CHANGE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

8260.58A
CHG 1

National Policy

Effective Date:
03/20/2017

SUBJ: United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design

1. Purpose. This change incorporates standardized methods for designing and evaluating Performance Based Navigation (PBN) instrument flight procedures (IFPs) in the United States and its territories.

2. Who this change affects. All personnel who are responsible for Instrument Flight Procedure (IFP) development and/or evaluation.

3. Where you can find this change. You can find this order on the Federal Aviation Administration's (FAA) web site.

4. Explanation of changes.

a. General.

(1) Advanced-Required Navigation Performance (A-RNP) added to all appropriate sections to enable A-RNP procedure design.

(2) Helicopter criteria added throughout as a transitional step in migrating Order 8260.42, U.S. Standard for Helicopter Area Navigation, helicopter PBN criteria into this order.

(3) Added "Use of A-RNP missed approach or departure cross track tolerance (XTT) less than 1 requires Flight Standards approval" in all applicable areas.

(4) Changed the wording on the use of NavSpecs and flight phase in determining the XTT to be used in design in all applicable areas.

b. Table of Contents. Updated to coincide with the pages changed.

c. Chapter 1.

(1) Paragraph 1-2-4.a. Added AC 90-100, U.S. Terminal and En Route Area Navigation (RNAV) Operations and AC 90-107, Guidance for Localizer Performance with Vertical Guidance and Localizer Performance without Vertical Guidance Approach Operations in the U.S. National Airspace System, to the reference list for definitions.

(2) Table 1-2-1. Added range of values to departure flight phase and footnotes 2 and 9 to A-RNP.

(3) Table 1-2-1 Note 1. Added “RNP AR APCH sections 1a and 1b.

(4) Table 1-2-1 Note 2. Added “ATT” to clarify intent for OEA construction

(5) Table 1-2-1. Added footnote 2 to RNP APCH.

(6) Table 1-2-1. Added footnote 8 and “Domestic” to the En route flight phase.

(7) Formula 1-2-2. Simplified the formula by adding “+ DTA” instead of requiring radius and magnitude of turn for both turns.

(8) Paragraph 1-2-5.b(2)(b). Added width changes for A-RNP.

(9) Paragraph 1-2-5.d. Explained construction of OEA at fixes with an RNP change.

(10) Paragraph 1-2-5.d(1). Provided text to allow latitude in OEA construction when connecting multiple legs.

(11) Table 1-2-2. Added Helicopter speeds to KIAS table

(12) Paragraph 1-2-5.d. Added “FO turn construction is not authorized for A-RNP.”

(13) Paragraph 1-3-1.c. Clarified turn type being addressed.

(14) Paragraph 1-3-1.g(2). Clarified that the 425 ft/NM climb gradient being discussed was a missed approach climb gradient.

d. Chapter 2.

(1) Paragraph 2-1-1. Added A-RNP and TK routes for en route design.

(2) Paragraph 2-1-2. Added section on copter ATS RNP 0.3 routes.

(3) Paragraph 2-2-1. Added A-RNP for STAR design.

(4) Paragraph 2-3-1. Added A-RNP for Feeder Route design.

e. Chapter 3.

(1) Paragraph 3-1-2. Listed optional NavSpecs for feeders and added emphases that for LP and LPV/GLS, A-RNP the minimum RNP value is the result of formula 3-1-1.

(2) Paragraph 3-1-3. Listed optional NavSpecs for initial and added emphases that for LP and LPV/GLS, A-RNP the minimum RNP value is the result of formula 3-1-1.

(3) Paragraph 3-1-4. Listed optional NavSpecs for intermediate.

(4) Paragraph 3-1-4.c(2). Added minimum intermediate XTT value criteria.

(5) Formula 3-1-1. Added formula to calculate minimum XTT.

(6) Formula 3-1-2. Renumbered existing 3-1-1 formula.

(7) Formula 3-3-5. Removed note and added new note to formula 3-3-6.

(8) Formula 3-3-6. Added note 3 to alleviate confusion on ISA deviation.

(9) Paragraph 3-3-5. Removed statement that Order 8260.3 table 3-2-2 doesn't apply.

(10) Paragraph 3-5-1. Listed optional NavSpecs for missed approach. Subtracted precipitous terrain adjustment from base DA; this was to stop the LPV MAS OCS from being raised when precipitous terrain adjustments were added.

(11) Formula 3-5-1. Added RASS adjustment to the CG termination altitude.

(12) Paragraph 3-6-1.b. Changed width from 2 and 3 NM to 2 and 3 x XTT and added "For LNAV there is no splay when an A-RNP RNP 0.3 is specified, the OEA remains linear."

(13) Paragraph 3-6-1.c. Deleted "plus any precipitous terrain" from base MDA. Precipitous adjustments have now been subtracted from base MDA with the new paragraph 3-5-1.

(14) Formula 3-6-2. Changed formula to use earth curvature to be consistent with the general formula in chapter 1. This prevents a section 1 extension that is too short when compared to formula 1-3-9 (Climb Distance Between Altitudes).

(15) Paragraph 3-6-2.c. Added description of linear segment with A-RNP 03 selection.

(16) Paragraph 3-6-3.d. Relabeled paragraph header to more clearly describe the paragraph.

(17) Paragraph 3-7-1.a. Included guidance on the use of A-RNP for added clarity.

(18) Paragraph 3-7-1.b. Changed SOC to "section 2 start altitude." This was done to keep from conflicting with use of SOC defined as the JK line.

(19) Paragraph 3-7-1.b(1). Changed SOC to "section 2 start altitude."

(20) Paragraph 3-7-1.b(2). Changed SOC to "section 2 start altitude."

(21) Formula 3-7-1. Changed SOC to "section 2 start altitude."

(22) Added new figure for A-RNP reduced RNP missed approach segment. Labeled as figure 3-7-1; causing all figures in section 3-7 to be renumbered and all references updated.

f. Chapter 4.

(1) Paragraph 4-1-1.a(2). Deleted example, "e.g., where use of a bank angle greater than 20 degrees is needed." The example caused confusion and some were interpreting it to mean they could use more than 20 degrees of bank when less than 1 RNP.

(2) Paragraph 4-1-1.a(3). Limited the application of the reduced leg length to TF-TF connections without turns.

(3) Paragraph 4-2-1.b. Removed the prohibition of RNP AR when precipitous terrain is identified in final. This resulted from a request made by NBAA and an analysis conducted by the PBN Aviation Rulemaking Committee (PARC).

(4) Paragraph 4-2-1.c. Added exception to Order 8260.3C paragraph 3-2-2.b(1)(b) and stated not to apply the 10 percent HAT increase. This resulted from an analysis conducted by the PARC.

(5) Paragraph 4-2-2.a. Limited centerline crossing point to 5200 feet for offset final.

(6) Paragraph 4-2-2.b. Updated text to clarify.

(7) Paragraph 4-3-3.a. Added "DA must be no closer to LTP than the VEB OCS origin" to attach the FAS OEA to the section 1 RNAV MAS and deleted reference to Order 8260.19.

(8) Paragraph 4-3-3.b. Removed the requirement to get AFS approval for an RF since this is application of an RNAV MAS on an RNP AR IAP.

g. Chapter 5.

(1) Paragraph 5-1-1. Added A-RNP as an optional NavSpec.

(2) Paragraph 5-1-1.c(3). Deleted this paragraph. There are other methods such as VA-DF to accomplish this and it was not used by any procedures in the NAS.

(3) Paragraph 5-2-1.a(2). Added a taper inward when ICA OEA exceeds OEA based on smaller RNP value.

(4) Paragraph 5-3-1.a(1)(a)2. Removed contradictory definition of ICA and added A-RNP.

(5) Paragraph 5-3-1.a(1)(a)3. Added "straight segment" after amending definition of ICA.

(6) Figure 5-3-1. Amended figure to show a delineation between the ICA and straight segment.

(7) Paragraph 5-4-1.b.(2) Reworded to clarify the OCS slope application in a straight segment after the ICA.

(8) Paragraph 5-4-1.b(3). Added "straight segment" after amending definition of ICA.

(9) Paragraph 5-4-1.b(3)(a). Added "straight segment" after amending definition of ICA.

(10) Paragraph 5-4-1.b(3)(b). Corrected OCS start altitude from LNAV engagement altitude to specified turn altitude.

(11) Paragraph 5-4-1.b.(4). Reworded to clarify OCS slope application and make consistent throughout departures.

5. Distribution. We will distribute this change electronically.

John S. Duncan
Director, Flight Standards Service

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Table of Contents

Chapter 1. General Information

Section 1-1. Purpose

1-1-1. Purpose of this order. This order provides guidance for the design and evaluation of Performance Based Navigation (PBN) Instrument Flight Procedures (IFPs). For the purposes of this order, PBN IFPs are those based on Area Navigation (RNAV) or Required Navigation Performance (RNP) to include transitions to an Instrument Landing System (ILS) or Ground Based Augmentation (GBAS) Landing System (GLS) final segment [see appendix C and Order 8260.19, section 4-6 and chapter 8 paragraph "Equipment requirements notes."

1-1-2. Audience. All personnel who are responsible for IFP development and/or evaluation.

1-1-3. Where you can find this order. You can find this order on the Federal Aviation Administration's (FAA) Web site.

1-1-4. What this order cancels.

a. Order 8260.53 titled "Standard Instrument Departures that Use RADAR Vectors to Join RNAV Routes" dated 07/25/2005.

b. Order 8260.58 titled "United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design" dated 09/21/2012.

Section 1-2. Basic Criteria

1-2-1. General.

a. Source directive. Order 8260.3, United States Standard for Terminal Instrument Procedures (TERPS), applies unless otherwise specified by this directive.

b. Related directives. The following orders are referenced in the directive or otherwise related to the development/documentation of PBN procedures.

(1) Order 8260.19, Flight Procedures and Airspace.

(2) Order 8260.42, United States Standard for Helicopter Area Navigation (RNAV).

(3) Order 8260.46, Departure Procedures (DP) Program.

c. Scope. This chapter contains only that information common to all PBN IFPs. Criteria which do not have general application are located in the chapter's specific to the flight phase, navigation type, or application.

1-2-2. Formulas/Calculations. Formulas in this directive use degree calculations. The examples provided use only two decimal places; therefore, the answers are approximate values. Actual calculations must use the maximum number of values after the decimal place for each step. Rounding of the final result should be for documentation purposes only. For the purposes of this order, the term "r" represents the mean radius of the earth used in spherical calculations and is equal to 20890537 feet. For mathematics convention and other common equation terms see Order 8260.3, appendix D.

1-2-3. Geospatial standards. PBN IFPs must be evaluated geodetically [see appendix E].

1-2-4. PBN concept. The PBN concept is made up of three interrelated elements: the navigation specification, the NAVAID infrastructure, and the navigation application. These three elements define the minimum required aircraft/system performance used as the basis for the obstacle evaluation areas described in this order.

a. Navigation specification (NavSpec). The NavSpec is a set of aircraft/aircrew certification and operational approval requirements that support a navigation application within a defined airspace concept. NavSpecs which require on-board performance monitoring and alerting are termed RNP specifications. Those that do not require on-board performance monitoring and alerting are termed RNAV specifications. The NavSpec defines the performance required by an RNAV or RNP system as well as any functional requirements (e.g., ability to conduct curved path legs). See current version of AC 90-100, AC 90-101, AC 90-105, and AC 90-107 for definitions. NavSpecs include:

(1) Performance. The performance required in terms of accuracy, integrity, and continuity.

(2) Functions. The functions available to achieve the required performance.

(3) Navigation sensors. The navigation sensors that may be used to achieve the required performance.

(4) Procedures. Flight crew and other procedures to achieve the required performance.

b. NAVAID infrastructure. NAVAID infrastructure relates to space or ground-based NAVAIDS addressed in the NavSpec.

c. Navigation application. Also referred to as flight phase. A navigation application is the operation in which a specific NavSpec and associated performance requirements applies (e.g., ATS route, IFP segment, etc.).

Table 1-2-1. Navigation Accuracy by NavSpec/Flight Phase

Navigation Specification	Flight Phase						
	En route Domestic	STAR/ Feeder/TAA	Initial	Intermediate	Final	Missed[1]	Departure
RNAV 2	2	2					2
RNAV 1[2]		1	1	1		1	1
RNP 2	2						
RNP 1[2]		1	1	1		1	1
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
A-RNP[2,6, 9]	2 or 1[8]	1 - 0.3	1 - 0.3	1 - 0.3		0.3 - 1	0.3 - 1
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	
RNP 0.3[7]	0.3	0.3	0.3	0.3		0.3	0.3

1. Missed approach section 2 only. RNP AR APCH sections 1a and 1b.

2. STAR/Feeder/TAA, departure, initial, intermediate, and missed section 2. Beyond 30 NM from ARP the effective XTT/ATT for the purpose of IFP design is 2.

3. RNP APCH part A is enabled by GNSS and baro-VNAV and part B is enabled by SBAS.

4. Part A only.

5. Part B along-track performance is 40 meters; angular performance requirements apply to lateral.

6. A-RNP permits a range of scalable RNP lateral navigation accuracies. Apply the largest RNP for the flight phase unless a smaller value is required to achieve a desired ground track or is operationally required.

7. Primarily intended for helicopter operations only. RNP APCH applies to the final flight phase.

8. Remote Continental use 2 (see latest version of AC 90-105 for definition of remote continental).

9. Use of A-RNP missed approach or departure XTT less than 1 requires Flight Standards approval.

1-2-5. Obstacle Evaluation Area (OEA) construction.

a. Course.

(1) Lateral and longitudinal dimensions. Construct straight-line courses as a geodesic path. Construct parallel and trapezoidal boundary lines as a locus of points measured perpendicular to the geodesic path. Determine OEA lateral boundary relative to course centerline using ellipsoidal calculations.

(2) Vertical dimension (surface elevations). Obstacle clearance evaluation/clearance surfaces are generally defined as either a level or sloping plane relative to a defined origin MSL elevation. Evaluate the orthometric height above the geoid (MSL) of obstacles and terrain relative to these surfaces.

(3) Alignment. The alignment tolerance is ± 0.03 degrees of all course differentials. The general alignment restriction between TF/CF legs at or above FL 195 is limited to a maximum course change of 70 degrees, while below FL 195 is 90 degrees; however, specific requirements stated in a segment's chapter/section take precedence. When preceded by a DF leg, the alignment restriction applies to both the early and late tracks. The general alignment restriction between TF and RF legs is no course change exceeding alignment.

Note: When using pre-established fixes, acceptably small differences in fix coordinates can cause legs to exceed alignment tolerance. The alignment tolerance can be exceeded when the calculated ideal fix coordinates round to match the pre-existing fix coordinates [see Order 8260.19, paragraph 8-5-2].

b. Area dimensions. For IFP design purposes, the term XTT is the larger of basic XTT and the effective XTT associated with a leg.

(1) Length.

(a) Minimum length (fix-to-fix). Generally, minimum leg length is the lesser of $2 \times$ XTT or 1 NM, but where applicable may also be no less than;

1. The sum of the distance of turn anticipation (DTA) for each fly-by (FB) turn [see formula 1-2-1].

Note: Not applicable for FB turns of 10 degrees or less.

Formula 1-2-1. Distance Turn Anticipation

$$\mathrm{DTA} = \mathrm{R} \times \tan\left(\frac{\beta}{2}\right)$$

Where:
β = magnitude of heading change in degrees
R = turn radius

Example:

$$\mathrm{DTA} = 3.52 \times \tan\left(\frac{75}{2}\right)$$
$$\mathrm{DTA} \approx 2.7$$

Note: This formula produces a value with the same unit as R.

2. For TF legs following a fly-over (FO) turn a length sufficient to allow the aircraft to return to course centerline. Determine using formula 1-2-2.

Formula 1-2-2. TF Minimum Leg Length Following FO Turn

If $\beta < \mathrm{acos}\left(\sqrt{3}-1\right)$ use:

$$L=R \times \left[\sin(\beta) + 2 \times \sin\left(\mathrm{acos}\left[\frac{1+\cos(\beta)}{2}\right]\right)\right] + DTA$$

If $\beta \geq \mathrm{acos}\left(\sqrt{3}-1\right)$ use:

$$L = R \times \left[\sin(\beta) + 4 - \sqrt{3} - \sqrt{3} \times \cos(\beta)\right] + DTA$$

Note: L must not be less than 1 NM

Where:
R = turn radius at the first fix
β = magnitude of heading change at the first fix
DTA = value from formula 1-2-1 for the second fix

Note: When multiple courses precede the FO fix (e.g., VA-DF legs) use the track resulting in the greatest magnitude of heading change at the first fix.

Example:

$$L = 5.6 \times \left[\sin(33) + 2 \times \sin\left(\mathrm{acos}\left[\frac{1+\cos(33)}{2}\right]\right)\right] + 2.7$$

$$L \approx 10.16$$

Note: This formula produces a value with the same unit as R.

(b) RF leg length may be calculated using formula 1-2-3. Use in conjunction with formula 1-2-4 when necessary to calculate an RF leg of a specific length.

Formula 1-2-3. RF Leg Length

$$L = \frac{\alpha \times \pi \times R}{180}$$

Where:
α = degrees of arc
R = arc radius

Example:

$$L = \frac{98.9 \times \pi \times 4.2}{180}$$

$$L \approx 7.25$$

Note: This formula produces a value with the same unit as R.

Formula 1-2-4. Degrees of an Arc

$$\alpha = \frac{180 \times L}{\pi \times R}$$

Where:
L = arc length
R = arc radius

Note: This formula works with any unit so long as L & R share the same unit.

Example:

$$\alpha = \frac{180 \times 7.25}{\pi \times 4.2}$$

$$\alpha \approx 98.90^\circ$$

(c) Maximum length (fix-to-fix). Maximum Standard Instrument Approach Procedure (SIAP) segment length is as specified in Order 8260.3, chapter 2. In no case should the length of any PBN leg exceed 500 NM.

(d) Along-track tolerance (ATT). OEAs are constructed and evaluated from ATT prior to a leg's initial fix (early) to ATT past its termination fix (late). ATT is equal to the navigation accuracy associated with the flight phase [see table 1-2-1]. ATT (same or adjacent legs) can overlap when legs meet minimum length requirements.

1. Except where specified otherwise (e.g., intermediate segment) use the ATT specific for the leg being constructed for both early and late ATT.

2. The baseline used for determining early/late ATT area depends on the leg/turn type**.**

a TF (no turn) and FO turn. ATT is relative to a line perpendicular to the inbound leg at the fix [see figure 1-2-1].

b FB turn. ATT is relative to the bisector used for OEA construction [see figure 1-2-2].

c RF. ATT is relative to a line drawn radially from the turn center point. Distance is measured from the fix along the RF arc [see figure 1-2-3].

Figure 1-2-1. ATT Straight

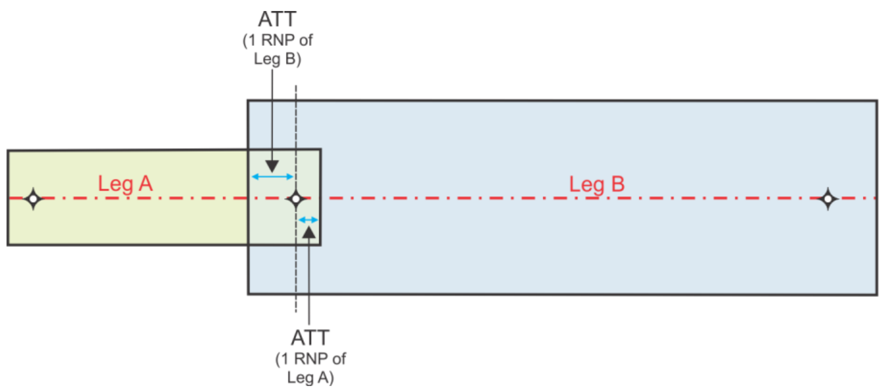


Figure 1-2-2. ATT Turning

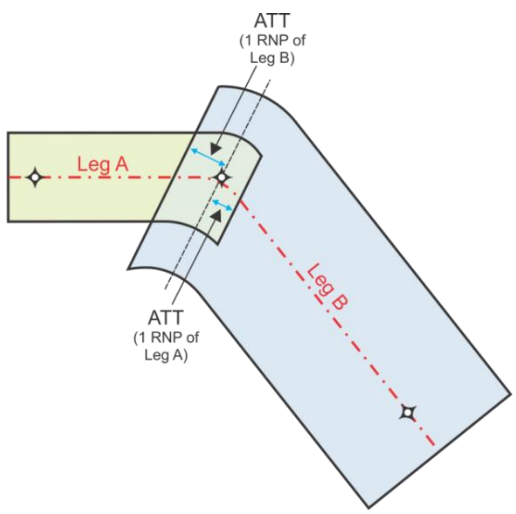
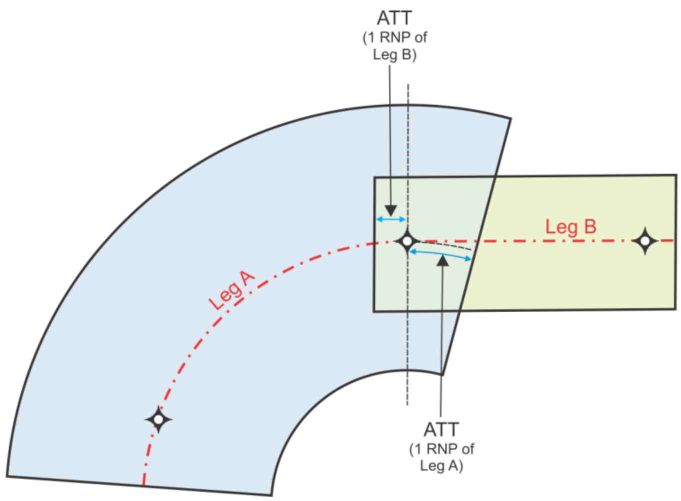


Figure 1-2-3. ATT RF



(2) Width.

(a) Cross-track tolerance (XTT). The XTT is used to determine the OEA lateral dimensions. The XTT is derived from table 1-2-1 navigation accuracy for the defined NavSpec and flight phase. Primary area width is 2 × XTT either side of course and secondary area width is 1 × XTT either side of the primary area, if applicable. The XTT for A-RNP and RNP AR is the specified RNP value for the leg being evaluated. Reference to route width is often specified as NM values measured from secondary area edge across the primary area to the secondary edge at the other side. For example, feeder widths may be referred to as "2-4-4-2."

(b) Width changes. RNP AR APCH and A-RNP width changes occur abruptly at the start fix of a leg with a new RNP. A-RNP width values may only be decreased prior to final and increased on departure and missed approach. For all other IFPs, OEA construction accommodates width changes at the transition to the final approach mode and at the transition to or from the en route mode. See the applicable chapter for width changes at the final approach transition. For the en route transition, legs that cross a point 30 NM from ARP, the OEA primary area width expands or tapers at a rate of 30 degrees relative to course to the appropriate width [see figure 1-2-4 and figure 1-2-5]. Calculate the total along-track distance required to complete the transition using formula 1-2-5. STAR/feeder and approach legs designed to cross within 30 NM of the ARP more than once do not change to RNAV 1/RNP 1/A-RNP (terminal mode) until the 30 NM limit is crossed for the last time. A departure or missed approach segment designed to cross a point 30 NM from the ARP more than once changes to RNAV 2/RNP 2/A-RNP (en route mode) and remains expanded when it crosses the boundary the first time. A-RNP width changes for mode transitions at 30 NM from ARP use the 30-degree splay method to/from effective XTT.

1. Non-RF width changes.

a Inbound. The secondary area tapers from en route mode width when the 30 NM point is crossed to terminal mode width abeam the point the primary area is fully tapered. Leg width tapers regardless of fix location within the tapering section unless a turn is associated with the fix. Delay OEA taper until the turn is complete and normal OEA turn construction is possible.

b Outbound. The secondary area expands from terminal mode width when the 30 NM point is crossed to en route mode width abeam the point the primary area is fully expanded. Leg width expands regardless of fix location within the expansion section unless a turn is associated with the fix. Start the OEA expansion so as to achieve full expansion to en route mode width prior to the turn.

(2) Airspeed. Locate and use the appropriate KIAS from table 1-2-2. Determine the KTAS for the turn using formula 1-2-7 based on the assumed altitude at the turn fix/point [see paragraph 1-2-5.c(1)].

Table 1-2-2. Indicated Airspeeds (KIAS)

Flight Phase		Indicated Airspeed by CAT					
		Copter	A	B	C	D	E
At or Above 10000 feet							
En route, STAR/Feeder/TAA, Initial, Intermediate, Missed, Departure		150	180	250	300	300	350
Below 10000							
En route, STAR/Feeder/TAA, Initial, Intermediate		150	150	180	250	250[1]	310
Final		90	90	120	140	165	250
Missed Approach (MA), Departure		150	110	150	240	265	310
Minimum Airspeed Restriction							
Minimum Airspeed Restriction[2]	STAR/Feeder/TAA, Initial, Departure	70	110	140	200[3]	210[3,4]	310
	Intermediate	70	110	140	180	180	310
	Missed Approach	70	100	130	165	185	310
	Final	70	Not Authorized				

[1] Consider using 265 KIAS where heavy aircraft routinely exceed 250 KIAS under 14 CFR § 91.117.

[2] Airspeed restrictions may be established at a charted fix to reduce turn radius, avoid obstacles, accommodate ATC request, etc. Use the fewest number of restrictions in the same IFP possible. Especially avoid consecutive restrictions requiring speed changes of less than 20 KIAS in the same or adjoining segments. Flight Standards or military authority approval is required for missed approach restrictions for other than obstacle avoidance.

[3] 250 above 10000 feet except for initial and/or STAR termination fix.

[4] 200 underlying Class B airspace per 14 CFR § 91.117(c).

Formula 1-2-7. True Airspeed

$$V_{KTAS} = \frac{V_{KIAS} \times 171233 \times \sqrt{303 - 0.00198 \times alt}}{(288 - 0.00198 \times alt)^{2.628}}$$

Where:
V_{KIAS} = indicated airspeed for applicable category and segment combination

Example:

$$V_{KTAS} = \frac{165 \times 171233 \times \sqrt{303\text{-}0.00198 \times 650}}{(288\text{-}0.00198 \times 650)^{2.628}}$$

$$V_{KTAS} \approx 170.88$$

(3) Maximum bank angles.

(a) Bank limited turns (assumed altitude at turn point/fix < 500 feet above airport elevation): 3 degrees.

(b) Low altitude transition turns (assumed altitude at turn point/fix from 500 feet above airport elevation up to and including FL 195):

1. XTT of the leg being constructed ≥ 1.0: 25 degrees

2. XTT of the leg being constructed < 1.0: 20 degrees

(c) High altitude transition turns (> FL 195): 5 degrees

(d) FB turns only: The lesser of one-half the track change (five degrees minimum) or the applicable low/high altitude transition bank angle. Where operationally beneficial (e.g., to reduce leg length) an exception to the one-half track change rule is authorized at a fix when the XTT for the outbound leg is not less than 1.0, a succeeding turn fix uses the applicable low/high altitude transition bank angle, and/or the succeeding leg meets minimum length requirements.

(4) Tailwind (V_{KTW}). Calculate the appropriate tailwind for the assumed altitude at the turn fix [see paragraph 1-2-5.c(1)] using formula 1-2-8. Where operationally advantageous the 99th percentile wind speed values determined from analysis of a five-year locally measured database may be substituted [see appendix A].

Formula 1-2-8. Assumed Tailwind

$$V_{KTW} = 0.00198 \times \text{alt} + 47$$

Note: If $\text{apt}_{\text{elev}} - \text{alt} \leq 2000$, $V_{KTW} = 30$

Example:

$V_{KTW} = 0.00198 \times 3400 + 47$
$V_{KTW} \approx 53.73$

(5) Turn radius (R). The design turn radius value is based on the turn parameters assumed tailwind [see formula 1-2-8], groundspeed [see formula 1-2-9], assumed altitude at the turn fix/point [see paragraph 1-2-5.c(1)], and bank angle [see paragraph 1-2-5.c(3)]. Calculate R using formula 1-2-10. For RF turn radius, see paragraph 1-2-5.d(3).

Formula 1-2-9. Groundspeed

If alt >FL 195 use:

$$V_{\text{ground}} = \text{lesser of 570 or } \frac{0.9941 \times \text{alt}}{100} + 287$$

If alt ≤ FL 195 use:

$$V_{\text{ground}} = \text{lesser of 500 or } V_{\text{KTAS}} + V_{\text{KTW}}$$

Where:
V_{KTAS} = calculated KTAS using alt and applicable KIAS
V_{KTW} = calculated or historical tailwind (knots) using alt

Example:

$$V_{\text{ground}} = \frac{0.9941 \times 26500}{100} + 287$$
$$V_{\text{ground}} \approx 550.44 \text{ knots}$$

Formula 1-2-10. Turn Radius

$$R = \frac{{V_{\text{ground}}}^2}{\tan(\phi) \times 68625.4}$$

For FB turns, if resulting DTA > 20 NM, then:

$$R = \frac{20}{\tan(\beta \times 0.5)}$$

Where:
β = magnitude of heading change in degrees
V_{ground} = ground speed (knots)
ϕ = designed bank angle or 5 degrees where > FL 195

Example:

$$R = \frac{550.44^2}{\tan(5) \times 68625.4}$$
$$R \approx 50.46 \text{ NM}$$

Formula 1-2-11. RF Bank Angle

$$\phi = \text{atan}\left(\frac{V_{ground}{}^{2}}{R \times 68625.4}\right)$$

Where:
V_{ground} = calculated ground speed (knots) at the highest assumed altitude in the leg
R = turn radius (NM)

Example:

$$\phi = \text{atan}\left(\frac{550.44^{2}}{50.46 \times 68625.4}\right)$$

$$\phi \approx 5.00°$$

d. Turn construction. When an RNP change is necessary, the construction of the OEA is accomplished using the RNP value of the leg being evaluated extended into the subsequent leg [see figure 1-2-1, figure 1-2-2, and figure 1-2-3].

(1) Turns at FB fixes [see figure 1-2-7]. The following steps detail the construction of the minimum OEA adjacent to a single FB turn fix. The centerlines and/or the lateral boundaries may need to be temporarily extended to achieve tangency with the turn arcs. To complete the OEA for a leg, apply the appropriate construction criteria for the remaining fix in the leg and then truncate and/or connect the components such that the most adverse boundary is created. The following steps detail construction of the minimum OEA for a FB turn fix. An OEA larger than the minimum is acceptable where connecting boundary lines becomes problematic due to turns and leg lengths. Leg lengths must comply with paragraph 1-2-5.b(1).

(a) *Step 1*. Establish a line through the turn fix that bisects the turn angle. With the origin on the bisector line, scribe an arc that is tangent to the inbound and outbound centerlines using a radius equal to R.

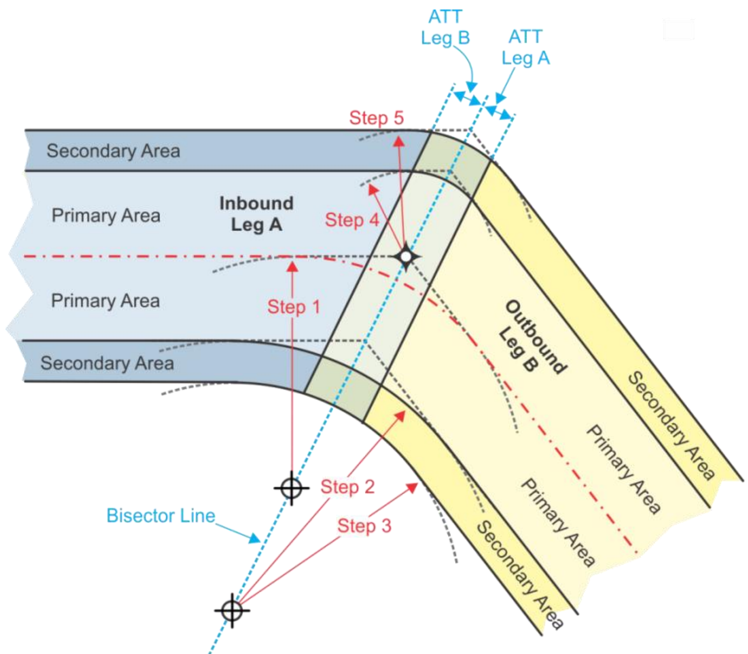
(b) *Step 2*. Primary area inner boundary. With the origin on the bisector line, scribe an arc that is tangent to the inner primary boundaries of the two legs using a radius equal to $R + XTT$.

(c) *Step 3*. Secondary area inner boundary (if applicable). Using the origin from *Step 2*, scribe an arc that is tangent to the inner secondary boundaries of the two legs using a radius equal to R.

(d) *Step 4*. Primary area outer boundary. Centered on the turn fix, scribe the primary area outer boundary arc using a radius equal to $2 \times XTT$.

(e) *Step 5*. Secondary area outer boundary (if applicable). Centered on the turn fix, scribe the secondary area outer boundary arc using a radius equal to $3 \times XTT$.

Figure 1-2-7. FB Turn Construction



(2) Turns at FO fixes [see figure 1-2-8 and figure 1-2-9].

(a) *Step 1.* FO turn construction incorporates a delay in start of turn to account for pilot reaction time and roll-in time. Calculate the extension distance using formula 1-2-12. FO turn construction is not authorized for A-RNP.

Formula 1-2-12. Reaction & Roll Distance

$$D_{rr} = \frac{V_{KTAS} \times 6}{3600}$$

Where:
V_{KTAS} = calculated KTAS using applicable altitude and KIAS combination

Example:

$$D_{rr} = \frac{253.62 \times 6}{3600}$$

$$D_{rr} \approx 0.42 \text{ NM}$$

(b) *Step 2.* Establish the baseline for construction of the turn expansion area as the line perpendicular to the inbound track at a distance past the turn fix equal to ATT + D_{rr}.

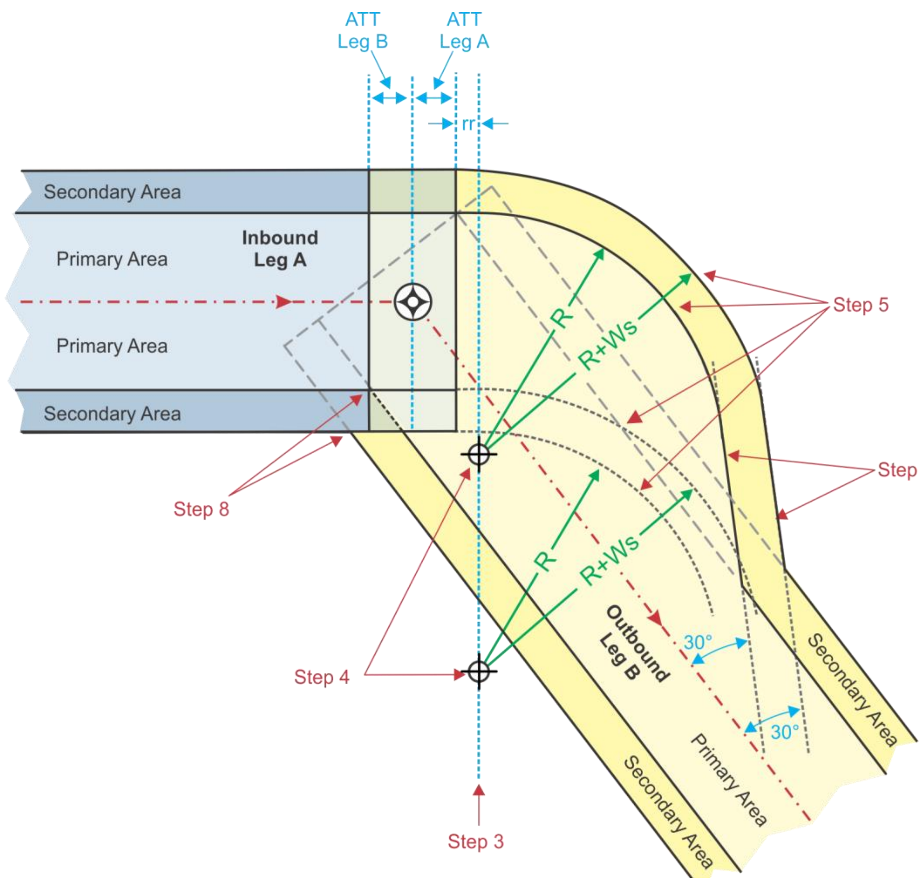
(c) *Step 3.* Determine R based on bank angle intended for design [see paragraph 1-2-5.c(3)].

(d) *Step 4*. On the baseline, locate the center points for the primary and secondary turn boundaries. The first is located at a distance R from the non-turning side primary boundary. The second is located at a distance R from the turning side secondary boundary.

(e) *Step 5*. From these center points construct arcs for the primary boundary of radius R. Complete the secondary boundary by constructing additional arcs of radius R + secondary area width from the same center points.

(f) *Step 6*. The arcs constructed in *Step 5* are tangent to the outer boundary lines of the inbound leg. Construct lines tangent to the arcs based on the first turn point tapering inward at an angle of 30 degrees relative to the outbound track that joins the arc primary and secondary boundaries with the outbound leg primary and secondary boundaries. If the arcs from the second turn point are inside the tapering lines as shown in figure 1-2-8, then they are disregarded and the expanded area construction is completed. If not, proceed to *Step 7*.

Figure 1-2-8. FO with No Second Arc Expansion



(g) *Step 7*. If both the inner and outer arcs lie outside the tapering lines constructed in *Step 6*, connect the respective inner and outer arcs with tangent lines and then construct the tapering lines from the arcs centered on the second center point.

(h) *Step 8*. The inside turn boundaries are the intersection of the preceding and succeeding leg primary and secondary boundaries

Section 1-3. Common Criteria

1-3-1. Common criteria. The following common requirements are applicable to PBN IFPs.

a. Descent gradient (DG) calculation. The applicable section of Order 8260.3, chapter 2 applies, except use formula 1-3-1 to calculate descent gradient.

Formula 1-3-1. Descent Gradient

$$DG = \ln\left(\frac{r + alt_b}{r + alt_e}\right) \times \frac{r}{D}$$

Where:
Alt_b = beginning altitude (feet)
Alt_e = ending altitude (feet)
D = distance (NM) between the points of interest

Example:

$$DG = \ln\left(\frac{r + 6500}{r + 3200}\right) \times \frac{r}{10.36}$$

$$DG \approx 318.46\ \mathrm{ft/NM}$$

b. Secondary area (when applicable). Obstacles located in secondary areas are subject to less obstacle clearance than those contained in the primary area. Unless otherwise specified, calculate the secondary ROC using formula 1-3-2.

Formula 1-3-2. Secondary ROC

$$ROC_{secondary} = (ROC_{min} + adj) \times \left(1 - \frac{d_{primary}}{w_s}\right) + RASS$$

Where:
ROC_{min} = min. secondary ROC (feet) at primary boundary [see Order 8260.3 chapter 2]
adj = ROC adjustments (feet) such as excessive length of final and precipitous terrain
RASS = remote altimeter setting source adjustment (feet) if applicable
$d_{primary}$ = dist. (feet) from primary area boundary to obstacle. Zero (0) if not in secondary
w_s = secondary area width (feet)

Example:

$$ROC_{secondary} = (250 + 74.32) \times \left(1 - \frac{405.86}{1822.83}\right) + 91.69$$

$$ROC_{secondary} \approx 343.80\ \mathrm{feet}$$

c. ATC turns to join initial and intermediate segments. The first leg of an initial or intermediate segment must be a TF that accommodates a 90-degree intercept angle. Use standard turn parameters at the start fix, except a 25-degree bank angle applies. Where a shorter leg is needed, reduce airspeed in increments of not less than five KIAS until the desired length is achieved [see table 1-2-2].

d. Initial approach segment. Initial approach segments consist of one or more TF or RF legs or a hold-in-lieu-of-procedure turn (HILPT). Standard length and alignment applies [see paragraph 1-2-5]. In some cases, initial segments are optional [see Order 8260.3, paragraph 2-4-1.a].

(1) Configuration. The default design incorporates a basic T configuration. The optional Basic Y configuration or RF leg initials may be used where beneficial.

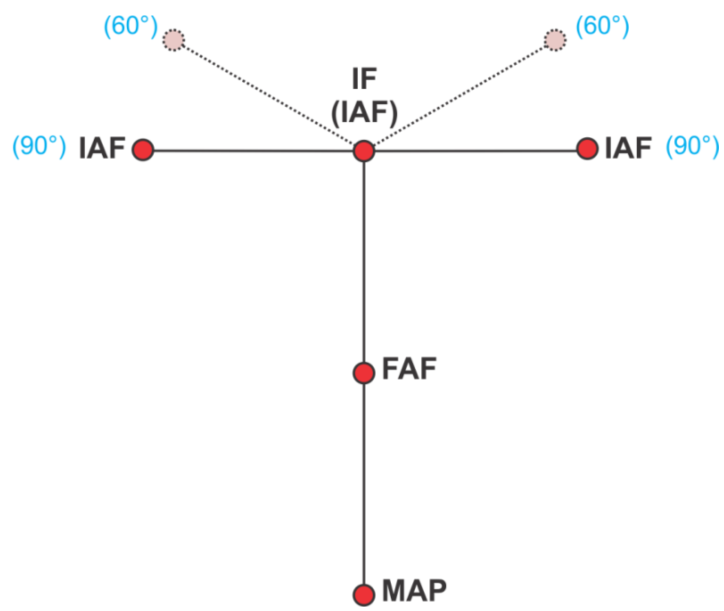
(a) Basic T. Two TF leg initial segments intercept the intermediate segment at 90-degree angles.

(b) Basic Y. One or both of the initial segments intercept at an angle less than 90 degrees, but normally not less than 60 degrees.

(c) Course reversal. Basic T/Y configurations normally include a HILPT course reversal initial established at a fix designated as an intermediate fix (IF)/Initial Approach Fix (IAF).

(d) Modified T/Y. Where not practical (e.g., maximum DG exceeded) one or both of the T/Y segments and/or the course reversal may be eliminated. Intercept angles less than 60 degrees and/or more than two segments may also be established where beneficial.

Figure 1-3-1. Basic T/Y Configuration



(2) Holding pattern. A holding pattern may be incorporated into the initial segment procedure design where an operational benefit can be derived; e.g., arrival holding at an IAF, course reversal pattern at the IF, etc. See Order 8260.3, chapter 17 for RNAV holding pattern construction guidance.

Formula 1-3-3. Distance on Baro Glidepath

$$d_{Baro} = \ln\left(\frac{r + alt_e}{r + alt_b}\right) \times \frac{r}{\tan(\theta)}$$

Where:
alt_e = ending altitude (feet)
alt_b = beginning altitude (feet)

Example:

$$d_{Baro} = \ln\left(\frac{r + 4500}{r + 1441.6 + 47}\right) \times \frac{r}{\tan(3)}$$

$$d_{Baro} \approx 57452.70 \text{ feet}$$

3. Glidepath altitude. Calculate the altitude of the glidepath at any distance from the LTP/FTP using formula 1-3-4.

Formula 1-3-4. Altitude on Baro Glidepath

$$Z_{Baro} = e^{\left(\frac{d \times \tan(\theta)}{r}\right)} \times (r + alt_b) - r$$

Where:
alt_b = beginning altitude (feet)
d = distance (feet) between the points of interest

Example:

$$Z_{Baro} = e^{\left(\frac{4708.89 \times \tan(3)}{r}\right)} \times (r + 404.6 + 45) - r$$

$$Z_{Baro} \approx 696.39 \text{ feet}$$

g. Missed approach and departure.

(1) Sloping OCS. The OCS slope is dependent on the starting OCS elevation and a specific obstacle of interest. When calculating the height of the sloping surface, a default slope of 40:1 may be used to determine potential controlling obstructions. The actual OCS slope associated with any given obstacle is calculated using formula 1-3-5 and the OCS elevation at a point of interest can be found using formula 1-3-6.

Formula 1-3-5. OCS Slope

$$OCS_{slope} = \frac{d_O}{\ln\left(\frac{r + O_{elev}}{r + OCS_{start}}\right) \times r}$$

Where:
O_{elev} = actual or $O_{adjusted}$ obstacle elevation (feet)
OCS_{start} = starting altitude (feet)of the OCS
d_O = dist. (feet) from AC_{start} to obstacle (primary) or point abeam obstacle (secondary)

Example:

$$OCS_{slope} = \frac{6076.12}{\ln\left(\frac{r + 1152.6}{r + 1000.6}\right) \times r}$$

$$OCS_{slope} \approx 39.98$$

Formula 1-3-6. OCS Elevation

$$OCS_{elev} = e^{\left(\frac{d_{OCS}}{r \times OCS_{slope}}\right)} \times (r + OCS_{start}) - r$$

Where:
d_{OCS} = distance (feet)from OCS_{start} point to the point of interest
OCS_{start} = starting altitude (feet) of the OCS

Example:

$$OCS_{elev} = e^{\left(\frac{2591.8}{r \times 28.5}\right)} \times (r + 1191.75) - r$$

$$OCS_{elev} \approx 1282.70 \text{ feet}$$

(2) Climb gradient (CG). Obstacle clearance in a climbing segment is dependent on the aircraft maintaining a minimum CG to a specified altitude. The minimum CG (also referred to as standard CG) is 200 ft/NM. When one or more obstacle penetrates the default OCS, a single increased CG that provides clearance over all penetrations may be established. A CG greater than 425 ft/NM is not authorized for missed approach. Calculate the minimum climb gradient required to achieve the termination altitude at a given distance using formula 1-3-7.The aircraft altitude at a point of interest can be found using formula 1-3-8 and the distance required to achieve an altitude at any CG can be found using formula 1-3-9

Chapter 2. En Route, Standard Terminal Arrivals, Feeder Routes, and Terminal Arrival Areas (TAA).

Section 2-1. En Route

2-1-1. Air Traffic Service (ATS) Q/T/TK Routes. Q, T, and TK routes may be developed to support en route PBN operations. The NavSpec is RNAV 2 En route (with associated XTT of 2). Optional NavSpec may be A-RNP En route (with associated XTT of 2 or 1 as appropriate). Secondary areas apply.

a. General.

(1) Q routes are for use from 18000 feet MSL through FL450 inclusive.

(2) T/TK routes are for use from as low as 1200 feet AGL up to but not including 18000 feet MSL.

(3) Leg/Fix type. Use TF legs only. Fixes may only be FB waypoints or NAVAIDs.

b. OEA construction.

(1) Area. Except for route termination fixes, apply paragraph 1-2-5. Where applicable, construction is bi-directional.

(2) Construction at route termination fixes. Order 8260.3 paragraph 15-1-2 applies except primary and secondary boundary arcs are centered ATT past the termination fix.

c. Obstacle clearance. Order 8260.3, section 15-2 applies. Secondary ROC may be calculated as specified in Order 8260.3, section 15-2 or formula 1-3-2 (of this order).

d. Altitudes. Order 8260.3, section 15-3 applies except MCA distances are measured from ATT past the fix.

2-1-2. ATS RNP 0.3 Routes (Copter only). RNP 0.3 routes may be developed to support en route PBN copter operations. The NavSpec is RNP 0.3 En route (with associated XTT of 0.3). Secondary areas apply.

a. General.

(1) RNP 0.3 routes are for use from as low as 1200 feet AGL up to but not including 18000 feet MSL.

(2) Leg/Fix type. Use TF legs only. Fixes may only be FB waypoints or NAVAIDs.

b. OEA construction.

(1) Area. Except for route termination fixes, apply paragraph 1-2-5. Where applicable, construction is bi-directional.

(2) Construction at route termination fixes. Order 8260.3 paragraph 15-1-2 applies except primary and secondary boundary arcs are centered ATT past the termination fix.

c. Obstacle clearance. Order 8260.3, section 15-2 applies. Secondary ROC may be calculated as specified in Order 8260.3, section 15-2 or formula 1-3-2 (of this order).

d. Altitudes. Order 8260.3, section 15-3 applies except MCA distances are measured from ATT past the fix.

Section 2-2. Standard Terminal Arrival (STAR)

2-2-1. PBN STAR. A PBN STAR may be established to transition from the en route environment to the terminal environment. The NavSpec is RNAV 1 STAR/Feeder/TAA (with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP STAR/Feeder/TAA (with associated XTT of 1 - 0.3 as appropriate). For STARs that serve multiple airports, use the most conservative distance to determine where the effective XTT is 2 [see table 1-2-1 footnote 2]. Secondary areas apply. Order 8260.3, section 2-2 applies in conjunction with the following PBN specific criteria.

a. General.

(1) Leg type. Use TF or RF legs, except a heading to a manual termination (VM) or from a fix to a manual termination (FM) leg may be established at the STAR termination.

(2) Fixes.

(a) All fixes prior to the termination fix must be FB.

(b) The termination fix may be either FB or FO depending on whether the STAR connects to a SIAP, the attributes of the common fix, and leg type. For this purpose, the first coded fix of the SIAP (i.e., the start of the SIAP "IF" leg) is considered a FB fix.

1. When the termination fix is a common fix followed by an FM or VM leg, the termination fix attribute must be FO and the SIAP fix should be FB.

2. For other cases, common fix attributes must be identical.

3. When the termination is not at a common fix, the STAR must terminate with a VM or FM leg at a FO fix.

Note: When more than one transition/common route terminates at the same fix, more than one of the above can apply simultaneously**.** In those cases, the waypoint attribute must be the same on each of the common routes/runway transitions.

b. Area. Apply paragraph 1-2-5 for area construction and alignment.

Note: When the STAR terminates at a fix on a SIAP, paragraph 1-2-5 applies between the last leg of a STAR and the first leg of SIAP. When a STAR terminates in a VM or FM leg ensure the fix altitude is at or above the MVA/MIA.

c. Obstacle clearance. Apply Order 8260.3, paragraph 2-2-1. Alternatively, formula 1-3-2 (of this order) may be used to calculate secondary ROC.

Section 2-3. Feeder Routes

2-3-1. Feeder route. A feeder route may be developed as an optional transition from the en route environment to the terminal structure [see Order 8260.19, paragraph 4-6-2]. Use TF and/or RF legs. The NavSpec is RNAV 1 STAR/Feeder/TAA (with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP STAR/Feeder/TAA (with associated XTT of 1 - 0.3 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply.

a. General. Apply paragraph 1-2-5 for course alignment.

b. Area. Apply paragraph 1-2-5 for area construction.

c. Obstacle clearance. Apply Order 8260.3, paragraph 2-3-1. Alternatively, formula 1-3-2 (of this order) may be used to calculate secondary ROC.

Section 2-4. Terminal Arrival Area (TAA)

2-4-1. General. A TAA may be established as an optional feeder/arrival transition from the en route structure. It consists of TAA arrival areas developed in conjunction with an approach procedure utilizing RNAV initial segments. In the TAA arrival areas, the PBN is RNAV 1 STAR/Feeder/TAA flight phase. Secondary areas are not applied; however, buffers are defined from each area boundary.

2-4-2. Approach procedure. Design in accordance with the applicable criteria in conjunction with the following guidance.

a. Initial approach segments.

(1) Use TF legs (FB fixes only) in a basic or modified T configuration only [see paragraph 1-3-1.d].

(2) Maximum segment length is 15 NM.

(3) A hold-in-lieu-of-procedure turn (HILPT) initial segment must be established at the IF/IAF at an altitude compatible with the TAA arrival area altitudes [see paragraph 2-4-3.e]. The inbound holding course must be aligned with the intermediate segment.

b. Intermediate approach segment. Establish a single dual purpose IF/IAF using TF (FB fixes only) aligned with the FAS.

c. Missed approach segment. Where possible, design missed approach segments to allow a “direct entry” into a missed approach holding pattern [see figure 2-4-1]. If the missed approach routing terminates at a base area IAF, align the missed approach holding pattern with the initial inbound course [see figure 2-4-2].

Figure 2-4-1. Default Missed Approach Holding Alignment

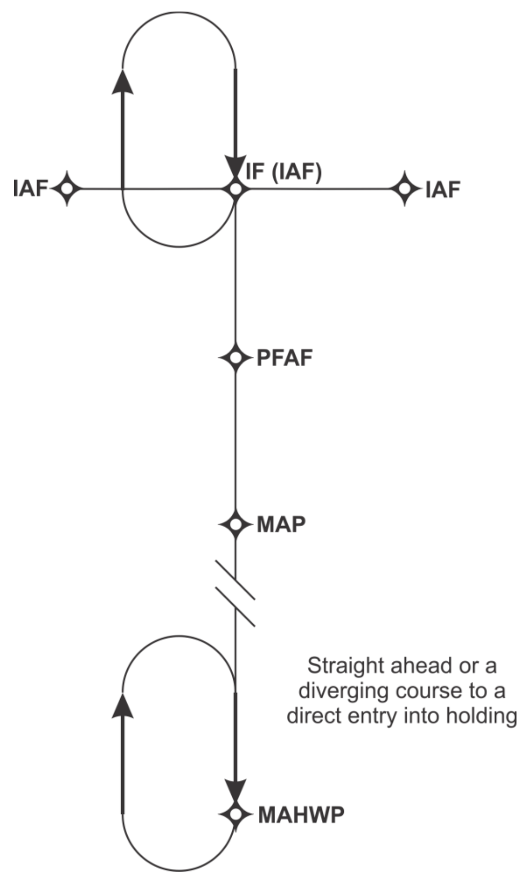
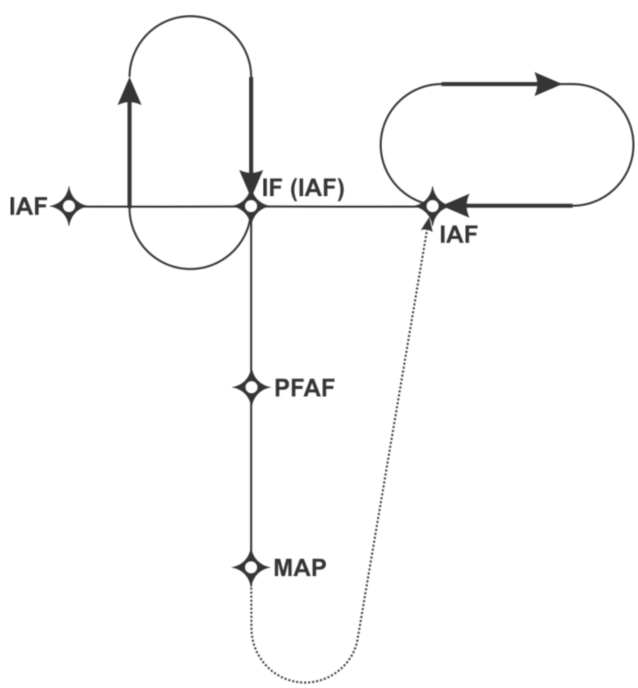
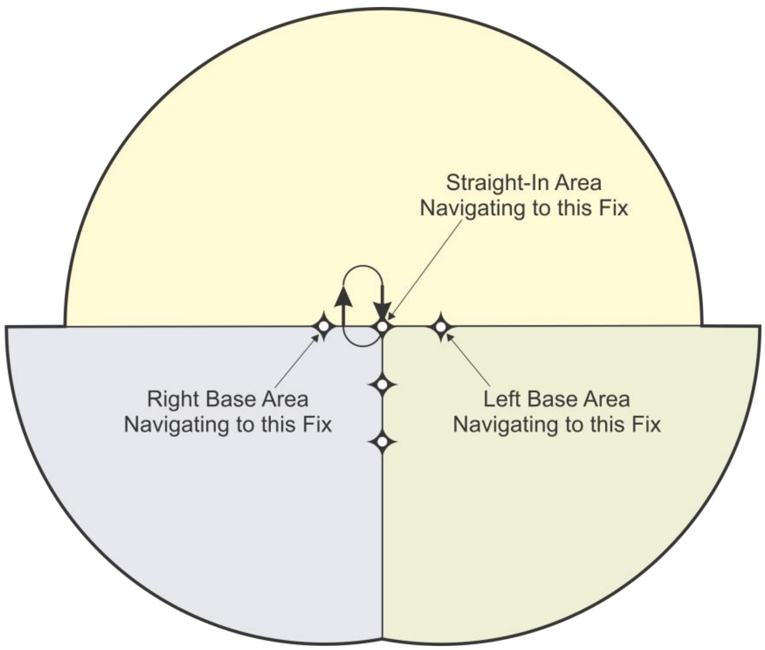


Figure 2-4-2. Missed Approach Holding Alignment at T IAF



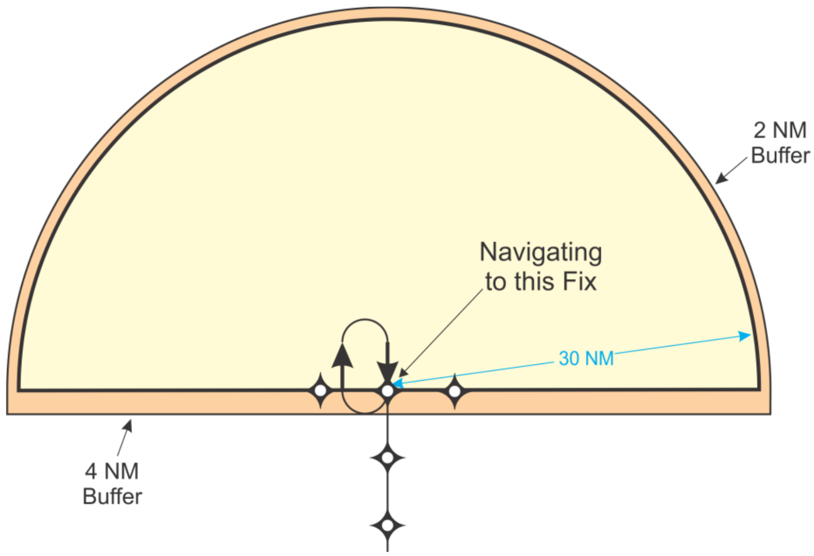
2-4-3. Arrival areas. A default TAA contains a straight-in area, a right base area, and a left base area. Each area is defined relative to a specific IAF [see figure 2-4-3]. The boundary between the straight-in area and the base areas is defined by extensions of the T initial segment track centerlines. The boundary between the right and left base areas is an extension of the intermediate segment track centerline.

Figure 2-4-3. Default TAA Arrival Areas



a. Straight-in area. Construct the base area side boundary by extending a 30-NM line from the IF/IAF through each T initial segment IAF. Construct the outside boundary by connecting the base area side boundary lines with a 30-NM arc centered on the IF/IAF [see figure 2-4-4]. Apply a 4-NM obstacle evaluation buffer on the base area side boundary and a 2-NM buffer on the outside boundary.

Figure 2-4-4. Straight-in Area



b. Right and left base area. The straight-in side boundaries are the initial segment track centerlines from IAF/IF to each IAF extended outward 30 NM. The boundary between the right and left base areas (inside boundary) is an extension of the intermediate segment track centerline. Construct the outside boundaries as 30-NM arcs centered on each IAF from the straight-in side boundary in the appropriate direction (clockwise or counter-clockwise) to the intersection of the intermediate segment track centerline extended [see figure 2-4-5]. Apply a 4-NM obstacle evaluation buffer on the straight-in and inside boundaries and a 2-NM buffer on the outside boundary.

Figure 2-4-5. Right Base Area

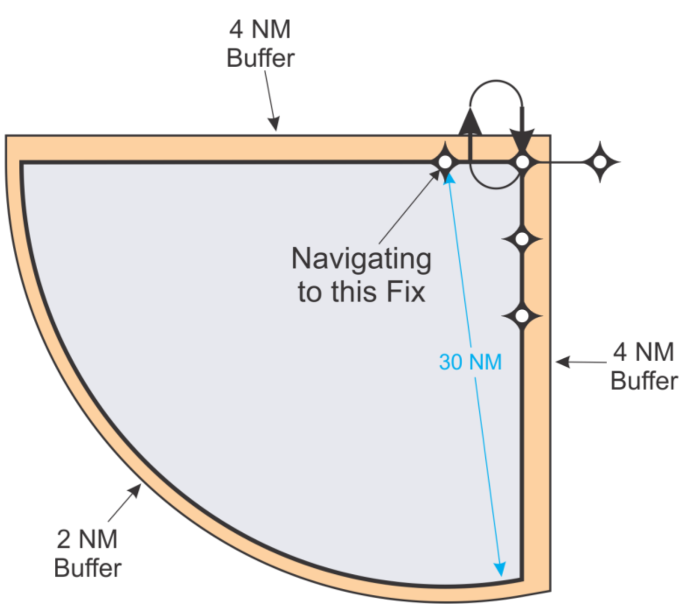
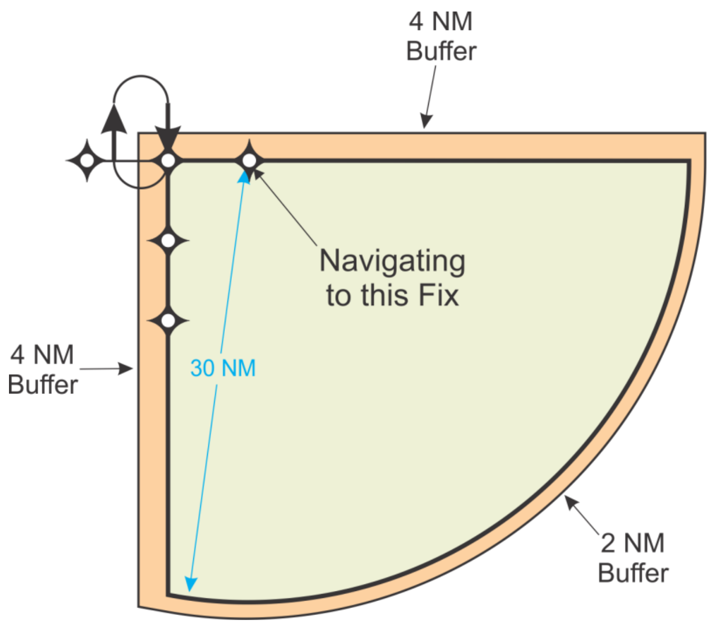


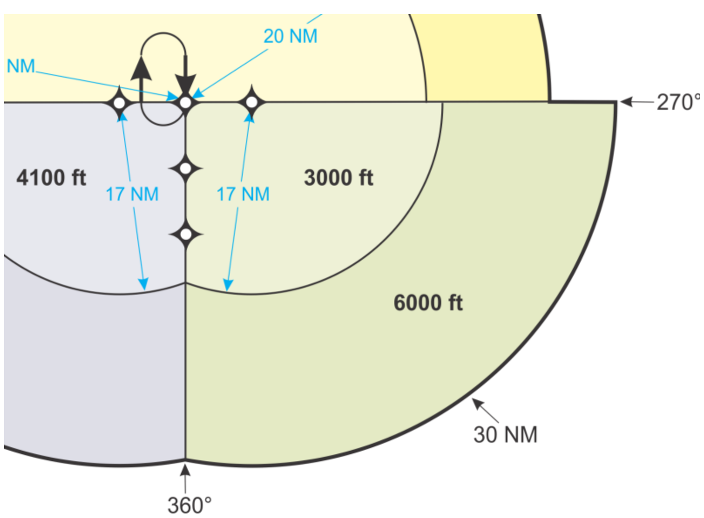
Figure 2-4-6. Left Base Area



c. Area modification. Modifications to the default TAA design may be necessary to achieve an acceptable descent gradient or to meet operational requirements.

(1) Stepdown arcs. Areas may be sub-divided using a stepdown arc [see figure 2-4-7]. Stepdown arcs are centered on the fix associated with the area and may not be less than 4 NM from the center fix or within 4 NM of the outer boundary. Only one stepdown arc may be established per area/sector. A 2-NM obstacle evaluation buffer applies from the stepdown arc. The altitude at the stepdown arc must not result in an excessive descent gradient in the associated NoPT initial calculated as length plus stepdown arc radius.

Figure 2-4-7. Area Modification; Stepdown Arcs



(2) Radial sectorization. The straight in or extended straight-in area [see paragraph 2-4-3.c(3)(a)] may be divided into up to three sectors defined radially by inbound courses to the IF/IAF [see figure 2-4-8]. Radial sectors can be used alone or in conjunction with stepdown arcs [see figure 2-4-9]. The angular size of a sector may not be less than 30 degrees, except a sector with a side defined by a base area boundary that also includes a stepdown arc may not be less than 45 degrees. A 4-NM obstacle evaluation buffer applies to radial sector boundaries.

Figure 2-4-8. Area Modification; Straight-in Area Radial Sectorization

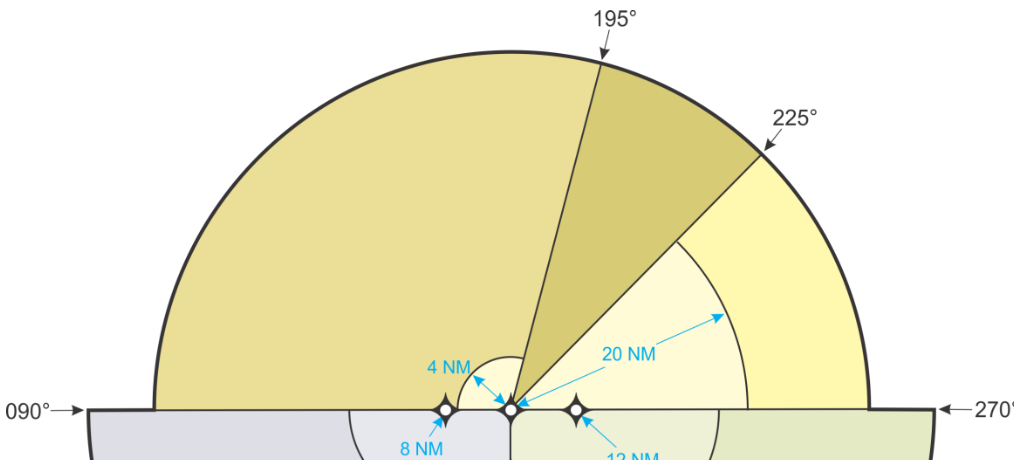
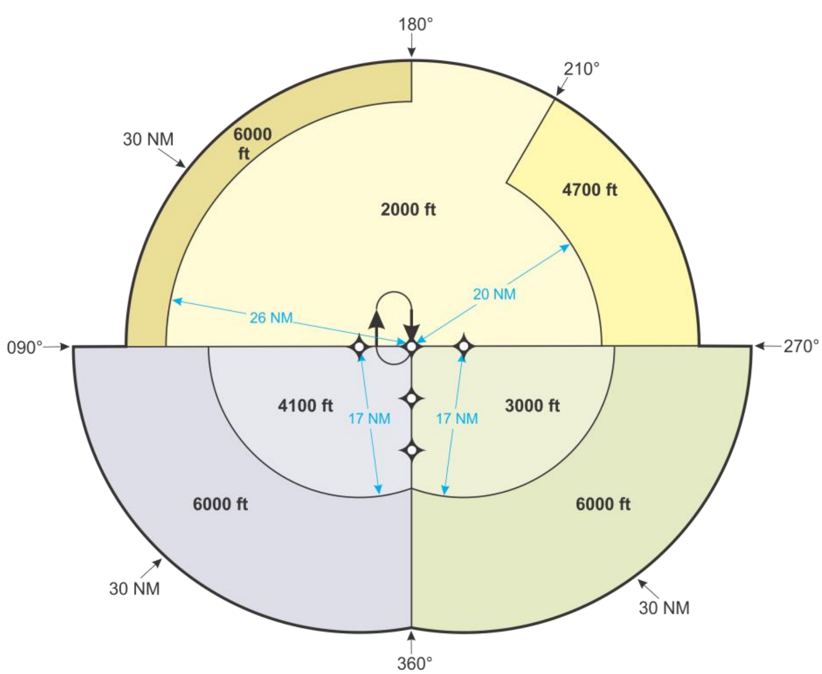


Figure 2-4-9. Area Modification; Radial Sectorization and Stepdown Arcs



(3) Base area elimination. One or both of the basic T initial approach segments and its associated base area may be eliminated [see figure 2-4-10 and figure 2-4-11].

(a) Construction. The straight-in area construction is extended into the area of the eliminated base area(s). Paragraph 2-4-3.b construction applies to a remaining base area. Paragraph 2-4-3.a applies except the outside boundary is a 30-NM arc connecting the base area side boundary line to the intermediate segment track centerline extended. When both base areas are eliminated, the straight-in area is a 30-NM circle centered on the IF/IAF.

Figure 2-4-10. Area Modification; Right Base Area Elimination

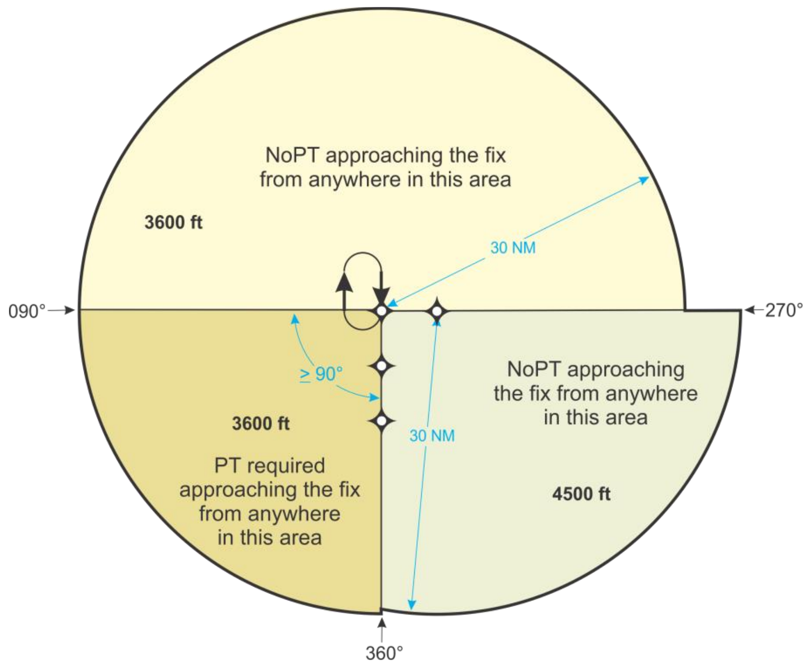
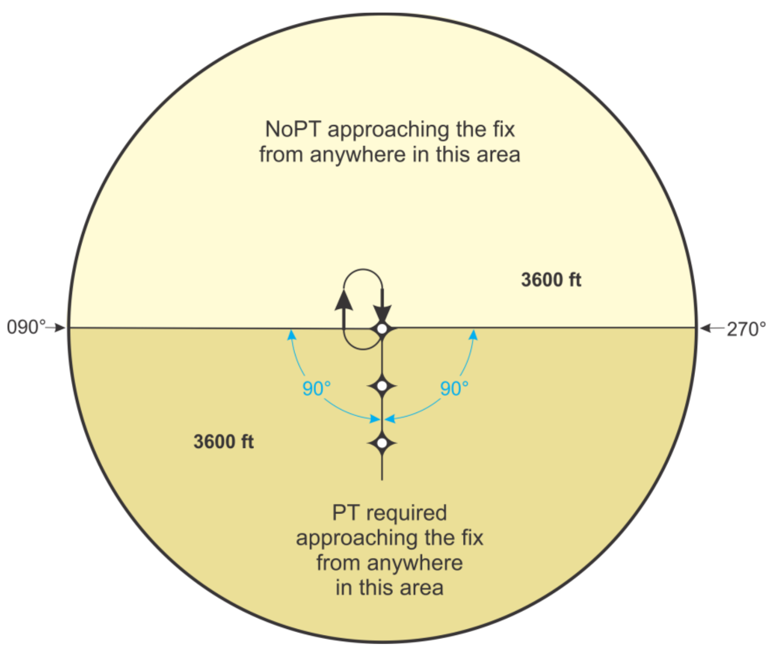
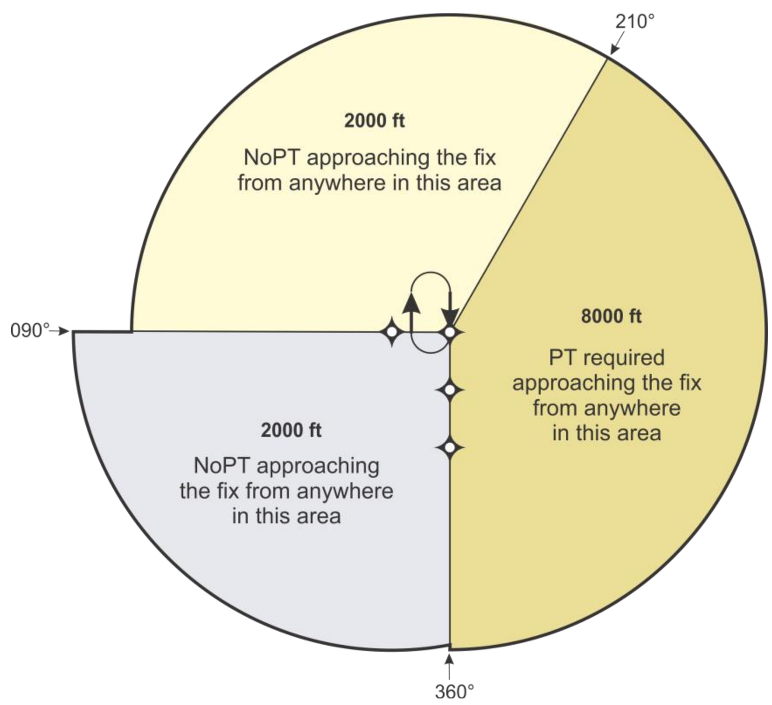


Figure 2-4-11. Area Modification; Both Right and Left Base Area Elimination



(b) No procedure (NoPT) exclusion. The sector associated with an eliminated base area must be excluded from a NoPT designation. A NoPT exclusion area may also be extended from an eliminated base area into the straight-in area when required to meet descent gradient standards.

Figure 2-4-12. Area Modification; NoPT Exclusion

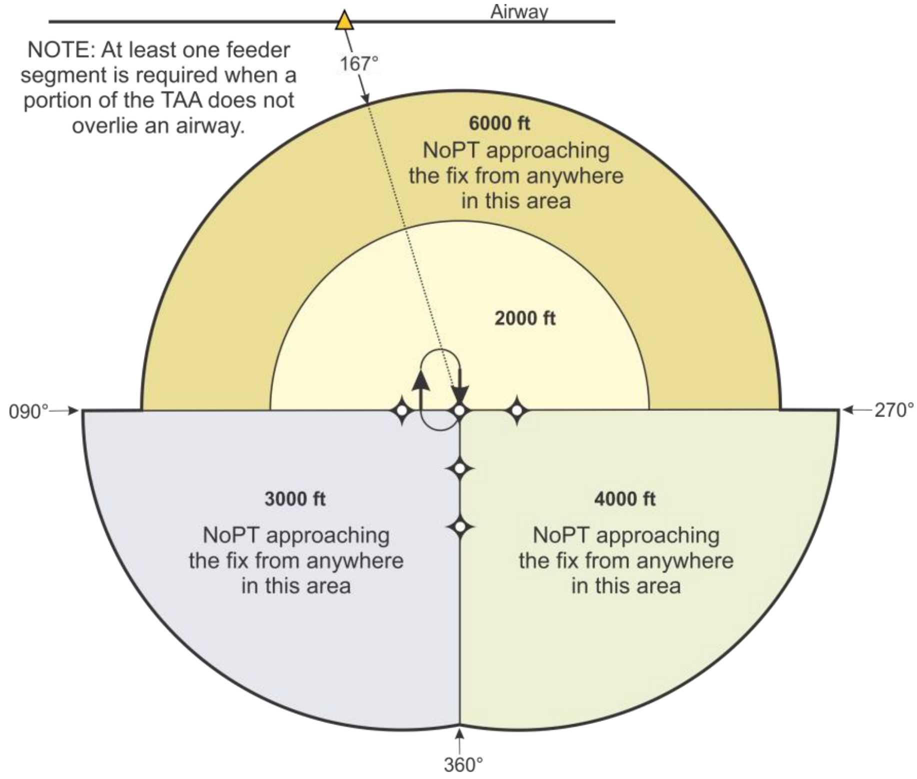


d. Obstacle clearance [see Order 8260.3, paragraph 2-3-1.c].

e. Altitude selection. A minimum altitude is specified for each area and sub-sector. Where possible establish a common IAF altitude for the right/left base and straight-in areas. Where not possible, area altitudes must permit establishment of a common altitude at the IF/IAF. Except for areas/sub-sectors excluded from a NoPT designation, the associated IAF altitude may not be lower than the applicable area/sub-sector altitude. Order 8260.3, paragraph 2-4-5.e applies to area/sub-sectors excluded from a NoPT designation.

2-4-4. Feeder route. Normally one of the TAA areas (excluding obstacle evaluation buffers) will overlie an airway. Where this is not the case, at least one feeder route must be established from the en route structure to the TAA boundary. Order 8260.3, paragraph 2-3-1 applies except alignment must be a direct course to the IF/IAF or right/left base IAF depending on the location of the feeder fix [see figure 2-4-13].

Figure 2-4-13. TAA with Feeder route



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Chapter 3. Area Navigation (RNAV) Approach

Section 3-1. General Criteria

3-1-1. Applicability. This chapter applies to procedures covered by the RNP APCH NavSpec (LPV, LP, LNAV/VNAV, and LNAV). It also applies to PBN legs that transition to an ILS or GLS final. Design transitions to a GLS final with a final track intercept within 20 NM of the airport. See Order 8260.19, chapter 8 paragraph "Minimums" for lines of RNAV minimums.

3-1-2. Feeder segment. Construct feeder segments as described in chapter 2 using one or more TF or RF legs. The NavSpec is RNAV 1 STAR/Feeder/TAA (with associated XTT of 1). Optional NavSpec may be A-RNP STAR/Feeder/TAA (with associated XTT of 1 - 0.3 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. The minimum XTT is the result of formula 3-1-1 for A-RNP to LP and LPV/GLS. Secondary areas apply.

3-1-3. Initial. Construct initial segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP APCH Initial (with associated XTT of 1). Optional NavSpec may be A-RNP Initial (with associated XTT of 1 - 0.3 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. The minimum XTT is the result of formula 3-1-1 for A-RNP to LP and LPV/GLS. Secondary areas apply.

3-1-4. Intermediate. Construct intermediate segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP APCH Intermediate (with associated XTT of 1). Optional NavSpec may be A-RNP Initial (with associated XTT of 1 - 0.3 as appropriate). Secondary areas apply. Paragraph 1-2-5.b(1)(d) applies except the ATT at the PFAF is based on the applicable final approach navigation accuracy from table 1-2-1.

a. RF leg. Except for RNAV intermediate to an ILS final [see appendix C], an RF leg must end at least 2 NM prior to the PFAF.

b. Alignment (maximum course change at the PFAF). Offset alignment is only authorized when the PFAF is a FB fix.

(1) LNAV and LP. Align the intermediate course within 30 degrees of the final approach course.

(2) LNAV/VNAV and LPV/GLS. Align the intermediate course within 15 degrees of the final approach course.

c. Area [see figure 3-1-1 and figure 3-1-2].

(1) LNAV and LNAV/VNAV. The intermediate segment primary area tapers uniformly from ±2 NM at a point 2 NM prior to the PFAF to the primary boundary 1 NM past the PFAF. The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the secondary boundary 1 NM past the PFAF.

(2) LP and LPV/GLS. The intermediate segment primary area tapers uniformly from ±2 NM at a point 2 NM prior to the PFAF to the primary boundary/X OCS outer boundary abeam the PFAF. The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the secondary/Y OCS outer boundary abeam the PFAF. When using a reduced XTT value, use the same XTT value throughout the entire intermediate segment and verify that the final segment supports the selected XTT with formula 3-1-1. Where the selected XTT is less than the minimum, increase the XTT or decrease the length of final. When the PFAF is located more than 50200 feet from LTP, the minimum XTT value is 0.5 NM. The minimum XTT is the result of formula 3-1-1.

Formula 3-1-1. Minimum XTT

$$\mathrm{Min}_{\mathrm{XTT}} = \frac{0.3048 \times (\mathrm{FAS}_{\mathrm{Length}} \times 0.10752 + 678.496)}{1852 \times 2}$$

Where:
$\mathrm{FAS}_{\mathrm{Length}}$ = length (feet) of the final approach segment

Example:

$$\mathrm{Min}_{\mathrm{XTT}} = \frac{0.3048 \times (50201.07 \times 0.10752 + 678.496)}{1852 \times 2}$$

$$\mathrm{Min}_{\mathrm{XTT}} = 0.5$$

Figure 3-1-1. LNAV, LNAV/VNAV Intermediate

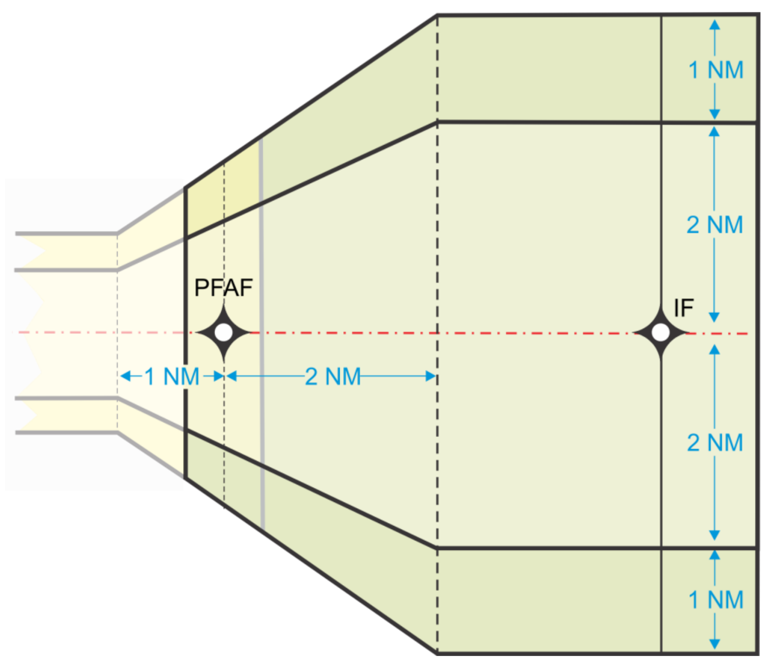
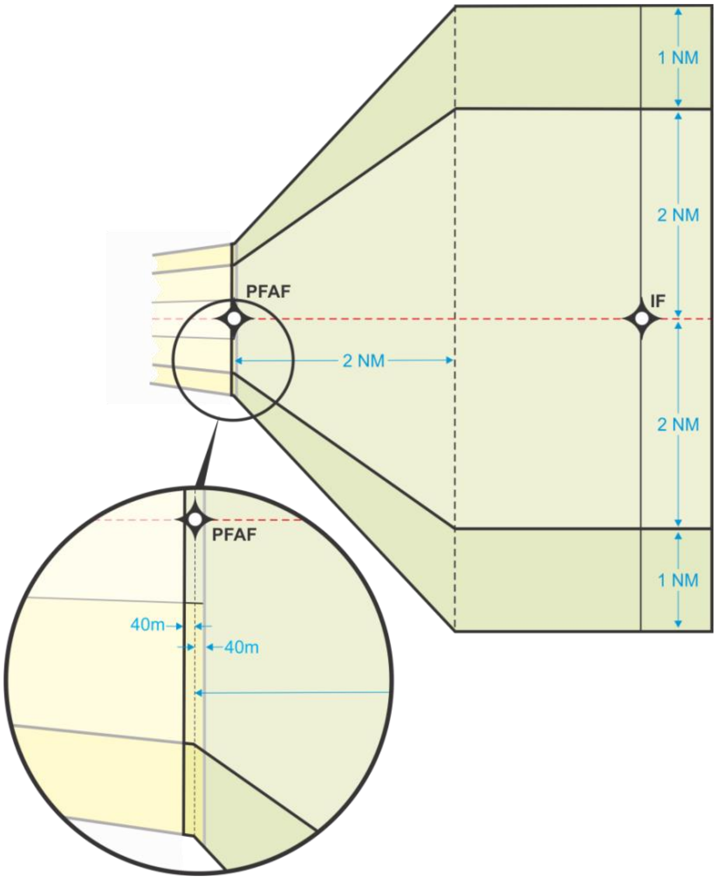


Figure 3-1-2. LP, LPV/GLS Intermediate



(3) Turn at IF or start of aligned leg prior to PFAF. When the standard FB turn construction results in boundaries outside the normal primary/secondary widths at the point 2 NM prior to the PFAF, the inside (turn side) boundaries may be constructed as straight lines from the tangent points on the turning construction arcs to the applicable final segment boundaries [see figure 3-1-3 and figure 3-1-4]. Redesign if straight line connections result in an area less than normal primary/secondary area width in the leg prior to PFAF.

Figure 3-1-3. Turn at IF Example LNAV, LNAV/VNAV

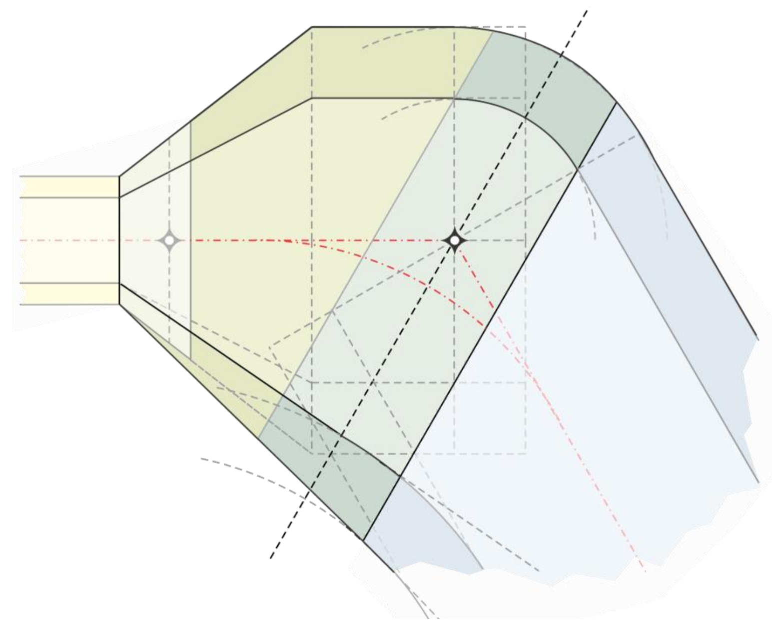
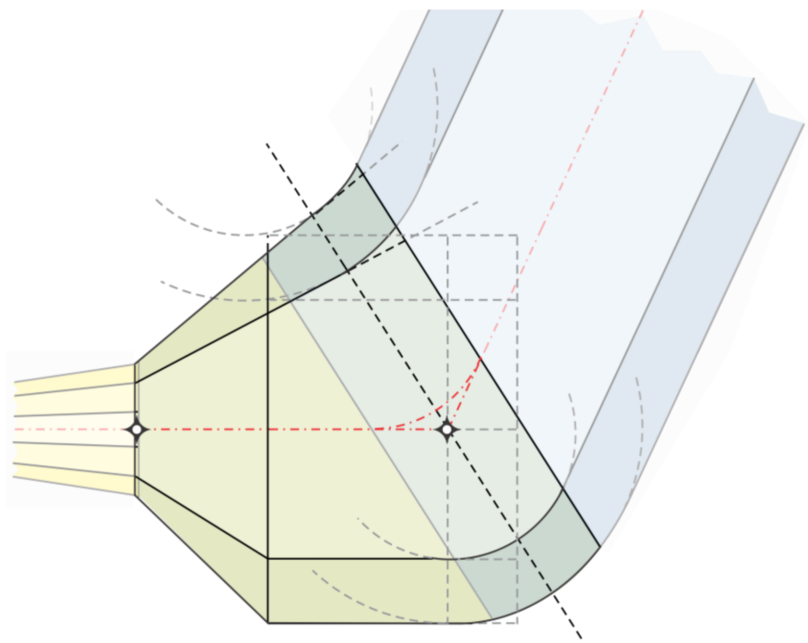


Figure 3-1-4. Turn at IF Example LP, LPV/GLS



(4) Offset construction. Where the intermediate course is not an extension of the final course, use the following construction techniques.

(a) *Step 1*. Construct line A perpendicular to the intermediate course 2 NM prior to the PFAF.

(b) *Step 2*. Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

(c) *Step 3*. Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

(d) *Step 4*. This step is dependent on procedure.

1. LNAV and LNAV/VNAV [see figure 3-1-5]. Construct arcs centered on the PFAF of 1 NM and 1.3-NM radius on the non-turn side of the fix.

2. LP and LPV/GLS [see figure 3-1-6]. Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to the final segment primary and secondary final segment lines at a point perpendicular to the final course at the PFAF.

(e) *Step 5* (applicable to LNAV and LNAV/VNAV Only). Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to tangent points on the arcs constructed by *Step 4*.

(f) *Step 6* (applicable to LNAV and LNAV/VNAV Only). Connect lines tangent to the arcs created in *Step 4* that taper inward at 30 degrees relative to the FAC to intersect the primary and secondary final segment boundaries as appropriate.

Figure 3-1-5. Offset Intermediate, Example LNAV

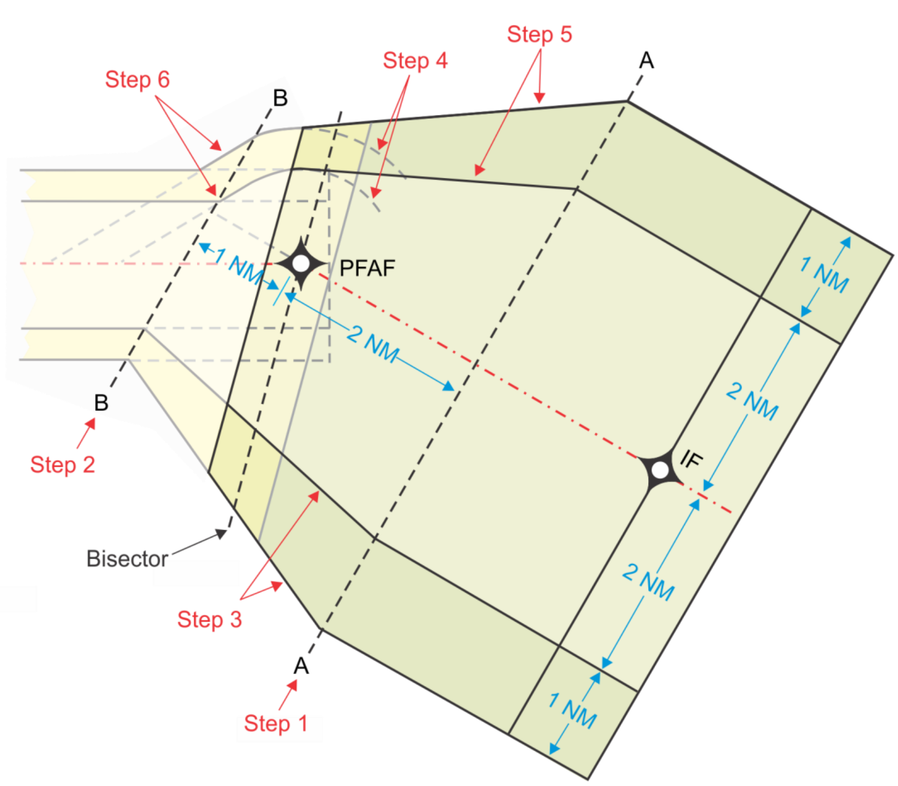
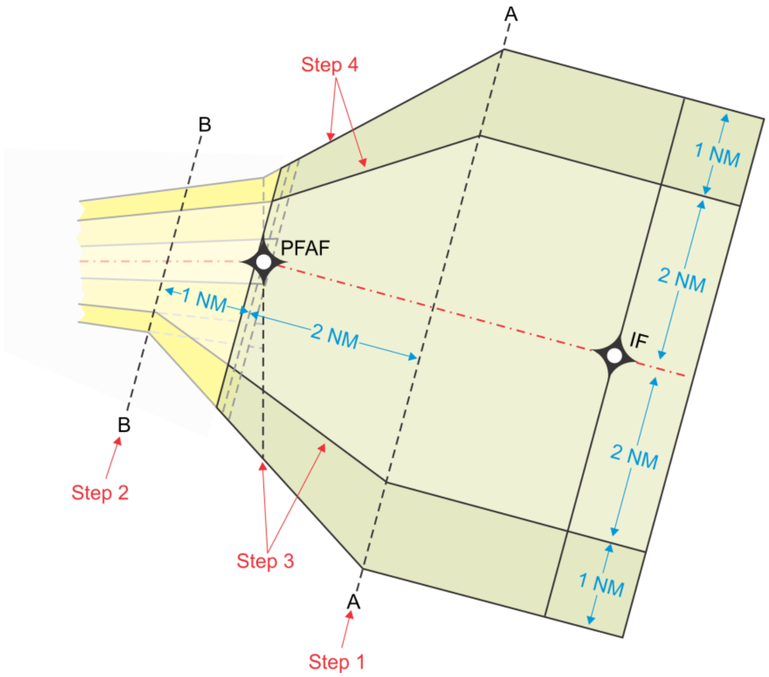


Figure 3-1-6. Offset Intermediate Example LPV/GLS



3-1-5. Final. Construct final segments as described in section 3-2 using one or more TF legs. RF legs and TF turns are not authorized. The NavSpec is RNP APCH Final [with associated XTT of 0.3 NM for part A (LNAV and LNAV/VNAV) and 40 meters for part B (LP and LPV/GLS)]. Secondary areas apply.

a. General. Paragraph 1-3-1.f applies except see paragraph 3-4-1 for LPV/GLS exceptions.

b. The final segment OEA primary and secondary boundaries follow the intermediate segment OEA primary and secondary boundaries from ATT prior to the PFAF to the applicable taper connection point and includes offset intermediate construction [see figure 3-1-1, figure 3-1-2, figure 3-1-3, figure 3-1-5, and figure 3-1-6].

c. FAS data block [see figure 3-1-7]. The FAS data block is documentation requirement used to define the lateral and vertical paths unique to SIAPs with LP, LPV, or GLS minimums. FAS data includes the following fields:

(1) Flight path alignment point (FPAP). The FPAP is defined by geodetic coordinates. When the FAC is aligned with the RCL, find the FPAP by extending a geodesic line from the LTP toward the DER a distance equal to the greater of the runway length or 9023 feet. For offset procedures, the FPAP is located on the extension of the desired final approach course at a distance from the FTP that provides the appropriate lateral course width.

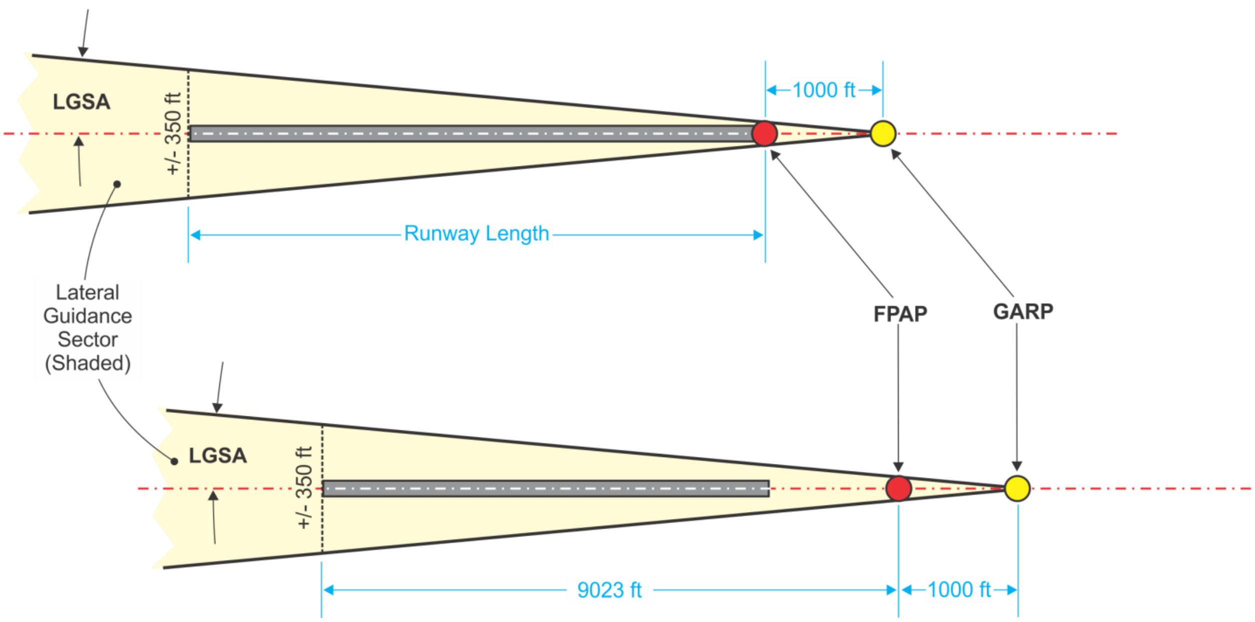
(2) Length offset. The length offset value is the distance between the departure end of runway and the FPAP, rounded to the nearest eight-meter value. It defines the location where lateral sensitivity changes to missed approach sensitivity. For offset procedures and where the FPAP is located at the departure end of the runway, length offset is zero (0).

(3) Course width at threshold. The course width at threshold is defined by the GNSS azimuth reference point (GARP) and the lateral guidance sector angle (LGSA) using formula 3-1-2. Convert the result to meters and round to the nearest 0.25-meter increment.

(a) GARP. The GARP is a point located 1000 feet beyond the FPAP on the extension of the FAC/RCL geodesic line. This point is used by the airborne system as the origin of the lateral guidance sector.

(b) LGSA. The LGSA originates at the GARP and is the angular dimension of lateral guidance relative to the FAC. The LGSA angle ranges from not more than ±2 degrees to not less than ±1.5 degrees.

Figure 3-1-7. FAS Data Block



Formula 3-1-2. Course Width At Threshold

$$\text{Course}_{\text{width}} = \text{greater of 350 feet or } \tan(1.5) \times d_{\text{GARP}}$$

Where:
d_{GARP} = distance (feet) from the LTP/FTP to the GARP

Example:

$$\text{Course}_{\text{width}} = \tan(1.5) \times 13560.66$$
$$\text{Course}_{\text{width}} \approx 355.10 \text{ feet}$$
$$\text{Course}_{\text{width}} = 108.25 \text{ meters}$$

Section 3-2. General Non-Vertically Guided Final Segment

3-2-1. General. This section contains obstacle evaluation criteria for LNAV and LP non-vertically guided approach procedures. LP is not applicable if straight-in minimums are not authorized [see paragraph 3-2-2.b and Order 8260.3 paragraph 2-6-2]. Do not develop a new LP to a runway where an LNAV/VNAV or LPV can be developed for at least one approach CAT, regardless of minima.

3-2-2. Alignment. Optimum non-vertically guided procedure final segment alignment is with the runway centerline extended through the LTP. When published in conjunction with a vertically-guided procedure, alignment must be identical with the vertically guided final segment. TF-TF turns are not allowed in the FAS.

a. Offset. When the final course must be offset, it may be offset up to 30 degrees (published separately from vertically guided) when the following conditions are met:

(1) Offset ≤ 5 degrees. Align the course through LTP.

(2) Offset > 5 degrees and 10 ≤ degrees. The course must cross the runway centerline extended at least 1500 feet prior to LTP (5200 feet maximum).

(3) Offset > 10 degrees and ≤ 20 degrees. The course must cross the runway centerline extended at least 3000 feet prior to LTP (5200 feet maximum). For offsets > 15 degrees, CAT C/D minimum published visibility 1 SM, minimum HAT of 300 feet.

(4) Offset > 20 to 30 degrees (CAT A/B only). The course must cross the runway centerline extended at least 4500 feet prior to the LTP (5200 feet maximum).

Note: Where offset alignment as specified above cannot be attained or the final course does not intersect the runway centerline or intersects the centerline more than 5200 feet from LTP, and an operational advantage can be achieved, the final may be aligned to lie laterally within 500 feet of the extended runway centerline at a point 3000 feet outward from LTP. For the purposes of OEA construction, use the Final End Point (FEP) as the FTP [see Order 8260.3, paragraph 2-6-2]. This option requires Flight Standards approval.

b. Circling. The optimum final course alignment is to the center of the landing area, but may be to any portion of the usable landing surface. The latest point the MAP can be located is the FEP. For the purposes of OEA construction, use the FEP as the FTP.

3-2-3. Area.

a. LNAV.

(1) Length. The OEA begins 0.3 NM prior to the PFAF and ends 0.3 NM past the LTP/FTP. Segment length is the distance from the PFAF location to the LTP/FTP. The maximum length is 10 NM.

Example:
$\text{ACT} = -30 + 4.24$
$\text{ACT} \approx -25.76°\text{C}$
$\text{ACT} = -25°\text{C}$

(b) Determining the critical low and high temperatures. Normally, the critical low temperature limit is the calculated ACT. Where the ACT results in an effective glidepath of less than 2.5 degrees, the temperature limit is raised to achieve the required glidepath angle. The critical high temperature limit is the temp that yields an effective glidepath of 1.13 times the maximum allowed glidepath angle for the fastest designed category (not to exceed 54 degrees Celsius). Use formula 3-3-4, formula 3-3-5, and formula 3-3-6 to find both the critical low and critical high temperature.

Formula 3-3-4. Temperature Induced DA Deviation

$$\Delta\text{DA}_{\text{Temp}} = e^{\frac{d_{250} \times \tan(\theta_{\text{Temp}})}{r}} \times (r + \text{LTP}_{\text{elev}} + \text{TCH}) - (r + \text{TDZE} + 250)$$

Where:
d_{250} = distance (feet) from LTP to a point 250 feet above TDZE using the designed GPA
θ_{Temp} = 2.5 for low temp deviations or 1.13 × the maximum allowable GPA of the fastest CAT for high temp deviations.

Example:

$$\Delta\text{DA}_{\text{Temp}} = e^{\frac{3806.69 \times \tan(2.5)}{r}} \times (r + 5321.8 + 55) - (r + 5326.3 + 250)$$
$$\Delta\text{DA}_{\text{Temp}} \approx -33.26 \text{ feet}$$

Note: This calculation is accomplished twice. Once for low and once for high temperature deviations.

Formula 3-3-5. ΔISA Adjusted

$$\Delta\text{ISA}_{\text{adjusted}} = \frac{\Delta\text{DA}_{\text{Temp}} \times [288 - 0.5 \times 0.00198 \times (\text{TDZE} + 250)]}{250 - \Delta\text{DA}_{\text{Temp}}}$$

Where:
$\Delta\text{DA}_{\text{Temp}}$ = calculated maximum DA deviation if flown at the respective critical temperatures

Example:

$$\Delta\text{ISA}_{\text{adjusted}} = \frac{-33.30 \times [288 - 0.5 \times 0.00198 \times (5326.3 + 250)]}{250 + 33.30}$$
$$\Delta\text{ISA}_{\text{adjusted}} \approx -33.20°\text{C}$$

Note 1: This calculation is accomplished twice. Once for low and once for high temperature deviations.

Formula 3-3-6. Adjusted ACT

$$ACT_{adjusted} = ISA_{airport} + \Delta ISA_{adjusted}$$

Where:
$ISA_{airport}$ = International Standard Atmosphere temperature °C for the airport
$\Delta ISA_{adjusted}$ = ISA adjustment (°C) required to achieve the respective low or high temp GPA

Example:

$ACT_{adjusted} = 4.24 - 33.20$
$ACT_{adjusted} \approx -28.96^{\circ}$

Note 1: $Critical_{Low}$ = warmer of ACT or $ACT_{adjusted}$

Note 2: $Critical_{High}$ = colder of 54°C or $ACT_{adjusted}$

Note 3: $\Delta ISA_{Low} = Critical_{Low} - ISA_{airport}$

(c) High temperature descent rate. Use formula 3-3-7 to determine the maximum expected descent rate at standard and critical high temperatures [see Order 8260.19, paragraph 8-7-1].

Formula 3-3-7. Descent Rate

$$dr = \frac{(V_{KTAS} + 10) \times 1852}{0.3048} \times \frac{60 \times \tan(\theta)}{3600}$$

Where:
V_{KTAS} = KTAS using 250 feet above TDZE and final approach KIAS for fastest CAT
θ = either designed GPA or 1.13 × maximum allowable GPA for the fastest CAT

Example:

$$dr = \frac{(184.10 + 10) \times 1852}{0.3048} \times \frac{60 \times \tan(3.50)}{3600}$$
$dr \approx 1202.23$ feet/minute

(2) OCS slope. The OCS slope and origin are determined using formula 3-3-8, formula 3-3-9, and formula 3-3-10:

b. Level OCS [see Order 8260.3, paragraph 2-1-3]. A level OCS is applied from 0.3 NM past the LTP/FTP to the point of intersection with the sloping OCS. If an obstacle is in the secondary area (transitional surface), adjust the height of the obstacle using formula 3-3-2, then evaluate it at the adjusted height as if it is in the primary area.

(1) Obstacle clearance. Apply the applicable ROC from table 3-3-2 to the obstacle with the highest effective height to determine the preliminary DA.

(2) Obstacle accuracies/ROC adjustments. Apply the non-RNP procedure evaluation sequence using a preliminary controlling obstacle based on the level surface evaluation method [see Order 8260.19, paragraphs 2-11-3 and 2-11-4]. Do not apply Order 8260.3, chapter 3 precipitous terrain and/or RASS adjustments when determining preliminary DA.

Table 3-3-2. Level OCS ROC by Approach Category

Aircraft Category	ROC
A	131
B	142
C	150
D/E	161

3-3-5. Decision altitude (DA). The minimum HAT is 250 feet [see Order 8260.3, table 3-2-2]. The DA based on the final segment evaluation is the highest of the following; the DA based on the minimum HAT, the DA based on the minimum offset DA distance [see paragraph 3-3-2], the DA based on evaluation of the level OCS, or the DA based on evaluation of the sloping OCS. APV precipitous terrain and RASS adjustments apply. The DA based on the evaluation of the sloping OCS is not required to be higher than the MDA of an LNAV procedure established on the same chart. Order 8260.19, paragraph 8-7-1.b applies, except document the controlling obstacle and ROC based on whichever evaluation (level or sloping OCS) results in the highest DA.

3-3-6. Raising GPA or adjusting TCH for penetrating obstructions. The GPA and/or TCH may be raised to eliminate or reduce final segment OCS penetrations.

Section 3-4. LPV/GLS Final

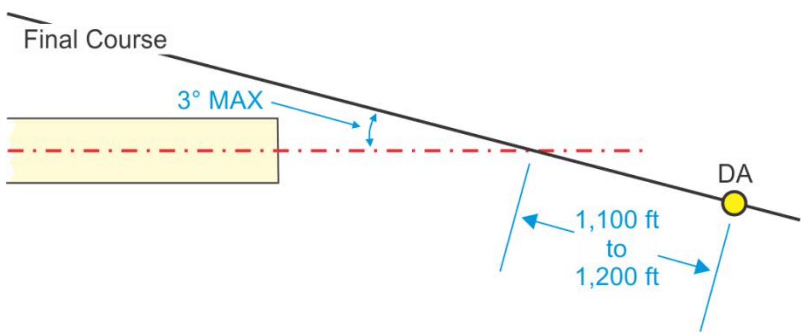
3-4-1. General. The OEA and associated OCSs are applicable to LPV and GLS final approach segments.

a. Exceptions. Paragraph 1-3-1 vertical path requirements apply except for procedures with HAT less than 250, the maximum GPA is 3.5 degrees and the maximum TCH is 60 feet regardless of height group.

b. Restrictions. For GLS procedures, final track intercept must occur within 20 NM of the airport.

3-4-2. Alignment. The final course is normally aligned with the runway centerline (RCL) extended through the LTP (± 5 feet). Where an operations requirement necessitates an offset course, the FAC must intersect the RCL extended 1100 to 1200 feet inside the DA point and the offset must not exceed three degrees measured from the point of intersection [see figure 3-4-1]. Where the course is offset, the minimum HAT is 250. TF-TF turns are not allowed in the FAS.

Figure 3-4-1. Offset Final Alignment



3-4-3. Area. The OEA originates 200 feet from LTP and extends to a point 40 meters beyond the PFAF. It is centered on the final approach course and expands uniformly from its origin to a point 50000 feet from the origin. Where the PFAF must be located more than 50200 feet from LTP, the OEA continues linearly (boundaries parallel to course centerline) beyond that point [see figure 3-4-2].

formula 3-4-15. If the result is greater than the penetration, you may determine the amount to increase TCH by applying formula 3-4-16. If this option is selected, re-evaluate the final segment using the revised TCH value.

Formula 3-4-15. Vertical Relief

$$Z_{TCH} = \frac{d_{origin} - 200}{OCS_{slope}}$$

Where:
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$Z_{TCH} = \frac{390.75 - 200}{34}$
$Z_{TCH} \approx 5.61$ feet

Formula 3-4-16. TCH Adjustment

$$\Delta TCH = \tan(\theta) \times OCS_{slope} \times p$$

Where:
p = penetration (feet) of the final OCS

Example:

$\Delta TCH = \tan(3) \times 34 \times 4.04$
$\Delta TCH \approx 7.20$ feet

Section 3-5. Missed Approach General

3-5-1. General. The NavSpec is RNP APCH Missed (with associated XTT of 1). *Exception: For LNAV and LP, apply ATT based on the applicable final flight phase at the beginning of section 1 (line C-D).* Optional NavSpec may be A-RNP Missed (with associated XTT of 1 - 0.3 as appropriate). Use of A-RNP missed approach XTT less than 1 requires Flight Standards approval. Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply where specified. Line C-D location and altitude is defined using the base MDA/DA. The base MDA/DA is the lowest value resulting from subtracting any RASS (primary and secondary setting source) and precipitous terrain adjustments from the lowest final segment MDA/DA (rounded to a publishable value).

Note: Due to rounding, it is sometimes possible for the MDA/DA minus RASS adjustment to be lower than the MDA/DA based on local altimeter.

3-5-2. Course-to-altitude (CA) leg. A CA leg is used as the first leg of an RNAV missed approach and must be followed by a DF leg. The CA leg must specify a course and altitude. The specified CA course must be an extension of the FAC. The specified CA altitude is determined as follows:

a. When the first fix after the coded MAP is on the FAC extended, the specified CA altitude is the DA, MDA, or 400 feet above the airport elevation whichever is lowest.

b. When a turning missed approach is based on a "climb-to" altitude before turning, the specified CA altitude is the charted "climb-to" altitude.

3-5-3. MA climb gradient termination. Where the default OCS slope is penetrated and the lowest HAT is required, a greater than standard CG may be required to clear the penetrating obstruction. Calculate the climb gradient termination altitude using formula 3-5-1 for input into the climb gradient formula 1-3-7. If a RASS adjustment is applicable, apply the CG associated with the lowest MDA/DA.

Formula 3-5-1. MA CG Termination Altitude

$$\mathrm{CG_{term}} = 48 \times \mathrm{D_O} + \mathrm{O_{MSL}} - \frac{\mathrm{d_{primary}}}{12} + \mathrm{AC_{start}} - \mathrm{OCS_{start}} + \mathrm{RASS}$$

Where:
$\mathrm{D_O}$ = dist. (NM) from $\mathrm{AC_{start}}$ to primary obs. or point from which $\mathrm{d_{primary}}$ measured
$\mathrm{d_{primary}}$ = dist. (feet) from edge of primary area to obs. Zero (0) if not in secondary
$\mathrm{AC_{start}}$ = starting altitude (feet) of the aircraft (e.g., SOC)
$\mathrm{OCS_{start}}$ = starting altitude (feet) of the OCS
RASS = remote altimeter setting source adjustment (feet) for final if applicable

Example:

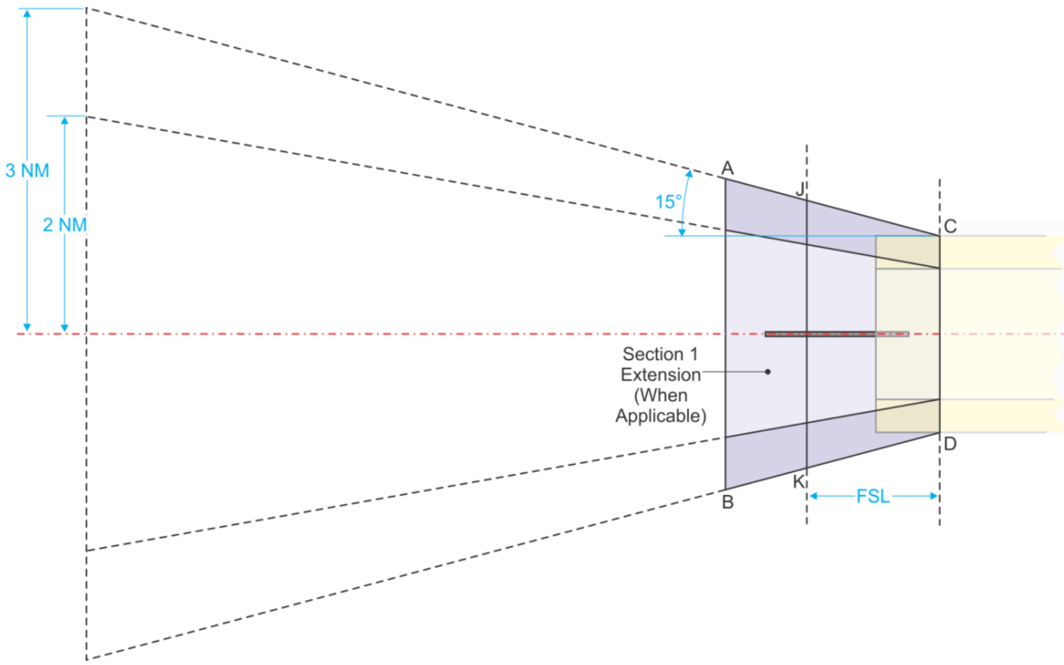
$$\mathrm{CG_{term}} = 48 \times 3.95 + 2147.41 - \frac{537.41}{12} + 1442 - 1217.21$$

$$\mathrm{CG_{term}} \approx 2517.02 \text{ feet}$$

Section 3-6. Missed Approach Section 1

3-6-1. Non-vertically guided. Section 1 begins final segment ATT prior to the MAP (line C-D) along a continuation of the final course and extends to the SOC (line J-K) or the point where the aircraft is projected to cross 400 feet above airport elevation (line A-B); whichever is the greater distance from the MAP [see figure 3-6-1 and figure 3-6-2].

Figure 3-6-1. LNAV Missed Approach Section 1 Area



a. Length.

(1) Flat surface length (FSL). The section 1 flat surface begins either 0.3 NM for LNAV or 40 meters for LP prior to the MAP and extends the FSL distance to line J-K. Calculate the FSL using formula 3-6-1.

Formula 3-6-1. LNAV/LP Flat Surface Length

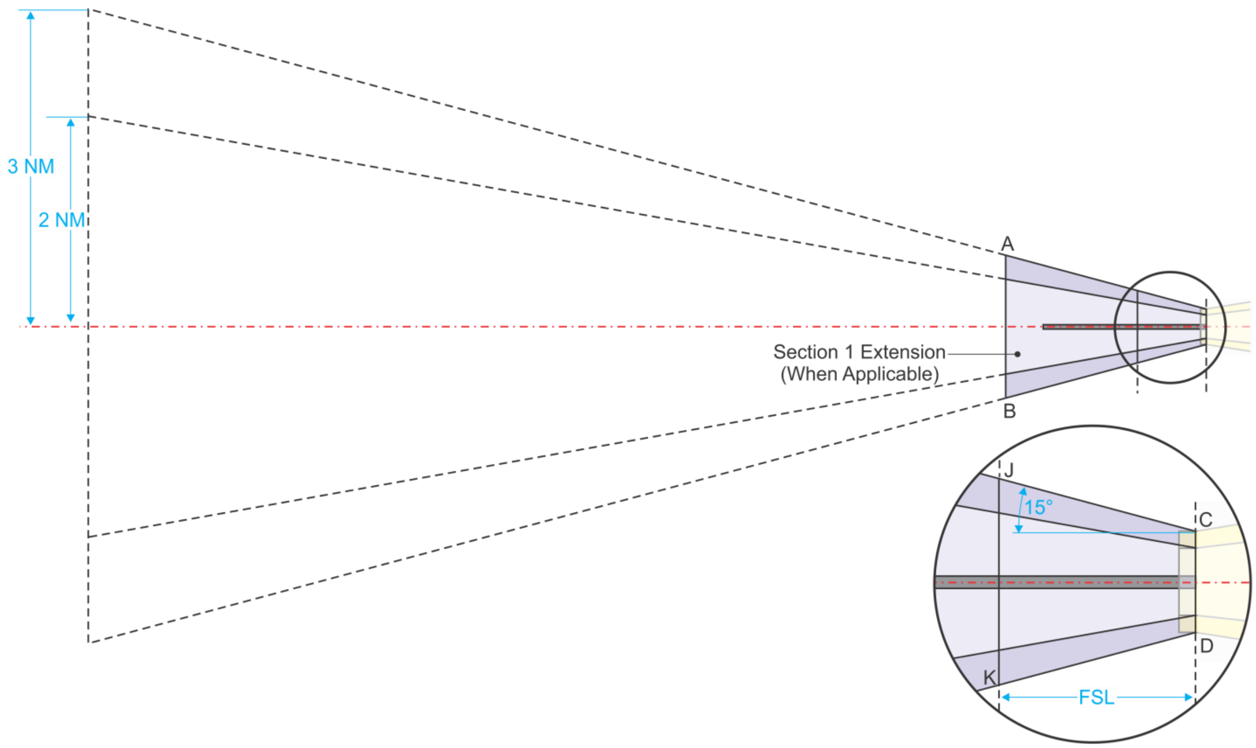
$$FSL = \frac{(V_{KTAS} + 10) \times 12}{3600} + 2 \times ATT_{NM}$$

Where:
V_{KTAS} = calculated KTAS using MDA and final approach KIAS
ATT_{NM} = applicable final segment ATT in NM

Example:

$$FSL = \frac{(171.91 + 10) \times 12}{3600} + 2 \times 0.3$$
$$FSL \approx 1.21 \text{ NM}$$

Figure 3-6-2. LP Missed Approach Section 1 Area



(2) Section 1 extension.

(a) Base MDA ≥ 400 feet above airport elevation. No extension required. Line A-B is coincident with line J-K.

(b) Base MDA < 400 feet above airport elevation. Calculate the section 1 extension using formula 3-6-2 and locate line A-B at this distance beyond line J-K.

Formula 3-6-2. Section 1 Extension

$$S1_{extension} = \ln\left(\frac{r + apt_{elev} + 400}{r + alt_b}\right) \times \frac{r}{CG}$$

Where:
alt_b = either the Base MDA for LNAV/LP or Base DA for LNAV/VNAV

Example:

$$S1_{extension} = \ln\left(\frac{r + 2900 + 400}{r + 2105}\right) \times \frac{r}{315}$$
$$S1_{extension} \approx 3.79\ \text{NM}$$

b. Width. The secondary area outer boundary starts at the outer edge of the final segment secondary area at line C-D and splays at 15 degrees relative to the missed approach course until reaching 3 XTT width from centerline. The primary area outer boundary starts at the edge of the primary area at line C-D and splays at the angle required to reach a width of 2 XTT from centerline adjacent to the point where secondary outer boundary reaches 3 XTT width. Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 3-6-3 or formula 3-6-4, depending on the final type. For LNAV there is no splay when an A-RNP RNP 0.3 is specified, the OEA remains linear.

Formula 3-6-3. LNAV and LNAV/VNAV MA Primary and Secondary Boundary

$$MAS_{Yprimary} = \frac{D_{splay} \times \tan(15) \times 1.4}{2.1} + 0.6$$
$$MAS_{Ysecondary} = D_{splay} \times \tan(15) + 0.9$$

Where:
D_{splay} = along track distance (NM) from beginning of MA splay to point of interest

Example:

$$MAS_{Yprimary} = \frac{6.04 \times \tan(15) \times 1.4}{2.1} + 0.6$$
$$MAS_{Yprimary} \approx 1.68\ \text{NM}$$

$$MAS_{Ysecondary} = 6.04 \times \tan(15) + 0.9$$
$$MAS_{Ysecondary} \approx 2.52\ \text{NM}$$

Formula 3-6-4. LP MA Primary and Secondary Boundary

$$MAS_{Yprimary} = \frac{D_{splay} \times \tan(15) \times (2 - {}^{1}\!/_{2}\, W_p)}{3 - W_s - {}^{1}\!/_{2}\, W_p} + {}^{1}\!/_{2}\, W_p$$
$$MAS_{Ysecondary} = D_{splay} \times \tan(15) + W_s + {}^{1}\!/_{2}\, W_p$$

Where:
D_{splay} = along track distance (NM) from beginning of MA splay to point of interest
${}^{1}\!/_{2}\, W_p$ = perpendicular dist. (NM) from FAS centerline to FAS primary boundary
W_s = final secondary area width (NM)

Example:

$$MAS_{Yprimary} = \frac{6.04 \times \tan(15) \times (2 - 0.20)}{3 - 0.09 - 0.20} + 0.20$$
$$MAS_{Yprimary} \approx 1.27\ \text{NM}$$

$$MAS_{Ysecondary} = 6.04 \times \tan(15) + 0.09 + 0.20$$
$$MAS_{Ysecondary} \approx 1.91\ \text{NM}$$

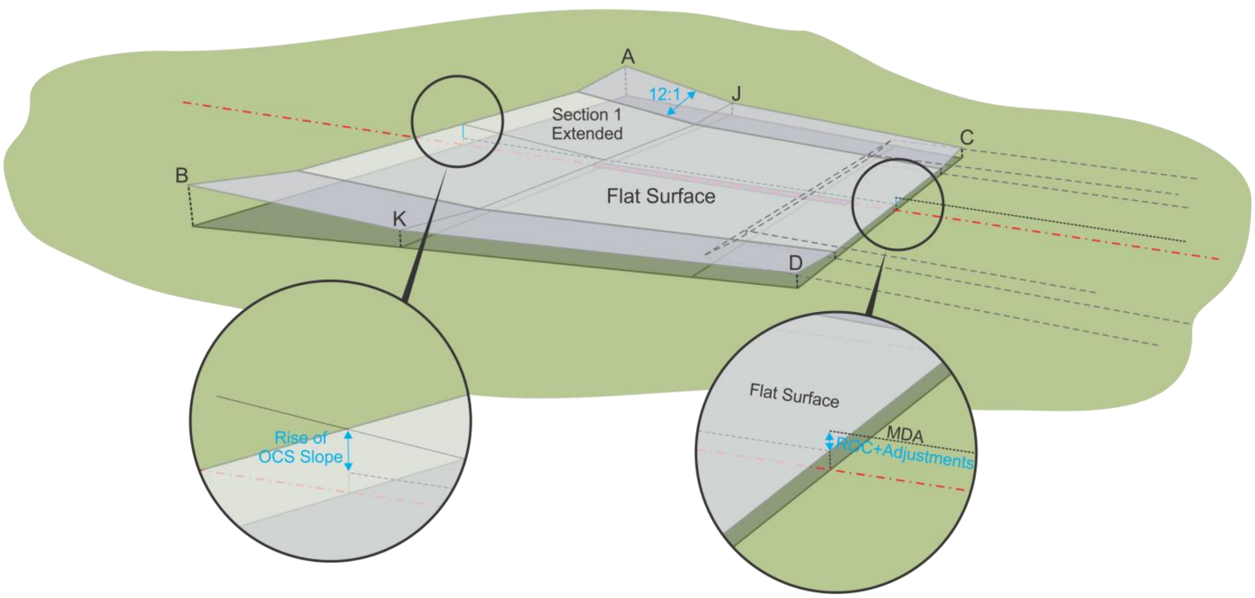
c. Obstacle clearance. Section 1 OCS consists of a flat surface and sloping surface extension [see figure 3-6-3]. The MSL height at the start of the missed approach surface (HMAS) is equal to the base MDA less 100 feet, and excessive length of final adjustments. When obstacles are mitigated by one of the following, re-evaluate the missed approach segment.

(1) Flat surface. The missed approach primary surface remains flat from line C-D to line J-K. Obstacles must not penetrate the flat surface. Where obstacles penetrate the flat surface, raise the MDA by the amount of penetration.

(2) Section 1 extension. From line J-K to line A-B, a sloping OCS surface rises along the missed approach course centerline at a slope ratio commensurate with the obstructions [see paragraph 1-3-1.g(1)]. Where obstacles penetrate this OCS, either adjust the MDA by the amount of penetration or apply a climb gradient to clear the obstacle [see paragraph 1-3-1.g(2)].

(3) Secondary areas apply from the edge of both the flat surface and section 1 extended with a 12:1 slope measured perpendicular to centerline.

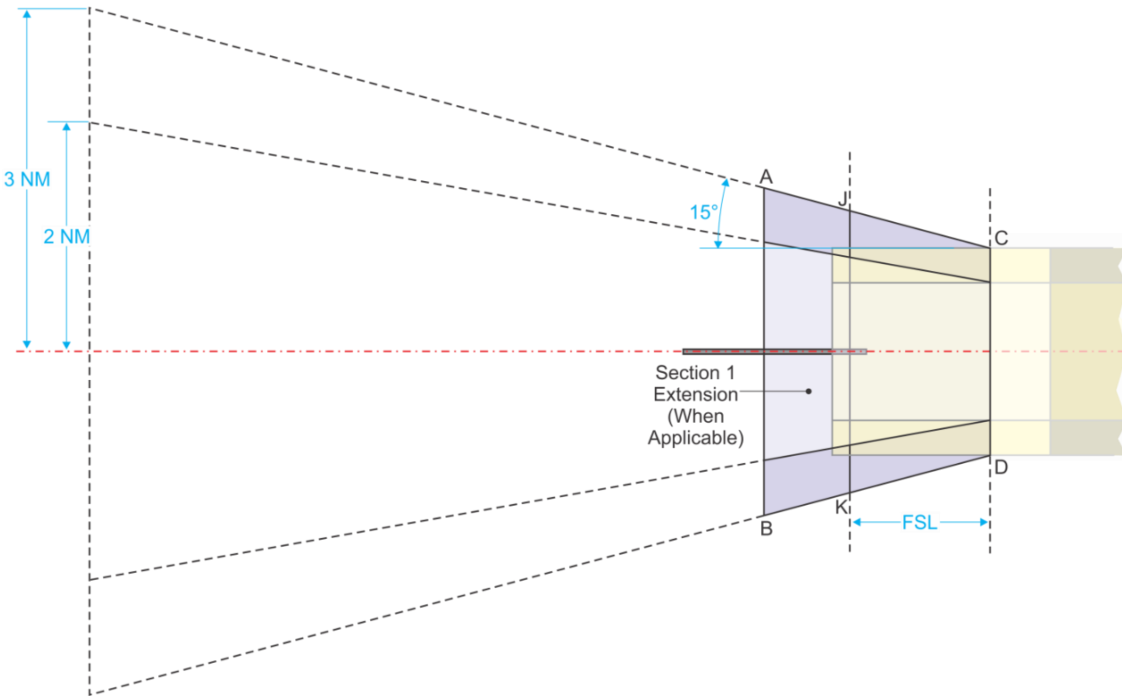
Figure 3-6-3. LNAV Missed Approach Section 1 OCS



3-6-2. LNAV/VNAV. The same criteria specified for non-vertically guided procedures apply with the following exceptions [see figure 3-6-4].

a. Line C-D is at the base DA point.

Figure 3-6-4. LNAV/VNAV Missed Approach Section 1 Area



b. Length. LNAV/VNAV FSL is based on 15 seconds at KTAS + 10 Kts tailwind without ATT. Calculate FSL using formula 3-6-5. Section 1 extension length is the same as non-vertically guided procedures [see formula 3-6-2].

Formula 3-6-5. LNAV/VNAV Flat Surface Length

$$\mathrm{FSL} = \frac{(V_{KTAS} + 10) \times 15}{3600}$$

Where:
V_{KTAS} = calculated KTAS using DA and final approach KIAS

Example:

$$\mathrm{FSL} = \frac{(173.02 + 10) \times 15}{3600}$$
$$\mathrm{FSL} \approx 0.76\ \mathrm{NM}$$

c. Width. The 15-degree OEA splay begins at the outer edge of the final segment secondary area at the base DA point (line C-D). Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 3-6-3. There is no splay when an A-RNP RNP 0.3 is specified, the OEA remains linear.

d. Obstacle clearance. The HMAS is determined by subtracting the applicable flat surface ROC for the CAT [see table 3-3-2] and applicable adjustments from the base DA. Where obstacles penetrate the flat surface, raise the DA by the amount of penetration. Where obstacles penetrate the sloping OCS, either calculate the DA adjustment with formula 3-6-6 or apply a higher than standard climb gradient to clear the obstruction [see paragraph 1-3-1.g(2)]. In any case, obstacle mitigation requires the missed approach to be re-evaluated.

Formula 3-6-6. LNAV/VNAV DA Adjustment Value

$$\Delta DA = r \times e^{\left(\frac{p \times MA_{slope} \times \tan(\theta)}{r \times [1 + MA_{slope} \times \tan(\theta)]}\right)} - r$$

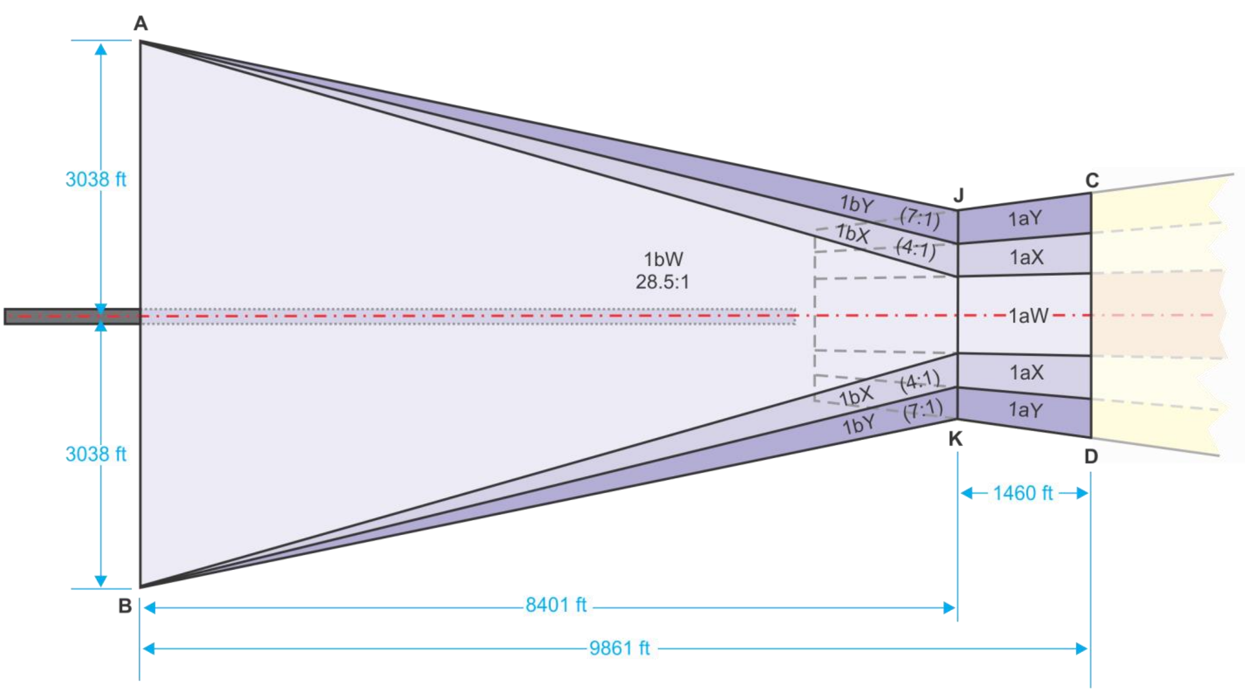
Where:
p = penetration (feet) of the MA OCS
MA_{slope} = missed approach OCS slope ratio

Example:

$$\Delta DA = r \times e^{\left(\frac{19.3 \times 40 \times \tan(3)}{r \times [1 + 40 \times \tan(3)]}\right)} - r$$
$$\Delta DA \approx 13.07 \text{ feet}$$

3-6-3. LPV/GLS. Section 1 begins at the base DA (line C-D) and ends at the SOC (line A-B). It accommodates height loss and establishment of missed approach climb gradient. Section 1 is centered on a continuation of the final approach track and is subdivided into sections 1a and 1b [see figure 3-6-5].

Figure 3-6-5. LPV/GLS Missed Approach Section 1 Area



a. Section 1a area/OCS elevation. Section 1a is a 1460 feet continuation of the FAS OCS beginning at the base DA point to accommodate height loss. The portion consisting of the continuation of the W surface is identified as section 1aW. The portions consisting of the continuation of the X or Y surfaces are respectively identified as section 1aX or 1aY. Calculate the width and elevation of the section 1aW, 1aX, and 1aY surfaces at any distance from LTP using the final segment formulas.

b. Section 1b areas. The section 1b area extends from line J-K at the end of section 1a for a distance of 8401 feet to line A-B. Section 1b is subdivided into sections 1bW, 1bX, and 1bY. Calculate the distance from course centerline to the boundary of these surfaces at any distance from the end of section 1a using formula 3-6-7.

(1) Section 1bW. Section 1bW extends from the end of section 1aW for a distance of 8401 feet. Its lateral boundaries splay from the width of the end of 1aW surface to a width of ±3038 feet either side of the missed approach course at the 8401 foot-point.

(2) Section 1bX. Section 1bX extends from the end of section 1aX for a distance of 8401 feet. Its inner boundary is the outer boundary of the 1bW surface. Its outer boundary splays from the end of the 1aX surface to a width of ±3038 feet either side of the missed approach course at the 8401-foot point.

(3) Section 1bY. Section 1bY extends from the end of section 1aY for a distance of 8401 feet. Its inner boundary is the outer boundary of the 1bX surface. Its outer boundary splays from the outer edge of the 1aY at the surface at the end of section 1a to a width of ± 3038 feet either side of the missed approach course at the 8401-foot point.

Formula 3-6-7. Section 1bW/X/Y Boundary

$$1b_{boundary} = \frac{d_{1aEnd} \times (3038 - 1a_{boundary})}{8401} + 1a_{boundary}$$

Where:
d_{1aEnd} = along track distance (feet) from end of section 1a to the point of interest
$1a_{boundary}$ = perpendicular dist. (feet) from centerline to respective ending 1a outer boundary

Example:

$$1b_{boundary} = \frac{2591.8 \times (3038 - 481.06)}{8401} + 481.06$$
$$1b_{boundary} \approx 1269.90 \text{ feet}$$

c. Section 1b OCS elevations.

(1) Section 1bW. The surface rises from the elevation of the 1aW surface at the end of section 1a at a slope ratio of 28.5:1. Calculate the section 1bW surface elevation with formula 1-3-6 for input into formula 3-6-8.

(2) Section 1bX. The surface rises at a slope ration of 4:1 perpendicular to the missed approach course from the edge of the 1bW surface. Calculate the adjustment (Q) for X surface obstacles using formula 3-4-8.

(3) Section 1bY. The surface rises at a slope ratio of 7:1 perpendicular to the missed approach course from the edge of the 1bX surface. Calculate the adjustment (Q) for Y surface obstacles using formula 3-4-10.

Formula 3-6-8. Section 1b Surface Penetration

$$p = O_{MSL} - Q - 1bW_{elev}$$

Where:
Q = obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface
$1bW_{elev}$ = elevation (feet) of the 1bW surface abeam the obstacle

Example:

$p = 1325.8 - 24.22 - 1282.70$
$p \approx 18.88$ feet

d. OCS penetration mitigation. To eliminate or avoid a penetration, take one or more of the following actions:

(1) Removing or adjusting the obstruction location and/or height.

(2) Raising GPA within categorical limits.

(3) Raising TCH [see paragraph 3-4-7].

(4) Adjusting DA. For a surface 1b penetration of p feet, the DA point must move Δd_{DA} [see formula 3-6-9] feet further from the LTP to raise the surface above the penetration.

Formula 3-6-9. Along-track DA Adjustment

$$\Delta d_{DA} = \frac{p \times 28.5 \times FAS_{slope}}{28.5 + FAS_{slope}}$$

Where:
p = penetration (feet) of the 1b OCS
FAS_{slope} = final approach segment OCS slope ratio

Example:

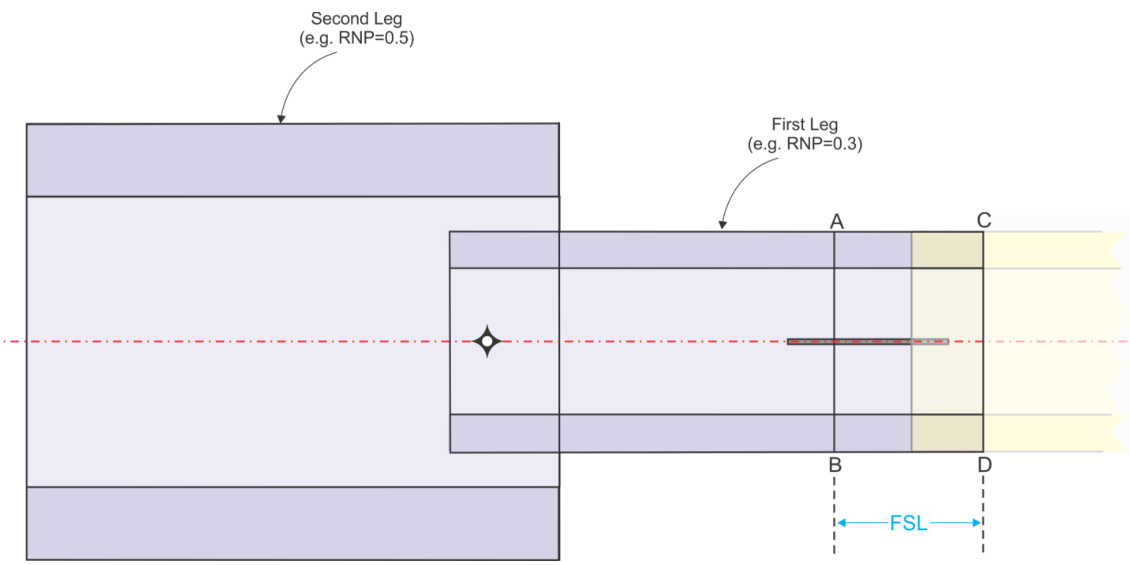
$$\Delta d_{DA} = \frac{18.88 \times 28.5 \times 34}{28.5 + 34}$$
$$\Delta d_{DA} \approx 292.72 \text{ feet}$$

Section 3-7. Missed Approach Section 2

3-7-1. General.

a. Obstacle evaluation area (OEA). The section 2 OEA begins at the end of section 1, and splays at least 15 degrees relative to the nominal track to reach full width. Refer to individual chapters for MA section 1 information. Once full OEA width has been obtained with an A-RNP reduced XTT, the OEA remains linear and width changes occur abruptly at the start fix of a leg with a new RNP. Use a reduced XTT only where operationally required and only for the distance necessary to achieve the desired ground track [see figure 3-7-1]. Use of A-RNP missed approach XTT less than 1 requires Flight Standards approval.

Figure 3-7-1. A-RNP Reduced XTT Area



b. Section 2 start altitude. When calculating the section 2 start altitude, use the base MDA/DA value from section 1 [see paragraph 3-5-1].

(1) Non-LPV/GLS. When line J-K and line A-B are not coincident, calculate the section 2 start altitude by inputting base MDA/DA, CG, and distance between J-K and A-B into formula 1-3-8.

(2) LPV/GLS. Use formula 3-7-1 to calculate the section 2 start altitude.

Formula 3-7-1. LPV/GLS Section 2 Start Altitude

$$\text{Section 2 start altitude} = \text{DA} - \tan(\theta) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

Example:

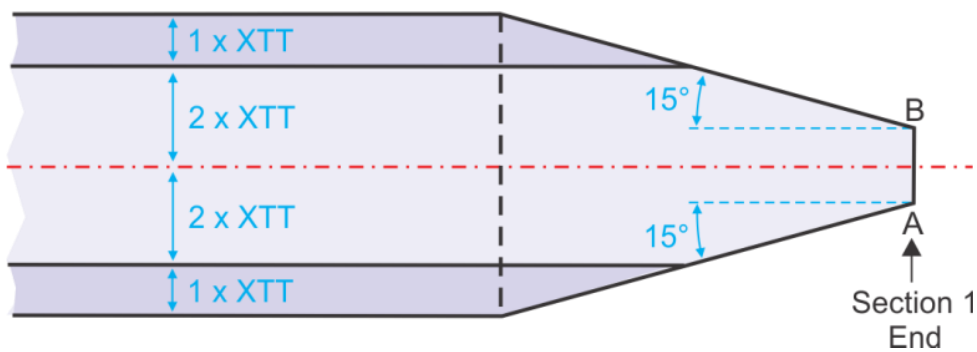
$$\text{Section 2 start altitude} = 1225 - \tan(3.1) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

$$\text{Section 2 start altitude} \approx 1422.45 \text{ feet}$$

c. Obstacle clearance surface (OCS) slope and origin. The section 2 OCS slope [see formula 1-3-5] begins at line A-B. Where a higher than standard CG is required, apply the associated OCS from the SOC to the CG termination altitude, then revert to the default OCS.

3-7-2. Straight missed approach. The straight course is a continuation of the FAC. The straight MA section 2 OEA begins at the end of section 1 and splays at 15 degrees relative to the nominal track until reaching full primary and secondary width [see figure 3-7-2].

Figure 3-7-2. Missed Approach Section 2 Straight Area



3-7-3. Turning missed approach.

a. Early and inside turn construction.

(1) First turn. The first MA turn may be specified at an altitude or be specified at a FB or FO fix.

(a) Turn-at-altitude. Order 8260.19, chapter 8 paragraph "Missed approach instructions" applies except a turn altitude must be specified for any amount of turn. The minimum turn altitude must equal or exceed the higher of the end of the section 1 end aircraft altitude (SOC) or 400 feet above airport elevation. A turn-at-altitude is followed by a DF leg usually ending with a DF-TF connection or holding pattern entry.

1. Turn initiation area (TIA). The TIA includes the applicable section 1 area starting at line C-D and ends where the specified turn altitude is reached (line L-L'). Construct the TIA from the end of section 1 to line L-L' using straight MA criteria. Evaluate section 2 obstacles by applying the prescribed OCS slope along the shortest distance from the TIA boundary to the obstacle. The obstacle-based turn altitude is the sum of starting ROC and OCS elevation at the TIA boundary needed to clear section 2 obstacles. Because TIA length and the OCS elevation at the end of the TIA is dependent on aircraft altitude, establishing an obstacle-based turn altitude may be an iterative process. Calculate lengths from line C-D using formula 3-7-2, formula 3-7-3, and formula 3-7-5.

a Non-LPV/GLS TIA. Calculate the TIA length using the appropriate FSL value [see section 3-5.]. Where an increased CG terminates below the turn altitude, apply formula 3-7-2, otherwise apply formula 3-7-3.

Formula 3-7-2. TIA Length CG Termination Below Turn Altitude (Non LPV/GLS)

$$\mathrm{TIA}_{\mathrm{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt}_{\mathrm{b}}} + \mathrm{D}_{\mathrm{climb}_{\mathrm{i}}} + \mathrm{D}_{\mathrm{climb}_{\mathrm{ii}}}$$

Where:
FSL = length (NM) of the missed approach flat surface
$\mathrm{alt}_{\mathrm{b}}$ = beginning altitude (feet) (i.e., the MDA for LNAV/LP or DA for LNAV/VNAV)
$\mathrm{D}_{\mathrm{climb}_{\mathrm{i}}}$ = climb distance (NM) required to reach the first $\mathrm{CG}_{\mathrm{term}}$ from MDA or DA
$\mathrm{D}_{\mathrm{climb}_{\mathrm{ii}}}$ = climb distance (NM) required to reach the turn altitude from the first $\mathrm{CG}_{\mathrm{term}}$

Example:

$$\mathrm{TIA}_{\mathrm{length}} = \frac{1.21 \times \mathrm{r}}{\mathrm{r} + 1900} + 4.44 + 3.26$$
$$\mathrm{TIA}_{\mathrm{length}} \approx 8.91 \text{ NM}$$

Formula 3-7-3. TIA Length Standard CG or CG Termination at or above Turn Altitude (Non-LPV/GLS)

$$\mathrm{TIA}_{\mathrm{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt}_{\mathrm{b}}} + \mathrm{D}_{\mathrm{climb}}$$

Where:
FSL = length (NM)of the missed approach flat surface
$\mathrm{alt}_{\mathrm{b}}$ = beginning altitude (feet) (i.e., either the MDA for LNAV/LP or DA for LNAV/VNAV)
$\mathrm{D}_{\mathrm{climb}}$ = climb distance (NM) required to reach the turn altitude from MDA or DA

Example:

$$\mathrm{TIA}_{\mathrm{length}} = \frac{1.21 \times \mathrm{r}}{\mathrm{r} + 1900} + 6.67$$
$$\mathrm{TIA}_{\mathrm{length}} \approx 7.88 \text{ NM}$$

b LPV/GLS TIA. Where an increased CG terminates below the turn altitude, apply otherwise apply formula 3-7-5.

Formula 3-7-4. TIA Length CG Termination Below Turn Altitude (LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + \mathrm{D_{climb_i}} + \mathrm{D_{climb_{ii}}}$$

Where:
$\mathrm{D_{climb_i}}$ = climb distance (NM) required to reach the first $\mathrm{CG_{term}}$ from SOC
$\mathrm{D_{climb_{ii}}}$ = climb distance (NM) required to reach the turn altitude from the first $\mathrm{CG_{term}}$

Example:

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + 3.79 + 3.26$$
$$\mathrm{TIA_{length}} \approx 8.67\ \mathrm{NM}$$

Formula 3-7-5. TIA Length Standard CG or CG Termination at or above Turn Altitude (LPV/GLS)

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + \mathrm{D_{climb}}$$

Where:
$\mathrm{D_{climb}}$ = climb distance (NM) required to reach the turn altitude from SOC

Example:

$$\mathrm{TIA_{length}} = \frac{9861 \times 0.3048}{1852} + 6.01$$
$$\mathrm{TIA_{length}} \approx 7.63\ \mathrm{NM}$$

2. OEA construction after TIA [see table 3-7-1 and figure 3-7-3].

Table 3-7-1. Early/Inside Turn Tie-Back Points

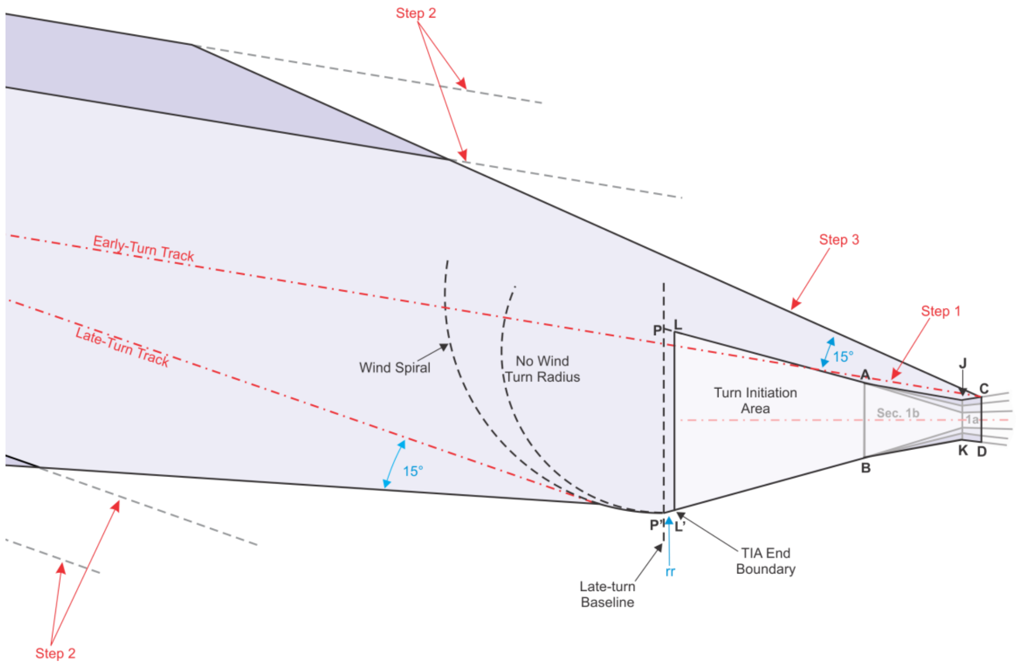
Turn Angle (measured from FAC/line C-D intersection)	Tie-Back Point
≤ 75 degrees	Point C
> 75 degrees	Point D
> 165 degrees	Point P’

a *Step 1*. Construct a line (representing the early-turn flight track) from the tie-back point, to the fix.

b *Step 2***.** Construct the inside turn primary and secondary OEA boundary lines parallel to this line.

c *Step 3*. From the tie-back point, construct a line slaying at 15 degrees to intersect the parallel boundary lines or leg end, whichever occurs earlier. Apply inside turn secondary areas only after the 15-degree splay line intersects the primary boundary line.

Figure 3-7-3. Early/Inside Turn Turn-at-Altitude Construction after TIA



(b) Turn-at-fix (FO or FB). TF legs are followed by a TF leg ending with holding pattern entry or TF-TF connection when the initial straight leg is less than full width. May be followed by an RF leg when the initial straight leg has reached full width, ending with an RF-TF or RF-RF connection. The recommended turn magnitude is 70 degrees; the maximum is 90 degrees. Use FB unless a FO is required for obstacle avoidance or where mandated by specific operational requirements. Use paragraph 1-2-5.d in cases where full primary and secondary width is achieved at a sufficient distance prior to the turn fix to permit construction. Otherwise, construct as follows:

1. Fix location. The first turn fix must be located on the final approach track extended. The distance to the turn fix must be sufficient to result in an early turn baseline at or beyond the end of section 1. Where the first fix must be located at the point the aircraft reaches or exceeds a specific altitude, calculate fix distance from line A-B with formula 1-3-9 using the standard or increased CG. If a fix is already established, calculate the aircraft altitude at the fix using formula 1-3-8. Calculate the aircraft SOC per paragraph 3-7-1.b.

2. Early turn baseline (line L – L'). The early turn baseline is established prior to the turn fix perpendicular to the inbound leg at the appropriate distance.

Table 3-7-2. Early turn Baseline Distance from Turn Fix

Fix Type	Distance
FB Fix	ATT + DTA*
FO Fix	ATT

*DTA = 0 for turns 10 degrees or less

3. Construction points. Inside turn construction uses points PI (primary intersection) and SI (secondary intersection). When defining these points, the leg prior to the turn fix is the inbound leg and the leg following the turn fix is the outbound leg.

a Point SI. This is the connection point for the secondary area boundary and is the intersection of line L-L' and the inbound leg secondary area boundary. When inbound leg has no secondary, points PI and SI are coincident.

b Point PI. This is the connection point for the primary area boundary and is the intersection of line L-L' and the inbound leg primary area boundary.

4. Inside turn construction. Primary/Secondary boundary expansion depends on the location of points PI and SI in relation to the outbound leg OEA boundary lines (extended when necessary) [see table 3-7-3 and figure 3-7-4, figure 3-7-5, and figure 3-7-6]. Where standard expansion is suitable for one, but not both splays, find the outbound connection point for the non-standard splay abeam the standard connection point. If the table 3-7-3 expansion line results in smaller primary areas than those resulting from the 15-degree inbound leg splay, relocate point PI and/or increase the splay angle to maintain or increase the size of the inbound and outbound leg primary areas. Construct as follows:

Table 3-7-3. Inside Turn Expansion

Construction Point	External to Outbound leg OEA (both primary and secondary)	Internal to Outbound leg Secondary area	Internal to Outbound leg Primary area
Point SI	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track	15 degrees relative outbound track
Point PI	Greater of ½ Turn-angle or Inbound leg Splay	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track

a *Step 1*. Construct line L-L' at the appropriate table 3-7-2 distance.

b *Step 2*. Construct secondary area boundary.

1 Case 1. SI is external to the outbound leg OEA. Construct an expansion line from SI to the outbound leg secondary boundary.

2 Case 2. SI is internal to either the outbound leg secondary or primary area. In this case, an alternative construction point (point SI') may be required depending on turn magnitude. Point SI' is defined as the intersection of line L-L' and the outside-turn secondary area boundary. Construct the expansion line from either point SI or SI' to the outbound leg secondary boundary whichever results in the larger area. When the expansion line reaches the outbound secondary boundary before reaching the point of intersection of the inbound and outbound leg secondary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg secondary boundaries.

c *Step 3*. Construct the primary area boundary. Construct an expansion line from point PI to the outbound leg primary boundary. When the *Step 2* expansion line reaches the outbound leg primary boundary before reaching point of intersection of the inbound and outbound leg primary boundaries, no expansion is required and the area is a simple connection of the inbound and outbound leg primary boundaries.

Figure 3-7-4. Early/Inside Turn, First Turn, Turn at Fix: SI/PI Collocated and External to Outbound Primary and Secondary

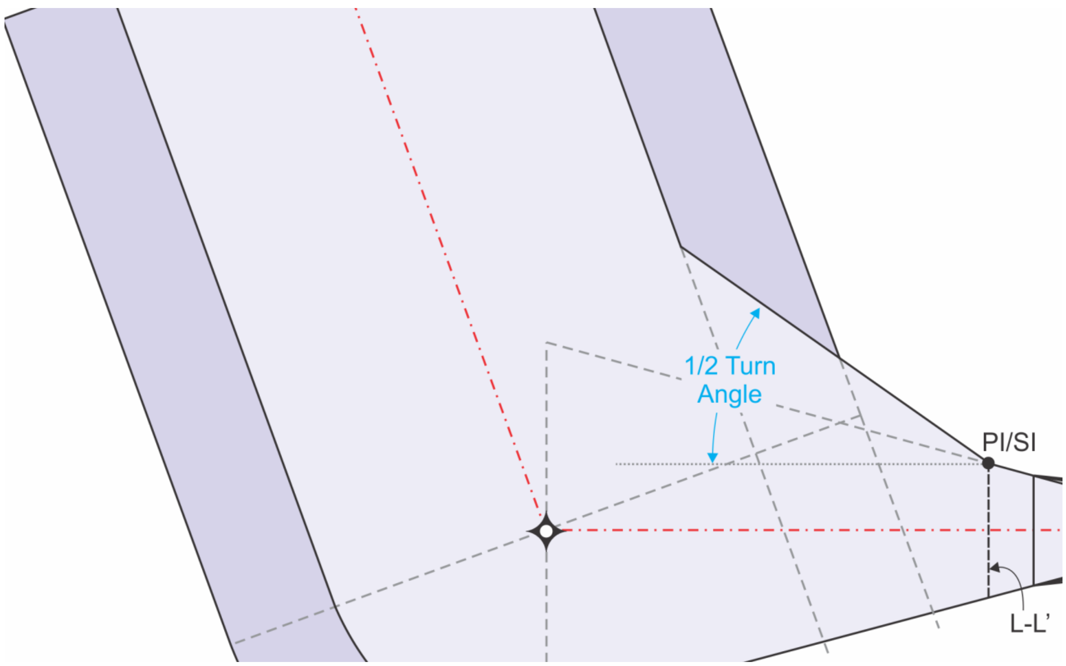


Figure 3-7-5. Early Inside Turn, First Turn, Turn at Fix: SI/PI internal to Outbound Primary

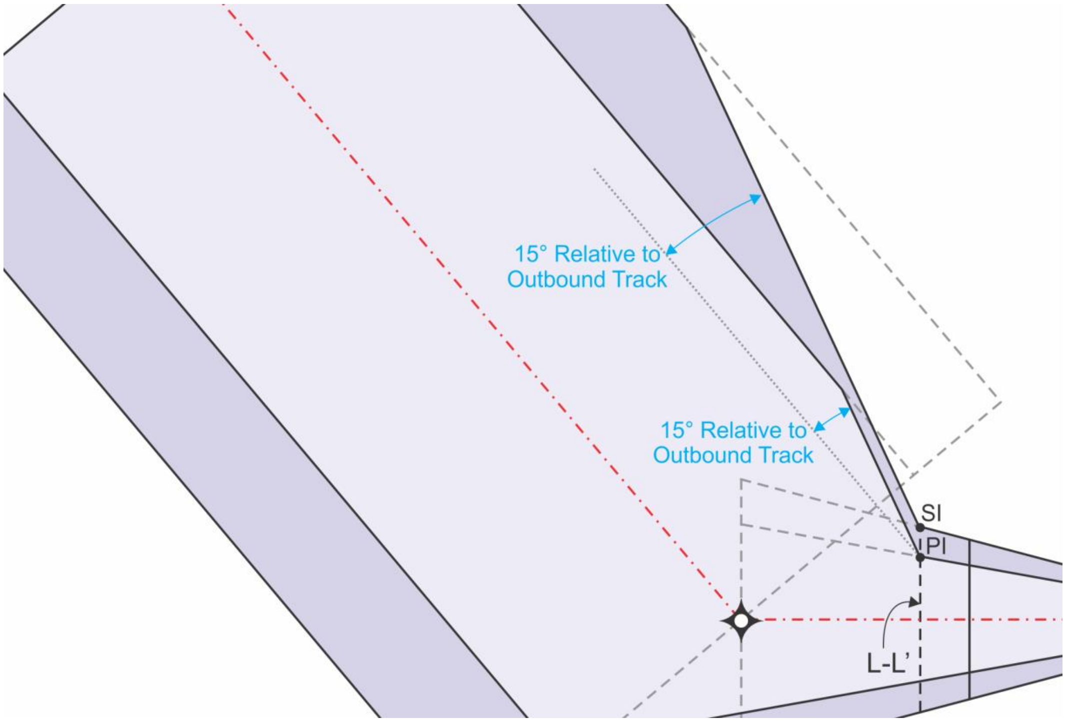
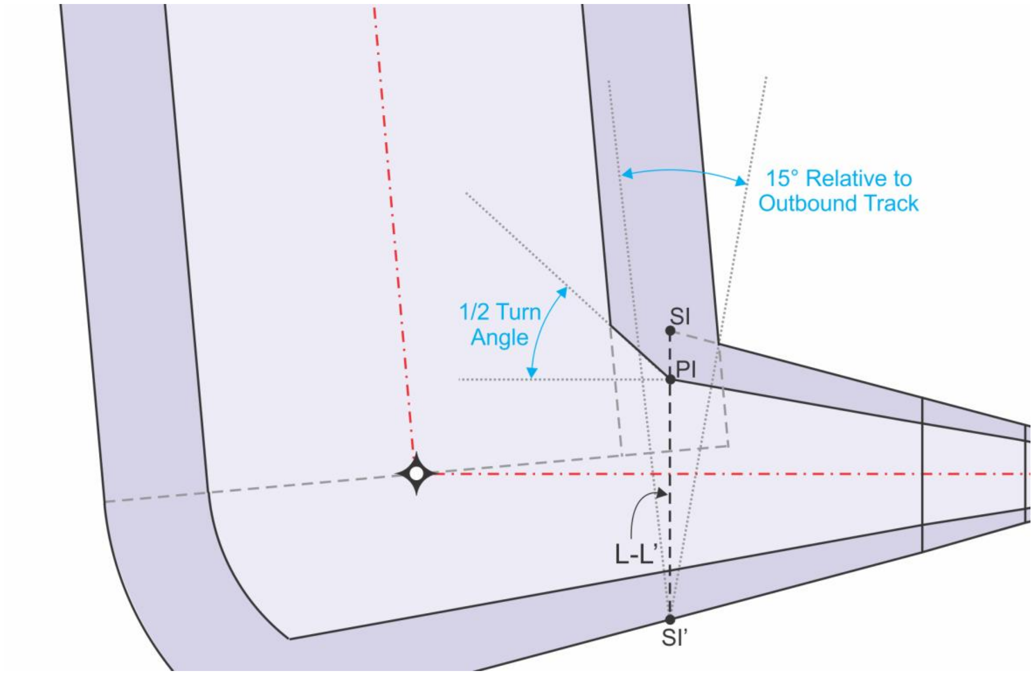


Figure 3-7-6. Early/Inside Turn, First Turn, Turn at Fix:

SI and PI internal to Outbound Secondary, splay from point SI'



(2) Second turn. The second MA turn is specified at either a FB or FO fix [see figure 3-7-7].

(a) DF-TF. This applies to a DF-TF connection following a turn-at-altitude.

1. Construct in accordance with paragraph 3-7-3.a(1)(b) with the following exceptions:

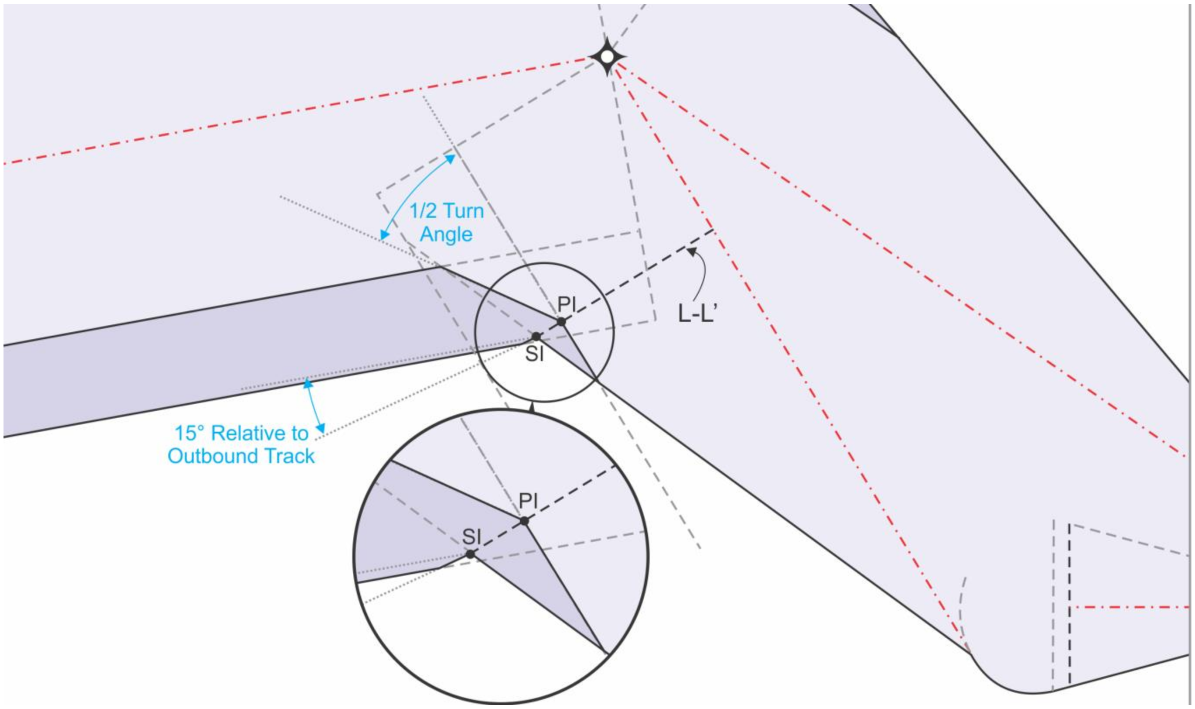
a Paragraph 3-7-3.a(1)(b)1 does not apply.

b Line L-L' is established perpendicular either on the early- or late-turn track, whichever is on the inside of the turn.

c When full primary- and secondary-width is reached at the early-turn baseline (L-L') construct in accordance with paragraph 1-2-5.d.

(b) Other than DF–TF connections. Construct in accordance with paragraph 1-2-5.d.

Figure 3-7-7. Early/Inside Turn, Second Turn, Turn at FB Fix DF-TF connection



b. Late and outside turn construction.

(1) Wind spiral application. Wind spiral (WS) construction applies to late and outside turns for turn-at-altitude, turn-at-fix (FO) for the first turn, and DF-TF (FO) for the second turn. See paragraph 1-3-1.g for design parameters.

(a) WS number and baselines. Baseline locations for WS construction may be dependent on Reaction and Roll distance [see formula 1-2-12 and table 3-7-4].

Table 3-7-4. Wind Spiral Number and Distance to Late Turn Baseline

WS/Baseline Parameters	Turn-at-Fix (FO)	Turn-at-Altitude
WS Number	1 or 2	1, 2, or 3
WS1 & WS2 Distance Late-Turn Baseline from turn fix/point	ATT+D_{rr}	TIA+ D_{rr}
WS3 Baseline	Not applicable	Parallel to line C-D

1. First turn baseline. For first turn construction, the late-turn baseline (line P-P') marks the construction line for wind spirals. Line P-P' is located at the table 3-7-4 distance with points P and P' placed at the continuation of the inbound leg's outer boundary [see paragraph 1-3-1.g(4)]. The no-wind turn radius for the outside turn wind spiral (WS1) and inside turn wind spiral (WS2) will be measured perpendicular to the inbound track from their respective point P. If a third wind spiral is used (WS3), the baseline will be parallel to line C-D with the no-wind turn radius measured inward from point C.

2. Second turn baseline [see figure 3-7-15]. To accommodate both inbound tracks, the second MA turn construction uses two WS baselines, line P'-P" for WS1 and line P-P' for WS2. Each late turn baseline is oriented perpendicular to the early- and late-turn tracks at the table 3-7-4 distance. The baseline for the inbound track nearer the outside-turn boundary is designated line P'-P", with point P" placed on the extended outer boundary and point P' placed at the no-wind turn radius inward along the baseline from point P". The baseline for the inbound track nearer the inside-turn boundary is designated line P-P', with point P' placed on inbound track and point P placed on the extended outer boundary. The no-wind turn radius for the inside turn wind spiral is measured inward along the baseline from point P.

(b) WS connection point and outside turn OEA boundary [see figure 3-7-8]. Each WS has various connection options along its path, which predicate the outside turn OEA boundary. The chosen connection must provide the most reasonably conservative track and protection area. Where excessive splay is required to reach full-width protection, consider lengthening the leg, restricting the speed, category, etc. to avoid protection and/or construction difficulties. Consider full-width protection to exist at the fix where the splay line is tangent to a full-width-radius circle about the fix [see figure 3-7-11].

1. Turn-at-altitude connection point. For turn- at- altitude, the 15-degree or greater splay line that joins the outbound leg outer boundaries may originate from the WS/direct-to-fix tangent point (point 1), the WS to WS tangent line origin (point 2) or the WS to WS tangent line end (point 3). Where the turn angle is ≤ 105 degrees, or the divergence angle between the WS to WS tangent line and the direct-to-fix line is ≤ 15 degrees, apply the splay line from the WS to WS tangent line origin. DF secondary areas begin/exist only where full width primary exists.

2. Turn-at-fix (FO) Connection Point. For turns at a fix, the connection point and the OEA boundary is dependent on the WS boundary relative to the outbound leg OEA (extended). The connection point is the point of tangency on the WS in both cases. When the WS is not contained in the outbound leg OEA, the outside boundary is a 30-degree converging line relative to the outbound course [see figure 3-7-9].When the WS is contained in the outbound leg OEA, the outside boundary is a 15-degree or greater splaying line relative to the outbound course from the WS/outbound leg parallel point until reaching the outbound leg boundaries [see figure 3-7-10].

Figure 3-7-8. Late/Outside Turn, WS Connection Points and Outside Turn OEA Boundary

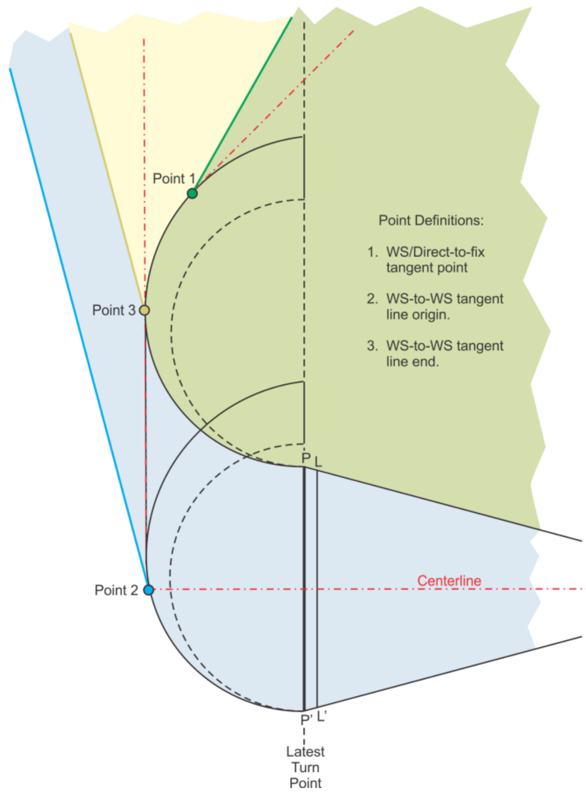


Figure 3-7-9. Late/Outside Turn, Wind Spiral, WS not contained in Outbound OEA

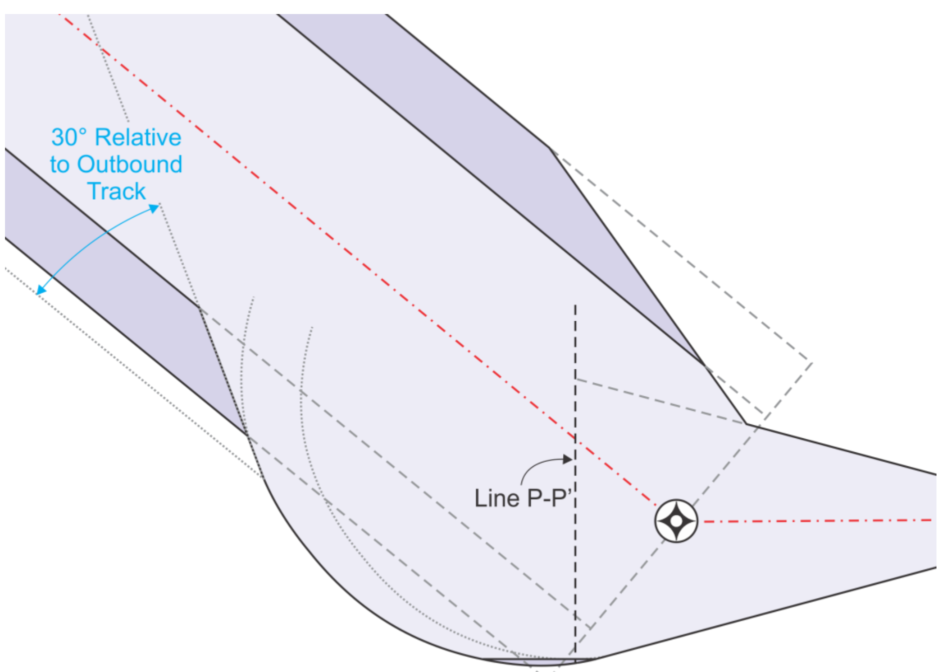
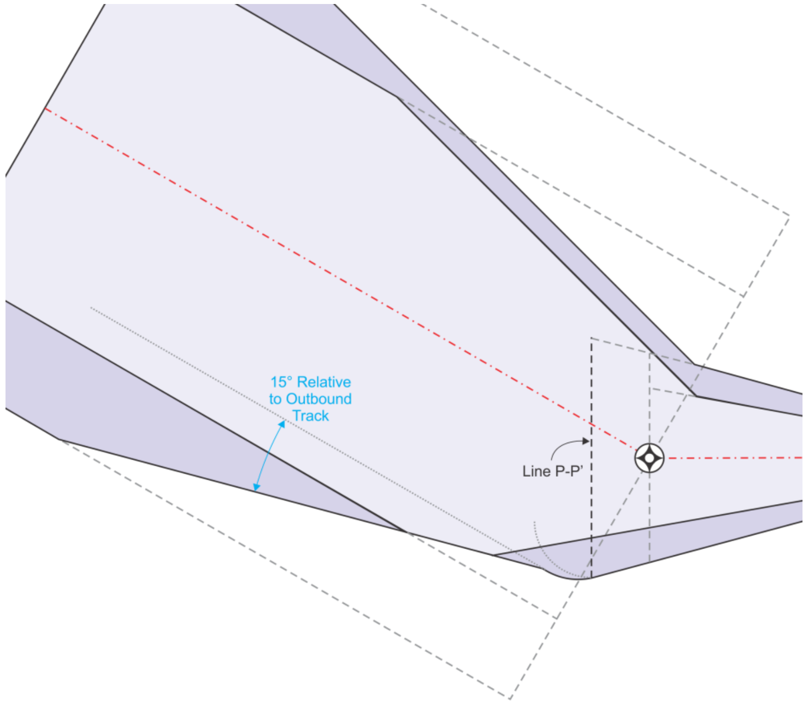


Figure 3-7-10. Late/Outside Turn, Wind Spiral, WS contained in Outbound OEA



(c) Determining multiple WS necessity. To determine multiple wind spiral necessity, construct the additional WS in the direction of turn from its prescribed location to its connection point. Where the additional WS intersects the preceding WS construction (including the connecting and expansion lines), connect the wind spirals with a tangent line that is parallel to the WS center points. Otherwise, revert to the previous WS construction.

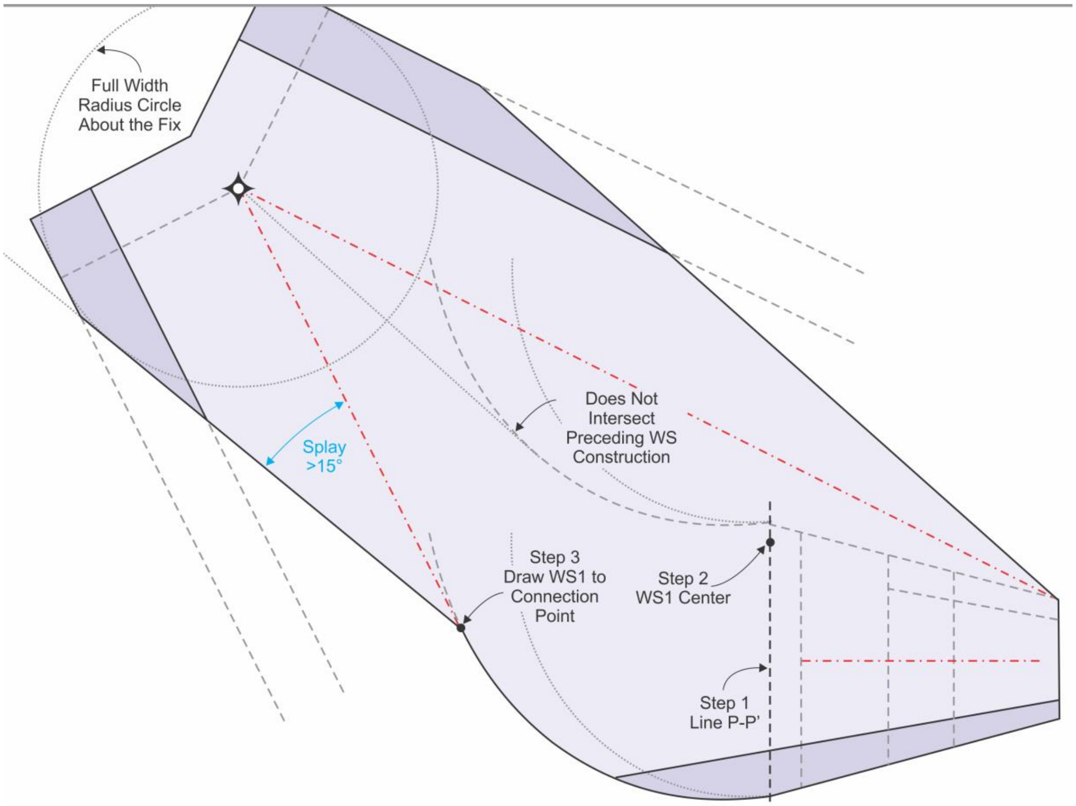
(2) First turn.

(a) Turn-at-altitude or turn-at-fix (FO).

1. *Step 1*. Construct the late-turn baseline (P-P') perpendicular to the straight missed approach track at the late-turn-point.

2. *Case 1*. Small turns using one WS [see figure 3-7-11].

Figure 3-7-11. Late/Outside Turn, First Turn, Case 1,Turn-at-Altitude or FO fix with 1 WS



a *Step 2*. Locate the WS1 center on line P-P' at no-wind turn radius distance from point P'.

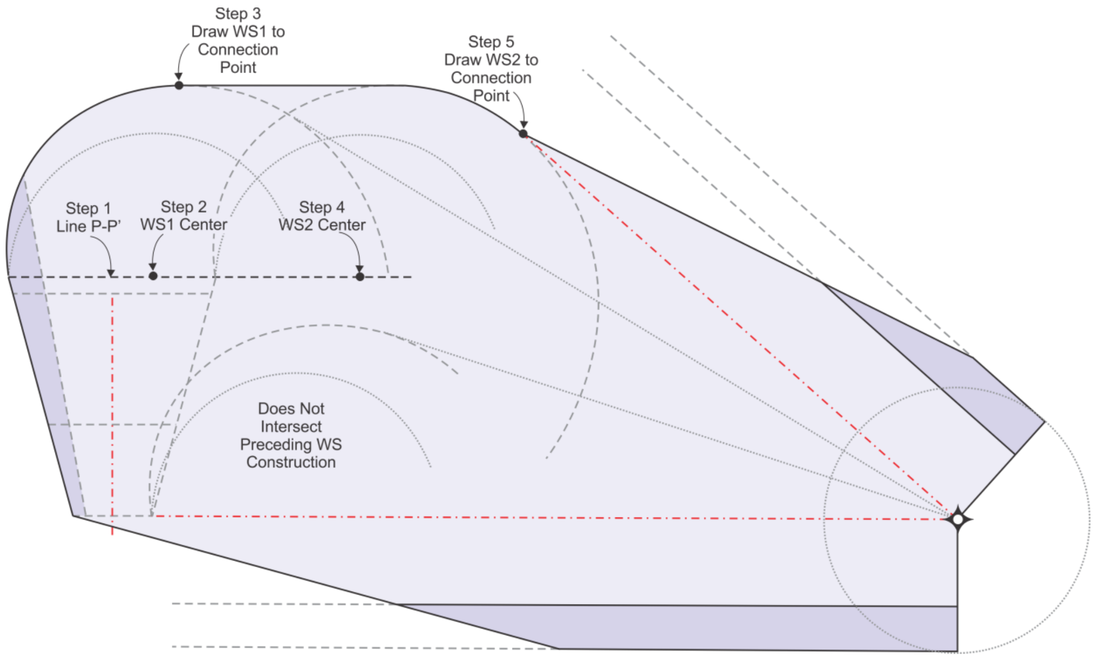
b *Step 3*. Construct WS1 from the outside-turn point in the direction of turn until reaching its connection point.

3. *Case 2*. Turns nearing or greater than 90 degrees using more than one WS [figure 3-7-12]. Apply *Steps 1-3* above, then:

a *Step 4*. Locate the WS2 center on P-P' at no-wind turn radius distance from point P.

b *Step 5*. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point.

Figure 3-7-12. Late/Outside Turn, First Turn, Case 2, Turn-at-Altitude or FO fix with 2 WS



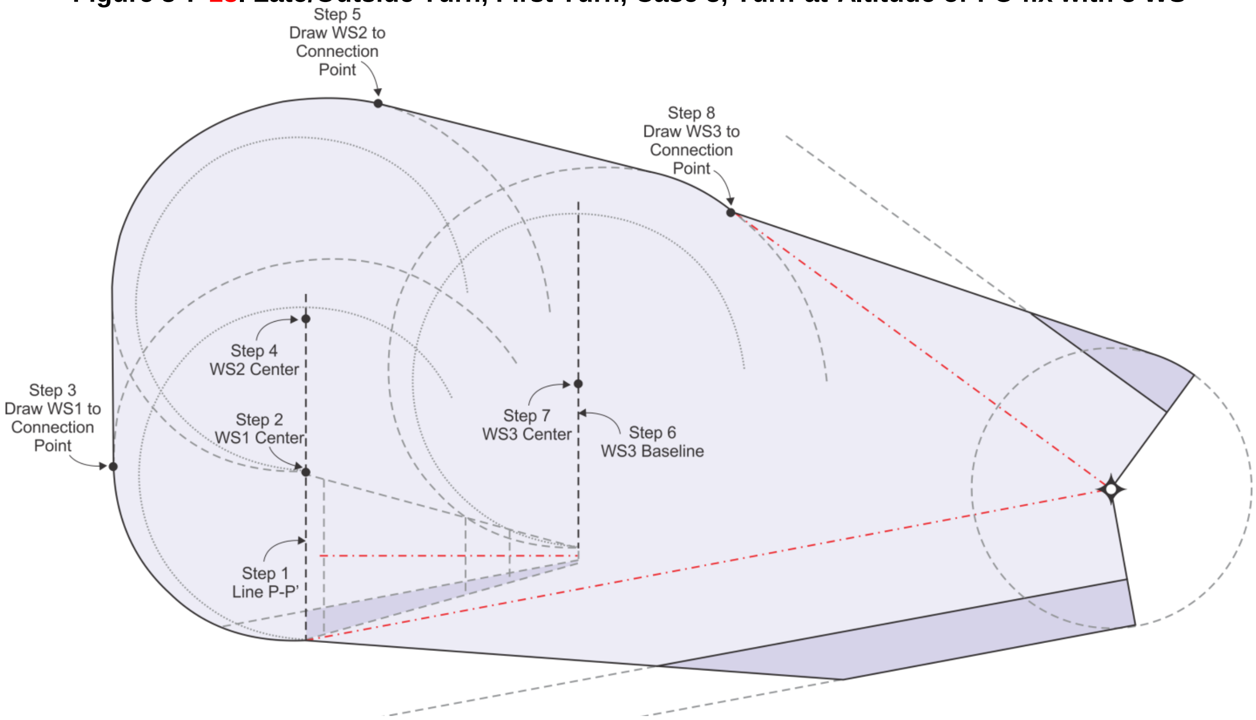
4. *Case 3*. Turns nearing or greater than 180 degrees using more than two WS [see figure 3-7-13]. Apply *Steps 1-5* above, then:

a *Step 6*. Construct the WS3 baseline perpendicular to the straight missed approach track along line C-D extended toward the turn side.

b *Step 7*.Locate the WS3 center on the baseline at no-wind turn radius distance from point C.

c *Step 8*. Construct WS3 from this point in the direction of turn until reaching its connection point.

Figure 3-7-13. Late/Outside Turn, First Turn, Case 3, Turn-at-Altitude or FO fix with 3 WS

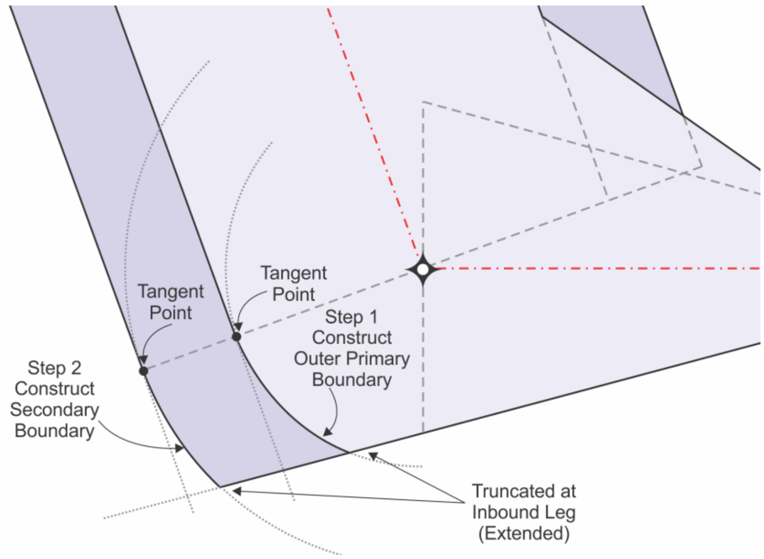


(b) Turn-at-fix (FB) [see figure 3-7-14].

1. *Step 1*. Construct the outer primary boundary using a radius equal to 2 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg primary boundary.

2. *Step 2*. Construct the secondary boundary using a radius equal to 3 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg secondary boundary.

Figure 3-7-14. Late/Outside Turn, First Turn, Turn at Fix (FB)



(3) Second turn.

(a) Turn-at-fix (FO) [see figure 3-7-15].

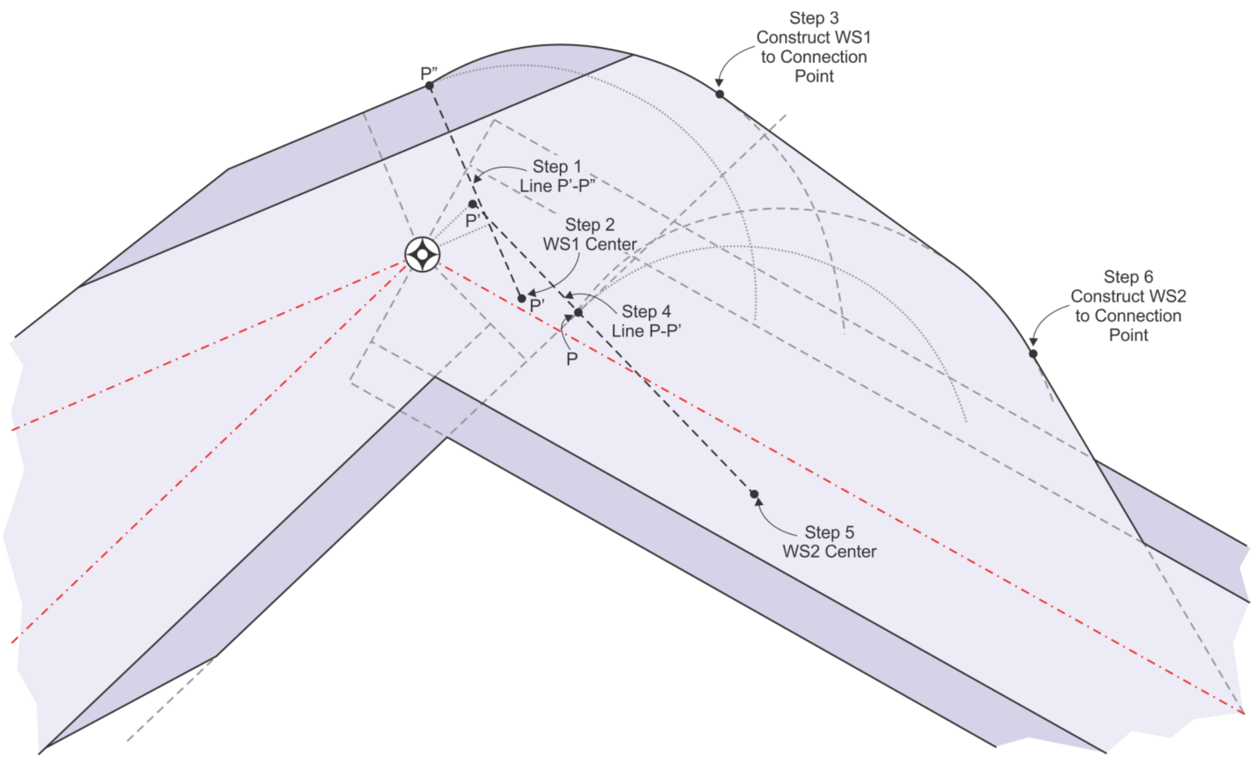
1. *Step 1*. Construct the WS1 baseline, (line P'-P") perpendicular to the DF track nearer the outside of the DF-TF turn, at the late turn point.

2. *Step 2*. Locate the WS1 center on line P'-P" at no-wind turn radius distance from point P."

3. *Step 3*. Construct WS1 from the outside turn point in the direction of turn until reaching its connection point.

4. *Step 4*. Construct the WS2 baseline, (line P-P') perpendicular to the DF track nearer the inside of the DF-TF turn, at the late turn point.

Figure 3-7-15. Late/Outside Turn, Second Turn, Turn-at fix, FO



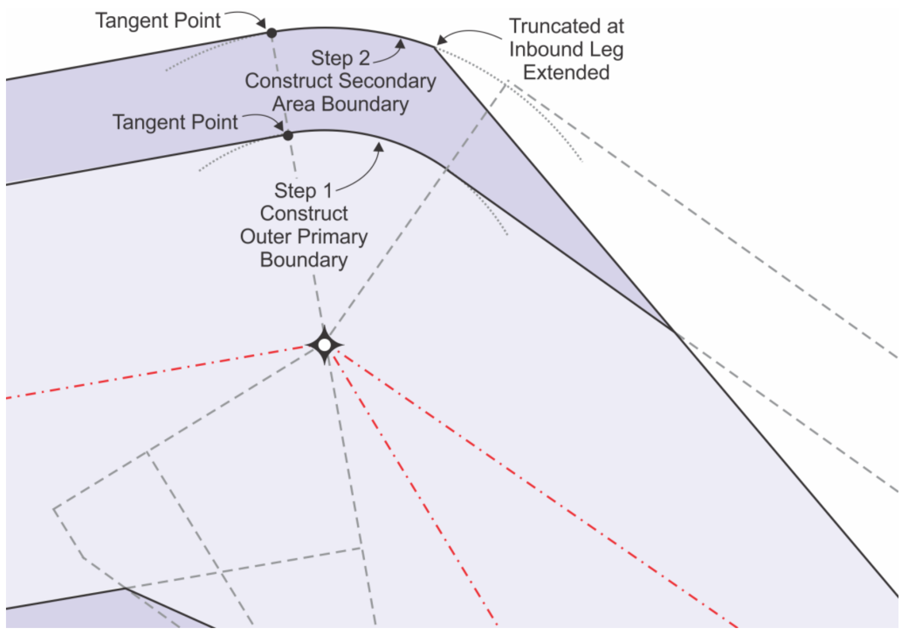
5. *Step 5*. Locate the WS2 center on line P-P’ at no-wind turn radius distance from point P.

6. *Step 6*. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point.

(b) Turn-at-fix (FB).

1. When the inbound leg outside boundary is less than full primary and secondary width reached perpendicular to the fix, construct in accordance with paragraph 3-7-3.b(2)(b) [see figure 3-7-16].

Figure 3-7-16. Late/Outside, Second Turn, Turn at FB fix, less than full OEA width



2. When the inbound leg outside boundary is full primary and secondary width perpendicular to the fix, construct in accordance with paragraph 1-2-5.d.

3-7-4. Obstacle Clearance Surface. Apply a sloping OCS [see paragraph 1-3-1.g and paragraph 3-7-1.c]. Calculate the aircraft SOC in accordance with paragraph 3-7-1.b. Where multiple measurements are required (e.g., a point of interest is equidistant from multiple primary boundaries, it lies along perpendiculars from multiple primary boundaries, etc.), apply the most adverse result from each of the combined primary/secondary measurements.

a. Primary area.

(1) Straight MA/TIA. Measure and apply the OCS slope from line A-B along the track distance to the point or abeam the point of interest [see figure 3-7-17].

(2) Turn-at-altitude (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the TIA boundary to the point of interest [see figure 3-7-17 and figure 3-7-18, and figure 3-7-19].

(3) Turn-at-a-fix (single and multiple legs). Apply the OCS slope from line A-B (parallel to track) to L-L', then along the shortest primary distance to the point of interest [see figure 3-7-20]. A-RNP obstacle distance is measured as the along-track distance from line A-B to a point abeam the obstruction.

Note: The shortest primary area distance is the length of the shortest line kept within the primary area that passes through the early-turn baseline of all preceding legs.

Figure 3-7-17. OCS, Primary Area, Turn -at-Altitude, Single leg, Small Turn

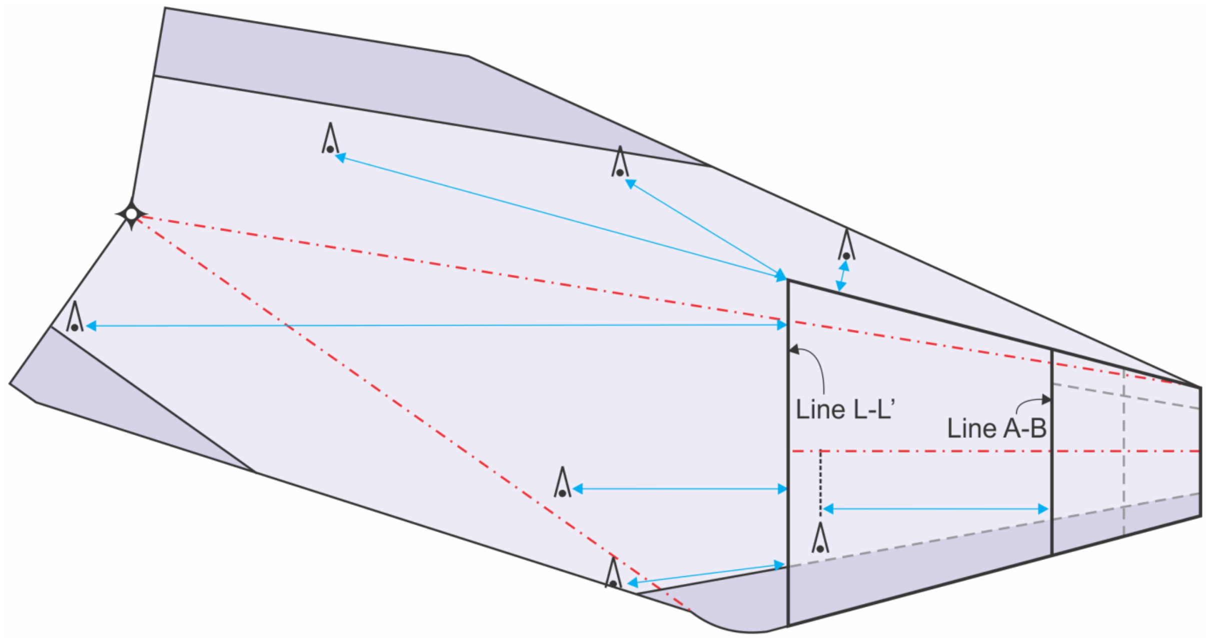


Figure 3-7-18. OCS Primary Area, Turn-at-altitude, Single Leg, Large Turn

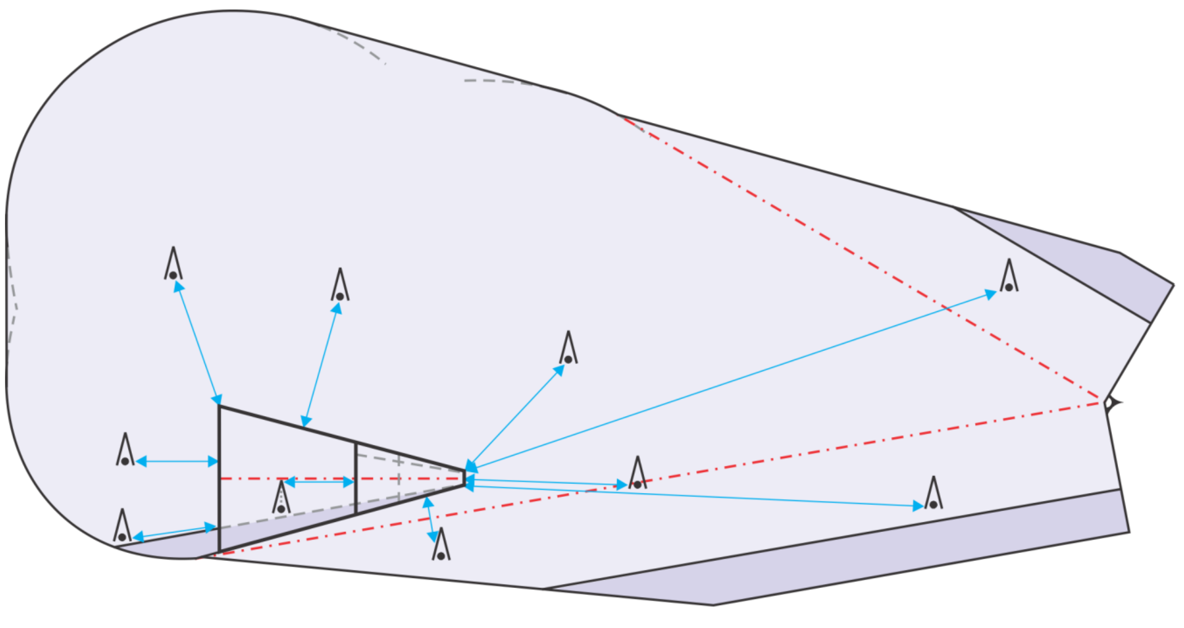


Figure 3-7-19. OCS, Primary Area, Turn-at-Altitude, Multiple legs

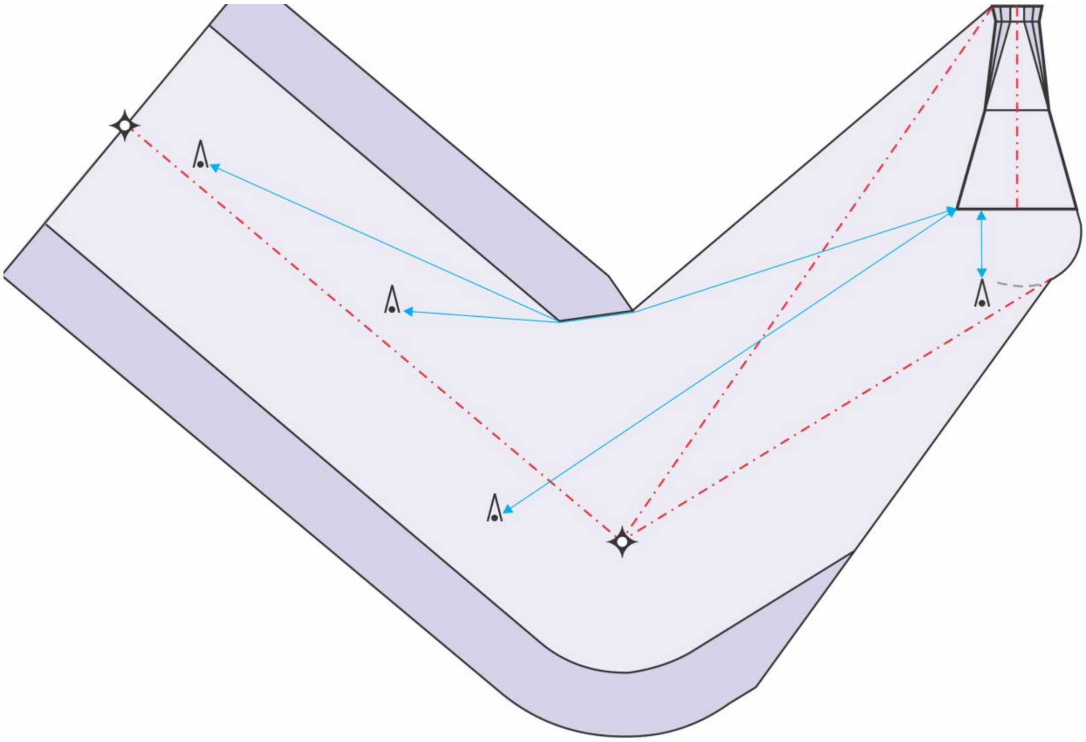
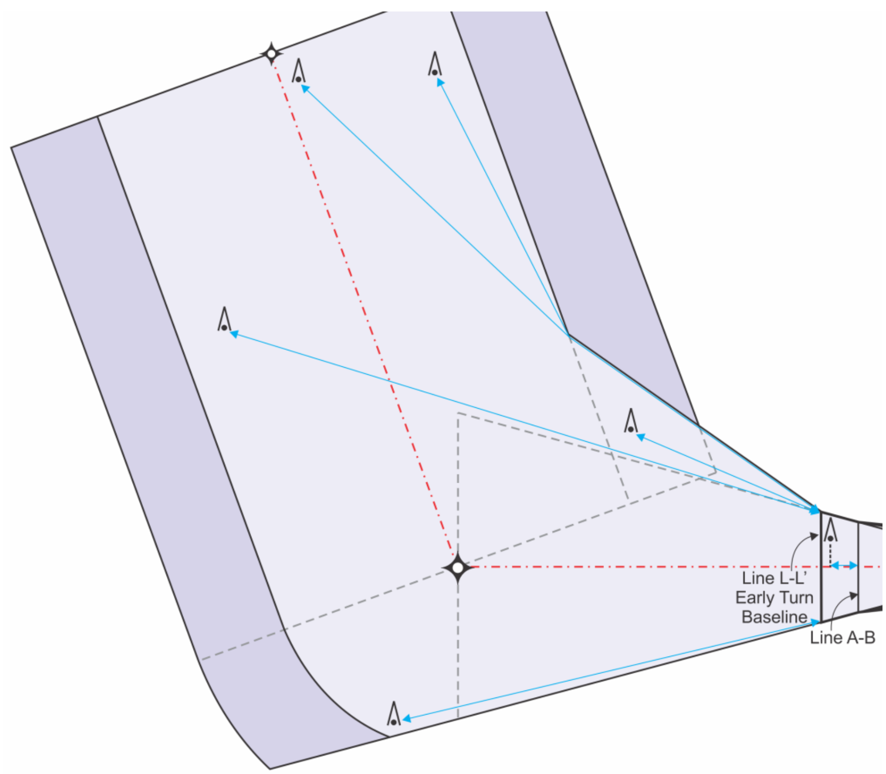
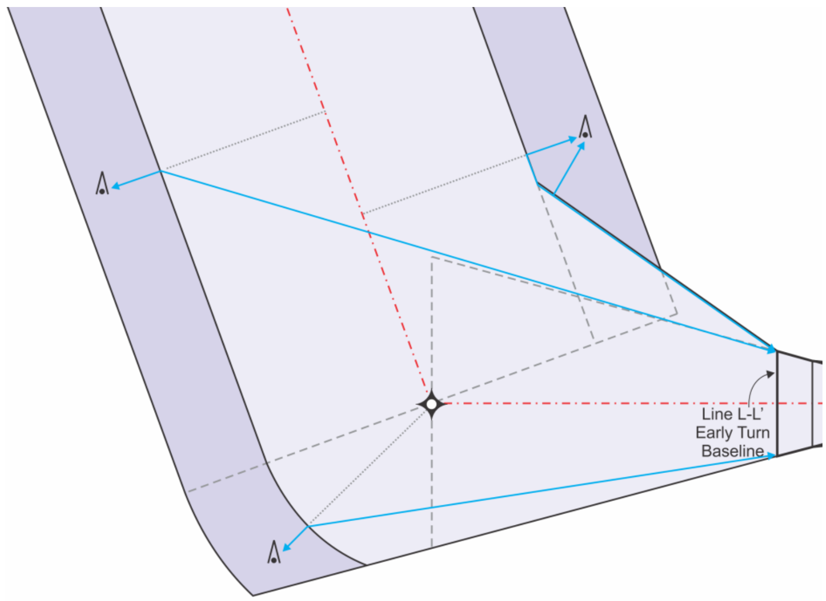


Figure 3-7-20. OCS, Primary Area, Turn at Fix



b. Secondary area. For secondary areas, calculate the primary OCS elevation as stated then apply a 12:1 OCS slope along the shortest secondary distance to the point of interest. In straight legs, this is normally perpendicular to the nominal track. In expansion areas, the slope rises in a direction perpendicular to the primary boundary (arc, diagonal corner-cutter, etc.) [see figure 3-7-21].

Figure 3-7-21. OCS, Secondary Area



Chapter 4. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Section 4-1. General Criteria

4-1-1. Concept and design. TF legs are preferred but RF legs may be used for turn path control, procedure simplification, or improved flyability. FO fixes that require turn construction are not authorized in RNP AR APCH segments.

a. OEA construction. Apply paragraph 1-2-5 with the following exceptions.

(1) Apply the largest RNP for the flight phase from table 1-2-1 unless a smaller value is required to achieve a desired ground track or is operationally required.

(2) RNP changes must occur at a fix and are linear (i.e., do not splay/taper 30 degrees relative to the course). RNP may be increased or decreased as needed prior to the FAS. RNP changes must not occur in the FAS. After crossing the LTP/FTP, RNP values may only increase. See figure 1-2-1, figure 1-2-2, and figure 1-2-3 for illustrations of RNP changes.

(3) The length of any leg between the initial approach fix and the missed approach point may be reduced to not less than 0.2 NM (regardless of RNP) when there are no more than three waypoints within 1 NM along-track distance and there is no leg shorter than 1 NM prior to a change in RF turn direction. No turns (> 0.03 degrees) allowed when applying this to TF-TF connections. Avoid establishing reduced length legs in sequence to avoid negative impact on chart/display readability.

b. Use of NAVAIDS. Do not incorporate a VOR/DME or VORTAC into an RNP AR procedure if the geodetic coordinates of the VOR and DME source are not identical to 0.01 seconds, regardless whether the facilities are considered collocated.

c. Lines of minima. No more than four lines may be established. Circling minimums are not established.

(1) Establish a default line. The default line is based on RNP 0.3 in the FAS and a default RNP AR APCH [see paragraph 4-3-1.a(1)] or RNAV 1 [see paragraph 4-3-1.a(2)] missed approach.

(2) When the HAT value of the default line is ≥ 300 or no-lights visibility ≥ 1 SM.

(a) Additional lines may be established when at least a 50-foot reduction in HAT or ¼ SM reduction in visibility can be achieved using one or more of the following;

<u>1.</u> Reduced FAS RNP (values < 0.3 but ≥ 0.10).

<u>2.</u> Reduced RNP MAS [see paragraph 4-3-1.a(3)].

<u>3.</u> MAS CG.

(b) Additional lines based on reduced RNP may also be established to meet operational requirements, e.g., to achieve track-to-airspace or track-to- track separation when these minima reductions cannot be achieved.

(c) When applying paragraph 4-1-1.c(2)(a) or 4-1-1.c(2)(b), a default line must be still be published.

(3) A line based on reduced FAS RNP may be established to achieve minimum DA to FROP distance. A default line is not required in this case.

4-1-2. Feeder segment. Construct feeder segments as described in chapter 2 using one or more TF or RF legs. The NavSpec is RNAV 1 STAR/Feeder/Arrival (with associated XTT of 1). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply.

4-1-3. Initial segment. Construct initial segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP AR APCH Initial (with associated XTT of 1). Secondary areas do not apply.

4-1-4. Intermediate segment. Construct intermediate segments as described in chapter 1 using one or more TF or RF legs. The NavSpec is RNP AR APCH Intermediate (with associated XTT of 1). Secondary areas do not apply. FB turns at the PFAF are limited to a maximum of 15 degrees. See appendix C for RF transition to ILS.

Section 4-2. Final Approach Segment (FAS)

4-2-1. General. The NavSpec is RNP AR APCH Final (with associated XTT of 0.3 – 0.1). Secondary areas do not apply. RNP approaches are 3D procedures; the final segment provides the pilot with final segment vertical and lateral path deviation information based on baro-VNAV systems. The minimum HAT value is 250 feet.

a. Vertical path. Chapter 1 applies with the following additional guidance determining a PFAF on an RF leg.

(1) Use formula 4-2-1 and formula 4-2-2 to determine the PFAFs Cartesian coordinates relative to the LTP/FTP. The location of the PFAF may be calculated geodetically from these Cartesian values.

(a) *Step 1*. Determine the flight track distance from LTP/FTP to PFAF using formula 1-3-3.

(b) *Step 2*. Determine the distance from LTP/FTP to the FROP [see paragraph 4-3-5].

(c) *Step 3*. Subtract *Step 2* from *Step 1* to calculate the distance around the arc to the PFAF from the FROP. Use formula 1-2-4 to determine number of degrees of arc; conversely, use formula 1-2-3 to convert degrees of arc to length.

Formula 4-2-1. PFAF on an RF Leg, Cartesian Coordinate "X" Value

$$X = d_{FROP} + R \times \sin(\alpha)$$

Where:
d_{FROP} = distance from LTP to final rollout point
α = degrees of arc
R = arc radius

Note: This formula works with any unit so long as d_{FROP} & R share the same unit.

Example:

$X = 9420.55 + 19079 \times \sin(98.9)$
$X \approx 28269.84$

Formula 4-2-2. PFAF on an RF Leg, Cartesian Coordinate "Y" Value

$$Y = R - [R \times \cos(\alpha)]$$

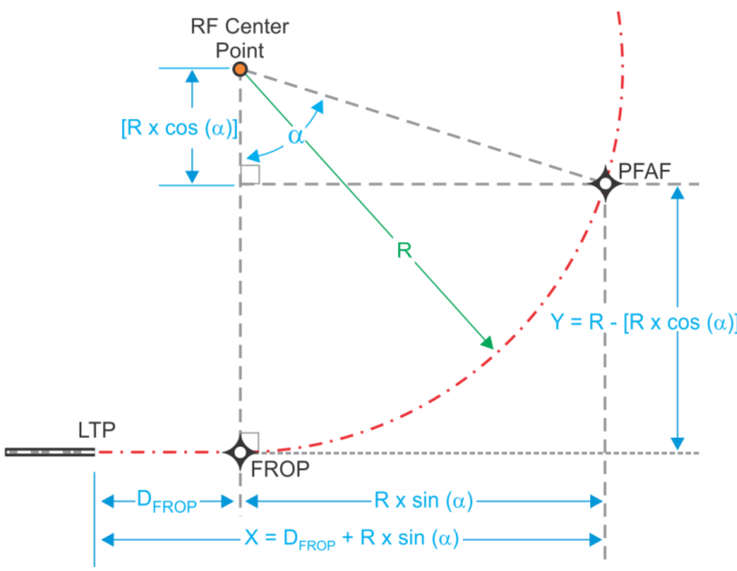
Where:
α = degrees of arc
R = arc radius

Note: This formula produces a value with the same unit as R.

Example:

$Y = 19079 - [19079 \times \cos(98.9)]$
$Y \approx 22030.72$

Figure 4-2-1. Calculating Cartesian Coordinates, PFAF on an RF leg



b. Restrictions. The true vertical path provided by baro-VNAV is influenced by temperature variations; i.e., during periods of cold temperature, the effective glidepath may be lower than published and during periods of hot weather, the effective glidepath may be higher than published. Because of this phenomenon, minimum and maximum temperature limits (for aircraft that are not equipped with temperature compensating systems) are published on the approach chart. Additionally, RNP AR approach procedures are not authorized where a remote altimeter setting source (RASS) is in use. See paragraph 3-3-4.a(1) to determine the critical temperatures and ΔISA_{LOW} for VEB calculations.

c. Precipitous terrain. Do not apply the 10 percent HAT increase identified in Order 8260.3C paragraph 3-2-2.b(1)(b) to RNP AR procedures.

4-2-2. Alignment.

a. The optimum alignment is a TF leg straight in from PFAF to LTP on runway centerline extended. If necessary, the TF course may be offset by up to three degrees. Where the course is offset, it must cross runway centerline extended at least 1500 feet (5200 feet maximum) out from LTP.

b. Turns in the FAS and final rollout point (FROP). TF-TF turns are not allowed in the FAS. Where turns are necessary in the FAS an RF leg must be established. The RF leg must terminate and be followed by a TF leg meeting FAS alignment at or prior to reaching the minimum FROP distance. The *minimum* FROP distance is the greater of the point on the vertical path 500 feet above LTP/FTP elevation or the point in the FAS at distance equal to 15 or 50 seconds prior to the DA point. The number of seconds applied is dependent on the initial missed approach RNP value (RNP_{IMAS}) [see formula 4-2-3]. If an RF leg is the last leg in the intermediate segment, the PFAF must meet the minimum FROP distance.

Formula 4-2-3. Minimum FROP distance

$$d_{500} = \frac{500 - \mathrm{TCH}}{\tan(\theta)}$$

$$d_{time} = \frac{\mathrm{DA} - (\mathrm{LTP}_{elev} + \mathrm{TCH})}{\tan(\theta)} + \frac{(V_{KTAS} + 15) \times 1852}{0.3048} \times \frac{S}{3600}$$

$$d_{FROP} = \text{greater of } d_{time} \text{ or } d_{500}$$

Where:
V_{KTAS} = calculated KTAS using PFAF altitude and final approach KIAS for the fastest CAT
S = seconds of flight

Note: For $RNP_{IMAS} \geq 1.0, S = 15$. For $RNP_{IMAS} < 1.0, S = 50$

Example:

$$d_{500} = \frac{500 - 47}{\tan(3)}$$

$$d_{500} \approx 8643.75 \text{ feet}$$

$$d_{time} = \frac{1760.4 - (1441.6 + 47)}{\tan(3)} + \frac{(152.25 + 15) \times 1852}{0.3048} \times \frac{15}{3600}$$

$$d_{time} \approx 9420.55 \text{ feet}$$

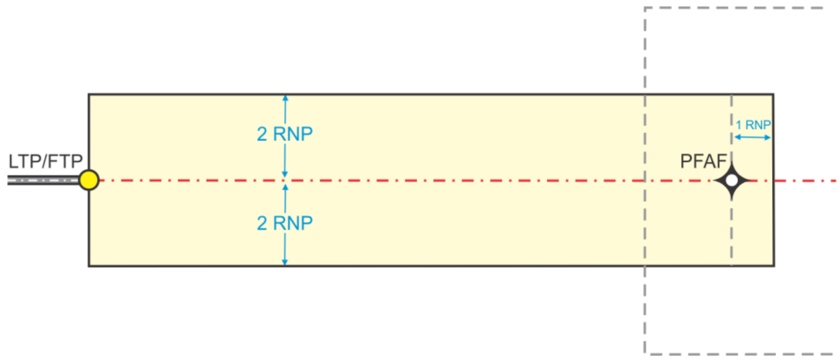
$$d_{FROP} \approx 9420.55 \text{ feet}$$

4-2-3. Area.

a. Length. The final segment OEA begins 1 × RNP prior to the PFAF and extends to the LTP/FTP.

b. Width. The final segment OEA width is 2 × RNP [see figure 4-2-2].

Figure 4-2-2. Final Segment OEA



4-2-4. Obstacle clearance. An OCS based on the Vertical Error Budget (VEB) is applied. The VEB origin varies depending on whether the procedure is designed for aircraft with wingspans ≤ 262 feet (wide body) or aircraft with wingspans ≤ 136 feet (narrow body). Design for wide body aircraft by default. When the DA can be reduced by at least 50 feet or visibility reduced by ¼ mile or where wide body operations are not anticipated (e.g., where the airport/runway infrastructure cannot support wide body aircraft) the approach may be designed for narrow body aircraft. In either case, the procedure must be properly annotated [see Order 8260.19, paragraph 4-6-10]. The VEB origin also varies depending on whether evaluating a TF or RF leg (with corresponding changes to the OCS height when both leg types are in the FAS).

a. Calculating the VEB. Total VEB is calculated by adding bias errors to four thirds times the standard deviation variations combined via the root sum square method. This is completed for both the PFAF and 250 feet above TDZE to determine the OCS slope and origin.

(1) Bias errors are:

(a) Body geometry error accounts for the low point of the aircraft below the altimeter reference point. This may be the landing gear for aircraft on straight legs, but it could be a wing tip for aircraft on RF legs.

1. Narrow body (BG_{NB}). Wingspan less than or equal to 136 feet.

a Straight legs: fixed at 15 feet

b RF legs: greater of 15 feet or $\frac{136}{2} \times \sin(\phi)$

2. Wide body (BG_{WB}). Wingspan less than or equal to 262 feet.

a Straight legs: fixed at 25 feet

b RF legs: greater of 25 feet or $\frac{262}{2} \times \sin(\phi)$

Formula 4-2-7. DA Distance Based on VEB OCS Penetration

$$d_{DA} = d_{LTP} + p \times OCS_{slope}$$

Where:
p = penetration (feet)of the OCS
d_{LTP} = along track distance (feet) from the LTP/FTP to obstacle

Example:

$d_{DA} = 4514.5 + 8.3 \times 23.42$
$d_{DA} \approx 4708.89$ feet

e. Published decision altitude. If the FAS OCS is not penetrated, the minimum HAT value of 250 feet applies. Except when using an RNAV MAS [see paragraph 4-3-1.a(2)], the DA distance from LTP/FTP must also not be less than missed approach $d_{heightloss}$ [see formula 4-3-4] plus d_{VEB}.

Section 4-3. Missed Approach Segment (MAS)

4-3-1. General. The NavSpec is RNP AR APCH Missed (with associated XTT of 1 – 0.1). Secondary areas do not apply. Optional NavSpec may be RNAV 1 or A-RNP Missed (with associated XTT of 0.3 - 1) with secondary areas. Use of A-RNP missed approach XTT less than 1 requires Flight Standards approval.

a. MAS RNP. Use of RNP < 1.0 in the missed approach limits may limit availability of the procedure. In order to serve the largest number of users, specify a default or RNAV MAS where possible.

(1) Default MAS (RNP AR APCH with RNP 1.0). Use except where not operationally beneficial. The construction is a continuation of the FAC. The OEA expands from the FAS RNP to an RNP value of 1.0.

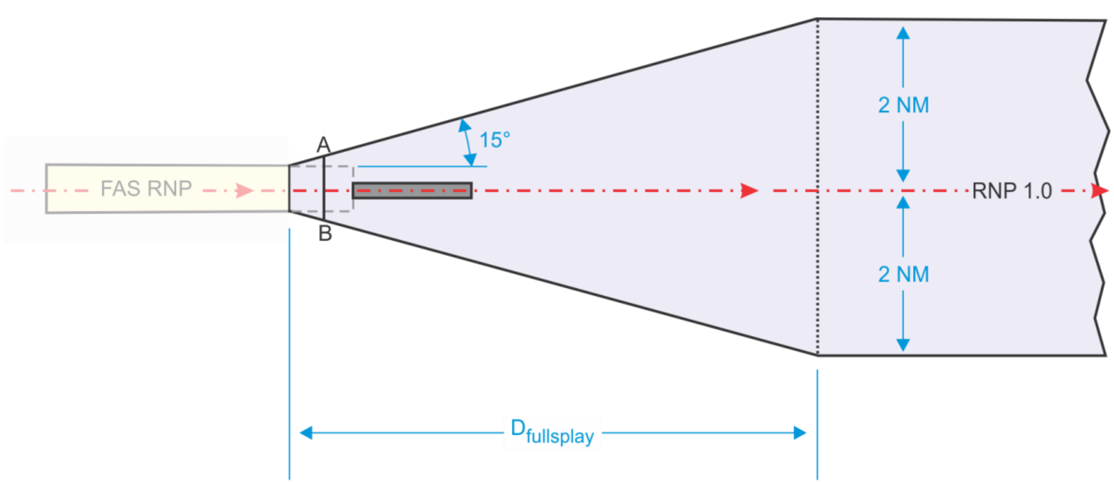
(2) RNAV MAS (RNAV 1 missed). Use where operationally beneficial (i.e., turn-at-altitude construction to allow a turn earlier than permitted by default MAS construction).

(3) Reduced RNP MAS (RNP AR APCH with RNP <1.0). Use when previous options are not practical. Construct straight or turning (using RF legs) missed approach.

4-3-2. Default MAS OEA construction. Establish the MAS using TF and/or RF legs.

a. Straight. The MAS leg expands from the FAS OEA DA at an angle of at least 15 degrees relative to course centerline until reaching a width of ± 2 NM (RNP 1.0) [see figure 4-3-1]. RNP 1.0 width must be achieved at or prior to reaching the first missed approach fix or the clearance limit if no other fix exists beyond the DA. The along-track distance (NM) required to complete the splay ($D_{fullsplay}$) may be calculated using formula 4-3-1. When RNP 1.0 is not reached using a 15-degree splay, establish an RNAV MAS or splay at the angle required to reach ± 2 NM at the turn point/fix (S_{angle}).

Figure 4-3-1. Default MAS OEA, Straight



4-3-3. RNAV MAS OEA construction [see figure 4-3-4]. Use LNAV/VNAV construction in accordance with section 3-5 and section 3-7 with the following exceptions;

a. DA must be no closer to LTP than the VEB OCS origin.

b. RF legs do not require AFS approval.

c. Paragraph 3-6-2 applies except the 15-degree OEA splay begins at the outer edge of the final OEA at the DA point instead of the final secondary area (i.e., the secondary start width is zero). Calculate the distance from course centerline to the primary and secondary boundary of the OEA at any distance from line C-D using formula 4-3-2.

Formula 4-3-2. RNP AR RNAV MAS Primary and Secondary Boundary

$$MAS_{Yprimary} = \frac{D_{splay} \times \tan(15) \times (1 - RNP_{FAS})}{1.5 - RNP_{FAS}} + 2 \times RNP_{FAS}$$
$$MAS_{Ysecondary} = D_{splay} \times \tan(15) + 2 \times RNP_{FAS}$$

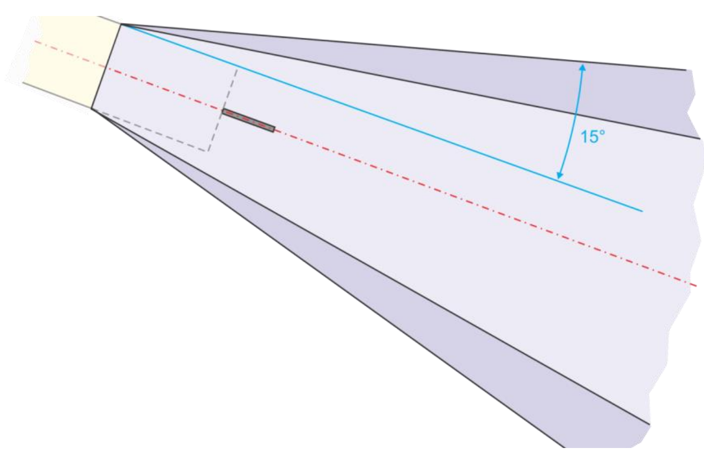
Where:
D_{splay} = along-track distance (NM) from beginning of MAS splay to point of interest
RNP_{FAS} = RNP value (NM) of the final segment

Example:

$$MAS_{Yprimary} = \frac{4.48 \times \tan(15) \times (1 - 0.3)}{1.5 - 0.3} + (2 \times 0.3)$$
$$MAS_{Yprimary} \approx 1.3 \text{ NM}$$

$$MAS_{Ysecondary} = 4.48 \times \tan(15) + 2 \times 0.3$$
$$MAS_{Ysecondary} \approx 1.8 \text{ NM}$$

Figure 4-3-4. Missed Approach Segment, RNAV MAS Area



4-3-4. Reduced RNP MAS. Establish using TF and/or RF legs. See paragraph 1-2-5.b for OEA construction. Where turns are necessary, the turn must occur after passing 500 feet above airport elevation and where possible, not prior to the DER. At no point may the turn be specified prior to $D_{MASturn}$ from DA [see formula 4-3-3].

Formula 4-3-3. Reduced RNP MAS, Minimum Distance DA to Turn

$$D_{MASturn} = \frac{(V_{KTAS} + 15) \times 10}{3600}$$

Where:
V_{KTAS} calculated KTAS using DA and final segment KIAS for the fastest CAT

Example:

$$D_{MASturn} = \frac{(170.38 + 15) \times 10}{3600}$$
$$D_{MASturn} \approx 0.51 \text{ NM}$$

4-3-5. OCS evaluation. The following applies to default and reduced RNP missed approaches. For RNAV missed approaches see sections 3-5, 3-6, and 3-7.

a. General. The OCS is composed of sections 1a and 1b, which are separated by line A-B.

(1) Section 1a. The OCS extends from the DA point downward at the VEB OCS slope ratio for a distance of $d_{heightloss}$ using formula 4-3-4 measured along the final course track to line A-B.

Formula 4-3-4. Height Loss Distance

$$d_{heightloss} = \frac{50}{\tan(\theta)}$$

Example:

$$d_{heightloss} = \frac{50}{\tan(3)}$$
$$d_{heightloss} \approx 954.06 \text{ feet}$$

(2) Section 1b OCS. From line A-B, section 1b OCS rises at a 40:1 slope Calculate the HMAS at line A-B using formula 4-3-5. Obstacle distance is measured as the along-track distance from line A-B to a point abeam the obstruction.

Chapter 5. Departure Procedures

Section 5-1. General Criteria

5-1-1. General. The NavSpec is RNAV 1 Departure or RNP 1 Departure (with associated XTT of 1). Optional NavSpec may be A-RNP Departure (with associated XTT of 1 – 0.3). Use of A-RNP departure XTT less than 1 requires Flight Standards approval.

a. ICA. Departure procedures begin with an ICA constructed in accordance with Order 8260.3, paragraph 14-1-6, except where modified by this order.

(1) The ICA must be long enough to allow LNAV engagement (500 feet above airport elevation).

(2) Use formula 1-3-9 to determine ICA length. Where a higher than standard climb gradient terminates prior to the minimum turning altitude, the ICA length will be the distance required to reach the CG termination altitude plus the distance between that altitude and the turning altitude at the reduced CG.

b. Leg type limitations. See Order 8260.46, paragraph 3-1-5 for permissible leg types.

Note: The 'AER' in Order 8260.46, table 3-1-1 is for coding purposes. Bearings and distances used for OEA construction and leg length analysis are not measured from the AER.

(1) VA leg. VA legs are all-primary area and the initial departure course is aligned within 15 degrees of the extended runway centerline [see paragraph 5-2-1].

(2) VI leg. VI legs are all-primary area and the initial departure course is aligned with extended runway centerline [see paragraph 5-2-1]. VI legs are associated with CF legs and due to possible Flight Management System route discontinuity, course changes of less than 10 degrees to intercept the CF leg are not authorized without approval from Flight Standards Service.

(3) DF leg. Secondary areas apply once the 15-degree splay from course line (early and late) have reached full primary width. DF-DF is only authorized when the first DF fix is within 15 degrees of the extended runway centerline.

(4) CF leg. Secondary areas apply once the 15-degree splay from course has reached full primary width or as defined in the turning departure section.

c. Leg length. Comply with paragraph 1-2-5.b(1) with the following exceptions.

(1) Do not develop legs exceeding 260 NM to ensure the geodesic path does not exceed the protected airspace for a great circle path.

(2) For LNAV engagement, the first leg must be designed to end at least 500 feet above airport elevation.

(3) The maximum allowable VA or VI leg length is 10 NM.

(4) For FO DF leg length feasibility check see appendix B.

Section 5-2. Straight Departure

5-2-1. Straight departure.

a. VI is a straight departures leg and is aligned with runway centerline extended. VA, DF, CF, and TF are straight departure legs and are aligned within 15 degrees of the runway centerline. Evaluate straight departure legs in accordance with Order 8260.3, paragraph 14-3-1 with the following provisions:

(1) The ICA is aligned along the runway centerline for the distance required for a climb to 500 feet above airport elevation.

(2) Continue splay until reaching basic area width as defined in chapter 1. If an A-RNP value is selected that results in an OEA narrower than the ending ICA width, taper inward at 30 degrees relative to course to join edge of primary area [see figure 5-2-2].

(3) The departure may not be offset from runway centerline when the first turn is an RF and the straight segment hasn't reached full OEA width construction [see paragraph 1-2-5.d].

(4) Straight route departure criteria apply only to the first course from DER. Any turn after the first departure course must be evaluated using turning criteria.

Figure 5-2-1. Straight Departure

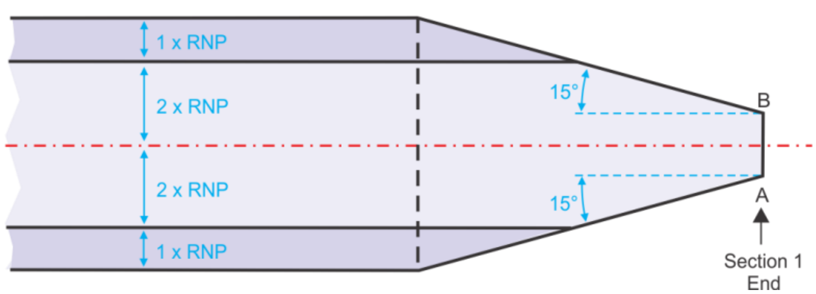
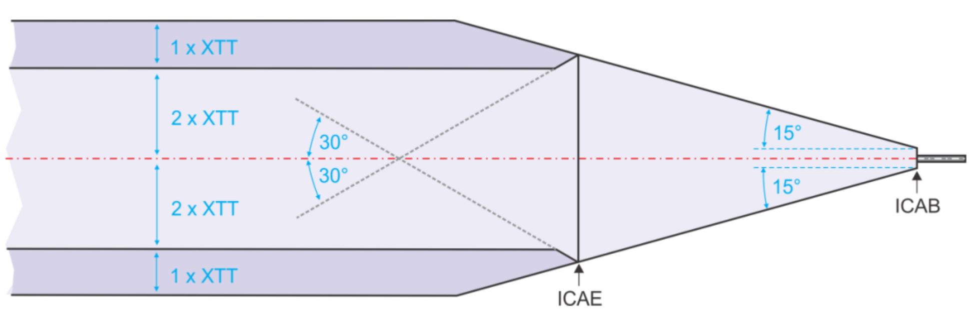


Figure 5-2-2. Straight Departure with 30 Degree Inward Taper



Section 5-3. Turning Departures

5-3-1. Turning departure.

a. Early and inside turn construction.

(1) First turn. The first turn may be a FB or FO fix or may follow a VA or VI leg.

(a) Turn following VA leg (turn-at-altitude). The turn altitude will either be the minimum required altitude, operationally specified, or determined by obstacle evaluation. The specified turn altitude must equal or exceed the ICA end aircraft altitude.

1. The OEA consists of the ICA/straight segment, section 1, and section 2. Excluding the ICA, section 1 is defined as the OEA on the DER side of the DRL. Section 2 is the OEA on the SER side of the DRL.

2. Construct the ICA/straight segment from the ICAB to line L-L'. Because straight segment length and the OCS elevation at L-L' are dependent on aircraft altitude, establishing an obstacle-based turn altitude may be an iterative process. If an A-RNP value is selected that results in an OEA narrower than the ending ICA/straight segment width, taper inward at 30 degrees relative to course.

3. OEA construction after ICA/straight segment [see table 5-3-1 and figure 5-3-1].

Table 5-3-1. Early-Turn Tie-Back Points

Turn Angle (measured from RWY C/L ICAE intersection)	Tie-Back Point
≤ 165 degrees	DRP
> 165 degrees	Point P'

a *Step 1.* Construct a line (representing the early-turn flight track) from the tie-back point, to the fix.

b *Step 2.* Construct the inner primary and secondary OEA boundary lines parallel to this line.

c *Step 3.* From the tie-back point, construct a line splaying at 15 degrees to intersect the parallel boundary lines or segment end, whichever occurs earlier. Apply secondary areas only after the 15-degree splay line intersects the primary boundary line. Where the inside turn boundary intersects the ICA inside 15-degree splay line the boundary must be a line connecting the DRP, point A, and full width point or original splay width abeam fix if full width has not been reached [see figure 5-3-2].

Section 5-4. Obstacle Evaluation

5-4-1. Obstacle evaluations.

a. Utilize the general concepts from paragraph 1-3-1.g. Where an obstacle requires multiple measurements (an obstacle is equidistant from multiple primary boundary points, it lies along perpendiculars from multiple primary boundary points, etc.), apply the most adverse result from each of the combined primary/secondary measurements [see figure 5-4-1through figure 5-4-7].

b. Primary OCS.

(1) ICA. Measure distance to obstacles using the distance from ICAB along runway centerline extended. The ICA OCS begins at the MSL elevation of the ICAB [see formula 1-3-5 to determine OCS slope].

(2) Straight departure. Measure and apply the OCS slope along the shortest primary area distance from the ICA to a point at/abeam the obstacle.

(3) Turn-at-altitude (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the ICA/straight segment boundary to a point at/abeam the obstacle.

(a) Section 1. For obstacles past the ICAB, measure from the closest point on the ICA/straight segment boundary. For obstacles between the DRL and ICAB, take the lesser of the distance from runway centerline and the closest point on the ICA boundary. The section 1 OCS begins at the MSL elevation of the OCS at ICAE.

(b) Section 2. Measure from DRP. The section 2 OCS begins at the specified turn altitude.

(4) Turn-at-a-fix (single and multiple legs). Apply the OCS slope along the shortest primary area distance from the ICA to a point at/abeam the obstacle.

(5) VI-CF.

(a) VI-CF standard construction and minimum VI-CF with turns of 30 degrees or less. Apply the OCS slope along the shortest primary area distance from the ICA boundary to a point at/abeam the obstacle.

(b) Minimum VI-CF with turns of more than 30 degrees. For obstacles past the DER, measure from the closest point on the ICA boundary. For obstacles between the DRP and DER, take the lesser of the distance from runway centerline and the closest point on the ICA boundary.

(6) Routes. Apply ICA, section 1 and section 2 methodology where applicable, then measure along the shortest primary area distance that passes through the early-turn baseline of all preceding legs.

Note: The shortest primary area distance is the length of the shortest line kept within primary area that passes through the early-turn baseline of all preceding legs.

c. Secondary OCS. For obstacles located in secondary areas, calculate the primary OCS elevation as stated, then apply a 12:1 OCS slope along the shortest secondary distance to the obstacle. In straight legs, this is normally perpendicular to the nominal track. In expansion areas, the slope rises in a direction perpendicular to the primary boundary (arc, diagonal corner-cutter, etc.).

Figure 5-4-1. VA-DF Obstacle Distance Measurements, Primary and Secondary Area, large turn