U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

National Policy

ORDER
8260.58

Effective Date:
09/21/2012

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

This order provides a consolidated United States Performance Based Navigation (PBN) procedure design criteria.

The PBN concept specifies aircraft area navigation (RNAV) system performance requirements in terms of accuracy, integrity, availability, continuity and functionality needed for the proposed operations in the context of a particular Airspace Concept. The PBN concept represents a shift from sensor-based to performance-based navigation. Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications are defined at a sufficient level of detail to facilitate global harmonization by providing specific implementation guidance.

John M. Allen

John M. Allen
Director, Flight Standards Service

Distribution: Electronic Only Initiated By: AFS-400

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Table of Contents

Paragraph No. ***Page No.***

VOLUME 1. GENERAL GUIDANCE AND INFORMATION

Table of Contents

Paragraph No. ***Page No.***

VOLUME 1. GENERAL GUIDANCE AND INFORMATION (CONTINUED)

VOLUME 2. UNITED STATES STANDARD FOR HELICOPTER AREA NAVIGATION (RNAV)

VOLUME 3. RNAV AND RNP 1 DEPARTURE PROCEDURES

Table of Contents

Paragraph No. ***Page No.***

VOLUME 3. RNAV AND RNP 1 DEPARTURE PROCEDURES (CONTINUED)

Table of Contents

Paragraph No. ***Page No.***

VOLUME 3. RNAV AND RNP 1 DEPARTURE PROCEDURES (CONTINUED)

VOLUME 4. TERMINAL ARRIVAL AREA (TAA) DESIGN CRITERIA

VOLUME 5. STANDARD FOR REQUIRED NAVIGATION PERFORMANCE (RNP) APPROACH PROCEDURES WITH AUTHORIZATION REQUIRED (AR)

Table of Contents

Paragraph No. ***Page No.***

VOLUME 5. STANDARD FOR REQUIRED NAVIGATION PERFORMANCE (RNP) APPROACH PROCEDURES WITH AUTHORIZATION REQUIRED (AR) (CONTINUED)

Table of Contents

Paragraph No. ***Page No.***

VOLUME 5. STANDARD FOR REQUIRED NAVIGATION PERFORMANCE (RNP) APPROACH PROCEDURES WITH AUTHORIZATION REQUIRED (AR) (CONTINUED)

VOLUME 6. UNITED STATES STANDARD FOR AREA NAVIGATION (RNAV)

Table of Contents

Paragraph No. ***Page No.***

VOLUME 6. UNITED STATES STANDARD FOR AREA NAVIGATION (RNAV) (CONTINUED)

Chapter 1 General Criteria (Continued)

Section 3 Basic Vertically Guided Final Segment General Criteria

Table of Contents

Paragraph No. ***Page No.***

VOLUME 6. UNITED STATES STANDARD FOR AREA NAVIGATION (RNAV) (CONTINUED)

United States Standard for

Performance Based Navigation (PBN)

<u>Volume 1</u>

General Guidance and Information

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Volume 1. General Guidance and Information

Chapter 1. General Information

1.0 Purpose of This Order. This order provides a consolidated United States Performance Based Navigation (PBN) procedure design criteria.

1.1 Audience. The primary audience for this Order is AeroNav Services, who has the responsibility to develop instrument departure procedures. The secondary audience includes other Air Traffic Organization (ATO) Service Area offices, Flight Standards headquarters and regional office Divisions/Branches, Special Mailing List ZVN-826; and Special Military and Public Addressees.

1.2 Where Can I Find This Order? This information is also available on the FAA's Web site at http://www.faa.gov/regulations_policies/orders_notices.

1.3 Cancellation. The order cancels the following Federal Aviation Administration (FAA) orders, policy memorandums, and Terminal Instrument Procedure (TERPS) Instruction Letters (TILs) and incorporates their content into this directive:

1.3.1 FAA Orders.

See March 1, 2013 Clarification Memo

- **Order 8260.44A**, Civil Utilization of Area Navigation (RNAV) Departure Procedures, dated 03/23/2000

- **Order 8260.45A**, Terminal Arrival Area (TAA) Design Criteria, dated 07/14/2000

- **Order 8260.52**, United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR), dated 06/03/2005

- **Order 8260.54A**, The United States Standard for Area Navigation (RNAV), dated 12/07/2007

1.3.2 Policy Memorandums.

See March 1, 2013 Clarification Memo

- Clarification #4 to FAA Order 8260.52, United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR), dated 02/03/2006

- Application of Obstacle Accuracy Uncertainty, FAA Order 8260.52, United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR), dated 03/22/2006

- Correction to RNP SAAAR Clarification Memo #4, dated 04/25/2006

- Area Navigation (RNAV) Terminal Instrument Procedures (TERPS) Geospatial Standards for Procedure Development Automation, dated 02/01/2007

- Area Navigation (RNAV) Turn Altitude Determination, dated 02/26/2007

- Use of Heading to an Intercept (VI) Legs on Area Navigation (RNAV) Departures, dated 12/17/2007

- Implementation of Order 8260.54A, United States Standard for Area Navigation (RNAV), dated 01/15/2008

- Correction to Order 8260.52, U.S. Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR), dated 03/14/2008

- Corrections to Embedded Calculators and References in FAA Order 8260.54A, The United States Standard for Area Navigation (RNAV), dated 09/16/2009

- Determining Average Cold Temperature (ACT) for Barometric Vertical Navigation (Baro-VNAV) Based Approach Procedures, dated 09/24/2010

- Clarification of Locating the Flight Path Alignment Point (FPAP) on Wide Area Augmentation System (WAAS) Approach Procedures, dated 01/11/2011

- Ground Based Augmentation System Landing System (GLS) Procedure Design Guidance, dated 06/23/2011

- Landing Threshold Geodetic Datum, dated 08/11/2011

- Heading to an Altitude (VA) Followed by a Direct-to Fix (DF) Segment Design Analysis, dated 09/07/2011

- Revised Performance Based Navigation (PBN) Fly-By (FB)/Radius-to-Fix (RF) Turn Maximum Bank Angle Limits; Omni-Directional Tailwind Requirements; and Minimum Initial Departure Leg Segment Length Design Criteria, dated 10/03/2011
-
- Performance Based Navigation Instrument Procedure Minimum Segment Length Standard, dated 02/06/2012

- Low/High Temperature Limits for Barometric Vertical Navigation (Baro-VNAV) Based Approach Procedures, dated 06/06/2012

1.3.3 Terminal Instrument Procedures (TERPS) Instruction Letters (TILs).

- TIL 00-009, Successive Fly-over Fixes, dated 07/18/2000

- TIL 01-020, FAA Order 8260.44, Interim Change 1, dated 05/01/2001
- TIL 01-024, Construction Criteria of Leg Segments VA to CF, dated 07/23/2001
- TIL 02-042, Area Navigation (RNAV) “Q” Route Processing, dated 12/12/2002

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Volume 1. General Guidance and Information

Chapter 2. Basic Criteria Information

2.0 General.

The following FAA orders apply.

8260.3, United States Standard for Terminal Instrument Procedures (TERPS).

8260.19, Flight Procedures and Airspace.

7130.3, Holding Pattern Criteria.

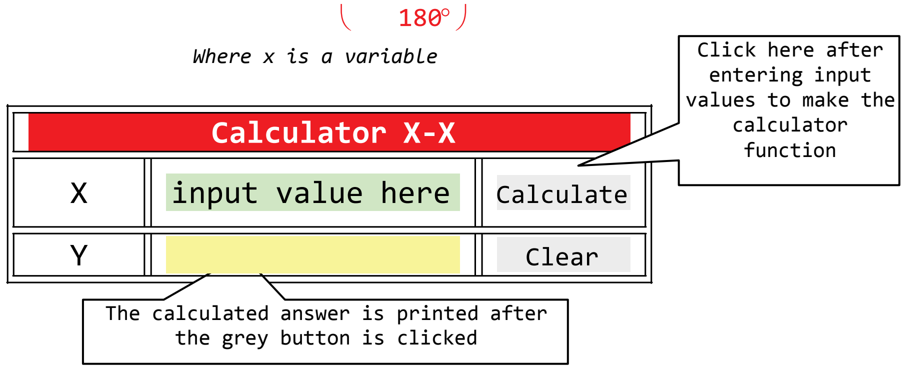
The feeder, initial, intermediate, final, and missed approach criteria described in this order supersede the other publications listed above. Application of Volume 4, TAA is encouraged in approach procedure design. The feeder criteria in Volume 6, chapter 1, paragraph 1.7 may be used to support RNAV Standard Terminal Arrival Route (STAR) and Tango (T) Air Traffic Service (ATS) route construction. See Order 8260.3, Volume 1, chapter 3 to determine visibility minima.

Calculators are numbered by chapter and depicted in standard mathematical notation. Each calculator is functional java script

Calculator X-X. Title

$$Y = \frac{x^2}{\tan\left(3° \times \frac{\pi}{180°}\right)}$$

Where x is a variable



2.1 Data Resolution.

See March 1, 2013 Clarification Memo

Perform calculations using an accuracy of at least 15 significant digits; i.e., floating point numbers must be stored using at least 64 bits. Do not round intermediate results. Round only the final result of calculations for documentation purposes. Required accuracy tolerance is 1 centimeter for distance and 0.002 arc-second for angles. The following list specifies the minimum accuracy standard for **documenting** data expressed numerically. This standard applies to the documentation of final results only;

See March 1, 2013 Clarification Memo

e.g., a calculated adjusted glidepath angle of 3.04178 degrees is documented as 3.05 degrees. The standard does not apply to the use of variable values during calculation. Use the most accurate data available for variable values.

2.1.1 Documentation Accuracy:

2.1.1 **a. WGS-84 latitudes and longitudes** to the nearest one hundredth (0.01) arc second; [nearest five ten thousandth (0.0005) arc second for Final Approach Segment (FAS) data block entries].

2.1.1 **b. LTP** mean sea level **(MSL) elevation** to the nearest foot;

2.1.1 **c. LTP height above ellipsoid (HAE)** to the nearest tenth (0.1) meter;

2.1.1 **d. Glidepath angle** to the next higher one hundredth (0.01) degree;

2.1.1 **e. Courses** to the nearest one hundredth (0.01) degree; and

2.1.1 **f. Course width at threshold** to the nearest quarter (0.25) meter;

2.1.1 **g. Distances** to the nearest hundredth (0.01) unit [except for “length of offset” entry in FAS data block which is to the nearest 8 meter value].

2.1.2 Mathematics Convention.

Formulas in the calculators in this document as depicted are written for *radian* calculation.

$$Y = \frac{X^2}{\tan\left(3° \times \frac{\pi}{180°}\right)}$$

Note: The value ft-per-NM (fpnm) value for 1 NM was previously defined as 6,076.11548 ft. For the purposes of RNAV criteria, 1 NM is defined as the result of the following calculation:

$$fpnm = \frac{1852}{0.3048}$$

round(a,f) rounds value **a** toward the nearest integer to **f** decimal places; e.g., **round(6.2354,2)=6.24, round(10.5645,3)=10.565, round(5241.499,0)=5241, round(5241.5001,0)=5242**

ceiling(a) rounds value **a** to the next integer toward positive infinity; e.g., **ceiling(2.3)=3, ceiling(-2.3)=-2.** The **ceiling** function may be defined as:

```
function ceiling(x)
if x=int(x) then
      ceiling=x
else
   if x<0 then
            ceiling=int(x)
            else
            ceiling=int(x)+1
   end if
end if
end function
```

floor(a) rounds value **a** to the next integer toward negative infinity; e.g., **floor(**2.3**)**=2, **floor(**-2.3**)**=-3. The **floor** function may be defined as:

```
function floor(x)
if x=int(x) then
            floor=x
      else
            if x<0 then
                  floor=int(x)-1
            else
                  floor=int(x)
            end if
end if
end function
```

min(x,y) returns the least (closest to negative infinity) of real values x or y; e.g., **min(-3,-5)=-5**, **min(3,5)=3**

max(x,y) returns the greatest (closest to positive infinity) of real values x or y; e.g., **max(-3,-5)=-3, max(3,5)=5**

2.1.2 **a. Conversions by Unit Factors:**

- Degree measure to radian measure:

$$radians = degrees \times \frac{\pi}{180°}$$ Example: $$0.908095 = 52.03° \times \frac{\pi}{180°}$$

- Radian measure to degree measure:

$$degrees = radians \times \frac{180°}{\pi}$$ Example: $$52.03° = 0.908095 \times \frac{180°}{\pi}$$

- Feet to meters:

$$meters = feet \times \frac{.3048\ m}{ft}$$ Example: $$37.6294\ m = 123.456\ ft \times \frac{.3048\ m}{ft}$$

- Meters to feet

$$feet = meters \times \frac{1\ ft}{.3048\ m}$$ Example: $$123.456\ ft = 37.6294\ m \times \frac{1\ ft}{.3048\ m}$$

- Feet to Nautical Miles (NM)

$$NM = feet \times \frac{.3048\ NM}{1852\ ft}$$ Example: $$1.38707\ NM = 8428\ ft \times \frac{.3048\ NM}{1852\ ft}$$

- NM to feet:

$$feet = NM \times \frac{1852\ ft}{.3048\ NM}$$ Example: $$8428\ ft = 1.38707\ NM \times \frac{1852\ ft}{.3048\ NM}$$

- NM to meters

$$meters = NM \times \frac{1852\ m}{NM}$$ Example: $$2689.66\ m = 1.4523\ NM \times \frac{1852\ m}{NM}$$

- Meters to NM

$$NM = meters \times \frac{NM}{1852\ m}$$ Example: $$1.4523\ NM = 2689.66\ m \times \frac{NM}{1852\ m}$$

- Temperature Degrees Celsius (°C) to Degrees Fahrenheit (°F):

$$T°F = \frac{1.8°F}{°C} \times T°C + 32°F$$ Example: $$68°F = 1.8\frac{°F}{°C} \times 20°C + 32°F$$

- Temperature Degrees Fahrenheit (°F) to degrees Celsius (°C)

$$T°C = \frac{°C}{1.8°F} \times (T°F - 32°F)$$ Example: $$20°C = \frac{°C}{1.8°F} \times (68°F - 32°F)$$

2.1.2 b. Definition of Mathematical Functions and Constants.

$a + b$ indicates addition
$a - b$ indicates subtraction
$a \times b$ or ab or $a \cdot b$ or a*b indicates multiplication
$\frac{a}{b}$ or a/b or $a \div b$ indicates division
$(a - b)$ indicates the result of the process within the parenthesis
$|a - b|$ indicates absolute value
$\approx$ indicates approximate equality
$\sqrt{a}$ or $a^{0.5}$ or a^0.5 indicates the square root of quantity "a"
a^2 or a^2 indicates $a \times a$
$\ln(a)$ or $\log(a)$ indicates the natural logarithm of "a"
$\tan(a)$ indicates the tangent of "a"
$\tan^{-1}(a)$ or $\operatorname{atan}(a)$ indicates the arc tangent of "a"

$\sin(a)$ indicates the sine of "a"

$\sin^{-1}(a)$ or $\text{asin}(a)$ indicates the arc sine of "a"

$\cos(a)$ indicates the cosine of "a"

$\cos^{-1}(a)$ or $\text{acos}(a)$ indicates the arc cosine of "a"

e The constant e is the base of the natural logarithm and is sometimes known as Napier's constant, although its symbol (e) honors Euler. With the possible exception of π, e is the most important constant in mathematics since it appears in myriad mathematical contexts involving limits and derivatives. Its value is approximately 2.718281828459045235360287471352662497757…

r The TERPS constant for the mean radius of the earth for spherical calculations in feet. **r** = 20890537

2.1.2 **c. Common equation terms.**

Terms: These terms/variables are common to all calculators.

AMSL is above mean sea level.
ϕ is bank angle.
β is magnitude of heading change in degrees.
θ is glidepath angle in degrees.
DA is decision altitude in feet AMSL.
alt is altitude in feet AMSL.
$\mathbf{ATT_i}$ is the along-track error for the segment initial fix.
$\mathbf{ATT_t}$ is the along-track error for the segment termination fix.
$\mathbf{V_{KIAS}}$ is knots indicated airspeed (Volume 6, table 1-3).
$\mathbf{apt_{elev}}$ is the published airport elevation in feet AMSL.
$\mathbf{LTP_{elev}}$ is the published threshold elevation in feet AMSL.
TCH is threshold crossing height in feet above threshold.
$\mathbf{PFAF_{alt}}$ is the minimum intermediate segment altitude in feet AMSL.
$\mathbf{O_{MSL}}$ is the obstacle elevation in feet AMSL.
$\mathbf{OBS_X}$ is the along track distance in feet from LTP to obstacle.
HATh is the difference between DA and LTP elevation rounded to the next higher foot value.
HAL is the difference between DA and FHP elevation rounded to the next higher foot value.

2.1.2 **d. Operation Precedence (Order of Operations).**

First: Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.
Second: Functions: Tangent, sine, cosine, arcsine, and other defined functions
Third: Exponentiations: Powers and roots
Fourth: Multiplication and Division: Products and quotients
Fifth: Addition and subtraction: Sums and differences
e.g.,

$5-3\times 2=-1$ because multiplication takes precedence over subtraction

$(5-3)\times 2=4$ because parentheses take precedence over multiplication

$\frac{6^2}{3}=12$ because exponentiation takes precedence over division

$\sqrt{9+16}=5$ because the square root sign is a grouping symbol

$\sqrt{9}+\sqrt{16}=7$ because roots take precedence over addition

$\frac{\sin(30°)}{0.5}=1$ because functions take precedence over division

$\sin\left(\frac{30°}{0.5}\right)=0.8660254$ because parentheses take precedence over functions

Notes on calculator usage:

1. Most calculators are programmed with these rules of precedence.

2. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity.

2.1.3 **Geospatial Standards.**

See March 1, 2013 Clarification Memo

The following standards apply to the evaluation of obstacle and terrain position and elevation data relative to RNAV OEAs and OCSs. Terrain and obstacle data are reported in NAD-83 latitude, longitude, and elevation relative to MSL in National Geodetic Vertical Datum of 1929 (NGVD-29) or North American Vertical Datum of 1988 (NAVD-88) vertical datum. Evaluate obstacles using their NAD-83 horizontal position and NAVD-88 elevation value compared to the WGS-84 referenced course centerline (along-track and cross-track), OEA boundaries, and OCS elevations as appropriate.

2.1.3 **a. WGS-84[G873]** for Position and Course Construction. This reference frame is used by the FAA and the U.S. Department of Defense (DoD). It is defined by the National Geospatial-Intelligence Agency (NGA) (formerly the National Imagery and Mapping Agency, formerly the Defense Mapping Agency [DMA]). In 1986, the Office of National Geodetic Survey (NGS), redefined and readjusted the North American Datum of 1927 (NAD-27), creating the North American Datum of 1983 (NAD-83). The WGS-84 was defined by the DMA. Both NAD-83 and WGS-84 were originally defined (in words) to be geocentric and oriented as the Bureau International d I'Heure (BIH) Terrestrial System.

In principle, the three-dimensional (3D) coordinates of a single physical point should therefore be the same in both NAD-83 and WGS-84 Systems; in practice; however, small differences are sometimes found. The original intent was that both systems would use the Geodetic Reference System of 1980 (GRS-80) as a reference ellipsoid. As it happened, the WGS-84 ellipsoid differs very slightly from GRS-80). The difference is 0.0001 m in the semi-minor axis. In January 2, 1994, the WGS-84 reference system was realigned to be compatible with the International Earth Rotation Service's Terrestrial Reference Frame of 1992 (ITRF) and renamed WGS-84 (G730). The reference system underwent subsequent improvements in 1996, referenced as WGS-84 (G873) closely aligned with ITRF-94, to the current realization adopted by the NGA in 2001, referenced as WGS-84 (G1150) and considered equivalent systems to ITRF 2000.

2.1.3 **b. NAVD-88** for elevation values. NAVD-88 is the vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations. It held fixed the height of the primary tidal bench mark, referenced to the new International Great Lakes Datum of 1985 local MSL height value, at Father Point/Rimouski, Quebec, Canada. Additional tidal bench mark elevations were not used due to the demonstrated variations in sea surface topography, (i.e., the fact that MSL is not the same equipotential surface at all tidal bench marks).

2.1.3 **c. OEA Construction and Obstacle Evaluation Methodology.**

See March 1, 2013 Clarification Memo

2.1.3 c. (1) Courses, fixes, boundaries (lateral dimension). Construct straight-line courses as a WGS-84 ellipsoid geodesic path. If the course outbound from a fix differs from the course inbound to the fix (courses measured at the fix), then a turn is indicated. Construct parallel and trapezoidal boundary lines as a locus of points measured perpendicular to the geodesic path. (The resulting primary and/or secondary boundary lines do not display a "middle bulge" due to curvature of the ellipsoids surface since they are not geodesic paths.) NAD-83 latitude/longitude positions are acceptable for obstacle, terrain, and airport data evaluation. Determine obstacle lateral positions relative to course centerline/OEA boundaries using ellipsoidal calculations (see Volume 1, appendix A).

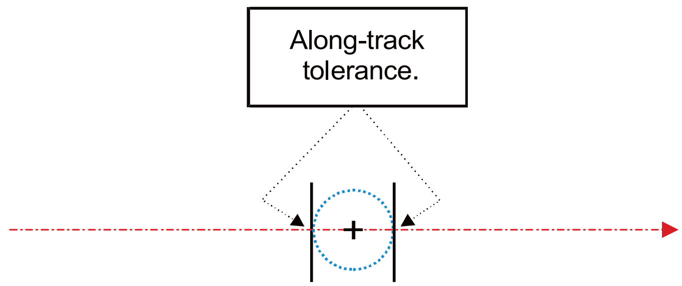
2.1.3 c. (2) Elevations (vertical dimension). Evaluate obstacles, terrain, and airport data using their elevation relative to their orthometric height above the geoid (for our purposes, MSL) referenced to the NAVD-88 vertical datum. The elevations of OCSs are determined spherically relative to their origin MSL elevation (NAVD-88). Department of Defense (DoD) procedure developers may use EGM-96 vertical datum.

2.1.4 **Reserved.**

2.1.5 **ATT Values.**

ATT is the value used (for segment construction purposes) to quantify along-track position uncertainty of an RNAV fix. In order to account for ATT in procedure design, OEAs are constructed and evaluated from the ATT value prior to a segment's initial fix to the ATT value past the segment termination fix. ATT values are not included in minimum segment length calculations.

Figure 2-1. ATT



Note: Cross-track tolerance (XTT) values were considered in determining minimum segment widths, and are not considered further in segment construction.

Table 2-1. ATT Values

<table>
<tr><td rowspan="3">GPS or DMF/DME/IRU</td><td>En Route
STARs, DPs, Feeder, Initial, Intermediate, Missed Approach (> 30 NM)</td><td>2.0 NM</td></tr>
<tr><td>Terminal
STARs, DPs, Feeder, Initial, Intermediate, Missed Approach (≤ 30 NM)</td><td>1.0 NM</td></tr>
<tr><td>Approach
(final)</td><td>0.3 NM</td></tr>
<tr><td>WAAS*
(LPV & LP)</td><td>Approach
(final)</td><td>40 m</td></tr>
</table>

*Applies to final segment only. Apply GPS values to all other segments of the approach procedure.

2.2 Terminal Instrument Procedures (TERPS) Standard for Geodetic Constructions. See Volume 1, appendix A.

Volume 1. General Guidance and Information

Chapter 3. Administrative Information

3.0 Distribution.

This order is distributed in Washington headquarters to the branch level in the Offices of Aviation Policy and Plans, Aviation Research, Airport Safety and Standards, the Air Traffic Organization (Safety, En Route and Oceanic Services, Terminal Services, System Operations Services, Mission Support Services, and Technical Operations Services), and Flight Standards Service; to the Aeronautical Information Management Group, AeroNav Services, Airspace and Rules Group, and the National Airway Systems Engineering Group; to the Regulatory Standards Division; to the branch level in the regional Flight Standards and Airports Divisions; to the Air Traffic and Technical Operations Service Areas, to all Flight Inspection Field Offices; to the Europe, Africa, and Middle East Area Office; to all Flight Standards Field Offices; Special Mailing List ZVN-826; and Special Military and Public Addressees.

3.1 Definitions and/or Acronyms.

In addition to the definitions common to procedure development contained in various 8260-series orders, the following definitions and/or acronyms apply:

3.1.1 **3-Dimensional (3D).** Approach procedures that provide longitudinal, lateral, and vertical path deviation information are 3D procedures. Instrument landing system (ILS), microwave landing system (MLS), precision approach radar (PAR), lateral navigation/vertical navigation (LNAV/VNAV), Localizer Performance with Vertical Guidance (LPV), and required navigation performance (RNP) are examples of 3D procedures.

3.1.2 **Adverse Assumption Obstacles (AAO).** A vertical additive applied to terrain height to compensate for the assumed existence of an unreported obstacle (see Order 8260.19).

3.1.3 **Air Traffic Service (ATS) Route.** A generic term that includes VOR Federal airways, colored Federal airways, jet routes, and RNAV routes. The term "ATS route" does not replace these more familiar route names, but serves only as an overall title when listing the types of routes that comprise the United States route structure.

3.1.4 **Airport Reference Point (ARP).** The official horizontal geographic location of an airport. It is the approximate geometric center of all usable runways at an airport.

3.1.5 **Along-Track Distance (ATD).** A distance specified in nautical miles (NM) along a defined track to an area navigation (RNAV) fix.

3.1.6 **Along-Track (ATRK) Tolerance (ATT).** The amount of possible longitudinal fix positioning error on a specified track expressed as a ± value.

Note: The acronym **ATRK FDT** (along-track fix displacement tolerance) has been used instead of ATT in the past. The change to ATT is a step toward harmonization of terms with International Civil Aviation Organization (ICAO) Pans-Ops.

See March 1, 2013 Clarification Memo

3.1.7 **Approach Surface Baseline (ASBL).** The ASBL is a line aligned to the runway centerline (RCL) that lies in a plane parallel to a tangent to the WGS-Ellipsoid at the landing threshold point. It is used as a baseline reference for vertical measurement of the height of glidepath and obstacle clearance surface (OCS).

3.1.8 **Area Navigation (RNAV).** A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or spaced-based navigation aids or within the limits of the capability of self contained aids, or a combination of these.

3.1.9 **Authorization Required (AR).** Aircraft may be equipped beyond the minimum standard for public required navigation performance (RNP) criteria and aircrews trained to achieve a higher level of instrument approach performance. AR criteria are based on a higher level of equipage and additional aircrew requirements. Procedures that utilize AR design criteria must be appropriately annotated.

3.1.10 **Average Coldest Temperature (ACT).** A value in Centigrade (°C) and/or Fahrenheit (°F) scale for the lowest temperature a Baro-VNAV (including RNP) procedure can be utilized. It is derived from historical weather data, or in the absence of historical data, a standardized temperature value below airport ISA is used.

3.1.11 **Barometric Altitude.** A barometric altitude measured above mean sea level (MSL) based on atmospheric pressure measured by an aneroid barometer. This is the most common method of determining aircraft altitude.

3.1.12 **Baseline.** Where a turn area expansion arc(s) may be centered, a line perpendicular to the inbound course after the leg termination fix ATT area. For CA, CI, VA or VI legs, the baseline is located at the leg termination point.

3.1.13 **Course Change.** A course change is the mathematical difference between the inbound and outbound tracks at a single fix.

3.1.14 **Course-to-a-Fix (CF).** A defined, repeatable course (track over the ground) to a specific database fix.

3.1.15 **Course-to-an-Altitude (CA).** A defined, repeatable course to a specific altitude at an unspecified position.

3.1.16 **Course-to-an-Intercept (CI).** A defined, repeatable course to intercept the subsequent leg.

3.1.17 **Cross-Track (XTT) Tolerance.** The amount of possible lateral positioning error expressed as a ± value.

Note: The acronym **XTRK FDT** (cross-track fix displacement tolerance) has been used instead of XTT in the past. The change to XTT is a step toward harmonization of terms with ICAO Pans-Ops.

3.1.18 **Decision Altitude (DA).** The DA is a specified barometric altitude at which a missed approach must be initiated if the required visual references to continue the approach have not been acquired. DA is referenced to MSL. It is applicable to vertically guided approach procedures.

3.1.19 **Departure End of Runway (DER).** The DER is the end of the runway that is opposite the landing threshold. It is sometimes referred to as the stop end of runway.

3.1.20 **Departure Reference Line (DRL).** An imaginary line of indefinite length perpendicular to the runway centerline at the DRP.

3.1.21 **Departure Reference Point (DRP).** A point on the runway centerline 2000 ft from the start end of runway.

3.1.22 **Descent Gradient (DG).** Description of aircraft descent profile specified in feet per nautical mile.

3.1.23 **Direct-to-a-Fix (DF).** An unspecified non-repeatable track starting from an undefined position to a specific database fix.

3.1.24 **Distance of Turn Anticipation (DTA).** The distance from (prior to) a fly-by fix at which an aircraft is expected to start a turn to intercept the course/track of the next segment.

3.1.25 **Early Turn Point (ETP).** Represents the earliest location where a flight track turn may commence.

3.1.26 **Earth Curvature (EC).** Allowance for the curvature of the earth used in distance calculations based on a spherical earth model with a radius of 20890537 ft.

3.1.27 **Fictitious Threshold Point (FTP).** The FTP is the equivalent of the landing threshold point (LTP) when the final approach course is offset from the runway centerline. It is not aligned through the LTP. It is located on the final approach course the same distance from the intersection of the final approach course and runway centerline extended as the LTP. FTP elevation is the same as the LTP. For the purposes of this document, where LTP is used, FTP may apply as appropriate.

3.1.28 **Final Approach Course (FAC).** Magnetic and/or true heading definition of the final approach lateral path.

3.1.29 **Final Approach Fix (PFAF).** See PFAF, paragraph 3.1.74.

3.1.30 **Final Approach Segment (FAS).** The FAS begins at the PFAF and ends at the LTP/FTP. The FAS is typically aligned with the runway centerline extended. The segment OEA normally extends a distance equal to ATT (1 RPN) beyond (outside) the segment initial and termination fixes. The FAS is divided into the OCS and the visual segment obstacle identification surface (OIS).

3.1.31 **Fix Displacement Tolerance (FDT).** FDT is a legacy term providing 2-dimensional (2D) quantification of positioning error. It is now defined as a circular area with a radius of ATT centered on an RNAV fix. The acronym ATT is now used in lieu of FDT.

3.1.32 **Flight Control Computer (FCC).** Aircraft computers which process information from various inputs to calculate flight path and flight guidance parameters.

3.1.33 **Flight Management System (FMS).** An FMS is a specialized computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew to the point that modern aircraft no longer carry flight engineers or navigators. A primary function is in-flight management of the flight plan. Using various sensors (such as GPS and INS often backed up by radio navigation) to determine the aircraft's position, the FMS can guide the aircraft along the flight plan. From the cockpit, the FMS is normally controlled through a Control Display Unit (CDU) which incorporates a small screen and keyboard or touchscreen. The FMS sends the flight plan for display on the EFIS, Navigation Display (ND) or Multifunction Display (MFD).

See March 1, 2013 Clarification Memo

3.1.34 **Flight Path Alignment Point (FPAP).** The FPAP is a 3D point defined by World Geodetic System of 1984/North American Datum of 1983 (WGS-84/NAD-83) latitude, longitude, MSL elevation, and WGS-84 Geoid height. The FPAP is used in conjunction with the LTP and the geometric center of the WGS-84 ellipsoid to define the final approach azimuth (LPV glidepath's vertical plane) associated with an LP or LPV final course.

3.1.35 **Flight Path Control Point (FPCP).** The FPCP is a 3D point defined by the LTP geographic position, MSL elevation, and threshold crossing height (TCH) value. The FPCP is in the vertical plane of the final approach course and is used to relate the glidepath angle of the final approach track to the landing runway. It is sometimes referred to as the TCH point or reference datum point (RDP).

3.1.36 **Final Roll-Out Point (FROP).** Where a course change is required at or inside the PFAF, the point that the aircraft rolls to a wings-level attitude aligned with the runway centerline extended is considered the FROP.

3.1.37 **Fly-By (FB) Fix.** Fly-by fixes/waypoints are used when an aircraft should begin a turn to the next course prior to reaching the waypoint separating the two route segments.

3.1.38 **Fly-Over (FO) Fix.** Fly-over fixes/waypoints are used when the aircraft must fly over the point prior to starting a turn.

See March 1, 2013 Clarification Memo

3.1.39 **Geoid Height (GH).** The GH is the height of the Geoid relative to the WGS-84 ellipsoid. It is a positive value when the Geoid is above the WGS-84 ellipsoid and negative when it is below. The value is used to convert a mean sea level (MSL) elevation to an ellipsoidal or geodetic height, the height above ellipsoid (HAE).

Note: The Geoid is an imaginary surface within or around the earth that is everywhere normal to the direction of gravity and coincides with MSL in the oceans. It is the reference surface for MSL heights.

See March 1, 2013 Clarification Memo

3.1.40 **Geographic Positioning Navigation (GPN).** Navigation based on geodetic calculation of geographic position referenced to the WGS-84 ellipsoid. Global positioning system (GPS), wide area augmentation system (WAAS), local area augmentation system (LAAS), flight management system (FMS), RNP, and RNAV are examples of GPN.

3.1.41 **Glidepath Angle (GPA).** The GPA is the angle of the specified final approach descent path relative to a horizontal line tangent to the surface of the earth at the runway threshold. In this order, the glidepath angle is represented in calculators and figures as the Greek symbol theta (θ).

3.1.42 **Glidepath Qualification Surface (GQS).** The GQS is a narrow inclined plane centered on the runway centerline that limits the height of obstructions between the DA and LTP. A clear GQS is required for authorization of vertically-guided approach procedure development.

3.1.43 **Global Azimuth Reference Point (GARP).** Global Navigation Satellite System (GNSS) Azimuth Reference Point. A calculated point 1000 ft beyond the FPAP lying on an extension of a geodesic line from the LTP/FTP through the FPAP. It may be considered the location of an imaginary localizer antenna.

3.1.44 **Global Navigation Satellite System (GNSS).** A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring. GNSS is augmented as necessary to support the required navigation performance for the actual phase of operation.

3.1.45 **Ground Point of Intercept (GPI).** The glidepath intercepts the ASBL at the GPI. The GPI is expressed as a distance in feet from the LTP. The GPI is derived from TCH and glidepath angle values: $GPI = \frac{TCH}{\tan(\theta\ )}$.

3.1.46 **Heading-to-an-Altitude (VA).** A specified heading to a specific altitude at an unspecified position. The resulting track is not wind corrected.

3.1.47 **Heading-to-an-Intercept (VI).** A specified heading to intercept the subsequent leg at an unspecified position. The resulting track is not wind corrected.

See March 1, 2013 Clarification Memo

3.1.48 **Height Above Ellipsoid (HAE).** The elevation of the glidepath origin (TCH point) for an LPV approach procedure is referenced to the LTP. RNAV avionics calculate heights relative to the WGS-84 ellipsoid. Therefore, it is important to specify the HAE value for the LTP. This value differs from a height expressed in feet above the geoid (essentially MSL) because the reference surfaces (WGS-84 ellipsoid and the geoid) do not coincide. Ascertain the height of the orthometric geoid (MSL surface) relative to the WGS-84 ellipsoid at the LTP. This value is considered the GH. For Westheimer Field, Oklahoma the GH is -87.29 ft. This means the geoid is 87.29 ft below the WGS-84 ellipsoid at the latitude and longitude of the runway 35 threshold.

* Calculate GH for CONUS using the appropriate NGS program. See the NGS website - http://www.ngs.noaa.gov/TOOLS/.

3.1.49 **Height Above Threshold (HATh).** The HATh is the height of the DA above LTP elevation.

3.1.50 **Initial Climb Area (ICA).** A segment variable in length starting at the DER which allows the aircraft sufficient distance to reach an altitude of at least 400 ft above the DER.

3.1.51 **Initial Course.** The course established initially after take-off beginning at the DER.

3.1.52 Inner-Approach Obstacle Free Zone (OFZ). The inner-approach OFZ is the airspace above a surface centered on the extended runway centerline. It applies to runways with an approach lighting system of any authorized type. (USAF NA)

3.1.53 Inner-Transitional OFZ. The inner-transitional OFZ is the airspace above the surfaces located on the outer edges of the runway OFZ and the inner-approach OFZ. It applies to runways with approach visibility minimums less than ¾ statute miles (SM). (USAF NA)

3.1.54 Initial Approach Fix (IAF). A fix that identifies the beginning of an initial approach segment.

3.1.55 Instrument Landing System (ILS). A precision instrument approach system which normally consists of a localizer, glide slope, outer marker (or suitable substitute, inner marker for Category II operations below RVR 1600, and an approach lighting system.

3.1.56 Intermediate fix (IF). The fix that identifies the beginning of the intermediate approach segment of an instrument approach procedure. The fix is not normally identified on the instrument approach chart as an IF.

3.1.57 International Standard Atmosphere (ISA). A model of standard variation of pressure and temperature.

3.1.58 Knots Indicated Airspeed (KIAS). The speed shown on the aircraft airspeed indicator.

See March 1, 2013 Clarification Memo

3.1.59 Landing Threshold Point (LTP). The LTP is a 3D point at the intersection of the runway centerline and the runway threshold (RWT). WGS-84/NAD-83 latitude, longitude, MSL elevation, and geoid height define it. For WAAS approach procedures, it is used in conjunction with the FPAP and the geometric center of the WGS-84 ellipsoid to define the vertical plane of an RNAV FAC. (USAF must use WGS-84 latitude and longitude only.)

Note: Where an FTP is used, apply LTP elevation (LTP_E).

3.1.60 Lateral Navigation (LNAV). LNAV is RNAV lateral navigation. This type of navigation is associated with nonprecision approach procedures (NPA) because vertical path deviation information is not provided. LNAV criteria are the basis of the LNAV minima line on RNAV GPS approach procedures.

3.1.61 Lateral Navigation/Vertical Navigation (LNAV/VNAV). An approach with vertical guidance (APV) evaluated using the Baro VNAV obstacle clearance surfaces conforming to the lateral dimensions of the LNAV obstruction evaluation area (OEA). The final descent can be flown using Baro VNAV, or LPV vertical guidance in accordance with Advisory Circular (AC) 90-97, Operational Approval of Barometric VNAV Instrument Approach Operations Using Decision Altitude.

3.1.62 **Localizer Performance (LP).** An LP approach is an RNAV NPA procedure evaluated using the lateral obstacle evaluation area dimensions of the precision localizer trapezoid, with adjustments specific to the WAAS. These procedures are published on RNAV GPS approach charts as the LP minima line.

3.1.63 **Localizer (LOC).** The component of the ILS which provides course guidance to the runway.

3.1.64 **Localizer Performance with Vertical Guidance (LPV).** An approach with vertical guidance (APV) evaluated using the OCS dimensions (horizontal and vertical) of the precision approach trapezoid, with adjustments specific to the WAAS. These procedures are published on RNAV GPS approach charts as the LPV minima line.

See March 1, 2013 Clarification Memo

3.1.65 **Maximum Allowable Descent Rate** (**MDR**). A vertical velocity limit of 1000 ft per minute. Design of Baro-VNAV approaches must ensure the MDR is not exceeded.

3.1.66 **Minimum Descent Altitude (MDA).** The lowest altitude, expressed in feet above mean sea level, to which descent is authorized on final approach where no glide slope is provided, or during a circle-to-land maneuver.

3.1.67 **Minimum En Route Altitude (MEA).** The lowest published altitude between radio fixes which assures acceptable navigational signal coverage and meets obstacle clearance requirements between those fixes. The MEA prescribed for a Federal airway or segment thereof, area navigation low or high route, or other direct route applies to the entire width of the airway, segment, or route between the radio fixes defining the airway, segment, or route.

3.1.68 **Non-Vertically Guided Procedures** (**NVGP**). Instrument approach procedures without vertical guidance. As used in this Order, NVGP include LNAV and LP approach procedures.

3.1.69 **Obstacle Clearance Surface (OCS).** An OCS is an upward or downward sloping surface used for obstacle evaluation where the flight path is climbing or descending. The separation between this surface and specified glidepath angle or minimum required climb path defines the MINIMUM required obstruction clearance at any given point.

3.1.70 **Obstacle Evaluation Area (OEA).** An area within defined limits that is subjected to obstacle evaluation through application of required obstacle clearance (ROC) or an OCS.

3.1.71 **Obstacle Free Zones (OFZ).** A three dimensional volume of airspace which protects for the transition of aircraft to and from the runway. Included are the Runway OFZ, the Inner-approach OFZ, and the Inner-transitional OFZ.

3.1.72 **Obstacle Identification Surface (OIS).** The OIS is an inclined surface conforming to the lateral dimensions of the OEA used for identification of obstacles that may require mitigation to maintain the required level of safety for the applicable segment. An OIS is normally associated with the visual portion of the FAS.

3.1.73 **Obstacle Positions ($OBS_{X,Y,Z}$).** $OBS_{X,\ Y\ \&\ Z}$ are the along track distance to an obstacle from the LTP, the perpendicular distance from the centerline extended, and the MSL elevation, respectively, of the obstacle clearance surfaces.

See March 1, 2013 Clarification Memo

3.1.74 **Precise Final Approach Fix (PFAF).** The PFAF is a calculated WGS-84 geographic position located on the final approach course where the designed vertical path (NPA procedures) or glidepath (APV and PA procedures) intercepts the intermediate segment altitude (glidepath intercept altitude). The PFAF marks the beginning of the FAS. The calculation of the distance from LTP to PFAF includes the earth curvature.

3.1.75 **Q Routes.** 'Q' is the designator assigned to published high altitude RNAV-based ATS routes in the United States.

3.1.76 **Reserved.**

3.1.77 **Radius to Fix (RF) Leg.** An RF leg is a constant radius circular repeatable path about a defined turn center that begins and terminates at a fix.

3.1.78 **Reference Datum Point (RDP).** The RDP is a 3D point defined by the LTP or FTP latitude/longitude position, MSL elevation, and a threshold crossing height (TCH) value. The RDP is in the vertical plane associated with the FAC and is used to relate the GPA of the final approach track to the landing runway. It is also referred to as the TCH point or FPCP.

3.1.79 **Reference Fix.** A point of known location used to geodetically compute the location of another fix.

3.1.80 **Reference Line.** For fix turns less than 90 degrees, a line parallel to the course line after the turn fix where an additional set(s) of turn area expansion arcs are centered.

3.1.81 **Reference Navigational Aid (NAVAID).** A navigational facility required for various leg construction (e.g., CF) to assign a magnetic variation to the course.

3.1.82 **Required Navigation Performance (RNP**). RNP is a statement of the 95 percent navigation accuracy performance that meets a specified value for a particular phase of flight or flight segment and incorporates associated on-board performance monitoring and alerting features to notify the pilot when the RNP for a particular phase or segment of a flight is not being met.

3.1.83 **Required Obstruction Clearance (ROC).** Sometimes referred to as required obstacle clearance, ROC is the minimum vertical clearance (in feet) that must exist between aircraft and the highest ground obstruction within the OEA of instrument procedure segments.

3.1.84 **Runway Threshold (RWT).** The RWT marks the beginning of the portion of the runway usable for landing. It extends the full width of the runway.

3.1.85 **Standard Instrument Approach Procedure (SIAP).** Instrument approach procedures published in the Federal Register under Title 14 of the Code of Federal Regulations (14 CFR) Part 97.

3.1.86 **Standard Instrument Departure (SID).** A preplanned instrument flight rule (IFR) air traffic control (ATC) departure procedure printed for pilot/controller use in graphic form to provide obstacle clearance and a transition from the terminal area to the appropriate en route structure. SIDs are primarily designed for system enhancement to expedite traffic flow and to reduce pilot/controller workload. ATC clearance must always be received prior to flying a SID.

3.1.87 **Standard Terminal Arrival (STAR).** A preplanned instrument flight rule (IFR) ATC arrival procedure published for pilot use in graphic and/or textual form. STARs provide transition from the en route structure to an outer fix or an instrument approach fix/arrival waypoint in the terminal area.

3.1.88 **Start of Climb (SOC).** The SOC is a point located at a calculated flat-surface length distance from the decision altitude for LNAV/VNAV or the missed approach point for LNAV and LP or at the end of section 1 for LPV/GLS procedures.

3.1.89 **Threshold Crossing Height (TCH).** The height of the glidepath above the threshold of the runway measured in feet. The LPV glidepath originates at the TCH value above the LTP.

3.1.90 **Track to Fix (TF) Leg.** A TF leg is a geodesic path between two fixes. The resulting track is wind corrected.

3.1.91 **True Airspeed (KTAS).** The airspeed of an aircraft relative to undisturbed air. KTAS is the KIAS corrected for air density error. KTAS increases with altitude when KIAS remains constant.

3.1.92 Turn Anticipation. The capability of RNAV airborne equipment to determine the location of the point along a course, prior to a FB fix which has been designated a turn fix, where a turn is initiated to provide a smooth path to intercept the succeeding course.

3.1.93 Turn Fix. A FB or FO fix denoting a course change.

3.1.94 Turn Initiation Area (TIA). The straight portion of a missed approach OEA whose end is identified by a turn at a specified altitude.

3.1.95 Vertical Error Budget (VEB). The VEB is a set of allowable values that contribute to the total error associated with a VNAV system. Application of equations using the VEB values determines the minimum vertical clearance that must exist between an aircraft on the nominal glidepath and ground obstructions within the OEA of instrument procedure segments. When the VEB is used in final segment construction, its application determines the OCS origin and slope ratio.

3.1.96 Visual Glide Slope Indicator (VGSI). The VGSI is an airport lighting aid that provides the pilot with a visual indication of the aircraft position relative to a specified glidepath to a touchdown point on the runway. PAPI and VASI are examples of VGSI systems.

3.1.97 Visual Segment. The visual segment is the portion of the FAS OEA between the DA and the LTP.

3.1.98 Waypoint (WP).

3.1.99 Wide Area Augmentation System (WAAS). The WAAS is a navigation system based on the GPS. Ground correction stations transmit position corrections that enhance system accuracy and add satellite based VNAV features.

3.2 Information Update.

For your convenience, FAA Form 1320-19, Directive Feedback Information, is included at the end of this order to note any deficiencies found, clarification needed, or suggested improvements regarding the contents of this revision. When forwarding your comments to the originating office for consideration, please provide a complete explanation of why the suggested change is necessary.

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United States Standard for

Performance Based Navigation (PBN)

<u>Volume 2</u>

Helicopter Area Navigation (RNAV)

RESERVED

Table of Contents

Paragraph No. ***Page No.***

VOLUME 2. UNITED STATES STANDARD FOR HELICOPTER AREA NAVIGATION (RNAV)

United States Standard for

Performance Based Navigation (PBN)

See March 1, 2013
Clarification Memo

Volume 3

RNAV and RNP 1 Departure Procedures

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Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 1. General Criteria

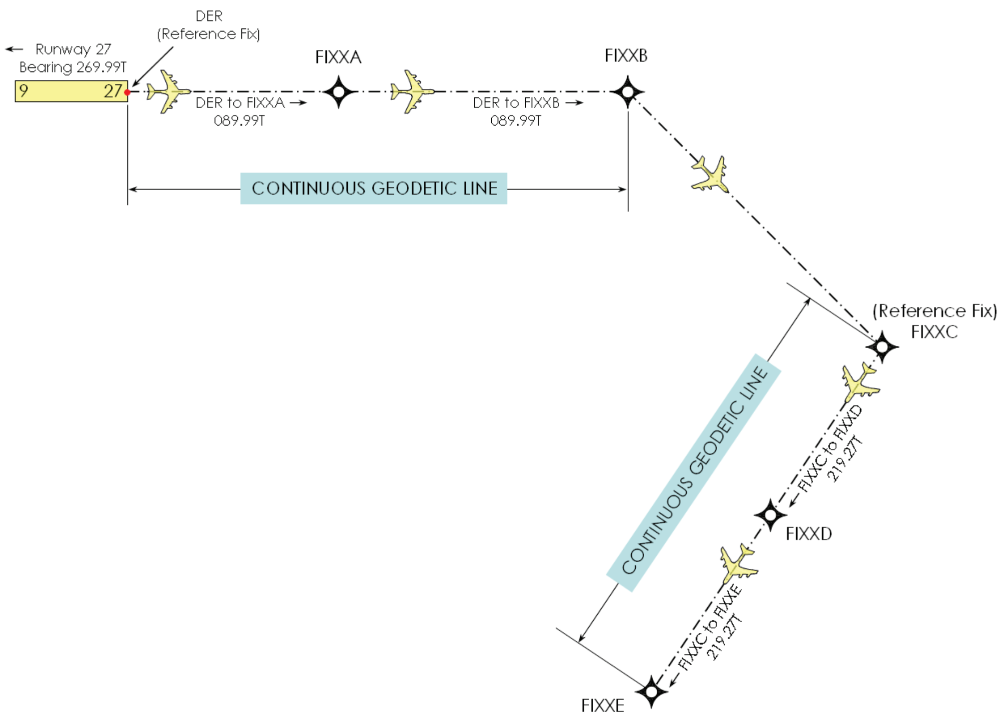
1.0 **Criteria Design Standards.** Use these standards to develop RNAV1and RNP1 instrument DPs. RNAV1is defined in AC 90-100A and RNP1operations are described in AC 90-105. This volume provides flexibility so procedure designers can select fix and leg type as required. Although ARINCleg combinations are included, this volume does not contain procedure coding guidance; DPsshould be coded as required to achieve the designed flight track. To aid in computer programming, mathematical calculations for area construction are presented as imbedded calculators.

1.1 **Fix Use.** To the extent practical and efficient, use existing fixes/NAVAIDs. FBfixes are recommended for procedure design; use FOfixes only when operationally necessary
or for obstacle clearance. Utilize fixes to designate restrictions/changes to course, speed, and/or altitude. ATTvalues are included in Volume 1 paragraph 2.1.5.

1.2 **Fix Definition.** The depiction below outlines a brief example of where a departure fix is on the extended runway centerline and how coordinates are determined. The coordinates are established using the reciprocal of the opposite direction runway true bearing and the appropriate distance applied from the DER. Where two or more segments are aligned along a continuous geodetic line, align and construct all succeeding fixes based on a true bearing and distance from the first reference fix in the sequence. Where turns are established, use the turn fix as the reference fix to construct succeeding fixes and segments aligned on a continuous geodetic line following the turn (see figure 1-1).

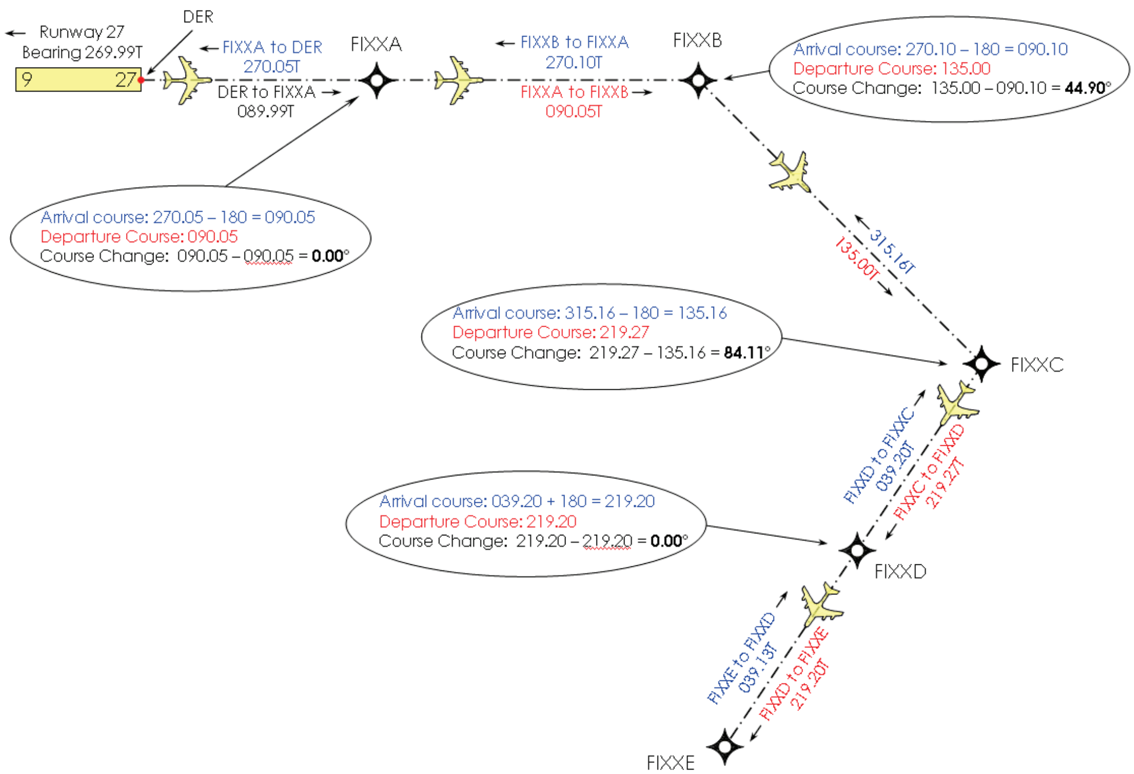
Implementation of this volume is conditional on the development of Companion Software Requirements Specifications that fully address applicable construction/design rules. Previous manual application may be grandfathered until automation can be fully implemented.

Figure 1-1. Fix Definition Example



1.3 **Course Change at Fixes.** The illustration below provides a course change example and how course is determined. The departure course at a particular fix is the bearing from that fix to the following fix. The arrival course at a particular fix is the reciprocal of the course from that fix to the preceding fix. The difference between the departure course and the arrival course at a fix equals the amount of turn at that fix (see figure 1-2).

Figure 1-2. Course Change Example



1.4 VAand VILeg Length Standards.

1.4.1 For LNAVengagement, VAlegs must be designed to end at least 500 ft above the airport elevation.

1.4.2 The minimum allowable VIleg length is the greater of 1NMfrom DERor the distance required to achieve 500 ft above the airport elevation. To allow a WP less than 2 NM from the DER without a climb gradient imposed, a fly-over WP may be used and published. No turn greater than 15° is permitted at this WP, and a succeeding WP must be established for a DF leg.

See March 1, 2013 Clarification Memo

1.4.3 The maximum allowable VAor VIleg length is 10NM.

1.5 Additional Leg Length Standards.

1.5.1 For segment length considerations, turns of 10degrees or less are considered straight. Comply with minimum leg length standards available in Volume 6 paragraph 1.3 unless construction rules require a greater length.

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1.6 **Segment Full Width Standards.** Comply with width guidelines defined in Volume 6 paragraph 1.1, except area increases to full en route width crossing 30NMfrom ARP. See paragraph 3-11.

1.7 **CFLeg Magnetic Variation Reference.** Specify an on-airport NAVAIDsubject to Order 8260.19 chapter 2 section 5 guidelines. Where not available, specify any NAVAIDthat can be reasonably expected to have characteristics of variation (ideally within 3degrees of departure airport), direction, and annual rate of change as close as possible to the departure airport.

1.8 **Naming Conventions, Computer Codes, Charting, and Documentation Instructions.** In addition to Order 8260.46 instructions, use the following guidance:

1.8.1 RNAV-1will be the default designation for RNAVDPs. RNP-1will be designated for all RNP1DPs. Annotate procedures with a standard note: "RNAV-1" or "RNP-1" on FAA Form 8260-15B (see Order 8260.46, appendix E).

1.8.2 All RNAVand RNP1DPswill contain a note that describes the equipment sensor limitations. Notes, as appropriate, are as follows:

Note 1: "DME/DME/IRUor GPSRequired"

Note 2: "GPSRequired"

1.8.3 A note may be required to address the need for specific DMEfacilities to be operational, for example, "For Non-GPSEquipped aircraft, ABC, JKL, and XYZ DMEsMust Be Operational." These are referred to as critical DMEfacilities.

1.8.4 Except as required by Order 8260.46 paragraph 2-1f(3), all RNAVor RNP1DPsthat are annotated "DME/DME/IRUor GPSREQUIRED" must also be annotated with the note "RADAR REQUIRED FOR NON-GPSEQUIPPED AIRCRAFT."

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Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 2. Construction Calculations

2.0 Projected Altitude (Alt_{proj}). To determine the highest altitude within the turn, determine the projected altitude for a known distance using calculator 2-1. The calculation assumes a climb of 500 ft/NM below 10000 MSL and 350 ft/NM at or above 10000 MSL. Utilize this altitude for applicable construction calculations.

Calculator 2-1. Projected Altitude

(1) $d_{500} = round[d_{500}, 0]$ $\quad d_{350} = round[d_{350}, 0]$

(2) **case** $(Start_{elev} \geq 10000)$:

$$Alt_{proj} = (r + Start_{elev}) \times e^{\frac{350 \times d_{350}}{r}} - r$$

case $(Start_{elev} < 10000)$:

$$Alt_{proj} = (r + Start_{elev}) \times e^{\frac{500 \times d_{500}}{r}} - r + (r + 10000) \times e^{\frac{350 \times d_{350}}{r}} - (r + 10000)$$

(3) **case** $(alt \text{ is not null AND } Alt_{proj} \geq alt)$: $Alt_{proj} = alt$

Where $Start_{elev}$ = segment starting MSL elevation
d_{500} = distance at climb gradient 500 in NM
d_{350} = distance at climb gradient 350 in NM
alt = published maximum MSL altitude (cap) if applicable

Calculator 2-1		
$Start_{elev}$		Calculate
d_{500}		
d_{350}		
alt		Clear
Alt_{proj}		

Note: OEA analysis may result in an altitude greater than the projected altitude. As an alternative, utilize a higher fix crossing altitude where required.

2.1 True Airspeed (V_{KTAS}). Determine the true airspeed using Volume 6 calculator 1-3a and Volume 6 table 1-3.

2.2 Tailwind (V_{KTW}). Calculate the tailwind component using Volume 6 calculator 1-3b.

2.3 Turn Radius (R). Establish the Turn Radius using Volume 6 calculator 1-3c.

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2.4 **Bank Angle.** Do not exceed the maximum bank angles listed in Volume 6 paragraph 1.2.

2.5 **DTA.** Distance of Turn Anticipation is a calculated value for use in determining minimum straight segment lengths where a turn is required at the initial and/or termination fix; see Volume 6 calculator 1-6.

2.6 **VA Segment Distance.** Where necessary, calculate segment distance using calculator 2-2.

Calculator 2-2. VA Segment Distance

case *(specified climb gradient):* $d = \dfrac{r \times fpnm \times \ln\left(\dfrac{r + TA}{r + DER_{elev}}\right)}{CG}$

case *(standard climb gradient):* $d_{200} = \dfrac{r \times fpnm \times \ln\left(\dfrac{r + TA}{r + DER_{elev}}\right)}{200}$

Where DER_{elev} = *DER MSL elevation*
TA = Turning (Climb-to) MSL Altitude
CG = climb gradient

Calculator 2-2		
DER_{elev}		Calculate
TA		
CG		Clear
d		

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2.7 **VA Segment Termination Altitude.** Calculate the termination altitude achieved at the end of a segment using calculator 2-3.

Calculator 2-3. VA Termination Altitude

$$Alt_{term} = \textbf{ceiling}\left[\frac{(r+DER_{elev})\times e^{\left(\frac{CG\times d}{r}\right)}-r}{100}\right]\times 100$$

Where DER_{elev} = DER MSL elevation

CG = Climb Gradient

d = VA segment distance in NM

Calculator 2-3		
DER_{elev}		Calculate
CG		
d		Clear
Alt_{term}		

2.8 **VA-DF Feasibility**. Evaluate VA-DF leg lengths using the VA-DF calculator in the "TERPS Tools" section of the Flight Procedure Standards Branch web site or using TARGETS.

2.9 **ROC, CG, and Climb Gradient Termination Altitude Calculation**. Determine ROC, CG, and climb gradient termination altitude (CG_{term}) using calculator 2-4.

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Calculator 2-4. ROC, CG, and Climb Gradient Termination Altitude

(1) *Note: CG is calculated in ft/NM. To convert to a percentage, use CG% = (ft/NM)×30.48/1852*

Where d_{OBS} *= shortest primary area distance to obstacle in NM*

OBS_{elev} *= obstacle MSL elevation*

$Start_{elev}$ *= Start MSL elevation*

d_{SOBS} *= perpendicular distance (feet) in the secondary area from primary area boundary, zero (0) if not in secondary area*

(2) $h = OBS_{elev} - Start_{elev}$

(3) *Remark- Calculate ROC, CG,* CG_{term}

case(*obstacle located in primary*): $ROC = \textbf{ceiling}\left[\frac{h}{0.76} - h\right]$

case(*obstacle located in secondary*): $ROC = \textbf{ceiling}\left[\left(\frac{h}{0.76} - h\right) - \frac{d_{SOBS}}{12}\right]$

(4) $CG = \textbf{ceiling}\left[\frac{r}{d_{OBS}} \times \ln\left(\frac{r + OBS_{elev} + ROC}{r + Start_{elev}}\right)\right]$

(5) $CG_{term} = 100 \times \textbf{ceiling}\left[\frac{OBS_{elev} + ROC}{100}\right]$

Calculator 2 4		
d_{OBS}		Calculate
OBS_{elev}		
$Start_{elev}$		
d_{SOBS}		Clear
ROC		
CG		
CG_{term}		

Implementation of this volume is conditional on the development of Companion Software Requirements Specifications that fully address applicable construction/design rules. Previous manual application may be grandfathered until automation can be fully implemented.

Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 3. Area Construction

See March 1, 2013 Clarification Memo

3.0 **Segment Areas.** Area construction is dependent upon segment leg lengths, turn magnitudes and established calculations. Ensure area construction meets leg length and turn magnitude criteria standards. Where the fix outbound course differs by more than 0.03 degrees from the fix inbound course (courses measured at the fix), a turn is indicated.

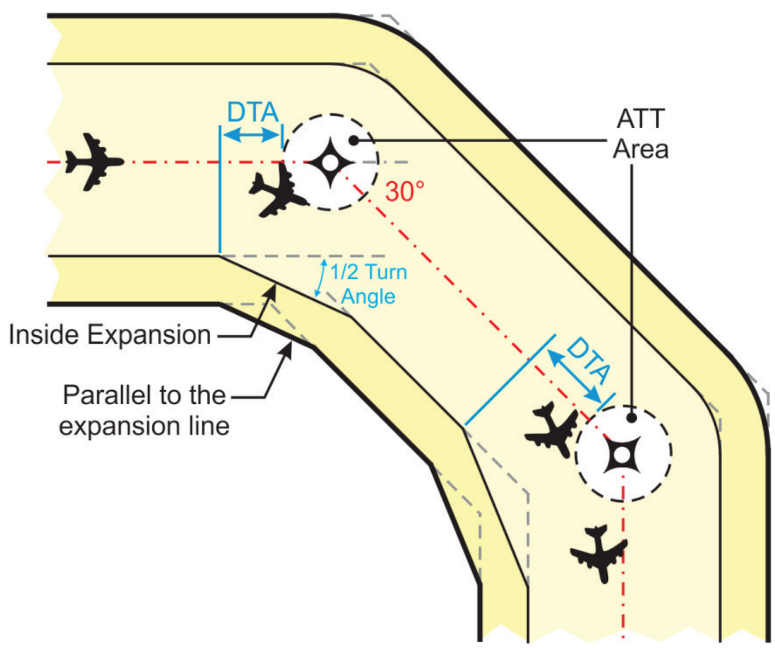
3.1 **Course Change Limitations.** For turns to join a CF or TF leg, the maximum allowable course change or magnitude of heading change below FL 195 is 90 degrees; course changes at or above FL 195 must not exceed 70 degrees.

3.2 **Fly-By Fix Turn Construction.**

3.2.1 **Inside Expansion Area.** DTA areas vary and are based upon the altitude at each fix.

3.2.1 **a. Known as the fix ETP**, the inside expansion origin is based on the calculated DTA, Volume 6 calculator 1-6. DTA is measured parallel to the course along the primary area boundary from the beginning of the ATT area. Increase the primary area at the ETP by an angle equal to one-half of the course change at the fix. Construct the secondary area boundary, parallel with the primary expansion boundary, using the full secondary area width (see figure 3-1).

Figure 3-1. FB Fix Turn



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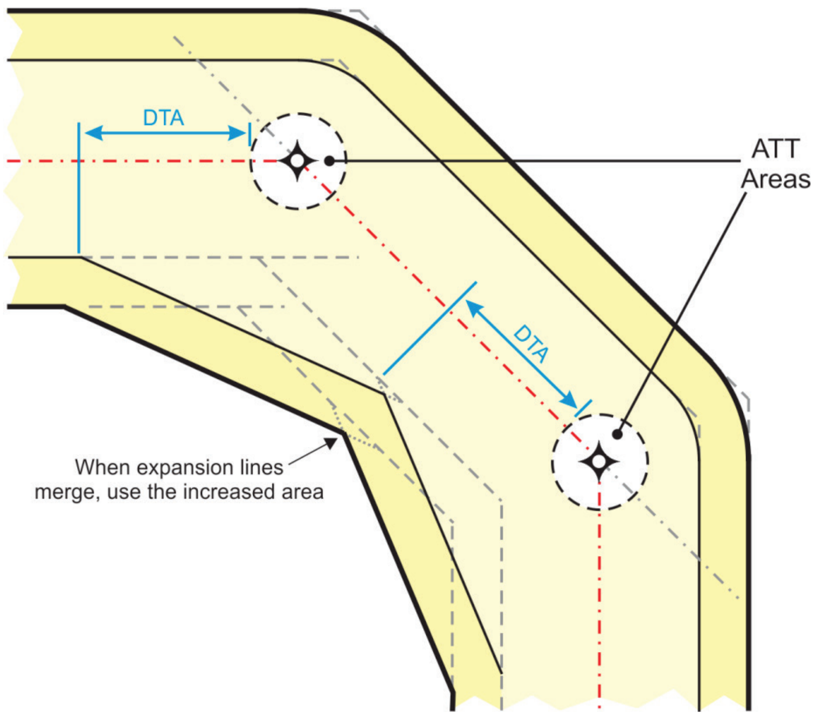
3.2.1 **b. In some cases, the calculated DTA** may cause the expansion lines to merge, increasing the size of the expanded areas. This construction is permissible; utilize the increased area (see figure 3-2).

Figure 3-2. FB Fix Turns, Merging Expansion Lines



3.2.2 **Outside Area Structure.** The outside area structure does not expand. From the fix, draw the primary boundary arc with a radius equal to the area half width and secondary area boundary arc equal to the primary area half width plus the width of the secondary.

3.3 Fly-Over Fix Turn Construction.

3.3.1 **Inside Area Structure.** Inside primary and secondary area segment boundaries intersect, no expansion is required.

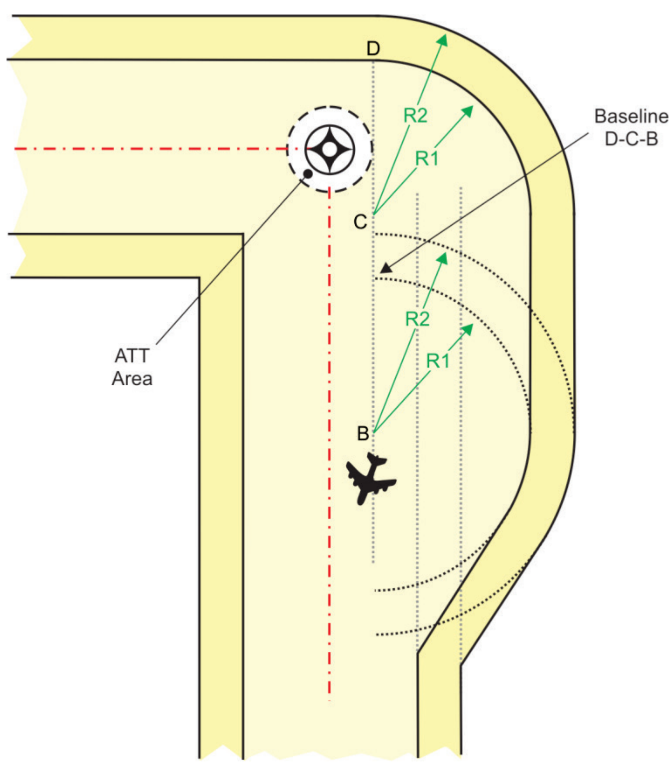
3.3.2 **Outside Expansion Area, TF, or CF Legs.** The primary area boundary (R1) is the calculated Turn Radius, Volume 6 calculator 1-3c, based on the altitude at the fix. The secondary area boundary (R2) is the calculated Turn Radius value plus 1 NM or, where beyond 30 NM from the ARP, the calculated Turn Radius plus 2 NM. Where the R1 and R2 boundary arcs cannot connect tangentially with lines 30 degrees relative to the outbound track, continue the arcs until intersecting the outbound standard-width boundaries.

3.3.2 **a. Turns less than 90 degrees.** After the ATT area, construct a baseline perpendicular to the inbound course to construct an arc(s) to establish boundaries of the outside expansion areas. Locate point C on the baseline based on the R2 value from the inbound segment boundary. Using point C as a center point, draw an arc with a radius equal to the R2 value from the inbound segment boundary. Draw a second arc with a radius equal to the R1 value, using C as a center point, from the baseline (point D). The point C arcs connect tangentially with lines 30 degrees relative to the outbound track that joins with the primary and secondary area boundaries.

Note: For turns near 90 degrees, additional outside turn protection may be required. Construct another set of R1 and R2 arcs using point B as the center point as outlined in paragraph 3.3.2b. Where these additional arcs penetrate the tangent 30 degree lines from the point C arcs, they shall be included in OEA construction.

3.3.2 **b. 90 degree turns.** Construct R1 and R2 arcs from point C as defined in paragraph 3.3.2a. From where the inbound primary boundary would intersect the baseline, locate point B on the baseline at a distance equal to the R2 value. Draw another set of R1 and R2 arcs for additional outside turn protection, using point B as the center point, in the same manner as the arcs from point C; the point B arcs are the same calculated values as the point C arcs. Connect the outside arcs with tangent lines to form the outside expanded area. The arcs of point B connect tangentially with lines 30 degrees relative to the outbound track that joins with the primary and secondary area boundaries (see figure 3-3).

**Figure 3-3. FO Fix Turn,
TF or CF Leg, 90 degree Turn**



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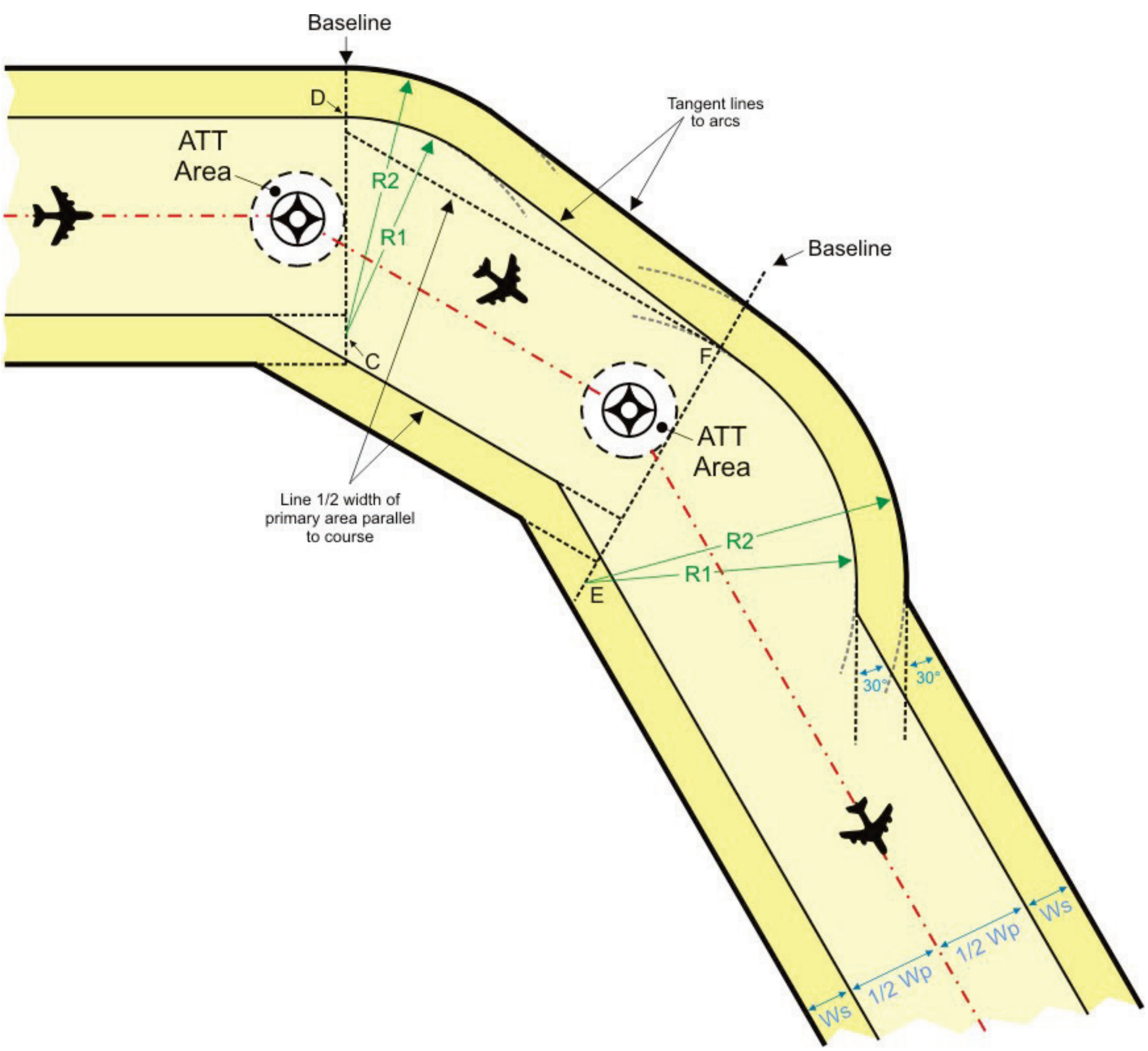
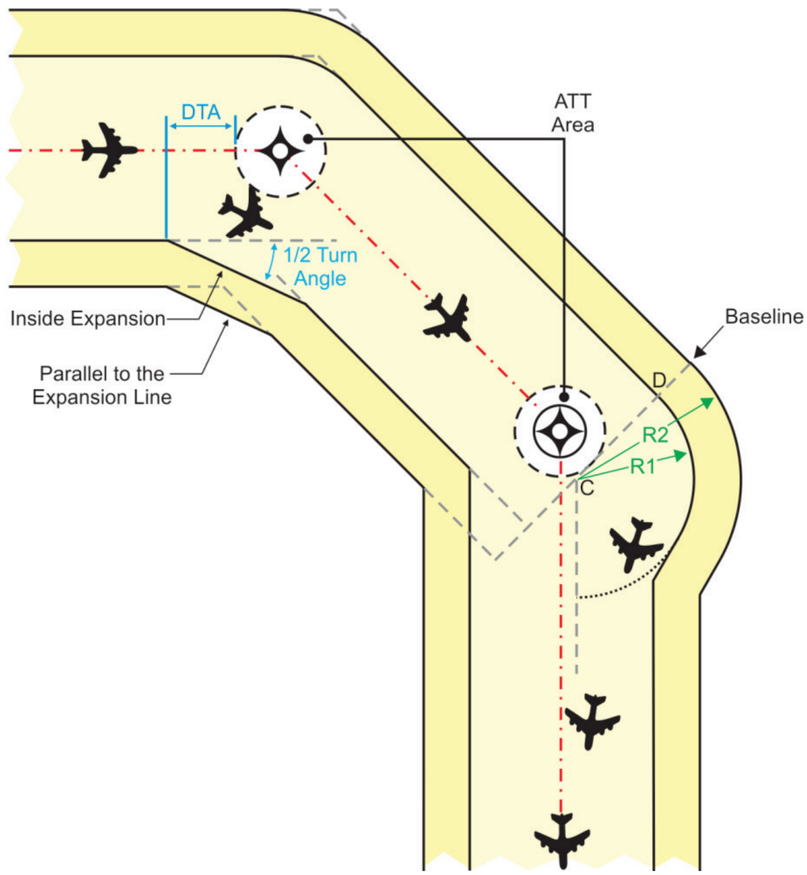
3.3.2 **c. Successive FO Fixes.** Applicable to successive FO fixes in close proximity, construct another baseline after the ATT area of the subsequent fix for the outside expansion boundaries. Construct a line on the outside of the turn, parallel to the course, offset by a distance one-half the segment width. Locate point F where the baseline intersects the segment one-half width line. Locate point E on the baseline at a distance of R1 from point F, based upon the altitude at the subsequent fix, from point F. Using E as a center point, draw arcs R1 and R2. Connect, via tangent lines, the arcs centered at C and E. The arcs of point E connect tangentially with lines 30 degrees relative to the outbound track that joins with the primary and secondary area boundaries (see figure 3-4).

Figure 3-4. Successive FO Fix Turns



3.3.3 **Expansion Areas for FB Fix to FO Fix.** Apply paragraph 3.2 for FB area construction and paragraph 3.3 for FO area construction (see figure 3-5).

Figure 3-5. FB Fix to FO Fix Turns



3.3.4 **Expansion Areas for FO Fix to FB Fix.** Apply paragraph 3.3 for FO area construction and paragraph 3.2 for FB area construction (see figure 3-6).

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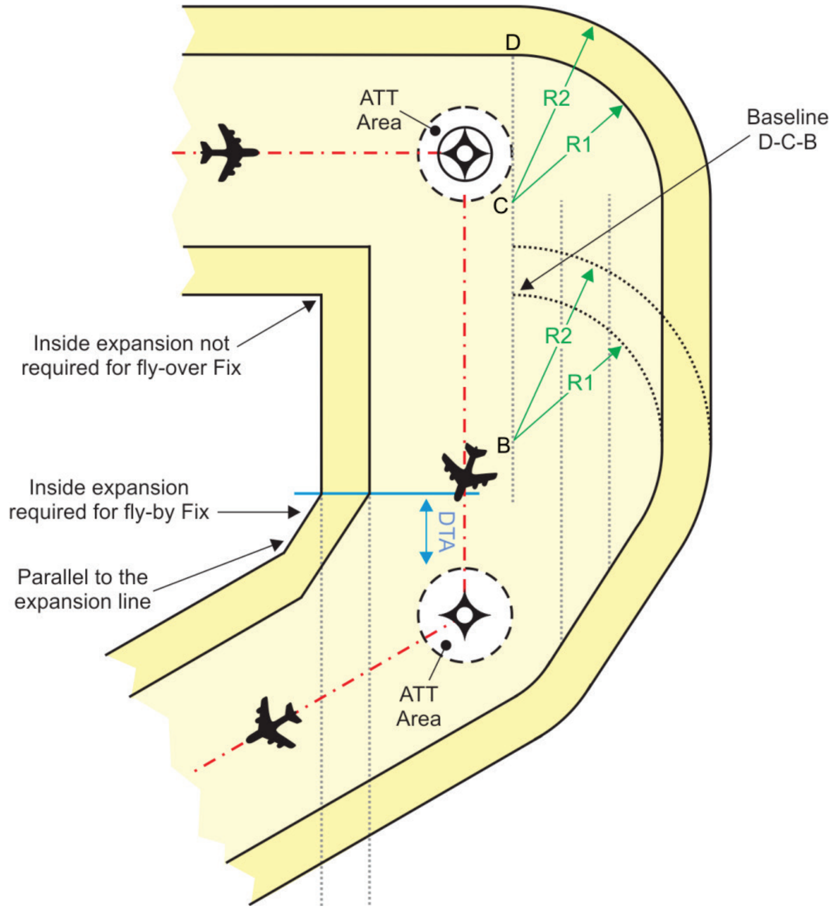
Figure 3-6. FO Fix to FB Fix Turns



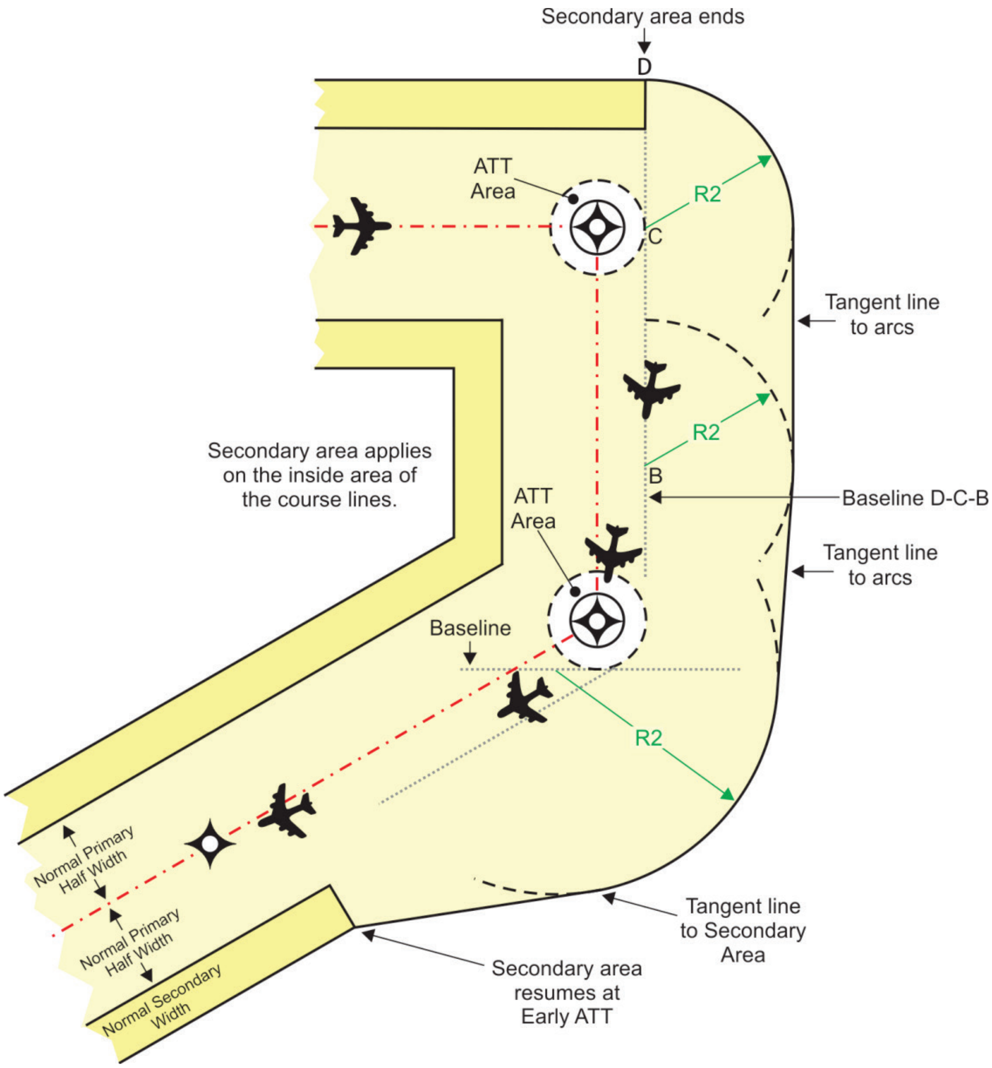
3.3.5 DF Leg FO Turn Construction.

3.3.5 a. **After turning at a FO fix,** obstacle clearance is provided as if the aircraft rolls out and flies direct from the rollout point to another fix, either FB or FO. The outside expansion area is all-primary area and encompasses areas of successive FO fixes; outside secondary areas are not applicable. Based upon the altitude at the fix, the outside boundary R2 arc is the calculated Turn Radius, Volume 6 calculator 1-3c, plus 1 or 2 NM as appropriate.

3.3.5 b. **After the ATT area,** construct a baseline to establish an arc for the outside boundary; label the secondary boundary on this baseline as point D. Locate point C at a distance of R2 from point D on the baseline. Using point C as a center point, swing the arc from point D. Draw a tangent line from the arc to the subsequent leg outer boundary to complete the outside boundary.

3.3.5 c. **For turns near 90 degrees,** locate point B on the baseline measured from the inside-turn primary boundary at the same R2 distance. Draw another R2 arc, using point B as the center point, from the inbound leg primary area width distance on the baseline to form a second expansion arc. Where this arc intersects the tangent line from the point C arc to the subsequent leg outer boundary, it must also be included. Join the two arcs by a tangent line to create the outside boundary. For 90 degree turns, construct the R2 arc, using point B as the center point, from the inbound leg primary area width distance on the baseline and join the two arcs by a tangent line to create the outside boundary (see figure 3-7).

Figure 3-7. DF Leg, FO Turn Construction 90 degrees or Less

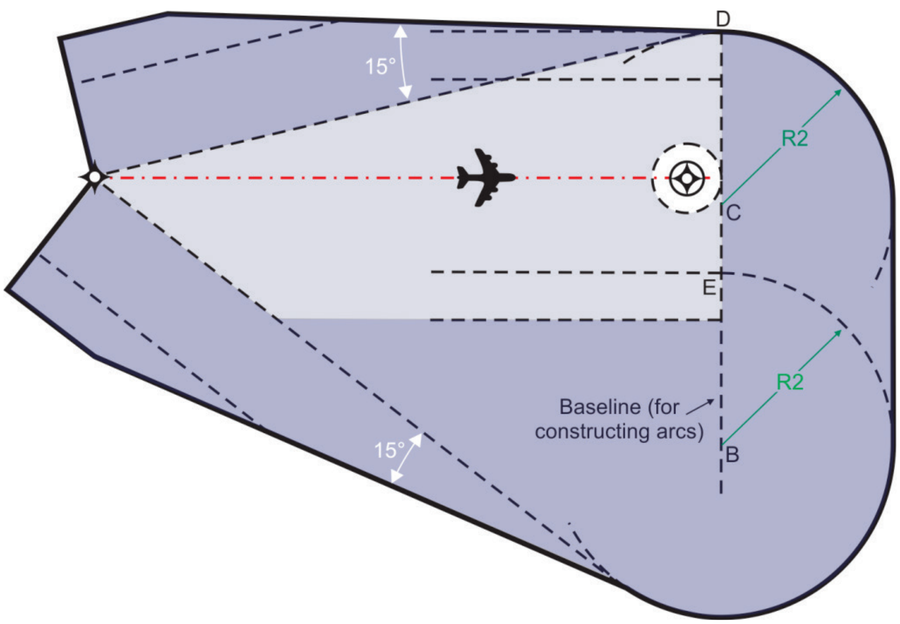


3.3.5 d. **For turns more than 90 degrees,** all inbound primary and secondary boundaries continue until the ATT area baseline. Locate point B at the same R2 distance from the inbound leg primary area width on the baseline (point E). Draw another R2 arc, using point B as the center point, from point E to form a second expansion arc. Join the two arcs by a tangent line to create the outside boundary.

3.3.5 d. (1) Draw a tangent line from the point B arc direct to the subsequent leg termination fix. From this line, splay 15 degrees to construct the outer boundary line until it reaches the combined dimensions of the primary and secondary width. The splay ends at the combined width and the boundary line then parallels the tangent line from the second arc until abeam the subsequent leg termination fix. Where a 15-degree splay does not reach the combined primary and secondary area width dimensions prior to or abeam the subsequent leg termination fix, create the boundary with a tangent line drawn from the combined width abeam the termination fix to the point B arc.

3.3.5 d. (2) On the non-turning side from the subsequent leg termination fix, draw a tangent line to the point C arc. From this line, splay 15 degrees to construct the outer boundary line until it reaches the combined dimensions of the primary and secondary width. The splay ends at the combined width and the boundary line, then parallels the tangent line from the termination fix until abeam the fix. Where a 15-degree splay does not reach the combined primary and secondary area width dimensions prior to or abeam the subsequent leg termination fix, create the boundary with a tangent line drawn from the combined width abeam the termination fix to the point C arc (see figure 3-8).

Figure 3-8. DF Leg, FO Turn Construction 180 degrees



3.4 **ICA.** Where the first departure leg terminates at a fix, the ICA ends at the fix ETP. Where a CF or DF is the first procedure leg and the leg terminates at a FB fix, utilize VI-CF leg construction in paragraph 3.9 or 3.10. Where a CF or DF is the first procedure leg and the leg terminates at a FO fix, apply paragraph 3.3 and 3.8. See Order 8260.3 Volume 4 for ICA specifics.

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3.5 **VA Legs.** Unless a higher gradient is required for obstacle clearance, utilize a standard climb gradient for area construction to determine the distance required to reach the designated climb-to altitude, see calculator 2-2 for distance calculation. See calculator 2-3 to calculate an altitude for a designated segment distance. The location where the climb-to altitude is reached concludes the ICA and is the leg termination point. Based upon the climb-to altitude at the leg termination point, the outside turn arc R2 is the calculated Turn Radius, Volume 6 calculator 1-3c, plus 1 NM.

3.6 **VI Legs.** VI legs are normally associated with CF legs as part of an initial DP design with a turn to intercept the CF leg constructed similar to a FB fix turn. The VI leg terminates at the intercept point to conclude the ICA. 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.

3.7 **VA or VI Leg Construction.** VA and VI leg segments are all-primary areas and the departure course is aligned on the extended runway centerline. As a minimum, the ICA 15-degree splays continue until leg termination; draw a perpendicular line where the leg terminates to conclude the ICA.

3.8 **VA-DF Leg Combinations** (see chapter 5 for leg length analysis)**.** The OEA consists of the ICA, 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. The subsequent DF leg, including inside and/or outside turn expansion areas, is an all-primary area and segment width is equal to the primary and secondary width dimensions combined abeam the DF leg termination fix (point S and point T).

3.8.1 **VA-DF Leg Combinations, Turns Less Than 90 degrees.**

3.8.1 **a. Inside Expansion Area.**

3.8.1 a. (1) From the DRP, draw a line to the subsequent leg termination fix. Create an outer 15-degree splay from this line to establish the inside turn boundary. The boundary continues to splay 15 degrees until area width equals full primary and secondary area width dimensions combined then the boundary parallels the DRP line until abeam the subsequent leg termination fix (point S) (see figure 3-9).

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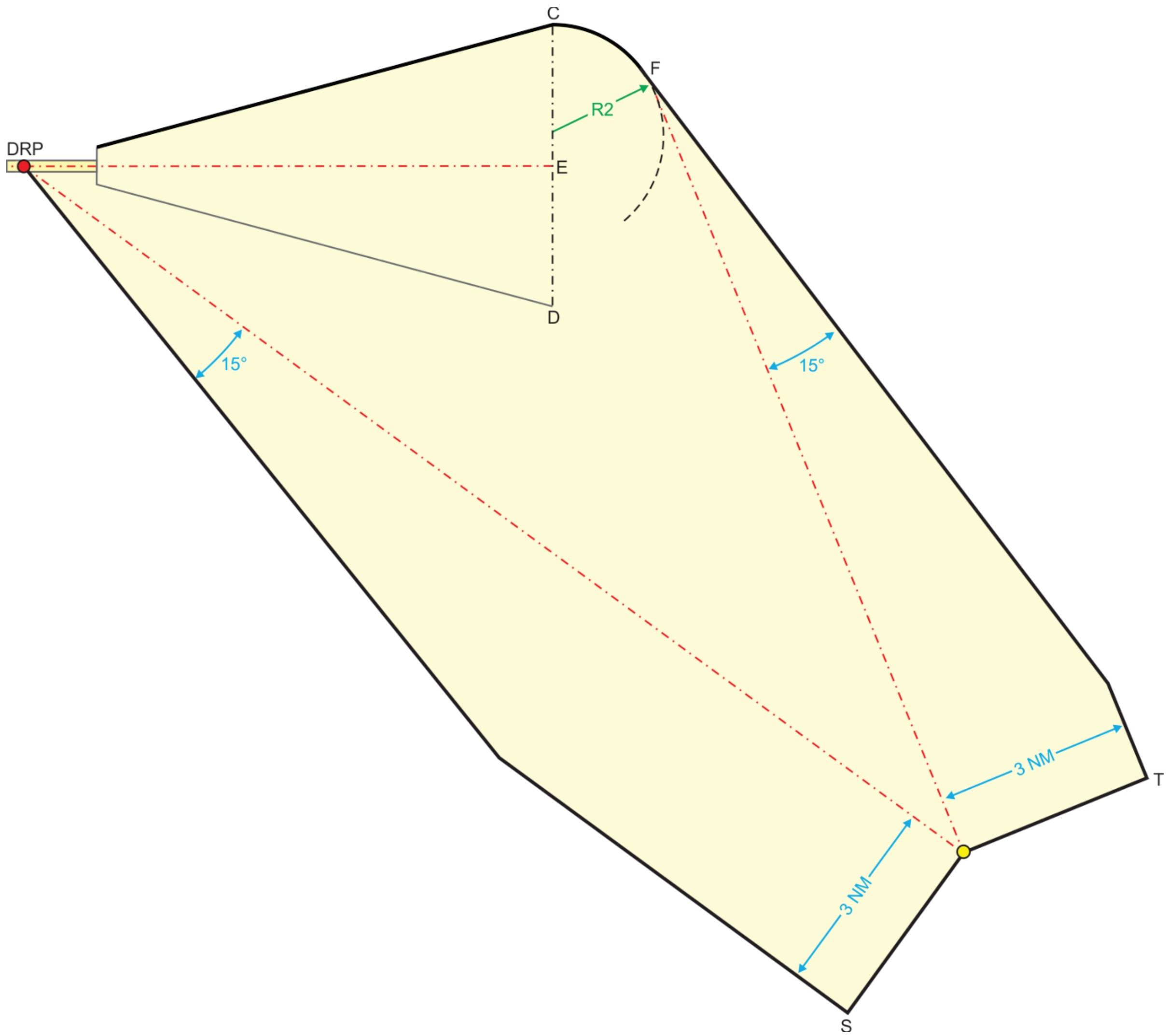
Figure 3-9. VA-DF Construction – Turn less than 90 degrees, DRP Inside Boundary Line



3.8.1 a. (2) Where the inside turn boundary does not reach the combined primary and secondary area width dimensions prior to or abeam the subsequent leg termination fix, create the boundary with a line drawn from the DRP to point S.

3.8.1 a. (3) Where the inside turn boundary intersects the ICA inside 15-degree splay line (see figure 3-10A), the boundary shall be a line beginning from point S, drawn back to point A and another line drawn from point A to the DRP (see figure 3-10B).

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Figure 3-10A. VA Leg Construction Alternate Inside Boundary

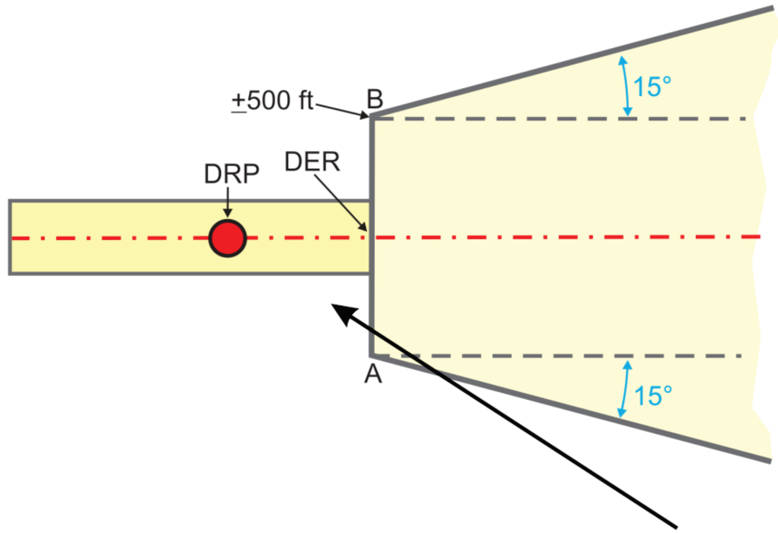
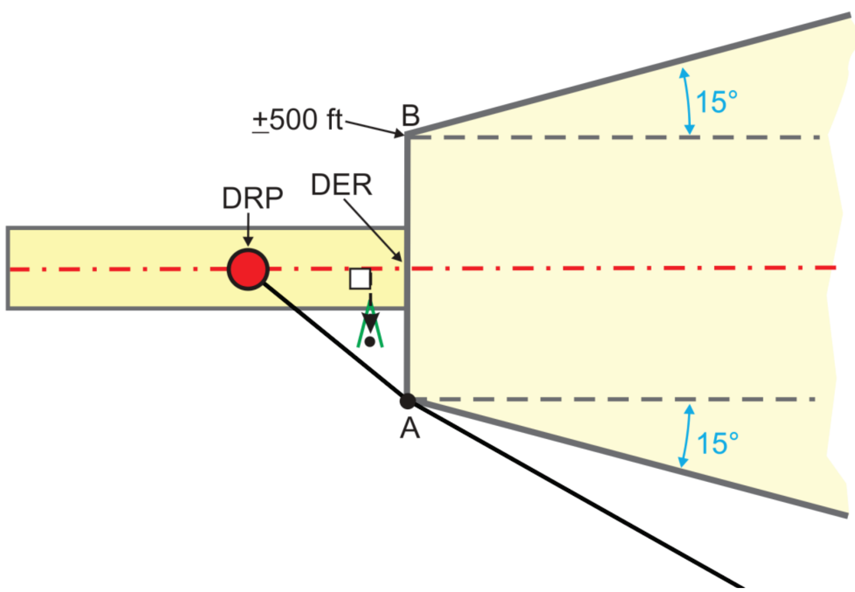


Figure 3-10B. VA Leg Construction Alternate Inside Boundary



3.8.1 b. Outside Expansion Area.

3.8.1 b. (1) The outside arc R2 begins at point C; center the arc on the perpendicular line (or an extension of this line) at the end of the VA leg. From the point C arc, draw a tangent line (identify tangent location as point F) to the subsequent leg termination fix. Create a 15-degree splay from this line to establish the outside turn expansion line. The 15-degree splay continues until area width equals full primary and secondary area width dimensions combined, then the boundary parallels the arc tangent line until abeam the subsequent leg termination fix (point T) (see figure 3-9).

Note: For turns near 90 degrees, construct a second outside arc from point D as outlined in paragraph 3.8.2c. Where this arc intersects the point F tangent line, it must also be included.

3.8.1 b. (2) Draw the outside boundary from point C direct to point T where paragraph 3.8.1b(1) design does not establish the combined primary and secondary full width dimensions at point T.

3.8.2 VA-DF Leg Combinations, Turns 90 degrees or more but less than 180 degrees.

3.8.2 **a. Inside Expansion Area.** Construct the inside turn expansion line to the DRP as specified in paragraph 3.8.1a.

3.8.2 **b. Outside Expansion Area.** Construct the outside area R2 arc as specified in paragraph 3.8.1b.

3.8.2 **c. Additional Outside Expansion Area.**

3.8.2 c. (1) Begin a second arc, with the same calculated Turn Radius, Volume 6 calculator 1-3c, of the first arc and also centered on the perpendicular line at the end of the segment, from point D to protect aircraft which may begin the turn in this vicinity. Construct a line tangent to both arcs (point F to point G) and construct another tangent line from the second arc (point H) to the DF leg termination fix. Create a 15-degree splay from this line to establish the outside turn expansion line. The 15-degree splay continues until area width equals full primary and secondary area width dimensions combined, then the boundary parallels the arc tangent line until abeam the DF leg termination fix (point T) (see figure 3-11).

3.8.2 c. (2) Draw the outside boundary from point G direct to point T where paragraph 3.8.2c(1) design does not establish the combined primary and secondary full width dimensions at point T.

Note: For turns near 180 degrees, construct an early turn protection arc as outlined in paragraph 3.8.3c. Where this arc intersects the point H tangent line, it must also be included (see figure 3-12).

Figure 3-11. VA-DF Construction
Turn more than 90 degrees

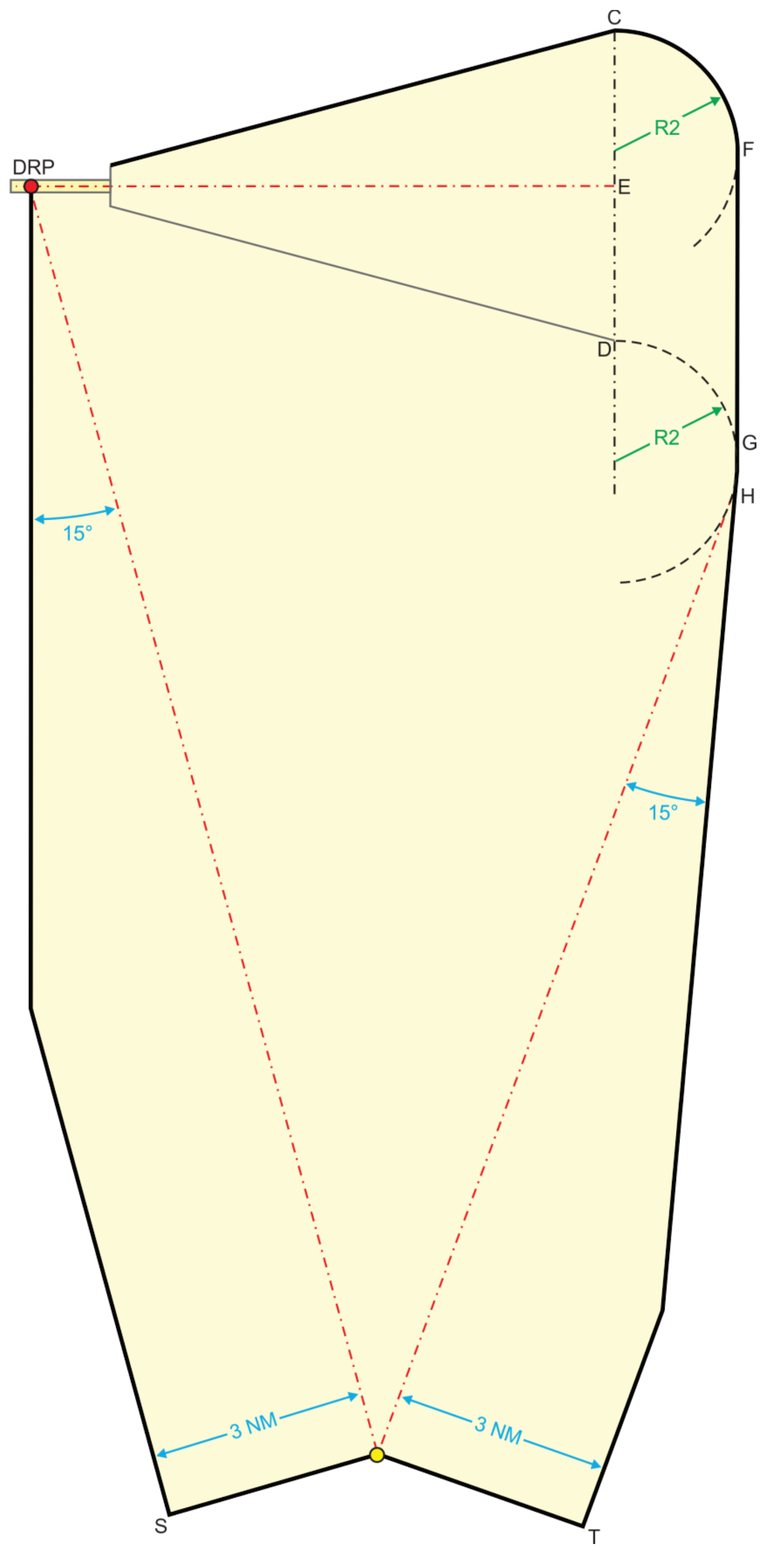
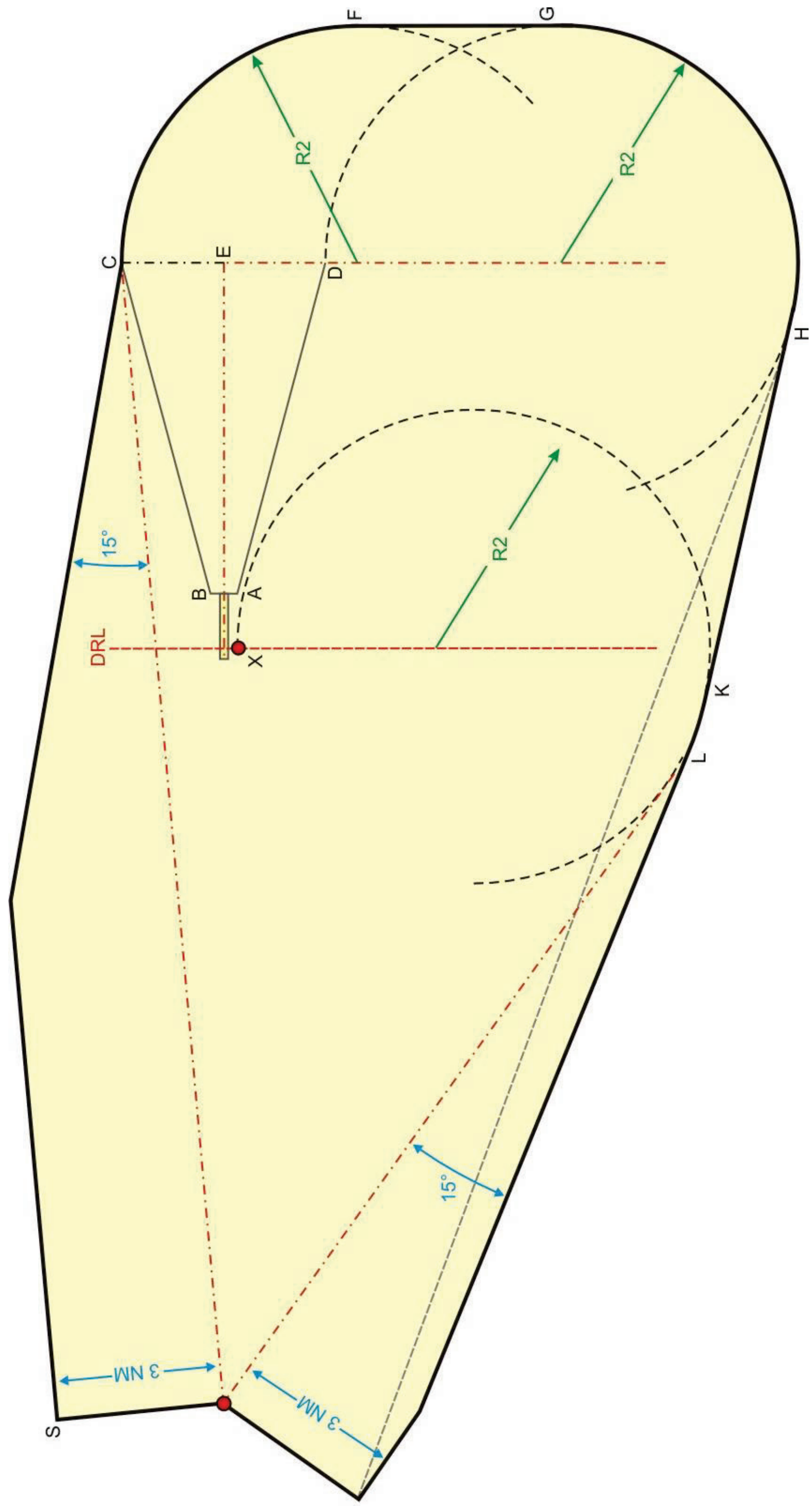


Figure 3-12.VA-OF Construction
180 degree Right Turn



3.8.3 VA-DF Leg Combinations, Turns 180 degrees or more.

3.8.3 **a. Inside Expansion Area.** Draw a line from point C to the DF leg termination fix. From this line, splay 15 degrees outward to construct the outer boundary until reaching the combined dimensions of the primary and secondary width. The splay ends at the combined width and the boundary line, then parallels the line to the DF leg termination fix until abeam the fix (point S). Where a 15-degree splay does not reach the combined primary and secondary area width dimensions prior to or at point S, create the boundary with a line drawn from point C to point S (see figure 3-12).

3.8.3 **b. Outside Expansion Area.** Construct two outside expansion arcs based on the calculated Turn Radius, Volume 6 calculator 1-3c, distance as specified in paragraphs 3.8.2b and 3.8.2c.

3.8.3 **c. Early Turn Protection Area.** A third arc is included to protect aircraft that may turn prior to the end of the VA leg. Based on the same calculated Turn Radius of the first arc, the arc begins at point X (500 ft from the runway centerline, centered on the DRL and abeam point A). Create the early turn expansion by drawing a tangent line from the second arc (point H) to the third arc (point K). Construct a tangent line from the third arc (point L) to the subsequent leg termination fix. Create a 15-degree splay from this line to establish the outside turn expansion line. The 15-degree splay continues until area width equals full primary and secondary area width dimensions combined, then the boundary parallels the arc tangent line until abeam the subsequent leg termination fix (point T) (see figure 3-12). Draw the outside boundary from point K direct to point T where design does not establish the combined primary and secondary full width dimensions at point T.

3.9 **Standard VI-CF Leg Combination Construction, Turns 90 degrees or less** (see figure 3-13). The VI leg is an all primary area and the CF leg secondary areas begin at the rollout point at full width.

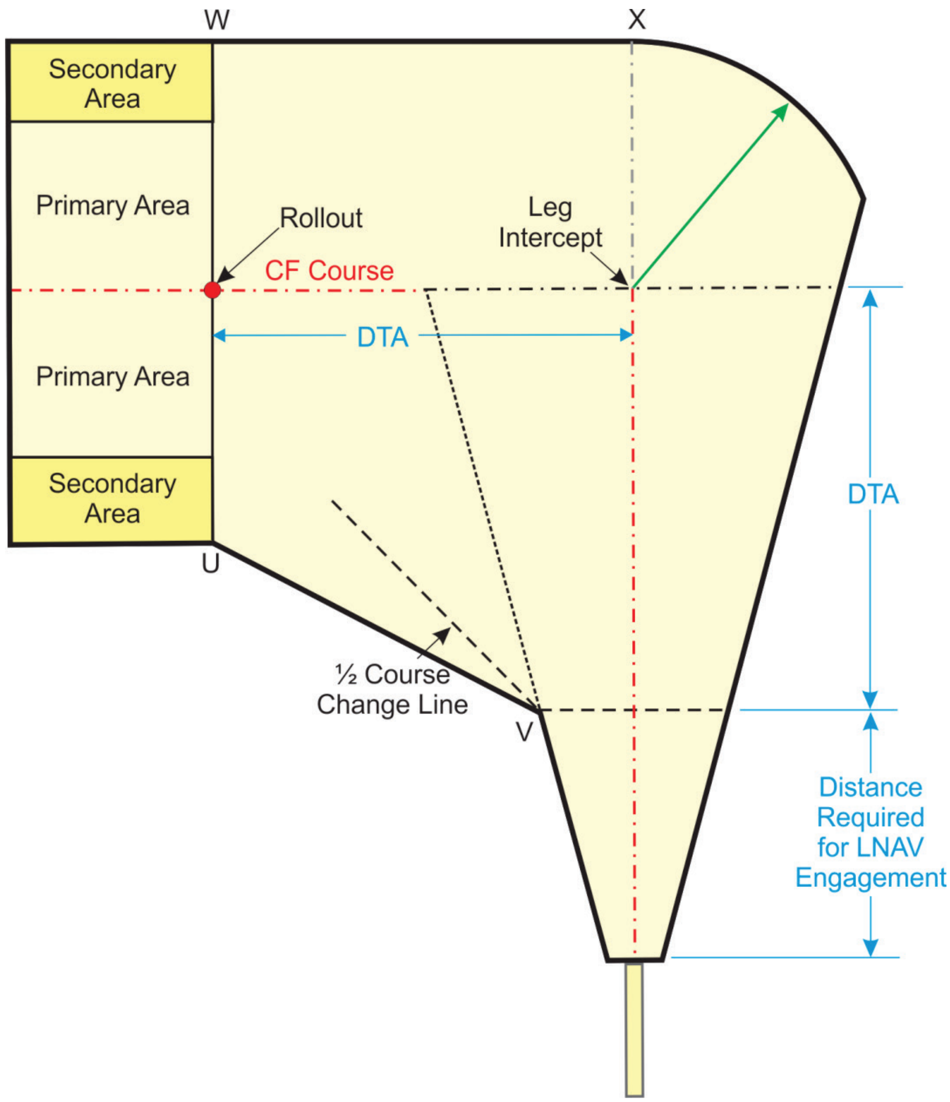
3.9.1 **Inside Expansion Area.** Inside expansion starts where the VI DTA area begins (point V) with an angle drawn at one-half of the course change at leg intercept and ends where the angle converges with the CF leg secondary boundary. Where the angle does not converge with the secondary boundary, draw a line from point V to the inside secondary area boundary abeam the rollout (point U) for area completion.

3.9.2 **CF Leg Construction.** Along the CF leg course, a rollout point is established from leg intercept at a distance of the calculated DTA, Volume 6 calculator 1-6, 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.

3.9.3 **Outside Expansion Area.** Outside protection is provided by constructing a line parallel to the CF leg course from the outside secondary area boundary abeam the rollout (point W) until intersecting the extended runway centerline (point X). Draw a

3 NM arc centered at leg intercept from point X until intersecting an extended outside ICA 15-degree splay line drawn beyond leg intercept to complete the area.

Figure 3-13. Standard VI-CF Construction, 90 degree Turn



3.10 Minimum VI-CF Leg Combination Construction, Turns 90 degrees or Less. 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 to 500 ft above the 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.

3.10.1 Inside Expansion Area.

3.10.1 a. **For turns of 30 degrees or less,** splay 15 degrees relative to the CF leg course from point A and continue this line until intersecting the CF leg secondary area boundary (see figure 3-14). The secondary area begins where this line crosses the primary area boundary.

3.10.1 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 figures 3-15 thru 3-17).

3.10.2 **CF Leg Construction.** Along the CF leg course, a rollout point is established from leg intercept at a distance of the calculated DTA, Volume 6 calculator 1-6, 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.

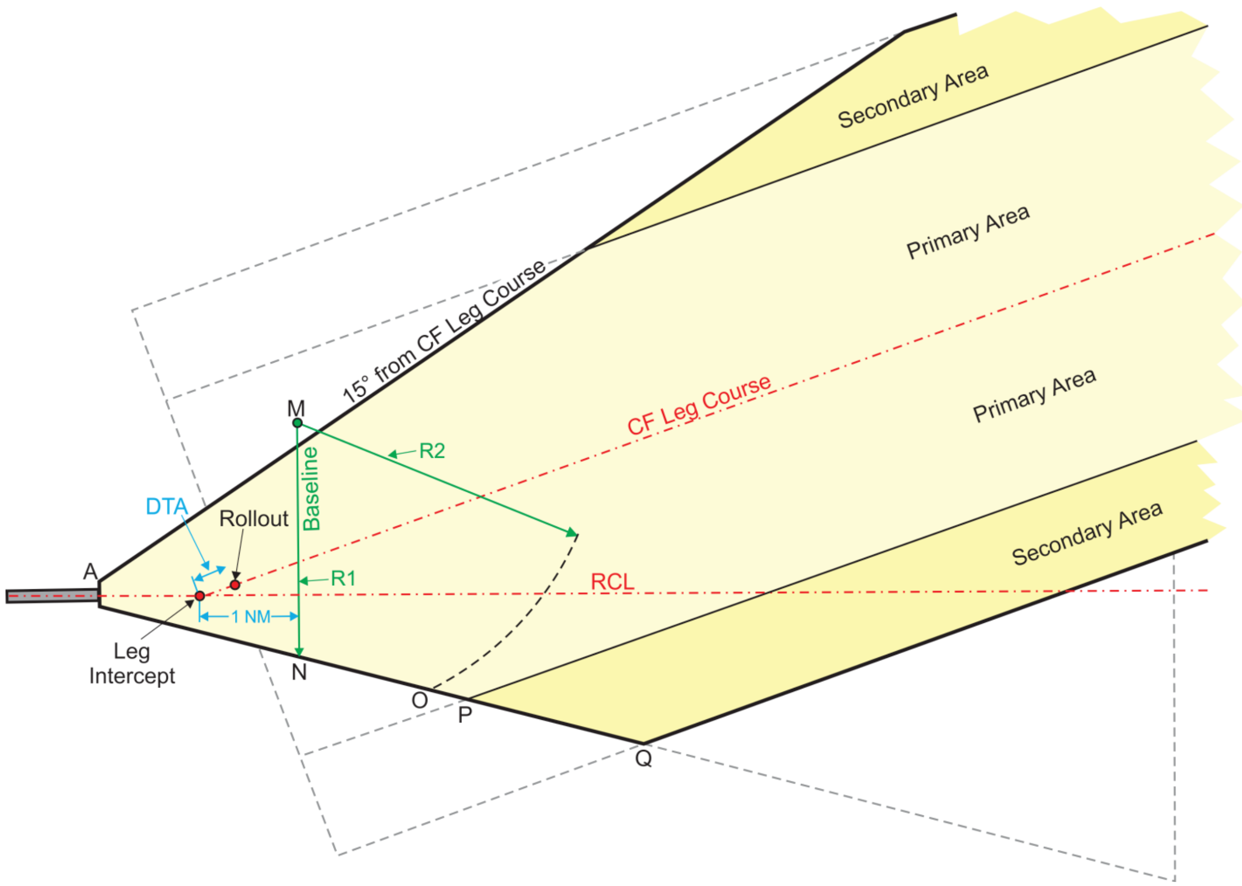
3.10.3 Outside Expansion Area.

3.10.3 a. **Establish a baseline 1 NM** past leg intercept perpendicular to the extended RCL. Locate point N at the intersection of the baseline and the outside ICA 15-degree splay line. Locate point M on the baseline from point N at a distance based upon the calculated Turn Radius, Volume 6 calculator 1-3c, determined by the altitude at leg intercept.

3.10.3 b. **Centered on point M,** the outside R2 arc is the calculated Turn Radius plus 1 NM and begins from the outside ICA 15-degree splay line (point O). Outside construction is based upon the R2 arc in relation to the primary and secondary areas boundaries of the CF leg.

3.10.3 c. **Where the R2 arc is inside** the CF leg primary area, the arc is not necessary. Instead, continue the outside ICA 15-degree splay line until intersecting the CF leg secondary boundary (point Q). The CF leg secondary area begins where the ICA splay crosses the CF leg primary area boundary (point P), see figure 3-14.

Figure 3-14. Minimum VI-CF Construction, Turn 30 Degrees or Less



3.10.3 d. **Where the R2 arc extends into** the CF leg secondary area, the arc is also not necessary. Instead, continue the outside ICA 15-degree splay line until intersecting the CF leg secondary boundary (point Q). From the beginning of the secondary area at point Q, taper 30 degrees inward relative to the CF leg course until intersecting the CF leg primary area boundary (see figure 3-15).

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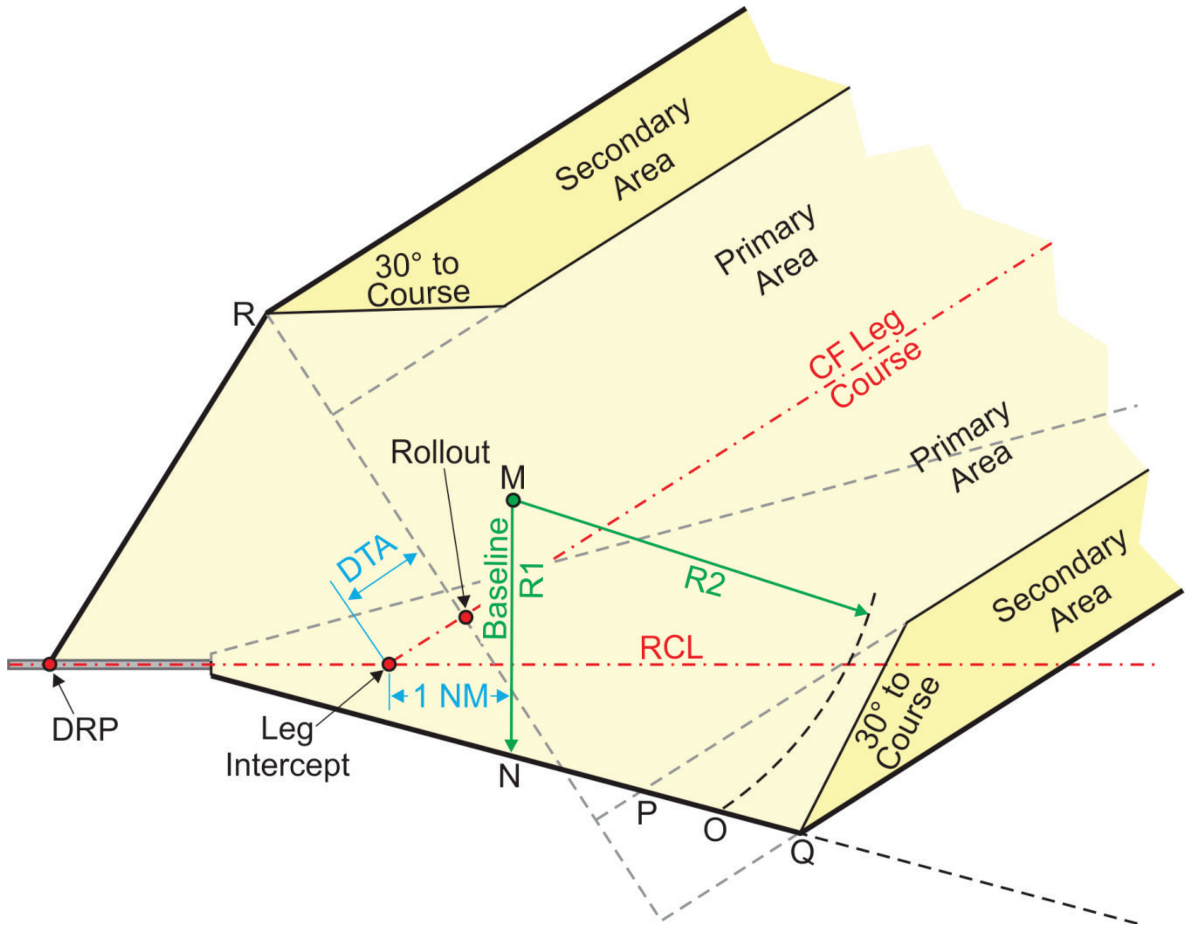
Figure 3-15. Minimum VI-CF Construction, Greater than 30 degree Turn



3.10.3 e. **Where the R2 arc continues outside** the CF leg secondary area boundary, the arc continues until reaching a tangent point to a line tapering 30 degrees inward relative to the CF leg course. The CF leg outside secondary area starts where the 30-degree taper line crosses the CF leg secondary boundary (see figure 3-16).

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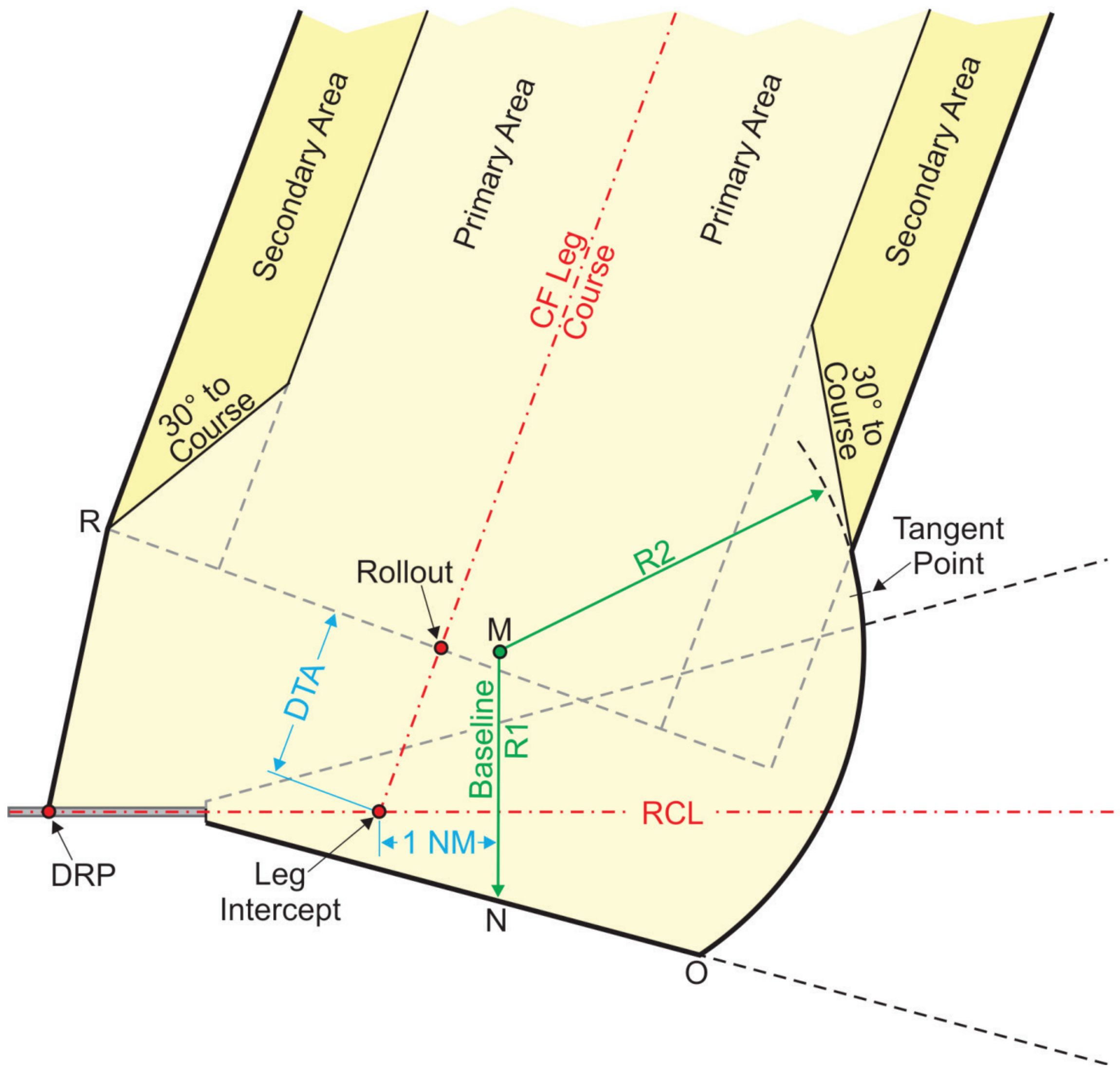
Figure 3-16. Minimum VI-CF Construction, 75 degree Turn



3.10.3 f. **For 90-degree turns,** locate point S along an extended baseline from point M at a distance based on the same calculated Turn Radius. Construct another outside R2 arc centered on point S based on the calculated Turn Radius plus 1 NM. Connect the two arcs with a tangent line and continue the second arc until reaching a tangent point to a line tapering 30 degrees inward relative to the CF leg course. The CF leg outside secondary area starts where the 30-degree taper line crosses the CF leg secondary boundary (see figure 3-17).

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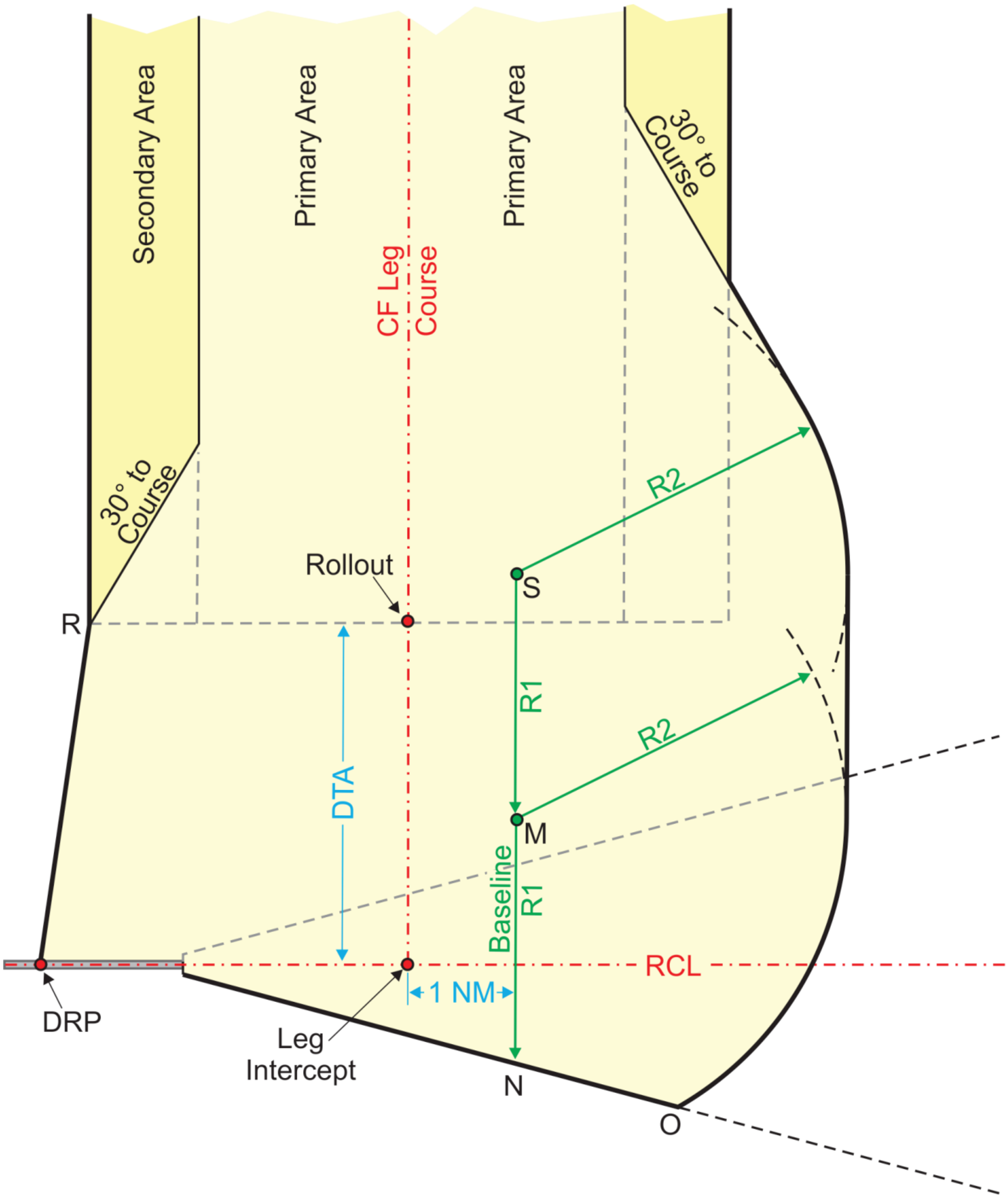
Figure 3-17. Minimum VI-CF Construction, 90 degree Turn



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3.11 Departure Area Width Joining En Route Width (crossing 30 NM from ARP) or Airway.

3.11.1 **Where the DParea width** has reached en route width and a turn is not required, the segment boundaries merge. If a turn is required, construct as specified in paragraph 3.2 or 3.3.

3.11.2 **Where the DParea width is less than** en route width:

3.11.2 **a. And a turn is not required,** the DPprimary and secondary areas immediately increase to en route width at the fix or NAVAIDwhere the DPjoins the airway/en route width.

3.11.2 **b. And a FB turn is established.**

3.11.2 **b.** (1) When the DTAarea begins at or prior to the intersection of the DP/en route width primary and secondary area boundaries expansion is required. On the inside turn expand the DPprimary and secondary boundaries at an angle equal to one-half of the course change as specified in paragraph 3.2. On the outside turn, increase to en route width adjacent to the intersection of the en route area except when joining an airway. When joining an airway extend the DPouter boundary until it merges with airway boundary.

3.11.2 **b.** (2) Where the DTAareas begins at or after the intersection of the DP/airway primary and secondary area boundaries, the segment boundaries merge (no inside or outside expansion is required).

3.11.2 **c. And a FOturn is established,** no inside expansion is required. The DPoutside area is as specified in paragraph 3.3.

3.12 **Departure Altitude.** Establish a departure altitude, which is the highest altitude of: the lowest MEAor highest MCAfor the direction of flight, an altitude that will allow random (diverse) IFRflight, an altitude where ATCradar service is provided, or an altitude that provides obstacle clearance with a standard climb gradient.

3.13 **End of Departure.** The departure evaluation terminates at an altitude that will allow random (diverse) IFRflight or at a fix/NAVAIDwhere radar service can be provided or a climb-in-hold evaluation is required.

Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 4. OEA Assessment

See March 1, 2013 Clarification Memo

4.0 **Obstacle Evaluation.** ICA obstacles are measured by the shortest distance from the DER to the obstacle beginning at the DER elevation. Obstacles abeam the runway or outside the ICA are calculated by the shortest primary area distance from the RCL or the DER, whichever is shortest, to the obstacle beginning at the DER elevation. Where applicable for VA-DF construction, obstacles in section 2 are evaluated utilizing only the shortest primary area distance from the DRP beginning at the VA segment termination MSL altitude (see figure 4-1). For all succeeding segments, the primary area is evaluated utilizing the shortest primary area distance to the obstacle (see figure 4-2). Where leg OEAs overlap, obstacles are evaluated in each leg.

4.1 **ROC.** All primary area obstacles are evaluated for the minimum climb gradient required to provide ROC (see Order 8260.3, Vol. 1, paragraph 203). In the secondary area, measure the 12:1 secondary OCS perpendicular to the nominal track. In expansion areas (arc, diagonal, corner-cutter, etc.), the slope rises perpendicular to the primary area boundary (see calculator 2-4).

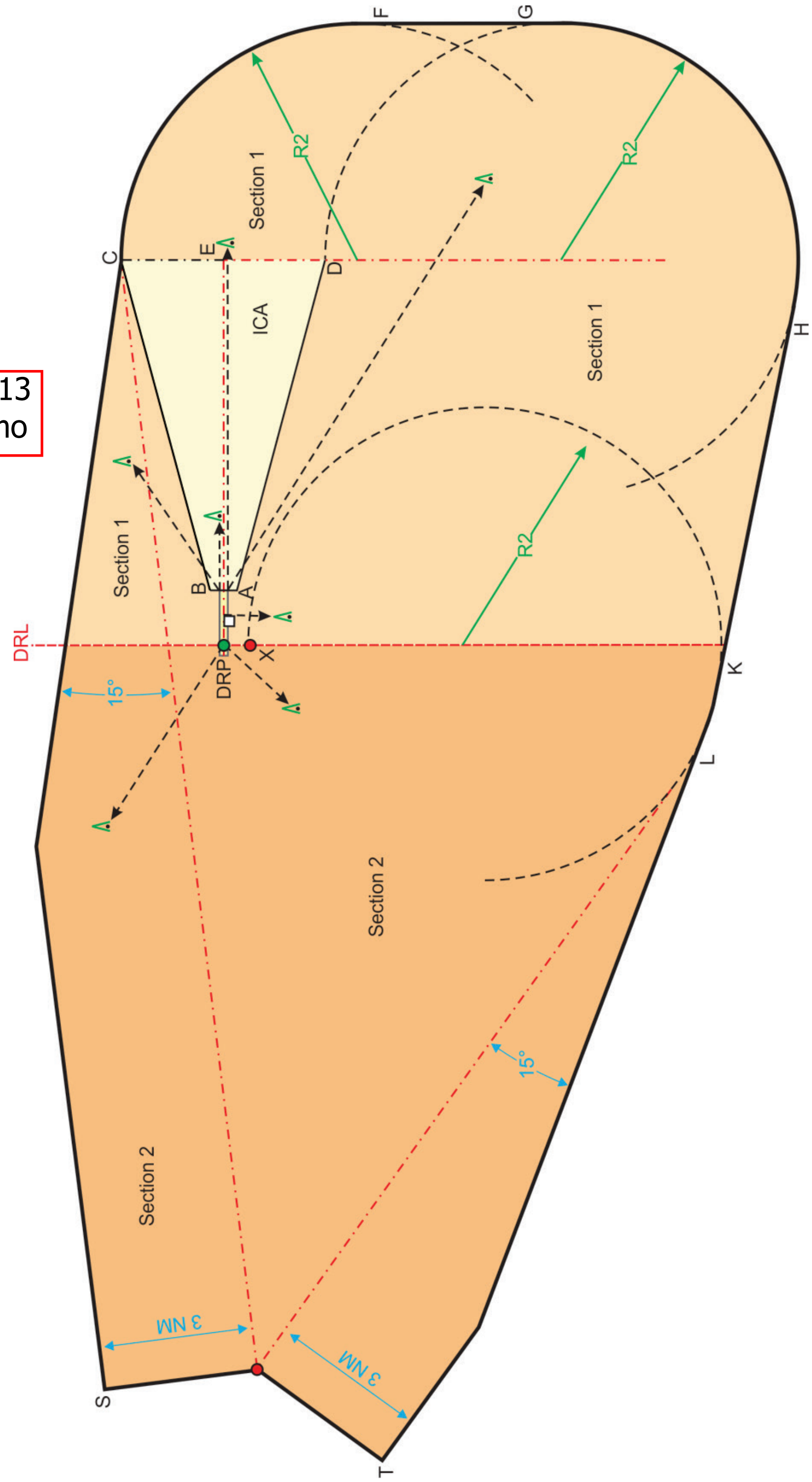
4.2 **CG.** Where the highest required climb gradient value is greater than 200 ft/NM, it will be published as the procedure minimum climb gradient (see calculator 2-4). Do not utilize a climb gradient in excess of 500 ft/NM without approval from Flight Standards Service.

4.3 **Climb in a Holding Pattern.** Where required, apply climb-in-hold criteria contained in Order 8260.3 Volume 1 paragraph 293b.

Implementation of this volume is conditional on the development of Companion Software Requirements Specifications that fully address applicable construction/design rules. Previous manual application may be grandfathered until automation can be fully implemented.

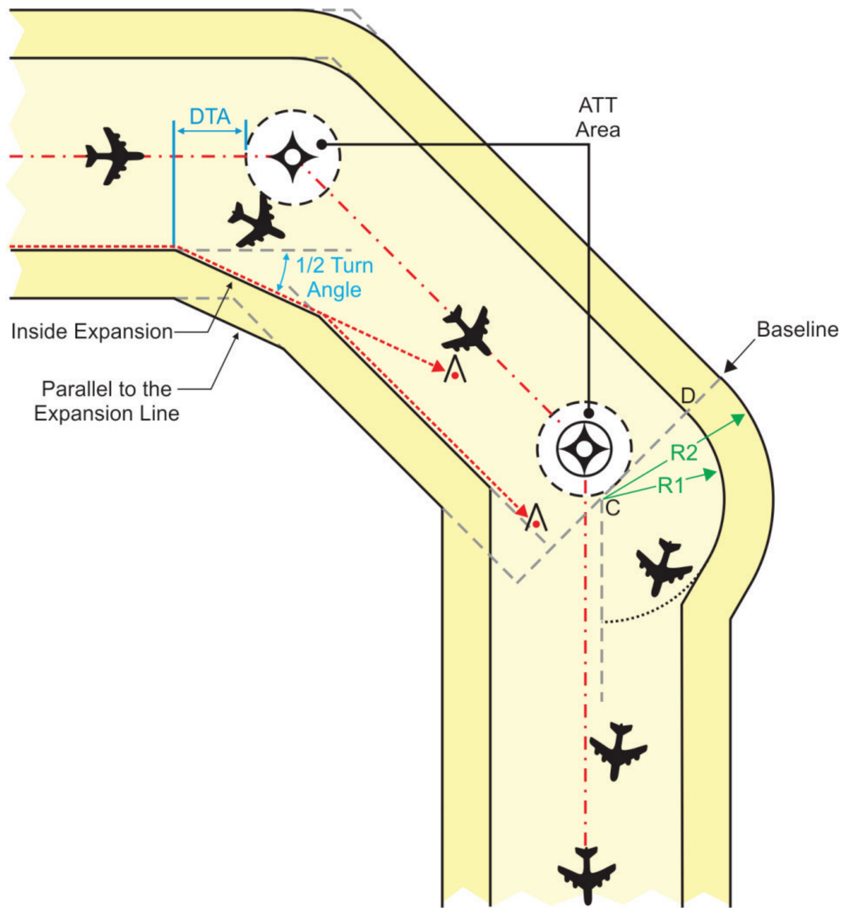
Figure 4-1. VA-DF Construction OEA Assessment

See March 1, 2013
Clarification Memo



Implementation of this volume is conditional on the development of Companion Software Requirements Specifications that fully address applicable construction/design rules. Previous manual application may be grandfathered until automation can be fully implemented.

Figure 4-2. Fix Turn Construction OEA Assessment



Implementation of this volume is conditional on the development of Companion Software Requirements Specifications that fully address applicable construction/design rules. Previous manual application may be grandfathered until automation can be fully implemented.

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Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 5. VA-DF Leg Length Analysis

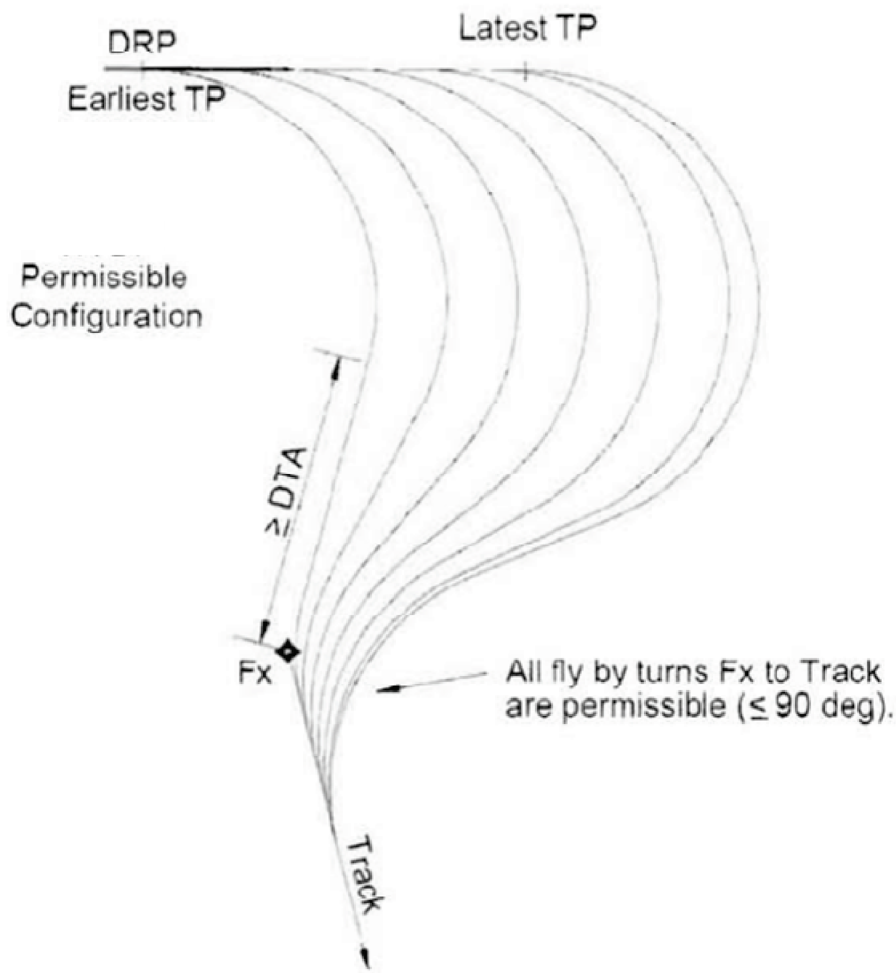
5.0 **Purpose.** This analysis is created to provide guidance for evaluating the DF maneuver but does not mirror OEA construction. In this assessment, the VA leg Earliest TP and Latest TP are treated as a FO fix.

5.1 **Earliest TP.** Measure from the DRP at airport elevation with 1100 ft/NM climb gradient, which reaches the earliest climb-to altitude or the DER, whichever occurs first. If the climb-to altitude is not reached by the DER, continue the climb determination starting at the DER using a climb gradient of 500 ft/NM until reaching 10000 ft, then 350 ft/NM.

5.2 **Latest TP.** Commencing at the DER at DER elevation, the latest TP is where an aircraft reaches the climb-to altitude at a climb gradient of 200 ft/NM or the minimum climb gradient required for obstacle clearance whichever is higher.

5.3 **Calculations.** Given the location of the DF leg termination fix and the outbound track from this fix, analyze a FO and FB turn at the termination fix from the ETP then every 0.1 NM until the latest TP to verify: a) if the fix is on or outside all paths scribed from the ETP until the latest TP based on the calculated turn radius; b) if the turn at the fix is 90 degrees or less; and c) where the fix is a FB, if the required DTA area is available. If all three conditions are met, the design passes analysis and is acceptable, see also the VA-DF calculator in the "Terminal Instrument Procedures (TERPS) Tools" section of the Flight Procedure Standards Branch web site. There is no course change limitation at the termination of the VA leg to join the DF leg (see figure 5-1).

Figure 5-1. VA-DF Permissible Configuration



United States Standard for

Performance Based Navigation (PBN)

<u>Volume 4</u>

Terminal Arrival Area (TAA)

Design Criteria

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Volume 4. Terminal Arrival Area (TAA) Design Criteria

Chapter 1. TAA and Approach Segment Construction

1.0 Minimum Safe/Sector Altitude (MSA).

Do not publish an MSA for an approach with a TAA.

1.1 Initial, Intermediate, Final and Missed Approach Segments.

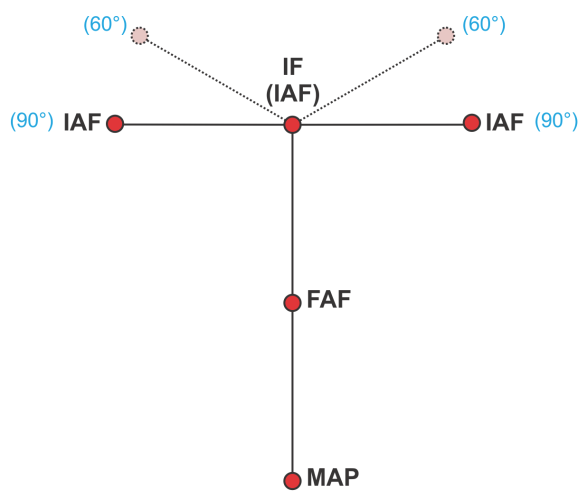
The following application guidelines are specific to the TAA and apply to all PBN procedures. The Basic T approach segment configuration, as described below, is the standard configuration for transition from the en route to the terminal environment. Deviations from the Basic T configuration should be made only when absolutely necessary. The TAA was conceived as a "free flight" concept; i.e., the pilot can maneuver as necessary within the TAA sector. It is assumed the pilot will maneuver to enter at a given IAF at an airspeed and intercept angle to correctly fly the procedure.

1.1.1 Initial Alignment to the Intermediate Segment.

See March 1, 2013 Clarification Memo

The MAXIMUM intercept angle of the initial segment to the intermediate segment is 90 degrees. The MINIMUM intercept angle is 60 degrees (see figure 1-1A).

Figure 1-1A. Initial/Intermediate Segment Alignment



The minimum length of the T initial segments is the larger of the table 1-1 value or the results of the Volume 6, paragraph 1.3.2 "Fly-By Turn" calculation. Since the TAA is considered a "Free Flight" concept, assume a 45-degree turn at the IAF. Use the value for the highest approach category published on the procedure. Descent gradient considerations may require longer segment lengths. Maximum leg length is 10 NM. If Volume 6 initial segment descent gradient criteria cannot be met, eliminate the T initial approach fix (IAF). Then, aircraft arriving from the direction of the eliminated T IAF will fly the course reversal holding pattern (see figure 1-1B). For parallel runway configurations, construct T IAFs so that they serve all parallel intermediate segments (see figure 1-1C).

Figure 1-1B. Basic T with an IAF Eliminated

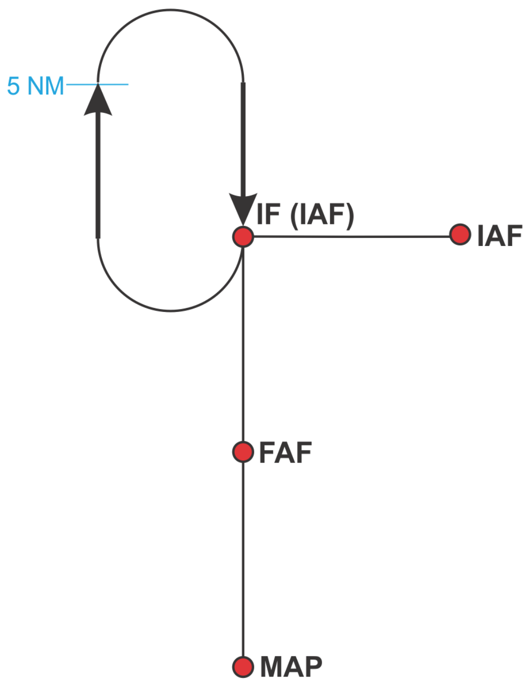


Figure 1-1C. Basic T Parallel Runway Application

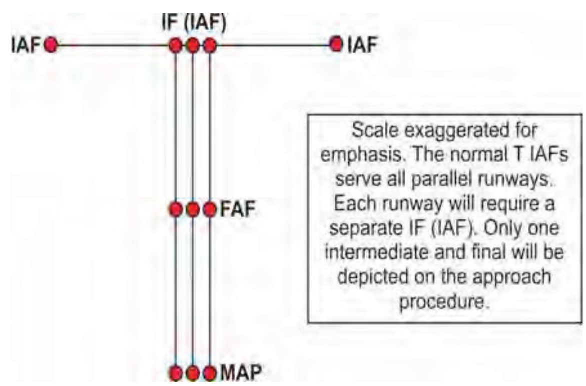


Table 1-1. Minimum Initial Segment Length for TAA Construction

Category	Minimum Length (NM)
A	3
B	4
C	5
D	5
E	6

Note: The TAA is a "free flight" area. Pilots are assumed to maneuver so as to enter the initial segment at approximately a 45-degree angle.

1.1.2 Intermediate Alignment to the Final Segment.

Align the intermediate segment with the final segment; i.e., turns over the FAF are not allowed.

1.1.3 Establish a holding pattern at the IF(IAF).

The inbound holding course shall be aligned with the inbound intermediate course (see figure 1-1C). Express all RNAV holding patterns in NM leg lengths vice timed holding under Order 7130.3.

1.1.4 Missed Approach Segments.

OPTIMALLY, construct missed approach segments to allow a "direct entry" into a missed approach holding pattern as illustrated in figure 1-2A. If the missed approach routing terminates at a T IAF, OPTIMUM alignment of the missed approach holding pattern is with the initial inbound course, with a direct entry into holding (see figure 1-2B).

Figure 1-2A. OPTIMUM Missed Approach Holding

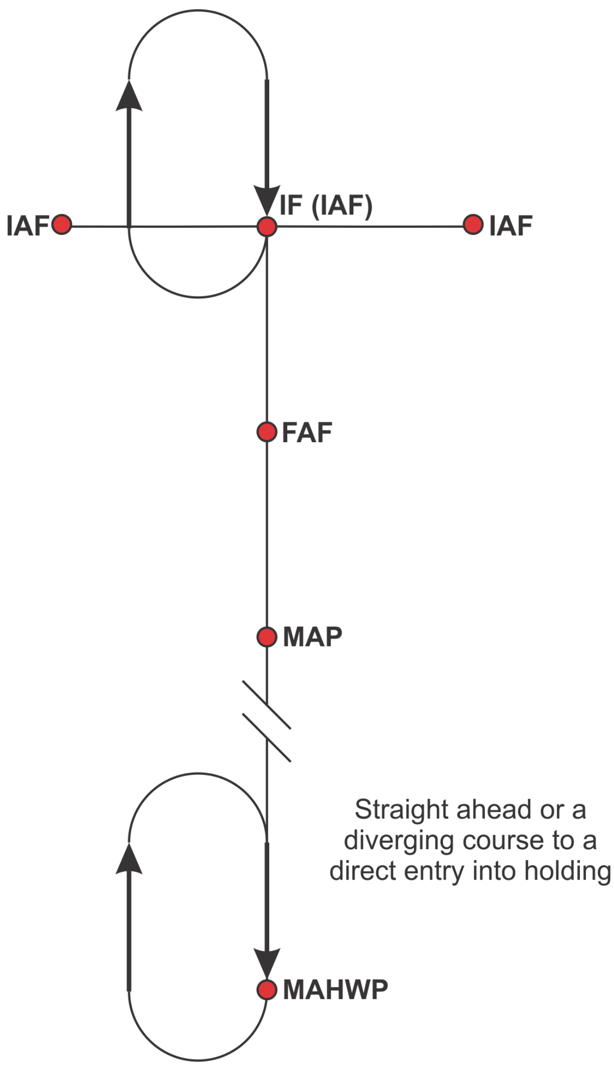
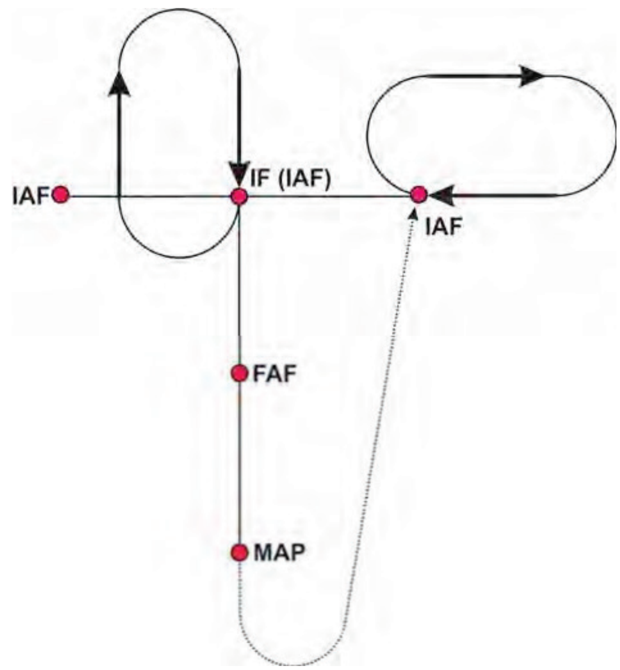


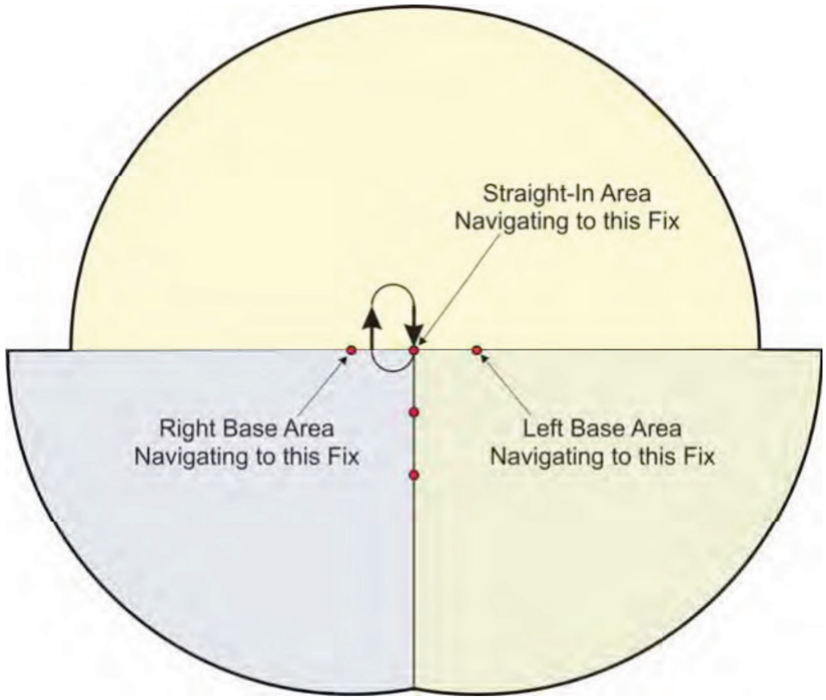
Figure 1-2B. Missed Approach Holding at an IAF



1.2 Standard TAA Areas.

The standard TAA contains three areas defined by the basic T segment centerline extensions: the straight-in area, right base area, and the left base area (see figure 1-3A). The TAA boundaries shall coincide with procedure flight tracks; e.g., the boundary between the straight-in area and either base area shall be the initial segment centerline extended; and the boundary between base areas shall be the intermediate segment centerline extended.

Figure 1-3A. Standard TAA



1.2.1 Straight-In Area.

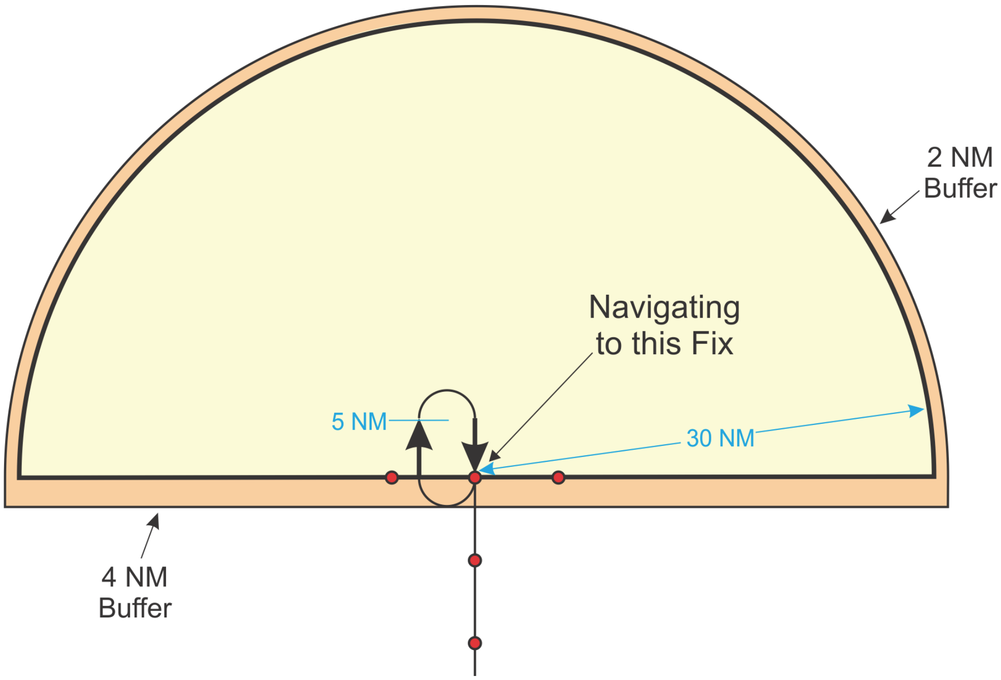
The arc boundary of the straight-in area is equivalent to a feeder fix. When crossing the boundary or when released by ATC within the straight-in area, the pilot can maneuver as necessary within the TAA sector to enter at a given IAF at an airspeed and intercept angle to correctly fly the procedure (assume 45 degrees for leg length calculation).

.

1.2.1 **a. Construction.** Draw a straight line through the T IAFs, extending 30 NM in each direction from the IF. Then, on the side of the line away from the airport, scribe a 30-NM arc centered on the IF connecting the straight-line end points (see figure 1-3B).

1.2.1 **b. Obstacle Clearance.** The area considered for obstacle clearance includes the entire straight-in area and its associated buffer areas (see figure 1-3B). Order 8260.3B paragraph 1720 applies.

Figure 1-3B. Straight-In Area



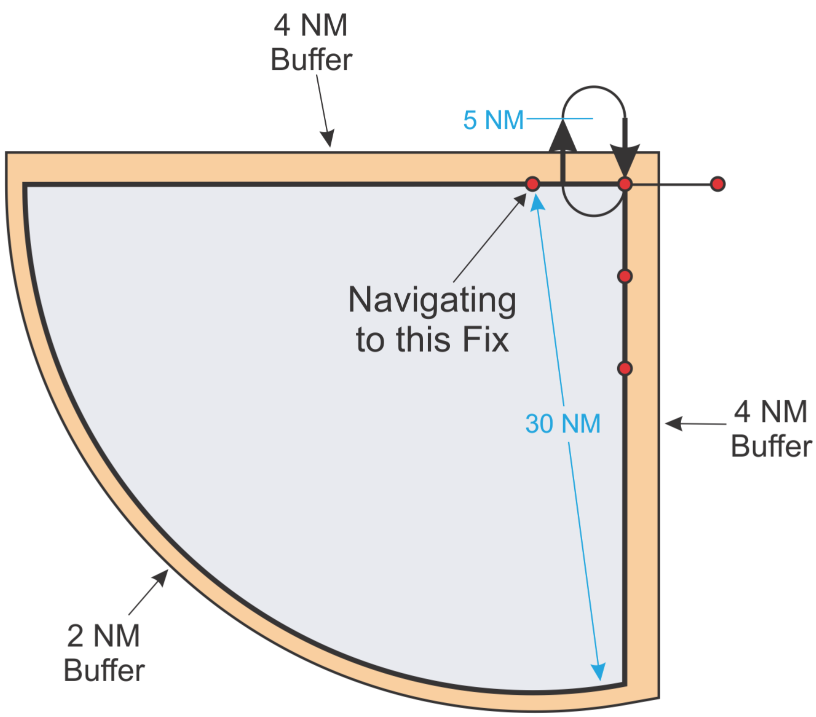
1.2.2 Right Base Area.

The arc boundary of the right base area is equivalent to a feeder fix. When crossing the boundary or when released by ATC within the right base area, an aircraft is considered at the feeder fix and is expected to maneuver as necessary within the TAA sector to enter at the IAF at an airspeed and intercept angle to correctly fly the procedure (assume 45 degrees for leg length calculation).

1.2.2 a. **Construction.** To construct the top boundary, extend the line from the IF through the T IAF for 30 NM beyond the T IAF. Draw a 30-NM arc, centered on the T IAF, from the end point of the top boundary counter-clockwise to the point it intersects a straight-line extension of the intermediate course (see figure 1-3C).

1.2.2 b. **Obstacle Clearance.** The area considered for obstacle clearance includes the entire right base area and its associated buffer areas. Order 8260.3 paragraph 1720 applies.

Figure 1-3C. Right Base Area



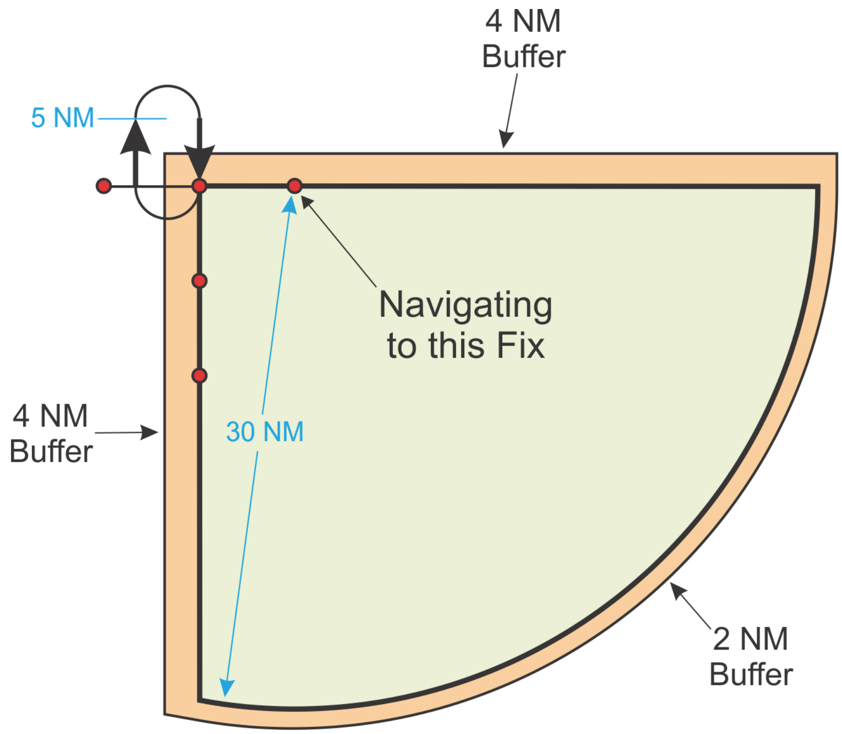
1.2.3 Left Base Area.

The arc boundary of the left base area is equivalent to a feeder fix. When crossing the boundary or when released by ATC within the left base area, an aircraft is considered at the feeder fix and is expected to maneuver as necessary within the TAA sector to enter at the IAF at an airspeed and intercept angle to correctly fly the procedure (assume 45 degrees for leg length calculation).

1.2.3 a. **Construction.** To construct the top boundary, extend the line from the IF through the T IAF for 30 NM beyond the T IAF. Draw a 30-NM arc, centered on the T IAF, from the end point of the top boundary clockwise to the point it intersects a straight-line extension of the intermediate course (see figure 1-3D).

1.2.3 b. **Obstacle Clearance.** The area considered for obstacle clearance includes the entire left base area and its associated buffer areas. Order 8260.3B paragraph 1720 applies.

Figure 1-3D. Left Base Area



1.3 Altitude Selection Within TAA.

OPTIMALLY, all TAA areas, course reversal holding pattern, and initial segment minimum altitudes should be the same. All NoPT routings shall join the IF(IAF) at a common altitude. When terrain or operational constraints force higher area altitudes that do not allow descent within gradient limits, the course reversal pattern at the IF(IAF) shall allow descent from the highest minimum sector altitude to the common IF(IAF) altitude.

1.3.1 Sectors/Stepdown Arcs.

When necessary to accommodate terrain diversity, operational constraints, or excessive descent gradients, the straight-in, left, and right base areas may be subdivided to gain relief, within the limitations noted below. Stepdown arcs, when used, shall be no closer than 4 NM from the WP upon which the arc is based and must be a minimum of 4 NM from the TAA outer boundary.

1.3.1 **a. Straight-in Area.** The straight-in area may be divided into as many as three sectors defined radially by magnetic inbound course to the IF(IAF). Each sector may be further sub-divided by a single stepdown arc centered on the IF(IAF). The minimum sector size shall be 30 degrees; except the minimum sector size shall be 45 degrees when the sector contains a stepdown arc and its radial boundaries terminate at the IF(IAF) (see figures 1-4A through 1-4D).

1.3.1 **b. The left and right base areas may not be radially sectored.** Only stepdown arcs (centered on the fix that defines the area) may be used, but are limited to one per sector (see figures 1-4A through 1-4D).

Figure 1-4A. A Sectorized TAA with Stepdown Arcs

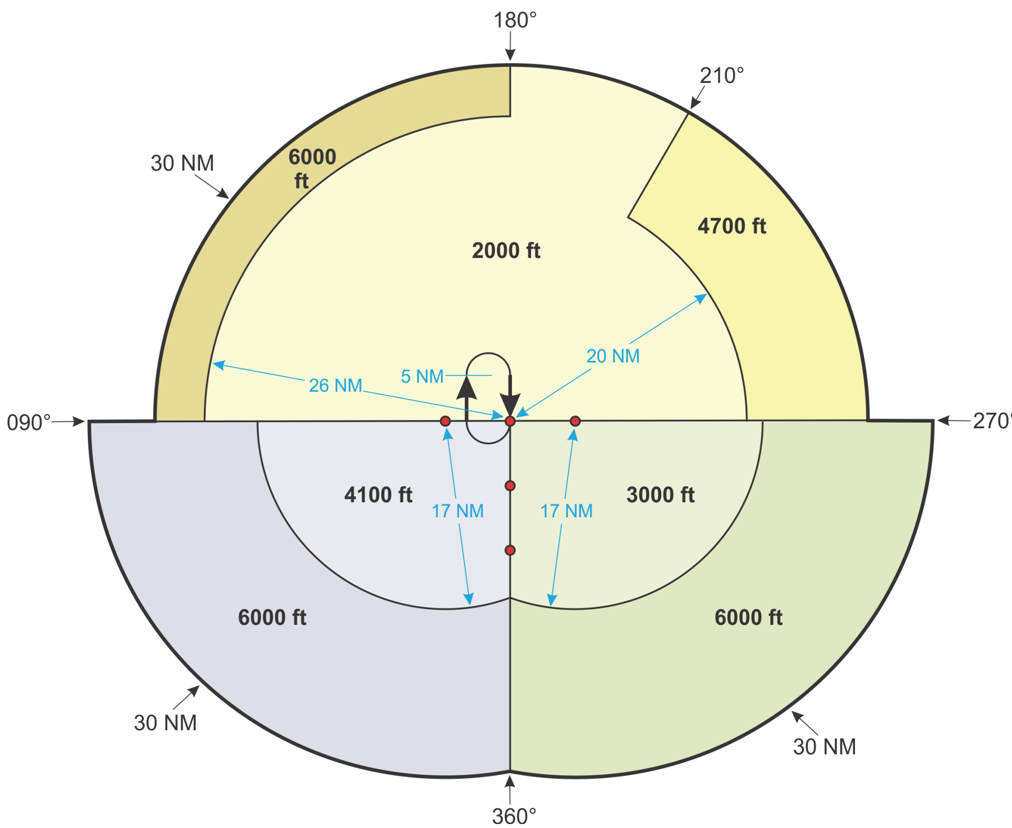


Figure 1-4B. TAA Maximum Sectorization with Maximum Stepdown Arcs

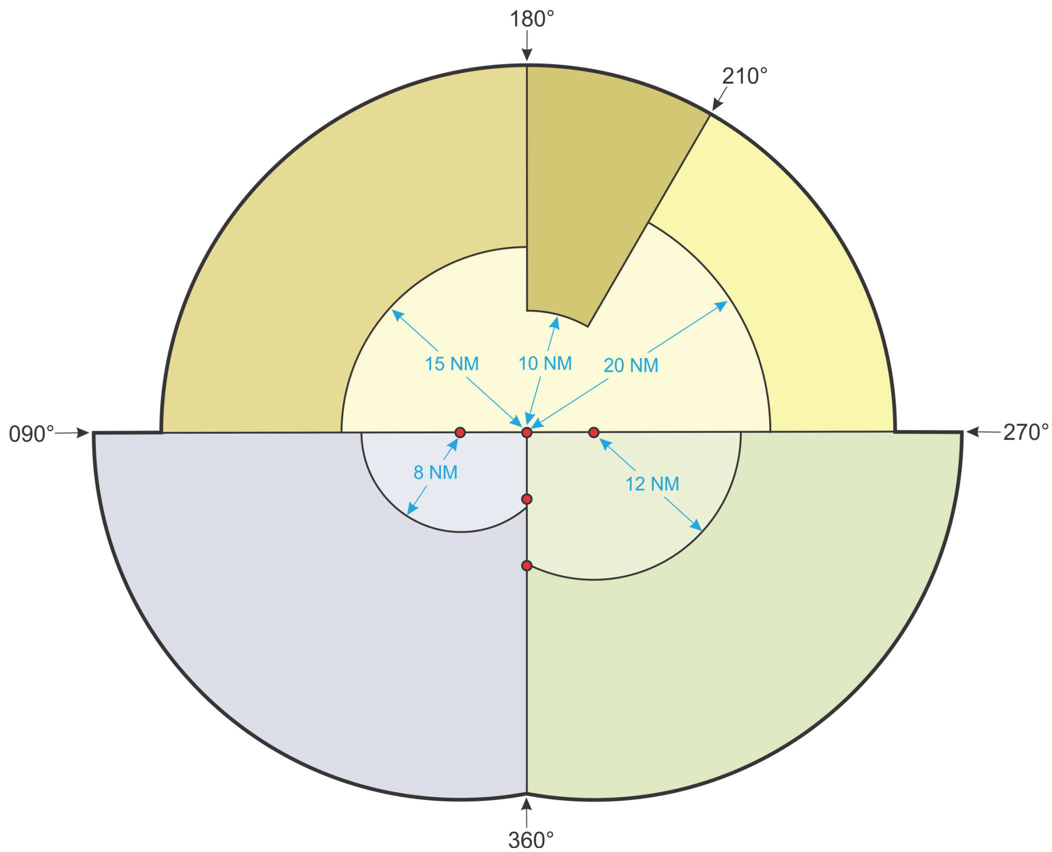


Figure 1-4C. TAA Maximum Sectorization with Maximum Stepdown Arcs

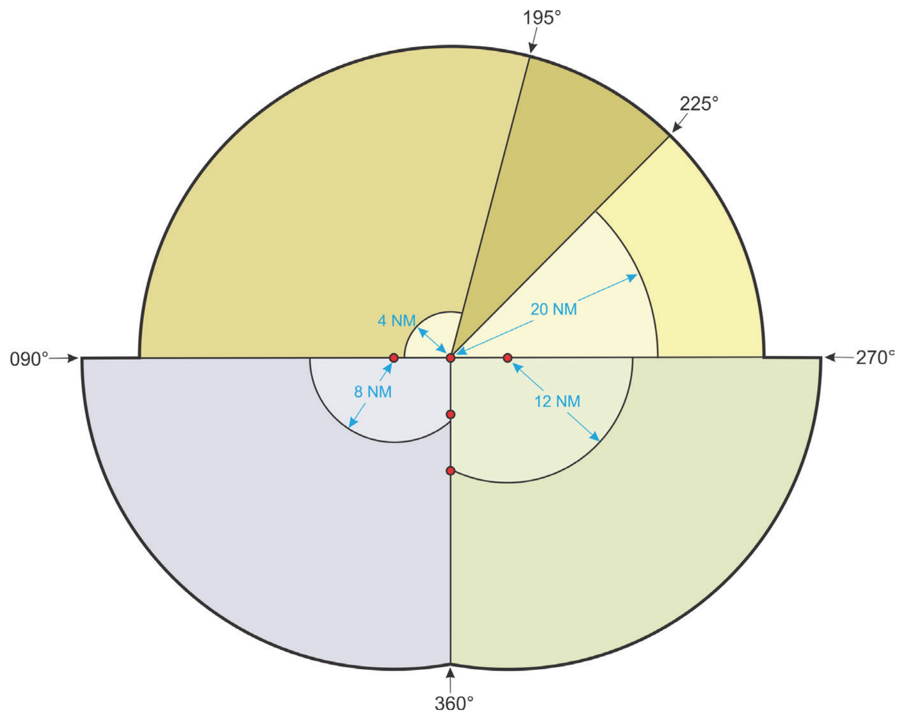
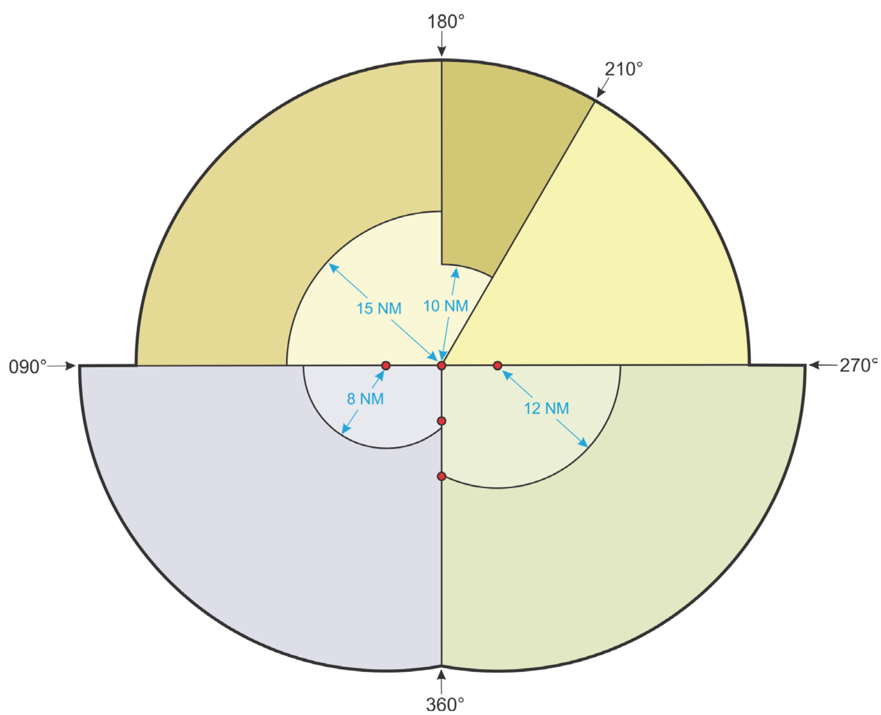


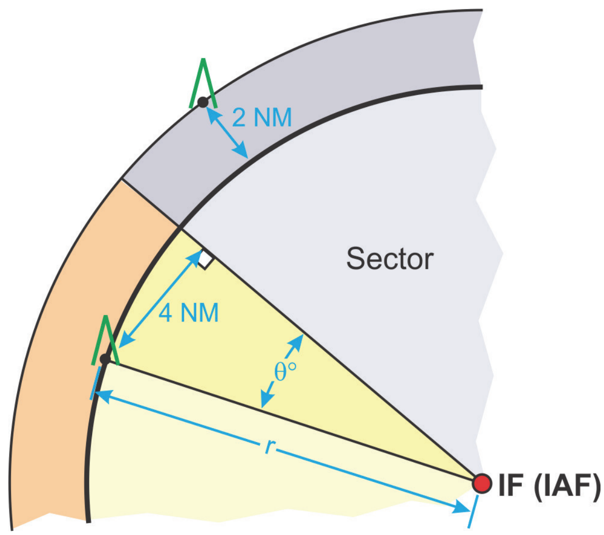
Figure 1-4D. TAA Maximum Sectorization with Maximum Stepdown Arcs



1.3.2 Altitude Sectors.

Sectors must provide appropriate required obstacle clearance within the sector boundaries and over all obstacles within a 4-NM buffer area (measured perpendicular to the radial boundary line) and within a 2-NM buffer from the outer boundary and any stepdown arcs. See figure 1-4E for a method to calculate the distance from a straight-in boundary line.

Figure 1-4E. Calculating Radial Sector Boundaries



$\theta = ArcSin\left(\frac{4}{r}\right)$

Where:

θ = angle in degrees

$r \geq 4$ NM

e.g., If r = 8 then $\theta = ArcSin\left(\frac{4}{8}\right) = 30°$

1.4 TAA Area Modifications.

Modifications to the standard TAA design may be necessary to accommodate operational requirements. Variations may eliminate one or both base areas, and/or limit or modify the angular size of the straight-in area. If the left or right base area is eliminated, modify the straight-in area by extending its 30-mile radius to join the remaining base area boundary. If the left and right base areas are eliminated, extend the straight-in 30-mile radius to complete 360 degrees of arc. Construct a sector that requires a course reversal in the extended straight-in area to accommodate entry at the IF(IAF) at angles greater than 90 degrees. This sector does not count toward the sectorization limitation stated in paragraph 1.3.1a (see figures 1-5A through 1-5E).

Figure 1-5A. TAA with Left and Right Base Areas Eliminated

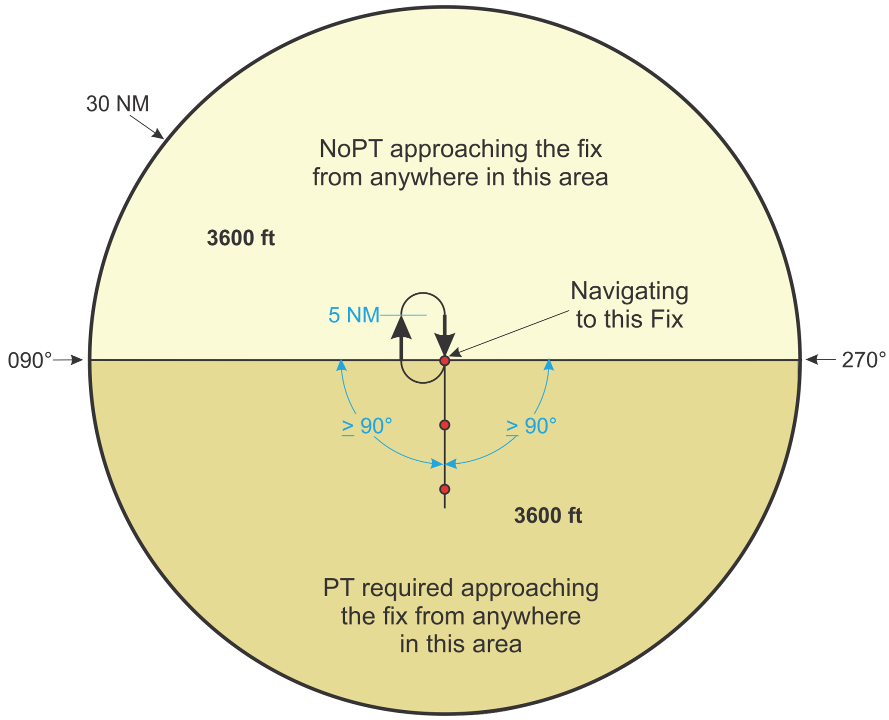


Figure 1-5B. TAA with Right Base Eliminated

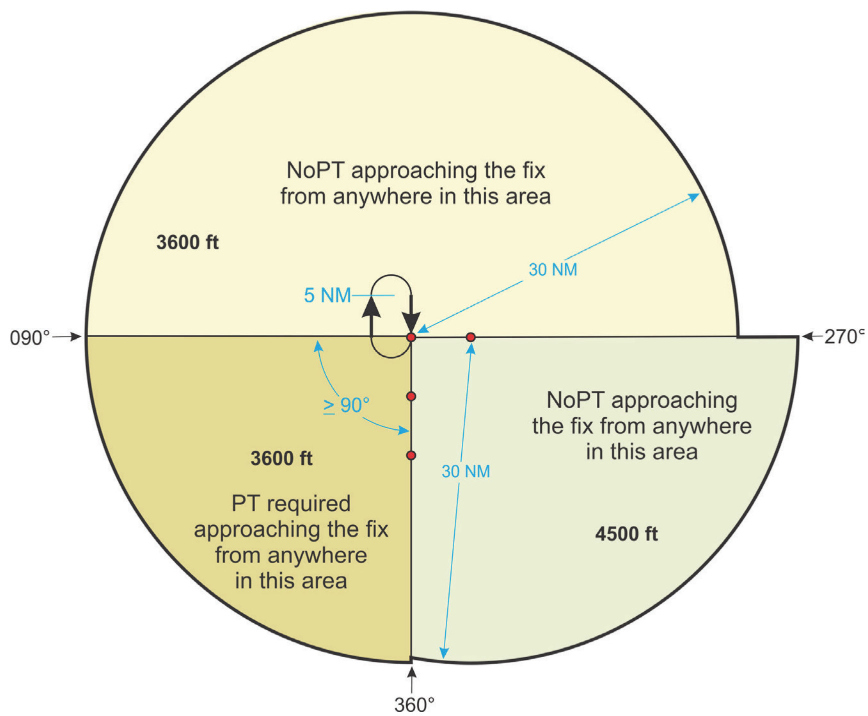


Figure 1-5C. TAA with Left Base Eliminated

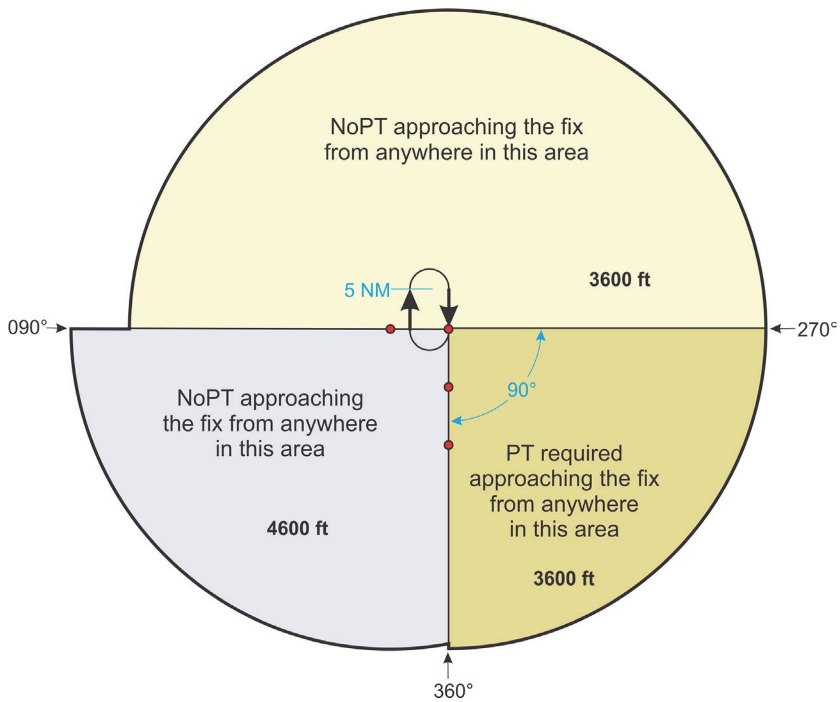


Figure 1-5D. TAA with Part of Straight-In Area Eliminated

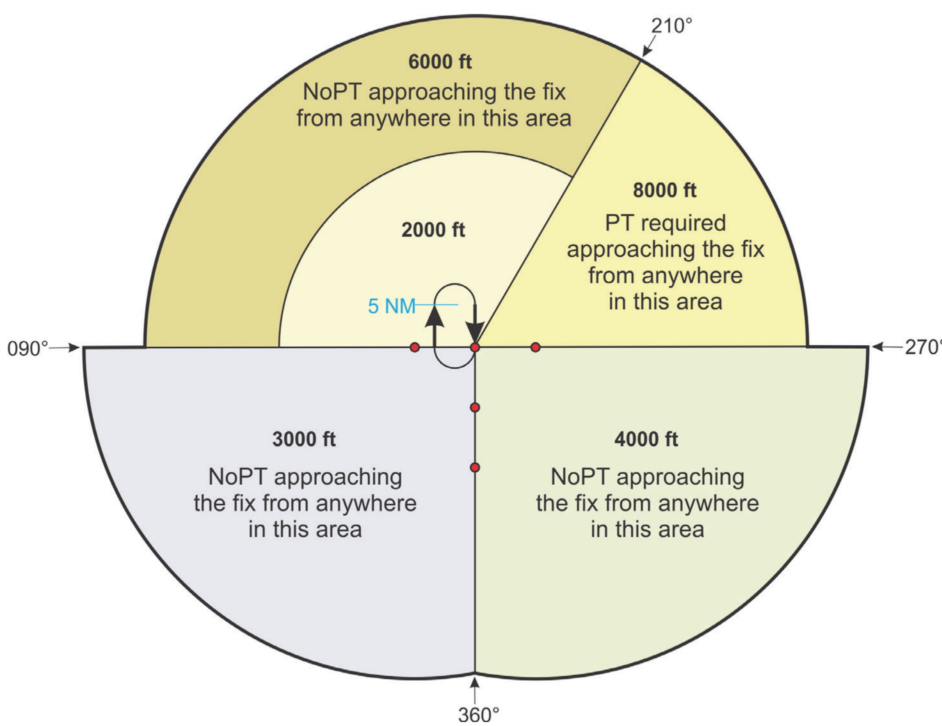
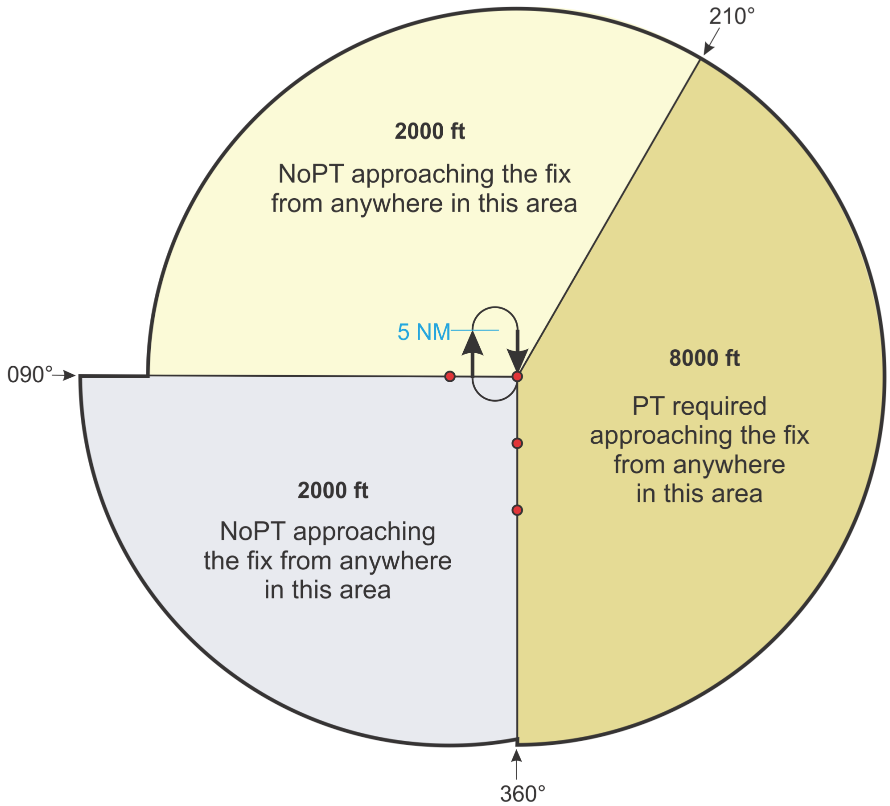


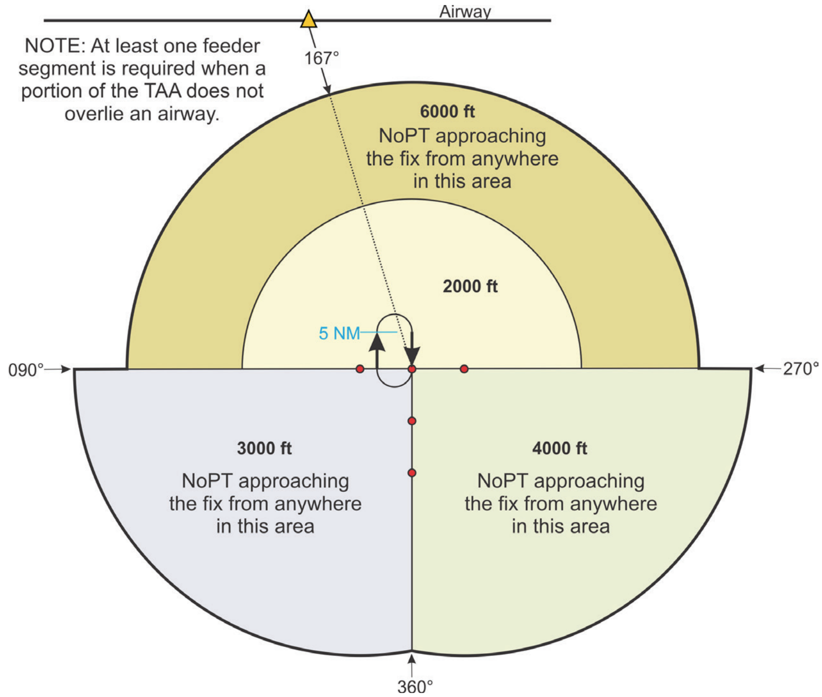
Figure 1-5E. TAA Example with Left Base and Part of Straight-In Area Eliminated



1.5 Connection to En Route Structure.

Normally, a portion of the TAA will overlie an airway. If this is not the case, construct at least one feeder route from an airway fix or NAVAID to the TAA boundary aligned along a direct course from the en route fix/NAVAID to the appropriate IF(IAF) and/or T IAF(s) (see figure 1-5F). Multiple feeder routes may be established if the procedure designer deems necessary.

Figure 1-5F. Examples of a TAA with Feeders from an Airway



1.6 Airspace Requirements.

The TAA should (USAF '**must**') be wholly contained within controlled airspace insofar as possible. The TAA will normally overlie Class "E" airspace (1200 ft floor) in the eastern 33 states, minus the Upper Peninsula of Michigan and a portion of southwest Texas. The remaining states will require close study to ensure controlled airspace containment for the TAA.

1.6.1 **If the TAA overlies Class B airspace,** in whole or in part, the ATC facility exercising control responsibility for the airspace may recommend minimum TAA sector altitudes. It is the responsibility of the ATC facility providing approach control service for the airport to resolve TAA altitude and overlapping airspace issues with adjoining ATC facilities. Modify the TAA to accommodate controlled/restricted/warning areas as appropriate.

1.6.2 **When notified that an RNAV approach** and a standard TAA are being initiated for an airport not underlying controlled airspace, the regional Air Traffic division(s) must initiate rulemaking action to establish a 1200 ft above ground level Class E airspace area with an appropriate radius of the ARP to accommodate the TAA. If a modified TAA is proposed, the airspace will be sized to contain the TAA. The TAA will not be charted or implemented until controlled airspace actions are completed.

Volume 4. Terminal Arrival Area (TAA) Design Criteria

Chapter 2. Documentation and Processing

2.0 Instructions for 8260-Series Forms.

2.1 Documenting the TAA.

Enter all normal terminal route and TAA information on the appropriate 8260-series forms. If the entire TAA cannot be documented on the 82603/5/7A, enter all TAA data on Form 8260-10, Continuation Sheet (see figures 2-1A and 2-1B). For TAA entries, the "From" and "To" entries do not describe routes of flight, but rather describe a volume of airspace within which an aircraft will proceed inbound from the 30-mile arc boundary toward an associated T IAF or IF(IAF). Enter the data in the specified standardized format detailed below to assist cartographers in developing the desired published display. Each entry shall coincide with the corresponding entry on Form 8260-9, Standard Instrument Approach Procedure Data Record, to provide correlation between terrain/obstacle data and the minimum altitude associated with the appropriate TAA area. Provide a graphic depiction of the TAA with areas defined and indicate the minimum altitude associated with each area/sector. Do not establish minimum altitudes that will require aircraft to climb while inbound toward the respective T IAF. Comply with existing instructions in Order 8260.19 relative to terminal routes, except as noted below:

2.1.1 **From.** For TAA entries, begin at the outermost boundary and work inward toward the respective T IAF. Enter an area/sector description beginning with the inbound magnetic course that is used as the sector boundary between the right base and straight-in sectors and proceed in a clockwise direction. Enter the magnetic value of the straight-line boundary (or its extension) described "TO" the associated T IAF, followed by the arc boundary distance (NM) for that point, and separate the entries by a "/"; e.g., 090/30. Then enter "CW" followed by a point along the same arc boundary intersected by the next straight-line boundary; e.g., 270/30. Thus, in a basic T configuration without stepdown sectors, the straight-in "From" entry would appear as "090/30 CW 270/30." Enter data in a similar manner to describe other areas and sectors.

2.1.1 **a. Sequentially number** (1, 2, etc.) the first line entry describing the area/sector for which different minimum altitudes are established. It is possible for an area/sector to be irregularly shaped, but have only one minimum altitude. Enter the associated data for such an area together as a group of sequential line entries.

2.1.1 **b. Enter "NoPT" following each line entry** that contains the specific 30-mile arc boundary for which that label is appropriate. If a course reversal is required, make no entry regarding PT requirements on the line entry describing the 30-mile arc boundary.

2.1.2 **To. Enter area/sector straight-line/arc boundary descriptions** as above, which in combination with the associated entry in the "From" block, encloses the area being documented. For example, the "To" stepdown arc entry associated with the "From" entry above for a basic T configuration without stepdown sectors would be the T IAF; therefore, enter the appropriate WP name and fix type; e.g., POPPS IAF, MAACH IAF, etc. If the area has been sectored, the "To" entry could be "090/22 CW 180/22."

2.1.3 **Course and Distance.** No entry is required for TAA area/sector documentation. Course and distance for feeder routes, when required, will be to the appropriate T IAF or IF(IAF) using the provisions of Order 8260.19.

2.1.4 **Altitude.** Enter the minimum altitude of the area/sector on each line.

2.2 **Form 8260-9, Standard Instrument Approach Procedure Data Record.**

Comply with existing Order 8260.19 instructions for documenting controlling obstacles/terrain, coordinates, minimum altitudes, etc., except as noted below:

2.2.1 **Part A, Block 1 - App. Segment.** Enter the number assigned to the particular area/sector as in paragraph 2.1.1a. Then enter associated documenting data across the form.

2.2.2 **Part A, Block 5 - Minimum Safe Altitudes.** Leave blank.

2.2.3 **Part C - Remarks.** Do not develop airspace data for the TAA. Develop airspace data for the approach procedure contained within the TAA under Order 8260.19, paragraph 8-60c(5).

Figure 2-1A. Sample 1, FAA Form 8260-10

U.S. DEPARTMENT OF TRANSPORTATION - FEDERAL AVIATION ADMINISTRATION

RNAV **STANDARD INSTRUMENT APPROACH PROCEDURE**

FLIGHT STANDARDS SERVICE - FAR PART 97. 33

Bearings, headings, courses, and radials are magnetic. Elevations and altitudes are in feet, MSL, except HAT, HAA, TCH, and RA. Altitudes are minimum altitudes unless otherwise indicated. Ceilings are in feet above airport elevation. Distances are in nautical miles unless otherwise indicated, except visibilities which are in statute miles or in feet RVR.

FROM:	TO:	ALTITUDE
1. 090/30 CW 180/30 (NoPT)	090/22 CW 180/22	6000
2. 210/30 CW 270/30 (NoPT)	210/20 CW 270/20	4700
3. 090/22 CW 180/22	POPPS (IAF)	2000
180/30 CW 210/30 (NoPT)	POPPS (IAF)	2000
210/20 CW 270/20	POPPS (IAF)	2000
4. 270/30 CW 360/30 (NoPT)	270/17 CW 360/17	6000
5. 270/17 CW 360/17	MAACH (IAF)	3000
6. 360/30 CW 090/30 (NoPT)	360/17 CW 090/17	6000
7. 360/17 CW 090/17	SISSY (IAF)	4100

(This example relative to figure 7A)

CITY AND STATE	ELEVATION: 123 TDZE: 123 AIRPORT NAME:	FACILITY IDENTIFIER:	PROCEDURE NO. / AMDT NO. / EFFECTIVE DATE:	SUP:
ANYWHERE, VA	ANYWHERE AIRPORT	ANY	RNAV RWY 18, ORIGINAL	AMDT: NONE DATED:

FAA FORM 8260 - 10 / February 1995 (Computer Generated) Page 1 of 1 Pages

Figure 2-1B. Sample 2, FAA Form 8260-10

U.S. DEPARTMENT OF TRANSPORTATION - FEDERAL AVIATION ADMINISTRATION

RNAV **STANDARD INSTRUMENT APPROACH PROCEDURE**

FLIGHT STANDARDS SERVICE - FAR PART 97. **33**

Bearings, headings, courses, and radials are magnetic. Elevations and altitudes are in feet, MSL, except HAT, HAA, TCH, and RA. Altitudes are minimum altitudes unless otherwise indicated. Ceilings are in feet above airport elevation. Distances are in nautical miles unless otherwise indicated, except visibilities which are in statute miles or in feet RVR.

FROM:	TO:	ALTITUDE
1. 090/30 CW 210/30 (NoPT)	090/17 CW 210/17	6000
2. 090/17 CW 210/17	ALPHA (IAF)	2000
3. 210/30 CW 270/30	ALPHA (IAF)	8000
4. 270/30 CW 360/30 (NoPT)	BRAVO (IAF)	4000
5. 360/30 CW 090/30 (NoPT)	CHRLY (IAF)	3000

(This example relative to figure 7B)

CITY AND STATE	ELEVATION: 123 TDZE: 123 AIRPORT NAME:	FACILITY IDENTIFIER:	PROCEDURE NO. / AMDT NO. / EFFECTIVE DATE:	SUP: AMDT: NONE DATED:
ANYWHERE, VA	ANYWHERE AIRPORT	ANY	RNAV RWY 18, ORIGINAL	

FAA FORM 8260 - 10 / February 1995 (Computer Generated)

Page 1 of 1 Pages

Figure 2-2A. Example 1

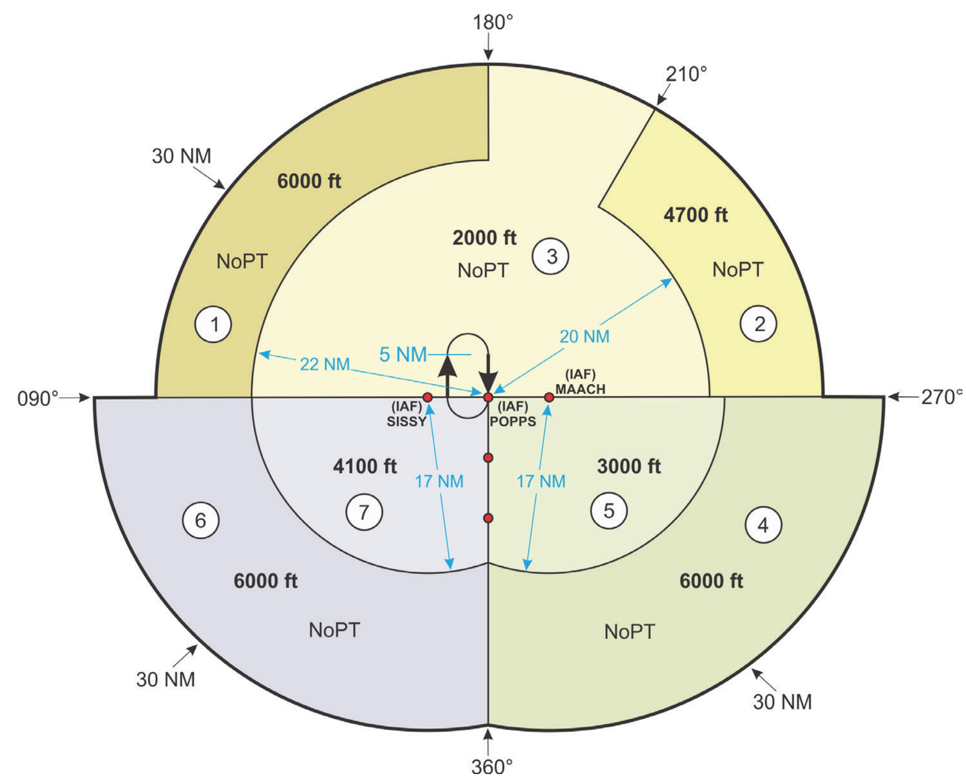
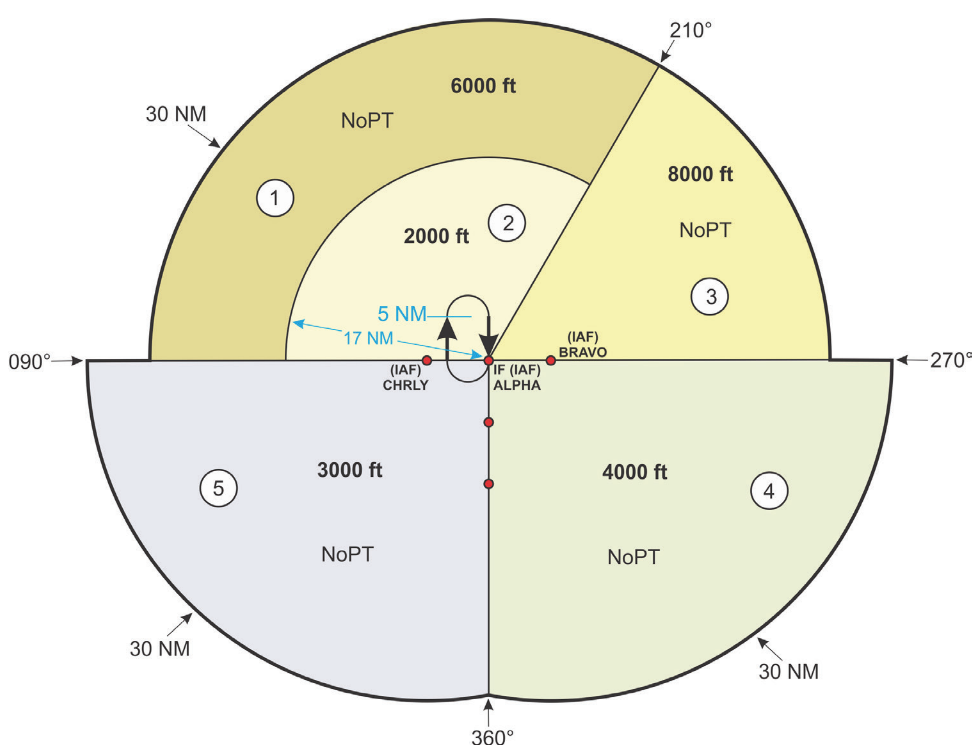


Figure 2-2B. Example 2



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United States Standard for

Performance Based Navigation (PBN)

<u>Volume 5</u>

Standard for Required Navigation Performance (RNP)

Approach Procedures with Authorization Required (AR)

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Volume 5. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Chapter 1. Basic Criteria Information

1.0 Design Concept.

Use these criteria to develop RNP AR instrument approach procedures. The following basic conditions are considered in the development of obstacle clearance criteria for RNP approach procedures: The aircraft descends and decelerates from the en route environment or a terminal transition route through the initial/intermediate approach segments to the PFAF. The aircraft arrives at the DA and continues with visual reference to a landing on the runway or initiates a missed approach. The design of the instrument procedure defines the boundaries of the airspace within which the instrument operation will be conducted. This is the airspace that will "contain" (account for) all of the major factors influencing RNP: System accuracy, flight technical error, navigation system error, and error values that provide an acceptable level of continuity, availability, and integrity. For obstacle clearance purposes, the boundaries are specified as a nautical mile measurement perpendicular to the designed flight path. This measurement is specified as an RNP value or level. The primary OEA of RNP instrument procedures is defined as ± 2×RNP. Table 1-1 lists RNP values applicable to specific instrument procedure segments.

Table 1-1. RNP Values

SEGMENT	RNP VALUES		
	MAXIMUM	STANDARD	MINIMUM
Feeder	2	2	1.0
Initial	1	1	0.1
Intermediate	1	1	0.1
Final	0.5	0.3	0.1
Missed Approach	1	1	0.1

Note: Prior to the PFAF, RNP values may decrease only. RNP values may not change in the FAS. After crossing the LTP/FTP, RNP values may increase only. See paragraph 4.2.1 for limitations of missed approach segment minimum values.

1.1 Applicability.

Approach procedures developed under these criteria are published under the authority of 14 CFR Part 97.33 and identified as "Authorization Required." General criteria contained in the latest editions of Order 8260.3 and RNAV and RNP specific criteria contained in Order 8260.19 apply unless modified by these criteria.

1.2 Procedure Identification.

Title RNP procedures "RNAV (RNP) RWY XX." Where more than one RNAV approach is developed to the same runway, identify each with an alphabetical suffix beginning at the end of the alphabet. Title the procedure with the lowest minimums with the "Z" suffix, etc. Title "Special" procedure with one of the following suffixes: "M", "N", or "P."

Examples

RNAV (GPS) Z RWY 13L (lowest HATh: example 250 ft)
RNAV (RNP) Y RWY 13L (2nd lowest HATh: example 300 ft)
RNAV (GPS) X RWY 13L (3rd lowest HATh: example 350 ft)
RNAV (RNP) M RWY 13L (Special procedure)

Note: Operational requirements may occasionally require a different suffix grouping; e.g., "Z" suffix procedures are RNP AR, "Y" suffix procedures contain LPV, etc.

1.3 Published Minimums.

RNP approach procedures are 3D approaches, lateral and vertical path deviation guidance is provided. Circling minimums are not developed. Evaluate the final segment for an RNP value of 0.3 and a standard RNP 1.0 or alternative RNAV MA, and publish the resulting minimums. If the resulting HATh value is ≥ 300 or no-lights visibility ≥ 1 SM, evaluate using a FAS RNP value < 0.3 but ≥ 0.10 and/or a MA CG or reduced MAS RNP, as appropriate, to determine lowest possible HATh/no-lights visibility. If at least a 50 ft reduction in HATh or ¼ SM reduction in visibility cannot be achieved, publish only the RNP 0.3 minimums, based on standard RNP or alternative RNAV MA. If the required reduction in minimums is possible, in addition to the RNP 0.3 minimums based on a standard MA, publish the lowest possible minimums. If the difference in minimums allows interim values that differ by at least 50 ft in HATh value or ¼ SM visibility, these values may also be published if desired (4 minima lines maximum). Note that RNP values lower than 0.3 may be selected to satisfy operational needs other than reduction of minimums; examples are: to achieve track to airspace separation, track to track separation, or to allow the DA to meet criteria of distance from the

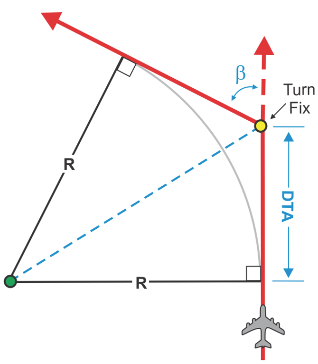
FROP. However, this does not negate the requirement to publish RNP 0.3 minimums with the standard RNP or alternative RNAV missed approach.

1.4 Calculating True Airspeed, Turn Radius, and Bank Angle. See Volume 6, paragraph 1.2.

1.5 DTA Application.

DTA is a calculated value for use in determining minimum straight segment length where a TF-TF turn is required at the beginning or ending fix (see figure 1-1). See paragraph 2.3 for determination of minimum segment length. Use calculator 1-1 to determine DTA for any given turn.

Figure 1-1. DTA



Calculator 1-1. DTA

$$DTA_{NM} = \mathbf{round}\left[R \times \tan\left(\frac{\beta^\circ}{2} \times \frac{\pi}{180^\circ}\right), 2\right]$$

$$DTA_{feet} = \mathbf{round}\left[R \times \tan\left(\frac{\beta^\circ}{2} \times \frac{\pi}{180^\circ}\right) \times fpnm, 0\right]$$

Calculator 1 1		
β°		Calculate
R		
DTA_{NM}		Clear
DTA_{feet}		

1.6 Calculation of Visibility Minimums.

See Order 8260.3, Volume 1, chapter 3.

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Volume 5. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Chapter 2. Terminal Segments

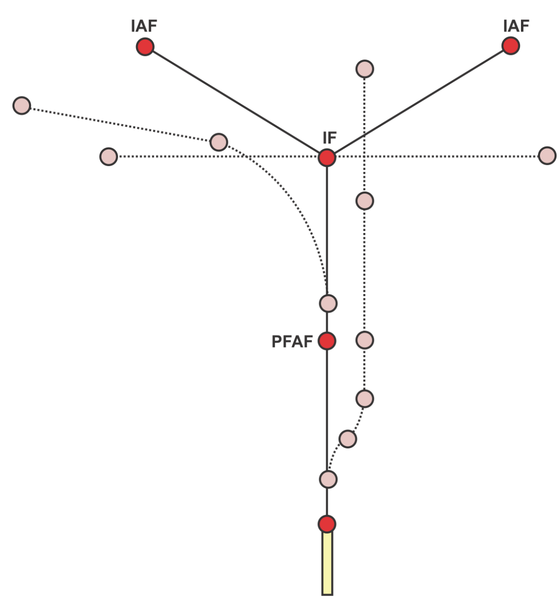
2.0 General.

Feeder, initial, and intermediate segments provide a smooth transition from the en route environment to the FAS. Descent to glidepath intercept and configuring the aircraft for final approach must be accomplished in these segments. Design RNP segments using the most appropriate leg type (TF or RF) to satisfy obstruction and operational requirements in feeder, initial, intermediate, final, and missed approach segments. Generally, designs with TF legs are preferred but RF legs may be used in lieu of TF-TF turns for turn path control, procedure simplification, or improved flyability.

2.1 Configuration.

RNP navigation enables the geometry of approach procedure design to be very flexible, especially when it incorporates a Terminal Arrival Area as described in Volume 4. The "Y" segment configuration is preferred where obstructions and air traffic flow allow. The approach design should provide the least complex configuration possible to achieve the desired minimums (see figure 2-1 for examples). FB turns at the PFAF are limited to a maximum of 15 degrees.

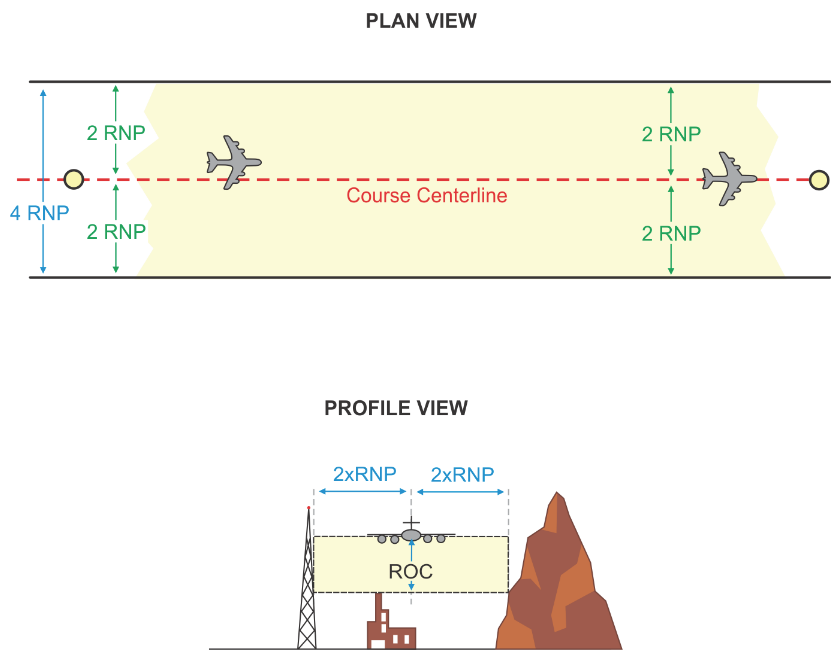
Figure 2-1. Optimum Configuration



2.2 RNP Segment Width.

RNP values are specified in increments of a hundredth (0.01) of a NM. Segment width is defined as 4×RNP; segment half-width (semi-width) is defined as 2×RNP (see figure 2-2). Standard RNP values for instrument procedures are listed in table 1-1.

Figure 2-2. RNP Segment Width



Apply the standard RNP values listed in table 1-1 unless a lower value is required to achieve the desired ground track or lowest minimums. The lowest RNP values are listed in the "MINIMUM" column of table 1-1.

2.3 RNP Segment Length.

Design segments with sufficient length to accommodate the required descent as close to the OPTIMUM gradient as possible and DTA (see paragraph 1.5) where fly-by turns are required. Minimum TF segment length is the greater of:

- DTA (does not apply to turns ≤ 10 degrees)
- The lesser of 2×RNP or 1 NM where RNP is less than 0.5.

Minimum RF segment length is 2×RNP. Paragraph 2.8 applies where RNP changes occur (RNP value changes 1 RNP prior to fix).

2.4 RNP Segment Descent Gradient.

Design instrument approach procedure segments to provide descent at the standard gradient to the extent possible. Table 2-1 lists the standard and maximum allowable descent gradients.

Table 2-1. Descent Gradient Constraints

See March 1, 2013 Clarification Memo

SEGMENT	DESCENT GRADIENT (FT/NM)	
	STANDARD	MAXIMUM
Feeder	250	500
Initial	250 800[1]	500 1000[1]
Intermediate	≤ 150	Equal to Final Segment Gradient[2]
Final	318 (3°)	See Vol. 6, table 1-4

1. DoD Only

2. If a higher than standard gradient is required, a prior segment must provide a gradient to allow the aircraft to configure for final segment descent.

2.4.1 Descent Gradient Calculation.

Determine total altitude lost between the plotted positions of the fixes. Determine the along-track distance in NM. For RF legs, determine the distance using Volume 6, calculator 1-9. Determine descent gradient using Volume 6, calculator 1-11.

See March 1, 2013 Clarification Memo

Calculator 2-1. RESERVED

2.4.1 Deceleration Segment (applicable ONLY).

2.5 RNP Segment ROC.

Minimum ROC requirements are listed by segment type in table 2-2.

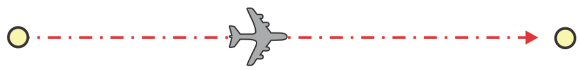
Table 2-2. Minimum ROC Value

Segment	ROC Value
Feeder	2000/1000
Initial	1000
Intermediate	500 or VEB Value
Final	VEB

2.6 TF Leg Segment.

A TF leg is a geodesic flight path between two fixes. The first fix is either the previous leg termination fix or the initial (first) fix of a TF leg (see figure 2-3).

Figure 2-3. TF Leg



2.6.1 OEA Construction of Turns at FB Waypoints that Join Two TF Legs.

See March 1, 2013 Clarification Memo

This construction is the standard for FB turn construction. Limit turns at a FB fix to a maximum of 70 degrees where aircraft are expected to cross (FB) the fix at altitudes above FL 195, 90 degrees at and below FL 195. Where TF-FB-TF construction is not feasible, use RF leg construction to accomplish the course change (see paragraph 2.7). Construct FB turning OEAs using the following steps:

STEP 1: Construct the turning flight path. Determine the R as described in Volume 6, paragraph 1.2 (calculator 1-3c). Placing the origin on the angle bisector line, scribe an arc of radius R tangent to the inbound and outbound legs (see figure 2-4A).

STEP 2: Construct the outer OEA boundary line. Using the turn fix as the origin, scribe an arc of radius 2×RNP tangent to the inbound (or preceding) and outbound (or succeeding) TF legs.

STEP 3: Construct inner turn expansion boundary line. Placing the origin on the angle bisector line, scribe an arc of radius R+1×RNP from the tangent point on the inbound (or preceding) leg inner boundary to the tangent point on the outbound (or succeeding) leg inner boundary.

The evaluation for the succeeding segment begins 1 RNP from the turn fix (example in figure 2-4A) or the angle bisector line (example in figure 2-4B), whichever is encountered first.

Figure 2-4A. Small Turn at a Fly-by Fix

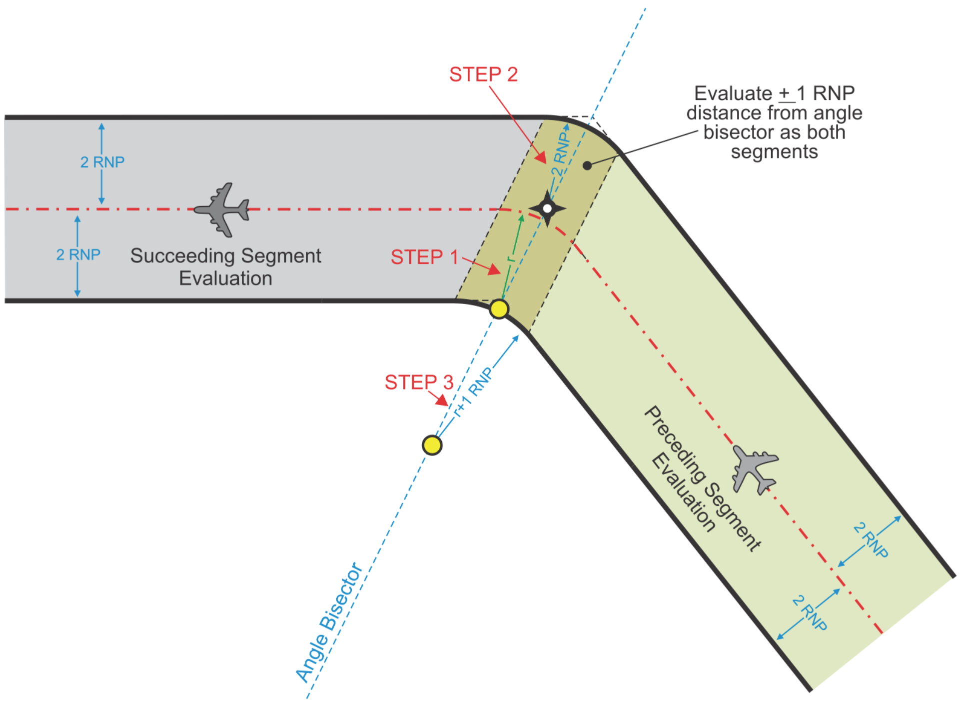
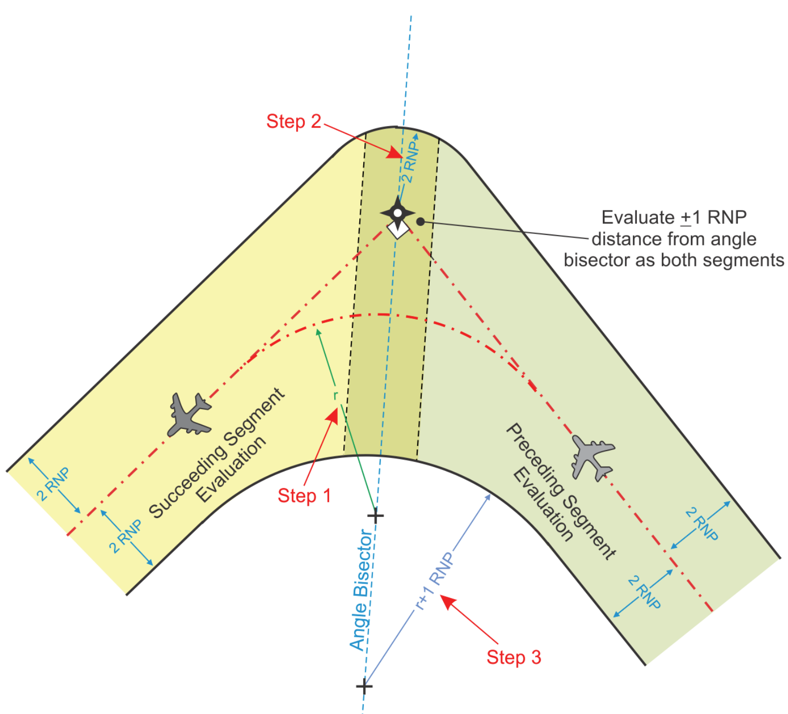


Figure 2-4B. Large Turn at a Fly-by Fix



2.7 RF Leg Segment.

See Volume 6, paragraph 1.3.3. Steps 5 and 7 do not apply.

Figure 2-5. Reserved.

2.8 Changing Segment Width (RNP Values).

Changes in RNP values must occur at a fix. The aircraft avionics transition to the new RNP value no later than reaching the fix marking the value change. Therefore, the area within ± 1 RNP of the fix must be evaluated for both segments. RNP reduction is illustrated in figure 2-6A, RNP increase is illustrated in figure 2-6B, and RNP changes involving RF legs are illustrated in figure 2-6C.

Figure 2-6A. RNP Reduction (Prior to PFAF only)

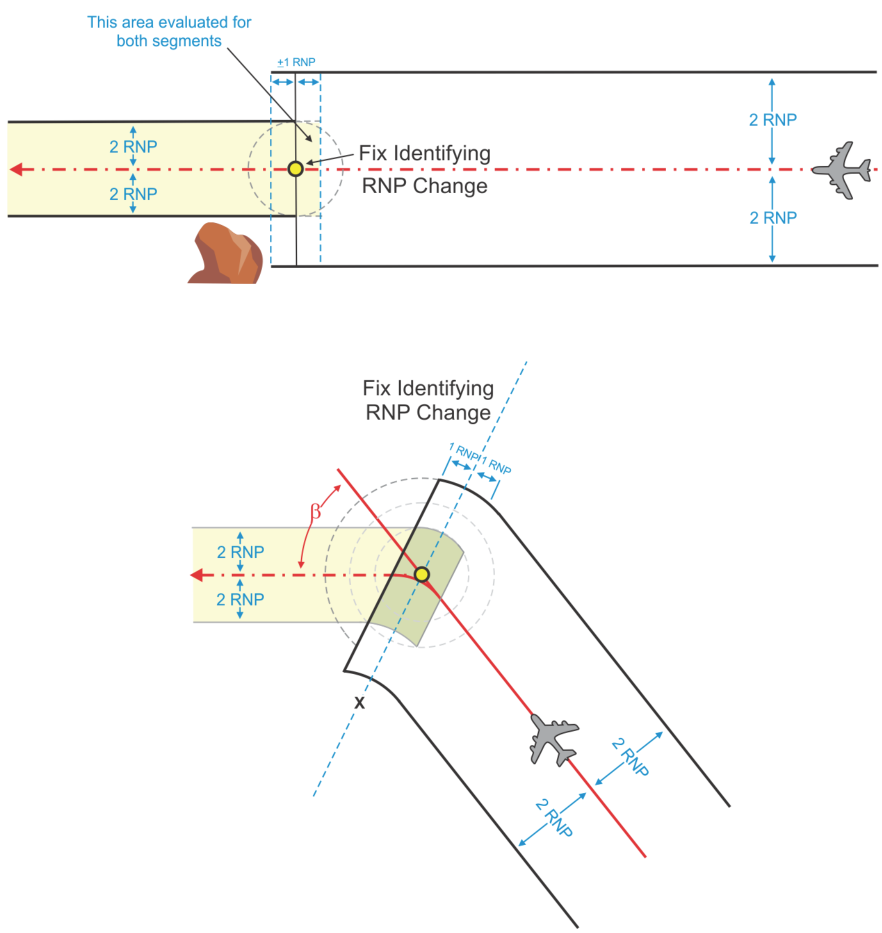


Figure 2-6B. RNP Increase (After Crossing the LTP/FTP)

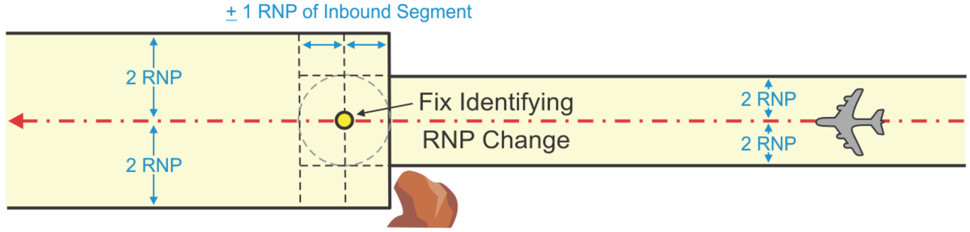
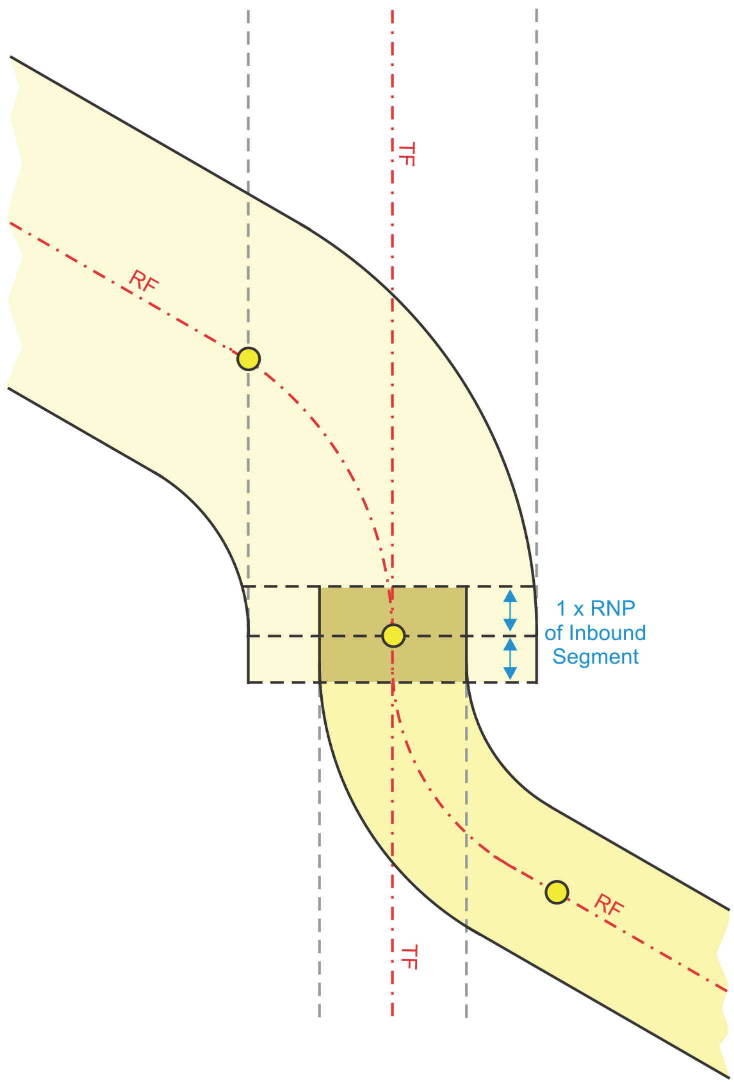


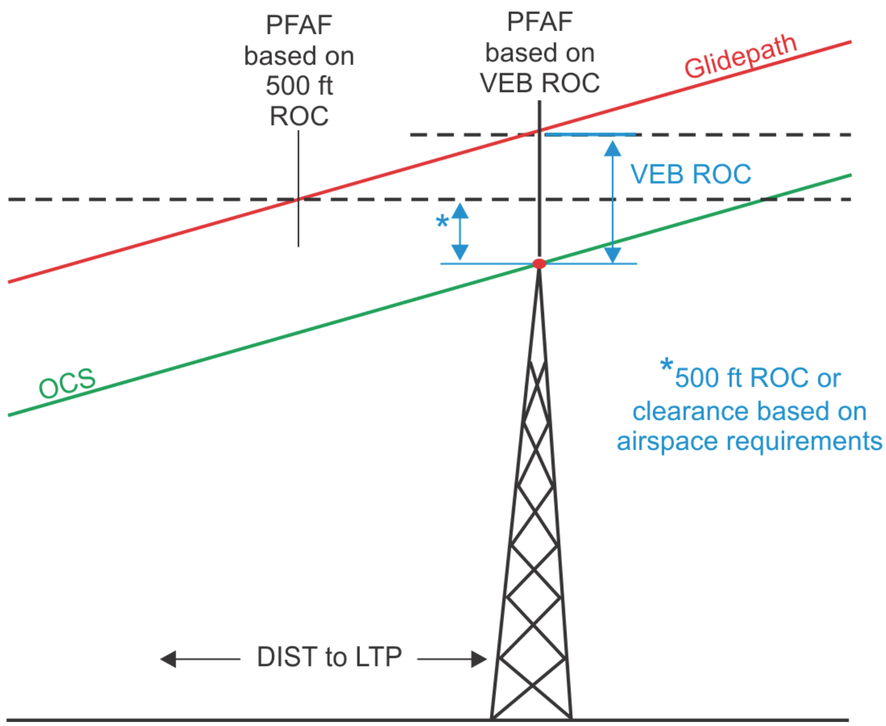
Figure 2-6C. RNP Change Involving RF Legs
(increase and decrease)



2.9 Effects of Cold Temperature on ROC in the Intermediate Segment.

When establishing the intermediate segment minimum altitude (glidepath intercept altitude), compare the difference between the 500-ft intermediate ROC value and the ROC value provided by the VEB OCS at the elevation of the intermediate segment controlling obstacle. If the VEB ROC value exceeds 500, apply this ROC value in lieu of 500 ft in the intermediate segment (see figure 2-7). Applying VEB ROC may raise the intermediate segment altitude.

Figure 2-7. Application of VEB in Lieu of ROC in Intermediate Segment



Volume 5. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Chapter 3. Final Approach Segment (FAS)

3.0 General.

RNP approaches are 3D procedures; the final segment provides the pilot with final segment vertical and lateral path deviation information based on BaroVNAV systems. Therefore, RNP procedures may not be developed for locations where the primary altimeter is a remote altimeter or where the final segment overlies precipitous terrain. The GQS described in Order 8260.3, Volume 3, paragraph 2.11 must be clear in order to publish a 3D procedure to the runway (for procedures with an RF turn in the final segment, the GQS terminates at the DA or FROP, whichever is closer to the LTP/FTP). The FAS OCS is based on limiting the vertical error performance of BaroVNAV avionic systems to stated limits. Minimum and maximum temperature limitations are specified on the approach chart for aircraft that do not have temperature-compensating systems. The minimum HATh value is 250 ft.

3.1 Reserved.

3.2 GPA and TCH Requirements.

See March 1, 2013 Clarification Memo

The OPTIMUM (design standard) GPA is 3 degrees. GPAs greater than 3 degrees but not more than the maximum (Volume 6, table 1-4) are authorized without approval when needed to provide obstacle clearance, minimum temperature limitations restrict approach availability when the approach is operationally needed, or to meet simultaneous parallel approach standards. Other cases and/or GPAs less than 3 degrees require Flight Standards or military authority approval (USAF not applicable). Vol 6 table1-4b lists the highest allowable GPA by aircraft category. If the required GPA is greater than the maximum for an aircraft category, do not publish minimums for that category. Volume 6 table 1-5 lists standard TCH values and recommended ranges of values appropriate for cockpit-to-wheel height groups 1 through 4. Three-dimensional procedures serving the same runway should share common TCH and GPA values. If an ILS serves the runway, use the ILS TCH and GPA values. If there is no ILS but a VGSI system with a suitable TCH and GPA serves the runway, use the VGSI TCH and GPA. Otherwise, select an appropriate TCH value from Volume 6 table 1-5, and 3-degree GPA.

3.2.1 High Temperature Limitation.

Publish a high temperature limit based on a maximum angle for the fastest published category. See Volume 6 paragraph 3.3.3 to determine the high temperature limit.

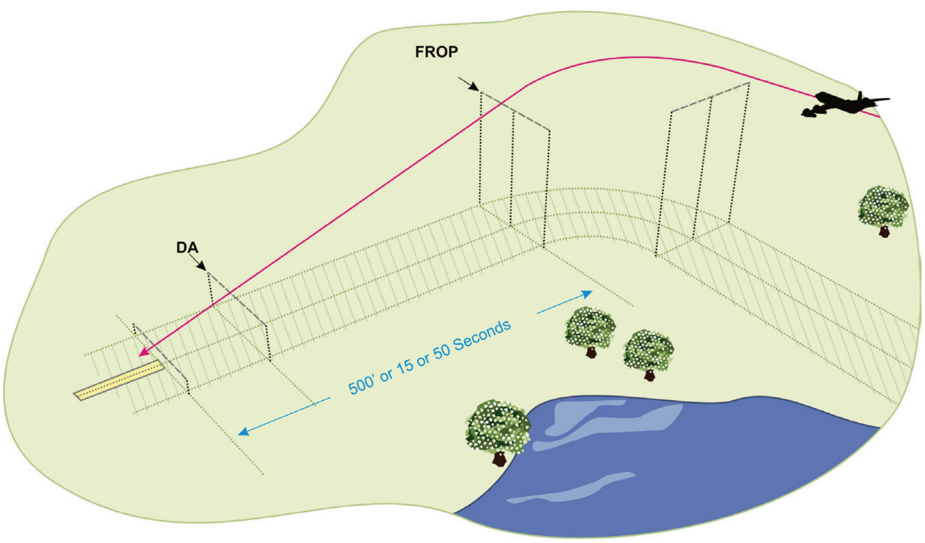
3.2.2 Low Temperature Limitation.

Publish a low temperature limit for the procedure. See Volume 6 paragraph 3.3.1 to determine the low temperature limit and its value below airport ISA (ΔISA_{LOW}).

3.3 Turns in the FAS.

FB turns are not allowed in the FAS. Where turns are necessary, use an RF leg. Design procedures that incorporate an RF turn leading to or in the final segment (RF termination fix at or inside the PFAF) to establish the aircraft on a straight segment aligned with the runway centerline prior to reaching DA. The FROP is the initial fix of the straight segment (see figure 3-1). Locate the FROP at a minimum distance (D_{FROP}) the greater of either 500 ft above LTP/FTP elevation or a distance appropriate for 15 or 50 seconds of flight depending on the initial missed approach RNP value (RNP_{IMAS}) using calculator 3-1.

Figure 3-1. FROP



Note: Where the PFAF is also the termination fix of an RF leg, the PFAF must meet FROP requirements.

Calculator 3-1. Distance to FROP

$$(1)\quad D_{500} = \frac{500\text{-}TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)}$$

$$(2)\quad D_{15sec} = \frac{HATh-TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)} + \left(V_{KTAS}+15\right)\times 25.32$$

$$(3)\quad D_{50sec} = \frac{HATh-TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)} + \left(V_{KTAS}+15\right)\times 84.39$$

$$(4)\quad \textbf{case } RNP_{IMAS} = 1.0: \quad D_{IMASvalue} = D_{15sec}$$
$$\textbf{case } RNP_{IMAS} < 1.0: \quad D_{IMASvalue} = D_{50sec}$$

$$(5)\quad D_{FROP} = \mathbf{max}\left[D_{500},\ D_{IMASvalue}\right]$$

where RNP_{IMAS} = Initial MAS RNP value

Calculator 3 1		
$\theta°$		Calculate
V_{KTAS}		
$HATh$		
TCH		
LTP/FTP_{elev}		
RNP_{IMAS}		
D_{500}		
D_{15sec}		
D_{50sec}		Clear
D_{FROP}		

3.4 Determining PFAF Location. (In all cases, the PFAF will be identified as a named fix.)

The OPTIMUM alignment is a TF segment straight in from PFAF to LTP on runway centerline extended (± 0.03° tolerance). If necessary, the TF course may be offset by up to 3 degrees. Where the course is offset, it must cross runway centerline extended at least 1500 ft out from LTP. A final segment may be designed using an RF leg segment when obstacles or operational requirements prevent a straight-in approach from PFAF to LTP. Determine the along-track distance from the LTP (FTP if offset) to the point where the glidepath intercepts the intermediate segment minimum altitude (D_{PFAF}). Calculate D_{PFAF} using Volume 6 calculator 1-15b.

3.4.1 PFAF Located on TF Leg.

See March 1, 2013 Clarification Memo

Geodetically calculate the latitude and longitude of the PFAF using the reverse true course of the TF leg (true course – 180 degrees) and D_{PFAF} measured along-track from the LTP (FTP if offset). Where the FAS consist of a single TF leg, HTML Calculators are provided on the AFS-420 web site to calculate D_{PFAF} and the WGS-84 latitude and longitude of the PFAF.

Figure 3-2. Reserved
Calculator 3-2. Reserved

3.4.2 PFAF Located on RF Leg.

The PFAF must be located at the initial fix of a TF or RF segment. The length in feet of the RF leg from the FROP to PFAF can be calculated by calculator 3-3.

Calculator 3-3. RF Leg Length

$$Length_{RF} = D_{PFAF} - D_{FROP}$$

where D_{PFAF} = results of volume 6, calculator 1-15b
D_{FROP} = results of calculator 3-1

Calculator 3 3		
D_{PFAF}		Calculate
D_{FROP}		
$Length_{RF}$		Clear

The number of degrees of arc given a specific arc length may be calculated using calculator 3-4.

Calculator 3-4. Degrees of an Arc

$$\text{Degrees of Arc } [\alpha°]: \quad \alpha° = \frac{180° \times L}{\pi \times R}$$

where L = arc length
R = arc radius

Calculator 3 4		
L		Calculate
R		
α°		Clear

Conversely, the length of an arc given a specific number of degrees of arc may be calculated using calculator 3-5.

Calculator 3-5. Length of an Arc

$$\text{Length of Arc } [L]: \; L = \frac{\alpha^\circ \times \pi \times R}{180^\circ}$$

where α° *= degrees of arc*

R *= arc radius*

Calculator 3 5		
α°		Calculate
R		
L		Clear

See March 1, 2013 Clarification Memo

3.4.2 **a. Determining RF PFAF Location Relative to LTP/FTP.** This method may be used for calculating WGS-84 latitude and longitude (see figure 3-3). Several software packages will calculate a geographical coordinate derived from Cartesian measurements from the LTP/FTP. Use calculators 3-6 and 3-7 to obtain the Cartesian values.

STEP 1: Determine the flight track distance (D_{PFAF}) from LTP/FTP to PFAF under Volume 6 calculator 1-15b.

STEP 2: Determine the distance (D_{FROP}) from LTP/FTP to the FROP (see paragraph 3.3).

STEP 3: Subtract D_{FROP} from D_{PFAF} to calculate the distance around the arc to the PFAF from the FROP. Use calculator 3-4 to determine number of degrees of arc; conversely, use calculator 3-5 to convert degrees of arc to length.

If the PFAF is in the RF segment, determine its X, Y coordinates using calculators 3-6 and 3-7:

Calculator 3-6. X Coordinate PFAF in an RF Segment

$$X = D_{FROP} + R \times \sin\left(\alpha° \times \frac{\pi}{180°}\right)$$

where D_{FROP} *= result of formula 3-1*

R *= arc radius*

$\alpha°$ *= degrees of arc*

Calculator 3 6		
$\alpha°$		Calculate
R		
D_{FROP}		Clear
X		

Calculator 3-7. Y Coordinate PFAF in an RF Segment

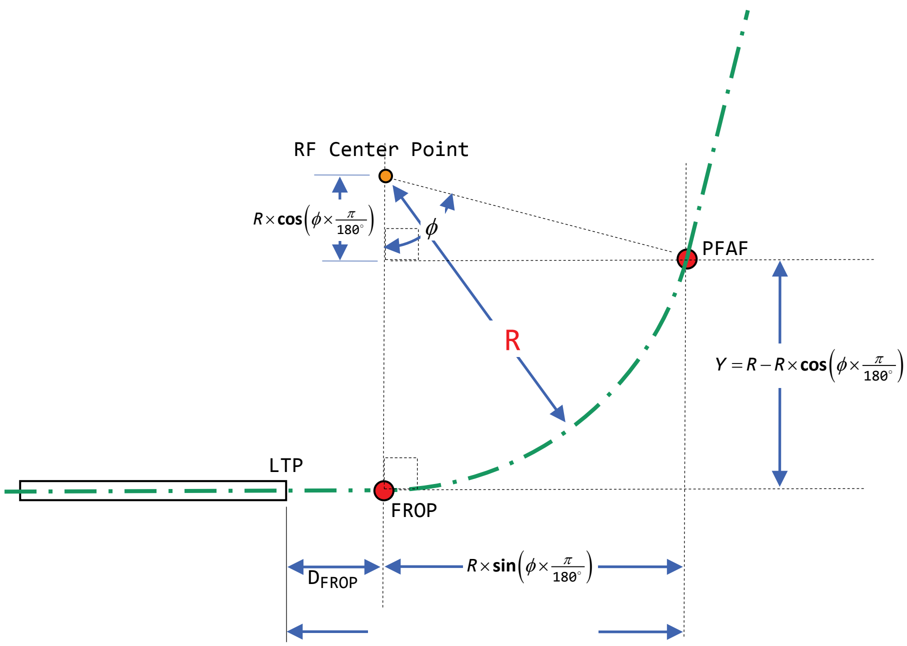
$$Y = R - \left[R \times \cos\left(\alpha° \times \frac{\pi}{180°}\right)\right]$$

where R *= arc radius*

$\alpha°$ *= degrees of arc*

Calculator 3 7		
$\alpha°$		Calculate
R		
Y		Clear

Figure 3-3. Determining PFAF Position (X, Y) Relative to LTP



3.5 Final Segment OEA.

The final segment OEA begins 1×RNP prior to the PFAF and extends to the LTP/FTP. The final segment OEA contains the evaluation surfaces for final approach and landing: VEB OCS which is evaluated to establish the DA point; the visual segment OIS to identify noteworthy obstructions between the DA point and the LTP/FTP; and the GQS which limits the height of obstructions in the vicinity of centerline between the DA point and the LTP/FTP. The OEA area between the DA and LTP/FTP is also evaluated for missed approach as described in chapter 4. The OCS origin distance from LTP/FTP (D_{VEB}) and its slope are determined through application of the VEB. The VEB provides origin and slope values for both TF and RF based final segments. Origin values are further divided into two categories: aircraft with wingspans ≤ 262 ft, and aircraft with wingspans ≤ 136 ft. Develop procedures using the value for wingspans ≤ 262 ft. (this is the nominal design value). Where the DA can be reduced by at least 50 ft or visibility reduced by ¼ mile, the approach <u>may</u> be developed using the value for wingspans ≤ 136 ft; however, the procedure must be restricted for use by aircraft with wingspans ≤ 136 ft only. The VEB calculations require input of values for two variables: final segment RNP value and temperature (°C) deviation (ΔISA_{LOW}) below the airport ISA temperature.

Calculate D_{VEB} and the OCS slope using Calculator 3-8.

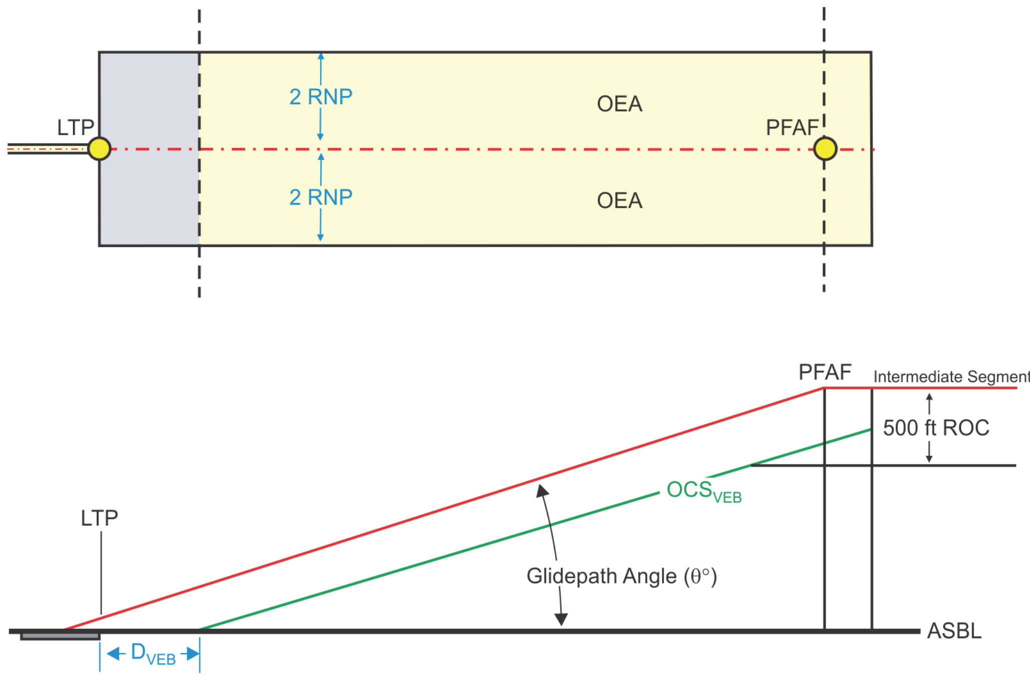
Calculator 3-8. VEB OCS Origin/Slope Calculator (see chapter 5 for formulas)

See March 1, 2013
Clarification Memo

Calculator 3 8			
Intermediate Segment Altitude (ft):			Calculate
LTP/FTP MSL Elevation (ft):			
TCH (ft):			
GPA:			
ACT(ºC):			
RNP Value (NM):			
Bank Angle (RF Only):			
OCS Slope Ratio :	*():1*		
D_{VEB}:	*Straight-in*	*RF turn*	
Wingspan <= 262			
Wingspan <= 136			
VEB Variables			
	Straight-in	*RF turn*	Clear
Airport ISA			
Delta ISA			
ASE PFAF			
ASE 250			
VAE PFAF			
VAE 250			
ISAD PFAF			
ISAD 250			
ROC PFAF Wingspan < = 262			
Wingspan < = 136			
ROC 250 Wingspan <= 262			
Wingspan <= 136			
BG Wingspan <= 262			
Wingspan <= 136			

Calculate the MSL elevation of the OCS at any distance 'd' from LTP/FTP using calculator 3-9.

Figure 3-4. Final Segment OEA and OCS



Calculator 3-9. OCS MSL Elevation

$$VEB_{MSL} = LTP_{elev} + \frac{d - D_{VEB}}{OCS_{slope}}$$

where d = distance along course centerline from RWT

D_{VEB} = distance of OCS origin from LTP derived from VEB Calculations

OCS_{slope} = OCS slope derived from VEB calculations

Calculator 3 9		
d		Calculate
D_{VEB}		
OCS_{slope}		
LTP/FTP_{elev}		Clear
VEB_{MSL}		

3.5.1 Obstacle Evaluation.

If the FAS OCS is not penetrated, the MINIMUM HATh value of 250 ft applies. Limitation: Determine the DA and DDA using calculator 3-10.

See March 1, 2013 Clarification Memo

Calculator 3-10. DA

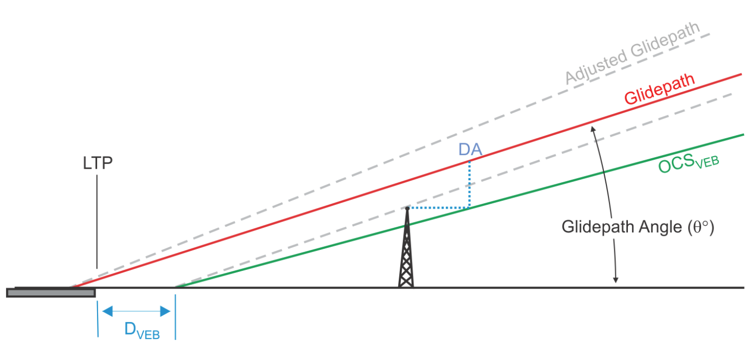
(1) $DA = HATh + LTP_{elev}$

(2) $D_{DA} = \text{ceiling}\left[\max\left(DVEB + \frac{50}{\tan\left(\theta° \times \frac{\pi}{180°}\right)}, r \times \left(\frac{\pi}{2} - \theta° \times \frac{\pi}{180°} - \text{asin}\left(\frac{\cos\left(\theta° \times \frac{\pi}{180°}\right) \times \left(r + LTP_{elev} + TCH\right)}{r + DA}\right)\right)\right)\right]$

Calculator 3 10		
TCH		Calculate
HATh		
D_{VEB}		
$\theta°$		
LTP/FTP_{elev}		
DA		Clear
D_{DA}		

Obstacles that penetrate an OCS may be mitigated by one of the following actions: remove or lower obstacle, lower the RNP value for the segment (if appropriate), adjust the lateral path, raise GPA, raise TCH (within Volume 6 table 1-5 limits), or adjust HATh (see figure 3-5 and calculator 3-11).

Figure 3-5. VEB Adjustment of DA or GPA



Note: D_{VEB} decreases slightly when GPA is increased. Therefore, if the angle is increased to accommodate a penetration, the VEB must be recalculated and the OCS re-evaluated.

Calculator 3-11. HATh Adjustment

$$(1)\quad HATh_{adjusted} = \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times \left(d + p \times OCS_{VEB}\right) + TCH - LTP_{elev}$$

$$(2)\quad DA_{adjusted} = \text{ceiling}\left[LTP_{elev} + HATh_{adjusted}\right]$$

$$(3)\quad D_{DA} = \text{ceiling}\left[r \times \left(\frac{\pi}{2} - \theta^\circ \times \frac{\pi}{180^\circ} - \text{asin}\left(\frac{\cos\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times \left(r + LTP_{elev} + TCH\right)}{r + DA_{adjusted}}\right)\right)\right]$$

where d = distance (ft) LTP to obstacle

p = amount of penetration (ft)

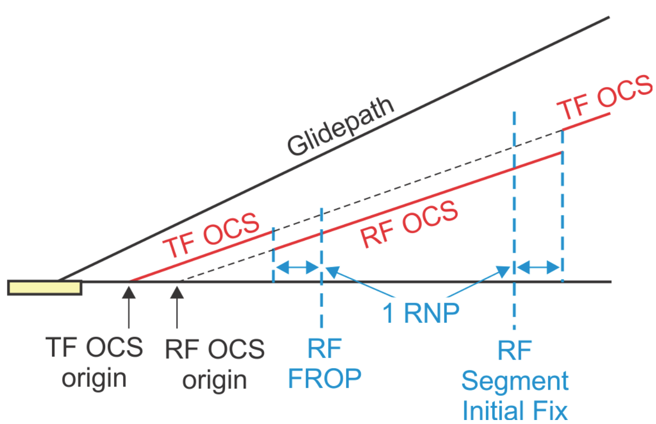
OCS_{VEB} = Slope of VEB OCS

Calculator 3 11		
d		Calculate
θ°		
OCS_{VEB}		
LTP/FTP_{elev}		
p		
TCH		
$HATh_{adjusted}$		Clear
$DA_{adjusted}$		
D_{DA}		

3.5.2 Applying VEB OCS to RF Final Segments.

Where RF legs are incorporated in the final segment, the OCS slope ratio will be consistent for the straight and curved path portions; however, the OCS origin will be different because the variables for aircraft body geometry are different for straight and curved path legs. The OCS elevation at any point is equal to the surface elevation of the course centerline abeam it (see figure 3-6).

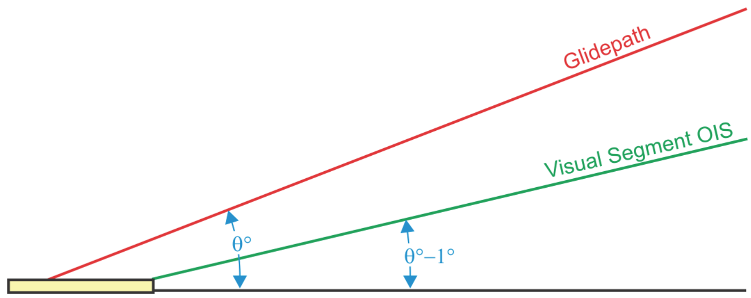
Figure 3-6. RF Final Segment OCS Evaluation



3.6 Visual Segment Evaluation.

In addition to the standard visual segment evaluation under Order 8260.3 apply an OIS that originates at the LTP/FTP and extends to the DA point at an angle of one degree less than the GPA (see figure 3-7).

Figure 3-7. VEB Visual Segment OIS



The OIS half-width at the LTP/FTP is 100 ft outside the runway edge. It splays at an angle of 10 degrees relative to course until reaching a width of ± 1×RNP, which it maintains until contacting the final segment OEA at DA (see figure 3-8).

Calculator 3-12. Splay Length

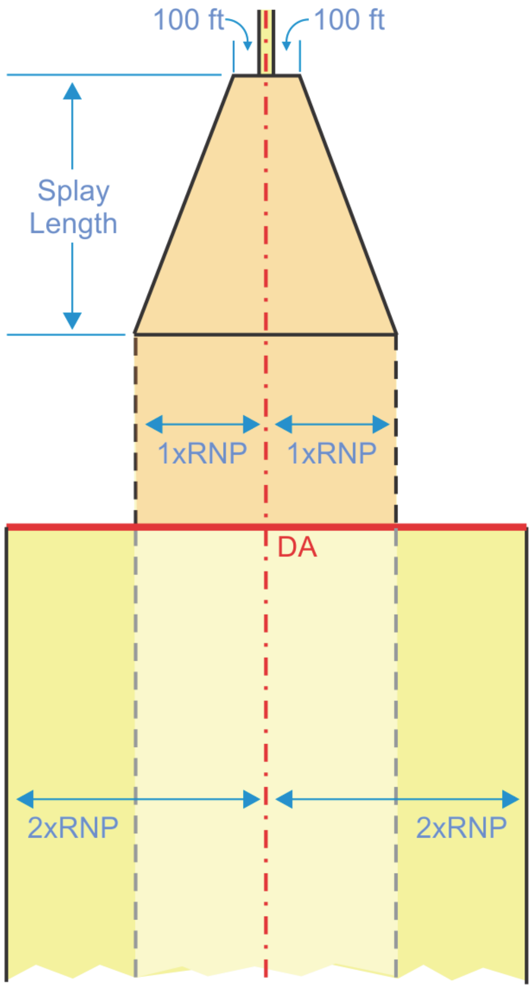
$$Splay_{Length} = \frac{(1 \times RNP \times fpnm) - \left(100 + \frac{Rwy\ Width}{2}\right)}{\tan\left(10° \times \frac{\pi}{180°}\right)}$$

where RNP = MA RNP value

Rwy Width = width (ft) of the runway

Calculator 3 12		
RNP		Calculate
Rwy Width		
$Splay_{Length}$		Clear

Figure 3-8. Visual Segment OIS at Full Width



Calculate the segment length ($Splay_{length}$) required to reach ± 1×RNP using calculator 3-12. If $Splay_{length}$ is greater than the distance from LTP/FTP to DA, construct a ± 1×RNP buffer area aligned with the runway centerline extended from the DA point toward the LTP/FTP for a distance of D_{buffer} calculated by calculator 3-13 and figure 3-9 based on largest category minima published and the PFAF altitude. The buffer OIS is a continuation of the VEB OCS from DA to the OCS origin, or D_{buffer}, whichever is less. An obstacle may penetrate the visual/buffer OIS (figures 3-8 and 3-9) provided it is charted (single or in group form where appropriate) and necessary mitigations are identified and approved by AFS-400.

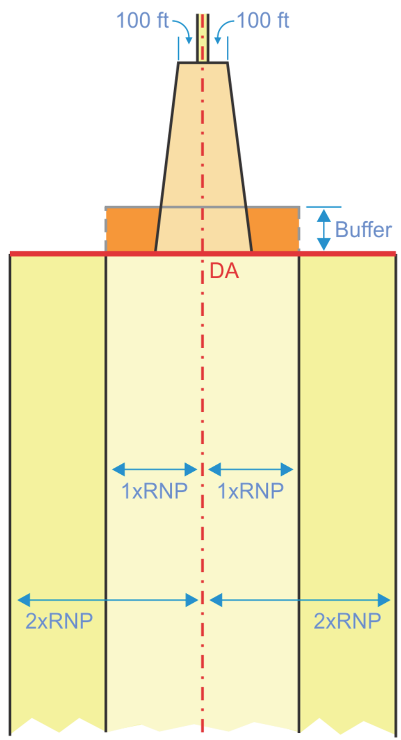
Calculator 3-13. Buffer Area Distance

$$buffer = (V_{KTAS} + 10) \times 8.44$$

where V_{KTAS} = result of Volume 6, paragraph 1.2

Calculator 3 13		
V_{KTAS}		Calculate
D_{buffer}		Clear

Figure 3-9. Visual Segment Not at Full Width



Volume 5. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Chapter 4. Missed Approach Segment (MAS)

4.0 **General.** These criteria are based on the following assumptions:

- Aircraft climb at a rate of at least 200 ft/NM (3.29%) in the missed approach segment.
- The OEA expansion where FAS RNP levels less than RNP-1 are continued into the MAS is based on IRU drift rates of 8 NM per hour.
- For RNP levels less than 1, turns are not allowed below 500 ft measured AGL.
- A 50-ft height loss is inherent in MA initiation.

Construct the missed approach segment using one of the following methods in order of precedence:

4.0 a. **RNP AR standard missed segment** (required in paragraph 1.3). The construction is a continuation of the FAC. The OEA expands at a 15-degree splay relative to course from the width of the FAS RNP value to an RNP value of 1.0. (This construction accommodates single thread equipage – serves broad scope.)

4.0 b. **RNAV missed segment**. Where turns are required before the RNP AR standard MAS would reach full width, construct the MAS under Volume 6 paragraph 3.4. (This construction accommodates single thread equipage – serves broad scope.)

4.0 c. **RNP AR missed segment with RNP<1.0.** Construct straight or turning (using RF legs) missed approach under Volume 6, paragraph 1.3.3. Steps 5 and 7 do not apply. (This construction accommodates dual thread equipage – serves narrower scope.)

4.1 MAS Leg Types.

a. AR.

The MA route is a series of segments. The following leg types are authorized for MA procedure design:

- TF
- RF

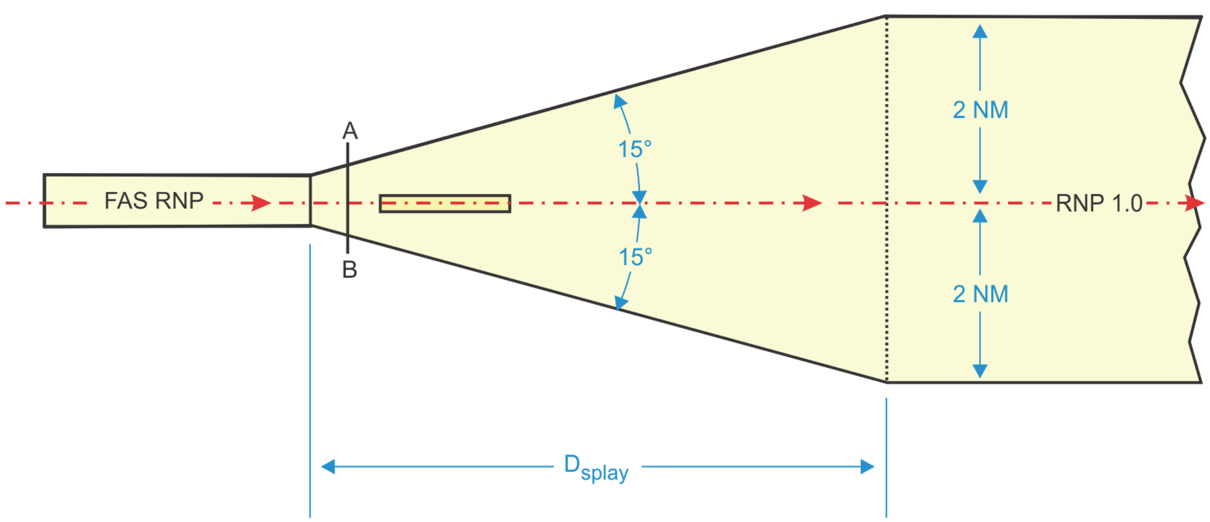
Additionally, if the RF leg RNP value is <1.0, the RF leg length must comply with paragraph 4.2.1.

b. RNAV. See Volume 6, paragraph 3.4

4.2 MAS RNP Level.

The standard MA segment splays from the FAS width at DA; 15 degrees relative to course centerline, to a width of ± 2 NM (RNP 1.0) (see figure 4-1A).

Figure 4-1A. Transition from FAS to MAS RNP Levels



The along-track distance (NM) required to complete the splay may be calculated using calculator 4-1.

Calculator 4-1. Along-Track Distance To Complete Splay

$$D_{splay} = 7.464 \times (1 - RNP_{FAS})$$

where RNP_{FAS} = RNP value of final segment

Calculator 4 1		
RNP_{FAS}		Calculate
D_{splay}		Clear

See March 1, 2013 Clarification Memo

Turns are not allowed until the splay is complete. If turns are required before D_{splay}, consider another construction technique; e.g., applying paragraph 4.2.1 or a conventional TERPS MAS.

4.2.1 RNP Values < 1.

Where turns are necessary, the turn initiation must occur after passing 500 ft AGL and at least $D_{MASturn}$ feet from DA. When possible, the turn should not occur until after DER. Calculate $D_{MASturn}$ using calculator 4-2.

Calculator 4-2. Distance MA Turn

$$D_{MASturn} = \frac{10}{3600} \times fpnm \times (V_{KTAS} - 10)$$

where V_{KTAS} is based on final approach airspeed at DA

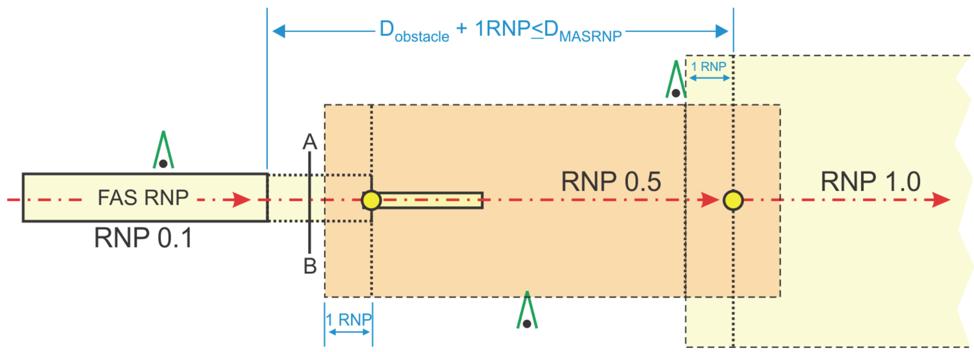
Calculator 4 2		
V_{KIAS}		Calculate
DA		
$D_{MASturn}$		Clear

Where the 40:1 OCS is penetrated and the resulting HAT or visibility can be reduced by at least 50 ft or ¼ SM respectively, consider limiting the MAS RNP value until clearing the obstruction.

Use the largest RNP value (FAS RNP ≤ MAS RNP ≤ 1.0) that clears the obstruction. The maximum distance (NM) (D_{MASRNP}) that the < 1.0 RNP value may be extended into the MAS is calculated using calculator 4-3 (see figure 4-1B).

Note: Use of MAS RNP values < 1.0 requires track guidance (TF or RF leg segments). Paragraph 2.8 applies to RNP increases.

Figure 4-1B. RNP Value <1.0



Calculator 4-3. Max Distance RNP 1.0 Can Extend into MAS

$$D_{MASRNP} = \left(RNP_{MAS} - 0.05\right) \times \frac{V_{KTAS} - 10}{8}$$

where RNP_{MAS} = Missed approach RNP Value <1.0

V_{KTAS} is based on slowest published category final approach airspeed at DA.

Calculator 4 3		
V_{KIAS}		Calculate
RNP_{MAS}		
DA		
D_{MASRNP}		Clear

4.3 MA Segment OCS Evaluation.

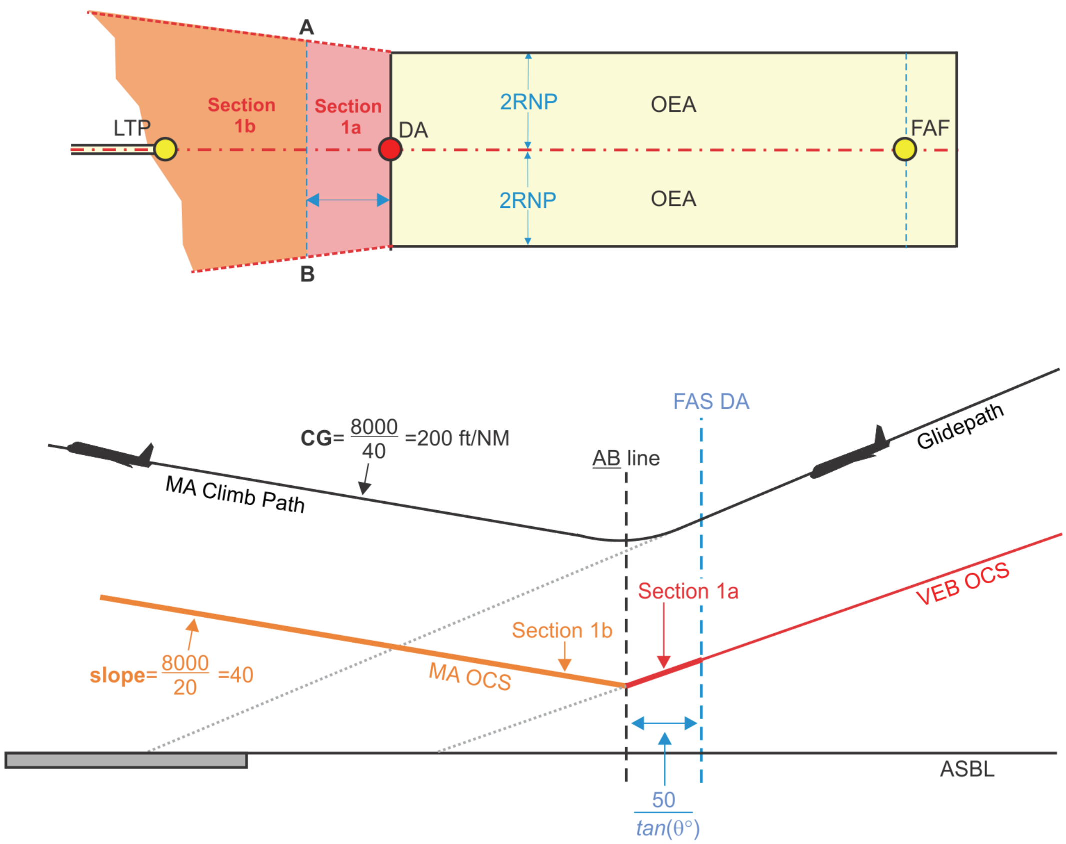
The MAS is composed of OCS sections 1a and 1b (see figure 4-2). Sections 1a and 1b are separated by the <u>AB</u> line. Section 1a OCS extends from the DA point downward at the VEB OCS slope ratio for a distance of $D_{heightloss}$ (calculated using calculator 4-4) measured along the final course track to the <u>AB</u> line. From the <u>AB</u> line, section 1b OCS rises at a 40:1 slope. Obstacles must not penetrate the OCS.

Calculator 4-4. Height Loss Distance

$$D_{heightloss} = \frac{50}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}$$

Calculator 4 4		
θ°		Calculate
$D_{heightloss}$		Clear

Figure 4-2. MAS OEA/OCS



Calculate the **MSL HMAS** at the **AB** line (**$HMAS_{ab}$**) using calculator 4-5.

Calculator 4-5. HMAS at the AB line

$$HMAS_{AB} = LTP_{elev} + \frac{D_{DA} - D_{OCSorigin} - \dfrac{50}{\tan\left(\theta° \times \dfrac{\pi}{180°}\right)}}{VEB_{OCSslope}}$$

where D_{DA} = Distance from LTP to DA

$D_{OCSorigin}$ = Distance from LTP to OCS origin

$VEB_{OCSslope}$ = Final segment OCS slope

Calculator 4 5		
LTP/FTP_{elev}		Calculate
D_{DA}		
$\theta°$		
$D_{OCSorigin}$		
$VEB_{OCSslope}$		Clear
$HMAS_{AB}$		

See March 1, 2013 Clarification Memo

The MSL height of the section 1b surface ($H_{section1b}$) at any obstruction can be calculated using calculator 4-6 after determining distance ($D_{section1b}$) by measuring the along-track centerline distance from the AB line to a point abeam the obstruction.

Calculator 4-6. Height of Section 1b Surface

$$H_{section1b} = HMAS_{AB} + \frac{D_{section1b}}{MA_{OCSslope}}$$

where $HMAS_{AB}$ = result of calculator 4-5

$D_{section1b}$ = atrk distance from AB line to abeam obstacle

$MA_{OCSslope}$ = Normally 40:1 (calculator entry 40)

Calculator 4 6		
$HMAS_{AB}$		Calculate
$D_{section1b}$		
$MA_{OCSslope}$		Clear
$H_{section1b}$		

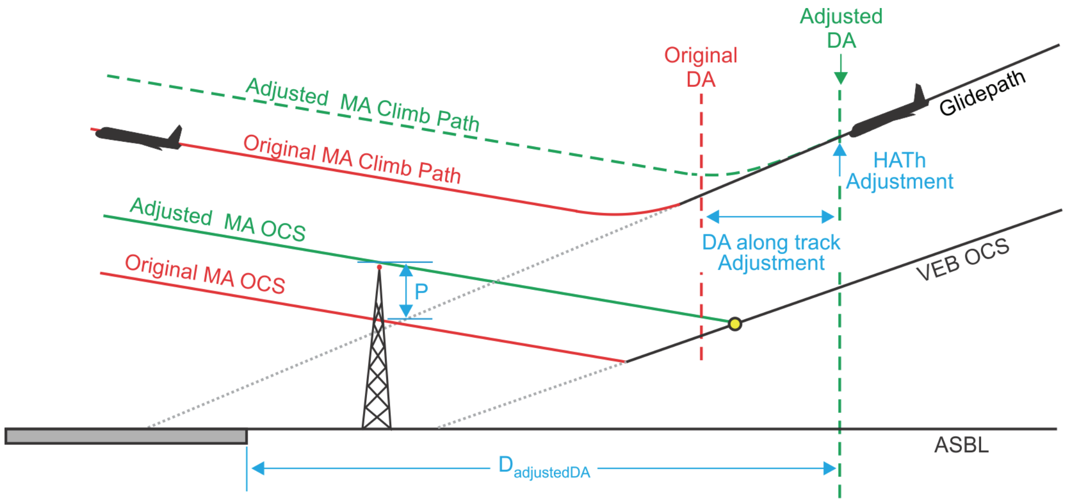
4.3.1 OCS Penetrations.

Where obstructions penetrate the OCS, take one or more of the following actions to achieve the lowest possible DA:

- Remove or lower the obstruction.
- Use RNP level < 1.0 to place obstacle outside the OEA.
- Alter MA track.
- Adjust DA.
- Require MA climb gradient.

4.3.1 a. **DA Adjustment.** See figure 4-3. To determine the DA required to mitigate a MA OCS penetration, determine the amount of increase required in the HATh value using calculator 4-7.

Figure 4-3. DA Adjustment



Calculator 4-7. HATh Adjustment

$$HATh_{adjustment} = \frac{p \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times MA_{OCSslope} \times VEB_{OCSslope}}{MA_{OCSslope} + VEB_{OCSslope}}$$

where p = *amount of penetration (ft)*

$MA_{OCSslope}$ = *normally 40:1*

$VEB_{OCSslope}$ = *results of VEB calulations*

Calculator 4 7		
p		Calculate
θ°		
$VEB_{OCSslope}$		
$MA_{OCSslope}$		Clear
$HATh_{adjustment}$		

Calculate the adjusted distance from LTP/FTP to DA using calculator 4-8.

Calculator 4-8. Adjusted LTP/FTP to DA Distance

See March 1, 2013 Clarification Memo

$$D_{adjustedDA} = \frac{HATh_{FAS} + HATh_{adjustment} - TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}$$

where $HATh_{FAS}$ = *HATh value for DA based on final segment eval*

$HATh_{adjustment}$ = *results of calculator 4-7*

Calculator 4 8		
$HATh_{FAS}$		Calculate
θ°		
$HATh_{adjustment}$		Clear
TCH		
$D_{adjustedDA}$		

Finally, calculate the adjusted DA value using calculator 4-9.

Calculator 4-9. Adjusted DA

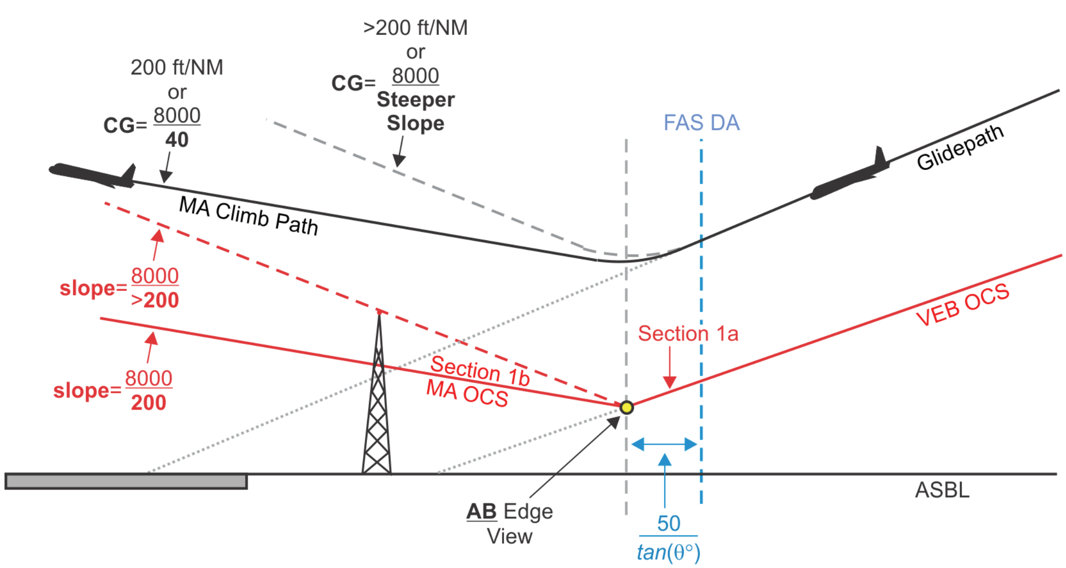
$$DA_{adjusted} = \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times D_{adjustedDA} + \left(LTP_{elev} + TCH\right)$$

where $D_{adjustedDA}$ = results of calculator 4-8

Calculator 4 9		
LTP/FTP_{elev}		Calculate
$D_{adjustedDA}$		
θ°		
TCH		Clear
$D_{adjusted}$		

4.3.1 **b. Calculating MA climb gradient.** See figure 4-4. Where the section 1b OCS is penetrated and resulting HAT or visibility can be reduced by at least 50 ft or ¼ SM respectively, consider avoiding the obstruction by requiring an MA climb gradient.

Figure 4-4. MA Climb Gradient



To determine the climb gradient required to clear a section 1b obstacle, apply calculator 4-10.

Calculator 4-10. MA CG

$$MA_{CG} = ceiling\left[\frac{8000\times\left(Obs_{elev} - HMAS_{AB}\right)}{5\times D_{ABobs}}\right]\times 5$$

where $HMAS_{AB}$ = *results of calculator 4-5*

D_{ABobs} = *ATD distance (ft) from AB line to obstacle*

Calculator 4 10		
D_{ABobs}		Calculate
Obs_{elev}		
$HMAS_{AB}$		Clear
MA_{CG}		

If the climb gradient exceeds 425 ft/NM, evaluate the MAS using the OCS slope appropriate for 425 ft/NM (18.82:1) and adjust DA for the remaining penetration per paragraph 4.3.1a.

Calculating CG termination altitude. Calculate the altitude above which the climb gradient is no longer required using calculator 4-11. Round the result to the next higher 100 ft increment.

Calculator 4-11. CG Termination altitude

$$TA_{CG} = \textbf{ceiling}\left[\frac{(DA - 50) + \left(CG\times\frac{D_{ABobs}}{fpnm}\right)}{100}\right]\times 100$$

where CG = *climb gradient*

D_{ABobs} = *atrk distance (ft) from AB line to obstacle*

Calculator 4 11		
DA		Calculate
CG		
D_{ABobs}		Clear
TA_{CG}		

Volume 5. Standard for Required Navigation Performance (RNP) Approach Procedures with Authorization Required (AR)

Chapter 5. Vertical Error Budget (VEB) ROC Equation Explanation

5.0 The ROC for the VEB is derived by combining known three standard deviation variations by the RSS method and multiplying by four thirds to determine a combined four standard deviation (4σ) value. Bias errors are then added to determine the total ROC.

5.1 VEB variables.

5.1.1 The sources of variation included in the ROC for the VEB are:

Actual navigation performance error (anpe)
Waypoint precision error (wpr)
Flight technical error (fte) fixed at 75 ft
Altimetry system error (ase)
Vertical angle error (vae)
Automatic terminal information system (atis) fixed at 20 ft

5.1.2 The bias errors for the ROC are:

Body geometry error (bg)
International standard atmosphere temperature deviation (isad)

Semi-span for narrow body fixed at 68
Semi-span for wide body fixed at 131

5.1.3 The **ROC** equation which combines these is:

$$roc = bg - isad + \frac{4}{3}\sqrt{anpe^2 + wpr^2 + fte^2 + ase^2 + vae^2 + atis^2}$$

5.1.4 Three Standard Deviation Formulas for Root-Sum of Squares Computations:

The anpe: $anpe = 1.225 \times rnp \times fpnm \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)$

The wpr: $wpr = 60 \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)$

The fte: $fte = 75$

The ase: $ase = -8.8 \times 10^{-8} \times (elev)^2 + 6.5 \times 10^{-3} \times (elev) + 50$

The vae: $vae = \left(\frac{elev - ltp_{elev}}{\tan\left(\theta° \times \frac{\pi}{180°}\right)} \right) \times \left(\tan\left(\theta° \times \frac{\pi}{180°}\right) - \tan\left((\theta° - 0.01°) \times \frac{\pi}{180°}\right) \right)$

The atis: $atis = 20$

5.2 Bias Error Computations.

The isad: $isad = \frac{(elev - ltp_{elev}) \times \Delta ISA}{288 + \Delta ISA - 0.5 \times 0.00198 \times elev}$

The bg bias:

Straight segments fixed values:

narrow body $bg = 15 \quad semi\text{-}span = 68$

wide body $bg = 25 \quad semi\text{-}span = 131$

RF segments:

narrow body $bg = \max\left(15, 68 \times \sin\left(\phi° \times \frac{\pi}{180°}\right)\right)$

wide body $bg = \max\left(25, 131 \times \sin\left(\phi° \times \frac{\pi}{180°}\right)\right)$

5.3 Sample Calculations.

Design Variables

Applicable facility temperature minimum is 20° C below standard: $(\Delta ISA = -20)$
Required navigational performance (RNP) is .14 NM: $(rnp = 0.14)$
Wing semispan of 68 ft: $(semispan = 68)$
RF segment.

Aircraft and Aircrew Authorization Required (AR) Fixed Values

Vertical flight technical error (FTE) of two standard deviations is assumed to be 75 ft: $(fte = 75)$

Automatic terminal information service (ATIS) two standard deviation altimeter setting vertical error is assumed to be 20 ft: $(atis = 20)$

The maximum assumed bank angle is 18 degrees: $(\phi° = 18°)$

Glidepath Variables

Precision Final Approach Fix Altitude (PFAF) is 4500 ft: $(4{,}500ft)$

Landing Threshold Point Elevation (ltpelev): $(ltp_{elev} = 1200)$

Threshold Crossing Height (TCH): $(tch = 55)$

Glide Path Angle (θ): $\theta° = 3$

Calculations:

$$roc = bg - isad + \frac{4}{3}\sqrt{anpe^2 + wpr^2 + fte^2 + ase^2 + vae^2 + atis^2}$$

The anpe:

$$anpe = 1.225 \times rnp \times \frac{1852}{0.3048} \times \tan\left(\theta° \times \frac{\pi}{180°}\right)$$
$$= 1.225 \times 0.14 \times \frac{1852}{0.3048} \times \tan\left(3° \times \frac{\pi}{180°}\right)$$
$$54.6117$$

The wpr:

$$wpr = 60 \times \tan\left(\theta° \times \frac{\pi}{180°}\right)$$
$$= 60 \times \tan\left(3° \times \frac{\pi}{180°}\right)$$
$$= 3.1445$$

The fte: $fte = 75$

The ase: $ase = -8.8 \times 10^{-8} \times (elev)^2 + 6.5 \times 10^{-3} \times (elev) + 50$

$$ASE250 = -8.8 \times 10^{-8} \times (ltp_{elev} + 250)^2 + 6.5 \times 10^{-3} \times (ltp_{elev} + 250) + 50$$
$$= -8.8 \times 10^{-8} \times (1200 + 250)^2 + 6.5 \times 10^{-3} \times (1200 + 250) + 50$$
$$= 59.2400$$

$$ASEpfaf = -8.8 \times 10^{-8} \times (PFAF)^2 + 6.5 \times 10^{-3} \times (PFAF) + 50$$
$$= -8.8 \times 10^{-8} \times (4500)^2 + 6.5 \times 10^{-3} \times (4500) + 50$$
$$= 77.4680$$

The vae: $vae = \left(\frac{elev - ltp_{elev}}{\tan\left(\theta° \times \frac{\pi}{180°}\right)}\right) \times \left(\tan\left(\theta° \times \frac{\pi}{180°}\right) - \tan\left((\theta° - 0.01°) \times \frac{\pi}{180°}\right)\right)$

$$VAE_{pfaf} = \left(\frac{PFAF - ltp_{elev}}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)} \right) \times \left(\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) - \tan\left((\theta^\circ - 0.01^\circ) \times \frac{\pi}{180^\circ}\right) \right)$$

$$= \left(\frac{4500 - 1200}{\tan\left(3^\circ \times \frac{\pi}{180^\circ}\right)} \right) \times \left(\tan\left(3^\circ \times \frac{\pi}{180^\circ}\right) - \tan\left((3^\circ - 0.01^\circ) \times \frac{\pi}{180^\circ}\right) \right)$$

$$= 11.0200$$

$$VAE_{250} = \left(\frac{250}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)} \right) \times \left(\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) - \tan\left((\theta^\circ - 0.01^\circ) \times \frac{\pi}{180^\circ}\right) \right)$$

$$= \left(\frac{250}{\tan\left(3^\circ \times \frac{\pi}{180^\circ}\right)} \right) \times \left(\tan\left(3^\circ \times \frac{\pi}{180^\circ}\right) - \tan\left((3^\circ - 0.01^\circ) \times \frac{\pi}{180^\circ}\right) \right)$$

$$= .8349$$

The isad: $isad = \frac{(elev - ltp_{elev}) \times \Delta ISA}{288 + \Delta ISA - 0.5 \times 0.00198 \times elev}$

$$ISAD_{pfaf} = \frac{(PFAF - ltp_{elev}) \times \Delta ISA}{288 + \Delta ISA - 0.5 \times 0.00198 \times (PFAF)}$$

$$= \frac{(4500 - 1200) \times (-20)}{288 - 20 - 0.5 \times 0.00198 \times (4500)}$$

$$= -250.4316$$

$$ISAD_{250} = \frac{250 \times \Delta ISA}{288 + \Delta ISA - 0.5 \times 0.00198 \times (ltp_{elev} + 250)}$$

$$= \frac{250 \times (-20)}{288 - 20 - 0.5 \times 0.00198 \times (1200 + 250)}$$

$$= -18.7572$$

The bg:

$$bg = semispan \times \sin\left(\phi^\circ \times \frac{\pi}{180^\circ}\right)$$

$$= 68 \times \sin\left(18^\circ \times \frac{\pi}{180^\circ}\right)$$

$$= 21.0132$$

$$ROC_{250} = bg - ISAD_{250} + \frac{4}{3} \times \sqrt{anpe^2 + wpr^2 + fte^2 + ASE_{250}{}^2 + VAE_{250}{}^2 + atis^2}$$

$$= 21.0132 + 18.7572 + \frac{4}{3} \times \sqrt{54.6117^2 + 3.1445^2 + 75^2 + 59.2400^2 + 0.8349^2 + 20^2}$$

$$= 189.0049$$

$$ROC_{pfaf} = bg - ISAD_{pfaf} + \frac{4}{3} \times \sqrt{anpe^2 + wpr^2 + fte^2 + ASE_{pfaf}{}^2 + VAE_{pfaf}{}^2 + atis^2}$$
$$= 21.0132 + 250.4316 + \frac{4}{3} \times \sqrt{54.6117^2 + 3.1445^2 + 75^2 + 77.4680^2 + 11.020^2 + 20^2}$$
$$= 435.5047$$

5.4 Calculating the Obstacle Clearance Surface (OCS) Slope Ratio.

The OCS slope is calculated by taking the difference in heights of the OCS surface at ROC_{pfaf} and ROC_{250}:

$$OCS_{slope} = \frac{\left(\dfrac{pfaf - ltp_{elev} - 250}{\tan\left(\theta^\circ \times \dfrac{\pi}{180^\circ}\right)} \right)}{\left(\left(pfaf - ltp_{elev}\right) - ROC_{pfaf}\right) - \left(250 - ROC_{250}\right)}$$

5.5 Calculating the OCS LTP/FTP to Origin Distance.

The OCS origin is calculated by taking the distance from threshold of the 250 ft point of the designed glidepath and subtracting the distance along the OCS slope from zero to the ROC_{250} point.

$$OCS_{origin} = \left(\frac{250 - tch}{\tan\left(\theta^\circ \times \dfrac{\pi}{180^\circ}\right)} \right) - \left(250 - ROC_{250}\right) \times OCS_{slope}$$

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United States Standard for

Performance Based Navigation (PBN)

Volume 6

Area Navigation (RNAV)

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Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 1. General Criteria

Section 1. Basic Criteria Information

1.0 Published Lines of Minimums.

1.0 a. Airplanes.

- Straight -In Aligned Procedures

  Rule #1: Publish LNAV/VNAV and *LPV minimums. If the GQS is penetrated, this rule does not apply.

  Rule #2: Publish LNAV minimums.

  Rule #3: *Publish LP minimums if...

  a. Neither LNAV/VNAV nor LPV minima are published, and
  b. The LP MDA is at least 20 ft lower than the LNAV MDA.

  Rule #4: Publish circling minimums if desired.

- Non Straight-In Aligned Procedures (Circling Only)

  Rule #1: Evaluate an LNAV final segment.

  Rule #2: The circling MDA must not be lower than the result of the LNAV final segment evaluation.

1.0 b. Helicopters.

- Public Helicopter Procedures To Heliports

  Rule #1: Publish LNAV minimums.

  Rule #2: *Publish LP minimums if the LP MDA is at least 20 ft lower than the LNAV MDA.

  *N/A if airport is not within WAAS coverage.

1.1 Segment OEA Width (General).

Table 1-2 lists primary and secondary width values for all segments of an RNAV procedure. Except for departures, where segments cross a point 30 NM from ARP, segment primary area width increases (expansion) or decreases (taper) at a rate of 30 degrees relative to course to the appropriate width (see figure 1-2A). Secondary area expansion/taper is a straight-line connection from the point the primary area begins expansion/taper to the point the primary area expansion/taper ends. Reference to route width values 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, en route segment width is “2-4-4-2.”

Feeder, “Q” and “T” routes segment width is 2-4-4-2. STARs and approach/departure procedure segment width is 2-4-4-2 at all distances greater than 30 NM from ARP (see paragraph 1.1.1 and 1.1.2 for width distances ≤ 30 NM). For these procedures, a segment designed to cross within 30 NM of the ARP more than once does not change to en route width until the 30 NM limit is crossed for approach and landing; i.e., crosses the limit for the last time before landing. A departure or missed approach segment designed to cross a point 30 NM from the ARP more than once changes when it crosses the boundary the first time and remains expanded.

Note: Q-routes supporting /E, /F, or /R aircraft may not be established if one or more critical DME facilities are identified.

Table 1-1. Reserved

Table 1-2. RNAV Linear Segment Width in NM Values (see figure 1-1).

<table>
<tr><th colspan="2">Segment</th><th>Primary Area Half-Width (P)</th><th>Secondary Area (S)</th></tr>
<tr><td rowspan="2">STARs, Feeder, Initial, Missed Approach & Departures</td><td rowspan="2">> 30 NM from ARP</td><td>± 4.00</td><td>2.00</td></tr>
<tr><td colspan="2">2-4-4-2</td></tr>
<tr><td rowspan="2">STARs, Feeder, Initial, Missed Approach & Departures</td><td rowspan="2">≤ 30 NM from ARP</td><td>± 2.00</td><td>1.00</td></tr>
<tr><td colspan="2">1-2-2-1</td></tr>
<tr><td colspan="2">Intermediate</td><td>Continues initial segment width until 2 NM prior to PFAF. Then tapers uniformly to final segment width.</td><td>Continues initial segment width until 2 NM prior to PFAF. Then it tapers to final segment width.</td></tr>
</table>

Figure 1-1. Segment Width Variables

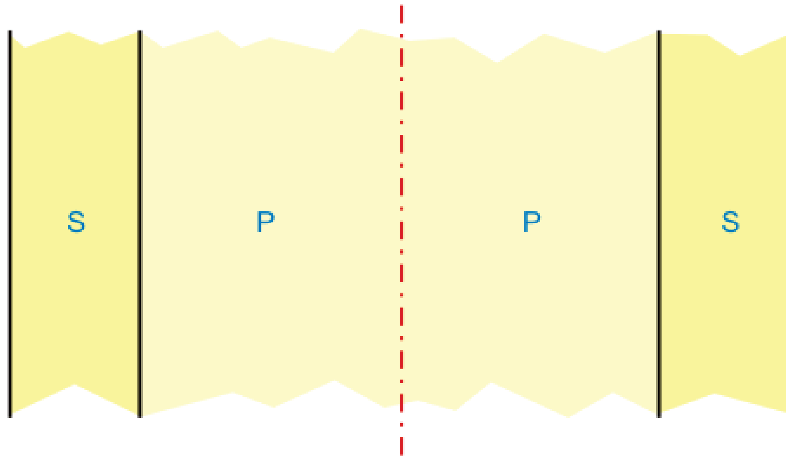
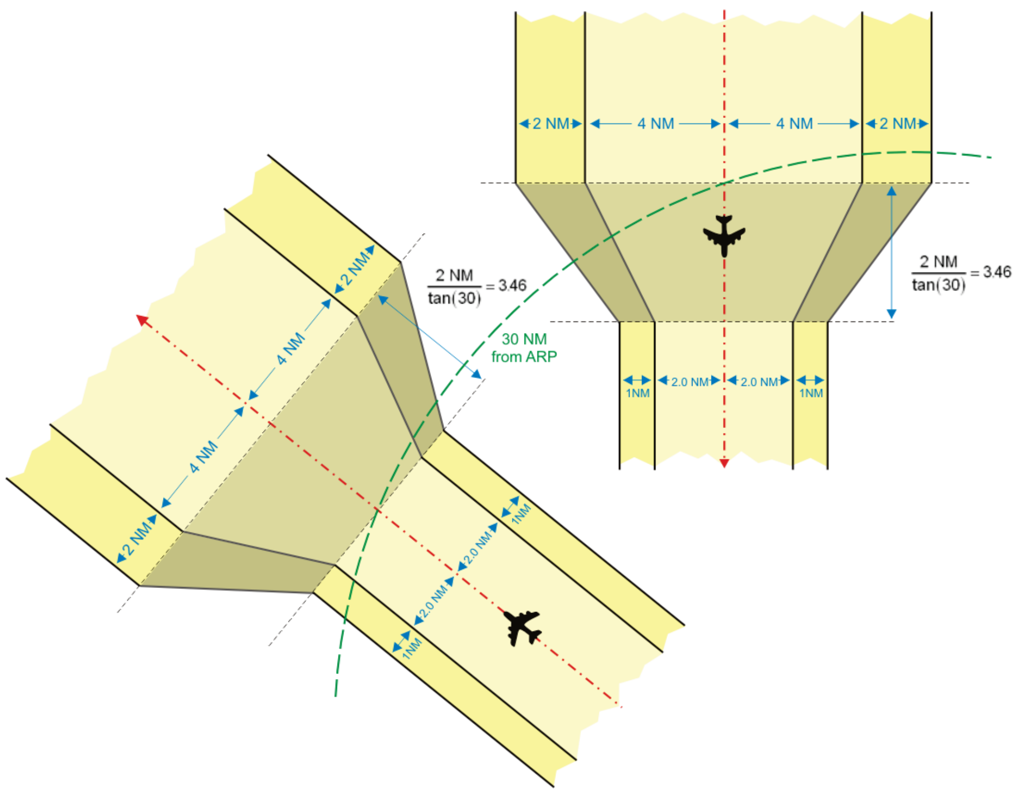


Figure 1-2A. Segment Width Changes at 30 NM



1.1.1 Width Changes at 30 NM from ARP (non-RF).

Receiver sensitivity changes at 30 NM from ARP. From the point the designed course crosses 30 NM from ARP, the primary OEA can taper inward at a rate of 30 degrees relative to course from ± 4 NM to ± 2 NM. The secondary area tapers from a 2 NM width when the 30 NM point is crossed to a 1 NM width abeam the point the primary area reaches the ± 2 NM width. The total along-track distance required to complete the taper is approximately 3.46 NM (21048.28 ft). Segment 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. **EXCEPTION:** The taper may occur in an RF turn segment if the taper begins at least 3.46 NM (along-track distance) from the RF leg termination fix; i.e., if it is fully contained in the RF leg.

1.1.2 Width Changes at 30 NM from ARP (RF).

When the approach segment crosses the point 30 NM from ARP in an RF leg, construct the leg beginning at a width of 2-4-4-2 prior to the 30 NM point and taper to 1-2-2-1 width after the 30 NM point. Calculate the perpendicular distance ($B_{primary}$, $B_{secondary}$) from the RF segment track centerline to primary and secondary boundaries at any along-track distance (specified as degrees of RF arc "α") from the point the track crosses the 30 NM point using calculator 1-1 (see figure 1-2B).

Calculator 1-1. RF Segment Taper Width

(1) $D = \dfrac{4-2}{\tan\left(30^\circ \times \dfrac{\pi}{180^\circ}\right)}$ $\alpha^\circ = \dfrac{180^\circ \times D}{\pi \times R}$

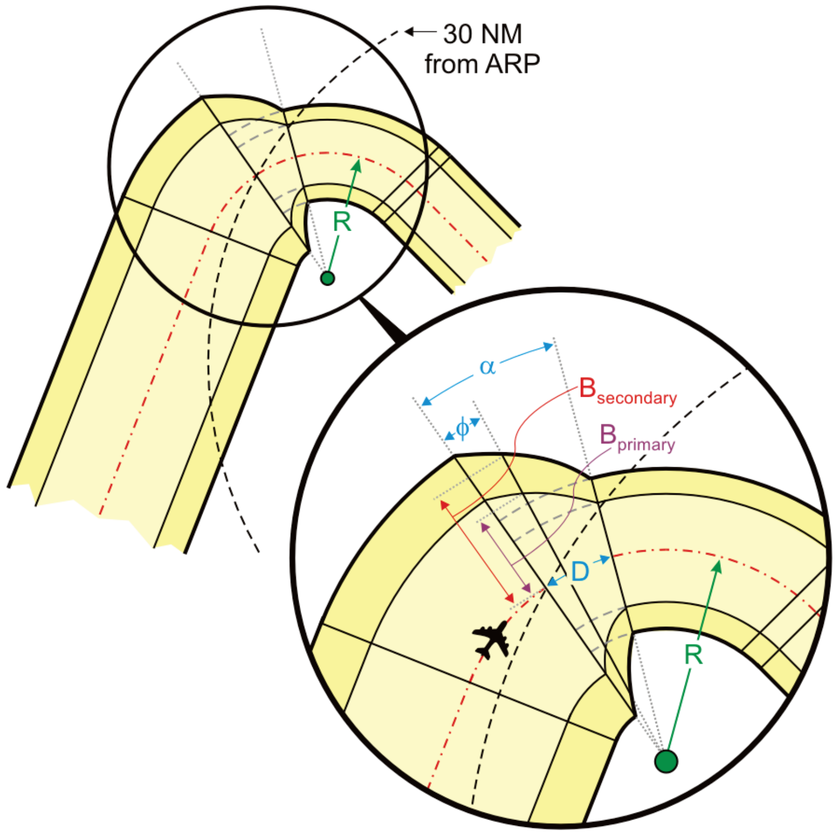
(2) $B_{primary} = 4 - 2 \times \dfrac{\phi^\circ \times \pi \times R}{180^\circ \times D}$

(3) $B_{secondary} = 6 - 3 \times \dfrac{\phi^\circ \times \pi \times R}{180^\circ \times D}$

where R = RF leg radius
φ° = number of degrees from start (distance on arc specified in degrees)
α° = degrees of arc (RF track)
Note: "D" will be in the same units as "R"

Calculator 1 1		
ϕ^o		Calculate
R		
D		
α^o		
$B_{primary}$		Clear
$B_{secondary}$		

Figure 1-2B. Segment Width Changes in RF Leg (advanced avionics required)



1.2 Turns.

See March 1, 2013 Clarification Memo

Where the inbound track to a fix differs from the outbound track by more than 0.03 degrees, a turn is indicated for construction purposes. For segment length considerations, turns of 10 degrees or less are considered straight.

1.2.1 Basic information.

Except as limited by the rules below, the standard design bank angle is assumed to be 18 degrees (14 degrees for CAT A-only procedures). The maximum bank angle is:

Fly-by turn rule: One-half the magnitude of track change for turns less than 50 degrees; 25 degrees for turns equal to or greater than 50 degrees (20 for RNP/ATT less than 1.0). Maximum bank angle below 500 ft above airport is 3 degrees.

Fly-over turn rule: Determine the OEA outer boundary radius based on standard bank angle. For segment length calculation, maximum bank angle is 25 degrees. Maximum bank angle below 500 ft above airport is 3 degrees.

EXCEPTION: Where minimum segment length is necessary and application of the above is not operationally acceptable, it may be ignored if the succeeding segment is compliant with minimum segment length and bank angle rules.

See March 1, 2013 Clarification Memo

RF turn rule: Calculated RF bank angle based on the design radius is not to exceed 25* degrees (20* for RNP/ATT values less than 1.0). Maximum bank angle below 500 ft above airport is 3 degrees.

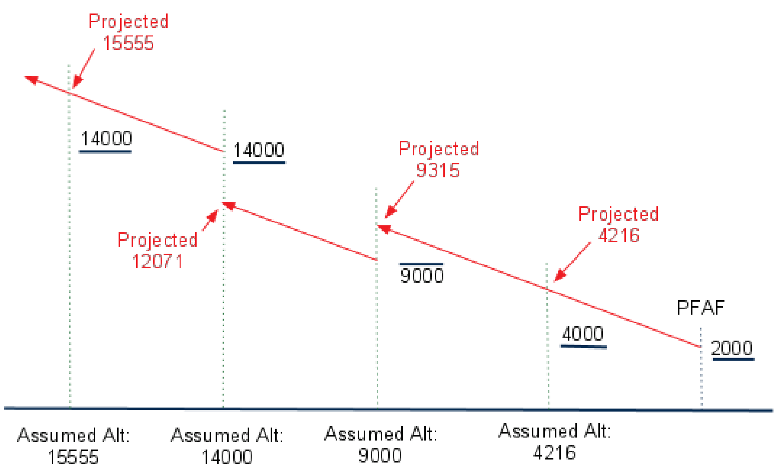
*15 degrees for CAT A and B-only procedures

Determine the highest altitude within a turn by:

For approach:

Altitude is determined by projecting either a 250 ft/NM (airplane) or 400 ft/NM (helicopter) vertical path from the PFAF to the fix along the fix-fix flight track. The turn altitude is the higher of the altitude of the slope at the fix or the minimum fix altitude, or an altitude cap if applicable (see figure 1-3). *Exception: If an altitude cap lower than the projected slope is specified at a fix, the slope continues upward from fix starting at the cap altitude.*

Figure 1-3. Estimating Fix altitude



Calculator 1-2. Reserved

See March 1, 2013 Clarification Memo

For missed approach – project a vertical path along the nominal flight track from the SOC point and altitude to the turn fix, that rises at a rate of 250 ft/NM (CAT A/B), 500 ft/NM (CAT C/D) or at a higher rate if a steeper climb gradient is specified. For turn-at-altitude construction, determine the altitude to calculate V_{KTAS} based on the climb-to altitude plus an additive based on a continuous climb of 250 (CAT A/B) or 500 (CAT C/D) feet per 12 degrees of turn [$\phi*250/12$ or $\phi*500/12$]. CAT D example: segment length, 1125 ft would be added for a turn of 27 degrees, 958 ft would be added for 23 degrees, 417 ft for 10 degrees of turn. Compare the vertical path altitude at the fix to the published missed approach altitude. The altitude to use is the lower of the two. For missed approach, the turn altitude must not be higher than the published missed approach altitude.

STEP 1: Determine the KTAS for the turn using calculator 1-3a. Locate and use the appropriate KIAS from table 1-3. Use the highest altitude within the turn.

Table 1-3. Indicated Airspeeds (KIAS)

Segment		Indicated Airspeed by Aircraft Category (CAT) A	B	C	D	E
At and Above 10000 ft						
RNAV and RNP Routes (e.g., Q - and T-Routes), Feeder, Initial, Intermediate, Missed, Departure		180	250	300	300	350
Below 10000						
T-Routes, Feeder, Initial, Intermediate		150	250		250[1]	310
Final		90	120	140	165	250
Missed Approach (MA), Departure		110	150	240	265	310
Minimum Airspeed Restriction[2]						
Minimum Airspeed Restriction[2]	Feeder, Initial, Departure	110	140	200[3]	210[3]	310
	Intermediate	110	140	180	180	310
	Missed Approach	100	130	165	185	310
	Final	Not Authorized				

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

2. Minimum airspeed restrictions are used to reduce turn radius and should be supported by an analysis of performance characteristics of representative aircraft. Only one speed restriction per approach segment is allowed based on fastest published CAT without AFS-400 or military authority approval. AFS-400 or military authority approval is also required for missed approach airspeed restrictions when used for other than obstacle/terrain avoidance requirements.

3. For Feeder and Departure, use 250 KIAS above 10000 ft.

1.2.2 Calculating the Turn Radius (R).

The design turn radius value is based on four variables: indicated airspeed, assumed tailwind, altitude, and bank angle. Apply the indicated airspeed from table 1-3 for the highest speed aircraft category that will be published on the approach procedure. Apply the highest expected turn altitude value.

Calculator 1-3a. True Airspeed

$$V_{KTAS} = \text{round}\left[\frac{V_{KIAS} \times 171233 \times \sqrt{303 - 0.00198 \times alt}}{(288 - 0.00198 \times alt)^{2.628}}, 0\right]$$

where *alt* = the aircraft's MSL elevation
V_{KIAS} = indicated airspeed

Calculator 1 3a		
V_{KIAS}		Calculate
alt		
V_{KTAS}		Clear

STEP 2: Calculate the appropriate tailwind component (V_{KTW}) using calculator 1-3b for the highest altitude within the turn. **EXCEPTION:** If the MSL altitude is 2000 ft or less above airport elevation, use 30 kts.

Calculator 1-3b. Tailwind

$$\textbf{case}(alt\text{-}apt_{elev} \le 2000):\ V_{KTW} = 30$$
$$\textbf{case}(alt\text{-}apt_{elev} > 2000):\ V_{KTW} = \textbf{round}[0.00198 \times alt + 47, 0]$$

where alt = the highest turn altitude
apt_{elev} = airport MSL elevation

Calculator 1 3b		
alt		Calculate
apt_{elev}		
V_{KTW}		Clear

*If the calculator 1-3b value is considered excessive at a specific location, the 99th percentile wind speed values determined from analysis of a five-year locally measured database may be substituted.

<u>STEP 3</u>: Calculate R using calculator 1-3c.

Calculator 1-3c. Turn Radius

$$(1)\ \ \textbf{case}\ (alt > 19500):\ V_{ground} = \textbf{round}\left[\textbf{min}\left[570, \frac{0.9941 \times alt}{100} + 287\right], 0\right]$$

$$\textbf{case}\ (alt \le 19500):\ V_{ground} = \textbf{min}[500, V_{KTAS} + V_{KTW}]$$

$$(2)\ \ R = \textbf{round}\left[\frac{(V_{ground})^2}{\tan\left(\phi° \times \frac{\pi}{180°}\right) \times 68625.4}, 2\right]$$

where ϕ° = the assumed bank angle
(normally 14° for CAT A only procedure, 18° for CATs B-D)
alt = turn altitude in feet

See March 1, 2013
Clarification Memo

Calculator 1 3c		
V_{KTAS}		Calculate
V_{KTW}		
alt		
$\Phi°$		Clear
R		

Note 1: (calculator 1-3c) For FB turns where the highest altitude in the turn is between 10000 ft and flight level 195, where the sum of "$V_{KTAS}+V_{KTW}$" is greater than 500 kts, use 500 kts.

Note 2: (calculator 1-3c) For FB turns, where the highest altitude in the turn is greater than flight level 195, use 570 kts as the value for "$V_{KTAS}+V_{KTW}$" and

5 degrees of bank rather than 18 degrees. If the resulting DTA is greater than 20 NM, then $R = \frac{20}{\tan\left(\frac{\phi^\circ}{2} \times \frac{\pi}{180^\circ}\right)}$ where ϕ is the amount of turn (heading change). Use calculator 1-8 to verify the required bank angle does not exceed 18 degrees.

1.3 Turn Construction.

1.3.1 Turns at FO Fixes (see figures 1-4 and 1-5).

1.3.1 a. Extension for Turn Delay.

Turn construction incorporates a delay in start of turn to account for pilot reaction time and roll-in time (rr). Calculate the extension distance in feet using calculator 1-4.

Calculator 1-4. Reaction & Roll Dist

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

Calculator 1 4		
V_{KTAS}		Calculate
rr		Clear

<u>STEP 1</u>: Determine R based on standard bank angle (see calculator 1-3c).

<u>STEP 2</u>: Determine rr (see calculator 1-4).

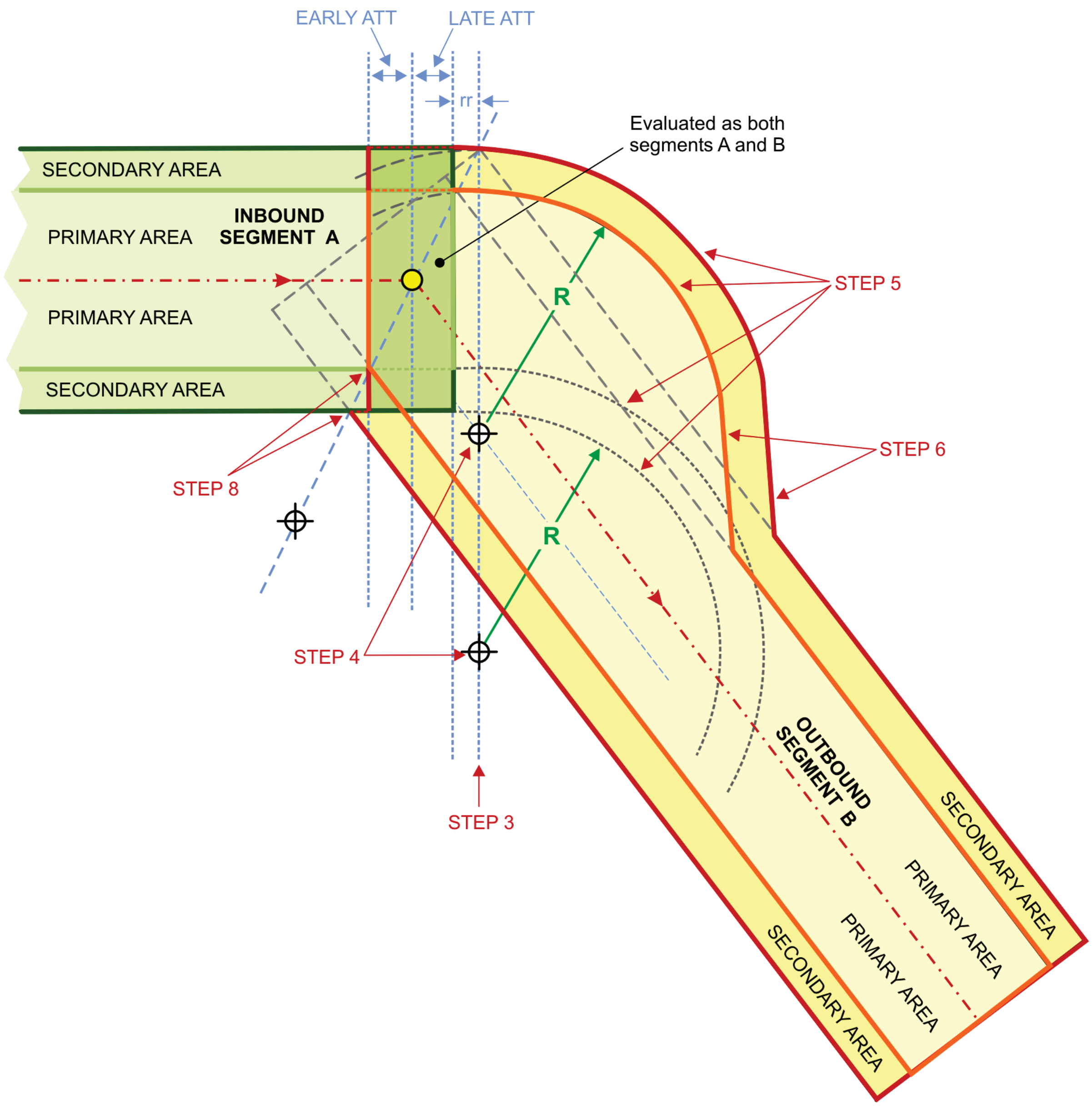
<u>STEP 3</u>: Establish the baseline for construction of the turn expansion area as the line perpendicular to the inbound track at a distance past the turn fix equal to (ATT+rr).

<u>STEP 4</u>: On the baseline, locate the center points for the primary and secondary turn boundaries. The first is located at a distance R from the non-turning side primary boundary. The second is located at a distance R from the turning side secondary boundary (see figures 1-4 and 1-5).

<u>STEP 5</u>: From these center points construct arcs for the primary boundary of radius R. Complete the secondary boundary by constructing additional arcs of radius ($R+W_S$) from the same center points. (W_S=width of the secondary). This is shown in figures 1-4 and 1-5.

STEP 6: The arcs constructed in step 5 are tangent to the outer boundary lines of the inbound segment. Construct lines tangent to the arcs based on the first turn point tapering inward at an angle of 30 degrees relative to the outbound track that joins the arc primary and secondary boundaries with the outbound segment primary and secondary boundaries. If the arcs from the second turn point are inside the tapering lines as shown in figure 1-4, then they are disregarded and the expanded area construction is completed. If not, proceed to step 7.

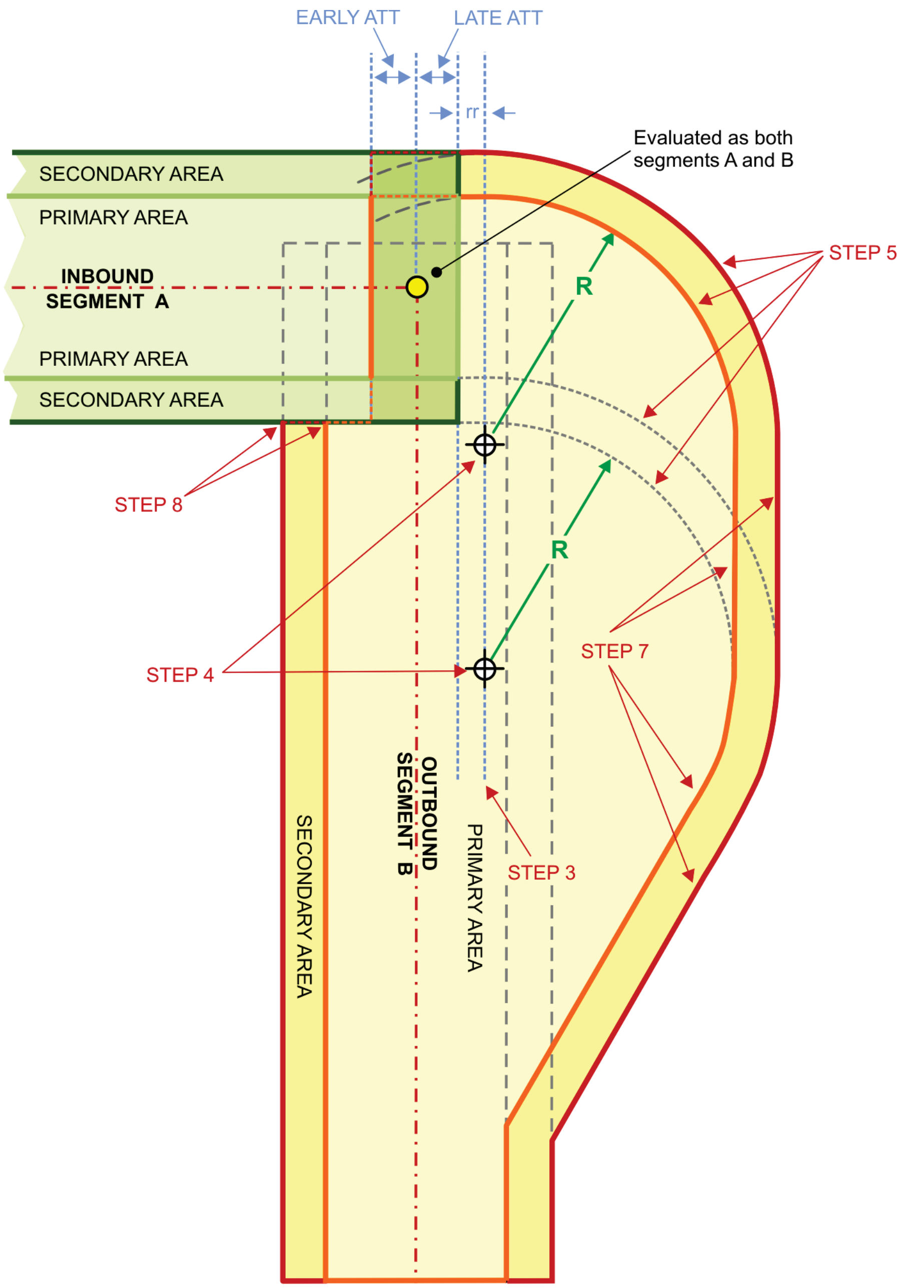
Figure 1-4. Fly-Over with No Second Arc Expansion



STEP 7: If both the inner and outer arcs lie outside the tapering lines constructed in step 6, connect the respective inner and outer arcs with tangent lines and then construct the tapering lines from the arcs centered on the second center point as shown in figure 1-5.

STEP 8: The inside turn boundaries are the simple intersection of the preceding and succeeding segment primary and secondary boundaries.

Figure 1-5. FO with Second Arc Expansion



The inbound OEA end (± ATT) is evaluated for both inbound and outbound segments.

1.3.1 **b. Minimum length of TF leg following a FO turn.** The leg length of a TF leg following a FO turn must be sufficient to allow the aircraft to return to course centerline. Determine the minimum leg length (L) using calculator 1-5.

Calculator 1-5. TF Leg Minimum Length Following FO Turn

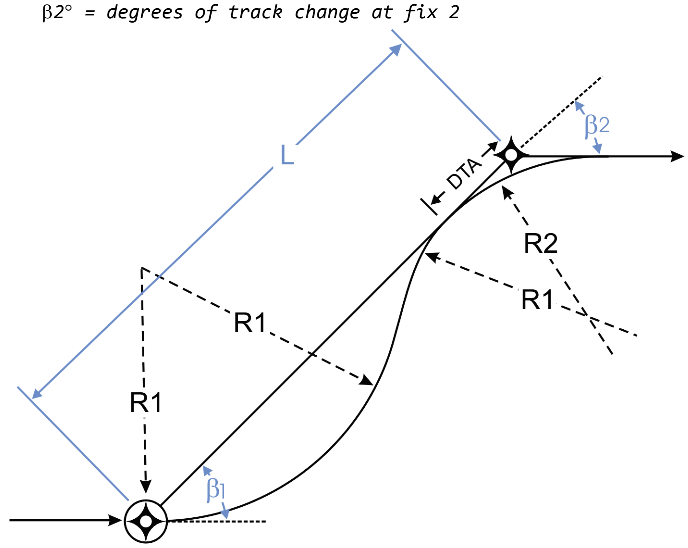
case $\left(\beta 1^\circ < \mathrm{acos}\left(\sqrt{3}-1\right)\times\frac{180^\circ}{\pi}\right)$:

$$L=\max\left[1,\mathrm{round}\left[R1\times\left(\sin\left(\beta 1^\circ\times\frac{\pi}{180^\circ}\right)+2\times\sin\left(\mathrm{acos}\left(\frac{1+\cos\left(\beta 1^\circ\times\frac{\pi}{180^\circ}\right)}{2}\right)\right)\right)+R2\times\tan\left(\frac{\beta 2^\circ}{2}\times\frac{\pi}{180^\circ}\right),2\right]\right]$$

case $\left(\beta 1^\circ \geq \mathrm{acos}\left(\sqrt{3}-1\right)\times\frac{180^\circ}{\pi}\right)$:

$$L=\max\left[1,\mathrm{round}\left[R1\times\left(\sin\left(\beta 1^\circ\times\frac{\pi}{180^\circ}\right)+4-\sqrt{3}-\sqrt{3}\times\cos\left(\beta 1^\circ\times\frac{\pi}{180^\circ}\right)\right)+R2\times\tan\left(\frac{\beta 2^\circ}{2}\times\frac{\pi}{180^\circ}\right),2\right]\right]$$

where R1 = turn radius (NM) from calculator 1-3c at first fix
R2 = turn radius (NM) from calculator 1-3c at second fix
β1° = degrees of track change at fix 1
β2° = degrees of track change at fix 2



Calculator 1 5		
β1°		Calculate
β2°		
R1		
R2		
Minimum Length		Clear

1.3.2 **FB Turn.** See figure 1-6.

STEP 1: Establish a line through the turn fix that bisects the turn angle. Determine R (see calculator 1-3c). Scribe an arc (with origin on bisector line) of radius R tangent to inbound and outbound courses. This is the designed turning flight path.

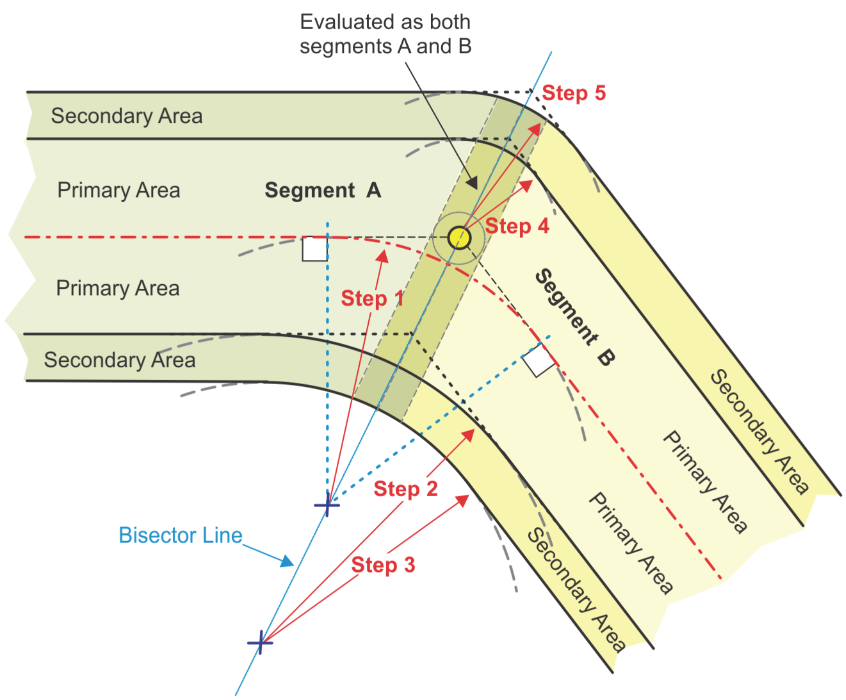
STEP 2: Scribe an arc (with origin on bisector line) that is tangent to the inner primary boundaries of the two segment legs with a radius equal to $R+\frac{Primary\ Area\ Half\text{-}width}{2}$ (example: half width of 2 NM, the radius would be R+1.0 NM).

STEP 3: Scribe an arc that is tangent to the inner secondary boundaries of the two segment legs using the origin and radius from step 2 minus the secondary width.

STEP 4: Scribe the primary area outer turning boundary with an arc with a radius equal to the segment half width centered on the turn fix.

STEP 5: Scribe the secondary area outer turning boundary with the arc radius from step 4 plus the secondary area width centered on the turn fix.

Figure 1-6. FB Turn Construction



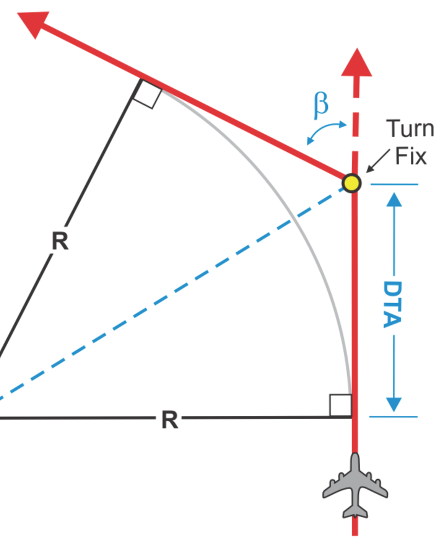
The minimum length must not be less than the total of DTAs for the leg. Calculate DTA using calculator 1-6.

Calculator 1-6. Distance of Turn Anticipation

$$DTA_{NM} = \mathbf{round}\left[R \times \mathbf{tan}\left(\frac{\beta^\circ}{2} \times \frac{\pi}{180^\circ}\right), 2\right]$$

$$DTA_{feet} = \mathbf{round}\left[R \times \mathbf{tan}\left(\frac{\beta^\circ}{2} \times \frac{\pi}{180^\circ}\right) \times fpnm, 0\right]$$

where R=turn radius (NM)
β°=degrees of heading change



Calculator 1 6		
R		Calculate
β°		
DTA_{NM}		Clear
DTA_{feet}		

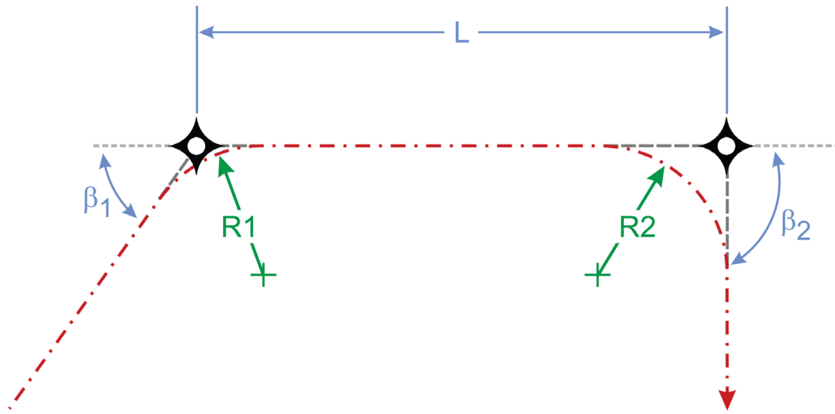
Calculate the minimum length for a TF leg following a FB turn using calculators 1-7a and 1-7b.

Calculator 1-7. TF Leg Minimum Length Following FB Turn

(1) if (RNP AR)
  $\lambda = \min(1, 2 \times RNP)$
else
  $\lambda = 1$
end if

(2) $$Minimum\ Length = \max\left[\lambda, \text{round}\left[R1 \times \tan\left(\frac{\beta 1^\circ}{2} \times \frac{\pi}{180^\circ}\right) + R2 \times \tan\left(\frac{\beta 2^\circ}{2} \times \frac{\pi}{180^\circ}\right), 2\right]\right]$$

where RNP = Segment RNP value (input if RNP AR)
R1 = turn radius for first fix from calculator 1-3c
R2 = turn radius for subsequent fix from formula 2-3c Note: zero when β2° is fly-over
β1° = degrees of heading change at initial fix
β2° = degrees of heading change at termination fix



Calculator 1 7a. RNP AR Procedures			Calculator 1 7b. Non RNP AR Procedures		
RNP		Calculate			
R1			R1		Calculate
R2			R2		
β1°			β1°		
β2°			β2°		
Minimum Length		Clear	Minimum Length		Clear

1.3.3 Radius-to-Fix (RF) Turn. Incorporation of an RF segment may limit the number of aircraft served by the procedure.

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.* The curved leg begins tangent to the previous segment course at its terminating fix and ends tangent to the next segment course at its beginning fix (see figure 1-7). OEA construction limits turn radius to a minimum value equal-to or greater-than the OEA (primary and secondary) half-width. The RF segment OEA boundaries are parallel arcs.

***Note:** RF legs segments are not applicable to the final segment or section 1 of the missed approach segment. RF legs in the intermediate segment must terminate at least 2 NM prior to the PFAF. Where RF legs are used, annotate the procedure (or segment as appropriate) "RF Required."

STEP 1: Determine the segment R that is required to fit the geometry of the terrain/airspace. Enter the required radius value into calculator 1-8 to verify the resultant bank angle is ≤ 25 degrees (maximum allowable bank angle). Where a bank angle other than 18 degrees is used, annotate the value in the remarks section of the FAA Form 8260-9 or appropriate military procedure documentation form.

Calculator 1-8. RF Bank Angle

(1) case $(alt>19500)$: $V_{ground}=\text{round}\left[\min\left[570, \frac{0.9941 \times alt}{100}+287\right], 0\right]$

case $(alt \le 19500)$: $V_{ground}=\min\left[500, V_{KTAS}+V_{KTW}\right]$

(2) $\phi° = \text{round}\left[\text{atan}\left(\frac{V_{ground}{}^{2}}{68625.4 \times R}\right) \times \frac{180°}{\pi}, 0\right]$

where V_{KTAS} = value from calculator 1-3a
V_{KTW} = value from calculator 1-3b
R = required radius
alt = highest aircraft altitude in RF turn

Calculator 1 8		
V_{KTAS}		Calculate
V_{KTW}		
R (NM)		
alt		
Φ°		Clear

Note: Where only categories A and B are published, verify the resultant bank angle is ≤ 15 degrees.

Segment length may be calculated using calculator 1-9. Minimum RF segment length is 2 NM. Where a TF segment is required between 2 RF segments, the minimum TF segment length is 1 NM.

Calculator 1-9. RF Segment Length

$$Segment_{Length} = \mathbf{round}\left[\frac{\pi \times R \times \alpha^\circ}{180^\circ}, x\right]$$

where R = RF segment radius (answer will be in the units entered)
α° = degrees of ARC
x = 0 if unit is feet, 2 if NM

Calculator 1 9		
R		Calculate
α°		
$Segment_{Length\_ft}$		Clear
$Segment_{Length\_NM}$		

<u>STEP 2</u>: <u>Turn Center</u>. Locate the turn center at a perpendicular distance R from the preceding and following segments.

<u>STEP 3</u>: <u>Flight path</u>. Construct an arc of radius R from the tangent point on the preceding course to the tangent point on the following course.

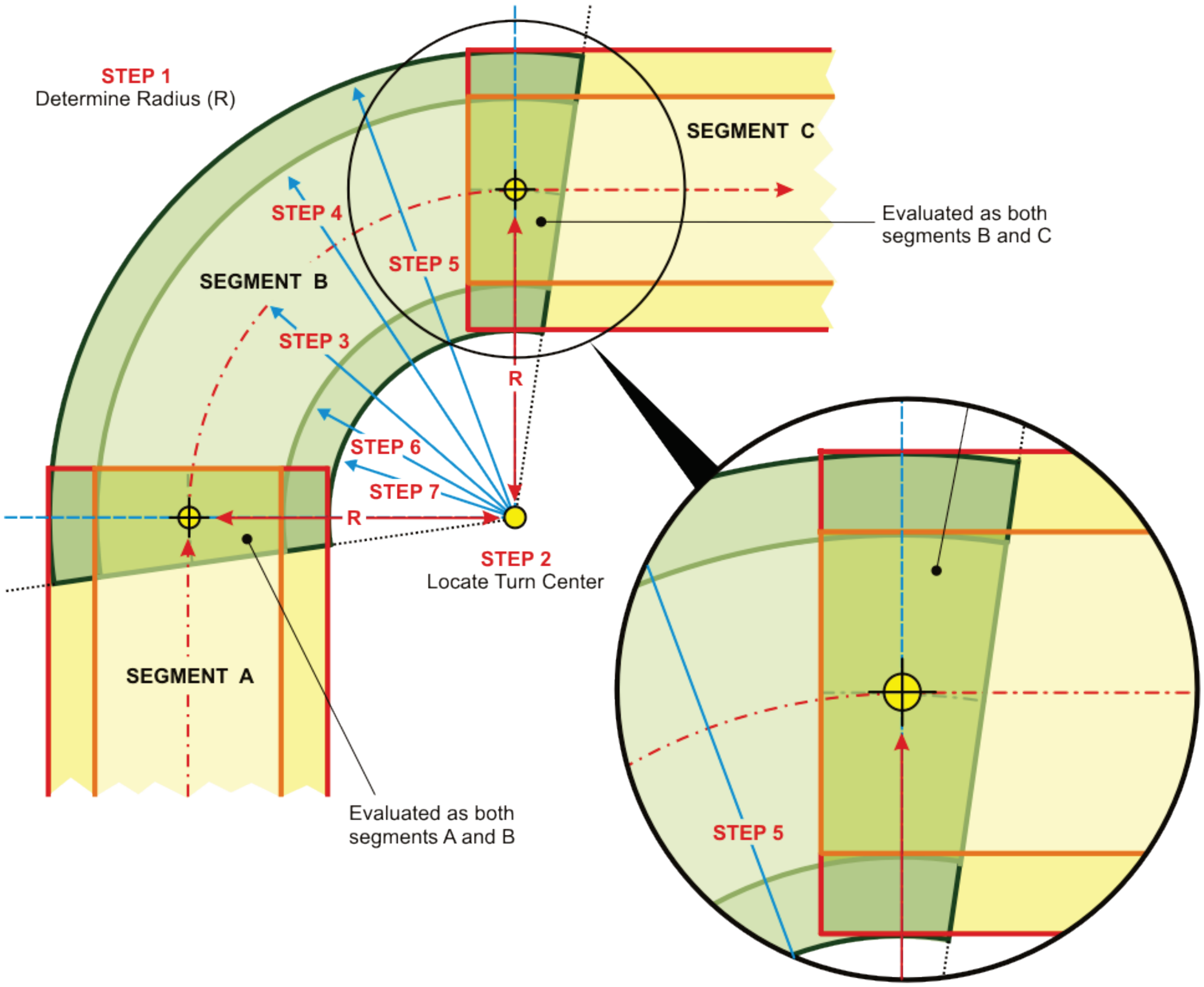
<u>STEP 4</u>: <u>Primary area outer boundary</u>. Construct an arc of radius R+*Primary area half-width* from the tangent point on the preceding segment primary area outer boundary to the tangent point on the following course primary area outer boundary.

<u>STEP 5</u>: <u>Secondary area outer boundary</u>. Construct an arc of radius R+*Primary area half-width+secondary area width* from the tangent point on the preceding segment secondary area outer boundary to the tangent point on the following course secondary area outer boundary.

<u>STEP 6</u>: <u>Primary area inner boundary</u>. Construct an arc of radius R-*Primary area half-width* from the tangent point on the preceding segment inner primary area boundary to the tangent point on the following course inner primary area boundary.

<u>STEP 7</u>: <u>Secondary area inner boundary</u>. Construct an arc of radius R-*(Primary area half-width+secondary area width)* from the tangent point on the preceding segment inner secondary area boundary to the tangent point on the following course inner secondary area boundary.

Figure 1-7. RF Turn Construction



1.3.4 **FO fix direct to fix.** Use calculator 1-10 to determine minimum segment length (L).

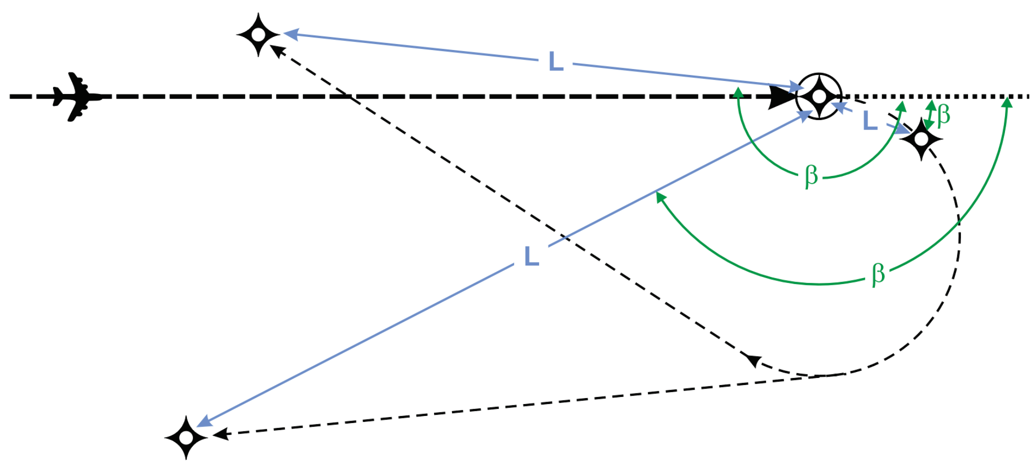
Calculator 1-10. TF/CF Leg Followed by a DF Leg

case $(\beta° > 30°)$: $L = \max\left[1, \text{round}\left[4 \times R \times \left(\sin\left(\frac{\beta° + 30°}{2} \times \frac{\pi}{180°}\right)^2\right), 2\right]\right]$

case $(\beta° \le 30°)$: $L = \max\left[1, \text{round}\left[2 \times R \times \sin\left(\beta° \times \frac{\pi}{180°}\right), 2\right]\right]$

where β° = magnitude of turn

R = turn radius for first fix from calculator 1-3c



Calculator 1 10		
R		Calculate
β°		
L		Clear

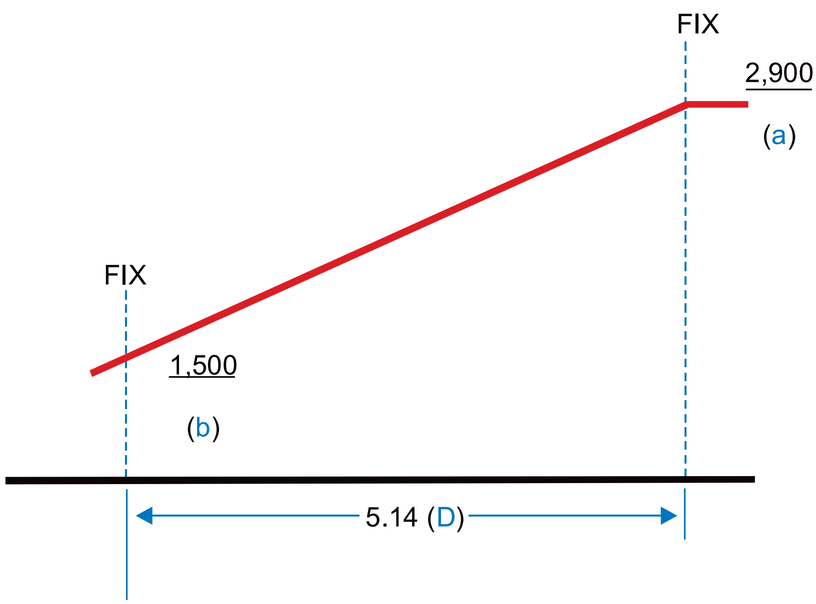
1.4 **Descent Gradient.**

The **optimum** descent gradient in the initial segment is 250 ft/NM (4.11%, 2.36 degrees); **maximum** is 500 ft/NM (8.23%, 4.70 degrees). For high altitude penetrations, the **optimum** is 800 ft/NM (13.17%, 7.50 degrees); **maximum** is 1000 ft/NM (16.46%, 9.35 degrees). The **optimum** descent gradient in the intermediate segment is 150 ft/NM (2.47%, 1.41 degrees); **maximum** is 318 ft/NM (5.23%, 3.0 degrees).

1.4.1 Calculating Descent Gradient (DG).

Determine total altitude lost between the plotted positions of the fixes. Determine the distance (D) in NM. Divide the total altitude lost by D to determine the segment descent gradient (see figure 1-8 and calculator 1-11).

Figure 1-8. Calculating Descent Gradient



Calculator 1-11. Descent Gradient

$$DG = \textbf{ceiling}\left[\frac{r \times \ln\left(\frac{r+a}{r+b}\right)}{D}\right]$$

where a = beginning altitude
b = ending altitude
D = distance (NM) between fixes

Calculator 1 11		
a		Calculate
b		
D		Clear
DG		

1.5 Feeder, Q, and T Route Segments.

See March 1, 2013 Clarification Memo

When the IAF is not part of the en route structure, it may be necessary to designate feeder routes from the en route structure to the IAF. The feeder segment may contain a sequence of TF segments (and/or RF segments). The maximum course change between TF segments is 70 degrees at and above FL195, and 90 degrees (70 degrees preferred) below FL195. Calculator 1-3c Notes 1 and 2 apply. Paragraph 1.3 turn construction applies. The feeder segment terminates at the IAF (see figures 1-9A and 1-9B).

1.5.1 Length.

The **minimum** length of a sub-segment is the greater of the value calculated under paragraph 1.3.1, 1.3.2, or 1.3.3 (as appropriate), or the value required for OEA construction. The **maximum** length of a sub-segment is 500 miles. The total length of the feeder segment should be as short as operationally possible.

1.5.2 Width.

See March 1, 2013 Clarification Memo

Primary area width is ± 4.0 NM from course centerline; secondary area width is 2.0 NM (2-4-4-2). These widths apply from the feeder segment initial fix to the approach IAF/termination fix. Where the initial fix is on an airway, chapter 2 construction applies.

Figure 1-9A. Feeder Route (Fly-by Protection)

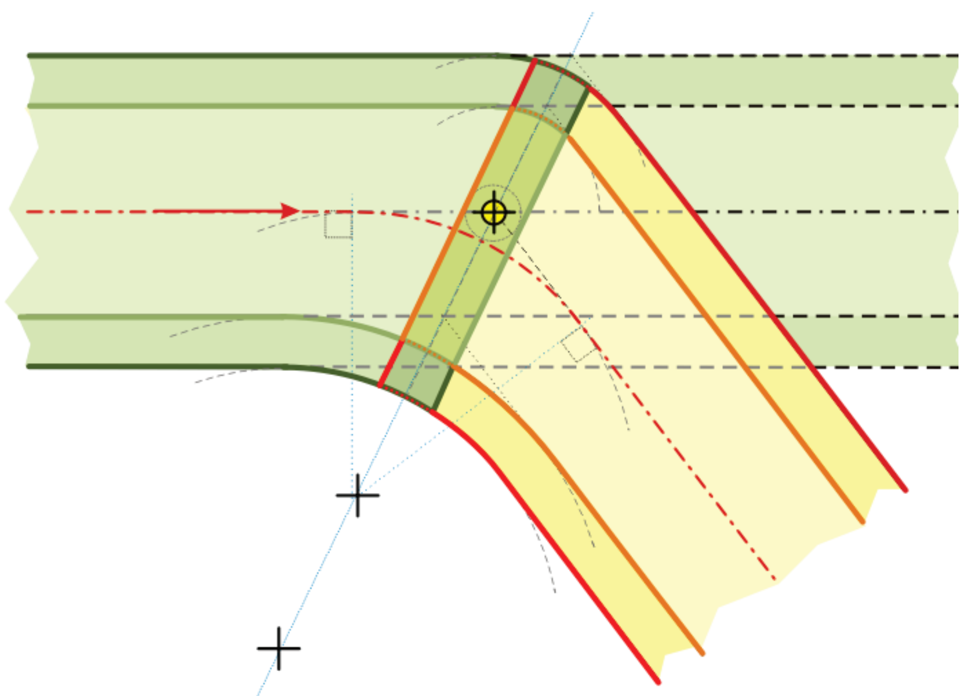
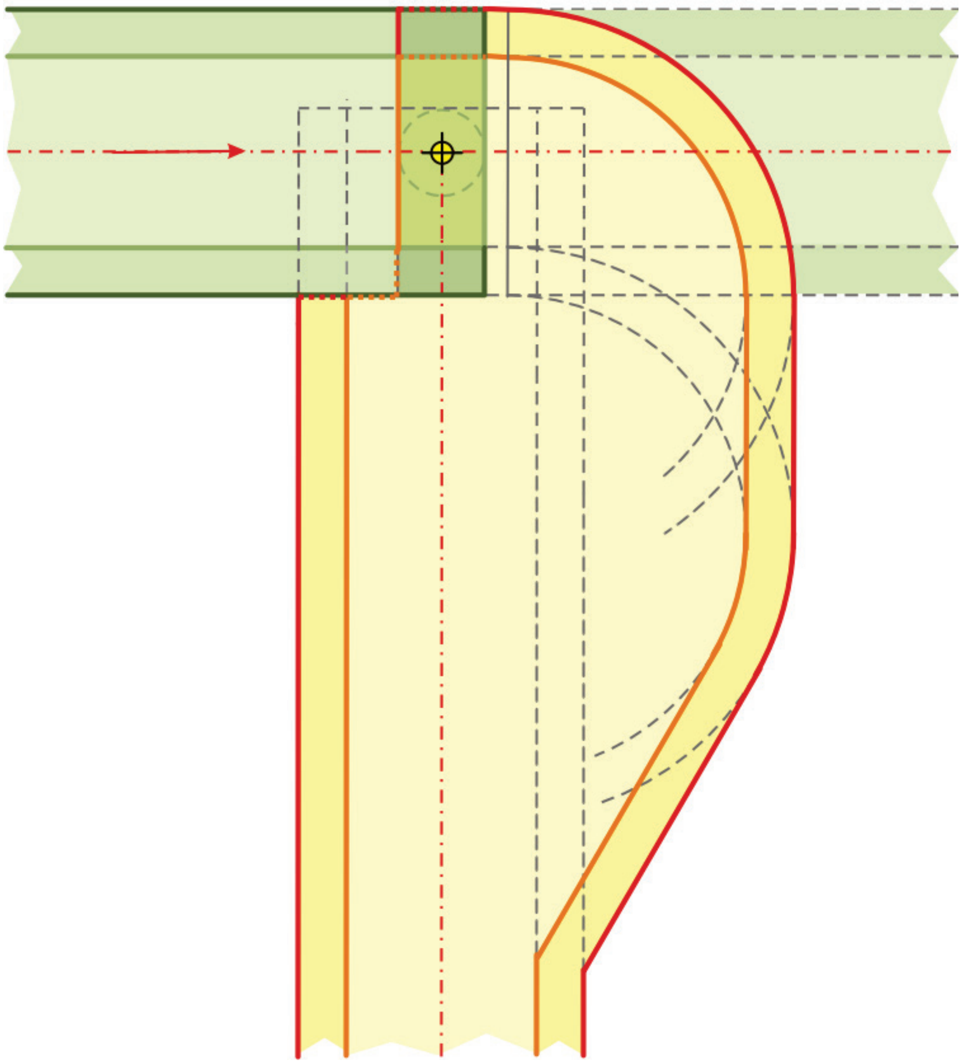


Figure 1-9B. Feeder Route (Fly-over Protection)



1.5.3 Obstacle Clearance.

The **minimum** ROC over areas not designated as mountainous under 14 CFR Part 95 is 1000 ft. The **minimum ROC** within areas designated in 14 CFR Part 95 as "mountainous" is 2000 ft. Order 8260.3 paragraphs 1720 b(1), b(2) and 1721 apply. The published minimum feeder route altitude must provide at least the **minimum** ROC value and must not be less than the altitude established at the IAF.

1.5.4 Descent Gradient (feeder, initial, intermediate segments)**.**

- The **optimum** descent gradient in the feeder and initial segments is 250 ft/NM (4.11%, 2.36 degrees); **maximum** is 500 ft/NM (8.23%, 4.70 degrees). For high altitude penetrations, the **optimum** is 800 ft/NM

(13.17%, 7.5 degrees); **maximum** is 1000 ft/NM (16.46%, 9.35 degrees).

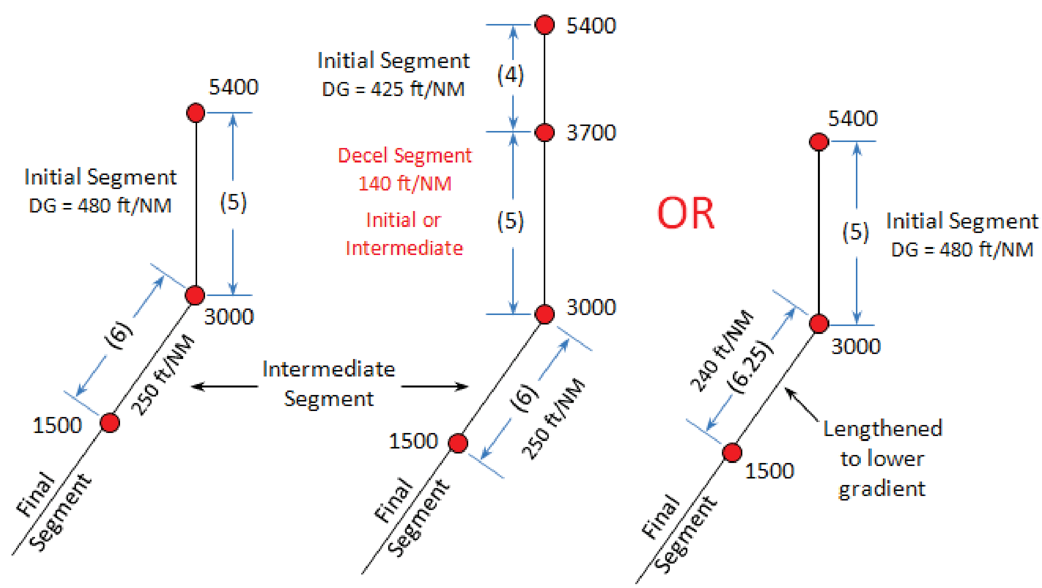
- The **optimum** descent gradient in the intermediate segment is 150 ft/NM (2.47%, 1.41 degrees); **maximum** is 318 ft/NM (5.23%, 3.0 degrees). Where the intermediate segment descent gradient exceeds 240 ft/NM because of terrain or obstacles, a deceleration segment must be constructed in the initial segment (*applicable ONLY where minimums are published for category "C" or faster aircraft and a deceleration segment is deemed necessary*). The **minimum** deceleration length is dependent on segment descent gradient and magnitude of turn at the IF. The **maximum** allowable descent gradient in the deceleration segment is 150 ft/NM. Refer to table 1-4 to determine the minimum deceleration segment length (see figure 1-10 for examples).

See March 1, 2013 Clarification Memo

Table 1-4a **Minimum Deceleration Segment Length**

Segment Descent Gradient (ft/NM)	Turn at IF ≤ 45° Minimum Length	Turn at IF >45° Minimum Length
0-74	2	4
75-149	3	4
150	5	5

Figure 1-10. Example of Deceleration Segment



1.6 Reserved.

1.7 Reserved.

Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 1. General Criteria

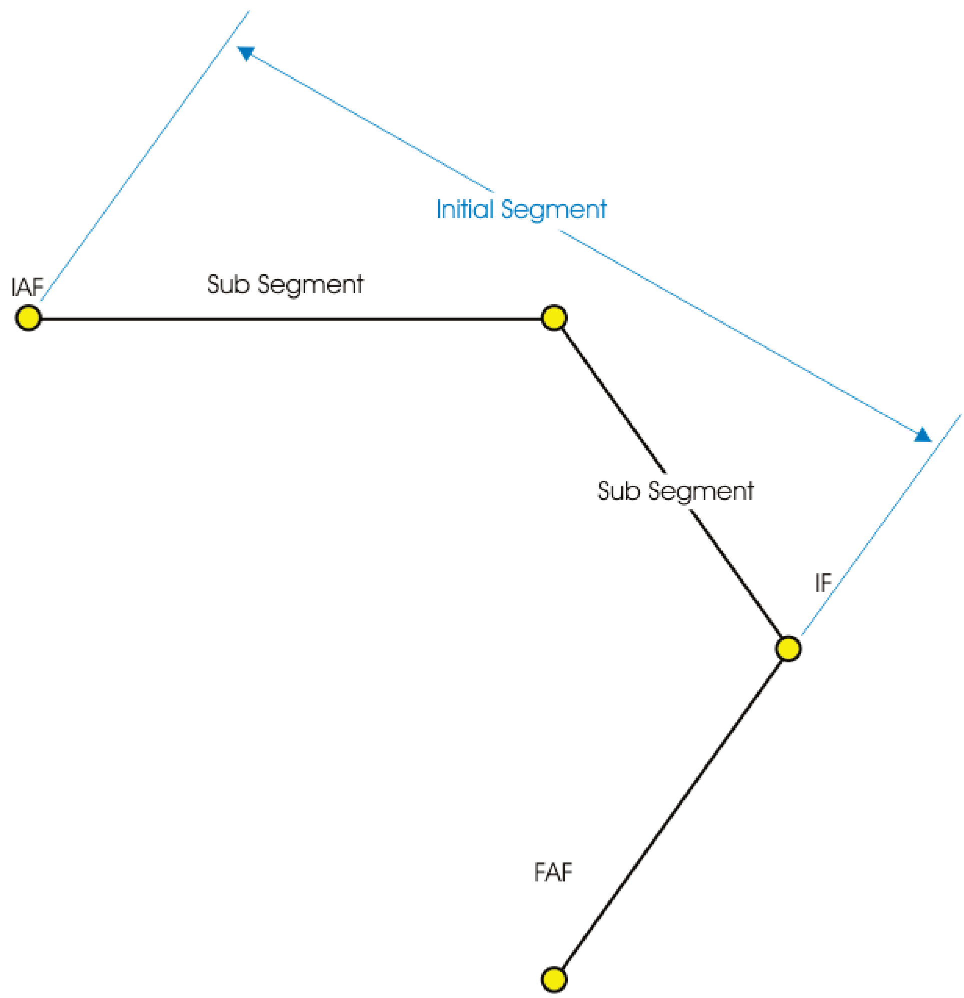
Section 2. Terminal Segments

1.8 Initial Segment.

See March 1, 2013 Clarification Memo

The initial segment begins at the IAF and ends at the intermediate fix (IF). The initial segment may contain sequences of straight sub segments (see figure 1-11). Paragraphs 1.8.2, 1.8.3, 1.8.4, and 1.8.5 apply to all sub segments individually. For DG limits, see paragraph 1.6.4.

Figure 1-11. Initial Sub Segments



1.8.1 Course Reversal.

See March 1, 2013 Clarification Memo

The **optimum** design incorporates the basic Y or T configuration. This design eliminates the need for a specific course reversal pattern. Where the **optimum** design cannot be used and a course reversal is required, establish a holding pattern at the initial or intermediate approach fix (see paragraph 1.8.6b). The **maximum** course change at the fix (IAF/IF) is to 90 degrees (70 degrees above FL 190).

1.8.2 Alignment.

See March 1, 2013 Clarification Memo

Design initial/initial and initial/intermediate TF segment intersections with the smallest amount of course change that is necessary for the procedure. No course change is **optimum**. Where a course change is necessary, it should normally be limited to 70 degrees or less; 30 degrees or less is preferred. The **maximum** allowable course change between TF segments is 90 degrees.

1.8.3 Area – Length.

The **maximum** segment length (total of sub segments) is 50 NM. Minimum length of sub segments is determined as described in paragraphs 1.3.1, 1.3.2, or 1.3.3 as appropriate.

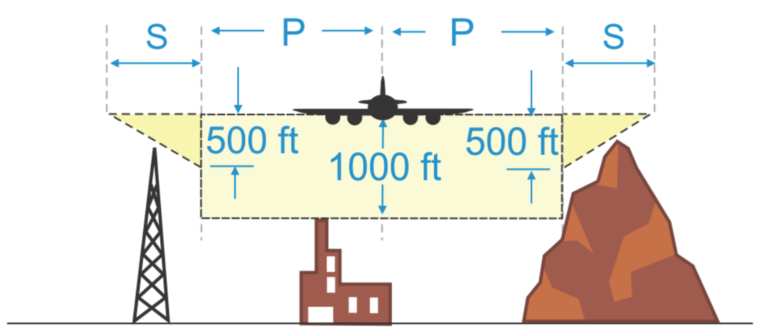
1.8.4 Area – Width (see table 1-2)**.**

1.8.5 Obstacle Clearance.

Apply 1000 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 1-12).

See March 1, 2013 Clarification Memo

Figure 1-12. Initial Segment ROC



Calculate the secondary ROC values using calculator 1-12a.

Calculator 1-12a. Secondary ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

where $d_{primary}$ = perpendicular distance (ft) from edge of primary area

W_S = Width of the secondary area

Calculator 1 12a		
$d_{primary}$		Calculate
W_S		Clear
$ROC_{secondary}$		

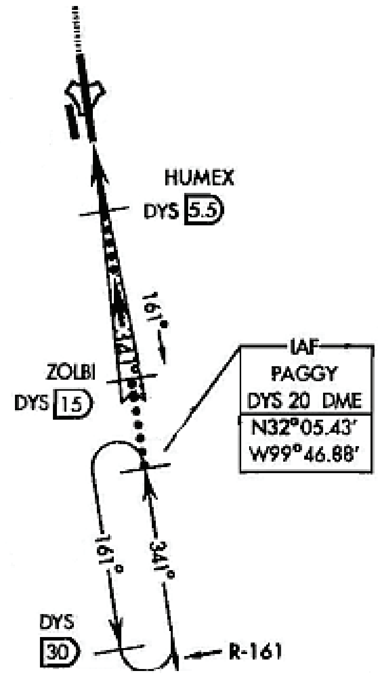
1.8.6 Holding Pattern Initial Segment.

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 FAA Order 7130.3 for RNAV holding pattern construction guidance.

1.8.6 **a. Arrival Holding.** Ideally, the holding pattern inbound course should be aligned with the subsequent TF leg segment (tangent to course at the initial fix of the subsequent RF segment), see figure 1-13A. If the pattern is offset from the subsequent TF segment course, the subsequent segment length must accommodate the resulting DTA requirement. Maximum offset is 90 degrees (70 degrees above FL190). Establish the minimum holding altitude at or above the IAF/IF (as appropriate) minimum altitude. MEA minimum altitude may be lower than the minimum holding altitude.

See March 1, 2013 Clarification Memo

Figure 1-13A. Arrival Holding Example

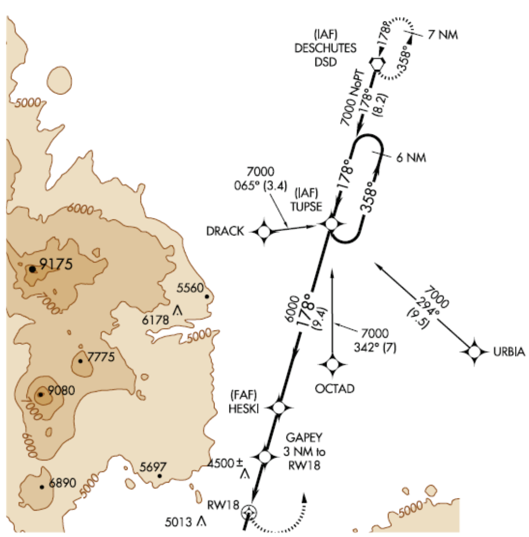


1.8.6

See March 1, 2013 Clarification Memo

b. Course Reversal (Hold-In-lieu of PT). Ideally, establish the minimum holding altitude as the minimum IF fix altitude (see figure 1-13B). In any case, the published holding altitude must result in a suitable descent gradient in the intermediate segment: optimum is 150 ft/NM (2.47%, 1.41 degrees); **maximum** is 318 ft/NM (5.23%, 3.0 degrees). If the pattern is offset from the subsequent TF segment course, the subsequent segment length must accommodate the resulting DTA requirement. **Maximum** offset is 90 degrees.

Figure 1-13B. Course Reversal Example



1.9 Intermediate Segment.

The intermediate segment primary and secondary boundary lines connect abeam the plotted position of the PFAF at the appropriate primary and secondary final segment beginning widths.

1.9.1 Alignment (Maximum Course Change at the PFAF).

- **LPV & LNAV/VNAV.** Align the intermediate course within 15 degrees of the final approach course (15 degrees maximum course change).

- **LNAV & LP.** Align the intermediate course within 30 degrees of the final approach course (30 degrees maximum course change).

Note: For RNAV transition to ILS final, no course change is allowed at the PFAF.

1.9.2 Length (Fix to Fix).

The **minimum** segment length is determined under paragraph 1.3. The **optimum** for CAT A/B length is 3 NM. The **optimum** CAT C/D length is 5 NM.

1.9.3 Width.

The intermediate segment primary area tapers uniformly from ± 2 NM at a point 2 NM prior to the PFAF to the outer boundary of the X OCS abeam the PFAF (1 NM past the PFAF for LNAV and LNAV/VNAV). The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the outer boundary of the Y OCS abeam the PFAF (1 NM past the PFAF for LNAV and LNAV/VNAV). See figures 1-14A and 1-14B.

Figure 1-14A. RNAV Intermediate Segment (LPV, ILS, LP)

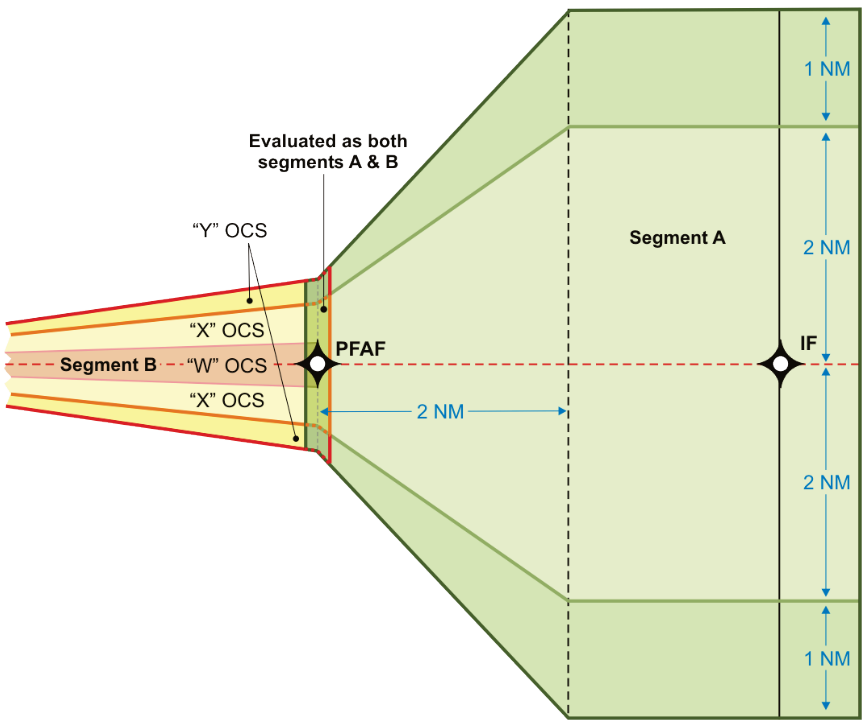
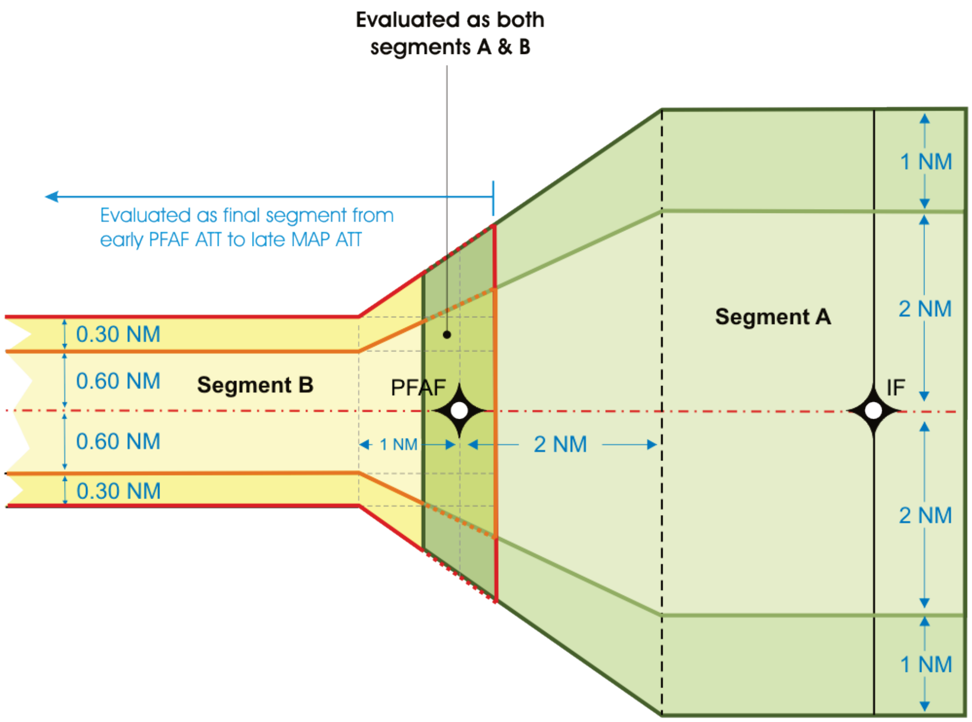


Figure 1-14B. RNAV Intermediate Segment (LNAV and LNAV/VNAV)



If a turn is designed at the IF, it is possible for the inside turn construction to generate boundaries outside the normal segment width at the taper beginning point 2 miles prior to the PFAF. Where these cases occur, the inside (turn side) boundaries are a simple straight line connection from the point 1 NM past the PFAF on the final segment, to the tangent point on the turning boundary arc as illustrated in figures 1-14C and 1-14D.

Figure 1-14C. LNAV, LNAV/VNAV Example

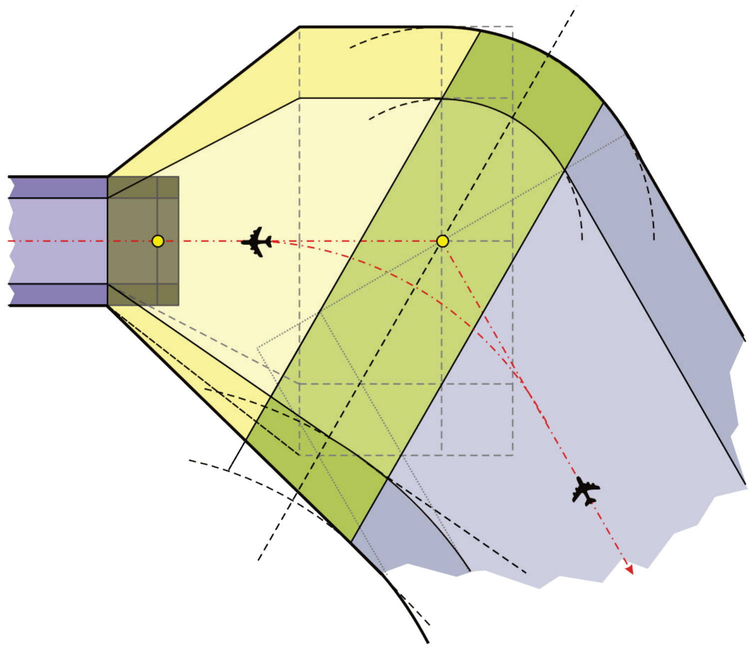
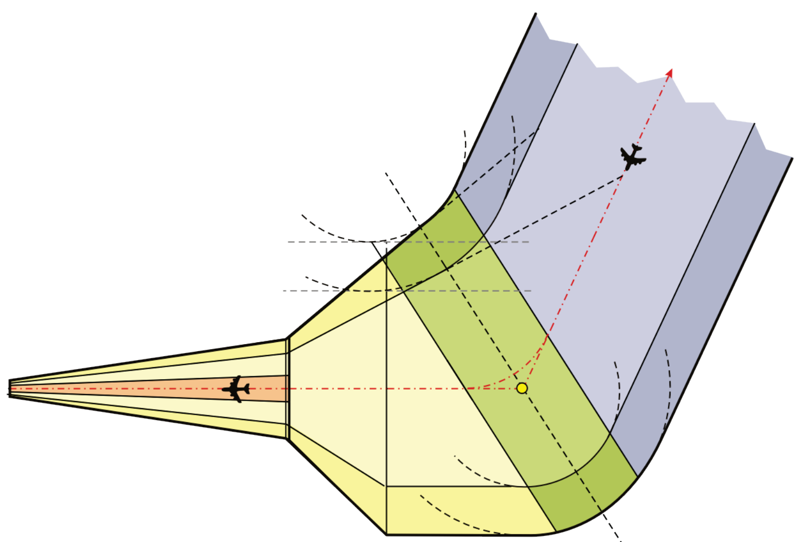


Figure 1-14D. LP, LPV Example



1.9.3 **a. LNAV/VNAV, LNAV Offset Construction.** Where LNAV intermediate course is not an extension of the final course, use the following construction (see figure 1-14E).

STEP 1: Construct line A perpendicular to the intermediate course 2 NM prior the PFAF.

STEP 2: Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

STEP 3: Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

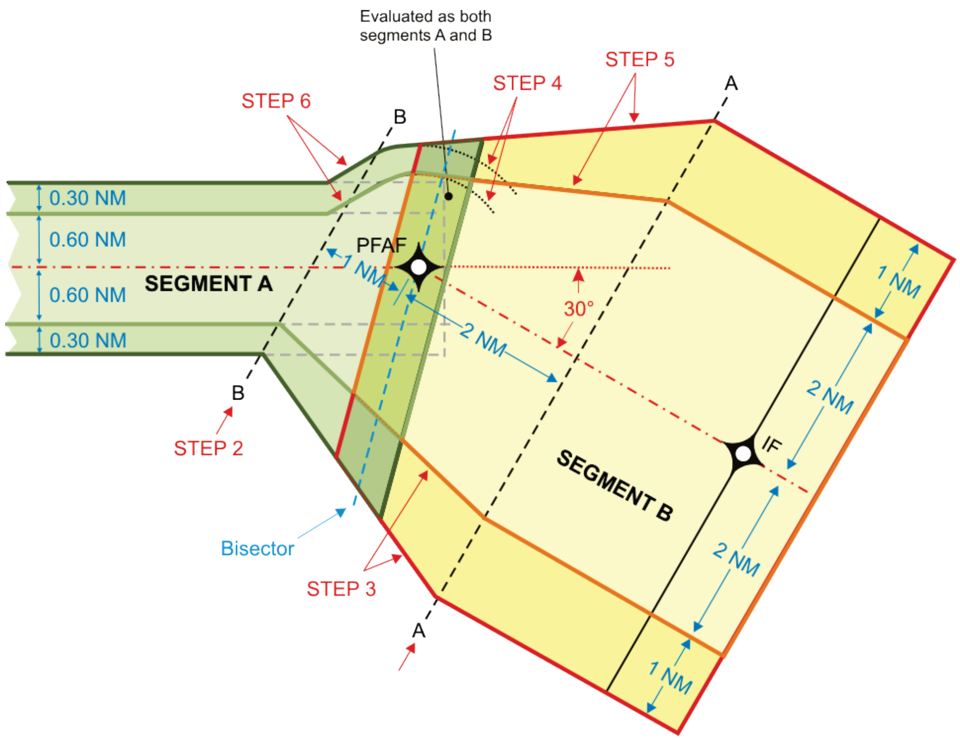
STEP 4: Construct arcs centered on the PFAF of 1 NM and 1.3 NM radius on the non-turn side of the fix.

STEP 5: Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to tangent points on the arcs constructed in step 4.

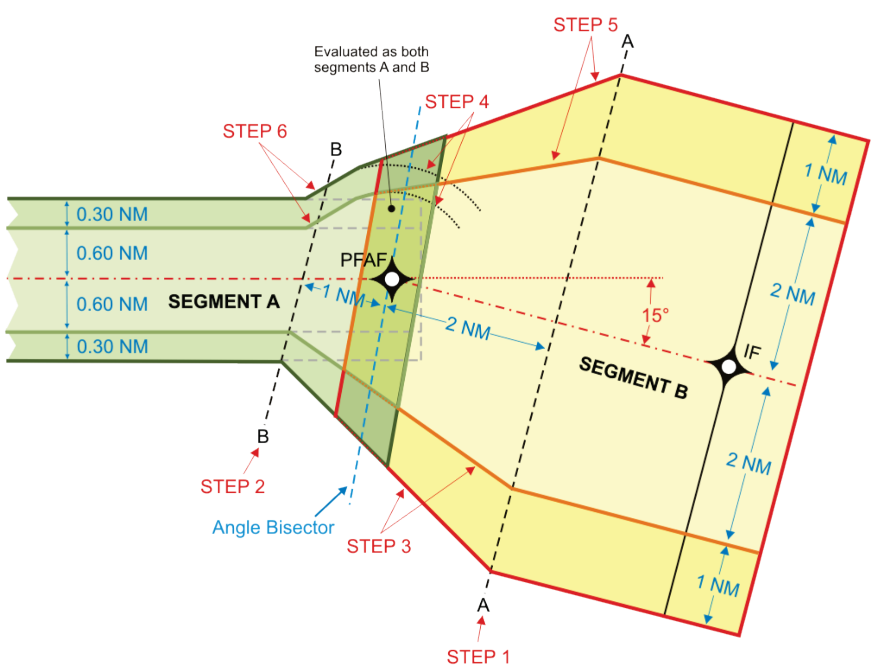
STEP 6: Connect lines tangent to the arcs created in step 4 that taper inward at 30 degrees relative to the FAC to intersect the primary and secondary final segment boundaries as appropriate.

The final segment evaluation extends to a point ATT prior to the angle bisector. The intermediate segment evaluation extends ATT past the angle bisector. Therefore, the area within ATT of the angle bisector is evaluated for both the final and intermediate segments.

Figure 1-14E. Offset LNAV Construction



Offset LNAV/VNAV Construction



1.9.3 **b. LPV, LP Offset Construction.** Where LP intermediate course is not an extension of the final course, use the following construction (see figure 1-14F).

<u>STEP 1</u>: Construct line A perpendicular to the intermediate course 2 NM prior the PFAF.

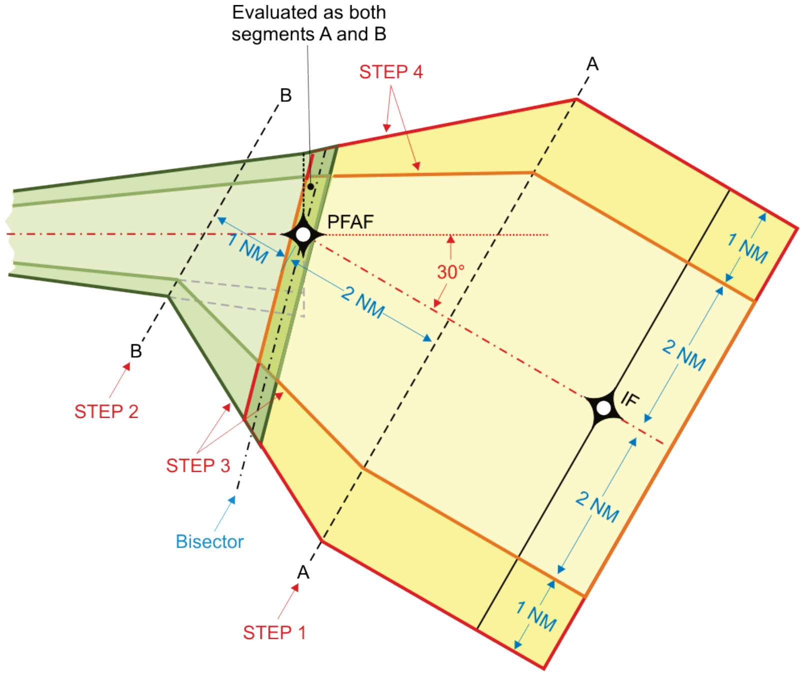
<u>STEP 2</u>: Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

<u>STEP 3</u>: Construct the inside turn boundaries by connecting the points of intersection of line A with the turn side intermediate segment boundaries with the intersection of line B with the turn side final segment boundaries.

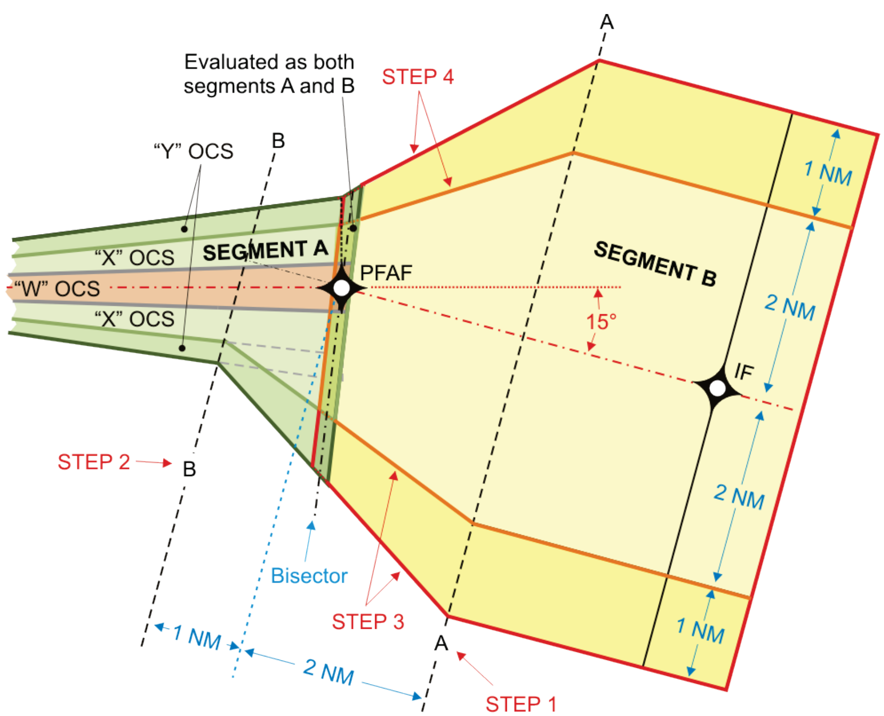
<u>STEP 4</u>: Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to the final segment primary and secondary final segment lines at a point perpendicular to the final course at the PFAF.

The final segment evaluation extends to a point ATT prior to the angle bisector. The intermediate segment evaluation extends ATT past the angle bisector. Therefore, the area within ATT of the angle bisector is evaluated for both the final and intermediate segments.

Figure 1-14F. Offset LP Construction



Offset LPV Construction

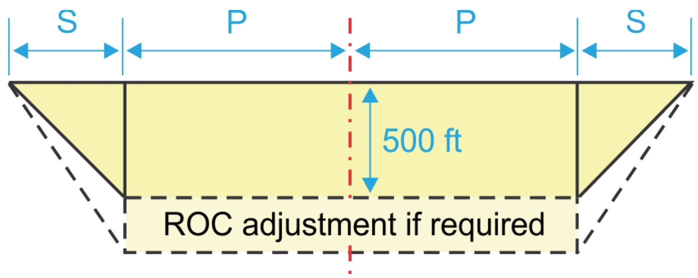


1.9.3 **c. RF intermediate segments.** Locate the intermediate leg's RF segment's terminating fix at least 2 NM outside the PFAF.

1.9.4 Obstacle Clearance.

Apply 500 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 1-15).

Figure 1-15. Intermediate Segment ROC



Calculate the secondary ROC values using calculator 1-12b.

Calculator 1-12b. Secondary ROC

$$ROC_{secondary} = (500 + adj) \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

where $d_{primary}$ = perpendicular distance (ft) from edge of primary area
W_S = Width of the secondary area
adj = TERPS para 3.2.2 adjustments

See March 1, 2013 Clarification Memo

Calculator 1 12b		
$d_{primary}$		Calculate
W_S		
adj		Clear
$ROC_{secondary}$		

1.9.5 **Minimum IF to LTP Distance.** (Applicable for LPV and LP procedures with no turn at PFAF)

Locate the IF <u>at least</u> d_{IF} (NM) from the LTP (see calculator 1-13).

Calculator 1-13. Min IF Distance

$$d_{IF} = 0.3 \times \frac{d}{350} - \frac{d}{fpnm}$$

See March 1, 2013 Clarification Memo

where d = distance (ft) from FPAP to LTP/FTP

Calculator 1 13		
d		Calculate
d_{IF}		Clear

Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 1. General Criteria

Section 3. Basic Vertically Guided Final Segment General Criteria

1.10 Authorized Glidepath Angles (GPAs).

The **optimum** (design standard) GPA is 3 degrees. GPAs greater than 3 degrees that conform to table 1-4 are authorized without Flight Standards/ military authority approval only when obstacles prevent use of 3 degrees. Flight Standards approval is required for angles less than 3 degrees or for angles greater than the minimum angle required for obstacle clearance.

Note: USAF only – apply guidance per AFI 11-230.

Table 1-4b **Maximum Allowable GPAs***

See March 1, 2013 Clarification Memo

Category	θ°
A**	5.7
B	4.2
C	3.6
D&E	3.1

* LPV: Where HATh < 250, CAT A-C Max 3.5 degrees, CAT D/E Max 3.1 degrees.
** CAT A 6.4 degrees if V_{KIAS} limited to 80 kts maximum. Apply the Order 8260.3, Volume 1, chapter 3 minimum HATh values based on GPA where they are higher than the values in this Volume.

1.11 Threshold Crossing Height (TCH).

Select the appropriate TCH from table 1-5. Publish a note indicating VGSI not coincident with the procedures designed descent angle (VDA or GPA, as appropriate) when the VGSI angle differs by more than 0.2 degrees or when the VGSI TCH is more than 3 ft different from the designed TCH.

Note: If an ILS is published to the same runway as the RNAV procedure, its TCH and GPA values should be used in the RNAV procedure design. The VGSI TCH/angle should be used (if within table 1-5 tolerances) where a vertically guided procedure does not serve the runway.

Table 1-5. TCH Requirements

Representative Aircraft Type	Approximate Glidepath-to-Wheel Height	Recommended TCH ± 5 Ft	Remarks
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate turbojets: T-37, T-38, C-12, C-20, C-21, T-1, T-3, T-6, UC-35, Fighter Jets	10 ft or less	40 ft	Many runways less than 6,000 ft long with reduced widths and/or restricted weight bearing which would normally prohibit landings by larger aircraft.
HEIGHT GROUP 2 F-28, CV-340/440/580, B-737, C-9, DC-9, C-130, T-43, B-2, S-3	15 ft	45 ft	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-17, C-32, C-135, C-141, E-3, P-3, E-8	20 ft	50 ft	Primary runways not normally used by aircraft with ILS glidepath-to-wheel heights exceeding 20 ft.
HEIGHT GROUP 4 B-747/767/777, L-1011, DC-10, A-300, B-1, KC-10, E-4, C-5, VC-25	25 ft	55 ft	Most primary runways at major airports.

Notes:

1: To determine the minimum allowable TCH, add 20 ft to the glidepath-to-wheel height.

2: To determine the maximum allowable TCH, add 50 ft to the glidepath-to-wheel height.

3: Maximum LPV TCH is 60 ft.

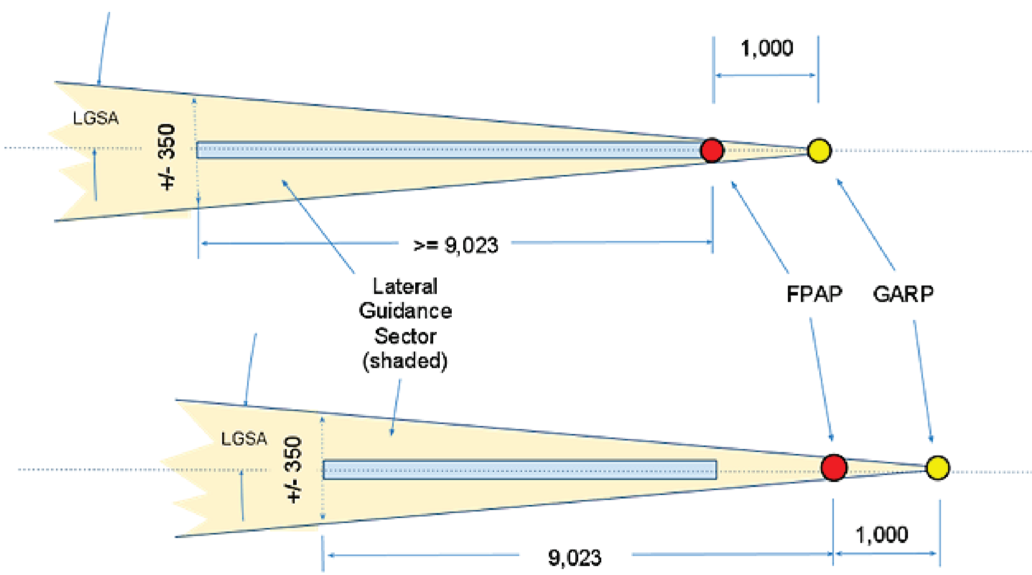
1.12 Determining the Flight Path Alignment Point (FPAP) Location (LPV and LP only).

See March 1, 2013 Clarification Memo

The FPAP is a WGS-84 latitude/longitude point that serves as the departure end of runway in the FAS data block in WAAS approach coding. The LTP/FTP and FPAP are used to define the final approach course alignment. The GNSS Azimuth Reference Point (GARP) is a calculated point 1000 ft beyond the FPAP lying on an extension of a geodesic line from the LTP/FTP through the FPAP. This point is used by the airborne system as the origin of the lateral guidance sector (see figure 1-16). It may be considered the location of an imaginary localizer antenna. The Lateral Guidance Sector Angle (LGSA) is the angular dimension of the lateral guidance sector boundaries relative to the course measured at the GARP. Specifying the calculated angle tailors the width of the lateral guidance sector to ± 350 ft at the LTP/FTP. This angle is sometimes referred to as the splay. The Offset Length value is the distance between the departure end of runway and the GARP.

See March 1, 2013 Clarification Memo

Figure 1-16. FPAP Geometry



Locate the FPAP at the departure end of runway or 9023 ft from LTP/FTP, whichever is the greater distance from the LTP/FTP.

Use the following calculation to determine:

Distance from LTP/FTP to FPAP (d_{FPAP})
Distance from LTP/FTP to GARP (d_{GARP})
Offset Length
LGSA
Width (the lateral guidance sector half width at LTP/FTP)

Calculator 1-14. FAS Data

(1) $d_{FPAP} = \mathbf{max}(RWY_{Length}, 9023)$

(2) $d_{GARP} = d_{FPAP} + 1000$

(3) $Offset_{Length} = d_{FPAP} - RWY_{Length}$

(4) $LGSA = \mathbf{round}\left[\mathbf{atan}\left(\frac{350}{d_{GARP}}\right) \times \frac{180°}{\pi}, 2\right]$

(5) $Width_{feet} = 350$
$Width_{meters} = 106.75$

(6) $case\ (RWY_{Length} > 12366):$

$LGSA = 1.5$

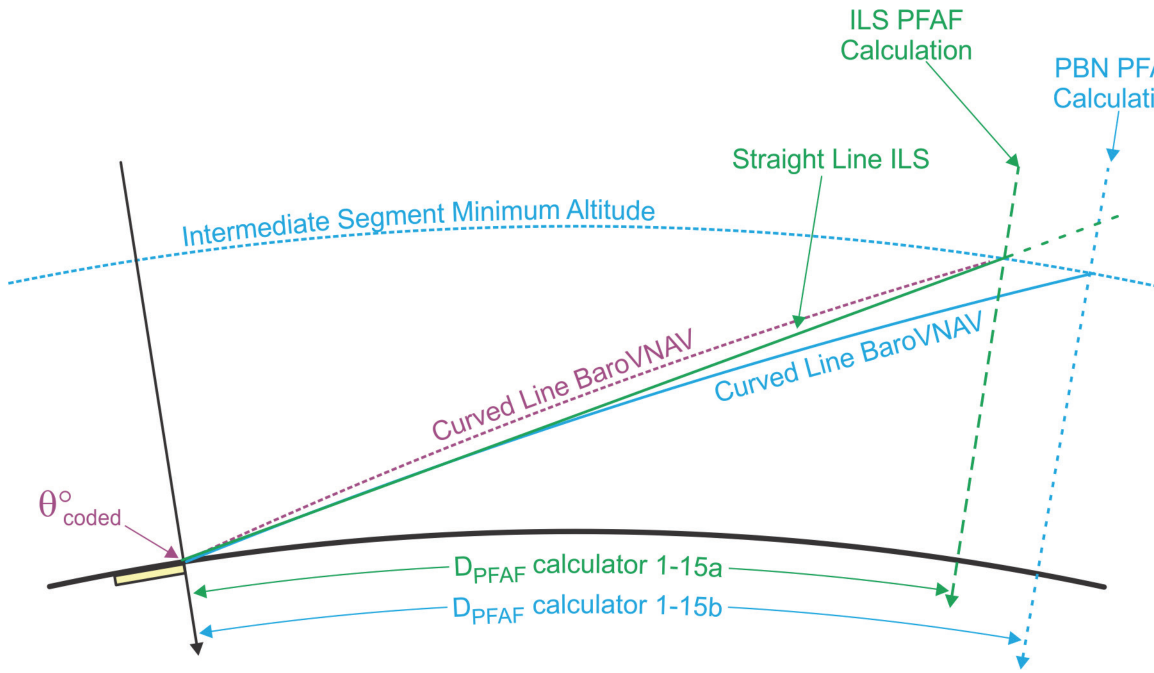
$Width_{feet} = \mathbf{round}\left[\mathbf{tan}\left(1.5° \times \frac{\pi}{180°}\right) \times d_{GARP}, 0\right]$

$Width_{meters} = \frac{\mathbf{round}\left[4 \times Width_{feet} \times 0.3048, 0\right]}{4}$

Calculator 1 14		
RWY_{Length}		Calculate
d_{FPAP}		
d_{GARP}		
$Offset_{Length}$		Clear
$LGSA$		
$Width_{feet}$		
$Width_{meters}$		

1.13 Determining PFAF Coordinates (see figure 1-17)**.**

Figure 1-17. Determining PFAF Distance to LTP



The acronym PFAF replaces FAF because the fix is precisely located. Geodetically calculate the latitude and longitude of the PFAF using the true bearing from the LTP to the PFAF and the horizontal distance (D_{PFAF}) from the LTP to the point the glidepath intercepts the intermediate segment altitude. The ILS/LPV glidepath is assumed to be a straight line in space. The LNAV/VNAV (BaroVNAV) glidepath is a curved line (logarithmic spiral) in space. The calculation of PFAF distance from the LTP for a straight line is different than the calculation for a curved line. Therefore, two calculators are provided for determining this distance. Calculator 1-15a calculates the PFAF and/or glide slope intercept point (PFAF, LPV nomenclature; GPIP, ILS nomenclature) distance from LTP; i.e., the point that the straight line glide slope intersects the minimum intermediate segment altitude). Calculator 1-15b calculates the LNAV/VNAV PFAF distance from LTP; i.e., the point that the curved line BaroVNAV based glidepath intersects the minimum intermediate segment altitude. If LNAV/VNAV minimums are published on the chart, use calculator 1-15b. If no LNAV/VNAV line of minima is published on the approach chart, use calculator 1-15a .

Note: Where an RNAV LNAV/VNAV procedure is published to an ILS runway and the ILS GPIP must be used, publish the actual LNAV/VNAV glidepath angle (θ_{BVNAV}) calculated using calculator 1-15c.

Calculator 1-15a. LPV PFAF/ILS GPIP

$$D_{PFAF}/D_{GPIP} = \textbf{round}\left[r \times \left(\frac{\pi}{2} - \theta^{\circ} \times \frac{\pi}{180^{\circ}} - a\sin\left(\frac{\cos\left(\theta^{\circ} \times \frac{\pi}{180^{\circ}}\right) \times \left(r + LTP_{elev} + TCH\right)}{r + alt}\right)\right), 0\right]$$

where alt = minimum intermediate segment altitude
LTP_{elev} = LTP MSL elevation
TCH = TCH value
θ° = glidepath angle

Calculator 1 15a		
LTP_{elev}		Calculate
θ°		
TCH		
alt		Clear
D_{PFAF}/D_{GPIP}		

Calculator 1-15b. LNAV/VNAV PFAF

$$PFAF(ft) = \textbf{round}\left[\frac{\ln\left(\frac{r + alt}{r + LTP_{elev} + TCH}\right) \times r}{\tan\left(\theta^{\circ} \times \frac{\pi}{180^{\circ}}\right)}, 0\right]$$

where alt = minimum intermediate segment altitude
LTP_{elev} = LTP MSL elevation
TCH = TCH value
θ° = glidepath angle

Calculator 1 15b		
LTP_{elev}		Calculate
TCH		
θ°		
alt		Clear
D_{PFAF}		

Calculator 1-15c. LNAV/VNAV Angle

$$\theta_{BVNAV} = \textbf{round}\left[\textbf{atan}\left(\ln\left(\frac{r+PFAF_{alt}}{r+LTP_{elev}+TCH}\right)\times\frac{r}{D_{PFAF}}\right)\times\frac{180^\circ}{\pi},2\right]$$

where LTP_{elev} = *LTP MSL elevation*
$PFAF_{alt}$ = *Minimum MSL altitude at PFAF*
D_{PFAF} = *distance of existing PFAF*
TCH = *TCH value*

Calculator 1 15c		
$PFAF_{alt}$		Calculate
LTP_{elev}		
TCH		
D_{PFAF}		Clear
θ_{BVNAV}		

1.14 Determining Glidepath Altitude at a Fix.

Calculate the altitude ($Z_{glidepath}$) of the glidepath at any distance (D_Z) from the LTP using calculator 1-16a for ILS and LPV, and calculator 1-16b for LNAV/VNAV.

Calculator 1-16a. ILS/LPV

$$Z_{glidepath} = \textbf{round}\left[\frac{(r+LTP_{elev}+TCH)\times\cos\left(\theta^\circ\times\frac{\pi}{180^\circ}\right)}{\cos\left(\frac{D_Z}{r}+\theta^\circ\times\frac{\pi}{180^\circ}\right)}-r,0\right]$$

where LTP_{elev} = *LTP MSL elevation*
TCH = *TCH value*
θ° = *glidepath angle*
D_Z = *distance (ft) from LTP to fix*

Calculator 1 16a		
LTP_{elev}		Calculate
TCH		
θ°		
D_Z		Clear
$Z_{glidepath}$		

Calculator 1-16b. LNAV/VNAV

$$Z_{glidepath} = \mathbf{round}\left[e^{\frac{D_Z \times \tan\left(\theta° \times \frac{\pi}{180°}\right)}{r}} \times \left(r + LTP_{elev} + TCH\right) - r, 0 \right]$$

where LTP_{elev} = LTP MSL elevation
TCH = Threshold crossing height
$\theta°$ = glidepath angle
D_Z = distance (ft) from LTP to fix

Calculator 1 16b		
LTP_{elev}		Calculate
TCH		
$\theta°$		
D_Z		Clear
$Z_{glidepath}$		

1.15 Common Fixes.

Design all procedures published on the same chart to use the same sequence of charted fixes.

1.16 Clear Areas and Obstacle Free Zones (OFZ).

Airports Division is responsible for maintaining obstruction requirements in AC 150/5300-13, Airport Design. Appropriate military directives apply at military installations. For the purpose of this volume, there are two OFZs that apply: the runway OFZ and the inner approach OFZ. The runway OFZ parallels the length of the runway and extends 200 ft beyond the runway threshold. The inner OFZ overlies the approach light system from a point 200 ft from the threshold to a point 200 ft beyond the last approach light. If approach lights are not installed or not planned, the inner OFZ does not apply. When obstacles penetrate either the runway or inner OFZ, visibility credit for lights is not authorized, and the lowest ceiling and visibility values are (USAF/USN NA):

- For GPA ≤ 4.2°: 300-¾ (RVR 4000)
- For GPA > 4.2°: 400-1 (RVR 5000)

1.17 Glidepath Qualification Surface (GQS).

See 8260.3, Volume 3, paragraph 211.

1.18 Precision Obstacle Free Area (POFA).

See 8260.3, Volume 3, paragraph 3.3.

Volume 6. United States Standard for Area Navigation (RNAV)

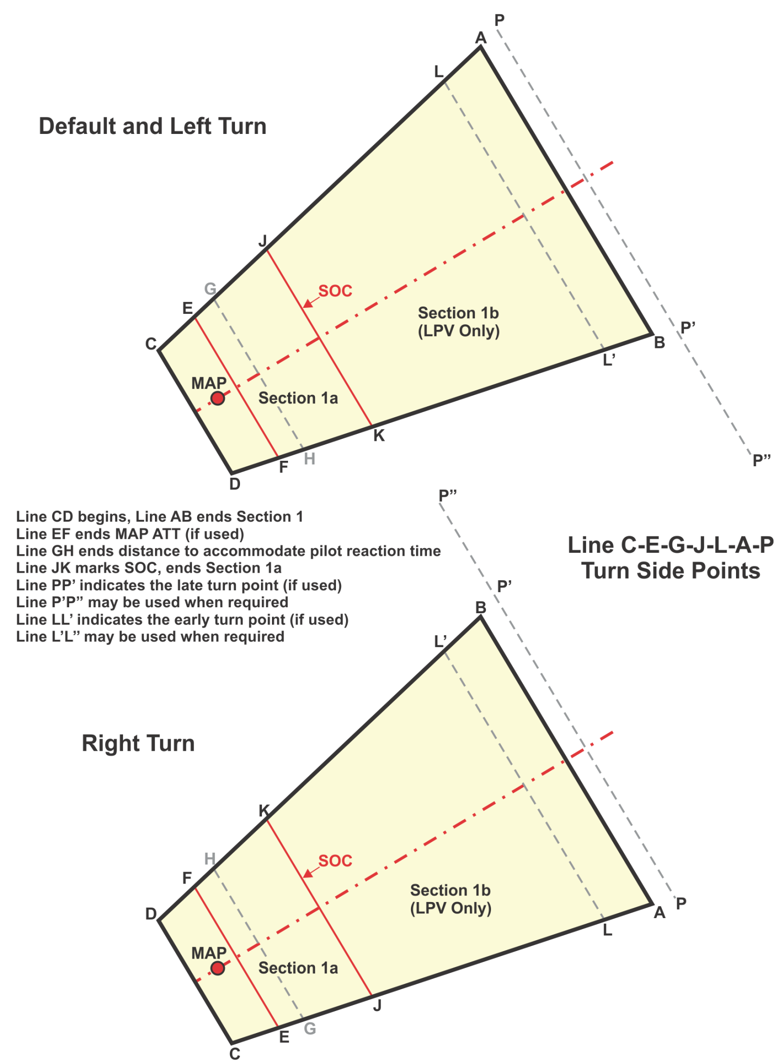
Chapter 1. General Criteria

Section 4. Missed Approach General Information

1.19 MAS Conventions.

Figure 1-18 defines the MAP point OEA construction line terminology and convention for section 1.

Figure 1-18. MAS Point/Line Identification



The missed approach obstacle clearance standard is based on a minimum aircraft climb gradient of 200 ft/NM, protected by a ROC surface that rises at 152 ft/NM. The MA ROC value is based on a requirement for a 48 ft/NM (200-152 = 48) increase in ROC value from the SOC point located at the JK line (AB line for LPV). The actual slope of the MA surface is (1 NM in feet)/152 ≈ 39.974. In manual application of TERPS, the rounded value of 40:1 has traditionally been applied. However, this Volume is written for automated application; therefore, the full value (to 15 significant digits) is used in calculations. The nominal OCS slope ($MA_{OCSslope}$) associated with any given missed approach climb gradient is calculated using calculator 1-17.

Calculator 1-17. MA OCS Slope

$$MA_{OCSslope} = \frac{fpnm}{CG - 48}$$

where CG = Climb Gradient (nominally 200 ft/NM)

Calculator 1 17		
CG		Calculate
$MA_{OCSslope}$		Clear

1.19.1 Charted MA Altitude.

Apply Order 8260.3 Volume 1, paragraphs 277d and 277f to establish the preliminary and charted MA altitudes.

1.19.2 Climb-In-Holding.

Apply Order 8260.3 Volume 1, paragraph 277e for climb-in-holding guidance.

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Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 2. Non-Vertically Guided Procedures

2.0 General.

This chapter contains obstacle evaluation criteria for LNAV and LP non-vertically guided approach procedures. For RNAV transition to LOC final, use LP criteria to evaluate the final and missed approach when RNAV is used for missed approach navigation. When constructing a "stand-alone" non-vertically guided procedure, locate the PFAF using calculator 1-15b, nominally based on a 3-degree vertical path angle. The PFAF location for circling procedures, that do not meet straight-in alignment, are based on the position of the MAP instead of the LTP.

2.1 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.

2.1.1 When the final course must be offset, it may be offset up to 30 degrees (published separately) when the following conditions are met:

2.1.1 a. **For offset ≤ 5 degrees**, align the course through LTP.

2.1.1 b. **For offset > 5 degrees and ≤ 10 degrees**, the course must cross the runway centerline extended at least 1500 ft prior to LTP (5200 ft maximum).

2.1.1 c. **For offset > 10 degrees and ≤ 20 degrees**, the course must cross the runway centerline extended at least 3000 ft prior to LTP (5200 ft maximum). (Offsets > 15 degrees, CAT C/D minimum published visibility 1 SM, minimum HATh of 300 ft)

2.1.1 d. **For offset > 20 to 30 degrees (CAT A/B only),** the course must cross the runway centerline extended at least 4500 ft prior to the LTP (5200 ft maximum).

Note: Where paragraphs 2.1.1a-d cannot be attained or the final course does not intersect the runway centerline or intersects the centerline more than 5200 ft from LTP, and an operational advantage can be achieved, the final may be aligned to lie laterally within 500 ft of the extended runway centerline at a point 3000 ft outward from LTP. This option requires Flight Standards approval.

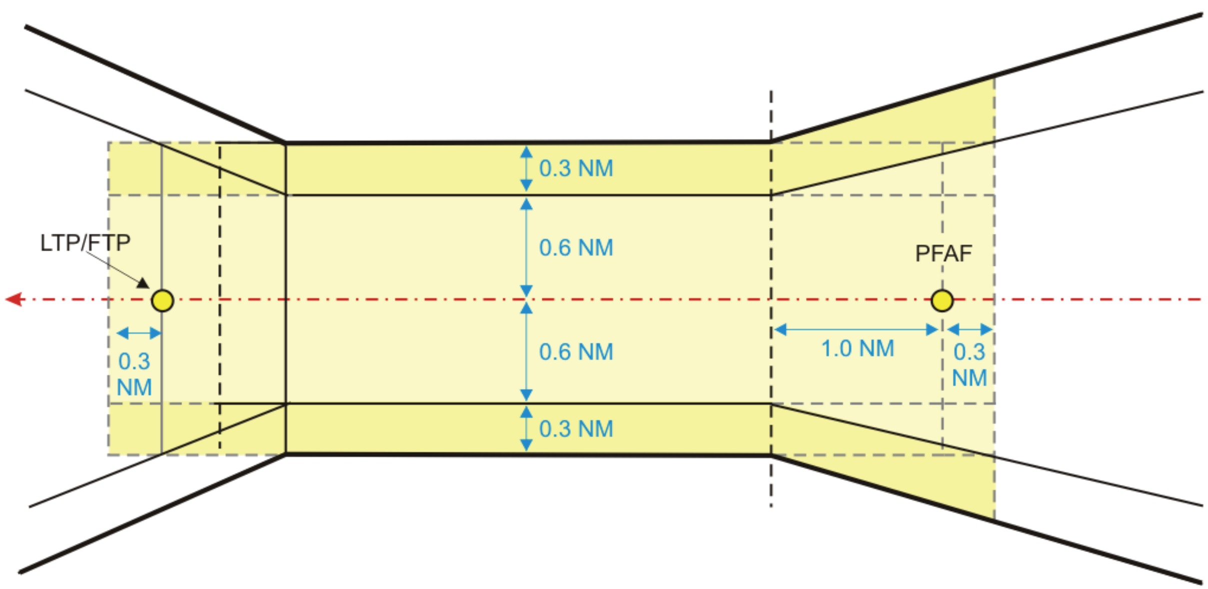
2.1.2 Circling.

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 abeam the nearest usable landing surface.

2.2 Area - LNAV Final Segment.

The intermediate segment primary and secondary areas taper from initial segment OEA width (1-2-2-1) to the width of the final segment OEA. The taper begins at a point 2 NM prior to the PFAF and ends 1.0 NM past the PFAF. The final segment OEA primary and secondary areas follow the tapering boundaries of the intermediate segment from ATT prior to the PFAF to the point 1 NM past the PFAF, and then are a constant width to 0.3 NM past the MAP (see figure 2-1).

Figure 2-1. LNAV Final Segment OEA



2.2.1 Length.

See March 1, 2013 Clarification Memo

The OEA begins 0.3 NM prior to the PFAF and ends 0.3 NM past the LTP. Segment length is the distance from the PFAF location to the LTP/FTP location. Determine the PFAF location per paragraph 1.13. The maximum length is 10 NM.

2.2.2 Width.

The final segment OEA primary and secondary boundaries are coincident with the intermediate segment boundaries (see paragraph 1.9) from a point 0.3 NM prior to the PFAF to a point 1.0 NM past the PFAF (see calculator 2-1). From this point, the Primary OEA boundary is ± 0.6 NM (≈ 3,646 ft) from course centerline. A 0.3 NM (≈ 1,823 ft) secondary area is located on each side of the primary area. Where the intermediate segment is not aligned with the final segment, the segment boundaries are constructed under paragraph 1.9.3a. Determine the half-width of the primary area (½W_p) and the width of the secondary area (W_s) using calculator 2-1.

Calculator 2-1. Tapering Segment Width

(1) $$\frac{1}{2}W_p = \frac{1.4 \times d}{3} + 0.6$$

(2) $$s = \frac{0.7 \times d}{3} + 0.3$$

where d = along-track distance from line "B" (see figure 1-13E)

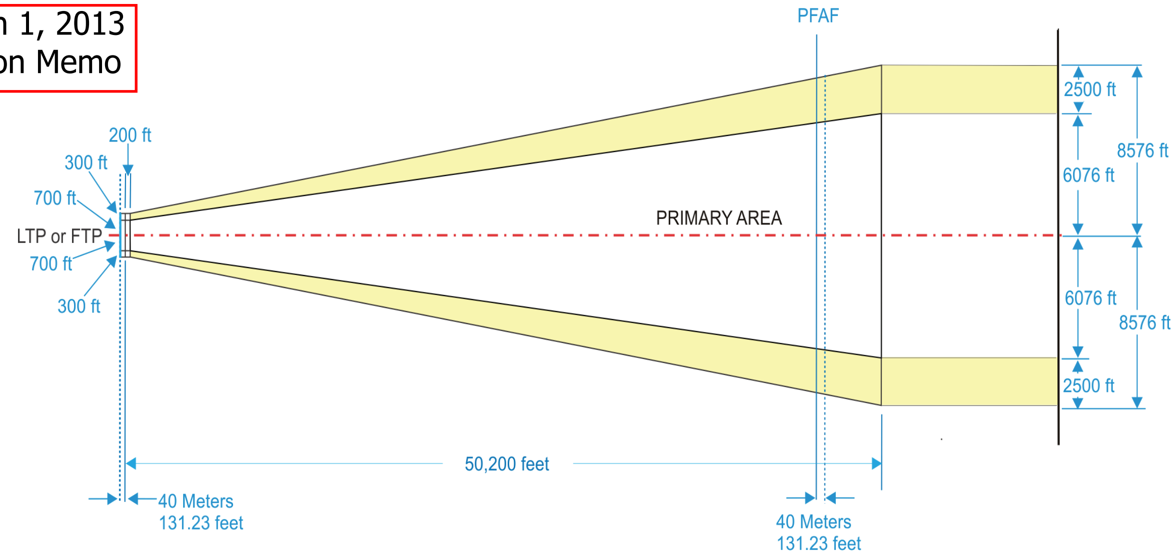
Calculator 2 1		
d		Calculate
½W_p		
W_s		Clear

2.3 Area – LP Final Segment.

The intermediate segment primary and secondary areas taper from initial segment OEA width (1-2-2-1) to the width of the final segment OEA. The taper begins at a point 2 NM prior to the PFAF and ends abeam the PFAF. The final segment OEA primary and secondary areas are linear (constant width) at distances greater than 50200 ft from LTP. Inside this point, they taper uniformly until reaching a distance of 200 ft from LTP. From this point the area is linear to the OEA end 131.23 ft (40 m) past the LTP (see figure 2-2).

Figure 2-2. LP Final Area

See March 1, 2013 Clarification Memo



2.3.1 Length.

The OEA begins 131.23 ft (40 m) prior to the PFAF and ends 131.23 ft (40 m) past the LTP. Segment length is the distance from the PFAF location to the LTP/FTP location. Determine the PFAF location per paragraph 1.13. The maximum length is 10 NM.

2.3.2 Width (see figure 2-2)**.**

The perpendicular distance ($\frac{1}{2}W_p$) from the course centerline to the outer boundary of the primary area is a constant 700 ft from a point 131.23 ft (40 m) past (inside) the LTP to a point 200 ft prior to (outside) the LTP. It expands from this point in a direction toward the PFAF. Calculate $\frac{1}{2}W_p$ from the 200 ft point to a point 50200 from LTP using calculator 2-2. The value of $\frac{1}{2}W_p$ beyond the 50200-ft point is 6076 ft.

Calculator 2-2. Primary Area Width

$$\frac{1}{2}W_P = 0.10752 \times D + 678.496$$

where D = Along-track distance
(≥ 200 ≤ 50200) from LTP/FTP

Calculator 2 2		
D		Calculate
½Wp		Clear

See March 1, 2013 Clarification Memo

The perpendicular distance (W_S) from the course centerline to the outer boundary of the secondary area is a constant 1000 ft from a point 131.23 ft (40 m) past (inside) the LTP to a point 200 ft prior to (outside) the LTP. It expands from this point in a direction toward the PFAF. Calculate W_S from the 200 ft point to a point 50200 from LTP using calculator 2-3. The value of W_S beyond the 50200-ft point is 8576 ft.

Calculator 2-3. Secondary Area Width

$$W_S = 0.15152 \times D + 969.696$$

where D = Along-track distance
($\geq$ 200 $\leq$ 50200) from LTP/FTP

Calculator 2 3		
D		Calculate
W_S		Clear

2.4 Obstacle Clearance.

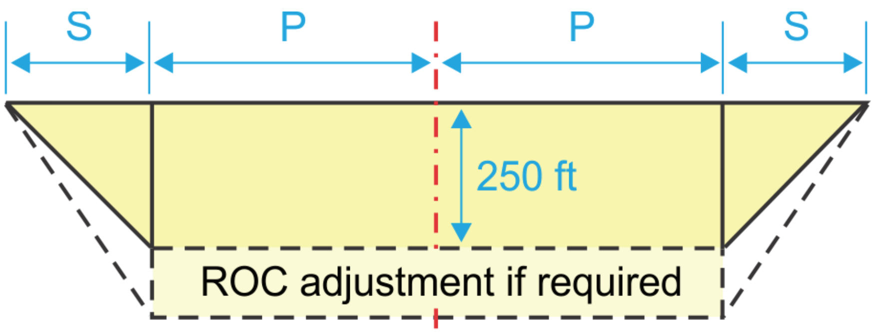
2.4.1 Primary Area.

Apply 250 ft of ROC to the highest obstacle in the primary area. Order 8260.3, Volume 1, chapter 3 precipitous terrain, remote altimeter, and excessive length of final adjustments apply.

2.4.2 Secondary Area.

Secondary ROC tapers uniformly from 250 ft (plus adjustments) at the primary area boundary to zero at the outer edge (see figure 2-3).

Figure 2-3. Primary/Secondary ROC



Calculate the secondary ROC value using calculator 2-4.

See March 1, 2013
Clarification Memo

Calculator 2-4. Secondary Area ROC

$$ROC_{secondary} = (250 + adj) \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

where $d_{primary}$ = perpendicular (relative to course centerline) distance (ft) from edge of primary area
W_S = Width of the secondary area
adj = TERPS Volume 1, chapter 3 adjustments

Calculator 2 4		
$d_{primary}$		Calculate
W_S		
adj		Clear
$ROC_{secondary}$		

2.5 Final Segment Stepdown Fixes.

Where the MDA can be lowered at least 60 ft or a reduction in visibility can be achieved, SDFs may be established in the final approach segment.

2.5.1 **Order 8260.3**, Volume 1, paragraph 288 applies, with the following:

2.5.1 a. **Establish step-down fix locations** in 0.10 NM increments from the LTP/FTP.

2.5.1 b. **The minimum distance** between stepdown fixes is 1 NM.

2.5.1 c. **For step-down fixes** published in conjunction with vertically-guided minimums, the published altitude at the fix must be equal to or less than the computed glidepath altitude at the fix.

Note: Glidepath altitude is calculated using the calculator associated with the basis of the PFAF calculation.

2.5.1 d. **The altitude at any stepdown fix** may be established in 20-ft increments and shall be rounded to the next HIGHER 20-ft increment. For example, 2104 becomes 2120.

2.5.1 e. **Where a RASS adjustment is in use**, the published stepdown fix altitude must be established no lower than the altitude required for the greatest amount of adjustment (i.e., the published minimum altitude must incorporate the greatest amount of RASS adjustment required).

2.5.1 f. **Order 8260.3, Volume 1**, paragraph 252 applies to LNAV and LP descent angles.

2.5.1 **g. Where turns are designed at the PFAF**, Order 8260.3 Volume 1, paragraph 289 applies with the following exception: the 7:1 OIS starts ATT prior to the angle bisector, and extends 1 NM parallel to the final approach centerline. See figure 1-13E (LNAV) and figure 1-13F (LP). Use the following calculators to determine OIS_Z at an obstacle and MFa based on an obstacle height (see calculator 2-5).

Calculator 2-5. OIS_Z & Minimum Fix Altitude

$$(1)\quad OIS_Z = a - c - \frac{O_X}{7}$$

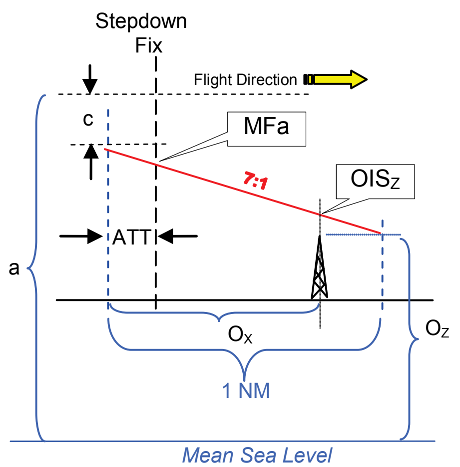
$$(2)\quad MFa = O_Z + c + \frac{O_X}{7}$$

where c = ROC plus adjustments (TERPS Vol 1, para 3.2.2)

a = MSL fix altitude

O_X = Obstacle along-track distance (ft) from ATT prior to fix (1 NM max)

O_Z = MSL obstacle elevation



Calculator 2 5		
a		Calculate
c		
O_X (1 NM Max)		
O_Z		Clear
OIS_Z		
MFa		

2.6 Minimum Descent Altitude (MDA).

The MDA value is the sum of the controlling obstacle elevation MSL (including vertical error value when necessary) and the ROC + adjustments. Round the sum to the next higher 20-ft increment; e.g., 623 rounds to 640. The minimum HATh value is 250 ft.

See March 1, 2013 Clarification Memo

2.7 MA Section 1. (MAS-1).

Section 1 begins ATT prior to the MAP and extends to the SOC or the point where the aircraft is projected to cross 400 ft above airport elevation, whichever is the greater distance from MAP (see figure 2-4).

2.7.1 Length.

2.7.1 a. Flat Surface Length (FSL).

2.7.1 a. (1) LNAV. Section 1 flat surface begins at the CD line (0.3 NM prior to the MAP) and extends (distance FSL feet) to the JK line.

2.7.1 a. (2) LP. Section 1 flat surface begins at the CD line 131.23 ft (40 m) prior to the MAP and extends (distance FSL feet) to the JK line.

Calculate the value of FSL using calculator 2-6.

2.7.1 b. Location of end of section 1 (AB line).

2.7.1 b. (1) $MDA \geq 400$ ft above airport elevation. The AB line is coincident with the JK line.

2.7.1 b. (2) $MDA < 400$. The AB line is located $\frac{1852}{(0.3048 \times CG)}$ feet beyond the JK line for each foot of altitude needed to reach 400 ft above airport elevation. The surface between the JK and AB lines is a rising surface with a slope commensurate with the rate of climb (nominally 40:1).

See March 1, 2013 Clarification Memo

Calculator 2-6. Flat Surface Length

$$FSL = 12 \times \frac{fpnm}{3600} \times \left(\left(V_{KIAS} \times \frac{171233 \times \sqrt{303 - 0.00198 \times MDA}}{(288 - 0.00198 \times MDA)^{2.628}} \right) + 10 \right) + 2 \times ATT$$

Calculator 2 6		
V_{KIAS}		Calculate
ATT		
MDA		Clear
FSL		

2.7.2 Width. LNAV and LP.

2.7.2 **a. LNAV.** The primary area boundary splays uniformly outward from the edge of the primary area at the CD line until it reaches a point 2 NM from course centerline. The secondary area outer boundary lines splay outward 15 degrees relative to the missed approach course from the outer edge of the secondary areas at the CD line (0.3 NM prior to MAP) until it reaches a point 3 NM from course centerline. Calculate the distance from course centerline to the primary and outer secondary boundary of the MAS-1 OEA at any distance from the CD line using calculator 2-7a.

See March 1, 2013 Clarification Memo

Calculator 2-7a. LNAV Primary & Secondary Width

$$(1)\quad MAS_{Yprimary} = d \times \frac{\tan\left(15^\circ \times \frac{\pi}{180^\circ}\right) \times 1.4 \times fpnm}{2.1 \times fpnm} + 0.6 \times fpnm$$

$$(2)\quad MAS_{Ysecondary} = d \times \tan\left(15^\circ \times \frac{\pi}{180^\circ}\right) + 0.9 \times fpnm$$

where d = along-track distance (ft) from the CD line ≤ 47620.380

Calculator 2 7a		
d		Calculate
LNAV $MAS_{Yprimary}$		
LNAV $MAS_{Ysecondary}$		Clear

2.7.2 **b. LP.** The primary area boundary splays uniformly outward from the edge of the primary area at the CD line until it reaches a point 2 NM from course centerline. The secondary area outer boundary lines splay outward 15 degrees relative to the missed approach course from the outer edge of the secondary areas at the CD line (0.3 NM prior to MAP) until it reaches a point 3 NM from course centerline. Calculate the distance from course centerline to the primary and outer secondary boundary of the MAS-1 OEA at any distance from the CD line using calculator 2-7b.

Calculator 2-7b. LP Primary & Secondary Width

See March 1, 2013 Clarification Memo

(1) $MAS_{Yprimary} = d \times \frac{\tan\left(15° \times \frac{\pi}{180°}\right) \times (2 \times fpnm - W_P)}{3 \times fpnm - W_S} + W_P$

(2) $MAS_{Ysecondary} = d \times \tan\left(15° \times \frac{\pi}{180°}\right) + W_S$

where d = along-track distance (ft) from the CD line ≤ 64297.064

Calculator 2 7b		
d		Calculate
W_P		
W_S		
LP $MAS_{Yprimary}$		Clear
LP $MAS_{Ysecondary}$		

See March 1, 2013 Clarification Memo

2.7.3 Obstacle Clearance. LNAV and LP.

The MAS-1 OCS is a flat surface. The MSL height of the surface (HMAS) is equal to the MDA minus 100 ft plus precipitous terrain, remote altimeter (only if full time), and excessive length of final adjustments (see calculator 2-8).

Calculator 2-8. HMAS

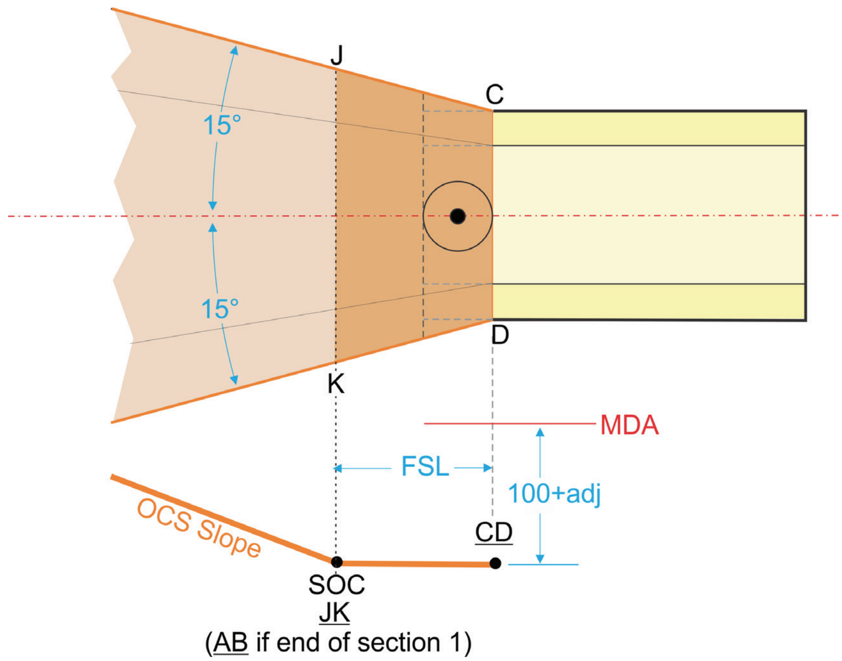
$$HMAS = MDA - (100 + adj)$$

where adj = final segment precipitous terrain, remote altimeter (only if full time), and excessive length of final adjustments

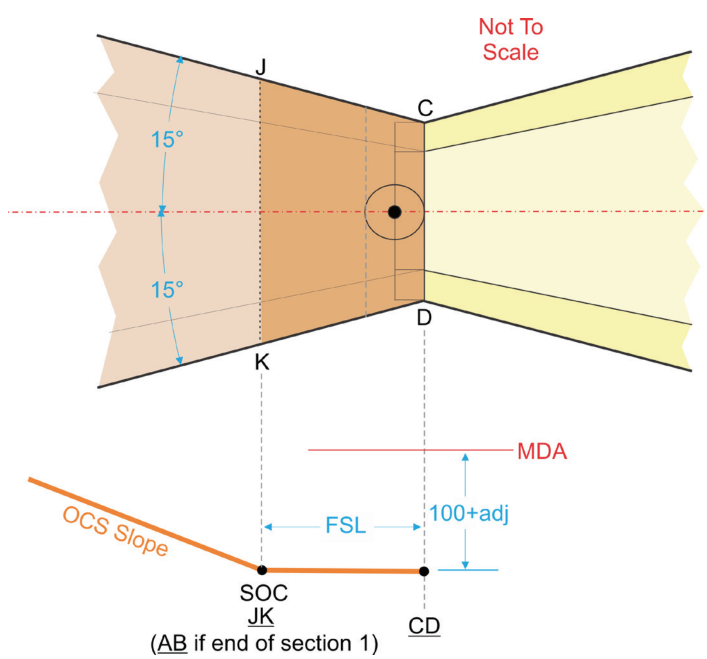
Calculator 2 8		
MDA		Calculate
adj		
HMAS		Clear

Figure 2-4. MA Section 1

LNAV



LP



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Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 3. Lateral Navigation with Vertical Guidance (LNAV/VNAV)

3.0 General.

An LNAV/VNAV approach is a vertically-guided approach procedure using Baro-VNAV or WAAS VNAV for the vertical guidance. Obstacle evaluation is based on the LNAV OEA dimensions and Baro-VNAV OCS. The actual vertical path provided by Baro-VNAV is influenced by temperature variations; i.e., during periods of cold temperature, the effective glidepath may be lower than published and during periods of hot weather, the effective glidepath may be higher than published. Because of this phenomenon, minimum and maximum temperature limits (for aircraft that are not equipped with temperature compensating systems) are published on the approach chart. Additionally, LNAV/VNAV approach procedures at airports where remote altimeter is in use or where the final segment overlies precipitous terrain must be annotated to indicate the approach is not authorized for Baro-VNAV systems. TERPS ROC adjustments for excessive length of final do not apply to LNAV/VNAV procedures. LNAV/VNAV minimum HATh value is 250 ft.

3.1 FAC Alignment.

Optimum final segment alignment is with the runway centerline (± 0.03 degree) extended through the LTP.

3.1.1 Where lowest minimums can only be achieved by offsetting the final course, it may be offset up to 15 degrees when the following conditions are met:

3.1.1 a. **For offset ≤ 5 degrees**, align the course through LTP.

3.1.1 b. **For offset > 5 degrees and ≤ 10 degrees**, the course must cross the runway centerline extended at least 1500 ft (5200 ft maximum) prior to LTP. (d1=1500) Determine the minimum HATh value using calculator 3-1.

3.1.1 c. **For offset > 10 degrees and ≤ 15 degrees**, the course must cross the runway centerline extended at least 3000 ft (5200 ft maximum) prior to LTP (d1=3000). Determine the minimum HATh value (MIN_{HATh}) using calculator 3-1.

Calculator 3-1. Offset Alignment Minimum DA

$$(1) \quad d2 = \frac{V_{KIAS}^2 \times \tan\left(\frac{\alpha^\circ}{2} \times \frac{\pi}{180^\circ}\right)}{68625.4 \times \tan\left(18^\circ \times \frac{\pi}{180^\circ}\right)} \times fpnm$$

$$(2) \quad Min_{HATh} = e^{\left(\frac{(d1+d2)\times\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}{r}\right)} \times (r + LTP_{elev} + TCH) - (r + LTP_{elev})$$

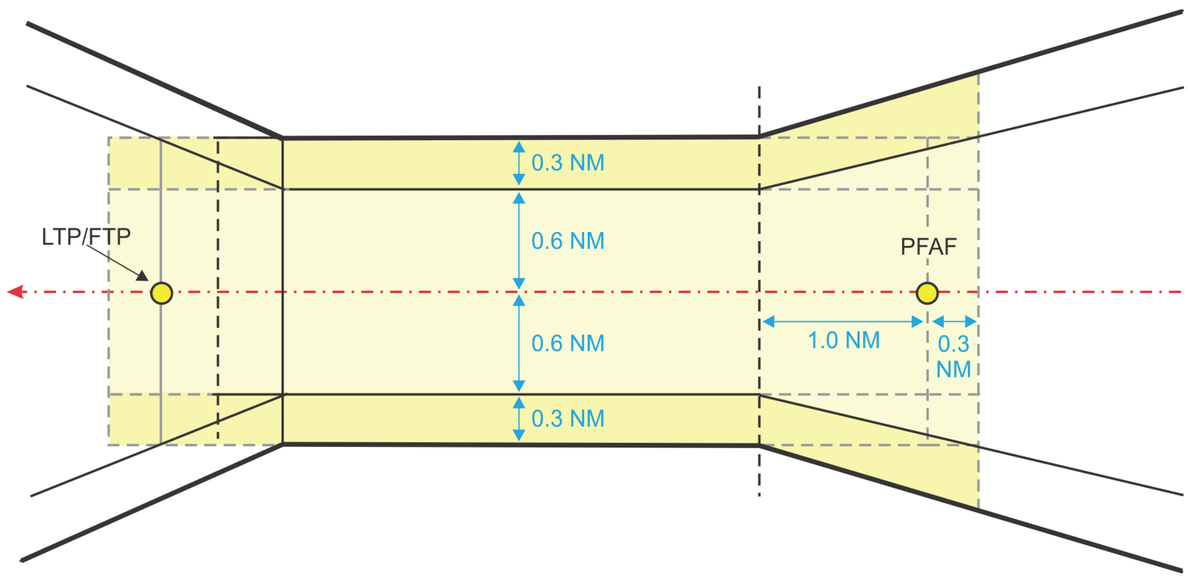
where
α° = degree of offset
θ° = glidepath angle (degrees)
LTP_{elev} = LTP MSL elevation
d1 = value from paragraph 3.1.1b/c as appropriate

Calculator 3 1		
d1		Calculate
α^o		
V_{KIAS}		
θ^o		
LTP_{elev}		Clear
TCH		
d2		
Min_{HATh}		

3.2 Area.

The intermediate segment primary and secondary areas taper from initial segment OEA width (1-2-2-1) to the width of the final segment OEA width (0.3-0.6-0.6-0.3). The taper begins at a point 2 NM prior to the PFAF and ends 1.0 NM following (past) the PFAF. The final segment OEA primary and secondary areas follow the tapering boundaries of the intermediate segment from ATT prior to the PFAF to the point 1 NM past the PFAF, and then are a constant width to 0.3 NM past the MAP (see figure 3-1).

Figure 3-1. LNAV/VNAV Final Segment OEA



3.2.1 Length.

The OEA begins 0.3 NM prior to the PFAF and ends 0.3 NM past the LTP. Segment length is determined by PFAF location. Determine the PFAF location per paragraph 1.13. The **maximum** length is 10 NM.

3.2.2 Width.

The final segment primary and secondary boundaries are coincident with the intermediate segment boundaries (see paragraph 1.9) from a point 0.3 NM prior to the PFAF to a point 1 NM past the PFAF. From this point, the Primary OEA boundary is ± 0.6 NM (≈ 3,646 ft) from course centerline. A 0.3 NM (≈ 1,823 ft) secondary area is located on each side of the primary area. Where the intermediate segment is not aligned with the final segment, the segment boundaries are constructed under paragraph 1.9.3a.

3.3 Obstacle Clearance Surface (OCS).

Obstacle clearance is provided by application of the Baro-VNAV OCS. The OCS originates at LTP elevation at distance D_{origin} from LTP as calculated by calculator 3-2.

Calculator 3-2. OCS Origin

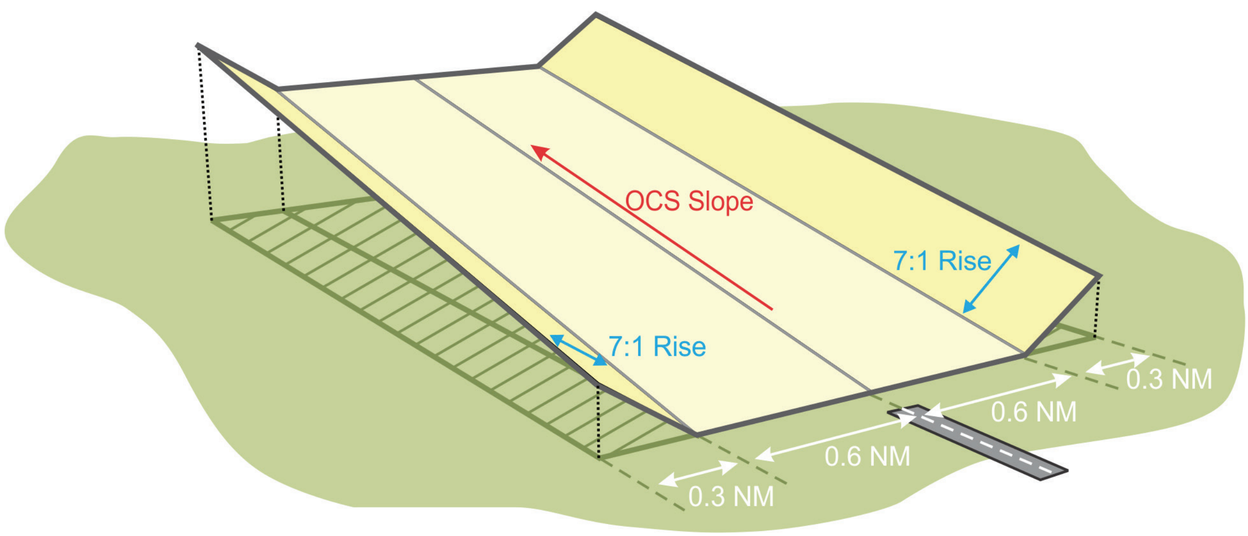
$$D_{origin(ft)} = \frac{250 - TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}$$

where
θ° = *glidepath angle*

Calculator 3 2		
TCH		Calculate
θ^o		
D_{origin}		Clear

The OCS is a sloping plane in the primary area, rising along the course centerline from its origin toward the PFAF. The OCS slope ratio is calculated under paragraph 3.3.3. 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 areas is a 7:1 surface sloping upward from the edge of the primary area OCS perpendicular to the flight track (see figure 3-2).

Figure 3-2. Final Segment OCS



The primary area OCS slope varies with the designed glidepath angle. The effective glidepath angle (actual angle flown) depends on the deviation from ISA temperature associated with airport elevation. Calculate the ISA temperature (Celsius and Fahrenheit) for the airport using calculator 3-3.

Calculator 3-3. Airport ISA

(1) $ISA_{airport°C} = 15 - 0.00198 \times airport\ elevation$

(2) $ISA_{airport°F} = 1.8 \times ISA_{airport°C} + 32$

Calculator 3 3		
Airport elevation		Calculate
$ISA_{airport}$ °C		
$ISA_{airport}$ °F		Clear

3.3.1 Determining Average Cold Temperature.

The OCS slope ratio (run/rise) provides obstacle protection within a temperature range that can reasonably be expected to exist at the airport. The slope ratio is based on the temperature spread between the airport ISA and the temperature to which the procedure is protected. This value is termed ΔISA_{LOW}. To calculate ΔISA_{LOW}, determine the ACT for which the procedure will be protected.

Establish a 5-year history window starting with the most recent year in which history is available for the entire calendar year (CY) (i.e., January 1 – December 31). The earliest year of the reporting window must be within six years of the current year.

Example:

The current year is 2010; the allowable reporting period is 2004 thru 2009. Complete data for CY 2009 is not yet available, but complete data is available for CY 2008 and preceding years. Use the complete 5-year history from January 1, 2004 to December 31, 2008 to establish the ACT. If complete data is available for CY 2009 and preceding years dating back to 2004, use the 5-year history from January 1, 2005 to December 31, 2009 to establish the ACT.

If a 5-year history is not available, then use a 4-year history. If a 4-year history is not available, then use a 3-year history. A 3-year history is the minimum history required. The 3 or 4-year history may include any years within the 5-year window defined above provided each of the years contains complete data for the full calendar year.

Calculate the preliminary ACT as follows:

(1) Within each of the years used, find the month with the average coldest temperature.

Example:

2004	2005	2006	2007	2008
45.4°F	44.7°F	43.4°F	42.2F	45.0°F

(2) Within each of the average coldest months determined in (1), find the coldest day.

Example:

2004	2005	2006	2007	2008
37°F	35°F	35°F	29°F	35°F

(3) Average the coldest day temperatures.

Example:

(°F) $$\frac{37+35+35+29+35}{5}=34.2$$

Note: If Fahrenheit values are used, convert to Celsius using calculator 3-4.

Example:

$$\frac{34.2-32}{1.8}=1.22$$

preliminary ACT = 1.22°C

(4) Round the Celsius value from (3) to the next warmer whole degree; e.g., -15.00 remains -15; -14.99 becomes -14). The resultant rounded value is the ACT.

Example from (3): ACT = 2°C

For procedure documentation use standard entry on FAA Form 8260-9 (or equivalent): "Average Cold Temperature based on (# years used)-year history (inclusive years; e.g., 2004-2008 or if individual years used; e.g., 2004, 2006, 2008)".

Examples:

"Average Cold Temperature based on 5-year history (2004-2008)"
"Average Cold Temperature based on 3-year history (2004, 2006, 2008)"

If historical temperature data is not available, determine the ACT as follows:

(1) Determine the temperature deviation from the airport ISA (ΔISA) using table 3-1 based on the Airport Reference Point geographical area:

Table 3-1. Standard ΔISA Values

Location	Value below airport ISA°C / °F
Conus	-30°C / -54°F
Alaska	-40°C / -72°F
Hawaii	-20°C / -36°F

(2) Use calculator 3-3 to calculate the airport ISA in degrees Celsius:

Example: 15-0.00198×677.4=13.66

(3) Determine the preliminary ACT based on the selected ΔISA value by adding ΔISA to the airport ISA value: Preliminary ACT=ΔISA+ISA

Example: -30+13.66=-16.34

(4) Round the calculated value to the next warmer whole degree; e.g., -15.00 remains -15; -15.01 thru -15.99 becomes -15. The resultant rounded value is the ACT.

Example from (3): ACT = -16°C

For procedure documentation identify the temperature deviation used to determine the ACT. Use standard entry on FAA Form 8260-9 (or equivalent):

Example:

"Average Cold Temperature based on standard -30°C ISA deviation."

Determine the published low temperature limit using calculator 3-4.

3.3.2 Determining Low Temperature Limit.

Normally, the low temperature limit is the calculated ACT. Where the ACT results in an effective glidepath that is less than 2.5 degrees, raise the low temperature limit to the temperature required to achieve an effective 2.5 degree glidepath. Use calculator 3-4 to determine the low temperature limit.

Calculator 3-4. Low Temperature Limit

{Low temperature based on warmer of effective glidepath angle of 2.5 degrees or ACT}

$$(1)\quad \Delta ISA_{ACT} = ACT - (15 - 0.00198 \times airport_{elev})$$

$$(2)\quad \Delta DA_{alt\_ACT} = \frac{250 \times \Delta ISA_{ACT}}{288 + \Delta ISA_{ACT} - 0.5 \times 0.00198 \times (LTP_{elev} + 250)}$$

$$(3)\quad d_{DA\_ft} = \textbf{ceiling}\left[\frac{r \times \ln\left(\frac{r + LTP_{elev} + 250}{r + LTP_{elev} + TCH}\right)}{\tan\left(\theta \times \frac{\pi}{180}\right)}\right]$$

$$(4)\quad \theta_{effective} = \frac{180}{\pi} \times \textbf{atan}\left(\frac{r}{d_{DA\_ft}} \times \ln\left(\frac{r + LTP_{elev} + 250 + \Delta DA_{alt\_ACT}}{r + LTP_{elev} + TCH}\right)\right)$$

$$(5)\quad \Delta DA_{alt\_2.5} = (r + LTP_{elev} + TCH) \times e^{\frac{d_{DA\_ft}}{r} \times \tan\left(2.5 \times \frac{\pi}{180}\right)} - (r + LTP_{elev} + 250)$$

$$(6)\quad \Delta ISA_{2.5} = \frac{\Delta DA_{alt\_2.5} \times (288 - 0.5 \times 0.00198 \times (LTP_{elev} + 250))}{250 - \Delta DA_{alt\_2.5}}$$

$$(7)\quad ACT_{2.5} = ISA_{airport} + \Delta ISA_{2.5}$$

$$(8)\quad \textbf{case}\ \theta_{effective} \geq 2.5^\circ \quad NA_{below°C} = \textbf{ceiling}[ACT]$$
$$NA_{below°F} = \textbf{ceiling}[ACT \times 1.8 + 32]$$
$$\Delta ISA_{Low°C} = \Delta ISA_{ACT}$$
$$\textbf{case}\ \theta_{effective} < 2.5^\circ \quad NA_{below°C} = \textbf{ceiling}[ACT_{2.5}]$$
$$NA_{below°F} = \textbf{ceiling}[ACT_{2.5} \times 1.8 + 32]$$
$$\Delta ISA_{Low°C} = \Delta ISA_{2.5}$$

where

$\theta°$ = designed glidepath angle in degrees

LTP_{elev} = LTP elevation in feet

TCH = Threshold crossing height in feet

$airport_{elev}$ = Airport elevation in feet above mean sea level

ACT = Average cold temperature at the airport in degrees celsius

Calculator 3 4		
$\theta°$		Calculate
LTP_{elev}		
TCH		
$airport_{elev}$		
ACT		
$NA_{below°C}$		Clear
$NA_{below°F}$		
$\Delta ISA_{Low°C}$		

3.3.3 Determining High Temperature Limitation.

The maximum temperature limit is the temperature that yields an effective glidepath angle equal to 1.13 times the maximum allowed glidepath angle for the published fastest category (see calculator 3-5).

Calculator 3-5. High Temperature Limit

```
- - - - -{ Determination of Max glidepath angles and indicated airspeeds }- - - - - -
if CAT="A" then
      V_KIAS = 90
      α = 5.7
end if
if CAT = "B" then
      V_KIAS = 120
      α = 4.2
end if
if CAT = "C" then
      V_KIAS = 140
      α = 3.6
end if
if CAT = "D" then
      V_KIAS = 165
      α = 3.1
end if
if CAT = "E" then
      V_KIAS = 250
      α = 3.1
end if
```

- - - -{Determination of Descent Rates (DR) at high temp limit and ISA standard temperature }- - - - - -

(1) $MDR_{angle} = 1.13 \times \alpha \times \frac{\pi}{180}$

(2) $DR_{high\_temp} = \text{ceiling}\left[\sin\left(MDR_{angle}\right) \times \left(\frac{\left(V_{KIAS}\right) \times 171233 \times \sqrt{303 - 0.00198 \times \left(LTP_{elev} + 250\right)}}{\left(288 - 0.00198 \times \left(LTP_{elev} + 250\right)\right)^{2.628}} + 10\right) \times 101.26859\right]$

(3) $DR_{standard\_temp} = \text{ceiling}\left[\sin\left(\theta \times \frac{\pi}{180}\right) \times \left(\frac{\left(V_{KIAS}\right) \times 171233 \times \sqrt{303 - 0.00198 \times \left(LTP_{elev} + 250\right)}}{\left(288 - 0.00198 \times \left(LTP_{elev} + 250\right)\right)^{2.628}} + 10\right) \times 101.26859\right]$

- - - - - - - - - - - - - - - - - -{ *High Temperature Limit* }- - - - - - - - - - - - - - - - - -

{*High temperature limit based on 1.13 times the max allowable glidepath angle for the fastest published aircraft category*}

(4) $ISA_{airport} = 15 - 0.00198 \times airport_{elev}$

(5) $$d_{DA\_ft} = \text{ceiling}\left[\frac{r \times \ln\left(\frac{r + LTP_{elev} + 250}{r + LTP_{elev} + TCH}\right)}{\tan\left(\theta \times \frac{\pi}{180}\right)}\right]$$

(6) $$\Delta DA_{alt} = e^{\frac{d_{DA\_ft}}{r} \times \tan\left(MDR_{angle}\right)} \times \left(r + LTP_{elev} + TCH\right) - \left(r + LTP_{elev} + 250\right)$$

(7) $$\Delta ISA_{high} = \frac{\Delta DA_{alt} \times \left(288 - 0.5 \times 0.00198 \times \left(LTP_{elev} + 250\right)\right)}{250 - \Delta DA_{alt}}$$

(8) $temp_{high°C} = ISA_{airport} + \Delta ISA_{high}$

$temp_{high°F} = temp_{high°C} \times 1.8 + 32$

(9) $case\ temp_{high°C} \geq 54 \quad NA_{above°C} = 54$

$NA_{above°F} = 130$

$case\ temp_{high°C} < 54 \quad NA_{above°C} = \text{floor}\left[temp_{high°C}\right]$

$NA_{above°F} = \text{floor}\left[temp_{high°F}\right]$

where

CAT = Aircraft approach category

θ = designed glidepath angle in degrees

LTP_{elev} = LTP elevation in feet

TCH = Threshold crossing height in feet

$airport_{elev}$ = Airport elevation in feet above mean sea level

Calculator 3 5		
CAT		Calculate
θ		
LTP_{elev}		
TCH		
$airport_{elev}$		
$NA_{above°C}$		Clear
$NA_{above°F}$		
$DR_{high\ temp}$		
$DR_{standard\ temp}$		

The calculator also determines the maximum expected descent rate at the high temperature limit, for the airport standard temperature, and the delta-ISA low value appropriate for the low temperature limit. Record this information per Order 8260.19, paragraph 4-97.

3.3.4 OCS Slope.

The OCS slope is dependent upon the published GPA (θ), airport ISA, and the ACT temperatures. Determine the OCS slope value using calculator 3-6.

See March 1, 2013 Clarification Memo

Calculator 3-6. OCS Slope

$$OCS_{slope} = \frac{1}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times \left(0.928 + 0.0038 \times \left(ACT^\circ C - ISA^\circ C\right)\right)}$$

Where

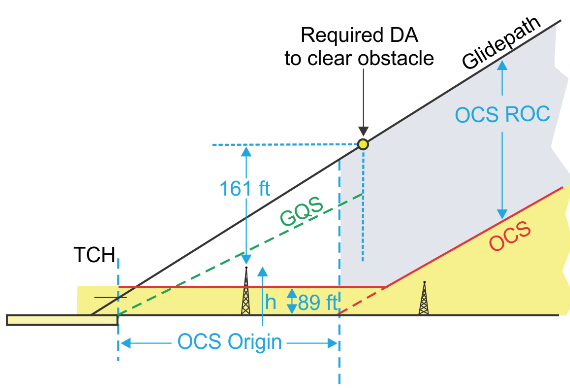
θ° = glidepath angle (degrees)
ISA°C = Airport ISA from calculator 3-3
ACT°C = Value from paragraph 3.3.1

Calculator 3 6		
θ°		Calculate
ISA°C		
ACT°C		Clear
OCS_{slope}		

3.3.5 Final Segment Obstacle Evaluation.

The final segment OEA is evaluated by application of an ROC and an OCS. ROC is applied from the LTP to the point the OCS reaches 89 ft above LTP elevation. The OCS is applied from this point to a point 0.3 NM outside the PFAF (see figure 3-3).

Figure 3-3. Obstacle Evaluation



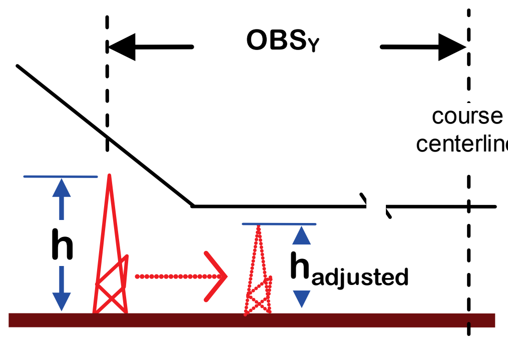
If an obstacle is in the secondary area (transitional surface), adjust the height of the obstacle using calculator 3-7, then evaluate it at the adjusted height as if it is in the primary area.

Calculator 3-7. Secondary Area Adjusted Obstacle Height

$$h_{adjusted} = h - \frac{OBS_Y - Width_{primary}}{7}$$

where

h = obstacle MSL elevation
$Width_{primary}$ = perpendicular distance (ft) of primary boundary from course centerline
OBS_Y = obstacle perpendicular distance (ft) from course centerline



Calculator 3 7		
h		Calculate
$Width_{primary}$		
OBS_Y		Clear
$h_{adjusted}$		

3.3.5 **a. ROC application.** Apply the appropriate value from table 3-2 to the higher of the following:

- height of the obstacle exclusion area or
- highest obstacle above the exclusion area.

Calculate the DA based on ROC application (DA_{ROC}) using calculator 3-8. Round the result to the next higher foot value.

Calculator 3-8. DA Based on ROC Application

$$DA_{ROC} = h + hL$$

where
- h = higher of:
  - Obstacle MSL elevation ($h_{adjusted}$ if in secondary)
  - or
  - height of obstacle exclusion surface (89 ft above LTP elevation)
- hL = value from table 3-2

Calculator 3 8		
h		Calculate
hL		
DA_{ROC}		Clear

3.3.5 b. OCS Evaluation.

The OCS begins D_{ORIGIN} from LTP at LTP elevation. Application of the OCS begins at the point the OCS reaches 89 ft above LTP elevation. Determine the distance from LTP that the OCS reaches 89 ft above LTP using calculator 3-9a. The MSL elevation of the OCS (OCS_{elev}) at any distance (OBS_X) from LTP ($OBS_X > D_{origin}$) is determined using calculator 3-9b.

Calculator 3-9a. Distance from LTP that OCS Application Begins

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

where
- D_{origin} = distance from calculator 3-2
- OCS_{slope} = slope from calculator 3-6

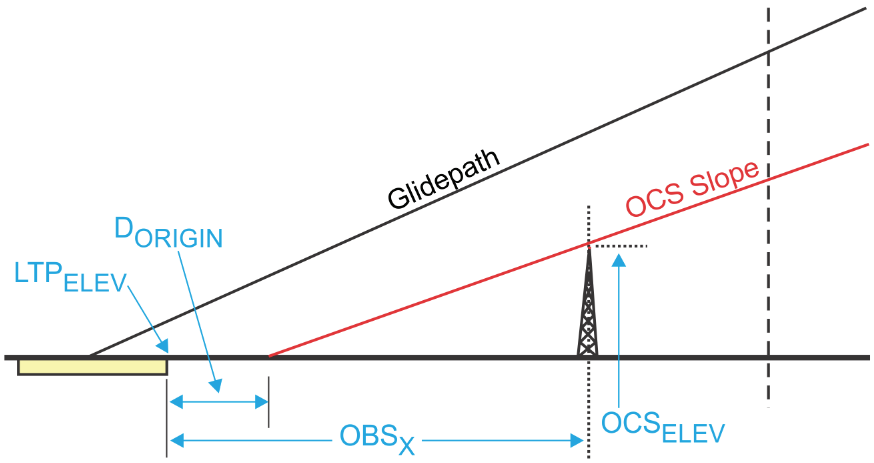
Calculator 3 9a		
LTP_{elev}		Calculate
OCS_{slope}		
D_{origin}		Clear
D_{OCS}		

Calculator 3-9b. OCS Elevation

$$OCS_{elev} = (r + LTP_{elev}) \times e^{\frac{OBS_X - D_{origin}}{r \times OCS_{slope}}} - r$$

where

D_{origin} = distance (ft) from LTP to OCS origin
OCS_{slope} = OCS slope ration (run/rise; e.g., 34)
OBS_X = distance (ft) measured along course from LTP



Calculator 3 9b		
LTP_{elev}		Calculate
OCS_{slope}		
D_{origin}		
OBS_X		Clear
OCS_{elev}		

Where obstacles penetrate the OCS, determine the minimum DA value (DA_{OCS}) based on the OCS evaluation by applying calculator 3-10 using the penetrating obstacle with the highest MSL value (see figure 3-4).

Calculator 3-10. DA Based On OCS

$$(1) \quad d=(r+LTP_{elev})\times OCS_{slope}\times \ln\left(\frac{r+O_{MSL}}{r+LTP_{elev}}\right)+D_{origin}$$

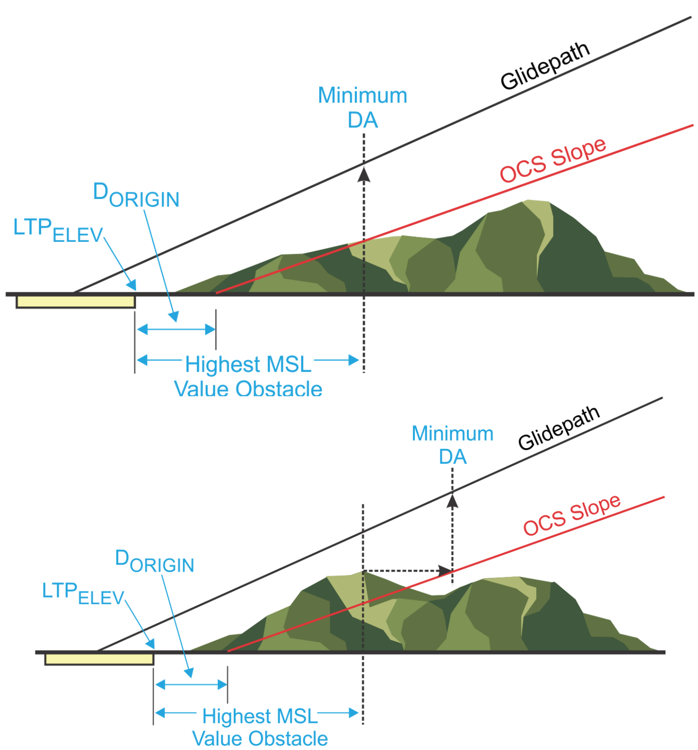
$$(2) \quad DA_{OCS}=e^{\frac{d\times \tan\left(\theta^{\circ}\times\frac{\pi}{180^{\circ}}\right)}{r}}\times(r+LTP_{elev}+TCH)-r$$

where

O_{MSL} = *obstacle MSL elevation*
D_{origin} = *value from calculator 3-2*
OCS_{slope} = *value from calcualtor 3-6*

Calculator 3 10		
LTP_{elev}		Calculate
TCH		
θ°		
OCS_{slope}		
O_{MSL}		Clear
D_{origin}		
DA_{OCS}		

Figure 3-4. OCS Penetrations



3.3.5 **c. Final Segment DA.** The published DA is the higher of DA_{LS} or DA_{OCS}.

3.3.5 **d. Calculating DA to LTP distance.** Calculate the distance from LTP to DA using calculator 3-11.

See March 1, 2013 Clarification Memo

Calculator 3-11. Distance to DA

$$D_{DA} = \frac{\ln\left(\frac{r+DA}{r+LTP_{eLev}+TCH}\right)\times r}{\tan\left(\theta^\circ\times\frac{\pi}{180^\circ}\right)}$$

Calculator 3 11		
LTP_{eLev}		Calculate
TCH		
θ°		
DA		Clear
D_{DA}		

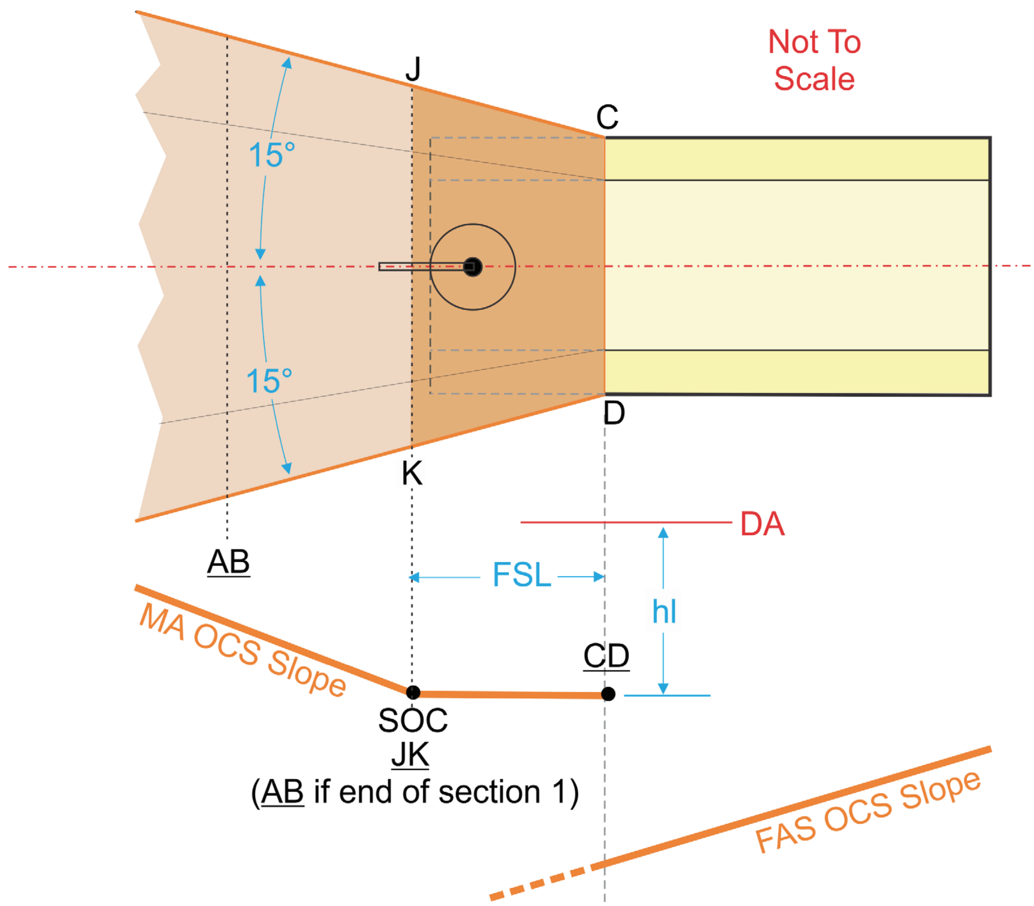
3.4 MA Section 1.

Section 1 extends from DA along a continuation of the final course to the SOC point or the point where the aircraft reaches 400 ft above airport elevation, whichever is farther. Turns are not allowed in section 1 (see figures 3-5 and 3-6).

3.4.1 Area.

Section 1 provides obstacle protection allowing the aircraft to arrest descent, and configure the aircraft to climb. It begins at the CD line which is perpendicular to the final approach track at DA (D_{DA} prior to threshold) and extends along the missed approach track to the AB line (the SOC point or the point the aircraft reaches 400 ft above airport elevation, whichever is farther from the DA point). The OEA contains a flat ROC surface and a rising OCS (40:1 standard) if climb to 400 ft above airport elevation is necessary (see figures 3-5 and 3-6).

Figure 3-5. Section 1 Area



3.4.1 a. Length.

The area from the DA point to SOC is termed the "Flat Surface." Calculate the Flat Surface Length in feet (FSL_{ft}) using calculator 3-12a based on final approach airspeed.

Calculator 3-12a. Flat Surface Length

$$FSL_{ft} = 15 \times \frac{fpnm}{3600} \times \left(\left(V_{KIAS} \times \frac{171233 \times \sqrt{303 - 0.00198 \times DA}}{(288 - 0.00198 \times DA)^{2.628}} \right) + 10 \right)$$

Calculator 3 12a		
V_{KIAS}		Calculate
DA		
FSL_{ft}		Clear

The end of the flat surface ends at the SOC, marked by the JK construction line. If the published DA is lower than 400 ft above airport, a 40:1 rising surface extension is added to section 1. Calculate the length (in feet) of the $s1_{extension}$ using calculator 3-12b.

Calculator 3-12b. Calculation of Extension for Climb to 400 ft

$$s1_{extension(ft)} = \frac{Z}{CG} \times fpnm$$

where

Z = number of feet to climb to reach 400 ft above airport
CG = climb gradient (standard 200 ft/NM)

Calculator 3 12b		
CG		Calculate
Z		
$s1_{extension(ft)}$		Clear

3.4.1 b. Width.

The OEA splays at an angle of 15 degrees relative to the FAC from the outer edge of the final segment secondary area (perpendicular to and 5468.5 ft from FAC) at the DA point. The splay ends when it reaches a point 3 NM from the missed approach course centerline (47620.38 ft [7.8 NM] from DA point).

3.4.1 c. OCS.

The HMAS below the DA point is determined by calculator 3-13 using the ROC value (hl) from table 3-2. Select the hl value for the fastest aircraft category for which minimums are published.

Table 3-2. Level Surface ROC Values (hl)

Aircraft Category	hl (ft)
A	131
B	142
C	150
D/E	161

Calculator 3-13. HMAS Elevation

$$HMAS = DA - hl$$

where
hl = level surface ROC from table 3-2

Calculator 3 13		
DA		Calculate
hl		
HMAS		Clear

3.4.1 c. (1) The missed approach surface remains level (flat) from the DA (CD line) point to the SOC point (JK line). Obstacles must not penetrate the flat surface. Where obstacles penetrate the flat surface, raise the DA by the amount of penetration and re-evaluate the missed approach segment (see figure 3-6).

3.4.1 c. (2) At SOC, the surface begins to rise along the missed approach course centerline at a slope ratio (40:1 standard) commensurate with the minimum required rate of climb (200 ft/NM standard); therefore, the OCS surface rise at any obstacle position is equal to the along-track distance from SOC (JK line) to a point abeam the obstacle. Obstacles must not penetrate the 40:1 surface. Where obstacles penetrate the 40:1 OCS, adjust DA by the amount (ΔDA) calculated by calculator 3-14 and re-evaluate the missed approach segment.

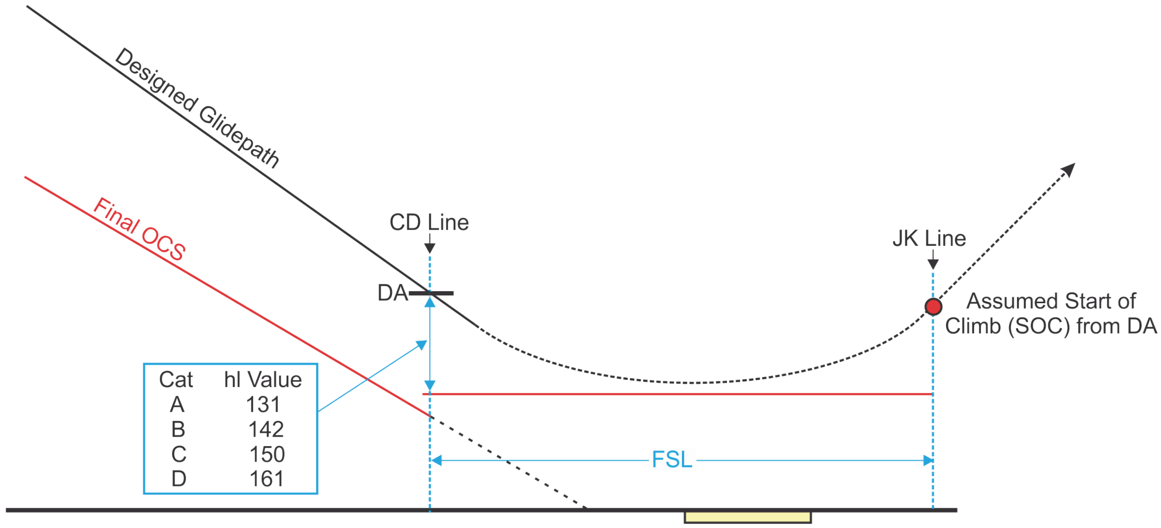
Calculator 3-14. DA Adjustment Value

$$\Delta DA = r \times e^{\frac{p \times \frac{MA_{slope} \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}{1 + MA_{slope} \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}}{r}} - r$$

where
p = amount of penetration
MA_{slope} = MA OCS slope (nominally 40:1)

Calculator 3 14		
p		Calculate
θ°		
MA_{slope}		Clear
ΔDA		

Figure 3-6. Missed Approach Flat Surface



Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 4. LPV/ILS/GLS Final Approach Segment (FAS) Evaluation

4.0 General.

The OEA and associated OCSs are applicable to LPV final approach segments. These criteria may also be applied to construction of an RNAV transition to an ILS final segment where the GPIP is located within 50200 ft of the LTP. For an RNAV transition to an ILS/GLS final, use LPV criteria to evaluate the final and MA section 1. For GLS procedures, design final track intercept within 20 NM of the airport using PBN or conventional routing.

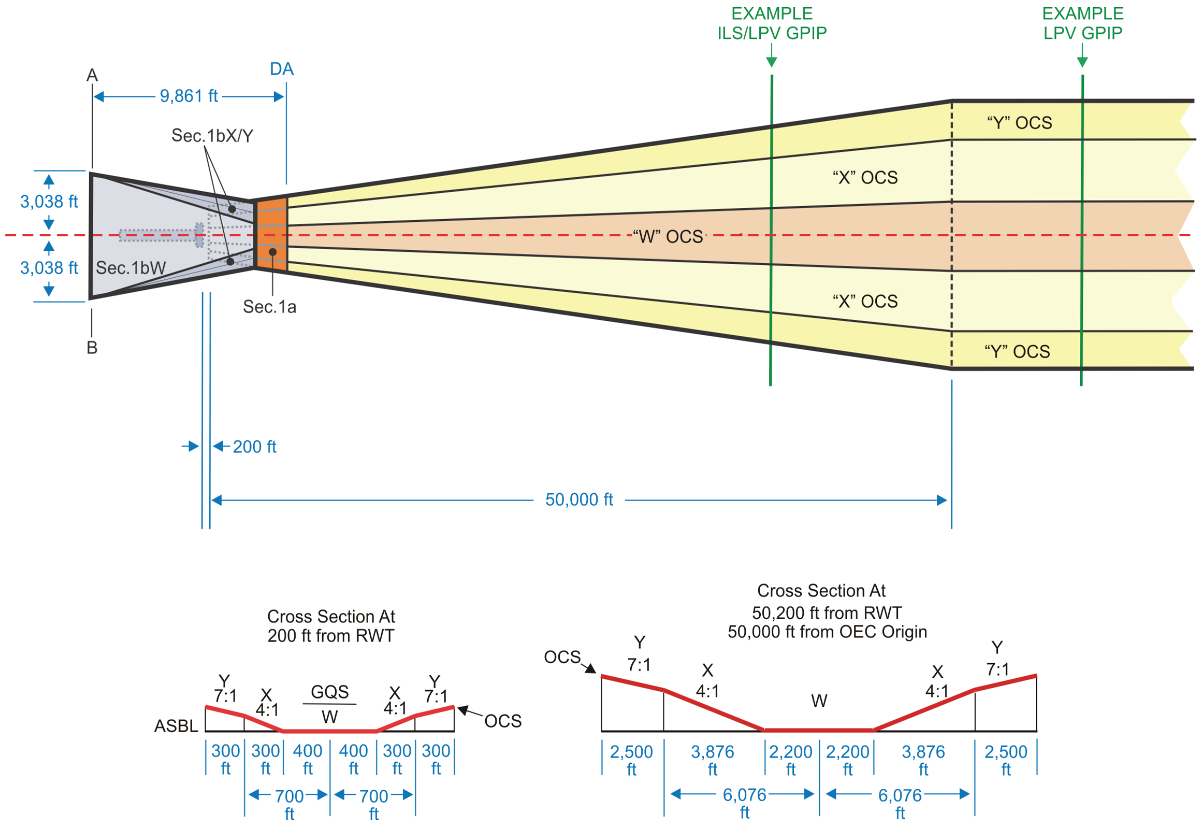
4.1 Final Segment OEA.

See March 1, 2013 Clarification Memo

The OEA originates 200 ft from LTP or FTP as appropriate, and extends to a point ≈131 ft (40 m ATT) beyond the GPIP (GPIP is determined using calculator 1-15a). It is centered on the final approach course and expands uniformly from its origin to a point 50000 ft from the origin where the outer boundary of the X surface is 6076 ft perpendicular to the course centerline. Where the GPIP must be located more than 50200 ft from LTP, the OEA continues linearly (boundaries parallel to course centerline) to the GPIP (see figure 4-1)*. The primary area OCS consists of the W and X surfaces. The Y surface is an early missed approach transitional surface. The W surface slopes longitudinally along the final approach track, and is level perpendicular to track. The X and Y surfaces slope upward from the edge of the W surface perpendicular to the final approach track. Obstacles located in the X and Y surfaces are adjusted in height to account for perpendicular surface rise and evaluated under the W surface.

***Note:** ILS continues the splay, only LPV and GLS are linear outside 50200 ft.

Figure 4-1. LPV/ILS Final/Missed Section 1 OCSs

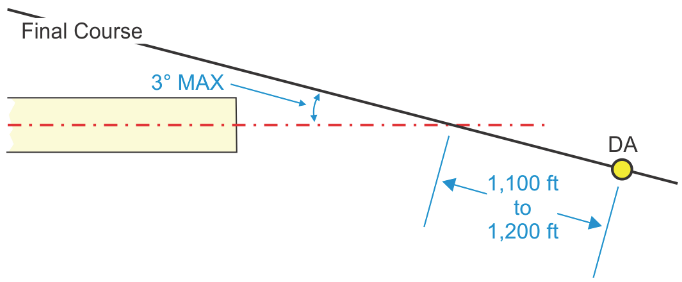


4.1.1 OEA Alignment.

The final course is normally aligned with the RCL extended (± 0.03 degree) through the LTP (± 5 ft). Where a unique operational requirement indicates a need to offset the course from RCL, the offset must not exceed 3 degrees measured geodetically* at the point of intersection. If the course is offset, it must intersect the RCL at a point 1100 to 1200 ft inside the DA point (see figure 4-2). Where the course is not aligned with RCL, the minimum HATh value is 250.

*** Note:** Geodetic measurements account for the convergence of lines of longitude. Plane geometry calculations are not compatible with geodetic measurements. See Volume 1, appendix A for geodetic calculation explanation. A geodetic calculator is available on the AFS-420 website.

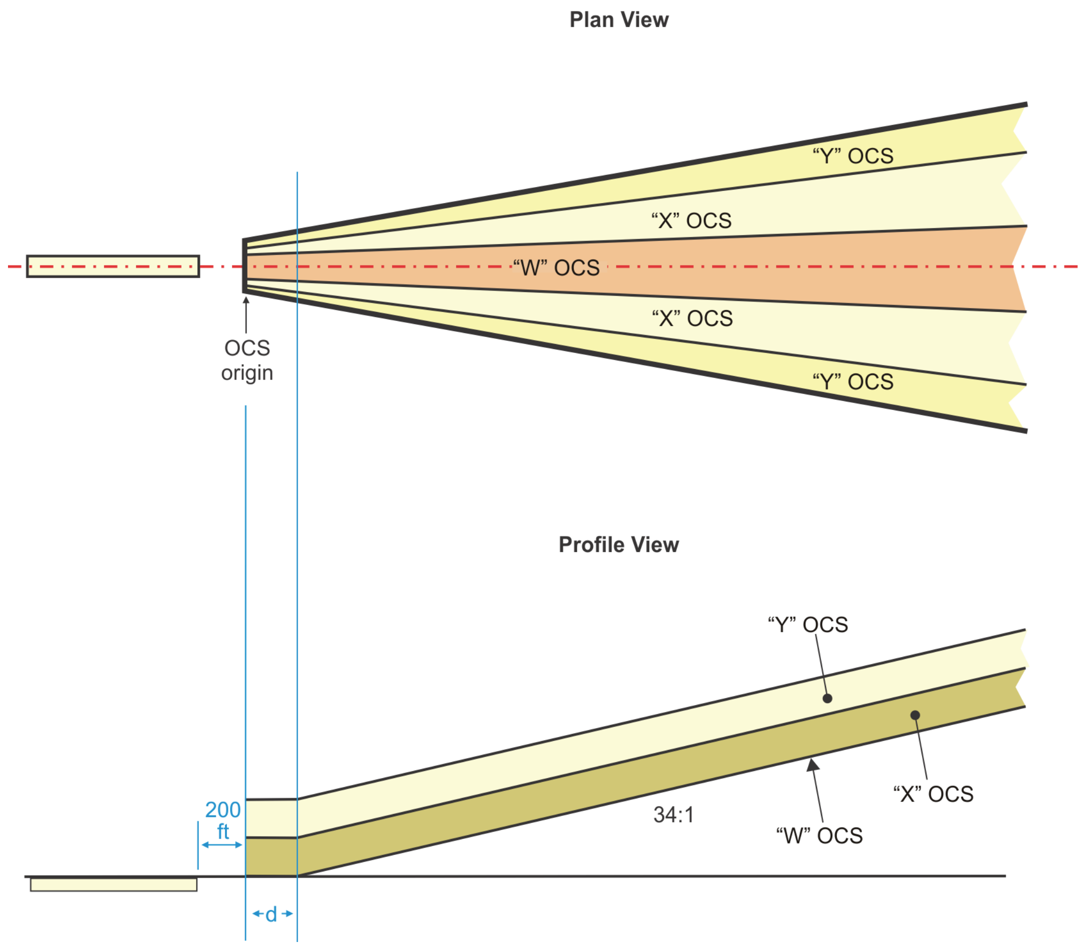
Figure 4-2. Offset Final Course



4.1.2 OCS Slope(s) (see figure 4-3)**.**

In this document, slopes are expressed as run over rise; e.g., 34:1. Determine the OCS slope (S) associated with a specific glidepath angle (θ) using calculator 4-1.

Figure 4-3. OCS Slope Origin



Calculator 4-1. OCS Slope

$$S = \frac{102}{\theta^\circ}$$

Calculator 4 1		
θ°		Calculate
S		Clear

4.1.3 OCS Origin.

The OEA (all OCS surfaces) originates from LTP elevation at a point 200 ft from LTP (see figure 4-3) measured along course centerline and extends to the GPIP. The longitudinal (along-track) rising W surface slope begins at a point 200+d feet from OEA origin. The value of d is dependent on the TCH/GPA relationship.

Where $\frac{TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)} \geq 954$, d equals 0.

Where $\frac{TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)} < 954$, calculate the value of d using calculator 4-2.

Calculator 4-2. Slope Origin Distance (d)

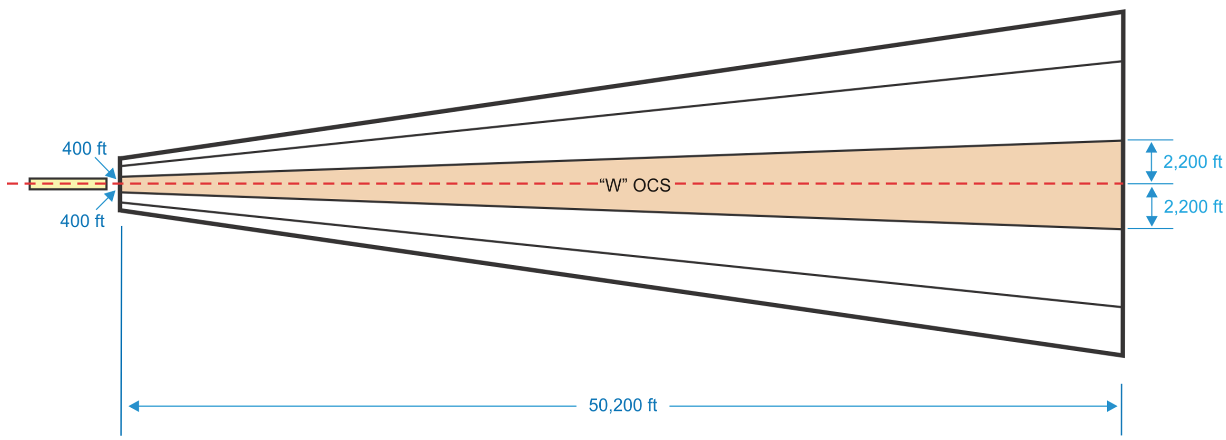
$$d = 954 - \frac{TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}$$

Calculator 4 2		
TCH		Calculate
θ°		
d		Clear

4.2 W OCS. (See figure 4-4)

All final segment OCS (W,X, and Y) obstacles are evaluated relative to the height of the W surface based on their along-track distance (OBS_X) from the LTP, perpendicular distance (OBS_Y) from the course centerline, and MSL elevation (OBS_{MSL}) adjusted for earth curvature and X/Y surface rise if appropriate. This adjusted elevation is termed obstacle evaluation elevation (O_{EE}) and is covered in paragraph 4.2.2.

Figure 4-4. W OCS



4.2.1 Width (perpendicular distance from course centerline to surface boundary)**.**

The perpendicular distance ($W_{boundary}$) from course centerline to the boundary is 400 ft at the origin, and expands uniformly to 2200 ft at a point 50200 ft from LTP/FTP. Calculate $W_{boundary}$ for any distance from LTP using calculator 4-3. For obstacle evaluation purposes, the distance from LTP is termed OBS_X.

Calculator 4-3. W OCS ½ Width

$$W_{boundary} = 0.036 \times OBS_X + 392.8$$

where

OBS_X = *along-track distance (ft) from LTP to obstacle*

Calculator 4 3		
OBS_X		Calculate
$W_{boundary}$		Clear

4.2.2 Height.

Calculate the MSL height (ft) of the W OCS (W_{MSL}) at any distance OBS_X from LTP using calculator 4-4.

Calculator 4-4. W OCS MSL Elevation

$$MSL = \frac{(r + LTP_{elev}) \times \cos\left(\operatorname{atan}\left(\frac{\theta^\circ}{102^\circ}\right)\right)}{\cos\left(\frac{OBS_X - (200 + d)}{r} + \operatorname{atan}\left(\frac{\theta^\circ}{102^\circ}\right)\right)} - r$$

where
OBS_X = obstacle along-track distance (ft) from LTP/FTP
d = value from paragraph 4.1.3

Calculator 4 4		
LTP_{elev}		Calculate
θ°		
d		
OBS_X		Clear
W_{MSL}		

The LPV (and ILS) glidepath is considered to be a straight line in space extending from TCH. The OCS is; therefore, a flat plane (does not follow earth curvature) to protect the straight-line glidepath. The elevation of the OCS at any point is the elevation of the OCS at the course centerline abeam it. Since the earth's surface curves away from these surfaces as distance from LTP increases, the MSL elevation (OBS_{MSL}) of an obstacle is reduced to account for EC. This reduced value is termed the obstacle effective MSL elevation (O_{EE}). Calculate O_{EE} using calculator 4-5.

Calculator 4-5. EC Adjusted Obstacle MSL Elevation

$$O_{EE} = OBS_{MSL} - \left((r + LTP_{elev}) \times \left(\frac{1}{\cos\left(\frac{OBS_Y}{r}\right)} - 1\right) + Q\right)$$

where
OBS_{MSL} = obstacle MSL elevation
OBS_Y = perpendicular distance (ft) from course centerline to obstacle
Q = adjustment for "X" or "Y" surface rise (0 if in W Surface). See calculator 4-7

Calculator 4 5		
LTP_{elev}		Calculate
Q		
OBS_{MSL}		
OBS_Y		Clear
O_{EE}		

4.2.3 W OCS Evaluation.

Compare the obstacle O_{EE} to W_{MSL} at the obstacle location. Lowest minimums are achieved when the W surface is clear. To eliminate or avoid a penetration, take one or more of the following actions listed in the order of preference.

4.2.3 a. **Remove or adjust the obstruction location and/or height.**

4.2.3 b. **Displace the RWT.**

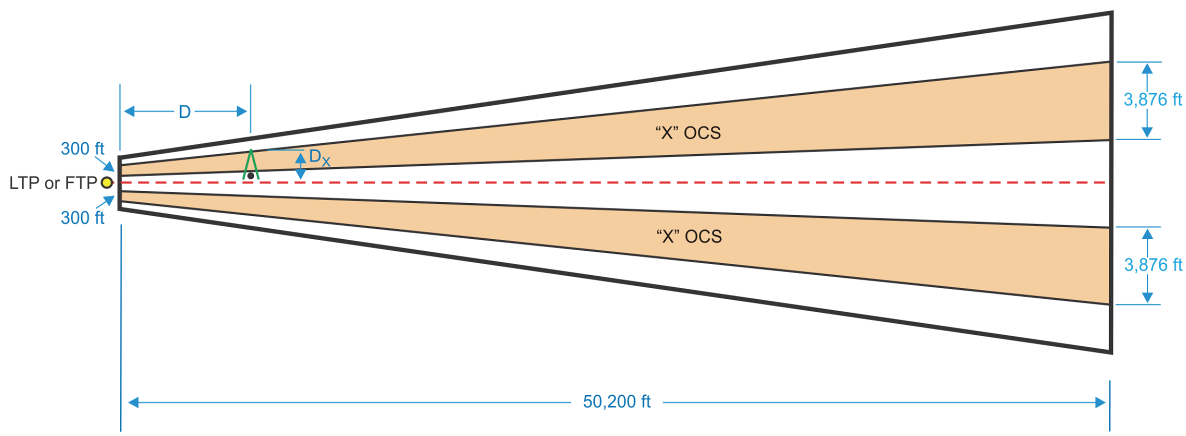
4.2.3 c. **Raise the GPA** (see paragraph 4.6) within the limits of table 1-5.

4.2.3 d. **Adjust DA** (for existing obstacles only) see paragraph 4.5.2.

4.2.3 e. **Raise TCH** (see paragraph 4.7).

4.3 **X OCS** (see figure 4-5).

Figure 4-5. X OCS



4.3.1 Width.

The perpendicular distance from the course centerline to the outer boundary of the X OCS is 700 ft at the origin and expands uniformly to 6076 ft at a point 50200 ft from LTP/FTP. Calculate the perpendicular distance ($X_{boundary}$) from the course centerline to the X surface boundary using calculator 4-6.

Calculator 4-6. Perpendicular Dist to X Boundary

$$X_{boundary} = 0.10752 \times OBS_X + 678.496$$

where
OBS_X = obstacle along-track distance (ft) from LTP/FTP

Calculator 4 6		
OBS_X		Calculate
$X_{boundary}$		Clear

Note: Where the intermediate segment is NOT aligned with the FAC, take into account the expansion of the final segment based on the intermediate segment taper.

4.3.2 X Surface Obstacle Elevation Adjustment (Q).

The X OCS begins at the height of the W surface and rises at a slope of 4:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the X surface is adjusted (reduced) by the amount of surface rise. Use calculator 4-7 to determine the obstacle height adjustment (Q) for use in calculator 4-5. Evaluate the obstacle under paragraphs 4.2.2 and 4.2.3.

Calculator 4-7. X OCS Obstacle Height Adjustment

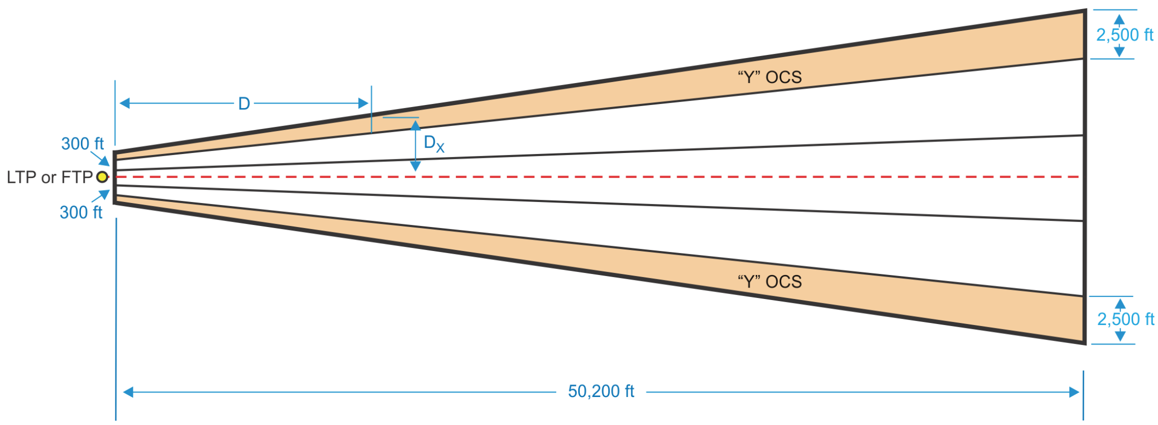
$$Q = \frac{OBS_Y - W_{boundary}}{4}$$

where
OBS_Y = perpendicular distance (ft) from course centerline to obstacle
$W_{boundary}$ = half-width of W surface abeam obstacle (calculator 4-3)

Calculator 4 7		
OBS_Y		Calculate
$W_{boundary}$		
Q		Clear

4.4 Y OCS (see figure 4-6).

Figure 4-6. Y Surface



4.4.1 Width.

The perpendicular distance from the course centerline to the outer boundary of the Y OCS is 1000 ft at the origin and expands uniformly to 8576 ft at a point 50200 ft from LTP/FTP. Calculate the perpendicular distance ($Y_{boundary}$) from the course centerline to the Y surface boundary using calculator 4-8.

Calculator 4-8. Perpendicular Distance to Y Boundary

$$Y_{boundary} = 0.15152 \times OBS_X + 969.696$$

where OBS_X = obstacle along-track distance (ft) from LTP/FTP

Calculator 4 8		
OBS_X		Calculate
$Y_{boundary}$		Clear

Note: Take into account the expansion of the final segment based on the intermediate segment taper.

4.4.2 Y Surface Obstacle Elevation Adjustment (Q).

The Y OCS begins at the height of the X surface and rises at a slope of 7:1 in a direction perpendicular to the final approach course. The MSL elevation of an obstacle in the Y surface is adjusted (reduced) by the amount of X and Y surface rise. Use calculator 4-9 to determine the obstacle height adjustment (Q) for use in calculator 4-5. Evaluate the obstacle under paragraphs 4.2.2 and 4.2.3.

Calculator 4-9. Y OCS Obstacle Height Adjustment

$$Q = \frac{X_{boundary} - W_{boundary}}{4} + \frac{OBS_Y - X_{boundary}}{7}$$

where

$W_{boundary}$ = perpendicular distance (ft) from course centerline to the W surface boundary

$X_{boundary}$ = perpendicular distance (ft) from course centerline to the X surface outer boundary

OBS_Y = perpendicular distance (ft) from course centerline to the obstacle in the Y surface

Calculator 4 9		
$X_{boundary}$		Calculate
$W_{boundary}$		
OBS_Y		Clear
Q		

4.5 HATh and DA.

The DA value may be derived from the HATh. Where the OCS is clear, the minimum HATh for LPV operations is the greater of 200 ft or the limitations noted on table 1-4. If the OCS is penetrated, minimum HATh is 250. Round the DA result to the next higher whole foot.

4.5.1 DA Calculation (Clear OCS).

Calculate the DA using calculator 4-10.

Calculator 4-10. DA Calculation

$$DA = \textbf{ceiling}\left[HATh + LTP_{elev}\right]$$

Calculator 4 10		
$HATh$		Calculate
LTP_{elev}		
DA		Clear

Calculate the along-course distance in feet from DA to LTP/FTP (X_{DA}) using calculator 4-11.

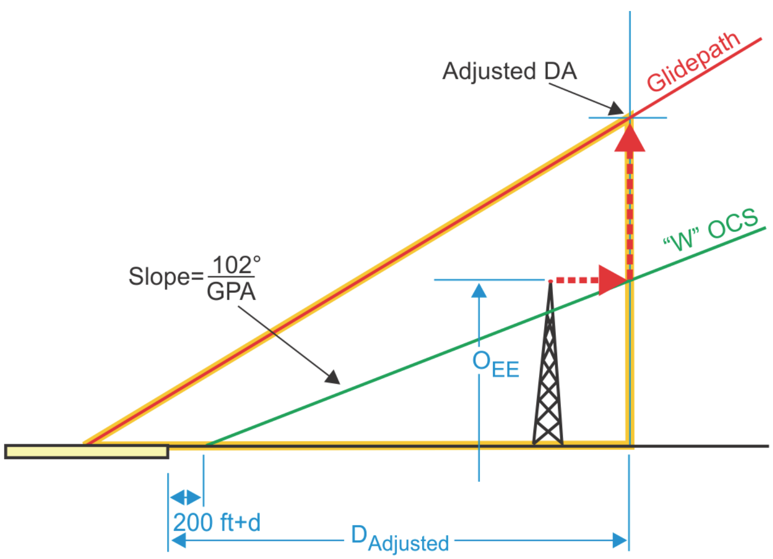
Calculator 4-11. Distance LTP to DA

$$X_{DA} = r \times \left(\frac{\pi}{2} - \theta° \times \frac{\pi}{180°} - \text{asin}\left(\frac{\cos\left(\theta° \times \frac{\pi}{180°}\right) \times (r + LTP_{elev} + TCH)}{r + DA} \right) \right)$$

Calculator 4 11		
LTP_{elev}		Calculate
TCH		
$\theta°$		
DA		Clear
X_{DA}		

4.5.2 **DA Calculation** (OCS Penetration), see figure 4-7**.**

Figure 4-7. DA Adjustment



Calculate the adjusted DA for an obstacle penetration of the OCS using calculator 4-12.

Calculator 4-12. Adjusted DA

(1) $$D_{adjusted} = r \times \left(\frac{\pi}{2} - \text{atan}\left(\frac{\theta°}{102°}\right) - \text{asin}\left(\frac{\cos\left(\text{atan}\left(\frac{\theta°}{102°}\right)\right) \times \left(r + LTP_{elev} - \frac{\theta° \times (200 + d)}{102°}\right)}{r + O_{EE}} \right) \right)$$

(2) $$DA_{adjusted} = \frac{(r + LTP_{elev} + TCH) \times \cos\left(\theta° \times \frac{\pi}{180°}\right)}{\cos\left(\frac{D_{adjusted}}{r} + \theta° \times \frac{\pi}{180°}\right)} - r$$

where
d = value from paragraph 4.1.3
O_{EE} = from calculator 4-5

Calculator 4 12		
LTP_{elev}		Calculate
TCH		
$\theta°$		
d		Clear
O_{EE}		
$DA_{adjusted}$		

4.6 Revising GPA for OCS Penetrations.

Raising the GPA may eliminate OCS penetrations. To determine the revised minimum GPA, use calculator 4-13.

Calculator 4-13. GPA Adjustment

$$(1)\quad SRD=\sqrt{(r+O_{EE})^2+(r+LTP_{elev})^2-2\times(r+O_{EE})\times(r+LTP_{elev})\times\cos\left(\frac{OBS_X-(200+d)}{r}\right)}$$

$$(2)\quad RS=\frac{1}{\tan\left(\operatorname{acos}\left(\frac{SRD^2+(r+LTP_{elev})^2-(r+O_{EE})^2}{2\times SRD\times(r+LTP_{elev})}\right)-\frac{\pi}{2}\right)}$$

$$(3)\quad \theta^\circ_{required}=\frac{102^\circ}{RS}$$

where

O_{EE} = *value from calculator 4-5*
OBS_X = *along-track distance (ft) from LTP to penetrating obstacle*
d = *value from paragraph 4.1.3*

Calculator 4 13		
LTP_{elev}		Calculate
d		
O_{EE}		
OBS_X		Clear
$\theta^\circ_{required}$		

4.7 Adjusting TCH to Reduce/Eliminate OCS Penetrations.

This paragraph is applicable <u>ONLY</u> where d from paragraph 4.1.3, calculator 4-2, is greater than zero. Adjusting TCH is the equivalent to relocating the glide slope antenna in ILS criteria. The goal is to move the OCS origin toward the LTP/FTP (no closer than 200 ft) sufficiently to raise the OCS at the obstacle location. To determine the maximum W surface vertical relief (Z) that can be achieved by adjusting TCH, apply calculator 4-14. If the value of Z is greater than the penetration (p), you may determine the amount to increase TCH by applying calculator 4-15. If this option is selected, re-evaluate the final segment using the revised TCH value.

Calculator 4-14. Vertical Relief

$$Z = \frac{d \times \theta^\circ}{102^\circ}$$

where d = "d" from paragraph 4.1.3, calculator 4-2

Calculator 4 14		
θ°		Calculate
d		
Z		Clear

Calculator 4-15. TCH Adjustment

$$TCH_{adjustment} = \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times \frac{102^\circ \times p}{\theta^\circ}$$

where p = penetration (ft) [$p \leq Z$]

Calculator 4 15		
θ°		Calculate
p		
$TCH_{adjustment}$		Clear

4.8 Missed Approach Section 1 (Height Loss and Initial Climb).

Section 1 begins at DA (CD line) and ends at the AB line. It accommodates height loss and establishment of missed approach climb gradient. Obstacle protection is based on an assumed minimum climb gradient of 200 ft/NM (≈30.38:1 slope). Section 1 is centered on a continuation of the final approach track and is subdivided into sections 1a and 1b (see figures 4-8A and 4-8B).

Figure 4-8A. Section 1 3D Perspective

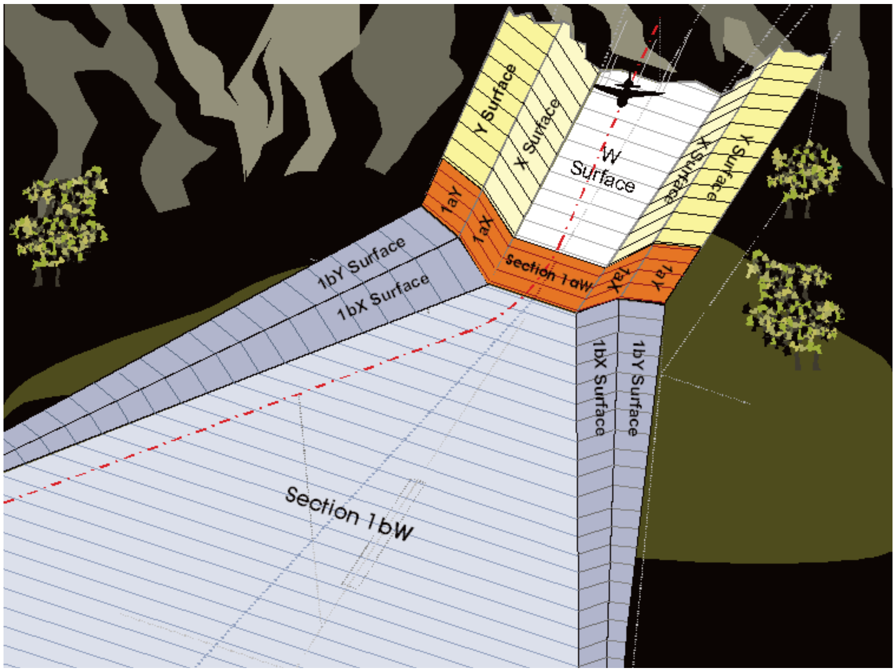
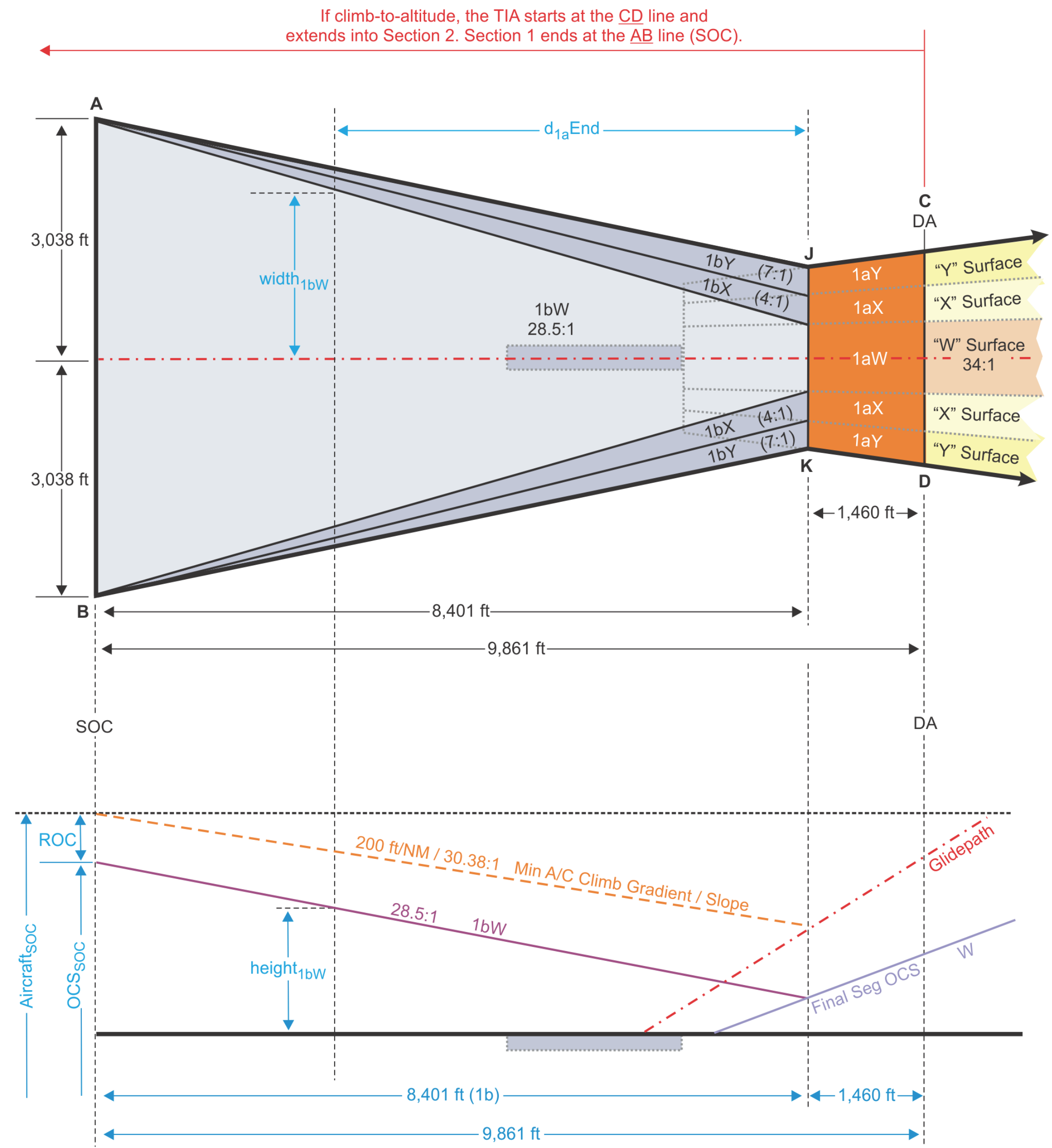


Figure 4-8B. Section 1 (a/b) 2D Perspective



4.8.1 Section 1a.

Section 1a is a `1460` ft continuation of the `FAS OCS` beginning at the `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` surfaces are identified as section 1aX. The portions consisting of the continuation of the **`Y`** surfaces are identified as section 1aY. Calculate the width and elevation of the section 1aW, 1aX, and 1aY surfaces at any distance from **`LTP`** using the final segment calculators.

4.8.2 **Section 1b.**

The section 1b surface extends from the JK line at the end of section 1a as an up-sloping surface for a distance of 8401 ft to the AB line. Section 1b is subdivided into sections 1bW, 1bX, and 1bY (see figure 4-8B).

4.8.2 **a. Section 1bW.** Section 1bW extends from the end of section 1aW for a distance of 8401 ft. Its lateral boundaries splay from the width of the end of the 1aW surface to a width of ± 3038 ft either side of the missed approach course at the ,401 ft point. Calculate the width of the 1bW surface ($width_{1bW}$) at any distance d_{1aEnd} from the end of section 1a using calculator 4-16.

Calculator 4-16. Section 1bW Boundary Perpendicular Distance

$$width_{1bW} = \frac{d_{1aEnd} \times (3038 - C_W)}{8401} + C_W$$

where

d_{1aEnd} = *along-track distance (ft) from end of section 1a*

C_W = *half-width of 1aW surface at section 1a end*

Calculator 4 16		
d_{1aEnd}		Calculate
C_W		
$width_{1bW}$		Clear

Calculate the elevation of the end of the 1aW surface ($elev_{1aEnd}$) using calculator 4-17.

Calculator 4-17. W OCS End Elevation

$$elev_{1aEnd} = \frac{(r + LTP_{elev}) \times \cos\left(\operatorname{atan}\left(\frac{\theta°}{102°}\right)\right)}{\cos\left(\frac{X_{DA} - d - 1660}{r} + \operatorname{atan}\left(\frac{\theta°}{102°}\right)\right)} - r$$

where

X_{DA} = along-track distance (ft) from LTP to DA
d = value from paragraph 4.1.3

Calculator 4 17		
LTP_{elev}		Calculate
$\theta°$		
d		
X_{DA}		Clear
$elev_{1aEnd}$		

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 elevation of the surface ($elev_{1bW}$) using calculator 4-18.

Calculator 4-18. Section 1bW OCS Elevation

$$elev_{1bW} = (r + elev_{1aEnd}) \times e^{\left(\frac{d1_{aEnd}}{28.5 \times r}\right)} - r$$

where

$d1_{aEnd}$ = along-track distance (ft) from end of section 1a

Calculator 4 18		
$elev_{1aEnd}$		Calculate
d_{1aEnd}		
$elev_{1bW}$		Clear

4.8.2 **b. Section 1bX.** Section 1bX extends from the end of section 1aX for a distance of 8401 ft. 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 ft either side of the missed approach course at the 8401 ft point. Calculate the distance from the missed approach course centerline to the surface outer boundary ($width_{1bX}$) using calculator 4-19.

Calculator 4-19. Section 1bX Boundary Perpendicular Distance

$$width_{1bX} = \frac{d_{1aEnd} \times (3038 - C_X)}{8401} + C_X$$

where

d_{1aEnd} = along-track distance (ft) from end of section 1a
C_X = perpendicular distance (ft) from course centerline to 1aX outer edge at section 1a end

Calculator 4 19		
d_{1aEnd}		Calculate
C_X		
$width_{1bX}$		Clear

The surface rises at a slope ratio of 4:1 perpendicular to the missed approach course from the edge of the 1bW surface. Calculate the elevation of the 1bX missed approach surface ($elev_{1bX}$) using calculator 4-20.

Calculator 4-20. Section 1bX OCS Elevation

$$elev_{1bX} = elev_{1bW} + \frac{a - width_{1bW}}{4}$$

where

a = perpendicular distance (ft) from the MA course

Calculator 4 20		
$elev_{1bW}$		Calculate
a		
$width_{1bW}$		Clear
$elev_{1bX}$		

4.8.2 **c. Section 1bY.** Section 1bY extends from the end of section 1aY for a distance of 8401 ft. 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 ft either side of the missed approach course at the 8401 ft point. Calculate the distance from the missed approach course centerline to the surface outer boundary ($width_{1bY}$) using calculator 4-21.

Calculator 4-21. Section 1bY Boundary Perpendicular Distance

$$width_{1bY} = \frac{d_{1aEnd} \times (3038 - C_Y)}{8401} + C_Y$$

where
d_{1aEnd} = along-track distance (ft) from end of section 1a
C_Y = perpendicular distance (ft) from course centerline to 1aY outer edge at section 1a end

Calculator 4 21		
d_{1aEnd}		Calculate
C_Y		
$width_{1bY}$		Clear

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 elevation of the 1bY missed approach surface ($elev_{1bY}$) using calculator 4-22.

Calculator 4-22. Section 1bY OCS Elevation

$$elev_{1bY} = elev_{1bX} + \frac{a - width_{1bX}}{7}$$

where
a = perpendicular distance (ft) from the MA course

Calculator 4 22		
$elev_{1bX}$		Calculate
a		
$width_{1bX}$		Clear
$elev_{1bY}$		

4.9 Surface Height Evaluation.

4.9.1 Section 1a.

Obstacles that penetrate these surfaces are mitigated during the final segment OCS evaluation. However in the missed approach segment, penetrations are not allowed; therefore, penetrations must be mitigated by:

- Raising TCH (if GPI is less than 954 ft).
- Removing or reducing obstruction height.
- Raising glidepath angle.
- Adjusting DA (for existing obstacles).

4.9.2 DA Adjustment for a Penetration of Section 1b Surface.

The DA is adjusted (raised and consequently moved further away from LTP) by the amount necessary to raise the 1b surface above the penetration. For a 1b surface penetration of p ft, the DA point must move ΔX_{DA} feet farther from the LTP as determined by calculator 4-23.

Calculator 4-23. Along-track DA adjustment

$$\Delta X_{DA} = \frac{2907 \times p}{28.5 \times \theta° + 102°}$$

where

p = amount of penetration (ft)

Calculator 4 23		
$\theta°$		Calculate
p		
ΔX_{DA}		Clear

This increase in the DA to LTP distance raises the DA (and HATh). Calculate the adjusted DA ($DA_{adjusted}$) using calculator 4-24. Round up the result to the next 1-ft increment.

Calculator 4-24. Adjusted DA

$$DA_{adjusted} = \textbf{ceiling}\left[\textbf{tan}\left(\theta° \times \frac{\pi}{180°}\right) \times \left(X_{DA} + \Delta X_{DA}\right) + LTP_{elev} + TCH\right]$$

where

ΔX_{DA} = *from calculator 4-23*

X_{DA} = *from calculator 4-11*

Calculator 4 24		
LTP_{elev}		Calculate
TCH		
$\theta°$		
X_{DA}		Clear
ΔX_{DA}		
$DA_{adjusted}$		

4.9.3 End of Section 1 Values.

Calculate the assumed MSL altitude of an aircraft on missed approach, the OCS MSL elevation, and the ROC at the end of section 1 (AB line) using calculator 4-25. The end of section 1 (AB line) is considered SOC.

Calculator 4-25. Section 1 End (SOC) Values

$$(1)\quad Aircraft_{SOC} = DA - \tan\left(\theta° \times \frac{\pi}{180°}\right) \times 1460 + 276.525$$

$$(2)\quad OCS_{SOC} = \left(r + elev_{1aEnd}\right)e^{\left(\frac{8401}{28.5 \times r}\right)} - r$$

$$(3)\quad ROC_{SOC} = Aircraft_{SOC} - OCS_{SOC}$$

where

DA = published decision altitude (MSL)

$elev_{1aEnd}$ = value from calculator 4-17

d = value from paragraph 4.1.3

Calculator 4 25		
DA		Calculate
$\theta°$		
$elev_{1aEnd}$		
$Aircraft_{SOC}$		Clear
OCS_{SOC}		
ROC_{SOC}		

Volume 6. United States Standard for Area Navigation (RNAV)

Chapter 5. Missed Approach Section 2

5.0 General.

5.0 a. Word Usage.

- **Nominal** refers to the designed/standard value, whether course/track or altitude, etc.
- **Altitude** refers to elevation (MSL).
- **Height** refers to the vertical distance from a specified reference (geoid, ellipsoid, runway threshold, etc.).

5.0 b. These criteria cover two basic MA constructions:

- Straight missed approach.
- Turning missed approach.

Note: These two construction methods accommodate the traditional combination of straight and turning missed approaches.

Refer to individual chapters for MA section 1 information. The section 2 OEA begins at the end of section 1 (AB line), and splays at 15 degrees relative to the nominal track to reach full width (1-2-2-1 within 30 NM), see figure 5-1. See paragraph 1.1 for segment width and expansion guidance. The section 2 standard OCS slope begins at the AB line (see paragraph 1.17 and calculator 1-20 for information and to calculate the OCS values).

Note: All references to 'standard OCS slope' and use of '40:1' or the '40:1 ratio' refer to the output of calculator 1-21 with an input CG of 200 ft/NM.

Where a higher CG than the standard OCS slope is required, apply the CG and its associated OCS from SOC (see chapter 4 for the section 1 OCS exception). Apply secondary areas as specified in this chapter. Measure the 12:1 secondary OCS perpendicular to the nominal track. In expansion areas, the slope rises in a direction perpendicular from the primary boundary (arc, diagonal corner-cutter, etc.), except where obstacles cannot be measured perpendicularly to a boundary, then measure to the closest primary boundary (see figures 5-1 through 5-16). Multiple higher than standard CGs require Flight Standards approval.

5.1 Straight MA.

The straight MA course is a continuation of the FAC. The straight MA section 2 OEA begins at the end of section 1, (the AB line) and splays at 15 degrees relative to the nominal track until reaching full primary and secondary width (1-2-2-1 within 30 NM). Apply the section 2 standard OCS (calculated for automation), or the OCS associated with a higher CG, beginning at the AB line from the section 1 end OCS elevation. Revert to the calculated standard OCS when the increased CG is no longer required. To determine primary OCS elevation at an obstacle, measure the along-track distance from the AB line to a point at/abeam the obstacle. Where the obstacle is located in the secondary area, apply the primary OCS slope to a point abeam the obstacle, then apply the 12:1 secondary slope (perpendicular to the track), from the primary boundary to the obstacle (see figure 5-1).

5.2 Turning MA (First Turn).

See March 1, 2013 Clarification Memo

Apply turning criteria when requiring a turn at or beyond SOC. Where secondary areas exist in section 1, they continue, (splaying if necessary to reach full width) into section 2, including non-turn side secondary areas into the first-turn wind spiral and outside arc construction (see figures 5-2 and 5-4 through 5-13). Terminate turn-at-fix turn-side secondary areas not later than the early turn point. Do not apply turn-side secondary areas for turn-at-altitude construction.

There are two types of turn construction for the first MA turn:

- Turn at an altitude (see paragraph 5.2.1).
  - Always followed by a DF leg ending with a DF-TF connection or holding pattern entry.

- Turn at a fix (see paragraph 5.2.2).
  - Followed by a TF leg ending with holding pattern entry, TF-TF connection, (or TF-RF, which requires advanced avionics) when the initial straight leg is less than full width.
  - May be followed by an RF leg (which requires advanced avionics) when the initial straight leg has reached full width, ending with an RF-TF or RF-RF connection.

Following a turn, the minimum segment length (except DF legs) must be the greater of:

- The minimum length calculated using the chapter 1 calculators 1-5 and 1-7; or,

- The distance from previous fix to the intersection of the 30 degrees converging outer boundary line extension and the nominal track, plus the greater of the segment end fix DTA or ATT.

Minimum DF leg length is the greater of:

- The length that is needed to accommodate rr distance value from calculator 1-4 based on the KTAS expected to use the procedure, applied between the WS direct-to-fix-line tangent point, and the earliest maneuvering point (early turn point) for the DF-TF fix. Convert to TAS using the TIA turn altitude plus the altitude gained at 250 ft/NM (CAT A/B), or 500 ft/NM (CAT C/D) from the TIA end center point to the DF fix.

- Results of calculator 1-10.

5.2.1 Turn-At-An-Altitude.

Apply turn-at-an-altitude construction unless the first missed approach turn is at a fix. Since pilots may commence a missed approach at altitudes higher than the DA/MDA and aircraft climb rates differ, turn-at-an-altitude construction protects the large area where turn initiation is expected. This construction also provides protection for 'turn as soon as practicable' and combination straight and tuning operations.

When a required aircraft turning altitude exceeds the minimum turning altitude (typically 400 ft above the airport), specify the turning altitude.

5.2.1 a. Turn Initiation Area (TIA).

Construct the TIA as a straight MA to the climb-to altitude, beginning from the earliest MA turn point (CD line) and ending where the specified minimum turning altitude (STEP 1) is reached (AB or LL' line, as appropriate). Base the TIA length on the climb distance required to reach the turning altitude (see appropriate STEP 2 below). The TIA minimum length must place the aircraft at an altitude from which obstacle clearance is provided in section 2 outside of the TIA. The TIA boundary varies with length, the shortest B-A-C-D, occurs where AB overlies JK. Where the TIA is contained within section 1, B-A-J-C-D-K defines the boundary. Where the required turn altitude exceeds that supported by section 1, the TIA extends into section 2, (see figure 5-2) and points L'-L-A-J-C-D-K-B define its boundary. In this case, L-L' is the early turn point based on the aircraft climbing at the prescribed CG. Calculate TIA length using calculators 5-2a1 through 5-2c2 as appropriate.

Note: Points E and F may not be used or may be overridden by the JK line.

STEP 1: Turn altitude. The turn altitude is either operationally specified (must be at or above altitude required by obstacles) or determined by obstacle evaluation. Evaluate the nominal standard OCS slope (40:1). If the OCS is penetrated, mitigate the penetration with one or a combination of the following:

a. Raise DA/MDA.
b. Establish a climb gradient that clears the obstacle.
c. Move MAP.
d. If penetration is outside TIA, consider raising the climb-to altitude.

5.2.1 a. (1) Determine the aircraft required minimum turning altitude based on obstacle evaluation:

- Identify the most significant obstacle in section 2 (straight MA).
  - For straight OCS/CG/length options.
- Identify the most significant/controlling obstacle outside the TIA, (typically turn-side).
- Find the shortest distance from the TIA lateral boundary to the obstacle.
- Apply this distance and the standard OCS slope, (or higher CG associated slope) to find the TIA-to-obstacle OCS rise.
- The minimum TIA OCS boundary elevation, (and OCS end elevation) equals the obstacle elevation minus OCS rise.
- The minimum turn altitude is the sum of TIA OCS boundary elevation and:
  - 100 ft for non-vertically guided procedures, or
  - The table 3-2 ROC value for vertically guided procedures, rounded to the next higher 100-ft increment.

Note 1: TIA lateral boundary is the straight segment (portion) lateral boundary until the required minimum turn altitude and TIA length are established.

Note 2: Repeat **STEP 1** until acceptable results are obtained.

The specified turn altitude must equal or exceed the section 1 end aircraft altitude. Apply calculator 4-25 to find LPV section 1 end altitude ($Aircraft_{SOC}$), and section 1 OCS end elevation (OCS_{SOC}). Find non-LPV section 1 end altitude using calculator 5-1.

Calculator 5-1. Section 1 End Aircraft Altitude (Non-LPV)

$$Aircraft_{SOC} = (r + MDA\ or\ DA) \times e^{\frac{AB_{NM} \times CG}{r}} - r$$

where
AB_{NM} = SOC to AB distance (NM)
CG = applied climb gradient (ft/NM)

Calculator 5 1		
MDA or DA		Calculate
SOC to AB distance NM		
CG		Clear
$Aircraft_{SOC}$		

The section 2 standard OCS slope, [or the higher slope associated with the prescribed climb (CG)] begins at the AB line OCS elevation (see figures 5-2 through 5-7). See appropriate final chapters for the variable values associated with each final type.

STEP 2 (LPV): Calculate LPV TIA length using calculator 5-2a1/5-2a2 (see paragraph 4.8 for further section 1 details). Apply TIA calculated lengths from the CD line.

Where an increased CG terminates prior to the TIA turn altitude, apply calculator 5-2a1, otherwise apply calculator 5-2a2.

Calculator 5-2a1. TIA Length Multi-CG (LPV)

$$TIA_{Length} = 9861 + \frac{r}{CG1} \times fpnm \times \ln\left(\frac{r + CG1_{termalt}}{r + Aircraft_{SOC}}\right) + \frac{r}{CG2} \times fpnm \times \ln\left(\frac{r + turn_{alt}}{r + CG1_{termalt}}\right)$$

where
$CG1_{termalt}$ = Initial CG termination altitude
$turn_{alt}$ = required turn altitude
$Aircraft_{SOC}$ = SOC Aircraft Altitude (calculator 4-25)
$CG1$ = Initial Climb Gradient ($\geq$ Standard 200 ft/NM)
$CG2$ = Second Climb Gradient (Standard 200 ft/NM)

Calculator 5 2a1		
$turn_{alt}$		Calculate
$Aircraft_{SOC}$		
$CG1_{termalt}$		
CG1 (ft/NM)		Clear
CG2 (ft/NM)		
TIA_{Length} (ft)		

Calculator 5-2a2. TIA Length Single-CG (LPV)

$$TIA_{Length} = 9861 + \frac{r}{CG} \times fpnm \times \ln\left(\frac{r + turn_{alt}}{r + Aircraft_{SOC}}\right)$$

where
$turn_{alt}$ = required turn altitude
$Aircraft_{SOC}$ = SOC Aircraft Altitude (calculator 4-25)
CG = Climb Gradient (Standard 200 ft/NM)

Calculator 5 2a2		
$turn_{alt}$		Calculate
$Aircraft_{SOC}$		
CG		Clear
TIA_{Length} (ft)		

STEP 2 (LNAV/LP): Calculate LNAV and LP TIA length using the appropriate FSL value (see paragraph 2.7 for further section 1 details). Where an increased CG terminates prior to the TIA turn altitude, apply calculator 5-2b1, otherwise apply calculator 5-2b2.

Calculator 5-2b1. TIA Length Multi-CG (LNAV/LP)

$$TIA_{Length} = FSL \times \frac{r}{(r + MDA)} + \frac{r}{CG1} \times fpnm \times \ln\left(\frac{r + CG1_{termalt}}{r + MDA}\right) + \frac{r}{CG2} \times fpnm \times \ln\left(\frac{r + turn_{alt}}{r + CG1_{termalt}}\right)$$

where
$CG1_{termalt}$ = Initial CG termination altitude
MDA = Aircraft Final MDA
CG1 = Initial Climb Gradient ($\geq$ Standard 200 ft/NM)
CG2 = Second Climb Gradient (Standard 200 ft/NM)

Calculator 5 2b1		
FSL(ft)		Calculate
$turn_{alt}$		
MDA		
$CG1_{termalt}$		
CG1 (ft/NM)		Clear
CG2 (ft/NM)		
TIA_{Length} (ft)		

Calculator 5-2b2. TIA Length Single-CG (LNAV/LP)

$$TIA_{Length} = FSL \times \frac{r}{(r+MDA)} + \frac{r}{CG} \times fpnm \times \ln\left(\frac{r+turn_{alt}}{r+MDA}\right)$$

where

$turn_{alt}$ = required turn altitude
DA = Final DA
CG = Climb Gradient (Standard 200 ft/NM)

Calculator 5 2b2		
FSL(ft)		Calculate
$turn_{alt}$		
MDA		
CG		Clear
TIA_{Length} (ft)		

STEP 2 (LNAV/VNAV): Calculate LNAV/VNAV TIA length using calculator 5-2c1 (see paragraph 3.4 for further section 1 details). Where an increased CG terminates prior to the TIA turn altitude, apply calculator 5-2c1, otherwise apply calculator 5-2c2.

Calculator 5-2c1. TIA Length Multi-CG (LNAV/VNAV)

$$TIA_{Length} = FSL \times \frac{r}{(r+DA)} + \frac{r}{CG1} \times fpnm \times \ln\left(\frac{r+CG1_{termalt}}{r+DA}\right) + \frac{r}{CG2} \times fpnm \times \ln\left(\frac{r+turn_{alt}}{r+CG1_{termalt}}\right)$$

where

$CG1_{termalt}$ = Initial CG termination altitude
DA = Aircraft Final DA
CG1 = Initial Climb Gradient ($\geq$ Standard 200 ft/NM)
CG2 = Second Climb Gradient (Standard 200 ft/NM)

Calculator 5 2c1		
FSL (ft)		Calculate
$turn_{alt}$		
DA		
$CG1_{termalt}$		
CG1 (ft/NM)		Clear
CG2 (ft/NM)		
TIA_{Length} (ft)		

Calculator 5-2c2. TIA Length Single-CG (LNAV/VNAV)

$$TIA_{Length} = FSL \times \frac{r}{(r+DA)} + \frac{r}{CG} \times fpnm \times \ln\left(\frac{r+turn_{alt}}{r+DA}\right)$$

where

$turn_{alt}$ = required turn altitude

DA = Final DA

CG = Climb Gradient (Standard 200 ft/NM)

Calculator 5 2c2		
FSL (ft)		Calculate
$turn_{alt}$		
DA		
CG		Clear
TIA_{Length} (ft)		

STEP 3: Locate the TIA end at a TIA distance length beyond CD (from STEP 2) (LL'), see figure 5-2.

5.2.1 b. OEA Construction after TIA.

The OEA includes areas to protect the earliest and latest direct tracks from the TIA to the fix. Construct the obstacle areas about each of the tracks as described below. See figures 5-2 through 5-9 for various turn geometry construction illustrations.

5.2.1 b. (1) Early-Turn Track and OEA Construction.

Where the early track from the FAC/CD intersection defines a turn less than or equal to 75 degrees relative to the FAC, the tie-back point is point C (see figure 5-3); if the early track defines a turn greater than 75 degrees relative to the FAC, the tie-back point is point D (see figure 5-4). Where the early track represents a turn greater than 165 degrees, begin the early turn track and the 15-degree splay from the non-turn side TIA end + rr (calculator 1-4) (PP'), see figure 5-5.

STEP 1: Construct a line (representing the earliest-turn flight track) from the tie-back point, to the fix (see figure 5-2).

STEP 2: Construct the outer primary and secondary OEA boundary lines parallel to this line (1-2-2-1 segment width) (see figure 5-2).

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 (see figure 5-2 and 5-3).

Apply secondary areas only after the 15-degree splay line intersects the primary boundary line.

5.2.1 b. (2) Late-Turn Track and OEA Construction.

Apply WS for late-turn outer boundary construction using the following calculations, construction techniques, and 15-degree bank angles. Calculate WS construction parameters for the appropriate aircraft category.

<u>STEP 1</u>: Find the no-wind R using calculator 5-3a.

Note: Apply the category's indicated airspeed from table 1-3 and the minimum assigned turn altitude when converting to true airspeed for this application.

Calculator 5-3a. No Wind R

$$R = \frac{(V_{KTAS} + 0)^2}{\tan\left(15^\circ \times \frac{\pi}{180^\circ}\right) \times 68625.4}$$

Calculator 5 3a		
V_{KTAS}		Calculate
R		Clear

<u>STEP 2</u>: Calculate the Turn Rate (TR) using calculator 5-3b. Maximum TR is 3 degrees per second. Apply the lower of 3 degrees per second or calculator 5-3b output.

Calculator 5-3b. TR

$$TR = \min\left[3, \frac{3431 \times \tan\left(15^\circ \times \frac{\pi}{180^\circ}\right)}{\pi \times V_{KTAS}}\right]$$

Calculator 5 3b		
V_{KTAS}		Calculate
TR		Clear

<u>STEP 2a</u>: Calculate the Turn Magnitude (TMAG) using the appropriate no-wind turn radius and the arc distance (in degrees) from start of turn (at <u>PP'</u>) to the point of tangency with a line direct to the fix.

STEP 2b: Calculate the highest altitude under paragraph 1.2. Determine altitude at subsequent fixes using fix-to-fix direct measurement and 500 ft/NM climb rate.

STEP 3: Find the omni-directional wind component (V_{KTW}) for the highest altitude in the turn using calculator 1-3b.

STEP 4: Apply this common wind value (**STEP 3**) to all first-turn wind spirals.

STEP 5: Calculate the wind spiral radius increase (ΔR) (relative R), for a given turn magnitude (β) using calculator 5-4.

Calculator 5-4. WS ΔR

$$\Delta R = \frac{V_{KTW} \times \beta^\circ}{3600 \times TR}$$

where

β = *Degrees of turn*
TR = *Calculator 5-3b (Max 3 degrees/second)*
V_{KTW} = *Calculator 1-3b Wind Speed*

Calculator 5 4		
V_{KTW}		Calculate
β °		
TR		
ΔR (NM)		Clear
ΔR (ft)		

Note: See ΔR examples in figures 5-2 to 5-5.

STEP 6: WS Construction (see paragraph 5.4).

5.2.2 Turn-At-A-Fix.

The first MA turn-at-a-fix may be a FB or FO fix. Use FB unless a FO is required for obstacle avoidance or where mandated by specific operational requirements. The turn fix early-turn-point must be at or beyond section 1 end.

5.2.2 a. Early/Late Turn Points.

The FB fix early-turn-point is located at (FIX-ATT-DTA) prior to the fix.

The FB fix late-turn-point is located at a distance (FIX + ATT – DTA + rr) from the fix.

The FO early-turn-point is located at a distance (FIX - ATT) prior to the fix.

The FO late-turn-point is located at a distance (FIX + ATT + rr) beyond the fix.

FB fixes (see figure 5-10).

$$Early_{TP} = Fix - ATT - DTA$$
$$Late_{TP} = Fix + ATT - DTA + rr$$

FO fixes (see figure 5-10).

$$Early_{TP} = Fix - ATT$$

$$Late_{TP} = Fix + ATT + rr$$

5.2.2 **b. Turn-at-a-Fix (First MA turn) Construction.**

The recommended maximum turn is 70 degrees; the absolute maximum is 90 degrees. The first turn fix must be located on the final approach track extended.

STEP 1: Calculate aircraft altitude at the AB line using calculator 5-1.

STEP 2: Calculate fix distance based on minimum fix altitude. Where the first fix must be located at the point the aircraft reaches or exceeds a specific altitude, apply calculator 5-5 (using the assigned/applied CG), to calculate fix distance (D_{fix}) (NM) from the AB line.

Calculator 5-5. Fix Distance (D_{fix})

$$D_{fix} = \ln\left(\frac{Alt_{fix} + r}{Aircraft_{SOC} + r}\right) \times \frac{r}{CG}$$

where

Alt_{fix} = Minimum altitude required at fix

$Aircraft_{SOC}$ = Aircraft AB line (SOC) altitude

CG = Climb Gradient (Standard 200 ft/NM)

Calculator 5 5		
Alt_{fix}		Calculate
$Aircraft_{SOC}$		
CG		Clear
D_{fix} (NM)		

STEP 3: Calculate the altitude an aircraft would achieve climbing at the assigned CG would achieve over an established fix using calculator 5-6.

Calculator 5-6. Altitude Achieved at Fix

$$Alt_{fix} = (r + Aircraft_{SOC}) \times e^{\left(\frac{CG \times D_{fix}}{r}\right)} - r$$

where

D_{fix} = Distance (NM) from AB line to fix

$Aircraft_{SOC}$ = Aircraft AB line (SOC) altitude

CG = Climb Gradient (Standard 200 ft/NM)

Calculator 5 6		
D_{fix} (NM)		Calculate
$Aircraft_{SOC}$		
CG		Clear
Alt_{fix}		

5.2.2 **c. FB Turn Calculations and Construction.** (Consider same direction-of-flight-distance as positive, opposite-flight-direction distance as negative).

5.2.2 c. (1) FB Turn Calculations.

<u>STEP 1</u>: Calculate the fix to early-turn distance ($D_{earlyTP}$) using calculator 5-7.

Calculator 5-7. Early Turn Distance

$$D_{earlyTP} = ATT + DTA$$

Calculator 5 7		
ATT		Calculate
DTA		
$D_{earlyTP}$		Clear

5.2.2 c. (2) Early-Turn Area Construction.

Table 5-1. Inside Turn Expansion Guide

Outbound Segment Boundary Relative ETP Connections	Expansion Line Required
Secondary & Primary **Prior** ETP	15° Line
Secondary **Prior** ETP	15° Line
Primary **Beyond** ETP	A/2
Secondary & Primary **Beyond** ETP	A/2

Note: ETP = LL' early-turn point connection, 15-degree line relative outbound segment, A/2 = half turn-angle

5.2.2 c. (3) Inside turn (FB) Construction is predicated on the location of the LL' line and primary/secondary boundary intersections (early turn connections), relative to the outbound segment (see table 5-1 and figures 5-11A, 5-11B, and 5-11C).

See similar construction figure 5-6.

Where no inside turn secondary area exists in section 1, apply secondary areas only after the turn expansion line/s intersect the outbound segment boundaries.

Apply the same technique to primary and secondary area connections when both inbound segment connection points fall either outside the outbound segment, or inside the outbound segment primary area. When both inbound connection points are within the outbound segment secondary area, or its extension, table 5-1 displays a connection method for each point.

Note: Where half-turn-angle construction is indicated, apply a line splaying at the larger of, half-turn-angle, or 15 degrees relative to the outbound track. Where a small angle turn exists and standard construction is suitable for one, but not both splays, connect the uncommon splay, normally primary, to the outbound primary boundary at the same along-track distance as the secondary connection. Maintain or increase primary area as required.

STEP 1: Construct a baseline (LL') perpendicular to the inbound track at distance $D_{earlyTP}$ (calculator 5-7) prior to the fix.

CASE 1: The outbound segment boundary, or its extension, is **beyond** the baseline (early-turn connection points are **prior** to the outbound segment boundary).

STEP 1: Construct the inside turn expansion area with a line, drawn at one-half the turn angle from the inbound segment primary early-turn connection point, to intercept the outbound segment primary boundary (see figures 5-6 and 5-11A).

<u>STEP 2 (if required)</u>: Construct the inside turn expansion area with a line, drawn at one-half the turn angle, from the inbound segment secondary early-turn connection point, to intercept the outbound segment secondary boundary (see figure 5-11A).

CASE 2: The outbound segment secondary boundary or its extension is **prior** to the <u>LL'</u> baseline and outbound segment primary boundary or its extension is beyond the <u>LL'</u> baseline, (early-turn connection points are both **within** the outbound segment secondary area or its extension).

<u>STEP 1</u>: Construct the inside-turn expansion area with a line splaying at 15 degrees relative to the outbound track from the inbound segment secondary early-turn connection point to intersect the outbound segment boundary.

<u>STEP 1 Alt</u>: Begin the splay from L' when the turn angle exceeds 75 degrees.

<u>STEP 2</u>: Construct the primary boundary with a line, drawn at one-half the turn angle, from the inbound segment primary early-turn connection point to intercept the outbound segment primary boundary (see figure 5-11B).

CASE 3: The outbound segment secondary and primary boundaries, or their extensions, are **prior** to the <u>LL'</u> baseline (early-turn connection points are **inside** the outbound segment primary area).

<u>STEP 1</u>: Construct the inside turn expansion area with a line, splaying at 15 degrees (relative to the outbound track) from the more conservative point, (L') or (the intersection of <u>LL'</u> and the inbound segment inner primary boundary), to intersect the outbound segment boundaries.

<u>STEP 1 Alt</u>: Begin the splay from L' when the turn angle exceeds 75 degrees.

In this case, the inside turn secondary area is terminated at the outbound segment primary boundary, as it falls before the early-turn points, <u>LL'</u> (see figure 5-11C for L' connection).

5.2.2 c. (4) Outside Turn (FB) Construction.

<u>STEP 1</u>: Construct the outer primary boundary using a radius of one-half primary width (2 NM), centered on the plotted fix position, drawn from the inbound segment extended primary boundary until tangent to the outbound segment primary boundary (see figures 5-7 and 5-11A through 5-11C).

<u>STEP 2</u>: Construct the secondary boundary using a radius of one-half segment width (3 NM), centered on the plotted fix position, drawn from the inbound segment extended outer boundary until tangent to the outbound segment outer boundary (see figures 5-7 and 5-11A through 5-11C).

5.2.2 **d. FO Turn Construction.**

5.2.2 d. (1) Inside Turn (FO) Construction.

STEP 1: Construct the early-turn baseline (LL') at distance ATT prior to the fix, perpendicular to the inbound nominal track.

STEP 2: Refer to paragraph 5.2.2.c(3), (skip STEP 1).

5.2.2 d. (2) Outside Turn (FO) Construction.

STEP 1: Construct the late-turn baseline (PP') at distance ATT + rr beyond the fix, perpendicular to the inbound nominal track. Calculate late-turn distance using calculator 5-8.

STEP 2: Apply wind spiral outer boundary construction for the first MA FO turn. See paragraph 5.2.1b.(2) for necessary data, using the higher of calculator 5-6 output, or the assigned fix crossing altitude for TAS and turn radius calculations. Apply paragraph 5.4 for wind spiral construction. A non-turn side secondary area may extend into the WS1 area.

5.2.2 d. (3) Obstacle Evaluations (see paragraph 5.2.3).

5.2.3 Section 2 Obstacle Evaluations.

5.2.3 a. Turn at an Altitude Section 2.

Apply the standard OCS slope, or the assigned CG associated slope to section 2 obstacles (during and after the turn) based on the shortest primary area distance (do) from the TIA boundary to the obstacle. Shortest primary area distance is the length of the shortest line kept within primary segments that passes through the early-turn baseline of all preceding segments.

STEP 1: Measure and apply the OCS along the do from the TIA boundary to the obstacle (single and multiple segments). See figures 5-2 through 5-13, (skip 5-10) for various obstacle measurement examples.

STEP 2: For obstacles located in secondary areas, measure and apply the OCS along the do from the TIA boundary to the primary boundary abeam the obstacle, then the 12:1 slope along the shortest distance to the obstacle, (taken perpendicular to the nominal track or in expansion areas, to the primary arc, the primary corner-cutter, corner apex, or other appropriate primary boundary). Where an obstacle requires multiple measurements (an obstacle is equidistant from multiple primary boundary points, or lies along perpendiculars from multiple primary boundary points, etc.), apply the most adverse result from each of the combined primary/secondary measurements (see figures 5-1 and 5-2 through 5-11C).

5.2.3 b. Turn at Fix Section 2.

Apply the standard OCS slope, (or the assigned CG associated slope) beginning at the AB line at the inbound-segment end OCS height.

STEP 1: Measure and apply the OCS along the do from the AB line (parallel to track) to LL', the shortest primary distance to the obstacle (single and multiple segments). See figures 5-2 through 5-13, (skip 5-10) for various obstacle measurement examples.

STEP 2: For obstacles located in secondary areas, measure and apply the OCS along the do from the TIA boundary to the primary boundary abeam the obstacle, then the 12:1 slope along the shortest distance to the obstacle, (taken perpendicular to the nominal track or in expansion areas, to the primary arc, the primary corner-cutter, corner apex, or other appropriate primary boundary). Where an obstacle requires multiple measurements (where an obstacle is equidistant from multiple primary boundary points, or lies along perpendiculars from multiple primary boundary points, etc.), apply the most adverse result from each of the combined primary/secondary measurements (see figures 5-6 through 5-8). Additional obstacle measurements examples appear in figures 5-1 through 5-11C.

5.3 Turning MA (Second Turn).

5.3.1 DF-TF Turn (Second Turn, following turn-at-altitude).

See March 1, 2013 Clarification Memo

Turns at the DF path terminator fix will be FB or FO to a TF leg. In either case, the outer boundary provides FO protection, and the inner boundary provides FB protection. Maximum turn angle is 90 degrees (applicable to both tracks within the DF segment). This application provides that construction under chapter 1, or this chapter will apply, including cases where the inside and outside turn construction differs.

5.3.1 a. DF-TF (FB) Turn.

5.3.1 a. (1) Inside DF-TF (FB) construction.

CASE 1: Full-width inside secondary exists at the early-turn point (LL').

STEP 1: Construct a baseline (LL') perpendicular to the inbound track nearer the turn-side boundary at distance $D_{earlyTP}$ (calculator 5-7) prior to the fix.

STEP 2: Apply paragraph 1.5.2 criteria.

CASE 2: Less than full-width inside secondary exists at (LL').

STEP 1: Apply paragraph 5.2.2.c(3) criteria.

5.3.1 a. (2) Outside DF-TF (FB) construction.

CASE 1: Full width outside secondary exists at the early turn point (L'L").

STEP 1: Construct a baseline (L'L") perpendicular to the inbound track nearer the non-turn side boundary at distance $D_{earlyTP}$ (calculator 5-7) prior to the fix.

STEP 2: Apply paragraph 1.5.2 criteria (see figures 5-6 through 5-8).

CASE 2: Less than full-width outside secondary exists at (L'L").

STEP 1: Apply paragraph 5.2.2.c(4) criteria.

5.3.1 b. DF-TF (FO) Turn.

5.3.1 b. (1) Inside DF-TF (FO) Turn Construction.

STEP 1: Construct a baseline (LL') perpendicular to the inbound track nearer the turn-side boundary at distance ATT prior to the fix (see figure 5-9).

Note: Where half-turn-angle construction is specified, apply a line splaying at the larger of half-turn-angle or 15 degrees relative to the outbound track.

CASE 1: No inside secondary area exists at LL'.

STEP 1: Create the OEA early-turn protection by constructing a line, splaying at the larger of one-half (½) the turn angle, or 15 degrees relative to the outbound track, from the intersection of LL' and the inbound segment inner primary boundary to connect with the outbound TF segment boundaries.

The TF secondary area begins at the intersection of this diagonal line and the outbound segment boundary.

CASE 2: Partial width inside secondary area exists at LL'.

STEP 1: Create the OEA early-turn primary area protection by constructing a line, splaying at the larger of one-half (½) the turn angle, or 15 degrees relative to the outbound track, from the intersection of LL' and the inbound segment inner primary boundary to connect with the TF segment primary boundary.

STEP 2: Create the OEA early-turn secondary protection by constructing a line, splaying at the larger of one-half (½) the turn angle, or 15 degrees relative to the outbound track, from the intersection of LL' and the inbound segment inner boundary to connect with the TF segment boundary.

CASE 3: Full-width inside secondary area exists at LL'.

STEP 1: Apply chapter 1 criteria (see figure 5-9).

5.3.1 b. (2) Outside DF-TF (FO) Turn Construction.

STEP 1: Construct the late-turn baseline for each inbound track, (PP') for the track nearer the inside-turn boundary, and (P'P'') for the outer track at distance (ATT + rr) beyond the fix, perpendicular to the appropriate inbound track (see figure 5-9).

Note: A DF-TF FO turn is limited to 90 degrees (both inbound tracks) and should require no more than one WS per baseline. Construct the outside track WS (WS1) on base line P'P''), then construct WS2 on baseline PP'.

STEP 2: Apply WS construction, see paragraph 5.2.1.b(2) for necessary data, and paragraph 5.4 for WS construction (see figure 5-9).

5.3.2 TF-TF Turn (Second Turn, following turn-at-fix).

See March 1, 2013 Clarification Memo

Turns at the TF path terminator fix will be FB or FO to a TF leg. In either case, the outer boundary provides FO protection, and the inner boundary provides FB protection. Maximum turn angle is 90 degrees. This application provides that construction under chapter 1, or this chapter will apply, including cases where the inside and outside turn construction differs.

5.3.2 a. TF-TF (FB) Turn.

5.3.2 a. (1) Inside TF-TF (FB) construction.

STEP 1: Apply paragraph 1.3.2 criteria.

5.3.2 a. (2) Outside TF-TF (FB) construction.

STEP 1: Apply paragraph 1.3.1 criteria.

5.3.2 b. TF-TF (FO) Turn.

5.3.2 b. (1) Inside TF-TF (FO) Turn Construction.

STEP 1: Apply paragraph 1.3.2 criteria.

5.3.2 b. (2) Outside TF-TF (FO) Turn Construction.

STEP 1: Apply paragraph 1.3.1 criteria.

5.4 Wind Spiral Cases.

WS construction applies to turn-at-an-altitude, turn-at-a-fix (FO) for the first MA turn, and DF-TF (FO) for the second turn. The late-turn line P' designator is typically placed where the baselines cross. Where baseline extension is required, mark each baseline inner end with P'.

Each WS has several connection options along its boundary. The chosen connection/s must provide the most reasonably conservative, (larger area) track and protection areas (see figures 5-14A/B/C for examples).

- A 15-degree or greater* splay line to join outbound segment outer boundaries, from:
  - WS/direct-to-fix tangent point
  - WS to WS tangent line origin
  - WS to WS tangent line end
  - WS/outbound segment parallel point (DF segment NA)
- A tangent line to join the next WS.
- A tangent line direct to the next fix (DF segment).
- A tangent line, converging at 30 degrees to the segment track (TF segment).

*__Note:__ See paragraph 5.4.1.a and 5.4.1.b for alternate connection details.

Outbound segment type and turn magnitude are primary factors in WS application. Refer to table 5-2 for basic application differences.

Table 5-2. MA First Turn Wind Spiral Application Comparison

	Turn-At-Fix (FO)	Turn-At-Altitude
WS1 Baseline (PP')	Fix + ATT + rr	TIA + rr
WS2 Baseline (PP')	Fix + ATT + rr	TIA + rr
WS Number	1 or 2	1, 2, or 3*
Final WS Connection (Tangent line)	30 degrees to outbound track	Direct-to-Fix

* Where a required turn exceeds that served by three wind spirals, consider adding fixes to avoid prohibitively large protection areas resulting from further wind spiral application.

5.4 **a. Turn-at-Fix (FO) and Turn-at-Altitude WS Comparison.**

Three cases for outer-boundary wind spirals commonly exist:

- **CASE 1:** Small angle turns use one wind spiral (WS1);
- **CASE 2:** Turns near/exceeding 90 degrees ~ use a second wind spiral (WS2); and
- **CASE 3:** Turns near/exceeding 180 degrees ~ use a third wind spiral (WS3).

5.4 a. (1) Turn-at-Altitude WS application concludes with a line tangent to the final WS direct to the next fix.

5.4 a. (2) Turn-at-Fix (FO) WS application concludes with a line tangent to the final WS converging at a 30-degree angle to the outbound segment nominal track. The intersection of this line with the nominal track establishes the earliest maneuvering point for the next fix. The minimum segment length is the greater of:

- The minimum length calculated using calculators 1-5 and 1-10; or,
- The distance from previous fix to the intersection of the 30-degree converging outer boundary line extension and the nominal track, plus DTA and ATT [see paragraph 5.2.2.c.(3)].

5.4 a. (3) Second MA Turn DF-TF Turn-at-Fix (FO) WS application concludes with a line tangent to the final WS converging at a 30-degree angle to the outbound segment nominal track. This construction requires two WS baselines, one for each inbound track. Each late turn baseline is located (ATT + rr) beyond the fix, oriented perpendicular to the specific track. The baseline for the inbound track nearer the inside-turn boundary is designated PP', the baseline associated with the outside-turn track is designated P'P''. For convenience P' is often placed at the intersection of the two baselines, but a copy properly goes with each baseline inner end where baseline extensions are required.

5.4.1 First MA Turn WS Construction.

Find late-turn point distance (D_{lateTP}) using calculator 5-8.

Calculator 5-8. Late-Turn Point Distance

$$D_{LateTP} = ATT + rr$$

where

rr = delay/roll-in calculator 1-4

Calculator 5 8		
ATT		Calculate
rr		
D_{lateTP}		Clear

5.4.1 **a. CASE 1:** Small angle turn using 1 WS.

STEP 1: Construct the WS1 baseline, (PP') perpendicular to the straight missed approach track at the late-turn-point (see table 5-2 for line PP' location, see figures 5-3 and 5-12).

STEP 2: Locate the wind spiral center on PP' at distance R (no-wind turn radius, using calculator 5-3; see figure 5-2) from the intersection of PP' and the inbound-segment outer-boundary extension (see figures 5-4 and 5-12).

STEP 3: Construct WS1 from this outer-boundary point in the direction of turn until tangent to the WS/Segment connecting line from table 5-2 (see figures 5-4 and 5-12).

CASE 1-1: Turn-altitude (WS1 ends when tangent to a line direct to fix)

STEP 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (1-2-2-1 segment width) (see figure 5-3).

STEP 2: Construct a line from the WS1 tangent point, splaying at 15 degrees from the WS1-to-fix track until it intersects the parallel boundary lines or reaches the segment end (see figures 5-2 through 5-6).

Note: Consider 'full-width protection at the fix' to exist where the splay line is tangent to a full-width- radius- circle about the fix.

STEP 2alt-1: Where **STEP 2** construction provides less than full-width protection at the DF fix, construct the OEA outer boundary with a line splaying from the WS1/direct-to-fix tangent point at 15 degrees relative to the direct-to-fix line, (or greater where required to provide full-width protection at the DF fix), until it intersects the parallel boundary lines (not later than tangent/tangent-extension to the full-width-arc about the fix), and provides full-width protection at or before the DF fix. DF secondary areas begin/exist only where full width primary exists (see figures 5-14A and 5-14B).

Note: Where excessive splay (dependent upon various conditions but generally in the 35-40 degree range), consider lengthening the segment, restricting the speed, category, etc. to avoid protection and/or construction difficulties.

CASE 1-2: Turn-at-Fix (FO) (WS1 ends when tangent to a 30-degree line converging to nominal track).

STEP 1: Construct the OEA outer boundary line using WS1 and the tangent 30-degree converging line until it crosses the outbound segment boundaries. See figure 5-12.

STEP 1a: Where WS1 lies within the outbound segment primary boundary, construct the OEA boundary using WS1 and a line (from the point WS1 is parallel to the outbound segment nominal track), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary lines.

STEP 1b: Where WS1 lies within the outbound segment secondary boundary, construct the OEA boundary using WS1 and a line (from the point WS1 is parallel to the outbound segment nominal track), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary line. Continue WS1 and the tangent 30-degree converging line to establish the inner primary/secondary boundary.

5.4.1 **b. CASE 2: Larger turn using more than 1 WS.** For turns nearing or greater than 90 degrees, WS2 may be necessary (see figures 5-4 and 5-13).

STEP 1: To determine WS2 necessity, locate its center on baseline PP', at distance R from the inbound-segment inner-boundary extension.

STEP 2: Construct WS2 from this inner-boundary point in the direction of turn until tangent to the WS/Segment connecting line from table 5-2 (see figure 5-13).

STEP 3: Where WS2 intersects WS1 construction, (including the connecting and expansion lines where appropriate), include WS2 in the OEA construction. Otherwise revert to the single WS construction.

STEP 3a: Connect WS1 and WS2 with a line tangent to both (see figures 5-4 and 5-13).

Note: The WS1/ WS2 tangent line should parallel a line between the WS center points.

CASE 2-1: Turn-at-Altitude: (WS2 ends when tangent to a line direct-to-fix)

STEP 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (1-2-2-1 segment width).

STEP 2: Construct a line from the WS2 tangent point, splaying at 15 degrees from the WS2-to-fix track until it intersects the parallel boundary lines or reaches the segment end (see figure 5-4).

Note: Consider 'full-width protection at the fix' exists where the splay line is tangent to a full-width- radius- circle about the fix.

STEP 2alt-1: Where **STEP 2** construction provides less than full-width protection at the DF fix, construct the OEA outer boundary with a line splaying from the WS2/direct-to-fix tangent point at 15 degrees relative to the direct-to-fix line, (or greater where required to provide full-width protection at the DF fix), until it intersects the parallel boundary lines (not later than tangent/tangent-extension to the full-width-arc about the fix), and provides full-width protection at or before the DF fix. Where the turn angle is ≤105 degrees, or the divergence angle between the WS/WS tangent line and the direct-to-fix line is ≤15 degrees, apply the splay line from the WS1/WS2 tangent line origin. DF secondary areas begin/exist only where full width primary exists (see figures 5-14A and 5-14C).

Note: Where excessive splay (dependent upon various conditions but generally in the 35-40 degrees range), consider using an earlier splay origin point, lengthening the segment, restricting the speed, category, etc. to avoid protection or construction difficulties (see paragraph 5.4 for origin points).

CASE 2-2: Turn-at-Fix (FO): (WS2 ends when tangent to a 30-degree line converging to nominal track).

STEP 1: Construct the OEA outer boundary line using WS2 and the 30-degree converging line until it crosses the outbound segment boundaries (see figure 5-13).

STEP 1a: Where WS2 lies within the outbound segment primary boundary, construct the OEA boundary using WS1, WS2 and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track, the more conservative), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary lines.

STEP 1b: Where WS2 lies within the outbound segment secondary boundary, construct the OEA boundary using WS1, WS2 and a line (from the point where WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary line. Continue WS2 and the tangent 30-degree converging line to establish the inner primary/secondary boundary.

5.4.1 c. **CASE 3: Larger turn using more than 2 WSs. (Not applicable to Turn-at-Fix due to 90-degree turn limit).** For turns nearing or greater than 180 degrees ~ (such as a missed approach to a holding fix at the IF),

STEP 1: Construct the WS3 baseline perpendicular to the straight missed approach track along the CD line-extended toward the turn side (see figure 5-5).

STEP 2: To determine WS3 necessity, locate its center on the WS3 baseline at distance R from point C (see figure 5-5).

STEP 3: Construct WS3 from point C in the direction of turn until tangent to the WS/Segment connecting line from table 5-2 (see figure 5-5).

STEP 4: Where WS3 intersects WS2 construction, include WS3 in the OEA construction. Otherwise revert to the dual WS construction (see figure 5-5).

STEP 5: Connect WS2 and WS3 with a line tangent to both (see figures 5-4 and 5-5).

Note: The WS2 & WS3 tangent line should parallel a line between the WS center points.

CASE 3-1: Turn-at-Altitude: (WS3 ends when tangent to a line direct to fix)

STEP 1: Construct the OEA outer primary and secondary boundary lines parallel to this track (1-2-2-1 segment width) (see figure 5-5).

STEP 2: Construct a line from the WS3 tangent point, splaying at 15 degrees from the WS3-to-fix track until it intersects the parallel boundary lines or reaches the segment end (see figure 5-5).

5.4.1 d. **Outside Turn Secondary Area.** Outbound segment secondary areas following wind spirals begin where either the 30-degree converging line crosses the secondary and primary boundaries from outside the segment, or the 15-degree splay line crosses the primary boundary from inside the segment.

5.4.2 Second MA Turn WS Construction (DF-TF FO).

To accommodate the two inbound tracks in the DF leg, the second MA turn DF-TF (FO) construction uses two WS baselines, PP' and P'P''.

Note: Apply table 5-2 PP' location information for each baseline (calculator is identical).

5.4.2 a. CASE 1: Small angle turn using 1 WS for each inbound DF track.

STEP 1: Construct the WS1 baseline, (P'P'') perpendicular to the DF track nearer the outside of the DF-TF turn, at the late-turn-point. See table 5-2 for line PP' location.

STEP 1a: Construct the WS2 baseline, (PP') perpendicular to the DF track nearer the inside of the DF-TF turn, at the late-turn-point. See table 5-2 for line PP' location.

STEP 2: Locate the WS1 center on P'P'' at distance R (no-wind turn radius, using calculator 5-3; see figure 5-2) from the intersection of P'P'' and the inbound segment outer-boundary extension.

STEP 2a: Locate the WS2 center on PP' at distance R (no-wind turn radius, using calculator 5-3; see figure 5-9) from the intersection of PP' and the inbound segment inner-boundary extension.

STEP 3: Construct WS1 from this outer boundary point in the direction of turn until tangent to the WS/Segment connecting line from table 5-2.

STEP 3a: Construct WS2 from this inner boundary point in the direction of turn until tangent to the WS/Segment connecting line from table 5-2.

STEP 4: Where WS2 intersects WS1 construction, include WS2 in the OEA construction, and connect WS1 to WS2 with a tangent line. Otherwise revert to the single WS construction.

CASE 1-1: WS1 and/or WS2 lie outside the outbound segment boundary.

STEP 1: Construct the OEA outer boundary using WS1 and/or WS2 and the tangent 30-degree converging line until it crosses the outbound segment boundaries (see figure 5-9).

CASE 1-2: WS1 and WS2 lie inside the outbound segment boundary.

STEP 1: Where WS1 and/or WS2 lie inside the outbound segment primary boundary, construct the OEA outer boundary using WS1 and/or WS2 and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary lines.

STEP 1a: Where WS1 and/or WS2 lie inside the outbound segment secondary boundary, construct the OEA outer boundary using WS1 and/or WS2 and a line (from the point WS1 or WS2 is parallel to the outbound segment nominal track), splaying at 15 degrees relative to the outbound segment nominal track until it intersects the outbound segment boundary line. Continue the final WS and 30-degree converging line to establish the primary/secondary boundary.

5.5 MA Climb Gradient.

Where the standard OCS slope is penetrated and the lowest HATh (final segment evaluation) is required, specify a missed approach CG to clear the penetrating obstruction. MA starting ROC is 100 ft for NVGP calculator 4-25 output for LPV, or table 3-2 values for other Vertically-Guided-Procedures, plus appropriate Order 8260.3 chapter 3 ROC adjustments. ROC for a sloping OCS applies (see Order 8260.3, Vol. 1, paragraph 203) measured parallel to the missed approach track to TIA end (Turn-at-Altitude), or early-turn point (Turn-at-Fix), then shortest primary distance to the next fix. Apply fix-to-fix distance for subsequent segments. Where a part-time altimeter is in use, consider the aircraft SOC altitude to be the MDA associated with the local altimeter (ensures adequate CG is applied).

STEP 1: Calculate the ROC, the altitude at which the ROC for the obstacle is achieved, and the required CG (ft/NM) using calculator 5-9. See calculator 1-21 for MA Slope calculations.

STEP 2: Apply the CG to:
- The altitude which provides appropriate ROC, or
- The point/altitude where the subsequent standard OCS slope clears all obstacles.

STEP 2a: Where a RASS adjustment is applicable for climb-to-altitude operations (prior to turn, terminate CG, etc.), apply the CG associated with the lower MDA/DA (calculator 5-9). To establish the RASS-based climb-to-altitude, add the difference between the Local altimeter-based MDA and the RASS-based MDA to the climb-to-altitude and round to the next higher 100-ft increment (see Order 8260.3 chapter 3 for further details).

Calculator 5-9. ROC/CG/Minimum Altitude/OCS

$$(1) \quad ROC_{obs} = ROC_{start} + 48 \times d$$

$$(2) \quad Alt_{min} = O_{elev} + ROC_{obs}$$

$$(3) \quad CG = \frac{r}{d} \times \ln\left(\frac{r + Alt_{min}}{r + Aircraft_{SOC}}\right)$$

where

ROC_{start} = *SOC ROC (table 3-2 value) or (100 ft for NVGP)*
d = *distance (NM) CG origin (SOC) to Obstacle*
O_{elev} = *Obstacle Elevation (MSL)*
$Aircraft_{SOC}$ = *aircraft altitude (MSL) at CG origin*

Calculator 5 9		
ROC_{start}		Calculate
O_{elev}		
d (NM)		
$Aircraft_{SOC}$		
ROC_{obs}		Clear
Alt_{min}		
CG		

Figure 5-1. Straight Missed Approach (Legs with Specified Tracks)

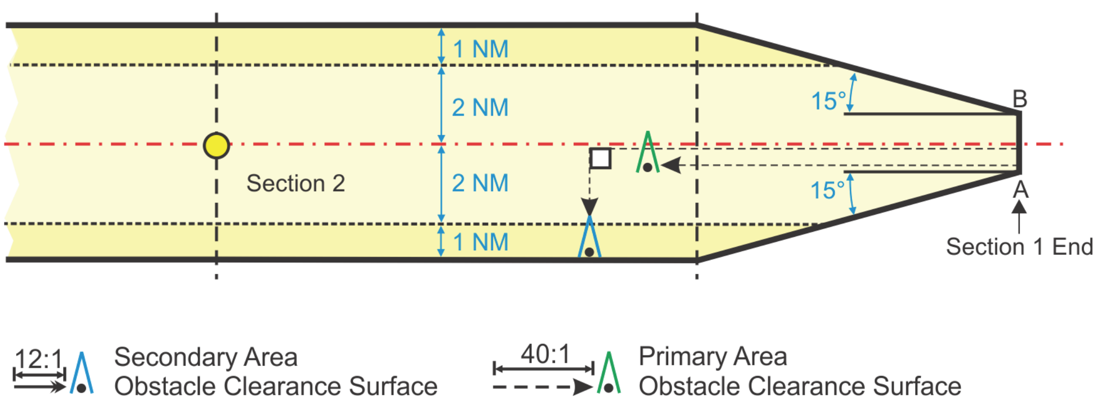


**Figure 5-2. Turn at Altitude –
Direct to Waypoint Small Angle Turn**

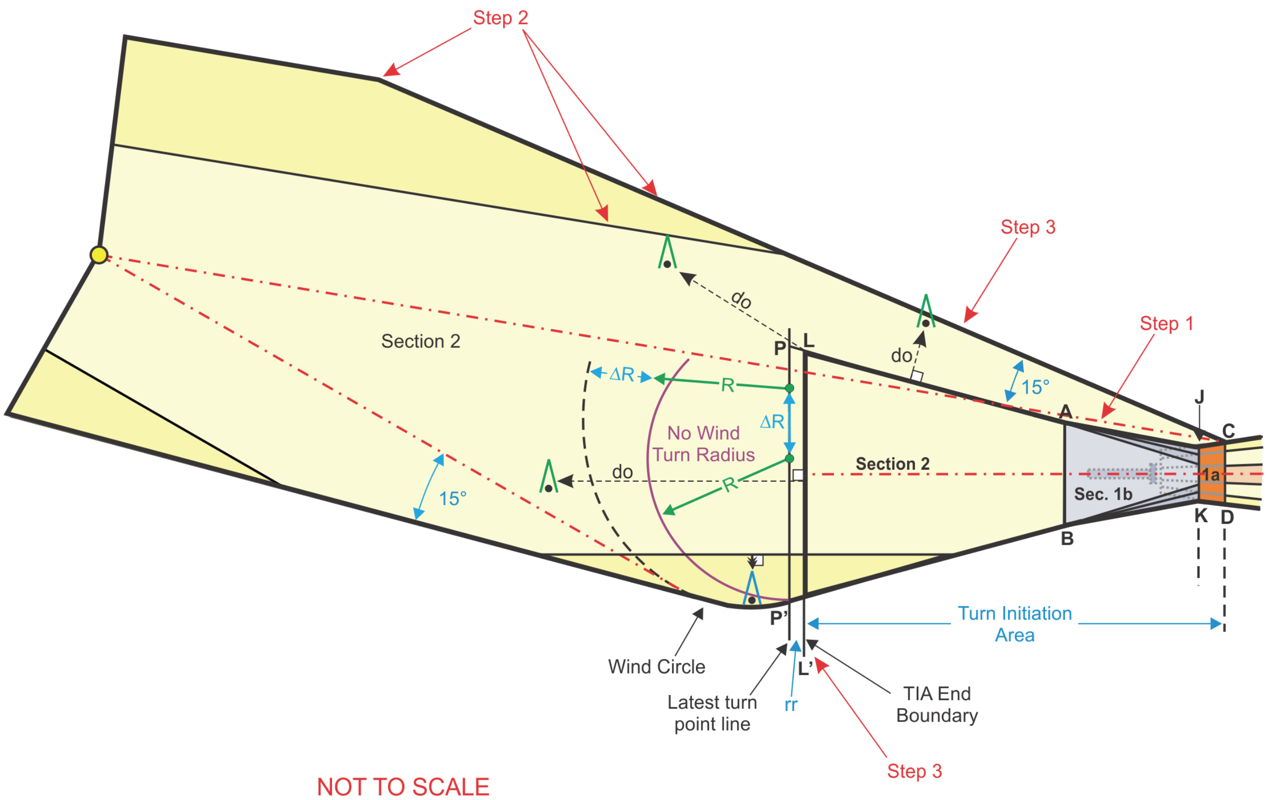


Figure 5-3. Turn at Altitude, TIA must Extend to the End of Section 1B

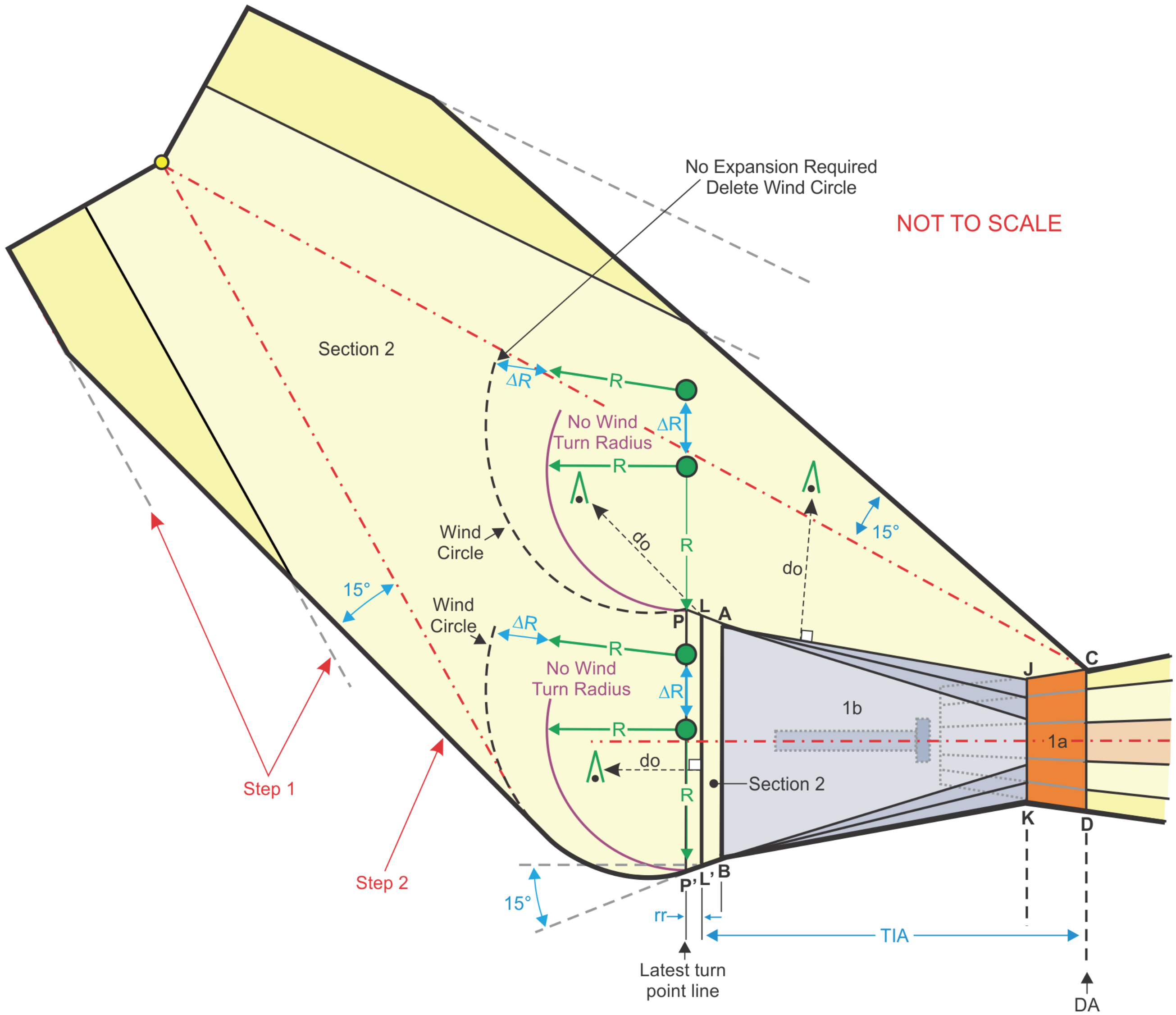


Figure 5-4. Turn at Altitude (Minimum Straight Segment)

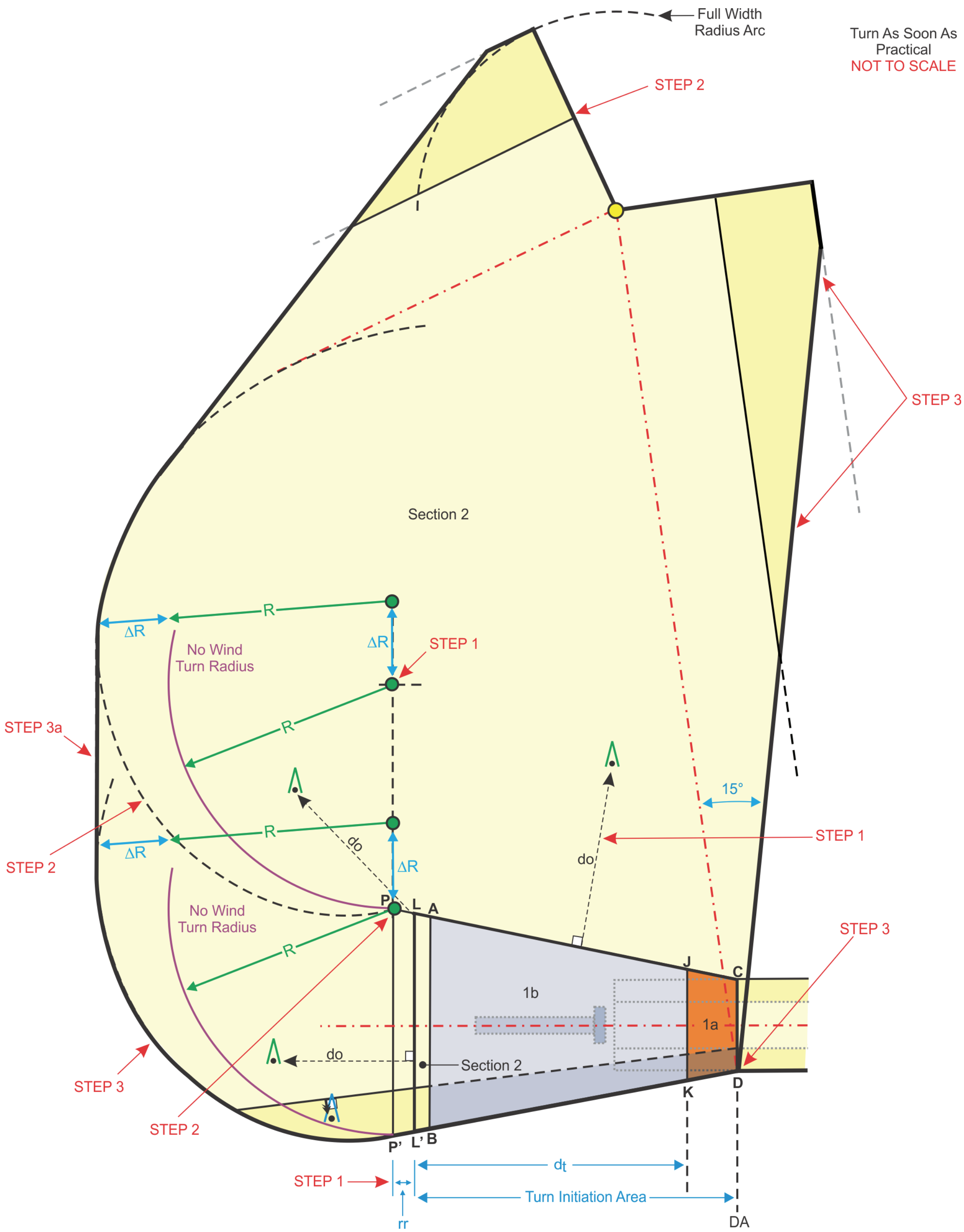


Figure 5-5. Turn at Altitude ≥ 180 degrees

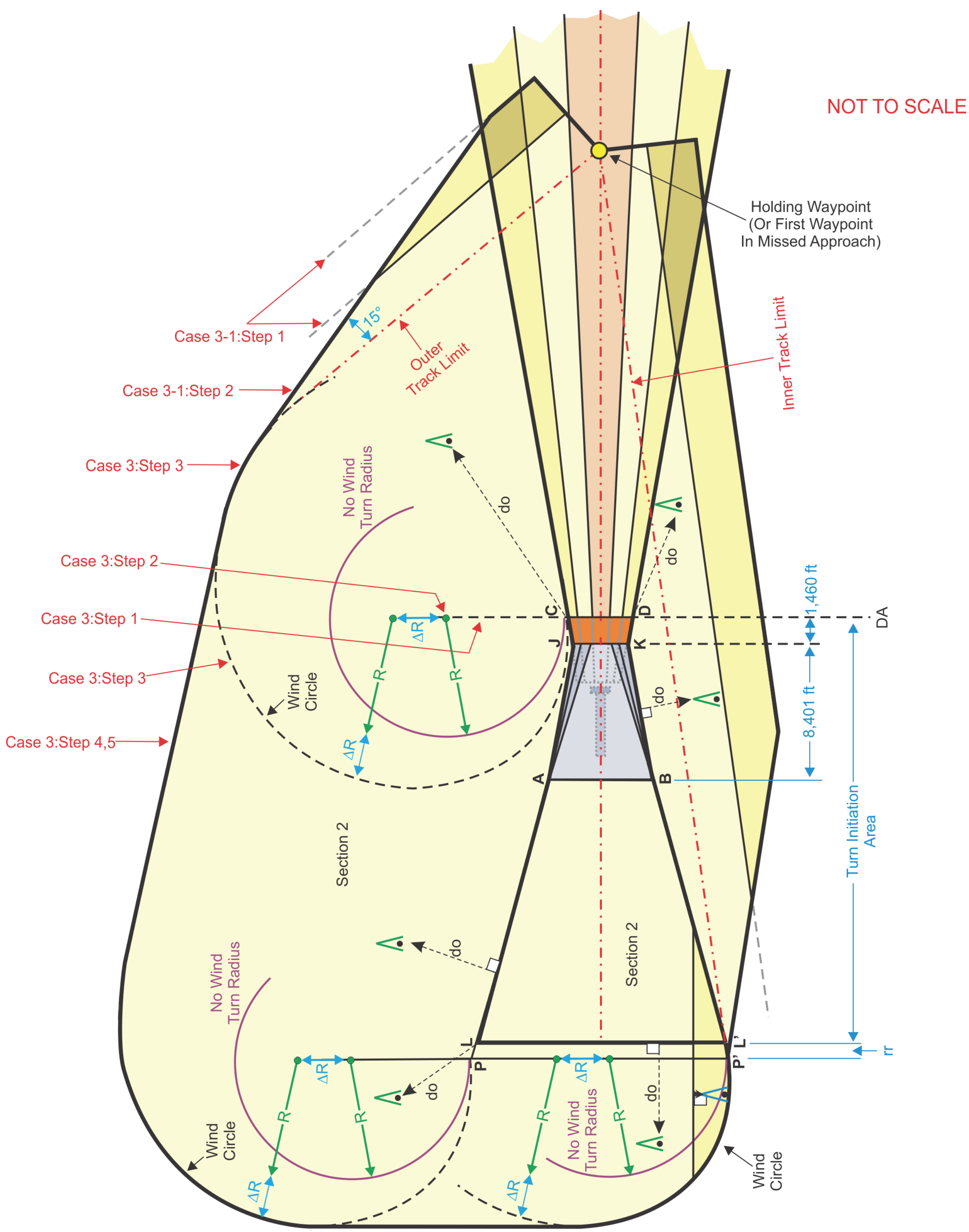


Figure 5-6. FB DF-TF Turn Following Turn at Altitude

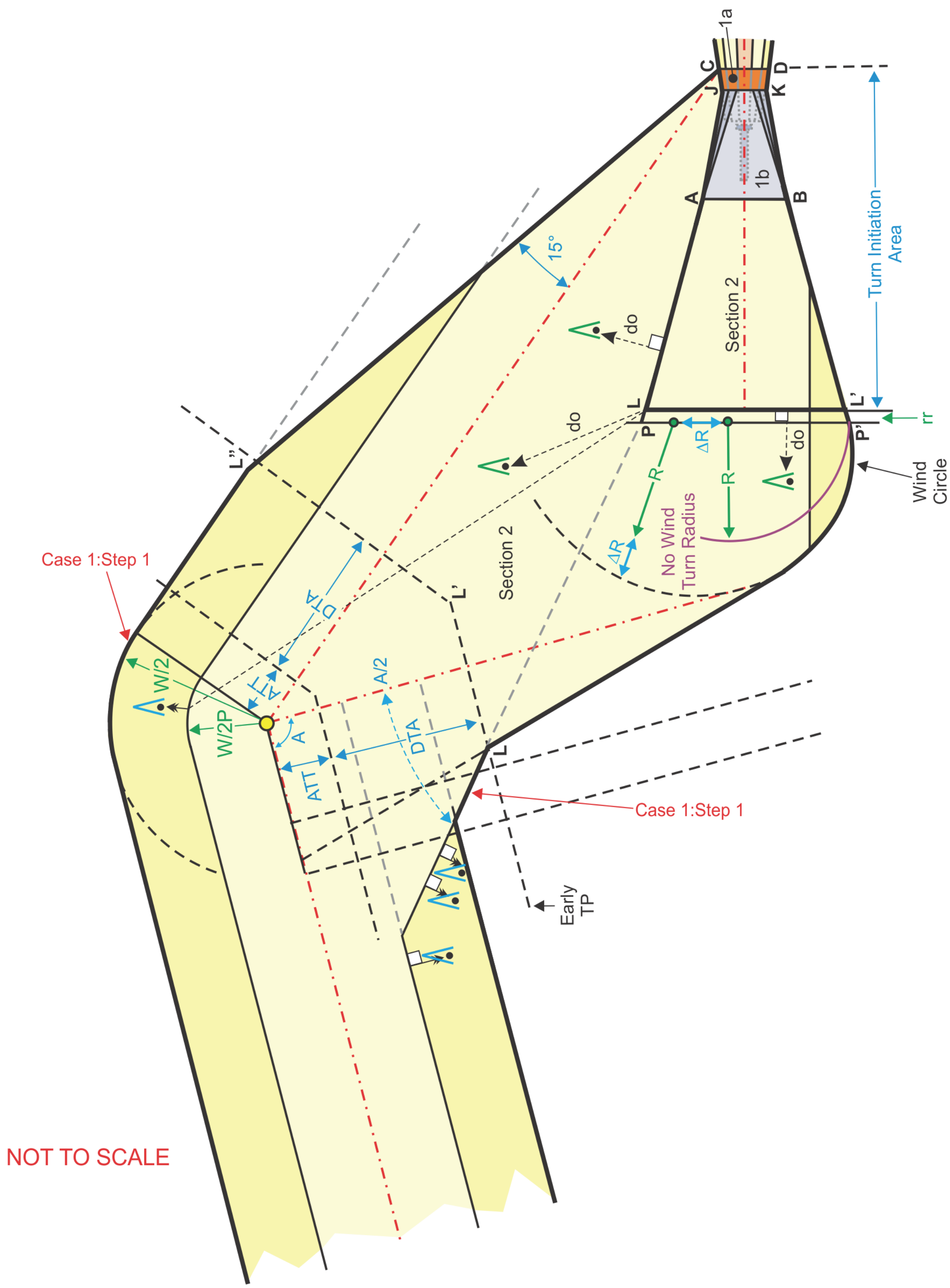
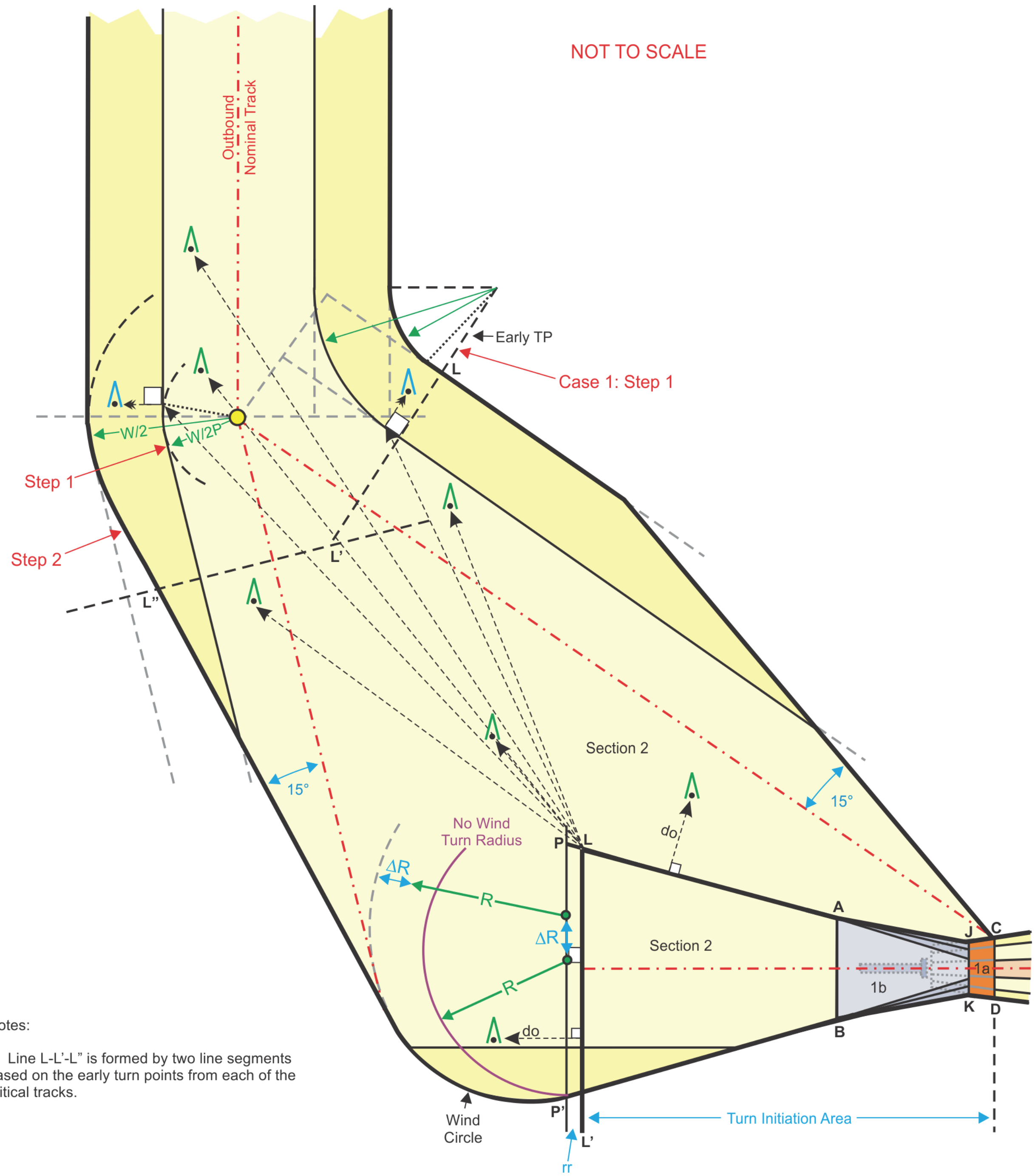


Figure 5-7. Turn at Altitude to FB Waypoint



Notes:

1. Line L-L'-L" is formed by two line segments based on the early turn points from each of the critical tracks.

Figure 5-8. Maximum Turn (FB)
Following Turn at Altitude

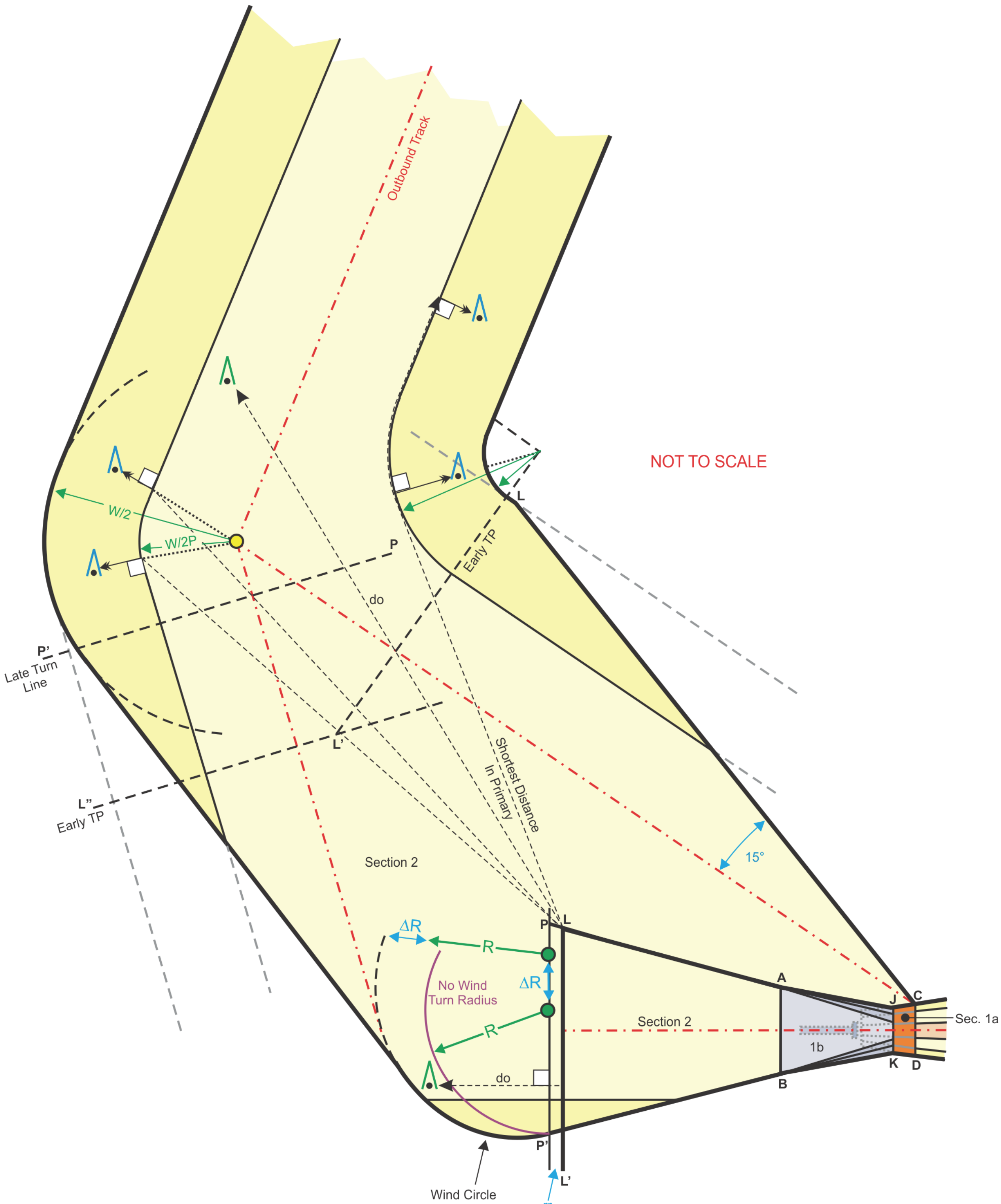


Figure 5-9. Turn at Altitude to a FO Waypoint

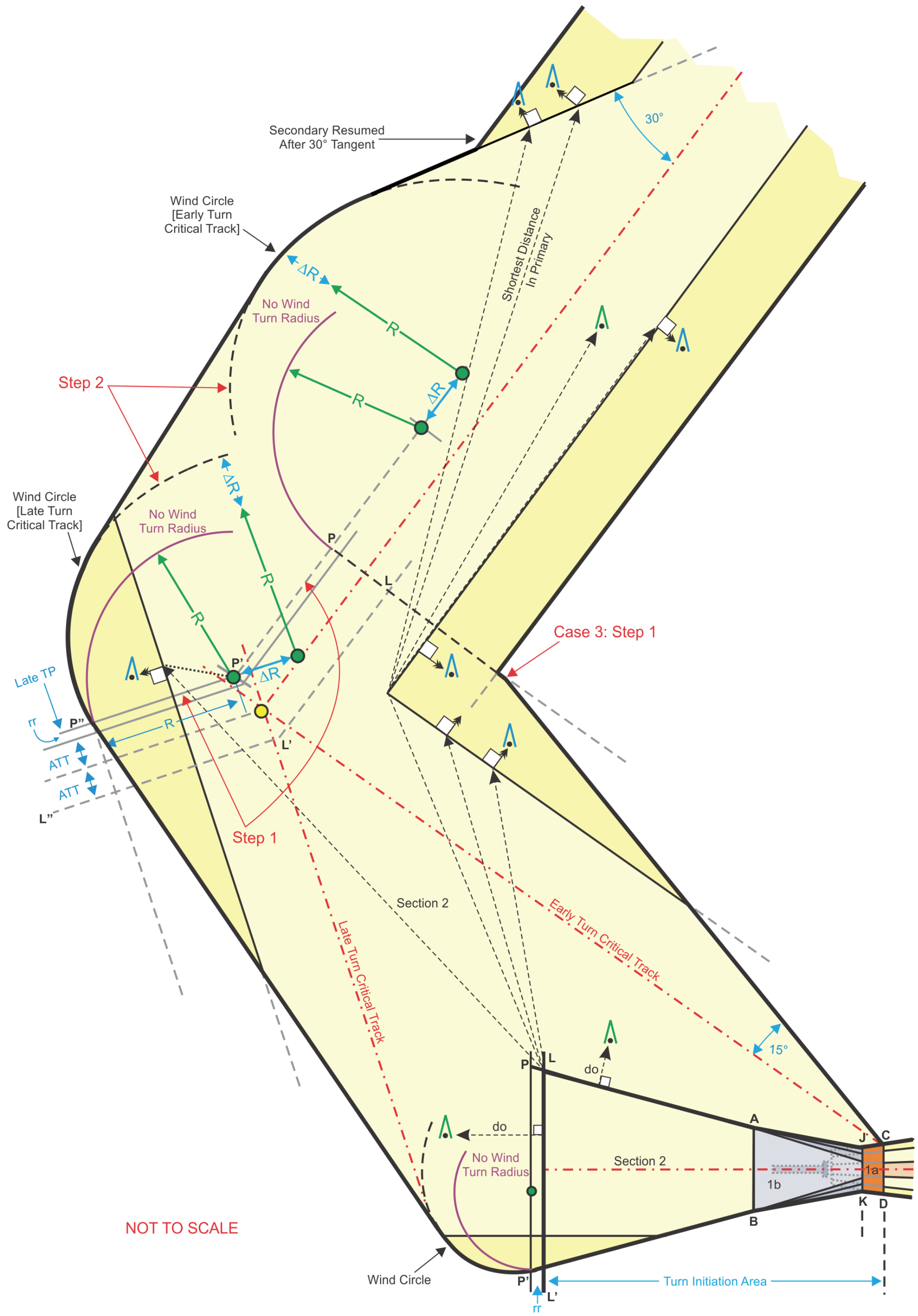
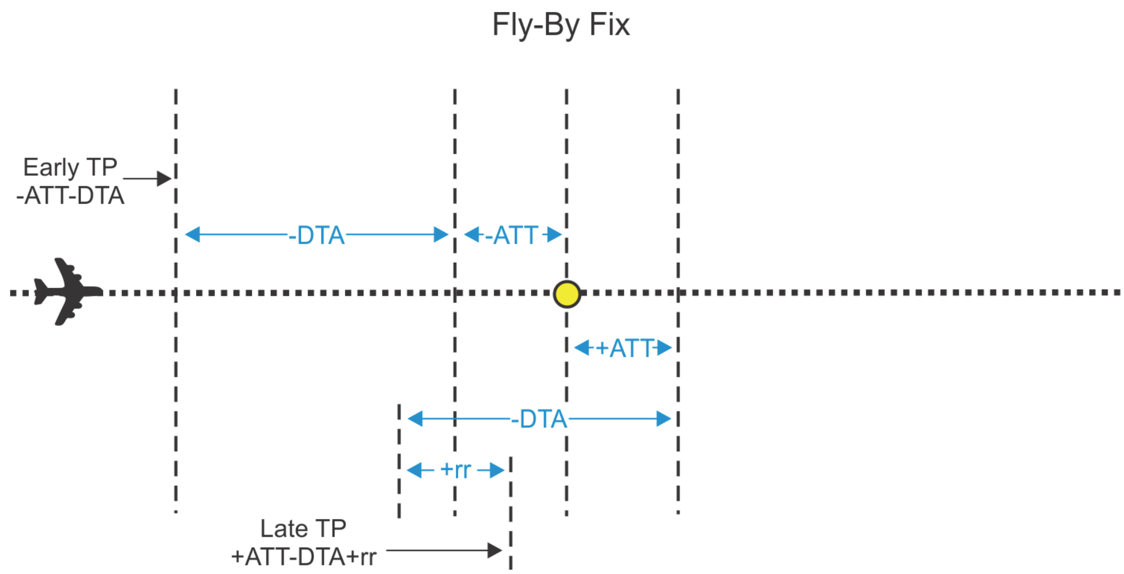


Figure 5-10. FO/FB Fix Diagrams



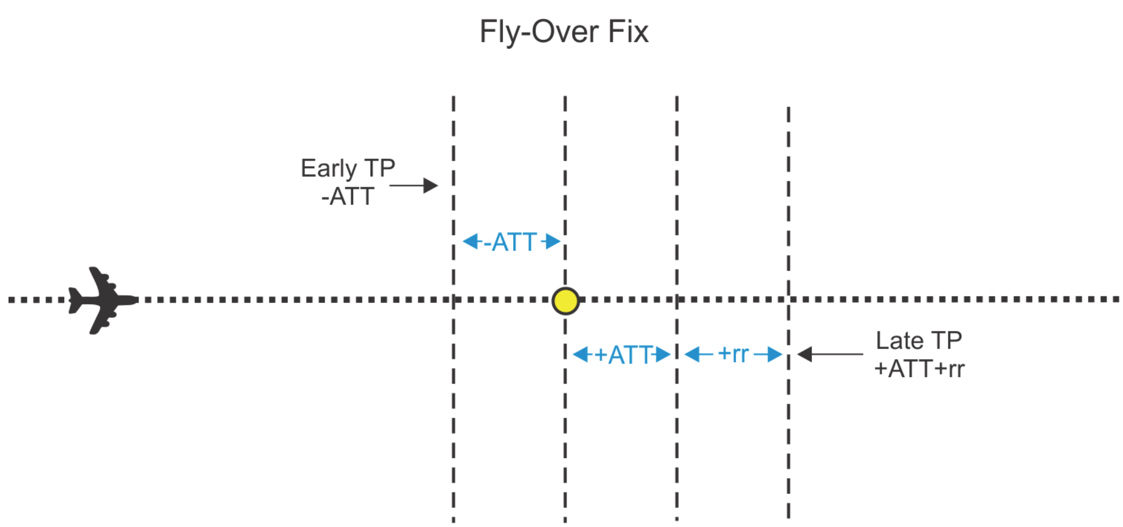


Figure 5-11A. Turn at Waypoint (FB)

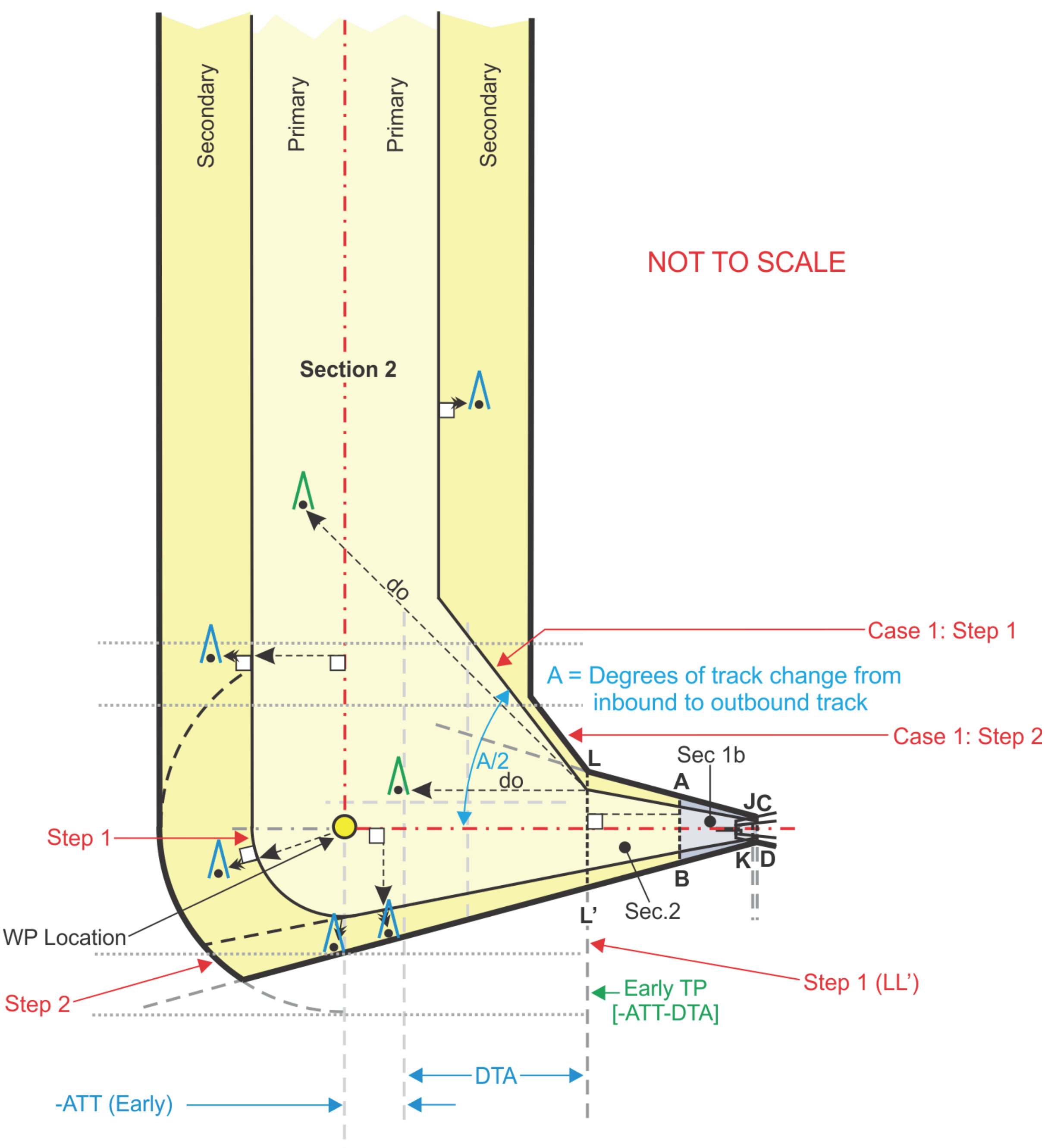


Figure 5-11B. Turn at Waypoint (FB)

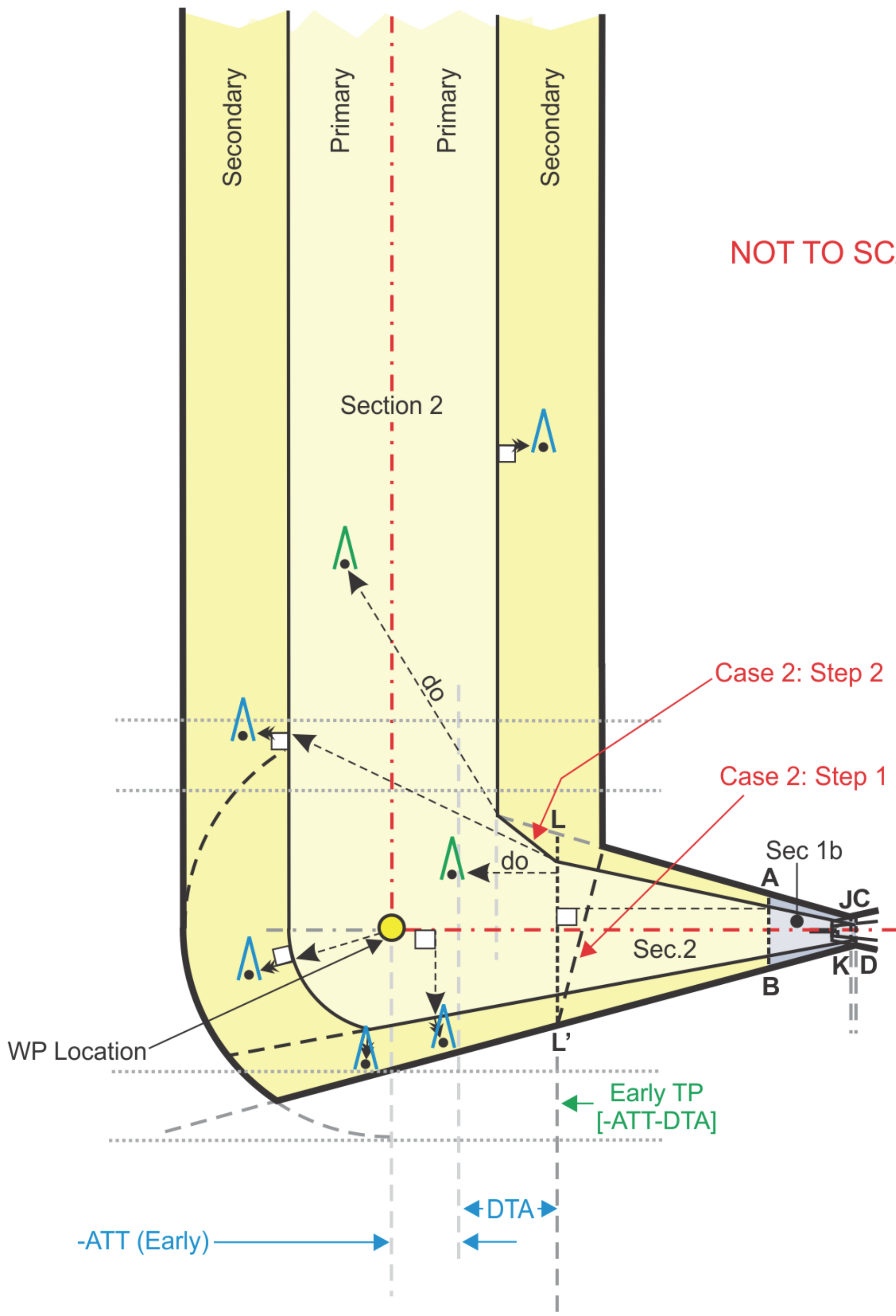


Figure 5-11C. Turn at Waypoint (FB)

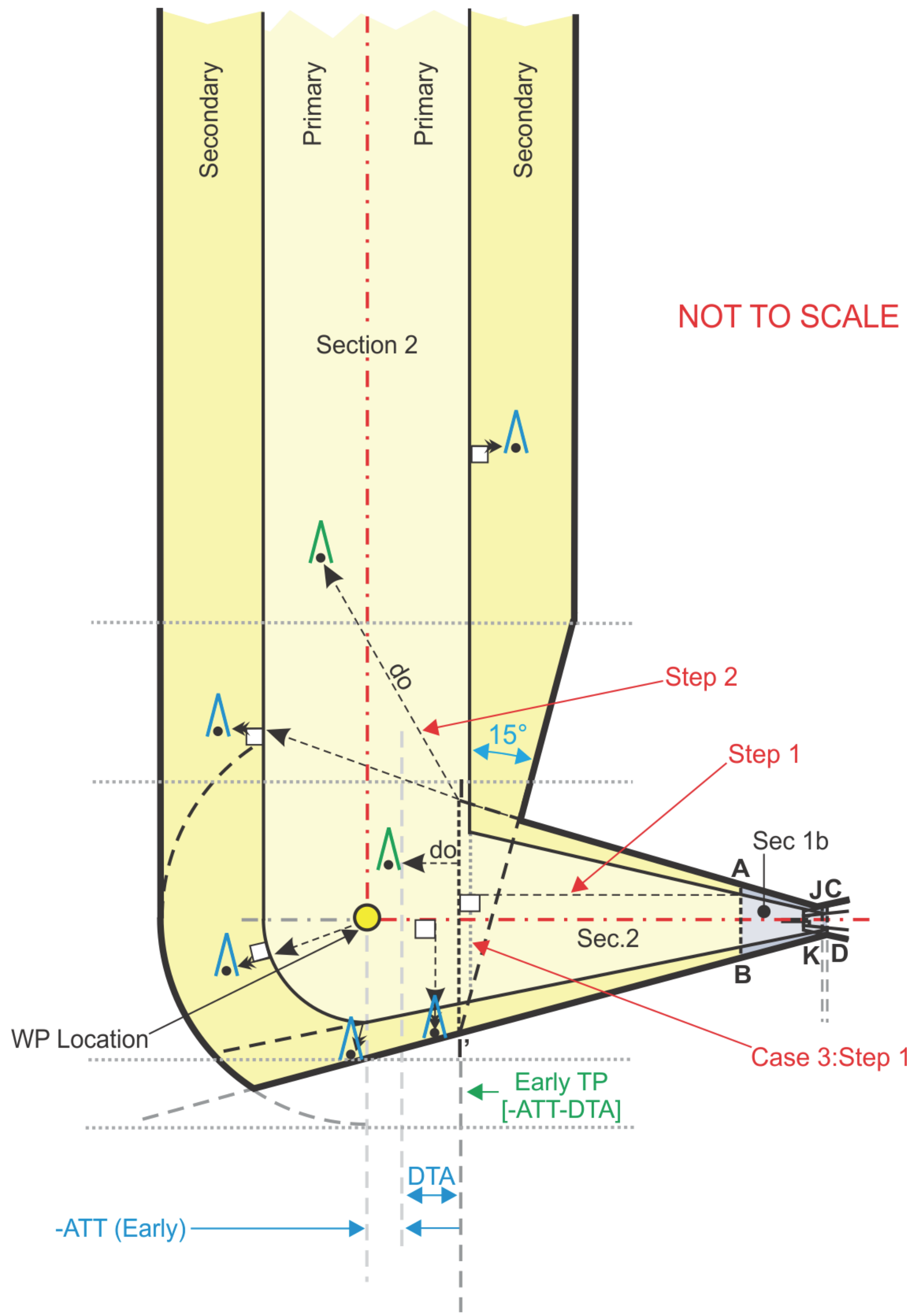


Figure 5-12. Turn at Waypoint (FO), < 75°

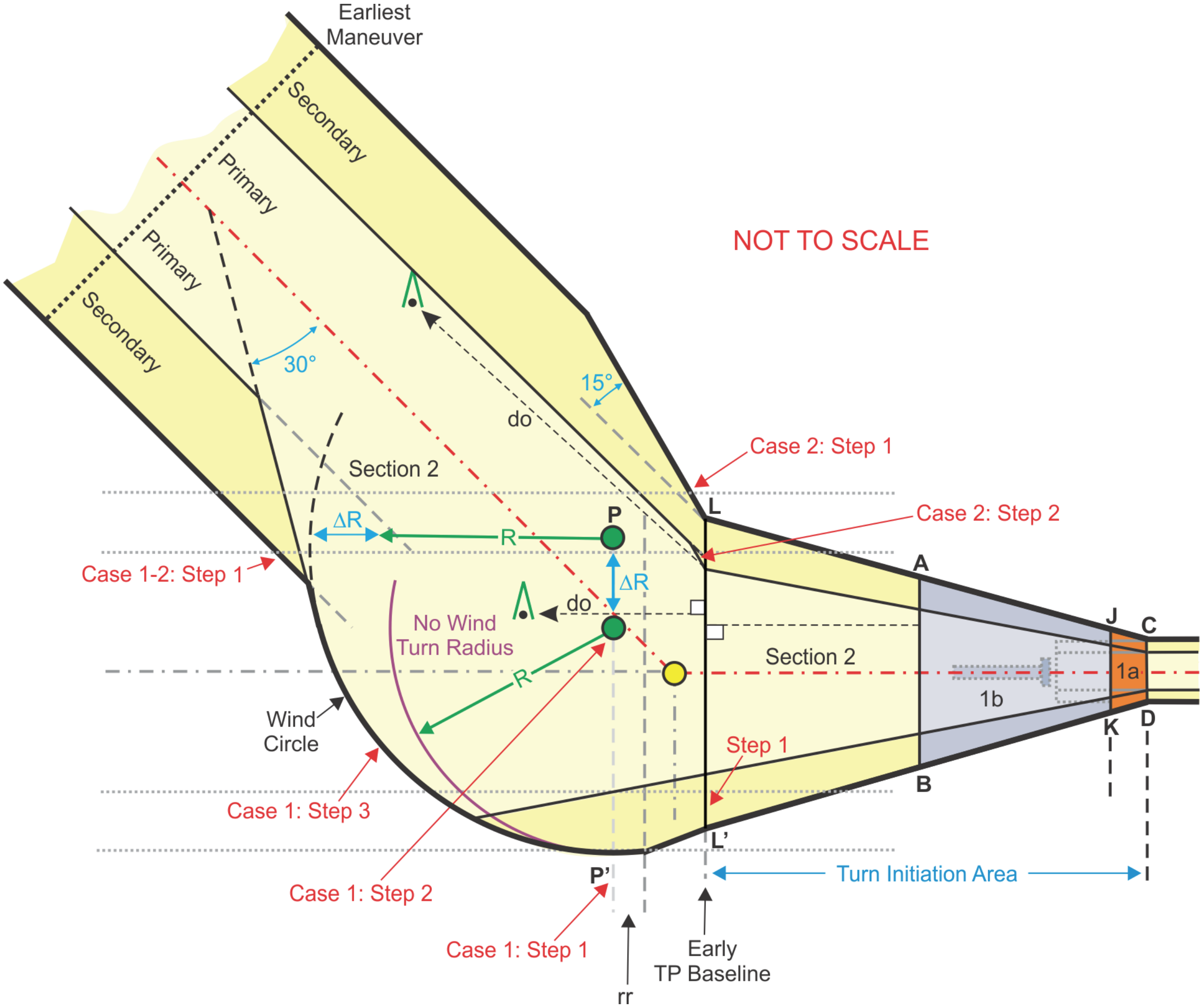


Figure 5-13. Turn at Waypoint (FO), 90°

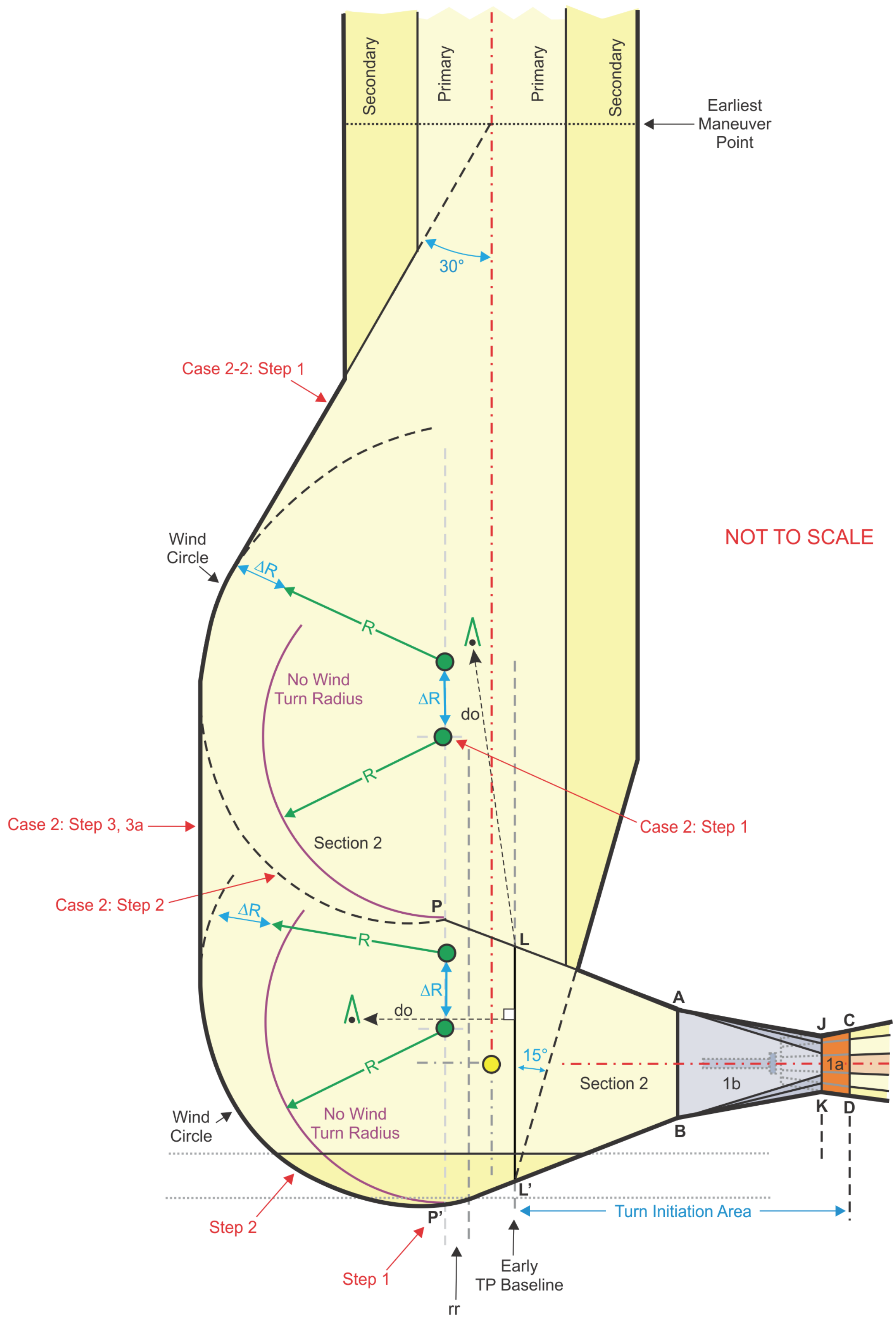
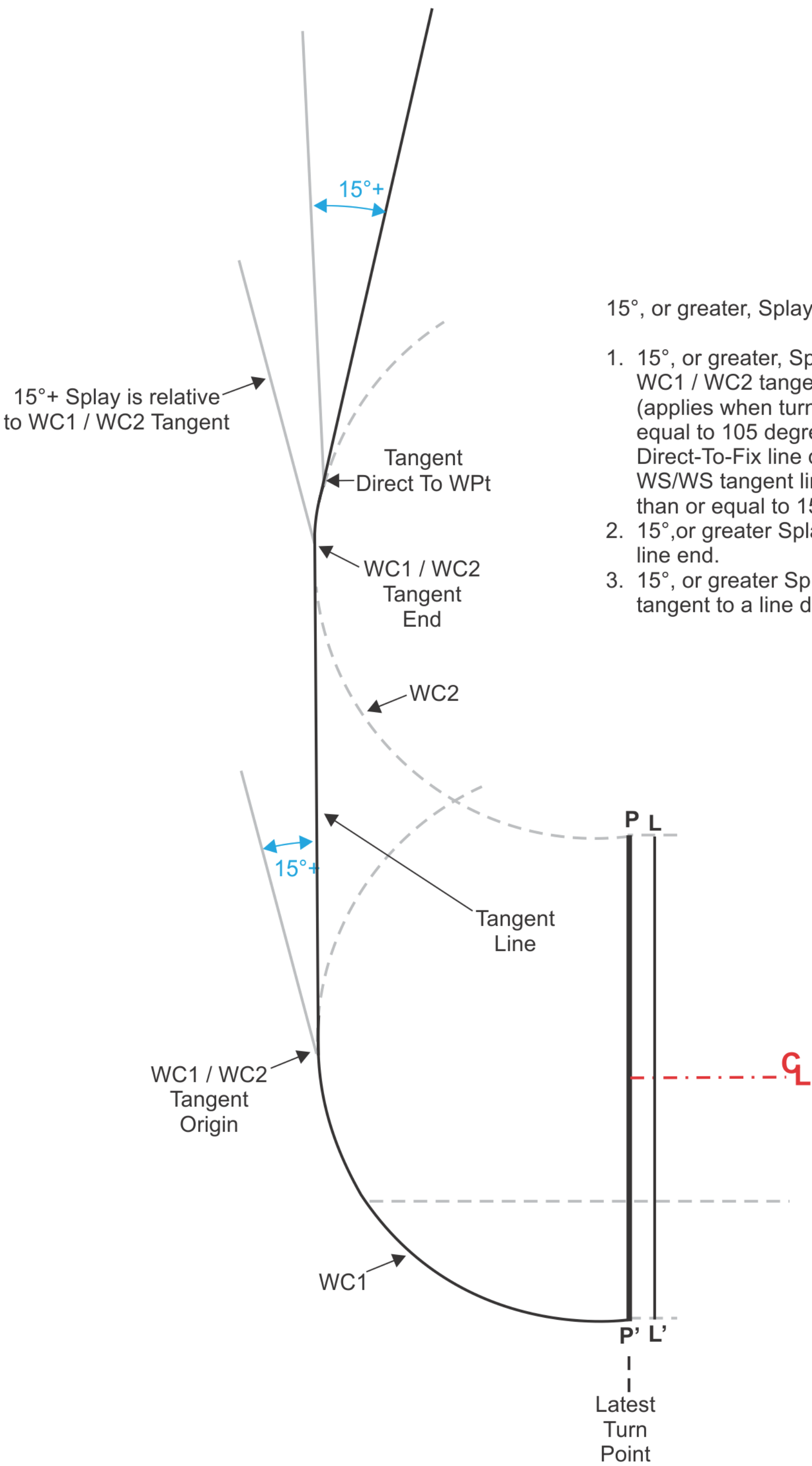


Figure 5-14A. WS Outer Boundary Connections



15°, or greater, Splay options:

1. 15°, or greater, Splay from WC1 / WC2 tangent line origin, (applies when turn is less than or equal to 105 degrees, or when Direct-To-Fix line differs from WS/WS tangent line less than or equal to 15 degrees) .
2. 15°,or greater Splay from WC/WC tangent line end.
3. 15°, or greater Splay from Point WC is tangent to a line direct to the WPt.

Figure 5-14B. WS1 Outer Boundary Connection

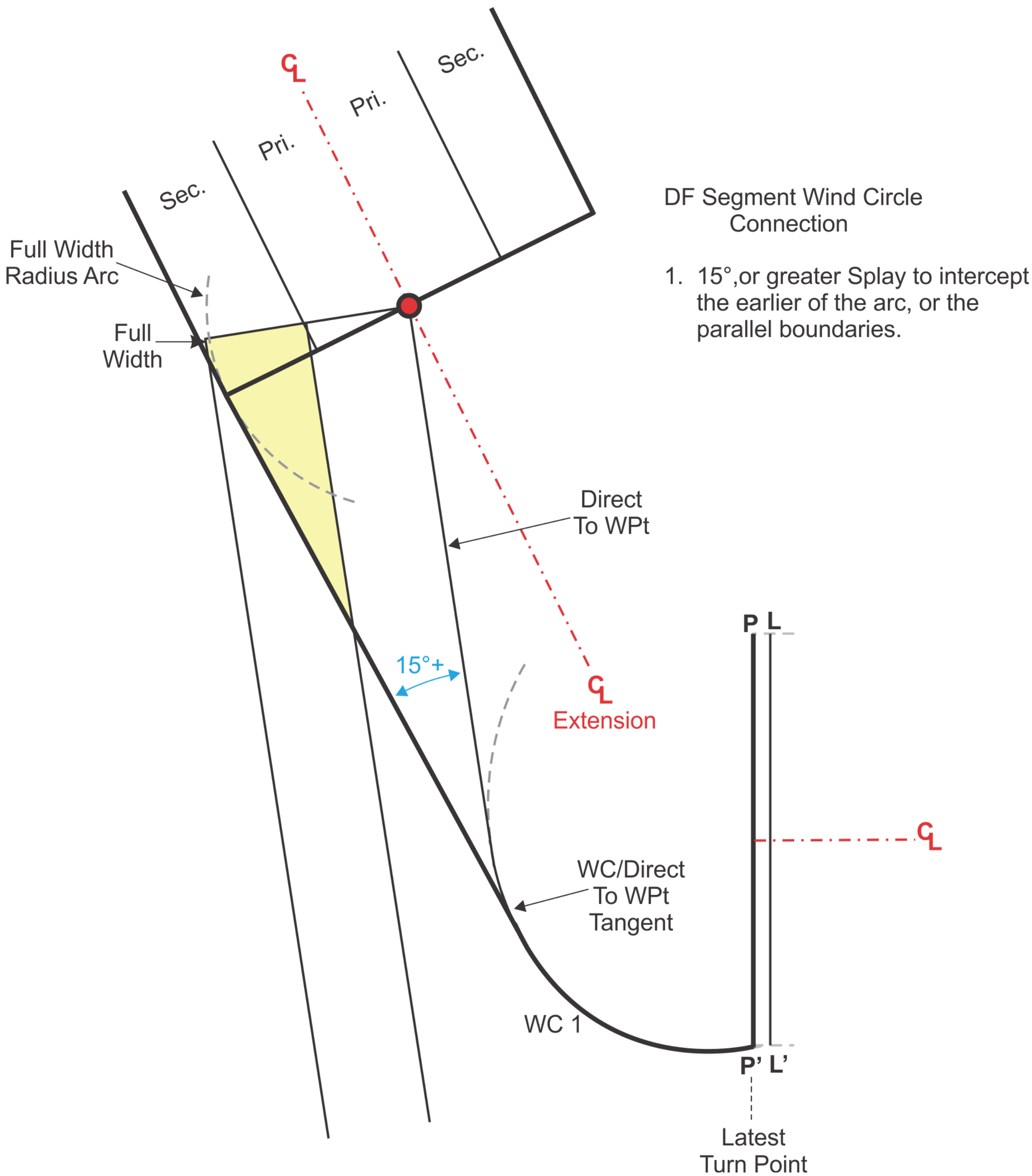
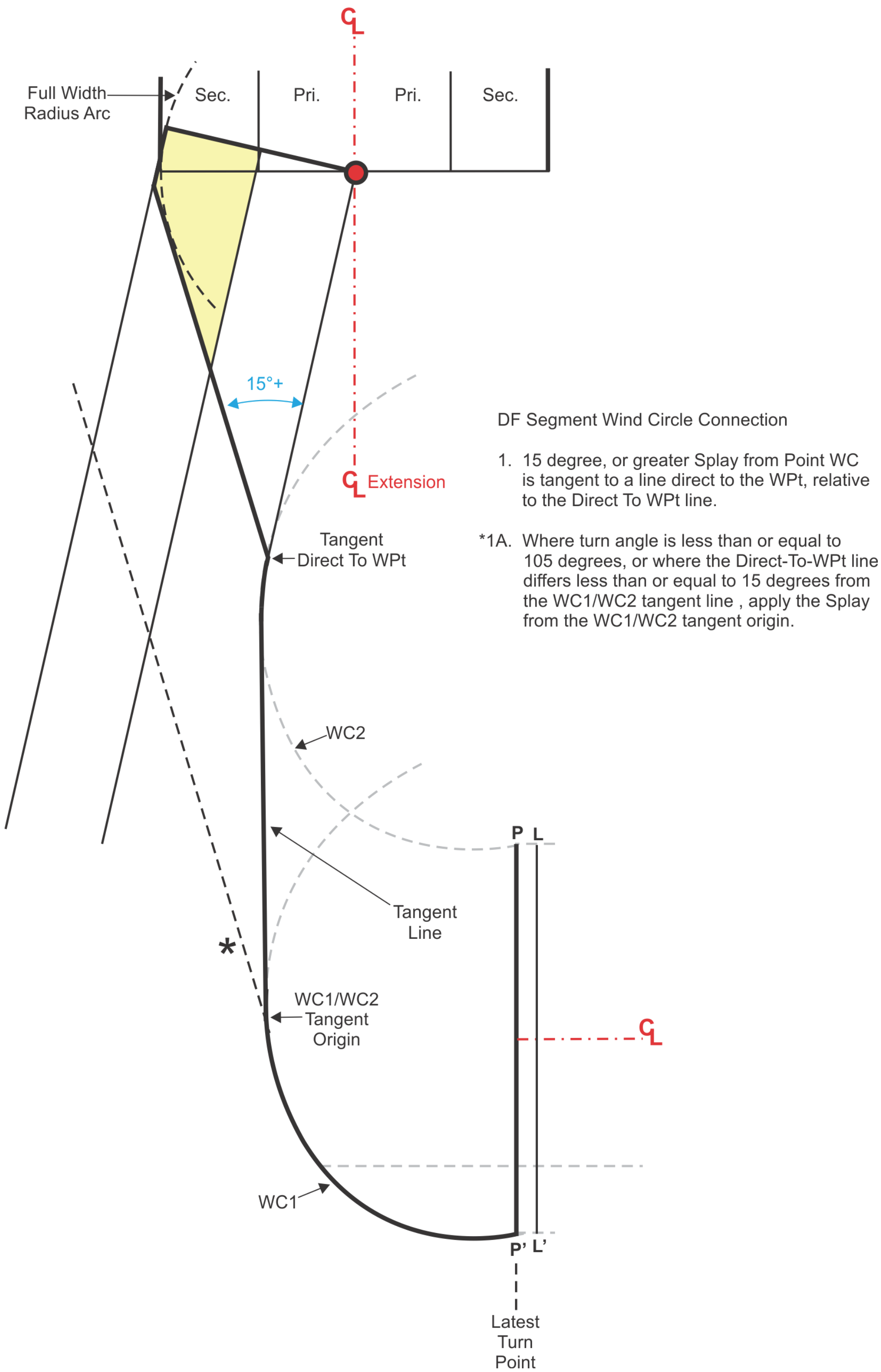


Figure 5-14C. WS Outer Boundary Connection (Multiple)



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