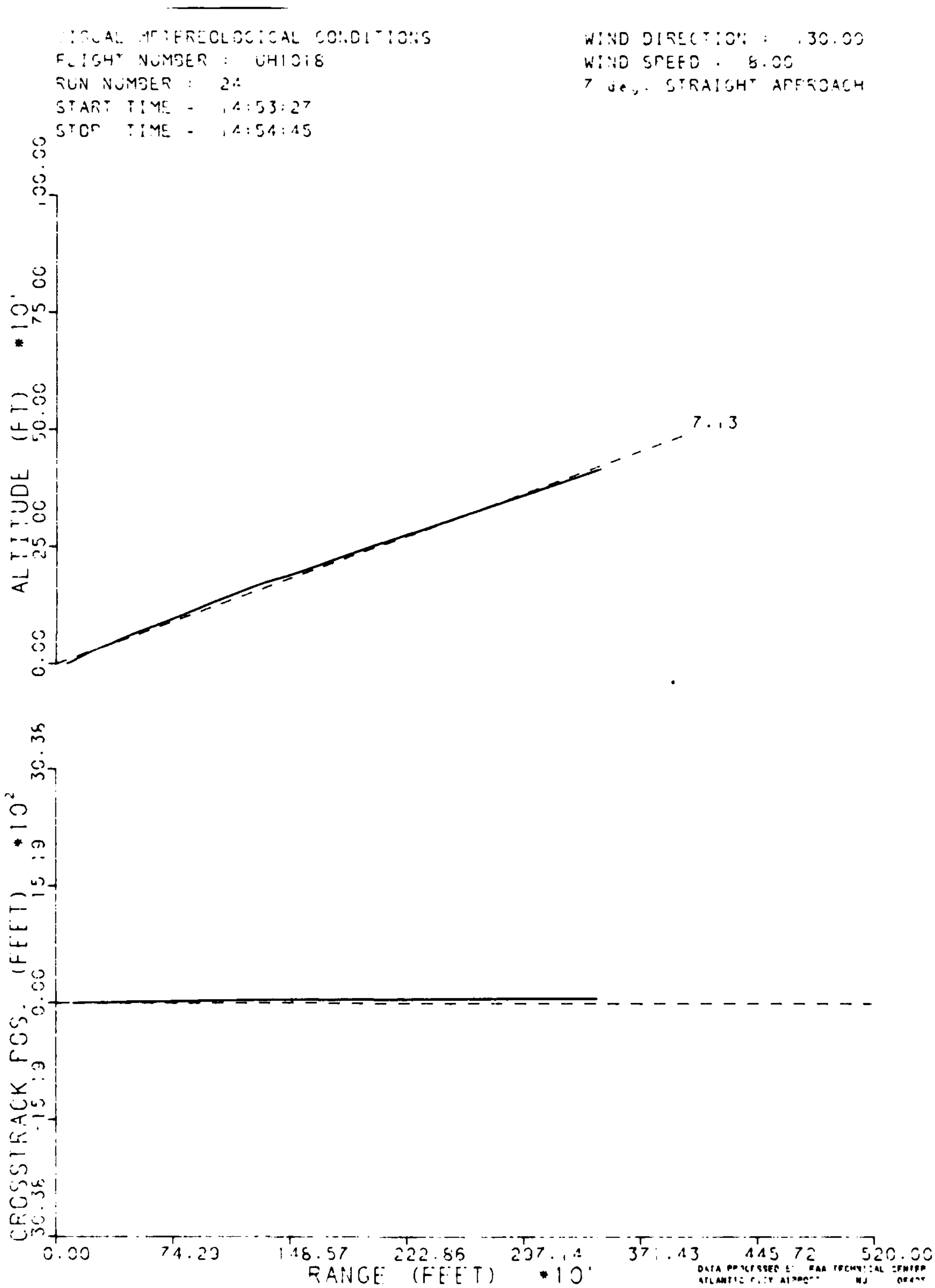


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS FOR APPROACHES (SHEET 2 OF 4)

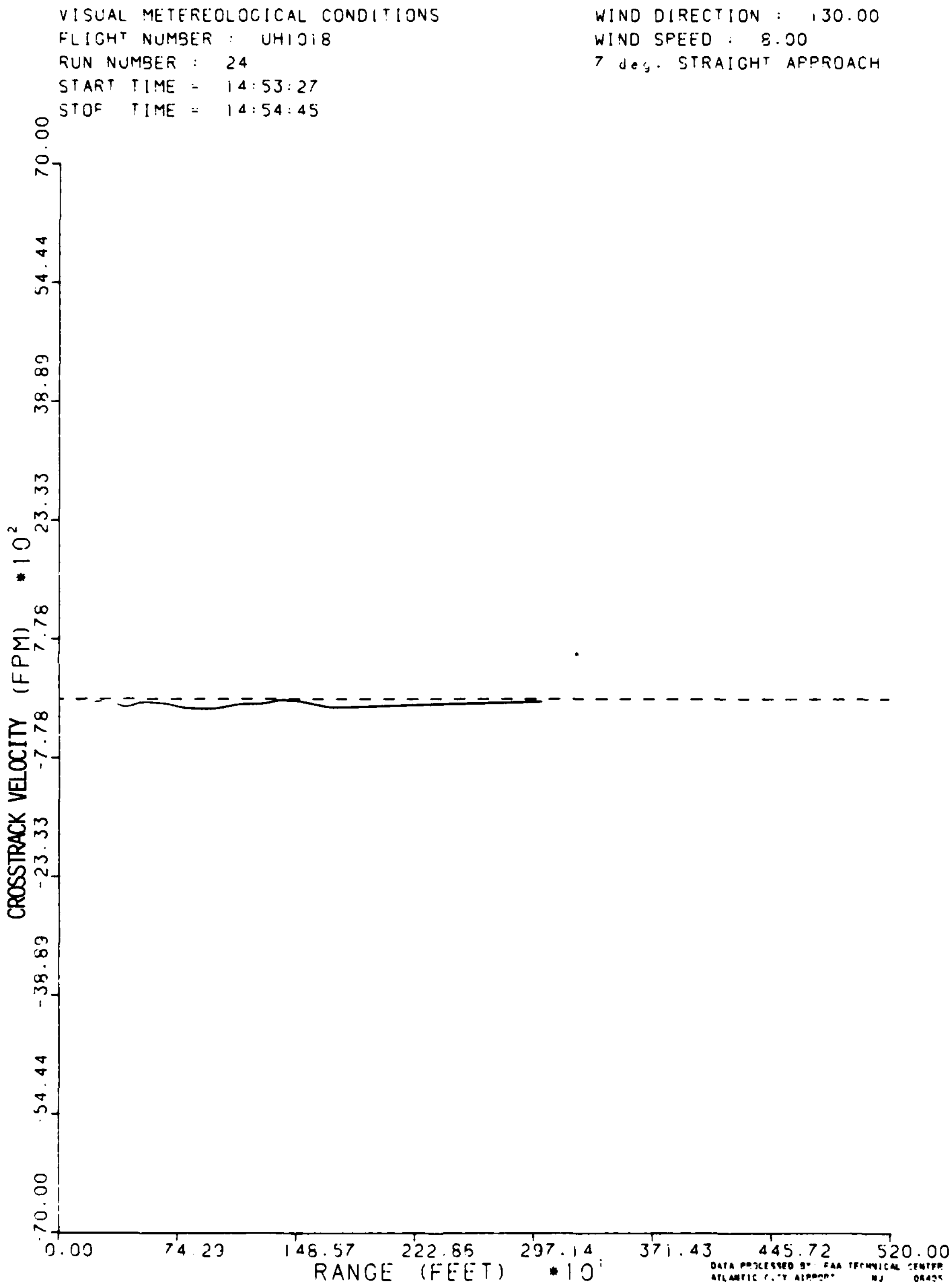


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS FOR APPROACHES (SHEET 3 OF 4)

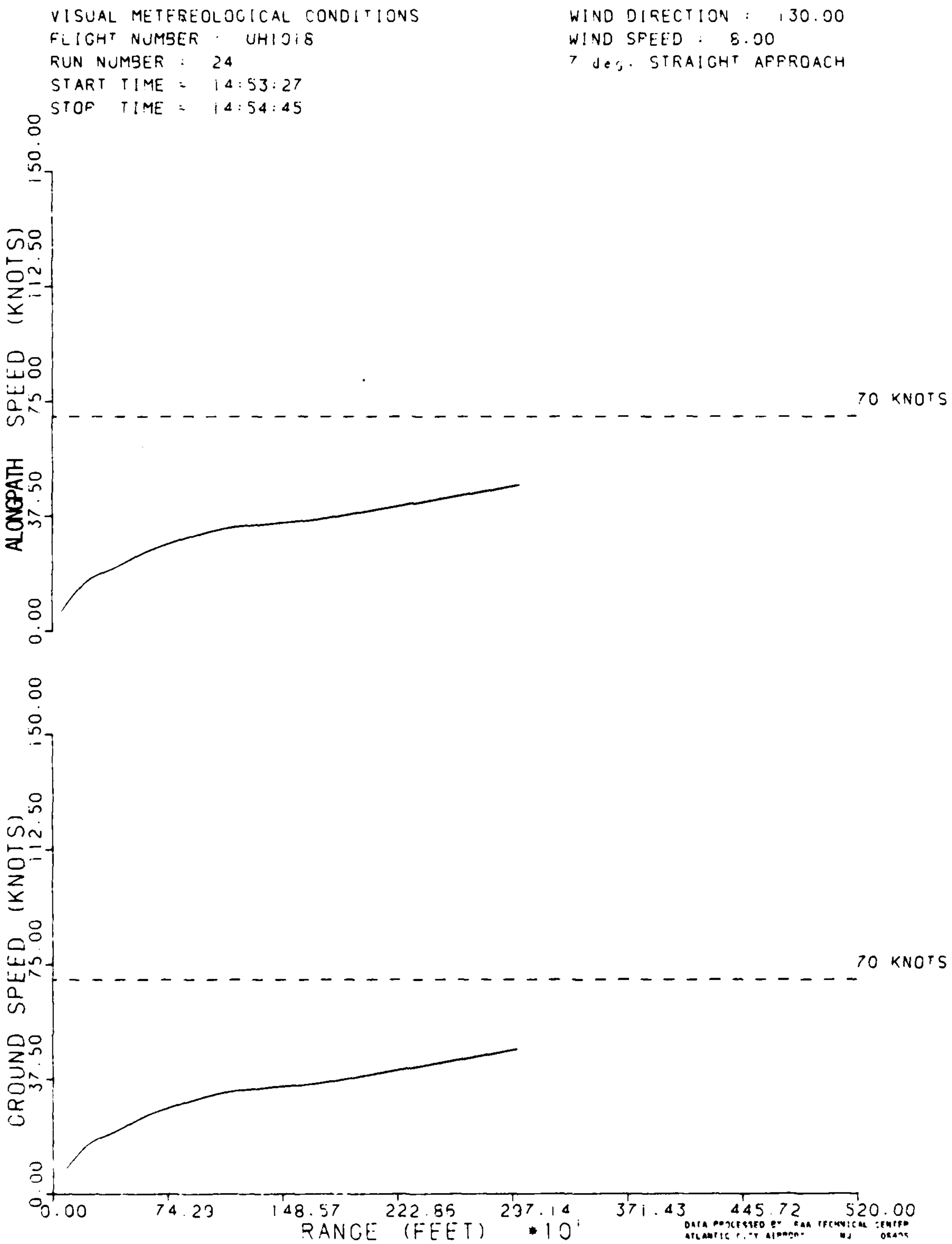


FIGURE 5. SAMPLE INDIVIDUAL PLOT FORMATS FOR APPROACHES (SHEET 4 OF 4)

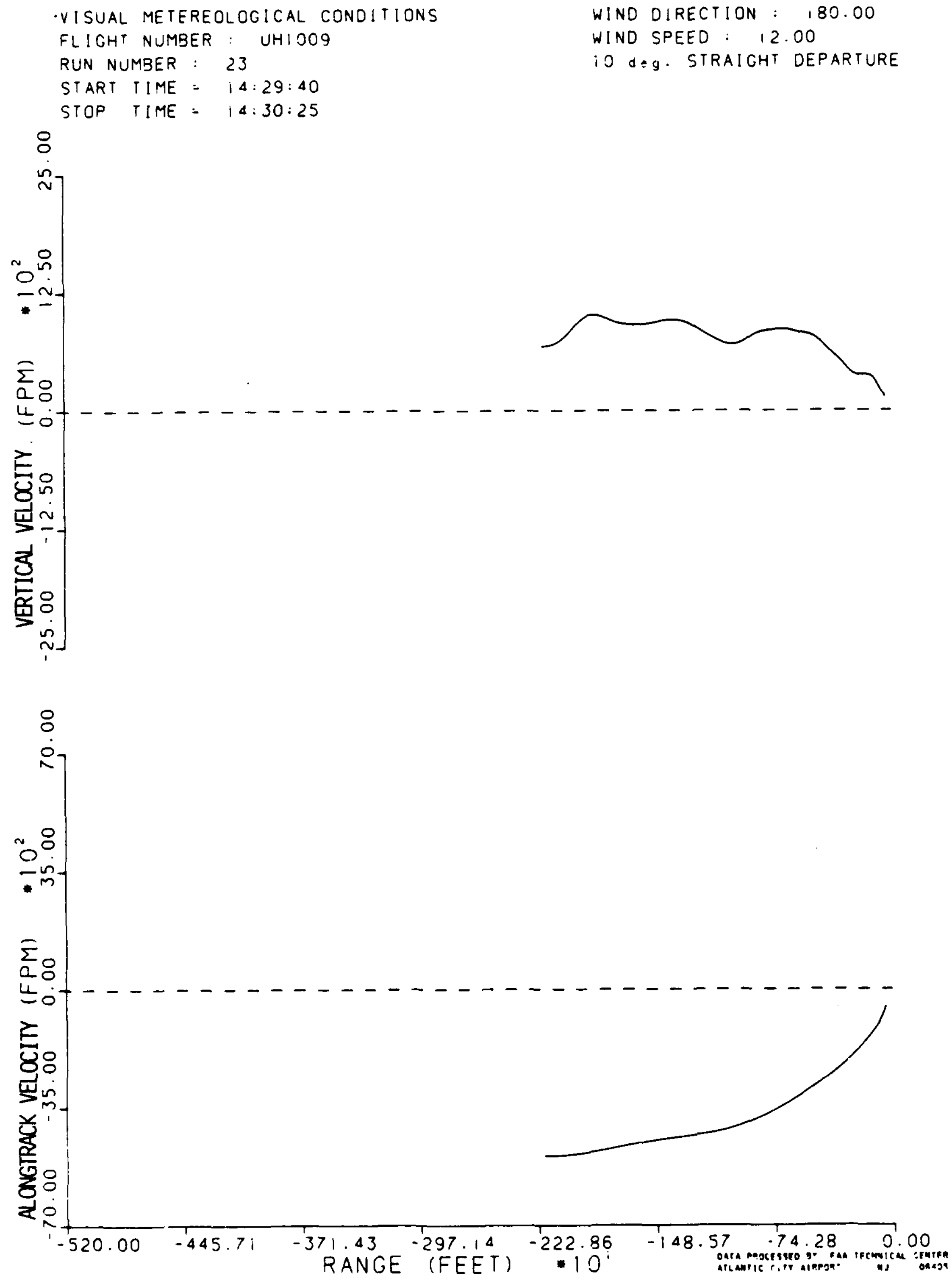
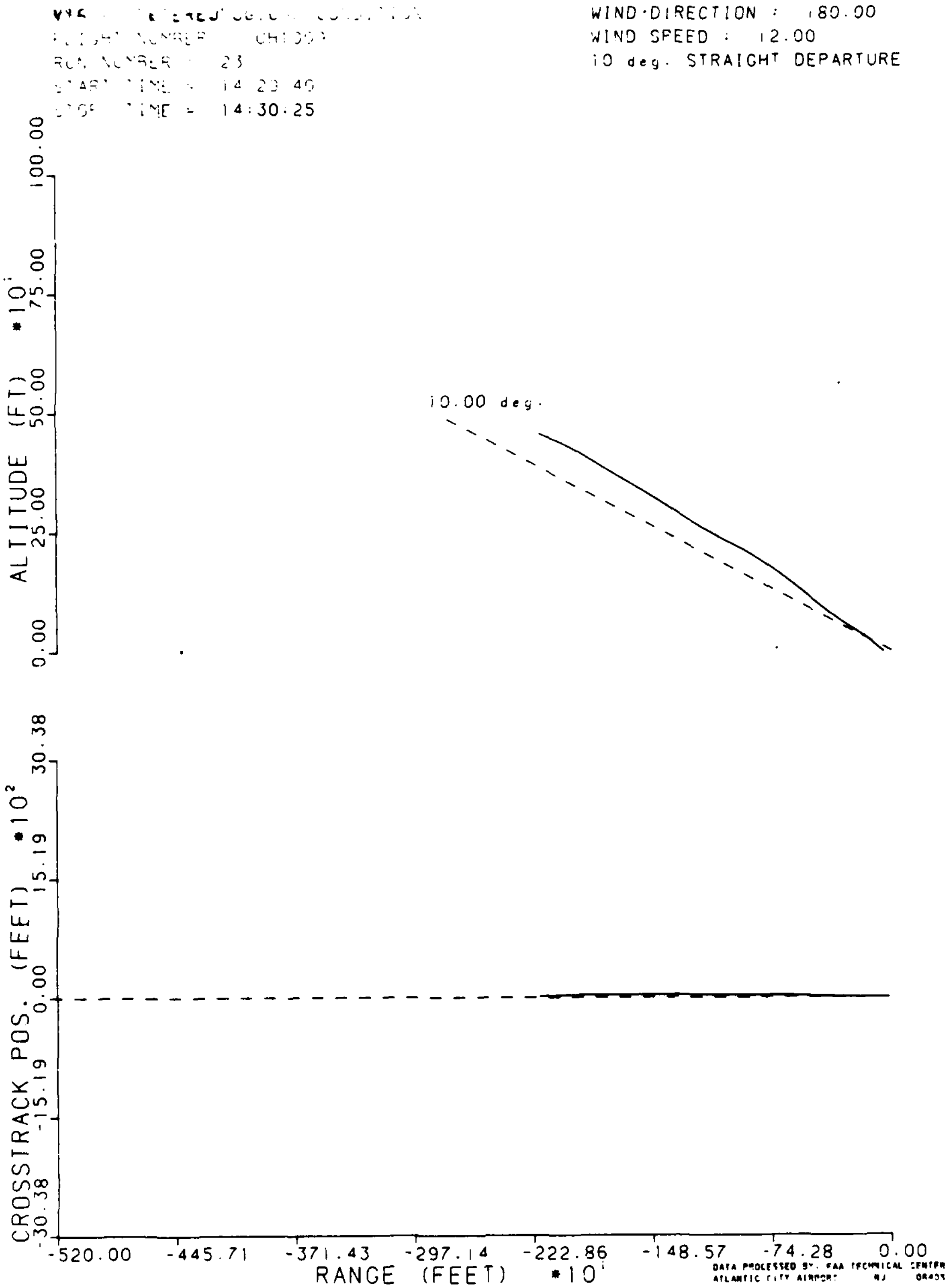


FIGURE 6. SAMPLE INDIVIDUAL PLOT FORMATS FOR DEPARTURES (SHEET 1 OF 4)



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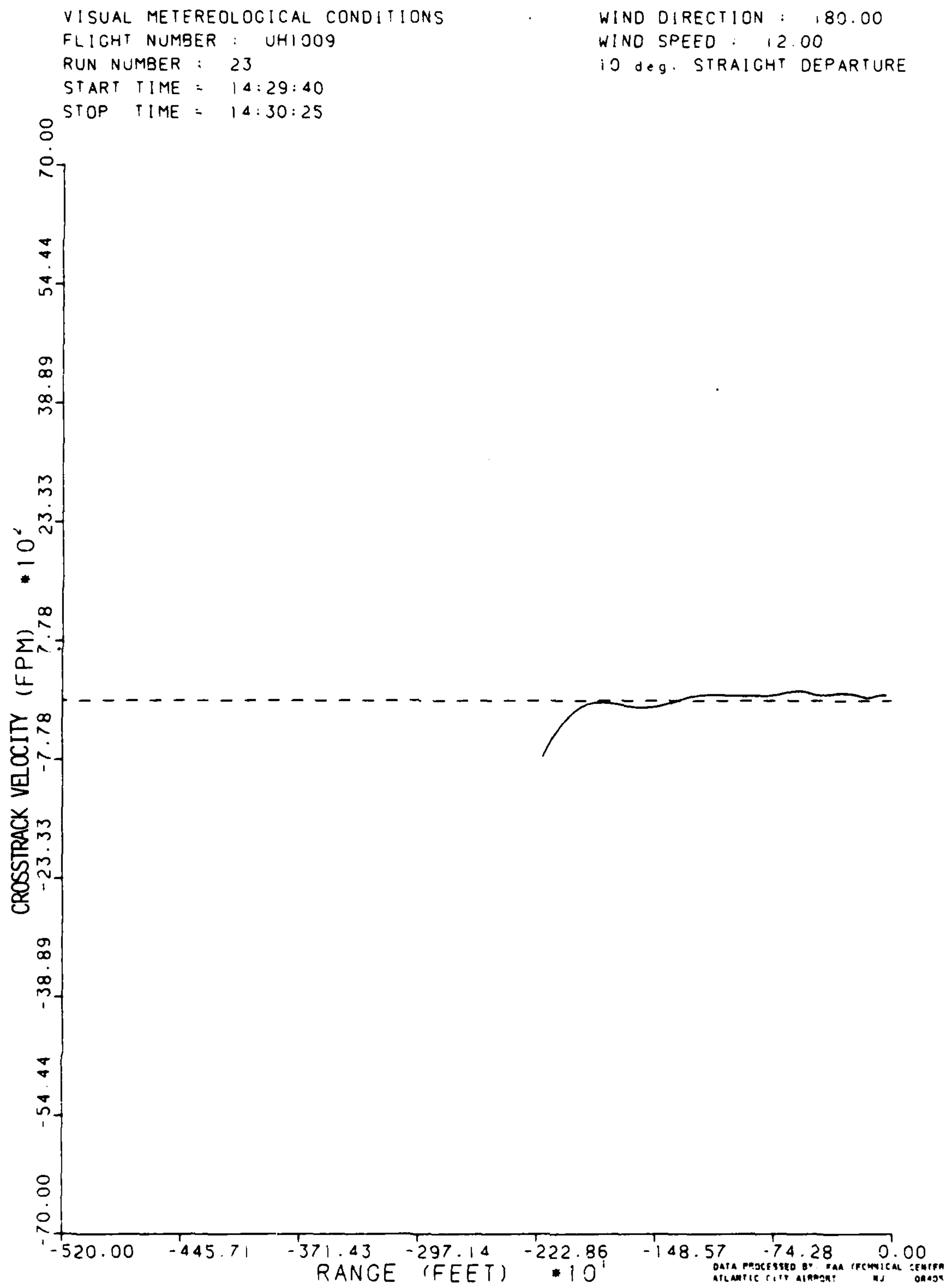

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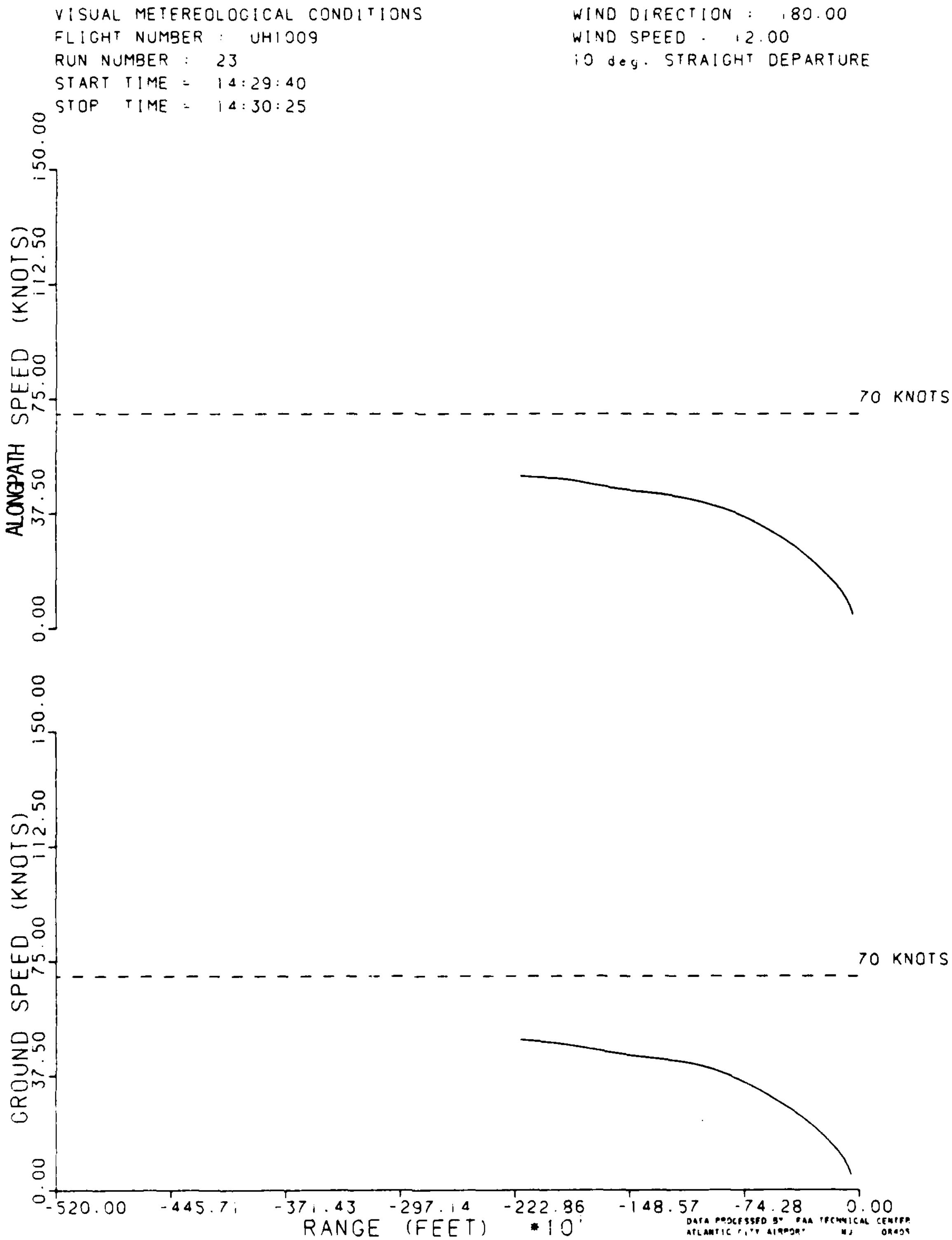


FIGURE 6. SAMPLE INDIVIDUAL PLOT FORMATS FOR DEPARTURES (SHEET 4 OF 4)

this report. Pilots were able to maintain the departure surface angle as well as the speed profile required.

STATISTIC PLOTS

Composite. To see how the subject pilots performed as a group, composite statistical plots of straight approaches and departures as well as straight segments of curved procedures were produced. Figure 7 shows the format for composite statistical plots of approaches. All the approach plots for the S-76 and UH-1 are found in volume II, appendix D of the report. Figure 8 shows a sample of the format for departure statistical composite plots. All departure composite plots for the S-76 and UH-1 are found in volume II, appendix E. OH-6 composite plots are not presented due to limited sample size. Similar crosstrack, altitude, and speed performance across all three angles for the S-76 and UH-1 was observed.

Isoprobability. Figure 9 shows a sample six sigma isoprobability plot. All the isoprobabiity plots for the S-76 approaches are presented in volume II, appendix F, those for the UH-1H approaches are presented in volume II, appendix G, and those for the OH-6 approaches are found in volume II, appendix H. All departure plots can be found in volume II, appendixes I, J, and K for the S-76, UH-1H, and OH-6, respectively. As with composite plots, similar performance was observed across the three angles for the S-76 and UH-1. Velocity profiles were well within the expected limits (see volume II, appendixes F, G, and H).

STATISTICS LISTINGS.

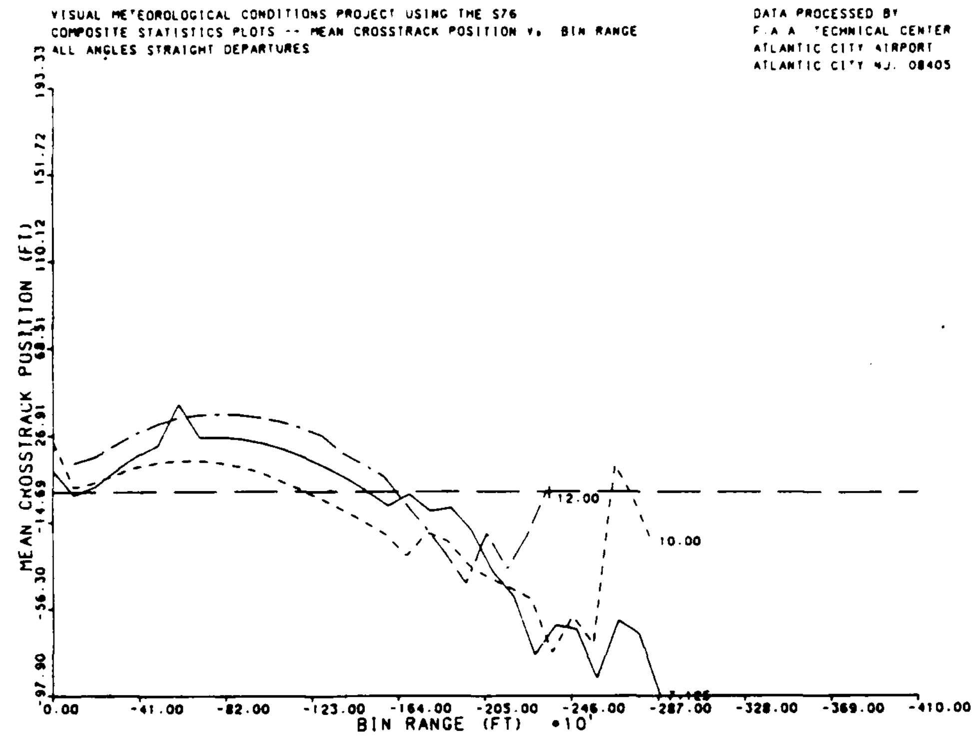
Summary statistics listings were produced for tracker crosstrack position, altitude, crosstrack, along-track and vertical velocity, altitude error, angular error, and along-path speed using bin range as the X axis. Volume II, appendix L contains these listings for all three aircraft. For pilot choice procedures, S-76 and OH-6 pilots, on the average, chose approaches slightly steeper than the current 7.125°, while UH-1 pilots chose even steeper approaches. For departures, pilots of all three helicopters chose procedures significantly steeper than the current 7.125° (greater than 11° for the S-76 and OH-6, and 9.5° for the UH-1 pilots (see table 4)).

PILOT QUESTIONNAIRES.

INFLIGHT QUESTIONNAIRE. The Cooper-Harper Modified Pilot Rating Scale used for the Inflight 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.

Pilots for all three aircraft rated all three angles as adequate. There is a very slight increase in the mean rating from the shallow to the steeper angles. With the exception of the rating for the 7.125° curved approach for the S-76, the curved approach ratings were slightly higher than their respective straight-in approaches, yet were still basically considered acceptable (see figure 10).

All three departure angles for both straight-out and curved paths were rated as adequate or acceptable for the three aircraft. All mean ratings were less than



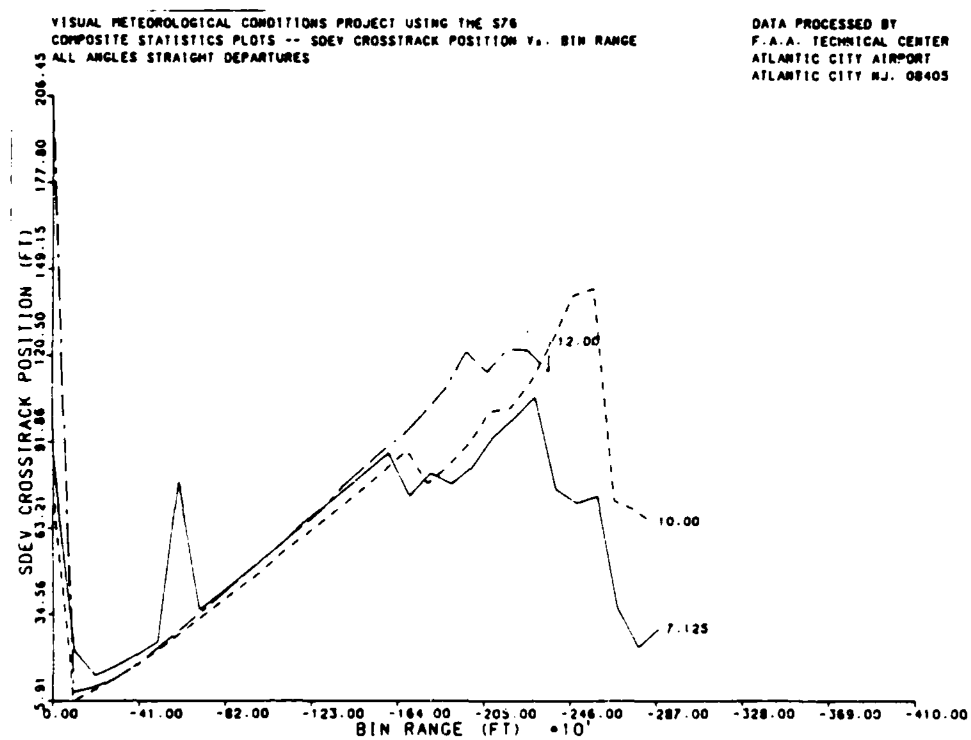
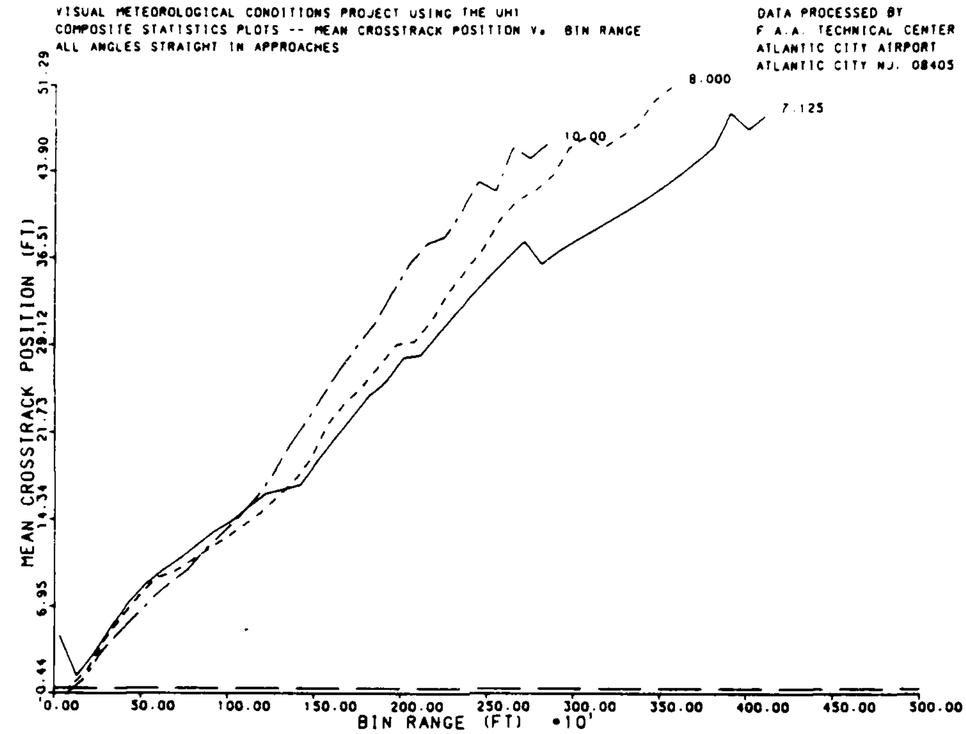


FIGURE 7. SAMPLE COMPOSITE PLOT FOR APPROACHES



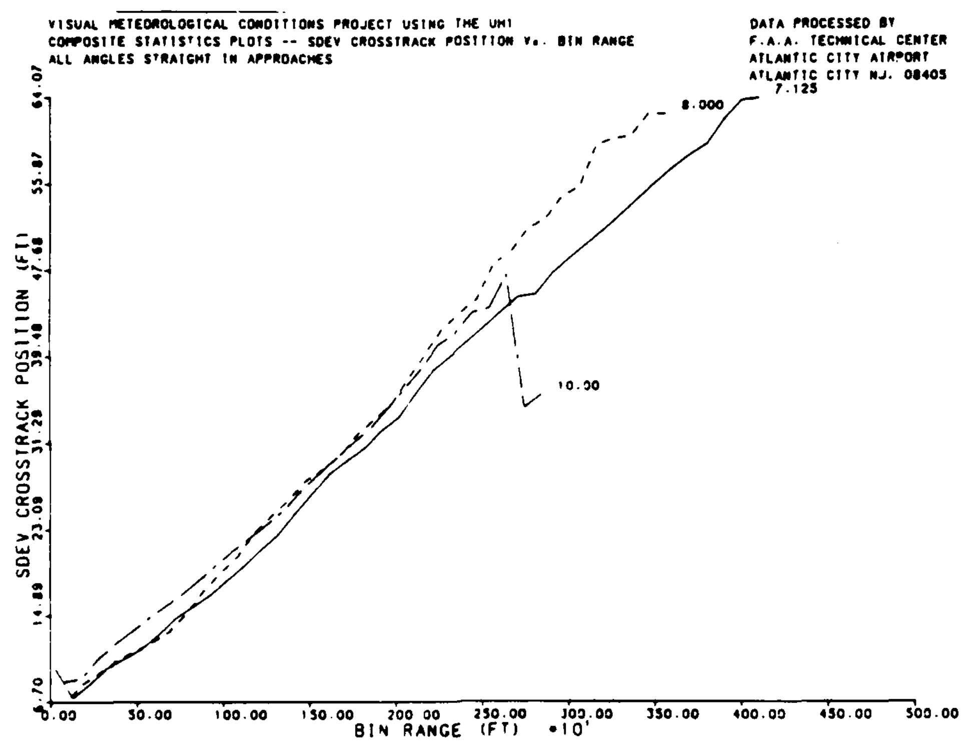


FIGURE 8. SAMPLE COMPOSITE PLOT FOR DEPARTURES

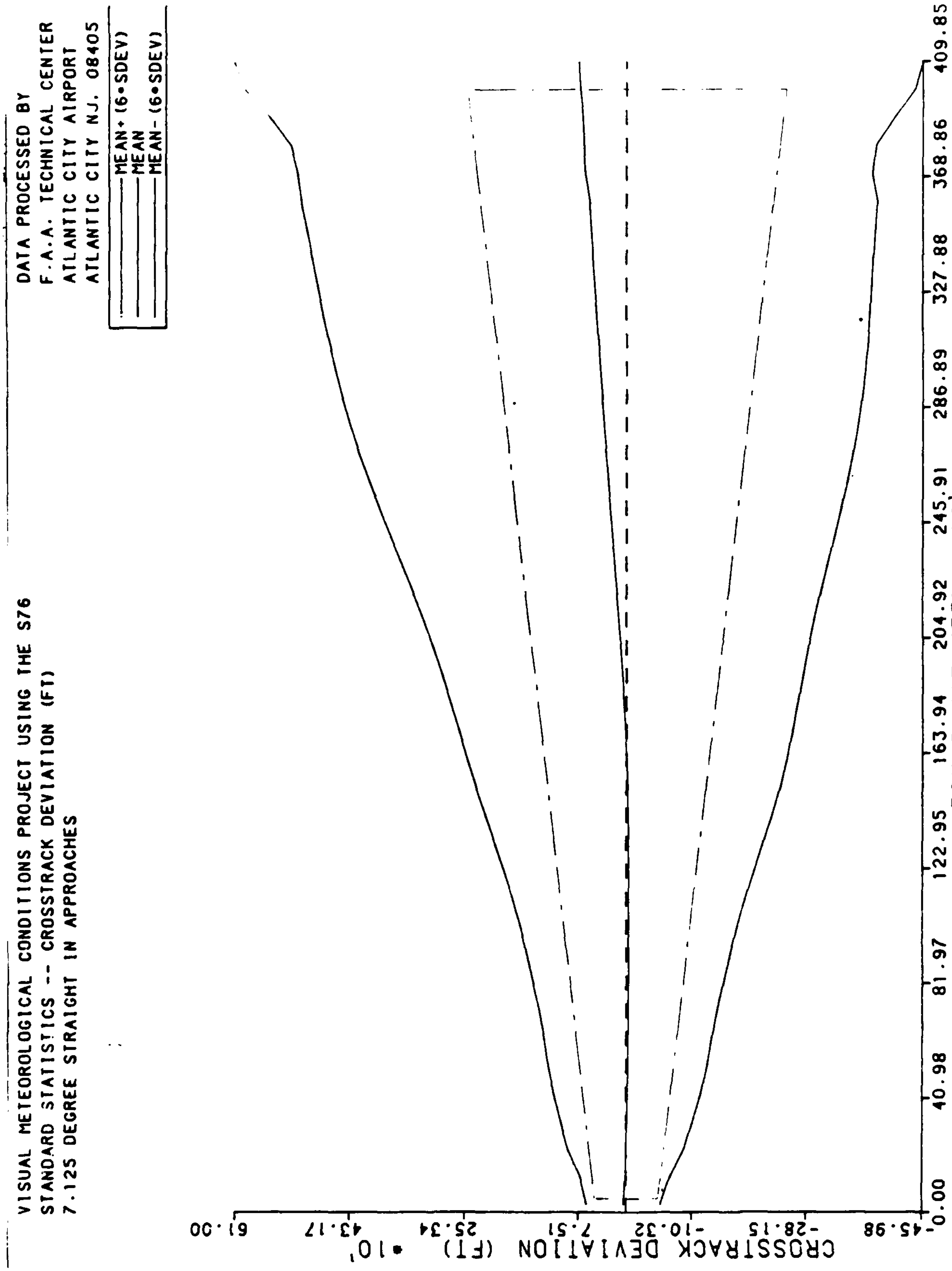


FIGURE 9. SAMPLE 6 SIGMA ISOPROBABILITY CONTOUR

TABLE 4. STATISTICS FOR PILOT CHOICE MANEUVERS

		S-76	UH-1	OH-6
Approaches	Mean	7.38°	8.21°	7.17°
	SD	1.82°	1.47°	2.01°
Departures	Mean	11.30°	9.51°	11.25°
	SD	3.14°	2.34°	4.04°

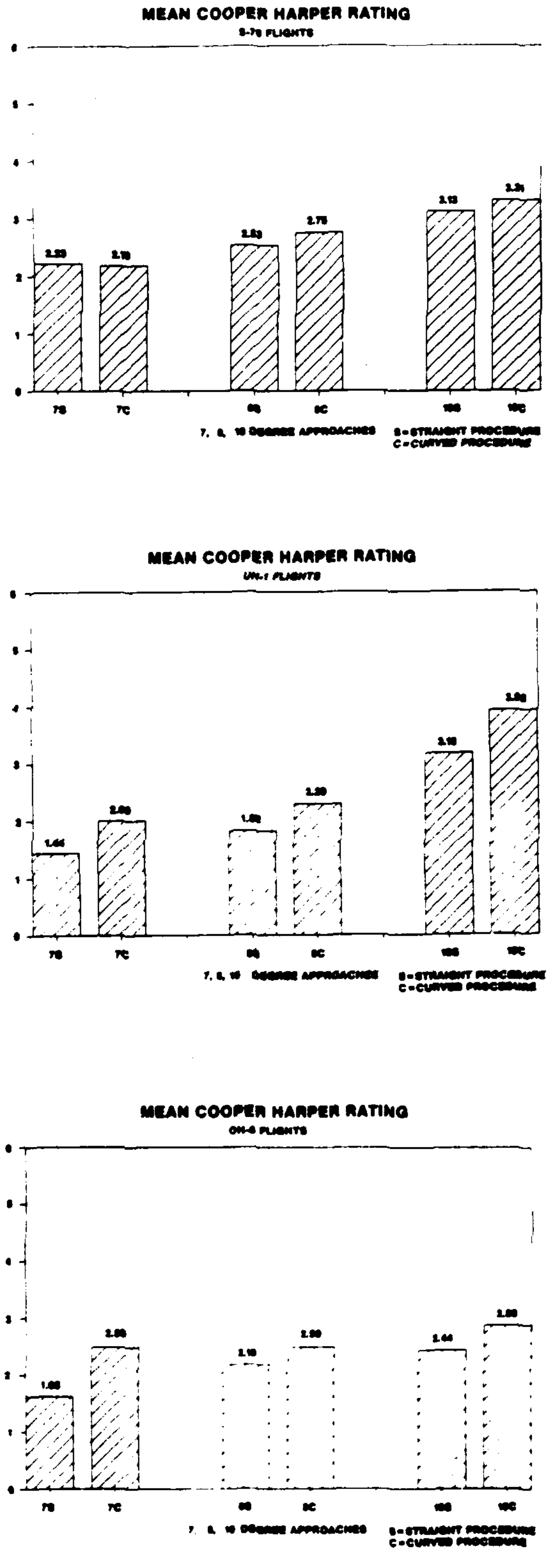


FIGURE 10. MEAN PILOT COOPER-HARPER RATINGS FOR APPROACHES

2.75. In all cases the difference between the ratings for the straight-out and the curved departures were insignificant (see figure 11).

Appendix M, volume II, contains plots of individual pilot approach ratings for all three aircraft. Appendix N contains similar plots for departures.

Post-Flight Questionnaire. The scale used for the Post-Flight Questionnaire was exactly opposite of the Cooper Harper Scale. The higher rating indicates better acceptance, i.e., higher implies better (see appendix C for the post-flight scale). For both the approaches and departures the ratings for safety margin, workload, and control decreased as the angle steepened. This indicates the pilots perceived the safety and control margins as lower for the steeper angles while the workload increased. However, for the departures the decrease in the ratings was not as large as for the approaches (see figures 12 and 13).

INFLIGHT PILOT COMMENTS.

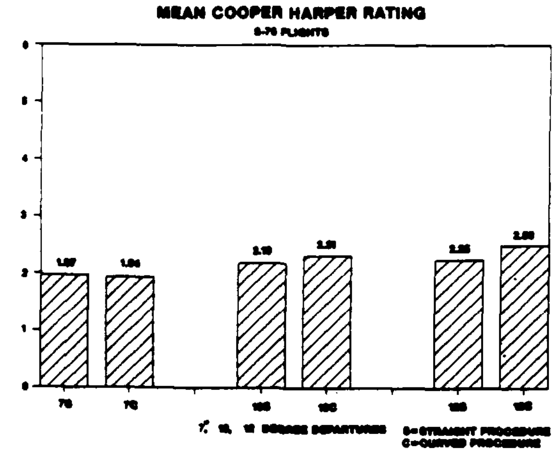
Approaches. Most of the S-76, UH-1, and OH-6 pilots felt the 7.125° straight-in and curved approaches were easy to perform and were very comfortable, particularly for passengers. Some indicated that only minor collective and pitch control adjustment were required and the concentration level was less fatiguing for 7 125° approaches. However, one S-76 pilot expressed the view that the 7.125° approach was harder to perform than the steeper ones.

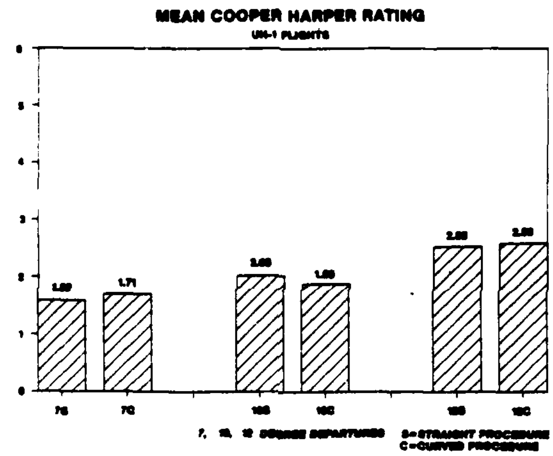
For the 8° approaches, pilots also reported that the approach felt comfortable and required minimal pitch or collective movement. However, one or two UH-1 pilots remarked that this approach was a little steeper than desired and a little more pitch adjustment was required. When compared to the 7.125° approach the major complaint from the S-76 pilots concerned the visibility problem that accompanied the steeper angle maneuvers.

The 10° approaches brought the most criticism. However, controllability doesn't appear to be the chief concern. Passenger comfort and pilot visibility were the prime concerns for the UH-1 as well as the S-76 pilots. Visibility was a major issue for S-76 pilots performing the 10° curved approaches. One OH-6 pilot remarked that an approach this steep would "put the coffee in the passenger's lap," while a UH-1 pilot said he "wouldn't do it in the civilian world." From the comments it appears that this angle requires more work on the part of the pilot and is also uncomfortable for the pilot to perform. One called the 10° approaches "annoying." Some commented that they almost or did hit the bottom of the collective control range.

Departures. The 7.125° shallow departures were considered comfortable and required only minor attention to the departure itself. Comments ranged from nice and shallow to "too shallow." The 7.125° curved departure was considered easy to fly by most, yet one UH-1 pilot said it was a little uncomfortable.

The 10° departures brought a wider range of comments from "not difficult" to "more difficult." Pilots felt this departure required more work on the pilot's part and required more attention to the manuever. One pilot said this maneuver requires the pilot to be on "top" of the controls. The concerns appear to be with the pedal limits and amount of torque required. Some felt the 10° departure required almost full left pedal (the departure procedures required a 90° left climbing turn) near aft cyclic limit, and almost reached full torque.





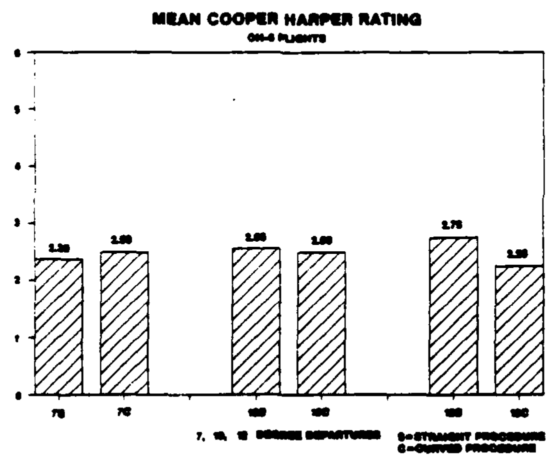


FIGURE 11. MEAN PILOT COOPER-HARPER RATINGS FOR DEPARTURES

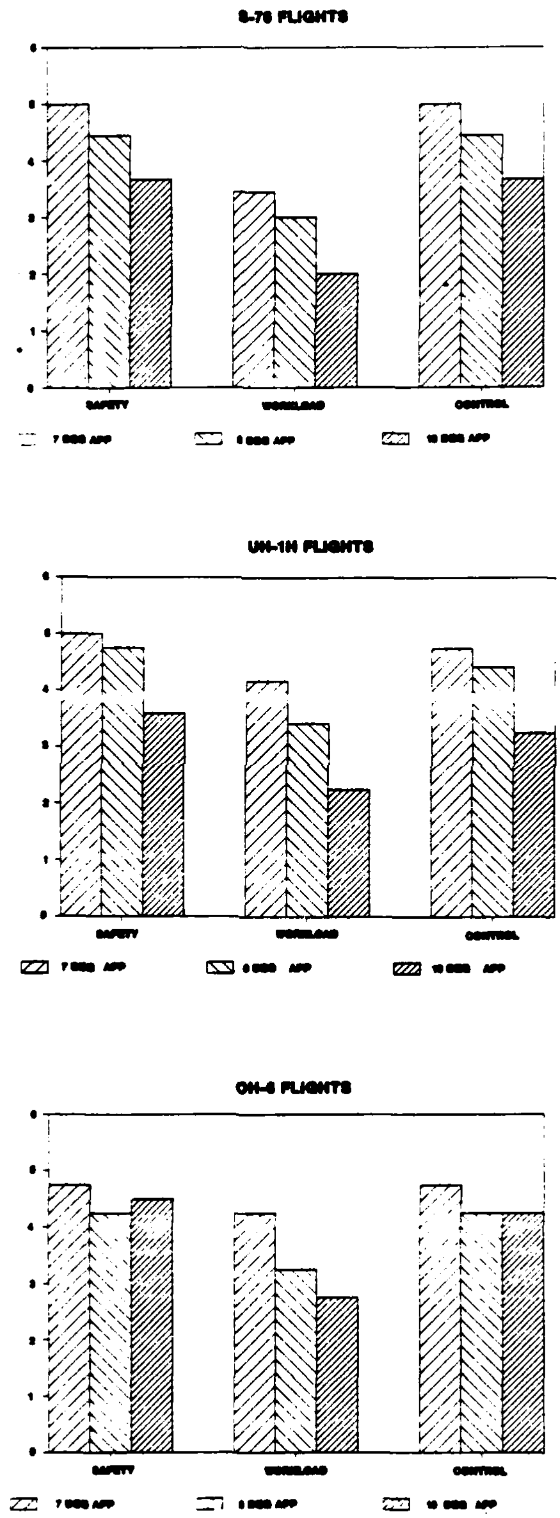


FIGURE 12. POST-FLIGHT QUESTIONNAIRE MEAN RESPONSES FOR APPROACHES

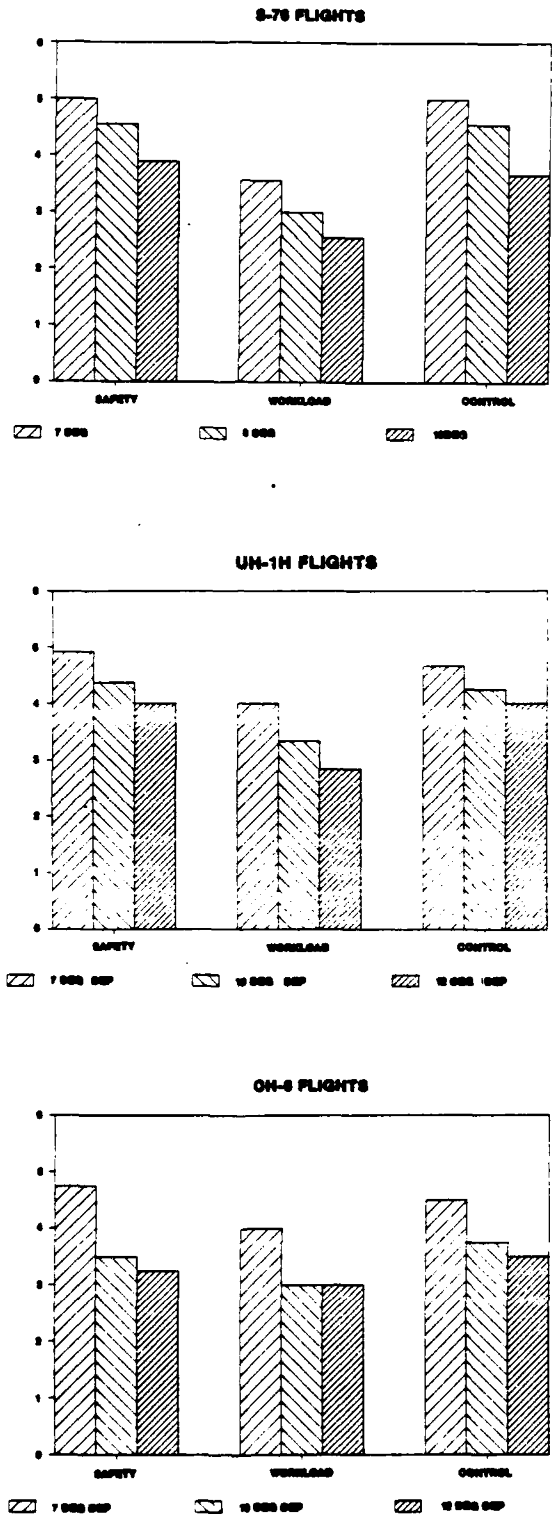


FIGURE 13. POST-FLIGHT QUESTIONNAIRE MEAN RESPONSES FOR DEPARTURES

One UH-1 pilot felt the steeper angle doesn't give the pilot enough room to accelerate. A S-76 pilot felt the 10° curved departures involved more concentration, while one UH-1 pilot felt the curved departure required less power, and another had trouble with the pedals while performing this manuever.

The 12° departures also brought a variety of responses from "not too difficult," "no problem," to "not comfortable" and "too steep." The main issue seemed to concern high power settings, not reaching climb airspeed soon enough, i.e., the airspeed obtained was too low, best rate of acceleration couldn't be reached, and the pedals were pushed to their limits. Pilot fatigue was a factor too. The steep curved departure was considered an extreme to be used only if something were in front of the aircraft. The pilot workload for performing steep curved departures was considered too high. Some felt they would only use a 12° departure on rare occasions.

POST-FLIGHT PILOT COMMENTS.

Approaches. The concensus seems to be that as the angle increased, so did pilot workload, while the desirability of the maneuver decreased. The 7.125° approaches were considered the most acceptable/desirable by the pilots. Although considered safe, the steeper angles created concern about passenger comfort levels. The 10° approaches, whether straight-in or curved, were generally undesirable and, when based on pilot comment, would not be recommended. Some issues of concern with the 10° maneuvers were passenger comfort, control of airspeed, level of difficulty, safety, amount of power required, and workload. Visibility was a big issue for S-76 pilots when performing the steeper angle maneuvers. Most disliked the steep, 10° approaches, considering the control actions to be too abrupt. One pilot felt the 10° approach would be unsafe in adverse wind conditions. However, all S-76 data were collected with a 10-15 knot tail wind component. In general, the shallower curved approaches were considered favorable, even with the tailwind conditions. Several S-76 pilots felt turning maneuvers provided flexibility for safety, noise abatement, obstacle clearance, and operational efficiency.

Departures. The shallow, 7.125° departure angle was preferred by the majority of pilots, primarily for safety reasons. Although there does not appear to be a problem with controllability or with workload for the straight-out 10° and 12° departures, the pilots seemed to feel the power needs were too great. This, plus the increased need to monitor airspeed for the steep angle manuevers, made these angles less desirable. The objection to the 12° departures was that low airspeed and high power placed the aircraft in the height-velocity avoid area for longer periods of time, particularly with the smaller aircraft. Steep angle curved departures were the most objectionable, particularly under strong adverse wind conditions. Comments indicated that safe use of steep angle curved departures required skillful use of the winds as well as skillful use of anti-torque pedals, which is an added burden. Safety seemed to be the main issue with the curved departures. Overall, the straight-out departures were the preferred manuevers.

CONCLUSIONS

In general, the following statements can be made:

1. By themselves, the test results do not support a decrease in the width of the primary surface for straight-in approaches to and straight out departures for visual flight rules (VFR) heliports. However, these tests were conducted in the absence of obstacles. Undoubtedly, the presence of obstacles would have influenced pilot performance by providing visual cues. Nevertheless, it is not certain that these visual cues would have decreased the spread of the data to the point that it would justify narrowing the width of the primary surface.

2. Mean and standard deviations of the altitude errors are similar for all three angles. The altitude errors indicate the pilots flew consistently above the desired surface for these angles, with the steepest angle showing the higher offsets.

3. Although pilot performance increased with increases in the approach angle being flown, these test results do not support an increase in the 7.125° slope of the primary approach surface. Undoubtedly, when the intended approach angle was 7.125°, the presence of objects just below the 8 to 1 surface will cause pilots to fly a higher approach angle in response. The acceptability of an 8° approach angle does not justify an 8° approach surface. There is a need for a safety margin between the approach angle and the approach surface in order to account for the dispersion in pilot performance.

4. Steeper approaches and departures can be safely flown when sufficient aircraft power reserve is available. However, sufficient reserve may not be available for all aircraft utilizing every public heliport.

5. Departure results indicate that pilots consistently operated well above the selected departure reference angle. However, pilots deviated from the intended departure path due to their perception that there would be a possible interference with runway traffic. No reduction in pilot performance was observed for increasing departure angles. Pilots perceived the three straight-out departure maneuvers as adequate but they favored the two shallower angles, 7.125° and 10°, more than the 12° angle. The shall angles were perceived as somewhat safer and more controllable, but not to a significant extent. However, when given a choice, the pilots consistently flew steeper departure angles than defined by the current surface.

6. Even though this test was not structured to define all aspects of the airspace requirements for the curved approaches and departures, similar statements can be made for the curved procedures. The airspeed profiles used in this test were above what pilots preferred to fly. This resulted in test data that indicated the lateral dimension of the minimum airspace required for curved approaches and departures should be larger than what is required for straight-in approaches and departures. However, the fact that pilots strongly expressed a preference for the flexibility that results from curved approach and departure paths indicates that further testing to define curved approach and departure airspace requirements is necessary.

7. When given a choice, pilots continually initiated approaches above the current out 7.125° surface. For all of these approaches pilots accurately tracked their selected glidepath profiles.

8. Pilots perceived all three angles for both straight-in and curved approaches as adequate, however, they favored the shallow 7.125° angle. Their perception indicates that the steeper angles increased their workload and reduced the safety and control margins. However, in terms of measured deviations, their performance for the steeper angle approaches was as good or better than performance for the shallower angles.

RECOMMENDATIONS

1. At this time a reduction in the visual flight rules (VFR) airspace for either heliport approaches or departures is not recommended.

2. Discussion with subject pilots and with industry has indicated that there is a tremendous interest in the flexibility provided by curved approaches and departures. Subject pilot comments following the test also indicated a strong desire for the flexibility of the curved approaches and departures. However, this test was not structured to define all aspects of the airspace requirements for curved approaches and departures. Additional testing is required to define the minimum airspace requirements for such procedures. Of particular interest is the minimum length of the final straight segment in a curved approach to (or departure from) a heliport and the lateral dispersion throughout the procedure.