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# Helicopter MLS Decelerating Approaches Test Plan

Scott B. Shollenberger
Barry R. Billmann

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16. Abstract

This series of tests are designed to identify limits for Distance Measurement Equipment/Precision (DME/P) equipment installed on helicopters flying decelerating approach profiles. The tests are designed to determine the deceleration limits that can be obtained when DME/P is used to derive range and range rate.

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TABLE OF CONTENTS


| | Page |
|---|---|
| EXECUTIVE SUMMARY | iii |
| 1. PURPOSE | 1 |
| 2. BACKGROUND | 1 |
| 3. OBJECTIVES | 2 |
| 4. RELATED DOCUMENTS | 2 |
| 5. SYSTEM EQUIPMENT | 3 |
| 6. FLIGHT PROFILES | 7 |
| 6.1 Baseline Profile Design | 11 |
| 6.2 Subject Pilot Flight Profile Design | 11 |
| 6.3 Workload Measurement | 11 |
| 6.4 Performance Measures | 12 |
| 6.5 Tracking Performance | 13 |
| 6.6 Airspace Consumption | 13 |
| 6.7 Premature Missed Approaches/Blunders | 13 |
| 7. SCHEDULE | 13 |

## LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1 | Antenna Location and Field Orientation | 8 |
| 2 | Approach Profile for MLS Decelerating Approaches | 9 |
| 3 | Atlantic City Heliport MLS Approach Plate | 10 |
| 4 | Schedule for Decelerating Approaches | 14 |


## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1 | Airborne Data Collection Specifications | 6 |
| 2 | Analog Data Recording Specifications | 7 |
| 3 | Baseline Profiles | 11 |
| 4 | Subject Pilot Profiles | 12 |
| 5 | Pilot Perceived Workload Based on Cooper/Harper Ratings | 12 |

## EXECUTIVE SUMMARY

This series of tests are designed to identify limits for Distance Measurement Equipment/Precision (DME/P) installed on helicopters flying decelerating approach profiles. The tests are designed to determine the deceleration limits that can be obtained when DME/P is used to derive range and range rate. The data will be collected by the UH-1 helicopter while flying decelerating profiles at the Federal Aviation Administration Technical Center's Development Heliport.

## 1. PURPOSE.

This series of tests are designed to identify limits for Distance Measurement Equipment/Precision (DME/P) equipment installed on helicopters flying decelerating approach profiles. The data will be collected while decelerating profiles are being flown by the interrogating aircraft (helicopter).

The tests are designed to determine the deceleration limits that can be obtained when DME/P data are used to derive range and range rate.

## 2. BACKGROUND.

Current instrument approaches employ techniques which require the pilot to fly at a constant speed during the final approach segment of a precision approach. This requires that the deceleration to a landing at the heliport be accomplished under visual conditions. Minimum decision heights (DH's) are limited by this visual deceleration requirement. Also, tracking performance and airspace requirements, especially missed approach airspace requirements, are aggrevated by the high approach speeds. This does not allow utilization of optimum terminal flight procedures in the heliport or airport environment. Air traffic control (ATC) coordination problems could arise.

Preliminary testing indicates that pilots object to the excessive time on final approach. A more optimum approach would be to intercept the final approach segment at high en route air speeds and decelerate according to a particular schedule during the approach. A major issue is the ability of DME/P with its inherent final approach (FA) mode accuracies to support such deceleration scheduling. In the long term, "zero/zero" helicopter approach capabilities can only be realized through the development of instrument decelerating approach techniques.

Flight tests of constant speed Microwave Landing System (MLS) approaches to minimum approach speeds of 60 knots yielded capabilities of 3°, 6°, and 9° glidepaths to 150, 200, and 350-foot DH's, respectively. These profiles were routinely achievable but may not be practical, in particular to center city heliport environments, due to missed approach requirements. The minimums for constant speed approaches are limited by the visual deceleration distance required to dissipate the approach speed. In order to get lower DH's at heliports, the need to decelerate prior to DH exists. Other issues such as MLS azimuth signal characteristics (control motion noise (CMN) and path following error (PFE)) should be addressed for aircraft which are decelerating in close proximity to the azimuth antenna (inside 1.3 nautical miles (nmi)).

The objectives of the project are not to prove the feasibility of decelerating approaches, but to document total system performance improvements which could result when using decelerative techniques during instrument approaches to a collocated MLS system at a heliport. Results obtained may also benefit the development of a CAT 3A MLS capability and an automatic wind shear detection system. This project will utilize a collocated MLS (separated by not more than 656 feet) for all testing.

Previous testing by the National Aeronautics and Space Administration (NASA) indicated pilots desired pitch, roll, and collective cues be added to the attitude director indicator (ADI). The gain scheduling of these cues remains an open issue as the standards have not yet been established. These will not be addressed during this testing.

## 3. OBJECTIVES.

This series of tests are designed to identify limits for DME/P equipment installed on helicopters flying decelerating approach profiles. The decelerations will be performed while executing decelerating instrument approaches to an MLS installed at a heliport. The specific project objectives include:

a. Develop and interface equipment into the UH-1 test bed aircraft to provide for a variable decelerating approach capability. This includes strip chart presentation of slant range rate derived from the DME/P.

b. Develop and interface equipment to provide for airborne full rate data collection of MLS data and aircraft attitude and acceleration data.

c. Using various deceleration profiles, develop MLS decelerating approach system tolerances for flying to a heliport. This test can also provide the basis for obtaining DME/P accuracy data for possible use in a wind shear alert system.

d. Collect statistical data on missed approach performance and airspace requirements when the approaches are initiated below 60 knots of airspeed.

e. Determine deceleration limits, based on Federal Aviation Administration (FAA) specification accuracies for final approach FA mode DME/P.

f. Determine DME/P range and range rate granularity, accuracy, and filter time constants required for maintaining the deceleration profile to the lowest practical minimums.

g. Identify azimuth and DME/P signal characteristics such as PFE and CMN when the aircraft is in a constant magnitude deceleration.

## 4. RELATED DOCUMENTS.

Many documents were reviewed and formed the basis for this study. The related documents include the following:

1. Helicopter Operations Development Plan, Helicopter Program Staff, ARD-706, Report No. FAA-RD-78-01, September 1978.

2. Terminal Instrument Procedures Handbook, FAA 8260.33, July 1976

3. Microwave Landing System (MLS) Advisory Circular, Issue No. 1, ICAO Circular 165-AN/104, 1981.

4. Rotorcraft Master Plan, Prepared by the Associate Administrator for Aviation Standards, Rotorcraft Program Office, May 1986.

5. FAA Heliport Design Guide, Advisory Circular (AC)150/5390xx (draft), October 1985.

6. ICAO Test Plan for U.S. Microwave Landing Systems, DOT/FAA, November 1985.

7. Survey of Hélicopter Control/Display Investigations of Instrument Decelerating Approach, National Aeronautics and Space Administration Technical Memorandum 78565, Ames Research Center, Moffett Field, California.

8. Demko, Paul S. and Boschma, James H., Cpt., Advances in Decelerating Steep Approach and Landing for Helicopter Instrument Approaches, USA Avionics R&D Activity, May 1979.

## 5. SYSTEM EQUIPMENT.

The testbed aircraft for the decelerating approach project will be the FAA Technical Center's Bell 205, UH-1H helicopter. This aircraft has been obtained through an interagency agreement with the U.S. Army Airborne Electronics Research Activity (AERA), Lakehurst. The UH-1H employs a research and development model Sperry 4-axis (collective/vertical, longitudinal cyclic/pitch, lateral cyclic/roll, and yaw/pedal) flight director system which includes the capability of a programmable deceleration profile directly interfaced with DME/P derived range and range rate.

The UH-1H is currently equipped with state-of-the-art electromechanical ADI's and horizontal situation indicators (HSI's) installed on both left and right instrument panels for displaying command and raw data guidance information to the pilots.

In addition to the ADI and HSI, other flight instrumentation capabilities available include:

a. Standard pilot static altitude and airspeed
b. Instantaneous vertical velocity
c. Radar altimeter
d. Gyro/magnetic compass indicators
e. Analog P/DME range rate
f. Analog height above touchdown (HAT)
g. Redundant attitude, turn coordination, and heading reference
h. Analog and digital standard DME and DME/P indicators.

In addition to the flight director system, the UH-1H avionics complement includes:

a. Dual very high frequency/instrument landing system (VOR/ILS)
b. Multiple MLS capability
c. Conventional and precision DME
d. Radar altitude system
e. Tri-axial accelerometer system
f. Instrumented flight controls (collective, cyclic, pedals)
g. Junction boxes for data collection system integration
h. Redundant attitude and heading reference system
i. Four independent very high frequency/ultra-high frequency/frequency module (VHF/UHF/FM) communications systems
j. Air data computer for airspeed, barometric altitude, and vertical velocity.

The UH-1H is equipped with an FAA Technical Center designed data collection system; a 6809 microprocessor-based system capable of recording, on magnetic tape media, all ship's state and navigational system data, airborne synchronized time, and flight technician event marks. Real time analog strip chart recording capability is also available.

The helicopter is equipped for laser, NIKE, and extended area instrumentation radar (EAIR) ground based tracking which is fully time syncronized for post-flight merged data reduction.

The tests will be flown at the FAA Technical Center's Interim Concept Development Heliport where a Hazeltine model 2400 MLS is installed. The accuracy of this system has been shown to meet FAA Standard 022B for MLS. The antenna system is collocated (azimuth and elevation antennas separated by less than 656 feet) to the right of the heliport as the site is viewed by an approaching helicopter on the inbound centerline course.

The Hazeltine model 2400 MLS is a low profile, precision approach and landing system utilizing microwave phased-array antenna technology, microprocessor control, and solid-state electronics. The time reference scanning beam (TRSB) signal format is transmitted on any one of 200 C-band MLS (5-5.25 gegahertz (GHz)) channels. The scanning beams are scanned rapidly "to" and "fro" throughout the coverage volume so that each aircraft receiving these beams can derive its own position angle directly from the time difference between the TRSB beam pulse pairs. In addition, information such as airport and runway identification, course guidance (fly left or fly right), and other operational data are transmitted on the same channel as part of a preamble message transmitted from the sector clearance antennas.

The azimuth proportional guidance capability is provided in a sector typically $-10^\circ$ to $+10^\circ$ from approach course centerline. Clearance guidance is provided by a fly left or fly right sector clearance system in a $\pm 40^\circ$ azimuth sector. When proportional guidance in the $\pm 10^\circ$ sector is not possible, clearance guidance is provided to supplement the proportional coverage sector.

The ground station signal structure is as follows:

Azimuth Station:

Beamwidth: 3.5°
Proportional guidance: up to ±10°
Clearance sector: up to ±40°
Range: 20 nmi (±40°)
Antenna aperture size: 5 ft x 3.5 in
Phased array shifters: 8
Transmitter power: 10 watts nominal

Elevation Station:

Beamwidth: 2.4°
Proportional guidance: 1° to 15°
(fly up 0° to 1°)
Range : 20 nmi
Antenna aperture size: 6 in x 6 ft
Phased Array Shifters: 8
Transmitter Power: 5 watts nominal

The Bendix MLS-20A MLS airborne receiver system receives the guidance signals from an MLS ground facility (transmitting navigational information) to provide approach and missed-approach (where available) landing guidance. The model 20A MLS consists of an ML-201A angle receiver, CD-202A control display, two omnidirectional antennas, and associated mounting connectors. A hard mounted tray holds the MLS receiver. Unlike conventional ILS's, the MLS receiver allows the desired azimuth and elevation angle to be selected in the cockpit. The Bendix model 20A system is also known as the System Test and Evaluation Program (STEP) receiver.

Pilot selectable elevation and azimuth guidance allows for a combination of approaches up to ±60° in azimuth (where available from the MLS ground system, in 1° increments) and elevation selection from 2° to 20.9° (in 0.1° increments). However, the actual boundary limitations of this MLS installation are determined by the signal structure of the MLS ground station (i.e., ±40° in azimuth coverage and 1° to 15° in elevation coverage for the Hazeltine model 2400 ground system).

Airborne data collection specifications for digital recording are depicted in table 1. Table 2 presents the analog data recording specifications.

TABLE 1. AIRBORNE DATA COLLECTION SPECIFICATIONS

| Parameter | Units | Sample Rate (Hz) | Resolution |
|---|---|---|---|
| Time | Hr/min/sec | - | 0.001 sec |
| Indicated Airspeed | Knots | 2/5 | 0.0977 kts |
| Vertical Velocity | Feet/minute | 2/5 | 0.488 fpm |
| Magnetic Heading | Degrees | 2/5 | 0.022 deg |
| Barometric Altitude | Feet | 2/5 | 1.95 ft |
| Radio Altimeter | Feet | 2/5 | 0.732 ft |
| MLS Horizontal (low) Deviation | Microamps | 2/5 | 0.02 uA |
| MLS Vertical (low) Deviation | Microamps | 2/5 | 0.02 uA |
| MLS Azimuth | Degrees | 19/39 | 0.005 deg |
| MLS Elevation | Degrees | 39 | 0.005 deg |
| DME | Feet | 2/5 | 3 ft (DME/P)<br>60 ft (std) |
| ARINC | | | |
| All Digital MLS Flags | - | 19/39 | - |
| All Cross Pointer Flags | - | 2/5 | - |
| Transverse (Lateral) Acceleration | G's | 2/5 | 0.0012 g's |
| Longitudinal Acceleration | G's | 2/5 | 0.0012 g's |
| Vertical Acceleration | G's | 2/5 | 0.0049 g's |
| Time Code Generator Time | Milliseconds | - | 0.001 ms |

TABLE 2. ANALOG DATA RECORDING SPECIFICATIONS

| Parameter | Units | Signal Level Range |
|---|---|---|
| RTT Cross Pointer | Millivolts | ±150 mV |
| Differential Cross Pointer | Millivolts | ±150 mV |
| RTT Flag | Millivolts | 0-500 mV |
| Tone Control Event Mark | Volts | 0 or 5 v |
| MLS Azimuth Deviation | Millivolts | ±150 mV |
| MLS Elevation Deviation | Millivolts | ±150 mV |
| MLS Antenna Switch | Volts | 0 or 5 v |

## 6. FLIGHT PROFILES.

Flight tests of constant speed MLS approaches yielded approach capabilities of 3°, 6°, and 9° glidepaths to 150, 200, and 350-foot DH's, respectively. These results were obtained without the aid of a flight director. Subsequent helicopter testing has shown a marked reduction in azimuth CMN and PFE inside 1.3 nmi distance from the antenna when compared with airplane derived values. During these preliminary tests, a four cue, three-axis flight director will be employed. The UH-1H will use flight director gain scheduling and deceleration profile generation based on DME/P in place of radar altimeter for the decelerating approaches. The approaches will be conducted in simulated instrument meteorlogical conditions (IMC). Subject pilots will utilize a hood or goggles to simulate IMC. Final approach segments will vary in length, depending on the elevation angle being flown. The deceleration will be commanded by the flight director and begin at a point in space where the programmed deceleration profile is intercepted. This point is independent of the selected MLS azimuth and elevation angles and is based on speed (range rate) and distance to touchdown (DME/P).

The orientation of the FAA Technical Center's Concept Development Heliport is shown in figure 1. The heliport is located at the approach end of runway 35 between the Air National Guard ramp and the Atlantic City Municipal Airport ramp. The decelerating approaches are shown in figures 2 and 3. Figure 2 shows a plan view of the approach on the selected elevation angle and 0° azimuth angle. Figure 3 is the approach plate to be used by the subject pilots showing the 354° approach to the heliport using zero azimuth and selected elevation angle (experimental approach plate).

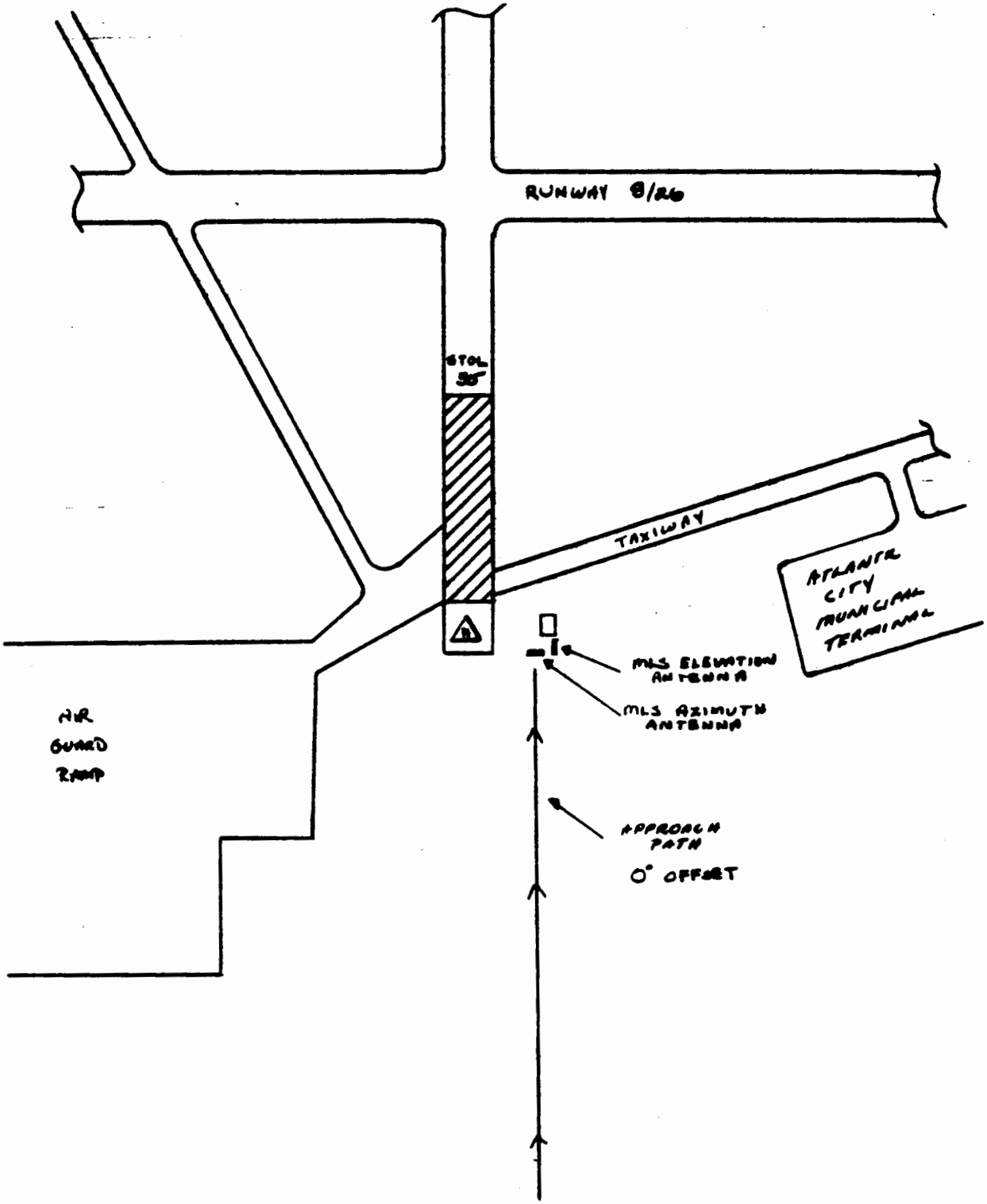



FIGURE 1 ANTENNA LOCATION AND FIELD ORIENTATION

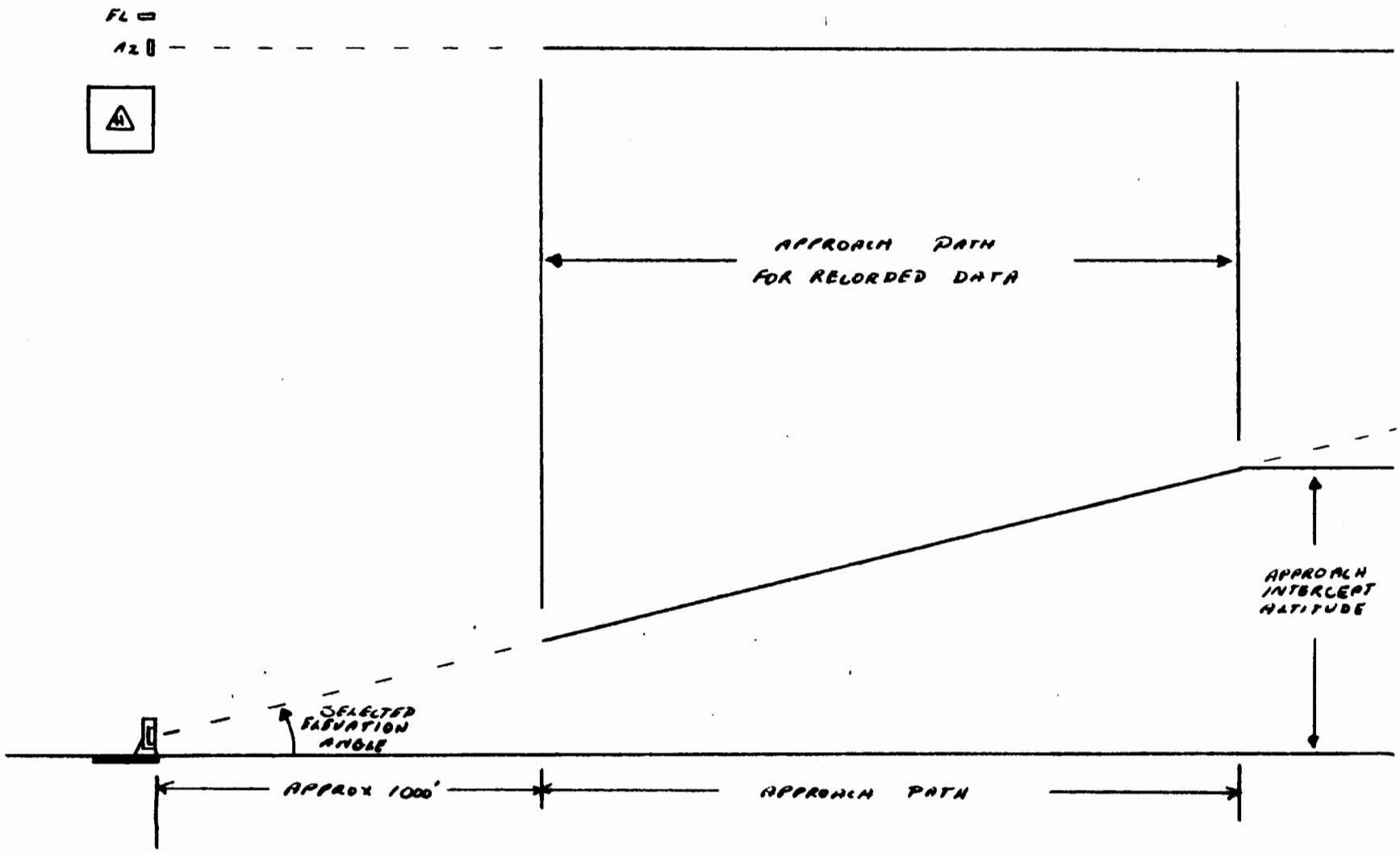



FIGURE 2 APPROACH PROFILE FOR MLS DECELERATING APPROACHES

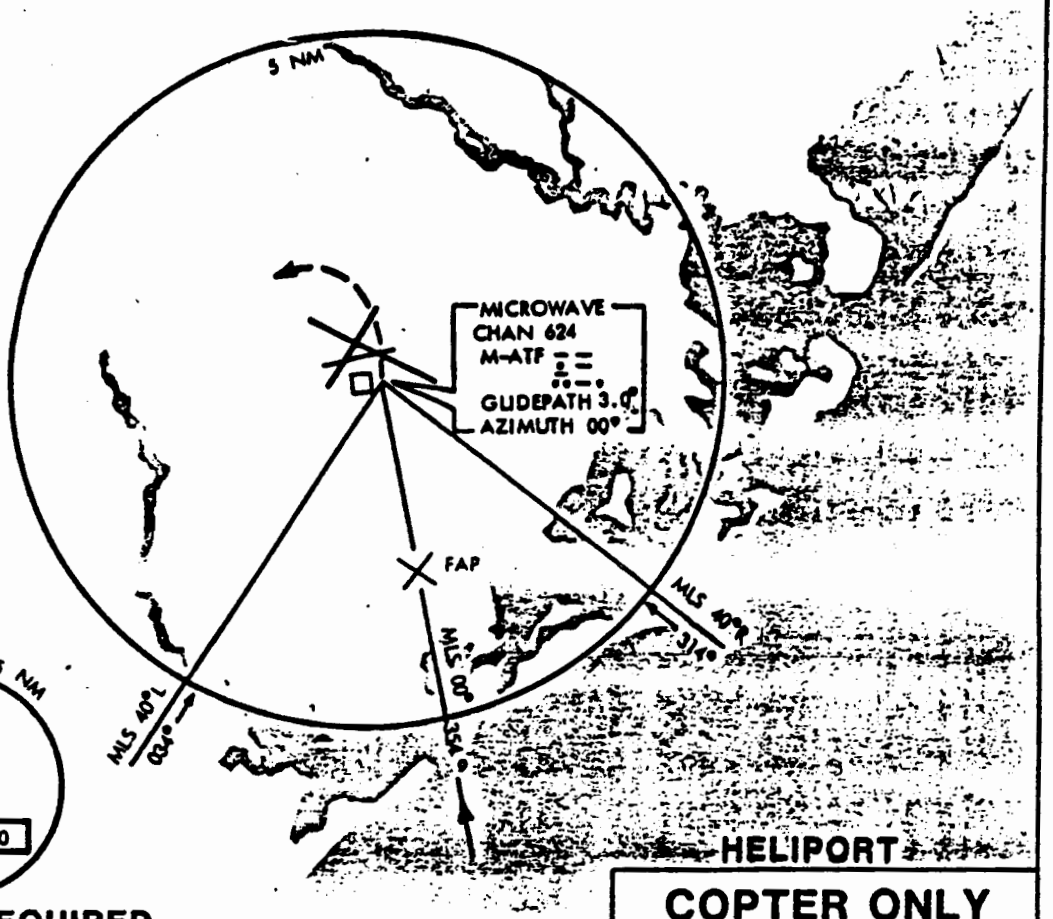
# COPTER 354 HELIPORT

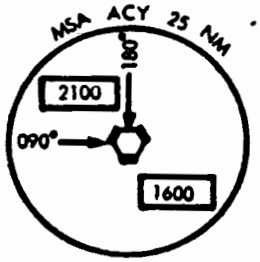
ATLANTIC CITY (ACY)
ATLANTIC CITY, NEW JERSEY

ATLANTIC CITY APP CON
124.6 385.5
ATLANTIC CITY TOWER
118.9 239.0
GND CON
121.9 284.6

ASR
ATIS 108.6

CLNC DEL
120.3

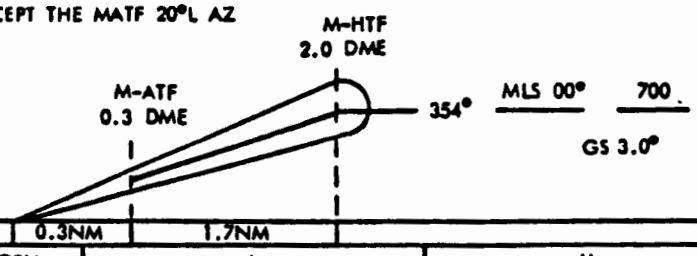



**RADAR REQUIRED**

**COPTER ONLY**

MISSED APPROACH : CLIMB STRAIGHT AHEAD TO 500, THEN CLIMBING LEFT TURN HEADING 160° to 1400 to INTERCEPT THE MATF 20°L AZ



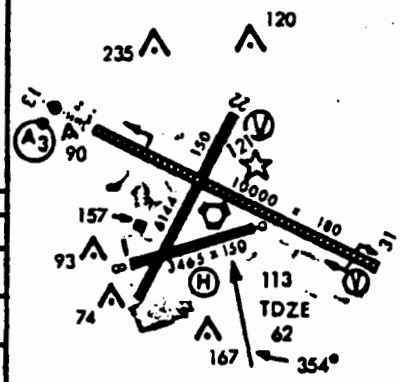

| CATEGORY | A | H |
|---|---|---|
| S-MLS 354° | 162-1/2 100 (RA100) | N/A |
| S-AZ 354° | 420-3/4 358(400-3/4) | N/A |
| | | |

HELIPAD LOCATED 135 FT. LEFT OF COURSE

EXPERIMENTAL ONLY

RATE OF DESCENT 395 FT/MIN AT 75 KNOTS

ELEV 76




TDZ/CL Rwy 13 and 31
HIRL Rwys 4-22 and 13-31
MIRL Rwy 8-26

| FAF TO MAP 2.0 NM | | | | | |
|---|---|---|---|---|---|
| Knots | 50 | 60 | 70 | 80 | 90 |
| Min Sec | 2:24 | 2:00 | 1:43 | 1:30 | 1:20 |

**COPTER**

39°27'N-74°35'W

ATLANTIC CITY, NEW JERSEY
ATLANTIC CITY (ACY)

FIGURE 3 ATLANTIC CITY HELIPORT MLS APPROACH PLATE

## 6.1 BASELINE PROFILE DESIGN.

These profiles will provide baseline data on flight director assisted constant speed approaches. Results of constant speed approach flights have been documented to a collocated antenna system at a heliport in the past. However, these results were obtained without the use of a flight director for flight data presentation. The following table presents the flight director assisted profiles, designated DH's, and elevation angles that will constitute the constant speed 60-knot approach baseline data. Vy for the test bed aircraft is 53 knots. Baseline profiles are presented in table 3.

TABLE 3. BASELINE PROFILES

| Elevation Angle (deg) | DH (ft) | Termination | Missed Approach Profile |
|---|---|---|---|
| 3 | 50 | Full Stop | --- |
| 3 | 50 | Missed Approach | Vy + 10 kts and 500 fpm climb |
| 3 | 50 | Missed Approach | Vy + 10 kts and 1000 fpm climb |
| 6 | 100 | Full Stop | --- |
| 6 | 100 | Missed Approach | Vy + 10 kts and 500 fpm climb |
| 6 | 100 | Missed Approach | Vy + 10 kts and 1000 fpm climb |
| 9 | 150 | Full Stop | --- |
| 9 | 150 | Missed Approach | Vy + 10 kts and 500 fpm climb |
| 9 | 150 | Missed Approach | Vy + 10 kts and 1000 fpm climb |

## 6.2 SUBJECT PILOT FLIGHT PROFILE DESIGN.

These profiles will provide data on the constant g force decelerating approaches to be flown by the subject pilots. All the following profiles are flight director assisted and flown to a collocated antenna system at a heliport. The following six approaches will be flown during each data collection flight. Each flight will be flown under a fixed set of conditions as shown in table 4.

The order in which each set of flight conditions will be flown will be randomized to minimize training effects. Each subject pilot will make 12 data collection flights in addition to the baseline data flights. The combination of experimental conditions for each flight is presented in table 4.

## 6.3 WORKLOAD MEASUREMENT.

During the preflight each pilot will be advised that he/she will be requested to rate the overall workload and Instrument Flight Rules (IFR) characteristics of each procedure. Each pilot will be briefed on the rating system criteria (table 5) and advised of the beginning and end points of each segment of flight to evaluate. The maximum, minimum, mean, and standard deviation of these ratings will be calculated.



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TABLE 4. SUBJECT PILOT FLIGHT PROFILES

| Flt No. | Minimum Slant Range Rate Limit (knots) | Approach Deceleration Magnitude (G's) | Missed Approach Profile |
|---|---|---|---|
| 1 | 40 | 0.025 | Vy + 10 kts and 500 fpm climb |
| 2 | 40 | 0.025 | Vy + 10 kts and 1000 fpm climb |
| 3 | 40 | 0.050 | Vy + 10 kts and 500 fpm climb |
| 4 | 40 | 0.050 | Vy + 10 kts and 1000 fpm climb |
| 5 | 40 | 0.100 | Vy + 10 kts and 500 fpm climb |
| 6 | 40 | 0.100 | Vy + 10 kts and 1000 fpm climb |
| 7 | 25 | 0.025 | Vy + 10 kts and 500 fpm climb |
| 8 | 25 | 0.025 | Vy + 10 kts and 1000 fpm climb |
| 9 | 25 | 0.050 | Vy + 10 kts and 500 fpm climb |
| 10 | 25 | 0.050 | Vy + 10 kts and 1000 fpm climb |
| 11 | 25 | 0.100 | Vy + 10 kts and 500 fpm climb |
| 12 | 25 | 0.100 | Vy + 10 kts and 1000 fpm climb |

TABLE 5. PILOT PERCEIVED WORKLOAD BASED ON COOPER/HARPER RATINGS

| Pilot Rating | Demands on Pilot | IFR Approach Characteristics | Deficiencies |
|---|---|---|---|
| 1-3 | Minimal | Satisfactory | Negligible |
| 4-6 | Considerable | Requires Improvement | Moderate |
| 7-9 | Intense | Unacceptable | Major |
| 10 | Uncontrollable | | |

## 6.4 PERFORMANCE MEASURES.

Techniques used in the Heliport Course Width Study will be employed to develop overall measures of performance. These measures will permit an objective comparison of results obtained under the different fixed flight conditions. The performance measures lie in four general areas: pilot workload and measurement, pilot tracking performance, airspace consumption, and premature missed approaches/blunders.

## 6.5 TRACKING PERFORMANCE.

Measures of pilot tracking performance and MLS system performance will be obtained from analysis of lateral and vertical course deviation indicators (CDI's) movement during the approach phase. During missed approach, deviations from the reference heading, airspeed, and climb rate will be analyzed to assess missed approach airspace requirements. MLS system performance will be measured using the following values CMN, PFE, and slant range rate error.

## 6.6 AIRSPACE CONSUMPTION.

Estimate of total navigational system error will be obtained through the use of laser and/or EAIR tracking. These systems will provide the ground truth position reference for determination of total navigation system error. The standard deviation of the total navigation system error will be used to identify airspace consumption under the various required flight profiles.

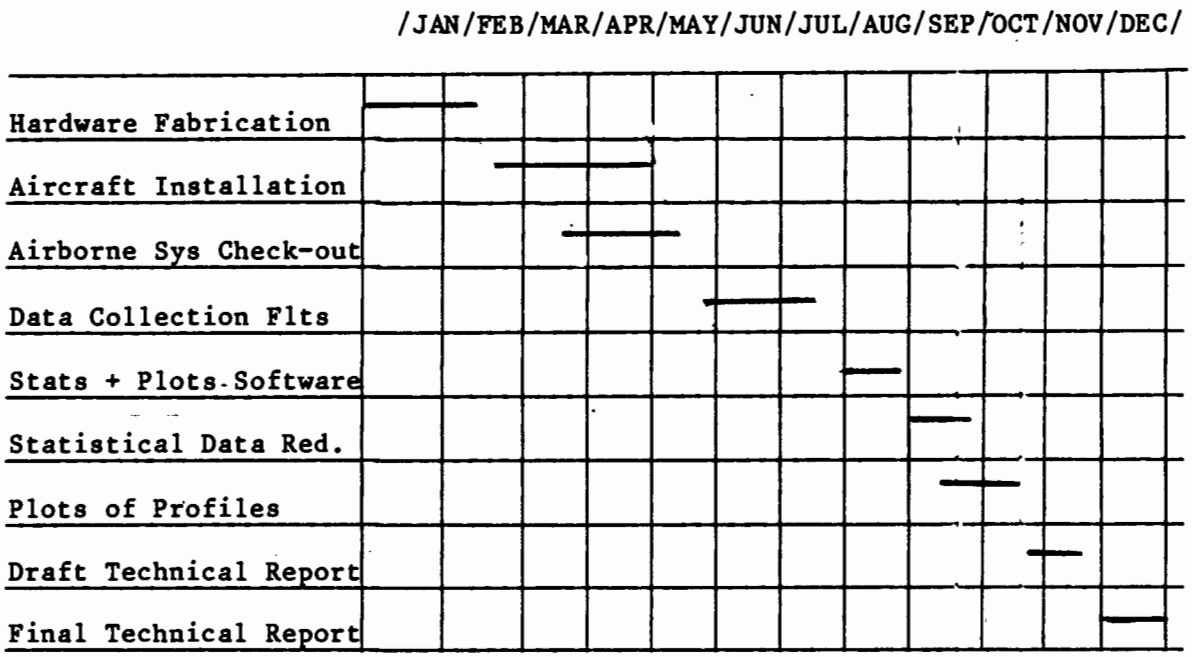
## 6.7 PREMATURE MISSED APPROACHS/BLUNDERS.

A missed approach will be considered a premature missed approach if there is a full scale deviation on the CDI at or prior to DH. The approach will be considered a blunder if the pilot errs in course intercept or reaction to flight director command cues. Recording flight director parameters will allow post-flight determination of flight director command cue blunders. Premature missed approaches and blunders will terminate the approach for go around for the next profile.

# 7. SCHEDULE

The project schedule is shown in figure 4. The project will begin in January 1987 and will be completed in December 1987 with a final technical report. Schedule changes may occur due to aircraft availability, maintainence schedules, weather, subject pilot availability, and ground tracking facility availability.

CALENDAR YEAR 1987




Note: Schedule dependent on concurrent project priorities.

FIGURE 4. SCHEDULE FOR DECELERATING APPROACHES