CHANGE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

8260.58A
CHG 2

National Policy

Effective Date:
09/11/2018

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

1. Purpose. This change publishes procedure design criteria for required navigation performance authorization required (RNP AR) departures. Also, changes were made based on PBN Aviation Rulemaking Committee (PARC) analysis of requests received from industry. Furthermore, this change incorporates the updated Flight Standards organization structure while removing all Flight Standards routing symbols/codes (in accordance with the Flight Standards Service Nomenclature).

2. Who this change affects. 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. Added required navigation performance authorization required (RNP AR) design standards.

b. Expanded appendix C to authorize PBN Transitions to Ground Based Augmentation System (GBAS) Landing System (GLS) and localizer performance with vertical guidance (LPV) final.

c. Added flexibility in obstacle evaluation area (OEA) construction to account for complex multiple/short legs.

d. Removed/replaced Flight Standards' routing symbols/codes with the appropriate organization title throughout the document.

e. Eliminated the secondary obstacle evaluation area for A-RNP legs.

f. Clarified that only radius-to-fix (RF) legs based on RNP APCH require Flight Standards approval.

g. Replace RNP AR APCH Final Rollout Point (FROP) distances based 15/50 seconds with FROP of 0.5 NM.

h. Clarified that base minimum descent altitude/decision altitude (MDA/DA) used for Missed Approach evaluation is the lowest value after subtracting remote altimeter setting source (RASS).

i. Clarified missed approach course-to-an-altitude (CA) leg paragraph.

5. Distribution. We will distribute this change electronically.

Rick Domingo
Executive Director, Flight Standards Service

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(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
RNP 2	2						
RNP 1[2]		1					1
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
A-RNP[2,6,9]	2 or 1[8]	1 or 0.3	1 or 0.3	1 or 0.3	0.3[4]/40m[5]	0.3 or 1	0.3 or 1
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	0.1 - 1	
RNP AR DP							0.3 - 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 cross track tolerance (XTT)/along track tolerance (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. RNP APCH applies to final flight phase.

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) and Flight Path 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 alignment restriction between TF and RF legs is no course change exceeding alignment tolerance. Otherwise, the general alignment restriction 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.

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. The OEAs defined in this order are the minimum size OEAs authorized; larger OEAs may be developed where operationally advantageous.

(1) Length.

(a) Minimum length (fix-to-fix). Generally, minimum leg length is the lesser of 2 × 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 $\beta < \text{acos}(\sqrt{3} - 1)$ use:

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

If $\beta \geq \text{acos}(\sqrt{3} - 1)$ 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:

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

$$L \approx 10.16$$

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.

(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, A-RNP, and RNP AR DP 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.

c. Turn parameters. For OEA construction, a turn is indicated when the course change exceeds the alignment tolerance of 0.03 degrees [see paragraph 1-2-5.a(3)].

(1) Altitude. Calculate the assumed altitude at a turn fix/point as specified below. The calculated assumed altitude need not exceed the maximum anticipated use specified by ATC. For other cases [e.g., Q or T routes, or standard terminal arrival (STAR) or standard instrument departure (SID) legs that precede/follow manual termination legs that make it impractical to determine a starting altitude/point] use the highest anticipated altitude at the turn fix based on specified altitudes, airspace, and anticipated use.

Note: Use of the highest anticipated altitude is required even when obstacle clearance is assured for flyability, path repeatability, and airspace/route separation.

(a) Calculate projected altitude. Except for turns inside the Precise Final Approach Fix (PFAF), projected altitudes are calculated using formula 1-3-8 based on the rise of an assumed vertical path from a specified start point.

1. Final approach segment.

a Turns inside the PFAF. Use the final segment vertical path, i.e., glidepath angle (GPA). Determine the projected altitude by calculating the vertical rise from the Landing Threshold Point (LTP)/Fictitious Threshold Point (FTP) using formula 1-3-4.

b Turns at the PFAF. There is no projected altitude. Use the specified PFAF altitude.

2. Intermediate and initial approach segments. The vertical path is 250 ft/NM (CAT A-E) or 400 ft/NM (COPTER). Determine the projected altitude by calculating the vertical path rise fix-to-fix from the start point/altitude to the turn fix. For the first leg, the start point is the PFAF at the specified PFAF altitude. For subsequent legs, start at the end fix of the preceding leg at the assumed fix altitude.

3. Feeder segments and STAR runway transitions that terminate on an instrument approach procedure (IAP). The vertical path is 250 ft/NM (CAT A-E) (COPTER TBD). Determine the projected altitude by calculating the vertical path rise fix-to-fix from the start point/altitude to the turn fix.

a Feeder. For the first leg, start at the initial approach fix (IAF) at the assumed IAF altitude. The start point/altitude for subsequent legs is the end fix at the assumed fix altitude of the preceding leg.

b STARs. For the first leg, start at the IAP fix at the assumed fix altitude. For subsequent legs, start at the end fix preceding leg at the assumed fix altitude. If a STAR transition serves more than one IAP, base the STAR on the IAP with the highest assumed altitude.

4. Missed approach (MA) and departure (prior to transition route). For MA legs, the vertical path is the higher of 250 ft/NM (CAT A-B), 500 ft/NM (CAT C-E), 400 ft/NM (COPTER), or the specified climb gradient (CG) in effect at the point of interest. For departure

(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 MSL							
En route, STAR/Feeder/TAA, Initial, Intermediate, Missed, Departure		150	180	250	300	300	350
Below 10000 feet MSL							
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 possible on the same IFP. 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 at or above 10000 feet MSL 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:

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

$$V_{KTAS} \approx 170.88$$

(3) Maximum bank angle

(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: 25.49 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

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

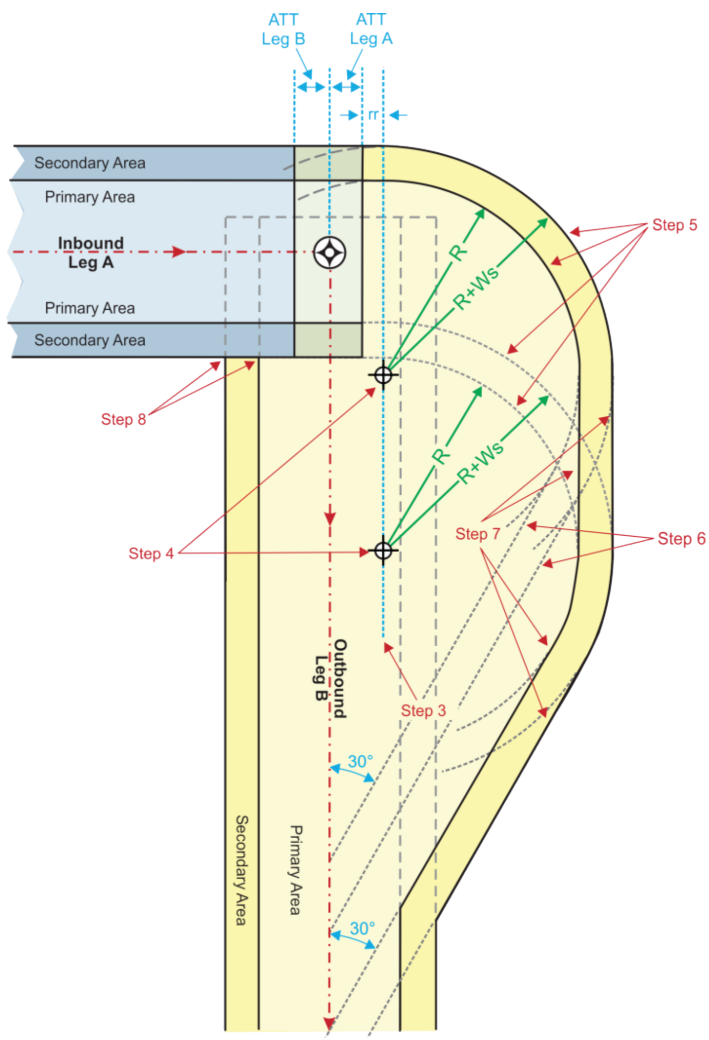
Note: If $\text{alt} - \text{apt}_{elev} \leq 2000$, $V_{KTW} = 30$

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).

Figure 1-2-9. FO with Second Arc Expansion



(3) Radius-to-fix (RF) Turn [see figure 1-2-10]. RF legs are used to control the ground track of a turn where obstructions prevent the design of a FB or FO turn, or to accommodate other operational requirements. Incorporation of an RF leg limits IFP availability to some users; therefore, an RNP APCH that requires RF leg capability to fly the procedure requires Flight Standards approval. OEA construction limits turn radius to a minimum value equal to or greater than the OEA (primary and secondary if applicable) half-width. The RF leg OEA boundaries are parallel arcs. For OEA construction, the RF start point is the radius extended to early ATT and the RF end point is the radius extended to late ATT.

(a) *Step 1*. Determine the leg R that is required to fit the geometry of the terrain/airspace. Enter this R value into formula 1-2-11 to verify the calculated bank angle (rounded to the nearest whole degree) is ≤ 25 degrees.

(b) *Step 2*. Locate the turn center at a perpendicular distance R from the inbound and outbound legs.

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:

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

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

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:

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

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

c. ATC turns to join initial and intermediate segments. The first leg of an initial and the first leg of an 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].

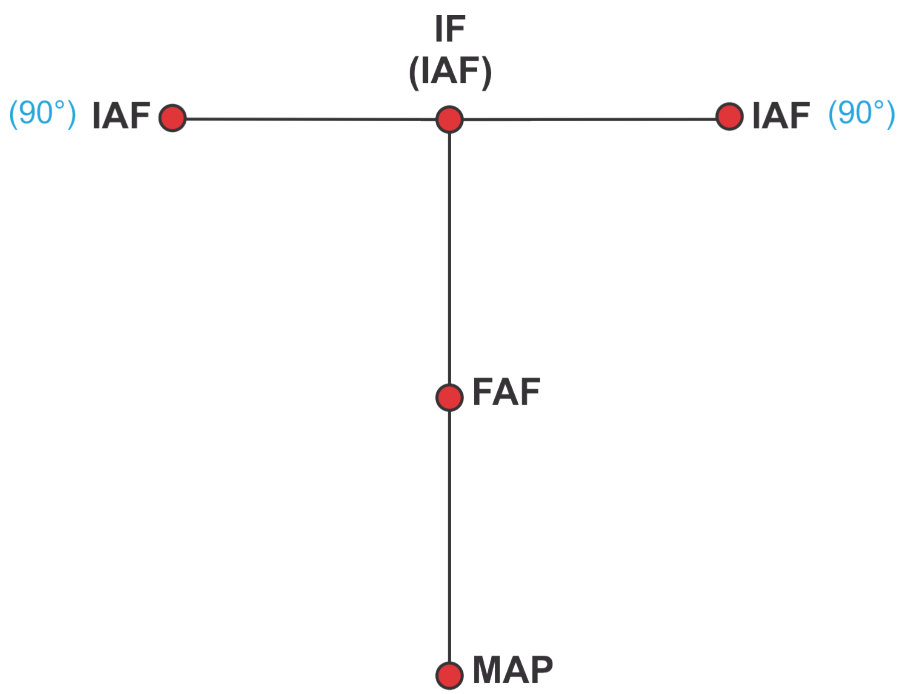
(1) Configuration. The default design incorporates a basic T configuration.

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

(b) Course reversal. Basic T configurations normally include a HILPT course reversal initial established at a fix designated as an intermediate fix (IF)/initial approach fix (IAF).

(c) Modified T. Where not practical (e.g., maximum DG exceeded) one or both of the T segments and/or the course reversal may be eliminated.

Figure 1-3-1. Basic T 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 1-3-11. Wind Spiral ΔR

$$\Delta R = \frac{V_{KTW} \times \beta_{increment}}{3600 \times TR}$$

Where:
$\beta_{increment}$ = incremental turn magnitude at point of interest
V_{KTW} = calculated or historical tailwind (knots) using the highest altitude in the turn
TR = calculated turn rate (degrees/second)

Example:

$$\Delta R = \frac{51.55 \times 35}{3600 \times 1.04}$$

$\Delta R \approx 0.48$ NM

(4) Construction baselines. Missed approach/departure construction baselines are commonly identified by the points that they are comprised of, which can be used to mark the beginning, ending, and/or tie-back point for the OEA. When these lines are used to identify tie-back points for turn construction, the placement of the point will be in alphabetical order from turn-side to non-turn side. For example, a right turning missed approach with lines C-D and L-L' will have points C and L on the right, while a left turning missed approach will have them on the left.

h. A-RNP NavSpec leg usage. Use of A-RNP legs requires chart note, "Use of FD or AP required." Except for obstacles excluded by Order 8260.19 paragraph 2-11-4, apply horizontal and vertical accuracy adjustments to obstacles in any segment/leg based on A-RNP.

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 flight phase with associated XTT of 2). Optional NavSpec may be A-RNP (En route flight phase 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 flight phase 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 used as FB waypoints.

b. OEA construction.

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

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 flight phase with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP (STAR/Feeder/TAA flight phase with associated XTT of 1 or 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, except for A-RNP. 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 flight phase with associated XTT of 1). Optional NavSpec may be RNP 1 or A-RNP (STAR/Feeder/TAA flight phase with associated XTT of 1 or 0.3 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply, except for A-RNP.

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.

Chapter 3. RNAV (GPS) 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. Incorporation of an RF leg limits IFP availability to some users; therefore, an RNAV (GPS) approach that requires use of an RF leg in the missed approach, intermediate, or in all initials requires Flight Standards approval. 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 flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (STAR/Feeder/TAA flight phase with associated XTT of 1 or 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, except for A-RNP.

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 flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Initial flight phase with associated XTT of 1 or 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, except for A-RNP.

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 flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Initial flight phase with associated XTT of 1 or 0.3 as appropriate). Secondary areas apply, except for A-RNP. Paragraph 1-1-1.a(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 RNP intermediate to an ILS/GLS/LPV 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. When an RF to the PFAF is used, comply with appendix C and taper relative to the RF track.

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

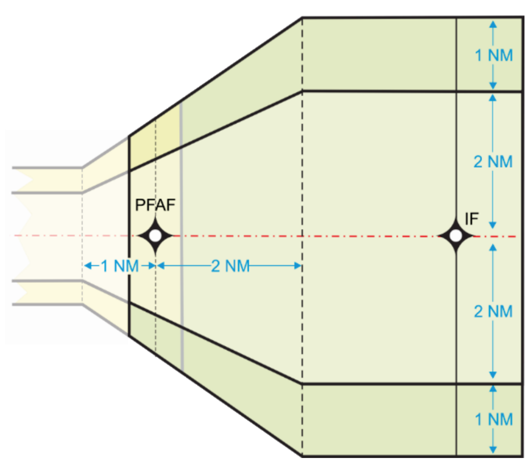
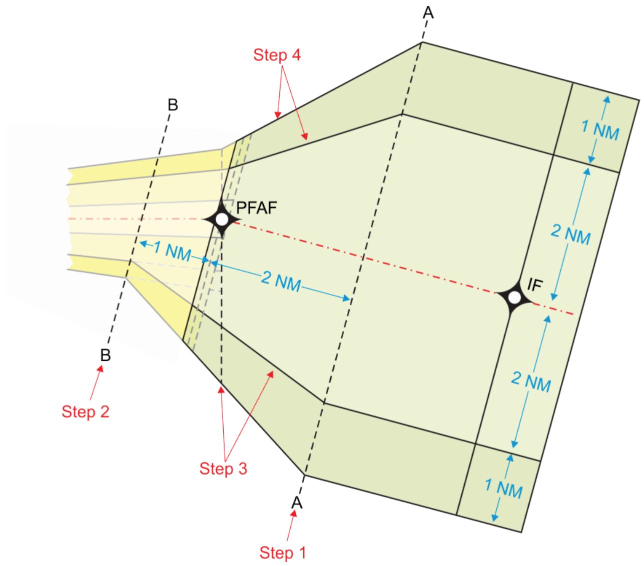


Figure 3-1-6. Offset Intermediate, Example LPV/GLS



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 flight phase [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)

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. The latest point the MAP can be located is LTP/FTP.

a. Straight-in with offset alignment. 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 and 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.

Formula 3-3-1. Offset Alignment Minimum Effective DA distance

$$d_{DAeffective} = \frac{{V_{KIAS}}^2 \times \tan(a_{offset} \times 0.5) \times 1852}{\tan(18) \times 68625.4 \times 0.3048} + d_{LTP}$$

Where:
V_{KIAS} = indicated final approach airspeed (knots) for applicable category
a_{offset} = degrees of offset between the final course and runway centerline extended
d_{LTP} = distance (feet) from LTP to the final course and runway centerline extended intersection

Example:

$$d_{DAeffective} = \frac{165^2 \times \tan(12.5 \times 0.5) \times 1852}{\tan(18) \times 68625.4 \times 0.3048} + 4300.67$$
$$d_{DAeffective} \approx 5113.16 \text{ feet}$$

3-3-3. Area. Apply paragraph 3-2-3.a.

3-3-4. Obstacle clearance surface (OCS). In the primary area, the elevation of the OCS at any point is the elevation of the OCS at the course centerline abeam it. The OCS in the secondary area is a 7:1 surface sloping upward from the edge of the primary area OCS perpendicular to the flight track [see formula 3-3-2 and figure 3-3-1]. The controlling obstacle is the obstacle that having penetrated the sloping OCS requires the highest GPA or most adverse DA or an obstacle that penetrates the level OCS that causes the most adverse DA. See latest version of FAA Order 8260.3 section 10-6 for obstacle assessment.

Formula 3-3-2. Secondary Area Adjusted Obstacle Elevation

$$O_{adjusted} = O_{MSL} - \frac{OBS_Y - {}^1\!/_2\, w_p}{7}$$

Where:
OBS_Y = perpendicular distance (feet) from the final approach centerline to the obstacle
${}^1\!/_2\, w_p$ = perpendicular distance (feet) from final approach centerline to primary area boundary

Example:

$$O_{adjusted} = O_{MSL} - \frac{OBS_Y - {}^1\!/_2\, w_p}{7}$$
$$O_{adjusted} = 3841.6 - \frac{4253.28 - 3645.67}{7}$$
$$O_{adjusted} \approx 3754.80 \text{ feet}$$

a. Sloping OCS [see Order 8260.3, paragraph 2-1-4]. The primary area OCS slope varies based on critical temperatures and designed glidepath angle.

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

Formula 3-3-6. Adjusted ACT

$$\text{ACT}_{\text{adjusted}} = \text{ISA}_{\text{airport}} + \Delta\text{ISA}_{\text{adjusted}}$$

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

Example:

$\text{ACT}_{\text{adjusted}} = 4.24 - 33.20$
$\text{ACT}_{\text{adjusted}} \approx -28.96^{\circ}$
$\text{ACT}_{\text{adjusted}} \approx -28^{\circ}$

Note 1: $\text{Critical}_{\text{Low}}$ = warmer of ACT or $\text{ACT}_{\text{adjusted}}$ rounded to the warmer whole degree.

Note 2: $\text{Critical}_{\text{High}}$ = colder of 54°C or $\text{ACT}_{\text{adjusted}}$ rounded to the colder whole degree.

Note 3: $\Delta\text{ISA}_{\text{Low}} = \text{Critical}_{\text{Low}} - \text{ISA}_{\text{airport}}$

(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

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

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:

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

Formula 3-3-8. OCS Slope

$$OCS_{slope} = \frac{1}{\tan(\theta) \times [0.928 + 0.0038 \times (Critical_{Low} - ISA_{airport})]}$$

Where:
$Critical_{Low}$ = calculated temperature (°C) that ensures no less than a 2.5° GPA
$ISA_{airport}$ = International Standard Atmosphere temperature (°C) for the airport

Example:

$$OCS_{slope} = \frac{1}{\tan(3) \times [0.928 + 0.0038 \times (-28.96 - 4.24)]}$$
$$OCS_{slope} \approx 23.80$$

Formula 3-3-9. Sloping OCS Origin

$$d_{origin} = \frac{TDZE + 250 - (LTP_{elev} + TCH)}{\tan(\theta)}$$

Example:

$$d_{origin} = \frac{5326.3 + 250 - (5321.8 + 55)}{\tan(3)}$$
$$d_{origin} \approx 3806.69 \text{ feet}$$

Formula 3-3-10. Distance from LTP that the Sloping OCS Application Begins

$$d_{OCS} = d_{origin} + r \times OCS_{slope} \times \ln\left(\frac{TDZE + 89 + r}{r + LTP_{elev}}\right)$$

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

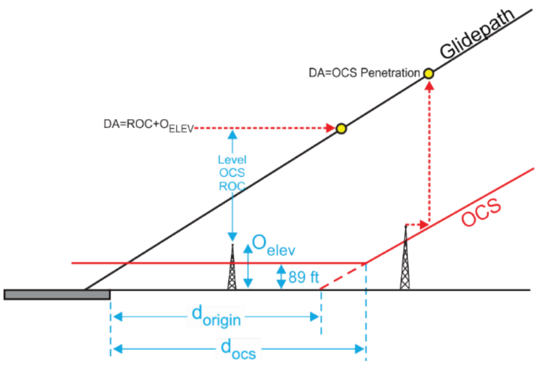
Example:

$$d_{OCS} = 3806.69 + r \times 23.80 \times \ln\left(\frac{5326.3 + 89 + r}{r + 5321.8}\right)$$
$$d_{OCS} \approx 6031.42 \text{ feet}$$

(3) Obstacle accuracies/ROC adjustments. If the controlling obstacle is within the sloping OCS area, apply the non-RNP procedure evaluation sequence based on the sloping 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.

(4) Sloping OCS DA adjustment [see figure 3-3-2]. The MSL elevation of the sloping OCS at any distance from LTP (beyond the OCS origin) is determined using formula 3-3-11. Where obstacles penetrate the OCS, determine the distance to the adjusted DA by entering the penetrating obstacle's actual or adjusted elevation [see formula 3-3-2] into formula 3-3-12.

Figure 3-3-2. LNAV/VNAV DA Adjustment



Formula 3-3-11. Sloping OCS Elevation

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

Where:
d_{LTP} = along track distance (feet) from LTP to point of interest
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$OCS_{elev} = e^{\left(\frac{19747.38 - 3911.63}{r \times 23.42}\right)} \times (r + 1125.4) - r$
$OCS_{elev} \approx 1801.61$ feet

Formula 3-3-12. Preliminary DA Distance Based on Sloping OCS Penetration

$$d_{DA} = (r + LTP_{elev}) \times OCS_{slope} \times \ln\left(\frac{r + O_{elev}}{r + LTP_{elev}}\right) + d_{origin}$$

Where:
O_{elev} = obstacle actual or $O_{adjusted}$ elevation (feet)
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$d_{DA} = (r + 1125.4) \times 23.42 \times \ln\left(\frac{r + 1263.7}{r + 1125.4}\right) + 3911.63$$

$$d_{DA} \approx 7150.61 \text{ feet}$$

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. If the controlling obstacle is within the level OCS area, apply the non-RNP procedure evaluation sequence 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 the controlling obstacle. 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:

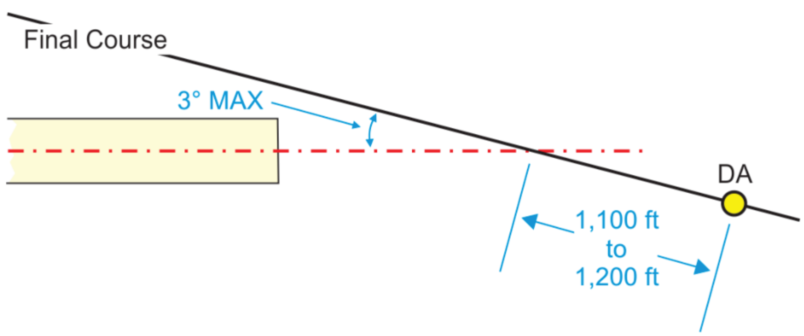
(1) The maximum GPA is 3.5 degrees for procedures with a HAT less than 250.

(2) 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) (±0.03 degrees) 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 3-4-5. OCS Angle

$$OCS_{angle} = atan\left(\frac{\theta}{102}\right)$$

Example:

$$OCS_{angle} = atan\left(\frac{3.1}{102}\right)$$
$$OCS_{angle} \approx 1.74^{\circ}$$

Formula 3-4-6. W OCS Elevation

$$OCS_{elev} = \frac{(r + LTP_{elev}) \times \cos(OCS_{angle})}{\cos\left[\frac{(d_{LTP} - d_{origin}) \times 180}{r \times \pi} + OCS_{angle}\right]} - r$$

Where:
OCS_{angle} = calculated angle of the obstacle clearance surface
d_{LTP} = along track distance (feet) from LTP to point of interest
d_{origin} = distance (feet) from LTP to OCS origin

Example:

$$OCS_{elev} = \frac{(r + 1125.4) \times \cos(1.74)}{\cos\left[\frac{(5280 - 200) \times 180}{r \times \pi} + 1.74\right]} - r$$
$$OCS_{elev} \approx 1280.35 \text{ feet}$$

(3) OCS evaluation. Compare the W OCS elevation abeam the obstacle location with the O_{EE}. Lowest minimums are achieved when the W surface is clear. See latest version of FAA Order 8260.3 section 10-6 for obstacle assessment. To eliminate or avoid a penetration, take one or more of the following actions:

(a) Remove or adjust the obstruction location and/or height.

(b) Displace the RWT.

(c) Raise GPA within the categorical limits.

(d) Adjust DA.

(e) Raise TCH.

e. X OCS.

(1) Width. The perpendicular distance from the course centerline to the outer boundary of the X OCS is 700 feet at the origin and expands uniformly to 6076 feet at a point 50200 feet from LTP/FTP. Calculate the perpendicular distance from the course centerline to the X surface boundary using formula 3-4-7.

Section 3-5. Missed Approach General

3-5-1. General. The NavSpec is RNP APCH (Missed flight phase 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 flight phase with associated XTT of 1 or 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, except for A-RNP. 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 and precipitous terrain adjustments from the lowest final segment MDA/DA (rounded to a publishable value).

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 a turning missed approach is based on a “climb-to” altitude before turning, the coded CA altitude is the charted “climb-to” altitude. The lowest permissible climb-to altitude is 400 feet above airport elevation plus any final precipitous terrain and primary RASS adjustments.

(1) A climb-to altitude is required for non-LPV/GLS procedures when the first fix after the coded MAP is not within one degree of the FAC extended and the lowest base MDA/DA is less than 400 feet above airport elevation.

(2) A climb-to altitude is required for LPV/GLS procedures when the first fix after the coded MAP is not within one degree of the FAC extended. Additionally, the climb-to altitude must not be less than the highest Section 2 start altitude [see paragraph 3-7-1.b(2)].

b. When a charted climb-to altitude is not required by the preceding paragraph, the coded CA altitude is the DA, MDA, or 400 feet above the airport elevation, whichever is lowest.

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

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

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

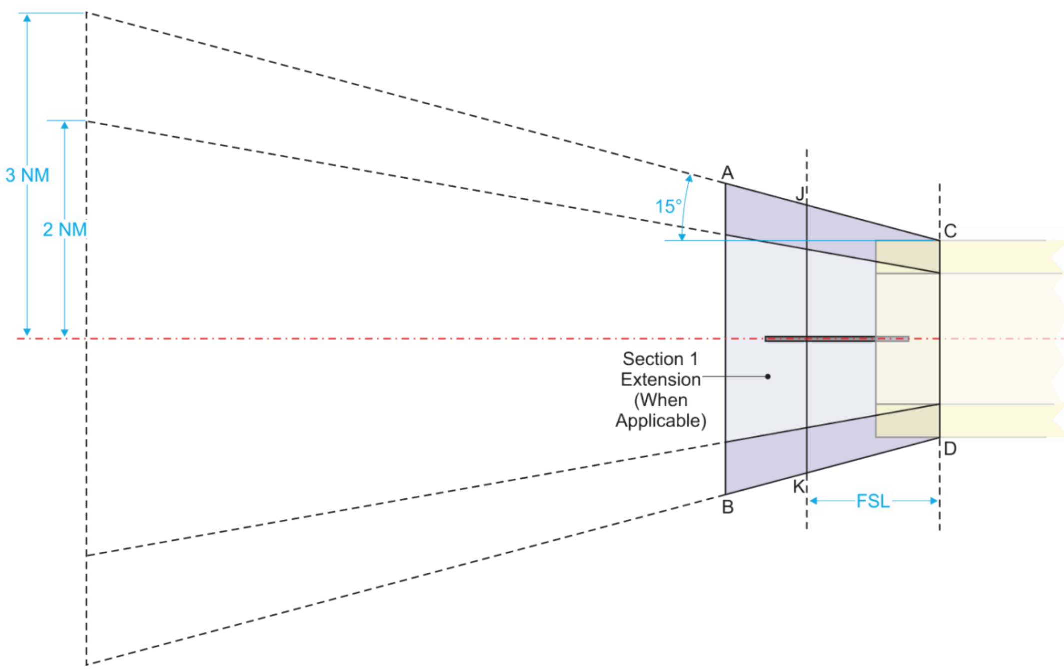
Example:

$$CG_{term} = 48 \times 3.95 + 2147.41 - \frac{537.41}{12} + 1442 - 1217.21$$
$CG_{term} \approx 2517.02$ 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

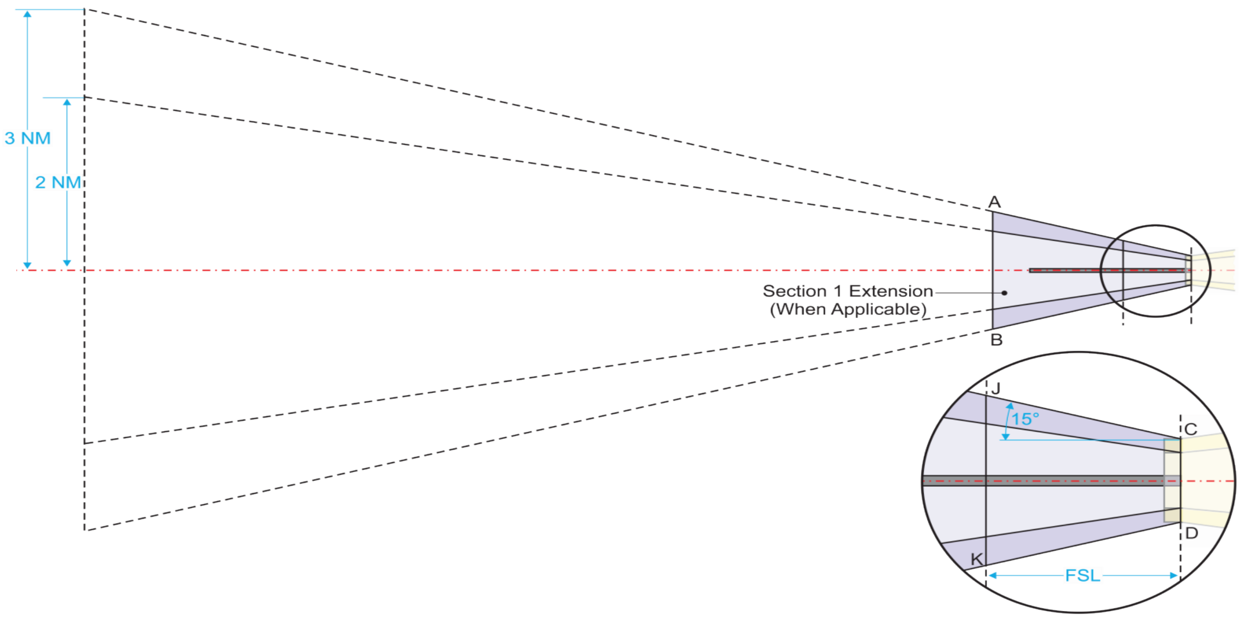
$$FSL = \frac{(V_{KTAS} + 10) \times 12}{3600} + 2 \times ATT_{NM}$$

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

Example:

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

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:

$$S1_{extension} = \ln\left(\frac{r + 2900 + 400}{r + 3205}\right) \times \frac{r}{315}$$
$$S1_{extension} \approx 0.30 \text{ NM}$$

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:

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

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

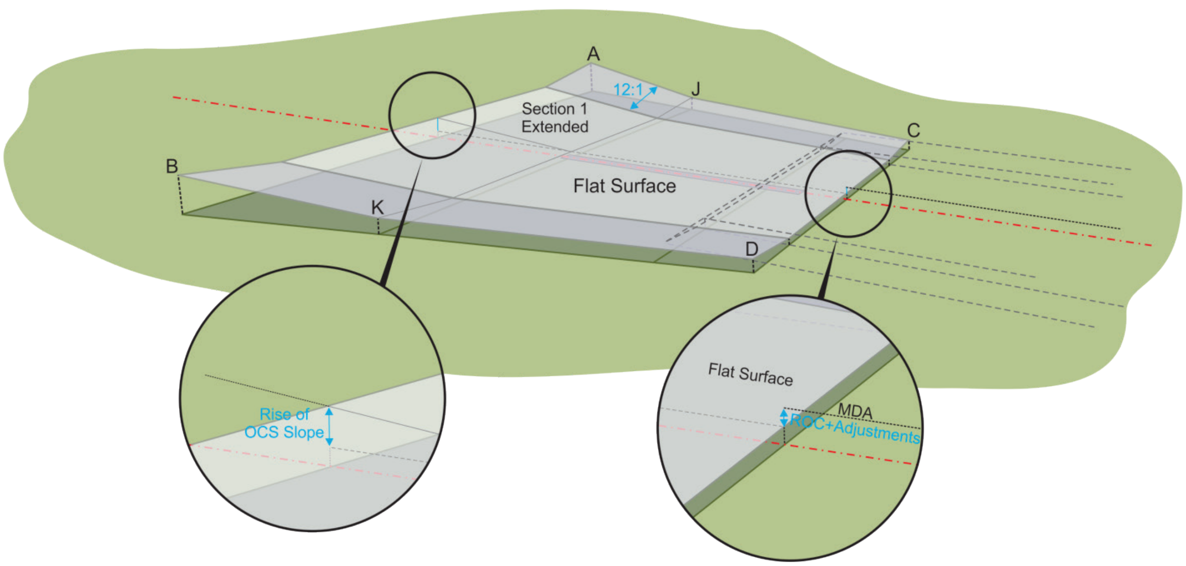
c. Obstacle clearance. Section 1 OCS consists of a flat surface and sloping surface extension [see figure 3-6-3]. The MSL height at the start of the missed approach surface (HMAS) is equal to the base MDA less 100 feet, and excessive length of final adjustments. When obstacles are mitigated by one of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

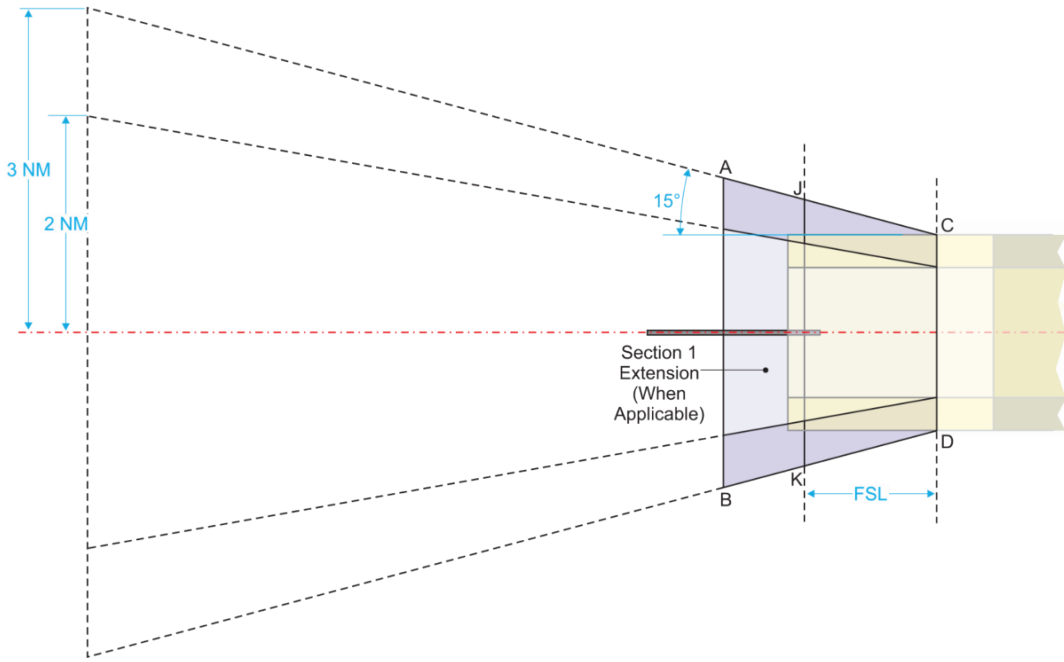
Figure 3-6-3. LNAV Missed Approach Section 1 OCS



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

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

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

Example:

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

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

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

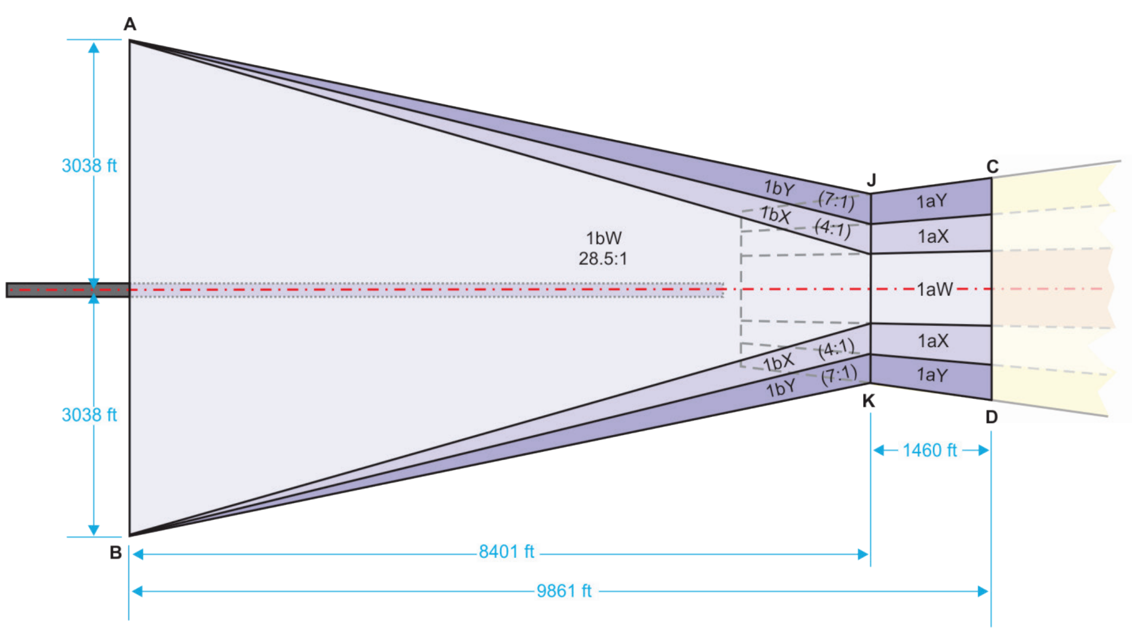
Where:
p = penetration (feet) of the MA OCS
MA_{slope} = missed approach OCS slope ratio

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:

$$\Delta d_{DA} = \frac{18.88 \times 28.5 \times 34}{28.5 + 34}$$

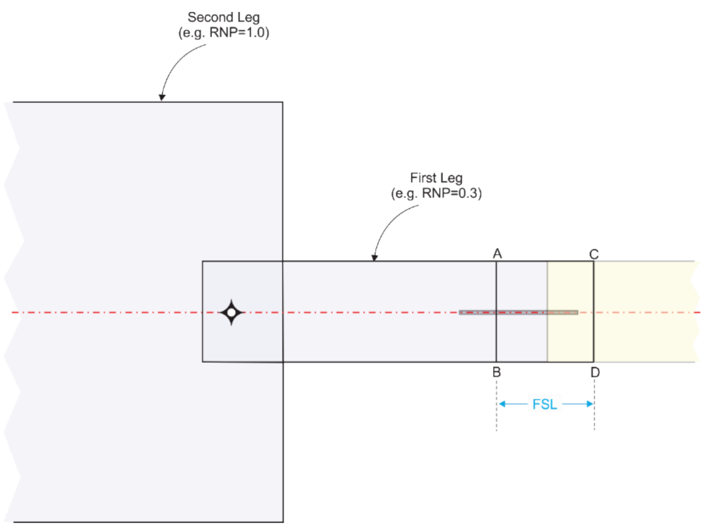
$\Delta d_{DA} \approx 292.72$ feet

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.

(1) Non-LPV/GLS. When line J-K and line A-B are not coincident, the section 2 start altitude is airport elevation + 400 feet + adjustments (final precipitous terrain and RASS).

(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:

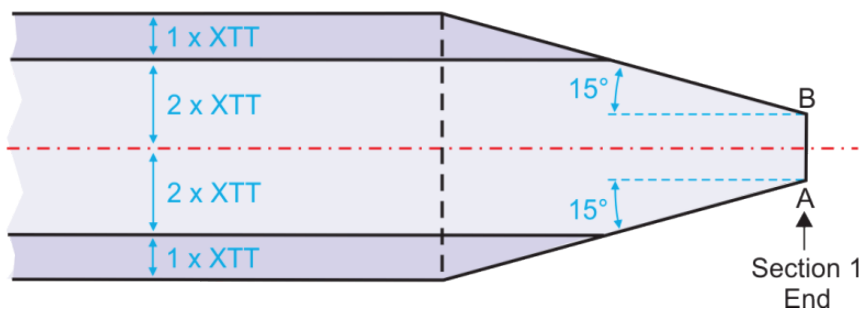
$$\text{Section 2 start altitude} = 1225 - \tan(3.1) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

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

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 or as soon as practicable. Order 8260.19, chapter 8 paragraph "Missed approach instructions" applies except as modified by paragraph 3-5-2. 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)

$$\mathrm{TIA_{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt_b}} + \mathrm{D_{climb_i}} + \mathrm{D_{climb_{ii}}}$$

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

Example:

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

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

$$\mathrm{TIA_{length}} = \frac{\mathrm{FSL} \times \mathrm{r}}{\mathrm{r} + \mathrm{alt_b}} + \mathrm{D_{climb}}$$

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

Example:

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

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)

$$\text{TIA}_{\text{length}} = \frac{9861 \times 0.3048}{1852} + \text{D}_{\text{climb}}$$

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

Example:

$$\text{TIA}_{\text{length}} = \frac{9861 \times 0.3048}{1852} + 6.01$$
$$\text{TIA}_{\text{length}} \approx 7.63 \text{ NM}$$

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

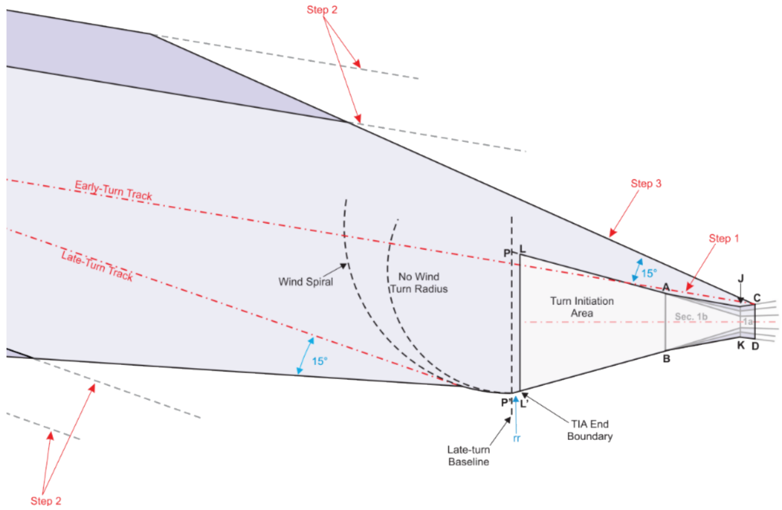
Turn Angle (measured from FAC/line C-D intersection)	Tie-Back Point
≤ 75 degrees	Point C
> 75 degrees	Point D
> 165 degrees	Point P'

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 PI	Greater of ½ Turn-angle or Inbound leg Splay	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track
Point SI	Greater of ½ Turn-angle or Inbound leg Splay	15 degrees relative outbound track	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: PI and SI Collocated and External to Outbound Primary and Secondary

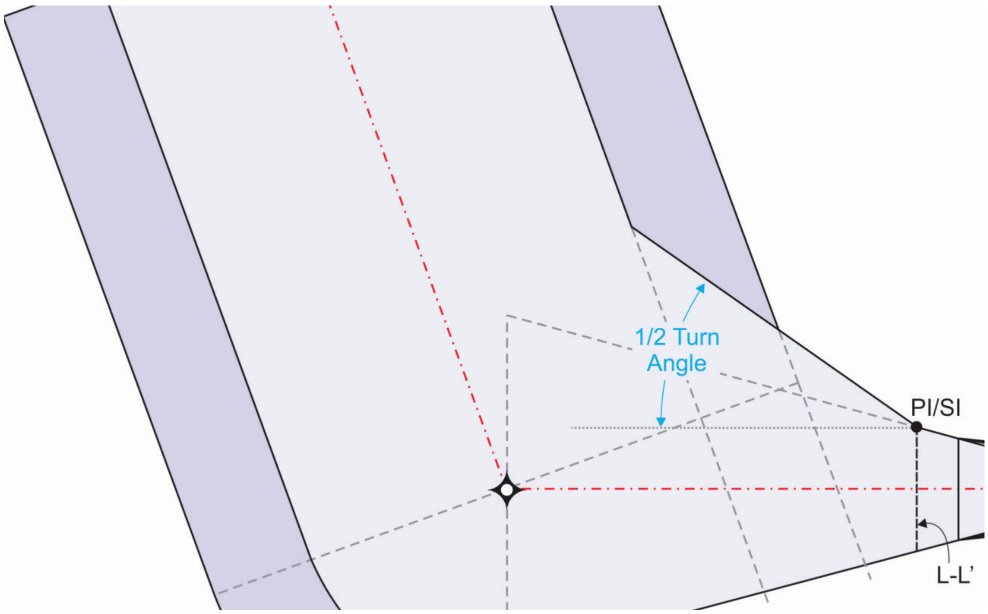
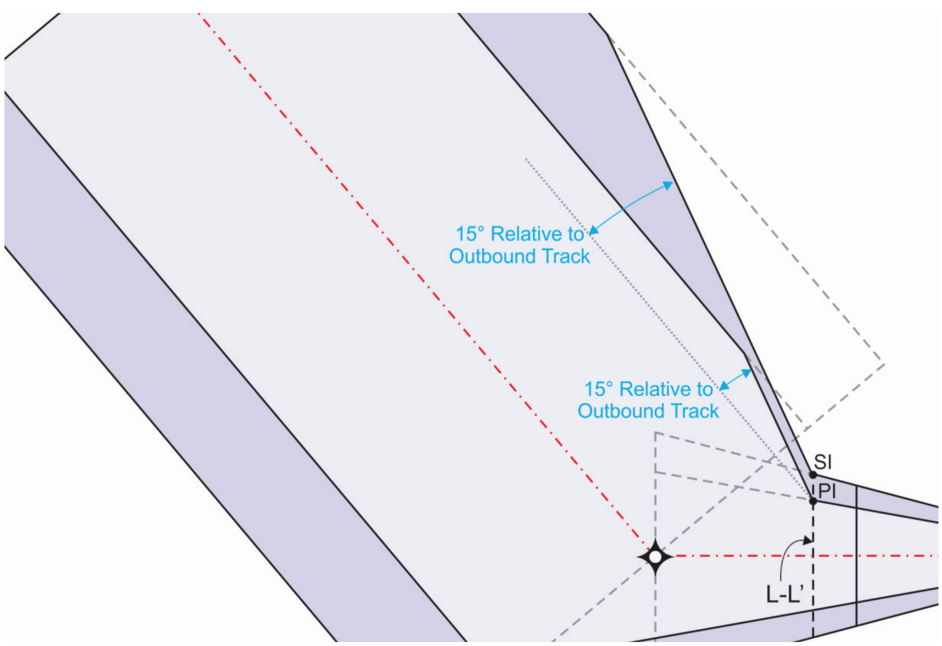


Figure 3-7-5. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Internal to Outbound Primary



Chapter 4. RNAV (RNP) Approach

Section 4-1. General Criteria

4-1-1. Concept and design. This chapter applies to procedures covered by the RNP AR APCH NavSpec. 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 (as appropriate);

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

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

3. 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 1-1-1.a(1)(a) or 1-1-1.a(1)(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 may be RNAV 1 (STAR/Feeder/Arrival flight phase with associated XTT of 1). When RF is used, the NavSpec is RNP 1 (STAR/Feeder/Arrival flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (STAR/Feeder/Arrival flight phase with associated XTT of 2 or 1 as appropriate). Use an effective XTT of 2 where applicable per table 1-2-1 footnote 2. Secondary areas apply, except for A-RNP.

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 flight phase with associated XTT of 1 – 0.1). 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 flight phase with associated XTT of 1 – 0.1). 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/GLS/LPV.

Section 4-2. Final Approach Segment (FAS)

4-2-1. General. The NavSpec is RNP AR APCH (Final flight phase with associated XTT of 0.3 – 0.1). Secondary areas do not apply. RNP AR APCH ops are 3D procedures in which the aircraft provides the pilot with lateral and vertical path guidance and deviation information throughout the procedure. During the FAS, the aircraft provides either baroVNAV vertical guidance or SBAS LPV lateral and vertical guidance. 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:

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

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 0.5 NM prior to the DA point. 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

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

d_{FROP} = greater of d_{500} or *0.5 NM*

Example:

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

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

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

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].

Section 4-3. Missed Approach Segment (MAS)

4-3-1. General. The NavSpec is RNP AR APCH (Missed flight phase with associated XTT of 1 – 0.1). Secondary areas do not apply. Optional NavSpec may be RNAV 1 or A-RNP (Missed flight phase with associated XTT of 1 or 0.3) with secondary areas (except for A-RNP). 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 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.

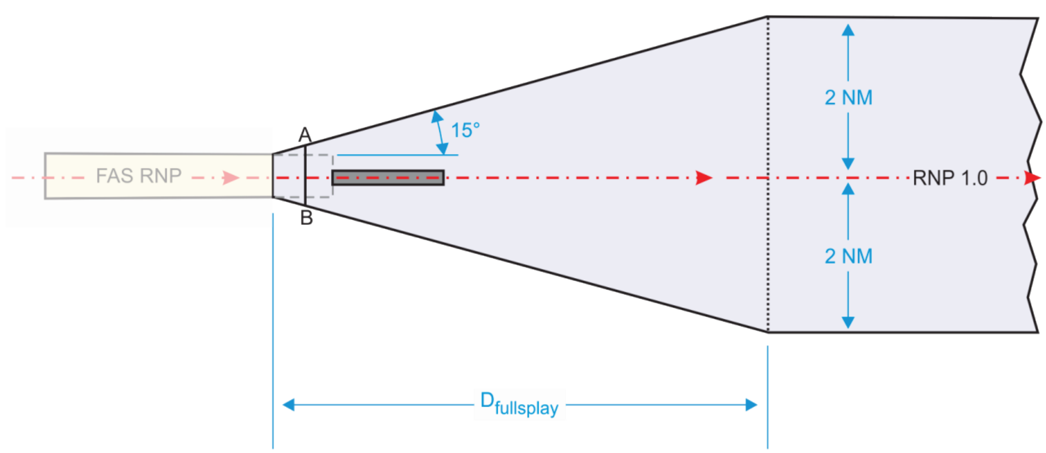
(2) RNAV MAS (RNAV 1 Missed flight phase). Use where operationally beneficial (i.e., turn-at-altitude construction to allow a turn earlier than permitted by default MAS construction).

(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 Flight Standards 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

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

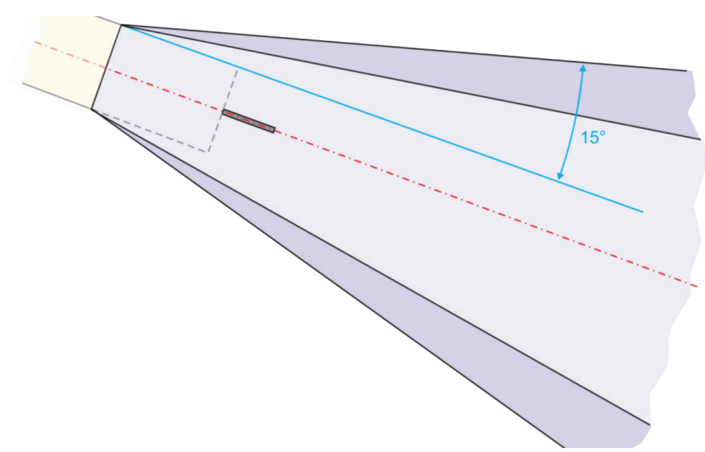
Where:
D_{splay} = along-track distance (NM) from beginning of MAS splay to point of interest
RNP_{FAS} = RNP value (NM) of the final segment

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



Chapter 5. Departure Procedures

Section 5-1. General Criteria

5-1-1. General. The NavSpec is RNAV 1 or RNP 1 (Departure flight phase with associated XTT of 1). Optional NavSpec may be A-RNP (Departure flight phase with associated XTT of 1 or 0.3) or RNP AR DP (Departure flight phase with associated XTT of 1 - 0.3). Use of A-RNP departure XTT less than 1 requires Flight Standards approval. RNP AR DPs are established using TF and/or RF legs. Secondary areas apply, except for RNP AR DP and A-RNP.

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.

(3) An RNP AR departure with an RF turn at DER has no ICA. The OEA is constructed using a 15-degree splay relative to RF track originating form +/- 500 feet either side of DER (ICAB) [see figure 5-3-8].

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. Only use a higher than standard CG for LNAV engagement when there is an operational need to bring the first turn closer to DER.

(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 or RNP AR DP 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

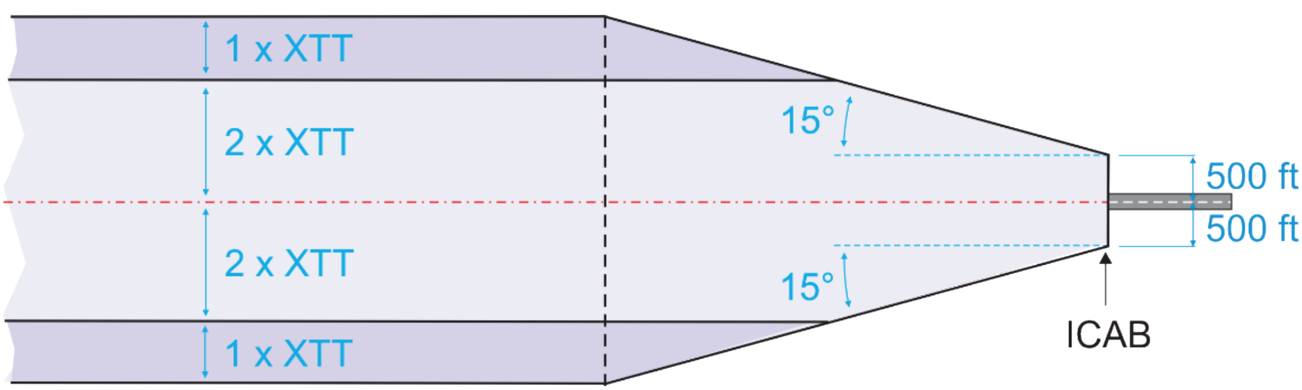


Figure 5-2-2. Straight Departure with 30-Degree Inward Taper

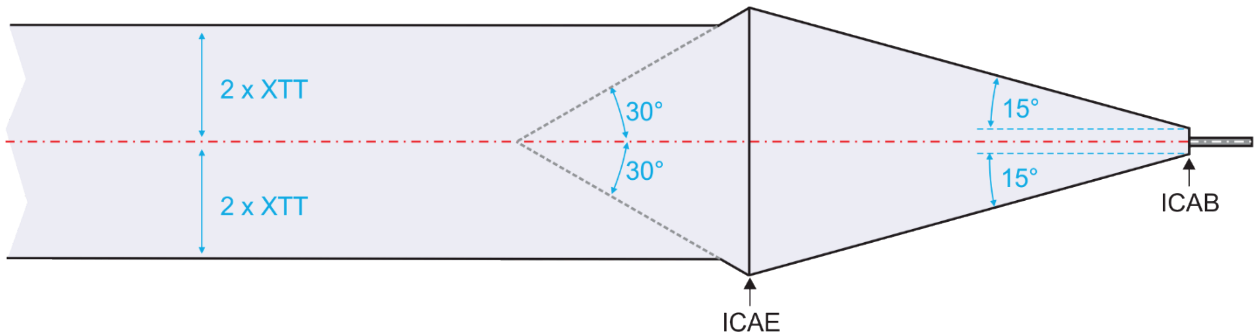
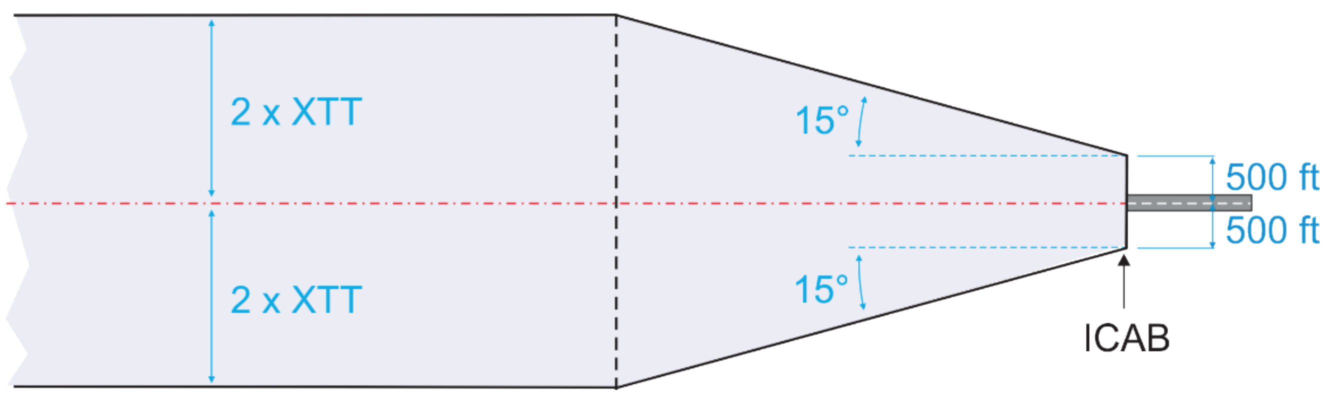


Figure 5-2-3. Straight RNP AR DP



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].

Figure 5-3-1. VA-DF Early/Inside Turn Construction after ICA

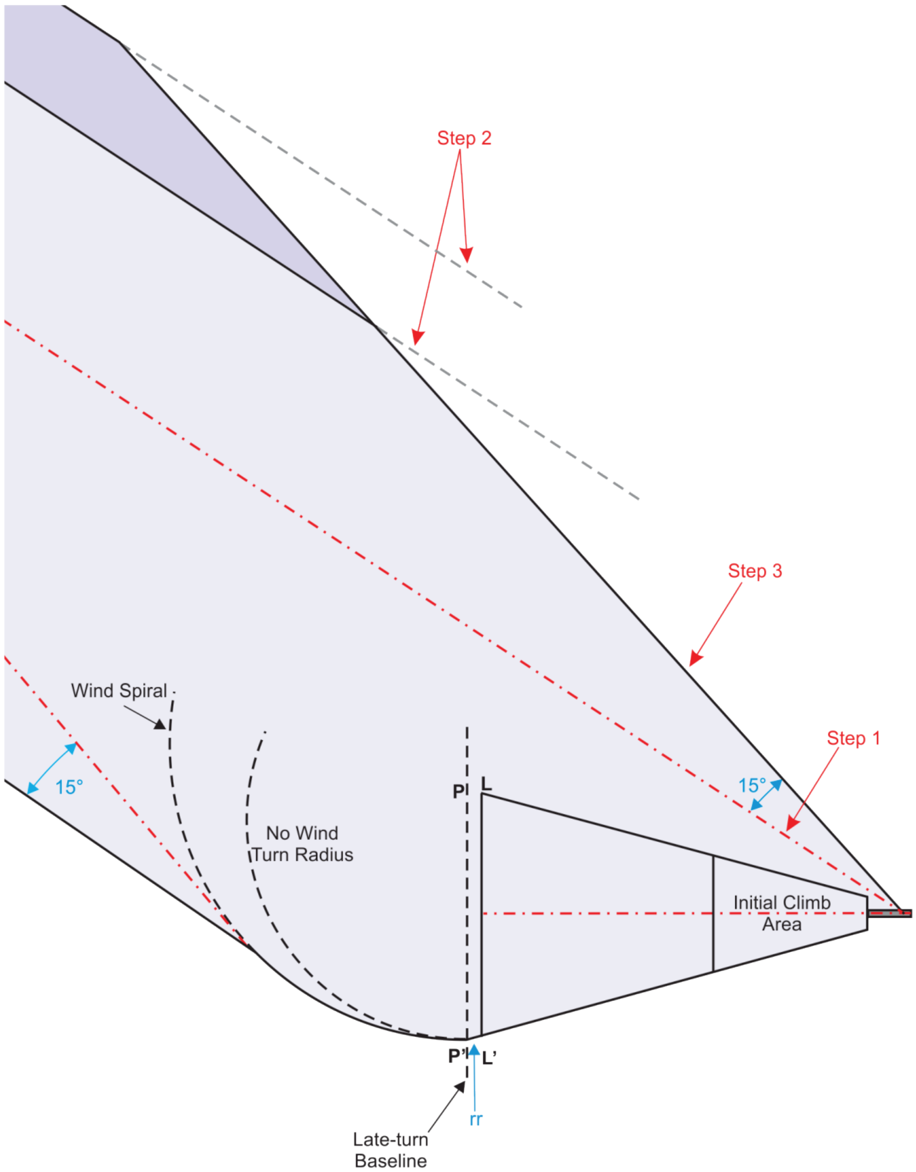
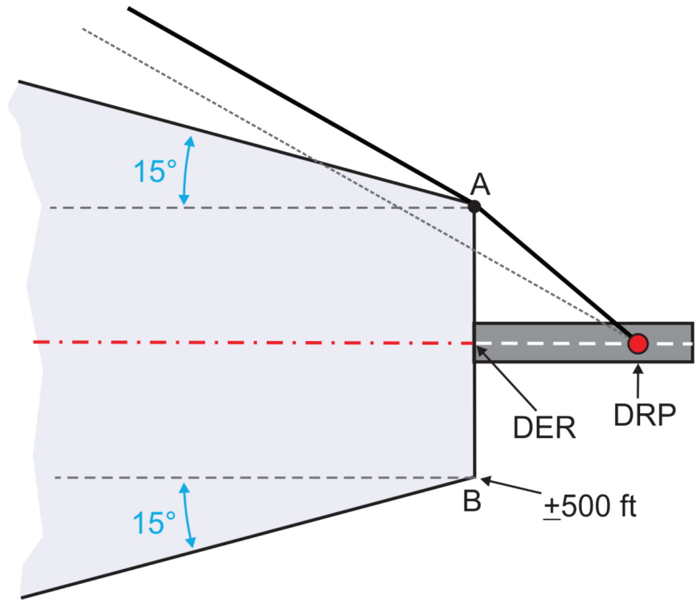


Figure 5-3-2. VA Leg Construction Alternate Inside Boundary



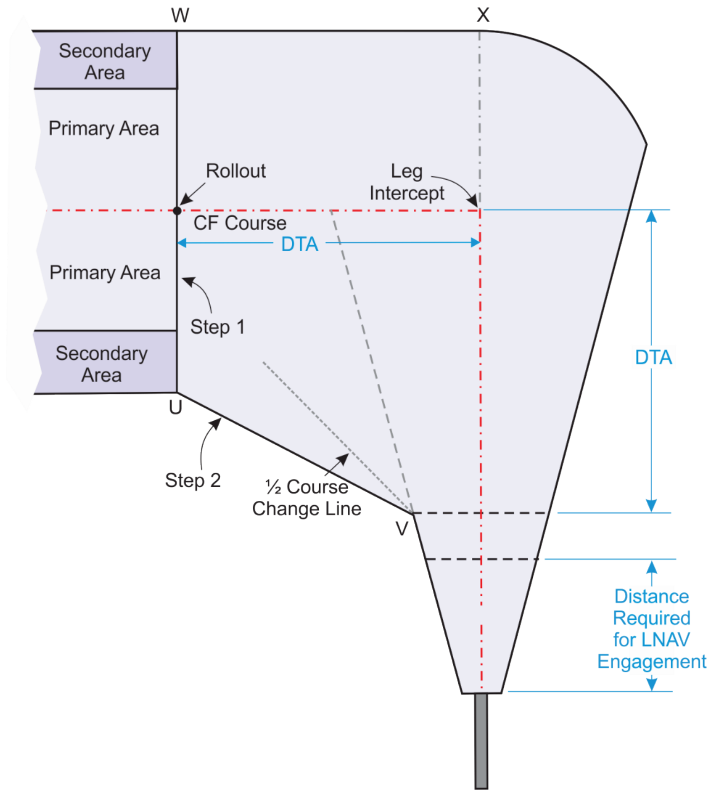
(b) Turn following VI leg. The VI leg contains an ICA constructed in accordance with paragraph 5-1-1.a terminating where LNAV engagement is reached (500 feet above airport elevation). The VI leg OEA is all primary area; secondary area may be applied in the CF leg at the rollout point.

1. OEA construction. Inside expansion starts where the VI DTA area begins (point V) with an angle drawn at one-half of the course change at leg intercept and ends where the angle converges with CF leg secondary boundary. Where the angle does not converge with secondary boundary, draw a line from point V to the inside secondary area boundary abeam the rollout (point U) for area completion [see figure 5-3-3].

a *Step 1.* Along the CF leg course, construct a line perpendicular to the CF leg at a distance from the intercept point equal to the calculated DTA based on the altitude at leg intercept. At the rollout point, the CF leg OEA is the full combined width of the primary and secondary areas.

b *Step 2.* Construct a line (representing the early-turn flight track) from the VI DTA (point V), to the CF leg full width abeam the rollout point.

Figure 5-3-3. Standard VI-CF Construction, 90-degree Turn



2. Minimum VI-CF leg combination construction. Where a short initial departure leg must be developed, the VI leg length may be designed to the greater of 1 NM from DER or the distance required to climb 500 feet above airport elevation. For this early turn, the OEA is modified to be somewhat like a FB fix turn for inside expansion and additional protection is also provided for outside area expansion built similarly to a FO fix turn.

a For turns of 30 degrees or less, splay 15 degrees relative to the CF leg course from point ICAB and continue this line until intersecting the CF leg secondary area boundary [see figure 5-3-4]. The secondary area begins where this line crosses the primary area boundary.

b For turns of more than 30 degrees, the inside boundary is from the DRP to the inside secondary area boundary abeam the rollout (point R). From point R, the secondary area tapers 30 degrees inward relative to the CF leg course until the CF leg standard primary area boundary [see figure 5-3-5 thru figure 5-3-7].

c CF leg construction. Along the CF leg course, a rollout point is established from leg intercept at a distance of the calculated DTA, based on the altitude at leg intercept. Establish a full primary and secondary width OEA at the rollout point; the area may or may not be fully utilized based upon the leg intercept turn.

Figure 5-3-4. Minimum VI-CF Construction, Turn 30 Degrees or Less

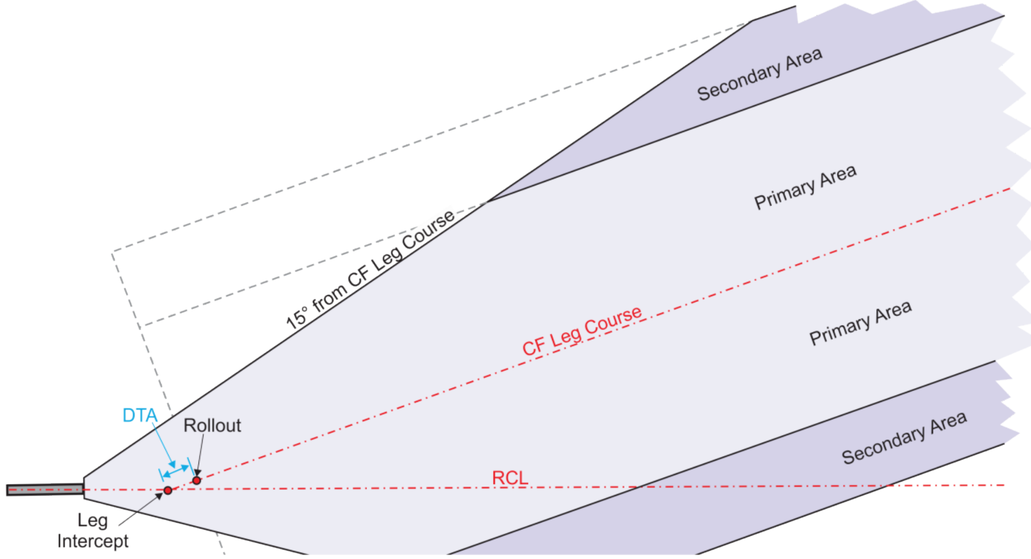


Figure 5-3-5 Minimum VI-CF Construction, Greater than 30-degree Turn

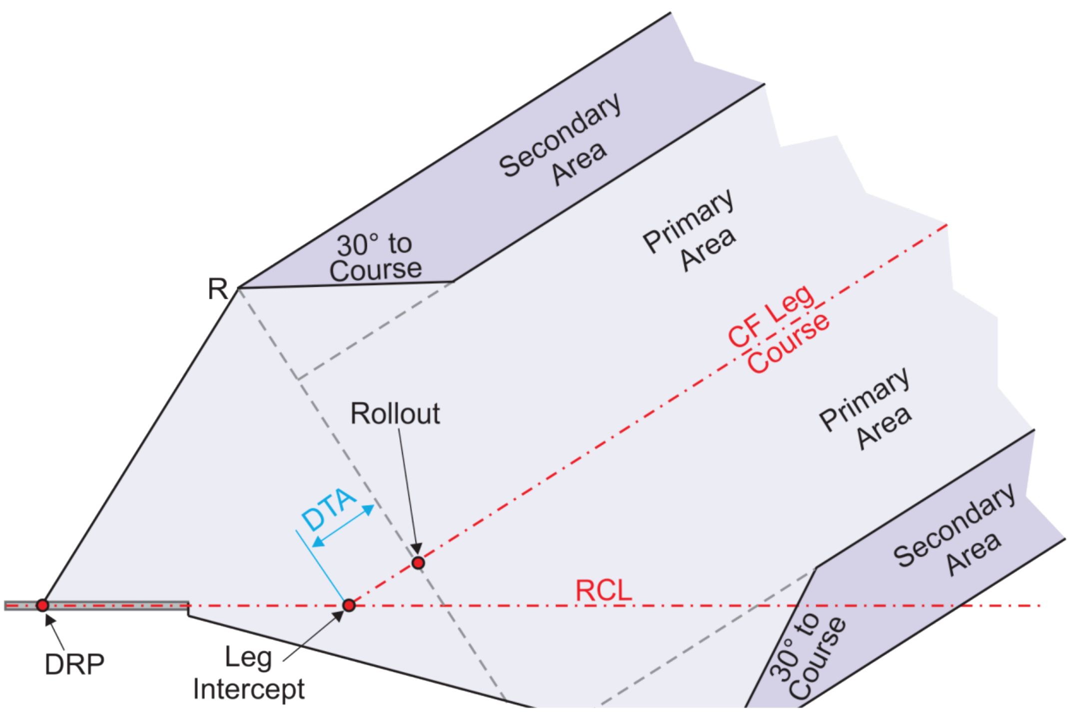


Figure 5-3-6. Minimum VI-CF Construction, 75-degree Turn

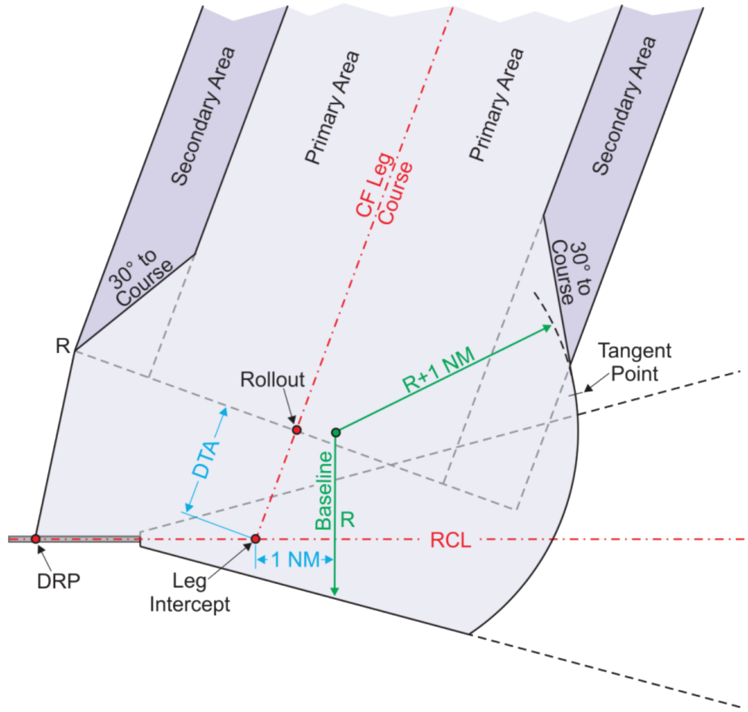
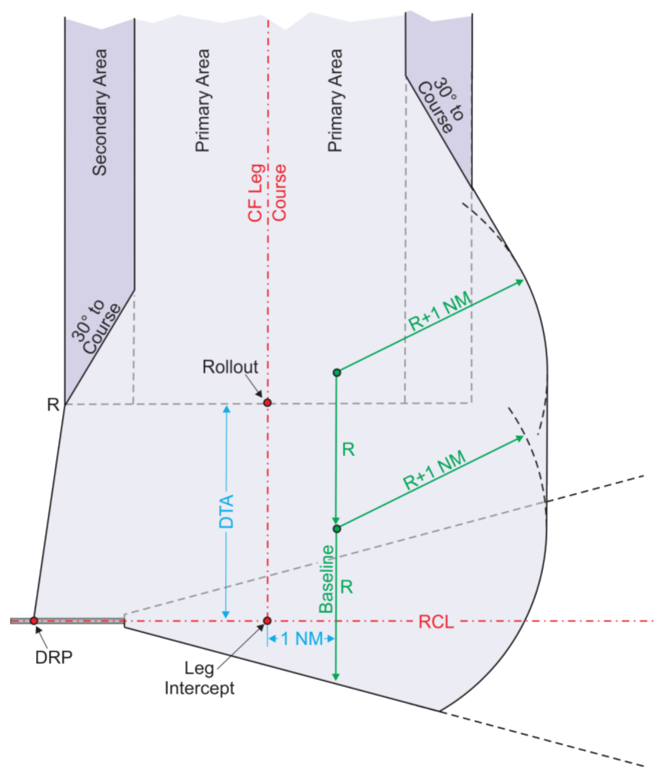


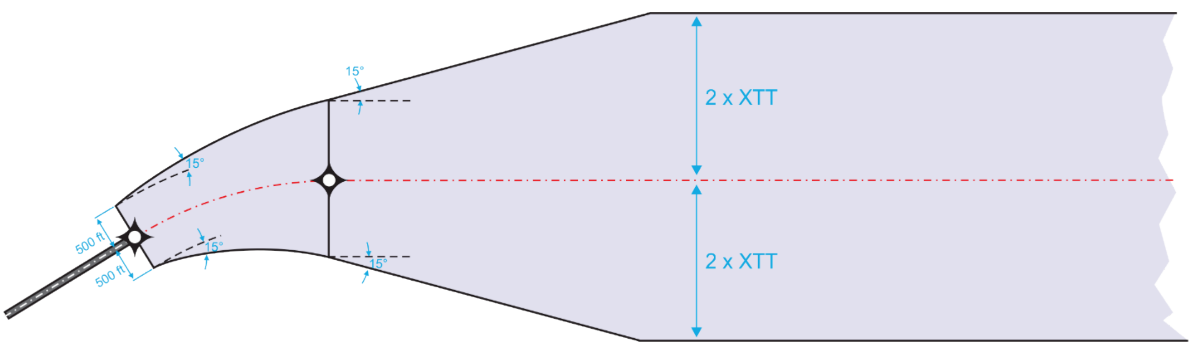
Figure 5-3-7. Minimum VI-CF Construction, 90-degree Turn



(c) Turn-at-fix (FO or FB). 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. If an A-RNP or RNP AR DP value is selected that results in an OEA narrower at an RF start point than the ending ICA width, taper inward at 30 degrees relative to course to join edge of primary area. Otherwise, construct as follows:

1. Fix location. The first turn fix must be located on the runway centerline extended (or course line for paragraph 5-2-1.a construction). The distance to the turn fix must be sufficient to result in an early turn baseline at or beyond LNAV engagement (500 feet above airport elevation). Where the first fix must be located at the point the aircraft reaches or exceeds a specific altitude, calculate fix distance from DER with formula 1-3-9 using the standard or assigned CG. If a fix is already established, project the aircraft altitude at the fix in accordance with chapter 1. For RNP-1 or A-RNP departures, an RF start point may be located no closer to DER than the greater of 1NM or LNAV engagement (500 feet above airport elevation). For RNP AR departure procedures, an RF start point may be located up to and including at the DER. If the RF start point is at DER or less than 1 NM from DER, chart restrictions to cross DER at or above 500 feet above airport elevation and a max airspeed of 210 KIAS at/until the RF start waypoint. If the RF start point is not at DER but is less than 1 NM from DER, publish a waypoint at DER (may be opposite end threshold if the coordinates are the same) this is to provide reference for the 500-ft crossing restriction. The RF must be tangent to the runway centerline (extended).

Figure 5-3-8. RF at DER



2. Early turn baseline (line L – L'). The early turn baseline is established perpendicular to the inbound leg at the appropriate table 5-3-2 distance prior to the fix. For RF turn construction, ATT need not be applied until sufficient distance from DER for OEA to reach full width.

Table 5-3-2. Early Turn Baseline Distance Prior to 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 expansion. 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 5-3-3]. 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 primary expansion line would result in a smaller primary area, continue the inbound leg splay until full primary width is reached or until intersecting the angle bisector line whichever occurs first, then splay per table 5-3-3. For RF legs, splay 15 degrees relative to RF path beginning at points PI and SI on an early turn baseline L-L' abeam the RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction then connect points PI and SI on an early turn baseline L-L' abeam the RF start point to the outbound leg OEA boundary lines perpendicular to the RF end point [see figure 5-3-12].

Table 5-3-3. Standard 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	
Point PI	Greater of ½ Turn-angle or Inbound leg Splay		15-degrees relative outbound track

5. Construction steps.

a *Step 1.* Construct line L-L' at the appropriate table 5-3-2 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 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 5-3-9. Early/Inside Turn, First Turn, Turn at Fix: PI and SI Collocated and External to Outbound Primary and Secondary

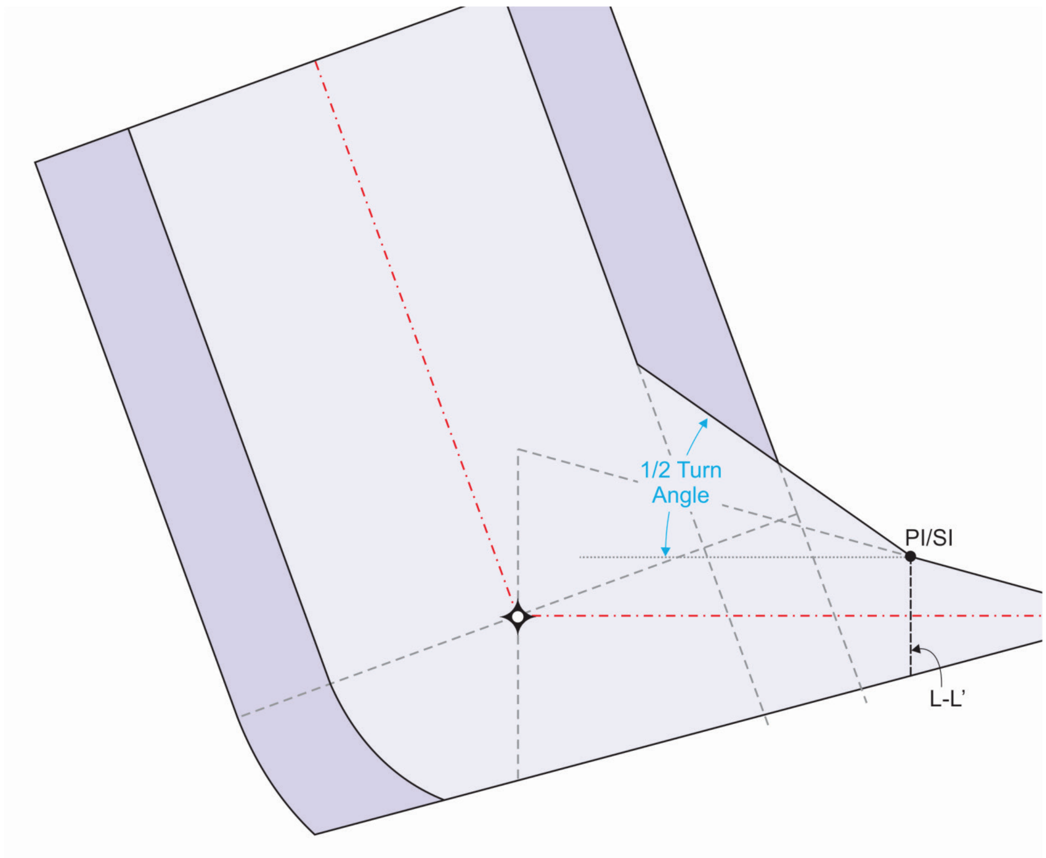


Figure 5-3-10. Early/Inside Turn, First Turn,
Turn at Fix: PI and SI Internal to Outbound Primary

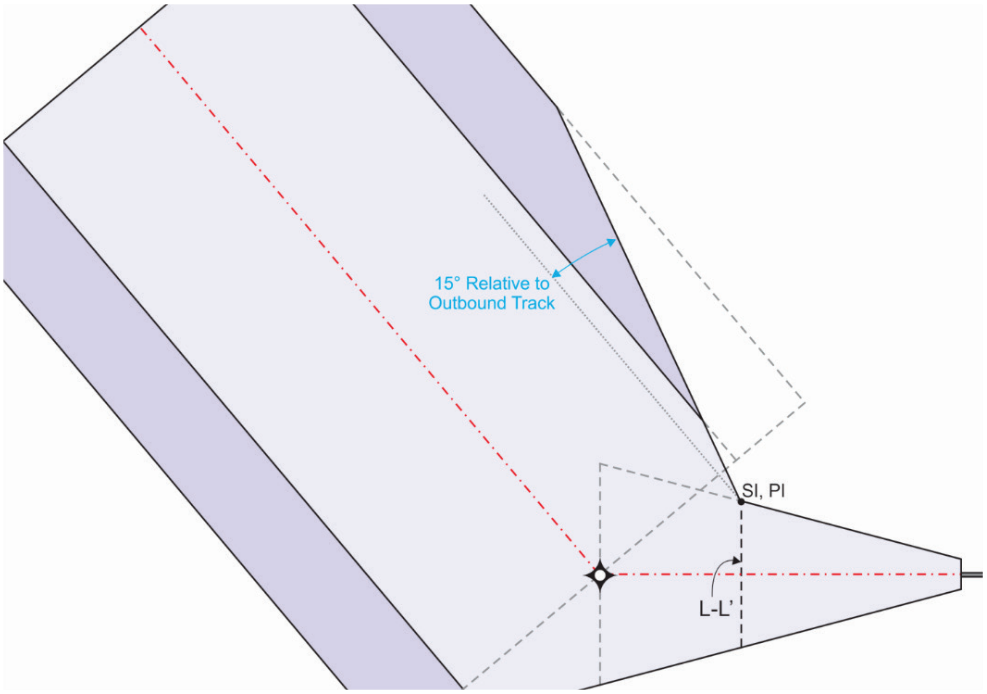


Figure 5-3-11. Early/Inside Turn, First Turn, Turn at Fix:
PI and SI Internal to Outbound Secondary, Splay from Point SI'

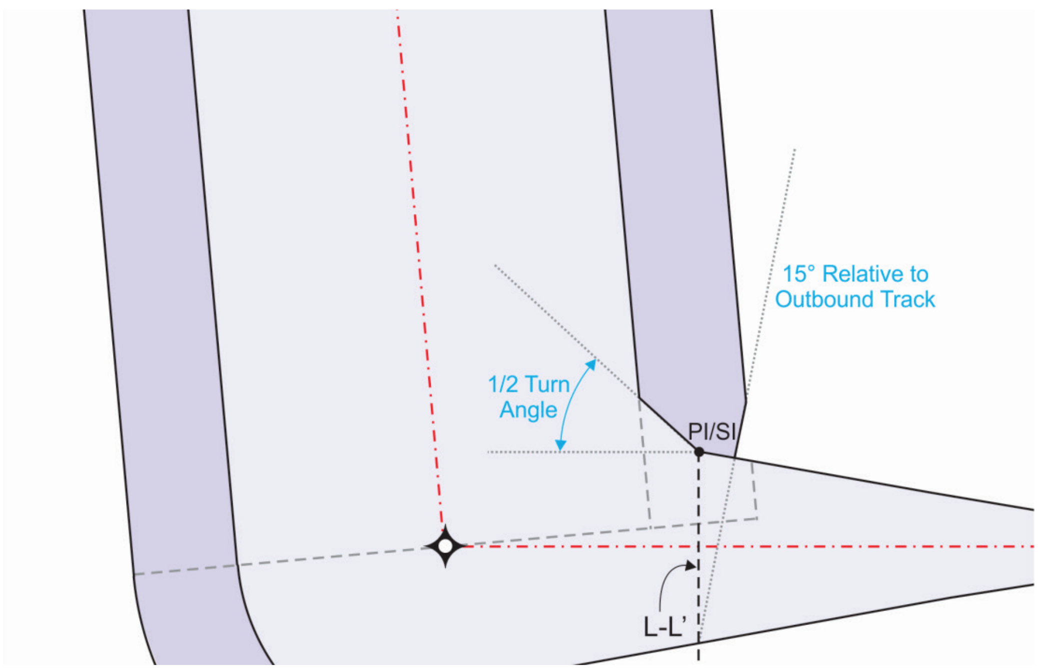


Figure 5-3-12 First Turn, Turn at Fix:
PI and SI Connecting to Abeam RF End Point

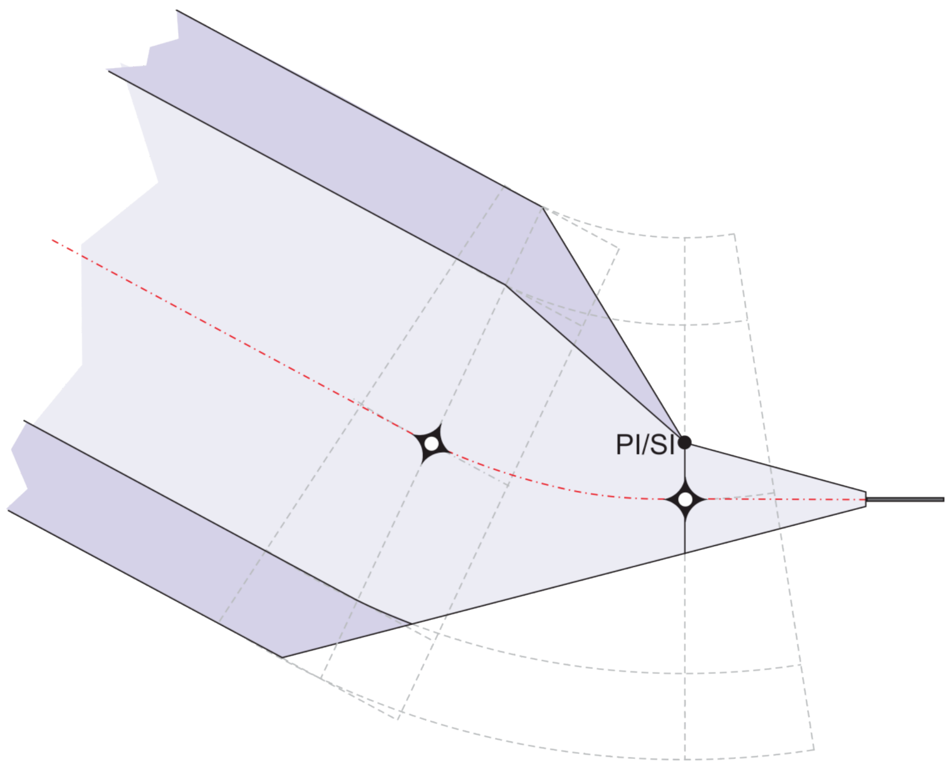
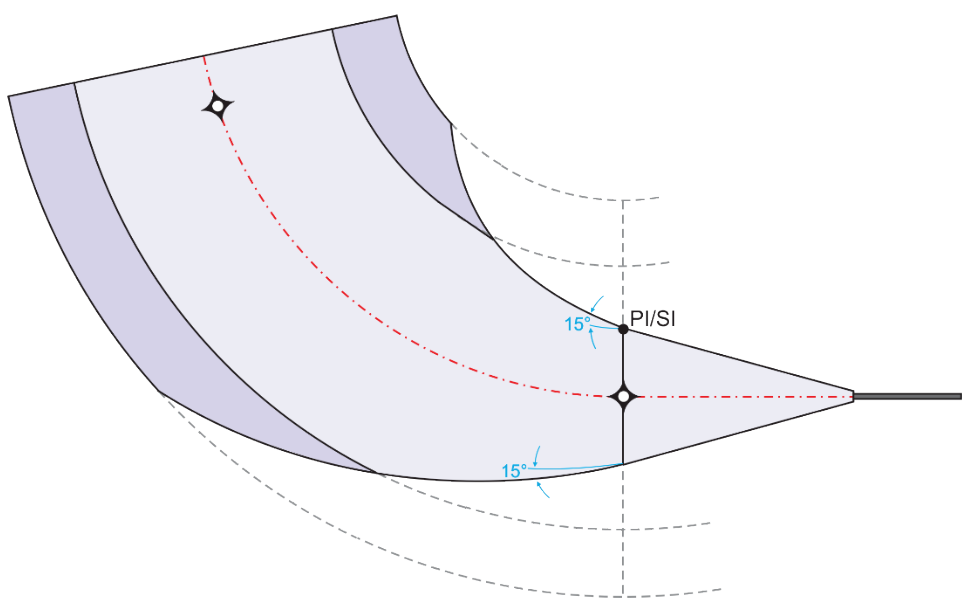


Figure 5-3-13 First Turn, Turn at Fix, RF



(2) Second turn. The second turn is specified at either a FB or FO fix.

(a) DF-TF or CF-TF.

1. Construct in accordance with paragraph 1-1-1.a(1)(c) with the following exceptions:

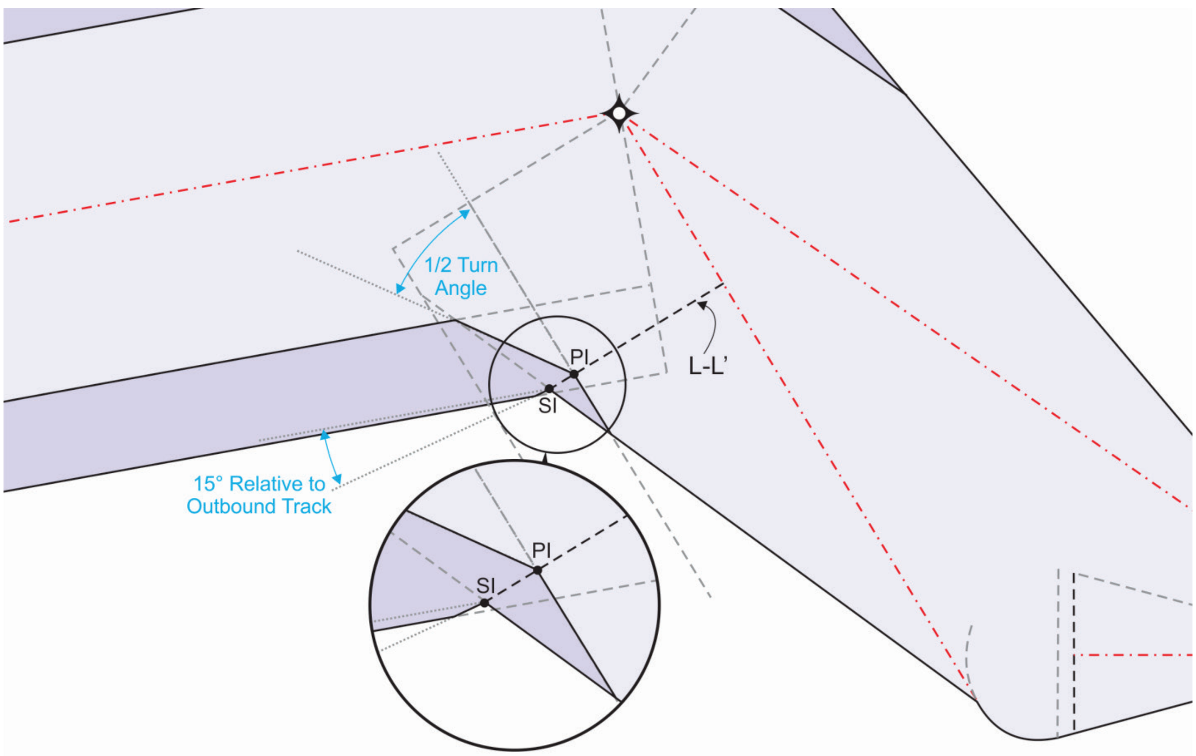
a Paragraph 5-3-1.a(1)1 does not apply.

b For DF-TF, 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.

(b) Other connections. Construct in accordance with paragraph 1-2-5.

Figure 5-3-14. 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). 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 5-3-4].

Table 5-3-4. 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 (Line P-P’) from turn fix/point	ATT + D_{rr}	ICA + D_{rr}
WS3 Baseline	ATT (early) for FO DF, otherwise not applicable	Parallel to DRL

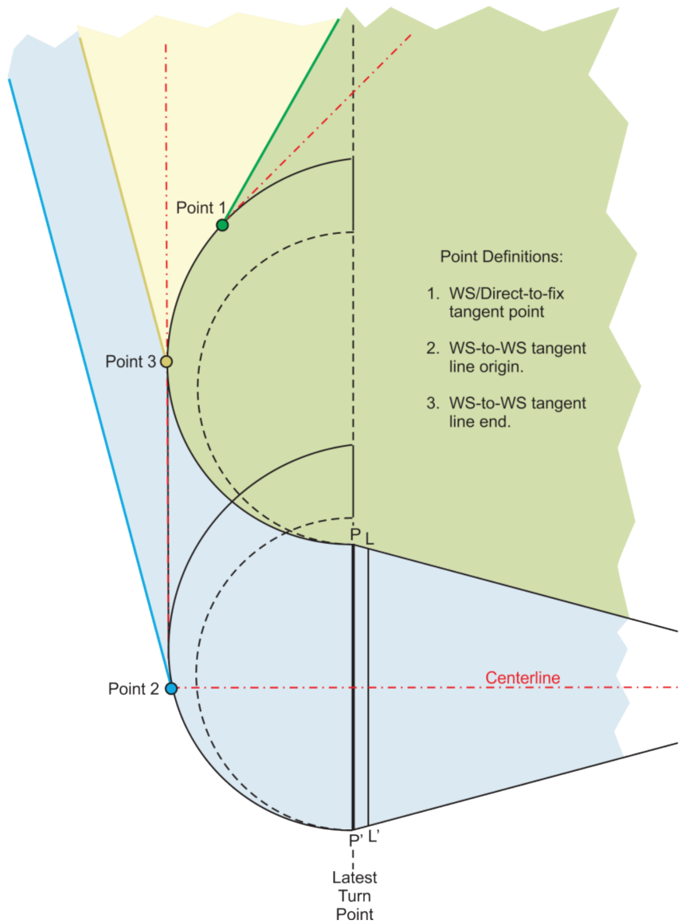
1. First turn baseline. For first turn construction, the late-turn baseline (line P-P’) marks the construction line for wind spirals. Line P-P’ is located at the table 5-3-4 distance with points P and P’ placed at the continuation of the inbound leg’s outer boundary [see paragraph 1-3-1.g(4)]. The no-wind 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 DRL with the no-wind turn radius measured inward from DRP, for DF-DF baseline will be line L-L’.

2. Second turn baseline [see figure 5-3-22]. To accommodate the two inbound tracks in the DF leg, the second 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 5-3-4 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 perpendicular to the inside track inward along the baseline from point P.

(b) WS connection point and outside turn OEA boundary. 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.

1. Turn-at-altitude. For turns at an 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.

Figure 5-3-15. WS Connection Points, Turn-at-Altitude



2. Turn-at-fix (FO). 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. 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.

Figure 5-3-16. Late/Outside Turn, Wind Spiral, WS Not Contained in Outbound OEA

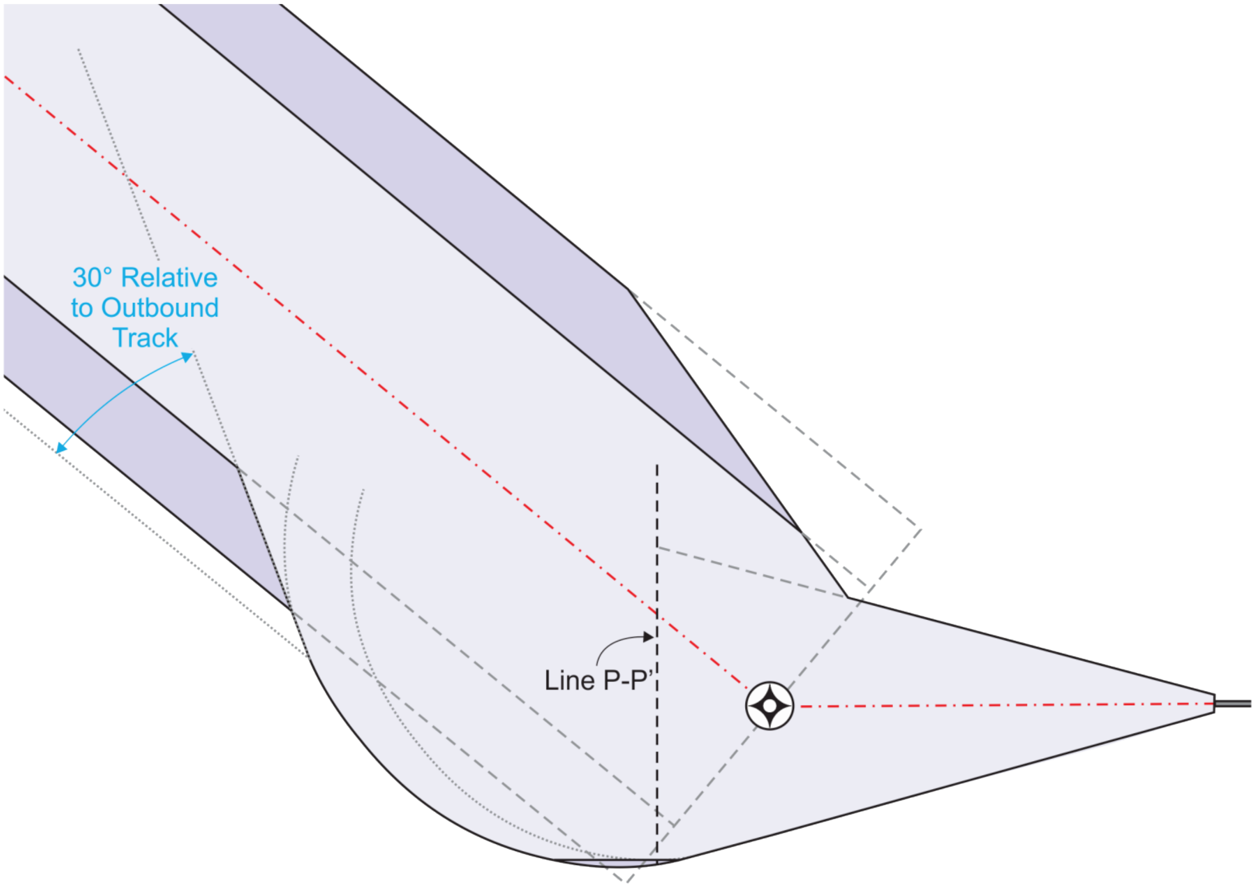
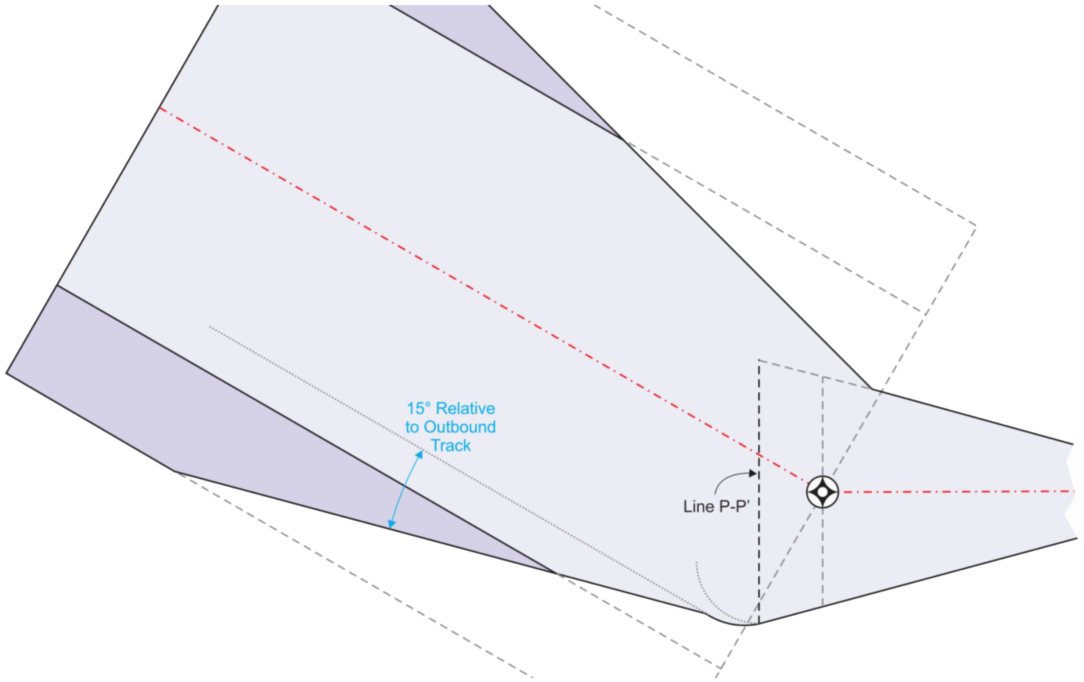


Figure 5-3-17. Late/Outside Turn, Wind Spiral, WS Contained in Outbound OEA



(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.

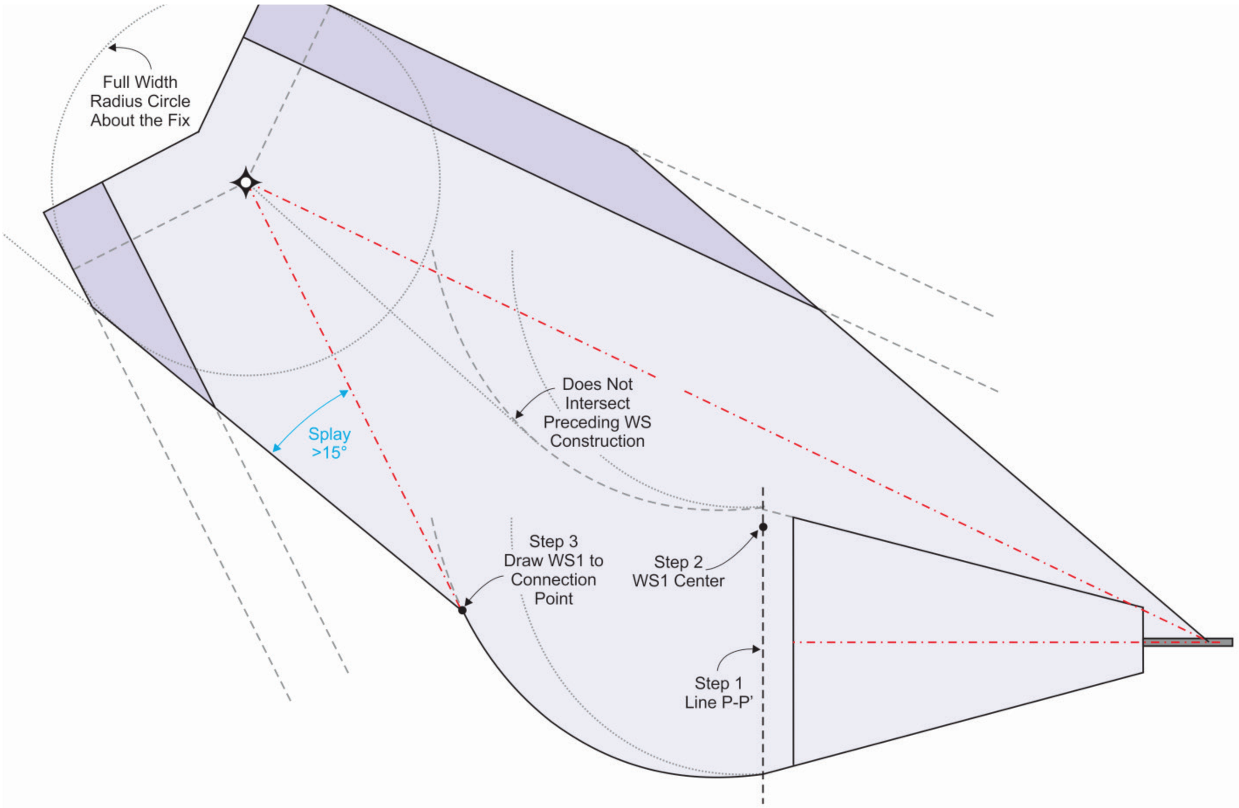
(2) First turn.

(a) Turn-at-altitude, turn-at-fix (FO), and minimum VI-CF construction.

1. *Step 1*. Construct the late-turn baseline (P-P') perpendicular to the runway centerline extended (or offset course if paragraph 5-2-1.a is used) at the late-turn-point. For minimum VI-CF construction late-turn point is 1 NM past the intercept point.

2. *Case 1*. Small turns using one WS.

Figure 5-3-18. Late/Outside Turn, First Turn, Case 1, Turn-at-Altitude or FO Fix with 1 WS

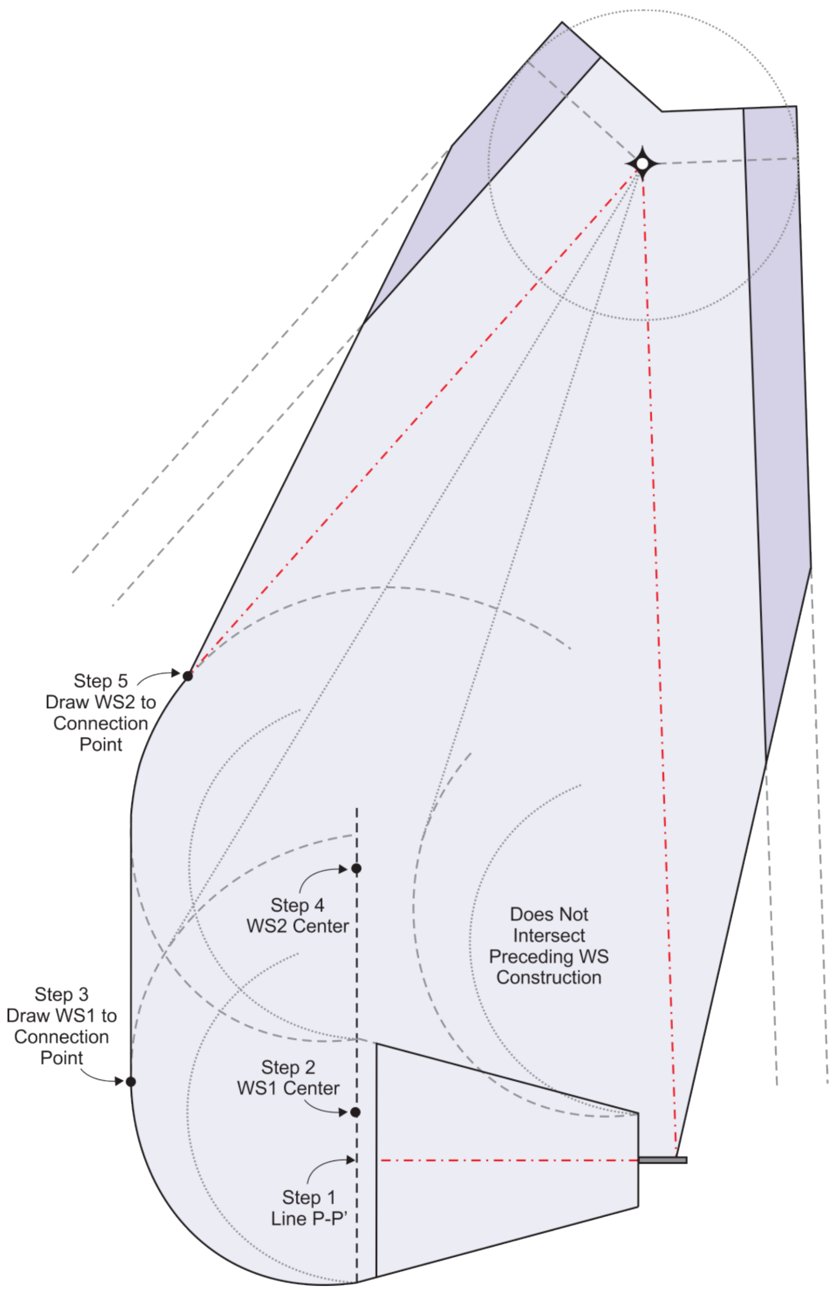


a *Step 2*. Locate the WS1 center on line P-P' at no-wind turn radius distance from point P'.

b *Step 3*. Construct WS1 from the outside turn point in the direction of turn until reaching its connection point. For minimum VI-CF construction use R (based on the highest projected turn altitude), place an arc center point at R distance from the outside turn point, construct an arc at distance R + 1 NM (this will result in a circle instead of a WS) [see figure 5-3-6].

3. *Case 2*. For turns nearing or greater than 90 degrees using more than one WS, complete *Steps 1-3* then:

Figure 5-3-19. Late/Outside Turn, First Turn, Case 2, Turn-at-Altitude or FO Fix with 2 WS

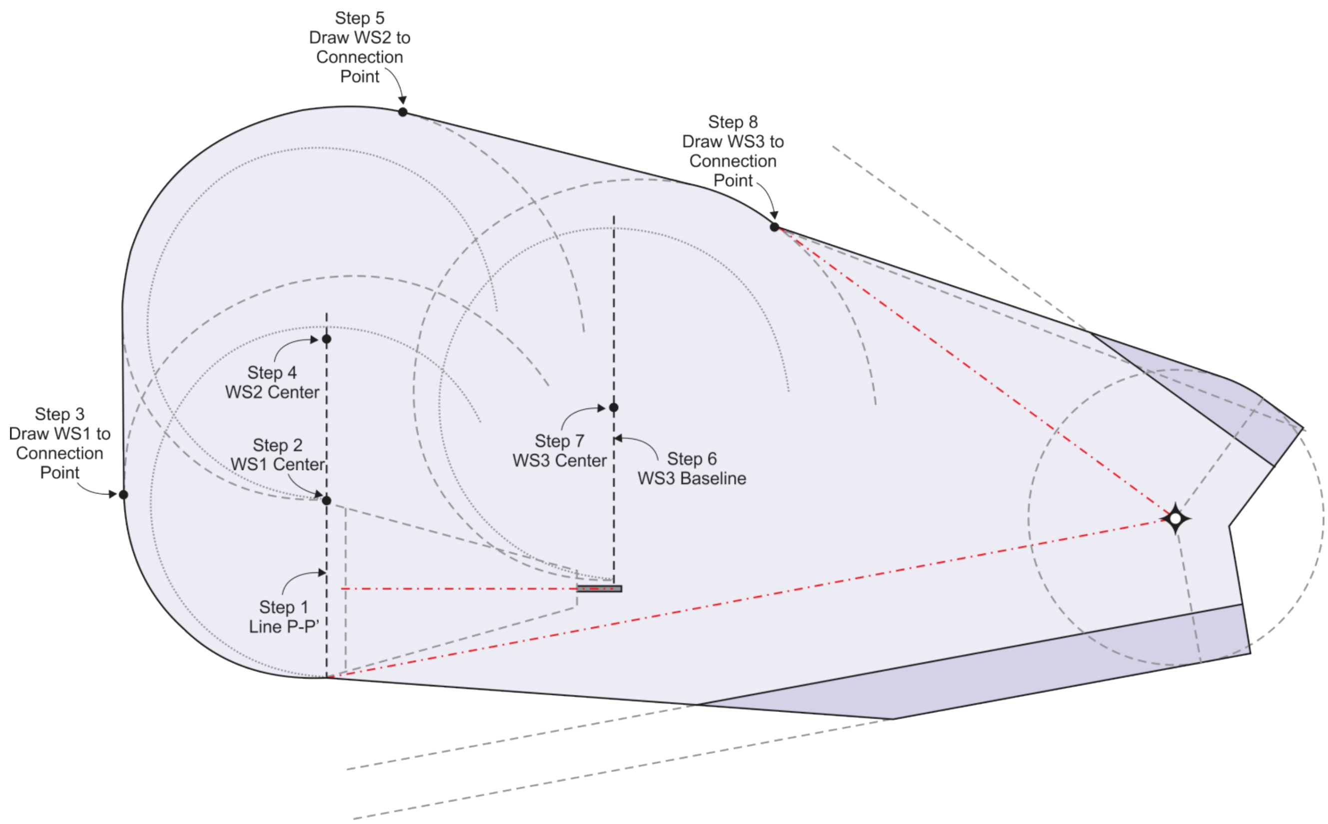


a *Step 4*. Locate the WS2 center on P-P' at no-wind turn radius distance from point P.

b *Step 5*. Construct WS2 from the inside turn point in the direction of turn until reaching its connection point. For minimum VI-CF construction use R (based on the highest projected turn altitude), place an arc center point at 2 × R distance from the outside turn point, construct an arc at distance R + 1 NM (this will result in a circle instead of a WS) [see figure 5-3-7].

4. *Case 3*. Turns nearing or greater than 180 degrees using more than two WS, complete *Steps 1-5* then:

Figure 5-3-20. Late/Outside Turn, First Turn, Case 3, Turn-at-Altitude with 3 WS



a *Step 6*. Construct the WS3 baseline perpendicular to the runway centerline along DRL extended toward the turn side. For FO DF the WS3 baseline is on line L-L' perpendicular to the runway centerline extended toward turn side.

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

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

(b) Turn-at-fix (FB) and standard VI-CF construction.

1. *Step 1*. Construct the outer primary boundary using a radius of 2 × segment XTT centered on the plotted fix position, truncated at the inbound leg extended primary boundary until tangent to the outbound leg primary boundary (not applicable to VI-CF).

2. *Step 2*. Construct the secondary boundary using a radius of 3 × segment XTT entered on the plotted fix position, truncated at the inbound leg extended outer boundary until tangent to the outbound leg outer boundary. For VI-CF this will be the outer primary boundary connecting to point X then parallel to CF course to point W [see figure 5-3-3].

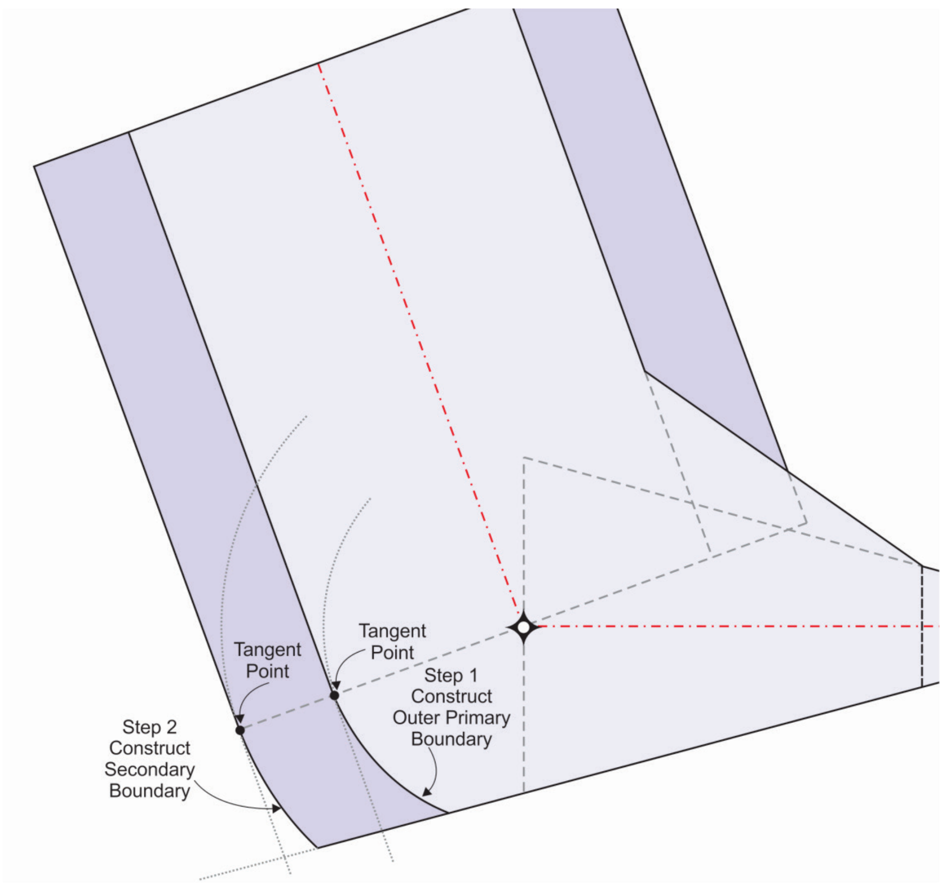
(c) Turn-at-fix, RF construction.

1. *Step 1.* Construct the outer primary boundary by splaying at 15 degrees relative to RF path from point abeam RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction, then construct by truncating the RF full width primary area at the initial straight leg extended splay line [see Figure 5-3-13].

2. *Step 2.* Construct the secondary boundary by splaying at 15 degrees relative to RF path from point abeam RF start point. Where the splay doesn't reach full OEA width at a point that supports standard construction, then construct by truncating the RF full width secondary area at the initial straight leg extended splay line [see figure 5-3-13]

3. Where the initial straight leg splay hasn't reached a width of 3 × segment XTT by the end of the first RF and the succeeding legs is a TF or RF with same direction turn, the initial straight leg splay may continue into the next leg until full width is reached [seefigure 5-3-12]; otherwise, increase splay as necessary to reach full OEA width by the end point of the first RF.

Figure 5-3-21. Late/Outside Turn, First Turn, FB fix



(3) Second turn.

(a) Turn-at-fix (FO).

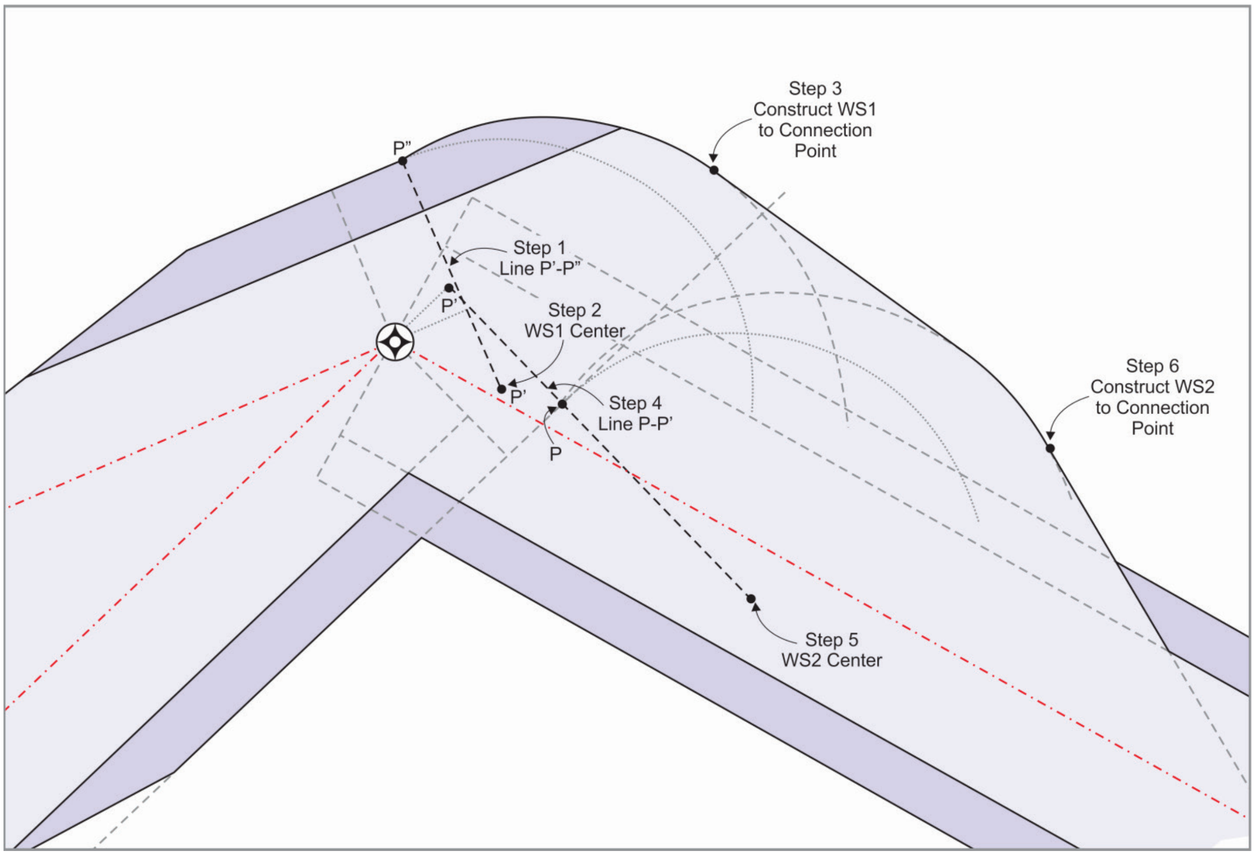
1. *Step 1*. Construct the WS1 baseline, (line P'-P") perpendicular to the DF track nearer the outside of the DF-TF turn at the late turn point.

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 the outside 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 the DF-TF at the late turn point.

Figure 5-3-22. Late/Outside Turn, Second Turn, FO fix



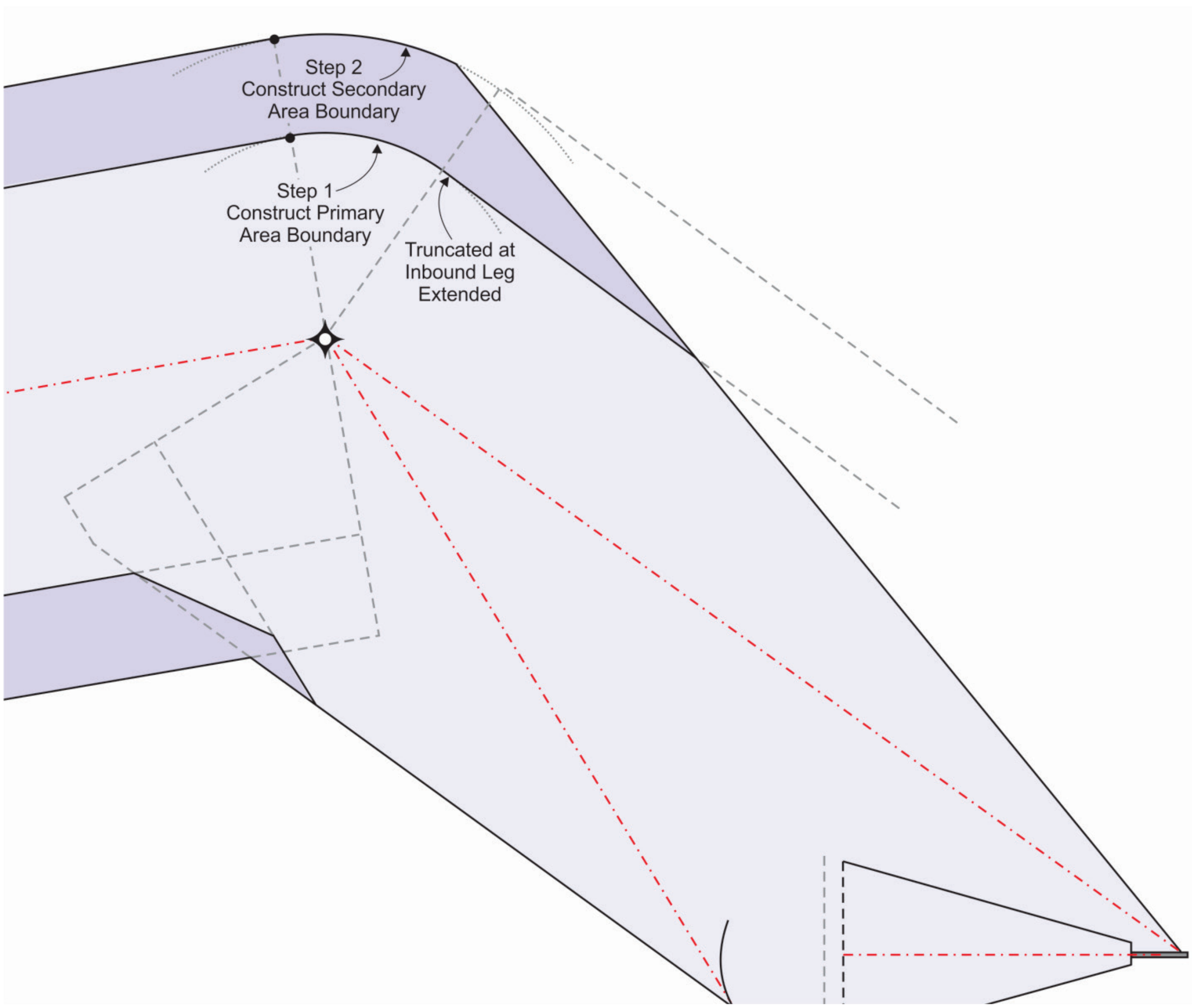
5. *Step 5*. Locate the WS2 center on line P-P' at no-wind turn radius distance from point P.

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 1-1-1.a(1)(b) [see figure 5-3-17].

Figure 5-3-23. Late/Outside Turn, Second Turn, Turn at FB Fix, Less Than Full OEA Width Perpendicular to Fix



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.

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 5-4-1 through figure 5-4-7]. For RNP AR DP apply horizontal and vertical accuracy adjustments to obstacles except for those excluded obstacles in Order 8260.19, paragraph 2-11-4.

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. For RNP AR DP, obstacle distance is measured as the along track distance from the ICAB to a point abeam the obstruction.

(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. For RNP AR DP, obstacle distance is measured as the along track distance from the ICAB to a point abeam the obstruction. When the RNP AR DP has a DER crossing restriction of 500 ft above airport elevation, the OCS begins 380 feet above DER.

(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.).

d. Maximum Altitude Restrictions. Apply Order 8260.3, paragraph 14-6-1, for fix error use ATT. For RF legs, late ATT lies along the RF track and on the construction line anchored at the RF center point [see figure 5-4-8].

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

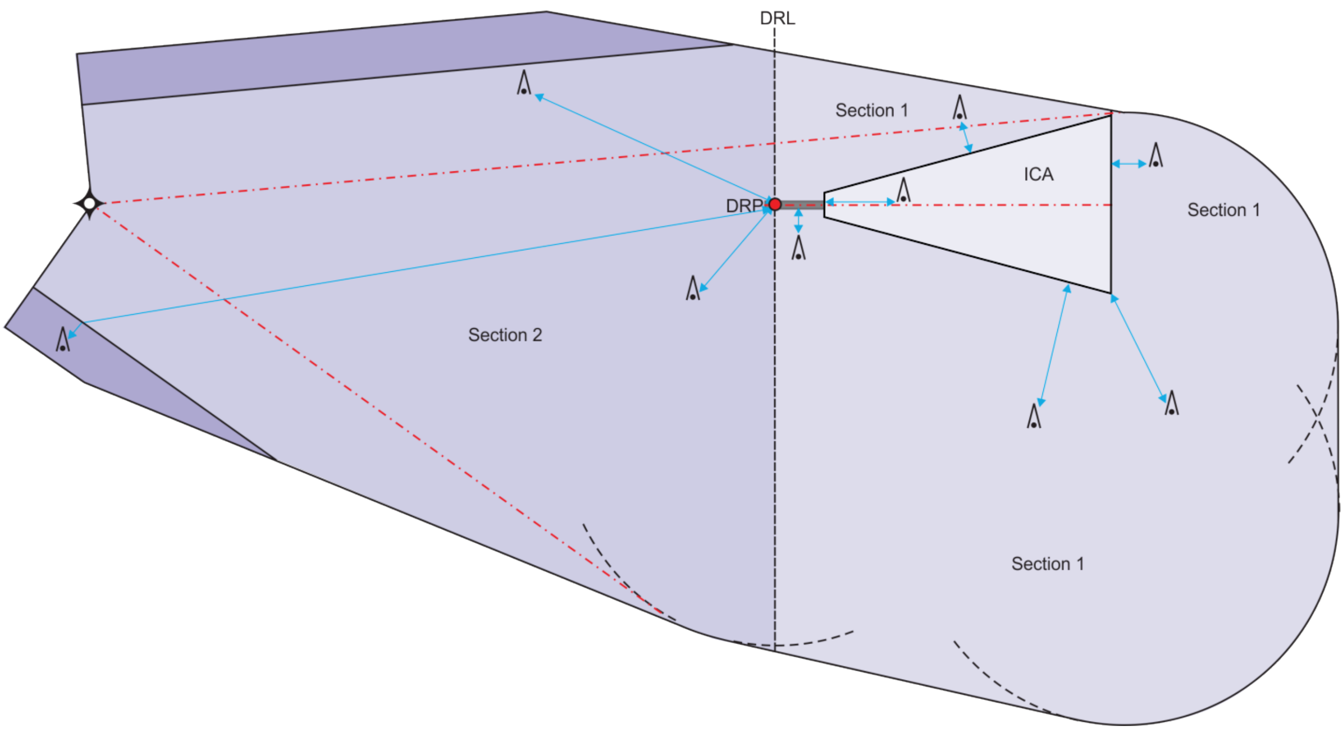
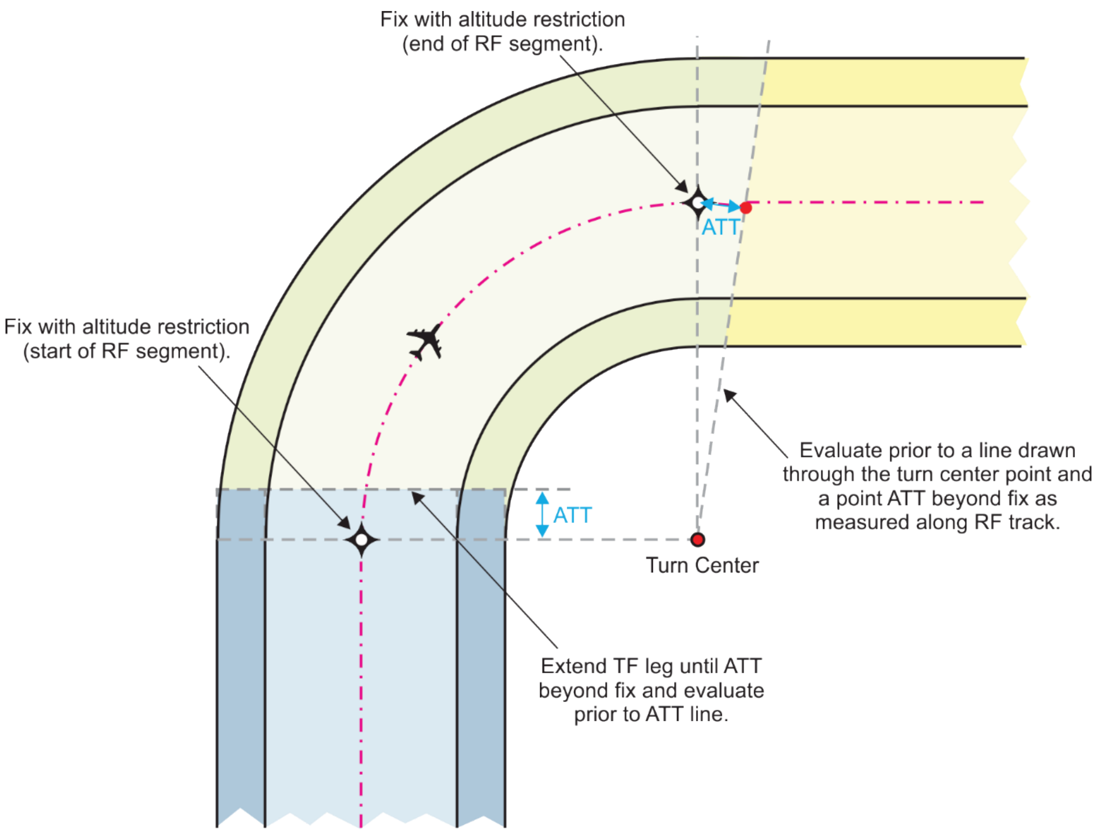


Figure 5-4-8. Maximum Altitude Restriction Evaluation



Section 5-5. Climb Gradient

5-5-1. Climb gradient. Where the default OCS slope is penetrated, a greater than standard CG may be required to clear the penetrating obstruction. A CG for LNAV engagement when used along with a reduced higher than standard CG and/or a CG greater than 500 ft/NM requires Flight Standards approval.

a. When climb gradients are used for obstacle clearance, compute the climb gradient per paragraph 1-3-1.g and formula 1-3-7 using the CG termination altitude from formula 5-5-1.

Formula 5-5-1. CG Termination Altitude

$$CG_{term} = \frac{O_{MSL} - \frac{d_{primary}}{12} - DER_{elev}}{0.76} + DER_{elev}$$

Where:
DER_{elev} = departure end of runway elevation (feet)
$d_{primary}$ = dist. (feet) from edge of primary to obstacle (zero if not in secondary)

Example:

$$CG_{term} = \frac{2147.41 - \frac{390.12}{12} - 1104.3}{0.76} + 1104.3$$

$CG_{term} \approx 2434.04$ feet

b. Mitigating obstacle penetrations. The preferred method of obstacle mitigation is to use a less onerous route. The next choice is a climb gradient, using paragraph 1-3-1.g(2). Also see Order 8260.3, chapter 14 and Order 8260.46.

c. Climb in a holding pattern. Where required, apply climb-in-hold criteria contained in Order 8260.3, section 17-7.

Section 5-6. Radar Vector SID

5-6-1. General. When operationally advantageous, a SID may be developed starting with or including a vector leg followed by an RNAV route. [See appendix D for implementation considerations.]

5-6-2. SID starting with vector leg. When designing an RNAV route following radar vectors, establish the first waypoint as an Initial Fix leg (IF). No OEA construction or DME/DME screening is required prior to the IF of the RNAV route being joined.

a. The IF beginning an RNAV route must fall within an area and be at an altitude protected by an MVA/MIA. The IF altitude may not be less than 500 feet above airport elevation. ATC must be consulted and consideration must be given to the time/distance required for RADAR identification and normal vectoring when designing the IF.

b. A single RNAV course must be defined from the IF.

c. The IF must be a FB fix. A TF leg must follow the IF. General OEA construction applies [see paragraph 1-2-5].

d. The length of the first leg must be sufficient to accommodate a 90-degree turn at the IF. Use standard turn parameters. 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]. An alternative method to allow design of a shorter first leg is to limit the amount of intercept to 45 degrees, this must be approved and applied by ATC.

e. Each SID is limited to one common route and must start with a single IF.

f. OCS slope and origin. A flat surface evaluation is conducted from the IF early ATT to late ATT. A sloping OCS [see formula 1-3-5] originates at IF late ATT. The OCS starting elevation is the MVA/MIA altitude minus ROC. Where multiple MVA/MIA sectors apply, the most demanding surface must be used. Climb gradients are not authorized as mitigation for obstacles that penetrate the flat or sloping OCS, the surface must be raised by increasing fix altitudes or redesigning the route.

5-6-3. SID including vector legs. A SID may start with an RNAV route that has a manual termination followed by vectors to join an RNAV route (Open SID). Construct and evaluate the route off the runway using the applicable straight or turning criteria. No OEA construction or DME/DME screening is required between the fix beginning a manual termination leg and the IF of the RNAV route being joined.

a. The RNAV route off the runway must terminate with either an FM or VM.

b. An FM beginning with a FB fix is preferred. This combination encompasses the most operators.

c. An FM that results in a turn must start with a FB fix.

d. An FM that doesn't require a turn may be either a FB or FO fix.

e. A VM must start with a FO.

f. The fix beginning a manual termination leg must fall within an area and at an altitude protected by either an MVA/MIA, free vector area, ATC prominent obstacle display, or DVA.

(1) When a sectored DVA is used, the heading/course of the manual termination leg must comply with the heading limitations of that DVA sector.

(2) If the manual termination leg starts with a FO fix and a sectored DVA is used, the turn to the heading/course must be contained within that DVA sector.

g. For an RNAV route following a vector segment, comply with paragraphs 5-6-2.a thru 5-6-2.f.

Appendix C. PBN Transition to ILS/GLS/LPV Final

1. Purpose. When establishing an RF intermediate segment that transitions to an ILS/GLS/LPV final, the design must account for high temperature conditions that may cause higher than indicated true altitudes during the glide slope capture.

2. Transition to ILS/GLS/LVP final. Design steps.

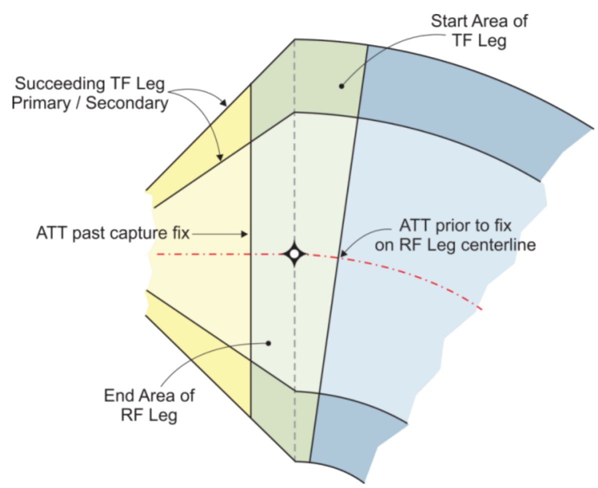
a. *Step 1*. Evaluate the final, intermediate, and initial segments in accordance with the applicable paragraphs, except:

(1) Establish a capture fix. Construct a TF leg aligned with the FAC that is common to all intermediate segments. The start fix of this leg is designated the capture fix. Alternatively where operationally necessary, the capture fix may be placed on or at the start of an RF leg. The preliminary location of the capture fix may be less than 2 NM but no closer than 1 NM prior to the PFAF.

(2) Intermediate OEA.

(a) RNAV (GPS) construction [see chapter 3]. The segment remains at full width until reaching 2 NM prior to the PFAF or the capture fix, whichever is closer to the PFAF. The primary and secondary boundaries abeam this point taper uniformly (relative to path) to the X and Y OCS outer boundaries abeam the PFAF. The preceding leg construction follows the tapering boundaries until reaching the appropriate ATT beyond the fix [see figure C-1 for RF example].

Figure C-1. Intermediate OEA, RNAV Construction



(b) RNP AR [see chapter 4] and A-RNP [see chapter3] construction . Use the same RNP value throughout the entire intermediate construction and verify that the final segment supports the selected RNP with formula C-1. Where the selected RNP is less than the minimum, increase the RNP or decrease the length of final. The capture leg ends at the plotted position of the PFAF.