Report No. FAA-CT-81-167

TERMINAL HELICOPTER INSTRUMENT PROCEDURES (TERPS)

Robert H. Pursel

TEST PLAN

APRIL 1981

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

NOTICE

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. OBJECTIVES.

The Federal Aviation Administration (FAA) Technical Center Helicopter Project is designed to provide actual flight test data to the FAA Office of Flight Operations (AFO) to aid in the updating and streamlining of helicopter terminal area procedures and criteria. The data gathered here will be used toward the revision of chapter 11 of the Terminal Instrument Procedures (TERPS) Manual which deals with "helicopter only" terminal operations. This project will deal primarily with the approach and missed approach phases of helicopter terminal operations. The project will explore and provide data on precision and non-precision instrument landing system (ILS) and omnidirectional radio range (VOR) approaches. The project will document the actual operating characteristics of representative Instrument Flight Rules (IFR) certificated helicopter types now in civil and military use.

To aid in the determination of total system error in the terminal/approach phase subject helicopter pilots of varying backgrounds and experience levels will be utilized. Among the approach variables to be evaluated are:

a. Final approach segment length
b. Final approach fix (FAF) altitude
c. Missed approach point (MAP) height and distance from landing area
d. Final approach angle
e. Final approach intercept angle
f. Final approach intercept distance
g. Height loss during missed approach
h. Missed approach guidance
i. Missed approach turn height
j. Missed approach maneuvering area
k. Missed approach climb
l. Visual approach segment

2. BACKGROUND.

Chapter 11 of the TERPS Manual deals with helicopter terminal procedures and criteria. This chapter was issued prior to the advent of today's sophisticated helicopters and is now being questioned as to its currency and adequacy.

The questions are coming from the helicopter industry and reflect their demands for lower instrument approach minimums for both precision and nonprecision approaches. These demands are based on the rapid growth of the helicopter industry and the advances in both avionics and airframes.

3. RELATED DOCUMENTATION/PROJECTS.

The AFO is also conducting a flight test program to collect TERPS data at the Lafayette Regional Airport, Lafayette, Louisiana (La.). The program will be conducted by the Standards Development Branch, AFO-560, Oklahoma City, Oklahoma

(Okla.). These tests will be conducted in cooperation with Petroleum Helicopters, Air Logistics, and a United States (U.S.) Army reserve unit based at Lafayette. Data will be collected with a precision tracking radar which will be located at Lafayette.

Close coordination has been and will continue to be maintained with AFO to avoid duplication of effort and to assure a usable product. The Lafayette tests will be conducted using representative aircraft, line pilots, and conditions which duplicate the actual operating environment as closely as possible. No onboard recording systems will be used and profiles to be flown will incorporate nominal values. Since the tests at the Technical Center will be more closely controlled and will involve fully instrumented aircraft, it is felt that these tests should explore the "beyond nominal" values presently allowed by TERPS and will, therefore, be complimentary to the Lafayette tests.

Pacer Systems of Arlington, Virginia (Va.), has been engaged by Systems Research and Development Service (SRDS) to study helicopter terminal instrument procedures. Draft copies of the reports produced by Pacer have been made available to the Helicopter IFR Operations group and will be used to define airborne data parameters and test procedures.

A 9550 request for RD&E effort entitled "Determination of Parameters for the Development of IFR Helicopter Landing and Takeoff Minimums" was submitted by AFO to SRDS in late 1978. The Pacer contract was awarded in response to this 9550.

4. SYSTEM/EQUIPMENT DESCRIPTION.

For the Technical Center tests a mix of helicopter types will be flown including a CH-53, a Bell 206L, an Army UH-1H, and the newly acquired Sikorsky S-76. All of these aircraft will be equipped with onboard recording gear.

5. DATA COLLECTION.

5.1 SUBJECTS AND AIRCRAFT.

Since the data to be collected should be representative of the general pilot population, it is important that the pilots used for these tests be selected from this group. Subject pilots with IFR ratings will be solicited for the B-206L, UH-1H, and S-76 flight tests. Civilian subjects for the CH-53 will be difficult to obtain, so FAA test pilots and some military pilots will be used. This cross section of pilots and aircraft of the light, medium, and heavy categories will enhance the acceptability of the data collected.

5.2 ILS VARIABLES.

A list of variables and areas of interest for the ILS approach test is shown in table 1. This list of variables is further defined into matrices for the different test aircraft. The matrices are slightly different because of the different equipment compliments on each aircraft. Matrices for the S-76, B-206L, CH-53, and UH-1H are shown in figures 1, 2, 3, and 4, respectively. Each component of the matrix and the expected results in varying each will be discussed.

5.2.1 Subject Pilots.

The importance of getting a representative sampling of the pilot population cannot be overstressed. The data resulting from these tests will be used to update TERPS, chapter 11, so the data must be representative of a wide variety of pilot experience levels. Through the offices of various pilot organizations such as the Appalachian Helicopter Pilots Association, the New England Helicopter Pilots Association, the Helicopter Association of America, etc., helicopter pilots of various experience levels will be recruited for these tests. Travel expenses and per diem will be paid to those selected. An estimated 2 days onsite time will be required for each pilot, with data flights limited to a 2-hour maximum. Subject pilots will use an instrument hood to simulate instrument meteorological conditions (IMC) conditions.

TABLE 1. TABLE OF VARIABLES AND AREAS OF INTEREST FOR ILS APPROACH TEST

ILS Approach

Variables	Fixed PARAMETERS	Areas of Interest
Intercept (Dist., Alt Angle, Segment Length)	G.S. Angle (3°)	FTE
	Azimuth Angle (0°)	Rate of Descent Profile
Gross Weight		
		Heading
Airspeed		
		Roll
DH Decision Height		
		Pitch
Stability Augmentation (On or Off)		Airspeed Profile X,Y,Z Position
Winds		
		Height Loss on Missed
Raw Deviation		
		Approach
Flight Director		
		Missed Approach Airspace
Coupled Approach		
		Height-Dist. on Missed Approach
Subject Pilots		
Land or Missed Approach		Runway Clearance (Time-Distance to Decelerate to Hover on Visual Seg)
Barometric or Radio Altimeter		
		Height-Velocity Envelope

5.2.2 Guidance.

Various levels of sophistication in guidance equipment are present in the helicopter fleet operating within the National Airspace System (NAS). These range from raw deviation error displays to complete helipilot systems allowing coupled approaches. The possible guidance selections vary for the test vehicles to be used on this program and are indicated on the matrices for each aircraft. The type of guidance system used can affect pilot workload, flight technical error, and, perhaps, the minimum decision height. The report "Study of Helicopter Performance and Terminal Instrument Procedures," FAA-RD-80-53, indicates that when flying, a flight director workload will tend to be greater than when flying a raw deviation display. However, as long as the work expended does not exceed the available workload and is acceptable to the pilot, then performance will increase accordingly.

Since the nature of ILS guidance is angular, the guidance beam will converge as the aircraft approaches the localizer and glide slope transmitters. This convergence means that for a given linear displacement of the aircraft from the center of the guidance beam, raw deviation deflection will increase as the aircraft comes closer to the localizer and glide slope sites. Flight director systems perform a desensitization to the raw data as a function of radar altitude or time, reducing system gain and at the same time reducing the pilots tendency to "chase the needles" at low altitudes. Thus, the type of airborne guidance may affect the permissible decision height (DH). A second related factor in the DH is the ability of the ground facility to provide adequate signal quality to that DH.

5.2.3 Stability Augmentation System.

Stability Augmentation Systems (SAS) are utilized to improve basic handling qualities of helicopters, in turn reducing pilot workload. If pilot workload is decreased, then more workload capacity is available to apply to the flight control task when required, thus, allowing for a performance increase. This factor will have a direct impact on the flight technical error (FTE), with less FTE expected with SAS-equipped helicopters than those without SAS. These flight tests will attempt to quantify the differences in FTE in these cases.

5.2.4 Intercept Angle and Turn-On Distance.

Intercept angle refers to the angle at which the aircraft intercepts the ILS localizer course. The shallower the angle, the more distance and resultant airspace is required (see figure 5). The greater the angle, the greater the chance of overshooting the localizer course. Greater time may also be required to stabilize on the localizer and this may adversely affect the tracking task.

Turn-on distance will also affect the tracking task. Short turn-ons will allow less time for stabilization and may require simultaneous intercept of glide slope and localizer and tracking of the glide slope in a descending turn. Shorter turn-ons and 90° intercept angles would tend to facilitate traffic flow. This program will attempt to establish a minimum practical turn-on distance and maximum practical intercept angle for various categories of helicopters.

5.2.5 Airspeed.

At the present time, it is felt that each individual subject pilot will be permitted to fly the approach airspeed he routinely uses for an ILS approach. There is expected to be some variability in this selection, but it will allow the collection of typical approach profile data.

The helicopter is unique in that it can achieve a zero airspeed. However, under IMC slow airspeed flight creates problems. Handling qualities can degrade below present standards. Existing airspeed systems utilizing Pitot tube pressure are inadequate and inaccurate for low speed IMC flight: lateral components of relative motion are not measured; there is no provision for measuring the direction of relative motion; only magnitude is measured and lags and inaccuracies are inherent in the system.

For these reasons, helicopters are certified for IMC flight at certain minimum airspeeds. Table 2 is a listing of the various certified or recommended IMC airspeeds for the types of helicopters to be used in these tests.

The advantages of flying approaches at slow airspeeds are apparent in figure 6. This chart depicts time-to-ground impact for various approach speeds and descent angles. Time-to-ground impact is time from a 200-foot decision height (DH), assuming the DH goes unnoticed and descent continues from 200 feet. The slower airspeeds allow a much greater time below the DH (during the visual segment) to obtain visual cues and maneuver the aircraft. This implies that the slower airspeeds may allow lower DH's (provided the ground guidance system can support the lower altitude operation).

TABLE 2. MINIMUM IFR AIRSPEEDS FOR HELICOPTERS TO BE USED IN TERPS TEST

	Minimum Indicated Airspeed (Knots)	Recommended Indicated Approach Speed (Knots)
Bell 206L	50	80
Bell UH-1H	60	80
Sikorsky CH-53A	70	90
Sikorsky S-76	60	100 - 125

In order to gather some data at the slower approach airspeeds, subject pilots will be asked to fly some approaches at airspeeds which are below minimum IFR airspeeds for the particular helicopter flown.

5.2.6 Altimetry.

Test approaches will include the alternate use of either barometric or radar altimetry for determination of DH. Data will be used to determine the errors in the use of barometric altimetry and to determine the minimum instrumentation configuration for low precision approach minimums.

5.2.7 Decision Height.

The test matrix will include various DH's to examine the adequacy of various guidance and instrumentation configurations at different DH's. At the decision height, the subject pilot will be instructed to either land or go-around. If the instruction is to land, the subject pilot will establish visual contact and decelerate to a hover. If the instruction is to go-around, one of two types of missed approach procedures will be used. One procedure will be to climb straight ahead to a preselected altitude. The second procedure will be to climb to a preselected altitude and start a climbing turn. The subject pilot will remain under the instrument hood to simulate IMC conditions for both missed approach procedures.

Data collected will be used to determine dispersion from localizer and glide slope at DH, height loss at missed approach, and missed approach performance and airspace required.

5.3 VOR VARIABLES.

The VOR test matrix is shown in figure 7. Emphasis will be placed on parameters which are considered outside of nominal values. Major areas of concern are the final approach fix distance, airspeed, and missed approach airspace requirements.

5.4 PRETEST PHASE.

The number of possible combinations that are defined in the ILS and VOR matrices is very large. For that reason, a pretest phase will be flown to reduce the number of possible variations and, therefore, the number of subject pilot runs. The pretest phase will be flown by FAA test pilots, who, together with project personnel and personnel from AFO-500 in Oklahoma City, will make determinations as to the final test matrix to be used by the subject pilots. Data will be collected during the pretest phase to check out all instrumentation and to exercise all data processing software.

5.5 CHARTING.

Master approach plates have been developed for both the ILS and the VOR test series. The plate format is such that the variables in intercept angle, distance, altitude, etc., can be inserted prior to the flight. Master approach plates for ILS series are depicted in figure 8; plates for the VOR series are depicted in figures 9 through 12.

5.6 AIRBORNE DATA.

Airborne instrumentation systems will vary in complexity among the different types of aircraft to be used for these tests. The systems on the CH-53A and the S-76 will be the most sophisticated, while the B-206L and UH-1H systems will be the least sophisticated.

5 6.1 CH-53A Airborne Data.

The following parameters will be collected on all CH-53A TERPS test flights:

- Time
- Pitch attitude
- Roll attitude
- Magnetic heading
- Airspeed
- Barometric altitude
- Barometric altitude rate
- Cyclic position
- Collective position
- Yaw position
- Inertial Navigation System
    - Groundspeed
    - Latitude
    - Longitude
    - True heading
    - Track angle
- VOR/Localizer deviation
- Flight director commands
- VOR bearing
- DME distance
- Radar altitude
- Flags and validities

5.6.2 S-76 Airborne Data.

The S-76 airborne data acquisition system is presently under development. The system will be patterned after the CH-53A system and recorded parameters will be similar.

5.6.3 B-206L Airborne Data.

A compact, lightweight airborne data system has been fabricated for the B-206L. The system will be completely self-contained and will house a real time clock, a digital tape cassette transport, and all signal conditioning required. The unit is pictured in figure 13. This unit, together with an air data computer, will be installed in the B-206L using the rear seat attach points. The following parameters will be collected on all B-206L TERPS test flights:

Time

Pitch attitude

Roll attitude

Magnetic heading

Airspeed

Barometric altitude

Barometric altitude rate

Cyclic position

Collective position

Yaw position

Localizer deviation

Glide slope deviation

VOR bearing

DME distance

Flags and validities

Event mark

5.6.4 UH-1H Airborne Data

The UH-1H airborne data acquisition system is presently under development. The system will be patterned after the B-206L system and recorded parameters will be similar.

6. DATA REDUCTION AND ANALYSIS.

Airborne data will be merged with ground tracking data to provide a composite data tape containing all flight test parameters. This data tape will then be used for generating statistical and graphical data pertinent to the tests.

6.1 ILS DATA.

a. Individual profile and plan view plots of each approach will be generated.

b. Composite profile and plan view plots will be generated.

c. The data will be sorted into categories dependent on the test variables. These categories would include aircraft (gross weight), equipment, intercept angle, etc.

d. Data within the selected category will be combined and partitioned at 250-foot altitude increments down to 500 feet; then at 50-foot altitude increments to decision height.

e. Statistics will be calculated for the partitioned data. This will include means, variances, skewness, and kurtosis. The data items treated in this way will include such terms as flight technical error, rates of climb/descent, airspeed, and height loss at missed approach.

f. For those approaches which result in missed approaches, missed approach profiles will be plotted and height loss at go-around will be measured and described statistically.

Data reduction and analysis technique for the Technical Center tests will be closely aligned with the techniques used in the AFO Lafayette tests, where possible, to assure comparability of data.

6.2 VOR DATA.

VOR data reduction will be handled in the same manner as ILS data reduction except that data will be partitioned as a function of distance to the MAP.

7. INSTRUMENTATION AND FACILITIES.

Ground tracking of the test approaches will be provided by the photo-optical theodolite system for ILS approaches and by either the Technical Center NIKE or EAIR radar systems for VOR approaches.

All special airborne instrumentation will be fabricated by project personnel. The systems have been described in section 4.

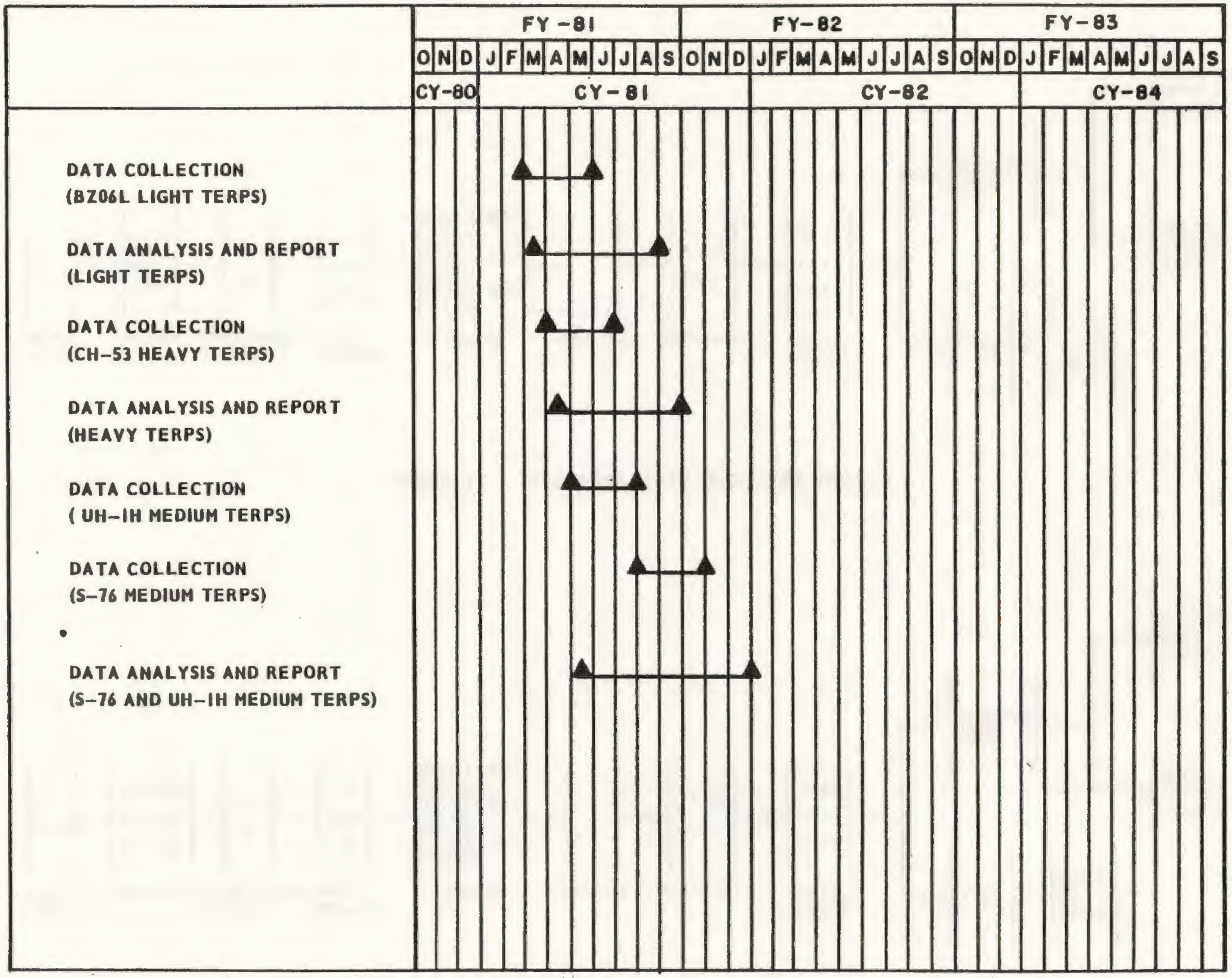
8. COORDINATION AND AREAS OF RESPONSIBILITY.

The areas of responsibility for the Helicopter TERPS test program are shown in table 3.

TABLE 3. AREAS OF RESPONSIBILITY

Organizational Responsibility	Products
ACT-100D	Test plan
	Subject pilots
	Test conduct
	Data collection
	Coordination
	Data processing and analysis
	Test report
ACT-640	Aircraft
	Project pilot assistance
	FAA subject pilots
ACT-740	Aircraft tracking
ARD-330	Coordination
AFO-560	Coordination
	Direct project participation

9. MILESTONE SCHEDULE.



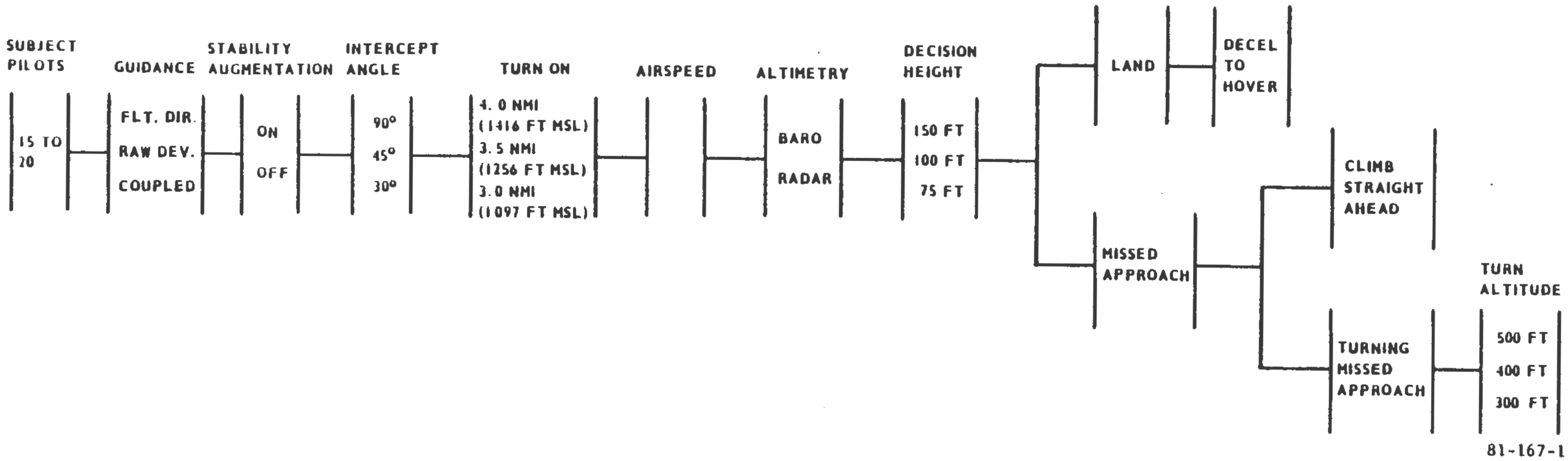


FIGURE 1. SIKORSKY S-76 ILS TEST MATRIX

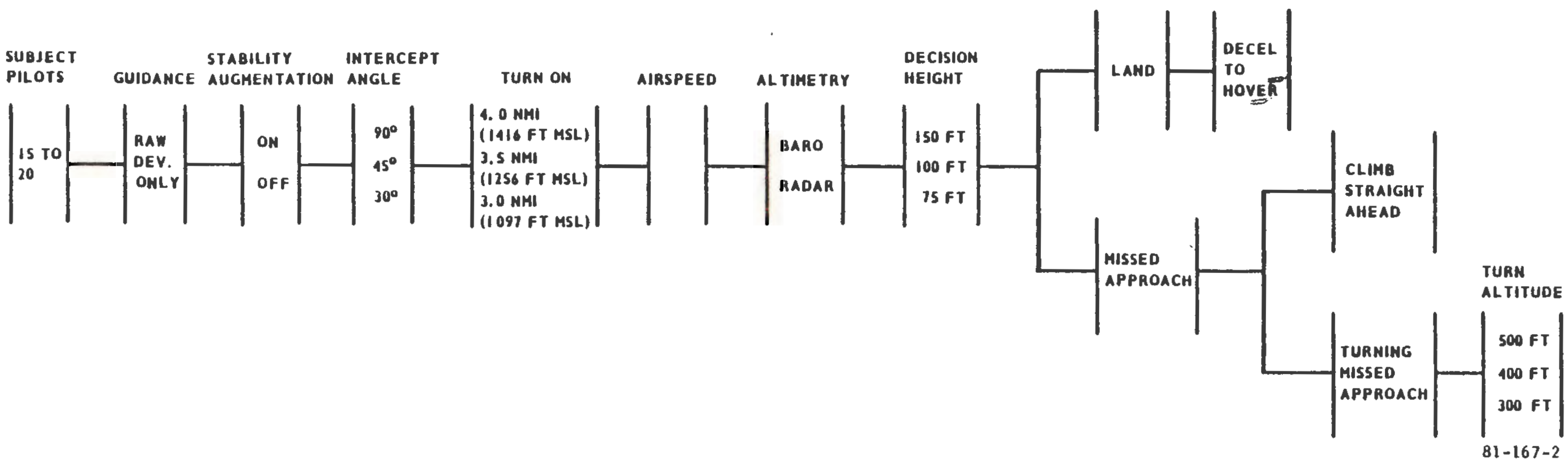


FIGURE 2. BELL 206L ILS TEST MATRIX

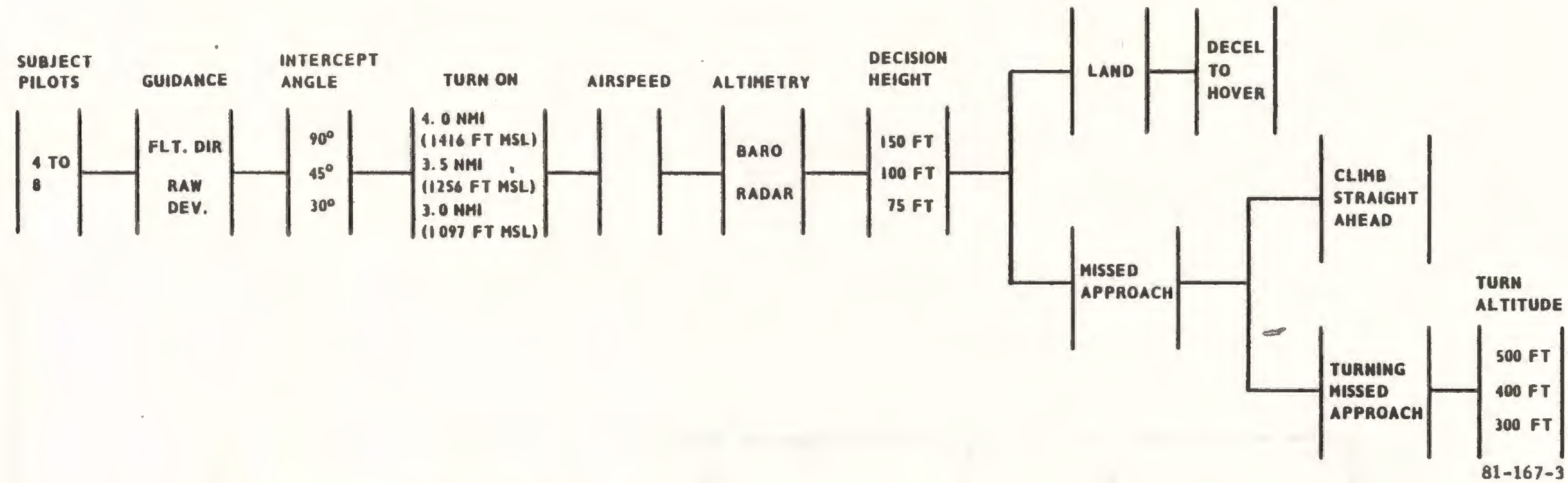


FIGURE 3. SIKORSKY CH-53A ILS TEST MATRIX

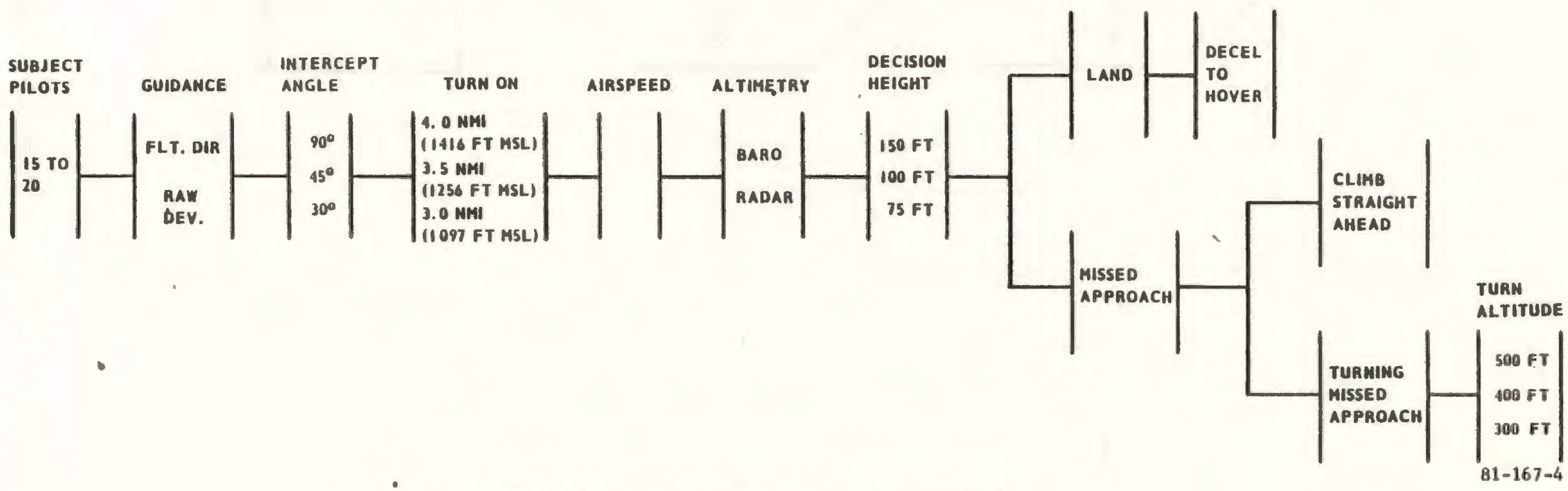


FIGURE 4. BELL UH-1H ILS TEST MATRIX

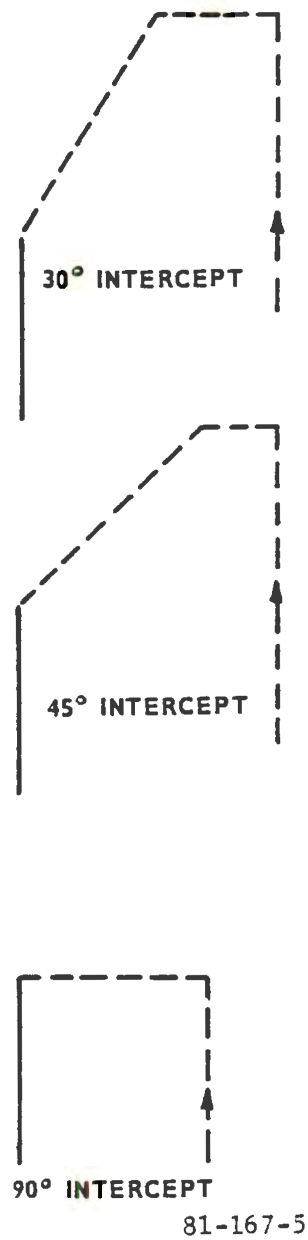
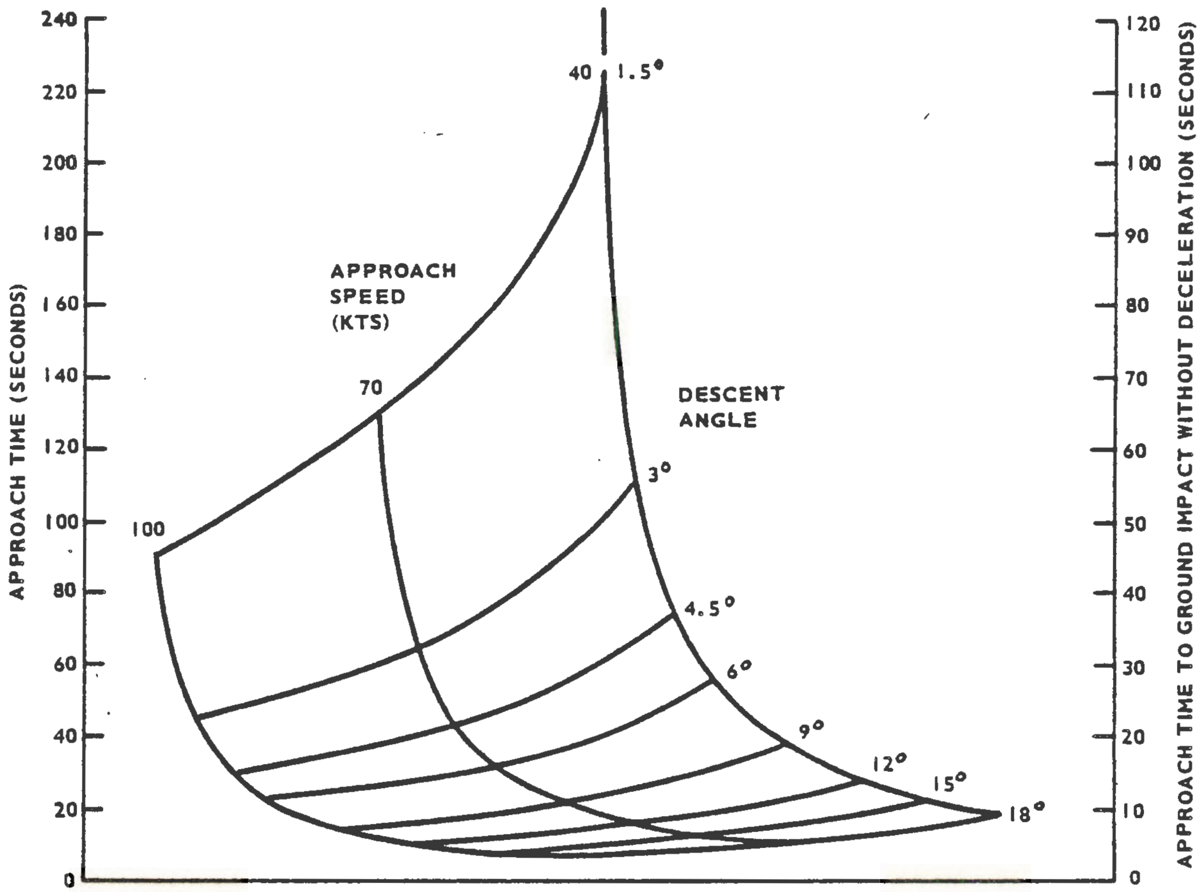


FIGURE 5. ILS COURSE INTERCEPT ANGLES



NOTE: TIMES ARE BASED ON A 200 FT DECISION HEIGHT. APPROACH TIME (LEFT HAND SCALE) ASSUMES A CONSTANT DECELERATION FROM THE PLOTTED APPROACH SPEED TO A HOVER, DECELERATING ALONG THE DEFINED DESCENT ANGLE. TIME TO GROUND IMPACT ASSUMES THAT THE DECISION HEIGHT IS UNNOTICED AND DESCENT CONTINUES UNABATED FROM 200 FT UNTIL GROUND IMPACT ALONG THE DEFINED DESCENT ANGLE.

81-167-6

FIGURE 6. TIME—TO—GROUND IMPACT FOR VARIOUS APPROACH SPEEDS SPEEDS AND DESCENT ANGLES

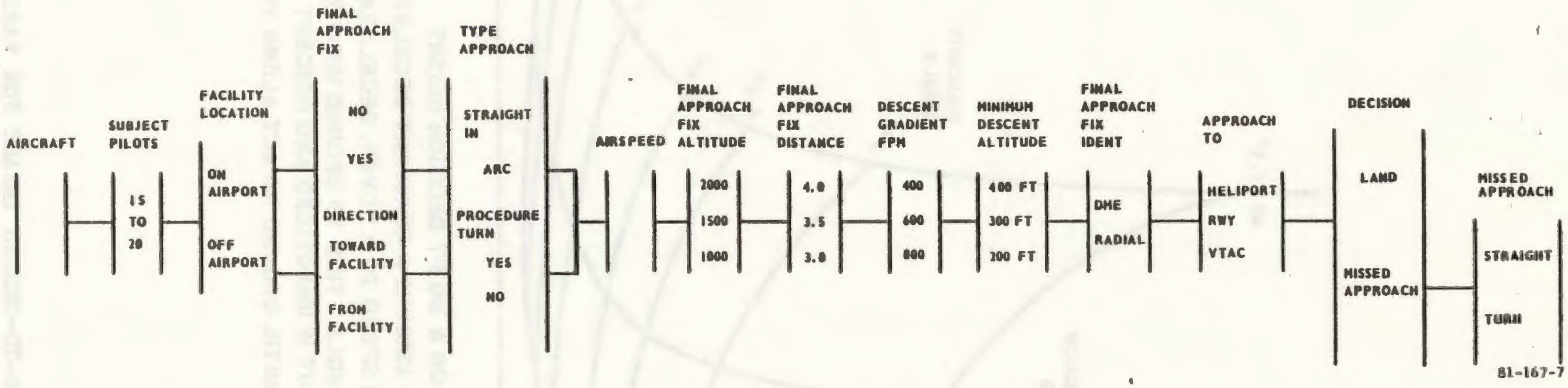
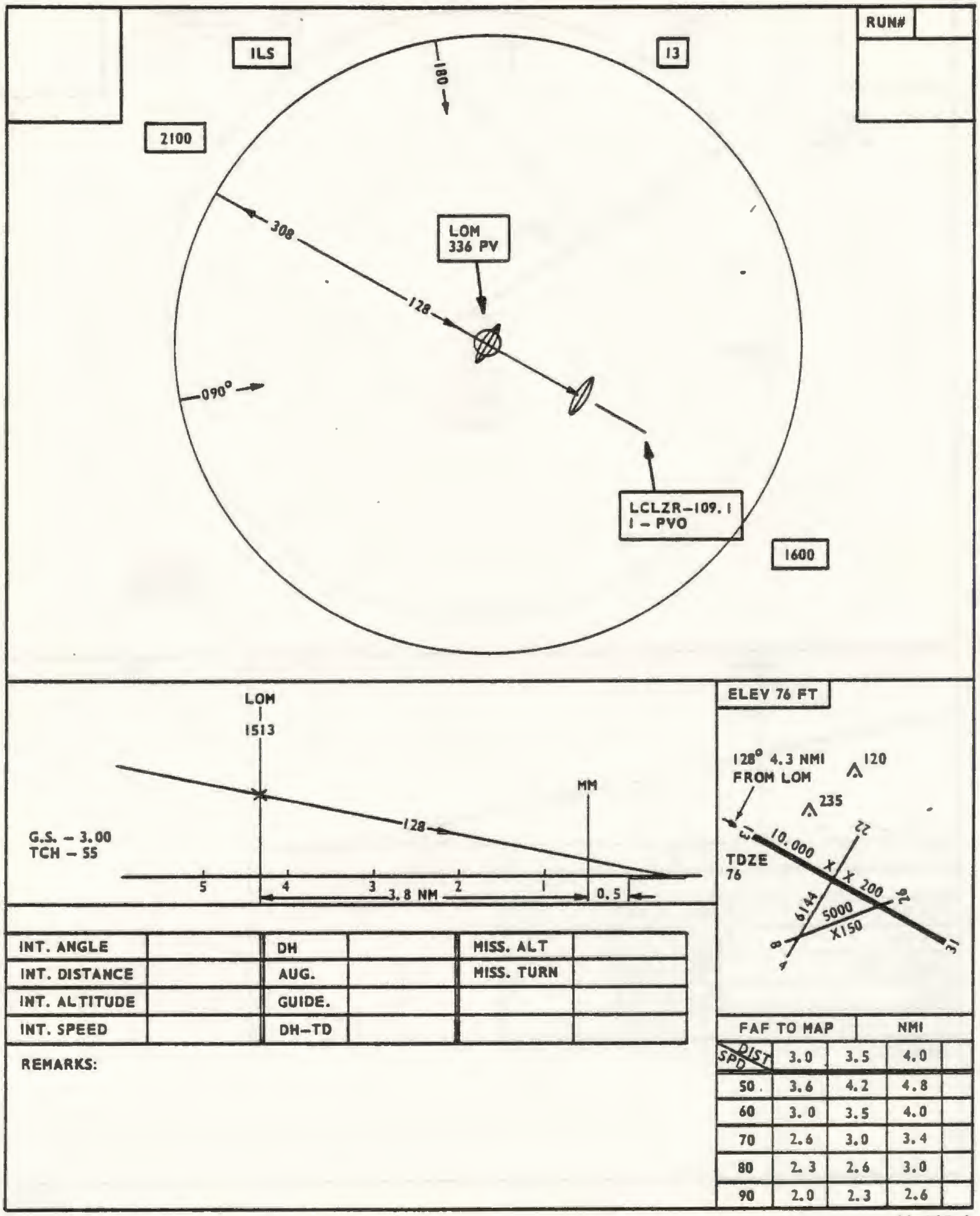


FIGURE 7. VOR TEST MATRIX



81-167-8

FIGURE 8. TYPICAL ILS APPROACH PLATE FOR TERPS TEST

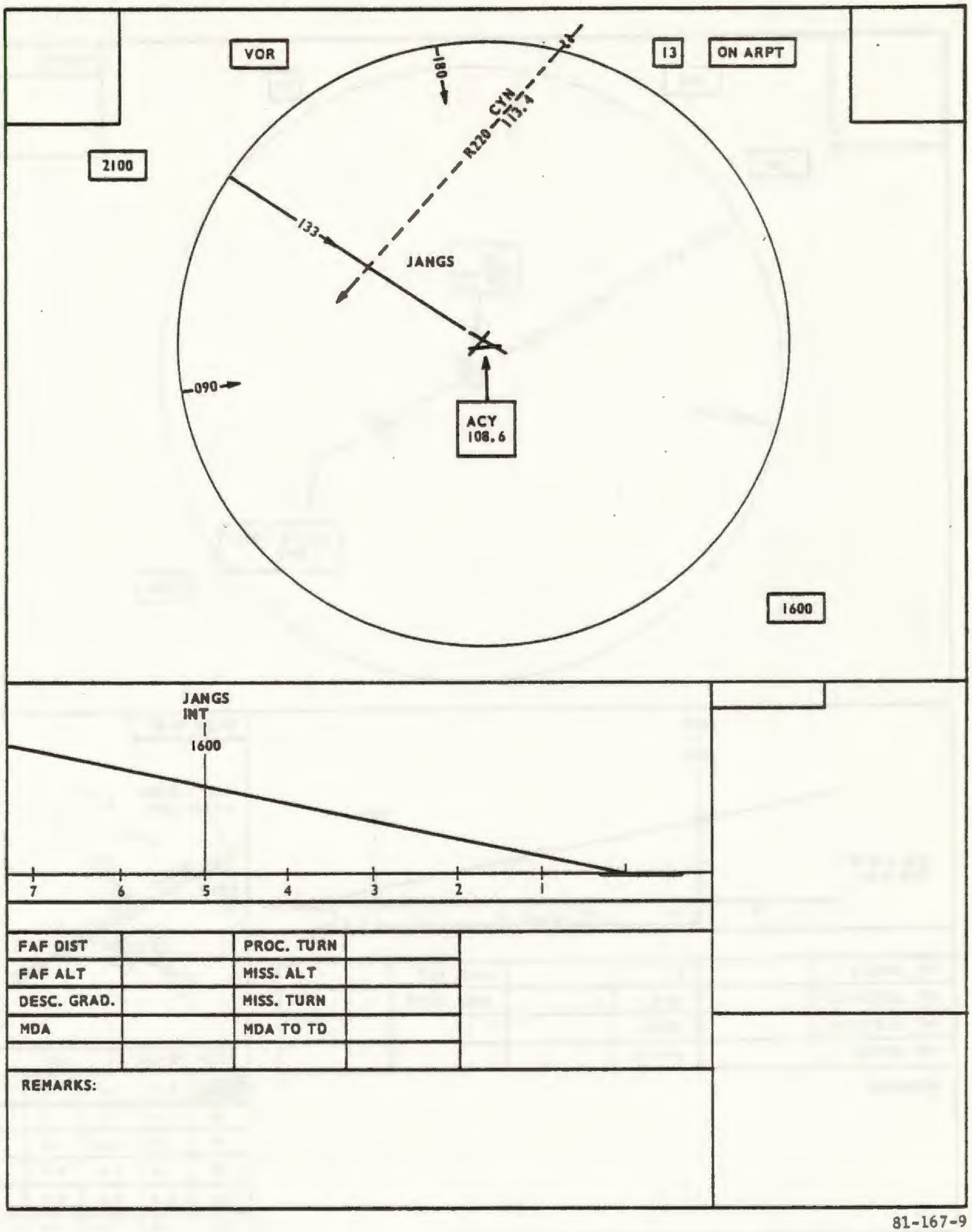


FIGURE 9. VOR RUNWAY 13 APPROACH PLATE FOR TERPS TEST

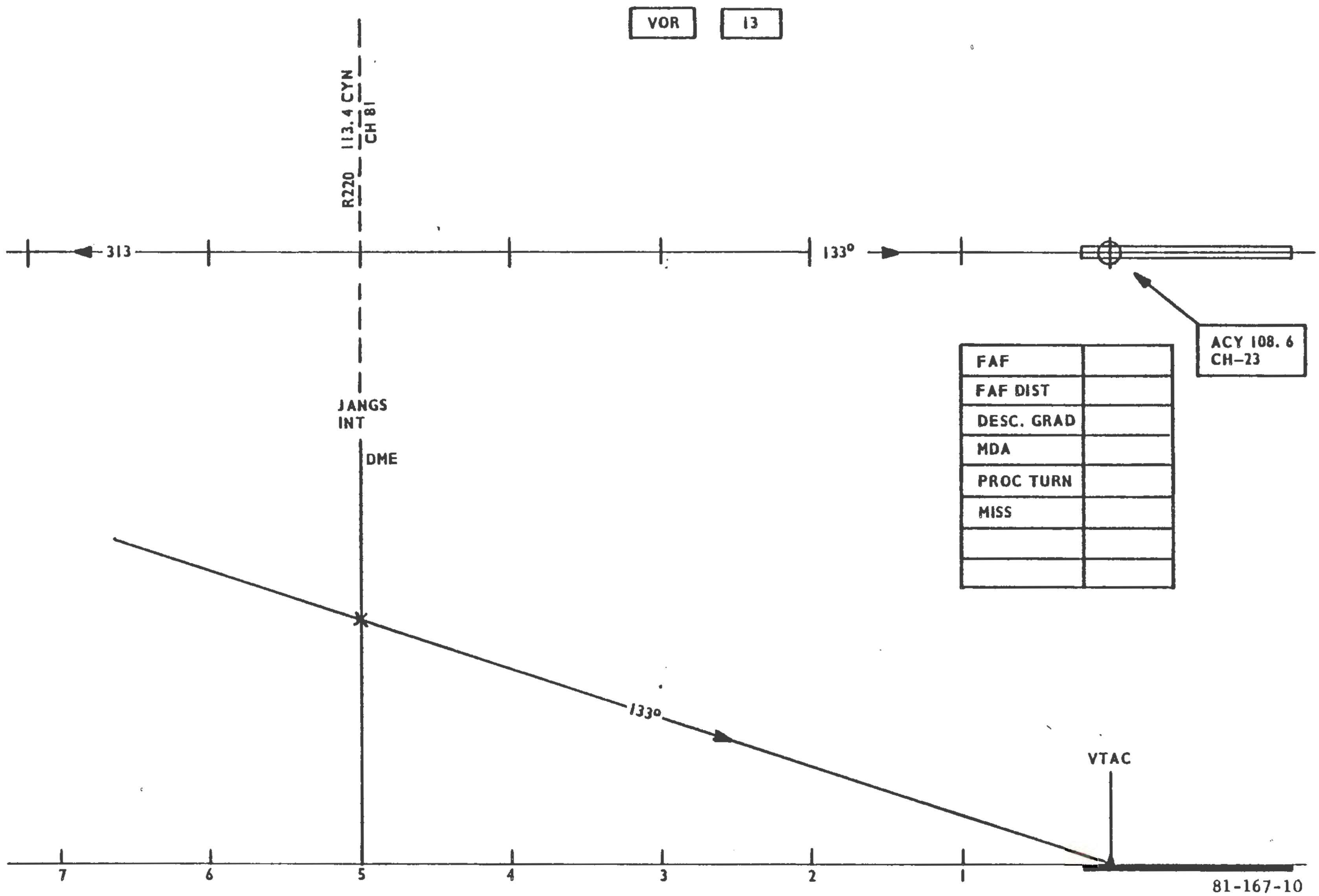
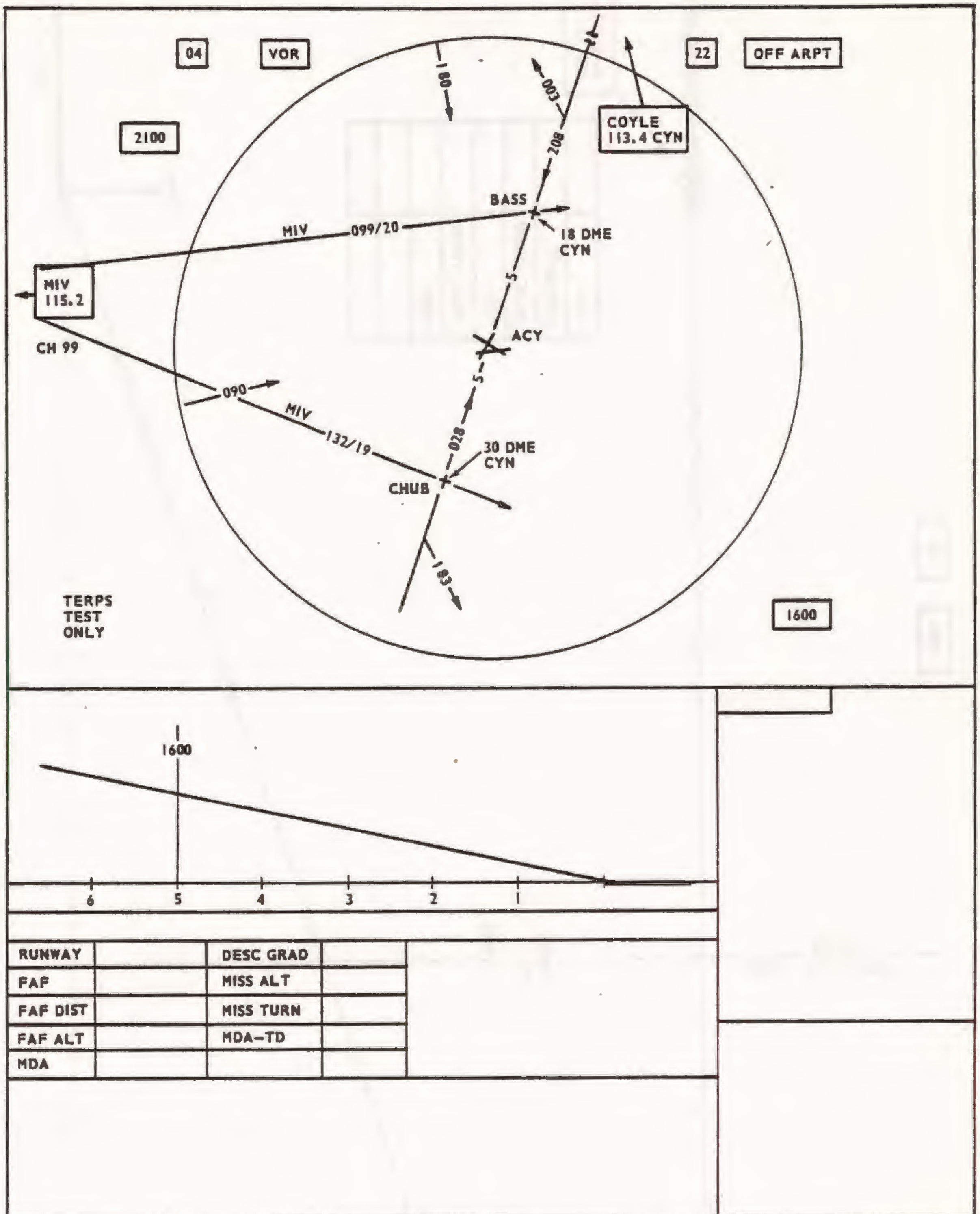


FIGURE 10. VOR RUNWAY 13 APPROACH PROFILE FOR TERPS TEST



81-167-11

FIGURE 11. VOR RUNWAY 4 AND VOR RUNWAY 22 APPROACH PLATE FOR TERPS TEST

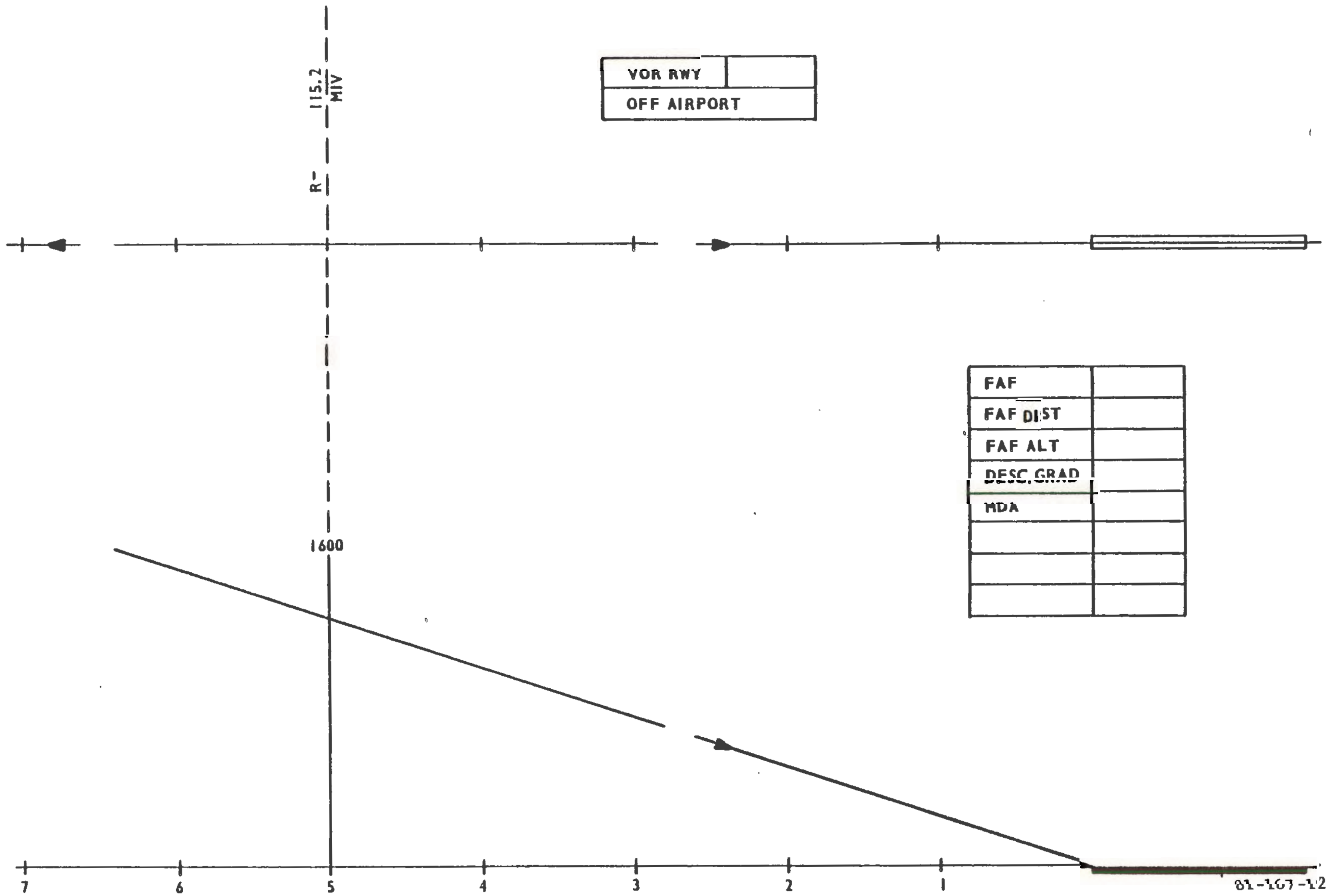


FIGURE 12. VOR RUNWAY 4/22 APPROACH PROFILE FOR TERPS TEST

81-167-13

FIGURE 13. BELL 206L AIRBORNE DATA ACQUISITION SYSTEM