APPENDIX D. INSTRUMENT FLIGHT PROCEDURES

1. GENERAL. This appendix contains obstacle clearance requirements for RNAV instrument flight procedures. Section I provides guidelines which are applicable to all RNAV procedures. Section II discusses the concept of 3-D RNAV only. Obstacle clearance requirements will be included in the U. S. Standard for Terminal Instrument Procedures (TERPs).

   a. Approval of RNAV procedures will be based on FAA capability to provide service, anticipated volume of traffic, and compatibility of the procedure with existing airways, routes, traffic and procedures.

   b. All approved area navigation routings and procedures will be assured adequate signal coverage and frequency protection. Those approved for public use will be published in the United States government flight information publication enroute and terminal charts, FAR's and/or Airman's Information Manual (AIM).

   c. Pilots should refer to AC 90-63, "Air Traffic Control Procedures for Random Area Navigation Routes" to insure correct use of off-airways routes.

   d. RNAV routes which require VOR/DME inputs will be provided uninterrupted VOR/DME signal reception as opposed to Victor airways which may incorporate signal gap areas.

   e. RNAV waypoints will be identified by lat/long (nearest 1/10 min.) and a radial and distance from the ground facility on which they are based. Additionally, geographical names (5 letter pronounceable words) will be assigned to waypoints if required for flight planning or ATC purposes. Along-Track Distance (ATD) fixes are normally used in lieu of a final approach waypoint when no lateral course change is required at that point. It is used to simplify pilot workload. An ATD fix may be used in lieu of a missed approach waypoint when the runway waypoint is NOT the MAP. Changeover points on RNAV routes will be defined using distance from an established waypoint.

   f. Terminal area routes are normally flown 'to' the waypoint, and are compatible with 3-D concepts. However, simplified procedures designed for the minimum equipment 2-D system may be flown 'to' or 'from' the waypoints. Changeover points will not be used unless more than one facility is required to support the procedure.

   g. RNAV route segments are numbered in a manner similar to VOR airways and jet routes. The suffix 'R' identifies the route as an RNAV route. For example, J 830 R indicates a high altitude RNAV route while V 762 R indicates a low altitude RNAV route. RNAV standard

Instrument Departures (SID) and Standard Terminal Arrival Routes (STAR) will be identified by the term RNAV immediately preceding the words "departure" and "arrival." For example: Brooks One RNAV Departure, Richards Three RNAV Arrival.

h. Terminal RNAV instrument procedures will be developed as requested by the users and required by the NAS. They may be of two types as follows:

(1) Simplified procedures will be developed at small airports, typically with less than 4000' runways, or in areas where air traffic problems are minimal. They will use at the most two waypoints and will be supplemented with ATD fixes. The runway threshold will be one of the waypoints. The other will provide transitions to the Final Approach course. They will be flyable with minimum equipment systems.

(2) Standard procedures will be developed in large terminals based upon air traffic requirements, and to the extent possible, the desires of the users. These procedures will use up to six or even ten waypoints in rapid succession. They will be flyable in aircraft with sufficient waypoint storage, but are expected to generate a high cockpit workload to the extent that they will be unflyable with minimum equipment.

i. RNAV instrument approach procedures will be identified as follows:

(1) Straight-in Approach. Procedures which meet criteria for authorization of straight-in landing minimums will be identified by the word RNAV and the runway to which the straight-in approach is made; for example, RNAV Rwy 21.

(2) Circling Approach. When a procedure does not meet criteria for straight-in landing minimums authorization, it will be identified alphabetically in sequence; for example: RNAV A, RNAV B, etc.

j. Units of Measurement. Units of measurement in RNAV procedures shall be expressed as follows:

(1) Radials and bearings in degrees magnetic.

(2) Altitudes in feet.

(3) Distances in nautical miles except visibility which shall be expressed in statute miles and RVR which shall be expressed in feet.

(4) Aircraft speeds in knots.

(5) Track angles shall be expressed in degrees.

SECTION I
2D RNAV CONSIDERATIONS

2. ENROUTE CRITERIA. Enroute procedures shall be evaluated using existing flight inspection facility performance data, or by flight inspection of the procedure when facility data is lacking.

a. RNAV Routes Protected Areas. The area to be protected is shown in Figure 1, the Area Navigation Route Width Summary, and is described as follows:

(1) Four miles each side of routes in which the tangent point distance of the route centerline is within 102 miles of the ground station. The route boundaries splay at 3.25° beginning at the point where the route centerline exits the eight-mile zone.

(2) When the tangent point distance is beyond the 102 mile limit, the minimum width of the protected area each side of the route at the tangent point distance is increased at the rate of 0.25 miles for each 10 miles increase in distance from the ground station. The route boundaries splay 3.25° from this minimum width at the tangent point distance.

(3) Parallel offset routes are not charted in flight information publications. When a pilot is cleared to fly a parallel offset route, he is expected to fly it in precisely the same fashion as the parent route. Parallel offsets will be used to separate overtaking traffic and other similar applications. Enroute, it will not always be possible to develop a parallel offset route on both sides of the parent route due to signal loss on the side of the parent route farthest from the reference station. When developing parallel offset routes consideration must be given to MOCA and MRA on both sides of the parent route. In the event that the MEA is higher than the parent route, offset parallel operations will normally not be authorized on the side to which the higher MEA applies.

(4) Enroute vertical separation will be provided as prescribed in Air Traffic Control procedures handbooks where climb or descent is made using 3-D RNAV airborne equipment.

(5) When using reference facilities not on the route the track angle must be computed relative to the reference facility being used. These track angles may change when using different reference facilities due to meridian divergence/convergence.

b. Obstacle Clearance Requirements. Obstacle clearance will be provided as described in Advisory Circular 95-1, paragraphs 4, 5, and 7, except that the primary obstacle clearance areas will be as specified in paragraphs 2.a.(1) and 2.a.(2) above.

(1) Secondary obstacle clearance areas extend laterally 2 miles on each side of the primary area and splay at 4.9° where the primary area splays at 3.25°.

(2) Obstacle clearance areas are expanded as specified in paragraph 3.c of AC 95-1 and as illustrated in Figure 3 to accommodate turns of more than 15 degrees.

c. Enroute Waypoint Displacement Area. The enroute waypoint displacement area is a rectangular or square area formed around the plotted position of the waypoint. The dimensions of this area are derived from the appropriate along-track and cross-track error values. See Table 2, Appendix D. The enroute waypoint displacement area shall be considered for each waypoint when developing RNAV enroute procedures.

3. TERMINAL CRITERIA. Terminal routes provide access to the enroute structure for aircraft departing an airport and routing to enter an instrument approach procedure for arriving aircraft. Parallel offset terminal routes will be used where practical for spacing and to separate overtaking aircraft. Terminal routes shall be evaluated by flight inspection concurrently with associated instrument approach and departure procedures.

Terminal arrival routes will be designed for efficient traffic flow to the final approach aid - normally ILS. To the extent possible the altitudes specified on the arrival routes will provide for a 300' per mile rate of descent from the enroute environment to the runway or the point where the final approach aid is intercepted. To facilitate the transition and to standardize the terminal route structure, the last waypoint on the arrival route will be established approximately 8 miles from the runway at the intermediate fix. The altitude at the eight mile waypoint should agree with the glide slope or provide an approximate 300'/mile gradient to the runway as appropriate to the type of final approach utilized.

Terminal departure routes will be designed from the departure end of the runway to the enroute structure. The first waypoint will be shown at the departure end of the runway. Immediate turns at the end of the runway are discouraged. Insofar as possible from the standpoint of airspace management the second waypoint will be established on the runway centerline extended.

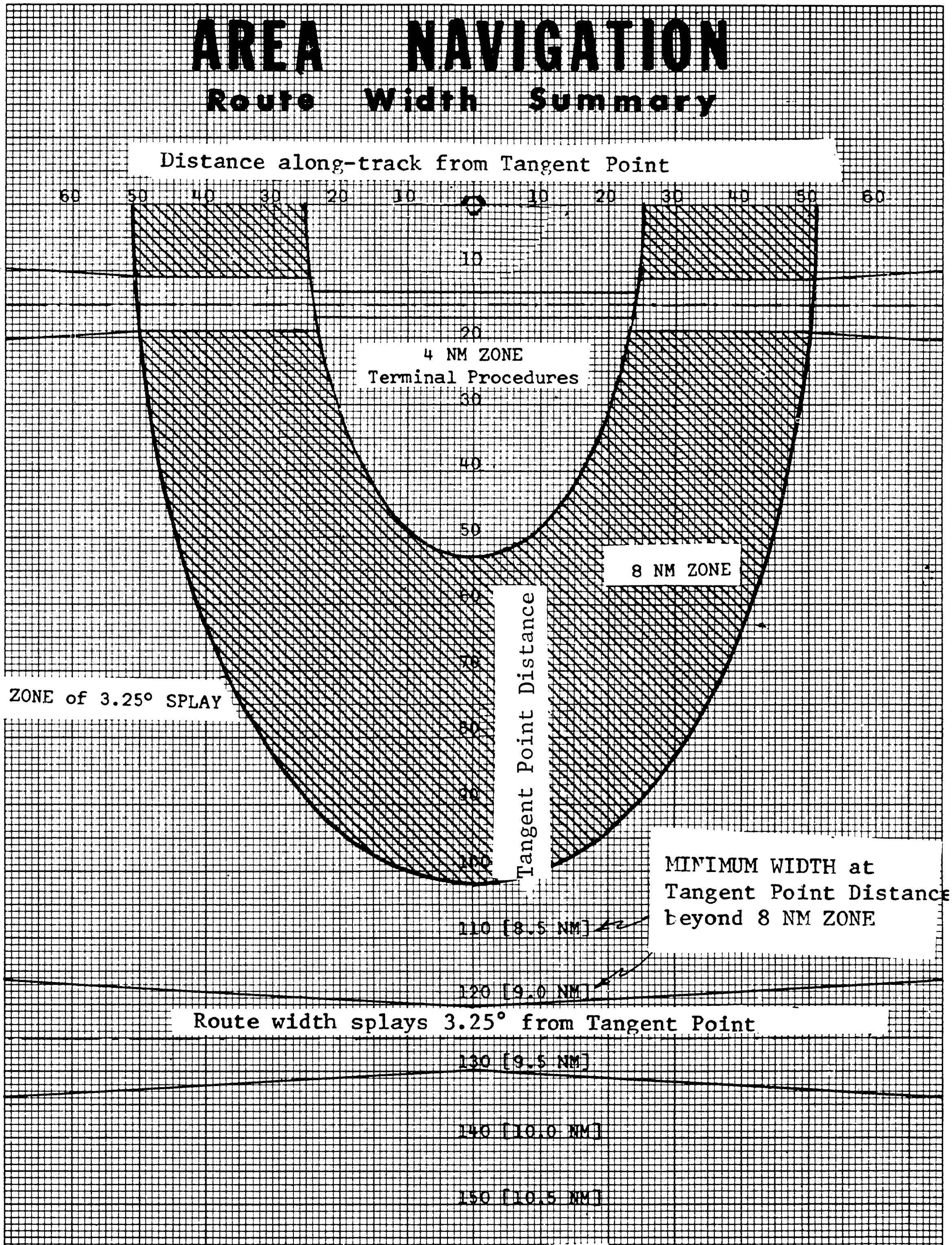
AREA NAVIGATION
Route Width Summary
Distance along-track from Tangent Point
60 50 40 30 20 10 0 10 20 30 40 50 60
4 NM ZONE
Terminal Procedures
8 NM ZONE
Tangent Point Distance
ZONE of 3.25° SPLAY
MINIMUM WIDTH at
Tangent Point Distance
beyond 8 NM ZONE
110 [8.5 NM]
120 [9.0 NM]
Route width splays 3.25° from Tangent Point
130 [9.5 NM]
140 [10.0 NM]
150 [10.5 NM]

FIGURE 1

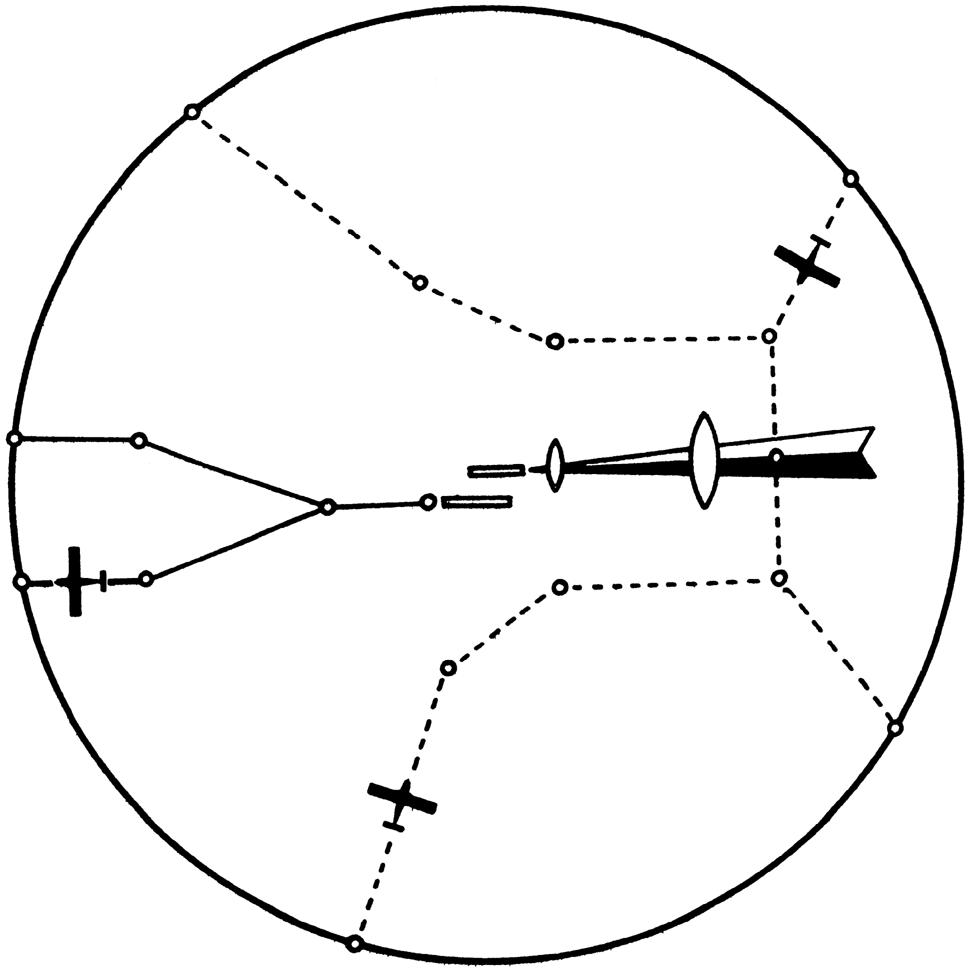

FIGURE 2. TYPICAL RNAV ARRIVAL AND DEPARTURE ROUTE CONFIGURATION

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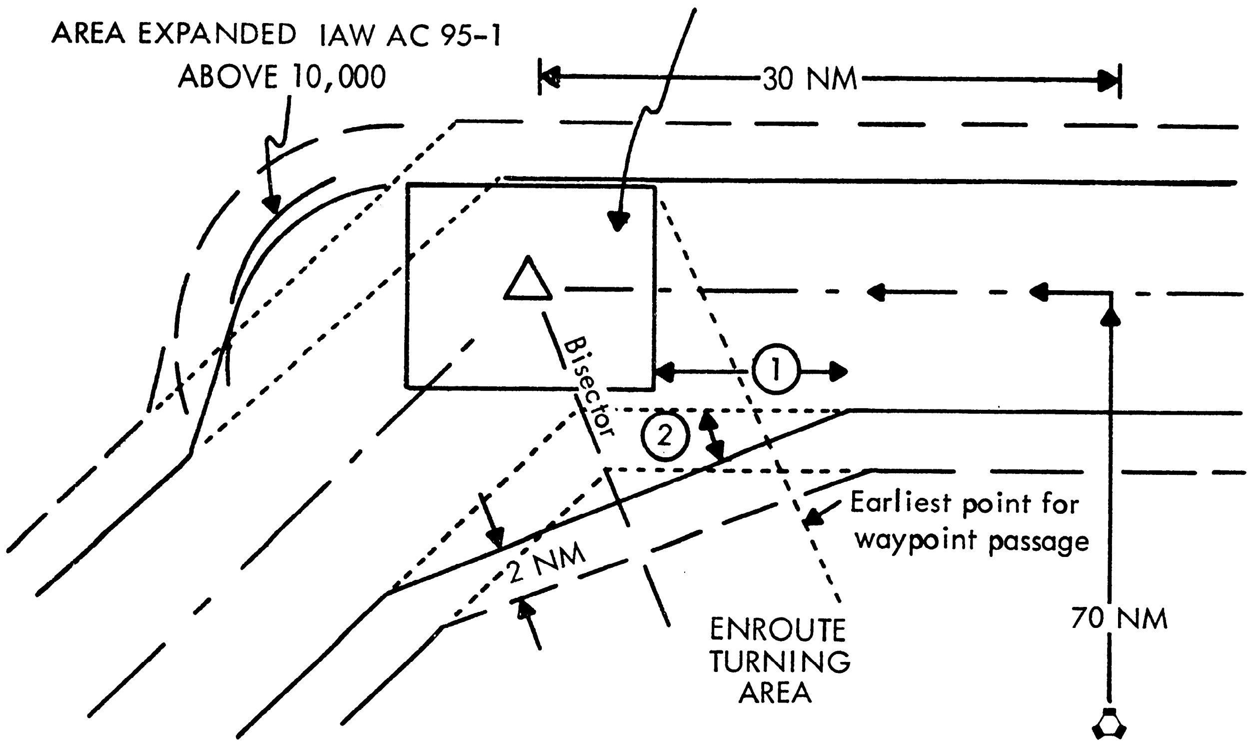
FIX AREAS DETERMINED BY CROSS-TRACK AND ALONG-TRACK ERRORS



1. Expansion for "corner cutter" begins at a distance prior to the earliest point the waypoint can be received: 3 NM below 8000' - 7 NM 8000-18000' - 12 NM above FL 180.
2. Angle of splay for expanding area is 1/2 the amount of the course change.

FIX AREAS DETERMINED BY CROSS-TRACK AND ALONG-TRACK ERRORS

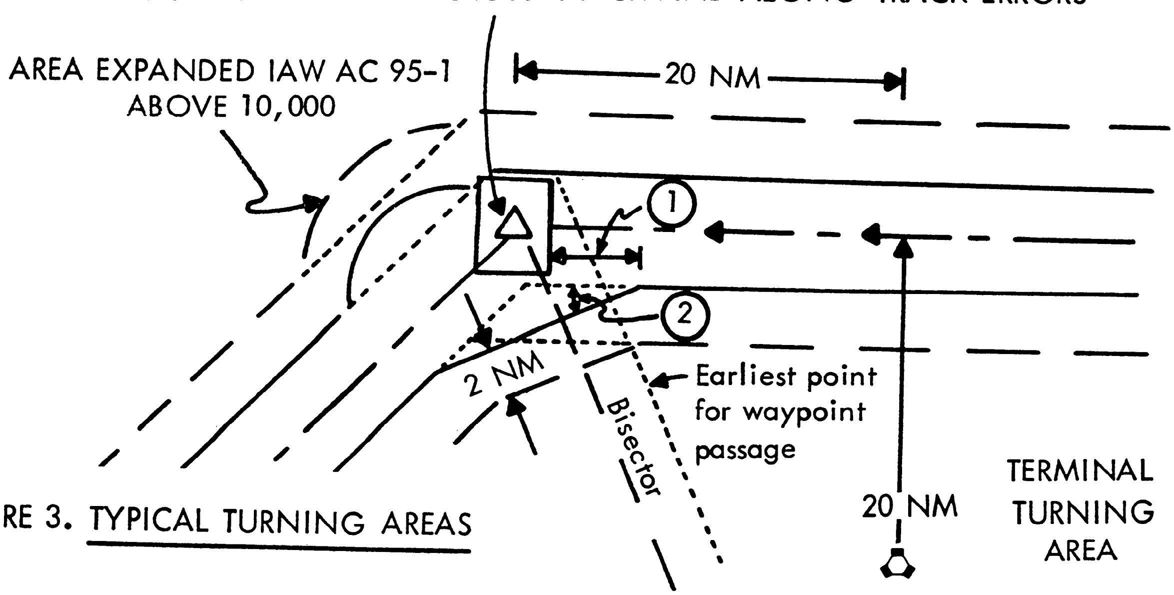


FIGURE 3. TYPICAL TURNING AREAS *

a. RNAV Routes Protected Areas. The area to be protected is as shown in Figure 1 and is described as follows:

(1) Primary obstacle clearance areas extend laterally two miles each side of routes in which the tangent point distance of the route centerline is within 53 miles of the ground station. The route boundaries splay 3.25^{o} beginning at the point where the route centerline exits the four-mile zone. *

(2) Secondary obstacle clearance areas extend laterally 1 mile each side of the primary area and splay 4.9^{o} where the primary area splays at 3.25^{o}. *

(3) Obstacle clearance areas are expanded as specified in paragraph 3.e in AC 95-1 and as illustrated in Figure 3 to accommodate turns of more than 15 degrees.

(4) Paragraphs 2.a(3) and 2.b(2) above which concern parallel offsets and turning areas also apply.

b. Obstacle Clearance Requirements. Obstacle clearance will be provided as described in FAA Handbook 8260.3A (TERPS), paragraph 232.c.

c. Terminal Waypoint Displacement Area. The terminal waypoint displacement area is a rectangular or square area formed around the plotted position of the waypoint. The dimensions of this area are derived from the appropriate along-track and cross-track error values. See Table 3, Appendix D. The terminal waypoint displacement error shall be considered for each waypoint when used in RNAV departures and arrivals, including initial and intermediate approach waypoints.

d. Holding Pattern Area Determination. The holding pattern is a race-track pattern flown at a waypoint or an ATD fix and at an IAS appropriate to the aircraft and altitude. The holding IAS for helicopters is 90 knots. The RNAV holding area will have the outbound leg length specified in nautical miles. Minimum leg length for helicopters is 2 NM. Determination of required area is made using Table 2 or Table 3, Appendix D, appropriate IAS, an omnidirectional wind of 50 knots increasing 3 knots per 2000' above 4000 AGL, pattern entry direction, ICAO standard atmosphere plus 15^{o}C and fix passage tolerance of 5 seconds. Turning radii are based on a standard rate turn or a 25^{o} angle of bank whichever is less. The following example is for helicopters holding at a sea level terminal area, but the method applies to all aircraft by using the appropriate IAS, altitude, and table for the mode of flight; i.e., enroute (Table 2) or terminal (Table 3). *

* **Example**: IAS = 90 KTS
Alt = 6000' MSL & AGL
OAT = 3° + 15° = 18°C

ATD = 30 NM
TPD = 30 NM
xwind = 50 + 3 = 53 KTS

From Table 3, Appendix D; cross-track error (x trk) = 2.4 NM, along-track error (alg trk) = 2.2 NM.

(1) The cross-track area is determined as follows.

(a) Holding side. The area on the holding side is determined by the cross-track navigation system errors, the effect of wind and the area required for a standard rate turn (max 25°) from entries along-track or the reciprocal and including all directions from the nonholding side.

The contribution due to winds will be .88 NM during the 180° turn outbound (assume crosswind for worst case).

The cross-track error value and the wind contribution are root-sum-squared, yielding:

$$RSS = \sqrt{2.4^2 + .88^2} = \underline{2.55\ NM}$$

The angle of bank at 90 KTS (95 KTS, TAS) for a standard rate turn is determined by the following:

$$\tan \phi = .00275V,\ V = KTS,\ TAS$$

$$= .00275(95) = .26125$$

$$\text{then } \phi = 14.64° = \underline{15°}$$

The turning radius (r) at TAS = 95 KTS and bank angle (Ø) of 15° is determined by the following:

$$r = \frac{1.4589 \times 10^{-5}\ V^2}{\tan \phi},\ \text{where } V = KTS,\ TAS$$

$$r = \frac{1.4589 \times 10^{-5}\ (95)^2}{.2679}$$

$$r = \underline{.49\ NM}$$

The cross-track contribution due to the turn is:
2r = .98 NM.

Hence, the total cross-track displacement on the HOLDING side is:

cross-track RSS + 2r: 2.55 + .98 = 3.53 NM. *

*

(b) Nonholding side. The cross-track displacement on the NONHOLDING side is either one-half of the route width at the ATD fix, as discussed below, or the area required to make an entry from the holding side, whichever is greater. One-half of the route width in the terminal area (50 NM or less) is 2.0 NM. In the enroute area (more than 50 NM but less than 102 NM) one-half of the route width is 4 NM. At distances greater than 102 NM, one-half of the route is 4 NM plus a 3.25° splay. (See Figure 1). For parallel entry at the 70° sector line (worst case), cross-track displacement is determined as follows (see Figure 3-1):

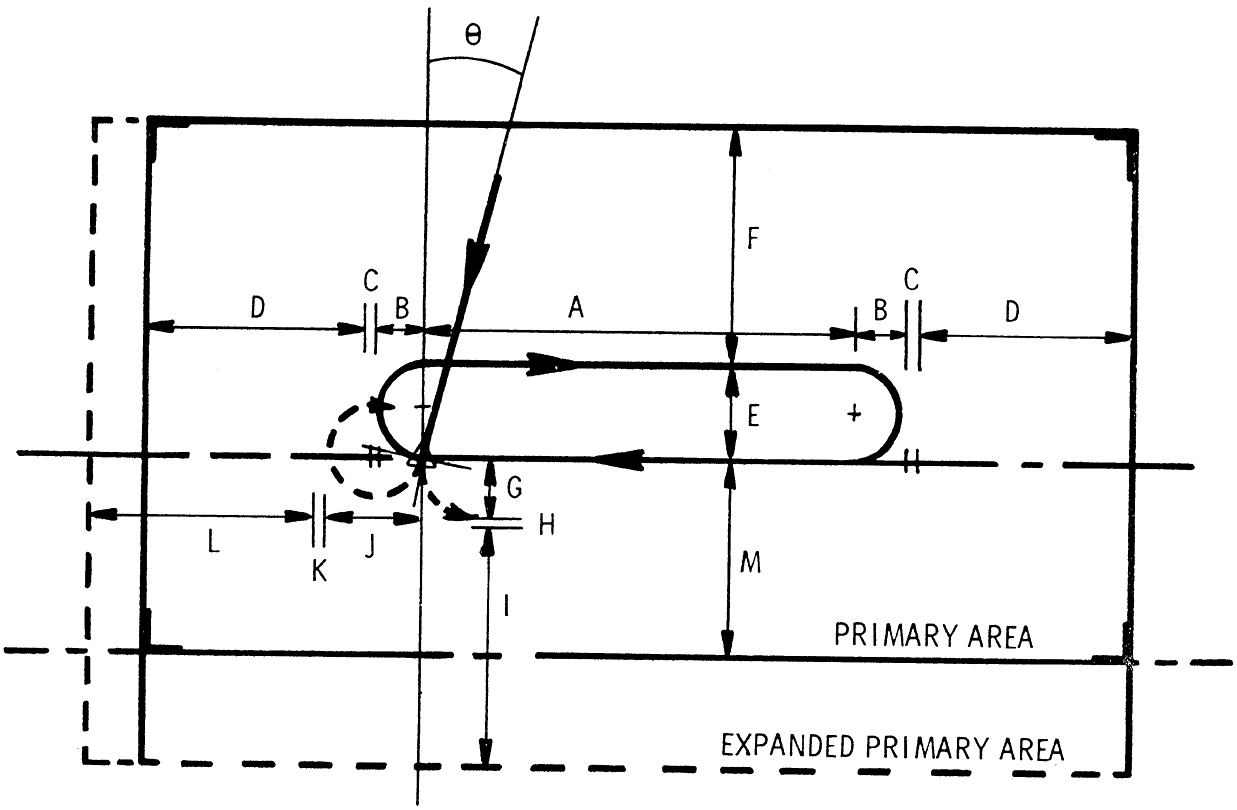


FIGURE 3-1. HOLDING AREA DETERMINATION

A - DME leg distance
B - Turn radius
C - Fix passage tolerance
D - Direct entry RSS
E - 2(Turn radius)
F - Cross-track RSS
G - Turn radius (1 + sin θ)
H - Fix passage tolerance (sin θ)
I - Nonholding side entry RSS
J - Turn radius (1 + cos θ)
K - Fix passage tolerance (cos θ)
L - Holding side entry RSS
M - 1/2 Route width

*

* The wind contribution during the 110° turn to parallel the outbound is .54 NM.

When RSS'd with the cross-track error:

$$RSS = \sqrt{(2.4)^2 + (.54)^2} = \underline{2.46 \text{ NM}}$$

The turn contribution is r(1 + sin θ): (here θ = 20°)

$$.49(1.3420) = \underline{.66 \text{ NM}}$$

The fix passage tolerance is:

$$(5 \text{ secs @ } 95 \text{ KTAS}) \sin 20° = .05 \text{ NM}$$

The cross-track displacement on the NONHOLDING side is then:

parallel entry RSS + r(1 + sin θ) + fix passage tolerance (sin θ):

$$2.46 + .66 + .05 = \underline{3.17 \text{ NM}}$$

Since this exceeds 2.0 NM half route width, it is the width to be protected.

(2) The along-track area for a direct (or reciprocal) entry or an entry from the nonholding side is determined as follows.

The contribution due to winds during the 180° turn outbound is .44 NM (assume direct entry and tailwind for worst case).

When RSS'd with the along-track error:

$$RSS = \sqrt{(2.2)^2 + (.44)^2} = \underline{2.24 \text{ NM}}$$

fix passage tolerance (5 secs) @ 95 KTAS = .13 NM.

The total along-track displacement is:

2 (nonholding side entry RSS) + 2(r) + 2 fix passage tolerance + DME leg

$$2(2.24) + 2(.49) + 2(.13) + 2 = \underline{7.72 \text{ NM}}$$ *

* (3) The along-track error for an entry from the holding side (70° sector line for worst case) will elongate the entry end and is determined as follows.

The wind contribution during the 160° turn to fly the pattern is .79 NM.

When RSS'd with the along-track error:

$$RSS = \sqrt{(2.2)^2 + (.79)^2} = \underline{2.33\ NM}$$

The turn contribution is $r(1 + \cos \theta)$: (here $\theta = 20°$)

$$.49(1.9397) = \underline{.95\ NM}$$

The fix passage tolerance is:

$$(5\ \text{secs @ } 95\ \text{KTAS})\cos 20° = \underline{.12\ NM}$$

The total along-track displacement is the sum of the entry, leg distance and inbound turn displacements:

holding side entry RSS + $r(1 + \cos \theta)$ + fix passage tolerance ($\cos \theta$) + DME leg + direct entry RSS + r + fix passage tolerance:

$$2.33 + .95 + .12 + 2.0 + 2.24 + .49 + .13 = \underline{8.26\ NM}$$

A secondary area of one-half of the cross-track error or 2 NM, whichever is greater, is added to the perimeter of the pattern for obstacle clearance. *

4. INSTRUMENT APPROACH PROCEDURE CRITERIA. FAA Handbook 8260.3A, The United States Standard for Terminal Instrument Procedures (TERPS), prescribes criteria for the design of instrument approach procedures. Although it does not at the present time contain special criteria for the design of RNAV procedures, most of the TERPS criteria are applicable to RNAV procedures with minor modifications. This appendix will therefore provide only the criteria necessary to modify TERPS for RNAV procedure application. In applying TERPS to RNAV procedures, the term "fix" is equivalent to "waypoint," thus, "Final Approach Fix (FAF)" becomes "Final Approach Waypoint (FAWP)."

a. Procedures Construction. An RNAV instrument approach procedure may have four separate segments. They are the initial, the intermediate, the final and the missed approach segments. In addition, an area for circling the airport under visual conditions shall be considered. The approach segments begin and end at waypoints or along-track distance (ATD) fixes which are identified to coincide with the associated segment. For example, the intermediate segment begins at the intermediate waypoint (INWP) and ends at the Final Approach Waypoint (FAWP) or ATD fix.

(1) Descent Gradients. TERPS descent gradients will apply to all RNAV procedures except where an uninterrupted descent gradient of 300 feet per mile (+20', -50') can be established from the initial approach through the final approach. It shall be done to provide stabilized descent throughout the arrival procedures.

* (2) Runway Waypoint and Flight Path Angle. Both standard and simplified procedures should incorporate a waypoint at the runway threshold. This waypoint will be used as the point from which the Flight Path Angle is computed. On ILS runways, the Flight Path Angle shall be computed using the runway waypoint elevation equal to the ILS threshold crossing height. Where no ILS glide path is present, the Flight Path Angle shall be computed from the runway waypoint elevation 50 feet higher than the runway threshold elevation for runways 4,000 feet and longer. It may be established as low as 37 feet for runways less than 4,000 feet in length. The procedure shall specify the runway waypoint elevation under additional flight data. Example: Rwy W/P elevation 1827'. *

b. Transition Routes. When transition routes are required from the en route structure to the initial approach waypoint, they should be designed to coincide with the local air traffic flow. En route RNAV obstacle clearance criteria (paragraph 2.b. above) shall apply to transition routes in which the tangent point distance (TPD) of the route centerline is more than 53 miles from the ground station. When the TPD is within 53 miles of the ground station, RNAV terminal route obstacle clearance criteria (paragraph 3.b. above) shall apply.

c. Initial Approach Segment. The RNAV instrument approach procedure commences at the Initial Approach Waypoint (IAWP). In the initial approach, the aircraft has departed the en route phase of flight and is maneuvering to enter the intermediate segment. Standard RNAV procedures -- as opposed to simplified procedures -- may utilize several initial approach segments to accommodate the traffic flow requirements. En route RNAV obstacle clearance criteria (paragraph 2.b. above) shall apply to initial approaches in which the TPD of the initial approach course is more than 53 miles from the ground station. When the TPD is within 53 miles of the ground station, RNAV terminal route obstacle clearance criteria (paragraph 3.b. above) shall apply.

(1) Initial approach segments based on a procedure turn shall not be established. Where course reversal is required, a holding pattern shall be established in lieu of a procedure turn. Standard holding pattern obstacle clearance shall apply.

d. Intermediate Approach Segment. The purpose of the intermediate segment is to blend the initial approach into the final approach and provide an area in which aircraft configuration, speed and positioning adjustments are made for entry into the final approach segment. The intermediate segment begins at the Intermediate Waypoint (INWP) and ends at the FAWP or ATD fix.

(1) Alignment. The course to be flown in the intermediate segment should be the same as the final approach course whenever possible. When it is not practical for the courses to be identical, the intermediate course may not differ from the final approach course by more than 60 degrees.

(2) Distance from runway. For Standard procedures the intermediate waypoint shall be established approximately 8 miles from the runway. For the Simplified procedure the intermediate fix will be established as necessary to accommodate a procedure which utilizes only two waypoints. See paragraph 1.h.

(3) Length. The minimum length is 3 miles with standard procedures.

e. Final Approach Segment. This is the segment in which alignment and final descent for landing are accomplished. The final approach segment begins at the final approach waypoint or Along-Track Distance (ATD) fix and ends at the missed approach point, normally the runway threshold waypoint. When it is not at the runway threshold, it is an ATD fix based on a distance to the runway waypoint. Final approach may be made to a runway for straight-in landing, or to an airport for a circling approach. Only one final approach shall be specified for a procedure.

(1) Alignment. Whenever possible, the final approach course shall be aligned with the straight-in landing runway. When the alignment exceeds 15^{o}, straight-in minimums are not authorized.

(2) Final Approach Area. The area considered for obstacle clearance starts at the earliest point the Final Approach Waypoint (FAWP) or ATD fix can be received and ends at the latest point the Missed Approach Waypoint (MAWP) can be received or at the runway threshold whichever occurs last. See Table 4, Appendix D, for fix errors. When the final approach course is a continuation of the intermediate course, an ATD fix shall be used instead of a FAWP. Additional ATD fixes may be established as step-down fixes.

(a) Length. The OPTIMUM length of the final approach segment is 5 miles. The MAXIMUM length is 10 miles. The MINIMUM length of the final approach segment shall provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the final approach waypoint. Table 1, Appendix D, shall be used to determine the minimum length needed to regain the course.

MINIMUM LENGTH OF THE FINAL APPROACH SEGMENT (MILES)						
APPROACH CATEGORY	Magnitude of turn over the Final Approach Waypoint (FAWP)					
	10°	20°	30°	40°	50°	60°
A	1.0	1.5	2.0	3.0	4.0	5.0
B	1.5	2.0	2.5	3.5	4.5	5.5
C	2.0	2.5	3.0	4.0	5.0	6.0
D	2.5	3.0	3.5	4.5	5.5	6.5

Table 1

(b) Width. The final approach primary area is centered longitudinally on the final approach course. The primary area is ± 2 miles wide either side of the final approach course at the final approach fix. It narrows to the width of the fix displacement area at the runway threshold. See Table 4, Appendix D. A secondary area one mile in width is established on each side of the primary area. Figure 4 illustrates a typical final approach area.

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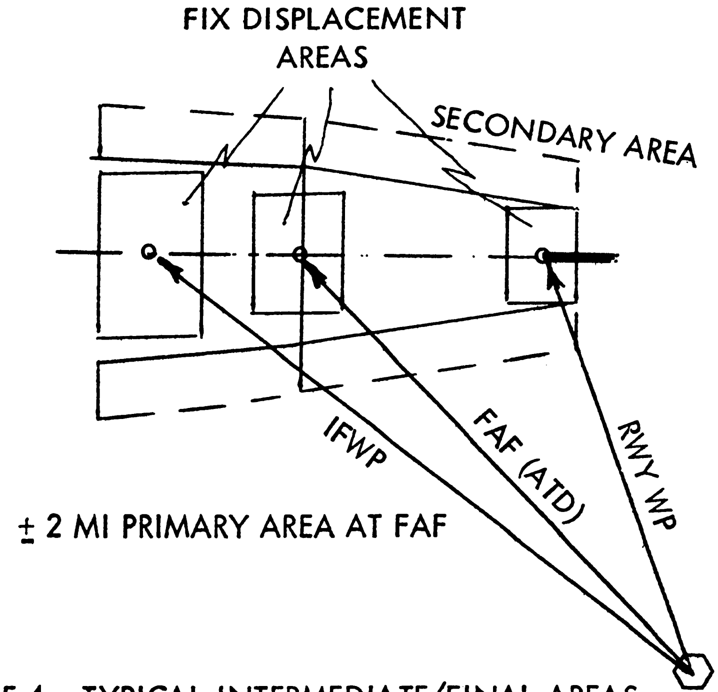


FIGURE 4. TYPICAL INTERMEDIATE/FINAL AREAS

*

(c) Obstacle Clearance. The minimum obstacle clearance in the primary area is 250 feet. In the secondary area the full obstacle clearance of the adjacent primary area is provided at the inner edge, tapering uniformly to zero at the outer edge of the secondary area.

f. Missed Approach Segment. A missed approach procedure shall be established for each instrument approach procedure. The missed approach shall be initiated no later than the runway threshold waypoint. The missed approach should be simple and shall specify an altitude and a clearance limit. The missed approach altitude specified in the procedure shall be sufficient to permit holding or enroute flight.

(1) Straight Missed Approach Area. The straight missed approach area may be used when the missed approach track does not differ more than 15 degrees from the final approach track. The area starts at the plotted position of the missed approach waypoint and has the same width as the final approach primary and secondary areas at the MAWP. The primary missed approach area splays at 15 degrees each side of the missed approach track until it reaches the width of the appropriate terminal or enroute obstacle clearance area. The secondary areas expand uniformly from one mile to the width of the appropriate enroute secondary areas. See Figure 5.

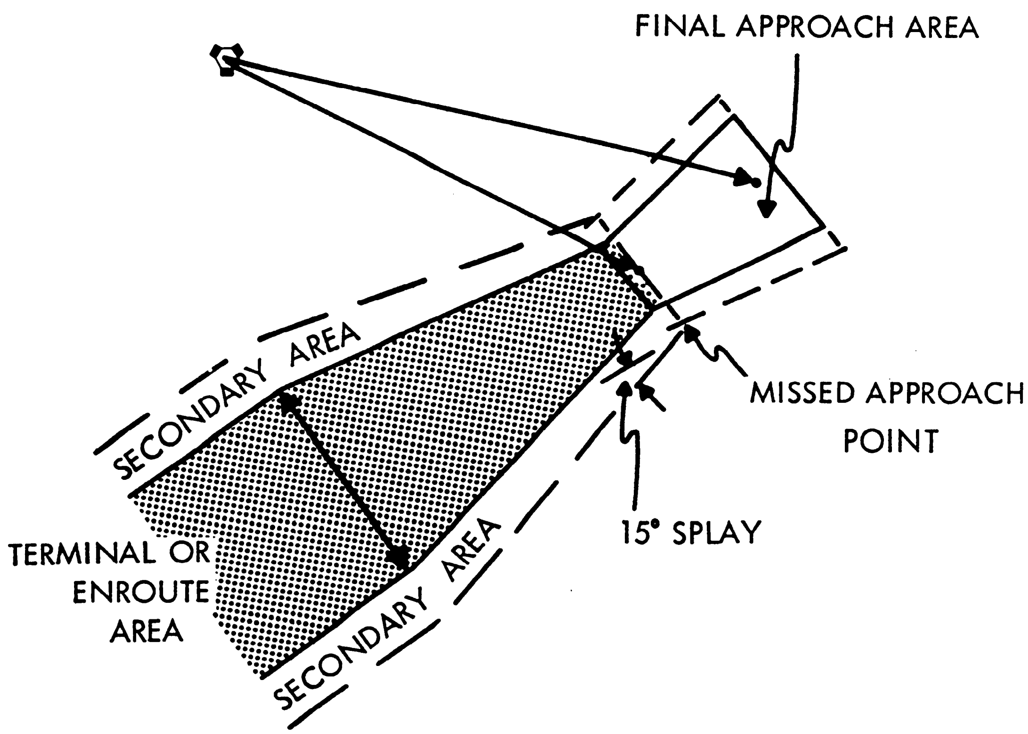


FIGURE 5. STRAIGHT MISSED APPROACH AREA *

(2) Straight Missed Approach Obstacle Clearance. Within the primary missed approach area no obstacle may penetrate the 40:1 missed approach surface. This surface begins at the plotted position of the MAWP when the along-track error at the MAWP is one mile or less. When the along-track error (Table 4, Appendix D) at the MAWP exceeds one mile, the surface begins at a distance past the plotted position of the MAWP equal to the amount of along-track error in excess of one mile. The missed approach surface beginning height is determined by subtracting the required final approach obstacle clearance from the minimum descent altitude. In the secondary area, no obstacle may penetrate a 12:1 slope which extends upward and outward from the 40:1 surface at the inner boundaries of the secondary area. See Figure 5.

NOTE: Helicopter procedures use a 20:1 missed approach surface with 4:1 slopes in the secondary areas. (Ref. TERPS 1119 & 1120)

(3) Turning Missed Approach. The turning missed approach will be as prescribed in FAA Handbook 8260.3A (TERPS) except that the starting point for the 40:1 obstacle clearance surface will be prescribed in the preceding paragraph (4.f.(2)).

g. Approach Minimums. Published civil RNAV approach minimums shall meet the criteria for nonprecision approach systems as specified in FAA Handbook 8260.3A (TERPS). Table 6 criteria which relates minimum visibility to distance from station shall be applied as a variation of cross-track displacement area (Table 4, Appendix D) as follows:

Cross-track	area	0.6 - 0.8 NM	use	Column	0-10
"	"	"	0.9 - 1.0 NM	"	"	10-15
"	"	"	1.1 - 1.2 NM	"	"	15-20
"	"	"	1.3 - 1.6 NM	"	"	20-25
"	"	"	Over 1.6 NM	"	"	Over 25

h. Approach Waypoint Displacement Area. The approach waypoint displacement area is a rectangular or square area formed around the plotted position of the waypoint. The dimensions of the area are derived from the appropriate along-track and cross-track error values. See Table 4, Appendix D. The approach waypoint displacement area shall be considered for each waypoint used in developing RNAV final approach procedures including the FAWP, MAWP, and any stepdown WP or ATD fixes used on final.

ENROUTE AREA FIX DISPLACEMENT ERROR (95% Probability)

DISTANCE ALONG TRACK FROM TANGENT POINT

DISTANCE FROM TANGENT POINT TO VORTAC

	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	200
0(x trk)	2.5	2.5	2.5	2.8	3.2	3.7	4.2	4.8	5.4	5.9	6.5	7.1	7.7	8.3	8.9	9.5	12.6
(alg trk)	1.5	1.5	1.5	1.5	1.5	1.6	1.9	2.2	2.5	2.8	3.0	3.3	3.6	3.9	4.2	4.5	6.0
10(x trk)	2.5	2.5	2.5	2.8	3.3	3.7	4.3	4.8	5.4	6.0	6.6	7.1	7.7	8.3	8.9	9.5	12.6
(alg trk)	1.5	1.5	1.5	1.5	1.5	1.7	2.0	2.3	2.6	2.9	3.1	3.4	3.7	4.0	4.3	4.6	6.1
20(x trk)	2.5	2.5	2.5	2.9	3.3	3.8	4.3	4.9	5.4	6.0	6.6	7.2	7.8	8.4	9.0	9.6	12.6
(alg trk)	1.5	1.5	1.5	1.7	1.9	2.1	2.3	2.6	2.8	3.1	3.4	3.6	3.9	4.2	4.5	4.8	6.2
30(x trk)	2.5	2.5	2.6	3.0	3.4	3.9	4.4	4.9	5.5	6.1	6.6	7.2	7.8	8.4	9.0	9.6	12.6
(alg trk)	1.9	2.0	2.1	2.2	2.3	2.5	2.7	2.9	3.2	3.4	3.7	3.9	4.2	4.5	4.7	5.0	6.4
40(x trk)	2.5	2.5	2.7	3.1	3.5	4.0	4.5	5.0	5.6	6.1	6.7	7.3	7.9	8.5	9.1	9.7	12.7
(alg trk)	2.5	2.6	2.6	2.7	2.9	3.0	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.8	5.0	5.3	6.7
50(x trk)	2.6	2.6	2.9	3.2	3.6	4.1	4.6	5.1	5.7	6.2	6.8	7.4	7.9	8.5	9.1	9.7	12.7
(alg trk)	3.1	3.2	3.2	3.3	3.4	3.6	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.2	5.4	5.7	7.0
60(x trk)	2.7	2.8	3.1	3.4	3.8	4.2	4.7	5.2	5.8	6.3	6.9	7.4	8.0	8.6	9.2	9.8	12.8
(alg trk)	3.7	3.8	3.8	3.9	4.0	4.1	4.3	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	7.3
70(x trk)	2.9	3.0	3.2	3.6	3.9	4.4	4.8	5.4	5.9	6.4	7.0	7.5	8.1	8.7	9.3	9.9	12.9
(alg trk)	4.4	4.4	4.4	4.5	4.6	4.7	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.3	6.5	7.7
80(x trk)	3.2	3.3	3.5	3.8	4.1	4.5	5.0	5.5	6.0	6.5	7.1	7.7	8.2	8.8	9.4	10.0	12.9
(alg trk)	5.0	5.0	5.1	5.1	5.2	5.3	5.4	5.5	5.7	5.8	6.0	6.2	6.3	6.5	6.7	6.9	8.0
90(x trk)	3.4	3.5	3.7	4.0	4.3	4.7	5.2	5.6	6.2	6.7	7.2	7.8	8.3	8.9	9.5	10.1	13.0
(alg trk)	5.6	5.6	5.7	5.7	5.8	5.9	6.0	6.1	6.2	6.4	6.5	6.7	6.8	7.0	7.2	7.4	8.5
100(x trk)	3.6	3.7	3.9	4.2	4.5	4.9	5.3	5.8	6.3	6.8	7.4	7.9	8.4	9.0	9.6	10.2	13.1
(alg trk)	6.2	6.2	6.3	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.1	7.2	7.4	7.5	7.7	7.9	8.9
110(x trk)	3.9	4.0	4.2	4.4	4.7	5.1	5.5	6.0	6.5	7.0	7.5	8.0	8.6	9.1	9.7	10.3	13.2
(alg trk)	6.8	6.9	6.9	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.8	7.9	8.1	8.2	8.4	9.4
120(x trk)	4.2	4.2	4.4	4.6	5.0	5.3	5.7	6.2	6.6	7.1	7.6	8.2	8.7	9.3	9.8	10.4	13.3
(alg trk)	7.4	7.5	7.5	7.6	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.5	8.6	8.8	9.0	9.9
130(x trk)	4.4	4.5	4.7	4.9	5.2	5.5	5.9	6.4	6.8	7.3	7.8	8.3	8.9	9.4	10.0	10.5	13.4
(alg trk)	8.1	8.1	8.1	8.2	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.2	9.3	9.5	10.4
140(x trk)	4.7	4.8	4.9	5.1	5.4	5.8	6.1	6.6	7.0	7.5	8.0	8.5	9.0	9.5	10.1	10.6	13.5
(alg trk)	8.7	8.7	8.7	8.8	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.9	10.0	10.9
150(x trk)	5.0	5.0	5.2	5.4	5.7	6.0	6.4	6.8	7.2	7.7	8.2	8.7	9.2	9.7	10.2	10.8	13.6
(alg trk)	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.5	10.6	11.4

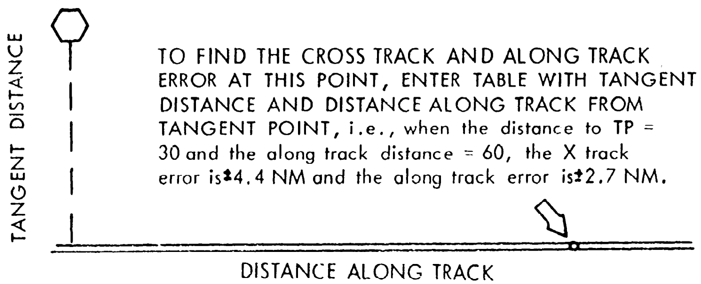


TABLE 2

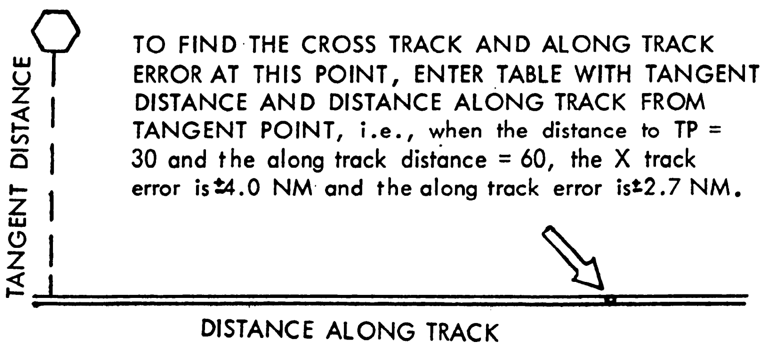
ERROR ELEMENTS	
GROUND	
VOR	1.9°
DME	0.1 NM
AIRBORNE	
VOR	3.0°
DME	3% or 0.5 NM
RNAV SYSTEM	0.5 NM
PILOT	
CROSS-TRACK	2.0
ALONG-TRACK	ZERO

*

TERMINAL AREA FIX DISPLACEMENT ERROR (95% PROBABILITY)

DISTANCE ALONG TRACK FROM TANGENT POINT (columns); DISTANCE FROM TANGENT POINT TO VORTAC (rows)

	0	10	20	30	40	50	60	70	80	90	100
0 (x trk)	1.5	1.5	1.7	2.2	2.7	3.3	3.9	4.5	5.1	5.7	6.3
(alg trk)	1.1	1.1	1.1	1.1	1.3	1.6	1.9	2.2	2 5	2.8	3,0
10 (x trk)	1.5	1.5	1.7	2.2	2.8	3.3	3.9	4.5	5.1	5.7	6.3
(alg trk)	1.1	1.1	1.1	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.1
20 (x trk)	1.5	1.5	1.8	2.3	2.8	3.4	4.0	4.6	5.2	5.8	6.4
(alg trk)	1.3	1.4	1.5	1.7	1.9	2.1	2.3	2.6	2.8	3.1	3.4
30 (x trk)	1.5	1.6	1.9	2.4	2.9	3.5	4.0	4.6	5.2	5.8	6.4
(alg trk)	1.9	2.0	2.1	2.2	2.3	2.5	2.7	2.9	3.2	3.4	3.7
40 (x trk)	1.6	1.8	2.1	2.5	3.0	3.6	4.1	4.7	5.3	5.9	6.5
(alg trk)	2.5	2.6	2.6	2.7	2.9	3.0	3.2	3.4	3.6	3.8	4.0
50 (x trk)	1.9	2.0	2.3	2.7	3.2	3.7	4.2	4.8	5.4	6.0	6.6
(alg trk)	3.1	3.2	3.2	3.3	3.4	3.6	3.7	3.9	4.1	4.3	4.5



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	1.0
ALONG-TRACK	ZERO

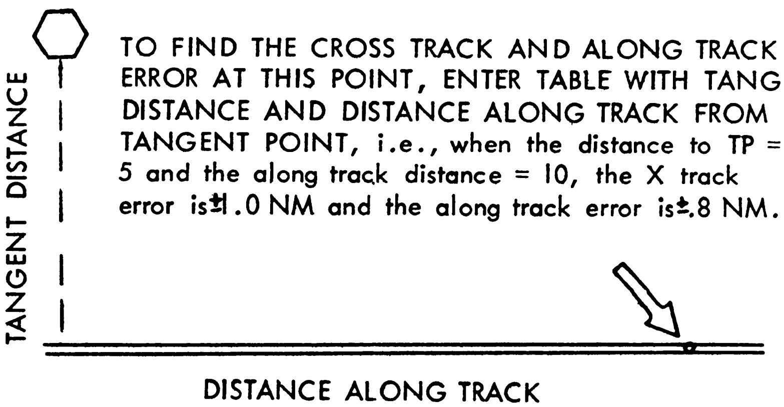
TABLE 3

Terminal waypoint displacement errors apply to waypoints used in arrival and departure procedures including Initial and Intermediate approach waypoints. (para 3c) *

*

FINAL AREA FIX DISPLACEMENT ERROR (95% PROBABILITY)

DISTANCE FROM TANGENT POINT TO VORTAC	DISTANCE ALONG TRACK FROM TANGENT POINT: 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

TABLE 4

Final waypoint displacement errors apply to the waypoints used in the Final approach segment. (para 4h) *

SECTION II

3D RNAV CONSIDERATIONS

5. BACKGROUND. Adding a third dimension of vertical guidance to the two dimensional RNAV system can achieve significant operational advantages. Briefly, a 3D RNAV capability permits altitude change by following vertical routes (tubes) of known dimensions thus vertical guidance is available for stabilized descent in instrument approach procedures using computed glide path information. In some cases, the computed glide path can make it possible to safely eliminate obstacles from consideration. This section discusses the operational problems and capabilities of 3D RNAV and provides criteria for vertical instrument flight procedures.

   a. Level Flight RNAV Longitudinal and Vertical Errors.

      (1) In level flight, the plus or minus vertical position error is due to altimetry and flight technical errors. Current standards for aircraft separation and obstacle clearance allow for these errors, and in addition, provide an allowance for atmospheric anomalies.

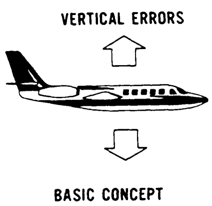


FIGURE 6. LEVEL FLIGHT VERTICAL ERROR

(2) Also, in level flight the combination of ground station, airborne equipment, and computer errors produce a plus-or-minus longitudinal position error called along-track error. No flight technical error is involved.

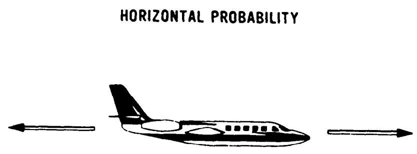


FIGURE 7. ALONG-TRACK ERROR

(3) Thus, providing airspace for aircraft in level flight using RNAV is simply a matter of containing the plus-or-minus vertical and longitudinal position errors as the aircraft progresses along the intended flight path.

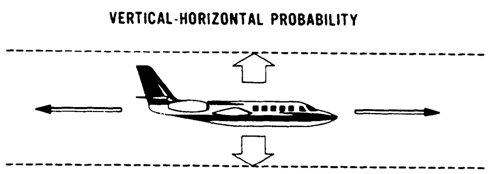


FIGURE 8. AIRSPACE IN LEVEL FLIGHT

b. Vertical Flight RNAV Errors. To provide vertical guidance during ascent or descent, the 3D RNAV equipment compares the indicated altitude with the desired altitude and presents the computer correction instrumentally; typically in the form of fly up/fly down cross pointer information. The computation and comparison process produces vertical position errors which are additional to those affecting the aircraft in level flight.

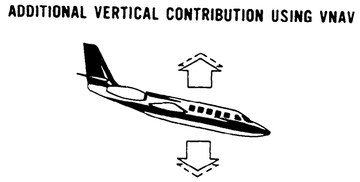


FIGURE 9. ADDITIONAL ERROR ALLOWANCE FOR ASCENDING/DESCENDING FLIGHT.

(1) The along-track error also has significance in vertically guided flight. When an aircraft is ahead or behind its assumed position, it will be either above or below its intended path.

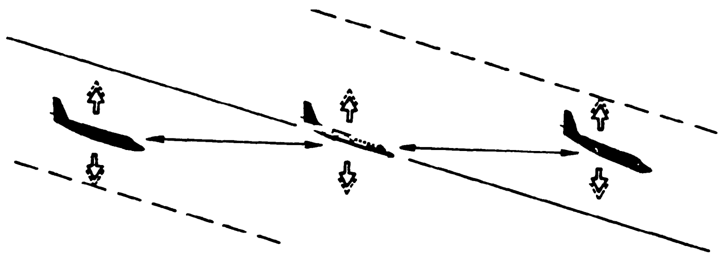


FIGURE 10. EFFECTS OF ALONG-TRACK ERROR.

(2) The angle at which climb or descent is made also affects the required obstacle clearance because as the vertical angle increases, there is a corresponding increase in the effect of the along-track error on the thickness of the tube.

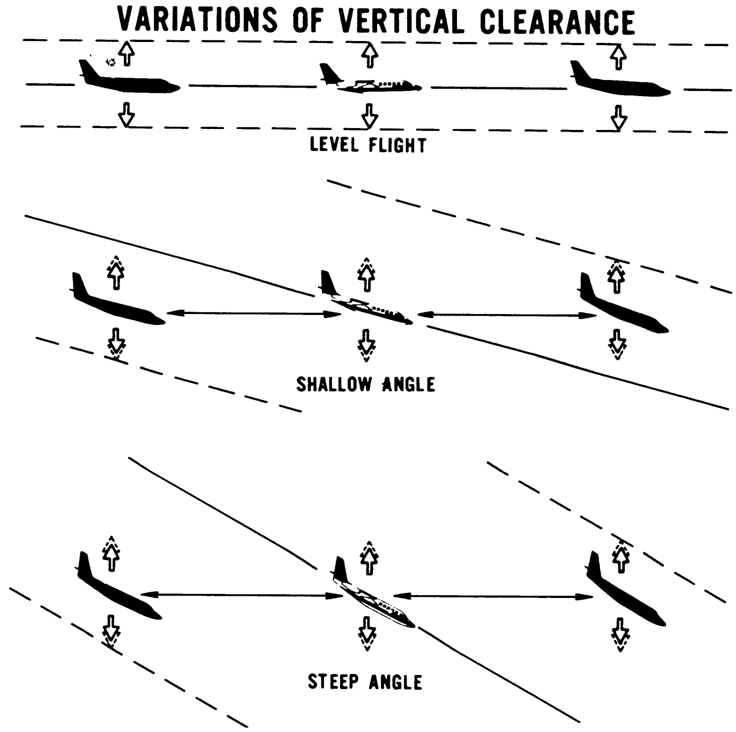


FIGURE 11. VARIATIONS OF TUBE SIZE TO CONTAIN POSITION ERRORS AS VERTICAL ANGLE INCREASES.

6. <u>CONCEPT OF VERTICAL OBSTACLE CLEARANCE</u>. In prescribing obstacle clearance for 3D RNAV, it is useful to think of the vertical route as being the center of a tube of airspace. The lateral dimension of the tube is the width of the RNAV route as described in Section I of this appendix. The vertical dimension of the tube is sufficient to contain the combined 3D RNAV vertical errors. The longitudinal dimension of the tube is limited only by its operational use; for example: The distance required to climb 10,000 feet at a climb angle of 2°, or the descent from the final approach waypoint to the missed approach waypoint at a descent angle of 3°. For obstacle clearance, it is necessary to consider only that portion of the tube which is at and below the designed vertical flight path. An aircraft is protected from obstacles when no obstacles penetrate the tube from below.

7. OBSTACLE CLEARANCE REQUIREMENTS. 3D obstacle clearance requirements will be included in FAA Handbook 8260.3A, "U.S. Standard for Terminal Instrument Procedures (TERPs).

NOTE: Use of 3D RNAV on 2D RNAV procedures is not prohibited. 2D RNAV procedures are annotated with Flight Path Angles measured from the TCH at the runway threshold waypoint to the altitude at the Final Approach ATD. These FPA may be flown as may any other FPA generated by the airborne equipment PROVIDED that the minimum and maximum altitudes specified in the flight procedures or in Air Traffic Control clearances are not violated.