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USAAVSCOM Technical Report 84-A-14

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NASA-FAA Helicopter Microwave Landing System Curved Path Flight Test

H.N. Swenson, J.R. Hamlin, and G.W. Wilson

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NASA-FAA HELICOPTER MICROWAVE LANDING SYSTEM CURVED PATH FLIGHT TEST

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SUMMARY

An ongoing series of joint NASA/FAA helicopter Microwave Landing System (MLS) flight tests was conducted at Ames Research Center. This paper deals with tests done from the spring through the fall of 1983. This flight test investigated and developed solutions to the problem of manually flying curved-path and steep glide-slope approaches into the terminal area using the MLS and flight director guidance. An MLS-equipped Bell UH-1H helicopter flown by NASA test pilots was used to develop approaches and procedures for flying these approaches. The approaches took the form of Straight-in, U-turn, and S-turn flightpaths with glide slopes of 6°, 9°, and 12°. These procedures were evaluated by 18 pilots from various elements of the helicopter community, flying a total of 221 hooded instrument approaches. Flying these curved path and steep glide slopes was found to be operationally acceptable with flight director guidance using the MLS.

INTRODUCTION

Helicopter instrument approaches to airports have long been constrained by the necessity to fly terminal area approaches that were developed for conventional takeoff and landing (CTOL) aircraft. The new Microwave Landing System (MLS) provides a volume of precision navigation airspace 100 times larger than that available from the present Instrument Landing System (ILS). This allows the helicopter to use its unique characteristics to fly precision curved-path and steep glide-slope approaches.

NASA, together with the FAA, has conducted several flight investigations to evaluate the effectiveness of the MLS for allowing helicopters to fly complex paths. In an early investigation, the full capability of MLS was demonstrated by flying a program of fully automated helical approaches to touchdown (ref. 1). This was followed by a flight-test program to determine the operational limitations of flying Straight-in MLS approaches using "raw data" or "angle only" information (ref. 2). The results of the most recent flight evaluation aimed at determining the operational limitations of manually flying curved-descending and steep glide-slope MLS approaches in an unaugmented UH-1H helicopter using flight director guidance are presented.

Three basic approach profiles were proposed by the FAA as being representative of approaches that may be required (or desirable) in future MLS environments:

(1) a Straight-in steep glide-slope approach which would serve as a baseline, (2) a U-turn approach to accommodate approaches from a direction opposite the desired landing direction, and (3) an S-turn which would accommodate a lateral offset during the initial portion of the approach. The specific flight test objectives were to: (1) establish the operational limitations of the profiles in terms of minimum desired segment lengths, glide slopes, and approach speeds when manually flown using flight director guidance, and (2) evaluate the profiles which appear operationally feasible using various helicopter pilots to obtain a statistical data base to aid the FAA in establishing Terminal Instrument Procedures (TERPS) for helicopter MLS Instrument Flight Rules (IFR) approaches.

This paper describes the features of the three approach profiles developed for the operational evaluation and summarizes the statistical results obtained during the operational evaluation flight test.

TEST EQUIPMENT AND LOCATION

Aircraft and Aircraft Systems

The test aircraft was a Bell UH-1H helicopter (fig. 1). The UH-1H is a single-engine, turbine-powered, semirigid single rotor helicopter with a maximum gross weight of 9500 lb. The UH-1H is capable of carrying 11 passengers and two crewmembers and has a maximum airspeed of 125 knots and a cruise airspeed of 90 to 100 knots. The modified test aircraft performance and handling qualities are equivalent to those of a basic UH-1H operating at weights of 8000 to 9000 lb.

The test aircraft was equipped with an advanced digital avionics and flight control system (V/STOLAND), which was used to define the precision approach profiles tested and to generate the flight director commands. The primary navigation sensors required were an MLS receiver, three-axis accelerometer, barometric altimeter, and an airspeed indicator. Other airborne equipment included flight-test instrumentation and data-recording and telemetry equipment. A complete description of the V/STOLAND system is provided in reference 3.

Figure 1.- Bell UH-1H.

The test-and-evaluation pilots flew the hooded instrument approaches from the left seat of the aircraft. The left side of the instrument panel (fig. 2) contained standard helicopter instrumentation, including barometric and radar altimeters, instantaneous vertical speed indicator (IVSI), airspeed indicator, dual tachometer (rotor/engine), and a torque meter. Attitude information was provided by an attitude director indicator (ADI) with superimposed flight director command bars. The cyclic pitch bar commanded logic for airspeed control, the cyclic roll bar commanded logic for heading and cross track deviation rate, and the collective command bar (displayed to the left of the ADI) commanded altitude rate. Below the ADI the horizontal situation indicator (HSI) provided lateral and vertical flightpath deviations in addition to compass information. Range-to-the-MLS station, using MLS precision distance measuring equipment (PDME) and the computed along-track distance-to-go-to-landing were displayed to the pilots digitally on the HSI. A multifunction display (MFD) showing a horizontal situation map was used only for approach setup purposes by the NASA safety pilot.

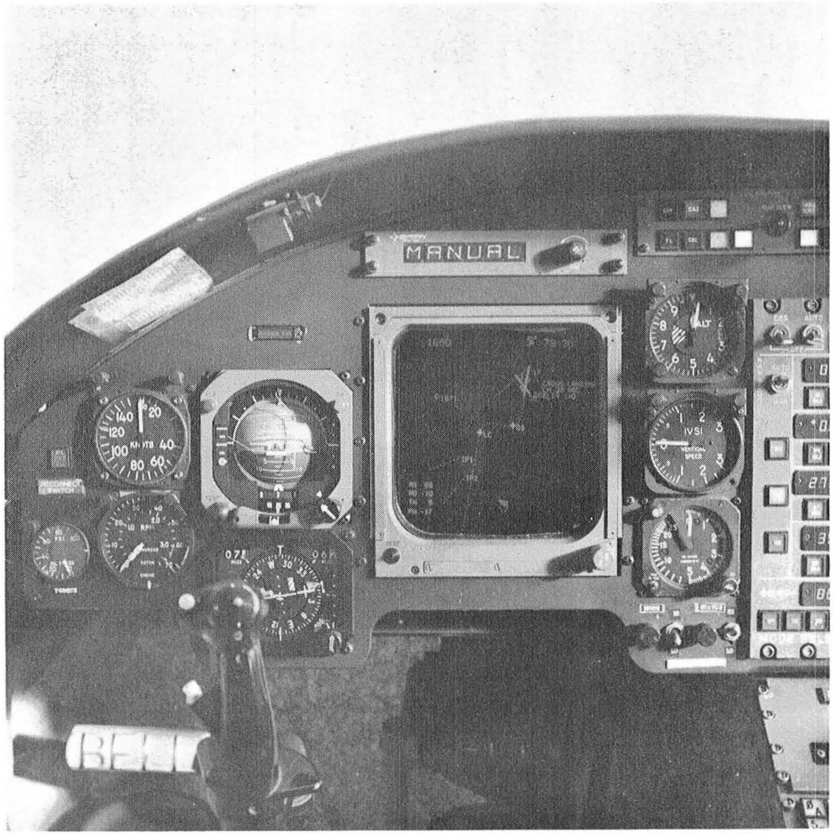


Figure 2.- Instrument panel.

Test Location

The flight tests were conducted at the Ames Flight Systems Research Facility at the Navy Auxiliary Landing Facility, Crows Landing, California. The hooded instrument helicopter MLS approaches, landings, and missed approaches were conducted to the STOLport located on runway 35 at the test facility. The MLS, located on runway 35 at the test facility, is a split sight system with the elevation transmitter located next to the STOLport which is painted on the runway, and the azimuth and PDME transmitters located 4473 ft beyond the elevation transmitter. The MLS is representative of a typical CAT II-type system which provides ±40° azimuth coverage and 0° to 15° elevation coverage. The facility and the test helicopter conducting a 9° glide slope are shown in figure 3.

The facility is equipped with a radar and laser tracking system, a data telemetry receiver, and data monitoring and recording equipment used to record quantitative data to measure the MLS and pilot performance.

Figure 3.- Nine-degree glide-slope helicopter approach to Crow's Landing, Calif.

Flight Test Methodology

The tests were conducted in two phases and required 150 aircraft flight hours. The first phase used NASA research pilots to investigate the basic guidance requirements for the transition from en route air traffic control (ATC) radar vectors to MLS coverage; develop the reference MLS curved approach profiles; and develop acceptable flight director display sensitivities and gain scheduling techniques for both approach and missed approach operations (see ref. 4).

To develop the MLS curved-approach profiles the profiles were broken into individual segments. The segments were: (1) the intercept of the precision approach path from a simulated ATC vector, (2) the curve, (3) the segments between curves, (4) the time between maneuvers, and (5) the final approach. Staying within the coverage of the MLS, the segments were made to be as short as possible and still remain operationally acceptable. The experiments resulted in a matrix of baseline-approach profiles in the form of Straight-in, U-turn, and S-turn precision steep angle approaches, and the definition of acceptable gains for the 3-cue flight director.

Phase II of the flight test was an operational validation of the procedures developed in Phase I. It included 18 evaluation pilots from various elements of the helicopter community (commercial operators, corporate pilots, the helicopter industry, NASA, DOD, FAA, and two pilots from the Deutsche Forschungs-und Versuchsanstait fur Luft-und Raunfahrt (DFVLR)). The experience levels for the pilots are summarized in table 1. Total helicopter time ranged between 350 and 8200 hr, and actual IFR time between 0 and 900 hr. Thirteen of the 18 pilots had flight director experience in either fixed-wing aircraft or helicopters.

For the operational evaluation, each pilot was provided an orientation and information package before his arrival for the flight test. The flight test was conducted on three consecutive days. The first day consisted of a standardized video tape briefing and 1 to 2 hr of training on a fixed-base simulator to familiarize the pilots with the approaches and the UH-1H cockpit displays and instruments. The second and third days were the test flights. Each pilot flew a total of 12 hooded approaches (two U-turn and two S-turn approaches at 6° and 9° glide slopes, and two Straight-in approaches at 9° and 12° flown to either a missed approach or landing). Six approaches were flown the first day and six the next. The NASA safety pilot acted as copilot during the approach and directed the evaluation pilot to land or to execute a missed approach.

TABLE 1.- EVALUATION PILOT EXPERIENCE LEVELS

Pilot number	Flight hours				Flight director experience		Bell helicopter experience	
	Total	Helicopter						
		Total	Actual IFR	Hooded	Fixed Wing	Helicopter	VFR	IFR
1	9,000	5,000	100	200	100	0	Yes	Yes
2	9,900	4,800	3	102	0	0	Yes	Yes
3	4,100	900	50	200	220	80	Yes	Yes
4	2,495	1,573	10	206	0	500	Yes	Yes
5	7,000	6,000	150	225	25	125	Yes	Yes
6	5,500	5,300	900	150	0	500	Yes	Yes
7	11,500	7,900	460	250	0	500	Yes	Yes
8	7,500	7,000	200	200	200	300	Yes	Yes
9	6,500	4,000	200	450	1,000	200	Yes	Yes
10	8,500	1,800	55	200	100	200	Yes	Yes
11	9,100	8,000	500	250	150	200	Yes	Yes
12	8,800	8,200	25	115	0	150	Yes	Yes
13	6,500	1,500	20	55	0	0	Yes	Yes
14	8,000	7,750	50	200	0	10	Yes	Yes
15	2,800	1,800	20	300	0	0	Yes	Yes
16	9,100	5,300	75	150	0	0	Yes	Yes
17	1,500	350	0	4	0	0	No	No
18	3,500	1,200	20	40	100	0	Yes	No
Average	6,739	4,354	158	183	105	154	Yes	Yes

At the end of each approach, the evaluation pilot rated the approach according to the scale presented in figure 4. (This scale was modified from the Cooper Harper scale (ref. 5) to simplify the pilot rating process for the guest pilots.) At the end of the flight test, each pilot was asked to fill out a detailed questionnaire. Sixteen of the 18 pilots filled out the questionnaire. During the evaluation phase, 221 approaches were flown.

RESULTS AND DISCUSSION

Phase I — Approach Profile Development

Phase I resulted in the establishment of the operational requirements and procedures for flying curved-path and steep glide-slope approaches, and also provided the detailed definition of the Straight-in, U-turn, and S-turn approaches to be flown in the operational evaluation. The subjective evaluations by the NASA test pilots led to the development of the approach profiles which were broken into individual segments as discussed earlier. This phase of testing indicated a need for a 25- to 30-sec stabilization time between any two segments of the approach. The operational limitations on the individual segments are presented, as is a description of the profiles developed for the operational evaluation.

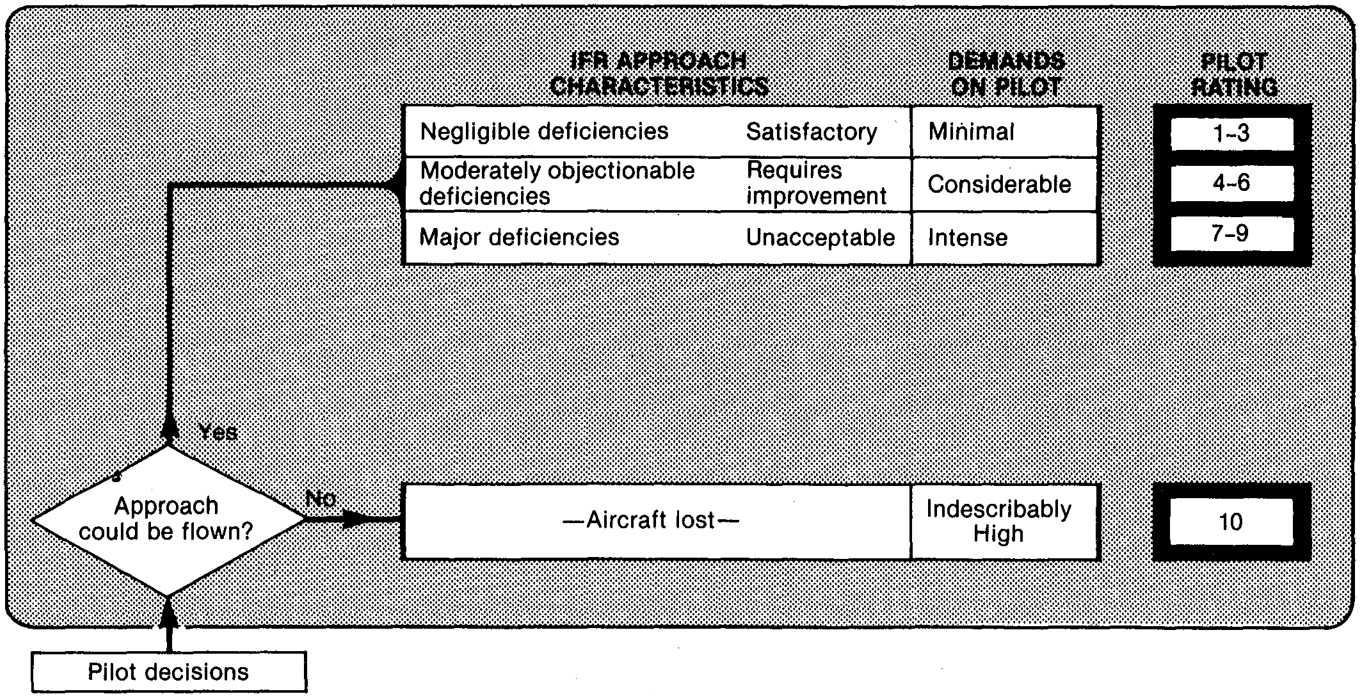


Figure 4.- Pilot rating scale.

Intercepts- Two types of intercepts were tested: the first type was a simulated ATC vector. The aircraft was vectored to intercept to a straight-and-level segment of an approach at angles of 30°, 60°, and 90°. In all cases the pilots were able to smoothly capture the desired approach path with little overshoot. The second type was a capture directly at the curve or a descent. The capture of a curve was accomplished by the onboard computer calculating the aircraft's position and computing a tangential straight-line intercept to the curve. To make the procedures operationally acceptable, both intercepts occurred during a straight-line level segment 25- to 30-sec prior to a curved segment or descent. This assured the helicopter would be stabilized prior to initiating a curve or descent.

Curve- The curved segments were flown in both level and descending flight with the rates of descent corresponding to the 6° and 9° glide slopes. The radius of curvature was based on a 10° bank-angle zero-wind condition at a nominal approach speed of 90 knots. The general consensus was that a curved descending approach was feasible with the flight director provided that there was sufficient separation (25 to 30 sec) between the initiation of descent and curve (or vice versa) to allow the pilot time to stabilize in one axis before initiating a maneuver in the other axis.

Segments between curves- The S-turn profile required a straight segment of about 25 to 30 sec to occur between the two curves. This allowed the pilot to stabilize the aircraft on a straight segment upon exiting from the first turn and prior to initiating the final turn.

Final approach segment- A final approach segment of about 2 n. mi. was required independent of the glide slope (6°, 9°, or 12°). The approach speed recommendations were 70 knots for the 6° glide slope, 65 knots for the 9° glide slope, and 60 knots for the 12° glide slope. This gave a nominal no-wind rate of descent of 750, 1030, and 1260 ft/min, respectively. The recommended decision heights for these glide slopes were 100, 150, and 200 ft above ground level (AGL), respectively.

This gave a constant deceleration range of 1000 ft from the decision height to the STOLport landing site (as was done in an earlier flight test (ref. 2).

Approach Profile Definition for the Operational Evaluation

Three approach profiles, a Straight-in, a U-turn, and an S-turn were defined for the operational evaluation. The Straight-in profile consisted of a 60° or 90° intercept angle to a straight approach segment of 1 n. mi. prior to intercepting a 12° or 9° glide slope with a 2 n. mi. final distance. The 1 n. mi. prior to descent provides the necessary 25-30 sec stabilization time. The approach plate for the 12° glide slope is shown in figure 5.

The U-turn profile was started from outside MLS coverage with no onboard navigation other than simulated ATC radar vectoring by the NASA safety pilot. Once inside MLS coverage, the onboard computer derived its position from the MLS signals and computed a trajectory for the helicopter to capture a tangent of the 180° U-turn. The U-turn radius was 3915 ft. The U-turn was flown to either a 6° or 9° glide slope. Twenty-five hundred feet after intercept to the U-turn the 6° glide slope was initiated. The 9° glide slope was initiated 2500 ft after the exit of the U-turn which gave the needed 25- to 30-sec stabilization time. The final approach segment was 2.62 n. mi. in length due to MLS geometrical coverage- and signal acquisition verification. The approach plate for the 9° glide slope is shown in figure 6.

The S-turn profile consisted of a 30° or 60° intercept angle to a 1 n. mi. straight segment prior to intercepting the S-turn maneuver. The 30° intercept was flown to a 6° glide slope which started 2500 ft before the S-turn maneuver which consisted of a 90° right turn curve of radius 3915 ft, followed by a 2500-ft straight segment, followed by a 90° left turn to a final straight approach of 2 n. mi. The approach plate for the 6° glide slope is shown in figure 7. The S-turn for the 9° glide slope is similar to the 6° except for a 60° intercept, and that the glide slope starts between the two turns; thus a 5000-ft segment was provided between the two turns to allow the needed 25- to 30-sec stabilization time.

Phase II — Operational Evaluation

Pilot evaluations- The pilot ratings for the different approaches are shown in figure 8 in terms of the means and standard deviations. The ratings for all the approaches (except the 12° Straight-in) fall within the "satisfactory" range of the scale. The 9° Straight-in approach was flown first. This could account for the 9° Straight-in approach receiving a slightly degraded ratings than the 9° S-turn and U-turn. The somewhat degraded ratings for the 12° approach indicate that the pilots found this approach more difficult than the others. This is attributed to a lack of collective control authority available to correct to the desired flightpath if the aircraft gets above the glide slope.

The pilot questionnaire was directed toward obtaining the pilots' evaluation of the approach profiles that they tested. Generally speaking, the consensus was that all the approach profiles were operationally acceptable. The only significant aspects of the procedures commented on were the recommended approach speed, the decision height, and appropriateness of single pilot IFR operations for the steep glide slopes tested.

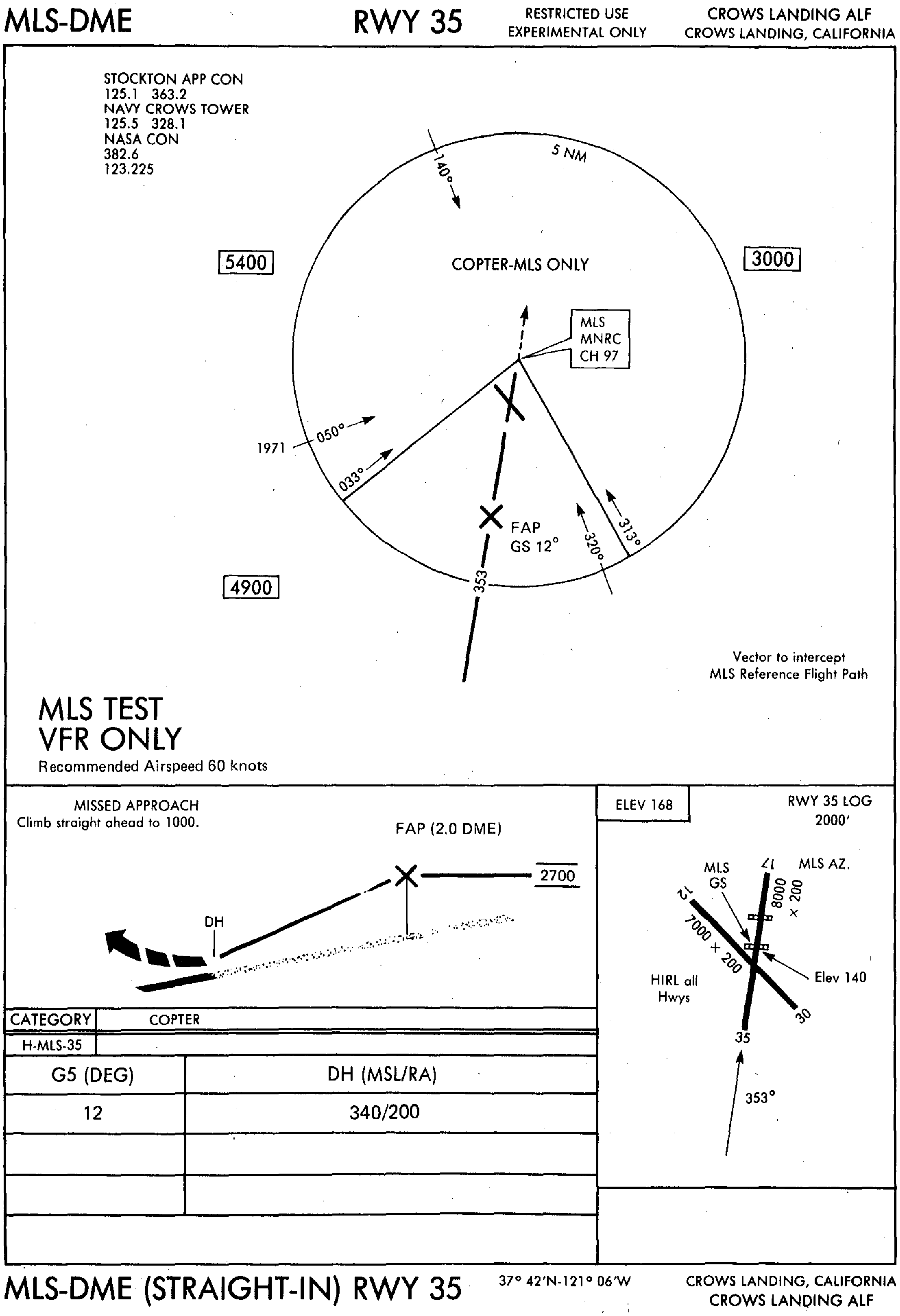


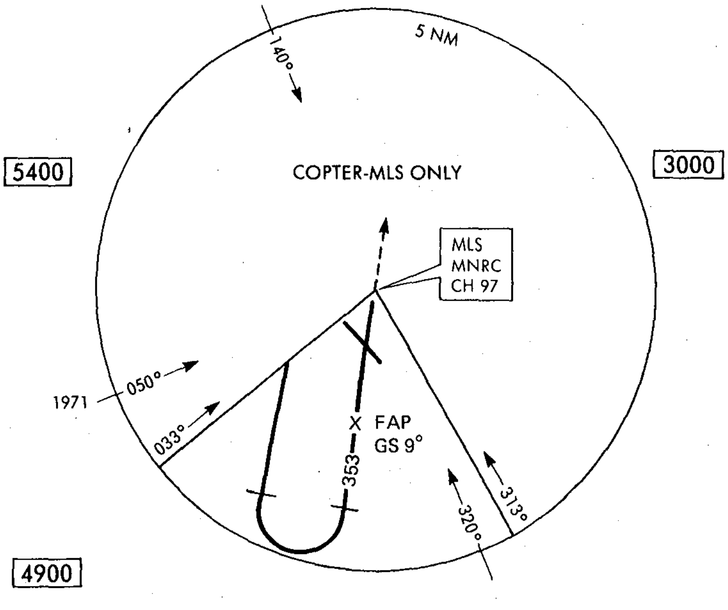
Figure 5.- Approach plate for 12° glide slope.

MLS-DME CP RWY 35

RESTRICTED USE
EXPERIMENTAL ONLY

CROWS LANDING ALF
CROWS LANDING, CALIFORNIA

STOCKTON APP CON
125.1 363.2
NAVY CROWS TOWER
125.5 328.1
NASA CON
382.6
123.225

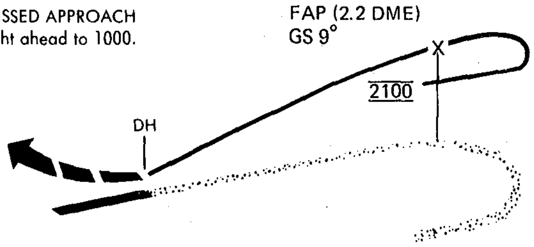


Vector to intercept
MLS Reference Flight Path

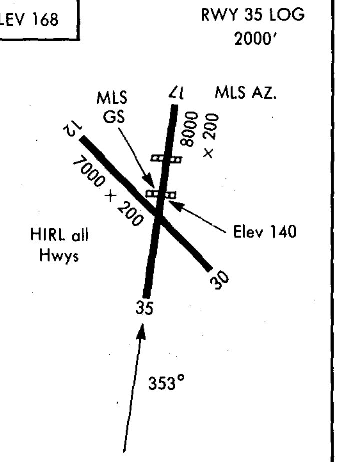
MLS TEST
VFR ONLY

Recommended Airspeed 65 knots

MISSED APPROACH
Climb straight ahead to 1000.



ELEV 168



CATEGORY	COPTER
H-MLS-35	

G5 (DEG)	DH (MSL/RA)
9	290/150

MLS-DME (U-TURN) RWY 35

37° 42′N-121° 06′W

CROWS LANDING, CALIFORNIA
CROWS LANDING ALF

Figure 6.- Approach plate for 9° glide slope.

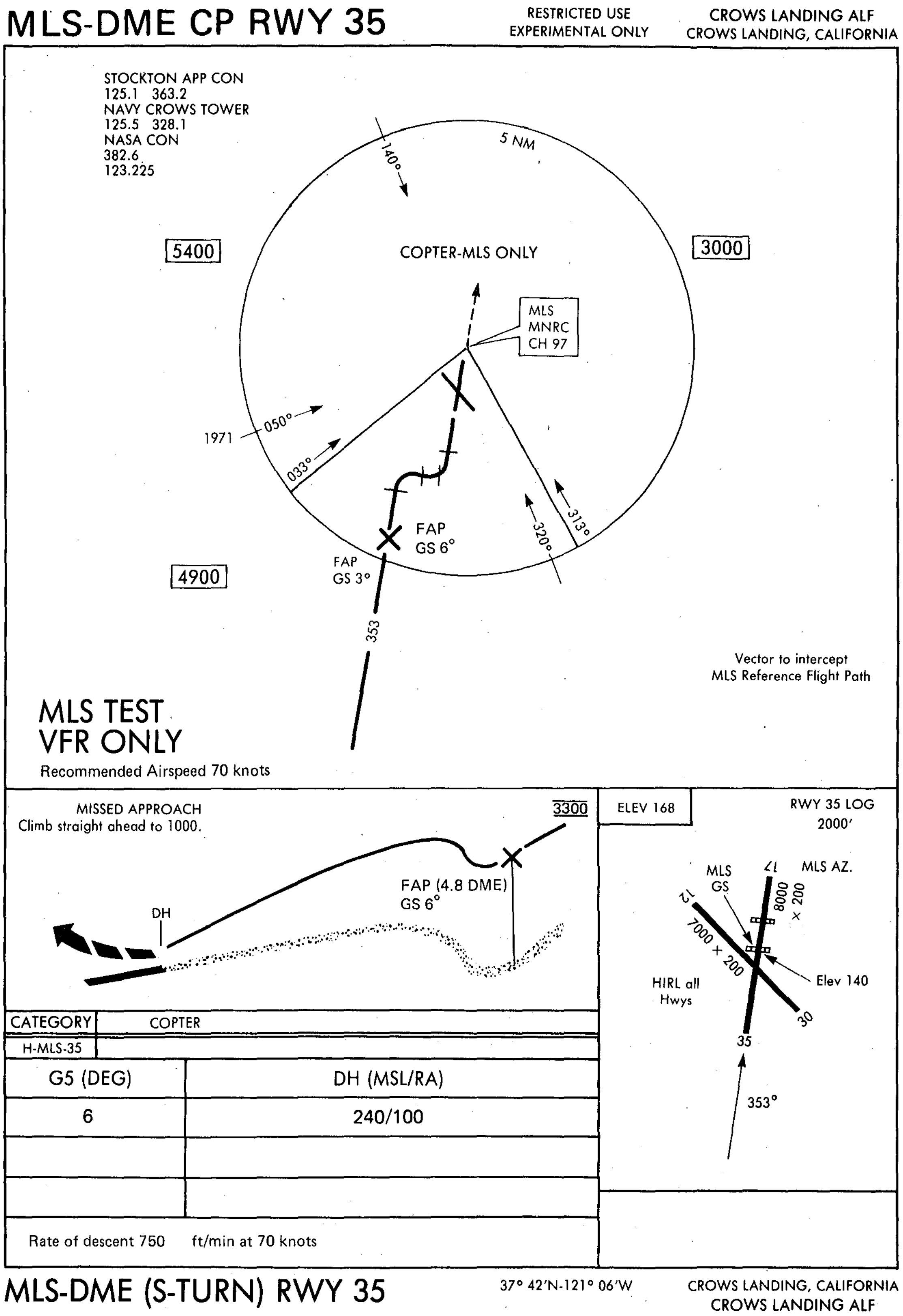


Figure 7.- Approach plate for 6° glide slope.

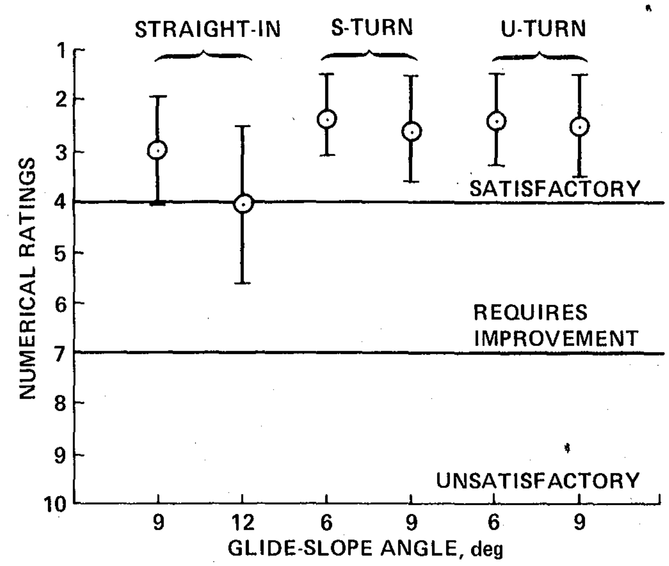


Figure 8.- Pilot acceptability ratings.

The evaluation pilots were advised during their preflight briefing that the airspeeds of 70, 65, and 60 knots for the 6°, 9°, and 12° glide slopes, respectively, were only recommended. They were told that they could fly at whatever airspeed they wished. The final questionnaire asked the pilots to recommend approach speeds for these glide slopes. The means and standard deviations of these results are shown in figure 9. The means of the recommended approach speed are 77.3, 66.3, and 61.3 knots for the 6°, 9°, and 12° glide slopes, respectively. The reason for these higher recommended speeds was the fact that, at present, IFR approaches are made at a much higher speed. Thus, they are more representative of the speeds IFR approaches are currently flown in rotorcraft operations.

The pilots were asked to assess the appropriateness of the recommended decision heights. The results are shown in table 2. The majority of the pilots felt that the recommended decision heights were acceptable. The pilots who found them unacceptable were primarily concerned about the high sink rate at decision height (DH) for the steeper glide slopes. The general consensus for a DH indicator was that about 200 ft AGL a barometric altimeter was acceptable, but below that some other indicator (such as a radar altimeter) would be necessary. All of the tests were run in a dual-pilot IFR scenario with the copilot "calling out" the altitudes above the approach. For comparison purposes, the evaluation pilots were asked to consider a single-pilot IFR scenario. The general consensus was that all the profiles tested would be appropriate for dual-pilot operations, but for single-pilot operations they recommended that the glide slopes be limited to between 7° and 8°. Three of the pilots recommended no single-pilot IFR operations.

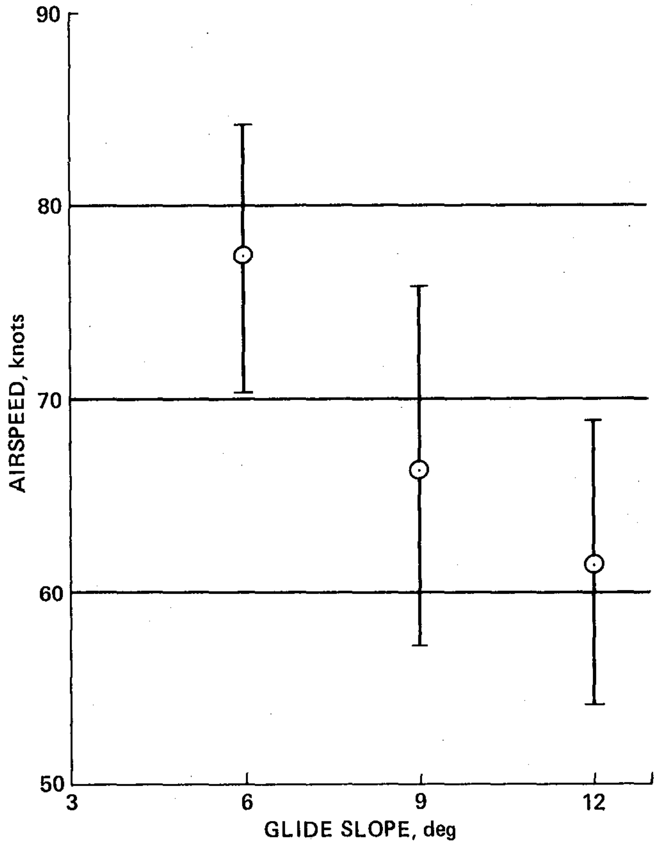


Figure 9.- Evaluation pilot recommended approach speeds.

Performance results- In all cases, the pilots were able to maintain reasonably precise flightpath control and were able to perform the required hover- or missed-approach procedure with no intervention by the NASA safety pilot.

TABLE 2.- DECISION HEIGHT ACCEPTABILITY

Decision height	Glide slope	Acceptable	Unacceptable
200 ft	12°	13	3
150 ft	9°	15	1
100 ft	6°	16	0

Plots of composite-lateral and vertical tracking, statistical-lateral and vertical approach envelopes, and statistical-lateral and vertical flightpath errors for the Straight-in 9° and 12° approaches, the U-turn 6° and 9° approaches, and the S-turn 6° and 9° approaches are shown in figures 10-15. The lateral-composite and lateral-statistical envelope plots show the x-y ground track from the intercept to either the landing or the missed approaches. The vertical-composite and statistical-envelope plots show the altitude (AGL) versus the distance to go to the touchdown point. The touchdown point is also referred to as the ground plane intercept point (GPIP). All the statistical plots show the mean bounded by the two-sigma standard deviations. It should be noted that during the missed approach, the aircraft was not under MLS guidance. The flight director missed-approach mode maintained runway heading in a heading-hold mode, thus subjecting the helicopter to cross-wind deflections during the missed approach. The statistical-lateral and vertical flightpath errors are shown as a function of distance to go to the GPIP. The flightpath error is defined as the total system (pilot and navigation systems) deviation from the intended flightpath.

Composite plots of the individual approach profiles are useful in identifying approaches that are representative of the general trend of the data. Examples of

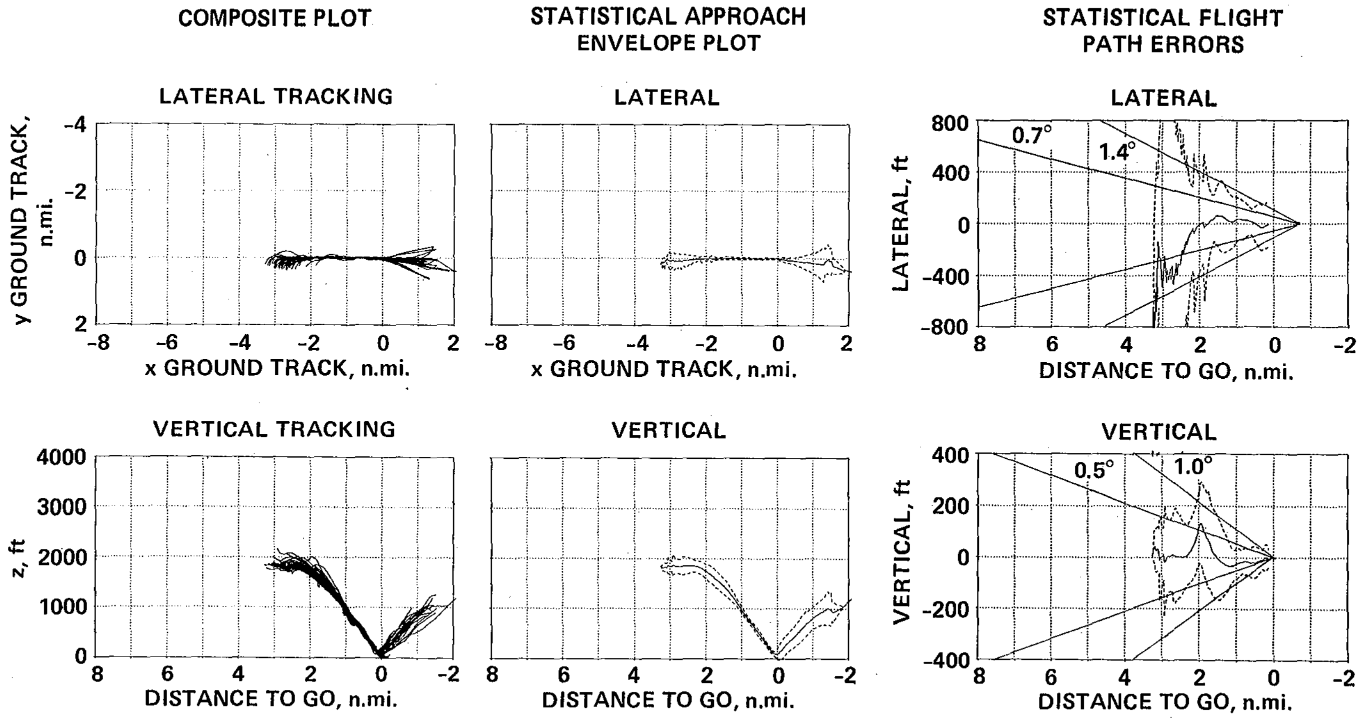


Figure 10.- Performance plots: Straight-in 9° glide slope.

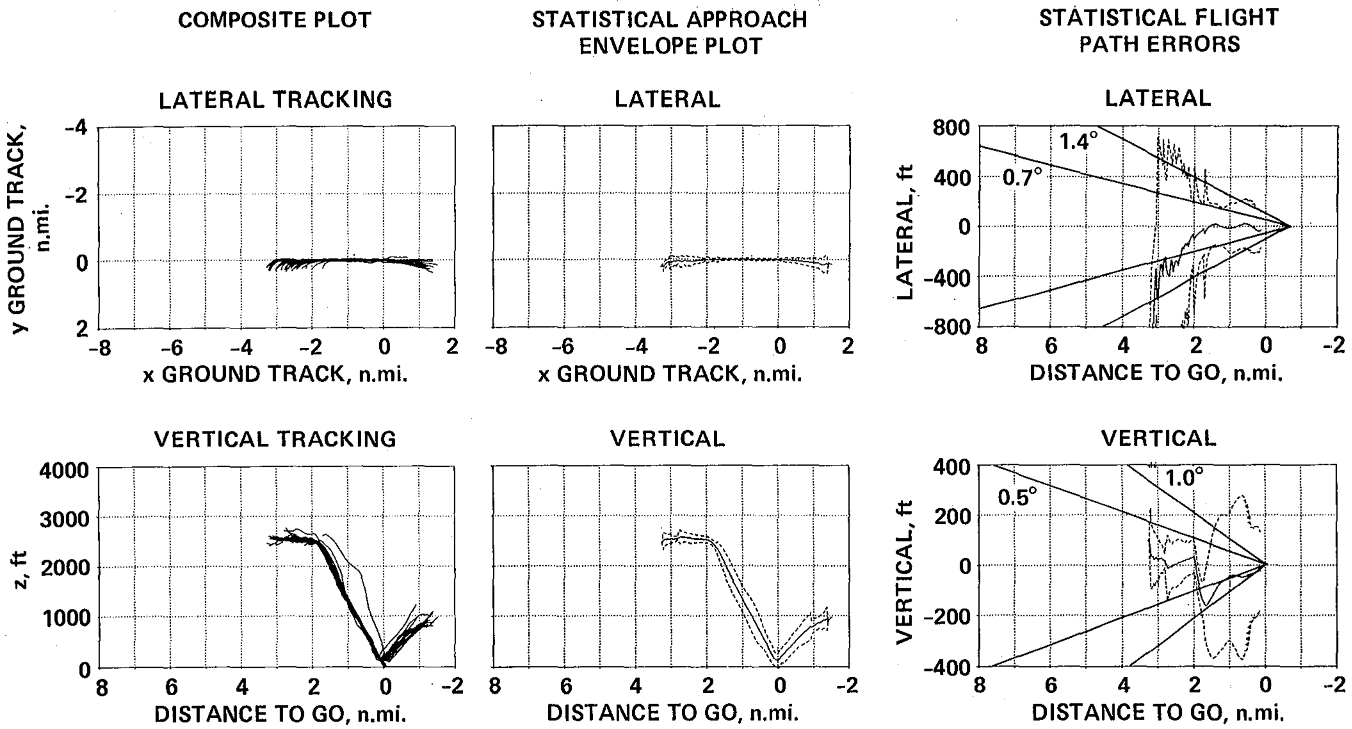


Figure 11.- Performance plots: Straight-in 12° glide slope.

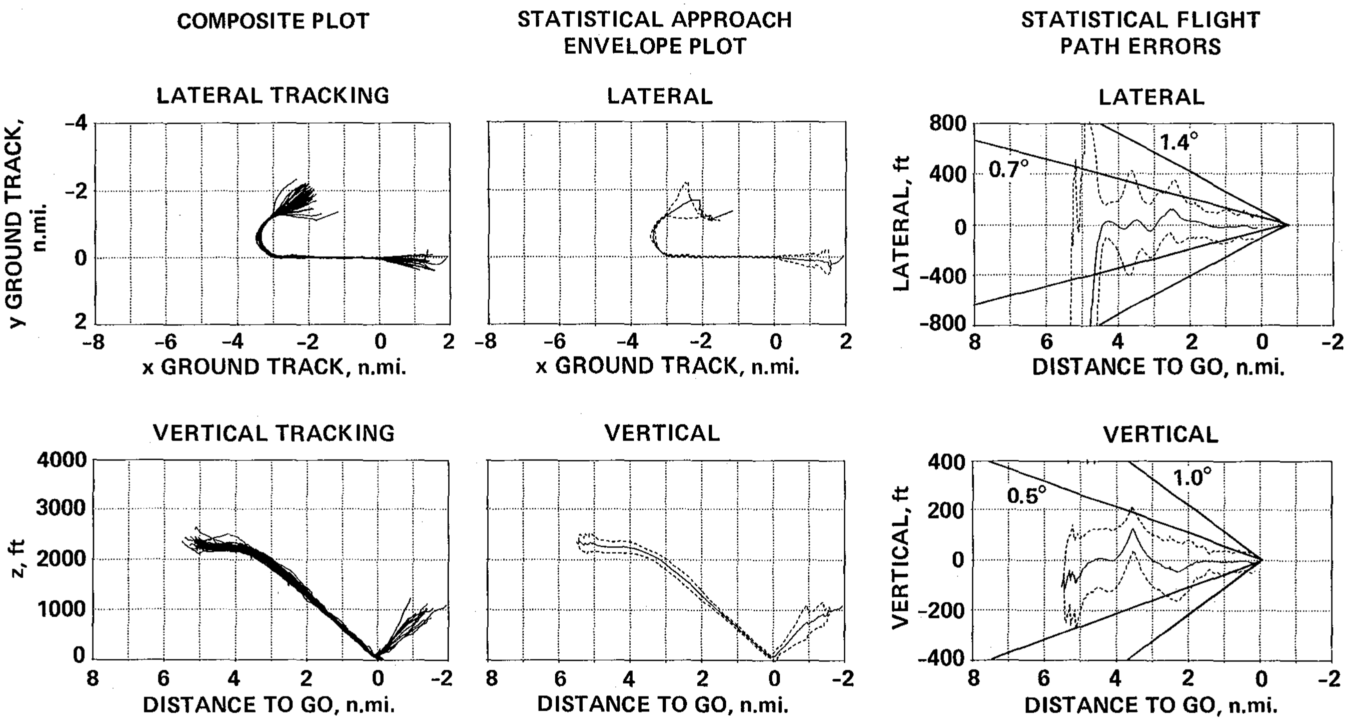


Figure 12.- Performance plots: U-turn 6° glide slope.

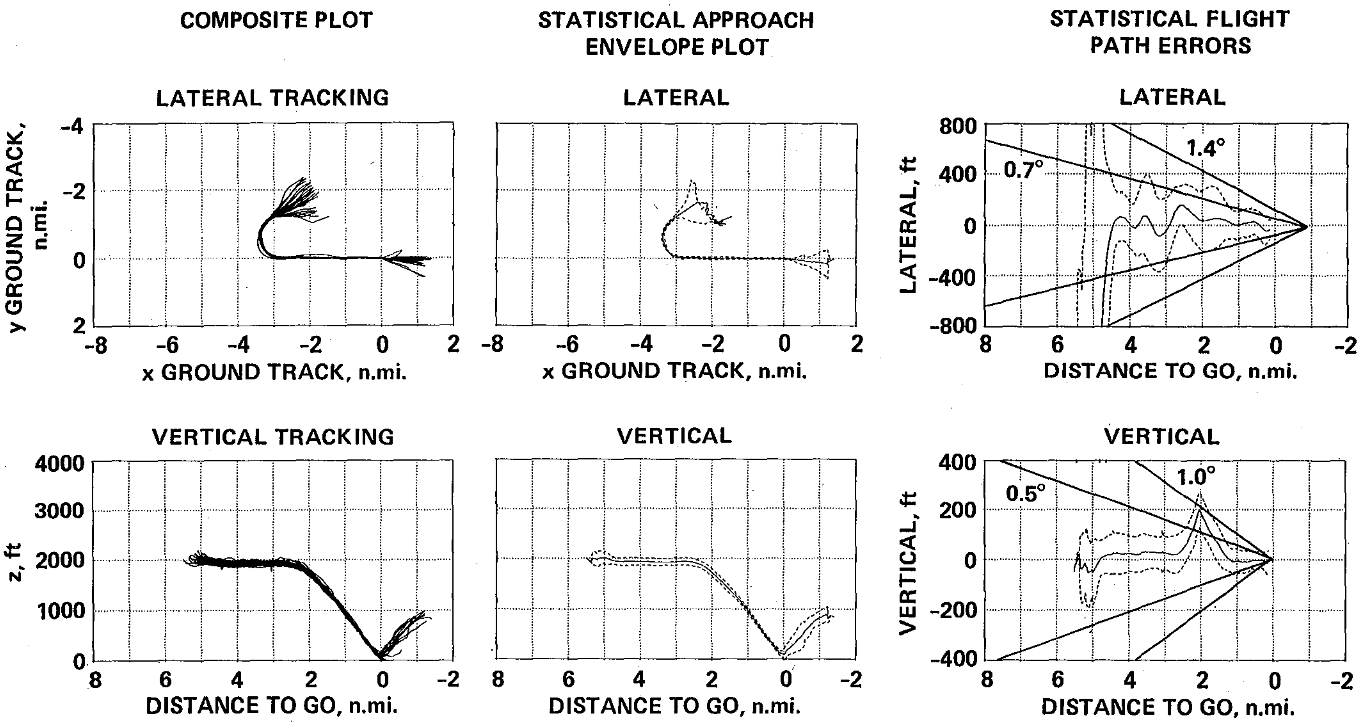


Figure 13.- Performance plots: U-turn 9° glide slope.

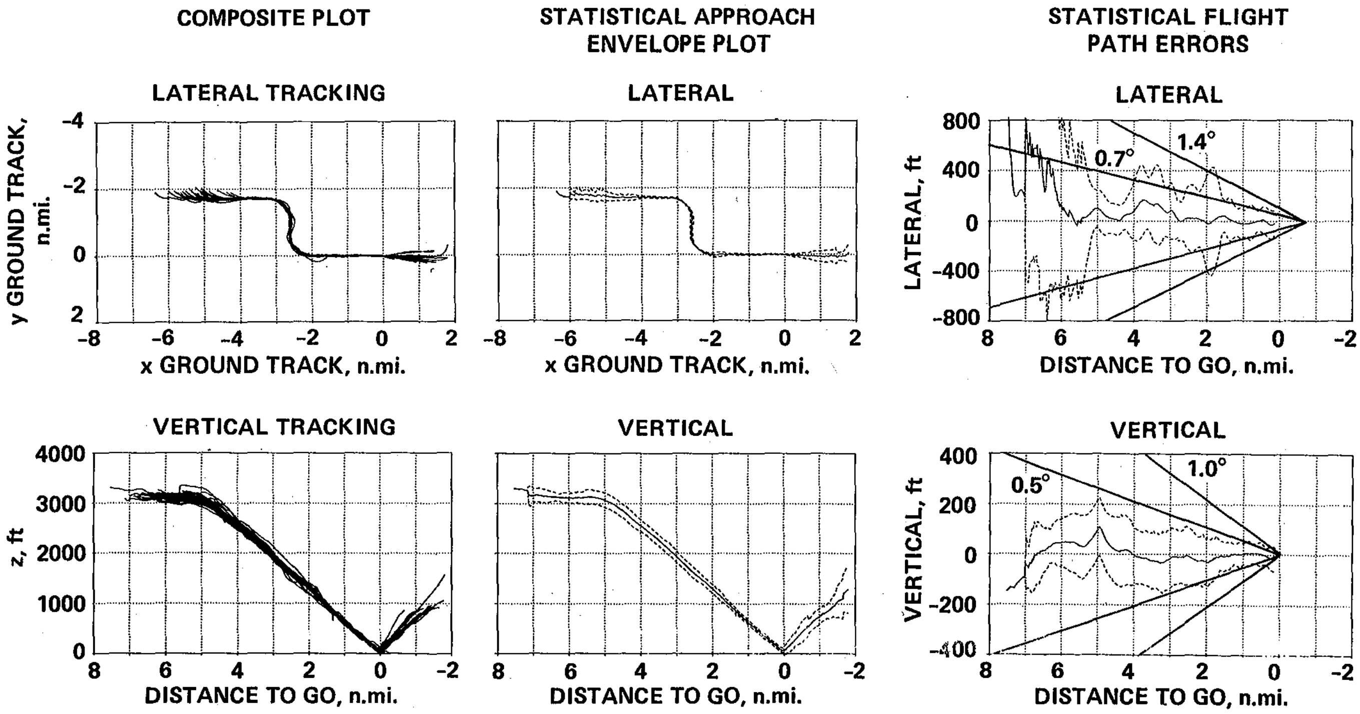


Figure 14.- Performance plots: S-turn 6° glide slope.

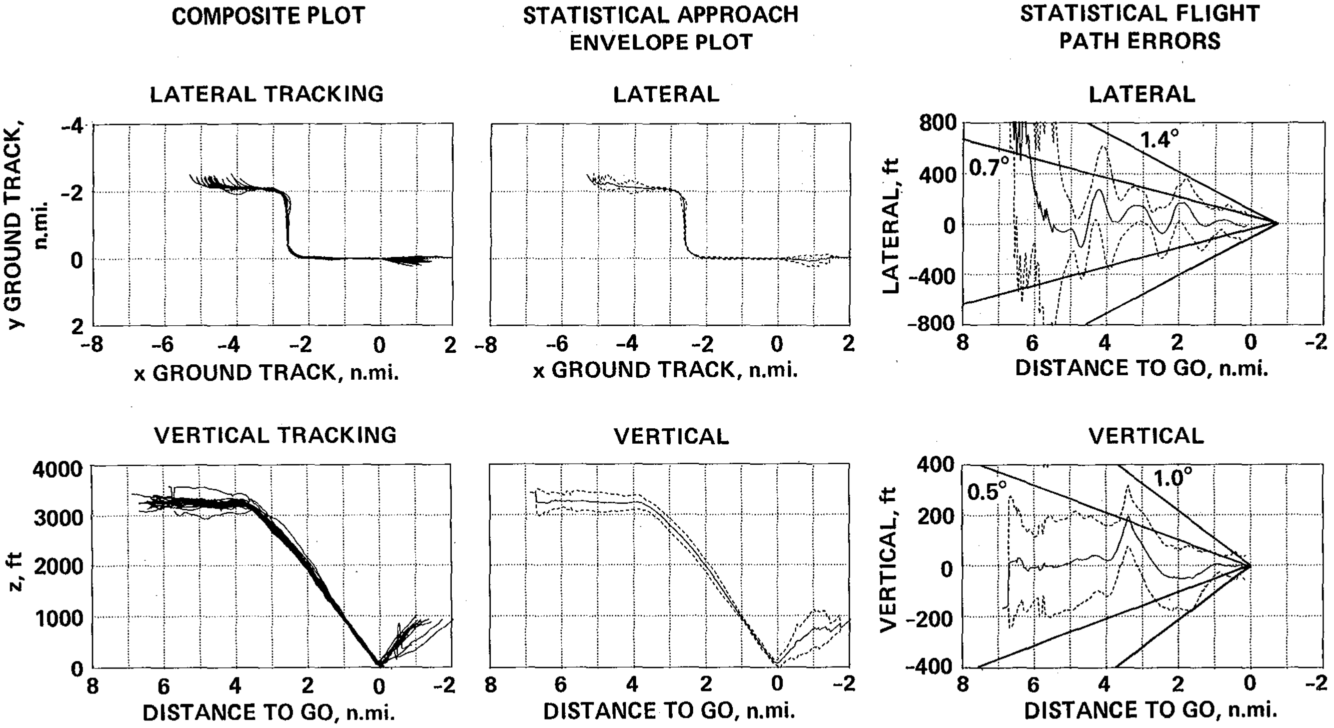


Figure 15.- Performance plots: S-turn 9° glide slope.

this are: (1) In figure 10 on the composite-lateral-tracking plot, there shows a large dispersion in the intercept point with the Straight-in approach profile. Two of the approaches start much closer to the touchdown point. A reason for this is that, prior to the flightpath capture, the aircraft was in a heading-hold mode simulating an ATC vector intercept, and did not have precision lateral guidance. (2) In figure 11 on the composite-vertical-tracking plot, there shows one approach track that is well above all the others. In this case, the pilot captured his lateral path past the glide-slope intercept point. He was not able to correct back to the glide slope due to the limited collective control authority available on the 12° glide slope. Also shown on the composite-lateral-tracking plot of figure 11 are two approaches that captured the lateral flightpath after the glide slope was to be captured at 2 n. mi.

The statistical-approach-envelope plots indicate the type of airspace required to conduct the approaches. The airspace that is required laterally is largest during the intercept and missed approach. The vertical airspace required was largest during the level portion of the approach prior to glide-slope intercept and during missed approach. During these portions of flight, the flight director was in an altitude-hold mode using the barometric altimeter as the primary sensor. The errors are attributed to the errors in barometric altitude. It can also be seen in all the vertical-statistical-approach envelope plots corresponding to 6° and 9° glide slopes (figs. 10 and 12-15) that glide-slope tracking was attained about 1 n. mi. before touchdown. The plot for the 12° glide slope (fig. 11) does not show comparable glide-slope tracking.

The statistical flightpath-error plots indicate how well the pilots were able to maintain their intended flightpaths. Laterally, the pilots had the most trouble during the curves with deviations on the order of ±400 ft. This is shown in figures 12-15. The large vertical deviation at the glide-slope intercept is primarily due to the mechanization of the flightpath error calculation. The flight director was designed to achieve a smooth transitioning from level flight to desired glide slope by intercepting asymptotically from below. The vertical flightpath error was defined such that any deviation from a straight line, drawn from the GPIP to the starting altitude at the intended glide slope would be an error. All the 6° and 9° glide-slope cases show a smooth capture from below, but the 12° shows a tendency to overshoot because of the steeper angle. Also shown on the plots are reference lines of 0.7° and 1.4° deviations from the intended path for lateral error and 0.5° and 1.0° of deviation for vertical error. Laterally, the 0.7° of deviation corresponds to a CAT II type of approach. Vertically, the 0.5° deviation corresponds to 33%, 22%, and 17% of the full scale deviations on the HSI for the 6°, 9°, and 12° glide slopes, respectively. In figures 12-15 the statistical flightpath errors come very close to this 0.7° deviation. The reason that the deviation was greater for the results depicted in figures 10 and 11 was that on the longer U-turn and S-turn approaches, the pilot had more time to establish himself on the intended approach profile than he did on the Straight-ins. In most cases, the pilots were able to maintain the glide slopes within 0.5° and 1.0° vertical deviation — the much greater glide-slope deviation shown in figure 11. This corresponds with the pilot opinion data which indicated that the 12° glide slope was more difficult to fly, but is also influenced by the one approach that clearly began his descent late.

Although it is not known exactly how to decide on appropriate decision heights for these glide slopes, altitude loss during a missed approach should definitely be an important parameter. Data pertaining to the altitude lost during a missed approach are shown in table 3. The data show the mean altitude lost, the two-sigma (95% probability), and the greatest altitude lost for the particular glide slope. The mean minimum approach altitudes (AGL) were 68.2, 103.5, and 145.5 ft for decision heights of 100, 150, and 200 ft, respectively. The two-sigma missed-approach envelopes for the same decision heights were bound by minimum altitudes of 48.8, 68.7, and 102.4 ft, respectively.

Data pertaining to the distance from decision height to the point at which the helicopter is to land is an important parameter for the design of a heliport location. During these flight tests, the pilots were instructed to decelerate to hover in such a way as to not "spill the coffee." The mean decision-height-to-hover distances and their corresponding standard deviations about that point, along with the longest and shortest distances, are presented in table 4. This table shows that for the steeper glide slopes it takes less distance to decelerate to a hover. A

TABLE 3.- MINIMUM MISSED APPROACH ALTITUDE STATISTICS

	6° glide slope 100 ft decision height	9° glide slope 150 ft decision height	12° glide slope 200 ft decision height
Mean altitude loss below decision height, ft	31.8	46.5	54.5
Two-sigma standard deviation, ft	19.4	34.8	43.12
Greatest altitude lost, ft	52.0	73.0	92.6

TABLE 4.- DISTANCE TO LAND FROM DECISION HEIGHT STATISTICS

	6° glide slope 100 ft decision height	9° glide slope 150 ft decision height	12° glide slope 200 ft decision height
Mean distance to land, ft	1453.0	1200.3	1028.5
Standard deviation about mean distance, ft	±591.6	±360.6	±263.1
Longest distance to land, ft	2617.4	1758.1	1433.0
Shortest distance to land, ft	210.4	619.1	713.0

possible explanation for this is that the higher glide slopes are flown at a slower speed; thus, the aircraft is closer to a flare configuration than at the higher speeds for the lower glide slopes.

CONCLUSIONS

The following conclusions were drawn from analysis of the in-flight pilot ratings, pilot questionnaires, and aircraft tracking data.

1. The results from the pilot comments and statistical aircraft tracking plots showed that the evaluation pilots were able to manually fly with good tracking performance the Straight-in, U-turn, and S-turn approaches in the UH-1H aircraft using flight-director guidance.

2. The approaches can be made at up to 9° glide slopes without degradation of pilot opinion. However, increasing the glide slope to 12° resulted in a degradation of the ratings and in concern about high sink rates at the decision height.

3. In Phase I of the flight test a 25- to 30-sec stabilization time between any two maneuvers was required and was verified by the pilot questionnaires.

4. For the 100, 150, and 200 ft decision heights the mean altitude lost during missed approaches was 31.8, 36.5, and 54.5 ft, and the mean distance to land was 1453.0, 1200.3, and 1028.5 ft, respectively.

5. The approaches flown should provide a data base for the FAA to develop TERPS criteria for curved path and steep glide-slope approaches.

REFERENCES

1. Foster, John D.; McGee, Leonard A.; and Dugan, Daniel C.: Helical Automatic Approaches of Helicopters with Microwave Landing Systems. NASA TP-2109, 1982.

2. Peach, L. L.; Bull, J. S.; Anderson, D. J.; Dugan, D. C.; Ross, V. L.; Hunting, A. W.; Pate, D. P.; and Savage, J. C.: NASA/FAA Flight-Test Investigation of Helicopter Microwave Landing System Approaches. Preprint No. 80-55, American Helicopter Society 36th Annual Forum, Washington, D.C., May 1980.

3. Liden, Sam: V/STOLAND Digital Avionics System for UH-1H Final Report. NASA CR-152179, Oct. 1978.

4. Phatak, A.; and Lee, M.: Navigation and Flight Director Guidance for NASA/FAA Helicopter MLS Curved Approach Flight Test Program. Prepared under Contract NAS2-10850, Apr. 1983.

5. Cooper, G. E.; and Harper, R. P.: The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities. NASA TN D-5153, Apr. 1969.

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16. Abstract

An ongoing series of joint NASA/FAA helicopter Microwave Landing System (MLS) flight tests was conducted at Ames Research Center. This paper deals with tests done from the spring through the fall of 1983. This flight test investigated and developed solutions to the problem of manually flying curved-path and steep glide slope approaches into the terminal area using the MLS and flight director guidance. An MLS-equipped Bell UH-1H helicopter flown by NASA test pilots was used to develop approaches and procedures for flying these approaches. The approaches took the form of Straight-in, U-turn, and S-turn flightpaths with glide slopes of 6°, 9°, and 12°. These procedures were evaluated by 18 pilots from various elements of the helicopter community, flying a total of 221 hooded instrument approaches. Flying these curved path and steep glide slopes was found to be operationally acceptable with flight director guidance using the MLS.

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