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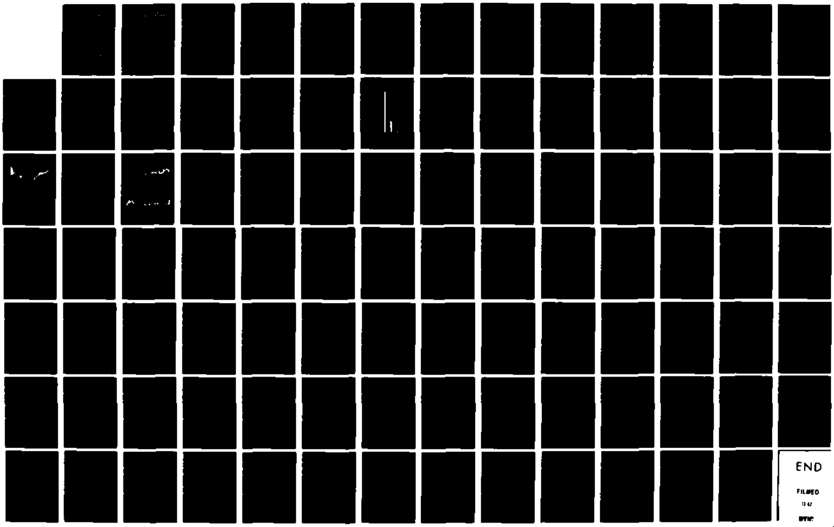

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Systems Research &
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Washington, D.C. 20591

Instrument Approach Aids for Helicopters

Edwin D. McConkey
Ronald E. Ace

AD A120678

July 1982

Final Report

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16. Abstract

This report identifies the various instrument approach procedures that are available to the helicopter operator. Emphasis is placed on the recently approved "Helicopter Only" procedures, the criteria for which are contained in Chapter 11 of the Terminal Instrument Procedures Handbook.

The objective of this study was to examine currently available solutions to helicopter approach needs. The study also covers new and innovative solutions to helicopter approach requirements. This was accomplished by:

- Identifying the various navigation aids now being used which may have general application to U.S. helicopter operations.
- Describing typical locations of use, typical approach procedures, and minimums for each of these aids.
- Providing estimated equipment costs for both the ground and airborne portions of these systems.
- Discussing the rationale used to support the use of a particular aid at a particular location or in a specific operational environment.

Results of this investigation are presented in the form of a series of helicopter instrument approach options for the user.

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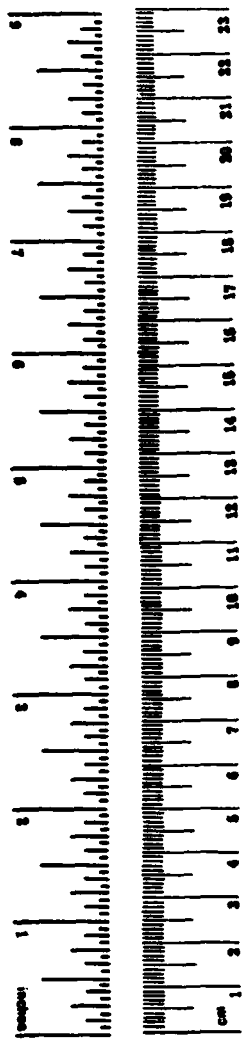
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

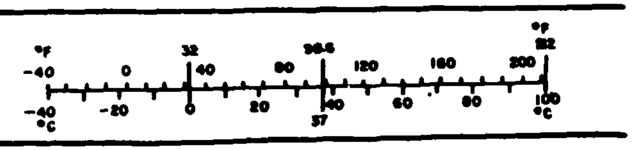
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 EXECUTIVE SUMMARY

This report identifies the various instrument approach procedures that are available to the helicopter operator. Emphasis is placed on the recently approved "Helicopter Only" procedures, the criteria for which are contained in Chapter 11 of TERPS[1], the Terminal Instrument Procedures Handbook.

1.1 OBJECTIVES

The objective of this study is to examine currently available solutions to helicopter approach needs. The study also covers new and innovative solutions to helicopter approach requirements. This was accomplished by:

- Identifying the various navigation aids now being used which may have general application to U.S. helicopter operations.
- Describing typical locations of use, typical approach procedures, and minimums for each of these aids.
- Providing estimated equipment costs for both the ground and airborne portions of these systems.
- Discussing the rationale used to support the use of a particular aid at a particular location or in a specific operational environment.

Results of this investigation are presented in the form of a series of helicopter instrument approach options for the user.

1.2 INSTRUMENTATION APPROACH PROCEDURES

1.2.1 Requirements

Approach procedures are developed with specific airspace boundaries. Aircraft staying within these boundaries are protected from trees, towers, mountains and other obstacles that can be hazardous to safety of flight.

The basic requirements to perform an instrument approach procedure are:

- approach course guidance
- fix identification
- vertical guidance

One additional requirement is sometimes imposed in congested terminal areas. This requirement is that of aircraft separation to aid air traffic control.

1.2.2 Airspace, Altitude and Visibility Criteria

The airspace utilized in an instrument approach procedure is divided into four segments. These segments are:

- initial approach
- intermediate approach
- final approach
- missed approach

Each of these segments is used for specific purposes in the approach procedure. The orientation and size of each segment is determined by the geography in the approach area and the navaids utilized for the procedure. Each segment contains a primary area and a secondary area. The primary area is located along each side of the segment centerline. The secondary area is located between the primary area and the airspace not utilized for the procedure. The obstacle clearance requirements in the primary area are more stringent than those of the secondary area.

The narrowest point in the approach procedure occurs in the final approach segment. Table 1.1 contains a ranking of the types of approach procedures relative to their height above threshold (or landing area) and their minimum airspace width in the final approach segment (primary plus secondary width).

Table 1.1 Helicopter Approach Criteria Summary

Type	Min Alt Above Obstacles	Mininum FAS Width*
ILS	200 ft (Category I)	1.8 nm
ARA	200 ft	8.0 nm (circle with center at destination)
LOC	250 ft	1.8 nm
VOR W/FAF	250 ft	2.0 nm
VOR/DME	250 ft	2.0 nm
TACAN	250 ft	2.0 nm
RNAV	250 ft	2.8 - 4.0 nm
VOR W/O FAF	300 ft	2.0 nm
NDB W/FAF	300 ft	2.5 nm
NDB W/O FAF	350 ft	2.5 nm
VOR/DME-ARC	500 ft	12.0 nm

*Primary Area plus secondary area

Visibility minimums for "Helicopter Only" procedures, prior to credit for approach lighting, is based upon the height above the landing area (HAL) or height above the surface (HAS). The following minimums apply:

- Straight in procedures
  - Precision approach (ILS) - 1/2 mile
  - Non precision (VOR, NDB, etc.)

HAL	Visibility Minimum
250-600 ft	1/2 mile
601-800 ft	3/4 mile
801 ft and up	1 mile

- Point in space procedures

HAS	Visibility Minimum
250-800 ft	3/4 mile
801 ft and up	1 mile

1.3 ESTABLISHED APPROACH AIDS

The navigation systems considered in this section have instrument approach criteria contained in TERPS or FAA Advisory Circulars. The cost range of ground and airborne equipment are described in Tables 1.2 and 1.3 respectively.

Table 1.2 Navigation Transmitter Costs

Transmitter	Equipment Cost Range*
Radar Transponder Beacon	$8K - $10K
NDB	$8K - $33K
DME	$50K
VOR	$100K
ILS	$260K - $430K
Localizer	$150K - $200K
Glideslope	$80K - $200K
Marker Beacon	$30K
TACAN	$150K - $600K

*Site preparation, installation, flight inspection and annual maintenance costs are not included in these cost estimates.
K-$1,000

Table 1.3 Airborne Equipment Costs

Equipment	Cost Range*
NDB with localizer	\$1.5K - \$7K
VOR	\$1.5K - \$7K
VOR with localizer and glideslope	\$2.2K - \$7.2K
DME	\$2.5K - \$12K
VOR/DME with RNAV	\$6.8K - \$45K
TACAN	\$9K
Airborne Radar/Radar Altimeter	\$19K - \$57K

*Cost does not include installation
K-\$1000

1.4 POTENTIAL APPROACH NAVAIDS

Several navaids which do not yet have general FAA approval are potentially available to helicopter operators for instrument approach procedure development. Among those which are considered in this investigation are the Microwave Landing System (MLS), Loran-C, Omega/VLF and the satellite based Global Positioning System (GPS). Of the systems named only MLS was designed for the requirements of civil aviation.

Table 1.4 contains the cost range of ground and airborne equipment for these candidate approach navigation systems. Also included is a summary of the major advantages and disadvantages of each system concept as applied to approach procedures.

1.5 SURVEY RESULTS

1.5.1 Pilot Preferences

A recent survey by Ralph R. Padfield[2] reported in Rotor and Wing magazine has been the basis for a subjective investigation into pilot acceptance of the various North Sea navigation and approach systems.

A questionnaire was distributed to the 130 pilots of Helicopter Service A/S in an effort to compile a subjective evaluation of the navigation systems used in daily operations. Thirty-five of the pilots polled responded. The pilots indicated their preferences for approach aids were:

offshore - airborne radar with radar altimeter
landside - ILS or VOR procedures

Table 1.4 Potential Approach Aids

System	Ground System Cost*	Airborne Cost**	Advantages/Disadvantages
MLS	$200K - $600K	$4K - $8K	High accuracy, multipath rejection capability/limited coverage
LORAN-C	$2M-$10M/station	$8K - $15K	Good repeatability/bias errors, precipitation static
Omega/VLF	not required	$30K-$60K	Worldwide coverage/not accurate enough for approach, precipitation static
Omega/VLF updated with VOR/DME	$150K for VOR/DME (if required)	$14K***	Improved Omega accuracy/ immature system concept
Differential Omega	not defined	not defined	Improved Omega Accuracy/ immature system concept
NAVSTAR/GPS	monitors for civil aviation not defined	not defined	High accuracy/not available until late 1980s, immature system concept

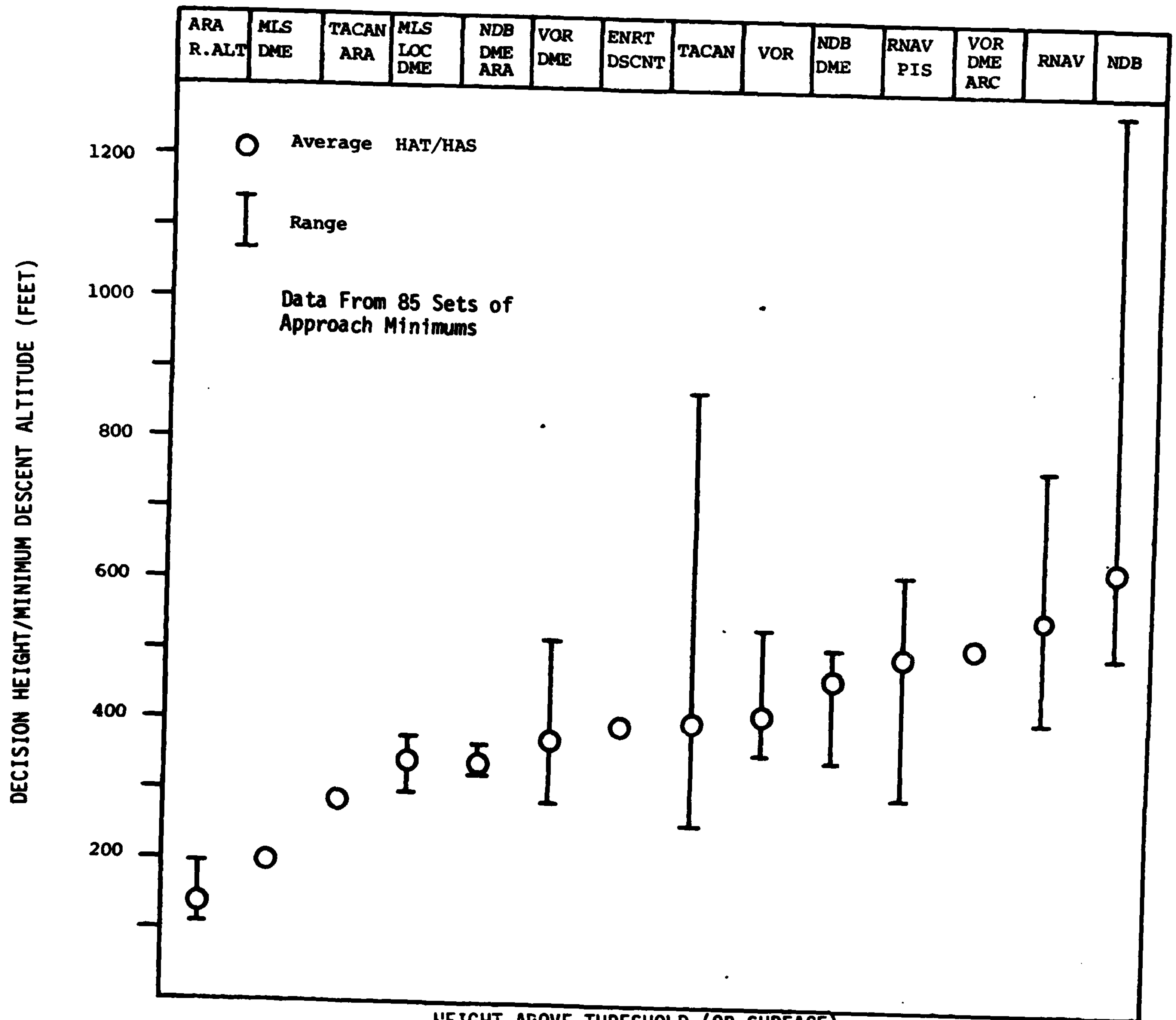
K-$1,000, M-$1,000,000
*Equipment Costs Only
**Not Including Installation
***Not Including VOR/DME Receivers

1.5.2 "Helicopter Only" Procedures

Since the development of "Helicopter Only" instrument approach criteria in the mid 1970s many such procedures have been approved and become operational. A survey of the current procedures was performed and their characteristics were evaluated on several different levels.

The minimum ceiling and visibility data for all approach procedures used in the survey were analyzed to determine the average HAT value, the minimum HAT, and the maximum HAT by procedure type. The results of this analysis are shown in Figure 1.1. In total 85 sets of minimums were considered. The survey includes Canadian MLS approaches and enroute descent procedures.

In the analysis of visibility data most procedures were able to achieve 1/2 mile minimums. A few, primarily the RNAV Point in Space procedures, had 3/4 mile minimums, and a limited number of procedures required 1 mile visibility. The MLS/DME procedure had a 1/4 mile



HEIGHT ABOVE THRESHOLD (OR SURFACE)
BY TYPE OF NAVAIDS USED IN THE PROCEDURE
Figure 1.1 Altitude Minimums

visibility limit. The visibility data is plotted on the histogram shown in Figure 1.2.

1.6 SUMMARY OF CONCLUSIONS

Offshore

1. For offshore approaches lowest altitude minimums can be achieved through the use of airborne radar/radar altimeter approach procedures. The main disadvantages of this procedure is the expense of the airborne equipment which can cost from $19,000 to $57,000 plus installation. This procedure requires two pilots. In areas with clusters of rigs a radar transponder, costing between $8,000 and $10,000, may be necessary to aid in identifying the destination. Using radars with beacon capability increases the airborne cost to at least $39,000.

2. The lowest cost offshore approach aid is an NDB. Ground station equipment cost for an offshore NDB is $8,600 to $13,300. Airborne equipment cost for this procedure is $1,500 to $7,000. The main disadvantages associated with this system is frequency congestion in the NDB MF band and the relatively high minimum descent altitudes.

3. The most promising and lowest cost non-approved navigation system that shows promise for use as an offshore approach aid is Loran-C. Airborne equipment costs are approximately $8,000 to $15,000 uninstalled. Ground system equipment would be a monitor receiver on the rig or a capability to receive system status information from a monitor site.

Landside

1. For land approaches the minimum cost approach procedures are those which can be constructed from existing navigation facilities.

2. Approaches with the lowest altitude minimums usually utilize ILS ground facilities. MLS procedures will be able to achieve the same or lower minimums and criteria should be available in the near future.

3. The most promising and lowest cost non-approved navigation system for remote areas and areas not served by existing navigation aids is Loran-C. However this system may not be available in the mid-continent area of CONUS and on the Alaskan north slope. The system is also has potential bias error problems and there is insufficient data available regarding operation in precipitation static and high noise conditions.

4. Differential Omega may have potential application for non-precision approach in remote areas. There is insufficient data available to develop approach procedure criteria at this time.

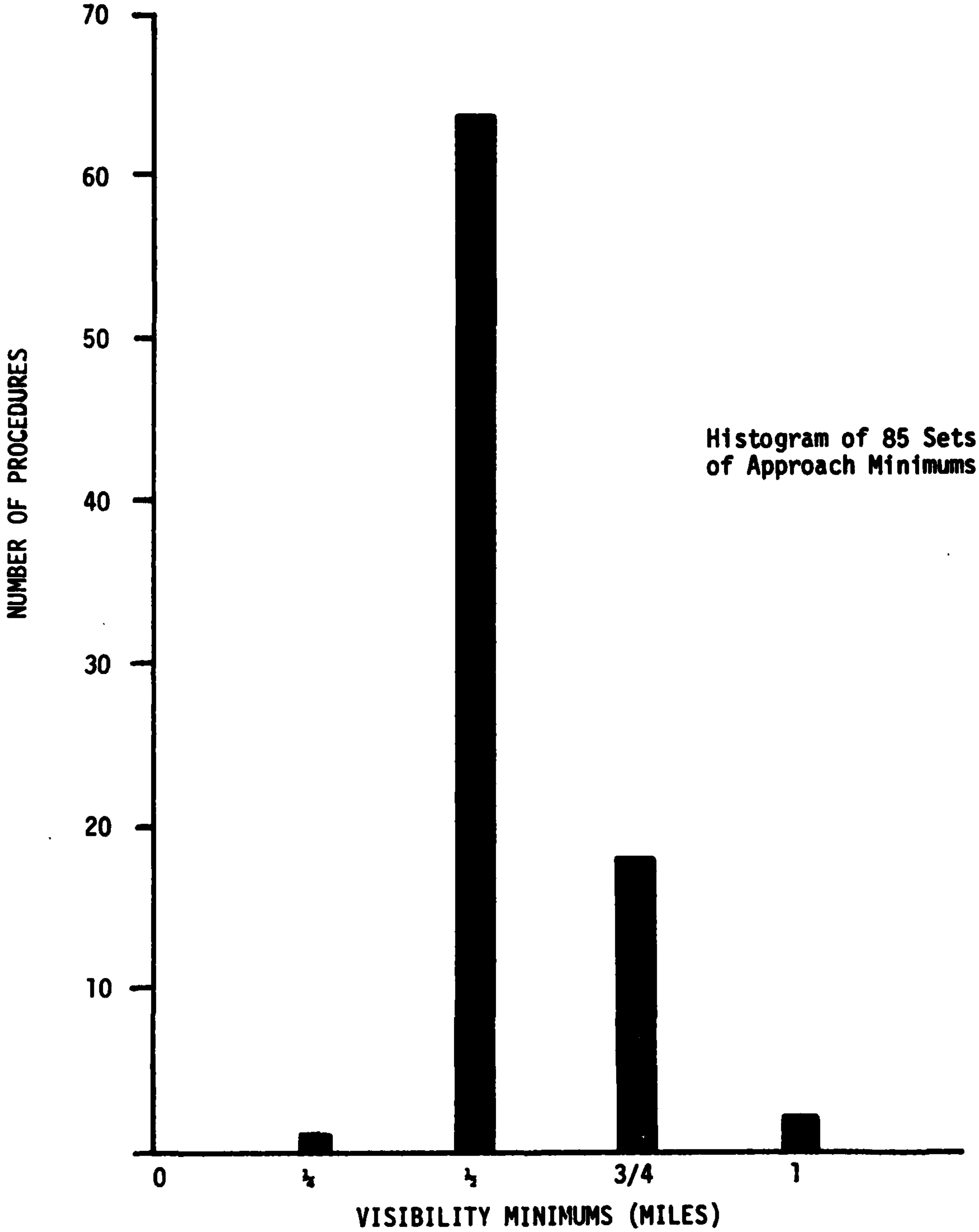


Figure 1.2 Visibility Minimums

2.0 INTRODUCTION

The commercial application of the unique capability of rotorcraft in general, and helicopters in particular, has initiated a whole new concept in support transportation. Critical high priority cargo, either personnel or equipment, can be delivered to remote destinations in a fraction of the time required by land or sea based transportation systems. Likewise, when remote sites are threatened by disaster, whether natural or man-made, evacuation of men and equipment can be accomplished quickly, efficiently, and with a minimum amount of risk. Several industries, such as the oil and gas exploration and production industry, have accepted the helicopter transportation concept to such an extent that dependence on aircraft availability on a day to day operational basis has become a necessity for remote projects. This requirement has led to exploratory investigation of an all-weather capability for the helicopter support fleet.

Although all-weather flying is a concept which has already been widely accepted by conventional fixed-wing aircraft, direct application of this concept to rotorcraft operations present some unique problems. It is to everyone's advantage, however, to promote compatible IFR procedures for all types of aviation operations. For example, radionavigation aids used to provide guidance to fixed-wing operations can usually be used to provide guidance to helicopter operations as well. Although apparent differences arise due to the application of differing performance criteria, the concepts used in developing approach procedures for both types of operations are similar. This similarity can be demonstrated through a close comparative examination of the design criteria laid out in the Terminal Instrument Procedures manual (TERPS)[1]. The first ten chapters of this document deal with the design criteria for approach procedures that apply to all aircraft, fixed or rotary wing. Chapter 11 of TERPS contains criteria that apply to helicopters only. Generally, these criteria are more severe than criteria in Chapters 1-10 and provide operational advantages to the helicopter operator.

This report identifies the various instrument approach procedures that are available to the helicopter operator. Also it discusses the inherent similarities and differences between fixed-wing procedures and their rotorcraft counterparts, designated, "Helicopter Only" approaches. Equipment costs are evaluated as they apply to helicopter operations, and a series of currently acceptable solutions to the helicopter instrument approach problem are developed. Additionally, the applicability of radionavigation systems currently under study for application to rotorcraft operations are discussed.

2.1 OBJECTIVES

The objective of this study is to examine currently available solutions to helicopter approach needs. The study also covers new and innovative solutions to helicopter approach requirements. This is accomplished by:

- Identifying the various navigation aids now being used which may have general application to U.S. helicopter operations.
- Describing typical locations of use, typical approach procedures, and minimums for each of these aids.
- Providing estimated equipment costs for both the ground and airborne portions of these systems.
- Discussing the rationale used to support the use of a particular aid at a particular location or in a specific operational environment.

Results of this investigation will be presented in the form of a series of helicopter instrument approach options for the user.

2.2 METHODOLOGY

This study was performed by collecting data concerning helicopter instrument approach procedures from a number of sources and cataloging the information according to approach procedure type. Among the information sources were the following:

- Procedure design criteria - TERPS, Advisory Circulars 90-45A, 90-80, 20-101A, 120-37 and RTCA-SC133 Working Papers
- Navaid characteristics - Literatue survey and contractor experience in navigation system requirements, FAA
- Navaid costs - National Plan for Navigation, FAA, manufacturers
- Operational Experience - Helicopter operators and pilots
- Procedure Examples - Jeppesen and USGS/NOS charts and user supplied charts, FAA Form 8260 - 7 descriptions.

Information from these sources was organized and compiled into a comprehensive set of procedure descriptions, navigation system characteristics and survey data. This information is presented in the following sections of this report.

3.0 INSTRUMENT APPROACH PROCEDURES

3.1 BACKGROUND

Instrument approach procedures are designed and developed to help pilots make safe and efficient approaches and landings in weather conditions of limited ceilings and/or visibility. The TERPS[1] document contains standardized approach criteria that have been approved to meet the requirements of both civil and military aviation. Recently, it has become increasingly evident that in some instances helicopters have requirements and performance characteristics that allow them to have instrument approach procedure standards that are different from those that apply to fixed-wing aircraft. Those unique helicopter standards which have been adopted to date are contained in Chapter 11 of TERPS. This section describes many of the approach requirements and the approach criteria that have been developed to meet these requirements as they apply to helicopter operations.

3.2 INSTRUMENT APPROACH REQUIREMENTS

Approach procedures are developed with specific airspace boundaries. Aircraft staying within these boundaries are protected from trees, towers, mountains and other obstacles that can be hazardous to safety of flight.

The basic requirements to perform an instrument approach procedure are:

- approach course guidance
- fix identification
- vertical guidance

One additional requirement is sometimes imposed in congested terminal areas. This requirement is that of aircraft separation to aid air traffic control.

3.2.1 Approach Course Guidance

Approach course guidance provides the pilot with an indication of the position of the aircraft with respect to the desired approach path. This guidance may be in the form of a course deviation indicator for VOR and ILS approach procedures, a DME distance value for DME Arc procedures, or a radar map and a compass reading for ARA procedures. To the trained instrument pilot, each of these presentations can be interpreted to determine the aircraft position with regard to the approach course and determine what, if any, steering inputs are necessary to keep the aircraft on the approach course.

3.2.2 Fix Identification

Fix identification provides the pilot with an indication of how position along the final approach course is progressing. The alongtrack position is used to identify points on the approach path where altitude changes or course changes should be made. Fix identification is provided by any one of a number of techniques. These techniques include:

- facility crossing (NDB or VOR)
- time measured after crossing a facility
- VOR radial
- NDB bearing
- DME distance
- marker beacon indicator
- range mark on an airborne radar display

3.2.3 Vertical Guidance

Vertical guidance is generally provided in one of four ways:

- electronic glide slope
- radar altimeter
- baro-altimeter
- 3D-RNAV (VNAV)

In an ILS approach, vertical guidance is provided by a vertical deviation indicator measured from an electronic glide path. In approaches over seawater or smooth terrain, vertical guidance is often provided by the use of a radar (or radio) altimeter. This device measures height above the terrain over which the aircraft is flying. In most non-precision approach procedures, vertical guidance is provided by a barometric altimeter. The baro-altimeter measures height with respect to a standard atmospheric pressure profile. At specified points in the procedure, usually identified by a position fix, the procedure calls for the pilot to descend to a lower altitude as determined from the baro-altimeter. The lowest such altitude in the procedure is called the minimum descent altitude (MDA).

The altimeter must be corrected in flight for pressure variations from the standard profile. Altitude minimums are stated in terms of height above mean sea level to account for the height of the surrounding terrain and obstacles. When sources of barometric altimeter corrections are remote from the airport of intended landing, minimum descent altitudes are increased to account for possible atmospheric pressure variations between the remote facility and the airport. The rate of increase in the minimums is 5 feet of altitude for each mile in excess of 5 miles from the remote sources to the airport.

The 3D-RNAV, or VNAV, guidance method is a combination of the baro altitude and area navigation systems. The 3D area navigation system allows the pilot to select an altitude associated with each waypoint. The pilot also selects the descent/ascent angle he wishes to fly to the waypoint. Three degree descents are typical for fixed-wing aircraft and descents of five to eight degrees are possible with helicopters. The navigation computer combines the desired waypoint altitude, the descent/ascent angle, measured baro-altitude and distance to waypoint data and determines a vertical deviation signal which is presented to the pilot on a vertical deviation indicator. VNAV guidance has the same problems that affect baro altitude plus inaccuracies introduced in the distance to waypoint computation caused by navigation system errors.

3.2.4 Aircraft Separation Requirements

In congested terminal areas, the instrument approach procedure is being used to aid air traffic control. This can be achieved because airspace protection limits for precision approach procedures are less than those required by ATC radar procedures. A terminal radar route width is ±1.5 nm while aircraft on parallel ILS approach paths can be separated by as little as 4300 ft which is equivalent to a route width of 2150 ft. This represents a 4.5 to 1 improvement in airspace utilization on final approach.

This same separation capability plus increased operational flexibility is expected from the recently developed microwave landing system (MLS). Additional ATC benefits can be derived by using this landing system. Some of the MLS features that can be utilized are offset radial approach paths, different approach descent angles for aircraft with differing performance capabilities, and segmented or curved approach paths using MLS/RNAV capabilities.

Procedures containing these capabilities of MLS has been demonstrated during the MLS development program. However, additional testing is required to establish a data base from which to develop standardized MLS approach criteria. This data base is being developed through continuing FAA research and development efforts.

3.3 INSTRUMENT APPROACH AIRSPACE

The airspace utilized in an instrument approach procedure is divided into four segments. These segments are:

- initial approach
- intermediate approach
- final approach
- missed approach

Each of these segments is used for specific purposes in the approach procedure. The orientation and size of each segment is determined by the geography in the approach area and the navaids utilized for the procedure. Each segment contains a primary area and a secondary area. The primary area is located along each side of the segment centerline. The secondary area is located between the primary area and the airspace not utilized for the procedure. The obstacles clearance requirements in the primary area are more stringent than those of the secondary area. Specific details on these requirements are described in the following paragraphs.

Figure 3.1 shows a typical approach procedure airspace diagram. This procedure is based on straight courses such as could be flown using VOR radials, NDB bearings, or localizer courses. The fixes and airspace boundaries used in this type of procedure are discussed in the sections describing the general characteristics of each approach segment. Specific details on the criteria used to establish approach airspace are found in TERPS[1]. Sections 3.3 through 3.6 and Section 3.8 contain general criteria

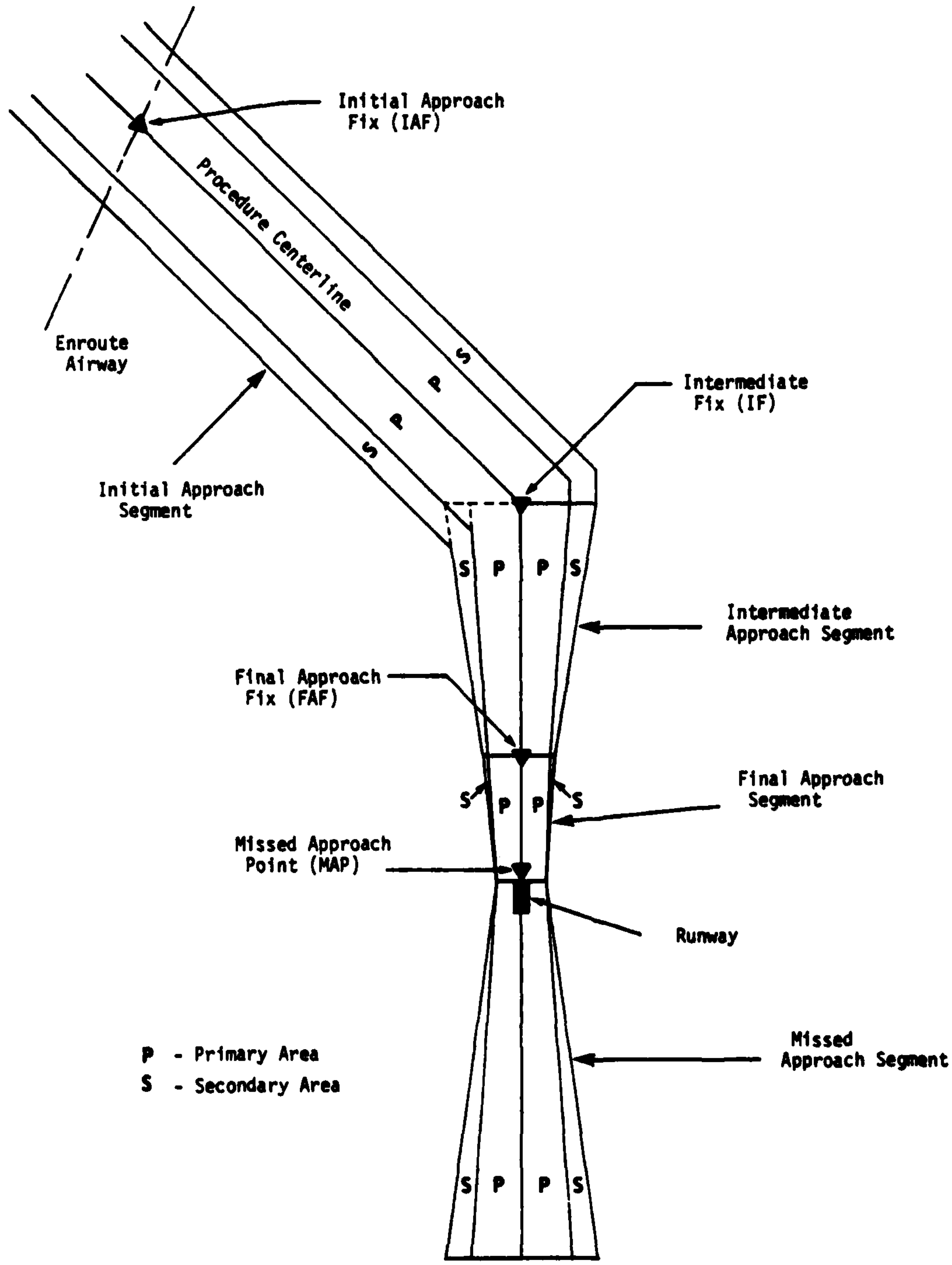


Figure 3.1 Approach Airspace

for both fixed-wing and helicopters. Sections 3.7 and 3.9 contain helicopter specific criteria.

3.3.1 Initial Approach Segment

The initial approach segment provides a transition from the enroute airway system to the approach procedure. The segment begins with a fix that is generally found in the enroute airways and it terminates at a point identified as the intermediate fix. The airspace four miles each side of the centerline connecting the fixes defines the primary area. The airspace two miles beyond the primary area defines the secondary area. The length of the initial approach segment is that which is necessary to position the aircraft to continue to the intermediate and final approach segments. The maximum length is 50 nm unless and operational requirement for a longer initial segment is desirable. Typically, initial segments of 10-20 nm are found in most approach procedures.

In some cases the initial approach fix is a facility which is also used as the missed approach point in the procedure. In such cases, it is often necessary for the aircraft to overfly the facility, reverse course, and descend to make the approach. When this occurs, the initial approach segment contains a procedure turn maneuver. In this case, the initial segment is the procedure turn area where the course reversal is performed. In such instances, usually found in locations where the VOR and NDB facilities are at the airport, the procedure contains neither an intermediate nor a final approach fix. The facility is used as the initial approach fix and the missed approach point.

Typically, the minimum altitude in the primary area must be at least 1000 ft above all obstacles. In the secondary area, the obstacle clearance must be 500 ft at the primary area boundary and the clearance linearly decreases to zero feet at the outer airspace boundary. The required obstacle clearance altitude is shown in Figure 3.2. Altitude descent gradients are generally limited from 250 to 500 ft/mile.

3.3.2 Intermediate Approach Segment

The function of the intermediate approach segment is to blend the initial segment into the final segment which is flown just prior to landing. The intermediate segment is aligned with the final segment. In this area, speed and aircraft configuration changes are made to stabilize the aircraft and prepare for the final descent prior to landing. In this segment, positive course guidance is necessary. The length of the segment may be as short as 5 nm and as long as 15 nm. The optimum distance is considered 10 nm. This segment terminates at the final approach fix. In specific VOR and NDB approach procedures where there is no intermediate or final approach fix, the intermediate segment is not used. The width of the primary and secondary areas in the intermediate segment are governed by those in the initial approach segment and the final approach segment. The boundaries of each area are established to blend the primary and secondary areas to form a continuous, smooth path. There must be at least 500 ft obstacle clearance in the primary area.

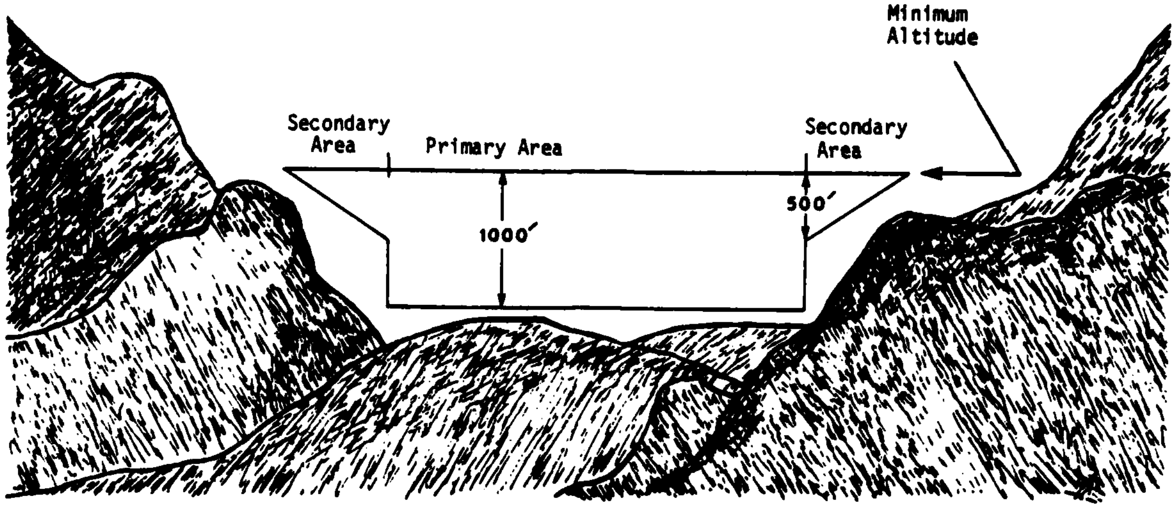


Figure 3.2 Required Obstacle Clearance in the Initial Approach Segment

In the secondary area, there is 500 ft clearance at the primary airspace boundary tapering to zero feet at the outer airspace boundary. In this segment, shallow gradients of 150 to 300 ft/mile are utilized to permit aircraft speed and configuration changes to be made.

3.3.3 Final Approach Segment

This segment is the area in which runway alignment and descent for landing are achieved. Typically, the final approach segment begins at the final approach fix and ends at the runway or missed approach point, whichever is encountered. For straight in approaches, the final approach path must be aligned with the runway centerline within a specified angle. Generally for nonprecision approaches, this angle is up to 30°. For precision approaches, this angle can not exeed 3°. Procedures which do not meet this criteria must be considered circling approaches and have higher approach minima. The size of the primary and secondary areas depend upon the navaid in use. These sizes are discussed in some detail in the sections describing specific types of procedures. The length and obstacle clearance requirements for final segments are also discussed in these sections.

3.3.4 Missed Approach Segment

The missed approach segment provides the pilot with a means to terminate the approach procedure and climb to a fix from where the enroute airspace may be re-entered or the approach procedure can be repeated as desired. The missed approach segment may be straight or contain a turn as required by geography, navaid coverage, or obstacle clearance requirements. At 15 nm from the MAP the width of a straight missed approach area is 8 nm for the primary area with 2 nm on each side of primary area for the secondary area. At the MAP, the primary and secondary areas connect with their counterparts in the final approach area. The requirements for turning missed approach procedures is quite complex geometrically and are based on aircraft performance categories by approach speed. In general, helicopters are in Category A for approach speeds less than 90 knots. This category requires the least amount of airspace. Specific details concerning turning missed approaches can be found in TERPS, Paragraph 275[1]. Obstacle clearance requirements in the primary area of the missed approach segment provide for a 40:1 ratio of distance flown to altitude gained (1.43°) as measured from the missed approach point. The secondary area surface slopes upward from the primary area at a 12:1 ratio of distance to altitude gained (4.76°). A diagram of the missed approach surface for the primary area is shown in Figure 3.3. A cross sectional diagram of the surface showing the relationship of the primary and secondary area is shown in Figure 3.4.

3.3.5 Visibility Criteria

Visibility criteria for fixed-wing and helicopters instrument approach procedures depend upon several factors. Among these factors are:

- Speed of the aircraft on final approach
- Height above threshold or airport of the minimum descent altitude
- Straight in or circling approach procedure
- Distance from the navigation facility to the missed approach point
- Approach area and runway lighting

In general for most approach procedures for Category A aircraft, which apply to helicopters, the minimum visibility criteria is one statute mile or 5000 ft. runway visual range. This minimum value applies to both straight in and circling approaches. Helicopters using procedures with Category A minimums may use visibility minimums of ½ the published Category A - visibility minimum, but no less than ¼ mile or 1200 RVR.

Helicopters are also permitted to operate with lower visbility criteria if the special Helicopter Only procedures contained in Chapter 11 of TERPS are used. These minimums are described in Section 3.9.

3.4 ILS AND LOCALIZER PROCEDURES

3.4.1 Final Approach Airspace

The final approach airspace for ILS and localizer procedures is shown in Figure 3.5. The airspace begins at a point 200 ft from the runway threshold and extends for a distance of 50,000 ft (8.2 nm) along the final approach course. Whenever possible the alignment of the final approach course is within 3° of the extended runway centerline. The final approach is 1000 ft wide at the threshold end and increases linearly with distance to 16,000 ft (2.63) at the 50,000 ft distance point.

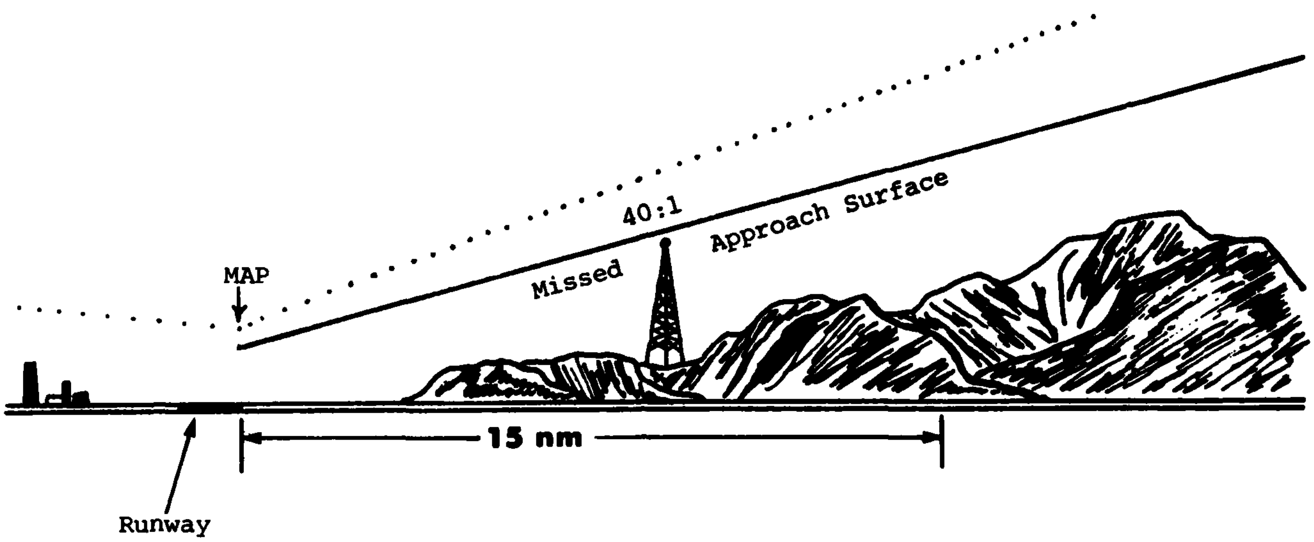


Figure 3.3 Missed Approach Surface

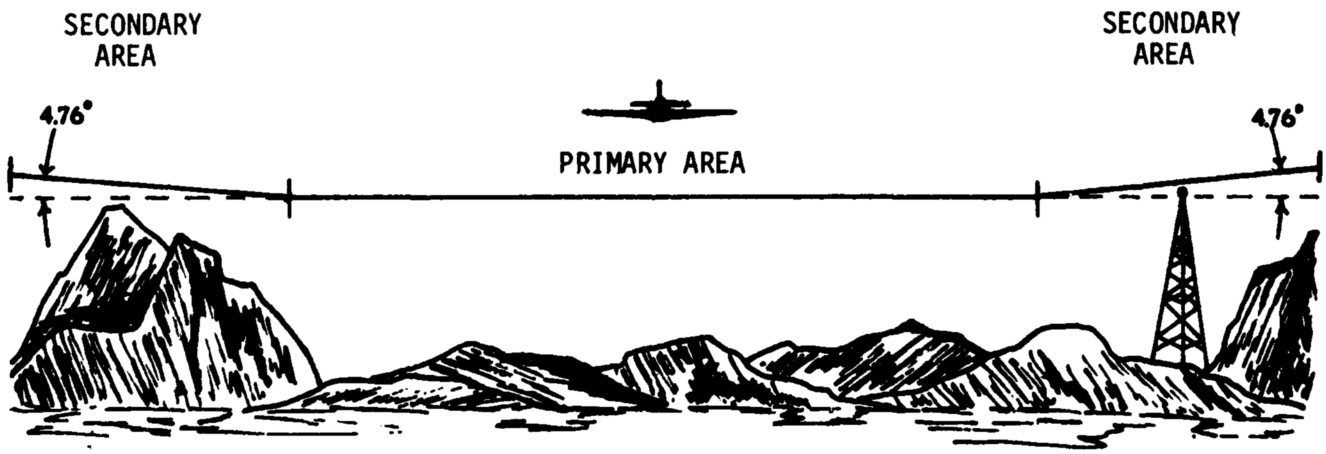


Figure 3.4 Cross Section of Missed Approach Surface

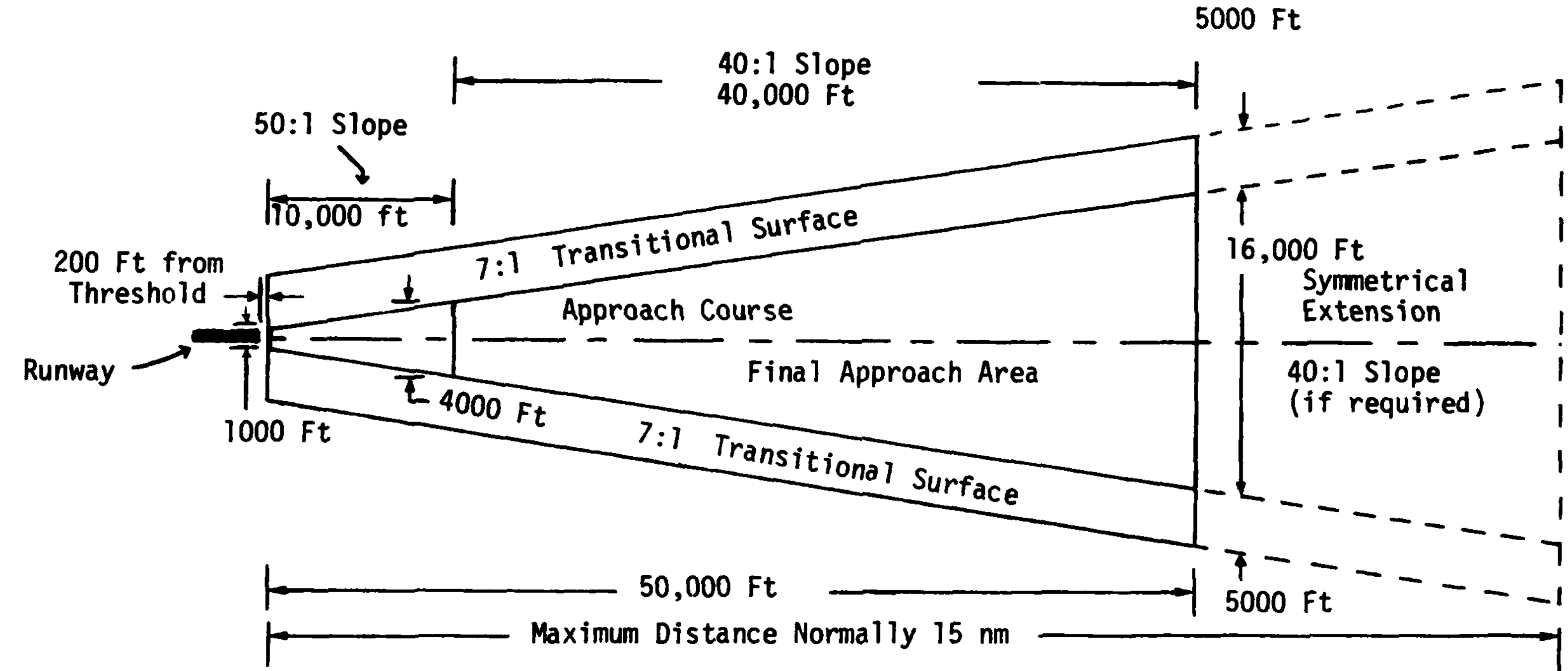


Figure 3.5 Final Approach Airspace for ILS and Localizer

For ILS procedures, only the segment of the airspace beginning at the glide slope intercept point, typically about 5 nm from threshold, is used for the final approach segment. For localizer approaches, the segment from the final approach fix, also typically 5 nm from threshold, is used as the final approach segment.

3.4.2 Obstacle Clearance Criteria

For ILS procedures, the obstacle clearance requirements are defined by an inclined plane which originates at the runway threshold elevation at a point 975 ft prior to reaching the glide slope intercept point. The plane is divided into two parts; the first 10,000 ft of the final approach area closest to the threshold is called the inner section, and the remainder of the final approach area called the outer section. The inclination of the surface is directly correlated with the glide slope angle. For typical civil system glide slopes of 3°, the ratio of distance to altitude is 34:1 in the inner section and 29.5:1 in the outer section. For military approaches, the typical glide slope is 2.5° which requires a ratio of 50:1 and 40:1 in the inner and outer sections, respectively. No obstacles may penetrate these inclined planes. If obstacles are present, then the plane must be raised which produces a steeper glide slope angle. The decision height (DH) can be no less than 200 ft above the threshold for Category I procedures.

A transitional surface is located 5000 ft on either side of the final approach area. These surfaces join the obstacle clearance plane at the boundary and slope upward at a 7:1 ratio (8.13°) in the cross sectional view.

The minimum obstacle clearance requirement for localizer only approaches is 250 ft above a horizontal plane placed at the highest obstacle in the final approach segment. The transitional surface slopes upward at a 7:1 ratio from this plane and no obstacle may penetrate this surface.

3.4.3 ILS Procedure

A typical ILS procedure is shown in Figure 3.6. Three initial approach fixes are designated. The first two IAFs are 10 nm DME arcs from the Palm Beach VORTAC. The third IAF is the compass locator/outer marker (LOM) designated as PB in the figure. When this IAF is used, a procedure turn is required to reverse course and proceed inbound along the approach course. The final approach fix (FAF) is also the PB LOM. The glide slope is intercepted just prior to the FAF. The final approach segment begins at glide slope intercept for the ILS procedure and at the FAF for a localizer only procedure. The missed approach procedure is straight along the final approach course and has the aircraft proceed to Keach Intersection which is defined as a 8.1 nm DME fix or the 12° radial from Pompano Beach VOR.

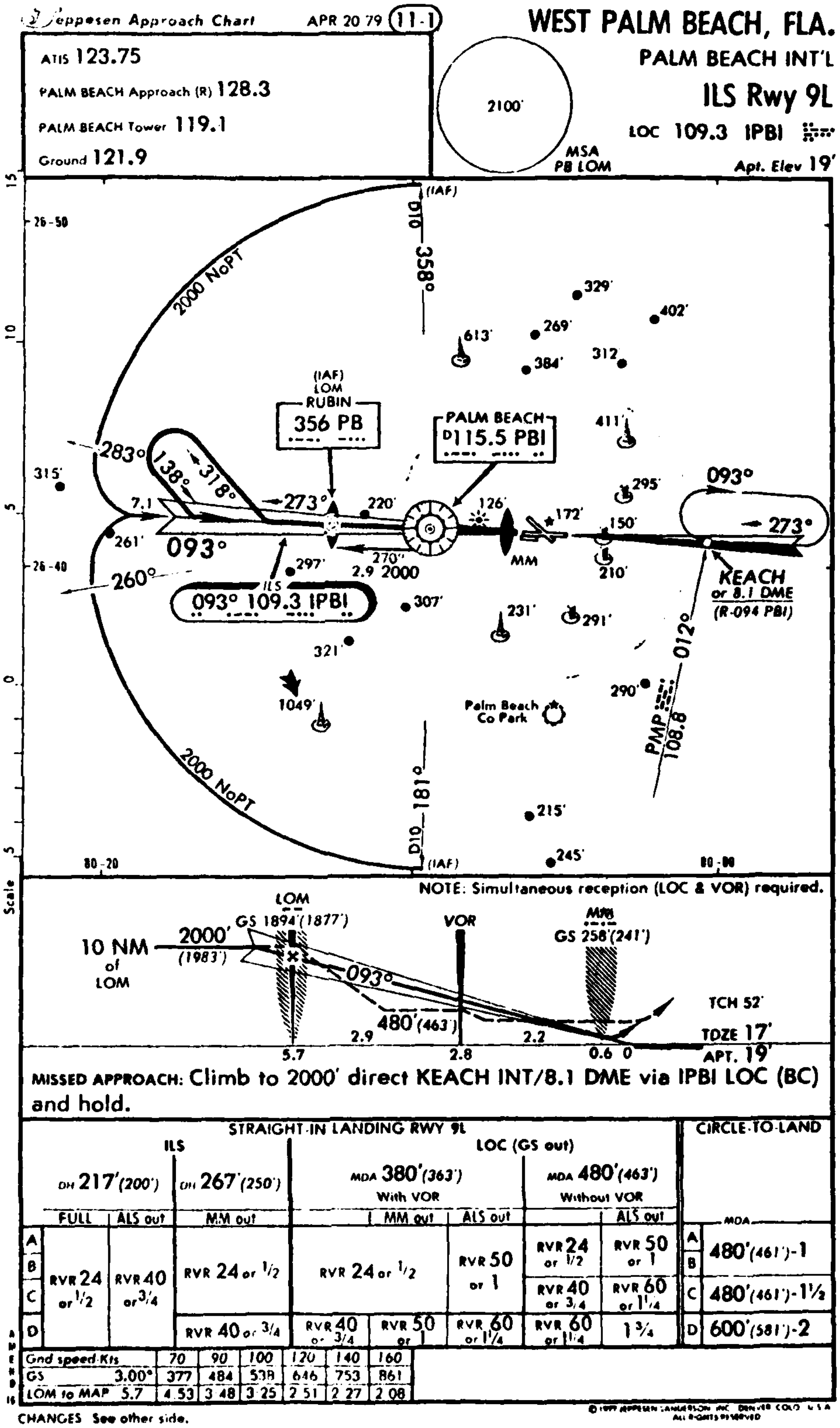


Figure 3.6 ILS Approach to West Palm Beach, Florida

3.5 VOR AND NDB PROCEDURES WITH NO FAF

3.5.1 Procedure Turn Airspace

Procedures using VOR or NDB facilities located on the airfield or in the landing area often have no FAF. In these procedures, the IAF and the MAP are defined as the facility itself. The procedure commences as the facility is overflown. The aircraft proceeds outbound along the reciprocal of the final approach course and performs a procedure turn to reverse course and proceed inbound along the final approach course. These procedures have no intermediate segment. The initial segment is the procedure turn airspace. When the final approach course is within ±30° of the runway centerline, the approach is considered to be a straight in type. Otherwise circling approach criteria must be used.

Procedure turn airspace boundaries are shown in Figures 3.7 and 3.8. In Figure 3.7, the standard procedure utilized for aircraft categories A-D are shown. The procedure turn is to be completed within 10 nm of the facility. When the procedure is to be used only by category A aircraft (which includes helicopters), the procedure can be designed with a 5 nm procedure turn. This airspace is shown in Figure 3.8. It is considerably smaller than that shown in Figure 3.7 and can often offer operational advantages to these slower aircraft.

3.5.2 Final Approach Airspace

The final approach airspace for VOR procedures with no FAF is shown in Figure 3.9. The length of the area is typically 10 nm. The airspace is 2 nm wide at the facility and increases to 6 nm at a distance of 10 nm from the facility. A secondary area is on either side of the primary area. It is 0 nm wide at the facility and 1.34 nm wide at the 10 mile point. In category A procedures, the length of the area can be reduced to include only the five nm of the airspace nearest the facility. The area for an NDB procedure with no FAF is slighlty larger, being 2.5 nm wide at the facility.

3.5.3 Obstacle Clearance Criteria

In the primary area of the final approach segment, the minimum altitude is 300 ft above the highest obstruction for VOR procedures. In the secondary area, the obstacle clearance is 300 ft at the inner boundary and linearly decreases to 0 ft at the outer boundary. For NDB procedures, the minimum altitude is increased to 350 ft in the primary area and 350 ft tapering to 0 ft at the outer edge in the secondary area.

3.5.4 NDB Approach With No FAF

A typical approach procedure using a NDB with no FAF is shown in Figure 3.10 for Muir Army Air Field at Fort Indiantown Gap, PA. This procedure is a Helicopter Only approach using the 286° bearing from the Bellgrove (BZJ) NDB. Bellgrove is defined as both the IAF and the MAP. The helicopter arrives at BZJ and proceeds outbound along a 106° bearing from the facility. The procedure turn must be completed within 5 nm of BZJ. The aircraft then proceeds inbound on the 286° bearing. When facility crossing is noted, the pilot must have the runway in view or perform the missed approach procedure. The procedure turn must be

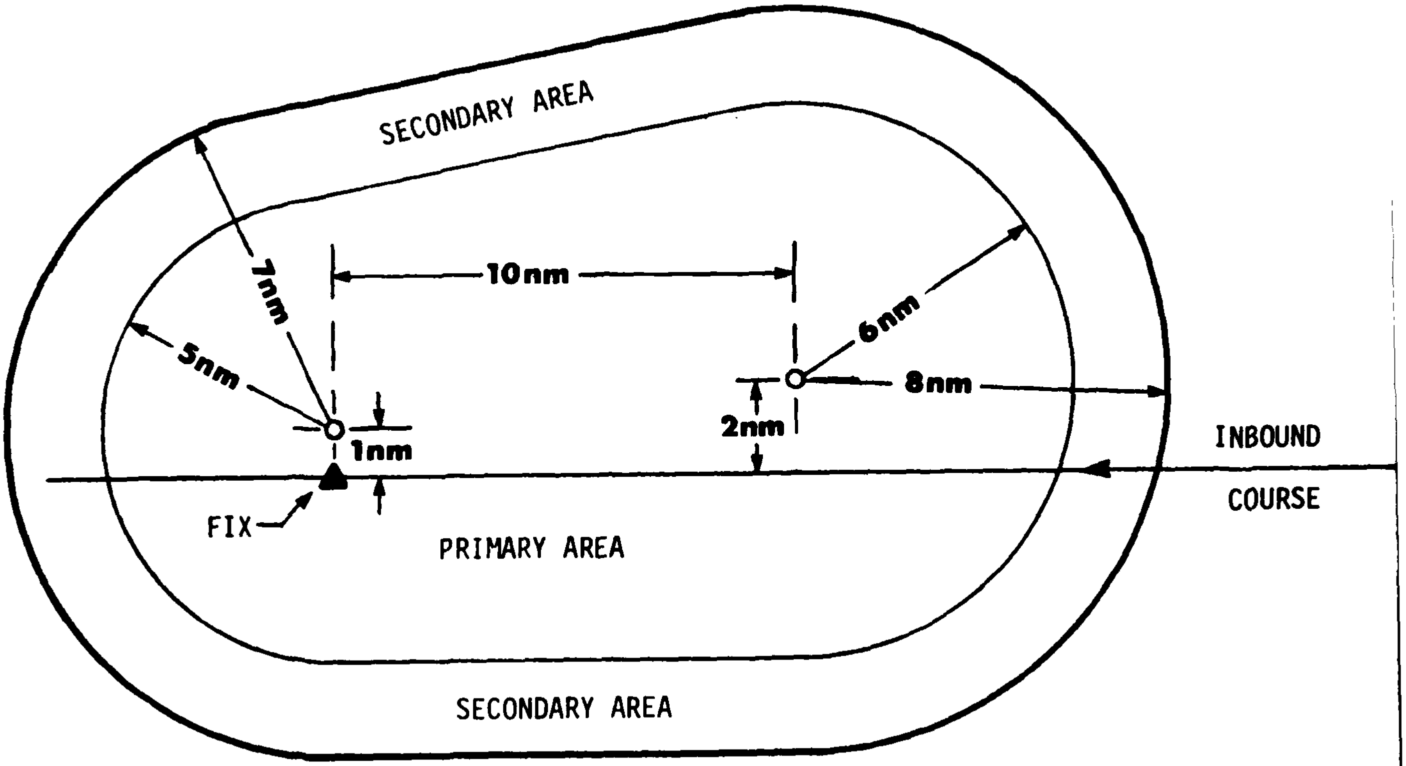


Figure 3.7 Standard Procedure Turn Area

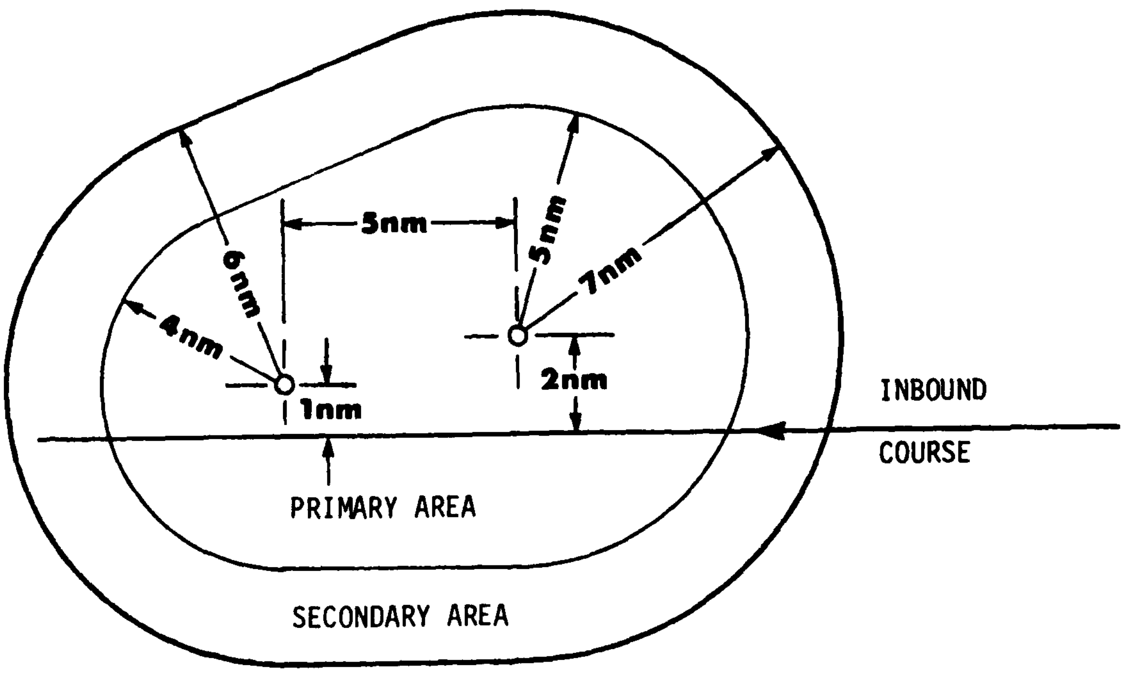


Figure 3.8 Reduced Procedure Turn Area

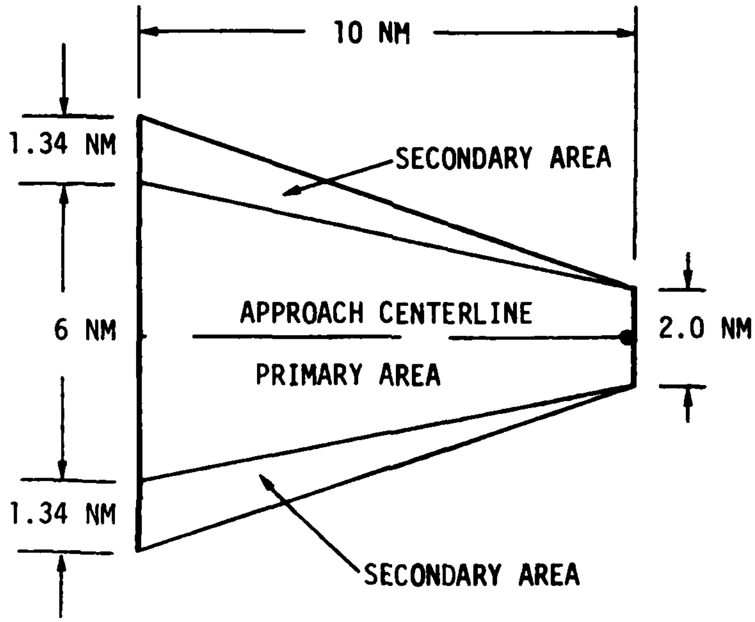


Figure 3.9 Final Approach Segment for VOR With No FAF

completed at an altitude of 2900 ft MLS. After completing the turn, the aircraft can be descended to 1080 ft MLS which is the minimum descent altitude. The missed approach procedure is a climbing left turn to 2900 ft with a holding pattern at the BZJ beacon.

3.6 VOR, VOR/DME, TACAN AND NDB PROCEDURES WITH FAF

3.6.1 Final Approach Airspace

Procedures which utilize a FAF may be flown by using either a procedure turn, a DME arc, or some other type of airway fix to define the IAF. The intermediate approach segment may be as described in Section 3.3.2 or it may be a procedure turn as described in Section 3.5.1. The final approach airspace is defined by the type of facility used to determine the final approach course. For a VOR or TACAN, the airspace is a segment of the trapezoidal airspace shown in Figure 3.11. The airspace is determined with respect to distance from the facility. At the VOR, the primary area is 2 nm wide. The area broadens to 5 nm at a distance of 30 nm from the facility. The secondary area is located on either side of the primary area and is 0 nm wide at the facility and 1 nm wide at the 30 nm point. The final approach segment is generally some portion of the airspace shown in Figure 3.11. The length of the final approach segment is typically 5 nm but it can be adjusted to meet operational conditions. Straight in approaches can be designed when the final approach course is within ±30° of the runway centerline. Otherwise circling approach criteria must be utilized. NDB final approach airspace is similar to VOR airspace except that it is 2.5 nm wide at the facility and extends only 15 nm from the facility.

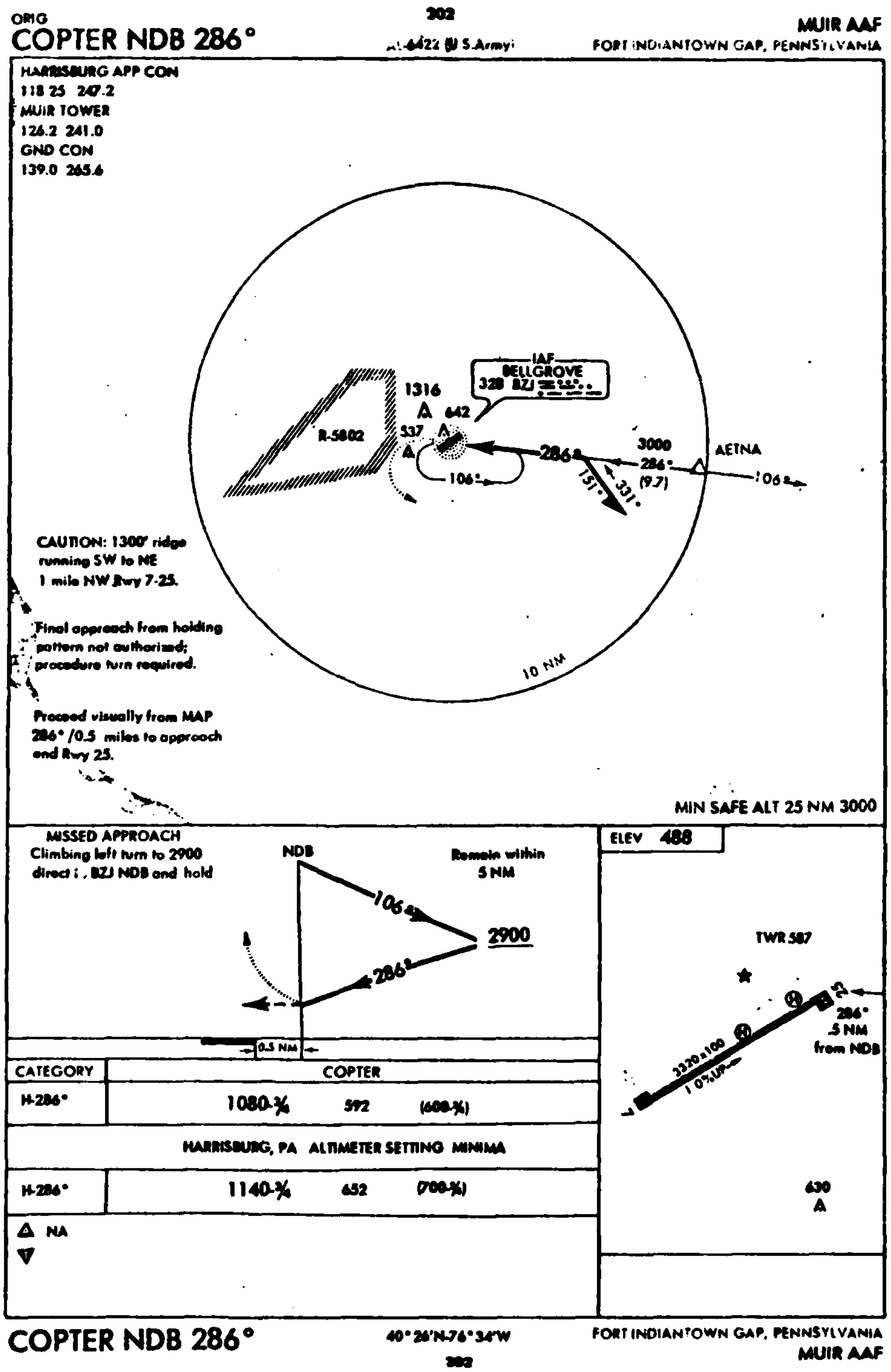


Figure 3.10 NDB Approach to Muir AAF, PA

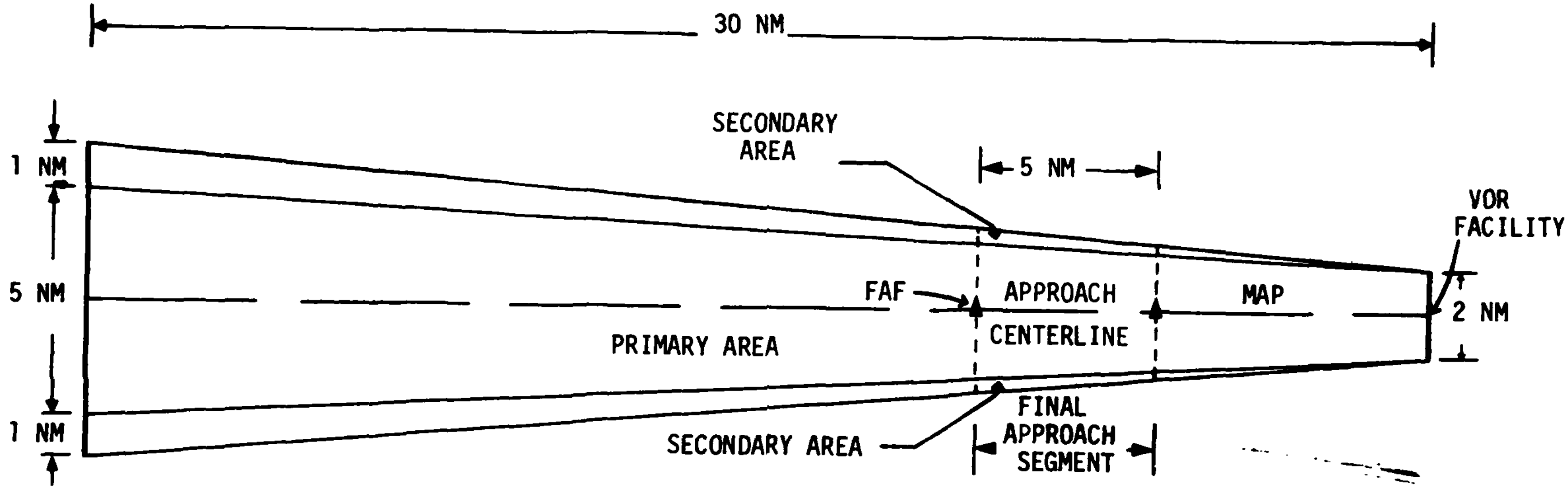


Figure 3.11 Final Approach Segment for VOR, VOR/DME and TACAN with FAF

A DME arc may be used as the final approach course in some areas. In this case, the FAF and MAP are defined as VOR or TACAN radials from the approach facility. The final approach airspace for an arc procedure is shown in Figure 3.12. For fixed-wing aircraft, the final approach course arc radius must be between 7 and 30 nm. The primary area airspace is 8 nm wide uniformly along the arc. The secondary area is defined by arcs 2 nm on either side of the primary area.

3.6.2 Obstacle Clearance

The minimum altitude in the primary area of the final approach segment for VOR, VOR/DME and TACAN procedures with a FAF is 250 ft above the highest obstruction. In the secondary area, the requirement is 250 ft tapering to zero at the outer boundary. For an NDB procedure, the minimum altitude is 300 ft in the primary area and 300 ft tapering to zero feet at the outer boundary. For a DME arc procedure, the minimum altitude is 500 ft in the primary area and 500 ft tapering to zero feet at the outer boundary in the secondary area.

3.6.3 VOR Approach With FAF

A typical VOR approach procedure utilizing a FAF is shown in Figure 3.13 for Vero Beach, FL. Three IAFs are shown. Two are DME Arcs from VFR VORTAC. The third is the VRB facility itself. Using this IAF, a procedure turn is need prior to proceeding inbound on the final approach course. The FAF is the VRB VORTAC facility. The MAP is defined as being 3.6 nm from the VORTAC along the final approach course. This distance is determined by timing the approach after facility crossing is noted. The time required to reach the MAP is shown in the time table shown at the bottom of the approach procedure.

Altitude along the DME arcs or the procedure turn is 1500 ft. After arriving at Bueye Intersection on the arc or after completing the procedure turn, descent to 1000 ft can be made. After crossing the FAF (VRB), descent to 380 ft can be made prior to arriving at the MAP.

3.6.4 DME Arc Procedure

A DME Arc Procedure is shown in Figure 3.14 for Intercoastal City, LA. The IAF is shown on the diagram as being the 15 nm DME, 180° radial from the White Lake (LLA) VOR/DME facility. The aircraft is flown north along the 15 nm DME arc at an altitude of 1500 ft until the 078° radial from LLA is crossed. After crossing this fix, the FAF, descent may be made to 520 ft. The MAP is defined as the 059° radial from LLA. At this point, the helipad must be in sight or the missed approach procedure, a continuation of the arc climbing to 1500 ft followed by a left turn direct to LLA, must be performed.

3.7 ARA APPROACH PROCEDURES

3.7.1 Background

Utilization of the helicopters in the offshore areas has brought about the development of the airborne radar approach procedure. The

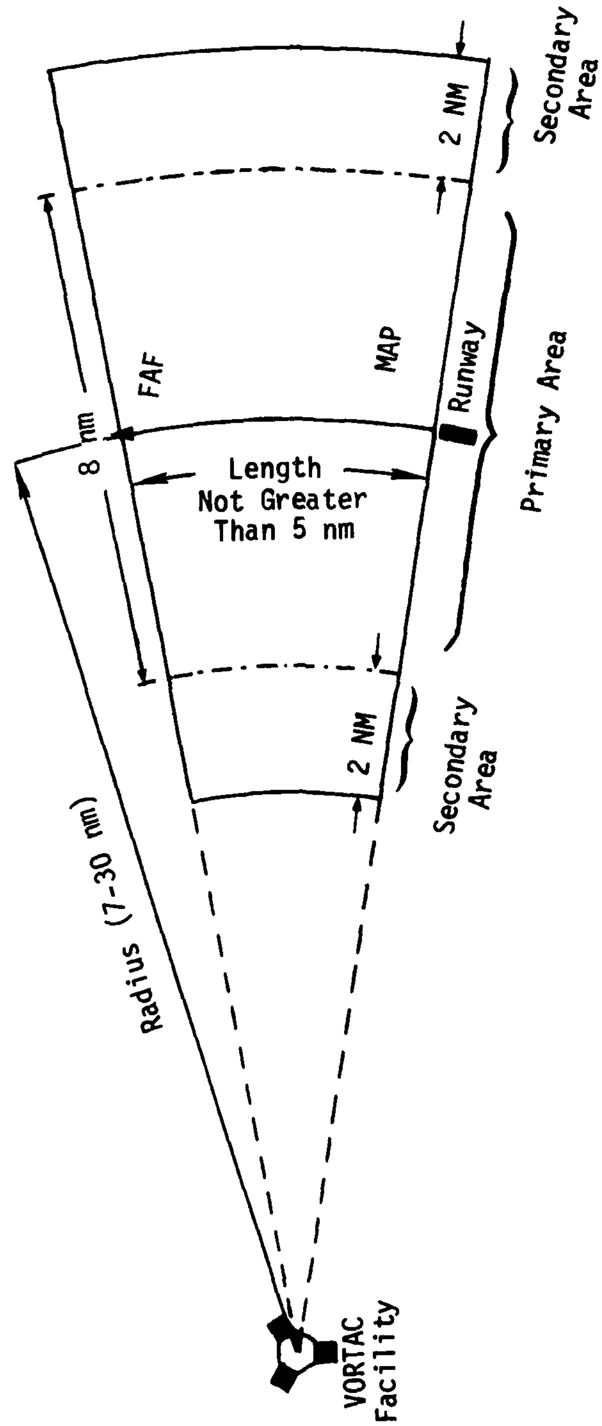


Figure 3.12 Final Approach Area for DME Arc Approach

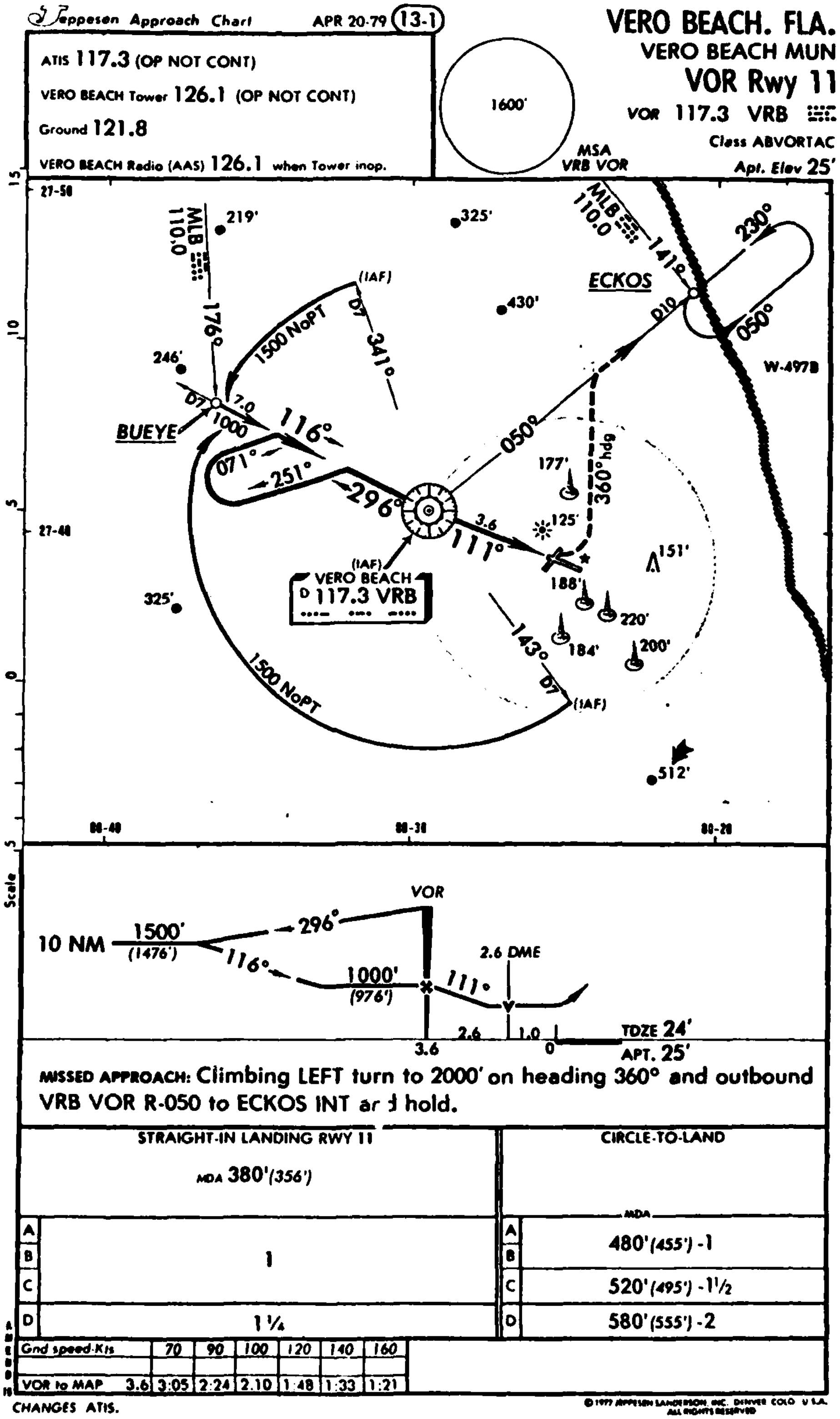


Figure 3.13 VOR Approach (with FAF) to Vero Beach, Florida

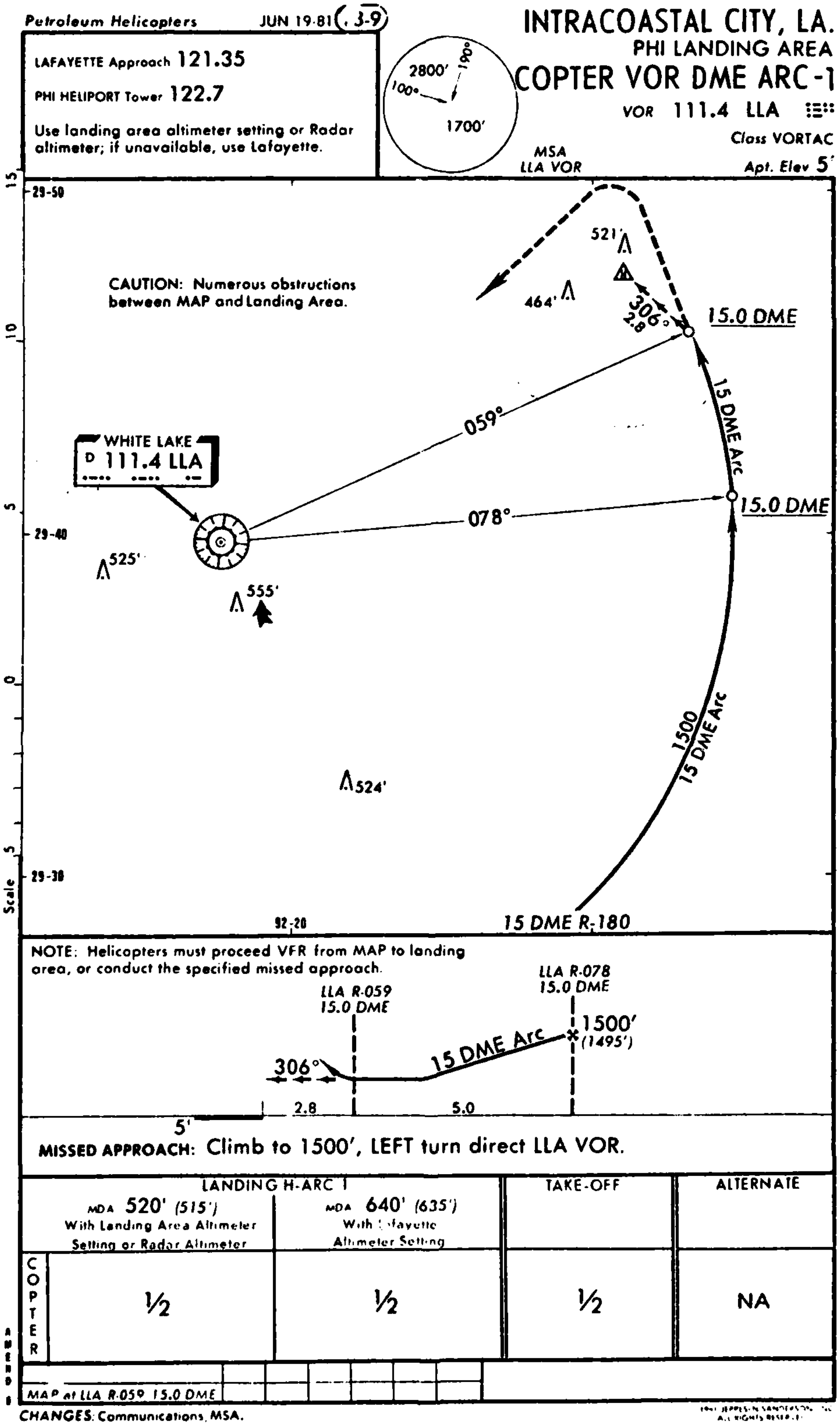


Figure 3.14 DME Arc Approach to Intercoastal City, LA

requirements for this procedure are described in FAA Advisory Circular 90-80[3] which has recently been issued. These procedures differ considerably from those that have been developed for fixed-wing aircraft in the TERPS manual. The procedure requires two pilots. The pilot in command (or second in command) acts as the radar observer. He interprets the airborne radar display, and by observing target returns he vectors the aircraft clear of obstructions to a point from which a visual approach can be made.

In some ways the ARA procedure resembles a NDB procedure with DME capability added. The target landing area is identified on the airborne radar display and distance from the area is shown by range marks on the display. Bearing to the landing area is determined by aircraft heading compensated for wind and target offset as shown on the radar display. These procedures are typically flown in such a manner so as to keep the final approach course into wind. Therefore, the final approach course is not defined until weather information is received from the landing area.

3.7.2 ARA Procedures

The ARA procedure begins at an intermediate fix defined by a VOR/DME, Loran-C, Omega/VLF, L/MF beacon, or other approved navigation aid. The radar operator then directs the aircraft to a downwind final approach point (DWFAP) from which the final approach is made.

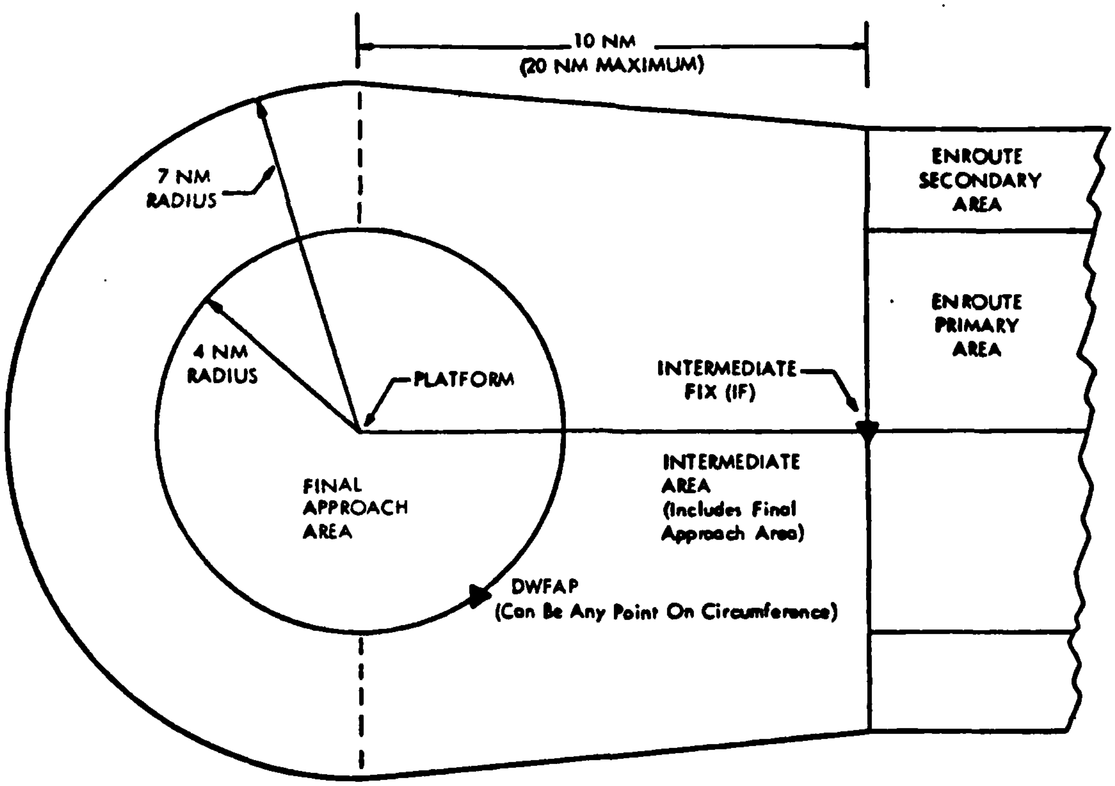
The intermediate segment is generally flown using one of two procedures. The first, and most common, is to overfly the approach target and turn downwind ±15° degrees from the reciprocal of the final approach course. A timed outbound segment is flown and the aircraft is turned to arrive over the DWFAP four miles from the approach target. The second procedure is an arc entry in which the aircraft proceeds directly toward the DWFAP at the four mile range point. The aircraft is then turned to fly inbound along the final approach course. The latter procedure is usually effective only if the intermediate segment course is within ±15° of the final approach course due to the limited sweep capability of the radar.

On the final segment, the aircraft is flown along the final approach course with the radar operator providing vectors to the flying pilot. Generally one of two final approach procedures are used. The first is the straight in method. The aircraft proceeds inbound to the minimum approved visibility range as identified by the radar operator using a range mark on the display. If the landing area is not visible, or if the aircraft is not in visual meteorological conditions, the aircraft is turned, usually 90°, to a clear zone and missed approach procedure is performed. The second type of approach procedure is the offset method. The aircraft proceeds along the final approach course to a specified distance from the approach target usually about one mile. The aircraft is then vectored on a 15° offset to fly to the right, or left of the target. Again if the target is not seen, or the aircraft is not in visual conditions, a missed approach to a clear zone, free of obstacles, is made.

The destination helipad may be different from the approach target. In this case the aircraft must be flown in visual conditions to the destination from the missed approach point.

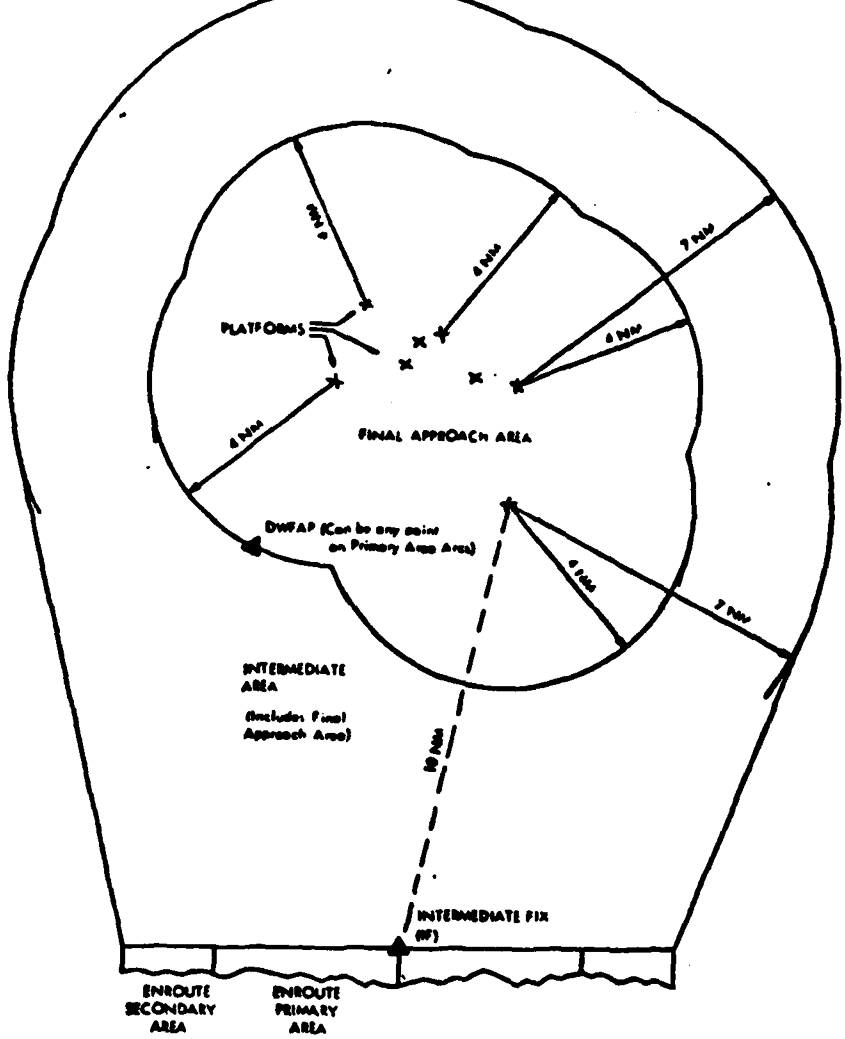
3.7.3 ARA Airspace

The primary and secondary area for an ARA procedure is shown in Figure 3.15. In instances where a cluster of platforms are available for landing, the intermediate and final approach areas are defined by drawing 4 nm and 7 nm arcs around each of the platforms. The outer surface formed by the intersection of the arcs define the airspace areas. An example of the intermediate and final approach airspace for a cluster of platforms is shown in Figure 3.16. The missed approach area is the same as the final approach area except for a circular area about the approach target. The radius of this area is equal to the minimum required visibility.



Single Platform Approach Procedure

Figure 3.15 Airspace Required for an ARA Approach to a Single Platform



Platform Cluster Approach Procedure

Figure 3.16 Airspace Required for an ARA Approach to a Cluster of Platforms

3.7.4 Obstacle Clearance

Obstacle clearance requirement in the intermediate area is 500 ft above the highest obstacle in the area.

In the final approach area the minimum descent altitude depends upon a number of factors. With a working radar and radio altimeter and with no obstacles within 1 mile of the final or missed approach course area, descent can be made to the following radio altitude:

- 200 ft or 50 ft above the landing area, whichever is higher

If the radio altimeter fails, or if there is an obstacle in the final/missed area, or if communication with the offshore heliport facility is lost then altitude must be increased to 250 ft above the highest obstacle in the final approach area.

3.7.5 Visibility

Landing visibility requirements for the ARA approach procedures are usually set at 1/2 nm or 3/4 nm. For takeoff minimums the visibility can be no lower than the landing minimums.

3.7.6 ARA Operational Concerns

The ARA procedure is a recent addition to the approach procedure inventory. It also represents a significant departure from the classical approach procedure. In order to obtain data and operational experience the FAA has recently completed two extensive ARA test programs. The results of these tests are documented in three reports (Ref. 4, 5, 6). One set of tests were performed by the FAA Technical Center with the assistance of Systems Control Technology, Inc. as a contractor. The other set of tests were performed by the FAA Aeronautical Center and NASA Ames Research Center with Air Logistics as a contractor.

Together the scope of these tests covered most technical and operational issues associated with ARA and the results of the tests form the basis of the procedure criteria contained the FAA Advisory Circular 90-80. The following paragraphs summarize some of the major operational problems as identified in the tests.

3.7.6.1 Target Identification

One major problem that arises with clusters of offshore rigs is identification of the approach target. The radar presentation provides little or no discrimination between targets. Rigs and ships look very similar on the display. Since the airborne radar beam width has limited aperture size, the beam width is necessarily wide (4 to 10 degrees). The target therefore tends to smear in azimuth, making the identification of the center of the target difficult. Range discrimination on the other hand is very good. However, the poor azimuth accuracy, the inability to distinguish between rigs and ships and the fact that the display presents an oblique view of the targets rather than a plan view all contribute to target identification problems. In both test programs the approach target was misidentified on several occasions.

Target identification can be enhanced greatly through the use of a radar transponder on the target rig. The radar must be equipped to receive the transponder signals as they are shifted in frequency from the primary signals. Some radars have the ability to display both the transponder and primary radar returns. This combined mode, as it is called, can cause loss of primary target information on the display in the vicinity of the transponder reply. Generally it was found that the transponder worked best for identification of the target but the primary return was best for tracking and course following.

Tests at FAATC utilizing specially designed reflectors for identification of the target on land areas were unsuccessful due to azimuth smear and ground clutter returns. Therefore, at the current time reflectors are considered an unacceptable method of target enhancement. Additional development and testing is being performed to improve reflector and radar technology. If successful, these tests could lead to the possible use of ARA procedures at land based landing areas.

3.7.6.2 Tracking Accuracy

Both test results showed a wide dispersion of approach paths caused largely by the inability to accurately identify the DWFAP. A secondary problem was a tendency for the pilot/radar observer team to home on the target rather than fly along a specified approach course. This problem was solved to a large extent in the FAATC/SCT tests by the addition of a cursor on the radar screen. The cursor required inputs from a course selection control and aircraft heading for presentation on the display. The cursor provided the radar observer with immediate visual cues for off-course conditions. The test results using the cursor for guidance reduced the approach path dispersion by a significant amount. It also was liked by the radar observers, as it reduced the amount of mental work required to provide course following vectors to the pilot.

In another test series two beacon techniques were tested to determine course following improvement. Two beacons were spaced at specified distances apart to aid the radar observer in lining up the aircraft on the final approach. This method was generally unacceptable for two reasons:

- azimuth smearing caused some difficulty in determining the exact beacon location on the display
- improper gain settings on the transponders caused the reply to break up and become unusable.

The latter problem could be improved upon, but overall the cursor appeared to produce more promising results as far as reducing approach path dispersion.

3.7.6.3 Crew Coordination

It should be reiterated that the ARA procedure is a two pilot operation and crew training and coordination is very important. The ARA procedure requires pilots who are familiar with the topography of the offshore area, especially when multiple rigs are in the same general vicinity.

3.8 VOR/DME RNAV PROCEDURES

3.8.1 Background

Like the ARA procedures, RNAV procedures are contained in a FAA Advisory Circular rather than the TERPS document[1]. This circular is AC90-45A[7].

The RNAV approach procedure has the advantage of being able to be aligned so as to obtain maximum operational benefit to the user provided navaid coverage is available. In most instances the approach path is aligned with the runway centerline; however, the alignment can be made to allow the approach path to go between obstacles to achieve a lower minimum descent altitude, assuming obstacle clearance criteria are met.

3.8.2 RNAV Airspace

The RNAV approach is divided into initial, intermediate, final and missed approach segments. These segments generally begin with a waypoint, but an alongtrack distance fix can be substituted if the approach path continues along the same course. This often occurs at the final approach waypoint, as the intermediate segment and the final segment are often along the same course. Therefore, a typical procedure would consist of an initial approach waypoint, an intermediate waypoint, and missed approach waypoint. The final approach fix would be defined as a distance to the missed approach waypoint. Sometimes an additional waypoint is used to define a point to fly to after completing the missed approach.

Simplified procedures can be utilized at small airfields where air traffic problems are minimal. In these instances only an initial approach waypoint and a missed approach waypoint are used.

Airspace criteria for the initial approach segment differs from criteria for procedures contained in TERPS described in Section 3.3.1. The width of the initial segment is ±2 nm, a secondary area is defined one mile on each side of the segment. An increase in airspace to ±4 nm may be necessary if the reference facility is from 25-53 nm from the initial approach segment.

The intermediate segment blends the initial segment into the final approach segment. The airspace criteria for this segment reflects this function and thus meets initial segment criteria at one end and final approach criteria at the other. The minimum length is 3 nm using standard procedures.

The final approach primary area is ±2 nm wide on either side of the final approach fix. Its width tapers to the fix displacement width, shown in Table 3.1, at the missed approach waypoint. This width is a function of distance and relative bearing from the reference VORTAC facility and can range from 0.8 nm to 2.0 nm. A secondary area of one mile in width is located on each side of the primary area. The length can be as little as 1 nm if no turn is made at the final approach fix. Five nm is a more typical length. The missed approach segment is adjacent to the final approach segment beginning at the missed approach waypoint. The width of this area equals the final approach segment at the missed approach waypoint and expands at a 15° rate until it reaches the width of the enroute airspace area. The secondary area also expands to be continuous at both the missed approach waypoint and the enroute area.

3.8.3 Obstacle Clearance

Obstacle clearance for the RNAV approach is similar to that for VOR/DME procedures. The minimum altitude in the primary area of the final segment is 250 ft above the highest obstacle. This value also applies at the inner edge of the secondary area and tapers to zero at the outer edge.

3.8.4 VNAV Procedures

AC90-45A provides for the use of VNAV (or 3D-RNAV) procedures to be used on 2D RNAV approach procedures so long as minimum and maximum altitudes specified for the flight procedures or by air traffic control are not violated. Otherwise no specific VNAV criteria are established at this time.

3.8.5 RNAV Approach Procedure

Figure 3.17 shows an approved RNAV procedure to South Lake Tahoe, California, Runway 18. The approach course is offset slightly from the runway centerline to avoid high terrain northeast of the airfield. The missed approach waypoint is located 3.4 nm from the runway threshold to assure adequate navaid reception from Lake Tahoe VORTAC and to avoid high terrain in the missed approach area. This sizeable distance from the missed approach waypoint to the runway makes necessary a four nm visibility requirement.

3.9 "HELICOPTER ONLY" CRITERIA

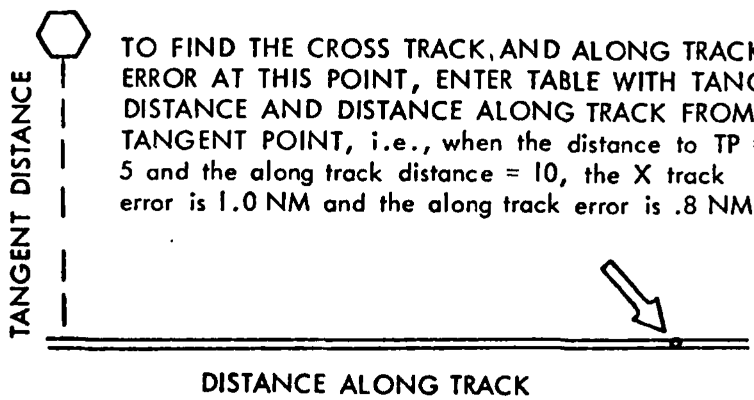
In recognition of unique capabilities of helicopters a special section, Chapter 11, was added to the TERPS document. These criteria apply only to helicopters and the procedures based on these criteria are designated "Helicopter Only".

Table 3.1 RNAV Fix Displacement Error

FINAL AREA FIX DISPLACEMENT AREA (95% PROBABILITY)

DISTANCE ALONG TRACK FROM TANGENT POINT

DISTANCE FROM TANGENT POINT TO VORTAC	0	5	10	15	20	25	30
0(x trk)		.8	.9	1.2	1.4	1.7	2.0
(alg trk)		.7	.7	.7	.8	.9	1.0
5(x trk)	.9	.9	1.0	1.2	1.4	1.7	2.0
(alg trk)	.6	.7	.8	.8	.9	1.0	1.1
10(x trk)	.9	.9	1.0	1.2	1.5	1.7	
(alg trk)	.8	.8	.9	.9	1.0	1.1	
15(x trk)	.9	.9	1.1	1.3	1.5	1.8	
(alg trk)	1.1	1.1	1.1	1.2	1.2	1.3	
20(x trk)	.9	1.0	1.1	1.3	1.6		
(alg trk)	1.3	1.4	1.4	1.4	1.5		
25(x trk)	1.0	1.1	1.2	1.4			
(alg trk)	1.6	1.6	1.7	1.7			
30(x trk)	1.2	1.2					
(alg trk)	1.9	1.9					



TO FIND THE CROSS TRACK, AND ALONG TRACK ERROR AT THIS POINT, ENTER TABLE WITH TANGENT DISTANCE AND DISTANCE ALONG TRACK FROM TANGENT POINT, i.e., when the distance to TP = 5 and the along track distance = 10, the X track error is 1.0 NM and the along track error is .8 NM.

ERROR ELEMENTS

GROUND
- VOR 1.9°
- DME 0.1 NM

AIRBORNE
- VOR 3.0°
- DME 3% or 0.5 NM

RNAV SYSTEM 0.5 NM

PILOT
- CROSS-TRACK 0.5
- ALONG-TRACK ZERO

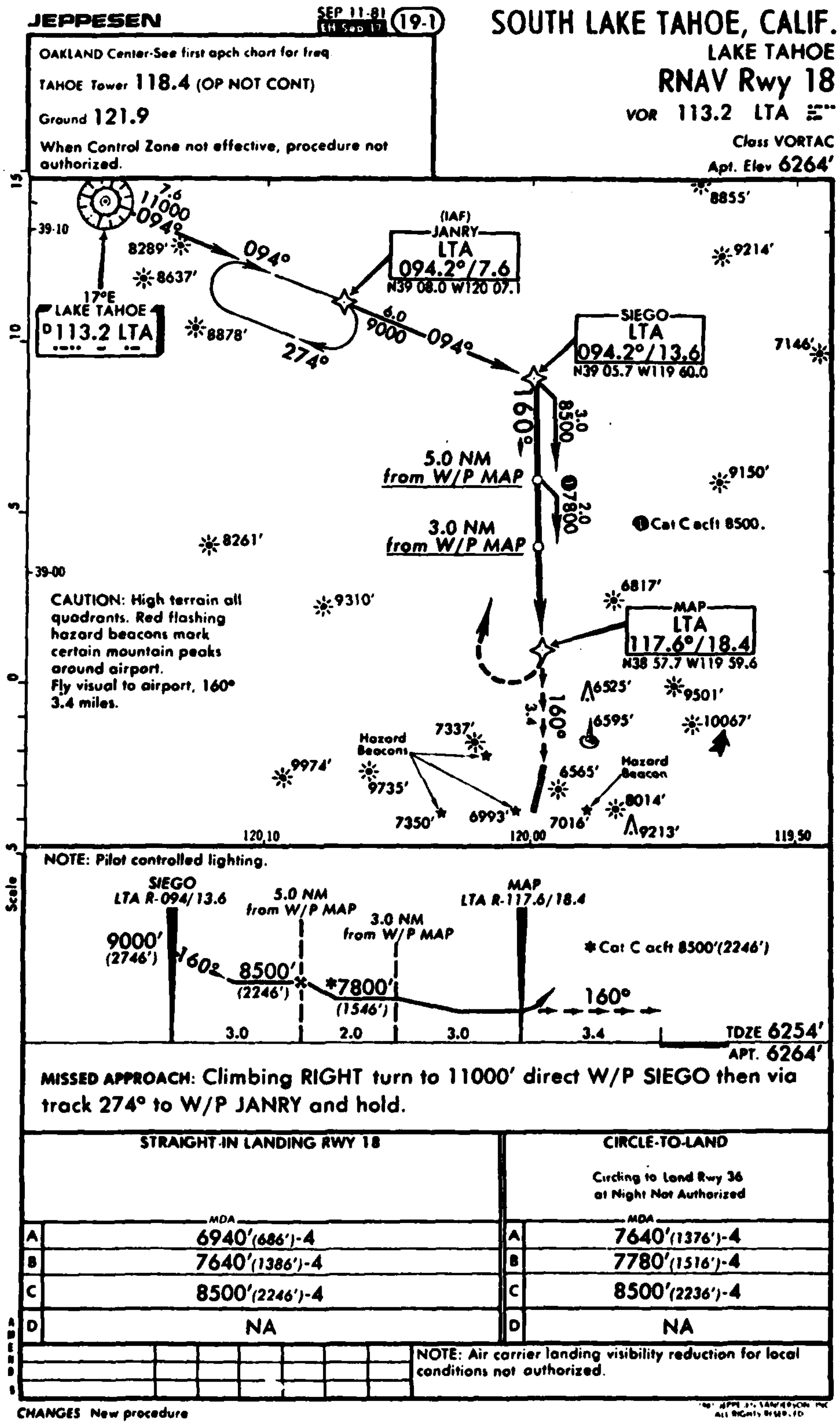


Figure 3.17 RNAV Approach to South Lake Tahoe, CA.

Some of the major differences between "Helicopter Only" criteria and standard TERPS criteria are outlined in this section. For detailed differences the TERPS manual should be referenced.

3.9.1 Procedure Limitations

"Helicopter Only" procedures are designed to meet low altitude, straight in procedures only. No circling approaches are permitted. The procedures apply to aircraft not exceeding an airspeed of 90 knots on final approach.

3.9.2 Point in Space Concept

These procedures provide for a point in space approach concept that allows the helicopter to perform an approach to a location rather than a designated runway or landing area. From the point in space the aircraft proceeds visually to a landing area or performs a missed approach if VFR (or SVFR in control zones) conditions are not encountered. The point in space procedure is used when the missed approach point is greater than 2600 ft from a landing area.

3.9.3 Descent Gradients

Typical descent gradient for standard procedures are 250 to 500 ft per mile. Gradients for helicopter procedures are 400 to 600 ft/mile. In special circumstances gradients of up to 800 ft/mile may be permitted.

3.9.4 Procedure Turns

Since helicopters meet Category A criteria for approach speeds the 5 nm procedure turn area shown in Figure 3.8 can be utilized. However, a larger procedure turn area can be used if considered desirable.

3.9.5 Intermediate Approach Segment

The optimum length for the intermediate segment is reduced to 2 nm. The minimum length for turns at the intermediate fix not exceeding 30° is one nm. The recommended maximum length is 5 nm.

3.9.6 Final Approach Segment

A number of changes in the final approach airspace criteria are made for helicopter procedures. Some of these changes are as follows:

- ILS
  The optimum length of the final approach segment is reduced to 3 nm. The minimum length is 2 nm and a length exceeding 4 nm should not be used unless an operational requirement applies.
- VOR and NDB with no FAF
  The length of the final approach segment upon completing the procedure turn is 5 nm. The 5 nm of the airspace nearest the facility shown in Figure 3.9 is utilized.

- VOR/DME, Tacan, VOR with FAF and NDB with FAF
  The minimum length of the final approach segment is 1 nm for turns over the facility of 30° or less, 2 nm for 60° turns and 3 nm for 90° turns. For final segments based on DME arcs the minimum radius of the arc is reduced from 7 to 4 nm.

3.9.7 Missed Approach Segment

The length of the missed approach segment is reduced from 15 nm to 7.5 nm. The slope of the missed approach surface is changed from a 40:1 ratio of distance flown to altitude gained to 20:1. The upward slope of the secondary area is changed from 12:1 to 4:1.

3.9.8 Visibility

A significant reduction in visibility criteria is applicable to helicopter procedures. The minimum visibility for point in space approaches is 3/4 mile if the height above the surface does not exceed 800 ft. Otherwise it is 1 mile.

For non-precision approaches the visibility minimum is ½ mile for height above landing areas (HAL) of 250 to 600 ft, 3/4 mile for a HAL of 601 to 800 ft and 1 mile for an HAL of greater than 800 ft.

For precision approach procedures the minimum visibility prior to applying credit for landing area lights is ½ mile or 2400 ft runway visual range. Credits for approved light systems of ¼ mile reduction can be obtained if the system is operative at the time of landing.

3.10 OTHER CANDIDATE APPROACH NAVAIDS

Under certain circumstances it may be possible to utilize other navigation aids for approach or approach type procedures. Some of these procedures and navaids are as follows:

- Loran-C
  At the present time Supplemental Type Certificates have been issued to two users for enroute operations using Loran-C in areas where conventional navaid coverage is limited. One area is in the Gulf of Mexico and the other is in Vermont where mountains limit useful VORTAC coverage. At present neither user has received approach procedure approval.
  Approach procedures using Loran-C would be patterned after RNAV procedures, as area navigation capability is inherent in these systems. Advisory Circular 90-45A contains criteria for approving non VOR/DME systems. However, at this time sizeable bias errors in the Loran-C systems currently approved for enroute operations has kept them from becoming approved for approach procedures.

- Omega/VLF
  The Omega/VLF system has become a widely accepted navigation aid for transoceanic aircraft. To a limited extent it has been used by some helicopter operators for enroute offshore operations. The system is not sufficiently accurate to be used for approach procedures under Advisory Circular 90-45A. However, in areas where obstacles clearance problems are minimal such as offshore, an enroute descent procedure has been adopted in a few instances. Omega/VLF is used in conjunction with airborne radar and radio altimeters in these instances. An example of an enroute procedure that uses Omega/VLF for offshore work is shown in Figure 3.18. The route may be used with VOR at higher altitudes if VLF is unavailable.

- Microwave Landing System
  Many test procedures have been flown and evaluated using the newly developed ICAO Standard MLS system. As these systems become operational they may be applied to helicopter operations in a number of ways. It is anticipated that initial utilization for helicopters will be in remote areas or in congested terminal areas where MLS flexibility can provide operational benefits. Some installations of non standard (ICAO standard) MLS systems have been utilized. Figure 3.19 shows a Co-Scan MLS system at Tuktoyaktut, N.W.T., Canada. The Procedure requires DME but is otherwise very similar to a conventional ILS procedure. The interim standard MLS (ISMLS, also called the Tull System) has also been used at a few locations.

- NAVSTAR/GPS

  As the U.S. Department of Defense satellite navigation system becomes operational there may be some civil helicopter operations which can utilize its accuracy and coverage for approach procedures. The FAA Technical Center has a current test program underway to evaluate this system for helicopter operations. The program is not yet complete but preliminary results should be available soon.

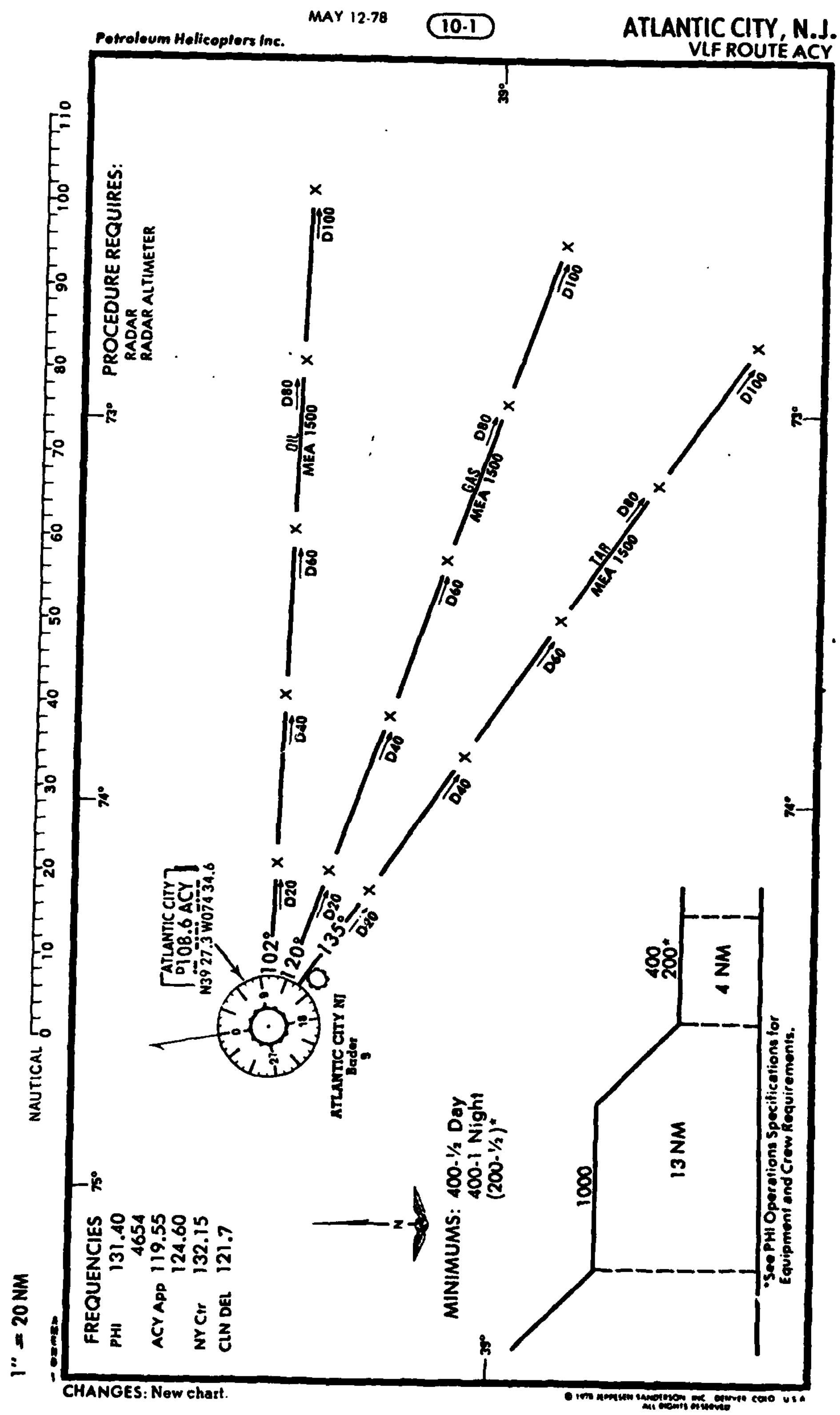


Figure 3.18 VLF/VOR Enroute Descent Procedure

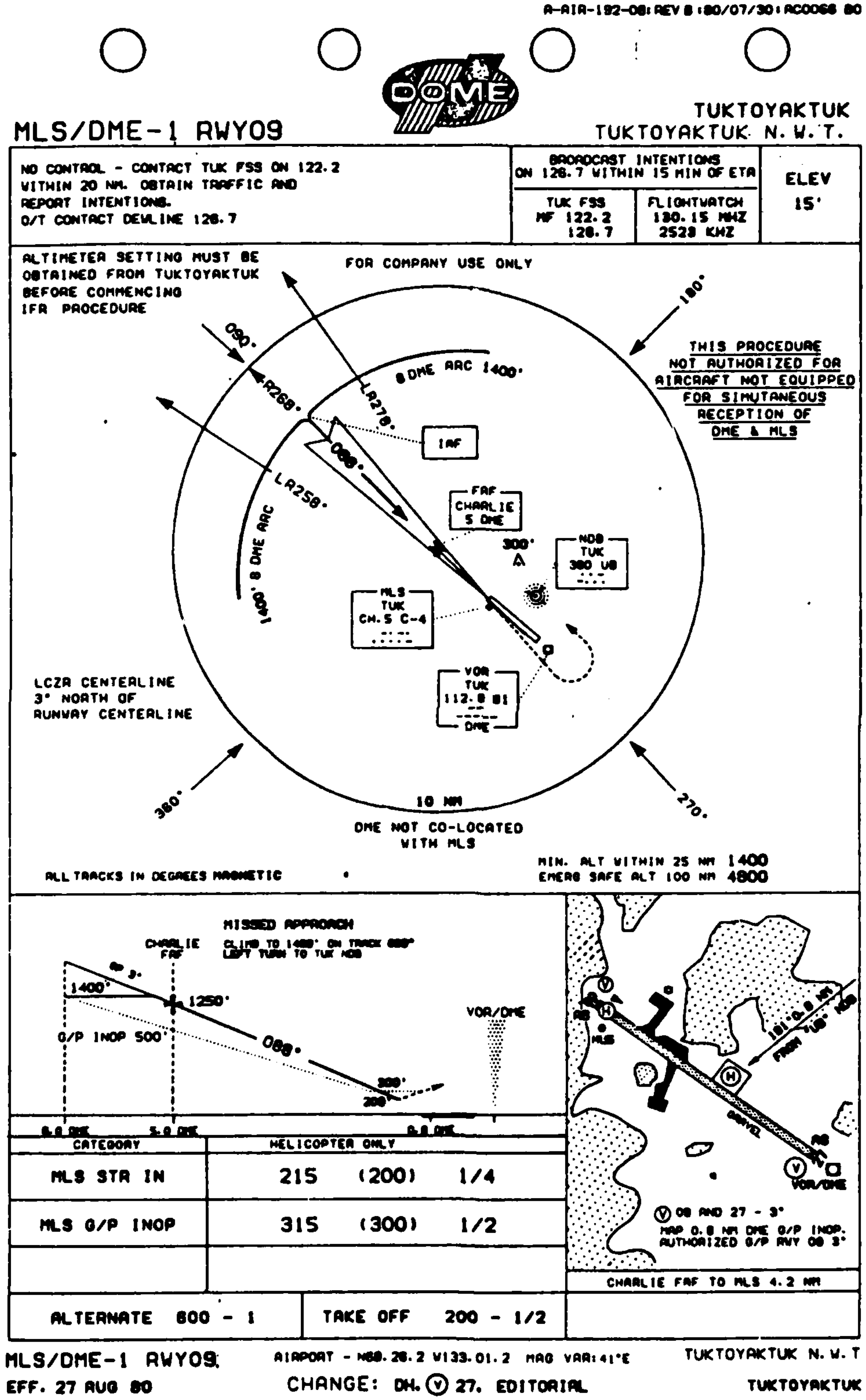


Figure 3.19 MLS/DME Approach at Tuktoyaktuk, N.W.T., Canada

4.0 ESTABLISHED NAVIGATION AIDS

In this section, each radionavigation signal aid will be evaluated to establish applicability to unique rotorcraft approach requirements. This evaluation includes systems currently being used for final approach guidance. The systems which are discussed in this section have instrument approach procedure criteria described in TERPS or FAA Advisory Circulars. Systems which may have the potential to be used in the future are discussed in Section 5.

4.1 VOR/DME AND TACAN

4.1.1 System Description

The VOR/DME system and the TACAN system have been designated as the primary navigation systems for domestic enroute, terminal area, and non-precision approach operations. They are also being evaluated for applicability to remote area and helicopter operations. As the cornerstone for the ATC enroute airway system in the continental U.S., VOR/DME is widely accepted as the primary short range navigation aid by both the user community and the regulatory agencies. At the current time the FAA operates approximately 770 VOR/DME and VORTAC staions and 150 VOR stations (which provide azimuth information only). It is expected that these stations will be upgraded and maintained at least through the 1995 time frame. Further implementation of VOR based area navigation (RNAV) procedures will increase the utility of VOR navigation, and should extend the expected life cycle of this system even further.

Using VHF radio transmission frequencies, VOR stations transmit azimuth information allowing aircraft equipment to establish an azimuth line of position relative to the ground station. When available, colocated DME transmitters provide distance information allowing the aircraft to compute a unique position fix, again in relation to the ground station. Successive position fixes then provide the basis for dynamic navigation computations. TACAN, primarily a military version of VOR/DME, functions in a similar manner using UHF frequencies. Many of the facilities defining major enroute airways use dual VOR and TACAN transmitters, termed VORTACs, enabling effective integration of military and civil air traffic into the same enroute structure.

4.1.2 System Accuracy and Coverage

Whenever plusible, VORTAC facilities defining the enroute structure have been strategically located to provide approach guidance to appropriate airports. Other ground stations have been installed specifically to provide this guidance at many of the major hub airports which cannot be conveniently serviced by enroute VORTACS. Perhaps the greatest detriment to the adoption of VOR as the universal non-precision approach aid is the range limitations imposed by the line of sight nature of VHF and UHF transmissions. Under ideal conditions of flat terrain, low altitude coverage (500 ft) is often limited to thirty miles or less due to earth curvature. At flight altitudes of 5000 feet AGL, reception ranges are only 85-90 nm. In areas of uneven or mountainous terrain these ranges can be reduced well below these nominal levels. In spite of the range limitation, the VORTAC system can provide an excellent source of non-precision approach guidance, particularly when the transmitter can be located directly on the airport. Typical ground station errors are ±1.4 degrees, or approximately 300 feet (2σ) cross-track error at 2 nm from the transmitter. TACAN accuracy tolerances are even tighter, the typical error being ±1.0 degrees (2σ) or approximately 200 feet crosstrack error at 2 nm from the transmitter. DME errors are 600 feet (2σ) during final approach operations near the transmitter. The DME component generally constitutes alongtrack error, which is not as critical for non-precision approach operations. It is these accuracies, as well as the widespread signal availability which has made VOR the widely accepted IFR approach system that it is.

4.1.3 System Limitations

In spite of this acceptance, the offshore and remote area helicopter environment has unique characteristics for which the VORTAC system is not ideally suited. Typical enroute altitudes for offshore support operations can be as low as 1500 feet with terminal area drilling platforms as much as 200 miles offshore. These distances will likely increase to 300 miles in the near future. Line of sight limitations make VOR navigation impossible at these altitudes and distances without heavily investing in a large number of additional transmitting facilities. Remote area operations are generally conducted in mountainous terrain, which effectively masks line of sight radionavigation signals. The purchase of additional transmitting facilities to support these operations would prove to be excessively costly.

4.1.4 System Costs

Although airborne receiving equipment is relatively inexpensive, transmitting facilities can represent a significant investment. The basic equipment cost of a new VOR/DME transmitting facility is approximatley $150,000 plus the expense of site survey and calibration. The additional costs associated with remote siting could be especially large. Except in cases of extenuating circumstances, it would not be practical to extend existing coverage by installing additional line of sight signal transmitters unless they supported the requirements of a much larger segment of the aviation user community than just the remote area or offshore helicopter operators. Operations conducted in those areas which do have adequate low altitude coverage can economically implement VOR/DME IFR approach procedures due to the relatively low cost of airborne receiver equipment. General aviation VOR receivers can be obtained for only $1,500 and DME receivers can be obtained for an additional $2,500. If signal coverage is adequate in a given area of interest, but approach path alignment is a problem, area navigation capability can be added for an additional $2,800 to $3,000. Thus an aircraft can be equipped for RNAV approach operations for only $6,800, a price well below any alternative system with the possible exception of a non-directional beacon system. If low altitude coverage is available in the area of operations, VOR/DME is an economically viable approach guidance navigation signal aid for helicopter operations.

4.1.5 VOR/DME and TACAN System Summary

In summary, the universal acceptance of the VORTAC signal system makes it an attractive option as an approach aid for helicopter operations as long as low altitude signal coverage is available. Receiver equipment is inexpensive and highly adaptive to localized requirements based on terrain and obstructions. Purchase and installation of additional transmitter facilities in order to improve low altitude coverage is not economically feasible, however, except when long term heavy traffic counts can be realistically anticipated. Sufficiently high traffic counts based solely on helicopter operations will not occur in the foreseeable future based on current projections. Thus the installation of additional VOR transmitter facilities, based solely on projected helicopter operations, should be closely examined on a case by case basis to determine individual economic viability. In those geographic areas where low altitude coverage is inadequate, alternative signal guidance systems and procedures should be very strongly considered.

4.2 NON DIRECTIONAL BEACONS (NDB)

4.2.1 System Description

Using the low and medium frequency bands, NDB stations transmit a nondirectional ground wave signal. This signal is received by an airborne Automatic Direction Finder (ADF), which determines the bearing of the transmitter relative to aircraft heading. While each bearing determination constitutes a Line Of Position (LOP), a minimum of two LOPs is required for complete position fixing. Bearing accuracy is generally accepted as ±3 degrees, but position fix accuracy may vary, depending on LOP geometry, signal stability, terrain associated propagation errors, and instrumentation accuracies. In order to comply with flight inspection requirements, the FAA has defined minimum accuracy standards for NDB stations in terms of maximum permissible needle swing of ±5 degrees for approach guidance and ±10 degrees for enroute guidance. Because of these relatively large tolerances, NDB approach minimums are higher than those associated with other radionavigation aids and the TERPs defined approach airspace is somewhat large. Operational ramifications of these TERPs requirements are more fully discussed in Section 3, but, in summary, these restrictions will impact remote area land-based operations to a greater extent than they will impact offshore operations. The NDB system is a much more effective approach aid into areas of level terrain, the best example of which is the open ocean.

4.2.2 System Capabilities and Limitations

The NDB radionavigation system is a low cost system which has been designated the secondary system for domestic enroute, terminal area, non-precision approach, remote area, and helicopter operations requirements. Additionally, many general aviation pilots find the transcribed weather broadcasts transmitted over this system to be particularly useful for planning enroute flight plan changes. Of the approximately 1500 operational aviation beacon transmitters, 600 are owned and operated by the FAA and 200 are operated by the military services.

The other 700 transmitters are all owned and operated by private individuals or corporations. In spite of the large number of privately owned stations, further expansion of this system is federally restricted in many operational areas due to a severe frequency congestion problem. Modification of bandwidth assignments may be introduced in the futue to alleviate this problem, but this action may, depending on specific bandwidth reductions involved, eliminate beacon voice transmission capability. Suggested courses of action are currently being investigated by a special committee (SC-146) of the Radio Technical Commission for Aeronautics (RTCA). Although the diliberations of this committee may impact voice transmission capabilities, the basic navigational characteristics of the system should remain the same. Universal acceptance of the NDB system appears to be based primarily on availability of coverage and adequate accuracy at low equipment costs. No replacement system, offering these advantages to the user, is currently forecast at least through the year 2000. Thus it is expected that the NDB system will be operated and maintained, at least as a non-voice navigation aid, for a number of years, regardless of what other national navigation decisions are made.

4.2.3 NDB Operations in the Gulf of Mexico

In the offshore oil fields of the Gulf of Mexico, the installation of privately owned beacons has created a frequency congestion problem of large proportions. One of the more unique solutions to this problem has been the concept of "time sharing" a particular frequency among several transmitting sites. Although this concept may provide minimal guidance to an aircraft during day VFR conditions, it is certainly not adequate for consideration as the primary source of navigational information during either night or IMC conditions. The concept currently being used allows up to six remotely located transmitters to share the same frequency assignment by limiting transmissions to a synchronized time schedule. Each station broadcasts for a period of up to 30 seconds and then is turned off while the other stations broadcast in their own time slots. Thus, for a four station group, the largest group currently in operation in the Gulf at this time, each station provides guidance for 30 seconds and then is silent for 90 seconds. It is impossible to consider a system which characteristically supplies no guidance for this long a period as a serious candidate for an IFR approach aid. With the current technological status of these systems, IFR approval for time synchronized groupings of NDB transmitters cannot be considered to be a viable option for solution of the frequency congestion problem.

4.2.4 System Costs

The primary benefit associated with the aviation radiobeacon system is the low cost involved in equipment acquisition and operation. This cost savings is applicable to both airborne equipment and ground equipment. Typical purchase cost of an aviation quality beacon station is between $8,600 and $33,000, well below the cost of any other FAA approved transmitter facility. Airborne ADF equipment is priced between $1,500 and $7,000 depending on the quality desired. Thus, the NDB system is best suited for those operations which operate into and out of a limited number of destinations in areas which have inadequate VOR coverage. Because of the low cost of both receiver and transmitter units associated with the NDB system, relative operational costs are more favorable to NDB operations when several aircraft are required to support the same facility. This is particularly true if the typical IFR ceilings for that area are not unusually low and obstruction clearance is not a major problem at the destination. Thus, the offshore oil rig support environment found in the Gulf of Mexico is highly conducive to the development of an NDB radionavigation network. Similar operations off of the North Atlantic Coast or remote area operations in mountainous areas may find it more practical to use other types of navigation aids if adequate coverage and FAA approval is available.

4.3 INSTRUMENT LANDING SYSTEM (ILS)

4.3.1 System Description

Since its introduction in the 1940's, ILS has grown to become the world wide ICAO standard for precision approach aids. Coincidentally, the associated localizer signal can be used as a non-precision approach aid if the glide slope signal is malfunctioning. Generally aligned to a single runway; ILS transmitters provide a precision signal to a very limited sector of the total airspace. The standard configuration has a localizer transmitter aligned to a specific runway centerline and provides azimuth coverage of ±40 degrees around the runway centerline. Vertical guidance is provided by a glide slope transmitter located approximately 1000' from the runway approach and threshold. The localizer and glide slope equipment define a single path in space along which the aircraft is to travel. This path is generally aligned with the runway centerline and provides a 3° glide path to the runway touch down zone. The airborne equipment determines angular deviations about the approach path. Typical full scale deviations are ±1.25° in the lateral direction and ±0.70° in the vertical. Outside of this proportional deviation and within the coverage area, guidance is provided by full scale deflections. These signals are often further processed by autopilot and flight director equipment. Marker beacons and/or a DME transmitter provide indications of aircraft along course position. Ground and airborne installations are rated for accuracy performance and categorized as Category I, II or III facilities, Category III being the most accurate. Decision heights typically range from 200 feet AGL for Category I procedures, 100 feet AGL for Category II procedures, to 0 feet AGL for Category III approaches. The airborne equipment and flight crew must be further certified for Category II and III operations. Since airborne categorization is highly dependent upon design characteristics such as the number and interface of redundant control channels, Category II and III installations are much more costly than Category I installations. Although the Microwave Landing System (MLS) is currently being developed as a potential replacement for ILS, international agreements protect ILS as least through 1995. Extension of this protection beyond 1995 is considered likely by many proponents.

ILS acceptance in the user community is widespread and growing rapidly. Approximately 2,600 air carrier and 47,000 general aviation aircraft are ILS equipped. Additionally, all air carrier aircraft added to the fleet in the future will be ILS equipped. User acceptance is based on both the economy of receiver equipment (many standard VOR receivers are also configured to be ILS receivers as well) and the large and growing number of operational ground transmitters. There are currently over 700 commissioned ILS transmitters, 90% of which are owned and operated by the Federal Aviation Adminstration. It is estimated that this number will approach 1000 by the end of 1982.

4.3.2 System Limitations

Three major limitations constrain the expansion of the ILS transmitter network: multipath errors; operational flexibility; and frequency congestion. Multipath errors occur when portions of the guidance signal are reflected off of terrain or man-made obstacles creating false indications of the actual signal position as interpreted by the receiver. Careful site selection and preparation can minimize this effect but temporary obstructions such as vehicles, taxiing aircraft, or snow banks can still be troublesome. In many mountainous areas, it is often impossible or unfeasible to site an ILS facility due to multipath problems. The second ILS limitation, operational flexibility, is a product of the single-track flight path characteristic of ILS. Aircraft of differing performance capabilities must fly a common path from the final approach fix to touchdown, typically a distance of 5-10 nm. The net result of this requirement is increased aircraft spacing requirements during instrument meteorological conditions. The third limitation, frequency congestion, is a limitation common to many current radionavigation systems. Three solutions have typically been offered to alleviate this problem whenever it has occurred in the past; allocating additional space in the frequency spectrum, refining the frequency separation standards (narrowing signal bandwidths) to allow more frequencies to be defined within a given frequency range, and developing the means to time share a specific frequency between two stations which might otherwise cause mutual interference for each other. Frequency time sharing requires that sophisticated transmitter and receiver equipment, at costs commensurate with general aviation operations, be developed. Since the frequency band has been already 95% allocated, the most technically feasible frequency congestion solution for the near term future appears to be narrowing the signal bandwidth tolerances for transmitter stations. This solution has significant cost implications for both the ground and airborne systems.

For the present, ILS has been found to be a highly reliable and accurate radionavigation approach aid. Category I signal in space accuracy standards result in a ±25 feet maximum course deviation at threshold crossing, while vertical accuracy is maintained at ±7 feet when passing 100 feet AGL. These tolerances are monitored continuously and a positive indication of a system out of tolerance situation causes the transmitter to be shut down. Reliability has been typically found to be on the order of 98.6% for operational Category I systems.

Category II and III installations have typically had a lesser level of reliability due to the increased number of components required for these facilities.

4.3.3 ILS Helicopter Applications

Although the concept of positive vertical guidance during the approach is appealing, adaptation to unique helicopter operations presents several drawbacks which may make ILS economically implausible for these operations. The high cost of siting and installing a transmitter station requires high traffic counts at that facility to provide economic justification. Helicopter operations are typically characterized by numberous destination helipads but only a limited number of flights into a specific location. This characteristic is indicative of the requirement for a low cost transmitter aid for approach guidance or the use of wide area coverage systems for approach guidance. Both of these alternatives are incapable of supplying positive vertical guidance.

Vertical guidance in the offshore environment may be difficult to achieve in spite of economic considerations, due to inherent stability requirements. Any pitching moment of the transmitter facility is greatly exaggerated as distance from the facility is increased. If a one degree pitch change, due to wave action on the approach rig, is made, the vertical guidance signal is also moved one degree resulting in a six hundred feet change in desired vertical position as represented in the cockpit of an aircraft on final approach 6 nm from the station. This magnitude of approach path movement is entirely unacceptable and it is not unusual for even the most stable of floating platforms to pitch to this extent during moderate wave conditions. Drill ships have been known to pitch up to ten to twelve degrees in heavy seas. Sensitivity to pitching motion can be reduced by mounting the transmitter on a complex gyro stabilized platform. This additional equipment would increase system costs and probably reduce system reliability. Monitoring equipment can be installed on deck mounted transmitters and ILS precision operations can be terminated when deck motions exceed established maximum allowable values. This will tend to make the system unusable during those conditions when it is most needed, however. Finally, although not definitely required, a means of aligning the final approach course into the wind would be very desirable in a noncluster approach environment. Again this type of equipment would undoubtedly increase costs and reduce system reliability.

4.3.4 ILS System Costs

A typical ILS equipment at an airport costs between $260,000 and $430,000. On an offshore platform, this cost would be considerably higher due to antenna stabilization equipment, specialized monitor receivers and selectable azimuth alignment capability. Airborne system costs are very moderate. Many VOR receivers include ILS circuitry at a price slightly greater than a VOR only receiver. Similarly, the costs of marker beacon receivers and/or ADF receivers used to identify approach fixes, range from $1,500 to $7,000 for ADF receivers and $100 to $600 for marker beacon receivers.

Excessive ground system costs are a major inhibiting factor in adopting ILS for unique helicopter operations, particularly in the offshore environment. Facilities capable of being shared by fixed-wing as well as helicopter operations are much more cost effective because of the increased traffic counts. Large scale helicopter operations can take advantage of this cost effectiveness by establishing an operations base at a fixed-wing airport having ILS capability and investing in the receiver equipment needed for the display of guidance information. This cost is minimal and enables a deployed fleet to return to the home base under weather conditions which are much lower than those allowed for non-precision approach aids.

4.4 AIRBORNE RADAR APPROACHES (ARA)

4.4.1 System Development

The Airborne Radar Approach (ARA) procedure was specifically designed to fulfill the needs of offshore helicopter support operations. As technology enabled the oil exploration and production industry to move to offshore locations, the requirement to meet support needs in a timely manner became apparent. The offshore wells in the Gulf of Mexico provided an environemnt conducive to the use of helicopters in this support role. Excellent flying weather, moderate temperatures, and 100-200 nm range requirements provided the environment for the development of a healthy helicopter support service industry. Operations were generally performed under VFR or special VFR conditions because of the minimum delays incurred awaiting improvement in area weather conditions. As oil exploration was expanded to other offshore locations, such as the North Sea and the mid-Atlantic coastal regions of the U.S., weather conditions were not as stable and IFR capability became mandatory for effective oil rig support operations. Because a single land based support center may service hundreds of offshore oil rigs by air, traditional radionavigation signal aids became economically unusable as approach aids. Initial attempts at using wide area coverage systems as approach aids were thwarted due to apparent system inaccuracies. The obvious solution was to develop a certifiable self-contained navigation system capable of supporting an approach procedure which did not require extensive investment in either ground or airborne equipment. The ARA is the result of this development.

4.4.2 Regulatory Approval

Approved as a special procedure by the FAA in May 1981 in Advisory Circular 90-80[3], the ARA has become an operational reality for authorized operators. Application for authorization must be made by each individual operator desiring to use ARA procedures for terminal approach to an offshore heliport. Approval is based on appropriate airborne equipment installation, an approved training program, and demonstrated knowledge of the intent and limitations of ARA procedures. Requirements are presented in detail in FAA Advisory Circular 90-80.

In order to establish an ARA approach to a specific offshore heliport facility, that facility must have:

- An approved source for reporting weather
- Two-way communications, platform-to-aircraft and platform-to-shore
- A radar transponder beacon, if required for the approach

The minimum airborne component complement includes:

- An acceptable radar system as defined in AC 90-80
- A radar altimeter

Although a total of fourteen requirements for the radar system are contained in AC 90-80, principal requirements include:

- Stabilized sector scanning antenna
- Selectable ranges
- Tilt control of ±15 degrees
- Primary (and beacon mode, if beacons are required)
- Beam width of 10° or less
- Minimum range 1800 feet

4.4.3 System Costs

The modification of existing weather radar systems by two principal manufacturers have enabled operators to purchase dual (and in some cases multi) purpose units which conform to the standards required for performing ARAs. These units are priced between $17,000 and $45,000* and can provide enroute and approach navigation guidance, as well as weather avoidance information. Although this cost range may appear excessive, a standard weather radar system, standard equipment for IFR helicopters, costs approximately $15,000. The additional benfits derived for the incremental cost is significant, particularly when the potential universality of ARAs in the offshore environment is considered.

Perhaps the greatest operational problem is using a self-contained radar system as a navigation aid is the difficulty of positively identifying the destination heliport, particularly when it is located in a cluster of rigs. Positive identification can be aided by the installation of transponder beacons on the destination rig. Beacon installation is relatively inexpensive (approximately $8000) and may be required by the approving authority prior to procedure certification. Even if not required, beacon transmitters are highly recommended for positive identification of the intended landing site.

Radar sets may have a primary mode in wich only the primary return is displayed on the screen, transponder mode in which only the transponder beacon return is displayed, or a combined mode in which both transponder and primary returns are displayed. Obviously, approaches requiring the

*Radar only, price does not include radar altimeter.

use of a transponder also require airborne equipment that has transponder or combined capability.

4.4.4 Operational Considerations

Because of the lack of terrain features involved in over the water approaches, ARA minimums are low when compared to the minimums associated with onshore sites. With all equipment installed and operational, approach minimums can be as low as 200 foot ceiling and 3/4 nm visibility when approaching an obstruction-free platform. Approaches to a cluster environment may have higher minimums depending on the location and height of nearby obstructions. Although designed as a non-precision procedure, these minimums are comparable to precision approach minimums to onshore sites. Certification of ARA procedures to onshore landing sites is currently being investigated, but technical and operational problems remain due to the difficulty of radar interpretation with increased clutter associated with onshore ground returns. Even if onshore ARA procedures are eventually approved, it is expected that minimums will be raised to a level more compatible with current non-precision minimums because of the terrain variations associated with the onshore environment. Projections indicate that the primary value of the ARA procedure will continue to be in the offshore environment where traditional signal approach aids are incapable of providing the services needed.

4.5 VOR/DME RNAV

4.5.1 System Considerations

Traditional straight-in VOR and VOR/DME approaches are inherently limited by the fact that the final approach course must be aligned with either a radial or a DME arc. Thus, as the system was being deployed, most transmitters were directly associated with specific airports in order to facilitate approaches to multiple runways. As the satellite airport concept at major city centers was developed, limited range transmitters were installed to provide IFR approach service at the smaller airports. Eventually this led to a frequency congestion problem, and with the advent of metropolitan area helicopter service and the associated heliport network, it became obvious that additional transmitter implementation would no longer be a practical solution to provide the services required. The area navigation concept was being investigated for application to the enroute structure and adaptation to terminal area requirements offered an obvious solution to the approach and problem. Under this concept, receiver position data could be obtained from conventional VOR/DME transmitters and, through the use of an onboard computer, a course to a desired destination, termed a waypoint, could be calculated. Total system accuracies were shown to be equivalent to the accuracies of the associated transmitters and technological advances brought airborne equipment costs well within the range of the general aviation user. The RNAV option has been particularly attractive to corporate users in the Northeast Corridor region who typically fly from one corporate owned helipad to another. Many of these corporate users have sought and been granted approval to design and implement RNAV approaches into their private facilities.

Currently, RNAV operations, including instrument approach procedures, are approved according to criteria contained in FAA Advisory Circular 90-45A[7]. This document utilizes TERPS criteria in most aspects of the RNAV procedure criteria. However, some of the approach segment dimensions have been modified to reflect fix displacement errors unique to VOR/DME RNAV equipment.

4.5.2 System Limitations

The greatest restriction to the development of RNAV approach procedures is the requirement to have adequate low altitude VOR/DME coverage at the location of interest. Although this is generally not a problem at city center or metropolitan area locations, helicopters operating in the offshore or remote area environments are often beyond the line-of-sight limits of VOR/DME coverage even at typical enroute altitudes. This makes the RNAV approach concept unusable for these operators without the costly installation of remotely located transmitting facilities. Although this may be economically feasible when potential landing sites are in close geographical proximity, such as an offshore oil rig cluster, it is doubtful whether traffic counts would be high enough to warrant the additional expense for most remote area operations. It is expected that the RNAV approach concept will continue to be an increasingly attractive option in those areas that already have extensive VOR/DME coverage at low altitudes, such as the Northeast Corridor region and other major city metropolitan areas.

4.5.3 System Costs

In areas where adequate signal coverage is available, the additional cost for an RNAV computer ranges from $2,800 to $30,000 assuming the aircraft is already equipped for VOR/DME navigation. The cost of VOR/DME ground and airborne equipment is discussed in Section 4.1.

4.6 OTHER APPROVED APPROACH SYSTEMS

Several other types of approach procedures are contained in TERPs. These include the low frequency and medium frequency range (L/MF Range), very high frequency and ultra high frequency direction finding (VHF/UHF DF), precision approach radar (PAR) and airport surveillance radar (ASR).

4.6.1 DF Procedures

The VHF and UHF DF procedures utilize aircraft communication transmissions for guidance. Direction sensitive receivers at FAA facilities are used to locate the aircraft. Vectors are then given to the pilot by Air Traffic Controllers. These procedures are primarily used for emergency situations and they are not in general use in civil aviation.

4.6.2 Radar Procedures

The PAR and ASR procedures use ATC radar facilities to track the aircraft. The ASR facility tracks the aircraft's horizontal position only. The PAR has the capability to track the aircraft altitude as well as horizontal position. An Air Traffic Controller vectors the aircraft onto the approach path and then informs the pilot as to his position relative to the approach course. The ASR is a non-precision approach procedure, as the controller has insufficient information to provide vertical guidance to the pilot. The controller does inform the pilot of the appropriate altitude for each segment of the approach. During a PAR approach, the controller informs the pilot of his deviation from the glide path in both the lateral and vertical direction. In both procedures the controller informs the pilot of his alongtrack position with regard to the touchdown point on the runway.

The DF and radar procedures involve one or more air traffic specialists and are very labor intensive in terms of controller personnel. In addition, two-way radio transmissions are necessary throughout the approach. In general, DF and radar procedures are used only when other approach options are not available.

4.6.3 LF/MF Range

The LF/MF Range is an obsolete navigation system. The system utilizes a ground based antenna array of four or five antennas. Two of the antennas are fed a LF/MF carrier frequency modulated with the Morse Code letter A. Two other antennas are similarly modulated with a Morse letter N. The fifth antenna, if present, is used for voice modulated weather information broadcast. When the pilot is on course, he hears a steady tone. When he is off course by more than 2° to 3°, he hears either a N or A depending upon his deviation direction and the course that he is following. The LF/MF Range has almost universally been replaced by NDB and VOR facilities. Its use as a helicopter approach aid is limited to only a few (if any) special applications.

4.7 APPROVED GROUND BASED EQUIPMENT

The mainstays of the civil instrument approach navaids for the last several years are VOR, NDB and ILS. In some instances these facilities have been augmented by the use of DME. Recently procedures have been developed utilizing RNAV and ARA equipment.

Except for the ARA system using no transponder, all of these systems require ground based equipment as well as airborne receivers. The ground based equipment may be owned and operated by the Federal Government or by private operators under Part 171 of the Federal Air Regulations. Part 171 contains minimum requirements for the approval and operation of VOR, NDB and ILS facilities.

5.0 POTENTIAL APPROACH NAVAIDS

Several navaids which do not yet have general FAA approval are potentially available to helicopter operators for instrument approach procedure development. Among those which are considered in this investigation are the Microwave Landing System (MLS), Loran-C, Omega/VLF and the satellite based Global Positioning System (GPS). Of the systems named, only MLS was designed for the requirements of civil aviation. Loran-C and Omega/VLF were designed primarily for long range oceanic marine navigation, both civil and military. GPS was designed to meet military navigation and positioning requirements. All systems are now being considered for possible civil air navigation roles.

5.1 MICROWAVE LANDING SYSTEM (MLS)

5.1.1 System Description

The Microwave Landing System (MLS) is in the final stages of development and testing by the FAA. Designed to serve initially as a supplement to ILS and later as the replacement for ILS, MLS offers improvements in reliability and accuracy, as well as solutions to many of the operational limitations commonly encountered with ILS. Preliminary results of the testing program indicate that MLS is capable of fulfilling both of its roles.

Operating in the 5.00-5.25GHZ (azimuth and elevation) frequency bands, the MLS signal provides the capability of determining azimuth angle, elevation angle, and range to accuracies as good or better than any other system in use or currently under development. Proportional coverage, however, is limited to 20 nm from the transmitter, ±10 to ±60 degrees from runway centerline, and 0-30 degrees in elevation. Range limitations imposed on the developing system and a 200 channel frequency allocation will help alleviate potential frequency congestion problems when MLS becomes a commonly accepted precision approach signal source and demand increases accordingly.

5.1.2 Operational Characteristics

Because direct operational MLS experience is limited to that gained during MLS development and demonstration programs in the 1970s, many of the expected operational characteristics are based on theory rather than practical experience. The multipath problem experienced by ILS is expected to be minimized because of the scanning beam design of the MLS signal and the higher frequencies involved. Wider azimuth coverage and possible integration of the received signal into an area navigation computer will allow lateral separation of aircraft of differing performance characteristics on final approach, significantly reducing the amount of common path routing. This should logically lead to reduced intrail separation requirements during IMC and help alleviate the current congestion caused by single path ILS facilities. Finally, MLS will allow selection of the final approach glide path angle to be used for an approach, enabling vertical separation as well as lateral separation to be maintained during the final approach phase of flight.

Coincidentally, this feature will allow those aircraft capable of using higher glide slope angles to remain higher throughout the approach, thus increasing noise abatement capability.

5.1.3 System Costs

A recent implementation plan calls for the installation of 380 facilities by 1986 and approximately 1250 facilities by 2000. This plan, of course, is pending final regulatory approval of MLS by the FAA and infers a simultaneous phase-out of ILS facilities currently in use at many airports across the country. This may create a short term economic disadvantage to the general aviation user sector as they are required to refurbish avionics in order to continue to receive the same instrument approach service. Although MLS receivers are not yet in mass production and costs have not been finalized, general aviation quality MLS receivers are expected to cost between $2000 and $5000. This is a considerable increase over the $700-$1000 it now costs to add an ILS glideslope capability to a VOR receiver. When viewed realistically on a long term basis, initial user costs should be more than offset by increased service benefits, such as reduced delays at major airports and the availability of precision guidance at locations suitable for ILS installation due to unsolvable siting problems. Once equipment becomes available and the regulatory approval procedures are defined, MLS implementation should prove to be very cost beneficial from the long term perspective providing no unexpected detrimental characteristics are uncovered during operational testing.

5.1.4 MLS Limitations and Benefits

Although MLS appears to offer significant improvements over ILS for many aircraft operations, direct application to unique helicopter operations is inhibited by many of the same drawbacks that inhibit ILS application. Transmitter costs, although lower, still require relatively high traffic counts to be truly cost beneficial. Most helicopter operations cannot meet the counts necessary to justify transmitter installation costs without fixed-wing support. Antenna stability in the offshore environment is still a problem which requires costly modification for useful resolution. Probably the most beneficial environment in which MLS can be applied to helicopter operations is in the congested terminal rea environment where precision final approaches, separated both laterally and vertically, can be established for helicopter operations, thus reducing delays for all airport users, both fixed-wing and rotorcraft.

Consequently, it is the congested airport environment which is providing the basis for the initial phases of operational testing currently being conducted by the FAA, in conjunction with several commuter airlines. Although rotorcraft are not directly involved, the concept remains the same, final approach track separation between aircraft of dissimilar performance capability. If economic benefit and relief from traffic congestion can be shown for commuter aircraft, the same benefits will ultimately be available for the rotorcraft operator.

Adoption of MLS as the national standard for precision approaches offers many advantages for helicopter operators, particularly those who operate into or out of congested terminal areas during peak traffic hours. Although adaptation to remote areas and offshore environment may prove to be too costly for cost effective implementation, other operating environments will realize benefits in reduced delay times and increased numbers of dedicated rotorcraft precision approach procedures into capacity limited major hub airports.

5.2 LORAN-C

5.2.1 Background

The Loran-C radionavigation system, operated by the U.S. Coast Guard, is a wide area coverage system which has evolved from the Loran-A system. Primarily designed as a marine system, it is currently being evaluated for suitability in the aviaiton community. Areas of investigation include domestic enroute and terminal area operations, non-precision approaches, and special use helicopter and remote area operations. The results of these evaluations will determine the ability of Loran-C to meet the navigation needs of the civil aviation community. The military services have already selected the Loran-C system as the primary radionavigation signal source for several of their missions which require operations outside the range of line-of-sight signal aids. This decision is expected to remain in effect at least until the full implementation of the satellite navigation system (GPS). Originally intended to be a marine aid, Loran-C was implemented to provide coverage primarily to the coastal waters, beyond the coverage of typical line-of-sight systems. For this reason coverage over much of the interior of the continental United States is severely limited or non-existant at the present time. Although this situation is being remedied by the installation of the Great Lakes Chain, a full evaluation of reliable coverage must still be accomplished in order to identify those areas which do not have adequate signal coverage. Theoretical estimates indicate that an additional three to five transmitting stations will be required to assure complete coverage of the continental U.S., a goal which must be realized prior to full acceptance by the aviation community and selection as a primary aviation navigation aid.

Historically the high costs associated with receiver equipment has been a major factor in limiting Loran-C expansion into the general aviation market. As these costs have been reduced, interest has increased particularly in those locations where the aviation community could noc be adequately serviced by line-of-sight systems, such as the Gulf of Mexico oil fields. Initial reports indicate users were very pleased with system reliability and performance, particularly in respect to the low levels of repeatability error values. As receiver costs continue to decrease, and coverage expands, general aviation interest can be expected to become more intense. Although military use of the Loran-C system is expected to be phase out with the implementation of GPS in the middle 1990s, civil applications may well continue into the twenty-first century.

5.2.2 System Description

Operationally, Loran-C is a high technology system which uses one of two methods to determine receiver position at the rate of ten to twenty-five fixes per second. Rho-rho fixing, although more dependable in regions of minimal coverage, requires the incorporation of a highly accurate time determination device, such as an atomic clock or a temperature controlled crystal clock, for position determination. This drives receiver costs above the levels acceptable to many general aviation users. For this reason current receiver designs use the range difference or hyperbolic principle. Primary navigation using Loran-C is based on the measurement of time differences between the signals being received from widely separated but synchronized transmitting stations organized into designated groups, or chains. The signal itself is a pulsed signal transmitted in the 90-110 kHz frequency range. Each chain is assigned its own pulse group repetition rate with each station in that chain broadcasting at a unique time delay relative to the master station to prevent simultaneous signals at the receiver. The receiver measures the time differences present at its location and establishes hyperbolic lines of position (LOPs). The intersection of two LOPs determines receiver position, although, because of hyperbolic geometry, a second, ambiguous position may be established. Although transmitter site selection is based on minimizing the practical effects of this phenomenon, the establishment of a third LOP effectively resolves position ambiguity.

5.2.3 System Accuracy

Other aspects of hyperbolic geometry are instrumental in determining the magnitude of error associated with position computation, however. Typically, the most accurate position determinations can be made when the receiver is located between two of the transmitters being used for the computation. Termed the base line, this position affords the greatest rate of time difference change in relation to receiver movement, a significant factor in system accuracy. In contrast, base line extension locations (the base line extended beyond either of the two stations) affords little or no change in the time difference values as the receiver is moved, contributing no information useful to position determination. A third geometric factor to be considered in the determination of the accuracy of Loran-C fixes is the crossing angles of the LOPs used to define position. Ideal crossing angles for a two LOP fix are 90 degrees. As actual receiver position is moved further from the transitting stations these angles become more acute, decreasing system accuracy. At the outer limits of transmitter ranges these errors can be significant. The errors associated with hyperbolic geometry, categorically termed geometric dilution of precision (GDOP) errors, vary with receiver position and cannot be eliminated without the installation of additional transmitter stations.

Another type of error inherent in Loran-C navigation is propagation modeling error. Caused by the variance in propagation rates of the ground wave as it travels over different types of surfaces, its effects can be minimized by using an accurate propagation map in position determination. Improved propagation models have been developed and are being included in most new-generation Loran-C receiver units. Properly implemented, these models will significantly improve predictable accuracy values (referenced to earth coordinates) without degrading the excellent repeatability accuracies currently enjoyed at most operational locations. It is hoped by Loran-C advocates that these improvements will upgrade system performance to a level commensurate with current non-precision approach requirements at those locations not affected by minimal coverage or large GDOP errors.

At those locations where coverage is available and transmitter geometry is not a problem, Loran-C has proven to be a highly accurate radionavigation signal aid. Overall positioning accuracies have been measured in recent tests and range from 0.2 to 1.0 nm while repeatable accuracies generally range from 0.01 to .05 nm. The new propagation models discussed above will significantly increase positioning accuracies, making Loran-C a strong contender for selection as an acceptable non-precision approach aid.

5.2.4 Benefits and Limitations

The Loran-C system has the potential to be particularly beneficial to remote area and helicopter operations. Its groundwave propagation characteristics, in conjunction with the repeatable accuracy it has deomonstrated, indicate that it is well adapted to remote area operations as well as to those offshore operations currently being conducted. Coverage is good in the coastal areas of the U.S. and in many of the remote mountainous areas where coverage from traditional sources is not generally available for low altitude operations. Additionally, Hawaii and Alaska, except for the Alaskan North Slope region, have excellent coverage and studies are currently underway to determine the feasibility of extending this coverage to include the North Slope. The only area within the United States which is not adequately covered is the mid continent area, and studies are now being planned to determine the number and locations of transmitters required to affect coverage in this area.

5.2.5 System Costs

Traditionally, equipment costs associated with Loran-C have been excessively high for general civil use. The purchase and installation of a new transmitter station costs between $2,500,000 and $10,000,000. Airborne equipment currently costs from $8,000 to $15,000 per unit, but low cost receiver development may cut this cost in half once they become commercially available. In spite of these relatively high costs, operational considerations have prevailed in the offshore oil field environment in the Gulf of Mexico where Loran-C is commonly used as a VFR navigation aid. The primary reason for this operational success is the high repeatable accuracy associated with Loran-C, even in locations affected by large GDOP errors. This trait has proven to be economically valuable in those operations where a single remote destination must be returned to on a regular basis.

5.2.6 Application as an Approach Aid

Loran-C approach procedures are patterned around RNAV approach criteria. These approaches are classified as non-precision procedures because precision vertical guidance is not available from the system. No standards for approach segment sizes have yet been developed and no such standards will probably be developed until it has been demonstrated that the large bias error problems associated with propagation model errors have been solved.

5.3 OMEGA

5.3.1 Background

The Omega system is a wide area coverage system which offers coverage on a global scale regardless of receiver altitude. Designed to a 2-4 nm accuracy standard, Omega is not considered to be accurate enough for primary use in the U.S. enroute system. It has been approved as a primary source for oceanic enroute navigation and is currently being evaluated for applicability to both remote area and helicopter operations. The system consists of a planned network of eight transmitter stations located in seven different countries. At the current time seven are operational providing coverage for the Northern Hemisphere and much of the Southern Hemisphere. Three stations are operated by the U.S. Coast Guard, one by contract, while the remaining four stations are operated by their host nations. The eighth station, located in Australia, will be operated by that country when it comes on line in the near future. Because of the limited system accuracy characteristics, civil aviation application is primarily limited to transoceanic flights where Omega is used alone or with self contained sysems, such as INS. Programs, such as Differential Omega, are currently under development which may increase basic Omega accuracies, allowing the system to have a more definitive role in domestic enroute operations.

5.3.2 System Description

Omega navigation is based on phase comparison of the sky wave transmitted from station pairs. Signals are time shared on four frequencies; 10.3 kHz, 11 1/3 kHz, 3.3 kHz and a unique frequency for each station. Station identification is determined by decoding the unique sequencing of synchronized transmitted signals. Phase comparison establishes the receiver position within a wavelength, termed "lane" when referring to the navigation computation. The width of a lane depends on the frequencies being monitored and can be as narrow as 8 nm. Since the lanes have a repetitive pattern and phase comparison can only determine receiver position within a lane, the navigation unit must know where it is on the earth's surface. Early Omega equipment was plagued by a phenomenon known as lane jumping and consequently could not be trusted to compute even gross position fixes. By monitoring two or three frequencies, lanes could be significantly widened, lessening the chance of inadvertent lane jumps. Although the multiple frequency monitor capability significantly increases the cost of receiver equipment, most units on the market today incorporate this feature into their design in the interest of navigational reliability.

With the solution of the lane jump problem, the biggest contributor to Omega position fix error became propagation errors, dependent on the height of the ionosphere, which fluctuate periodically as well as randomly. Seasonal and diurnal variations are predictable and can be corrected for, but random variations can be significant and require real-time monitor and data transfer capability to be corrected. This is the basis for the Differential Omega concept currently being developed and evaluated by several regulatory agencies. Under this concept, ground monitor stations will calculate the propagation errors present and transmit corrections to nearby aircraft using Omega for navigation. The corrections will then be applied to the navigation computation process to minimize propagation errors. Proponents of this concept believe that this process will increase Omega accuracy enough for it to be considered as an acceptable domestic enroute and/or terminal area navigation aid.

5.3.3 System Accuracy

Without system enhancements such as differential monitoring and transmitting stations, the Omega system does not perform to high enough accuracy standards to be considered for a more extensive role in aviation navigation than it currenly maintains. Predictable (earth reference) and repeatable (return reference) accuracies are on the order of 2-4 nm (2 drms) and relative (two receivers simultaneously) is about 1-2 nm (2 drms). These levels of accuracy are not adequate to meet the demands of the enroute domestic airway network, particularly in congested areas. Unless an innovative concept such as VOR/DME updating is introduced into the system, Omega will continue to be relegated to the oceanic enroute environment where the absence of other radio navigation signal aids provides a permissive atmosphere for a recognized global coverage system.

5.3.4 Systems Costs

Perhaps the most inhibitive factor contributing to the reluctance of the general aviation user to accept Omega is cost. Although installation of a transmitter station costs approximately $10,000,000 there are only a limited number of stations required to obtain world wide coverage (eight in the current system) and this cost is relatively low when the whole system is considered. Receiver equipment, on the other hand, is quite expensive. The lowest priced airborne Omega system. being offered in today's market cost approximately $30,000 per unit. Unless frequent transoceanic flights are accomplished, user equipment costs are far in excess of that which the typical general aviation user is willing to pay. Although differential navigation equipment has not yet been produced in quantity, it is expected that this concept will add about 5% to 10% to the cost of a typical Omega receiver unit.

Some enroute procedures utilizing Omega/VLF guidance for determining descent points have been developed for offshore helicopter operators. Such procedures are possible due to the lack of obstructions in the offshore environment. These procedures are described in detail in Section 7.3.5.

Omega is currently being evaluated for application to offshore and remote area helicopter requirements. Regardless of the technical conclusions drawn from this evaluation, the cost factor must be considered to be a major influence on acceptance in these environments. In spite of the global nature of Omega coverage, there are only limited helicopter operations to which Omega navigation can be applied.

In summary, the Omega system as it is presently configured meets the needs of some segments of the aviation community. However, because of the high cost of user equipment and the general availability of alternative signal source coverage in the localities serviced by helicopter operations, Omega cannot, at this time, be considered as a cost effective option for helicopter instrument approach applications except in circumstances where no other navigation solution is available.

5.4 NAVSTAR GPS

5.4.1 Background

Based on satellite technology, the NAVSTAR Glogal Positioning System (GPS) has been described as the navigation system of the future. Whether it will live up to this billing is yet to be determined. Designed primarily as a military system, it is hoped that spin-off benefits will be available to civil aviation users. Several barriers, both technical and regulatory, stand in the way of acceptance of GPS as the sole radionavigation signal source, however. Because it will be operated as a global military system, dependable civil availability may be questionable particularly during periods of international tension. This is particularly troublesome to ICAO, the International Civil Aviation Organization. It is highly unlikely the United States will adopt a national standard navigation system which is not endorsed by ICAO. Even on a national basis, technical barriers exist which will inhibit GPS acceptance as a civil system. Current plans are to transmit two signals from each satellite transmitter. The first will be available to civil aviation but will be designed to reduced accuracy standards. The second signal will contain encoded correction factors which will be made available only to military receivers. Current estimates indicate that the civil signal will be adequate for enroute and possibly non-precision approach operations but will not be accurate enough to be used as a precision approach aid. These estimates are based upon data collected from the limited complement of satellites which are currently operationally deployed (six satellities) and will be periodically updated as new satellite transmitters are added to the system.

5.4.2 Potential System Benefits

If the barriers to civil acceptance can be overcome, GPS offers the potential to be very beneficial to a wide variety of low altitude civil operations, particularly those operations commonly associated with rotorcraft. Two of the primary shortcomings associated with current navigation systems, line of sight range limitations and naturally occurring propagation errors, have been eliminated or at least minimized in the GPS concept. Coverage, with a full complement of satellite transmitters, will be global and system capacity is virtually unlimited. Because of the system concept, frequency congestion will also not be a concern. System accuracy estimates, although preliminary in nature, are, at a minimum, comparable to those associated with systems currently being used by helicopter operators in remote area and offshore environments. If accepted for civil use, GPS appears to be highly adaptable to the needs of helicopter operators.

5.4.3 System Costs

Equipment costs are currently an unknown entity. Estimates of the cost of receiver units range from $4000 per unit to $100,000 per unit. It is generally expected that final costs will realistically be approximately $25,000 per unit in a GPS oriented environment where the effects of mass production can be most influential. Although this cost may not be excessive in a unique commercial environment, such as that encountered in offshore support operations, many operators who found the VOR/DME system entirely adequate for their purposes, will be hesitant to endorse a national standard navigation system requiring this level of financial investment. Manufacturers are currently attempting to develop GPS receiver units which are priced more compatibly with VOR/DME receiver units. Unless this development effort is successful, general acceptance of GPS by the civil aviation community is very uncertain.

5.4.4 Implementation Plans

Current implementation plans call for GPS to be operational for military use in 1976. Civil application of the system will depend on the results of military operational evaluations and the decisions of national and international regulatory agencies. Acceptance for civil use should not be realistically expected prior to 1995 under the most optimistic of circumstances. Thus, although GPS displays the potential to alleviate many of the problems faced by helicopter operators in today's navigation environment, it must be considered as a potential long term system which will not be available in the short term.

5.5 ILS TYPE APPROACH PROCEDURES

A limited number of civil approach procedures have been developed utilizing the interim standard microwave landing system (ISMLS) and landing systems derived from military equipment. Generally, these systems have only been approved in instances when technical limitations inhibit the use of an approved approach and landing system. It is expected that these systems and procedures will no longer be approved now that the MLS system is achieving international approval.

The approach procedures utilizing these systems are the same or very similar to ILS procedures. The main operational advantage of these systems comes from the fact that by operating in the microwave frequency band, site related problems are considerably reduced. This fact made possible the placement of these systems in mountainous areas and other areas where ILS siting was impossible. MLS also provides additional benefits in terms of operational flexibility.

Since these procedures are being phased out, these systems will not be discussed in any further detail.

5.6 SUMMARY

On a short term basis only Loran-C and MLS appear to offer any immediate solutions for the helicopter operator. Widespread implementation of MLS is probably several years away but it does offer near term availability in congested terminal areas where its implementation can be justified on the basis of traffic levels, or as a non-federal navigation aid installed and operated under Part 171 of the FARs.

Omega/VLF is not sufficiently accurate by itself for approach applications. Airborne equipment is also quite expensive. Improvements in technology utilizing VOR/DME, Differential Omega, or some other means for updating offer some possibilities for this system. These improvements are yet to be operationally demonstrated, however.

GPS offers considerable promise for long term, accurate global coverage navigation. However, its full implementation and operational approval are still several years away.

6.0 PILOT PREFERENCES IN AN OPERATIONAL OFFSHORE ENVIRONMENT

Support of new oil fields off of the New England Coast is often compared to operations in the Gulf of Mexico. Poor flying weather will be a much more significant aspect in the North Atlantic than it was in the Gulf, however. A more realistic view of potential problems can be gained by comparison to the North Sea operations being conducted in Europe. North Sea weather and sea conditions are similar to those to be expected in the North Atlantic and the experience gained by European helicopter operations can be beneficially applied to New England coastal operations. Primary navigation systems in the North Sea include non-directional beacons, VOR, DME, OMEGA, DECCA and airborne radar approaches. These are the same systems which are expected to be operational in the New England environment with the exception that Loran-C will be available in place of DECCA. A recent survey by Ralph R. Padfield[2] reported in Rotor and Wing magazine, has been the basis for a subjective investigation into pilot acceptance of the various North Sea navigation and approach systems. This section presents the results of that survey.

6.1 THE SURVEY

A questionnaire was distributed to the 130 pilots of Helicopter Service A/S in a effort to compile a subjective evaluation of the navigation systems used in daily operations. Thirty-five of the pilots polled responded, a return of 27%, which is not unusual for return rates on unsolicited surveys. Responses were constructive and it was felt that the results were valid even though somewhat limited in sample size. Airborne equipment being evaluated included: the GNS-500A Omega receiver, used for enroute navigation; the Bendix RDR 1400 weather radar and an associated radio altimeter, used for offshore approaches; and King VOR, ILS, DME and ADF receivers, used for onshore and limited offshore operations. The ADF receivers were also occasionally used as an offshore approach aid if the other nav equipment was providing reliable indications.

Each system was rated for accuracy, reliability and ease of operation under operational conditions. Accuracy was defined as the percent of the time that the system being rated was 100% accurate and reliability was defined as the percent of the time that the equipment was operational. Ease of operation was presented on a rating scale from 1 to 5 with increasing value indicating increasing difficulty. Although these definitions are vague when compared to the definitions normally used for research and development flight test efforts, they have the operational orientation necessary for a survey of this type. In addition to the rating scales, several specific questions were asked of each survey participant. These included opinions as to the best and worst characteristic of each component evaluated and which of the components could be taken away and have the smallest effect on flight operations.

This survey, although not technically sophisticated, is well suited for gathering the subjective opinions of operational pilots. Since they are the individuals who have direct practical experience using these systems, their preferences are extremely valuable as major inputs to future implementation decisions.

6.2 RESULTS OF THE NORTH SEA SURVEY

The response from the survey of the helicopter pilots indicated overall satisfaction with the navigation systems which they were using in their day-to-day operations. Of those who had previously used DECCA and/or Loran-C consensus indicated that DECCA was less desirable and Loran-C was more desirable than the Omega system that was rated. Among other suggestions for navigation improvements were platform installation of VOR and DME transmitters or beacon transponders. Suggestions for future improvements included NAVSTAR and MLS implementation, as well as numerous avionics improvements such as cathode ray tube (CRT) cockpit displays.

The results of the system ratings are shown in Table 6.1. DME was rated the best in both accuracy and ease of operation while VOR/ILS was rated best in reliability. Of the systems commonly associated with offshore operations, (ADF, weather radar, and Omega), weather radar was rated best for accuracy and reliability while ADF was rated highest in ease of operation. The Omega system was rated lowest overall for all three rating categories. In response to the question concerning the most important navigation system for overall operations, the weather radar system was named most often and the DME system was not mentioned at all.

In addition to the competitive ratings between systems, each respondent was requested to list characteristics of each system which demonstrated both strong and weak points of the system. These characteristics are presented in Table 6.2. Although some exceptions can be found, this characteristic analysis is indicative of the same trends found in the rating scale analysis. Perhaps the greatest discrepancy can be found by comparing the results of the Omega system. Rated last in both accuracy and ease of operation, both of these characteristics were given as strong qualities in the characteristics analysis. Most of the responses show strong correlation tendencies between the two analyses.

Because of the limited nature of this survey, specific conclusions with universal implications cannot be drawn. In spite of this limitation, subjective trend indications can be ascertained. The VOR/ILS systems are very highly regarded by the respondents but the line-of-sight limitations inherent in these systems make them economically impractical for offshore application. Airborne Radar Approaches (ARA) are also very highly regarded as an offshore supplement to onshore VOR systems. The accuracy of both the Omega and the ADF systems, the two systems involving the minimum level of cost outlay for ground station installation, is suspect in the minds of many of the respondents. Thus, this survey indicates that for the typical North Sea offshore pilot the VOR/ILS coupled with an ARA capability is the most ideal navigation complement for offshore support operations.

Table 6.1 Table of Survey Results

ACCURACY

Question: What amount of time is the equipment 100% accurate when all of its components indicate they are working properly?

	OMEGA/VLF	WxRadar	VOR/ILS	DME	ADF
Mean*	71.8%	94.6%	95.0%	97.0%	70.7%
Mode**	50%	100%	100%	100%	80 and 90%
Range***	30-100%	70-100%	50-100%	75-100%	50-100%

RELIABILITY

Question: What amount of time is the equipment operational?

Mean	81.5%	95.1%	95.9%	91.4%	94.6%
Mode	95%	95%	98%	98%	95 and 98%
Range	45-98%	75-100%	70-100%	40-100%	70-100%

EASE OF OPERATION

Rate the ease of operation (Rating Scale 1 to 5; 5 most difficult)

Mean Value	2.40	1.97	1.37	1.14	1.57

* Mean - average of all responses
** Mode - most responses
*** Range - minimum and maximum responses

Tabel 6.2 Characteristics of Nav Systems

Question: What are the best and worst characteristics of each component?

	Best Characteristics	Worst Characteristics
OMEGA	1. Amount of information available 2. Relative ease of operation 3. Accuracy when working properly	1. Reversion to DR in heavy percipitation 2. Difficulty of inflight initialization
WxRadar	1. Application to IFR approaches 2. Good "picture" 3. Reliability 4. Accuracy	1. Screening by heavy precipitation 2. Too much sea clutter 3. Target disappears at close range
VOR/ILS	1. Accuracy 2. Bad weather performance	1. Line-of-sight limitation
DME	1. Accuracy 2. Ease of operation	1. Line-of-sight limitation
ADF	1. Long range 2. Many transmitters	1. Inaccuracy 2. Constant fluctuation 3. Dependence on ground station power output 4. Non-precision approach minimums

7.0 "HELICOPTER ONLY" APPROACH PROCEDURE SUMMARY

Since the development of "Helicopter Only" instrument approach criteria in the mid 1970s many such procedures have been approved and become operational. A survey of the current procedures was performed and their characteristics were evaluated on several different levels.

7.1 SURVEY OBJECTIVES

Several objectives were considered in the survey. The following parameters were deemed to be significant:

- Type of navaid used
- Number of each type of procedure
- Location
  - onshore
  - offshore
  - geographical area
- Height above threshold (HAT) or height above landing (HAL)
- Visibility minimums
- Patterns and trends associated with procedures

7.2 DATA SOURCES

"Helicopter Only" instrument approach procedure data was obtained from several sources. The first was responses to a request for instrument approach procedure information from FAA Regions requested by FAA Systems Research and Development Service. The data obtained in this survey were copies of Special Instrument Approach Procedure, Form 8260-7. The information contained on this from is the raw data used by aviation charting agencies to produce the instrument approach procedure charts.

The second source of data was a review of Flight Information Publications (FLIPs) for Low Altitude Instrument Approach Procedures published by the U.S. Department of Defense. The U.S. Coverage series contains charts for public approaches to civil and military airfields in the 48 conterminous states.

The regional responses and FLIP charts were supplemented by charts obtained directly from U.S. helicopter operators who were known to have obtained approval for special approach procedures. In one instance a Canadian operator was contacted because this organization was utilizing a type of microwave landing system equipment. Its use presented a unique opportunity to obtain data on a system which has potential application to some helicopter operations. This equipment differs from the Standard Microwave Landing System recently adopted by ICAO.

The data obtained in the survey were cross referenced to a list of helicopter procedures maintained at the FAA Headquarters in Washington, D.C. Most procedures contained on the list were obtained by one or more of the survey methods. Occasionally procedures not on the list were obtained in the survey. The differences between the list and the procedures obtained are generally due to the fact that the list was prepared at a later date than the regional survey was performed. The differences are not considered to be significant as far as affecting the results of the survey analysis.

7.3 ANALYSIS AND RESULTS OF THE SURVEY

From the survey 74 "Helicopter Only" approach procedures were obtained. Of these 74 procedures, 53 were designed for use at civilian airfields or offshore platforms and 21 were designed for military or U.S. Coast Guard facilities. Of the 53 civil procedures, 22 are to offshore platforms, drill rigs or drill ships, and 31 are to landside heliports or airports.

In addition three enroute descent procedures for offshore areas were obtained. These procedures have approach procedure characteristics and were considered in the analysis. Also, two procedures using MLS in Northern Canada were included due to their unique application.

7.3.1 Offshore Approaches

Of the 22 offshore approaches 5 had two values for minimum descent altitude depending upon the availability of airborne radar. In the analysis of HAT data and the types of procedures these approaches were considered as two separate procedures because they used different equipment and had different minimums. Therefore the addition of these brings the total offshore procedures to 27. These approaches are categorized as follows:

Location	Number
Alaska North Slope	3
Gulf of Alaska (including inlets)	19
Alaska (specific location not listed)	5
TOTAL	27

Approach Type	No.	Average HAT	HAT MIN	HAT MAX
ARA-R-ALT	7	141 ft	107 ft	200 ft
TACAN/ARA	1	287	-	-
NDB/DME/ARA	4	344	327	369
TACAN	1	427	-	-
VOR/DME	5	463	406	485
NDB/DME	4	494	487	509
NDB	5	534	506	569

Visibilities

All 27 offshore procedures had visibility minimums of 0.5 mile.

It is interesting to note that all of the offshore approach procedures are found in the State of Alaska. Discussion of this point with FAA and operational personnel produced the following explanation.

ARA approach procedures are used in the Gulf of Mexico and in the Atlantic offshore areas. However, the radar is used as a VFR aid rather than as an instrument approach aid. Enroute descent procedures utilizing VOR, NDB, Omega/VLF or Loran-C along with radar altitude have been used for several years in the CONUS offshore. These procedures have been approved with minimum altitudes as low as 400 ft above the water. This low altitude plus the assistance of airborne radar to help locate obstructions and to identify the rigs allows the aircraft to proceed VFR to the landing area from the enroute descent altitude.

It is also of interest to note that several approach procedures were often available at the same rig or drill ship. Five of the offshore areas had more than one approach procedure. One drill platform, the Ocean Ranger, had six different HAT values for the various type of procedures. They were as follows:

Type of Navaid	HAT
ARA - radio altimeter	107 ft
TACAN - ARA	287
NDB-DME-ARA	327
TACAN*	427
NDB - DME	487
NDB	627

The 3 North Slope approaches have characteristics of both offshore and landside procedures. The heliport is not located on the rig but rather on land near the rig. An NDB procedure, utilizing an on-airport facility, and a VOR/DME procedure, utilizing a facility 21 miles to the west at Deadhorse, both have landside characteristics. However, an ARA procedure to the heliport has been developed. This procedure is designed to have the final approach course into the wind. The following conditions are imposed on the operator:

1) The rig is identified by the NDB at the heliport or a radar beacon transponder on the rig.

2) Final approach course is identified and confirmed using the NDB.

3) The final approach course from the 2 nm radar fix to the MAP shall use minimum range and scan positions on the radar.

4) The procedure requires an operating radar altimeter.

5) In the event of a radar failure a missed approach must begin immediately.

6) Either beacon or primary radar mode may be used during final approach.

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*The platform has been destroyed since the survey was performed. According to the manufacturer there are presently no plans to re-establish the TACAN system on other platforms.

Of these six conditions, items 1 and 6 differ from the other six ARA procedures with reference to the ground based beacon transponder. Use of this device assures the flight crew of positive identification of the rig. The potential problem of misidentification of the rig from a false target using the primary radar mode is circumvented by use of the transponder.

The offshore NDB, NDB/DME and NDB/DME/ARA approach procedures had some characteristics of ARA Radar Altimeter approaches. The primary similarity was that of the final approach direction being into the wind. The NDB procedure began by overheading the facility flying outbound at the minimum enroute altitude and on a bearing offset 15° from the reciprocal of the final approach course. A procedure turn is made at a time determined distance from the facility and the aircraft is turned to intercept the final approach course. Descent to MDA is made after the procedure turn is complete. The MAP is the NDB facility.

For the NDB/DME and NDB/DME/ARA procedures the initial approach is typically made on a 4 nm DME arc to intercept the final approach course. The arc may be flown in either direction. The MAP is identified by a 0.5 nm DME fix and confirmed by radar. If radar is not available, a higher MDA is required. The HAT based on radar is a 300 ft altitude based on NDB procedures plus the height of obstructions in the final approach area. In offshore areas this may be maximum wave height. It is assumed that ships and other rigs can be avoided by use of the radar. The HAT without radar is based on the 300 ft NDB obstacle clearance plus the height of the rig which is the tallest obstacle in the final approach areas.

7.3.2 Landside Civil Approaches

The landside approaches designed for civil operations totaled 31 in number. The location and type of approaches are as follows:

Location	
Alaska	1
Gulf of Mexico Area	10
Northeast Corridor	20
TOTAL	31

Approach Type	No.	Average HAT	HAT MIN	HAT MAX
NDB/DME	1	348	-	-
VOR/DME	10	352	290	520
RNAV (PIS)	10	502	300	620
VOR/DME - ARC	1	515	-	-
RNAV	9	560	411	768

(PIS) - Point in Space

Visibility

Of the 31 approaches 14 had limits of ½ mile and 17 had limits of 3/4 mile.

The NDB/DME approach is located in Alaska at Yakataga on the Gulf of Alaska. This procedure has a very low HAT of 348 ft for an NDB procedure. This minimum is only 48 ft above the 300 ft minimum required by NDB procedures. This procedure had a ½ mile visibility limit.

All but one of the VOR/DME and VOR/DME-ARC approaches were found in the Gulf of Mexico area to provide IFR capabilities for helicopters returning from the offshore area. The remaining approach was for Atlantic City, New Jersey and served the same purpose. The arc procedure is from Intercoastal City, Louisana and is shown in Figure 3.14. The HAT values are generally typical of VOR/DME and VOR/DME-ARC approaches. The New Jersey procedure had a 3/4 mile visibility limit. The remainder of the procedures had ½ mile limits. All 19 of the RNAV approach procedures were in the northeastern U.S. These approaches had initial approach waypoints which are a part of the Northeast Corridor RNAV route (Reference 11). The point in space approaches are to MAPs that are greater than 2600 ft from the airport. Regular RNAV approaches have MAPs closer than 2600 ft. Visibilities for the former must be at least 3/4 mile which was the value found on all 10 of the RNAV (PIS) procedures from the survey. Visibilities for the regular RNAV approaches ranged from ½ mile (3) to 3/4 mile (6).

7.3.3 Military Approach Procedures

Twenty one approaches to military airfields and U.S. Coast Guard stations were surveyed. These approaches were from the following states:

California	8
Alabama	3
Washington	2
New Jersey	2
Michigan	1
Montana	1
Tennessee	1
G_orgia	1
Florida	1
Pennsylvania	1
TOTAL	21

These approaches used the following navaids and had the following HAT values:

Approach Type	No.	Average HAT	HAT MIN	HAT MAX
TACAN	10	401	258	874
VOR	7	416	359	535
NDB	4	736	539	1274

Visibilities

The visibility values for the 21 military airfields breakdown as follows:

½ mile	-	18
3/4 mile	-	1
1 mile	-	2

The 3/4 and 1 mile limits are due to large HAT values which automatically increases visibility limits as described in Section 3.9.8.

These 21 approaches are generally typical of TACAN, VOR and NDB procedures. The terrain at some location was quite rugged which generally causes significant increases in HAT values. The major benefit to be gained by using Helicopter Only procedures in these areas is to shorten the lengths of intermediate, final and missed approach segments and to use the reduced visibility criteria. Shortening the segments may permit lower MDA/HAT values because some obstacles may fall outside areas otherwise required by standard procedures. Helicopter Only procedures also can use steeper descent and climb gradient values to advantage in reducing MDA/HAT values.

7.3.4 Co-Scan MLS Approach Procedures

During the survey of operators that use Helicopter Only procedures a set of approach procedures to a Canadian North Slope airport using a Co-Scan microwave landing system were obtained. Although these procedures are for an area outside the U.S. and the navaid is not the recently adopted ICAO Standard MLS the procedure represents an interesting data point relative to the use of private precision approach facilities.

The navigation aids required for this procedures consist of a MLS localizer/glidepath and a DME facility. The MLS localizer is used to generate left/right steering signals and the glide path provides vertical guidance. The DME is used to generate a 8 mile arc for entry into the procedure, and it is used to define the intermediate fix and final approach fix. It is also used to define the missed approach point when the glide path is inoperative. In this case the approach became a MLS-localizer/DME procedure. A MLS-localizer/DME approach is also available for the reciprocal runway. The following data was obtained concerning the MLS procedures:

Location

Tucktoyaktuk, N.W.T., Canada

Approach Type	No.	Average HAT	HAT MIN	HAT MAX
MLS/DME	1	200	-	-
MLS-LOC/DME	2	341	300	382

Visibility

Helicopter visibility minimums for the MLS/DME procedure is ¼ mile. Visibility minimums for the localizer/DME procedures is ½ mile.

The MLS/DME and MLS-localizer/DME procedures are essentially the same as conventional ILS procedures. The flat terrain in the North Slope region permit the use of low ceiling and visibility minimums. The MLS/DME approach procedure is shown in Figure 3.19.

7.3.5 Enroute Descent Procedures

Prior to the development of the ARA procedure some offshore operators developed what is called an Enroute Descent Procedure. These procedures require the use of an enroute navigation aid plus airborne radar and radar altimeter. The aircraft is flown to an enroute fix using the enroute navaid, such as VOR, Omega/VLF or Loran-C. This fix is typically located about 15 to 20 nm from the destination. Navigation is then switched to the magnetic compass and airborne radar to identify and avoid obstacles such as other rigs and ships. At the 5 nm range to the destination final descent to 400 ft agl is initiated. An enroute descent procedure to an offshore platform near Atlantic City, New Jersey is shown in Figure 3.18.

The radar observer continues to direct the pilot to the rig on an offset course that assures adequate separation between the aircraft, the rig and ships operating in the area. The procedure takes the aircraft within the visibility limit of the procedure which is usually ½ mile day time and 1 mile at night. If the destination is not seen acquired visually, a missed approach procedure is performed and the aircraft returns to the enroute fix and climbs to the enroute altitude.

In the course of the survey three enroute descent procedure were obtained. The following pertinent data were analyzed:

Locations

Atlantic City, New Jersey
Jacksonville, Florida
Morgan City, Louisiana

Minimums

All procedures have day time minimums of 400 ft ceiling and ½ mile visibility. At night the visibility criteria is increased to 1 mile. On the Atlantic City route minimums of 200 ft and ½ mile can be utilized with additional requirements placed on the crew and the aircraft equipment. This minimum is identical to those available with the ARA procedure.

7.4 SURVEY SUMMARY

The minimum ceiling and visibility data for all approach procedures used in the survey were analyzed to determine the average HAT value, the minimum HAT, and the maximum HAT by procedure type. The results of this analysis are shown in Figure 1.1. In total, 85 sets of minimums were considered. The survey includes the Canadian MLS approaches and the enroute descent procedures.

It is of interest to note the rank in terms of average HAT value closely follows the rank in terms of minimum altitude above obstructions in the final approach area as discussed in the approach criteria in Section 3. The ARA and MLS procedures have the lowest minimums and NDB procedures have the highest. In between lie the VOR, VOR/DME and TACAN procedures.

In the analysis of visibility data most procedures were able to achieve ½ mile minimums. A few, primarily the RNAV Point in Space procedures, had 3/4 mile minimums, and a limited number of procedures required 1 mile visibility. The MLS/DME procedure had a ¼ mile visibility limit. The actual numerical breakdown is:

¼ mile	-	1
½ mile	-	64
3/4 mile	-	18
1 mile	-	2

The visibility data is plotted on the histogram shown in Figure 1.2.

8.0 CONCLUSIONS

The study program was primarily a survey of approach procedure criteria and current approach procedures. The results and analyses of the survey produced the following conclusions concerning instrument approach procedures for helicopter operations.

8.1 INSTRUMENT APPROACH REQUIREMENTS

1. Approach procedures must provide obstacle avoidance throughout the instrument part of approach and missed approach. This produces a requirement for the procedure to provide for:

   - approach cause guidance (lateral control)
   - fix identification (along track control)
   - vertical guidance (vertical control)

2. In the offshore environment there is an additional requirement to identify and avoid ships which may be operating in the approach airspace. This requirement can be satisfied through the use of altitude minimums that consider the tallest ships operating in the area or with airborne radar equipment.

3. Highly accurate navigation systems, such as ILS and MLS, can potentially be used to reduce aircraft separation criteria below ATC surveillance radar limits in congested terminal area operations. This is currently being done through the use of simultaneous ILS approach procedures to parallel runways separated by 400 ft or more. Similar procedures using the proportional coverage capability of MLS could provide independent helicopter approach paths to metropolitan airports.

8.2 APPROACH PROCEDURE CRITERIA

1. Ranked first in terms of minimum altitude over obstacles and second in terms of final approach segment width at the missed approach point the following list is obtained:

   Rank (lowest to highest minimums)

   ILS
   ARA
   VOR with final approach fix
   VOR/DME
   TACAN
   RNAV
   VOR without final approach fix
   NDB with final approach fix
   NDB without final approach fix
   VOR/DME-ARC

2. Minimum visibility requirement with no approach lighting credits for helicopter approach procedures is ½ mile for all approach procedures except point in space approaches which is 3/4 mile. From a practical standpoint however, most landing areas either have lighting to achieve the ½ mile criteria, or if they have no lighting, they have visibility minimums greater than ½ mile. Visibility requirements increase with high altitude minimums. For height above the landing area (HAL) values of 601 to 800 ft the visibility minimum is 3/4 mile. For HAL values exceeding 800 ft, the visibility criteria is 1 mile.

3. Minimum length of the intermediate and final approach segments for most straight in, non-precision helicopter procedures is 1 nm each. Optimum length of the intermediate segment is 2 nm. The minimum and optimum length of the final approach segment for ILS procedures is 2 nm and 3 nm respectively.

8.3 NAVIGATION AID CHARACTERISTICS AND COSTS

1. The following navigation aids can be used to provide instrument approach procedures as defined in the TERPS document:

   ILS
   VOR
   NDB
   DME
   TACAN
   Localizer

2. The VOR/DME RNAV system and Airborne Radar equipment may provide instrument approach procedure capability as defined in FAA Advisory Circulars 90-45A and 90-80, respectively. The radar system can only be utilized in the offshore areas.

3. The following navigation systems have no prescribed methods for obtaining instrument approach procedure approval at the present time:

   Loran-C
   ARA to land-based heliports/airports
   Omega/VLF and Differential Omega/VLF
   MLS (standards are in development)

4. Omega/VLF systems that do not automatically update with VOR/DME have not been shown to be sufficiently accurate for instrument approach procedures. Loran-C equipment has been shown to provide highly consistent performance. However, some tests have shown bias errors and potential problems involving signal reception in high noise environments and precipitation static conditions. These potential problems have limited Loran-C use to specialized enroute operations at the present time.

5. The following airborne navigation equipment are ranked in order of increasing cost:

Equipment	Cost Range
NDB with localizer	$1,500 - $7,000
VOR	$1,500 - $7,000
VOR with localizer and glideslope	$2,200 - $7,200
DME	$2,500 - $12,000
VOR/DME with RNAV	$6,800 - $45,000
Loran-C	$8,000 - $15,000
TACAN	$9,000
Airborne Radar/Radar Altimeter	$19,000 - $57,000
Omega/VLF	$30,000 - $60,000

6. The following ground based navigation transmitters are ranked in order of increasing cost:

Transmitter	Equipment Cost Range
Radar Transponder Beacon	$8,000 - $10,000
NDB	$8,600 - $33,000
DME	$50,000
VOR	$100,000
ILS	$260,000 - $430,000
Localizer	$150,000 - $200,000
Glideslope	$80,000 - $200,000
Marker Beacon	$30,000
TACAN	$150,000 - $600,000
Loran-C	$10,000,000/station (full size) $2,500,000/station (mini)

Site preparation, installation, flight inspection and annual maintenance costs are not included in these cost estimates. These costs can vary considerably from site to site and can often equal or exceed the equipment costs.

8.4 SURVEY RESULTS

1. The survey of North Sea helicopter pilots indicated that their preferences for approach aids were:

   offshore - airborne radar with radar altimeter
   landside - ILS or VOR procedures

   (The survey covered only a limited number of pilots with experience on a limited number of landing aids)

2. The survey of current civil Helicopter Only approach procedures had the following geographical characteristics:

Location	Approach Type
Alaskan Offshore	ARA/radar altimeter NDB/DME/ARA NDB/DME NDB
Gulf of Mexico Offshore	Enroute Descent/ARA
Atlantic Offshore	Enroute Descent/ARA
Gulf of Mexico landside	VOR/DME VOR/DME Arc
Northeast Corridor	RNAV RNAV (point in space)

3. The survey of current military Helicopter Only approach procedures indicated that TACAN, VOR and NDB procedures were used at various locations throughout the military airfields in CONUS

4. Actual altitude minimums for the approach procedures in the survey correlated closely with the minimum altitude criteria ranked in Section 8.2, Paragraph 1. The minimum altitude ranged from a low of 107 ft for an ARA/radar altitude offshore approach to a high of 1274 ft for an NDB procedure. Height-above-landing-area values were:

Procedure Type	Average HAT/HAL
ARA	141 ft
MLS/DME	200 ft
TACAN/ARA	287 ft
MLS-LOC/DME	341 ft
NDB/DME/ARA	341 ft
VOR/DME	389 ft
TACAN	403 ft
VOR	416 ft
NDB/DME	464 ft
RNAV (PIS)	502 ft
VOR/DME ARC	515 ft
RNAV	560 ft
NDB	624 ft

5. Of the 85 values for visibility minimums in the survey the minimums ranged from ¼ to 1 mile. The count of each visibility value was as follows:

Visibility Minimum	Number	Percent
¼ mile	1	1.2%
½ mile	64	75.3%
3/4 mile	18	21.2%
1 mile	2	2.3%
Total	85	100.0%

8.5 SUMMARY OF CONCLUSIONS

Offshore

1. For offshore approaches lowest altitude minimums can be achieved through the use of airborne radar/radar altimeter approach procedures. The main disadvantages of this procedure is the expense of the airborne equipment which can cost from $19,000 to $57,000 plus installation. This procedure requires two pilots. In areas with clusters of rigs a radar transponder, costing between $8,000 and $10,000, may be necessary to aid in identifying the destination. Using radars with beacon capability increases the airborne cost to at least $39,000.

2. The lowest cost offshore approach aid is an NDB. Ground station equipment cost for an offshore NDB is $8,600 to $13,300. Airborne equipment cost for this procedure is $1,500 to $7,000. The main disadvantages associated with this system is frequency congestion in the NDB MF band and the relatively high minimum descent altitudes.

3. The most promising and lowest cost non-approved navigation system that shows promise for use as an offshore approach aid is Loran-C. Airborne equipment costs are approximately $8,000 to $15,000 uninstalled. Ground system equipment would be a monitor receiver on the rig or a capability to receiver system status information from a monitor site.

Landside

1. For land approaches the minimum cost approach procedures are those which can be constructed from existing navigation facilities.

2. Approaches with the lowest altitude minimums usually utilize ILS ground facilities. MLS procedures will be able to achieve the same or lower minimums and criteria should be available in the near future.

3. The most promising and lowest cost non-approved navigation system for remote areas and areas not served by existing navigation aids is Loran-C. However this system may not be available in the mid-continent area of CONUS and on the Alaskan north slope. The system also has potential bias error problems and there is insufficient data available regarding operation in precipitation static and high noise conditions.

4. Differential Omega may have potential application for non-precision approach is remote areas. There is insufficient data available to develop approach procedure criteria at this time.

REFERENCES

1. Anonymous, "United States Standard for Terminal Instrument Procedures (TERPS)", FAA Handbook Number 8260.3B, Federal Aviation Administration, Washington, D.C., July 1976.

2. Ralph R. Padfield, "How Do North Sea Pilots Rate Their Navaids?", Rotor and Wing International, Peoria, Illinois, September 1981.

3. Anonymous, "Approval of Airborne Radar Approach (ARA) Procedures for Helicopters to Offshore Platforms", FAA Advisory Circular 90-80, Federal Aviation Administration, Washington, D.C., 1981.

4. L.D. King and R.J. Adams, "Airborne Radar Approach System Flight Test Experiment", Report Number FAA RD-79-99, prepared for the Federal Aviation Administration, Washington, D.C., prepared by Systems Control, Inc. (Vt), West Palm Beach, Florida, October 1979.

5. L.D. King, "Airborne Radar Approach Flight Test Evaluating Various Track Orientation Techniques", Report Number FAA-RD-80-60, prepared for the Federal Aviation Administration, Washington, D.C., prepared by Systems Control, Inc. (Vt), West Palm Beach, Florida, June 1980.

6. Donald P. Pate and James H. Yates, Ph.D., "Airborne Radar Approach FAA/NASA Gulf of Mexico Helicopter Flight Test Program", Report Number AFO-507-78-2, Federal Aviation Administration Office of Flight Operations, Washington, D.C., January 1980.

7. Anonymous, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System", FAA Advisory Circular 90-45A, Federal Aviation Administration, Washington, D.C., February 21, 1975.

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