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

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United States Standard for

Performance Based Navigation (PBN)

Volume 1

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.

- **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.

- 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.

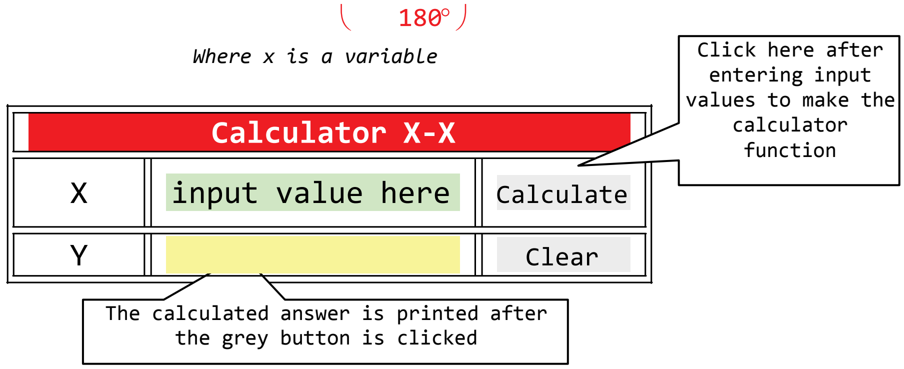
The feeder, initial, intermediate, final, and missed approach criteria described in this order supersede the other publications listed above. Application of Volume 4, TAA is encouraged in approach procedure design. The feeder criteria in Volume 6, chapter 1, paragraph 1.7 may be used to support RNAV 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.

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 <u>only</u> 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 **<u>documenting</u>** data expressed numerically. This standard applies to the documentation of final results only;

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 $\text{atan}(a)$ indicates the arc tangent of "a"

$\sin(a)$ indicates the sine of "a"
$\sin^{-1}(a)$ or $asin(a)$ indicates the arc sine of "a"
$\cos(a)$ indicates the cosine of "a"
$\cos^{-1}(a)$ or $acos(a)$ 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 2.71828182845904523536028747135266249775 7…

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.,

$5-3\times2=-1$ because multiplication takes precedence over subtraction

$(5-3)\times2=4$ 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

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

$\sin\left(\frac{30^\circ}{0.5}\right)=0.8660254$ 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.**

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.**

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).

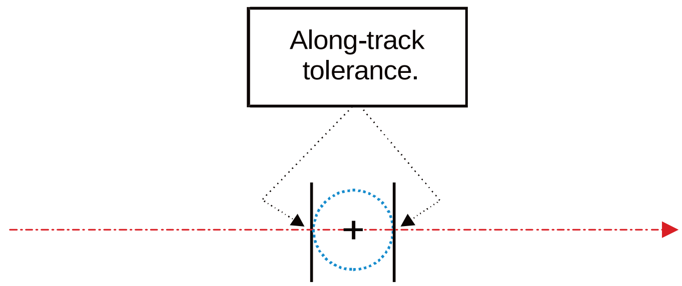
2.1.3 c. (2) Elevations (vertical dimension). Evaluate obstacles, terrain, and airport data using their elevation relative to their orthometric height above the geoid (for our purposes, MSL) referenced to the NAVD-88 vertical datum. The elevations of OCSs are determined spherically relative to their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

GPS or DME/DME/IRU	**En Route** *STARs, DPs, Feeder, Initial, Intermediate, Missed Approach (> 30 NM)*	2.0 NM
	Terminal *STARs, DPs, Feeder, Initial, Intermediate, Missed Approach (≤ 30 NM)*	1.0 NM
	Approach *(final)*	0.3 NM
WAAS* (LPV & LP)	**Approach** *(final)*	40 m

*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.

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).

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.

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.

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.

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.

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.

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.

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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Volume 1. General Guidance and Information

Appendix A. TERPS Standard Formulas for Geodetic Calculations

1.0 Purpose.

The ellipsoidal formulas contained in this document must be used in determining RNAV flight path (GPS, RNP, WAAS, LAAS) fixes, courses, and distance between fixes.

Notes:

Algorithms and methods are described for calculating geodetic locations (latitudes and longitudes) on the World Geodetic System of 1984 (WGS-84) ellipsoid, resulting from intersections of geodesic and non-geodesic paths. These algorithms utilize existing distance and azimuth calculation methods to compute intersections and tangent points needed for area navigation procedure construction. The methods apply corrections to an initial spherical approximation until the error is less than the maximum allowable error, as specified by the user.

Several constants are required for ellipsoidal calculations. First, the ellipsoidal parameters must be specified. For the WGS-84 ellipsoid, these are:

$$a = \text{semi-major axis} = 6,378,137.0 \text{ m}$$
$$b = \text{semi-minor axis} = 6,356,752.314245 \text{ m}$$
$$1/f = \text{inverse flattening} = 298.257223563$$

Note that the semi-minor axis is derived from the semi-major axis and flattening parameters using the relation $b = a(1 - f)$.

Second, an earth radius is needed for spherical approximations. The appropriate radius is the geometric mean of the WGS-84 semi-major and semi-minor axes. This gives

$$SPHERE\_RADIUS\ (r) = \sqrt{ab} = 6,367,435.679716 \text{ m}.$$

Perform calculations with at least 15 significant digits.

For the purpose of determining geodetic positions, perform sufficient iterations to converge within 1 cm in distance and 0.002 arc seconds in bearing.

2.0 Introduction.

The algorithms needed to calculate geodetic positions on the earth for the purpose of constructing and analyzing Terminal Instrument Procedures (TERPS) require the following geodetic calculation process some of which are illustrated in figure A-1:

Process 1: Find the destination latitude and longitude, given starting latitude and longitude as well as distance and starting azimuth (often referred to as the "direct" or "forward" calculation).

Process 2: Compute the geodesic arc length between two points, along with the azimuth of the geodesic at either point (often referred to as the "inverse" calculation).

Process 3: Given a point on a geodesic, find a second geodesic that is perpendicular to the given geodesic at that point.

Process 4: Given two geodesics, find their intersection point(s) (see label 4).

Process 5: Given two constant-radius arcs, find their intersection point(s) (see label 5).

Process 6: Given a geodesic and a separate point, find the point on the geodesic nearest the given point (see label 6).

Process 7: Given a geodesic and an arc, find their intersection point(s) (see label 7).

Process 8: Given two geodesics and a radius value, find the arc of the given radius that is tangent to both geodesics and the points where tangency occurs (see label 8).

Process 9: Given an arc and a point, determine the geodesic(s) tangent to the arc through the point and the point(s) where tangency occurs (see label 9).

Process 10: Given an arc and a geodesic, determine the geodesic(s) that are tangent to the arc and perpendicular to the given geodesic and the point(s) where tangency occurs (see label 10).

Process 11: Compute the length of an arc.

Process 12: Determine whether a given point lies on a particular geodesic.

Process 13: Determine whether a given point lies on a particular arc.
The following algorithms have been identified as required for analysis of TERPS procedures that use locus of points curves:

Process 14: Given a geodesic and a locus, find their intersection point.

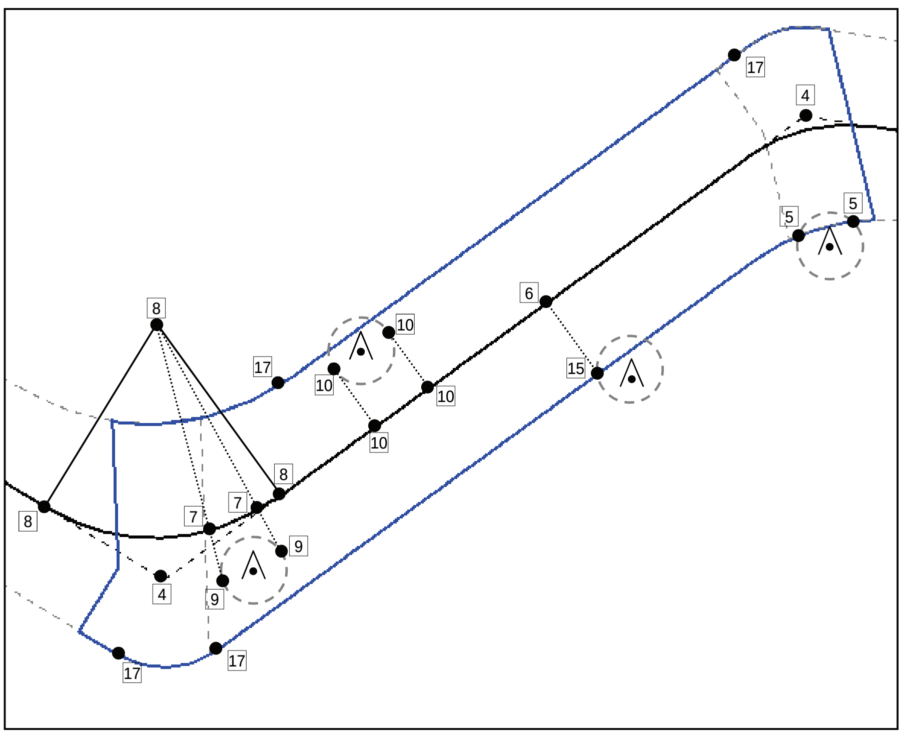
Process 15: Given a fixed-radius arc and a locus, find their intersection point(s) (see label 15).

Process 16: Given two loci, find their intersection.

Process 17: Given two loci and a radius, find the center of the arc tangent to both loci and the points of tangency (see label 17).

The algorithm prototypes and parameter descriptions are given below using a C-like syntax. However, the algorithm steps are described in pseudo-code to maintain clarity and readability.

Figure A-1.Typical Geodetic Constructions for TERPS



Numbers refer to the algorithm in the list above that would be used to solve for the point.

2.1 Data Structures.

2.1.1 Geodetic Locations.

For convenience, one structure is used for both components of a geodetic coordinate. This is referred to as an `LLPoint`, which is declared as follows using C syntax:

```
typedef struct {
        latitude;
        longitude;
    } LLPoint;
```

2.1.2 Geodesic Curves.

A geodesic curve is the minimal-length curve connecting two geodetic locations. Since the planar geodesic is a straight line, we will often informally refer to a geodesic as a "line." Geodesics will be represented in data using two `LLPoint` structures.

2.1.3 Fixed Radius Arc.

A geodetic arc can be defined by a center point and radius distance. The circular arc is then the set (or locus) of points whose distance from the center point is equal to the radius. If an arc subtends an angle of less than `360` degrees, then its start azimuth, end azimuth, and orientation must be specified. The orientation is represented using a value of `±1`, with `+1` representing a counterclockwise arc and `-1` representing a clockwise arc. The distance between the start and end points must be checked. If it is less than a predetermined tolerance value, then the arc will be treated like a complete circle.

2.1.4 Locus of Points Relative to a Geodesic.

A locus of points relative to a geodesic is the set of all points such that the perpendicular distance from the geodesic is defined by a continuous function $w(P)$ which maps each point P on the geodesic to a real number. For the purposes of procedure design, $w(P)$ will be either a constant value or a linear function of the distance from P to geodesic start point. In the algorithms that follow, a locus of points is represented using the following C structure:

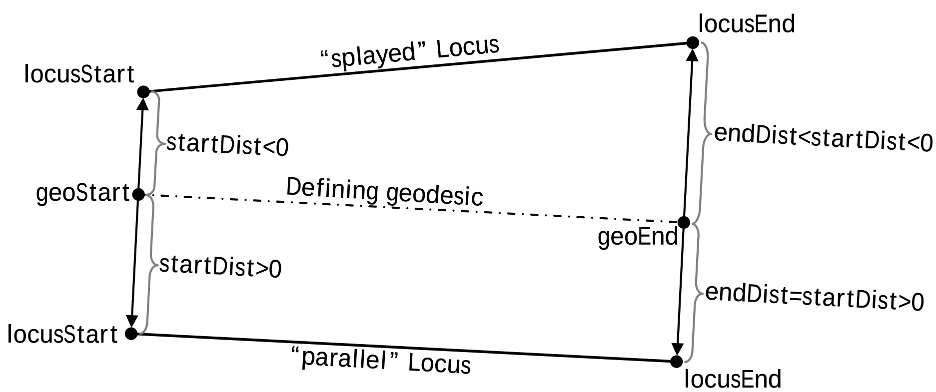
```
typedef struct {
  LLPoint geoStart;   /* start point of geodesic */
  LLPoint geoEnd;     /* end point of geodesic   */
  LLPoint locusStart; /* start point of locus    */
  LLPoint locusEnd;   /* end point of locus      */
  double startDist;   /* distance from geodesic  *
                       * to locus at geoStart    */
  double endDist;     /* distance from geodesic  *
                       * to locus at geoEnd      */
  int    lineType;    /* 0, 1 or 2               */
} Locus;
```

The `startDist` and `endDist` parameters define where the locus lies in relation to the defining geodesic. If `endDist=startDist`, then the locus will be described as being "parallel" to the geodesic, while if `endDist≠startDist`, then the locus is "splayed." Furthermore, the sign of the distance parameter determines which side of the geodesic the locus is on. The algorithms described in this paper assume the following convention: if the distance to the locus is positive, then the locus lies to the right of the geodesic; if the distance is negative, then the locus lies to the left. These directions are relative to the direction of the geodesic as viewed from the `geoStart` point. See figure A-2 for an illustration.

If memory storage is limited, then either the `startDist/endDist` or `locusStart/locusEnd` elements may be omitted from the structure, since one may be calculated from the other. However, calculating them once upon initialization and then storing them will reduce computation time.

The `lineType` attribute is used to specify the locus's extent. If it is set to `0` (zero), then the locus exists only between `geoStart` and `geoEnd`. If `lineType=1`, then the locus begins at `geoStart` but extends beyond `geoEnd`. If `lineType=2`, then the locus extends beyond both `geoStart` and `geoEnd`.

Figure A-2. Two Examples Loci Defined Relative To A Single Geodesic



3.0 Basic Calculations.

3.1 Iterative Approach.

For most of the intersection and projection methods listed below, an initial approximation is iteratively improved until the calculated error is less than the required accuracy. The iterative schemes employ a basic secant method, relying upon a linear approximation of the error as a function of one adjustable parameter.

To begin the iteration, two starting solutions are found and used to initialize a pair of two-element arrays. The first array stores the two most recent values of the parameter being adjusted in the solution search. This array is named `distarray` when the search parameter is the distance from a known point. It is named `crsarray` when the search parameter is an angle measured against the azimuth of a known geodesic. The second array (named `errarray` in the algorithms below) stores the error values corresponding to the two most recent parameter values. Thus, these arrays store a linear representation of the error function. The next solution in each iteration is found by solving for the root of that linear function using the `findLinearRoot` function:

```
    static double findLinearRoot(double* x, double* y,
                      long* err) {
  if (x[0] == x[1]) {
    /* function has duplicate x values, no root */
    return x[0];
  }
  else if (y[0] == y[1]) {
    if (y[0]*y[1] == 0.0) {
      return x[0];
    }
    /* duplicate y values in root function */
    return 0.5*(x[0]+x[1]);
  }
    return -y[0]*(x[1]-x[0])/(y[1]-y[0]) + x[0]
}
```

This function returns the value of the search parameter for which the linear error approximation is zero. The returned root is used as the next value in the adjustable parameter and the corresponding error value is calculated. Then the parameter and error arrays are updated and another new root is found.

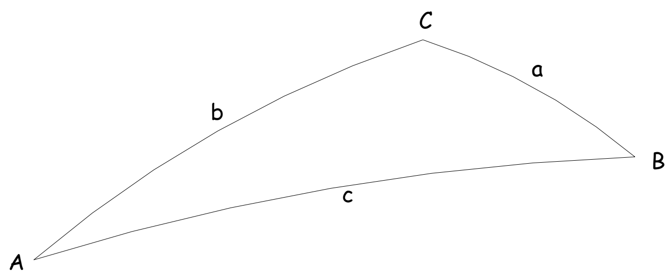
This iteration scheme works well for the algorithms described in this paper. Convergence is achieved very quickly because each starting solution is very close to the final solution, where the error is well approximated by a linear function.

3.2 Starting Solutions.

Starting solutions must be provided to start iterating toward a precise solution. Initial solutions may be found in all cases by using spherical triangles to approximate the geodetic curves being analyzed, and then solve for unknown distance and azimuth values using spherical trigonometry formulas.

3.2.1 Spherical Direction Intersect.

Given two points A and B and two bearings A to C and B to C, find C.



Run Inverse to find arc length from A to B and bearings A to B and B to A. Compute differences of bearings to find angles A and B of the spherical triangle ABC.

More than one valid solution may result. Choose the solution closest to the original points.

Apply the spherical triangle formulas to find the angle C and arc lengths from A to C and from B to C:

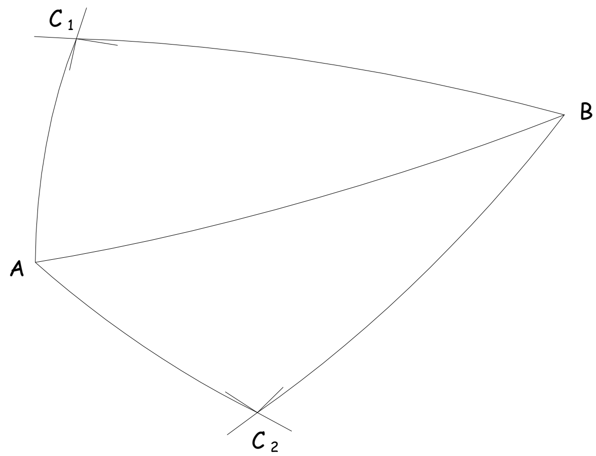
$$C = \cos^{-1}\left(-\cos(A)\cdot\cos(B) + \sin(A)\cdot\sin(B)\cos\left(\frac{c}{R}\right)\right),$$

$$a = R\cdot\cos^{-1}\left(\frac{\cos(A)+\cos(B)\cdot\cos(C)}{\sin(B)\cdot\sin(C)}\right),\ b = R\cdot\cos^{-1}\left(\frac{\cos(B)+\cos(A)\cdot\cos(C)}{\sin(A)\cdot\sin(C)}\right).$$

Note: If distances a or b result from a reciprocal bearing, assign appropriate negative sign(s).

Run Direct from A to find C. Use given bearing and computed length b.

3.2.2 Spherical Distance Intersection.



Given A, B and distances AC and BC, find C_1 and C_2.

Run Inverse to find length and bearings between A and B.

Use spherical triangles to find angles A =BAC_1 = BAC_2, B =ABC_1 = ABC_2, and C = BC_1A = BC_2A:

$$A = \cos^{-1}\left(\frac{\cos\left(\frac{a}{R}\right) - \cos\left(\frac{b}{R}\right)\cos\left(\frac{c}{R}\right)}{\sin\left(\frac{b}{R}\right)\sin\left(\frac{c}{R}\right)}\right),\ B = \cos^{-1}\left(\frac{\cos\left(\frac{b}{R}\right) - \cos\left(\frac{a}{R}\right)\cos\left(\frac{c}{R}\right)}{\sin\left(\frac{a}{R}\right)\sin\left(\frac{c}{R}\right)}\right),$$

and $C = \cos^{-1}\left(\frac{\cos\left(\frac{c}{R}\right) - \cos\left(\frac{a}{R}\right)\cos\left(\frac{b}{R}\right)}{\sin\left(\frac{a}{R}\right)\sin\left(\frac{b}{R}\right)}\right)$.

Run Direct from A to find C_1 and C_2.

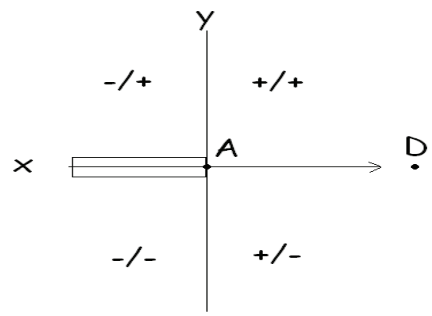
To compute the bearing from A to $C_{1,}$ start with the bearing from A to B and subtract angle A.

To compute the bearing from A to $C_{2,}$ start with the bearing from A to B and add angle A.

Use Inverse and spherical triangle formulas to get remaining bearings.

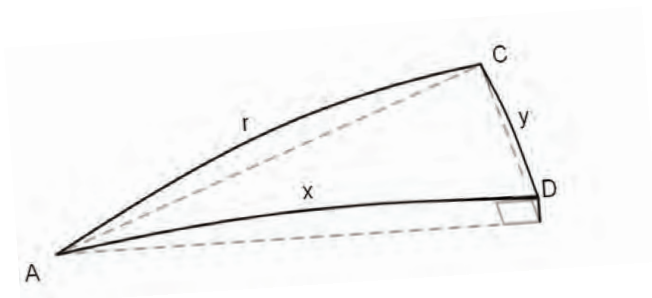
3.2.3 Spherical Tangent Point.

In both cases of the tangent point, distances are signed according to the following sign legend:



Where the arrow indicates the bearing from the first point A to the target point D.

3.2.4 Two Points and a Bearing Case.



Given two points, A and C, and a bearing from the first point (A). Find the point D along the given bearing extended which is closest to C.

Run Inverse to find length and bearings between A and C.

Find difference in bearings to compute angle A.

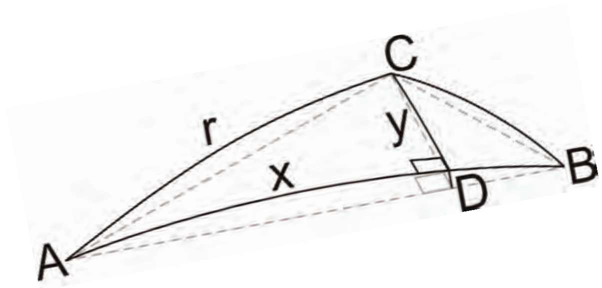
Use right spherical triangles to calculate y and x:

$$y = R\sin^{-1}\left(\sin(\frac{r}{R})\sin(A)\right),$$

$$x = R\cos^{-1}\left(\cos(\frac{r}{R})/\cos(\frac{y}{R})\right).$$

Run Direct from A to find D using given bearing and computed length x.

3.2.5 Given Three Points Case.



Given three points (A, B, C), find the point (D) on the geodesic line from the first two points which is the perpendicular foot from the third point.

Use Inverse to determine bearing from A to B.

Use Inverse to determine bearing and length from A to C.

Find the difference in bearings to determine angle A.

Use right spherical triangles to find the lengths x and y:

$$y = R\sin^{-1}\left(\sin(\frac{r}{R})\sin(A)\right),$$

$$x = R\cos^{-1}\left(\cos(\frac{r}{R})/\cos(\frac{y}{R})\right).$$

Use Direct to calculate D from A using the computed bearing from A to B and computed distance x.

3.3 Tolerances.

Two different convergence tolerances must be supplied so that the algorithms cease iterating once the error becomes sufficiently small. The first tolerance parameter is used in the forward and inverse routines; it is referred to as `eps` in the algorithm descriptions. The second parameter, labeled `tol`, is used in the intersection and projection routines to limit the overall error in the solution. Since the intersection and projection routines make multiple calls to the inverse and forward algorithms, the `eps` parameter should be several orders of magnitude smaller than the `tol` parameter to ensure that the iteration methods return correct results. Empirical studies have shown that `eps = 0.5e-13` and `tol = 1.0e-9` work well.

Finally, a maximum iteration count and convergence tolerances must be supplied to ensure that no algorithms can remain in an infinite loop if convergence is not reached. This parameter can be set by the programmer, but should be greater than five to ensure that all of the algorithms can reach convergence.

3.4 Direct and Inverse Algorithms.

The Direct and Inverse cases utilize formulae from T. Vincenty's, Survey Review XXIII, No. 176, April 1975: Direct and Inverse Solutions of Geodesics on the Ellipsoid with Application of Nested Equations.

Vincenty's notation is annotated below:

$a, b,$ major and minor semi axes of the ellipsoid.

$f,$ flattening $= \dfrac{a-b}{a}$.

$\phi,$ geodetic latitude, positive north of the equator.

$L,$ difference in longitude, positive east.

$s,$ length of the geodesic.

$\alpha_1, \alpha_2,$ bearings of the geodesic, clockwise from north; α_2 in the direction P_1P_2 produced.

$\alpha,$ bearing of the geodesic at the equator.

$u^2 = \dfrac{a^2 - b^2}{b^2}\cos^2 \alpha$.

$U,$ reduced latitude, defined by $\tan U = (1 - f)\tan\phi$.

$\lambda,$ difference in longitude on the auxiliary sphere.

$\sigma,$ angular distance P_1P_2, on the sphere.

$\sigma_1,$ angular distance on the sphere from the equator to P_1.

$\sigma_m,$ angular distance on the sphere from the equator to the midpoint of the line.

3.4.1 Vincenty's Direct Formula.

$$\tan\sigma_1 = \frac{\tan U_1}{\cos\alpha_1} \tag{1}$$

$$\sin\alpha = \cos U_1 \sin\alpha_1 . \tag{2}$$

$$A = 1 + \frac{u^2}{16384}\left\{4096 + u^2\left[-768 + u^2\left(320 - 175u^2\right)\right]\right\} \tag{3}$$

$$B = \frac{u^2}{1024}\left\{256 + u^2\left[-128 + u^2\left(74 - 47u^2\right)\right]\right\} \tag{4}$$

$$2\sigma_m = 2\sigma_1 + \sigma \tag{5}$$

$$\Delta\sigma = B\sin\sigma\left\{\cos\left(2\sigma_m\right) + \frac{1}{4}B\left[\cos\left(\sigma\right)\left(2\cos^2\left(2\sigma_m\right) - 1\right) - \frac{1}{6}B\cos\left(2\sigma_m\right)\left(4\sin^2\sigma - 3\right)\left(4\cos^2\left(2\sigma_m\right) - 3\right)\right]\right\} \tag{6}$$

$$\sigma = \frac{s}{bA} + \Delta\sigma \tag{7}$$

Equations (5), (6), and (7) are iterated until there is a negligible change in σ. The first approximation of σ is the first term of (7).

Note 1: For 1 cm accuracy, σ can change no more than `1.57e-009`.

$$\tan\phi_2 = \frac{\sin U_1 \cos\sigma + \cos U_1 \sin\sigma \cos\alpha_1}{\left(1 - f\right)\left[\sin^2\alpha + \left(\sin U_1 \sin\sigma - \cos U_1 \cos\sigma \cos\alpha_1\right)^2\right]^{\frac{1}{2}}} \tag{8}$$

$$\tan\lambda = \frac{\sin\sigma \sin\alpha_1}{\cos U_1 \cos\sigma - \sin U_1 \sin\sigma \cos\alpha_1} \tag{9}$$

$$C = \frac{f}{16}\cos^2\alpha\left[4 + f\left(4 - 3\cos^2\alpha\right)\right] \tag{10}$$

$$L = \lambda - \left(1 - C\right) f \sin\alpha\left\{\sigma + C\sin\sigma\left[\cos\left(2\sigma_m\right) + C\cos\sigma\left(2\cos^2\left(2\sigma_m\right) - 1\right)\right]\right\} \tag{11}$$

$$\tan\alpha_2 = \frac{\sin\alpha}{-\sin U_1 \sin\sigma + \cos U_1 \cos\sigma \cos\alpha_1} \tag{12}$$

The latitude is found by computing the arctangent of (8) and α_2 is found by computing the arctangent of (12).

3.4.2 Vincenty's Inverse Formula.

$\lambda = L$ (first approximation) (13)

$$\sin^2 \sigma = \left(\cos U_2 \sin \lambda\right)^2 + \left(\cos U_1 \sin U_2 - \sin U_1 \cos U_2 \cos \lambda\right)^2 \quad (14)$$

$$\cos \sigma = \sin U_1 \sin U_2 + \cos U_1 \cos U_2 \cos \lambda \quad (15)$$

$$\tan \sigma = \frac{\sin \sigma}{\cos \sigma} \quad (16)$$

$$\sin \alpha = \frac{\cos U_1 \cos U_2 \sin \lambda}{\sin \sigma} \quad (17)$$

$$\cos\left(2\sigma_m\right) = \cos \sigma - \frac{2 \sin U_1 \sin U_2}{\cos^2 \alpha} \quad (18)$$

λ is obtained by equations (10) and (11). This procedure is iterated starting with equation (14) until the change in λ is negligible. See Note 1.

$$s = bA\left(\sigma - \Delta\sigma\right) \quad (19)$$

Where $\Delta\sigma$ comes from equations (3), (4), and (6)

$$\tan \alpha_1 = \frac{\cos U_2 \sin \lambda}{\cos U_1 \sin U_2 - \sin U_1 \cos U_2 \cos \lambda} \quad (20)$$

$$\tan \alpha_2 = \frac{\cos U_1 \sin \lambda}{\cos U_1 \sin U_2 \cos \lambda - \sin U_1 \cos U_2} \quad (21)$$

The inverse formula may give no solution over a line between two nearly antipodal points. This will occur when λ, as computed by (11), is greater than π in absolute value. To find $\alpha_1, \alpha_2,$ compute the arctangents of (20) and (21).

The remainder of this appendix will assume the direct and inverse use the following named functions:

`Long WGS84Dest (LLPoint, origin, double course, double distance, LLPoint* dest, double eps)` returns an `LLPoint` representing the destination point, where the inputs are:

`LLPoint origin =` Starting `LLPoint` with lat/lon in radian

`Double course =` Azimuth of geodesic at origin in radians

`Double distance=` Distance to desired point (in `NM`)

`LLPoint* dest` = Reference to `LLPoint` that will be updated with lat/lon of destination

`Double eps` = Maximum error allowed in computation

`Long WGS84Inverse (LLPoint origin, LLPoint dest, double* crs, double* bcrs, double* dist, double eps)` returns course and distance where the inputs are:

`LLPoint origin` = Coordinates of starting point

`LLPoint dest` = Coordinates of destination point

`Double* crs` = Reference to double that will be updated with course at origin in radians

`Double* bcrs` = Reference to double that will be updated with reciprocal course at destination in radians

`Double* dist` = Reference to return value that will contain the distance between `origin` and `dest`

`Double eps` = Maximum error allowed in computation

3.5 Geodesic Oriented at Specified Angle.

In `TERPS` procedure design, it is often required to find a geodesic that lies at a prescribed angle to another geodesic. For instance, the end lines of an obstacle evaluation area (`OEA`) are typically projected from the flight path at a prescribed angle. Since the azimuth of a geodesic varies over the length of the curve, the angle between two geodesics must be measured by comparing the azimuth of each geodesic at the point where they intersect. The following pseudo-code represents an algorithm that will calculate the correct azimuth at any point on a geodesic described by its start and end points. This azimuth can easily be extended to find the azimuth of an intersecting geodesic at the point if the angle of intersection is known.

3.5.1 Input/Output.

`double WGS84GeodesicCrsAtPoint(LLPoint startPt, LLPoint endPt, LLPoint testPt, int length, double* startCrs, double* revCrs, double* distToPt, long* err, double tol, double eps)` returns a `double` representing the azimuth of the intersecting geodesic, where the inputs are:

`LLPoint startPt`	=	Coordinates of start point of given geodesic
`LLPoint endPt`	=	Coordinates of end point of geodesic
`LLPoint testPt`	=	Point at which course of geodesic is to be determined
`double* startCrs`	=	Azimuth of geodesic at `startPt` in radians
`double* revCrs`	=	Reciprocal azimuth of geodesic at `endPt` in radians
`double* distToPt`	=	Distance from `startPt` to `testPt` in `NM`
`double tol`	=	Accuracy tolerance for intersection calculation
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.5.2 Algorithm Steps.

STEP 1: Use the `WGS84PtIsOnLine` algorithm to check that `testPt` actually lies on geodesic defined by `startPt` and `endPt`.

STEP 2: Use Inverse algorithm to determine course and distance from `testPt` to `startPt`. Denote course as `crsToStart`.

STEP 3: Use Inverse algorithm to determine course and distance from `testPt` to `endPt`. Denote course as `crsToEnd`.

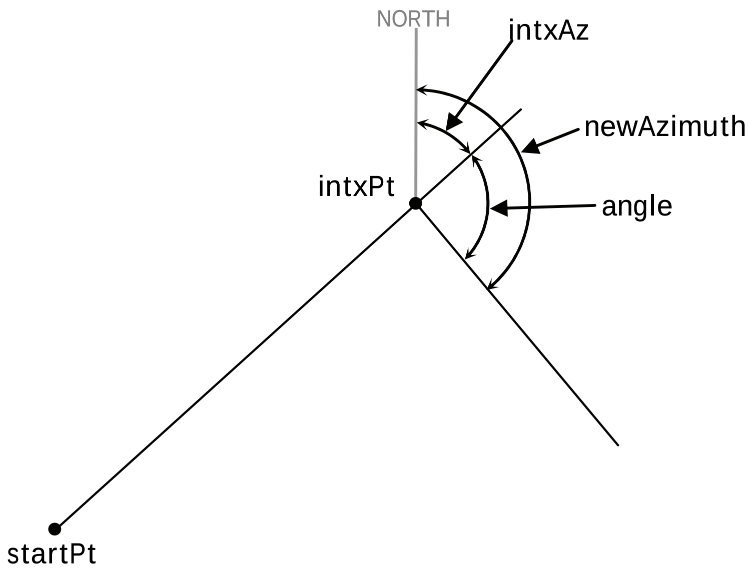
STEP 4: If `testPt` lies on geodesic between `startPt` and `endPt`, then the correct azimuth is `crsToEnd`.

STEP 5: If `testPt` lies on the geodesic beyond `endPt`, then the correct azimuth is `crsStart` + π.

STEP 6: Return the calculated azimuth.

Note that if angle is positive, then the new geodesic will lie to the right of the given geodesic (from the perspective of standing at the start point and facing toward the end point); otherwise, the new geodesic will lie to the left.

Figure A-3. Projecting A Geodesic Through A Point Along The Specified Azimuth



3.6 Determine If Point Lies on Geodesic.

This algorithm returns a true value if a point lies on and within the bounds of a given geodesic. The bounds of the geodesic are specified by two pieces of information: the end point coordinates and an integer length code. If the length code is set to `0`, then the geodesic is understood to exist only between its start and end points, so a value of true will be returned only if the test point also lies between the start and end points. If the length code is set to 1, then the geodesic is understood to extend beyond its end point to a distance of one half of earth's circumference from its end point. If the length code is set to `2`, then the geodesic is understood to extend beyond both the start and end points.

Note that this algorithm relies on the concept of equality for two `LLPoint` structures. This will be defined to mean that the distance between the two `LLPoints`, as calculated using the inverse algorithm, is less than `tol`.

3.6.1 Input/Output.

`int WGS84PtIsOnLine(LLPoint startPt, LLPoint endPt, LLPoint testPt, LineType lengthCode, double tol, double  eps)` returns an integer value indicating whether `testPt` lies on geodesic, where the inputs are:

`LLPoint startPt`	=	Geodetic coordinate of line start point
`LLPoint endPt`	=	Geodetic coordinate of line end point
`LLPoint testPt`	=	Geodetic coordinate of point to test

`LineType lengthCode`	=	Integer that specifies extent of line. `0`: geodesic exists only between `startPt` and `endPt`. `1`: geodesic extends beyond `endPt`. `2`: geodesic extends behind `startPt`.
`double tol`	=	Maximum difference allowed in distance
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.6.2 Algorithm Steps.

See figure A-4 for an illustration of the variables.

STEP 1: Use inverse algorithm to calculate the azimuth and distance from `startPt` to `endPt`. Denote these values by `crs12` and `dist12`, respectively.

STEP 2: Use `WGS84PtIsOnCrs` algorithm to determine if `testPt` lies on geodesic given by `startPt` and `endPt`:

1. Use inverse algorithm to calculate the distance from `startPt` to `testPt`. Denote this value by `tmpDist1Test`.
2. Use direct algorithm to project a point from `startPt`, along `crs12`, a distance equal to `tmpDist1Test`. Denote this point by `comparePt`.
3. Use `WGS84PointsAreSame` algorithm to determine if `testPt` is equal to `comparePt`.

STEP 3: Examine `error` to determine whether `testPt` lies on the geodesic within `tol` as follows:

1. If (`error` ≤ `tol`) then,
   a. If (`lengthCode > 0`) or (`dist13-dist12` ≤ `tol`) then,
      (1) `onLine = true`.
   b. Else,
      (1) `onLine = false`.
2. End if.
3. Else if (`lengthCode = 2`),

a. Use the direct algorithm to project point from `startPt`, along `crs12+π` a distance `dist13`. Again, denote this point again by `testPt2.`

b. Use the inverse algorithm to recalculate `error`, which is the distance from `testPt` to `testPt2.`

c. If (`error ≤ tol`) then `onLine = true`,

(1) Else `onLine = false`.

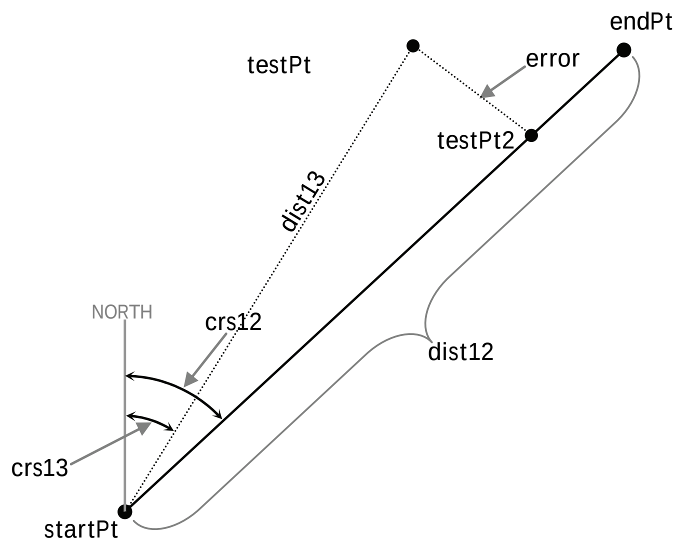
4. End if.

5. Else,

a. `onLine = false`.

6. End if.

Figure A-4. Entities For Testing Whether a Point Lies on a Geodesic



3.7 Determine If Point Lies on Arc.

This algorithm returns a non-zero (true) value if the sample point lies on and between the bounds of the given arc. The arc is defined by its center point, radius, start azimuth, end azimuth, and orientation. A positive orientation parameter indicates that the arc is traversed in a counterclockwise sense, while a negative orientation parameter indicates that the arc is traversed clockwise. This algorithm is used in conjunction with the arc intersection functions (Algorithms 4.2, 4.3, and 4.6) to determine whether the computed intersections lie within the bounds of the desired arc.

3.7.1 Input/Output.

`int WGS84PtIsOnArc(LLPoint center, double radius, double startCrs, double endCrs, ArcDirection orientation, LLPoint testPt, double tol)` returns an integer value indicating whether `testPt` lies on arc, where the inputs are:

`LLPoint center`	=	Geodetic coordinates of arc center
`double radius`	=	Arc radius
`double startCrs`	=	True azimuth from center to start of arc
`double endCrs`	=	True azimuth from center to end of arc
`ArcDirection orientation`	=	Orientation of the arc [+`1` for counter-clockwise; -`1` for clockwise]
`LLPoint testPt`	=	Geodetic coordinate of point to test
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.7.2 Algorithm Steps.

See figure A-5 for an illustration of the variables.

STEP 1: Use inverse algorithm to calculate distance and azimuth from center to `testPt`. Denote values as `dist` and `crs`, respectively.

STEP 2: If `(abs(dist-radius) > tol)` then `testPt` is not correct distance from center,

a. `onArc = false`.

STEP 3: Else,

a. Use Algorithm 6.0 – Calculate `Angular Arc Extent` to calculate the angle subtended by the full arc. Denote this value by `arcExtent`.

b. If `(arcExtent = 360°)` then,

(1) `onArc = true.`

c. Else,

(1) Use the inverse algorithm to calculate the azimuth from center to `testPt`. Denote this value by `testCrs`.

(2) Use Algorithm 6.0 - Calculate `Angular Arc Extent` to calculate the angle subtended by and arc starting at `startCrs`, but ending at `testCrs`, with the same `orientation`. Denote this value by `subExtent`.

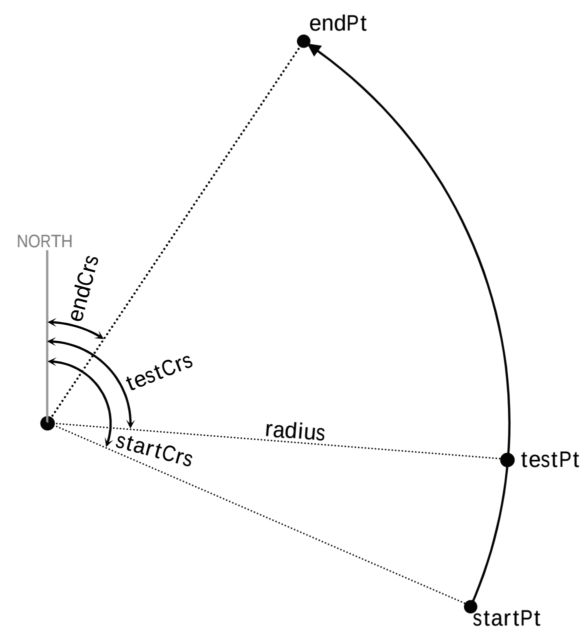
(3) If `(-.002 ≤ subExtent ≤ arcExtent +.002)` then traversing arc from `startCrs` to `endCrs`, one would encounter `testPt`, so it must lie on arc,

(a) `onArc = true`.

d. End if.

STEP 4: End if.

Figure A-5. Entities for Testing Whether a Point Lies on an Arc



3.8 Calculate Length of Fixed Radius Arc.

A fixed radius arc on an ellipsoid does not generally lie in a plane. Therefore, the length of the arc cannot be computed using the usual formula for the circumference of a circle. The following algorithm takes the approach of dividing the arc into many sub-arcs. Three points are then calculated on each sub-arc. Since any three points in space uniquely determine both a plane and an arc, the three points on each sub-arc are used to calculate the radius and subtended angle of the planar arc that contains all three points. The length of the approximating planar arc is then calculated for each sub-arc. The sum of the sub-arc lengths approaches the length of the original arc as the number of sub-arc increases (and each sub-arc's length decreases).

A simpler method that is sufficiently accurate for arcs with radius less than about `300` nautical miles (`NM`) is described in section 6.4.

3.8.1 Input/Output.

`double WGS84DiscretizedArcLength (LLPoint center, double radius, double startCrs, double endCrs, int orient, int *n, double tol)` returns a double precision value representing the length of the arc, where the inputs are:

`LLPoint center`	=	Geodetic coordinates of arc center
`double radius`	=	Arc radius
`double startCrs`	=	True azimuth from center to start of arc
`double endCrs`	=	True azimuth from center to end of arc
`int orient`	=	Orientation of the arc [+`1` for counter-clockwise; `-1` for clockwise]
`int *n`	=	Reference to integer used to return number of steps in discretized arc
`double tol`	=	Maximum allowed error
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.8.2 Algorithm Steps.

See figure A-6 for an illustration of the variables.

<u>STEP 1</u>: Set initial number of sub-arcs to use. The fixed value `n` = `16` has been found through trial-and-error to be a good starting value. Alternatively, the initial

value of n may be calculated based on the arc's subtended angle and its radius (i.e., its approximate arc length).

STEP 2: Convert `center` point to Earth-Centered, Earth-Fixed (ECEF) coordinates, `v0` according to Algorithm 6.1.

STEP 3: Compute subtended angle, `subtAngle`, using Algorithm 6.0.

STEP 4: Set iteration count, `k = 0`.

STEP 5: Do while `k = 0` or ((`error > tol`) and (`k` ≤ `maximumIterationCount`)):

a. Calculate subtended angle of each sub-arc, `dtheta = subtAngle/n`.

b. Use direct algorithm from `center`, using `startCrs` and distance `radius`, to project start point of arc. Denote this point by `p1`.

c. Convert `p1` to `ECEF` coordinates. Denote this vector by `v1`.

d. Initialize `arcLength = 0`.

e. For `i = 0` to `n`:

(1) Compute azimuth from arc center to end point of sub-arc number `i: theta = startCrs + i*dtheta.`

(2) Use direct algorithm from `center`, using azimuth `theta+0.5*dtheta` and distance `radius`, to project middle point of sub-arc. Denote this point by `p2`.

(3) Convert `p2` to `ECEF` coordinate `v2`.

(4) Use direct algorithm from `center`, using azimuth `theta+dtheta` and distance `radius`, to project endpoint of sub-arc. Denote this point by `p3`.

(5) Convert `p3` to `ECEF` coordinate `v3`.

(6) Subtract `v2` from `v1` to find chord vector between `p1` and `p2`. Denote this vector by `chord1`. Compute `x1 = |chord1|`.

(7) Subtract `v2` from `v3` to find chord vector between `p3` and `p2`. Denote this vector by `chord2`. Compute `x2 = |chord2|`.

(8) Compute dot product of `chord1` and `chord2`. Denote this value as `d`.

(9) Use the following calculation to compute the length `L` of the sub-arc (see figure A-7):

(a) `xi = d/(x1*x2)`

(b) `sigma = sqrt(1-xi^2)`

(c) `R = (x2*sqrt((x1/x2 - xi)^2 + sigma^2))/(2*sigma)`

(d) `A = 2(π - arccos(xi))`

(e) `L = R*A`

$$\xi = \frac{d}{x_1 x_2}$$
$$\sigma = \sqrt{1-\xi^2}$$
$$R = \frac{x_2\sqrt{\left(x_1/x_2 - \xi\right)^2 + \sigma^2}}{2\sigma}$$
$$A = 2\left(\pi - \cos^{-1}\xi\right)$$
$$L = R \cdot A$$

Note that since the arc length is a planar (not geodetic) calculation, the subtended angle `A` is not equal to `dtheta`.

(10) Add `L` to cumulative `length` to get total length of sub-arcs through sub-arc number `i: length = length + L`.

f. End for loop.

g, Compute error, which is the change in length calculation between this iteration and the last: `error = abs(length – oldLength)`.

h. Increment the iteration count: `k = k+1`.

i. Double the number of sub-arcs: `n = 2*n`.

j. Save the current length for comparison with the next iteration: `oldLength = length`.

STEP 6: End while loop.

STEP 7: Return `length`.

Figure A-6. Calculating Arc Length

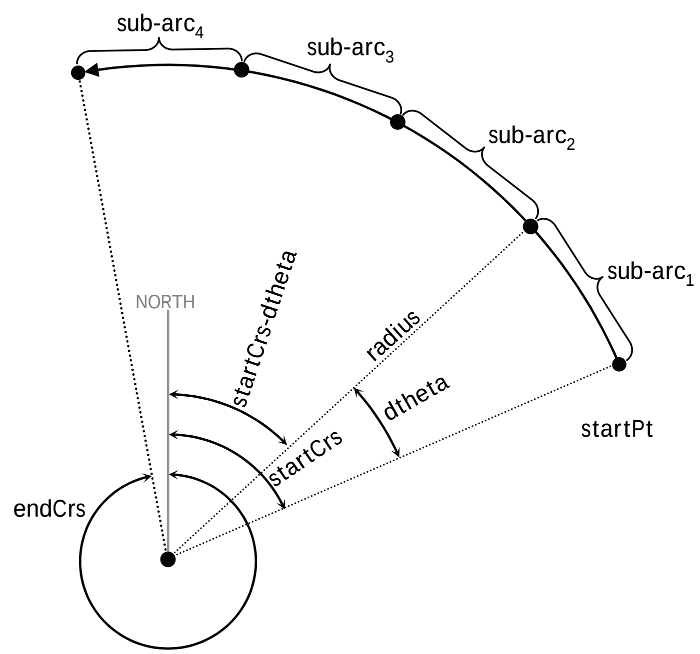
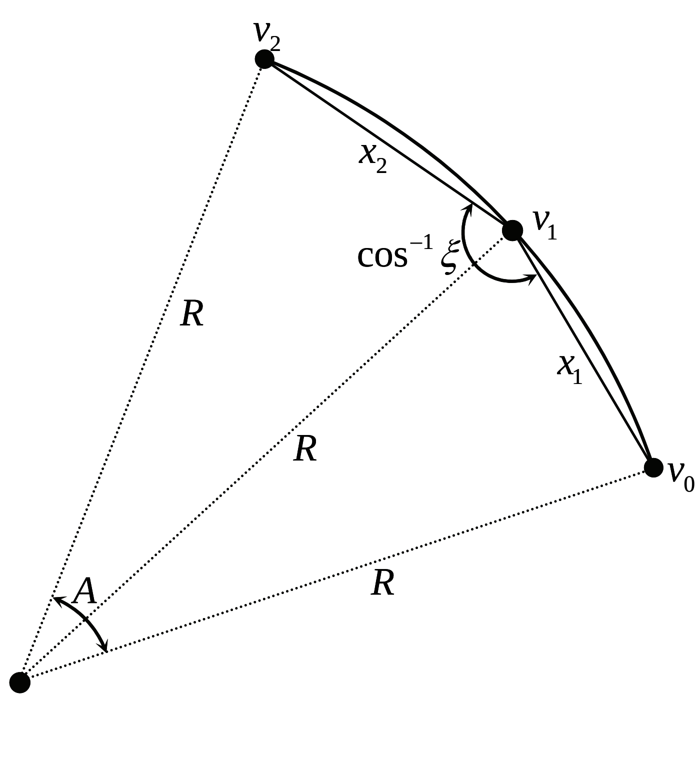


Figure A-7. Calculating the Sub-Arc Length



3.9 Find Distance from Defining Geodesic to Locus.

When computing a position on a locus of points, it is necessary to solve for the distance from the defining geodesic to the locus. This distance is constant if the locus is designed to be "parallel" to the defining geodesic. However, it is necessary to allow the locus distance to vary linearly with distance along the geodesic, since in some cases the locus will splay away from the defining geodesic. To account for this, we have included `startDist` and `endDist` attributes in the `Locus` structure defined above. For a given point on the geodesic (or given distance from the geodesic start point), the distance to the locus can then be calculated.

The two algorithms described below carry out the computation of locus distance for different input parameters. If the distance from the geodesic start point to the point of interest is known, then `WGS84DistToLocusD` may be used to calculate the locus distance. If instead a point on the defining geodesic is given, the `WGS84DistToLocusP` may be used. The latter algorithm simply computes the distance from the geodesic start point to the given point and then invokes the former algorithm. Therefore, steps are described for `WGS84DistToLocusD` only.

3.9.1 Input/Output.

`double WGS84DistToLocusD (Locus loc, double distance)`
returns the distance from the defining geodesic to the locus at the given distance from `loc.geoStart`, where the inputs are:

`Locus loc`	=	Locus of interest
`double distance`	=	Distance from locus start point to point where distance is to be computed

`double WGS84DistToLocusP (Locus loc, LLPoint geoPt, double *faz, double tol, double eps)` returns the distance from the defining geodesic to the locus at the given point, where the inputs are:

`Locus loc`	=	Locus of interest
`LLPoint geoPt`	=	Point on defining geodesic
`double *faz`	=	Pointer used to return forward azimuth of geodesic at `geopt`. This is needed if `geopt` is not between `geoStart` and `geoEnd`.
`double tol`	=	Maximum allowable error
`double eps`	=	Convergence parameter for forward/inverse algorithm

3.9.2 Algorithm Steps.

The following steps are followed if the `distance` from `loc.geoStart` is given. If a point on the geodesic (`geoPt`) is given instead, then first use the inverse algorithm to compute the `distance` from `geoPt` to `loc.geoStart` and then follow the following steps (note that `distance` must be signed negative if the locus's line type is `2` and `geoPt` is farther from `geoEnd` than it is from `geoStart`):

STEP 1: Use the inverse function to compute the length of the locus's defining geodesic. Denote this value as `geoLen`.

STEP 2: If (`geoLen = 0`) then `distToLoc = 0.0`.

STEP 3: Else.

$$\texttt{distToLoc=loc.startDist+}\frac{\texttt{distance}}{\texttt{geoLen}}\texttt{*}\left(\texttt{loc.endDist-loc.startDist}\right)$$

STEP 4: End if.

STEP 5: Return `distToLoc`.

3.10 Project Point on Locus from Point on Defining Geodesic.

Given a point on the defining geodesic, this algorithm computes the corresponding point on the locus.

3.10.1 Input/Output.

`LLPoint WGS84PtOnLocusP (Locus loc, LLPoint geoPt, LLPoint* ptonloc, double* perpCrs, double tol, double eps)` returns the point on the locus that is abeam the given point, where the inputs are:

`Locus loc`	=	Locus of Interest
`LLPoint geoPt`	=	Point on defining geodesic
`LLPoint* ptonloc`	=	Pointer to `LLPoint`, updated with coordinates of point on locus abeam given point.
`double* perpCrs`	=	Pointer to double, updated with azimuth from point on geodesic to point on locus.
`double tol`	=	Maximum allowable error
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.10.2 Algorithm Steps.

STEP 1: Use Algorithm 3.9 (with point input) to determine the distance from `geoPt` to the locus. Denote this distance as `distp`.

STEP 2: If (`distp = 0`) return `geoPt`.

STEP 3: Use the inverse algorithm to compute the course from `geoPt` to the start point of the defining geodesic. Denote this value as `fcrs`.

STEP 4: If (`distp > 0.0`) then the locus lies to the right of the geodesic. Let `*perpCrs = fcrs + π/2`.

STEP 5: Else, the locus lies to the left of the geodesic. Let

`*perpCrs = fcrs - π/2`.

STEP 6: End if.

STEP 7: Use the direct algorithm to project a point along `*perpCrs`, distance `abs(distp)` from `geoPt`. Denote the point as `ptonLoc`.

STEP 8: Return `ptonLoc`.

3.11 Determine If Point Lies on Locus.

This algorithm compares the position of a given point with the position of the corresponding point on the locus. The corresponding point on the locus is found by projecting the given point onto the locus's defining geodesic curve, computing the correct distance from there to the locus, and then projecting a point at that distance perpendicular to the geodesic. If distance from the corresponding point to the given point is less than the error tolerance, then a reference to the projected point on the geodesic is returned. Otherwise a null reference is returned.

An alternative implementation could simply return true or false, rather than references. However, it is more efficient to return the projected point as this is often needed in subsequent calculations.

3.11.1 Input/Output.

`int WGS84PtIsOnLocus (Locus loc, LLPoint testPt, LLPoint* ptOnGeo, double  tol, double eps)` returns a reference to the projection of `testPt` on the locus's defining geodesic if `testPt` lies on the locus and NULL otherwise, where the inputs are:

`Locus loc`	=	Locus of Interest
`LLPoint testPt`	=	Point to test against locus
`LLPoint* ptOnGeo`	=	Pointer to `LLPoint`, updated with point on defining geodesic abeam the given point on the locus.
`double tol`	=	Maximum allowable error
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.11.2 Algorithm Steps.

See figure A-8 for an illustration of the variables.

STEP 1: If `testPt` is the same as `loc.geoStart` or `loc.geoEnd` then return a reference to `ptOnGeo` containing the appropriate point.

STEP 2: Use Algorithm 5.1 to project `testPt` onto the locus's defining geodesic. Denote the projected point as `ptOnGeo`.

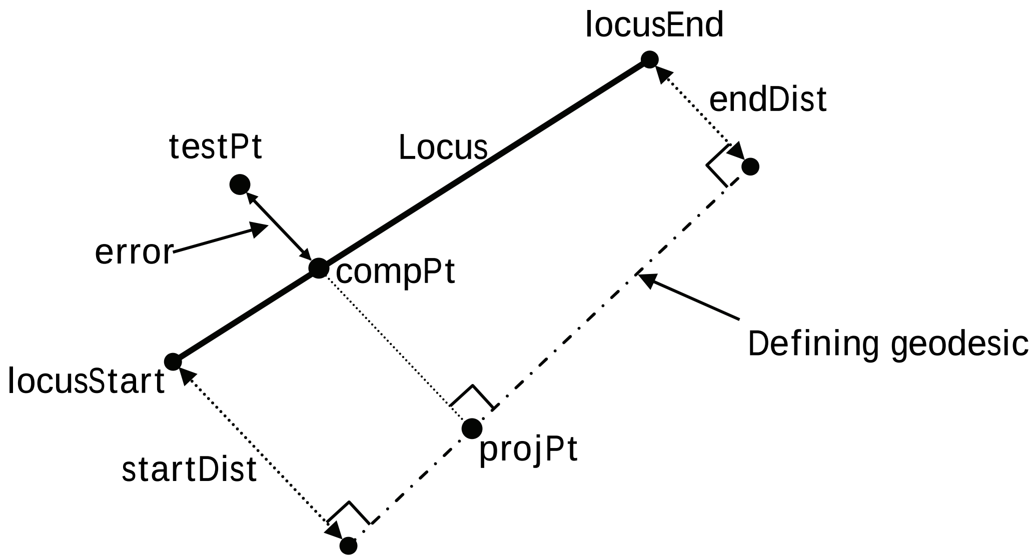
STEP 3: Use Algorithm 3.6 to determine whether `ptOnGeo` lies on the locus's defining geodesic. This will account for an infinite or semi-infinite locus. If it does not, then return `0` (false).

STEP 4: Use the Inverse Algorithm to find the course between `loc.geoStart` and `testPt`. Use this course to determine which side of the locus `testPt` falls. Apply the appropriate sign to this distance, `distFromPoint`.

STEP 5: Use Algorithm 3.9 to calculate the correct expected locus distance, `locDist`.

STEP 6: If `abs(distFromPoint - locDist) <= tol`, then the point is on the locus. Return a reference to the projection on the defining geodesic.

Figure A-8. Locating a Point Relative to a Locus



3.12 Compute Course of Locus.

This algorithm is analogous to the inverse algorithm for a geodesic. It is used by other locus algorithms when the direction of the locus is needed.

3.12.1 Input/Output.

`double WGS84LocusCrsAtPoint (Locus loc, LLPoint testPt, LLPoint* geoPt, double* perpCrs, double tol)` returns the course of the locus at the given point. Also sets values of calculation byproducts, including the corresponding point on the locus's geodesic and the course from the given point toward the geodesic point, where the inputs are:

`Locus loc`	=	Locus of Interest
`LLPoint testPt`	=	Point at which course will be calculated
`LLPoint* geoPt`	=	Projection of `testPt` on defining geodesic
`double* perpCrs`	=	Course for `testPt` to `geoPt`
`double tol`	=	Maximum allowable error
`double eps`	=	Convergence parameter for forward/inverse algorithms

3.12.2 Algorithm Steps.

See figure A-9 for an illustration of the variables.

STEP 1: Use Algorithm 3.11 to determine whether `testPt` lies on `loc`. This same step will return a reference to the projection of `testPt` onto the defining geodesic. Denote this reference as `geoPt`.

STEP 2: If (`geoPt = NULL`), then `testPt` is not a valid point at which to calculate the locus's course. Return `-1.0`. (Valid course values are in the range $[0, 2\pi]$.)

STEP 3: Use the inverse algorithm to calculate the course and distance from `testPt` to `geoPt`, denoted by `perpCrs` and `perpDist`, respectively.

STEP 4: Use Algorithm 3.9 to calculate `distToLoc`, the distance from the geodesic to the locus at `geoPt`. This step is required to determine which side of the geodesic the locus lies on because `perpDist` will always be positive.

STEP 5: Calculate the slope of the locus relative to the geodesic:
$\texttt{slope} = (\texttt{loc.endDist} - \texttt{loc.startDist}) / \texttt{geoLen}$

STEP 6: Convert the slope to angular measure in radians
$\texttt{slope} = \texttt{atan}(\texttt{slope})$.

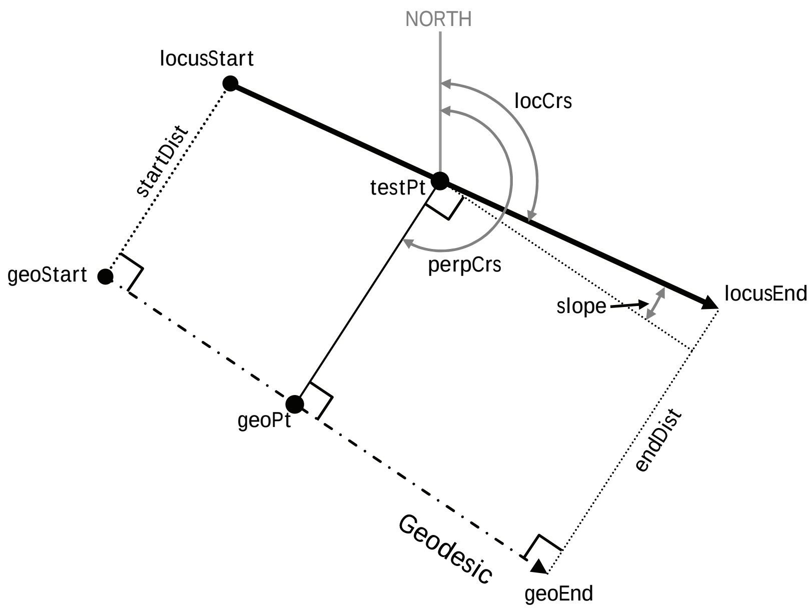
STEP 7: Adjust the value of the perpendicular course by `slope`. This accounts for how the locus is approaching or receding from the geodesic
$\texttt{perpCrs} = \texttt{perpCrs} + \texttt{slope}$.

STEP 8: If (`distToLoc < 0`), then `testPt` lies to the left of the geodesic, so `perpCrs` points to the right of the locus's course:
$\texttt{locCrs} = \texttt{perpCrs} - \pi/2$

STEP 9: Else, `testPt` lies to the right of the geodesic so `perpCrs` points to the left of the locus's course: $\texttt{locCrs} = \texttt{perpCrs} + \pi/2$

STEP 10: Return `locCrs`.

Figure A-9. Angle Used to Calculate the Course of a Locus



4.0 Intersections.

4.1 Intersection of Two Geodesics.

The following algorithm computes the coordinates where two geodesic curves intersect. Each geodesic is defined by its starting coordinates and azimuth at that coordinate. The algorithm returns a single set of coordinates if the geodesics intersect and returns a null solution (no coordinates) if they do not.

4.1.1 Input/Output.

`long WGS84CrsIntersect(LLPoint pt1, double crs13, double* crs31, double* dist13, LLPoint pt2, double crs23, double* crs32, double* dist23, LLPoint* intx, double tol)` returns a reference to an `LLPoint` structure that contains the intersection coordinates, where the inputs are:

`LLPoint pt1`	=	Start point of first geodesic
`double crs13`	=	Azimuth from `pt1` to intersection point
`double* crs31`	=	Reference to azimuth from intersection point to `pt1`
`double* dist13`	=	Reference to distance from `pt1` to intersection
`LLPoint pt2`	=	Start point of second geodesic

`double crs23`	=	Azimuth from `pt2` to intersection point
`double* crs32`	=	Reference to azimuth from intersection to `pt2`
`double* dist23`	=	Reference to distance between `pt2` and intersection point
`LLPoint* intx`	=	Reference to intersection point
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.1.2 Algorithm Steps.

See figure A-10 for an illustration of the variables.

STEP 1: Use inverse algorithm to calculate distance, azimuth and reverse azimuth from `pt1` to `pt2`. Denote these values by `dist12`, `crs21` and `crs12`, respectively. Run a check to see if `pt1` lies on the geodesic defined by `pt2` and `crs23` and if `pt2` lies on the geodesic defined by `pt1` and `crs13:`

a. If `pt1` falls on geodesic `2` and `pt2` falls on geodesic `1`.

(1) Return an error. Courses are collinear. There are infinite intersections.

b. If `pt1` falls on geodesic `2`.

(1) Return intersection = `pt1`.

c. If `pt2` falls on geodesic `1`.

(1) Return intersection = `pt2`.

STEP 2: Calculate the signed azimuth difference in angle between `crs12` and `crs13`, denoted by `angle1`.

STEP 3: Calculate the signed azimuth difference in angle between `crs21` and `crs23`, denoted by `angle2`.

STEP 4: If (`sin(angle1)*sin(angle2) < 0`) then the courses lay on opposite sides of the `pt1-pt2` line and cannot intersect in this hemisphere. Use reciprocal course so that the nearest intersection may be found:

a. If `abs(angle1) > abs(angle2),`

(1) angle1 = (crs13+π) - crs12.

b. Else,

(1) angle2 = crs21 - (crs23+π).

STEP 5: End if.

STEP 6: Locate the approximate intersection point, intx, using a spherical earth model. See the documents referenced in section 2.2 methods to accomplish this.

STEP 7: The following steps describe the function iterateLineIntersection which is called once the initial approximation, intx, of the line intersection is found. The purpose of the iterateLineIntersection function is to further refine the solution.

STEP 8: Use the inverse algorithm to calculate dist13, the distance from pt1 to intx.

STEP 9: Use the inverse algorithm to calculate dist23, the distance from pt2 to intx.

STEP 10: If dist13 < tol, then the intersection point is very close to pt1. Calculation errors may lead to treating the point as if it were beyond the end of the geodesic. Therefore, it is helpful to move pt1 a small distance along the geodesic:

1. Use the direct algorithm to move pt1 from its original coordinates 1 NM along azimuth crs13 + π.

2. Use the inverse algorithm to calculate the azimuth acrs13 for the geodesic from the new pt1.

STEP 11: Repeat steps 10, 10(1), and 10(2) for pt2 and crs23.

STEP 12: If (dist23 < dist13) then the intersection point is closer to pt2 than pt1. In this case, the iterative scheme will be more accurate if we swap pt1 and pt2.This is because we iterate by projecting the approximate point onto the geodesic from pt1 and then calculating the error in azimuth from pt2. If the distance from pt2 to the intersection is small, then small errors in distance can correspond to large errors in azimuth, which will lead to slow convergence. Therefore, we swap the points so that we are always measuring azimuth errors farther from the geodesic starting point:

a. `newPt = pt1`

b. `pt1 = pt2`

c. `pt2 = newPt`

d. `acrs13 = crs13`

e. `crs13 = crs23`

f. `crs23 = acrs13`

g. `dist13 = dist23`; We only need one distance so the other is not saved.

h. `swapped = 1`; This is a flag that is set so that the solutions can be swapped back after they are found.

STEP 13: End if.

STEP 14: Initialize the distance array: `distarray[0] = dist13`. Errors in azimuth from `pt2` will be measured as a function of distance from `pt1`. The two most recent distances from `pt1` are stored in a two element array. This array is initialized with the distance from `pt1` to `intx`.

STEP 15: Use the direct algorithm to project `intx` onto the geodesic from `pt1`. Use `pt1` as the starting point, and a distance of `distarray[0]` and azimuth of `crs13`.

STEP 16: Use the inverse algorithm to measure the azimuth `acrs23` from `pt2` to `intx`.

STEP 17: Initialize the error array:
`errarray[0]` = `signedAzimuthDifference`(`acrs23`, `crs23`).
`signedAzimuthDifference` function; `errarray[0]` will be in the range $(-\pi, \pi)$.

STEP 18: Initialize the second element of the distance array using a logical guess: `distarray[1]=1.01*dist13`.

STEP 19: Use the direct algorithm to project the second approximation of `intx` onto the geodesic from `pt1`. Use `pt1` as the starting point, and a distance of `distarray[1]` and azimuth of `crs13`.

STEP 20: Use the inverse algorithm to measure the azimuth `acrs23` from `pt2` to `intx`.

STEP 21: Initialize the error array:

errarray[1] = signedAzimuthDifference(acrs23, crs23).

STEP 22: Initialize k = 0

STEP 23: Do while (k=0) or ((error > tol) and (k ≤ MAX_ITERATIONS)):

a. Use linear approximation to find root of errarray as a function of distarray. This gives an improved approximation to dist13.

b. Use the direct algorithm to project the next approximation of the intersection point, newPt, onto the geodesic from pt1. Use pt1 as the starting point, and a distance of dist13 (calculated in previous step) and azimuth of crs13.

c. Use inverse algorithm to calculate the azimuth acrs23 from pt2 to intx.

d. Use the inverse algorithm to compute the distance from newPt to intx (the previous estimate). Denote this value as the error for this iteration.

e. Update distarray and errarray with new values:

```
distarray[0] = distarray[1]
distarray[1] = dist13
errarray[0]  = errarray[1]
errarray[1]  = signedAzimuthDifference(acrs23,crs23)
```

f. Increment k: k = k + 1

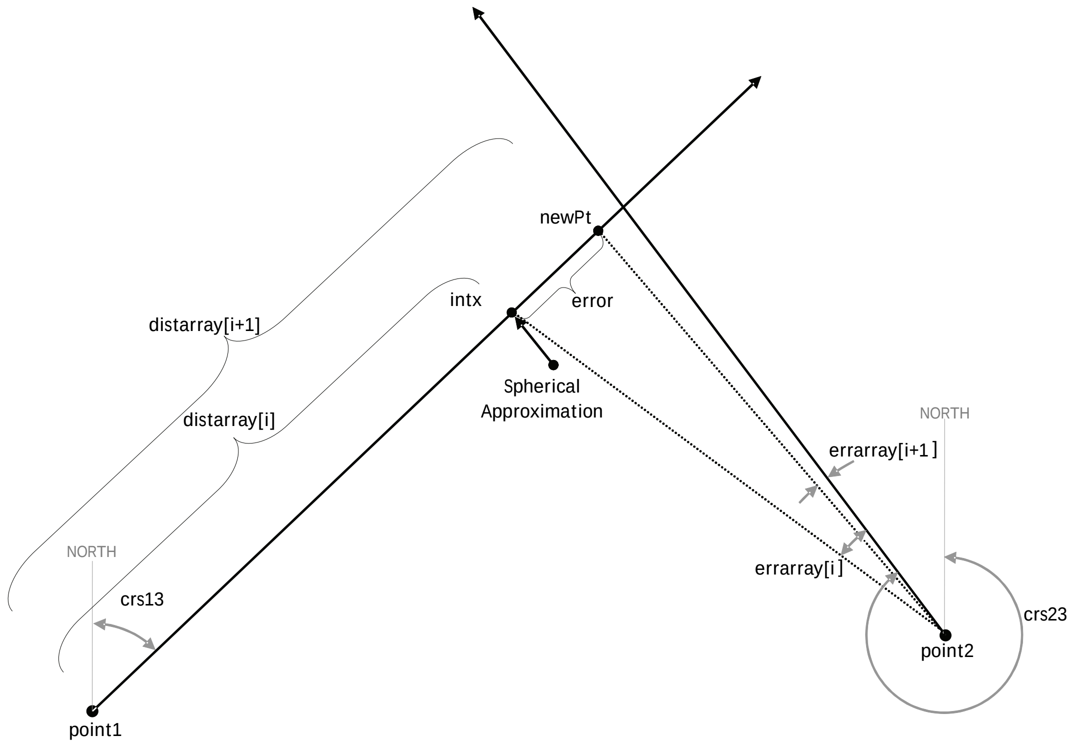
STEP 24: End while loop.

STEP 25: Check if k reached MAX_ITERATIONS. If so, then the algorithm may not have converged, so an error message should be displayed.

STEP 26: The distances and azimuths from pt1 and pt2 to intx are available at the end of this function, since they were calculated throughout the iteration. It may be beneficial to return them with the intx coordinates, since they may be needed by the calling function. If this is done, and if swapped = 1, then the original identities of pt1 and pt2 were exchanged and the azimuths and distances must be swapped again before they are returned.

STEP 27: Return intx.

Figure A-10. Finding the Intersection of Two Geodesics



4.2 Intersection of Two Arcs.

The following algorithm computes the intersection points of two arcs. Each arc is defined by its center point coordinates and radius. The algorithm will return a null solution (no points) if the arcs do not intersect; it will return a single set of coordinates if the arcs intersect tangentially; and it will return two sets of coordinates if the arcs overlap.

4.2.1 Input/Output.

`long WGS84ArcIntersect(LLPoint center1, double radius1, LLPoint center2, double radius2, LLPointPair intx, int* n, double tol)` returns a reference to an `LLPoint` structure array that contains the coordinates of the intersection(s), where the inputs are:

`LLPoint center1`	=	Geodetic coordinates of first arc center
`double radius1`	=	Radius of first arc in nautical miles
`LLPoint center2`	=	Geodetic coordinates of second arc center
`double radius2`	=	Radius of second arc in nautical miles

`LLPointPair intx`	=	Two-element array of `LLPoint` objects that will be updated with intersections' coordinates
`int* n`	=	Reference to integer number of intersection points returned
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.2.2 Algorithm Steps.

See figure A-11 for an illustration of the variables.

This algorithm treats the arcs as full circles. Once the intersections of the circles are found, then each intersection point may be tested and discarded if it does not lie within the bounds of the arc.

STEP 1: Use inverse algorithm to calculate the distance and azimuth between `center1` and `center2`. Denote these values as `dist12` and `crs12`, respectively.

STEP 2: If (`radius1 + radius2 –dist12 + tol < 0`) or (`abs(radius1-radius2) > dist12`) then the circles are spaced such that they do not intersect. If the first conditional is true, then the arcs are too far apart. If the second conditional is true, then one arc is contained within the other.

a. Return no intersections.

STEP 3: Else if (`abs(radius1+radius2-dist12)` ≤ `tol`) then the circles are tangent to each other and intersect in exactly one point:

a. Use direct algorithm to project point from `center1`, along `crs12`, distance `radius1`.

b. Return projected point.

STEP 4: End if.

STEP 5: Calculate approximate intersection points, `intx[0]` and `intx[1]`, according to section 3.2.

STEP 6: Iterate to improve approximation to `pt`:

a. `k = 0`

b. Use inverse algorithm to find azimuth from `center2` to `pt`, denote this value as `crs2x`.

c. Use direct algorithm to move `pt` along `crs2x` to circumference of `circle 2`. Use `center2` as starting point, `crs2x` as azimuth, `radius2` as distance.

d. Use inverse algorithm to compute distance and azimuth from `center1` to `pt`. Denote these values as `dist1x` and `crs1x`, respectively.

e. Compute error at this iteration step: `error = radius1 - dist1x.`

f. Initialize arrays to store error as function of course from `center1`:

```
errarray[1] = error
crsarray[1] = crs1x
```

g. While (`k` ≤ `maximumIterationCount`) and (`abs(errarray[1])` > `tol`), improve approximation:

(1) Use direct function to move `pt` along `crs1x` to circumference of `circle1`. Use `center1` as starting point, `crs1x` as azimuth, and `radius1` as distance. Note that `crs1x` was calculated as last step in previous iteration.

(2) Use inverse function to find azimuth from `center2` to `pt`, `crs2x`.

(3) Use direct function to move `pt` along `crs2x` to circumference of `circle2`. Use `center2` as starting point, `crs2x` as azimuth, and `radius2` as distance.

(4) Use inverse algorithm to compute distance and azimuth from `center1` to `pt`. Denote these values as `dist1x` and `crs1x`, respectively.

(5) Update function arrays:

```
crsarray[0] = crsarray[1]
crsarray[1] = crs1x
errarray[0] = errarray[1]
errarray[1] = error
```

(6) Use linear root finder to find the azimuth value that corresponds to zero error. Update the variable `crs1x` with this root value.

(7) Increment `k`: `k = k + 1`

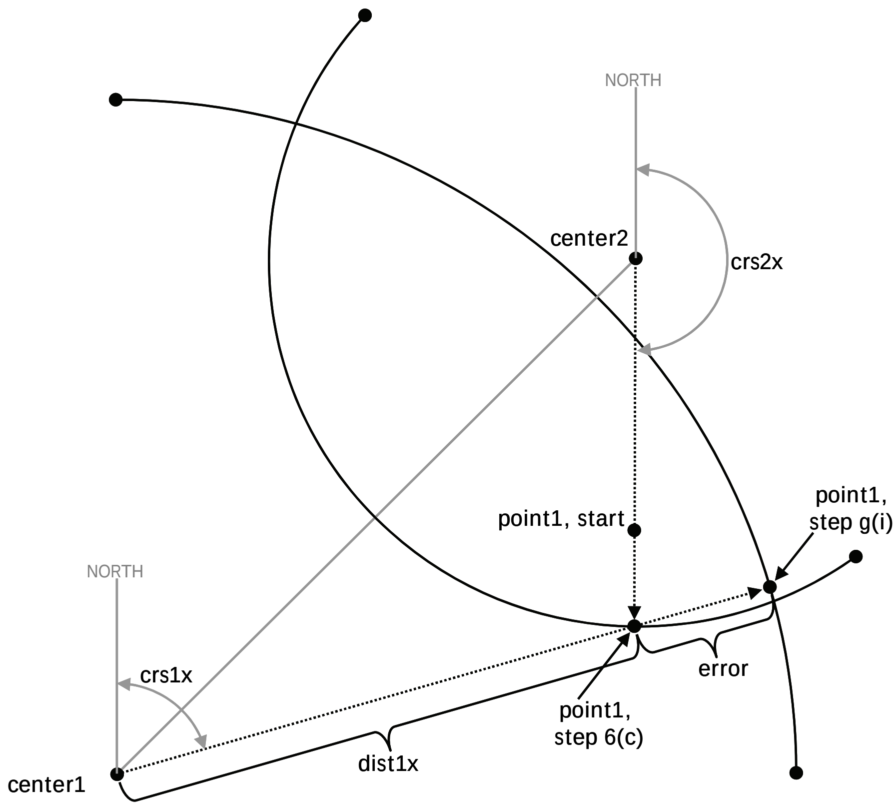
h. End while loop.

STEP 7: Store `point` in array to be returned: `intx[0] = point`.

STEP 8: Repeat step 6 for approximation `intx[1]`.

STEP 9: Return array `intx`.

Figure A-11. Intersection of Two Arcs



4.3 Intersections of Arc and Geodesic.

The following algorithm computes the point where a geodesic intersects an arc. The geodesic is defined by its starting coordinates and azimuth. The arc is defined by its center point coordinates and radius. The algorithm will return a null solution (no points) if the arc and geodesic do not intersect; it will return a single set of coordinates if the arc and geodesic intersect tangentially; and it will return two sets of coordinates if the arc and geodesic overlap.

4.3.1 Input/Output.

`long WGS84LineArcIntersect(LLPoint pt1, double crs1, LLPoint center, double radius, LLPointPair intx, int* n, double tol)` returns a reference to an `LLPoint` structure array that contains the coordinates of the intersection(s), where the inputs are:

`LLPoint pt1`	=	Geodetic coordinates of start point of geodesic
`double crs1`	=	Initial azimuth of geodesic at start point
`LLPoint center`	=	Geodetic coordinates of arc center point
`double radius`	=	Arc radius in nautical miles
`LLPointPair intx`	=	Two-element array of `LLPoint` objects that will be updated with intersections' coordinates
`int* n`	=	Reference to number of intersection points returned
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.3.2 Algorithm Steps.

This algorithm treats the arc and geodesic as unbounded. Once intersection points are found, they must be tested using Algorithms 3.6 and 3.7 to determine which, if any, lie within the curves' bounds. This algorithm fails if the arc and geodesic describe the same great circle. A test for this case is embedded in step 7. See figure A-12 for an illustration of the variable names.

STEP 1: Use Algorithm 5 .1 to find the perpendicular projection point from arc center point (`center`) to the geodesic defined by starting point `pt1` and azimuth `crs1`. Denote this point by `perpPt`. Denote the distance as `perpDist`.

STEP 2: Use inverse Algorithm to calculate the azimuth of the geodesic at `perpPt`. Denote the azimuth from `perpPt` to `pt1` as `crs`.

STEP 3: If `(abs(perpDist – radius) < tol)`, then the geodesic is tangent to the arc and intersection point is at `perpPt`,

a. Return `intx[0] = perpPt`.

<u>STEP 4</u>: Else if (perpDist > radius) then geodesic passes too far from center of circle; there is no intersection,

a. Return empty array.

<u>STEP 5</u>: End if.

<u>STEP 6</u>: Use spherical triangle approximation to find distance from perpPt to one intersection points. Since the spherical triangle formed from center, perpPt, and either intersection point has a right angle at the perpPt vertex, the distance from perpPt to either intersection is:

dist = SPHERE_RADIUS*acos(cos(radius/SPHERE_RADIUS)/cos(perpDist/SPHERE_RADIUS)) where SPHERE_RADIUS is the radius of the spherical earth approximation.

Note that a test must be performed so that if cos(perpDist/SPHERE_RADIUS) = 0, then no solution is returned.

<u>STEP 7</u>: Find ellipsoidal approximation intx[0] to first intersection by starting at perpPt and using direct algorithm with distance dist and azimuth crs. This will place intx[0] on the geodesic.

<u>STEP 8</u>: Initialize iteration count k = 0.

<u>STEP 9</u>: Use inverse algorithm to calculate the distance from center to intx[0]. Denote this value by radDist. In the same calculation, calculate azimuth from intx[0] to center. Denote this value by rcrs; it will be used to improve the solution.

<u>STEP 10</u>: Calculate error for this iteration: error = radius – radDist.

<u>STEP 11</u>: Initialize arrays that will hold distance and error function values so that linear interpolation may be used to improve approximation:

```
distarray[0] = dist
errarray[0] = error
```

<u>STEP 12</u>: Do one iterative step using spherical approximation near intersection point (see figure B-13):

a. Use the inverse algorithm to calculate the azimuth from intx[0] to perpPt. Denote this value by bcrs.

b. Compute the angle between the arc's radial line and the geodesic at intx[0]. This is depicted by B in figure A-13:

```
B=abs(signedAzimuthDifference(bcrs, rcrs)
```

c. Calculate the angle opposite the radial error:
`A=acos[sin(B)*cos(abs(error)/sphereRad)]`

d. If `(abs(sin(A)) < eps)` then the triangle is nearly isosceles, so use simple formula for correction term `c: c = error`.

e. Else, if `(abs(A) < eps`) then the error is very small, so use flat approximation: `c = error/cos(B)`.

f. Else, use a spherical triangle approximation for `c`:
`c=sphereRad*asin[sin(error/sphereRad)/sin(A)]`

g. End if.

h. If (`error > 0`), then `intx[0]` is inside the circle, so approximation must be moved away from `perpPt: dist = dist + c`.

i. Else `dist = dist – c`.

j. End if.

k. Use the direct algorithm to move `intx[0]` closer to solution. Use `perpPt` as the starting point with distance `dist` and azimuth `crs`.

l. Use the inverse algorithm to calculate the distance from `center` to `intx[0]`. Denote this value again as `radDist`.

m. Initialize second value of `distarray` and `errarray`:

```
distarray[1] = dist
errarray[1]  = radius-radDist
```

<u>STEP 13</u>: Do while (`abs(error) > tol`) and (`k <maximumIterationCount`):

a. Use a linear root finder to find the distance value that corresponds to zero error. Update the variable `dist` with this root value.

b. Use the direct algorithm again to move `intx[0]` closer to solution. Use `perpPt` as the starting point with distance `dist` and azimuth `crs`.

c. Use the inverse algorithm to calculate the distance from `center` to `intx[0]`. Denote this value `radDist`.

d. Update `distarray` and `errarray` with the new values:

```
distarray[0] = distarray[1]
```

```
errarray[0]  = errarray[1]
distarray[1] = dist
errarray[1]  = error
```

e. Increment the iteration count: `k = k + 1`

STEP 14: End while loop.

STEP 15: Prepare variables to solve for second solution, `intx[1]`:

a. Second solution lies on other side of `perpPt`, so set `crs = crs +` π.

b. Use direct algorithm to find `intx[1]`. Start at `perpPt`, using `crs` for the azimuth and `dist` for the distance, since the distance from `perpPt` to `intx[0]` is a very good approximation to the distance from `perpPt` to `intx[1]`.

c. Use inverse algorithm to calculate `radDist`, the distance from center to `intx[1]`.

d. Initialize the error function array: `errarray[0] = radius – radDist`.

STEP 16: Repeat steps 13-14 to improve solution for `intx[1]`.

STEP 17: Return `intx[0]`and `intx[1]`.

Figure A-12. Locating First Intersection of Geodesic and Arc

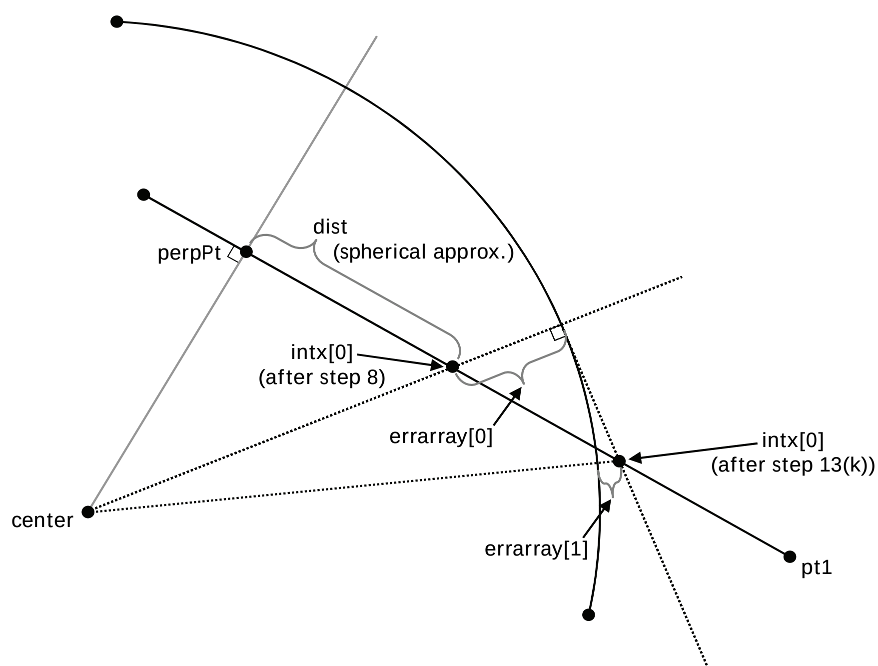
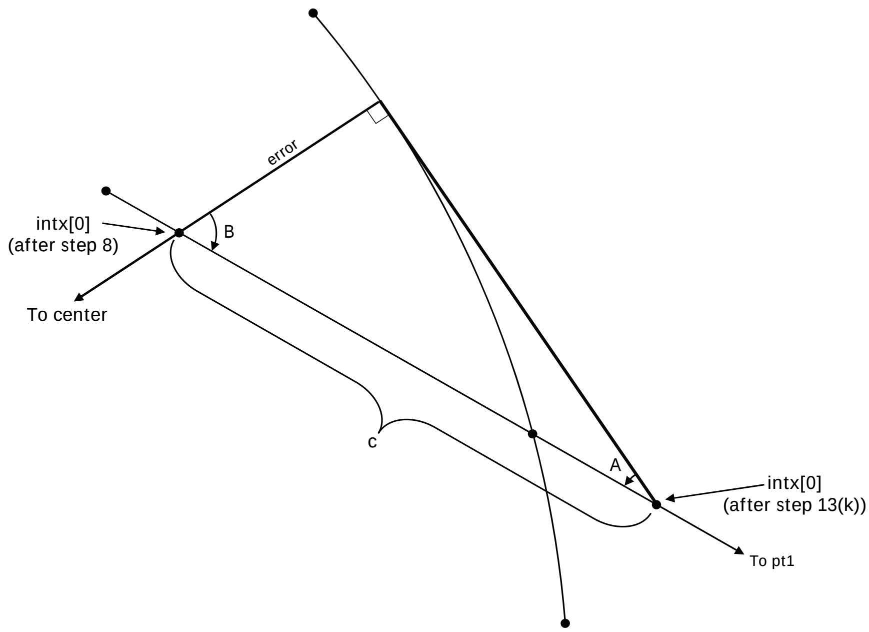


Figure A-13. Area Near the Appropriate Geodesic-Arc Intersection Point With Spherical Triangle Components That Are Used to Improve the Solution



4.4 Arc Tangent to Two Geodesics.

This algorithm is useful for finding flight path arcs, such as fitting a fly-by turn or radius-to-fix (`RF`) leg between two track-to-fix (`TF`) legs. Note that for the arc to be tangent to both the incoming and outgoing geodesics, the two tangent points must be different distances from the geodesics' intersection point.

4.4.1 Input/Output.

`long WGS84TangentFixedRadiusArc(LLPoint pt1, double crs12, LLPoint pt3, double crs3, double radius, ArcDirection* dir, double tol)` returns a reference to an `LLPoint` structure array that contains the coordinates of the center point and both tangent points of the arc that is tangent to both given geodesic, where the inputs are:

`LLPoint pt1`	=	Geodetic coordinates of start point of first geodesic
`double crs12`	=	Azimuth of first geodesic at `pt1`
`LLPoint pt3`	=	Geodetic coordinates of end point of second geodesic
`double crs3`	=	Azimuth of second geodesic at `pt3`

`double radius`	=	Radius of desired arc
`ArcDirection* dir`	=	Reference to an integer that represents direction of turn. `dir = 1` for left hand turn `dir = -1` for right hand turn
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.4.2 Algorithm Steps.

See figure A-14 for an illustration of the variable names.

STEP 1: Use Algorithm 4.1 to locate the intersection point of the given geodesics. The first geodesic has azimuth `crs12` at `pt1`, while the second geodesic has azimuth `crs3` at `pt3`. Denote their intersection point by `pt2`.

STEP 2: If intersection point `pt2` is not found, then no tangent arc can be found,

a. Return empty array.

STEP 3: End if.

STEP 4: Use the inverse algorithm to calculate the distance from `pt1` to `pt2` (denoted by `dist12`). Also calculate the azimuth at `pt2` to go from `pt2` to `pt1`. Denote this value by `crs21`.

STEP 5: Use the inverse algorithm to compute the azimuth at `pt2` to go from `pt2` to `pt3`. Denote this value by `crs23`.

STEP 6: Calculate angle between courses at `pt2` (see Algorithm 6.2). Denote this value by `vertexAngle`:
`vertexAngle=signedAzimuthDifference(crs21,crs23)`

STEP 7: If `abs(sin(vertexAngle)) < tol`, then either there is no turn or the turn is `180` degrees. In either case, no tangent arc can be found,

a. Return empty array.

STEP 8: Else if `vertexAngle > 0` then course changes direction to the right: `dir = -1`.

STEP 9: Else, the course changes direction to the left: `dir = 1`

STEP 10: End if.

STEP 11: Use spherical triangle calculations to compute the approximate distance from `pt2` to the points where the arc is tangent to either geodesic. Denote this distance by `distToStart`:

a. `B=vertexAngle/2`.

b. If (`radius > sphereRad*B`) then no arc of the required radius will fit between the given geodesics,

(1) Return empty array.

c. End if.

d. Calculate `distToStart` using the approximate formula from Napier's Rule of Circular Parts.

```
distToStart=sphereRad*asin(tan(radius/sphereRad)/tan(B))
```

STEP 12: Initialize the iteration count: `k = 0`

STEP 13: Initialize the error measure: `error = 0.0`

STEP 14: Do while (`k = 0`) or ((`abs(error) > tol`) and (`k ≤ maximumIterationCount`)) :

a. Adjust the distance to tangent point based on current error value (this has no effect on first pass through, because `error = 0):` `distToStart=distToStart+(error/sin(vertexAngle))` .

b. Use the direct algorithm to project `startPt` distance `distToStart` from `pt1`. Use `pt1` as the starting point with azimuth of `crs12` and distance of `distToStart`.

c. Use the inverse algorithm to compute azimuth of geodesic at `startPt`. Denote this value by `perpCrs`.

d. If `(dir < 0)`, then the tangent arc must curve to the right. Add $\pi/2$ to `perpCrs` to get the azimuth from `startPt` to center of arc:

```
perpCrs=perpCrs+π/2
```

e. Else, the tangent arc must curve to the left. Subtract π/2 from perpCrs to get the azimuth from startPt to center of arc:

perpCrs=perpCrs-π/2

f. End if.

g. Use the direct algorithm to locate the arc center point, centerPoint. Use startPt as the starting point, perpCrs for the azimuth, and radius for the distance.

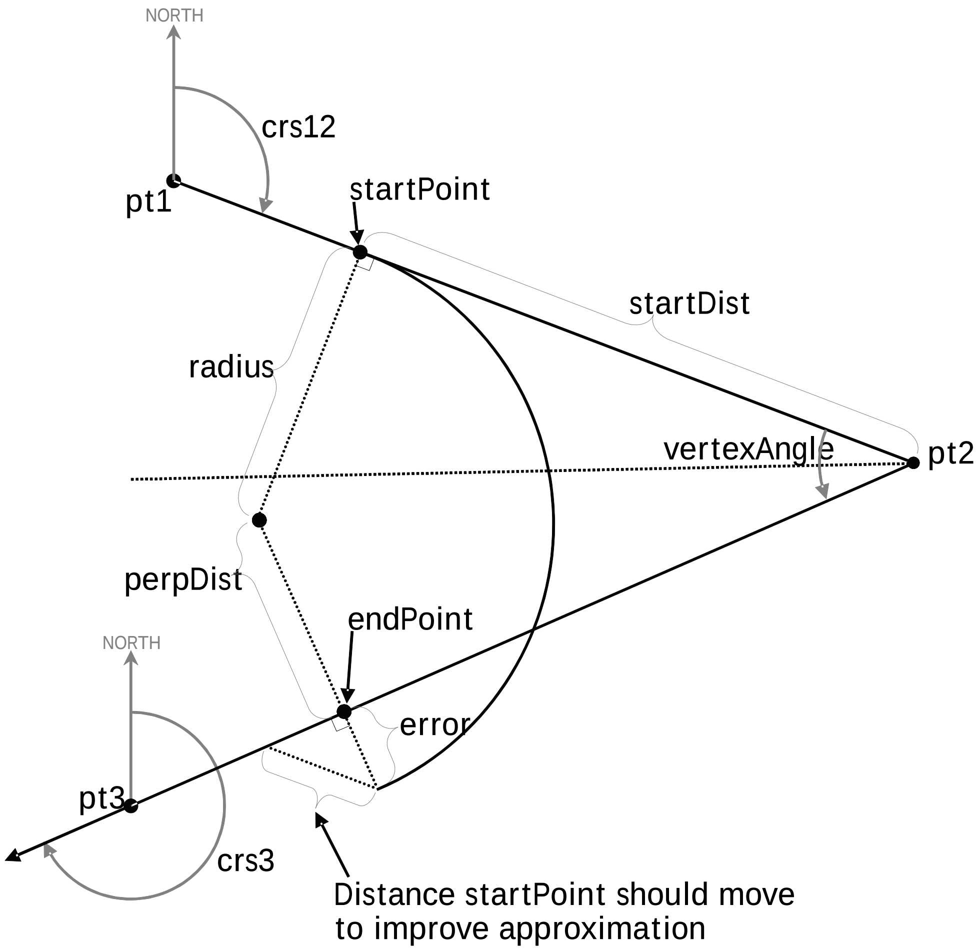
h. Use Algorithm 5.1 to project centerPoint to the second geodesic. Denote the projected point by endPt. This is approximately where the arc will be tangent to the second geodesic. Denote the distance from centerPoint to endPoint as perpDist.

i. Calculate the tangency error: error = radius – perpDist. This error value will be compared against the required tolerance parameter. If its magnitude is greater than tol, then it will be used to adjust the position of startPoint until both startPoint and endPoint are the correct distance from centerPoint.

<u>STEP 15</u>: End while.

<u>STEP 16</u>: Return the values for centerPoint, the center of the arc, startPoint, the tangent point on the first geodesic, and endPoint, the tangent point of second geodesic.

Figure A-14. Finding Arc Center and Points at Which Arc is Tangent to Two Geodesics



4.5 Intersections of Geodesic and Locus.

This algorithm is useful for finding the corner points of `TF` sub-segment's `OEA`, where a parallel (represented as a locus of points) intersects the geodesic end line.

4.5.1 Input/Output.

`long WGS84GeoLocusIntersect(LLPoint geoSt, LLPoint geoEnd, LLPoint* pint, Locus loc, double tol) returns a reference to an LLPoint` structure array that contains the coordinates of the intersection point., where the inputs are:

`LLPoint geoSt`	=	Geodetic coordinates of start point of geodesic
`LLPoint geoEnd`	=	Geodetic coordinates of end point of geodesic
`Locus loc`	=	Structure defining locus of points
`LLPoint* pint`	=	Reference to `LLPoint` that will be updated with intersection coordinates.
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.5.2 Algorithm Steps.

See figure A-15 for an illustration of the variable names.

STEP 1: Use the geodesic intersection algorithm (Algorithm 4.1) to find a first approximation to the point where the given geodesic and locus intersect. Use the start and end coordinates of the locus along with the start and end coordinates of given geodesic as inputs to the geodesic intersection algorithm. This will erroneously treat the locus as a geodesic; however, the calculated intersection will be close to the desired intersection. The geodesic intersection algorithm will return the approximate intersection point, `pt1`, along with the courses and distances from the `pt1` to the start points of the locus and given geodesic. Denote these courses and distances as `crs31`, `dist13`, `crs32`, `dist23`, respectively.

STEP 2: If `pt1` is not found, then the locus and geodesic to not intersect,

a. Return empty point.

STEP 3: End if.

STEP 4: Use the inverse algorithm to calculate the course from `geoSt` to `geoEnd`. Denote this value as `fcrs`. This value is needed by the direct algorithm to locate new points on the given geodesic.

STEP 5: Use the inverse algorithm to calculate the distance and course from `pt1` to `geoSt`. Denote these values as `distBase` and `crsBase`, respectively.

STEP 6: Obtain the forward course of the locus's defining geodesic. This course is stored as `loc.geoAz`. Denote this course as `tcrs`. This value is needed to project the approximate point onto the defining geodesic in order to calculate the appropriate `locus` distance.

STEP 7: Use Algorithm 5.1 to project `pt1` onto the locus's defining geodesic. Use `pt1`, `loc.geoStart`, and `tcrs` as inputs. Denote the returned point as `pInt`, the returned course as `crsFromPt`, and the returned distance as `distFromPt`.

STEP 8: Use Algorithm 3.9 to calculate the distance from the defining geodesic to the locus at `pInt`. Denote this value as `distLoc`. Note that `distLoc` may be positive or negative, depending on which side of defining geodesic the locus lays.

STEP 9: Calculate the distance from `pt1` to the locus. This is the initial error: `errarray[1] = distFromPt – abs(distLoc)`.

STEP 10: Save the initial distance from `geoSt` to the approximate point: `geodarray[1] = distBase`. We will iterate to improve the approximation by finding a new value for `distBase` that makes `errarray` zero.

STEP 11: Calculate a new value of `distBase` that will move `pt1` closer to the locus. This is done by approximating the region where the given geodesic and locus intersect as a right Euclidean triangle and estimating the distance from the current `pt1` position to the locus (see figure A-16).

a. Calculate the angle between the geodesic from `pt1` to `pInt` and the geodesic from `pt1` to `geoSt`:

```
theta=abs(signedAzimuthDifference(crsFrompt,crsBase))
```

b. Calculate a new value for `distBase`:
```
newdistbase=distbase-errarray[1]/cos(theta)
```

STEP 12: Initialize the iteration count: `k = 0.`

STEP 13: Do while (`abs(errarray[1] > tol`) and (`k < maxIterationCount`)):

a. Use `geoSt`, `fcrs`, and `newDistBase` in the direct algorithm to update the value of `pt1`.

b. Save the current values of `errarray` and `geodarray:`

```
errarray[0] = errarray[1]
geodarray[0] = geodarray[1]
```

c. Set `geodarray[1] = newDistBase`.

d. Repeat steps 7, 8, and 9 to calculate the distance from `pt1` to the locus, `distloc`, and the corresponding update to `errarray[1]`.

e. Use a linear root finder with `geodarray` and `errarray` to find the distance value that makes the error zero. Update `newDistBase` with this root value.

STEP 14: End while.

STEP 15: Return `pint=pt1`.

Figure A-15. Intersection of Geodesic with Locus of Points

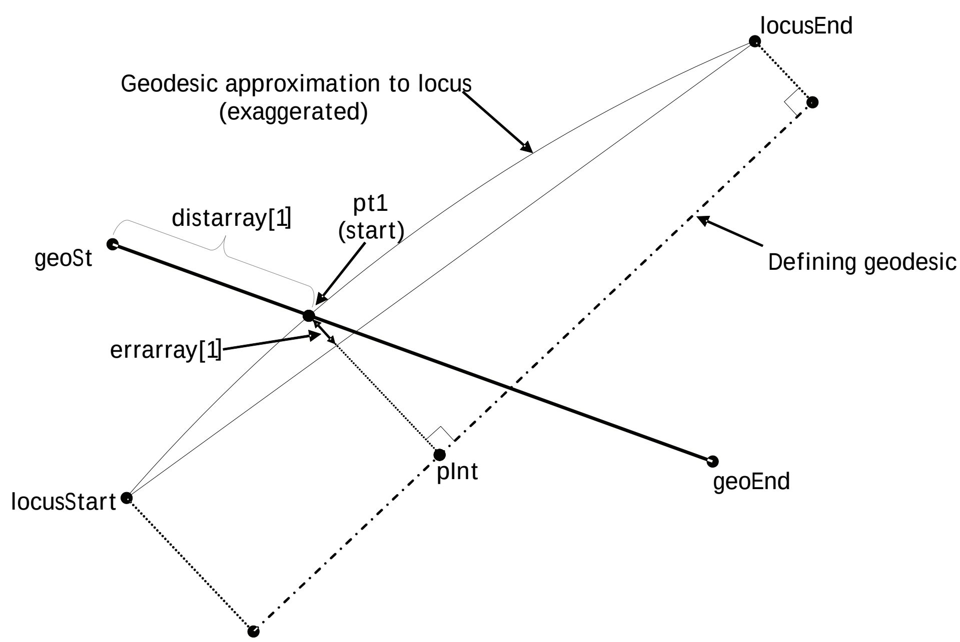
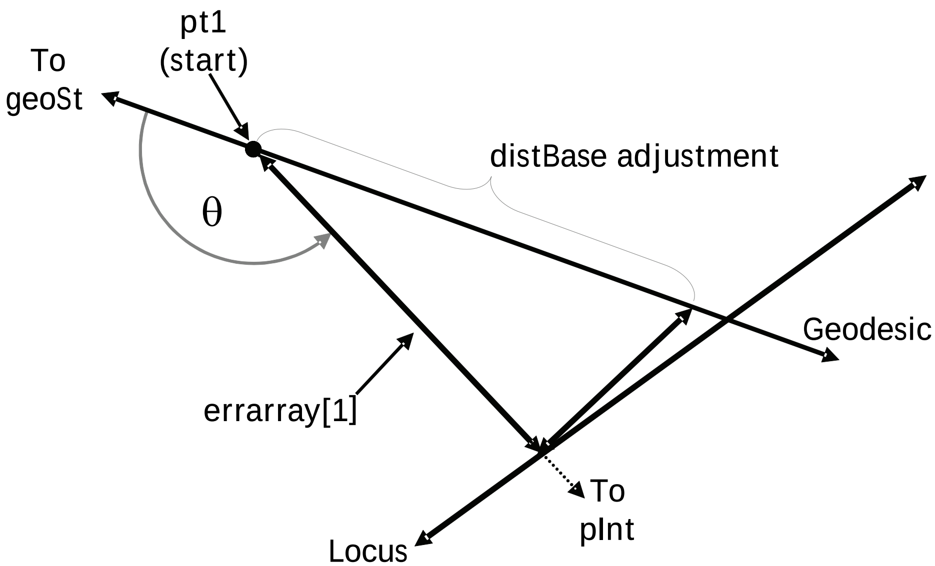


Figure A-16. Computing First Update to Locus-Geodesic Intersection



4.6 Intersections of Arc and Locus.

This algorithm solves for the intersection of a fixed radius arc and a locus. It is very similar to Algorithm 4.3, which computes the intersections of an arc and a geodesic. It begins by treating the locus as a geodesic and applying Algorithm 4.3 to find approximate intersection points. The approximation is improved by traveling along the locus, measuring the distance to the arc center at each point. The difference between this distance and the given arc radius is the error. The error is modeled as a series of linear functions of position on the locus. The root of each function gives the next approximation to the intersection. Iteration stops when the error is less than the specified tolerance.

4.6.1 Input/Output.

`long WGS84LocusArcIntersect(Locus loc, LLPoint center, double radius, LLPointPair intx, int* n, double tol)` returns a reference to an `LLPoint` structure array that contains the coordinates of the intersection(s), where the inputs are:

`Locus loc`	=	Locus of interest
`LLPoint center`	=	Geodetic coordinates of arc
`double radius`	=	Arc radius

`LLPointPair intx`	=	Two-element array of `LLPoint` that will be updated with intersection coordinates
`int* n`	=	Number of intersections found
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.6.2 Algorithm Steps.

See figure A-17 for an illustration of the variables.

STEP 1: Initialize number of intersections `n = 0`.

STEP 2: Use the inverse algorithm to compute the course from `loc.locusStart` to `loc.locusEnd`. Denote this value as `fcrs`.

STEP 3: Use Algorithm 5.2 to project the center of the arc to the locus. Denote the projected point as `locpt`. Denote the distance and course from `center` to `locpt` as `distFromPoint` and `crsFromPoint`, respectively. If `locpt` is on or within the radius of the arc, then it will be used to find the intersection(s) of the locus and the arc, `intx`.

STEP 4: If (`distFromPoint > radius`), then no approximate intersections were found. Return `NULL`.

STEP 5: End if.

STEP 6: Else if `distFromPoint` is equal to `radius` within tolerance level, then:

a. Locus is tangent to arc. One intersection exists.

b. `intx[0]=locpt`.

STEP 7: End if.

STEP 8: Otherwise, `distFromPoint` must be less than `radius`, meaning there are two possible intersections. These two approximate intersections are found using spherical trigonometry and the direct algorithm. Denote the approximate intersections as `intx[0]` and `intx[1].`

STEP 9: Use the inverse algorithm to compute the forward and reverse course from `loc.geoStart` to `loc.geoEnd`. Store these values as `fcrs1` and `bcrs`, respectively.

STEP 10: For `i=0`, `i<n1:`

a. Use Algorithm 5.1 to project `intx[0]` to the locus's defining geodesic. Denote the projected point as `perpPt`.

b. Use the inverse algorithm to calculate `distbase`, the distance from `perpPint` to `loc.geoStart`.

c. Use Algorithm 3.10 to project `locPt` onto the locus from `perpPint`.

d. Use the inverse algorithm to calculate `distCent`, the distance from `locPt` to `center`.

e. Calculate the error and store it in an array:
`errarray[1] = distCent – radius`

f. If (`abs(errarray[1]) < tol`), then `locPt` is close enough to the circle. Set `intx[n] = locPt`, `n = n+1`, and continue to the end of the "for" loop, skipping steps g through m below.

g. Save the current value of `distbase` to an array:
`geodarray[1] = distbase`.

h. Initialize the iteration count: `k = 0`

i. Perturb `distbase` by a small amount to generate a second point at which to measure the error: `newDistbase = 1.001*distbase`.

j. Do while (`k < maxIterationCount`) and (`abs(errarray[1]) > tol`).

k. Project `Pt1` on the defining geodesic a distance `newDistbase` along course `fcrs1` from `loc.geoStart`.

(1) Use Algorithm 3.10 to project `locPt` onto the locus from `Pt1`.

(2) Use the inverse algorithm to calculate `dist1`, the distance from `locPt` to `center`.

(3) Calculate the error: `error = dist1 – radius`.

(4) Update the distance and error arrays:

```
geodarray[0] = geodarray[1]
geodarray[1] = newDistbase
errarray[0] = errarray[1]
errarray[1] = error
```

(5) Use a linear root finder with `geodarray` and `errarray` to find the distance value that makes the error zero. Update `newDistbase` with this root value.

l. End while.

m. If `locPt` is on the locus according to Algorithm 3.11, then

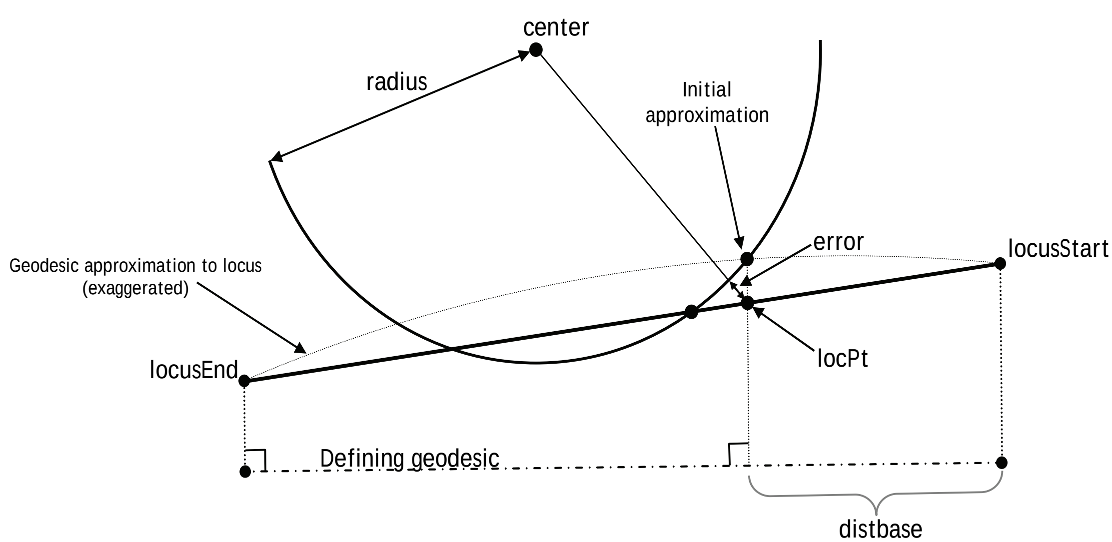
(1) Copy `locPt` to the output array: `intx[n] = locPt`.

(2) Update the count of intersection points found: `n = n + 1`.

STEP 11: End for loop.

STEP 12: Return `intx`.

Figure A-17. Finding the Intersection of an Arc and a Locus



4.7 Intersections of Two Loci.

4.7.1 Input/Output.

`long WGS84LocusIntersect(Locus loc1, Locus loc2, LLPoint* intx, double tol)` returns a reference to an `LLPoint` structure array that contains the intersection coordinates, where the inputs are:

`Locus loc1`	=	First locus of interest
`Locus loc2`	=	Second locus of interest
`LLPoint* intx`	=	Reference to `LLPoint` that will be updated with intersection coordinates.
`Double tol`	=	Maximum error allowed in solution
`Double eps`	=	Convergence parameter for forward/inverse algorithms

4.7.2 Algorithm Steps.

See figure A-18 for an illustration of the variables and calculation steps.

STEP 1: Use the inverse algorithm to calculate the course of the geodesic approximation to `loc1`. Use `loc1.locusStart` and `loc1.locusEnd` as start and end points. Denote this course as `crs1`.

STEP 2: Use the inverse algorithm to calculate the course of the geodesic approximation to `loc2`. Use `loc2.locusStart` and `loc2.locusEnd` as start and end points. Denote this course as `crs2`.

STEP 3: Use `loc1.locusStart`, `crs1`, `loc2.locusStart`, and `crs2` as input to Algorithm 4.1 to calculate an approximate solution to the locus intersection. Denote the approximate intersection point at `p1`.

STEP 4: If (`p1 = NULL`), then the loci do not intersect, so return `NULL`.

STEP 5: Use the inverse algorithm to calculate the course of `loc1`'s defining geodesic. Use `loc1.geoStart` and `loc1.geoEnd` as the start and end points, and denote the course as `tcrs1`.

STEP 6: Project `p1` to the geodesic of `loc1` using Algorithm 5.1 with `loc1.geoStart` and `tcrs1` as input parameters. Store the projected point as `pint1`.

STEP 7: If (`pint1 = NULL`), then no projected point was found so return `NULL`.

STEP 8: Use the inverse algorithm to calculate `distbase`, the distance from `loc1.geoStart` to `pint1`.

STEP 9: Initialize iteration counter: `k = 0`

STEP 10: Do while (`k = 0`) or ((`k < maxIterationCount`) and (`abs(error) > tol`)):

a. If (`k > 0`) then apply direct algorithm to project new `pint1` on `loc1`. Use starting point `loc1.geoStart`, course `tcrs1`, and distance `distbase`.

b. Use Algorithm 3.10 to project a point on `loc1` from the current `pint1`. Denote the projected point as `ploc1`.

c. Project `ploc1` to the geodesic of `loc2` using Algorithm 5.1 with `loc2.geoStart` and `tcrs2` as input parameters. Store the projected point as `pint2`.

d. Use Algorithm 3.10 to project a point on `loc2` from `pint2`. Denote the projected point as `ploc2`. If `ploc1` were truly at the intersection of the `loci`, then `ploc2` and `ploc1` would be the same point. The distance between them measures the error at this calculation step.

e. Compute the error by using the inverse algorithm to calculate the distance between `ploc1` and `ploc2`.

f. Update the error and distance arrays and store the current values:
```
errarray[0]  = errarray[1]
errarray[1]  = error
distarray[0] = distarray[1]
distarray[1] = distbase
```

g. If (`k = 0`), then project `ploc2` onto `loc1` to get a new estimate of `distbase`:

(1) Project `ploc2` to the geodesic of `loc1` using Algorithm 5.1 with `loc1.geoStart` and `tcrs1` as input parameters. Store the projected point as `pint1`.

(2) Use the inverse algorithm to calculate `distbase`, the distance from `loc1.geoStart to pint1`.

h. Else,

(1) Use a linear root finder with `distarray` and `errarray` to find the distance value that makes the error zero. Update `distbase` with this root value. This is possible only after the first update step because two values are required in each array.

i. End if.

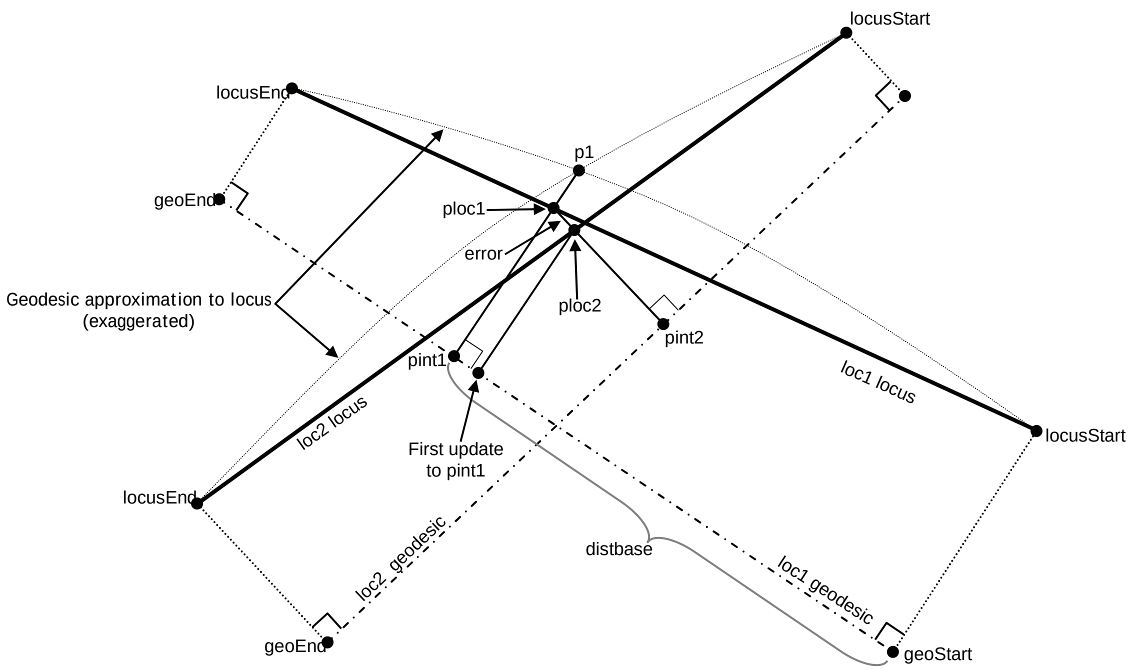
j. Increment iteration count: `k = k + 1`.

<u>STEP 11</u>: End while.

<u>STEP 12</u>: Use Algorithm 3.11 with inputs of `loc1` and `ploc1` to determine if `ploc1` lies on the `loc1`. Then use Algorithm 3.11 with inputs of `loc2` and `ploc1` to determine if `ploc1` lies on the `loc2`. If `ploc1` does not lie on both `loci`, return `NULL`.

<u>STEP 13</u>: Return `ploc1`.

Figure A-18. Computing the Intersection of Two Loci



4.8 Arc Tangent to Two Loci.

Computing a tangent arc of a given radius to two loci is very similar to fitting an arc to two geodesics. The following algorithm uses the same basic logic as Algorithm 4.4.

4.8.1 Input/Output.

`long WGS84LocusTanFixedRadiusArc(Locus loc1, Locus loc2, double radius, LLPoint* centerPoint, LLPoint* startPoint, LLPoint* endPoint, ArcDirection* dir, double tol)` returns a reference to an

`LLPoint` structure array that contains the coordinates of the center point and both tangent points of the arc that is tangent to both given `loci`, where the inputs are:

`Locus loc1`	=	Structure defining first `locus`
`Locus loc2`	=	Structure defining second `locus`
`double radius`	=	Radius of desired arc
`LLPoint* centerpoint`	=	Reference to `LLPoint` that will contain arc's center coordinates.
`LLPoint* startPoint`	=	Reference to `LLPoint` that will contain arc's start point coordinates.
`LLPoint* endpoint`	=	Reference to `LLPoint` that will contain arc's endpoint coordinates.
`ArcDirection* dir`	=	Reference to an integer that represents direction of turn. dir = 1 for left hand turn dir = -1 for right hand turn
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

4.8.2 Algorithm Steps.

See figure A-19.

STEP 1: Use inverse algorithm to calculate `crs12`, the course from `loc1.locusStart` to `loc1.locusEnd`.

STEP 2: Use inverse algorithm to calculate `gcrs1` and `geoLen1`, the course and distance from `loc1.geoStart` to `loc1.geoEnd`.

STEP 3: Use inverse algorithm to calculate `crs32`, the course from `loc2.locusEnd` to `loc2.locusStart`. Convert `crs32` to its reciprocal: $\texttt{crs32} = \texttt{crs32} + \pi$.

STEP 4: Apply Algorithm 4.4 to find the arc tangent to the geodesic approximations to `loc1` and `loc2`. Use `loc1.locusStart`, `crs12`, `loc2.locusEnd`, `crs32`, and `radius` as input parameter. Denote the array of points returned as `intx`. `intx[0]` will be the approximate arc center point, intx[1] will be the tangent point near loc1, and intx[2] will be the tangent point near loc2. Also returned will be the direction of the arc, dir.

STEP 5: If (intx = NULL) then there is no tangent arc. Return NULL.

STEP 6: Calculate the approximate angle at the vertex where loc1 and loc2 intersect. This will be used only to estimate the first improvement to the tangent point intx[1]. Thus we use an efficient spherical triangles approximation (see figure A-20):

a. Use the spherical inverse function to calculate the rcrs1, the course from intx[0] (the approximate arc center) to intx[1] (the approximate tangent point on loc1).

b. Use the spherical inverse function to calculate the rcrs2, the course from intx[0] to intx[2] (the other approximate tangent point).

c. Calculate the angle difference between rcrs1 and rcrs2:

$$\mathtt{angle} = \text{abs}\left(\text{signedAzimuthDifference}\left(\mathtt{rcrs1}, \mathtt{rcrs2}\right)\right)$$

d. $$\mathtt{vertexAngle} = 2 * \mathtt{acos}\left(\sin\left(\frac{\mathtt{angle}}{2}\right)\cos\left(\frac{\mathtt{radius}}{\mathtt{SPHERE\_RADIUS}}\right)\right)$$

STEP 7: Calculate the inclination angle of loc1 relative to its geodesic:

$$\mathtt{locAngle} = \mathtt{atan}\left[\left(\mathtt{loc1.endDist} - \mathtt{loc1.startDist}\right) / \mathtt{geoLen1}\right]$$

STEP 8: Initialize distbase = 0.1.

STEP 9: Initialize the iteration count: k = 0.

STEP 10: Do while (k = 0) or ((k < maxIterationCount) and abs(error) > tol)):

a. Use direct algorithm with starting point loc1.geoStart, course gcrs1, and distance distbase to project point geoPt.

b. Use Algorithm 3.10 to project a point on loc1 from the current geoPt1. Denote the projected point as intx[1].

d. Use Algorithm 3.12 to calculate lcrs1, the course of loc1 at intx[1].

e. Convert `lcrs1` into the correct perpendicular course toward the arc center (note that `dir>0` indicates a left-hand turn):

$$\texttt{lcrs1} = \texttt{lcrs1} - \texttt{dir} * \frac{\pi}{2}$$

f. Use the direct algorithm with starting point `intx[1]`, course `lcrs1`, and distance `radius` to project the arc center point, `intx[0]`.

g. Use Algorithm 5.2 to project `intx[0]` onto `loc2`. Reassign `intx[2]` as the projected point.

h. Use the inverse algorithm to calculate `r2`, the distance from `intx[0]` to `intx[2]`.

i. Calculate the error: `error = r2 – radius`.

j. Update the distance and error function arrays:
```
distarray[0] = distarray[1]
distarray[1] = distbase
errarray[0] = errarray[1]
errarray[1] = error
```

k. If (`k = 0`), then estimate better `distbase` value using spherical approximation and calculated error:

$$\texttt{distbase} = \texttt{distbase} + \texttt{error} * \frac{\cos(\texttt{locAngle})}{\sin(\texttt{vertexAngle})}$$

l. Else, use a linear root finder with `distarray` and `errarray` to find the distance value that makes the error zero. Update `distbase` with this root value.

m. End if.

<u>STEP 12</u>: End while.

<u>STEP 13</u>: Return `intx`.

Figure A-19. Arc Tangent to Two Loci

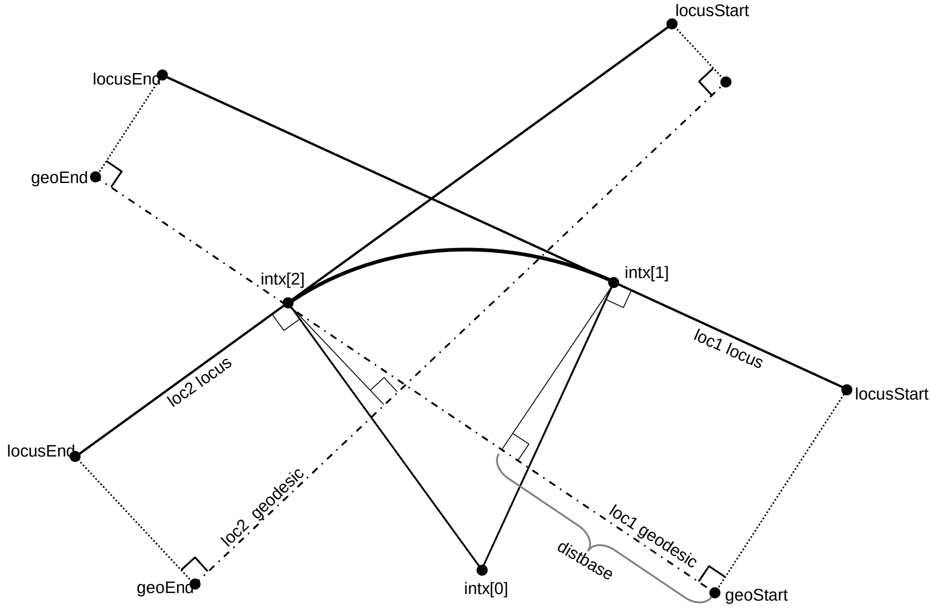
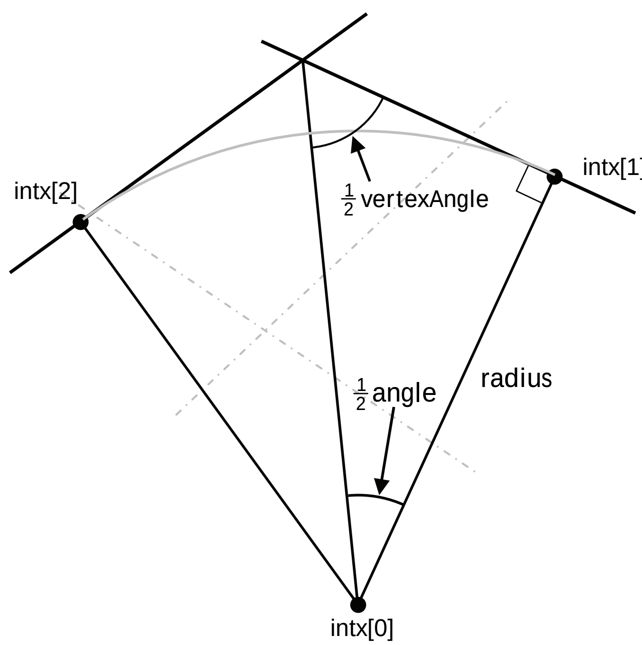


Figure A-20. Spherical Triangle Construction Used for Calculating the Approximate Vertex Angle at the Intersection of Two Loci



5.0 Projections.

5.1 Project Point to Geodesic.

This algorithm is used to determine the shortest distance from a point to a geodesic. It also locates the point on the geodesic that is nearest the given point.

5.1.1 Input/Output.

`long WGS84PerpIntercept(LLPoint pt1, double crs12, LLPoint* pt2, LLPoint pt3, double* crsFromPoint, double* distFromPoint, double tol)` returns a reference to an `LLPoint` structure that contains the coordinates of the projected point, where the inputs are:

`LLPoint pt1`	=	Coordinates of geodesic start point
`double crs13`	=	Initial azimuth of geodesic at start point
`LLPoint pt3`	=	Coordinates of point to be projected to geodesic
`LLPoint* pt2`	=	Reference to `LLPoint` that will be updated with coordinates of projected point.
`double* crsFromPoint`	=	Reference to azimuth of geodesic from `pt3` to projected point, in radians.
`double* distFromPoint`	=	Reference to distance from `pt3` to projected point, in radians.
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

5.1.2 Algorithm Steps.

This algorithm treats the geodesic as unbounded, so that projected points that lie “behind” the geodesic starting point `pt1` will be returned. If it is desired to limit solutions to those that lie along the forward direction of the given geodesic, then step 4g may be modified to return a `NULL` solution (see figure A-21).

<u>STEP 1</u>: Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from `pt1` to `pt3`. Denote these values as `crs13`, `crs31`, and `dist13`, respectively.

STEP 2: Calculate the angle between the given geodesic and the geodesic between `pt1` and `pt3`. This is accomplished using `signedAzimuthDifference` function (see Algorithm 6.2):

```
angle=abs(signedAzimuthDifference(crs13, crs12))
```

STEP 3: If (`dist13 <= tol`), then `pt2` is the same point as `pt1`.

STEP 4: If π`/2-angle < tol`, then the projected point `pt2` is very close to or behind `pt1` (the start of the geodesic), so extend the geodesic backward far enough to catch the projection. Use a spherical triangle approximation to calculate the needed extension distance:

a. `B=angle`

b. `a=dist13/sphereRad`

c. `b=asin(sin(B)sin(a))`

d. `dist12=2*sphereRad*atan(tan(0.5*(a-b))*sin(0.5*(A-B)))`

e. If `abs(dist12) < tol`, then the projected point is identical to `pt1` to within the required accuracy:

   (1) `crsFromPoint = crs31`;

   (2) `distFromPoint = dist13`;

   (3) Return `pt2 = pt1`

f. End if.

g. Use the direct algorithm to move `pt1` along reverse geodesic course. Use `1.1*dist12` for the distance, `crs12+`π for the azimuth, and then store the new location in the temporary variable `newPt1`. A distance greater than `dist12` is used to compensate for possible errors in the spherical approximation.

h. Use the inverse algorithm to calculate the azimuth from `newPt` to `pt1`. This value replaces the original azimuth value `crs12`,

   (1) Rename `newPt1` as `pt1: pt1 = newPt1`.

STEP 5: Calculate the approximate distance from pt1 to the projected point using the spherical triangle formula from steps 4(a) through 4(d). Denote the approximate distance found as dist13.

STEP 6: Use the direct algorithm to project a point on the given geodesic distance dist13 from pt1. Use pt1 for the starting point, dist12 for distance, and crs12 for azimuth. Denote the computed point by pt2.

STEP 7: Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

STEP 8: Use the inverse algorithm to calculate the azimuth crs23 and distance dist23 from pt3 to pt2.

STEP 9: Calculate the angle between the geodesics that intersect at pt3, and cast that angle into the range $[0,\pi]$ using the following formula (see Algorithm 5.1):

angle=abs(signedAzimuthDifference(crs21, crs23))

STEP 10: Calculate the error and store it as the first element in the error function array: errarray[0] = angle - $\pi/2$.

STEP 11: Store the current distance from pt1 to pt2 in the distance function array: distarray[0] = dist12.

STEP 12: A second distance/error value must be calculated before linear interpolation may be used to improve the solution. The following formula may be used:

distarray[1]=distarray[0]+errarray[0]*dist23

STEP 13: Use the direct algorithm to project point on the given geodesic distance distarray[1] from pt1. Use pt1 for the starting point, distarray[1] for distance, and crs12 for azimuth. Denote the computed point by pt2.

STEP 14: Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

STEP 15: Use the inverse algorithm to calculate the azimuth crs23 from pt2 to pt3.

STEP 16: Calculate the error in angle (see Algorithm 5.1):

errarray[1]=abs(signedAzimuthDifference(crs21, crs23))-$\pi/2$

STEP 17: Initialize the iteration count: k = 0.

STEP 18: Do while (`k = 0`) or ((`error > tol`) and (`k < maxIterationCount`))

a. Use linear approximation to find root of `errarray` as a function of `distarray`. This gives an improved approximation to `dist12`.

b. Use the direct algorithm to project point on the given geodesic distance `dist12` from `pt1`. Use `pt1` for the starting point, `dist12` for distance, and `crs12` for azimuth. Denote the computed point by `pt2`.

c. Use the inverse algorithm to calculate the azimuth `crs21` from `pt2` to `pt1`.

d. Use the inverse algorithm to calculate the distance `dist23`, azimuth `crs32`, and reverse azimuth `crs23` from `pt3` to `pt2`.

e. Update `distarray` and `errarray` with the new values:

```
distarray[0] = distarray[1]
errarray[0] =  errarray[1]
distarray[1] = dist13
errarray[1]=   abs(signedAzimuthDifference(crs21,
               crs23))-π/2
```

f. Calculate the difference between the two latest distance values. This serves as the error function for measuring convergence:

```
error=abs(distarray[1]-distarray[0])
```

STEP 19: End `while`.

STEP 20: Set `crsToPoint = crs32`.

STEP 21: Set `distToPoint = dist23`.

STEP 22: Return `pt2`.

Figure A-21. Projecting a Point to a Geodesic

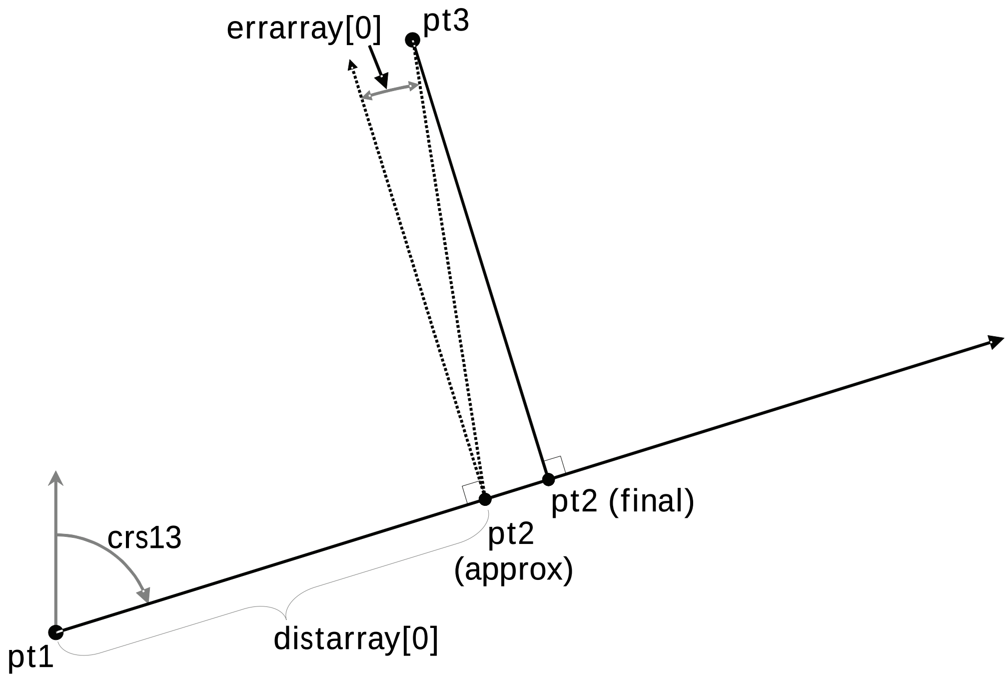
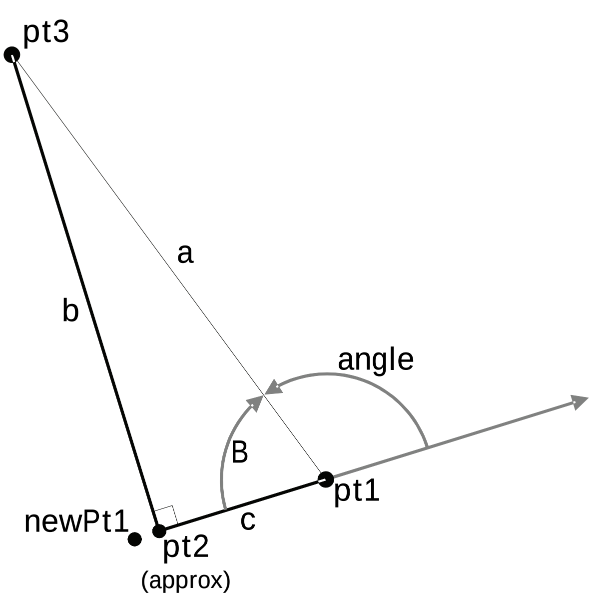


Figure A-22. Elements of Spherical Triangle Used to Determine New Geodesic Starting Point When Projected Point Lies Behind Given Starting Point



5.2 Project Point to Locus.

This algorithm returns the point on a locus nearest the given sample point. It is used in Algorithm 4.8 to calculate an arc tangent to two loci.

5.2.1 Input/Output.

`LLPoint* WGS84LocusPerpIntercept(Locus loc, LLPoint pt2, double* crsFromPoint, double* distFromPoint, double tol)` returns a reference to an `LLPoint` structure that contains the coordinates of the projected point, where the inputs are:

`Locus loc`	=	Locus structure to which point will be projected
`LLPoint pt2`	=	Coordinates of point to be projected to locus
`double* crsFromPoint`	=	Reference to value that will store the course from `pt2` to projected point
`double* distFromPoint`	=	Reference to value that will store the distance from `pt2` to projected point
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

5.2.2 Algorithm Steps.

See figure A-23 for an illustration of the variables.

STEP 1: Define the course and distance from `loc.geoStart` to `loc.geoEnd` as `gcrs` and `gdist`, respectively. This course and distance is a part of the locus structure:

a. `gcrs=loc.geoAz`

b. `gdist=loc.geoLength`

STEP 2: If (`abs(loc.startDist-loc.endDist) < tol`), then the locus is "parallel" to its defining geodesic. In this case, the projected point on the locus will lie on the geodesic joining `pt2` with its projection on the defining geodesic, and the calculation is simplified:

a. Apply Algorithm 5.1 to project `pt2` onto the defining geodesic of `loc`. Use `loc.geoStart, gcrs,` and `pt2` as input parameters. The intersection point, `perpPt`, will be returned along with the course and distance from `pt2` to `perpPt`. Denote the course and distance values as `crsFromPoint` and `distFromPoint`, respectively.

b. Use Algorithm 3.10 to project a point `locPt` on the locus from `perpPt` on the geodesic.

c. Use the inverse algorithm to recalculate `distFromPoint` as the distance between `pt2` and `locPt`.

d. Return `locPt`.

STEP 3: End if.

STEP 4: Use the inverse algorithm to compute `lcrs`, the course from `loc.locusStart` to `loc.locusEnd`.

STEP 5: Use Algorithm 5.1 to project `pt2` onto the geodesic approximation of the locus. Pass `loc.locusStart`, `lcrs`, and `pt2` as parameters. Denote the computed point as `locPt`. (In general, this point will not exactly lie on the locus. We will adjust its position so that it is on the locus in a subsequent step.)

STEP 6: Calculate the locus inclination angle, relative to its geodesic:

```
locAngle=atan((loc.startDist-loc.endDist)/gdist)
```

STEP 7: Use Algorithm 5.1 to project `locPt` onto the locus's defining geodesic. Pass `loc.geoStart`, `gcrs`, and `locPt` as parameters. Denote the computed point as `geoPt`.

STEP 8: Use the inverse function to calculate the distance from `loc.geoStart` to `geoPt`. Store this value as `distarray[1]`.

STEP 9: Initialize the iteration count: `k = 0`

STEP 10: Do while (`k = 0`) or (`abs(errarray[1]) > tol`) and (`k < maxIterationCount`))

a. Use Algorithm 3.10 with `distarray[1]` to project a point onto the locus. Reassign `locPt` as this point.

b. Use Algorithm 3.12 to recompute `lcrs`, the course of the locus at `locPt`.

c. Use the inverse algorithm to compute `crsToPoint` and `distToPoint`, the course and distance from `locPt` to `pt2`.

d. Compute the signed angle between the locus and the geodesic from `locPt` to `pt2`:

```
angle=signedAzimuthDifference(lcrs, crsToPoint)
```

e. Store the approximate error as:
```
errarray[1]=-distToPoint*cos(angle)
```

This converts the error in angle into an error in distance which can be compared to `tol`.

f. If (`k = 0`) then a direct calculation is used to improve the approximation:

```
newDist=distarray[1]+errarray[1]*cos(locAngle)
```

g. Else, use a linear root finder with `distarray` and `errarray` to solve for the distance value that makes the error zero. Denote this value as `newDist`.

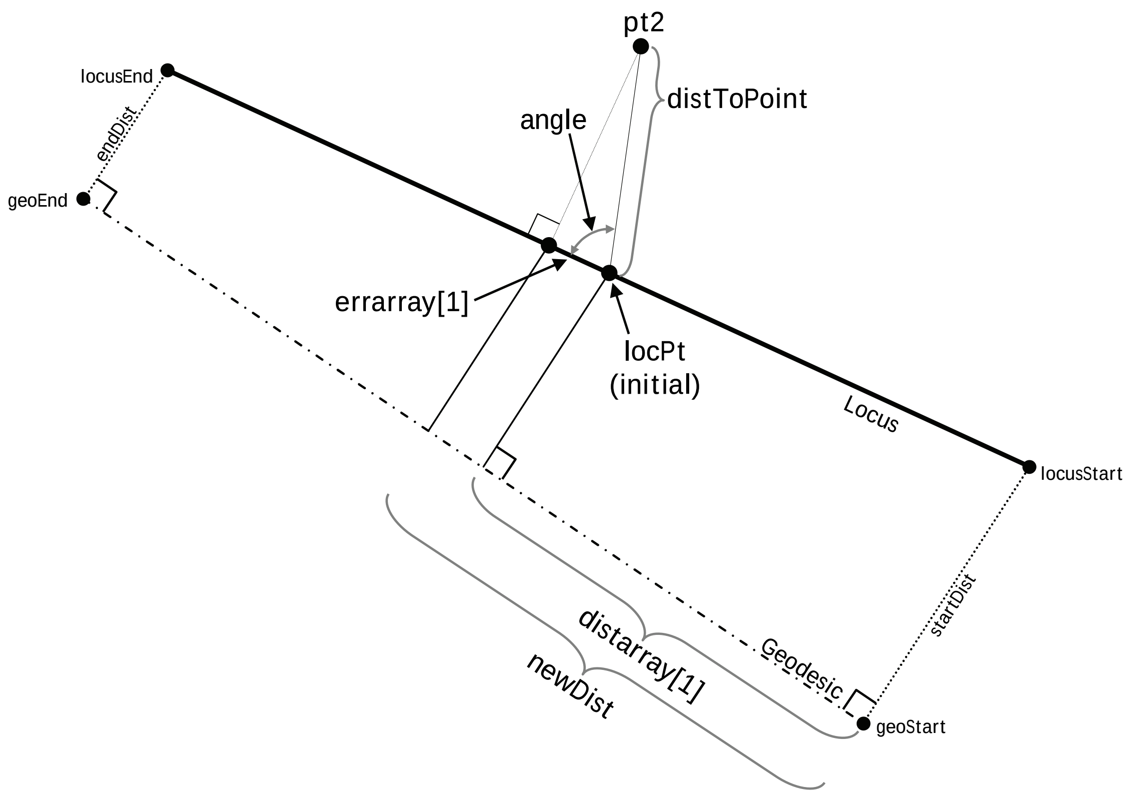
h. End if.

i. Update the distance and error arrays:
```
distarray[0] = distarray[1]
errarray[0]  = errarray[1]
distarray[1] = newDist
```

<u>STEP 11</u>: End while.

<u>STEP 12</u>: Return `locPt`.

Figure A-23. Projecting a Point to a Locus



5.3 Tangent Projection from Point to Arc.

This projection is used in obstacle evaluation when finding the point on an RF leg or fly-by turn path where the distance to an obstacle must be measured.

5.3.1 Input/Output.

`long WGS84PointToArcTangents(LLPoint point, LLPoint center, double radius, LLPointPair tanPt, int* n, double tol)` returns a reference to an `LLPoint` structure that contains the coordinates of the points where geodesics through `point` are tangent to arc, where the inputs are:

`LLPoint point`	=	Point from which lines will be tangent to arc
`LLPoint center`	=	Geodetic `centerpoint` coordinates of arc
`double radius`	=	Radius of arc
`LLPointPair tanPt`	=	Two-element array of `LLPoint` objects that will be updated with tangent points' coordinates

`int* n`	=	Reference to number of tangent points found (0, 1, or 2)
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

5.3.2 Algorithm Steps.

This algorithm treats the arc as a complete circle, so either zero or two tangent points will be returned. If the arc is bounded and two tangent points are found, then each point must be tested using Algorithm 3.7 to determine whether they lie within the arc's bounds (see figure A-24).

STEP 1: Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from point to `center`. Denote these values by `crsToCenter`, `crsFromCenter`, and `distToCenter`, respectively.

STEP 2: If `abs(distToCenter – radius) < tol`, then point lies on the arc and is a tangent point:

a. Set `n = 1`.

b. Return `tanPt = point`.

STEP 3: Else, if `distToCenter < radius`, then point lies inside of the arc and no tangent points exist,

a. Return no solution.

STEP 4: End if.

STEP 5: There must be two tangent points on the circle, so set `n = 2`.

STEP 6: Use spherical trigonometry to compute approximate tangent points:

a. $a = \text{distToCenter}/\text{SPHERE\_RADIUS}$

b. $b = \text{radius}/\text{SPHERE\_RADIUS}$

c. $C = a\cos\left(\tan(b)/\tan(a)\right)$.

This is the approximate angle between the geodesic that joins `point` with `center` and the geodesic that joins `center` with either tangent point.

STEP 7: Initialize iteration count `k = 0`.

STEP 8: Do while (`k = 0`) or (`abs(error) > tol` and
`k < maxIterationCount`:

a. Use the direct algorithm to locate `tanPt[0]` on arc. Use `center` as the starting point, `radius` as the distance, and `courseFromCenter+C` as the azimuth.

b. Use the inverse algorithm to calculate the azimuth from `tanPt[0]` to `center`. Denote this value as `radCrs`.

c. Use the inverse algorithm to calculate the azimuth from `tanPt[0]` to point. Denote this value as `tanCrs`.

d. Use the function in Algorithm 6.2 to calculate the angle between the two courses and cast it into the range $(-\pi, \pi]$:

$$\texttt{diff} = \text{signedAzimuthDifference}(\texttt{radCrs}, \texttt{tanCrs})$$

e. Compute the error $\texttt{error} = \text{abs}(\texttt{diff}) - \frac{\pi}{2}$.

f. Adjust the value of `C` to improve the approximation `C = C + error`.

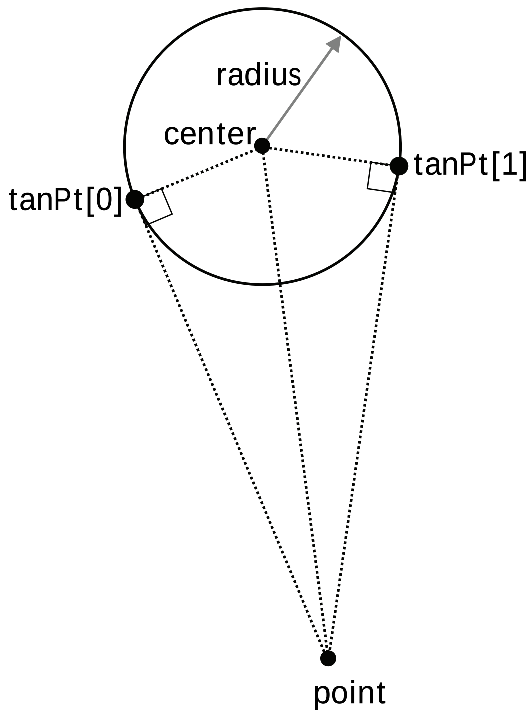
g. Increment the iteration count `k = k + 1`.

STEP 9: End while loop.

STEP 10: Repeat steps 7-9 to solve for `tanPt[1]`. In each iteration; however, use `crsFromPoint-C` for azimuth in step 8(a).

STEP 11: Return `tanPt[0]`and `tanPt[1]` .

Figure A-24. Projecting Point to Tangent Points on an Arc



5.4 Project Arc to Geodesic.

This algorithm is used for obstacle evaluation when finding a point on the straight portion of TF leg where distance to an obstacle must be measured.

5.4.1 Input/Output.

`long WGS84PerpTangentPoints(LLPoint lineStart, double crs, LLPoint center, double radius, LLPointPair linePts, LLPointPair tanPts, double tol)` updates geodesic intercepts, but returns no output, where input values are:

`LLPoint lineStart`	=	Start point of geodesic to which arc tangent points will be projected
`double crs`	=	Initial course of geodesic
`LLPoint center`	=	Geodetic coordinates of arc center
`double radius`	=	Arc radius
`LLPointPair linePts`	=	Two-element array of projected points on Geodesic

`LLPointPair tanPts`	=	Two-element array of tangent points on arc
`double tol`	=	Maximum error allowed in solution
`double eps`	=	Convergence parameter for forward/inverse algorithms

5.4.2 Algorithm Steps.

See figure A-25 for an illustration of the variable names.

STEP 1: Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from `lineStart` to `center`. Denote these values as `distStartToCenter`, `crsStartToCenter`, and `crsCenterToStart`, respectively.

STEP 2: Compute the angle between the given geodesic and the geodesic that joins `lineStart` to `center` (see Algorithm 6.2):

$$\texttt{angle1} = \text{signedAzimuthDifference}(\texttt{crs}, \texttt{crsStartToCenter})$$

STEP 3: If `abs(distStartToCenter*(crsStartToCenter-crs)) < tol`, then center lies on the given geodesic, which is a diameter of the circle. In this case, the tangent points and project points are the same:

a. Use the direct algorithm to compute `tanPts[0]`. Use `lineStart` as the starting point, `crs` as the azimuth, and `distStartToCenter-radius` as the distance.

b. Use the direct algorithm to compute `tanPts[0]`. Use `lineStart` as the starting point, `crs` as the azimuth, and `distStartToCenter+radius` as the distance.

c. Set `linePts[0] = tanPts[0]`.

d. Set `linePts[1] = tanPts[1]`.

e. Return all four points.

STEP 4: End if.

STEP 5: Use Algorithm 5.1 to project `center` to the geodesic defined by `lineStart` and `crs`. Denote the projected point by `perpPt`.

STEP 6: Use the inverse algorithm to calculate the distance, azimuth, and reverse azimuth from `perpPt` to `lineStart`. Denote these values by `dist12` and `crs21`, respectively.

STEP 7: Set `delta = radius`.

STEP 8: Initialize iteration count: `k = 0`.

STEP 9: Do while (`k = 0`) or (`abs(error) > tol` and `k < maxIterationCount`):

a. Use the direct algorithm to compute `linePts[0]`. Use `perpPt` as the starting point, `delta` as the distance, and `crs21`+π as the azimuth.

b. Use the inverse algorithm to calculate the course from `linePts[0]` to `perpPt`. Denote this value by `strCrs`.

c. Calculate the azimuth, `perpCrs`, from `linePts[0]` to the desired position of `tanPts[0]`. The azimuth depends upon which side of the line the circle lies, which is given by the sign of `angle1`:

(1) If the circle lies to the right of the line:
`perpCrs = strCrs +` π`/2`.

(2) If the circle lies to the left of the line:
`perpCrs = strCrs -` π`/2`.

d. Use Algorithm 5.1 to project `center` onto the geodesic passing through `linePts[0]` at azimuth `perpCrs`. Algorithm 5.1 will return the projected point, `tanPts[0]`, along with the distance from `center` to `tanPts[0]`. Denote this distance by `radDist`.

e. Calculate the error, the amount that `radDist` differs from `radius`:
`error = radDist - radius`.

f. Adjust the distance from `lineStart to linePts[0]`:
`delta = delta - error`.

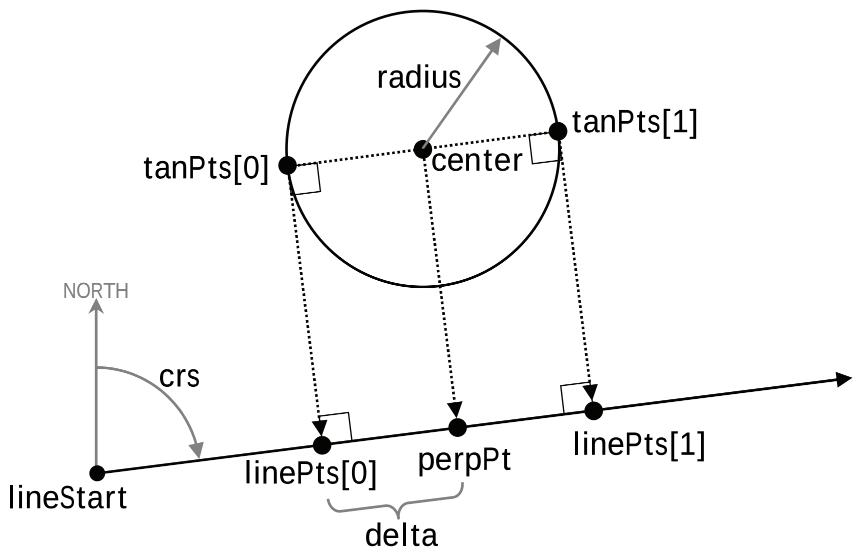
g. Increment the iteration count: `k = k + 1`.

STEP 10: End while loop.

STEP 11: Repeat steps 7-10 to solve for `linePts[1]` and `tanPts[1]`. In each iteration; however, use `crs21` for azimuth in step a). Note that using the final `delta` value for the first iteration in the search for `linePts[1]` will make the code more efficient (i.e., don’t repeat step 7).

STEP 12: Return `linePts[0]`, `linePts[1]`, `tanPts[0]`, and `tanPts[1]`.

Figure A-25. Projecting an Arc to a Geodesic



Attachment A - Useful Functions.

6.0 Calculate Angular Arc Extent.

When calculating the angle subtended by an arc, one must take into account the possibility that the arc crosses the northern branch cut, where `0°` = `360°`. The following algorithm accounts for this case.

Input/Output.

`double WGS84GetArcExtent(double startCrs, double endCrs, int orientation, double tol)` returns a double precision value containing the arc's subtended angle, where the input values are:

`double startCrs`	=	Azimuth from center to start point of arc
`double endCrs`	=	Azimuth from center to end point of arc
`int orientation`	=	Integer that indicates the direction in which the arc is traversed to go from `startCrs` to `endCrs`.
`orientation`	=	`1` if the arc is traversed counter-clockwise,
`orientation`	=	`-1` if the arc is traversed clockwise.
`double tol`	=	Maximum error allowed in calculations

6.01 Algorithm Steps.

<u>STEP 1</u>: If `(abs(startCrs-endCrs) < tol)` return `2*`π.

<u>STEP 2</u>: If `orientation < 0`, then orientation is clockwise. Cast the arc into a positive orientation (counter-clockwise) so only one set of calculations is required:

a. `temp = startCrs`

b. `startCrs = endCrs`

c. `endCrs = temp`

<u>STEP 3</u>: End if.

<u>STEP 4</u>: If `startCrs > endCrs`, then `angle = startCrs – endCrs`.

STEP 5: Else `angle = 2*π + startCrs – endCrs`.

STEP 6: End if.

STEP 7: If `orientation < 0`, then `angle = -angle`.

STEP 8: Return `angle`.

6.1 Converting Geodetic Latitude/Longitude to ECEF Coordinates.

Geodetic coordinates may be converted to rectilinear ECEF coordinates using the following formulae[1]. Given geodetic latitude φ, geodetic longitude θ, semi-major axis a and flattening parameter f, calculate the square of the eccentricity

$e^2 = f(2 - f)$ and the curvature in the prime vertical: $N = \dfrac{a}{\sqrt{1-e^2\sin^2\varphi}}$.

The ECEF coordinates are then

$$x = N\cos\varphi\cos\theta$$
$$y = N\cos\varphi\sin\theta$$
$$z = N\left(1-e^2\right)\sin\varphi$$

6.2 Signed Azimuth Difference.

It is often necessary to calculate the signed angular difference in azimuth between two geodesics at the point where they intersect. The following functions casts the difference between two geodesics into the range $[-\pi,\pi)$:

$$\texttt{signedAzimuthDifference}(a_1,a_2) = \mathrm{mod}(a_1 - a_2 + \pi, 2\pi) - \pi$$

This function returns the angle between the two geodesics as if the geodesic that is oriented along azimuth a_1 were on the positive x-axis and the geodesic oriented along azimuth a_2 passed through the origin. In other words, if $\mathrm{signedAzimuthDifference}(a_1,a_2) > 0$ azimuth a_2 is to the left when standing at the geodesics' intersection point and facing in the direction of azimuth a_1.

[1] Dana, Peter H., "Coordinate Conversion Geodetic Latitude, Longitude, and Height to ECEF, X, Y, Z", http://www.colorado.edu/geography/gcraft/notes/datum/gif/llhxyz.gif>, 11 February, 2003

The mod function in the definition of `signedAzimuthDifference` must always return a non-negative value. Note that the C language's built in `fmod` function does not have this behavior, so a replacement must be supplied. The following code suffices:

```
double mod(double a, double b) {
a = fmod(a,b);
  if (a < 0.0) a = a + b;
return a;  }
```

6.3 Approximate Fixed Radius Arc Length.

Algorithm 3.8 describes a method for computing the length of an arc to high precision. The following algorithm provides a solution accurate to 1 centimeter for an arc whose radius is less than about 300 nautical miles (NM). This algorithm approximates the ellipsoid at the center of the arc in question with a "best fit" sphere, whose radius is computed as the geometric mean of the meridional and prime-vertical curvatures at the arc's center.

Given the arc center's latitude θ, the ellipsoidal semi-major axis a and flattening f, compute the local radius of curvature R as follows:

$$e^2 = f\left(2 - f\right)$$
$$M = \frac{a\left(1-e^2\right)}{\left(1-e^2\sin^2\theta\right)^{\frac{3}{2}}}$$
$$N = \frac{a}{\sqrt{1-e^2\sin^2\theta}}$$
$$R = \sqrt{MN}$$

If the radius and subtended angle of the of the constant radius arc are r and A, respectively, then the length of the arc is given by:

$$L = AR\sin\left(\frac{r}{R}\right).$$

Attachment C

7.0 Sample Function Test Results.

The following pages provide test inputs with expected outputs. This data is included here to make it easy to verify that an independent implementation of these algorithms produces the same results. All of these results were obtained using the tolerance parameter $\texttt{tol} = 1.0\text{e}-9$ and forward/inverse convergence parameter $\texttt{eps} = 0.5\text{e}-13$.

Test results are not included for those algorithms that are fairly straightforward applications of other algorithms, such as 3.9, 3.10, and 3.11.

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WGS84 Direct Test Results

Test Identifier	Starting Latitude	Starting Longitude	Distance (NM)	Initial Azimuth (degrees)	Computed Destination Latitude	Computed Destination Longitude
test1	40:10:24.50000N	70:12:45.60000W	200.0	90.0	40:05:30.77099N	65:52:03.22158W
test2	40:10:24.50000N	70:12:45.60000W	200.0	0.0	43:30:29.87690N	70:12:45.60000W
test3	40:10:24.50000N	70:12:45.60000W	200.0	180.0	36:50:12.19034N	70:12:45.60000W
test4	40:10:24.50000N	70:12:45.60000W	200.0	270.0	40:05:30.77099N	74:33:27.97842W
test5	40:10:24.50000N	70:12:45.60000W	200.0	46.0	42:26:44.93817N	66:58:26.80185W
test6	40:10:24.50000N	70:12:45.60000W	200.0	127.0	38:06:56.47029N	66:50:21.71131W
test7	40:10:24.50000N	70:12:45.60000W	200.0	199.0	37:00:37.63806N	71:34:01.15378W
test8	40:10:24.50000N	70:12:45.60000W	200.0	277.0	40:29:56.05779N	74:33:04.77416W
test9	40:10:24.50000N	70:12:45.60000W	2.0	90.0	40:10:24.47060N	70:10:09.05140W
test10	40:10:24.50000N	70:12:45.60000W	2.0	0.0	40:12:24.58831N	70:12:45.60000W
test11	40:10:24.50000N	70:12:45.60000W	2.0	180.0	40:08:24.41100N	70:12:45.60000W
test12	40:10:24.50000N	70:12:45.60000W	2.0	270.0	40:10:24.47060N	70:15:22.14860W
test13	40:10:24.50000N	70:12:45.60000W	2.0	46.0	40:11:47.90520N	70:10:52.95004W
test14	40:10:24.50000N	70:12:45.60000W	2.0	127.0	40:09:12.20998N	70:10:40.61155W
test15	40:10:24.50000N	70:12:45.60000W	2.0	199.0	40:08:30.95052N	70:13:36.54366W
test16	40:10:24.50000N	70:12:45.60000W	2.0	277.0	40:10:39.10616N	70:15:20.99098W
test17	40:10:24.50000N	70:12:45.60000W	3000.0	90.0	24:30:24.17902N	13:01:17.08239W
test18	40:10:24.50000N	70:12:45.60000W	3000.0	0.0	89:58:28.94717N	109:47:14.40000E
test19	40:10:24.50000N	70:12:45.60000W	3000.0	180.0	10:00:44.08298S	70:12:45.60000W
test20	40:10:24.50000N	70:12:45.60000W	3000.0	270.0	24:30:24.17902N	127:24:14.11761W
test21	40:10:24.50000N	70:12:45.60000W	3000.0	46.0	55:17:03.30750N	4:30:00.21623E
test22	40:10:24.50000N	70:12:45.60000W	3000.0	127.0	3:28:31.38990N	32:28:57.95936W
test23	40:10:24.50000N	70:12:45.60000W	3000.0	199.0	8:09:04.17050S	84:46:29.97795W
test24	40:10:24.50000N	70:12:45.60000W	3000.0	277.0	29:06:16.65778N	130:30:47.88401W
test25	50:10:52.50000N	123:06:57.10000W	200.0	90.0	50:03:56.42973N	117:56:18.19536W
test26	50:10:52.50000N	123:06:57.10000W	200.0	0.0	53:30:36.93183N	123:06:57.10000W
test27	50:10:52.50000N	123:06:57.10000W	200.0	180.0	46:51:01.16657N	123:06:57.10000W
test28	50:10:52.50000N	123:06:57.10000W	200.0	270.0	50:03:56.42973N	128:17:36.00464W
test29	50:10:52.50000N	123:06:57.10000W	200.0	46.0	52:25:49.36941N	119:11:51.80053W
test30	50:10:52.50000N	123:06:57.10000W	200.0	127.0	48:06:24.18375N	119:08:33.75213W
test31	50:10:52.50000N	123:06:57.10000W	200.0	199.0	47:01:13.78683N	124:42:04.78016W
test32	50:10:52.50000N	123:06:57.10000W	200.0	277.0	50:28:19.21956N	128:17:55.21964W
test33	50:10:52.50000N	123:06:57.10000W	2.0	90.0	50:10:52.45833N	123:03:50.41132W
test34	50:10:52.50000N	123:06:57.10000W	2.0	0.0	50:12:52.37823N	123:06:57.10000W
test35	50:10:52.50000N	123:06:57.10000W	2.0	180.0	50:08:52.62108N	123:06:57.10000W
test36	50:10:52.50000N	123:06:57.10000W	2.0	270.0	50:10:52.45833N	123:10:03.78868W
test37	50:10:52.50000N	123:06:57.10000W	2.0	46.0	50:12:15.75291N	123:04:42.74250W
test38	50:10:52.50000N	123:06:57.10000W	2.0	127.0	50:09:40.32859N	123:04:28.06612W
test39	50:10:52.50000N	123:06:57.10000W	2.0	199.0	50:08:59.14786N	123:07:57.83998W
test40	50:10:52.50000N	123:06:57.10000W	2.0	277.0	50:11:07.06846N	123:10:02.41284W
test41	50:10:52.50000N	123:06:57.10000W	3000.0	90.0	29:37:18.55208N	61:31:12.91277W
test42	50:10:52.50000N	123:06:57.10000W	3000.0	0.0	80:00:57.51620N	56:53:02.90000E
test43	50:10:52.50000N	123:06:57.10000W	3000.0	180.0	0:02:43.03479N	123:06:57.10000W
test44	50:10:52.50000N	123:06:57.10000W	3000.0	270.0	29:37:18.55208N	175:17:18.71277E

test45	50:10:52.50000N	123:06:57.10000W	3000.0	46.0	56:40:22.79938N	33:42:20.71403W
test46	50:10:52.50000N	123:06:57.10000W	3000.0	127.0	11:23:14.37898N	84:34:26.55554W
test47	50:10:52.50000N	123:06:57.10000W	3000.0	199.0	1:35:14.22889N	137:32:13.52544W
test48	50:10:52.50000N	123:06:57.10000W	3000.0	277.0	33:39:39.03338N	171:08:27.87014E
test49	42:44:32.10000N	66:27:19.60000E	200.0	90.0	42:39:10.81410N	70:58:29.15259E
test50	42:44:32.10000N	66:27:19.60000E	200.0	0.0	46:04:32.07438N	66:27:19.60000E
test51	42:44:32.10000N	66:27:19.60000E	200.0	180.0	39:24:25.11928N	66:27:19.60000E
test52	42:44:32.10000N	66:27:19.60000E	200.0	270.0	42:39:10.81410N	61:56:10.04741E
test53	42:44:32.10000N	66:27:19.60000E	200.0	46.0	45:00:33.43147N	69:50:07.10761E
test54	42:44:32.10000N	66:27:19.60000E	200.0	127.0	40:40:50.71563N	69:57:17.17656E
test55	42:44:32.10000N	66:27:19.60000E	200.0	199.0	39:34:47.61048N	65:03:08.96220E
test56	42:44:32.10000N	66:27:19.60000E	200.0	277.0	43:03:35.51327N	61:56:24.98803E
test57	42:44:32.10000N	66:27:19.60000E	2.0	90.0	42:44:32.06784N	66:30:02.45101E
test58	42:44:32.10000N	66:27:19.60000E	2.0	0.0	42:46:32.13452N	66:27:19.60000E
test59	42:44:32.10000N	66:27:19.60000E	2.0	180.0	42:42:32.06478N	66:27:19.60000E
test60	42:44:32.10000N	66:27:19.60000E	2.0	270.0	42:44:32.06784N	66:24:36.74899E
test61	42:44:32.10000N	66:27:19.60000E	2.0	46.0	42:45:55.46641N	66:29:16.78884E
test62	42:44:32.10000N	66:27:19.60000E	2.0	127.0	42:43:19.84058N	66:29:29.61668E
test63	42:44:32.10000N	66:27:19.60000E	2.0	199.0	42:42:38.60108N	66:26:26.60774E
test64	42:44:32.10000N	66:27:19.60000E	2.0	277.0	42:44:46.69688N	66:24:37.95230E
test65	42:44:32.10000N	66:27:19.60000E	3000.0	90.0	25:52:49.48262N	124:39:55.85184E
test66	42:44:32.10000N	66:27:19.60000E	3000.0	0.0	87:25:13.54228N	113:32:40.40000W
test67	42:44:32.10000N	66:27:19.60000E	3000.0	180.0	7:25:57.78702S	66:27:19.60000E
test68	42:44:32.10000N	66:27:19.60000E	3000.0	270.0	25:52:49.48262N	8:14:43.34816E
test69	42:44:32.10000N	66:27:19.60000E	3000.0	46.0	55:52:47.54426N	144:47:50.12500E
test70	42:44:32.10000N	66:27:19.60000E	3000.0	127.0	5:30:44.95719N	104:18:35.77997E
test71	42:44:32.10000N	66:27:19.60000E	3000.0	199.0	5:39:14.93608S	51:58:13.27568E
test72	42:44:32.10000N	66:27:19.60000E	3000.0	277.0	30:21:08.45258N	4:52:35.40656E
test73	31:12:52.30000N	125:28:47.50000E	200.0	90.0	31:09:21.00038N	129:21:55.26637E
test74	31:12:52.30000N	125:28:47.50000E	200.0	0.0	34:33:15.83037N	125:28:47.50000E
test75	31:12:52.30000N	125:28:47.50000E	200.0	180.0	27:52:22.52362N	125:28:47.50000E
test76	31:12:52.30000N	125:28:47.50000E	200.0	270.0	31:09:21.00038N	121:35:39.73363E
test77	31:12:52.30000N	125:28:47.50000E	200.0	46.0	33:30:10.60726N	128:20:48.89100E
test78	31:12:52.30000N	125:28:47.50000E	200.0	127.0	29:10:03.77133N	128:31:13.43437E
test79	31:12:52.30000N	125:28:47.50000E	200.0	199.0	28:02:57.01708N	124:15:14.09016E
test80	31:12:52.30000N	125:28:47.50000E	200.0	277.0	31:33:48.07660N	121:36:24.04854E
test81	31:12:52.30000N	125:28:47.50000E	2.0	90.0	31:12:52.27886N	125:31:07.43524E
test82	31:12:52.30000N	125:28:47.50000E	2.0	0.0	31:14:52.56685N	125:28:47.50000E
test83	31:12:52.30000N	125:28:47.50000E	2.0	180.0	31:10:52.03253N	125:28:47.50000E
test84	31:12:52.30000N	125:28:47.50000E	2.0	270.0	31:12:52.27886N	125:26:27.56476E
test85	31:12:52.30000N	125:28:47.50000E	2.0	46.0	31:14:15.83349N	125:30:28.18558E
test86	31:12:52.30000N	125:28:47.50000E	2.0	127.0	31:11:39.90782N	125:30:39.23361E
test87	31:12:52.30000N	125:28:47.50000E	2.0	199.0	31:10:58.58265N	125:28:01.95668E
test88	31:12:52.30000N	125:28:47.50000E	2.0	277.0	31:13:06.93605N	125:26:28.60187E
test89	31:12:52.30000N	125:28:47.50000E	3000.0	90.0	19:27:03.05786N	179:41:20.83695E
test90	31:12:52.30000N	125:28:47.50000E	3000.0	0.0	81:07:29.93181N	125:28:47.50000E
test91	31:12:52.30000N	125:28:47.50000E	3000.0	180.0	18:59:46.09922S	125:28:47.50000E
test92	31:12:52.30000N	125:28:47.50000E	3000.0	270.0	19:27:03.05786N	71:16:14.16305E

test93	31:12:52.30000N	125:28:47.50000E	3000.0	46.0	52:04:30.90569N	171:09:46.53647W
test94	31:12:52.30000N	125:28:47.50000E	3000.0	127.0	3:37:54.96189S	163:12:50.99996E
test95	31:12:52.30000N	125:28:47.50000E	3000.0	199.0	16:50:15.39672S	110:24:43.33889E
test96	31:12:52.30000N	125:28:47.50000E	3000.0	277.0	24:24:11.81091N	69:01:02.24210E
test97	49:10:24.50000S	75:12:45.60000W	200.0	90.0	49:03:42.87631S	70:08:25.93407W
test98	49:10:24.50000S	75:12:45.60000W	200.0	0.0	45:50:31.05302S	75:12:45.60000W
test99	49:10:24.50000S	75:12:45.60000W	200.0	180.0	52:30:11.00366S	75:12:45.60000W
test100	49:10:24.50000S	75:12:45.60000W	200.0	270.0	49:03:42.87631S	80:17:05.26593W
test101	49:10:24.50000S	75:12:45.60000W	200.0	46.0	46:48:17.31010S	71:43:18.85029W
test102	49:10:24.50000S	75:12:45.60000W	200.0	127.0	51:06:09.21946S	70:59:16.31551W
test103	49:10:24.50000S	75:12:45.60000W	200.0	199.0	52:18:31.88478S	76:58:48.10816W
test104	49:10:24.50000S	75:12:45.60000W	200.0	277.0	48:39:31.53843S	80:12:23.46911W
test105	49:10:24.50000S	75:12:45.60000W	2.0	90.0	49:10:24.45978S	75:09:42.72995W
test106	49:10:24.50000S	75:12:45.60000W	2.0	0.0	49:08:24.60011S	75:12:45.60000W
test107	49:10:24.50000S	75:12:45.60000W	2.0	180.0	49:12:24.39920S	75:12:45.60000W
test108	49:10:24.50000S	75:12:45.60000W	2.0	270.0	49:10:24.45978S	75:15:48.47005W
test109	49:10:24.50000S	75:12:45.60000W	2.0	46.0	49:09:01.18981S	75:10:34.11555W
test110	49:10:24.50000S	75:12:45.60000W	2.0	127.0	49:11:36.63156S	75:10:19.49448W
test111	49:10:24.50000S	75:12:45.60000W	2.0	199.0	49:12:17.86267S	75:13:45.17447W
test112	49:10:24.50000S	75:12:45.60000W	2.0	277.0	49:10:09.84830S	75:15:47.09213W
test113	49:10:24.50000S	75:12:45.60000W	3000.0	90.0	29:08:15.41939S	14:06:51.81153W
test114	49:10:24.50000S	75:12:45.60000W	3000.0	0.0	0:58:06.24146N	75:12:45.60000W
test115	49:10:24.50000S	75:12:45.60000W	3000.0	180.0	81:01:11.20478S	104:47:14.40000E
test116	49:10:24.50000S	75:12:45.60000W	3000.0	270.0	29:08:15.41939S	136:18:39.38847W
test117	49:10:24.50000S	75:12:45.60000W	3000.0	46.0	7:52:38.83544S	41:28:29.05694W
test118	49:10:24.50000S	75:12:45.60000W	3000.0	127.0	52:04:51.42106S	7:52:24.35518E
test119	49:10:24.50000S	75:12:45.60000W	3000.0	199.0	73:51:36.66725S	168:08:53.56896E
test120	49:10:24.50000S	75:12:45.60000W	3000.0	277.0	25:11:20.18815S	132:13:38.05215W
test121	43:10:45.70000S	123:42:43.40000W	200.0	90.0	43:05:19.50216S	119:09:38.75232W
test122	43:10:45.70000S	123:42:43.40000W	200.0	0.0	39:50:39.63379S	123:42:43.40000W
test123	43:10:45.70000S	123:42:43.40000W	200.0	180.0	46:30:44.75296S	123:42:43.40000W
test124	43:10:45.70000S	123:42:43.40000W	200.0	270.0	43:05:19.50216S	128:15:48.04768W
test125	43:10:45.70000S	123:42:43.40000W	200.0	46.0	40:49:05.78329S	120:33:14.53881W
test126	43:10:45.70000S	123:42:43.40000W	200.0	127.0	45:07:29.89631S	119:57:05.47191W
test127	43:10:45.70000S	123:42:43.40000W	200.0	199.0	46:19:13.99376S	125:16:37.84869W
test128	43:10:45.70000S	123:42:43.40000W	200.0	277.0	42:41:04.43281S	128:11:59.62018W
test129	43:10:45.70000S	123:42:43.40000W	2.0	90.0	43:10:45.66735S	123:39:59.39209W
test130	43:10:45.70000S	123:42:43.40000W	2.0	0.0	43:08:45.67398S	123:42:43.40000W
test131	43:10:45.70000S	123:42:43.40000W	2.0	180.0	43:12:45.72532S	123:42:43.40000W
test132	43:10:45.70000S	123:42:43.40000W	2.0	270.0	43:10:45.66735S	123:45:27.40791W
test133	43:10:45.70000S	123:42:43.40000W	2.0	46.0	43:09:22.30610S	123:40:45.46715W
test134	43:10:45.70000S	123:42:43.40000W	2.0	127.0	43:11:57.91229S	123:40:32.37455W
test135	43:10:45.70000S	123:42:43.40000W	2.0	199.0	43:12:39.18273S	123:43:36.82325W
test136	43:10:45.70000S	123:42:43.40000W	2.0	277.0	43:10:31.04038S	123:45:26.17463W
test137	43:10:45.70000S	123:42:43.40000W	3000.0	90.0	26:06:37.08296S	65:19:15.88930W
test138	43:10:45.70000S	123:42:43.40000W	3000.0	0.0	6:59:37.06995N	123:42:43.40000W
test139	43:10:45.70000S	123:42:43.40000W	3000.0	180.0	86:59:08.38590S	56:17:16.60000E
test140	43:10:45.70000S	123:42:43.40000W	3000.0	270.0	26:06:37.08296S	177:53:49.08930E

test141	43:10:45.70000S	123:42:43.40000W	3000.0	46.0	2:51:33.84923S	90:17:19.02340W
test142	43:10:45.70000S	123:42:43.40000W	3000.0	127.0	50:58:42.47481S	48:01:25.22327W
test143	43:10:45.70000S	123:42:43.40000W	3000.0	199.0	75:32:45.23169S	140:44:35.89858E
test144	43:10:45.70000S	123:42:43.40000W	3000.0	277.0	21:49:17.43560S	178:34:03.34260W
test145	30:13:55.50000S	54:53:17.40000E	200.0	90.0	30:10:32.24599S	58:44:04.46955E
test146	30:13:55.50000S	54:53:17.40000E	200.0	0.0	26:53:23.96278S	54:53:17.40000E
test147	30:13:55.50000S	54:53:17.40000E	200.0	180.0	33:34:20.90547S	54:53:17.40000E
test148	30:13:55.50000S	54:53:17.40000E	200.0	270.0	30:10:32.24599S	51:02:30.33045E
test149	30:13:55.50000S	54:53:17.40000E	200.0	46.0	27:52:57.82170S	57:35:36.72392E
test150	30:13:55.50000S	54:53:17.40000E	200.0	127.0	32:12:18.30198S	58:01:31.85506E
test151	30:13:55.50000S	54:53:17.40000E	200.0	199.0	33:23:02.92727S	53:35:33.92865E
test152	30:13:55.50000S	54:53:17.40000E	200.0	277.0	29:46:10.92312S	51:05:09.54001E
test153	30:13:55.50000S	54:53:17.40000E	2.0	90.0	30:13:55.47966S	54:55:35.92341E
test154	30:13:55.50000S	54:53:17.40000E	2.0	0.0	30:11:55.21431S	54:53:17.40000E
test155	30:13:55.50000S	54:53:17.40000E	2.0	180.0	30:15:55.78508S	54:53:17.40000E
test156	30:13:55.50000S	54:53:17.40000E	2.0	270.0	30:13:55.47966S	54:50:58.87659E
test157	30:13:55.50000S	54:53:17.40000E	2.0	46.0	30:12:31.93209S	54:54:57.02201E
test158	30:13:55.50000S	54:53:17.40000E	2.0	127.0	30:15:07.87646S	54:55:08.05224E
test159	30:13:55.50000S	54:53:17.40000E	2.0	199.0	30:15:49.22963S	54:52:32.28676E
test160	30:13:55.50000S	54:53:17.40000E	2.0	277.0	30:13:40.82086S	54:50:59.91478E
test161	30:13:55.50000S	54:53:17.40000E	3000.0	90.0	18:52:29.86498S	108:49:20.15190E
test162	30:13:55.50000S	54:53:17.40000E	3000.0	0.0	19:58:48.22673N	54:53:17.40000E
test163	30:13:55.50000S	54:53:17.40000E	3000.0	180.0	80:08:58.44983S	54:53:17.40000E
test164	30:13:55.50000S	54:53:17.40000E	3000.0	270.0	18:52:29.86498S	0:57:14.64810E
test165	30:13:55.50000S	54:53:17.40000E	3000.0	46.0	7:58:13.96628N	88:37:37.35172E
test166	30:13:55.50000S	54:53:17.40000E	3000.0	127.0	46:16:23.75384S	116:51:12.92431E
test167	30:13:55.50000S	54:53:17.40000E	3000.0	199.0	71:41:54.15847S	2:36:27.57861E
test168	30:13:55.50000S	54:53:17.40000E	3000.0	277.0	14:01:56.87883S	3:23:24.56420E
test169	71:03:45.50000S	155:13:37.40000E	200.0	90.0	70:47:04.46404S	165:21:13.27121E
test170	71:03:45.50000S	155:13:37.40000E	200.0	0.0	67:44:32.20108S	155:13:37.40000E
test171	71:03:45.50000S	155:13:37.40000E	200.0	180.0	74:22:54.50904S	155:13:37.40000E
test172	71:03:45.50000S	155:13:37.40000E	200.0	270.0	70:47:04.46404S	145:06:01.52879E
test173	71:03:45.50000S	155:13:37.40000E	200.0	46.0	68:37:38.70618S	161:47:11.03268E
test174	71:03:45.50000S	155:13:37.40000E	200.0	127.0	72:51:42.35787S	164:14:58.08728E
test175	71:03:45.50000S	155:13:37.40000E	200.0	199.0	74:09:55.67082S	151:16:06.01068E
test176	71:03:45.50000S	155:13:37.40000E	200.0	277.0	70:23:23.03906S	145:22:23.31016E
test177	71:03:45.50000S	155:13:37.40000E	2.0	90.0	71:03:45.39916S	155:19:45.39068E
test178	71:03:45.50000S	155:13:37.40000E	2.0	0.0	71:01:45.98931S	155:13:37.40000E
test179	71:03:45.50000S	155:13:37.40000E	2.0	180.0	71:05:45.01026S	155:13:37.40000E
test180	71:03:45.50000S	155:13:37.40000E	2.0	270.0	71:03:45.39916S	155:07:29.40932E
test181	71:03:45.50000S	155:13:37.40000E	2.0	46.0	71:02:22.42883S	155:18:01.80054E
test182	71:03:45.50000S	155:13:37.40000E	2.0	127.0	71:04:57.35874S	155:18:31.58931E
test183	71:03:45.50000S	155:13:37.40000E	2.0	199.0	71:05:38.48847S	155:11:37.40237E
test184	71:03:45.50000S	155:13:37.40000E	2.0	277.0	71:03:30.83602S	155:07:32.22736E
test185	71:03:45.50000S	155:13:37.40000E	3000.0	90.0	37:33:28.76348S	130:07:28.60879W
test186	71:03:45.50000S	155:13:37.40000E	3000.0	0.0	21:04:35.11214S	155:13:37.40000E
test187	71:03:45.50000S	155:13:37.40000E	3000.0	180.0	59:09:32.80147S	24:46:22.60000W
test188	71:03:45.50000S	155:13:37.40000E	3000.0	270.0	37:33:28.76348S	80:34:43.40879E

test189	71:03:45.50000S	155:13:37.40000E	3000.0	46.0	25:50:57.88581S	167:05:40.45264W
test190	71:03:45.50000S	155:13:37.40000E	3000.0	127.0	49:25:34.58238S	94:31:25.79851W
test191	71:03:45.50000S	155:13:37.40000E	3000.0	199.0	57:40:40.95961S	2:56:35.65351E
test192	71:03:45.50000S	155:13:37.40000E	3000.0	277.0	35:23:25.31483S	86:40:04.05968E

WGS84 Inverse Test Results

Test Identifier	Starting Latitude	Starting Longitude	Destination Latitude	Destination Longitude	Computed Azimuth (degrees)	Computed Reverse Azimuth (degrees)	Computed Distance (NM)
test1	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	90.00000	272.80147	200.00000
test2	40:10:24.50000N	70:12:45.60000W	43:30:29.87690N	70:12:45.60000W	0.00000	180.00000	200.00000
test3	40:10:24.50000N	70:12:45.60000W	36:50:12.19034N	70:12:45.60000W	180.00000	0.00000	200.00000
test4	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	74:33:27.97842W	270.00000	87.19853	200.00000
test5	40:10:24.50000N	70:12:45.60000W	42:26:44.93817N	66:58:26.80185W	46.00000	228.13861	200.00000
test6	40:10:24.50000N	70:12:45.60000W	38:06:56.47029N	66:50:21.71131W	127.00000	309.13021	200.00000
test7	40:10:24.50000N	70:12:45.60000W	37:00:37.63806N	71:34:01.15378W	199.00000	18.15487	200.00000
test8	40:10:24.50000N	70:12:45.60000W	40:29:56.05779N	74:33:04.77416W	277.00000	94.19092	200.00000
test9	40:10:24.50000N	70:12:45.60000W	40:10:24.47060N	70:10:09.05140W	90.00000	270.02805	2.00000
test10	40:10:24.50000N	70:12:45.60000W	40:12:24.58831N	70:12:45.60000W	0.00000	180.00000	2.00000
test11	40:10:24.50000N	70:12:45.60000W	40:08:24.41100N	70:12:45.60000W	180.00000	0.00000	2.00000
test12	40:10:24.50000N	70:12:45.60000W	40:10:24.47060N	70:15:22.14860W	270.00000	89.97195	2.00000
test13	40:10:24.50000N	70:12:45.60000W	40:11:47.90520N	70:10:52.95004W	46.00000	226.02019	2.00000
test14	40:10:24.50000N	70:12:45.60000W	40:09:12.20998N	70:10:40.61155W	127.00000	307.02239	2.00000
test15	40:10:24.50000N	70:12:45.60000W	40:08:30.95052N	70:13:36.54366W	199.00000	18.99087	2.00000
test16	40:10:24.50000N	70:12:45.60000W	40:10:39.10616N	70:15:20.99098W	277.00000	96.97215	2.00000
test17	40:10:24.50000N	70:12:45.60000W	24:30:24.17902N	13:01:17.08239W	90.00000	302.81413	3000.00000
test18	40:10:24.50000N	70:12:45.60000W	89:58:28.94717N	109:47:14.40000E	0.00000	0.00000	3000.00000
test19	40:10:24.50000N	70:12:45.60000W	10:00:44.08298S	70:12:45.60000W	180.00000	0.00000	3000.00000
test20	40:10:24.50000N	70:12:45.60000W	24:30:24.17902N	127:24:14.11761W	270.00000	57.18587	3000.00000
test21	40:10:24.50000N	70:12:45.60000W	55:17:03.30750N	4:30:00.21623E	46.00000	285.35933	3000.00000
test22	40:10:24.50000N	70:12:45.60000W	3:28:31.38990N	32:28:57.95936W	127.00000	322.25100	3000.00000
test23	40:10:24.50000N	70:12:45.60000W	8:09:04.17050S	84:46:29.97795W	199.00000	14.57444	3000.00000
test24	40:10:24.50000N	70:12:45.60000W	29:06:16.65778N	130:30:47.88401W	277.00000	60.28734	3000.00000
test25	50:10:52.50000N	123:06:57.10000W	50:03:56.42973N	117:56:18.19536W	90.00000	273.97445	200.00000
test26	50:10:52.50000N	123:06:57.10000W	53:30:36.93183N	123:06:57.10000W	0.00000	180.00000	200.00000
test27	50:10:52.50000N	123:06:57.10000W	46:51:01.16657N	123:06:57.10000W	180.00000	0.00000	200.00000
test28	50:10:52.50000N	123:06:57.10000W	50:03:56.42973N	128:17:36.00464W	270.00000	86.02555	200.00000
test29	50:10:52.50000N	123:06:57.10000W	52:25:49.36941N	119:11:51.80053W	46.00000	229.05914	200.00000
test30	50:10:52.50000N	123:06:57.10000W	48:06:24.18375N	119:08:33.75213W	127.00000	310.00613	200.00000
test31	50:10:52.50000N	123:06:57.10000W	47:01:13.78683N	124:42:04.78016W	199.00000	17.81022	200.00000
test32	50:10:52.50000N	123:06:57.10000W	50:28:19.21956N	128:17:55.21964W	277.00000	93.00968	200.00000
test33	50:10:52.50000N	123:06:57.10000W	50:10:52.45833N	123:03:50.41132W	90.00000	270.03983	2.00000
test34	50:10:52.50000N	123:06:57.10000W	50:12:52.37823N	123:06:57.10000W	0.00000	180.00000	2.00000
test35	50:10:52.50000N	123:06:57.10000W	50:08:52.62108N	123:06:57.10000W	180.00000	0.00000	2.00000
test36	50:10:52.50000N	123:06:57.10000W	50:10:52.45833N	123:10:03.78868W	270.00000	89.96017	2.00000
test37	50:10:52.50000N	123:06:57.10000W	50:12:15.75291N	123:04:42.74250W	46.00000	226.02867	2.00000
test38	50:10:52.50000N	123:06:57.10000W	50:09:40.32859N	123:04:28.06612W	127.00000	307.03179	2.00000
test39	50:10:52.50000N	123:06:57.10000W	50:08:59.14786N	123:07:57.83998W	199.00000	18.98704	2.00000
test40	50:10:52.50000N	123:06:57.10000W	50:11:07.06846N	123:10:02.41284W	277.00000	96.96046	2.00000
test41	50:10:52.50000N	123:06:57.10000W	29:37:18.55208N	61:31:12.91277W	90.00000	312.48202	3000.00000
test42	50:10:52.50000N	123:06:57.10000W	80:00:57.51620N	56:53:02.90000E	0.00000	360.00000	3000.00000
test43	50:10:52.50000N	123:06:57.10000W	0:02:43.03479N	123:06:57.10000W	180.00000	0.00000	3000.00000
test44	50:10:52.50000N	123:06:57.10000W	29:37:18.55208N	175:17:18.71277E	270.00000	47.51798	3000.00000

test45	50:10:52.50000N	123:06:57.10000W	56:40:22.79938N	33:42:20.71403W	46.00000	303.05928	3000.00000
test46	50:10:52.50000N	123:06:57.10000W	11:23:14.37898N	84:34:26.55554W	127.00000	328.48986	3000.00000
test47	50:10:52.50000N	123:06:57.10000W	1:35:14.22889N	137:32:13.52544W	199.00000	12.06222	3000.00000
test48	50:10:52.50000N	123:06:57.10000W	33:39:39.03338N	171:08:27.87014E	277.00000	49.84895	3000.00000
test49	42:44:32.10000N	66:27:19.60000E	42:39:10.81410N	70:58:29.15259E	90.00000	273.06555	200.00000
test50	42:44:32.10000N	66:27:19.60000E	46:04:32.07438N	66:27:19.60000E	360.00000	180.00000	200.00000
test51	42:44:32.10000N	66:27:19.60000E	39:24:25.11928N	66:27:19.60000E	180.00000	0.00000	200.00000
test52	42:44:32.10000N	66:27:19.60000E	42:39:10.81410N	61:56:10.04741E	270.00000	86.93445	200.00000
test53	42:44:32.10000N	66:27:19.60000E	45:00:33.43147N	69:50:07.10761E	46.00000	228.34339	200.00000
test54	42:44:32.10000N	66:27:19.60000E	40:40:50.71563N	69:57:17.17656E	127.00000	309.32917	200.00000
test55	42:44:32.10000N	66:27:19.60000E	39:34:47.61048N	65:03:08.96220E	199.00000	18.07623	200.00000
test56	42:44:32.10000N	66:27:19.60000E	43:03:35.51327N	61:56:24.98803E	277.00000	93.92550	200.00000
test57	42:44:32.10000N	66:27:19.60000E	42:44:32.06784N	66:30:02.45101E	90.00000	270.03070	2.00000
test58	42:44:32.10000N	66:27:19.60000E	42:46:32.13452N	66:27:19.60000E	360.00000	180.00000	2.00000
test59	42:44:32.10000N	66:27:19.60000E	42:42:32.06478N	66:27:19.60000E	180.00000	0.00000	2.00000
test60	42:44:32.10000N	66:27:19.60000E	42:44:32.06784N	66:24:36.74899E	270.00000	89.96930	2.00000
test61	42:44:32.10000N	66:27:19.60000E	42:45:55.46641N	66:29:16.78884E	46.00000	226.02210	2.00000
test62	42:44:32.10000N	66:27:19.60000E	42:43:19.84058N	66:29:29.61668E	127.00000	307.02451	2.00000
test63	42:44:32.10000N	66:27:19.60000E	42:42:38.60108N	66:26:26.60774E	199.00000	18.99001	2.00000
test64	42:44:32.10000N	66:27:19.60000E	42:44:46.69688N	66:24:37.95230E	277.00000	96.96952	2.00000
test65	42:44:32.10000N	66:27:19.60000E	25:52:49.48262N	124:39:55.85184E	90.00000	305.21226	3000.00000
test66	42:44:32.10000N	66:27:19.60000E	87:25:13.54228N	113:32:40.40000W	360.00000	0.00000	3000.00000
test67	42:44:32.10000N	66:27:19.60000E	7:25:57.78702S	66:27:19.60000E	180.00000	0.00000	3000.00000
test68	42:44:32.10000N	66:27:19.60000E	25:52:49.48262N	8:14:43.34816E	270.00000	54.78774	3000.00000
test69	42:44:32.10000N	66:27:19.60000E	55:52:47.54426N	144:47:50.12500E	46.00000	289.76179	3000.00000
test70	42:44:32.10000N	66:27:19.60000E	5:30:44.95719N	104:18:35.77997E	127.00000	323.83257	3000.00000
test71	42:44:32.10000N	66:27:19.60000E	5:39:14.93608S	51:58:13.27568E	199.00000	13.92399	3000.00000
test72	42:44:32.10000N	66:27:19.60000E	30:21:08.45258N	4:52:35.40656E	277.00000	57.70460	3000.00000
test73	31:12:52.30000N	125:28:47.50000E	31:09:21.00038N	129:21:55.26637E	90.00000	272.01250	200.00000
test74	31:12:52.30000N	125:28:47.50000E	34:33:15.83037N	125:28:47.50000E	0.00000	180.00000	200.00000
test75	31:12:52.30000N	125:28:47.50000E	27:52:22.52362N	125:28:47.50000E	180.00000	360.00000	200.00000
test76	31:12:52.30000N	125:28:47.50000E	31:09:21.00038N	121:35:39.73363E	270.00000	87.98750	200.00000
test77	31:12:52.30000N	125:28:47.50000E	33:30:10.60726N	128:20:48.89100E	46.00000	227.53504	200.00000
test78	31:12:52.30000N	125:28:47.50000E	29:10:03.77133N	128:31:13.43437E	127.00000	308.52956	200.00000
test79	31:12:52.30000N	125:28:47.50000E	28:02:57.01708N	124:15:14.09016E	199.00000	18.39361	200.00000
test80	31:12:52.30000N	125:28:47.50000E	31:33:48.07660N	121:36:24.04854E	277.00000	94.98210	200.00000
test81	31:12:52.30000N	125:28:47.50000E	31:12:52.27886N	125:31:07.43524E	90.00000	270.02014	2.00000
test82	31:12:52.30000N	125:28:47.50000E	31:14:52.56685N	125:28:47.50000E	0.00000	180.00000	2.00000
test83	31:12:52.30000N	125:28:47.50000E	31:10:52.03253N	125:28:47.50000E	180.00000	360.00000	2.00000
test84	31:12:52.30000N	125:28:47.50000E	31:12:52.27886N	125:26:27.56476E	270.00000	89.97986	2.00000
test85	31:12:52.30000N	125:28:47.50000E	31:14:15.83349N	125:30:28.18558E	46.00000	226.01450	2.00000
test86	31:12:52.30000N	125:28:47.50000E	31:11:39.90782N	125:30:39.23361E	127.00000	307.01608	2.00000
test87	31:12:52.30000N	125:28:47.50000E	31:10:58.58265N	125:28:01.95668E	199.00000	18.99345	2.00000
test88	31:12:52.30000N	125:28:47.50000E	31:13:06.93605N	125:26:28.60187E	277.00000	96.98000	2.00000
test89	31:12:52.30000N	125:28:47.50000E	19:27:03.05786N	179:41:20.83695E	90.00000	294.84102	3000.00000
test90	31:12:52.30000N	125:28:47.50000E	81:07:29.93181N	125:28:47.50000E	0.00000	180.00000	3000.00000
test91	31:12:52.30000N	125:28:47.50000E	18:59:46.09922S	125:28:47.50000E	180.00000	360.00000	3000.00000
test92	31:12:52.30000N	125:28:47.50000E	19:27:03.05786N	71:16:14.16305E	270.00000	65.15898	3000.00000

test93	31:12:52.30000N	125:28:47.50000E	52:04:30.90569N	171:09:46.53647W	46.00000	271.27816	3000.00000
test94	31:12:52.30000N	125:28:47.50000E	3:37:54.96189S	163:12:50.99996E	127.00000	316.76433	3000.00000
test95	31:12:52.30000N	125:28:47.50000E	16:50:15.39672S	110:24:43.33889E	199.00000	16.92311	3000.00000
test96	31:12:52.30000N	125:28:47.50000E	24:24:11.81091N	69:01:02.24210E	277.00000	68.81857	3000.00000
test97	49:10:24.50000S	75:12:45.60000W	49:03:42.87631S	70:08:25.93407W	90.00000	266.16411	200.00000
test98	49:10:24.50000S	75:12:45.60000W	45:50:31.05302S	75:12:45.60000W	0.00000	180.00000	200.00000
test99	49:10:24.50000S	75:12:45.60000W	52:30:11.00366S	75:12:45.60000W	180.00000	0.00000	200.00000
test100	49:10:24.50000S	75:12:45.60000W	49:03:42.87631S	80:17:05.26593W	270.00000	93.83589	200.00000
test101	49:10:24.50000S	75:12:45.60000W	46:48:17.31010S	71:43:18.85029W	46.00000	223.40538	200.00000
test102	49:10:24.50000S	75:12:45.60000W	51:06:09.21946S	70:59:16.31551W	127.00000	303.75602	200.00000
test103	49:10:24.50000S	75:12:45.60000W	52:18:31.88478S	76:58:48.10816W	199.00000	20.36902	200.00000
test104	49:10:24.50000S	75:12:45.60000W	48:39:31.53843S	80:12:23.46911W	277.00000	100.76518	200.00000
test105	49:10:24.50000S	75:12:45.60000W	49:10:24.45978S	75:09:42.72995W	90.00000	269.96156	2.00000
test106	49:10:24.50000S	75:12:45.60000W	49:08:24.60011S	75:12:45.60000W	0.00000	180.00000	2.00000
test107	49:10:24.50000S	75:12:45.60000W	49:12:24.39920S	75:12:45.60000W	180.00000	0.00000	2.00000
test108	49:10:24.50000S	75:12:45.60000W	49:10:24.45978S	75:15:48.47005W	270.00000	90.03844	2.00000
test109	49:10:24.50000S	75:12:45.60000W	49:09:01.18981S	75:10:34.11555W	46.00000	225.97237	2.00000
test110	49:10:24.50000S	75:12:45.60000W	49:11:36.63156S	75:10:19.49448W	127.00000	306.96929	2.00000
test111	49:10:24.50000S	75:12:45.60000W	49:12:17.86267S	75:13:45.17447W	199.00000	19.01253	2.00000
test112	49:10:24.50000S	75:12:45.60000W	49:10:09.84830S	75:15:47.09213W	277.00000	97.03815	2.00000
test113	49:10:24.50000S	75:12:45.60000W	29:08:15.41939S	14:06:51.81153W	90.00000	228.53270	3000.00000
test114	49:10:24.50000S	75:12:45.60000W	0:58:06.24146N	75:12:45.60000W	0.00000	180.00000	3000.00000
test115	49:10:24.50000S	75:12:45.60000W	81:01:11.20478S	104:47:14.40000E	180.00000	180.00000	3000.00000
test116	49:10:24.50000S	75:12:45.60000W	29:08:15.41939S	136:18:39.38847W	270.00000	131.46730	3000.00000
test117	49:10:24.50000S	75:12:45.60000W	7:52:38.83544S	41:28:29.05694W	46.00000	208.40144	3000.00000
test118	49:10:24.50000S	75:12:45.60000W	52:04:51.42106S	7:52:24.35518E	127.00000	238.15368	3000.00000
test119	49:10:24.50000S	75:12:45.60000W	73:51:36.66725S	168:08:53.56896E	199.00000	130.11219	3000.00000
test120	49:10:24.50000S	75:12:45.60000W	25:11:20.18815S	132:13:38.05215W	277.00000	134.10803	3000.00000
test121	43:10:45.70000S	123:42:43.40000W	43:05:19.50216S	119:09:38.75232W	90.00000	266.88737	200.00000
test122	43:10:45.70000S	123:42:43.40000W	39:50:39.63379S	123:42:43.40000W	0.00000	180.00000	200.00000
test123	43:10:45.70000S	123:42:43.40000W	46:30:44.75296S	123:42:43.40000W	180.00000	0.00000	200.00000
test124	43:10:45.70000S	123:42:43.40000W	43:05:19.50216S	128:15:48.04768W	270.00000	93.11263	200.00000
test125	43:10:45.70000S	123:42:43.40000W	40:49:05.78329S	120:33:14.53881W	46.00000	223.88618	200.00000
test126	43:10:45.70000S	123:42:43.40000W	45:07:29.89631S	119:57:05.47191W	127.00000	304.37967	200.00000
test127	43:10:45.70000S	123:42:43.40000W	46:19:13.99376S	125:16:37.84869W	199.00000	20.10232	200.00000
test128	43:10:45.70000S	123:42:43.40000W	42:41:04.43281S	128:11:59.62018W	277.00000	100.05767	200.00000
test129	43:10:45.70000S	123:42:43.40000W	43:10:45.66735S	123:39:59.39209W	90.00000	269.96883	2.00000
test130	43:10:45.70000S	123:42:43.40000W	43:08:45.67398S	123:42:43.40000W	0.00000	180.00000	2.00000
test131	43:10:45.70000S	123:42:43.40000W	43:12:45.72532S	123:42:43.40000W	180.00000	0.00000	2.00000
test132	43:10:45.70000S	123:42:43.40000W	43:10:45.66735S	123:45:27.40791W	270.00000	90.03117	2.00000
test133	43:10:45.70000S	123:42:43.40000W	43:09:22.30610S	123:40:45.46715W	46.00000	225.97759	2.00000
test134	43:10:45.70000S	123:42:43.40000W	43:11:57.91229S	123:40:32.37455W	127.00000	306.97509	2.00000
test135	43:10:45.70000S	123:42:43.40000W	43:12:39.18273S	123:43:36.82325W	199.00000	19.01016	2.00000
test136	43:10:45.70000S	123:42:43.40000W	43:10:31.04038S	123:45:26.17463W	277.00000	97.03094	2.00000
test137	43:10:45.70000S	123:42:43.40000W	26:06:37.08296S	65:19:15.88930W	90.00000	234.37420	3000.00000
test138	43:10:45.70000S	123:42:43.40000W	6:59:37.06995N	123:42:43.40000W	0.00000	180.00000	3000.00000
test139	43:10:45.70000S	123:42:43.40000W	86:59:08.38590S	56:17:16.60000E	180.00000	180.00000	3000.00000
test140	43:10:45.70000S	123:42:43.40000W	26:06:37.08296S	177:53:49.08930E	270.00000	125.62580	3000.00000

test141	43:10:45.70000S	123:42:43.40000W	2:51:33.84923S	90:17:19.02340W	46.00000	211.73748	3000.00000
test142	43:10:45.70000S	123:42:43.40000W	50:58:42.47481S	48:01:25.22327W	127.00000	247.60161	3000.00000
test143	43:10:45.70000S	123:42:43.40000W	75:32:45.23169S	140:44:35.89858E	199.00000	108.26051	3000.00000
test144	43:10:45.70000S	123:42:43.40000W	21:49:17.43560S	178:34:03.34260W	277.00000	128.69292	3000.00000
test145	30:13:55.50000S	54:53:17.40000E	30:10:32.24599S	58:44:04.46955E	90.00000	268.06441	200.00000
test146	30:13:55.50000S	54:53:17.40000E	26:53:23.96278S	54:53:17.40000E	0.00000	180.00000	200.00000
test147	30:13:55.50000S	54:53:17.40000E	33:34:20.90547S	54:53:17.40000E	180.00000	360.00000	200.00000
test148	30:13:55.50000S	54:53:17.40000E	30:10:32.24599S	51:02:30.33045E	270.00000	91.93559	200.00000
test149	30:13:55.50000S	54:53:17.40000E	27:52:57.82170S	57:35:36.72392E	46.00000	224.68558	200.00000
test150	30:13:55.50000S	54:53:17.40000E	32:12:18.30198S	58:01:31.85506E	127.00000	305.37336	200.00000
test151	30:13:55.50000S	54:53:17.40000E	33:23:02.92727S	53:35:33.92865E	199.00000	19.68306	200.00000
test152	30:13:55.50000S	54:53:17.40000E	29:46:10.92312S	51:05:09.54001E	277.00000	98.90168	200.00000
test153	30:13:55.50000S	54:53:17.40000E	30:13:55.47966S	54:55:35.92341E	90.00000	269.98063	2.00000
test154	30:13:55.50000S	54:53:17.40000E	30:11:55.21431S	54:53:17.40000E	0.00000	180.00000	2.00000
test155	30:13:55.50000S	54:53:17.40000E	30:15:55.78508S	54:53:17.40000E	180.00000	360.00000	2.00000
test156	30:13:55.50000S	54:53:17.40000E	30:13:55.47966S	54:50:58.87659E	270.00000	90.01937	2.00000
test157	30:13:55.50000S	54:53:17.40000E	30:12:31.93209S	54:54:57.02201E	46.00000	225.98607	2.00000
test158	30:13:55.50000S	54:53:17.40000E	30:15:07.87646S	54:55:08.05224E	127.00000	306.98452	2.00000
test159	30:13:55.50000S	54:53:17.40000E	30:15:49.22963S	54:52:32.28676E	199.00000	19.00631	2.00000
test160	30:13:55.50000S	54:53:17.40000E	30:13:40.82086S	54:50:59.91478E	277.00000	97.01923	2.00000
test161	30:13:55.50000S	54:53:17.40000E	18:52:29.86498S	108:49:20.15190E	90.00000	246.00043	3000.00000
test162	30:13:55.50000S	54:53:17.40000E	19:58:48.22673N	54:53:17.40000E	0.00000	180.00000	3000.00000
test163	30:13:55.50000S	54:53:17.40000E	80:08:58.44983S	54:53:17.40000E	180.00000	0.00000	3000.00000
test164	30:13:55.50000S	54:53:17.40000E	18:52:29.86498S	0:57:14.64810E	270.00000	113.99957	3000.00000
test165	30:13:55.50000S	54:53:17.40000E	7:58:13.96628N	88:37:37.35172E	46.00000	218.90713	3000.00000
test166	30:13:55.50000S	54:53:17.40000E	46:16:23.75384S	116:51:12.92431E	127.00000	265.83428	3000.00000
test167	30:13:55.50000S	54:53:17.40000E	71:41:54.15847S	2:36:27.57861E	199.00000	63.35732	3000.00000
test168	30:13:55.50000S	54:53:17.40000E	14:01:56.87883S	3:23:24.56420E	277.00000	117.80900	3000.00000
test169	71:03:45.50000S	155:13:37.40000E	70:47:04.46404S	165:21:13.27121E	90.00000	260.42680	200.00000
test170	71:03:45.50000S	155:13:37.40000E	67:44:32.20108S	155:13:37.40000E	360.00000	180.00000	200.00000
test171	71:03:45.50000S	155:13:37.40000E	74:22:54.50904S	155:13:37.40000E	180.00000	360.00000	200.00000
test172	71:03:45.50000S	155:13:37.40000E	70:47:04.46404S	145:06:01.52879E	270.00000	99.57320	200.00000
test173	71:03:45.50000S	155:13:37.40000E	68:37:38.70618S	161:47:11.03268E	46.00000	219.84014	200.00000
test174	71:03:45.50000S	155:13:37.40000E	72:51:42.35787S	164:14:58.08728E	127.00000	298.41826	200.00000
test175	71:03:45.50000S	155:13:37.40000E	74:09:55.67082S	151:16:06.01068E	199.00000	22.77938	200.00000
test176	71:03:45.50000S	155:13:37.40000E	70:23:23.03906S	145:22:23.31016E	277.00000	106.30428	200.00000
test177	71:03:45.50000S	155:13:37.40000E	71:03:45.39916S	155:19:45.39068E	90.00000	269.90331	2.00000
test178	71:03:45.50000S	155:13:37.40000E	71:01:45.98931S	155:13:37.40000E	360.00000	180.00000	2.00000
test179	71:03:45.50000S	155:13:37.40000E	71:05:45.01026S	155:13:37.40000E	180.00000	0.00000	2.00000
test180	71:03:45.50000S	155:13:37.40000E	71:03:45.39916S	155:07:29.40932E	270.00000	90.09669	2.00000
test181	71:03:45.50000S	155:13:37.40000E	71:02:22.42883S	155:18:01.80054E	46.00000	225.93054	2.00000
test182	71:03:45.50000S	155:13:37.40000E	71:04:57.35874S	155:18:31.58931E	127.00000	306.92270	2.00000
test183	71:03:45.50000S	155:13:37.40000E	71:05:38.48847S	155:11:37.40237E	199.00000	19.03153	2.00000
test184	71:03:45.50000S	155:13:37.40000E	71:03:30.83602S	155:07:32.22736E	277.00000	97.09595	2.00000
test185	71:03:45.50000S	155:13:37.40000E	37:33:28.76348S	130:07:28.60879W	90.00000	204.21144	3000.00000
test186	71:03:45.50000S	155:13:37.40000E	21:04:35.11214S	155:13:37.40000E	360.00000	180.00000	3000.00000
test187	71:03:45.50000S	155:13:37.40000E	59:09:32.80147S	24:46:22.60000W	180.00000	180.00000	3000.00000
test188	71:03:45.50000S	155:13:37.40000E	37:33:28.76348S	80:34:43.40879E	270.00000	155.78856	3000.00000

test189	71:03:45.50000S	155:13:37.40000E	25:50:57.88581S	167:05:40.45264W	46.00000	195.07128	3000.00000
test190	71:03:45.50000S	155:13:37.40000E	49:25:34.58238S	94:31:25.79851W	127.00000	203.51009	3000.00000
test191	71:03:45.50000S	155:13:37.40000E	57:40:40.95961S	2:56:35.65351E	199.00000	168.59567	3000.00000
test192	71:03:45.50000S	155:13:37.40000E	35:23:25.31483S	86:40:04.05968E	277.00000	156.67990	3000.00000

WGS84PtIsOnGeodesic Test Results

Test Identifier	Geodesic Start Point Latitude	Geodesic Start Point Longitude	Geodesic End Point Latitude	Geodesic End Point Longitude	Test Point Latitude	Test Point Longitude	Length Code	Result
test1	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	41:32:28.56417N	68:47:19.47018W	0	1
test2	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	42:04:35.80000N	68:12:34.70000W	0	1
test3	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	41:47:53.25338N	68:30:44.96922W	0	1
test4	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	41:26:00.91053N	68:54:13.28237W	0	1
test5	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	41:09:22.65915N	69:11:50.60000W	0	1
test6	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	0	1
test7	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	0	1
test8	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:09:22.65915N	69:11:50.60000W	0	1
test9	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	40:10:24.50000N	70:12:45.60000W	0	1
test10	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	38:47:17.80000N	69:11:50.60000W	0	0
test11	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	39:35:17.80000N	69:11:50.60000W	0	0
test12	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	44:47:17.80000N	69:11:50.60000W	0	0
test13	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	41:47:17.80000N	68:11:50.60000E	0	0
test14	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	42:04:35.80000N	70:12:34.70000E	0	1
test15	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	41:47:18.13124N	69:53:49.92815E	0	1
test16	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:29:59.59453N	68:32:40.35274E	0	1
test17	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:29:10.95567N	68:31:50.60000E	0	1
test18	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	0	1
test19	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	40:43:56.24806N	68:47:00.28971E	0	1
test20	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:07:48.28268N	69:11:50.60000E	0	1
test21	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	40:10:24.50000N	68:12:45.60000E	0	1
test22	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	40:27:32.30453N	68:30:09.76991E	0	1
test23	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	38:47:17.80000N	72:11:50.60000E	0	0
test24	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	43:47:17.80000N	72:11:50.60000E	0	0
test25	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	40:12:17.80000S	69:11:50.60000W	0	0
test26	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	39:55:35.80000S	68:12:34.70000W	0	1
test27	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	40:12:53.41991S	68:30:06.40714W	0	1
test28	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	40:34:15.03903S	68:52:01.67681W	0	1
test29	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	40:53:18.36384S	69:11:50.60000W	0	1
test30	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	0	1
test31	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	41:50:24.50000S	70:12:45.60000W	0	1
test32	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:53:18.36384S	69:11:50.60000W	0	1
test33	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	41:50:24.50000S	70:12:45.60000W	0	1
test34	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	42:12:17.80000S	69:11:50.60000W	0	0
test35	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	38:12:17.80000S	69:11:50.60000W	0	0
test36	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	43:12:17.80000S	69:11:50.60000W	0	0
test37	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	40:12:17.80000S	68:11:50.60000E	0	0
test38	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	39:55:35.80000S	70:12:34.70000E	0	1
test39	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	40:13:19.06538S	69:54:40.06070E	0	1
test40	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	40:11:49.41238S	69:56:11.14294E	0	1

test41	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	40:54:53.06605S	69:11:50.60000E	0	1
test42	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	0	1
test43	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	0	1
test44	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	41:47:33.72993S	68:15:50.60000E	0	1
test45	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	41:50:24.50000S	68:12:45.60000E	0	1
test46	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	43:29:17.80000S	69:11:50.60000E	0	0
test47	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	38:29:17.80000S	69:11:50.60000E	0	0
test48	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	41:49:17.80000S	69:11:50.60000E	0	0

WGS84PtIsOnArc Test Results

Test Identifier	Arc Center Latitude	Arc Center Longitude	Arc Radius	Arc Start Azimuth	Arc End Azimuth	Arc Direction	Test Point Latitude	Test Point Longitude	Result
test1	40:10:24.50000N	70:12:45.60000W	100.0	90.0	100.0	-1	39:55:12.84696N	68:04:03.03796W	1
test2	40:10:24.50000N	70:12:45.60000W	100.0	100.0	90.0	1	40:04:24.98785N	68:02:37.73455W	1
test3	40:10:24.50000N	70:12:45.60000W	100.0	100.0	90.0	1	40:27:01.27947N	68:03:50.83114W	0
test4	40:10:24.50000N	70:12:45.60000W	100.0	20.0	120.0	-1	39:39:01.64315N	68:09:21.02760W	1
test5	40:10:24.50000N	70:12:45.60000W	100.0	355.0	10.0	-1	41:50:27.82240N	70:11:34.70000W	1
test6	40:10:24.50000N	70:12:45.60000W	100.0	15.0	350.0	1	41:50:27.82240N	70:11:34.70000W	1
test7	40:10:24.50000N	70:12:45.60000W	100.0	15.0	350.0	-1	41:50:27.82240N	70:11:34.70000W	0
test8	40:10:24.50000N	70:12:45.60000W	100.0	250.0	300.0	-1	40:22:32.07141N	72:22:27.11102W	1
test9	40:10:24.50000N	70:12:45.60000W	100.0	330.0	200.0	1	41:12:48.70166N	71:55:32.15119W	1
test10	40:10:24.50000N	70:12:45.60000W	100.0	200.0	230.0	-1	38:51:33.35407N	68:53:10.34405W	0
test11	40:10:24.50000N	70:12:45.60000E	100.0	90.0	100.0	-1	39:57:28.59246N	72:21:55.36432E	1
test12	40:10:24.50000N	70:12:45.60000E	100.0	100.0	90.0	1	40:04:25.10140N	72:22:53.47612E	1
test13	40:10:24.50000N	70:12:45.60000E	100.0	100.0	90.0	1	40:26:53.80980N	72:21:41.88661E	0
test14	40:10:24.50000N	70:12:45.60000E	100.0	20.0	120.0	-1	39:39:10.70047N	72:16:14.18085E	1
test15	40:10:24.50000N	70:12:45.60000E	100.0	355.0	10.0	-1	41:50:27.82240N	70:11:34.70000E	1
test16	40:10:24.50000N	70:12:45.60000E	100.0	15.0	350.0	1	41:50:27.82240N	70:11:34.70000E	1
test17	40:10:24.50000N	70:12:45.60000E	100.0	15.0	350.0	-1	41:50:27.82240N	70:11:34.70000E	0
test18	40:10:24.50000N	70:12:45.60000E	100.0	250.0	300.0	-1	40:22:28.60052N	68:03:03.59248E	1
test19	40:10:24.50000N	70:12:45.60000E	100.0	330.0	200.0	1	41:13:31.30530N	68:30:43.58125E	1
test20	40:10:24.50000N	70:12:45.60000E	100.0	200.0	230.0	-1	39:05:41.34977N	71:51:29.95766E	0
test21	40:10:24.50000S	70:12:45.60000E	100.0	90.0	100.0	-1	40:12:40.39213S	72:23:13.39076E	1
test22	40:10:24.50000S	70:12:45.60000E	100.0	100.0	90.0	1	40:04:25.10140S	72:22:53.47612E	0
test23	40:10:24.50000S	70:12:45.60000E	100.0	100.0	90.0	1	39:39:10.70047S	72:16:14.18085E	0
test24	40:10:24.50000S	70:12:45.60000E	100.0	20.0	120.0	-1	40:26:53.80980S	72:21:41.88661E	1
test25	40:10:24.50000S	70:12:45.60000E	100.0	355.0	10.0	-1	38:30:19.45513S	70:11:34.70000E	1
test26	40:10:24.50000S	70:12:45.60000E	100.0	15.0	350.0	1	38:30:19.45513S	70:11:34.70000E	1
test27	40:10:24.50000S	70:12:45.60000E	100.0	15.0	350.0	-1	38:30:19.45513S	70:11:34.70000E	0
test28	40:10:24.50000S	70:12:45.60000E	100.0	250.0	300.0	-1	40:23:20.88344S	68:03:11.35606E	1
test29	40:10:24.50000S	70:12:45.60000E	100.0	330.0	200.0	1	39:47:33.58163S	68:06:05.87892E	1
test30	40:10:24.50000S	70:12:45.60000E	100.0	200.0	230.0	-1	41:45:30.73148S	70:53:47.69121E	0
test31	40:10:24.50000S	70:12:45.60000W	100.0	90.0	100.0	-1	40:12:32.98018S	68:02:17.71481W	1
test32	40:10:24.50000S	70:12:45.60000W	100.0	100.0	90.0	1	40:04:11.30750S	68:02:39.04105W	0
test33	40:10:24.50000S	70:12:45.60000W	100.0	100.0	90.0	1	39:23:12.36192S	68:18:22.61369W	0
test34	40:10:24.50000S	70:12:45.60000W	100.0	20.0	120.0	-1	40:39:21.80200S	68:07:26.05449W	1
test35	40:10:24.50000S	70:12:45.60000W	100.0	355.0	10.0	-1	38:30:19.45513S	70:11:34.70000W	1
test36	40:10:24.50000S	70:12:45.60000W	100.0	15.0	350.0	1	38:30:19.45513S	70:11:34.70000W	1
test37	40:10:24.50000S	70:12:45.60000W	100.0	15.0	350.0	-1	38:30:19.45513S	70:11:34.70000W	0
test38	40:10:24.50000S	70:12:45.60000W	100.0	250.0	300.0	-1	40:23:44.12558S	72:22:16.19656W	1
test39	40:10:24.50000S	70:12:45.60000W	100.0	330.0	200.0	1	39:54:28.73386S	72:21:18.43758W	1
test40	40:10:24.50000S	70:12:45.60000W	100.0	200.0	230.0	-1	41:29:48.15752S	68:52:34.09229W	0

WGS84PtIsOnLocus Test Results

Test Identifier	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic End Latitude	Geodesic End Longitude	Locus Start Latitude	Locus StarT Longitude	Locus End Latitude	Locus End Longitude	Locus Start Distance (NM)	Locus E nd Distance (NM)	Test Point Latitude	Test Point Longitude	Result
test1	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:55:05.00175N	70:50:23.28330W	1
test2	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:55:05.00771N	70:51:24.71201W	1
test3	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:35.01559N	70:51:34.00000W	42:55:31.77993N	70:24:20.66356N	-1.0	-1.0	42:55:35.00776N	70:50:13.66761W	1
test4	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:52:34.96830N	70:51:34.00000W	42:52:19.73219N	70:24:22.07127N	2.0	2.2	42:52:34.01413N	70:49:26.93090W	1
test5	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:57:35.04624N	70:51:34.00000W	42:53:31.75031N	70:24:21.54367N	-3.0	1.0	42:56:58.69196N	70:47:27.05896W	1
test6	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:50:34.93590N	70:51:34.00000W	42:50:31.70455N	70:24:22.86205N	4.0	4.0	42:50:34.81843N	70:46:22.99515W	1
test7	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:59:35.07618N	70:51:34.00000W	42:59:01.83008N	70:24:19.12109N	-5.0	-4.5	42:59:28.77609N	70:45:58.16124W	1
test8	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:48:34.90279N	70:51:34.00000W	42:48:07.66680N	70:24:23.91522N	6.0	6.4	42:48:27.53797N	70:43:32.97138W	1
test9	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	43:01:35.10543N	70:51:34.00000W	43:01:31.86459N	70:24:18.01754N	-7.0	-7.0	43:01:34.93635N	70:45:20.32134W	1
test10	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:46:34.86899N	70:51:34.00000W	42:53:31.75031N	70:24:21.54367N	8.0	1.0	42:48:36.37428N	70:43:41.44040W	1
test11	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:53:60.00000N	70:50:23.28330W	0
test12	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:46:34.86899N	70:51:34.00000W	42:46:31.64108N	70:24:24.61658N	8.0	8.0	42:42:00.00000N	70:43:42.62942W	0
test13	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:54:04.98608S	70:50:23.30236W	1
test14	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:54:04.99204S	70:51:24.70232W	1
test15	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:55:35.01559S	70:51:34.00000W	42:55:31.77993S	70:24:20.66356S	1.0	1.0	42:55:35.00776S	70:50:13.66761W	1
test16	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:52:34.96830S	70:51:34.00000W	42:52:19.73219S	70:24:22.07127S	-2.0	-2.2	42:52:34.01413S	70:49:26.93090W	1
test17	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:57:35.04624S	70:51:34.00000W	42:53:31.75031S	70:24:21.54367S	3.0	-1.0	42:56:58.69196S	70:47:27.05896W	1
test18	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:50:34.93590S	70:51:34.00000W	42:50:31.70455S	70:24:22.86205S	-4.0	-4.0	42:50:34.81843S	70:46:22.99515W	1
test19	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:59:35.07618S	70:51:34.00000W	42:59:01.83008S	70:24:19.12109S	5.0	4.5	42:59:28.77609S	70:45:58.16124W	1
test20	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:48:34.90279S	70:51:34.00000W	42:48:07.66680S	70:24:23.91522S	-6.0	-6.4	42:48:27.53797S	70:43:32.97138W	1
test21	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	43:01:35.10543S	70:51:34.00000W	43:01:31.86459S	70:24:18.01754S	7.0	7.0	43:01:34.93635S	70:45:20.32134W	1
test22	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:46:34.86899S	70:51:34.00000W	42:53:31.75031S	70:24:21.54367S	-8.0	-1.0	42:48:36.37428S	70:43:41.44040W	1
test23	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:53:60.00000S	70:50:23.30236W	0
test24	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:46:34.86899S	70:51:34.00000W	42:46:31.64108S	70:24:24.61658S	-8.0	-8.0	42:42:00.00000S	70:43:42.62942W	0

WGS84LocusCrsAtPoint Test Results

Test Identifier	Input	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic End Latitude	Geodesic End Longitude	Locus Start Latitude	Locus Start Longitude	Locus End Latitude	Locus End Longitude	Locus Start Distance (NM)	Locus End Distance (NM)	Test Point Latitude	Test Point Longitude
	Output	Geodesic Point Latitude	Geodesic Point Longitude	Locus Azimuth at Test Point (degrees)	Azimuth from Test Point to Geodesic Point (degrees)								
Test1	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:55:05.00175N	70:50:23.28330W
	Output	42:54:34.99393N	70:50:23.29283W	180.01337	90.01337								
Test2	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:55:05.00771N	70:51:24.71201W
	Output	42:54:34.99990N	70:51:24.71327W	180.00176	90.00176								
Test3	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:35.01559N	70:51:34.00000W	42:55:31.77993N	70:24:20.66356N	-1.0	-1.0	42:55:35.00776N	70:50:13.66761W
	Output	42:54:34.99218N	70:50:13.68926W	180.01519	90.01519								
Test4	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:52:34.96830N	70:51:34.00000W	42:52:19.73219N	70:24:22.07127N	2.0	2.2	42:52:34.01413N	70:49:26.93090W
	Output	42:54:34.98039N	70:49:26.86188W	0.59697	90.59697								
Test5	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:57:35.04624N	70:51:34.00000W	42:53:31.75031N	70:24:21.54367N	-3.0	1.0	42:56:58.69196N	70:47:27.05896W
	Output	42:54:34.92612N	70:47:27.21838W	191.35663	101.35663								
Test6	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:50:34.93590N	70:51:34.00000W	42:50:31.70455N	70:24:22.86205N	4.0	4.0	42:50:34.81843N	70:46:22.99515W
	Output	42:54:34.88240N	70:46:22.65989W	0.05882	90.05882								
Test7	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:59:35.07618N	70:51:34.00000W	42:59:01.83008N	70:24:19.12109N	-5.0	-4.5	42:59:28.77609N	70:45:58.16124W
	Output	42:54:34.86353N	70:45:58.60448W	181.49561	91.49561								
Test8	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:48:34.90279N	70:51:34.00000W	42:48:07.66680N	70:24:23.91522N	6.0	6.4	42:48:27.53797N	70:43:32.97138W
	Output	42:54:34.71836N	70:43:32.17826W	1.23674	91.23674								
test9	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	43:01:35.10543N	70:51:34.00000W	43:01:31.86459N	70:24:18.01754N	-7.0	-7.0	43:01:34.93635N	70:45:20.32134W
	Output	42:54:34.83124N	70:45:21.02628W	180.07067	90.07067								

Test10	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:46:34.86899N	70:51:34.00000W	42:53:31.75031N	70:24:21.54367N	8.0	1.0	42:48:36.37428N	70:43:41.44040W
	Output	42:54:34.72821N	70:43:40.67998W	-19.20067	70.79933								
Test11	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368N	-0.5	-0.5	42:55:05.00175N	70:50:23.28330W
	Output	42:54:34.99393N	70:50:23.29283W	180.01337	90.01337								
Test12	Input	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:46:34.86899N	70:51:34.00000W	42:46:31.64108N	70:24:24.61658N	8.0	8.0	42:46:34.59884N	70:43:42.62942W
	Output	42:54:34.72928N	70:43:41.61315W	0.08915	90.08915								
Test13	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:54:04.98608S	70:50:23.30236W
	Output	42:54:34.99393S	70:50:23.29283W	179.98663	89.98663								
Test14	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:54:04.99204S	70:51:24.70232W
	Output	42:54:34.99990S	70:51:24.70107W	179.99824	89.99824								
Test15	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:55:35.01559S	70:51:34.00000W	42:55:31.77993S	70:24:20.66356S	1.0	1.0	42:55:35.00776S	70:50:13.66761W
	Output	42:54:34.99218S	70:50:13.68926W	359.98481	89.98481								
Test16	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:52:34.96830S	70:51:34.00000W	42:52:19.73219S	70:24:22.07127S	-2.0	-2.2	42:52:34.01413S	70:49:26.93090W
	Output	42:54:34.98039S	70:49:26.86188W	179.40303	89.40303								
Test17	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:57:35.04624S	70:51:34.00000W	42:53:31.75031S	70:24:21.54367S	3.0	-1.0	42:56:58.69196S	70:47:27.05896W
	Output	42:54:34.92612S	70:47:27.21838W	348.64337	78.64337								
Test18	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:50:34.93590S	70:51:34.00000W	42:50:31.70455S	70:24:22.86205S	-4.0	-4.0	42:50:34.81843S	70:46:22.99515W
	Output	42:54:34.88240S	70:46:22.65989W	179.94118	89.94118								
Test19	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:59:35.07618S	70:51:34.00000W	42:59:01.83008S	70:24:19.12109S	5.0	4.5	42:59:28.77609S	70:45:58.16124W
	Output	42:54:34.86353S	70:45:58.60448W	358.50439	88.50439								
Test20	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:48:34.90279S	70:51:34.00000W	42:48:07.66680S	70:24:23.91522S	-6.0	-6.4	42:48:27.53797S	70:43:32.97138W
	Output	42:54:34.71836S	70:43:32.17826W	178.76326	88.76326								
Test21	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	43:01:35.10543S	70:51:34.00000W	43:01:31.86459S	70:24:18.01754S	7.0	7.0	43:01:34.93635S	70:45:20.32134W
	Output	42:54:34.83124S	70:45:21.02628W	359.92933	89.92933								

Test22	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:46:34.86899S	70:51:34.00000W	42:53:31.75031S	70:24:21.54367S	-8.0	-1.0	42:48:36.37428S	70:43:41.44040W
	Output	42:54:34.72821S	70:43:40.67998W	199.20067	109.20067								
Test23	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:54:04.99214S	70:51:34.00000W	42:54:01.75778S	70:24:21.32373S	-0.5	-0.5	42:54:04.98608S	70:50:23.30236W
	Output	42:54:34.99393S	70:50:23.29283W	179.98663	89.98663								
Test24	Input	42:54:35.00000S	70:51:34.00000W	42:54:31.76521S	70:24:21.10373W	42:46:34.86899S	70:51:34.00000W	42:46:31.64108S	70:24:24.61658S	-8.0	-8.0	42:46:34.59884S	70:43:42.62942W
	Output	42:54:34.72928S	70:43:41.61315W	179.91085	89.91085								

WGS84DiscretizedArcLength Test Results

Test Identifier	Arc Center Latitude	Arc Center Longitude	Arc Radius	Start Azimuth	End Azimuth	Direction	Computed Arc Length (NM)	Direct Computation Result (Section 6.4) (NM)	Difference (meters)
test1	38:13:25.10000N	77:54:23.40000W	5.0	91.0	226.0	-1	11.780968	11.780968	1.60e-007
test2	38:13:25.10000N	77:54:23.40000W	5.0	91.0	226.0	1	19.634947	19.634947	2.60e-008
test3	38:13:25.10000N	77:54:23.40000W	5.0	0.0	0.0	1	31.415915	31.415915	2.17e-007
test4	38:13:25.10000N	77:54:23.40000W	50.0	0.0	0.0	1	314.148211	314.148211	2.83e-006
test5	38:13:25.10000N	77:54:23.40000W	100.0	0.0	0.0	1	628.230102	628.230102	4.62e-005
test6	38:13:25.10000N	77:54:23.40000W	150.0	0.0	0.0	1	942.179365	942.179365	3.33e-004
test7	38:13:25.10000N	77:54:23.40000W	200.0	0.0	0.0	1	1255.929721	1255.929722	1.39e-003
test8	38:13:25.10000N	77:54:23.40000W	250.0	0.0	0.0	1	1569.414934	1569.414936	4.23e-003
test9	38:13:25.10000N	77:54:23.40000W	300.0	0.0	0.0	1	1882.568820	1882.568826	1.05e-002
test10	38:13:25.10000N	77:54:23.40000W	350.0	0.0	0.0	1	2195.325269	2195.325282	2.27e-002
test11	38:13:25.10000N	77:54:23.40000W	400.0	0.0	0.0	1	2507.618252	2507.618275	4.42e-002
test12	38:13:25.10000N	77:54:23.40000W	450.0	0.0	0.0	1	2819.381836	2819.381879	7.95e-002
test13	38:13:25.10000N	77:54:23.40000W	500.0	0.0	0.0	1	3130.550201	3130.550274	1.34e-001
test14	30:34:17.18000N	105:40:50.70000W	4.0	30.0	340.0	1	3.490658	3.490658	1.27e-008
test15	30:34:17.18000N	105:40:50.70000W	4.0	30.0	340.0	-1	21.642078	21.642078	7.24e-008
test16	30:34:17.18000N	105:40:50.70000W	4.0	0.0	0.0	1	25.132736	25.132736	7.62e-008
test17	30:34:17.18000N	105:40:50.70000W	4.0	0.0	0.0	-1	25.132736	25.132736	7.63e-008
test18	30:34:17.18000N	105:40:50.70000E	4.0	30.0	340.0	1	3.490658	3.490658	1.23e-008
test19	30:34:17.18000N	105:40:50.70000E	4.0	30.0	340.0	-1	21.642078	21.642078	7.28e-008
test20	30:34:17.18000N	105:40:50.70000E	4.0	0.0	0.0	1	25.132736	25.132736	7.63e-008
test21	30:34:17.18000N	105:40:50.70000E	4.0	0.0	0.0	-1	25.132736	25.132736	7.62e-008
test22	30:34:17.18000S	105:40:50.70000E	4.0	30.0	340.0	1	3.490658	3.490658	2.65e-008
test23	30:34:17.18000S	105:40:50.70000E	4.0	30.0	340.0	-1	21.642078	21.642078	7.89e-008
test24	30:34:17.18000S	105:40:50.70000E	4.0	0.0	0.0	1	25.132736	25.132736	7.62e-008
test25	30:34:17.18000S	105:40:50.70000E	4.0	0.0	0.0	-1	25.132736	25.132736	7.62e-008
test26	30:34:17.18000S	105:40:50.70000W	4.0	30.0	340.0	1	3.490658	3.490658	2.65e-008
test27	30:34:17.18000S	105:40:50.70000W	4.0	30.0	340.0	-1	21.642078	21.642078	7.89e-008
test28	30:34:17.18000S	105:40:50.70000W	4.0	0.0	0.0	1	25.132736	25.132736	7.62e-008
test29	30:34:17.18000S	105:40:50.70000W	4.0	0.0	0.0	-1	25.132736	25.132736	7.62e-008
test30	30:34:17.18000N	105:40:50.70000W	40.0	30.0	340.0	1	34.905798	34.905798	9.65e-005
test31	30:34:17.18000N	105:40:50.70000W	40.0	30.0	340.0	-1	216.415945	216.415946	9.71e-005
test32	30:34:17.18000N	105:40:50.70000W	40.0	0.0	0.0	1	251.321743	251.321743	5.82e-007
test33	30:34:17.18000N	105:40:50.70000W	40.0	0.0	0.0	-1	251.321743	251.321743	5.82e-007
test34	00:04:00.00000N	90:33:72.0000W	11.1	136.0	380.0	1	22.472820	22.472820	7.34e-008
test35	00:04:00.00000N	90:33:72.0000W	11.1	136.0	380.0	-1	47.270415	47.270415	3.17e-007
test36	00:04:00.00000N	90:33:72.0000W	11.1	0.0	0.0	1	69.743235	69.743235	4.14e-007
test37	00:04:00.00000N	90:33:72.0000W	11.1	136.0	20.0	1	22.472820	22.472820	7.34e-008
test38	00:04:00.00000N	90:33:72.0000W	11.1	136.0	20.0	-1	47.270415	47.270415	3.17e-007
test39	00:04:00.00000N	90:33:72.0000W	11.1	0.0	0.0	1	69.743235	69.743235	4.14e-007
test40	80:00:00.00000N	90:33:72.0000W	11.1	136.0	20.0	1	22.472821	22.472821	2.25e-007
test41	80:00:00.00000N	90:33:72.0000W	11.1	136.0	20.0	-1	47.270416	47.270416	7.27e-007
test42	80:00:00.00000N	90:33:72.0000W	11.1	0.0	0.0	1	69.743237	69.743237	9.51e-007

WGS84CrsIntersect Test Results

Test Identifier	Point 1 Latitude	Point 1 Longitude	Point 2 Latitude	Point 2 Longitude	Azimuth at Point 2 (degrees)	Azimuth from Intersection to Point 1 (degrees)	Distance to Point 1 from Intersection (NM)	Azimuth at Point 2 (degrees)	Azimuth from Intersection to Point 2 (degrees)	Distance to Point 2 from Intersection (NM)	Intersection Latitude	Intersection Longitude
test1	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	90.0	271.09328	77.96062	187.0	6.79842	115.70425	40:09:39.83588N	68:31:04.02698W
test2	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	90.0	273.49211	249.49410	127.0	309.24501	197.11484	40:02:47.62539N	64:47:40.82715W
test3	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	180.0	0.00000	2400.88568	183.0	2.22965	2517.34979	0:01:16.52501N	70:12:45.60000W
test4	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	175.0	355.32391	298.99250	190.0	9.07914	417.80313	35:12:07.90080N	69:41:00.06384W
test5	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	175.0	173.09453	979.39618	170.0	166.54243	877.94705	56:24:04.10502N	72:44:22.05038W
test6	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	170.0	352.06299	1472.94791	175.0	356.13925	1574.29532	15:50:52.84758N	65:55:13.50649W
test7	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	140.0	321.55556	182.84945	175.0	355.30205	256.71971	37:48:35.70387N	67:44:28.20017W
test8	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	35.0	216.45257	170.25572	200.0	200.13304	25.67248	42:28:43.18186N	68:00:48.75631W
test9	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	35.0	215.81864	98.37315	225.0	44.50036	47.79193	41:30:38.37291N	68:57:39.59637W
test10	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	40.0	221.23764	131.59286	200.0	19.92283	15.13463	41:50:21.91143N	68:19:36.20912W
test11	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	40.0	221.33298	141.28719	170.0	350.01830	7.04762	41:57:39.18157N	68:11:02.27771W
test12	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	190.0	9.32285	315.31940	200.0	18.05830	449.41589	34:59:10.92270N	71:19:18.57958W
test13	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	230.0	232.66774	233.26393	250.0	251.36850	95.79181	42:36:17.85665N	66:10:46.71710W
test14	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	300.0	117.24240	217.12520	270.0	85.84998	277.49771	41:54:31.96856N	74:24:39.29939W
test15	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	320.0	135.96039	394.31108	300.0	114.50787	390.41454	45:03:45.85754N	76:10:13.00551W
test16	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	30.0	211.06420	143.97676	300.0	119.74072	19.87930	42:14:30.07630N	68:35:51.38889W
test17	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	30.0	211.32507	177.09156	0.0	180.00000	38.22767	42:42:50.26602N	68:12:40.70000W
test18	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:40.70000W	20.0	202.00674	361.27463	10.0	190.65118	226.90835	45:47:51.26800N	67:16:23.97908W
test19	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	90.0	268.92420	76.71333	187.0	7.21051	125.94256	40:09:41.25343S	68:32:41.62303W
test20	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	90.0	266.46490	252.57903	127.0	304.80422	200.97896	40:02:36.27306S	64:43:40.26353W
test21	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	180.0	0.00000	1101.09725	183.0	4.51831	1229.27714	58:30:33.90883S	70:12:45.60000W
test22	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	175.0	354.66840	244.37912	190.0	10.99389	375.33991	44:13:53.42080S	69:43:09.64545W
test23	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	175.0	176.07150	1613.09944	170.0	171.91685	1500.62255	13:17:28.78613S	72:31:44.37321W
test24	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	170.0	346.59757	915.38118	175.0	353.11720	1027.96638	55:06:51.99323S	65:38:55.06563W
test25	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	140.0	318.34632	173.46551	175.0	354.67361	258.02597	42:21:45.91619S	67:42:22.30757W
test26	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	35.0	213.62474	181.79580	200.0	199.88520	26.04680	37:40:05.03771S	68:01:27.49821W
test27	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	35.0	214.03300	125.42532	225.0	45.29430	31.67886	38:26:57.80473S	68:41:11.55669W
test28	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	40.0	218.83891	134.40675	200.0	20.10452	23.26402	38:26:28.42788S	68:22:48.33817W
test29	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	40.0	218.71155	149.88184	170.0	349.97744	9.94061	38:14:23.79253S	68:10:29.24046W
test30	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	190.0	10.58888	220.37689	200.0	21.89034	366.67130	43:47:20.08397S	71:05:33.40366W
test31	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	230.0	227.56916	241.38324	250.0	248.85250	95.09771	37:31:08.17381S	66:20:20.79110W
test32	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	300.0	123.01996	262.87140	270.0	94.18427	322.48262	37:52:47.65820S	75:00:21.64521W
test33	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	320.0	143.73376	481.89310	300.0	124.81855	472.56869	33:50:26.35101S	76:24:08.89427W
test34	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	30.0	208.96661	155.79494	300.0	120.22233	19.80226	37:54:39.07071S	68:34:20.89766W
test35	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	30.0	208.74599	191.45410	0.0	180.00000	41.16601	37:23:22.97816S	68:12:40.70000W
test36	40:10:24.50000S	70:12:45.60000W	38:04:35.80000S	68:12:40.70000W	20.0	198.17757	450.56059	10.0	189.39006	304.54802	33:03:55.91555S	67:09:49.72585W
test37	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	90.0	268.92596	76.58779	187.0	7.21051	125.94493	40:09:41.39485S	69:52:39.75365E
test38	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	90.0	266.46650	252.46360	127.0	304.80408	200.99143	40:02:36.70030S	73:41:41.93617E
test39	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	180.0	360.00000	1100.01245	183.0	4.51599	1228.18896	58:29:28.97645S	68:12:45.60000E
test40	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	175.0	354.66902	243.96896	190.0	10.99261	374.92389	44:13:28.91712S	68:42:18.37446E
test41	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	175.0	176.07091	1610.92321	170.0	171.91563	1498.42964	13:19:39.62658S	65:53:56.00212E

test42	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	170.0	346.60210	914.56078	175.0	353.11950	1027.16253	55:06:04.19759S	72:46:16.27258E
test43	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	140.0	318.34837	173.26198	175.0	354.67383	257.87324	42:21:36.78854S	70:42:57.94500E
test44	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	35.0	213.62839	181.28240	200.0	199.88718	25.59220	37:40:30.71712S	70:23:42.21581E
test45	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	35.0	214.02959	125.88761	225.0	45.28920	31.13428	38:26:34.79410S	69:44:39.40243E
test46	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	40.0	218.84201	134.03158	200.0	20.10593	23.57520	38:26:45.97904S	70:02:24.89276E
test47	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	40.0	218.71293	149.71326	170.0	349.97713	10.07419	38:14:31.69353S	70:14:53.93008E
test48	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	190.0	10.58725	219.81660	200.0	21.88681	366.07776	43:46:47.03577S	67:20:06.32333E
test49	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	230.0	227.56795	241.51240	250.0	248.84962	95.33926	37:31:02.93863S	72:05:17.59883E
test50	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	300.0	123.01975	262.85184	270.0	94.18239	322.33652	37:52:48.29840S	63:25:10.79761E
test51	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	320.0	143.73218	481.65350	300.0	124.81546	472.23033	33:50:37.96322S	62:01:32.51590E
test52	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	30.0	208.96702	155.72986	300.0	120.22106	19.68914	37:54:42.49075S	69:51:07.91279E
test53	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	30.0	208.74764	191.18346	0.0	180.00000	40.92873	37:23:37.23265S	70:12:40.70000E
test54	40:10:24.50000S	68:12:45.60000E	38:04:35.80000S	70:12:40.70000E	20.0	198.18057	449.67428	10.0	189.39157	303.69451	33:04:46.53740S	71:15:21.73045E
test55	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	90.0	271.09153	77.83566	187.0	6.79843	115.70185	40:09:39.97893N	69:54:17.39524E
test56	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	90.0	273.49022	249.35829	127.0	309.24487	197.10176	40:02:48.12197N	73:37:39.78188E
test57	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	180.0	360.00000	2396.68305	183.0	2.22965	2513.14398	0:05:29.92696N	68:12:45.60000E
test58	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	175.0	355.32338	298.43668	190.0	9.08018	417.24213	35:12:41.19161N	68:44:27.81826E
test59	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	175.0	173.09685	978.62238	170.0	166.54702	877.15717	56:23:18.10799N	65:41:19.19227E
test60	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	170.0	352.06155	1470.73841	175.0	356.13855	1572.10201	15:53:04.69652N	72:29:58.69976E
test61	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	140.0	321.55370	182.61724	175.0	355.30186	256.53723	37:48:46.62826N	70:40:52.06822E
test62	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	35.0	216.44892	169.85183	200.0	200.13123	25.32646	42:28:23.68275N	70:24:22.98760E
test63	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	35.0	215.82362	98.95285	225.0	44.50715	47.13287	41:31:06.58993N	69:28:18.70067E
test64	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	40.0	221.23455	131.27707	200.0	19.92155	15.38722	41:50:07.65641N	70:05:38.28221E
test65	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	40.0	221.33147	141.13344	170.0	350.01860	7.16484	41:57:32.25170N	70:14:20.75633E
test66	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	190.0	9.32443	314.47941	200.0	18.06144	448.54404	35:00:00.73673N	67:06:22.55872E
test67	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	230.0	232.66920	233.38410	250.0	251.37180	96.01994	42:36:22.23058N	72:14:52.24641E
test68	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	300.0	117.24218	217.14214	270.0	85.85158	277.39053	41:54:32.43403N	64:00:50.69032E
test69	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	320.0	135.96191	394.17976	300.0	114.51132	390.18698	45:03:40.19394N	62:15:25.92213E
test70	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	30.0	211.06373	143.91656	300.0	119.74208	19.77535	42:14:26.98106N	69:49:37.30186E
test71	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	30.0	211.32322	176.85994	0.0	180.00000	38.02981	42:42:38.39108N	70:12:40.70000E
test72	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:40.70000E	20.0	202.00309	360.70415	10.0	190.64949	226.37015	45:47:19.54035N	71:08:48.89165E

WGS84ArcIntersect Test Results

Test Identifier	Arc 1 Center Latitude	Arc 1 Center Longitude	Arc 1 Radius	Arc 2 Center Latitude	Arc 2 Center Longitude	Arc 2 Radius	Intersection 1 Latitude	Intersection 1 Longitude	Intersection 2 Latitude	Intersection 2 Longitude
test1	40:10:24.50000N	70:12:45.60000W	100.0	52:04:35.80000N	68:12:40.70000W	270.0	N/A	N/A	N/A	N/A
test2	40:10:24.50000N	70:12:45.60000W	500.0	42:04:35.80000N	68:12:40.70000W	10.0	N/A	N/A	N/A	N/A
test3	0:00:00.00000N	0:00:00.00000E	150.0	0:00:00.00000N	4:59:27.60000W	150.0	0:00:36.09395S	2:29:43.80000W	0:00:36.09395N	2:29:43.80000W
test4	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	270.0	48:22:59.73249N	72:12:38.32104W	47:52:02.19529N	65:45:38.36390W
test5	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	500.0	46:29:29.71744N	77:40:33.97739W	45:10:28.61546N	61:09:37.26553W
test6	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	1000.0	36:14:44.69990N	60:52:32.48344W	37:48:21.06721N	80:28:07.28278W
test7	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	1200.0	32:04:17.90465N	67:44:28.29488W	32:37:16.67926N	74:36:44.61637W
test8	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	1300.0	N/A	N/A	N/A	N/A
test9	40:10:24.50000N	70:12:45.60000W	500.0	52:04:35.80000N	68:12:40.70000W	10.0	N/A	N/A	N/A	N/A
test10	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	270.0	47:52:02.19529S	65:45:38.36390W	48:22:59.73249S	72:12:38.32104W
test11	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	500.0	45:10:28.61546S	61:09:37.26553W	46:29:29.71744S	77:40:33.97739W
test12	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	1000.0	37:48:21.06721S	80:28:07.28278W	36:14:44.69990S	60:52:32.48344W
test13	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	1200.0	32:37:16.67926S	74:36:44.61637W	32:04:17.90465S	67:44:28.29488W
test14	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	1300.0	N/A	N/A	N/A	N/A
test15	40:10:24.50000S	70:12:45.60000W	500.0	52:04:35.80000S	68:12:40.70000W	10.0	N/A	N/A	N/A	N/A
test16	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	270.0	48:22:59.73249S	72:12:38.32104E	47:52:02.19529S	65:45:38.36390E
test17	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	500.0	46:29:29.71744S	77:40:33.97739E	45:10:28.61546S	61:09:37.26553E
test18	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	1000.0	36:14:44.69990S	60:52:32.48344E	37:48:21.06721S	80:28:07.28278E
test19	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	1200.0	32:04:17.90465S	67:44:28.29488E	32:37:16.67926S	74:36:44.61637E
test20	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	1300.0	N/A	N/A	N/A	N/A
test21	40:10:24.50000S	70:12:45.60000E	500.0	52:04:35.80000S	68:12:40.70000E	10.0	N/A	N/A	N/A	N/A
test22	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	270.0	47:52:02.19529N	65:45:38.36390E	48:22:59.73249N	72:12:38.32104E
test23	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	500.0	45:10:28.61546N	61:09:37.26553E	46:29:29.71744N	77:40:33.97739E
test24	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	1000.0	37:48:21.06721N	80:28:07.28278E	36:14:44.69990N	60:52:32.48344E
test25	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	1200.0	32:37:16.67926N	74:36:44.61637E	32:04:17.90465N	67:44:28.29488E
test26	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	1300.0	N/A	N/A	N/A	N/A
test27	40:10:24.50000N	70:12:45.60000E	500.0	52:04:35.80000N	68:12:40.70000E	10.0	N/A	N/A	N/A	N/A
test28	6:10:24.50000S	70:12:45.60000E	500.0	6:04:35.80000N	68:12:40.70000E	500.0	0:57:26.91899S	63:41:24.65688E	0:51:39.75573N	74:44:00.46476E
test29	90:00:00.00000N	70:12:45.60000E	500.0	78:04:35.80000N	68:12:40.70000E	500.0	81:42:32.06863N	112:26:25.42164E	81:42:32.06863N	23:58:55.97836E
test30	90:00:00.00000S	70:12:45.60000E	500.0	78:04:35.80000S	68:12:40.70000E	500.0	81:42:32.06863S	23:58:55.97836E	81:42:32.06863S	112:26:25.42164E

WGS84GeodesicArcIntersect Test Results

Test Identifier	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic Azimuth	Arc Center Latitude	Arc Center Longitude	Arc Radius	Intersection 1 Latitude	Intersection 1 Longitude	Intersection 2 Latitude	Intersection 2 Longitude
test1	40:04:35.80000N	67:12:40.70000W	350.0	40:10:24.50000N	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test2	40:04:35.80000N	67:12:40.70000W	200.0	40:10:24.50000N	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test3	40:04:35.80000N	68:12:40.70000W	325.0	40:10:24.50000N	70:12:45.60000W	100.0	39:55:07.50121N	68:04:04.19322W	41:49:07.05128N	69:51:08.02313W
test4	40:04:35.80000N	67:12:40.70000W	270.0	40:10:24.50000N	70:12:45.60000W	100.0	40:04:25.03104N	68:02:37.73049W	39:57:42.51976N	72:21:57.92383W
test5	40:04:35.80000N	67:12:40.70000W	300.0	40:10:24.50000N	70:12:45.60000W	100.0	40:26:58.44233N	68:03:50.25317W	41:41:50.22946N	71:06:22.56112W
test6	40:04:35.80000N	67:12:40.70000W	240.0	40:10:24.50000N	70:12:45.60000W	100.0	39:39:05.08426N	68:09:19.50227W	38:31:25.09106N	70:31:48.24036W
test7	42:54:35.80000N	70:11:34.70000W	180.0	40:10:24.50000N	70:12:45.60000W	100.0	41:50:27.82240N	70:11:34.70000W	38:30:19.45513N	70:11:34.70000W
test8	42:54:35.80000N	70:11:34.70000W	148.0	40:10:24.50000N	70:12:45.60000W	100.0	41:37:21.88671N	69:07:30.61751W	40:14:53.46014N	68:02:21.53739W
test9	42:54:35.80000N	70:11:34.70000W	211.0	40:10:24.50000N	70:12:45.60000W	100.0	41:40:11.55047N	71:10:59.87403W	40:05:20.45327N	72:22:58.34527W
test10	40:24:35.80000N	75:11:34.70000W	90.0	40:10:24.50000N	70:12:45.60000W	100.0	40:22:32.07141N	72:22:27.11102W	40:11:17.30268N	68:02:17.43363W
test11	40:24:35.80000N	75:11:34.70000W	71.0	40:10:24.50000N	70:12:45.60000W	100.0	41:12:48.70166N	71:55:32.15119W	41:44:39.12385N	69:28:24.56005W
test12	40:24:35.80000N	75:11:34.70000W	117.0	40:10:24.50000N	70:12:45.60000W	100.0	38:58:10.68147N	71:42:17.04664W	38:34:08.21242N	70:48:01.94345W
test13	37:09:35.80000N	70:21:34.70000W	0.0	40:10:24.50000N	70:12:45.60000W	100.0	38:30:33.27210N	70:21:34.70000W	41:50:14.67279N	70:21:34.70000W
test14	37:09:35.80000N	70:21:34.70000W	34.0	40:10:24.50000N	70:12:45.60000W	100.0	38:51:33.35407N	68:53:10.34405W	39:40:46.86281N	68:08:35.72134W
test15	37:09:35.80000N	70:21:34.70000W	331.0	40:10:24.50000N	70:12:45.60000W	100.0	38:53:33.43923N	71:35:33.98874W	39:55:14.26604N	72:21:28.46764W
test16	40:04:35.80000N	73:12:40.70000E	350.0	40:10:24.50000N	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test17	40:04:35.80000N	73:12:40.70000E	200.0	40:10:24.50000N	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test18	40:04:35.80000N	72:12:40.70000E	315.0	40:10:24.50000N	70:12:45.60000E	100.0	39:57:28.59246N	72:21:55.36432E	41:49:06.70033N	69:51:05.23564E
test19	40:04:35.80000N	73:12:40.70000E	270.0	40:10:24.50000N	70:12:45.60000E	100.0	40:04:25.10140N	72:22:53.47612E	39:57:42.95307N	68:03:33.19723E
test20	40:04:35.80000N	73:12:40.70000E	300.0	40:10:24.50000N	70:12:45.60000E	100.0	40:26:53.80980N	72:21:41.88661E	41:41:48.45569N	69:19:03.39492E
test21	40:04:35.80000N	73:12:40.70000E	240.0	40:10:24.50000N	70:12:45.60000E	100.0	39:39:10.70047N	72:16:14.18085E	38:31:26.01350N	69:53:35.03132E
test22	42:54:35.80000N	70:11:34.70000E	180.0	40:10:24.50000N	70:12:45.60000E	100.0	41:50:27.82240N	70:11:34.70000E	38:30:19.45513N	70:11:34.70000E
test23	42:54:35.80000N	70:11:34.70000E	148.0	40:10:24.50000N	70:12:45.60000E	100.0	41:38:51.44804N	71:14:26.22964E	40:11:43.96597N	72:23:13.80920E
test24	42:54:35.80000N	70:11:34.70000E	211.0	40:10:24.50000N	70:12:45.60000E	100.0	41:38:52.66082N	69:11:07.98528E	40:08:17.38700N	68:02:21.75495E
test25	40:24:35.80000N	65:11:34.70000E	90.0	40:10:24.50000N	70:12:45.60000E	100.0	40:22:28.60052N	68:03:03.59248E	40:11:08.47196N	72:23:13.71817E
test26	40:24:35.80000N	65:11:34.70000E	71.0	40:10:24.50000N	70:12:45.60000E	100.0	41:13:31.30530N	68:30:43.58125E	41:44:55.52500N	70:56:05.26696E
test27	40:24:35.80000N	65:11:34.70000E	117.0	40:10:24.50000N	70:12:45.60000E	100.0	38:55:28.33410N	68:47:03.42056E	38:35:19.72896N	69:32:28.24986E
test28	37:09:35.80000N	70:21:34.70000E	0.0	40:10:24.50000N	70:12:45.60000E	100.0	38:30:33.27210N	70:21:34.70000E	41:50:14.67279N	70:21:34.70000E
test29	37:09:35.80000N	70:21:34.70000E	31.0	40:10:24.50000N	70:12:45.60000E	100.0	39:05:41.34977N	71:51:29.95766E	39:31:54.37145N	72:12:37.10649E
test30	37:09:35.80000N	70:21:34.70000E	331.0	40:10:24.50000N	70:12:45.60000E	100.0	38:39:57.65316N	69:17:30.06177E	40:20:03.37282N	68:02:45.21636E
test31	40:04:35.80000S	73:12:40.70000E	350.0	40:10:24.50000S	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test32	40:04:35.80000S	73:12:40.70000E	200.0	40:10:24.50000S	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test33	40:04:35.80000S	72:12:40.70000E	315.0	40:10:24.50000S	70:12:45.60000E	100.0	40:12:40.39213S	72:23:13.39076E	38:30:19.48047S	70:13:59.97421E
test34	40:04:35.80000S	73:12:40.70000E	270.0	40:10:24.50000S	70:12:45.60000E	100.0	40:04:25.10140S	72:22:53.47612E	39:57:42.95307S	68:03:33.19723E
test35	40:04:35.80000S	73:12:40.70000E	300.0	40:10:24.50000S	70:12:45.60000E	100.0	39:39:10.70047S	72:16:14.18085E	38:31:26.01350S	69:53:35.03132E
test36	40:04:35.80000S	73:12:40.70000E	240.0	40:10:24.50000S	70:12:45.60000E	100.0	40:26:53.80980S	72:21:41.88661E	41:41:48.45569S	69:19:03.39492E
test37	38:04:35.80000S	70:11:34.70000E	180.0	40:10:24.50000S	70:12:45.60000E	100.0	38:30:19.45513S	70:11:34.70000E	41:50:27.82240S	70:11:34.70000E
test38	38:04:35.80000S	70:11:34.70000E	148.0	40:10:24.50000S	70:12:45.60000E	100.0	38:31:34.10858S	70:33:03.48677E	40:38:16.13339S	72:18:29.56104E
test39	38:04:35.80000S	70:11:34.70000E	211.0	40:10:24.50000S	70:12:45.60000E	100.0	38:31:47.32219S	69:50:45.35130E	40:40:24.17522S	68:07:50.24284E
test40	40:24:35.80000S	65:51:34.70000E	90.0	40:10:24.50000S	70:12:45.60000E	100.0	40:23:20.88344S	68:03:11.35606E	40:13:31.47512S	72:23:12.41522E
test41	40:24:35.80000S	65:51:34.70000E	71.0	40:10:24.50000S	70:12:45.60000E	100.0	39:47:33.58163S	68:06:05.87892E	38:46:58.13955S	71:24:05.30746E
test42	40:24:35.80000S	65:51:34.70000E	117.0	40:10:24.50000S	70:12:45.60000E	100.0	41:34:54.09546S	69:02:08.00210E	41:46:21.53454S	69:35:18.59270E

test43	43:09:35.80000S	70:21:34.70000E	0.0	40:10:24.50000S	70:12:45.60000E	100.0	41:50:14.67279S	70:21:34.70000E	38:30:33.27210S	70:21:34.70000E
test44	43:09:35.80000S	70:21:34.70000E	34.0	40:10:24.50000S	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test45	43:09:35.80000S	70:21:34.70000E	335.0	40:10:24.50000S	70:12:45.60000E	100.0	41:44:46.94173S	69:28:53.61272E	39:33:21.66496S	68:12:06.66151E
test46	40:04:35.80000S	67:12:40.70000W	350.0	40:10:24.50000S	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test47	40:04:35.80000S	67:12:40.70000W	200.0	40:10:24.50000S	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test48	40:04:35.80000S	68:12:40.70000W	315.0	40:10:24.50000S	70:12:45.60000W	100.0	40:12:32.98018S	68:02:17.71481W	38:30:19.55929S	70:11:21.32978W
test49	40:04:35.80000S	67:12:40.70000W	270.0	40:10:24.50000S	70:12:45.60000W	100.0	40:04:25.03104S	68:02:37.73049W	39:57:42.51976S	72:21:57.92383W
test50	40:04:35.80000S	67:12:40.70000W	300.0	40:10:24.50000S	70:12:45.60000W	100.0	39:39:05.08426S	68:09:19.50227W	38:31:25.09106S	70:31:48.24036W
test51	40:04:35.80000S	67:12:40.70000W	240.0	40:10:24.50000S	70:12:45.60000W	100.0	40:26:58.44233S	68:03:50.25317W	41:41:50.22946S	71:06:22.56112W
test52	38:04:35.80000S	70:11:34.70000W	180.0	40:10:24.50000S	70:12:45.60000W	100.0	38:30:19.45513S	70:11:34.70000W	41:50:27.82240S	70:11:34.70000W
test53	38:04:35.80000S	70:11:34.70000W	148.0	40:10:24.50000S	70:12:45.60000W	100.0	38:31:55.04879S	69:49:49.11075W	40:36:19.17675S	68:06:20.78959W
test54	38:04:35.80000S	70:11:34.70000W	211.0	40:10:24.50000S	70:12:45.60000W	100.0	38:31:27.49080S	70:32:08.75118W	40:42:18.41652S	72:16:54.09843W
test55	40:24:35.80000S	74:11:34.70000W	90.0	40:10:24.50000S	70:12:45.60000W	100.0	40:23:44.12558S	72:22:16.19656W	40:14:45.41675S	68:02:21.20257W
test56	40:24:35.80000S	74:11:34.70000W	71.0	40:10:24.50000S	70:12:45.60000W	100.0	39:54:28.73386S	72:21:18.43758W	38:51:32.35724S	68:53:12.00023W
test57	40:24:35.80000S	74:11:34.70000W	117.0	40:10:24.50000S	70:12:45.60000W	100.0	41:17:23.70708S	71:50:29.04635W	41:50:26.40135S	70:15:52.05998W
test58	43:09:35.80000S	70:21:34.70000W	0.0	40:10:24.50000S	70:12:45.60000W	100.0	41:50:14.67279S	70:21:34.70000W	38:30:33.27210S	70:21:34.70000W
test59	43:09:35.80000S	70:21:34.70000W	34.0	40:10:24.50000S	70:12:45.60000W	100.0	41:29:48.15752S	68:52:34.09229W	40:34:48.23070S	68:05:51.32589W
test60	43:09:35.80000S	70:21:34.70000W	331.0	40:10:24.50000S	70:12:45.60000W	100.0	41:27:45.66110S	71:36:19.10893W	40:21:28.52278S	72:22:35.77672W

WGS84TangentFixedRadiusArc Test Results

Test Identifier	Geodesic 1 Start Latitude	Geodesic 1 Start Longitude	Geodesic 1 Azimuth	Geodesic 2 Start Latitude	Geodesic 2 Start Longitude	Geodesic 2 Azimuth	Arc Radius	Arc Direction	Arc Center Latitude	Arc Center Longitude	Tangent Point 1 Latitude	Tangent Point 1 Longitude	Tangent Point 2 Latitude	Tangent Point 2 Longitude
test1	40:10:24.50000N	70:12:45.60000W	90.0	42:04:35.80000N	68:12:34.70000W	7.0	75.0	1	41:25:26.56571N	69:59:17.04094W	40:10:23.74429N	69:59:31.88877W	41:17:07.03907N	68:20:18.39888W
test2	40:10:24.50000N	70:12:45.60000W	90.0	42:04:35.80000N	68:12:34.70000W	307.0	25.0	1	40:31:46.79892N	66:27:03.20189W	40:06:47.06612N	66:28:25.95221W	40:51:25.07414N	66:06:41.57854W
test3	40:10:24.50000N	70:12:45.60000W	180.0	42:04:35.80000N	68:12:34.70000W	10.0	25.0	1	37:49:18.52460N	69:41:12.45766W	37:49:22.75065N	70:12:45.60000W	37:45:17.76097N	69:10:04.65398W
test4	40:10:24.50000N	70:12:45.60000W	175.0	42:04:35.80000N	68:12:34.70000W	10.0	20.0	1	37:58:58.93078N	69:32:51.13441W	37:57:20.15294N	69:58:03.52834W	37:55:45.22180N	69:07:53.72716W
test5	40:10:24.50000N	70:12:45.60000W	140.0	42:04:35.80000N	68:12:34.70000W	355.0	30.0	1	39:24:32.81954N	68:33:23.26170W	39:05:36.47498N	69:03:21.38752W	39:27:10.17660N	67:54:49.02689W
test6	40:10:24.50000N	70:12:45.60000W	35.0	42:04:35.80000N	68:12:34.70000W	20.0	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
test7	40:10:24.50000N	70:12:45.60000W	35.0	42:04:35.80000N	68:12:34.70000W	45.0	50.0	-1	40:57:48.66322N	68:07:20.87268W	41:27:16.30680N	69:00:53.40061W	41:33:03.54197N	68:54:23.62947W
test8	40:10:24.50000N	70:12:45.60000W	40.0	42:04:35.80000N	68:12:34.70000W	20.0	10.0	1	41:55:40.79274N	68:31:10.13947W	41:49:05.67932N	68:21:05.52942W	41:52:16.83907N	68:18:34.47631W
test9	40:10:24.50000N	70:12:45.60000W	40.0	42:04:35.80000N	68:12:34.70000W	350.0	5.0	1	41:59:13.16537N	68:18:06.96458W	41:55:55.15030N	68:13:04.79341W	42:00:05.41038N	68:11:30.78144W
test10	40:10:24.50000N	70:12:45.60000W	190.0	42:04:35.80000N	68:12:34.70000W	20.0	15.0	1	38:10:11.23560N	70:20:17.73040W	38:12:44.89584N	70:39:02.59725W	38:05:21.93366N	70:02:17.49744W
test11	40:10:24.50000N	70:12:45.60000W	300.0	42:04:35.80000N	68:12:34.70000W	90.0	15.0	-1	41:43:02.57956N	73:12:06.06904W	41:29:47.49856N	73:21:29.21152W	41:58:01.44478N	73:13:16.42120W
test12	40:10:24.50000N	70:12:45.60000W	320.0	42:04:35.80000N	68:12:34.70000W	120.0	50.0	-1	42:22:04.52412N	71:13:56.01200W	41:49:17.86811N	72:04:39.94655W	43:06:10.85660N	70:41:56.46903W
test13	40:10:24.50000N	70:12:45.60000W	30.0	42:04:35.80000N	68:12:34.70000W	120.0	15.0	-1	41:54:13.54118N	68:28:45.14229W	42:01:57.90713N	68:45:58.79336W	42:07:14.26829N	68:18:43.75999W
test14	40:10:24.50000N	70:12:45.60000W	30.0	42:04:35.80000N	68:12:34.70000W	180.0	10.0	-1	42:07:16.10426N	68:26:00.95597W	42:12:26.23456N	68:37:31.72202W	42:07:16.89107N	68:12:34.70000W
test15	40:10:24.50000N	70:12:45.60000W	20.0	42:04:35.80000N	68:12:34.70000W	190.0	20.0	-1	42:33:38.00509N	68:33:07.56179W	42:40:47.45417N	68:58:25.31418W	42:30:11.24393N	68:06:28.78422W
test16	40:10:24.50000S	70:12:45.60000W	90.0	38:04:35.80000S	68:12:34.70000W	7.0	75.0	1	38:55:19.66495S	69:57:30.23681W	40:10:23.45763S	69:57:13.42772W	39:05:15.38970S	68:22:08.10115W
test17	40:10:24.50000S	70:12:45.60000W	90.0	38:04:35.80000S	68:12:34.70000W	307.0	25.0	1	39:41:24.87800S	66:18:33.94822W	40:06:24.60062S	66:17:08.09870W	39:21:05.93754S	65:59:42.39589W
test18	40:10:24.50000S	70:12:45.60000W	180.0	38:04:35.80000S	68:12:34.70000W	10.0	25.0	1	41:48:21.64034S	69:39:19.85614W	41:48:26.50432S	70:12:45.60000W	41:53:01.81471S	69:06:28.19550W
test19	40:10:24.50000S	70:12:45.60000W	175.0	38:04:35.80000S	68:12:34.70000W	10.0	20.0	1	41:53:23.08049S	69:33:48.78224W	41:55:13.61589S	70:00:29.02018W	41:57:06.70642S	69:07:29.45776W
test20	40:10:24.50000S	70:12:45.60000W	140.0	38:04:35.80000S	68:12:34.70000W	355.0	30.0	1	40:53:21.50747S	68:32:50.30433W	41:13:01.31780S	69:02:47.99272W	40:50:44.90598S	67:53:26.70965W
test21	40:10:24.50000S	70:12:45.60000W	35.0	38:04:35.80000S	68:12:34.70000W	20.0	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

test22	40:10:24.50000S	70:12:45.60000W	35.0	38:04:35.80000S	68:12:34.70000W	45.0	50.0	-1	38:59:07.56203S	67:51:47.61082W	38:31:17.23392S	68:44:54.62547W	38:23:43.49887S	68:36:56.20242W
test23	40:10:24.50000S	70:12:45.60000W	40.0	38:04:35.80000S	68:12:34.70000W	20.0	10.0	1	38:21:17.65803S	68:33:50.38808W	38:27:34.84485S	68:23:56.35353W	38:24:44.64049S	68:21:54.05514W
test24	40:10:24.50000S	70:12:45.60000W	40.0	38:04:35.80000S	68:12:34.70000W	350.0	5.0	1	38:12:57.08171S	68:17:09.17935W	38:16:05.07958S	68:12:12.22289W	38:12:05.00846S	68:10:54.32298W
test25	40:10:24.50000S	70:12:45.60000W	190.0	38:04:35.80000S	68:12:34.70000W	20.0	15.0	1	41:21:05.57583S	70:09:04.40926W	41:18:28.19792S	70:28:40.65479W	41:26:30.42675S	69:50:29.08027W
test26	40:10:24.50000S	70:12:45.60000W	300.0	38:04:35.80000S	68:12:34.70000W	90.0	15.0	-1	38:11:39.46782S	73:47:56.44226W	38:24:20.78704S	73:58:07.81572W	37:56:40.09827S	73:46:48.10003W
test27	40:10:24.50000S	70:12:45.60000W	320.0	38:04:35.80000S	68:12:34.70000W	120.0	50.0	-1	37:18:22.45450S	71:50:53.37418W	37:49:40.64492S	72:39:57.99848W	36:35:56.07395S	71:17:47.86633W
test28	40:10:24.50000S	70:12:45.60000W	30.0	38:04:35.80000S	68:12:34.70000W	120.0	15.0	-1	38:15:18.86600S	68:27:05.40167W	38:08:02.37874S	68:43:44.12803W	38:02:19.38377S	68:17:33.22322W
test29	40:10:24.50000S	70:12:45.60000W	30.0	38:04:35.80000S	68:12:34.70000W	180.0	10.0	-1	38:02:17.85831S	68:25:14.17729W	37:57:27.29149S	68:36:18.51623W	38:02:18.53972S	68:12:34.70000W
test30	40:10:24.50000S	70:12:45.60000W	20.0	38:04:35.80000S	68:12:34.70000W	190.0	20.0	-1	37:17:13.88439S	68:27:34.64341W	37:10:42.09265S	68:51:15.15355W	37:20:43.05501S	68:02:53.31084W
test31	40:10:24.50000S	68:12:45.60000E	90.0	38:04:35.80000S	70:12:34.70000E	7.0	75.0	1	38:55:19.71316S	68:27:39.15441E	40:10:23.50671S	68:27:55.56302E	39:05:15.43802S	70:03:01.29112E
test32	40:10:24.50000S	68:12:45.60000E	90.0	38:04:35.80000S	70:12:34.70000E	307.0	25.0	1	39:41:25.57535S	72:06:36.70261E	40:06:25.30217S	72:08:02.42702E	39:21:06.63156S	72:25:28.25205E
test33	40:10:24.50000S	68:12:45.60000E	180.0	38:04:35.80000S	70:12:34.70000E	10.0	25.0	1	41:46:59.98555S	68:46:10.63681E	41:47:04.84568S	68:12:45.60000E	41:51:40.05992S	69:19:01.62673E
test34	40:10:24.50000S	68:12:45.60000E	175.0	38:04:35.80000S	70:12:34.70000E	10.0	20.0	1	41:52:26.37245S	68:51:35.20384E	41:54:16.88004S	68:24:55.35570E	41:56:09.94304S	69:17:54.15406E
test35	40:10:24.50000S	68:12:45.60000E	140.0	38:04:35.80000S	70:12:34.70000E	355.0	30.0	1	40:53:00.52340S	69:52:16.78699E	41:12:40.22975S	69:22:19.13720E	40:50:23.93467S	70:31:40.17600E
test36	40:10:24.50000S	68:12:45.60000E	35.0	38:04:35.80000S	70:12:34.70000E	20.0	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
test37	40:10:24.50000S	68:12:45.60000E	35.0	38:04:35.80000S	70:12:34.70000E	45.0	50.0	-1	38:58:15.99199S	70:34:27.34186E	38:30:25.98705S	69:41:20.68237E	38:22:52.33996S	69:49:18.75679E
test38	40:10:24.50000S	68:12:45.60000E	40.0	38:04:35.80000S	70:12:34.70000E	20.0	10.0	1	38:21:56.65274S	69:51:00.76931E	38:28:13.89538S	70:00:54.83463E	38:25:23.66587S	70:02:57.19466E
test39	40:10:24.50000S	68:12:45.60000E	40.0	38:04:35.80000S	70:12:34.70000E	350.0	5.0	1	38:13:14.64955S	70:08:04.12833E	38:16:22.65986S	70:13:01.09183E	38:12:22.57289S	70:14:19.00895E
test40	40:10:24.50000S	68:12:45.60000E	190.0	38:04:35.80000S	70:12:34.70000E	20.0	15.0	1	41:19:48.53358S	68:16:44.73461E	41:17:11.20581S	67:57:08.86172E	41:25:13.27841S	68:35:19.75280E
test41	40:10:24.50000S	68:12:45.60000E	300.0	38:04:35.80000S	70:12:34.70000E	90.0	15.0	-1	38:11:40.61138S	64:37:37.05220E	38:24:21.93390S	64:27:25.68277E	37:56:41.23801S	64:38:45.31315E
test42	40:10:24.50000S	68:12:45.60000E	320.0	38:04:35.80000S	70:12:34.70000E	120.0	50.0	-1	37:18:44.79574S	66:35:00.43984E	37:50:03.14293S	65:45:55.73018E	36:36:18.21450S	67:08:05.70311E
test43	40:10:24.50000S	68:12:45.60000E	30.0	38:04:35.80000S	70:12:34.70000E	120.0	15.0	-1	38:15:26.42644S	69:58:20.50710E	38:08:09.92689S	69:41:41.76083E	38:02:26.92225S	70:07:52.65334E
test44	40:10:24.50000S	68:12:45.60000E	30.0	38:04:35.80000S	70:12:34.70000E	180.0	10.0	-1	38:02:49.25073S	69:59:55.13263E	37:57:58.65008S	69:48:50.73899E	38:02:49.93235S	70:12:34.70000E
test45	40:10:24.50000S	68:12:45.60000E	20.0	38:04:35.80000S	70:12:34.70000E	190.0	20.0	-1	37:19:00.32748S	69:57:10.89521E	37:12:28.38650S	69:33:29.89561E	37:22:29.58087S	70:21:52.79009E

test46	40:10:24.50000N	68:12:45.60000E	90.0	42:04:35.80000N	70:12:34.70000E	7.0	75.0	1	41:25:26.60664N	68:25:52.36461E	40:10:23.78448N	68:25:37.91699E	41:17:07.07993N	70:04:51.00769E
test47	40:10:24.50000N	68:12:45.60000E	90.0	42:04:35.80000N	70:12:34.70000E	307.0	25.0	1	40:31:47.54306N	71:58:04.95738E	40:06:47.80578N	71:56:42.34739E	40:51:25.82191N	72:18:26.57839E
test48	40:10:24.50000N	68:12:45.60000E	180.0	42:04:35.80000N	70:12:34.70000E	10.0	25.0	1	37:51:10.80607N	68:44:19.53963E	37:51:15.03684N	68:12:45.60000E	37:47:09.94546N	69:15:28.10850E
test49	40:10:24.50000N	68:12:45.60000E	175.0	42:04:35.80000N	70:12:34.70000E	10.0	20.0	1	38:00:10.41235N	68:52:32.81783E	37:58:31.60944N	68:27:20.01909E	37:56:56.65308N	69:17:30.61773E
test50	40:10:24.50000N	68:12:45.60000E	140.0	42:04:35.80000N	70:12:34.70000E	355.0	30.0	1	39:24:56.40398N	69:51:43.36317E	39:05:59.95608N	69:21:45.17977E	39:27:33.77651N	70:30:17.81305E
test51	40:10:24.50000N	68:12:45.60000E	35.0	42:04:35.80000N	70:12:34.70000E	20.0	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
test52	40:10:24.50000N	68:12:45.60000E	35.0	42:04:35.80000N	70:12:34.70000E	45.0	50.0	-1	40:58:50.90375N	70:19:10.81896E	41:28:19.01585N	69:25:37.89916E	41:34:06.34313N	69:32:08.06055E
test53	40:10:24.50000N	68:12:45.60000E	40.0	42:04:35.80000N	70:12:34.70000E	20.0	10.0	1	41:55:09.03646N	69:53:43.95858E	41:48:33.97658N	70:03:48.54891E	41:51:45.11040N	70:06:19.53131E
test54	40:10:24.50000N	68:12:45.60000E	40.0	42:04:35.80000N	70:12:34.70000E	350.0	5.0	1	41:58:57.74099N	70:07:06.10358E	41:55:39.73901N	70:12:08.27010E	41:59:49.98252N	70:13:42.26099E
test55	40:10:24.50000N	68:12:45.60000E	190.0	42:04:35.80000N	70:12:34.70000E	20.0	15.0	1	38:11:57.14712N	68:05:36.93299E	38:14:30.86947N	67:46:51.62699E	38:07:07.73150N	68:23:37.55015E
test56	40:10:24.50000N	68:12:45.60000E	300.0	42:04:35.80000N	70:12:34.70000E	90.0	15.0	-1	41:43:03.43894N	65:13:22.97799E	41:29:48.35505N	65:03:59.84075E	41:58:02.30748N	65:12:12.70228E
test57	40:10:24.50000N	68:12:45.60000E	320.0	42:04:35.80000N	70:12:34.70000E	120.0	50.0	-1	42:21:48.75747N	67:11:53.44646E	41:49:02.23303N	66:21:09.56547E	43:05:54.90302N	67:43:53.33289E
test58	40:10:24.50000N	68:12:45.60000E	30.0	42:04:35.80000N	70:12:34.70000E	120.0	15.0	-1	41:54:06.60769N	69:56:40.44962E	42:01:50.95973N	69:39:26.81837E	42:07:07.31140N	70:06:41.86897E
test59	40:10:24.50000N	68:12:45.60000E	30.0	42:04:35.80000N	70:12:34.70000E	180.0	10.0	-1	42:06:49.39078N	69:59:08.53808E	42:11:59.48512N	69:47:37.82330E	42:06:50.17739N	70:12:34.70000E
test60	40:10:24.50000N	68:12:45.60000E	20.0	42:04:35.80000N	70:12:34.70000E	190.0	20.0	-1	42:32:22.60485N	69:51:44.28487E	42:39:31.91024N	69:26:26.96605E	42:28:55.91068N	70:18:22.54478E

WGS84GeoLocusIntersect Test Results

Test Identifier	Geodesic Input	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic End Latitude	Geodesic End Longitude						
	Locus Input	Locus Geodesic Start Latitude	Locus Geodesic Start Longitude	Locus Geodesic End Latitude	Locus Geodesic End Longitude	Locus Start Latitude	Locus Start Longitude	Locus End Latitude	Locus End Longitude	Locus Start Distance (NM)	Locus End Distance (NM)
	Output	Intersection Latitude	Intersection Longitude								
test1	Geodesic Input	43:47:17.80000N	69:11:50.60000W	39:34:35.80000N	69:12:34.70000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:34:51.08997N	70:54:12.49358W	42:29:44.86980N	68:54:29.59541W	-40.0	-40.0
	Output	42:13:22.21447N	69:12:07.67540W								
test2	Geodesic Input	41:47:17.80000N	69:11:50.60000W	42:04:35.80000N	68:12:34.70000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:16:32.54683N	70:23:04.51876W	42:10:54.51067N	68:23:00.30232W	-10.0	-10.0
	Output	41:57:19.79045N	68:37:45.07858W								
test3	Geodesic Input	41:47:17.80000N	69:11:50.60000W	41:47:17.80000N	65:12:34.70000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:01:10.70138N	69:57:20.70132W	41:58:16.13817N	68:02:11.16321W	15.0	10.0
	Output	41:48:04.24394N	68:12:34.32299W								
test4	Geodesic Input	41:47:17.80000N	69:11:50.60000W	39:36:04.50000N	67:26:41.20000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:03:01.62624N	70:00:25.34804W	41:53:11.72828N	67:53:53.81471W	12.0	18.0
	Output	41:11:48.40128N	68:42:35.01577W								
test5	Geodesic Input	41:47:17.80000N	69:11:50.60000W	39:36:04.50000N	69:11:50.60000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:17:46.04493N	70:25:08.52603W	42:10:54.51067N	68:23:00.30232W	-12.0	-10.0
	Output	41:26:42.33213N	69:11:50.60000W								
test6	Geodesic Input	41:47:17.80000N	69:11:50.60000W	40:10:24.50000N	70:12:45.60000W						
	Locus Input	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:16:32.54683N	70:23:04.51876W	42:17:12.26361N	68:33:27.97949W	-10.0	-20.0
	Output	41:09:26.33503N	69:36:02.59565W								
test7	Geodesic Input	38:47:17.80000N	69:11:50.60000W	42:04:35.80000N	68:12:34.70000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:58:16.13817N	68:02:11.16322W	40:01:10.70138N	69:57:20.70132W	-10.0	-15.0
	Output	41:40:37.83025N	68:20:06.26330W								
test8	Geodesic Input	38:47:17.80000N	69:11:50.60000W	41:36:04.50000N	69:11:50.60000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	42:12:10.13809N	68:25:05.67147W	40:16:32.54683N	70:23:04.51876W	12.0	10.0

	Output	41:27:24.30947N	69:11:50.60000W								
test9	Geodesic Input	39:47:17.80000N	69:11:50.60000W	41:10:24.50000N	70:12:45.60000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:55:44.00859N	67:58:02.32477W	40:04:15.53037N	70:02:28.53823W	-14.0	-10.0
	Output	40:25:30.20295N	69:39:29.15454W								
test10	Geodesic Input	39:47:17.80000N	69:11:50.60000W	41:05:17.80000N	72:11:50.60000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:39:11.51094N	67:31:12.85281W	39:48:49.10840N	69:36:53.95760W	-40.0	-35.0
	Output	39:55:22.68250N	69:29:41.62067W								
test11	Geodesic Input	39:47:17.80000N	68:31:50.60000W	39:47:17.80000N	72:11:50.60000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:35:59.92546N	67:26:04.91588W	39:39:30.54353N	69:21:38.70685W	-45.0	-50.0
	Output	39:47:49.91827N	69:13:40.39367W								
test12	Geodesic Input	40:47:17.80000N	68:31:50.60000W	39:15:17.80000N	72:11:50.60000W						
	Locus Input	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:40:28.08041N	67:33:16.16949W	39:42:36.95607N	69:26:43.33456W	-38.0	-45.0
	Output	40:51:17.20232N	68:21:40.00231W								
test13	Geodesic Input	41:47:17.80000N	68:11:50.60000E	42:34:35.80000N	69:12:34.70000E						
	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:34:48.34098N	67:31:15.95275E	42:30:56.94337N	69:28:29.96911E	-40.0	-42.0
	Output	N/A	N/A								
test14	Geodesic Input	41:47:17.80000N	68:11:50.60000E	42:04:35.80000N	70:12:34.70000E						
	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:12:09.29285N	70:00:02.80815E	-10.0	-12.0
	Output	42:01:21.05406N	69:48:40.14334E								
test15	Geodesic Input	41:47:17.80000N	68:11:50.60000E	41:47:17.80000N	69:12:34.70000E						
	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:34:48.34098N	67:31:15.95275E	42:29:04.57278N	69:31:40.10061E	-40.0	-39.0
	Output	41:47:21.72812N	68:46:38.51557E								
test16	Geodesic Input	41:47:17.80000N	67:11:50.60000E	39:36:04.50000N	69:26:41.20000E						
	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:09:38.28182N	70:04:13.77003E	-10.0	-8.0
	Output	40:37:49.71683N	68:24:40.01729E								
test17	Geodesic Input	41:47:17.80000N	68:31:50.60000E	39:34:35.80000N	68:31:50.60000E						
	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:07:20.47150N	68:17:54.70834E	42:03:20.08407N	70:14:39.72588E	5.0	2.0
	Output	40:21:38.98519N	68:31:50.60000E								
test18	Geodesic Input	41:47:17.80000N	68:41:50.60000E	40:10:24.50000N	68:12:45.60000E						

	Locus Input	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:07:44.92286N	70:07:21.77389E	-10.0	-5.0
	Output	40:31:50.20654N	68:19:04.04752E								
test19	Geodesic Input	38:47:17.80000N	68:11:50.60000E	42:04:35.80000N	69:12:34.70000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:59:32.70797N	70:20:54.30885E	40:04:16.21255N	68:23:03.35373E	-8.0	-10.0
	Output	40:21:27.32287N	68:40:03.99226E								
test20	Geodesic Input	38:47:17.80000N	69:11:50.60000E	41:36:04.50000N	69:11:50.60000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	42:01:26.43878N	70:17:47.11005E	40:07:57.29566N	68:16:52.92374E	-5.0	-4.0
	Output	41:00:37.22699N	69:11:50.60000E								
test21	Geodesic Input	39:47:17.80000N	69:11:50.60000E	41:10:24.50000N	68:12:45.60000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	42:00:48.53800N	70:18:49.53023E	40:01:11.72389N	68:28:11.53713E	-6.0	-15.0
	Output	40:22:24.93524N	68:47:13.10535E								
test22	Geodesic Input	38:47:17.80000N	72:11:50.60000E	40:05:17.80000N	69:11:50.60000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:39:14.30455N	70:53:59.62806E	39:44:31.54766N	68:55:47.78511E	-40.0	-42.0
	Output	40:03:55.52616N	69:15:09.86384E								
test23	Geodesic Input	39:47:17.80000N	72:11:50.60000E	39:47:17.80000N	68:11:50.60000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:42:25.31152N	70:48:50.79796E	39:44:31.54766N	68:55:47.78511E	-35.0	-42.0
	Output	39:47:56.96798N	68:58:57.69087E								
test24	Geodesic Input	41:47:17.80000N	72:01:50.60000E	40:15:17.80000N	69:01:50.60000E						
	Locus Input	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:45:36.08581N	70:43:41.45993E	39:50:42.75433N	68:45:35.91786E	-30.0	-32.0
	Output	40:24:52.23963N	69:19:46.81959E								
test25	Geodesic Input	40:32:17.80000S	69:31:50.60000W	39:45:35.80000S	68:32:34.70000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:47:14.99172S	70:17:56.70673W	39:37:07.26246S	68:43:14.91695W	-5.0	-30.0
	Output	40:15:45.41972S	69:10:37.42061W								
test26	Geodesic Input	40:12:17.80000S	69:11:50.60000W	39:55:35.80000S	68:12:34.70000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:44:05.24805S	70:23:07.30456W	39:48:13.36527S	68:24:52.75546W	-10.0	-12.0
	Output	40:03:21.16483S	68:39:49.20815W								
test27	Geodesic Input	40:12:17.80000S	69:11:50.60000W	40:12:17.80000S	65:12:34.70000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:40:55.26981S	70:28:17.39464W	39:44:31.65649S	68:31:00.79721W	-15.0	-18.0
	Output	40:12:30.90626S	68:58:24.71946W								

test28	Geodesic Input	40:12:17.80000S	69:11:50.60000W	42:05:35.80000S	67:26:34.70000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:51:02.37334S	70:11:43.31749W	39:56:49.41116S	68:10:31.43442W	1.0	2.0
	Output	40:35:40.81313S	68:50:43.69996W								
test29	Geodesic Input	40:12:17.80000S	69:11:50.60000W	42:25:35.80000S	69:11:50.60000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:51:40.23723S	70:10:41.01456W	39:57:26.20299S	68:09:29.77411W	2.0	3.0
	Output	40:57:17.62289S	69:11:50.60000W								
test30	Geodesic Input	40:12:17.80000S	69:11:50.60000W	41:50:24.50000S	70:12:45.60000W						
	Locus Input	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:40:55.26981S	70:28:17.39464W	39:43:17.68107S	68:33:03.33213W	-15.0	-20.0
	Output	40:43:15.13120S	69:30:42.16309W								
test31	Geodesic Input	43:12:17.80000S	69:11:50.60000W	39:55:35.80000S	68:12:34.70000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	39:58:39.75911S	68:07:26.39841W	41:51:40.23723S	70:10:41.01456W	-5.0	-2.0
	Output	40:06:31.28916S	68:15:42.78110W								
test32	Geodesic Input	43:12:17.80000S	69:11:50.60000W	40:55:35.80000S	69:11:50.60000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:00:30.02435S	68:04:21.19705W	41:54:49.41461S	70:05:29.19346W	-8.0	-7.0
	Output	41:05:16.19670S	69:11:50.60000W								
test33	Geodesic Input	42:12:17.80000S	69:11:50.60000W	40:50:24.50000S	70:12:45.60000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	39:48:13.36527S	68:24:52.75546W	41:44:05.24805S	70:23:07.30456W	12.0	10.0
	Output	41:16:14.12186S	69:53:51.98283W								
test34	Geodesic Input	42:12:17.80000S	69:11:50.60000W	40:45:17.50000S	72:11:50.60000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:13:56.09360S	67:41:37.98194W	42:06:08.48229S	69:46:42.39287W	-30.0	-25.0
	Output	41:59:37.91453S	69:39:10.91231W								
test35	Geodesic Input	42:12:17.80000S	69:11:50.60000W	42:12:17.80000S	72:11:50.60000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:20:00.99821S	67:31:15.37383W	42:14:16.98565S	69:33:04.43858W	-40.0	-38.0
	Output	42:12:31.30889S	69:31:07.42859W								
test36	Geodesic Input	40:12:17.80000S	67:11:50.60000W	41:30:17.80000S	70:11:50.60000W						
	Locus Input	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:01:06.76102S	68:03:19.42649W	41:55:27.22164S	70:04:26.76787W	-9.0	-8.0
	Output	41:03:44.09408S	69:08:30.81544W								
test37	Geodesic Input	40:42:17.80000S	68:11:50.60000E	39:52:35.80000S	69:12:34.70000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:25:04.68264S	67:31:27.86642E	39:30:21.55001S	69:30:40.99953E	-40.0	-41.0

	Output	40:15:33.08735S	68:44:47.55891E								
test38	Geodesic Input	40:12:17.80000S	68:11:50.60000E	39:55:35.80000S	70:12:34.70000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:49:27.87799S	70:02:18.78242E	-15.0	-10.0
	Output	39:58:31.84128S	69:52:29.29742E								
test39	Geodesic Input	40:12:17.80000S	68:11:50.60000E	40:12:17.80000S	72:12:34.70000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:47:15.34302S	68:07:34.11126E	39:51:18.35063S	70:05:23.36577E	-5.0	-7.0
	Output	40:13:16.89179S	69:43:44.03190E								
test40	Geodesic Input	38:01:17.80000S	68:11:50.60000E	40:12:17.80000S	69:56:34.70000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:44:32.88343S	69:54:07.36243E	-15.0	-18.0
	Output	39:55:56.20199S	69:43:03.93718E								
test41	Geodesic Input	38:01:17.80000S	69:11:50.60000E	41:12:17.80000S	69:11:50.60000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:43:19.04394S	69:52:04.68943E	-15.0	-20.0
	Output	40:25:31.95062S	69:11:50.60000E								
test42	Geodesic Input	38:01:17.80000S	69:11:50.60000E	41:50:24.50000S	68:12:45.60000E						
	Locus Input	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:44:32.88343S	69:54:07.36243E	-15.0	-18.0
	Output	41:17:14.59269S	68:21:44.54338E								
test43	Geodesic Input	43:29:17.80000S	68:11:50.60000E	39:55:35.80000S	70:12:34.70000E						
	Locus Input	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:10:51.57579S	70:38:22.52584E	42:09:14.44140S	68:44:05.27630E	-25.0	-30.0
	Output	41:34:33.35900S	69:18:28.69285E								
test44	Geodesic Input	42:29:17.80000S	69:11:50.60000E	38:55:35.80000S	68:11:50.60000E						
	Locus Input	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:00:29.47695S	70:20:48.75282E	41:56:04.38538S	68:22:07.56499E	-8.0	-9.0
	Output	41:26:23.00508S	68:53:29.08873E								
test45	Geodesic Input	42:29:17.80000S	69:11:50.60000E	40:50:24.50000S	68:12:45.60000E						
	Locus Input	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	39:57:25.99787S	70:15:39.83219E	41:53:33.42022S	68:17:57.59846E	-3.0	-5.0
	Output	41:34:00.90066S	68:38:24.24396E								
test46	Geodesic Input	40:29:17.80000S	70:11:50.60000E	38:45:07.50000S	67:11:50.60000E						
	Locus Input	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	39:58:02.71210S	70:16:41.57960E	41:52:17.88059S	68:15:52.73784E	-4.0	-3.0
	Output	40:19:41.24209S	69:54:30.11308E								

WGS84LocusArcIntersect Test Results

Test Identifier	Locus Inputs	Locus Geodesic Start Latitude	Locus Geodesic Start Longitude	Locus Geodesic End Latitude	Locus Geodesic End Longitude	Locus Start Latitude	Locus Start Longitude	Locus End Latitude	Locus End Longitude	Locus Start Distance	Locus End Distance
	Arc Inputs	Arc Center Latitude	Arc Center Longitude	Arc Radius							
	Outputs	Intersection 1 Latitude	Intersection 1 Longitude	Intersection 2 Latitude	Intersection 2 Longitude						
test1	LocusInputs	40:04:35.80000N	67:12:40.70000W	44:59:45.92088N	68:26:00.21137W	39:56:32.24583N	68:10:17.89287W	44:49:00.82197N	69:41:53.85880W	-45.0	-55.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	41:16:20.97483N	68:33:49.64706W	N/A	N/A						
test2	LocusInputs	40:04:35.80000N	67:12:40.70000W	35:21:11.74762N	69:17:59.12450W	40:19:46.76257N	68:07:58.28686W	35:38:35.67860N	70:21:53.80953W	45.0	55.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	38:52:37.32110N	68:51:25.92398W	N/A	N/A						
test3	LocusInputs	40:04:35.80000N	68:12:40.70000W	44:06:29.08145N	72:11:23.83279W	40:10:19.71054N	68:01:59.52680W	44:15:37.90140N	71:54:52.50907W	10.0	15.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	40:10:40.48392N	68:02:17.74643W	41:44:11.11144N	69:26:43.29973W						
test4	LocusInputs	40:04:35.80000N	67:12:40.70000W	39:53:37.86852N	73:42:48.01440W	39:24:33.84810N	67:12:40.70000W	39:13:42.17201N	73:39:02.85208W	-40.0	-40.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	39:24:15.45160N	68:17:38.63126W	39:18:24.79605N	72:03:32.01227W						
test5	LocusInputs	40:04:35.80000N	67:12:40.70000W	42:25:59.29666N	73:03:41.42140W	39:47:15.03035N	67:25:39.04894W	42:03:31.24636N	73:18:28.55441W	-20.0	-25.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	40:02:54.56086N	68:02:47.12641W	41:27:12.33255N	71:37:11.75223W						
test6	LocusInputs	40:04:35.80000N	67:12:40.70000W	37:26:38.49374N	72:39:00.04197W	40:24:30.80802N	67:27:43.97508W	37:47:30.86022N	72:56:21.95509W	23.0	25.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	40:09:14.29595N	68:02:19.62879W	38:40:57.69877N	71:10:40.22633W						
test7	LocusInputs	42:54:35.80000N	70:11:34.70000W	37:54:23.25449N	70:11:34.70000W	42:54:34.63546N	69:55:14.95265W	37:54:22.70515N	70:00:12.39331W	-12.0	-9.0

	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	41:49:41.81253N	69:56:23.66945W	38:30:50.35272N	69:59:38.85328W						
test8	LocusInputs	42:54:35.80000N	70:11:34.70000W	38:36:54.74970N	66:48:53.11210W	42:45:33.45879N	70:31:08.92001W	38:25:55.70018N	67:13:10.97191W	17.0	22.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	41:48:11.21428N	69:44:43.27879W	39:41:58.47789N	68:08:06.44802W						
test9	LocusInputs	42:54:35.80000N	70:11:34.70000W	38:34:20.92985N	73:28:27.37397W	42:47:21.88895N	69:55:16.82351W	38:30:28.69575N	73:19:31.79717W	-14.0	-8.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	41:47:15.33175N	70:45:57.13556W	39:49:26.30016N	72:19:59.93614W						
test10	LocusInputs	40:24:35.80000N	75:11:34.70000W	40:13:30.13260N	68:39:33.29289W	40:09:35.15249N	75:11:34.70000W	39:53:32.47781N	68:41:28.29400W	15.0	20.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	40:05:22.18528N	72:22:58.48688W	N/A	N/A						
test11	LocusInputs	40:24:35.80000N	75:11:34.70000W	41:52:02.63088N	68:51:37.82571W	40:17:01.57931N	75:08:10.50021W	41:46:14.44889N	68:49:34.67458W	8.0	
	ArcInputs	6.0	40:10:24.50000N								
	Outputs	70:12:45.60000W	100.0	41:03:30.88159N	72:04:03.66717W	41:40:47.06916N	69:16:07.93303W				
test12	LocusInputs	40:24:35.80000N	75:11:34.70000W	37:59:52.60403N	69:33:17.73371W	40:34:24.08080N	75:05:01.48924W	38:11:04.65506N	69:24:54.64598W	-11.0	-13.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	39:22:31.10917N	72:06:39.15758W	38:30:24.52137N	70:07:20.17531W						
test13	LocusInputs	37:09:35.80000N	70:21:34.70000W	42:09:50.66942N	70:21:34.70000W	37:09:34.10973N	70:01:33.74416W	42:09:49.71595N	70:06:47.22254W	16.0	11.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	38:30:36.75113N	70:02:54.77447W	41:50:21.16270N	70:06:25.67783W						
test14	LocusInputs	37:09:35.80000N	70:21:34.70000W	41:15:08.98180N	66:39:17.43518W	37:14:37.77298N	70:30:55.36855W	41:19:17.77892N	66:46:46.42762W	-9.0	-7.0
	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	38:40:34.86821N	69:15:50.39090W	39:59:51.92500N	68:03:11.54227W						
test15	LocusInputs	37:09:35.80000N	70:21:34.70000W	41:29:39.48761N	73:34:58.78500W	37:15:24.56960N	70:08:25.90396W	41:34:48.49958N	73:23:33.80854W	12.0	10.0

	ArcInputs	40:10:24.50000N	70:12:45.60000W	100.0							
	Outputs	38:40:27.45727N	71:09:21.24587W	40:18:13.26914N	72:22:56.80903W						
test16	LocusInputs	40:04:35.80000N	73:12:40.70000E	44:59:45.92088N	71:59:21.18863E	39:48:00.15827N	71:17:40.20472E	44:43:50.98219N	70:09:07.24848E	-90.0	-80.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	41:46:00.68336N	70:51:43.52402E	N/A	N/A						
test17	LocusInputs	40:04:35.80000N	73:12:40.70000E	35:21:11.74762N	71:07:22.27550E	40:36:07.65151N	71:15:28.17727E	35:49:22.22773N	69:22:33.06760E	95.0	90.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	38:30:43.20226N	70:24:16.36558E	N/A	N/A						
test18	LocusInputs	40:04:35.80000N	72:12:40.70000E	43:30:53.45685N	67:21:10.09784E	40:14:29.48962N	72:25:36.35111E	43:49:30.21672N	67:44:10.09926E	14.0	25.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	40:16:35.49023N	72:23:04.19012E	41:49:56.03913N	70:26:23.17962E						
test19	LocusInputs	40:04:35.80000N	73:12:40.70000E	39:53:37.86852N	66:42:33.38560E	39:32:34.26062N	73:12:40.70000E	39:28:40.60461N	66:44:54.61550E	-32.0	-25.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	39:33:23.20779N	72:13:25.35838E	39:31:28.71124N	68:13:08.42930E						
test20	LocusInputs	40:04:35.80000N	73:12:40.70000E	42:25:59.29666N	67:21:39.97860E	39:55:03.56268N	73:05:31.79786E	42:17:00.31604N	67:15:43.86529E	-11.0	-10.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	40:13:44.90572N	72:23:12.06451E	41:35:55.71369N	69:04:18.25538E						
test21	LocusInputs	40:04:35.80000N	73:12:40.70000E	37:26:38.49374N	67:46:21.35803E	40:15:51.48849N	73:04:11.23785E	37:39:10.22938N	67:35:57.37599E	13.0	15.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	39:57:08.54828N	72:21:51.60527E	38:36:13.70124N	69:29:05.91728E						
test22	LocusInputs	42:54:35.80000N	70:11:34.70000E	37:54:23.25449N	70:11:34.70000E	42:54:17.16834N	71:16:53.48450E	37:54:09.52152N	71:08:26.12075E	-48.0	-45.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	41:38:47.56150N	71:14:35.87008E	38:40:33.81918N	71:09:38.04827E						
test23	LocusInputs	42:54:35.80000N	70:11:34.70000E	38:36:54.74970N	73:34:16.28790E	42:45:33.45879N	69:52:00.47999E	38:26:55.82263N	73:12:10.65574E	17.0	20.0

	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	41:48:29.43066N	70:38:53.21696E	39:41:45.96241N	72:17:19.72669E						
test24	LocusInputs	42:54:35.80000N	70:11:34.70000E	38:34:20.92985N	66:54:42.02603E	42:46:50.80632N	70:29:02.27938E	38:26:06.61768N	67:13:38.98386E	-15.0	-17.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	41:47:43.40196N	69:42:02.50041E	39:42:31.14816N	68:07:53.50977E						
test25	LocusInputs	40:24:35.80000N	65:11:34.70000E	40:13:30.13260N	71:43:36.10711E	39:57:34.60638N	65:11:34.70000E	39:41:33.83675N	71:40:32.63802E	27.0	32.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	39:53:11.08875N	68:04:30.93940E	N/A	N/A						
test26	LocusInputs	40:24:35.80000N	65:11:34.70000E	41:52:02.63088N	71:31:31.57429E	40:13:14.42778N	65:16:40.71507E	41:41:24.26479N	71:35:17.06907E	12.0	11.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	40:58:28.40606N	68:17:39.16683E	41:37:44.27698N	71:17:08.46322E						
test27	LocusInputs	40:24:35.80000N	65:11:34.70000E	37:59:52.60403N	70:49:51.66629E	40:38:51.35239N	65:21:07.27556E	38:11:56.32557N	70:58:53.55929E	-16.0	-14.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	39:25:51.87086N	68:16:33.76002E	38:30:27.42682N	70:19:30.21732E						
test28	LocusInputs	37:09:35.80000N	70:21:34.70000E	42:09:50.66942N	70:21:34.70000E	37:09:12.03214N	71:36:38.04189E	42:09:20.38191N	71:44:56.41786E	60.0	62.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	38:56:06.49229N	71:39:23.30959E	41:22:52.71681N	71:43:31.92819E						
test29	LocusInputs	37:09:35.80000N	70:21:34.70000E	41:24:05.81315N	73:46:45.59830E	37:14:44.72265N	70:10:50.58087E	41:28:28.20339N	73:37:51.07864E	-10.0	-8.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	38:45:47.16793N	71:21:43.16537E	40:00:12.62742N	72:22:22.79266E						
test30	LocusInputs	37:09:35.80000N	70:21:34.70000E	41:29:39.48761N	67:08:10.61500E	37:17:49.45718N	70:40:12.75662E	41:37:22.57804N	67:25:18.75938E	17.0	15.0
	ArcInputs	40:10:24.50000N	70:12:45.60000E	100.0							
	Outputs	38:32:19.44329N	69:47:05.36481E	40:42:42.10179N	68:08:47.23533E						
test31	LocusInputs	40:04:35.80000S	73:12:40.70000E	35:08:30.42508S	72:09:14.02356E	40:07:30.99907S	72:50:51.17492E	35:11:43.38567S	71:45:09.30741E	-17.0	-20.0

	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	N/A	N/A	N/A	N/A						
test32	LocusInputs	40:04:35.80000S	73:12:40.70000E	44:45:10.49519S	70:48:49.90312E	39:47:12.86823S	72:11:43.61271E	44:24:55.27506S	69:38:47.31879E	50.0	54.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	41:39:29.00627S	71:12:51.34782E	N/A	N/A						
test33	LocusInputs	40:04:35.80000S	72:12:40.70000E	36:27:08.38182S	67:49:48.47323E	40:05:18.25476S	72:11:45.42067E	36:28:29.21623S	67:47:58.39809E	-1.0	-2.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	38:30:19.51072S	70:11:27.28055E	N/A	N/A						
test34	LocusInputs	40:04:35.80000S	73:12:40.70000E	39:53:37.86852S	66:42:33.38560E	39:09:33.04483S	73:12:40.70000E	39:08:42.68217S	66:46:46.39327E	55.0	45.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	39:11:05.72257S	71:57:05.49382E	39:11:02.25193S	68:28:29.05646E						
test35	LocusInputs	40:04:35.80000S	73:12:40.70000E	37:26:38.49374S	67:46:21.35803E	40:15:51.48849S	73:04:11.23785E	37:36:39.95775S	67:38:02.45124E	-13.0	-12.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	39:56:39.83307S	72:21:46.06481E	38:35:25.48014S	69:32:05.80065E						
test36	LocusInputs	40:04:35.80000S	73:12:40.70000E	42:25:59.29666S	67:21:39.97860E	39:48:07.10444S	73:00:21.11336E	42:10:42.83913S	67:11:35.58816E	19.0	17.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	40:04:47.04502S	72:22:55.48617E	41:31:16.72059S	68:55:09.20530E						
test37	LocusInputs	38:04:35.80000S	70:11:34.70000E	43:04:47.81441S	70:11:34.70000E	38:04:34.46263S	70:29:18.51824E	43:04:45.46340S	70:34:46.50160E	-14.0	-17.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	38:31:11.62401S	70:29:45.34652E	41:49:14.99630S	70:33:18.33807E						
test38	LocusInputs	38:04:35.80000S	70:11:34.70000E	42:16:02.95041S	73:45:33.85544E	38:24:06.71761S	69:31:39.73455E	42:32:52.83250S	73:12:02.21580E	37.0	30.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	38:33:41.56924S	69:39:34.02709E	41:11:49.98705S	71:56:32.15188E						
test39	LocusInputs	38:04:35.80000S	70:11:34.70000E	42:18:57.42808S	66:43:26.95968E	38:15:23.23243S	70:34:25.87614E	42:27:09.69405S	67:00:23.77562E	-21.0	-15.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							

	Outputs	38:30:35.91066S	70:22:22.12255E	40:59:38.89521S	68:18:29.60201E						
test40	LocusInputs	40:24:35.80000S	65:51:34.70000E	40:13:30.13260S	72:23:36.10711E	41:39:38.45017S	65:51:34.70000E	41:23:21.12281S	72:30:27.67815E	75.0	70.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	41:34:42.11106S	69:01:43.31833E	41:26:48.13779S	71:37:49.38289E						
test41	LocusInputs	40:24:35.80000S	65:51:34.70000E	38:37:15.53538S	71:53:43.64116E	40:27:26.10432S	65:52:51.47157E	38:39:06.23077S	71:54:43.10773E	3.0	
	ArcInputs	2.0	40:10:24.50000S								
	Outputs	70:12:45.60000E	100.0	39:50:38.66908S	68:05:10.58480E	38:48:21.65069S	71:26:44.41888E				
test42	LocusInputs	40:24:35.80000S	65:51:34.70000E	42:31:36.14552S	71:53:17.58283E	40:22:48.79823S	65:52:45.98838E	42:30:40.89788S	71:53:49.28758E	-2.0	-1.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	41:30:04.01423S	68:53:01.27732E	41:48:16.79755S	69:45:17.54741E						
test43	LocusInputs	43:09:35.80000S	70:21:34.70000E	38:09:24.03567S	70:21:34.70000E	43:09:34.98423S	70:35:14.47789E	38:09:23.48139S	70:32:59.33158E	10.0	
	ArcInputs	9.0	40:10:24.50000S	70:12:45.60000E							
	Outputs	100.0	41:49:05.47847S	70:34:35.62154E	38:31:34.72650S	70:33:08.46967E					
test44	LocusInputs	42:09:35.80000S	70:21:34.70000E	37:57:18.93348S	73:53:33.13110E	42:09:02.22981S	70:20:27.82742E	37:56:47.34314S	73:52:28.61147E	-1.0	-1.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	41:48:28.50199S	70:38:59.27618E	39:50:56.92924S	72:20:25.64340E						
test45	LocusInputs	43:09:35.80000S	70:21:34.70000E	38:35:33.30636S	67:40:00.75564E	43:11:17.14290S	70:16:37.37426E	38:36:20.67340S	67:37:40.08878E	-4.0	-2.0
	ArcInputs	40:10:24.50000S	70:12:45.60000E	100.0							
	Outputs	41:43:03.84950S	69:22:56.07645E	39:36:34.42863S	68:10:29.08623E						
test46	LocusInputs	40:04:35.80000S	67:12:40.70000W	35:08:30.42508S	68:16:07.37644W	40:11:50.97658S	68:07:56.58748W	35:15:37.84100S	69:10:20.62043W	-43.0	-45.0
	ArcInputs	40:10:24.50000S	70:12:45.60000W	100.0							
	Outputs	39:22:25.63807S	68:18:55.98559W	N/A	N/A						
test47	LocusInputs	40:04:35.80000S	67:12:40.70000W	44:45:10.49519S	69:36:31.49688W	39:48:58.60203S	68:07:33.46836W	44:28:43.55420S	70:33:39.49919W	45.0	44.0
	ArcInputs	40:10:24.50000S	70:12:45.60000W	100.0							

	Outputs	41:33:34.0401 0S	68:59:26.8628 6W	N/A	N/A						
test48	LocusInputs	40:04:35.8000 0S	68:12:40.7000 0W	36:27:08.3818 2S	72:35:32.9267 7W	39:55:23.2157 5S	68:00:43.7999 1W	36:19:43.284 47S	72:25:28.6458 3W	13.0	11.0
	ArcInputs	40:10:24.5000 0S	70:12:45.6000 0W	100.0							
	Outputs	39:52:21.9892 9S	68:04:43.1350 5W	38:32:16.8257 1S	69:47:22.0623 3W						
test49	LocusInputs	40:04:35.8000 0S	67:12:40.7000 0W	39:53:37.8685 2S	73:42:48.0144 0W	39:52:35.2435 1S	67:12:40.7000 0W	39:43:38.981 59S	73:41:51.3189 0W	12.0	10.0
	ArcInputs	40:10:24.5000 0S	70:12:45.6000 0W	100.0							
	Outputs	39:52:39.5690 3S	68:04:38.7058 4W	39:47:22.4378 0S	72:19:21.7385 6W						
test50	LocusInputs	40:04:35.8000 0S	67:12:40.7000 0W	37:26:38.4937 4S	72:39:00.0419 7W	40:12:23.6530 5S	67:18:33.1054 1W	37:33:19.536 73S	72:44:32.3991 0W	-9.0	-8.0
	ArcInputs	40:10:24.5000 0S	70:12:45.6000 0W	100.0							
	Outputs	39:51:22.1708 7S	68:04:58.7312 4W	38:33:52.8622 5S	70:46:51.0549 5W						
test51	LocusInputs	40:04:35.8000 0S	67:12:40.7000 0W	42:25:59.2966 6S	73:03:41.4214 0W	39:54:11.5185 1S	67:20:28.4948 1W	42:17:54.228 55S	73:09:01.9993 6W	12.0	
	ArcInputs	9.0	40:10:24.5000 0S	70:12:45.6000 0W							
	Outputs	100.0	40:12:56.7452 6S	68:02:18.0598 0W	41:36:12.1797 0S	71:20:37.1459 8W					
test52	LocusInputs	38:04:35.8000 0S	70:11:34.7000 0W	43:04:47.8144 1S	70:11:34.7000 0W	38:04:33.8280 6S	70:33:06.4772 2W	43:04:45.984 03S	70:32:02.7621 6W	17.0	15.0
	ArcInputs	40:10:24.5000 0S	70:12:45.6000 0W	100.0							
	Outputs	38:31:33.7683 5S	70:33:00.7342 1W	41:49:21.9263 0S	70:32:18.7801 8W						
test53	LocusInputs	38:04:35.8000 0S	70:11:34.7000 0W	42:16:02.9504 1S	66:37:35.5445 6W	38:08:18.3689 2S	70:19:06.1664 2W	42:18:51.947 05S	66:43:09.5742 2W	7.0	
	ArcInputs	5.0	40:10:24.5000 0S								
	Outputs	70:12:45.6000 0W	100.0	38:30:44.0931 5S	70:01:02.1551 2W	40:43:33.7987 1S	68:09:09.8591 4W				
test54	LocusInputs	38:04:35.8000 0S	70:11:34.7000 0W	42:18:57.4280 8S	73:39:42.4403 2W	38:11:17.1184 4S	69:57:26.6712 6W	42:24:58.669 38S	73:27:17.2069 4W	-13.0	-11.0
	ArcInputs	40:10:24.5000 0S	70:12:45.6000 0W	100.0							
	Outputs	38:30:19.2704 6S	70:12:08.8825 1W	40:55:39.9262 8S	72:09:46.0694 1W						
test55	LocusInputs	40:24:35.8000 0S	74:11:34.7000 0W	40:13:30.1326 0S	67:39:33.2928 9W	40:31:36.0887 9S	74:11:34.7000 0W	40:18:29.530 53S	67:39:04.3669 0W	7.0	
	ArcInputs	5.0	40:10:24.5000 0S								

	Outputs	70:12:45.60000W	100.0	40:30:09.48667S	72:20:57.91099W	40:19:54.87523S	68:02:44.28575W				
test56	LocusInputs	40:24:35.80000S	74:11:34.70000W	38:37:15.53538S	68:09:25.75884W	40:29:19.63188S	74:09:26.68754W	38:40:01.57510S	68:07:56.53991W	5.0	
	ArcInputs	3.0	40:10:24.50000S								
	Outputs	70:12:45.60000W	100.0	39:59:27.59845S	72:22:15.85364W	38:53:50.98943S	68:49:29.99867W				
test57	LocusInputs	40:24:35.80000S	74:11:34.70000W	42:31:36.14552S	68:09:51.81717W	40:18:21.23809S	74:07:25.46446W	42:26:04.62097S	68:06:41.82104W	-7.0	-6.0
	ArcInputs	40:10:24.50000S	70:12:45.60000W	100.0							
	Outputs	41:05:49.43225S	72:02:08.19523W	41:49:47.02230S	69:57:20.41362W						
test58	LocusInputs	43:09:35.80000S	70:21:34.70000W	38:09:24.03567S	70:21:34.70000W	43:09:34.62530S	70:05:10.96760W	38:09:23.35138S	70:08:53.99850W	12.0	10.0
	ArcInputs	40:10:24.50000S	70:12:45.60000W	100.0							
	Outputs	41:50:20.72573S	70:06:13.83966W	38:30:22.24016S	70:08:39.65340W						
test59	LocusInputs	43:09:35.80000S	70:21:34.70000W	38:57:14.60461S	66:46:39.46882W	43:06:47.86496S	70:27:14.25600W	38:55:40.03026S	66:49:55.83317W	-5.0	-3.0
	ArcInputs	40:10:24.50000S	70:12:45.60000W	100.0							
	Outputs	41:36:12.38507S	69:04:54.50326W	40:25:02.16784S	68:03:28.13705W						
test60	LocusInputs	43:09:35.80000S	70:21:34.70000W	38:44:26.17734S	73:27:19.42040W	43:06:11.82930S	70:13:13.26597W	38:42:09.85051S	73:21:37.86961W	7.0	
	ArcInputs	5.0	40:10:24.50000S								
	Outputs	70:12:45.60000W	100.0	41:36:07.22647S	71:20:47.96044W	40:08:27.78107S	72:23:09.88582W				
test61	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368W	-0.5	-0.5
	ArcInputs	42:54:35.00000N	70:51:34.00000W								
	Outputs	1.0	42:55:05.00175N	70:50:23.28330W	N/A	N/A					
test62	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:05.00782N	70:51:34.00000W	42:55:01.77259N	70:24:20.88368W	-0.5	-0.5
	ArcInputs	42:54:35.00000N	70:50:14.00000W								
	Outputs	1.0	42:55:05.00771N	70:51:24.71201W	42:55:04.98026N	70:49:03.26644W					
test63	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:55:35.01559N	70:51:34.00000W	42:55:31.77993N	70:24:20.66356W	-1.0	-1.0
	ArcInputs	42:55:35.00000N	70:48:52.00000W								

	Outputs	1.0	42:55:35.00776N	70:50:13.66761W	42:55:34.94358N	70:47:30.33244W					
test64	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:52:34.96830N	70:51:34.00000W	42:52:31.73523N	70:24:21.98336W	2.0	
	ArcInputs	2.0	42:53:05.00000N								
	Outputs	70:47:32.00000W	1.5	42:52:34.94884N	70:49:27.38914W	42:52:34.81332N	70:45:36.67632W				
test65	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:57:35.04624N	70:51:34.00000W	42:57:31.80885N	70:24:19.78251W	-3.0	-3.0
	ArcInputs	42:56:35.00000N	70:46:12.00000W								
	Outputs	1.0	42:57:34.92404N	70:46:16.50227W	42:57:34.91687N	70:46:07.32432W					
test66	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:50:34.93590N	70:51:34.00000W	42:50:31.70455N	70:24:22.86205W	4.0	
	ArcInputs	4.0	42:51:35.00000N								
	Outputs	70:44:52.00000W	1.5	42:50:34.81843N	70:46:22.99515W	42:50:34.64098N	70:43:21.22225W				
test67	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:59:35.07618N	70:51:34.00000W	42:59:31.83707N	70:24:18.90050W	-5.0	-5.0
	ArcInputs	42:58:35.00000N	70:43:32.00000W								
	Outputs	2.0	42:59:34.93584N	70:45:53.64821W	42:59:34.60458N	70:41:10.09281W					
test68	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:48:34.90279N	70:51:34.00000W	42:48:31.67317N	70:24:23.73978W	6.0	
	ArcInputs	6.0	42:49:35.00000N								
	Outputs	70:42:12.00000W	1.5	42:48:34.63290N	70:43:42.71949W	42:48:34.38556N	70:40:41.58538W				
test69	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	43:01:35.10543N	70:51:34.00000W	43:01:31.86459N	70:24:18.01754W	-7.0	-7.0
	ArcInputs	43:00:05.00000N	70:43:32.00000W								
	Outputs	2.0	43:01:34.93635N	70:45:20.32134W	43:01:34.68291N	70:41:43.28921W					
test70	LocusInputs	42:54:35.00000N	70:51:34.00000W	42:54:31.76521N	70:24:21.10373W	42:46:34.86899N	70:51:34.00000W	42:46:31.64108N	70:24:24.61658W	8.0	
	ArcInputs	8.0	42:47:35.00000N								
	Outputs	70:42:12.00000W	1.5	42:46:34.59884N	70:43:42.62942W	42:46:34.35162N	70:40:41.67545W				

WGS84LocusIntersect Test Results

Test Identifier											
	Locus 1 Inputs	Locus 1 Geodesic Start Latitude	Locus 1 Geodesic Start Longitude	Locus 1 Geodesic End Latitude	Locus 1 Geodesic End Longitude	Locus 1 Start Latitude	Locus 1 Start Longitude	Locus 1 End Latitude	Locus 1 End Longitude	Locus 1 Start Distance	Locus 1 End Distance
	Locus 2 Inputs	Locus 2 Geodesic Start Latitude	Locus 2 Geodesic Start Longitude	Locus 2 Geodesic End Latitude	Locus 2 Geodesic End Longitude	Locus 2 Start Latitude	Locus 2 Start Longitude	Locus 2 End Latitude	Locus 2 End Longitude	Locus 2 Start Distance	Locus 2 End Distance
	Output	Intersection Latitude	Intersection Longitude								
test1	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:34:51.08997N	70:54:12.49358W	42:29:44.86980N	68:54:29.59541W	-40.0	-40.0
	Locus 2 Inputs	43:47:17.80000N	69:11:50.60000W	39:34:35.80000N	69:12:34.70000W	43:47:17.16766N	69:39:27.23479W	39:34:35.45517N	69:38:26.67528W	20.0	20.0
	Output	41:48:06.52416N	69:38:56.60400W								
test2	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:16:32.54683N	70:23:04.51876W	42:10:54.51067N	68:23:00.30232W	-10.0	-10.0
	Locus 2 Inputs	41:47:17.80000N	69:11:50.60000W	42:04:35.80000N	68:12:34.70000W	41:37:59.88025N	69:06:54.98918W	41:55:15.39563N	68:07:46.38917W	10.0	10.0
	Output	41:41:38.52019N	68:54:37.00390W								
test3	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:01:10.70138N	69:57:20.70132W	41:58:16.13817N	68:02:11.16321W	15.0	10.0
	Locus 2 Inputs	41:47:17.80000N	69:11:50.60000W	41:47:17.80000N	65:12:34.70000W	41:37:17.67775N	69:11:32.04562W	41:32:17.60977N	65:13:02.49575W	10.0	15.0
	Output	41:36:57.43292N	68:23:48.56010W								
test4	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:03:01.62624N	70:00:25.34804W	41:53:11.72828N	67:53:53.81471W	12.0	18.0
	Locus 2 Inputs	41:47:17.80000N	69:11:50.60000W	39:36:04.50000N	67:26:41.20000W	41:52:34.94174N	69:00:29.14443W	39:42:12.84894N	67:13:19.99273W	-10.0	-12.0
	Output	41:20:04.46258N	68:32:58.40655W								
test5	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:17:46.04493N	70:25:08.52603W	42:10:54.51067N	68:23:00.30232W	-12.0	-10.0
	Locus 2 Inputs	41:47:17.80000N	69:11:50.60000W	39:36:04.50000N	69:11:50.60000W	41:47:16.05011N	68:51:47.49988W	39:36:03.62845N	68:57:36.71338W	-15.0	-11.0
	Output	41:44:55.25922N	68:51:53.96578W								
test6	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:04:35.80000N	68:12:34.70000W	40:16:32.54683N	70:23:04.51876W	42:17:12.26361N	68:33:27.97949W	-10.0	-20.0

	Locus 2 Inputs	41:47:17.80000N	69:11:50.60000W	40:10:24.50000N	70:12:45.60000W	41:49:02.24222N	69:16:39.55217W	40:12:31.91500N	70:18:40.06838W	4.0	5.0
	Output	40:44:08.21825N	69:58:43.82937W								
test7	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:58:16.13817N	68:02:11.16322W	40:01:10.70138N	69:57:20.70132W	-10.0	-15.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000W	42:04:35.80000N	68:12:34.70000W	38:50:20.03849N	69:29:19.75003W	42:09:21.41521N	68:40:03.67472W	-14.0	-21.0
	Output	41:03:48.90937N	68:56:49.95173W								
test8	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	42:12:10.13809N	68:25:05.67147W	40:16:32.54683N	70:23:04.51876W	12.0	10.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000W	41:36:04.50000N	69:11:50.60000W	38:47:17.45707N	69:20:47.75726W	41:36:03.56507N	69:26:30.32332W	-7.0	-11.0
	Output	41:13:51.01043N	69:25:43.47422W								
test9	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:55:44.00859N	67:58:02.32477W	40:04:15.53037N	70:02:28.53823W	-14.0	-10.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000W	40:10:24.50000N	70:12:45.60000W	38:59:28.65387N	68:43:52.41332W	40:20:21.26770N	69:50:05.44188W	25.0	20.0
	Output	40:17:45.13434N	69:47:54.68645W								
test10	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:39:11.51094N	67:31:12.85281W	39:48:49.10840N	69:36:53.95760W	-40.0	-35.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000W	40:05:17.80000N	72:11:50.60000W	39:47:44.17230N	68:26:14.20595W	41:02:28.85406N	71:31:12.02592W	70.0	65.0
	Output	40:08:19.82805N	69:15:22.32498W								
test11	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:35:59.92546N	67:26:04.91588W	39:39:30.54353N	69:21:38.70685W	-45.0	-50.0
	Locus 2 Inputs	38:47:17.80000N	68:31:50.60000W	38:47:17.80000N	72:11:50.60000W	40:22:21.42255N	68:29:21.10582W	40:07:20.95796N	72:13:56.03192W	95.0	80.0
	Output	40:21:46.09771N	68:40:43.79783W								
test12	Locus 1 Inputs	42:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	41:40:28.08041N	67:33:16.16949W	39:42:36.95607N	69:26:43.33456W	-38.0	-45.0
	Locus 2 Inputs	38:47:17.80000N	68:31:50.60000W	37:15:17.80000N	72:11:50.60000W	40:08:26.72939N	69:25:11.93346W	38:40:51.77139N	73:12:28.75973W	91.0	98.0
	Output	N/A	N/A								

test13	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:34:48.34098N	67:31:15.95275E	42:30:56.94337N	69:28:29.96911E	-40.0	-42.0
	Locus 2 Inputs	41:47:17.80000N	68:11:50.60000E	42:34:35.80000N	69:12:34.70000E	41:17:38.57897N	68:53:19.82604E	42:03:10.50228N	69:56:00.78533E	43.0	45.0
	Output	N/A	N/A								
test14	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:12:09.29285N	70:00:02.80815E	-10.0	-12.0
	Locus 2 Inputs	41:47:17.80000N	68:11:50.60000E	42:04:35.80000N	70:12:34.70000E	41:32:35.48231N	68:15:50.24846E	41:48:50.47117N	70:16:21.80709E	15.0	16.0
	Output	41:42:45.75260N	69:29:17.30429E								
test15	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:34:48.34098N	67:31:15.95275E	42:29:04.57278N	69:31:40.10061E	-40.0	-39.0
	Locus 2 Inputs	41:47:17.80000N	68:11:50.60000E	41:47:17.80000N	69:12:34.70000E	41:57:18.05539N	68:11:45.86629E	41:56:18.03064N	69:12:38.95923E	-10.0	-9.0
	Output	41:56:37.06762N	68:56:31.29856E								
test16	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:09:38.28182N	70:04:13.77003E	-10.0	-8.0
	Locus 2 Inputs	41:47:17.80000N	67:11:50.60000E	39:36:04.50000N	69:26:41.20000E	41:50:25.61894N	67:17:03.53451E	39:39:42.68648N	69:32:52.00800E	-5.0	-6.0
	Output	40:42:15.66902N	68:29:20.00613E								
test17	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:07:20.47150N	68:17:54.70834E	42:03:20.08407N	70:14:39.72588E	5.0	2.0
	Locus 2 Inputs	41:47:17.80000N	68:31:50.60000E	39:34:35.80000N	68:31:50.60000E	41:47:17.79222N	68:30:30.39292E	39:34:35.73523N	68:27:57.80380E	1.0	3.0
	Output	40:18:31.31171N	68:28:47.22609E								
test18	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:04:35.80000N	70:12:34.70000E	40:16:31.86263N	68:02:25.99064E	42:07:44.92286N	70:07:21.77389E	-10.0	-5.0
	Locus 2 Inputs	41:47:17.80000N	68:41:50.60000E	40:10:24.50000N	68:12:45.60000E	41:46:10.22678N	68:48:21.28237E	40:09:05.30829N	68:20:23.68524E	-5.0	-6.0
	Output	40:41:23.80558N	68:29:32.62774E								
test19	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:59:32.70797N	70:20:54.30885E	40:04:16.21255N	68:23:03.35373E	-8.0	-10.0
	Locus 2 Inputs	38:47:17.80000N	68:11:50.60000E	42:04:35.80000N	69:12:34.70000E	38:45:43.54228N	68:20:33.98734E	42:02:42.67727N	69:23:00.95832E	7.0	8.0

	Output	40:36:11.72260N	68:54:48.39606E								
test20	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	42:01:26.43878N	70:17:47.11005E	40:07:57.29566N	68:16:52.92374E	-5.0	-4.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000E	41:36:04.50000N	69:11:50.60000E	38:47:17.77201N	69:14:24.07363E	41:36:04.43046N	69:15:50.52514E	2.0	3.0
	Output	41:04:06.94297N	69:15:33.55517E								
test21	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	42:00:48.53800N	70:18:49.53023E	40:06:06.79553N	68:19:58.22200E	-6.0	-7.0
	Locus 2 Inputs	38:47:17.80000N	69:11:50.60000E	40:10:24.50000N	68:12:45.60000E	38:49:41.12802N	69:17:27.85361E	40:13:19.86103N	68:19:36.00018E	5.0	6.0
	Output	40:08:53.27343N	68:22:44.48587E								
test22	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:39:14.30455N	70:53:59.62806E	39:48:51.48716N	68:48:39.66995E	-40.0	-35.0
	Locus 2 Inputs	38:47:17.80000N	72:11:50.60000E	40:05:17.80000N	69:11:50.60000E	39:00:16.42738N	72:21:30.40595E	40:27:19.19138N	69:27:20.34409E	15.0	25.0
	Output	40:26:06.25375N	69:29:53.11403E								
test23	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:42:25.31152N	70:48:50.79796E	39:48:14.38002N	68:49:40.88406E	-35.0	-36.0
	Locus 2 Inputs	39:47:17.80000N	72:11:50.60000E	39:47:17.80000N	69:11:50.60000E	40:27:19.25403N	72:12:43.27810E	40:25:19.18808N	69:11:00.58042E	40.0	38.0
	Output	40:25:42.09261N	69:27:47.18567E								
test24	Locus 1 Inputs	42:04:35.80000N	70:12:34.70000E	40:10:24.50000N	68:12:45.60000E	41:45:36.08581N	70:43:41.45993E	39:50:42.75433N	68:45:35.91786E	-30.0	-32.0
	Locus 2 Inputs	41:47:17.80000N	72:11:50.60000E	40:15:17.80000N	69:11:50.60000E	42:14:05.92481N	71:48:22.06420E	40:42:18.33009N	68:46:57.62062E	32.0	33.0
	Output	41:38:45.61961N	70:36:24.07170E								
test25	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:25:01.88807S	70:54:00.26901W	39:34:01.71595S	68:48:20.02988W	-40.0	-35.0
	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	39:25:35.80000S	68:12:34.70000W	40:37:33.30027S	68:38:14.16936W	39:51:57.45011S	67:37:07.05316W	36.0	38.0
	Output	N/A	N/A								
test26	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:44:05.24805S	70:23:07.30456W	39:48:13.36527S	68:24:52.75546W	-10.0	-12.0

	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	39:55:35.80000S	68:12:34.70000W	40:07:35.34521S	69:14:03.22375W	39:49:58.20740S	68:15:18.03727W	-5.0	-6.0
	Output	39:54:52.24216S	68:31:25.59353W								
test27	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:40:55.26981S	70:28:17.39464W	39:44:31.65649S	68:31:00.79721W	-15.0	-18.0
	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	40:12:17.80000S	65:12:34.70000W	40:02:17.50254S	69:11:33.04859W	40:01:17.47180S	65:12:54.00184W	-10.0	-11.0
	Output	40:02:33.17060S	68:48:36.22812W								
test28	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:51:02.37334S	70:11:43.31749W	39:56:49.41116S	68:10:31.43442W	1.0	2.0
	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	42:05:35.80000S	67:26:34.70000W	40:10:35.71331S	69:08:37.07963W	42:03:15.74654S	67:22:12.94439W	-3.0	-4.0
	Output	40:33:04.17399S	68:47:59.71025W								
test29	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:51:40.23723S	70:10:41.01456W	39:57:26.20299S	68:09:29.77411W	2.0	3.0
	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	42:25:35.80000S	69:11:50.60000W	40:12:17.68228S	69:06:37.35813W	42:25:35.60119S	69:05:05.52129W	-4.0	-5.0
	Output	40:51:57.10883S	69:06:10.74013W								
test30	Locus 1 Inputs	41:50:24.50000S	70:12:45.60000W	39:55:35.80000S	68:12:34.70000W	41:40:55.26981S	70:28:17.39464W	39:43:17.68107S	68:33:03.33213W	-15.0	-20.0
	Locus 2 Inputs	40:12:17.80000S	69:11:50.60000W	41:50:24.50000S	70:12:45.60000W	40:11:27.30497S	69:14:12.68764W	41:49:06.86266S	70:16:22.84949W	2.0	3.0
	Output	40:52:52.40604S	69:40:09.58552W								
test31	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	39:58:39.75911S	68:07:26.39841W	41:51:40.23723S	70:10:41.01456W	-5.0	-2.0
	Locus 2 Inputs	43:12:17.80000S	69:11:50.60000W	39:55:35.80000S	68:12:34.70000W	43:08:10.82604S	69:35:47.37235W	39:52:20.45272S	68:31:36.29102W	-18.0	-15.0
	Output	40:33:38.43603S	68:44:35.40196W								
test32	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:00:30.02435S	68:04:21.19705W	41:54:49.41461S	70:05:29.19346W	-8.0	-7.0
	Locus 2 Inputs	43:12:17.80000S	69:11:50.60000W	40:55:35.80000S	69:11:50.60000W	43:12:17.59574S	69:05:00.40914W	40:55:35.52833S	69:03:55.66338W	5.0	6.0
	Output	40:57:49.85657S	69:03:56.69283W								

test33	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:05:23.65941S	67:56:06.51681W	42:01:07.05660S	69:55:04.01517W	-16.0	-17.0
	Locus 2 Inputs	43:12:17.80000S	69:11:50.60000W	41:50:24.50000S	70:12:45.60000W	43:05:27.11300S	68:55:09.55756W	41:41:47.30664S	69:51:38.39963W	14.0	18.0
	Output	41:51:43.92702S	69:45:04.44818W								
test34	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:32:07.98119S	67:10:24.55960W	42:24:53.32280S	69:15:09.51219W	-60.0	-55.0
	Locus 2 Inputs	43:12:17.80000S	69:11:50.60000W	41:45:17.50000S	72:11:50.60000W	42:12:48.71741S	68:21:45.17937W	40:42:57.94861S	71:16:28.51249W	70.0	75.0
	Output	42:00:18.17296S	68:47:07.75272W								
test35	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:20:00.99821S	67:31:15.37383W	42:14:16.98565S	69:33:04.43858W	-40.0	-38.0
	Locus 2 Inputs	43:12:17.80000S	69:11:50.60000W	43:12:17.80000S	72:11:50.60000W	41:57:17.07312S	69:13:38.69558W	41:52:16.98865S	72:09:55.44922W	75.0	80.0
	Output	41:57:16.43557S	69:14:20.41022W								
test36	Locus 1 Inputs	39:55:35.80000S	68:12:34.70000W	41:50:24.50000S	70:12:45.60000W	40:50:11.29811S	66:38:54.23203W	42:51:30.15103S	68:29:23.51673W	-90.0	-98.0
	Locus 2 Inputs	41:12:17.80000S	67:11:50.60000W	42:30:17.80000S	70:11:50.60000W	40:07:50.59278S	68:02:20.22470W	41:21:13.00297S	71:02:42.74576W	75.0	78.8
	Output	N/A	N/A								
test37	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:25:04.68264S	67:31:27.86642E	39:30:21.55001S	69:30:40.99953E	-40.0	-41.0
	Locus 2 Inputs	40:12:17.80000S	68:11:50.60000E	39:22:35.80000S	69:12:34.70000E	40:26:04.93621S	68:30:47.96796E	39:34:51.58798S	69:29:36.49340E	20.0	18.0
	Output	40:02:03.43498S	68:58:38.15474E								
test38	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:49:27.87799S	70:02:18.78242E	-15.0	-10.0
	Locus 2 Inputs	40:12:17.80000S	68:11:50.60000E	39:55:35.80000S	70:12:34.70000E	40:10:19.37749S	68:11:24.60959E	39:52:38.87779S	70:11:50.67961E	-2.0	-3.0
	Output	39:55:03.75907S	69:56:15.20886E								
test39	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:47:15.34302S	68:07:34.11126E	39:51:18.35063S	70:05:23.36577E	-5.0	-7.0
	Locus 2 Inputs	40:12:17.80000S	68:11:50.60000E	40:12:17.80000S	72:12:34.70000E	40:02:17.50440S	68:12:08.25927E	40:00:17.44311S	72:12:13.51920E	-10.0	-12.0

	Output	40:02:27.42225S	69:54:26.29229E								
test40	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:44:32.88343S	69:54:07.36243E	-15.0	-18.0
	Locus 2 Inputs	38:01:17.80000S	68:11:50.60000E	40:12:17.80000S	69:56:34.70000E	38:01:49.06303S	68:10:45.76086E	40:13:22.25096S	69:54:22.52989E	1.0	2.0
	Output	39:57:32.74476S	69:41:29.82264E								
test41	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:43:19.04394S	69:52:04.68943E	-15.0	-20.0
	Locus 2 Inputs	38:01:17.80000S	69:11:50.60000E	41:12:17.80000S	69:11:50.60000E	38:01:17.79319S	69:13:06.53044E	41:12:17.76952S	69:14:29.58125E	-1.0	-2.0
	Output	40:23:10.15763S	69:14:07.43973E								
test42	Locus 1 Inputs	41:50:24.50000S	68:12:45.60000E	39:55:35.80000S	70:12:34.70000E	41:40:56.32203S	67:57:12.65839E	39:44:32.88343S	69:54:07.36243E	-15.0	-18.0
	Locus 2 Inputs	38:01:17.80000S	69:11:50.60000E	41:50:24.50000S	68:12:45.60000E	38:00:55.02621S	69:09:21.49922E	41:49:48.38430S	68:08:49.69566E	2.0	3.0
	Output	41:22:22.77502S	68:16:27.47836E								
test43	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:10:51.57579S	70:38:22.52584E	42:09:14.44140S	68:44:05.27630E	-25.0	-30.0
	Locus 2 Inputs	43:29:17.80000S	68:11:50.60000E	39:55:35.80000S	70:12:34.70000E	43:30:05.86262S	68:14:21.66324E	39:56:44.04610S	70:16:11.26613E	2.0	3.0
	Output	41:25:37.23971S	69:27:12.71895E								
test44	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:00:29.47695S	70:20:48.75282E	41:56:04.38538S	68:22:07.56499E	-8.0	-9.0
	Locus 2 Inputs	43:29:17.80000S	68:11:50.60000E	39:55:35.80000S	68:11:50.60000E	43:29:16.97488S	68:25:34.80469E	39:55:34.91839S	68:26:08.51484E	10.0	11.0
	Output	41:52:35.54339S	68:25:50.12077E								
test45	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:01:42.80403S	70:22:52.44969E	41:57:19.81081S	68:24:12.67104E	-10.0	-11.0
	Locus 2 Inputs	43:29:17.80000S	69:11:50.60000E	41:50:24.50000S	68:12:45.60000E	43:23:08.26920S	69:30:36.97906E	41:43:36.31250S	68:33:35.19449E	15.0	17.0
	Output	41:46:49.25922S	68:35:22.68060E								
test46	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:44:05.62309S	71:35:48.62363E	42:39:04.17634S	69:34:51.53641E	-80.0	-78.0

	Locus 2 Inputs	43:29:17.80000S	69:11:50.60000E	41:45:07.50000S	66:11:50.60000E	42:55:41.16916S	69:46:17.72457E	41:10:04.65932S	66:49:24.86243E	42.0	45.0
	Output	N/A	N/A								
test47	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:24:48.94167S	71:02:16.73937E	42:21:42.91321S	69:05:08.70917E	-48.0	-50.0
	Locus 2 Inputs	42:09:17.80000S	70:11:50.60000E	42:09:17.80000S	66:11:50.60000E	41:24:17.29349S	70:10:26.53430E	41:20:17.23054S	66:13:22.04429E	45.0	49.0
	Output	41:24:17.32470S	70:03:47.79505E								
test48	Locus 1 Inputs	39:55:35.80000S	70:12:34.70000E	41:50:24.50000S	68:12:45.60000E	40:50:05.06559S	71:46:21.29806E	42:51:59.99285S	69:57:19.49762E	-90.0	-99.0
	Locus 2 Inputs	42:29:17.80000S	69:11:50.60000E	44:01:17.80000S	66:11:50.60000E	41:48:42.56241S	68:32:33.37476E	43:15:31.54446S	65:29:49.92129E	50.0	55.0
	Output	N/A	N/A								

WGS84LocusTanFixedRadiusArc Test Results

Test Identifier	Locus 1 Input	Locus 1 Geodesic Start Latitude	Locus 1 Geodesic Start Longitude	Locus 1 Geodesic End Latitude	Locus 1 Geodesic End Longitude	Locus 1 Start Latitude	Locus 1 Start Longitude	Locus 1 End Latitude	Locus 1 End Longitude	Locus 1 Start Distance (nm)	Locus 1 End Distance (nm)	
	Locus 2 Input	Locus 2 Geodesic Start Latitude	Locus 2 Geodesic Start Longitude	Locus 2 Geodesic End Latitude	Locus 2 Geodesic End Longitude	Locus 2 Start Latitude	Locus 2 Start Longitude	Locus 2 End Latitude	Locus 2 End Longitude	Locus 2 Start Distance (nm)	Locus 2 End Distance (nm)	Arc Radius (nm)
	Output	Arc Direction	Arc Center Latitude	Arc Center Longitude	Tangent Point 1 Latitude	Tangent Point 1 Longitude	Tangent Point 2 Latitude	Tangent Point 2 Longitude				
test1	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:11:24.54424N	70:12:45.60000W	40:06:30.74430N	65:51:59.39953W	-1.0	-1.0	
	Locus 2 Inputs	38:45:52.61565N	68:43:43.42897W	42:04:35.80000N	68:12:34.70000W	38:45:59.57764N	68:44:59.62433W	42:04:43.10740N	68:13:54.67112W	-1.0	-1.0	2.0
	Output	1	40:12:42.90980N	68:34:26.17064W	40:10:42.84203N	68:34:29.05890W	40:12:28.74286N	68:31:50.63189W				
test2	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:11:24.54424N	70:12:45.60000W	40:07:30.71740N	65:51:55.57562W	-1.0	-2.0	
	Locus 2 Inputs	38:45:52.61565N	68:43:43.42897W	42:04:35.80000N	68:12:34.70000W	38:46:06.52583N	68:46:15.82380W	42:04:43.10740N	68:13:54.67112W	-2.0	-1.0	2.0
	Output	1	40:13:05.94559N	68:35:07.04402W	40:11:05.86817N	68:35:09.12978W	40:12:51.19787N	68:32:31.58271W				
test3	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:09:24.45559N	70:12:45.60000W	40:04:30.79747N	65:52:07.04176W	1.0	1.0	
	Locus 2 Inputs	38:45:52.61565N	68:43:43.42897W	42:04:35.80000N	68:12:34.70000W	38:45:45.63986N	68:42:27.23774W	42:04:28.47712N	68:11:14.73398W	1.0	1.0	3.0
	Output	1	40:11:41.86765N	68:33:16.75939W	40:08:41.76592N	68:33:21.14059W	40:11:20.55656N	68:29:23.52219W				
test4	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:09:24.45559N	70:12:45.60000W	40:03:30.82374N	65:52:10.86008W	1.0	2.0	
	Locus 2 Inputs	38:45:52.61565N	68:43:43.42897W	42:04:35.80000N	68:12:34.70000W	38:45:38.65027N	68:41:11.05062W	42:04:28.47712N	68:11:14.73398W	2.0	1.0	2.0
	Outputs	1	40:10:16.88671N	68:31:25.71947W	40:08:16.83227N	68:31:29.47643W	40:10:03.24871N	68:28:50.19280W				
test5	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:11:24.54424N	70:12:45.60000W	40:06:30.74430N	65:51:59.39953W	-1.0	-1.0	

	Locus 2 Inputs	38:45:52.61565N	68:43:43.42897W	42:04:35.80000N	68:12:34.70000W	38:45:45.63986N	68:42:27.23774W	42:04:28.47712N	68:11:14.73398W	1.0	1.0	2.0
	Outputs	1	40:12:40.65368N	68:31:48.78239W	40:10:40.58699N	68:31:51.74766W	40:12:26.42800N	68:29:13.25421W				
test6	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:11:24.54424N	70:12:45.60000W	40:07:30.71740N	65:51:55.57562W	-1.0	-2.0	
	Locus 2 Inputs	39:01:03.20612N	64:47:37.88516W	41:04:35.80000N	68:12:34.70000W	38:59:30.11207N	64:49:15.15895W	41:03:47.85119N	68:13:22.43586W	-2.0	-1.0	2.0
	Outputs	1	40:11:11.47812N	66:48:27.88628W	40:09:11.45603N	66:48:33.10050W	40:12:45.83878N	66:46:51.01920W				
test7	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	36:50:12.19034N	70:12:45.60000W	40:10:24.47060N	70:10:09.05140W	36:50:12.18382N	70:11:30.85698W	-2.0	-1.0	
	Locus 2 Inputs	38:10:03.48978N	71:19:20.31330W	41:04:35.80000N	69:12:34.70000W	38:10:32.28515N	71:20:27.08581W	41:05:35.81205N	69:14:52.14842W	-1.0	-2.0	3.0
	Outputs	1	40:02:07.33483N	70:06:18.24880W	40:02:08.38728N	70:10:12.59388W	40:00:39.58907N	70:02:53.61827W				
test8	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	36:50:55.82985N	69:51:03.26240W	40:10:14.00441N	70:15:21.54623W	36:50:50.82261N	69:52:17.75645W	2.0	1.0	
	Locus 2 Inputs	38:02:20.08909N	70:59:31.55324W	41:04:35.80000N	69:12:34.70000W	38:01:55.78214N	70:58:22.10446W	41:03:45.03132N	69:10:10.92536W	1.0	2.0	2.0
	Outputs	1	39:33:03.94733N	70:08:17.79894W	39:32:52.95267N	70:10:52.28475W	39:32:13.76421N	70:05:56.86447W				
test9	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	37:35:08.04987N	67:31:03.26743W	40:11:41.67410N	70:10:45.63905W	37:35:45.28280N	67:30:04.02642W	-2.0	-1.0	
	Locus 2 Inputs	37:45:08.92078N	67:50:36.68693W	41:04:35.80000N	68:12:34.70000W	37:45:03.92163N	67:51:52.07835W	41:04:25.30511N	68:15:12.76089W	-1.0	-2.0	3.0
	Outputs	1	38:09:11.85636N	67:58:23.76723W	38:07:20.13532N	68:01:22.77621W	38:09:27.92001N	67:54:36.46855W				
test10	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:52:36.59194N	67:36:46.62423W	40:09:15.60015N	70:10:37.39889W	42:52:00.69938N	67:35:41.22861W	2.0	1.0	
	Locus 2 Inputs	39:55:58.22492N	69:41:27.77537W	43:04:35.80000N	68:12:34.70000W	39:56:37.33295N	69:43:55.28280W	43:04:56.31878N	68:13:51.63678W	-2.0	-1.0	2.0
	Outputs	1	41:21:07.17487N	69:07:28.71056W	41:19:57.56277N	69:05:18.90622W	41:20:26.72878N	69:04:58.69814W				
test11	Locus 1 Inputs	40:10:24.50000N	70:12:45.60000W	42:41:33.37650N	67:18:27.47257W	40:11:41.67410N	70:14:45.56095W	42:42:13.47196N	67:19:28.01914W	-2.0	-1.0	

	Locus 2 Inputs	38:47:21.082 27N	67:28:11.049 43W	42:04:35.800 00N	68:12:34.700 00W	38:47:40.921 31N	67:25:39.675 82W	42:04:46.215 51N	68:11:15.351 30W	2.0	1.0	2.0
	Outputs	1	42:00:55.564 89N	68:13:02.909 37W	41:59:35.847 42N	68:11:02.562 25W	42:01:16.982 68N	68:10:24.500 96W				
test12	Locus 1 Inputs	40:10:24.500 00N	70:12:45.600 00W	36:53:06.456 88N	70:56:01.642 36W	40:10:34.919 46N	70:14:02.688 42W	36:53:26.367 62N	70:58:29.160 09W	1.0	2.0	
	Locus 2 Inputs	37:29:19.581 28N	71:54:04.490 05W	40:04:35.800 00N	69:12:34.700 00W	37:28:05.079 86N	71:52:06.219 43W	40:03:57.199 27N	69:11:34.832 83W	2.0	1.0	2.0
	Outputs	1	38:53:33.203 66N	70:29:18.124 52W	38:53:54.263 04N	70:31:49.447 79W	38:52:17.757 84N	70:27:18.546 19W				
test13	Locus 1 Inputs	40:10:24.500 00N	70:12:45.600 00W	41:46:39.602 65N	74:04:18.294 68W	40:08:40.492 57N	70:14:03.841 14W	41:45:46.340 67N	74:04:55.276 67W	-2.0	-1.0	
	Locus 2 Inputs	40:59:32.625 80N	72:36:48.383 18W	41:04:35.800 00N	68:12:34.700 00W	41:00:32.585 02N	72:36:52.381 81W	41:06:35.869 47N	68:12:34.700 00W	-1.0	-2.0	2.0
	Outputs	-1	40:59:45.331 28N	72:06:21.690 23W	40:58:00.362 64N	72:07:38.620 39W	41:01:45.254 31N	72:06:29.561 62W				
test14	Locus 1 Inputs	40:10:24.500 00N	70:12:45.600 00W	43:02:23.578 55N	67:56:26.256 58W	40:09:24.433 55N	70:10:30.058 11W	43:01:52.206 97N	67:55:16.512 06W	2.0	1.0	
	Locus 2 Inputs	43:40:32.943 22N	72:11:18.241 39W	42:04:35.800 00N	68:12:34.700 00W	43:42:19.591 29N	72:10:02.385 29W	42:05:27.780 65N	68:11:54.406 31W	-2.0	-1.0	2.0
	Outputs	-1	42:12:06.973 04N	68:32:37.780 57W	42:13:08.443 40N	68:34:56.482 41W	42:13:50.862 69N	68:31:16.863 80W				
test15	Locus 1 Inputs	40:10:24.500 00N	70:12:45.600 00W	39:30:57.684 85N	65:58:09.515 26W	40:11:23.631 81N	70:12:32.004 53W	39:32:54.838 06N	65:57:35.357 82W	-1.0	-2.0	
	Locus 2 Inputs	41:23:57.635 85N	67:49:25.737 53W	38:04:35.800 00N	68:12:34.700 00W	41:24:03.117 84N	67:50:45.132 38W	38:04:46.243 10N	68:15:06.102 22W	1.0	2.0	2.0
	Outputs	-1	39:51:21.557 10N	68:04:58.824 54W	39:53:19.411 10N	68:04:28.855 74W	39:51:10.298 89N	68:02:23.689 37W				
test16	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	40:05:30.770 99S	65:52:03.221 58W	40:11:24.544 24S	70:12:45.600 00W	40:07:30.717 40S	65:51:55.575 62W	1.0	2.0	
	Locus 2 Inputs	41:23:11.704 67S	68:44:56.512 07W	38:04:35.800 00S	68:12:34.700 00W	41:23:27.023 65S	68:42:18.386 98W	38:04:43.113 48S	68:11:19.277 04W	2.0	1.0	2.0
	Outputs	1	40:09:04.418 61S	68:32:58.982 77W	40:11:04.496 07S	68:32:56.834 33W	40:09:18.875 49S	68:30:23.618 82W				
test17	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	40:05:30.770 99S	65:52:03.221 58W	40:09:24.455 59S	70:12:45.600 00W	40:03:30.823 74S	65:52:10.860 08W	-1.0	-2.0	

	Locus 2 Inputs	40:51:02.568 24S	65:49:04.579 09W	38:04:35.800 00S	68:12:34.700 00W	40:52:10.594 42S	65:51:14.904 08W	38:05:08.509 46S	68:13:38.436 18W	-2.0	-1.0	2.0
	Outputs	1	40:03:14.478 49S	66:37:33.384 95W	40:05:14.445 65S	66:37:26.294 02W	40:02:07.807 89S	66:35:23.422 43W				
test18	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	43:30:29.876 90S	70:12:45.600 00W	40:10:24.470 60S	70:10:09.051 40W	43:30:29.868 64S	70:11:23.152 09W	-2.0	-1.0	
	Locus 2 Inputs	40:56:44.386 23S	70:24:30.082 51W	38:04:35.800 00S	68:12:34.700 00W	40:56:13.101 74S	70:25:37.657 28W	38:03:35.713 46S	68:14:46.283 92W	-1.0	-2.0	3.0
	Outputs	1	40:25:56.597 23S	70:06:18.828 40W	40:25:55.848 92S	70:10:14.547 14W	40:27:29.089 86S	70:02:56.519 01W				
test19	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	43:29:41.803 26S	69:48:49.551 37W	40:10:34.937 24S	70:15:21.559 54W	43:29:47.302 91S	69:50:11.635 25W	2.0	1.0	
	Locus 2 Inputs	40:46:58.965 10S	70:43:33.361 04W	38:04:35.800 00S	68:12:34.700 00W	40:47:34.755 34S	70:42:29.939 66W	38:05:44.686 44S	68:10:30.177 29W	1.0	2.0	2.0
	Outputs	1	40:13:25.078 66S	70:12:23.800 09W	40:13:36.121 95S	70:14:59.803 79W	40:14:36.571 01S	70:10:17.905 79W				
test20	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	42:41:33.376 50S	67:18:27.472 57W	40:09:07.291 11S	70:10:45.714 53W	42:40:53.272 07S	67:17:26.947 63W	-2.0	-1.0	
	Locus 2 Inputs	41:23:57.635 85S	68:49:25.737 53W	38:04:35.800 00S	69:12:34.700 00W	41:24:03.117 84S	68:50:45.132 38W	38:04:46.243 10S	69:15:06.102 22W	-1.0	-2.0	3.0
	Outputs	1	41:11:40.445 78S	68:56:19.657 74W	41:13:37.479 45S	68:59:20.932 78W	41:11:23.248 99S	68:52:22.321 54W				
test21	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	37:24:53.776 02S	67:48:48.292 35W	40:11:33.360 17S	70:10:37.326 86W	37:25:26.924 44S	67:47:45.478 85W	2.0	1.0	
	Locus 2 Inputs	40:23:45.261 80S	71:17:39.828 70W	38:04:35.800 00S	68:12:34.700 00W	40:22:17.492 77S	71:19:27.002 96W	38:03:53.323 48S	68:13:28.422 49W	-2.0	-1.0	2.0
	Outputs	-1	38:19:04.226 08S	68:29:21.213 74W	38:17:57.687 53S	68:31:28.147 15W	38:17:38.591 51S	68:31:08.128 37W				
test22	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	37:35:08.049 87S	67:31:03.267 43W	40:09:07.291 11S	70:14:45.485 47W	37:34:30.808 62S	67:32:02.492 05W	-2.0	-1.0	
	Locus 2 Inputs	41:21:34.316 10S	67:26:28.970 88W	38:04:35.800 00S	68:12:34.700 00W	41:21:12.424 83S	67:23:52.292 53W	38:04:25.363 03S	68:11:19.870 10W	2.0	1.0	2.0
	Outputs	1	38:11:04.159 43S	68:12:22.746 71W	38:12:19.771 40S	68:10:24.461 67W	38:10:42.677 13S	68:09:53.007 75W				
test23	Locus 1 Inputs	40:10:24.500 00S	70:12:45.600 00W	43:27:18.010 78S	71:00:24.952 85W	40:10:14.066 28S	70:14:02.681 87W	43:26:56.045 70S	71:03:06.913 12W	1.0	2.0	

	Locus 2 Inputs	42:35:45.27780S	72:06:36.63038W	40:04:35.80000S	69:12:34.70000W	42:37:05.45079S	72:04:35.69054W	40:05:14.39206S	69:11:34.81405W	2.0	1.0	2.0
	Outputs	1	41:09:00.28976S	70:25:29.09105W	41:08:38.53506S	70:28:05.30341W	41:10:18.25757S	70:23:28.27022W				
test24	Locus 1 Inputs	40:10:24.50000S	70:12:45.60000W	38:26:46.46774S	73:53:15.48461W	40:12:08.49221S	70:14:03.90752W	38:27:37.21779S	73:53:56.33533W	-2.0	-1.0	
	Locus 2 Inputs	38:59:53.21474S	73:29:12.95994W	39:04:35.80000S	69:12:34.70000W	38:58:53.22454S	73:29:09.34242W	39:02:35.68826S	69:12:34.70000W	-1.0	-2.0	2.0
	Outputs	-1	39:02:21.67793S	72:38:46.91955W	39:04:03.70982S	72:40:08.19904W	39:00:21.62999S	72:38:41.87165W				
test25	Locus 1 Inputs	40:10:24.50000S	70:12:45.60000W	37:15:52.75197S	68:07:31.78007W	40:11:24.52218S	70:10:29.99173W	37:16:21.59037S	68:06:25.83960W	2.0	1.0	
	Locus 2 Inputs	36:21:10.67774S	71:47:01.13406W	38:04:35.80000S	68:12:34.70000W	36:19:28.94358S	71:45:42.08355W	38:03:43.77956S	68:11:56.71384W	-2.0	-1.0	2.0
	Outputs	-1	37:57:02.69588S	68:31:21.63789W	37:56:05.07632S	68:33:34.74930W	37:55:19.15511S	68:30:04.71414W				
test26	Locus 1 Inputs	40:10:24.50000S	68:12:45.60000E	40:05:30.77099S	72:33:27.97842E	40:11:24.54424S	68:12:45.60000E	40:07:30.71740S	72:33:35.62438E	1.0	2.0	
	Locus 2 Inputs	41:23:11.70467S	69:40:12.88793E	38:04:35.80000S	70:12:34.70000E	41:23:27.02365S	69:42:51.01302E	38:04:43.11348S	70:13:50.12296E	2.0	1.0	2.0
	Outputs	1	40:09:04.64798S	69:52:10.38091E	40:11:04.72555S	69:52:12.51866E	40:09:19.10487S	69:54:45.74500E				
test27	Locus 1 Inputs	40:10:24.50000S	68:12:45.60000E	40:05:30.77099S	72:33:27.97842E	40:09:24.45559S	68:12:45.60000E	40:03:30.82374S	72:33:20.33992E	-1.0	-2.0	
	Locus 2 Inputs	40:51:02.56824S	72:36:04.82091E	38:04:35.80000S	70:12:34.70000E	40:52:10.59442S	72:33:54.49592E	38:05:08.50946S	70:11:30.96382E	-2.0	-1.0	2.0
	Outputs	1	40:03:15.21615S	71:47:36.65550E	40:05:15.18367S	71:47:43.73613E	40:02:08.54536S	71:49:46.61823E				
test28	Locus 1 Inputs	40:10:24.50000S	68:12:45.60000E	43:30:29.87690S	68:12:45.60000E	40:10:24.47060S	68:15:22.14860E	43:30:29.86864S	68:14:08.04791E	-2.0	-1.0	
	Locus 2 Inputs	40:56:44.38623S	68:00:39.31749E	38:04:35.80000S	70:12:34.70000E	40:56:13.10174S	67:59:31.74272E	38:03:35.71346S	70:10:23.11608E	-1.0	-2.0	3.0
	Outputs	1	40:25:28.59897S	68:19:12.51023E	40:25:27.85071S	68:15:16.81863E	40:27:01.08104S	68:22:34.80466E				
test29	Locus 1 Inputs	40:10:24.50000S	68:12:45.60000E	43:29:41.80326S	68:36:41.64863E	40:10:34.93724S	68:10:09.64046E	43:29:47.30291S	68:35:19.56475E	2.0	1.0	

	Locus 2 Inputs	40:46:58.965 10S	67:41:36.038 96E	38:04:35.800 00S	70:12:34.700 00E	40:47:34.755 34S	67:42:39.460 34E	38:05:44.686 44S	70:14:39.222 71E	1.0	2.0	2.0
	Outputs	1	40:13:05.036 69S	68:13:04.979 01E	40:13:16.079 09S	68:10:28.987 97E	40:14:16.523 26S	68:15:10.868 66E				
test30	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	42:41:33.376 50S	71:07:03.727 43E	40:09:07.291 11S	68:14:45.485 47E	42:40:53.272 07S	71:08:04.252 37E	-2.0	-1.0	
	Locus 2 Inputs	41:23:57.635 85S	69:35:43.662 47E	38:04:35.800 00S	69:12:34.700 00E	41:24:03.117 84S	69:34:24.267 62E	38:04:46.243 10S	69:10:03.297 78E	-1.0	-2.0	3.0
	Outputs	1	41:11:18.773 46S	69:28:47.001 30E	41:13:15.796 50S	69:25:45.730 71E	41:11:01.578 21S	69:32:44.315 95E				
test31	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	37:24:53.776 02S	70:36:42.907 65E	40:11:33.360 17S	68:14:53.873 14E	37:25:26.924 44S	70:37:45.721 15E	2.0	1.0	
	Locus 2 Inputs	40:23:45.261 80S	67:07:29.571 30E	38:04:35.800 00S	70:12:34.700 00E	40:22:17.492 77S	67:05:42.397 04E	38:03:53.323 48S	70:11:40.977 51E	-2.0	-1.0	2.0
	Outputs	-1	38:18:15.297 86S	69:56:51.276 53E	38:17:08.771 55S	69:54:44.356 35E	38:16:49.679 07S	69:55:04.361 25E				
test32	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	37:35:08.049 87S	70:54:27.932 57E	40:09:07.291 11S	68:10:45.714 53E	37:34:30.808 62S	70:53:28.707 95E	-2.0	-1.0	
	Locus 2 Inputs	41:21:34.316 10S	70:58:40.429 12E	38:04:35.800 00S	70:12:34.700 00E	41:21:12.424 83S	71:01:17.107 47E	38:04:25.363 03S	70:13:49.529 90E	2.0	1.0	2.0
	Outputs	1	38:11:21.506 67S	70:12:50.643 10E	38:12:37.123 56S	70:14:48.930 82E	38:11:00.022 97S	70:15:20.391 60E				
test33	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	43:27:18.010 78S	67:25:06.247 15E	40:10:14.066 28S	68:11:28.518 13E	43:26:56.045 70S	67:22:24.286 88E	1.0	2.0	
	Locus 2 Inputs	42:35:45.277 80S	66:18:32.769 62E	40:04:35.800 00S	69:12:34.700 00E	42:37:05.450 79S	66:20:33.709 46E	40:05:14.392 06S	69:13:34.585 95E	2.0	1.0	2.0
	Outputs	1	41:08:35.701 13S	68:00:08.093 19E	41:08:13.948 66S	67:57:31.896 48E	41:09:53.660 93S	68:02:08.910 61E				
test34	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	38:26:46.467 74S	64:32:15.715 39E	40:12:08.492 21S	68:11:27.292 48E	38:27:37.217 79S	64:31:34.864 67E	-2.0	-1.0	
	Locus 2 Inputs	38:59:53.214 74S	64:55:56.440 06E	39:04:35.800 00S	69:12:34.700 00E	38:58:53.224 54S	64:56:00.057 58E	39:02:35.688 26S	69:12:34.700 00E	-1.0	-2.0	2.0
	Outputs	-1	39:02:22.266 16S	65:46:45.495 14E	39:04:04.298 28S	65:45:24.215 95E	39:00:22.217 94S	65:46:50.532 25E				
test35	Locus 1 Inputs	40:10:24.500 00S	68:12:45.600 00E	37:15:52.751 97S	70:17:59.419 93E	40:11:24.522 18S	68:15:01.208 27E	37:16:21.590 37S	70:19:05.360 40E	2.0	1.0	

	Locus 2 Inputs	36:21:10.67774S	66:38:08.26594E	38:04:35.80000S	70:12:34.70000E	36:19:28.94358S	66:39:27.31645E	38:03:43.77956S	70:13:12.68616E	-2.0	-1.0	2.0
	Outputs	-1	37:57:10.38318S	69:54:04.25802E	37:56:12.76197S	69:51:51.14391E	37:55:26.83944S	69:55:21.17757E				
test36	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	40:05:30.77099N	72:33:27.97842E	40:09:24.45559N	68:12:45.60000E	40:03:30.82374N	72:33:20.33992E	1.0	2.0	
	Locus 2 Inputs	38:52:47.19234N	68:57:43.98857E	42:04:35.80000N	70:12:34.70000E	38:52:13.67562N	69:00:11.54546E	42:04:18.24336N	70:13:51.74273E	2.0	1.0	2.0
	Outputs	1	40:10:43.92255N	69:26:42.17253E	40:08:43.85504N	69:26:39.21907E	40:10:10.37031N	69:29:12.48839E				
test37	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	40:05:30.77099N	72:33:27.97842E	40:11:24.54424N	68:12:45.60000E	40:07:30.71740N	72:33:35.62438E	-1.0	-2.0	
	Locus 2 Inputs	39:13:29.53578N	72:28:55.25646E	42:04:35.80000N	70:12:34.70000E	39:12:28.52052N	72:26:42.26184E	42:04:03.98622N	70:11:26.38299E	-2.0	-1.0	2.0
	Outputs	1	40:11:08.56456N	71:38:56.66811E	40:09:08.54388N	71:38:51.39855E	40:12:09.97080N	71:41:11.24340E				
test38	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	36:50:12.19034N	68:12:45.60000E	40:10:24.47060N	68:15:22.14860E	36:50:12.18382N	68:14:00.34302E	-2.0	-1.0	
	Locus 2 Inputs	39:10:02.81529N	68:04:02.52380E	42:04:35.80000N	70:12:34.70000E	39:10:31.56185N	68:02:54.78528E	42:05:35.80077N	70:10:15.11366E	-1.0	-2.0	3.0
	Outputs	1	39:39:58.78561N	68:19:02.28704E	39:39:59.83137N	68:15:09.19344E	39:38:32.84035N	68:22:27.11164E				
test39	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	36:50:55.82985N	68:34:27.93760E	40:10:14.00441N	68:10:09.65377E	36:50:50.82261N	68:33:13.44355E	2.0	1.0	
	Locus 2 Inputs	39:19:02.15978N	67:44:48.14899E	42:04:35.80000N	70:12:34.70000E	39:18:29.10241N	67:45:52.68873E	42:03:26.92161N	70:14:46.65709E	1.0	2.0	2.0
	Outputs	1	39:55:11.69116N	68:14:35.29494E	39:55:00.63826N	68:11:59.99070E	39:54:04.52166N	68:16:44.57011E				
test40	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	37:35:08.04987N	70:54:27.93257E	40:11:41.67410N	68:14:45.56095E	37:35:45.28280N	70:55:27.17358E	-2.0	-1.0	
	Locus 2 Inputs	38:45:10.91527N	69:34:50.91008E	42:04:35.80000N	69:12:34.70000E	38:45:05.92527N	69:33:34.47694E	42:04:25.30587N	69:09:54.18228E	-1.0	-2.0	3.0
	Outputs	1	39:08:09.55199N	69:27:04.93864E	39:06:16.31747N	69:24:05.04175E	39:08:25.58999N	69:30:55.36592E				
test41	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:52:36.59194N	70:48:44.57577E	40:09:15.60015N	68:14:53.80111E	42:52:00.69938N	70:49:49.97139E	2.0	1.0	

	Locus 2 Inputs	39:40:36.03510N	67:09:25.73456E	42:04:35.80000N	70:12:34.70000E	39:41:57.92929N	67:07:32.03241E	42:05:18.23971N	70:11:37.71848E	-2.0	-1.0	2.0
	Outputs	-1	41:42:57.59835N	69:45:22.81427E	41:44:07.68026N	69:43:12.69417E	41:44:22.45121N	69:43:29.43785E				
test42	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	42:41:33.37650N	71:07:03.72743E	40:11:41.67410N	68:10:45.63905E	42:42:13.47196N	71:06:03.18086E	-2.0	-1.0	
	Locus 2 Inputs	38:47:21.08227N	70:56:58.35057E	42:04:35.80000N	70:12:34.70000E	38:47:40.92131N	70:59:29.72418E	42:04:46.21551N	70:13:54.04870E	2.0	1.0	2.0
	Outputs	1	42:00:40.36069N	70:12:10.19254E	41:59:20.64842N	70:14:10.53796E	42:01:01.77707N	70:14:48.59080E				
test43	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	36:53:06.45688N	67:29:29.55764E	40:10:34.91946N	68:11:28.51158E	36:53:26.36762N	67:27:02.03991E	1.0	2.0	
	Locus 2 Inputs	37:29:19.58128N	66:31:04.90995E	40:04:35.80000N	69:12:34.70000E	37:28:05.07986N	66:33:03.18057E	40:03:57.19927N	69:13:34.56717E	2.0	1.0	2.0
	Outputs	1	38:54:00.30276N	67:56:19.25960E	38:54:21.36433N	67:53:47.92086E	38:52:44.84907N	67:58:18.84232E				
test44	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	41:46:39.60265N	64:21:12.90532E	40:08:40.49257N	68:11:27.35886E	41:45:46.34067N	64:20:35.92333E	-2.0	-1.0	
	Locus 2 Inputs	40:59:32.62580N	64:48:21.01682E	41:04:35.80000N	69:12:34.70000E	41:00:32.58502N	64:48:17.01819E	41:06:35.86947N	69:12:34.70000E	-1.0	-2.0	2.0
	Outputs	-1	41:01:38.01665N	66:14:41.46526E	40:59:52.99891N	66:13:24.61688E	41:03:37.99584N	66:14:35.28150E				
test45	Locus 1 Inputs	40:10:24.50000N	68:12:45.60000E	43:02:23.57855N	70:29:04.94342E	40:09:24.43355N	68:15:01.14189E	43:01:52.20697N	70:30:14.68794E	2.0	1.0	
	Locus 2 Inputs	43:40:32.94322N	66:13:51.15861E	42:04:35.80000N	70:12:34.70000E	43:42:19.59129N	66:15:07.01471E	42:05:27.78065N	70:13:14.99369E	-2.0	-1.0	2.0
	Outputs	-1	42:11:59.99855N	69:52:47.82475E	42:13:01.46706N	69:50:29.12565E	42:13:43.88507N	69:54:08.74643E				

WGS84PerpIntercept Test Results

Test Identifier	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic Azimuth (degrees)	Test Point Latitude	Test Point Longitude	Azimuth From Test Point To Intercept (degrees)	Distance From Test Point To Intercept (NM)	Intercept Latitude	Intercept Longitude
test1	40:10:24.50000N	70:12:45.60000W	38.0	42:04:35.80000N	68:12:40.70000W	129.31642	0.41489	42:04:20.02035N	68:12:14.84062W
test2	40:10:24.50000N	70:12:45.60000W	62.0	42:04:35.80000N	68:12:40.70000W	153.29737	59.66462	41:11:10.62477N	67:37:10.15895W
test3	40:10:24.50000N	70:12:45.60000W	90.0	42:04:35.80000N	68:12:40.70000W	181.29165	115.13091	40:09:25.68132N	68:16:03.75475W
test4	40:10:24.50000N	70:12:45.60000W	127.0	42:04:35.80000N	68:12:40.70000W	218.31581	145.78046	40:09:07.48064N	70:10:32.43942W
test5	40:10:24.50000N	70:12:45.60000W	150.0	42:04:35.80000N	68:12:40.70000W	241.33453	135.01795	40:58:00.14293N	70:49:04.80560W
test6	40:10:24.50000N	70:12:45.60000W	0.0	42:04:35.80000N	68:12:40.70000W	271.34146	89.41691	42:05:38.63720N	70:12:45.60000W
test7	40:10:24.50000N	70:12:45.60000W	335.0	42:04:35.80000N	68:12:40.70000W	246.33745	129.70818	41:10:42.02846N	70:50:01.67112W
test8	40:10:24.50000N	70:12:45.60000W	305.0	42:04:35.80000N	68:12:40.70000W	216.31402	145.61723	40:06:15.57774N	70:05:03.11962W
test9	40:10:24.50000N	70:12:45.60000W	180.0	38:04:35.80000N	72:12:40.70000W	88.76710	94.68092	38:05:36.99418N	70:12:45.60000W
test10	40:10:24.50000N	70:12:45.60000W	230.0	38:04:35.80000N	72:12:40.70000W	318.72576	34.59985	38:30:34.10445N	72:41:45.37882W
test11	40:10:24.50000N	70:12:45.60000W	270.0	38:04:35.80000N	72:12:40.70000W	358.70998	124.63008	40:09:18.54080N	72:16:20.21715W
test12	40:10:24.50000S	70:12:45.60000W	38.0	38:04:35.80000S	68:12:40.70000W	126.73606	2.00964	38:05:47.98305S	68:10:38.28715W
test13	40:10:24.50000S	70:12:45.60000W	62.0	38:04:35.80000S	68:12:40.70000W	150.71427	65.51427	39:01:40.59903S	67:31:33.29933W
test14	40:10:24.50000S	70:12:45.60000W	90.0	38:04:35.80000S	68:12:40.70000W	178.70822	124.62717	40:09:18.36107S	68:09:00.88927W
test15	40:10:24.50000S	70:12:45.60000W	127.0	38:04:35.80000S	68:12:40.70000W	215.73655	156.61476	40:10:50.64448S	70:12:00.36233W
test16	40:10:24.50000S	70:12:45.60000W	150.0	38:04:35.80000S	68:12:40.70000W	238.75798	144.43973	39:17:48.31169S	70:51:45.99999W
test17	40:10:24.50000S	70:12:45.60000W	0.0	38:04:35.80000S	68:12:40.70000W	268.76542	94.80986	38:05:37.16104S	70:12:45.60000W
test18	40:10:24.50000S	70:12:45.60000W	335.0	38:04:35.80000S	68:12:40.70000W	243.76128	138.61172	39:04:08.70412S	70:52:19.87385W
test19	40:10:24.50000S	70:12:45.60000W	305.0	38:04:35.80000S	68:12:40.70000W	213.73448	156.49404	40:13:57.58564S	70:06:08.18853W
test20	40:10:24.50000S	70:12:45.60000W	180.0	42:04:35.80000S	72:12:40.70000W	91.33964	89.29531	42:05:38.46633S	70:12:45.60000W
test21	40:10:24.50000S	70:12:45.60000W	230.0	42:04:35.80000S	72:12:40.70000W	321.30417	30.78578	41:40:30.62405S	72:38:21.72071W
test22	40:10:24.50000S	70:12:45.60000W	270.0	42:04:35.80000S	72:12:40.70000W	1.28990	115.12817	40:09:25.84116S	72:09:17.92603W
test23	40:10:24.50000S	68:12:45.60000E	38.0	38:04:35.80000S	70:12:40.70000E	126.73774	2.11300	38:05:51.69739S	70:14:49.40745E
test24	40:10:24.50000S	68:12:45.60000E	62.0	38:04:35.80000S	70:12:40.70000E	150.71599	65.57735	39:01:43.94797S	70:53:50.37701E
test25	40:10:24.50000S	68:12:45.60000E	90.0	38:04:35.80000S	70:12:40.70000E	178.70998	124.63008	40:09:18.54080S	70:16:20.21715E
test26	40:10:24.50000S	68:12:45.60000E	127.0	38:04:35.80000S	70:12:40.70000E	215.73831	156.53943	40:10:46.85840S	68:13:24.28550E
test27	40:10:24.50000S	68:12:45.60000E	150.0	38:04:35.80000S	70:12:40.70000E	238.75971	144.32946	39:17:44.81540S	67:33:42.64546E
test28	40:10:24.50000S	68:12:45.60000E	0.0	38:04:35.80000S	70:12:40.70000E	268.76710	94.68092	38:05:36.99418S	68:12:45.60000E
test29	40:10:24.50000S	68:12:45.60000E	335.0	38:04:35.80000S	70:12:40.70000E	243.76299	138.49604	39:04:05.58767S	67:33:09.49758E
test30	40:10:24.50000S	68:12:45.60000E	305.0	38:04:35.80000S	70:12:40.70000E	213.73624	156.42241	40:13:53.89461S	68:19:16.11563E
test31	40:10:24.50000S	72:12:45.60000E	180.0	42:04:35.80000S	70:12:40.70000E	91.34146	89.41691	42:05:38.63720S	72:12:45.60000E
test32	40:10:24.50000S	72:12:45.60000E	230.0	42:04:35.80000S	70:12:40.70000E	321.30598	30.70974	41:40:34.16471S	69:47:03.52290E
test33	40:10:24.50000S	72:12:45.60000E	270.0	42:04:35.80000S	70:12:40.70000E	1.29165	115.13091	40:09:25.68132S	70:16:03.75475E
test34	40:10:24.50000N	68:12:45.60000E	38.0	42:04:35.80000N	70:12:40.70000E	129.31459	0.50899	42:04:16.44172N	70:13:12.42516E
test35	40:10:24.50000N	68:12:45.60000E	62.0	42:04:35.80000N	70:12:40.70000E	153.29558	59.71928	41:11:07.73298N	70:48:13.29934E
test36	40:10:24.50000N	68:12:45.60000E	90.0	42:04:35.80000N	70:12:40.70000E	181.28990	115.12817	40:09:25.84116N	70:09:17.92603E
test37	40:10:24.50000N	68:12:45.60000E	127.0	42:04:35.80000N	70:12:40.70000E	218.31405	145.70504	40:09:10.93426N	68:14:52.79291E
test38	40:10:24.50000N	68:12:45.60000E	150.0	42:04:35.80000N	70:12:40.70000E	241.33274	134.91123	40:58:03.16688N	67:36:24.05438E
test39	40:10:24.50000N	68:12:45.60000E	0.0	42:04:35.80000N	70:12:40.70000E	271.33964	89.29531	42:05:38.46633N	68:12:45.60000E
test40	40:10:24.50000N	68:12:45.60000E	335.0	42:04:35.80000N	70:12:40.70000E	246.33565	129.59677	41:10:44.67776N	67:35:27.86348E
test41	40:10:24.50000N	68:12:45.60000E	305.0	42:04:35.80000N	70:12:40.70000E	216.31226	145.54520	40:06:18.96327N	68:20:21.80300E

test42	40:10:24.50000N	72:12:45.60000E	180.0	38:04:35.80000N	70:12:40.70000E	88.76542	94.80986	38:05:37.16104N	72:12:45.60000E
test43	40:10:24.50000N	72:12:45.60000E	230.0	38:04:35.80000N	70:12:40.70000E	318.72407	34.51477	38:30:30.24106N	69:43:40.27830E
test44	40:10:24.50000N	72:12:45.60000E	270.0	38:04:35.80000N	70:12:40.70000E	358.70822	124.62717	40:09:18.36107N	70:09:00.88927E

WGS84LocusPerpIntercept Test Results

Test Identifier	Inputs	Locus Geodesic Start Latitude	Locus Geodesic Start Longitude	Locus Geodesic End Latitude	Locus Geodesic End Longitude	Locus Start Latitude	Locus Start Longitude	Locus End Latitude	Locus End Longitude	Locus Start Distance (NM)	Locus End Distance (NM)	Test Point Latitude	Test Point Longitude
	Outputs	Azimuth From Test Point To Intercept (degrees)	Distance From Test Point To Intercept (nm)	Intercept Latitude	Intercept Longitude								
test1	Inputs	40:10:24.50000N	70:12:45.60000W	42:46:07.45918N	67:25:36.90158W	40:11:01.46238N	70:13:47.29029W	42:46:45.90859N	67:26:39.45541W	-1.0	-1.0	42:04:35.80000N	68:12:34.70000W
	Outputs	309.31753	0.64273	42:05:00.24258N	68:13:14.76673W								
test2	Inputs	40:10:24.50000N	70:12:45.60000W	42:46:07.45918N	67:25:36.90158W	40:09:47.52843N	70:11:43.92830W	42:45:29.00021N	67:24:34.36924W	1.0	1.0	42:04:35.80000N	68:12:34.70000W
	Outputs	129.31753	1.35727	42:03:44.17073N	68:11:10.11749W								
test3	Inputs	40:10:24.50000N	70:12:45.60000W	42:46:07.45918N	67:25:36.90158W	40:09:47.52843N	70:11:43.92830W	42:44:50.53170N	67:23:31.85839W	1.0	2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	129.60401	2.08646	42:03:15.94272N	68:10:25.22603W								
test4	Inputs	40:10:24.50000N	70:12:45.60000W	42:46:07.45918N	67:25:36.90158W	40:11:01.46238N	70:13:47.29029W	42:47:24.34843N	67:27:42.03074W	-1.0	-2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	309.03106	1.37192	42:05:27.64952N	68:14:00.58323W								
test5	Inputs	40:10:24.50000N	70:12:45.60000W	41:40:24.61603N	66:17:03.91251W	40:11:17.51431N	70:13:22.35551W	41:42:13.03866N	66:18:12.69511W	-1.0	-2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	153.01195	57.96492	41:12:49.81350N	67:37:43.49832W								
test6	Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	65:52:03.22158W	40:08:24.41100N	70:12:45.60000W	40:04:30.79747N	65:52:07.04176W	2.0	1.0	42:04:35.80000N	68:12:34.70000W
	Outputs	181.00609	116.68342	40:07:51.80394N	68:15:14.93906W								
test7	Inputs	40:10:24.50000N	70:12:45.60000W	38:06:56.47029N	66:50:21.71131W	40:12:00.39619N	70:11:11.34983W	38:08:29.64659N	66:48:45.71750W	-2.0	-2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	218.31689	143.82663	40:10:41.23180N	70:08:54.51269W								
test8	Inputs	40:10:24.50000N	70:12:45.60000W	37:15:52.75197N	68:07:31.78007W	40:09:54.47230N	70:13:53.37924W	37:14:55.04445N	68:09:43.61910W	1.0	2.0	40:04:35.80000N	69:12:34.70000W
	Outputs	240.93040	38.37214	39:45:48.10411N	69:56:04.27064W								
test9	Inputs	40:10:24.50000N	70:12:45.60000W	43:25:53.95085N	69:15:43.32087W	40:10:36.97688N	70:14:02.16772W	43:26:20.17044N	69:18:24.04024W	-1.0	-2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	283.05132	65.25203	42:18:48.35558N	69:38:15.57457W								

test10	Inputs	40:10:24.50000N	70:12:45.60000W	43:30:29.87690N	70:12:45.60000W	40:10:24.47060N	70:10:09.05140W	43:30:29.86864N	70:11:23.15209W	2.0	1.0	42:04:35.80000N	68:12:34.70000W
	Outputs	271.05601	88.06612	42:05:12.28968N	70:10:50.66239W								
test11	Inputs	40:10:24.50000N	70:12:45.60000W	43:29:41.80326N	70:36:41.64863W	40:10:19.25950N	70:14:03.57478W	43:29:30.75486N	70:39:25.80395W	-1.0	-2.0	42:04:35.80000N	68:12:34.70000W
	Outputs	266.05671	100.72052	41:56:20.94047N	70:27:13.96006W								
test12	Inputs	40:10:24.50000N	70:12:45.60000W	42:10:25.78109N	73:44:43.81529W	40:11:11.81273N	70:11:57.40023W	42:11:14.53862N	73:43:56.74833W	1.0	1.0	42:04:35.80000N	69:12:34.70000W
	Outputs	218.66979	116.72692	40:32:44.27479N	70:48:14.72623W								
test13	Inputs	40:10:24.50000N	70:12:45.60000W	36:50:12.19034N	70:12:45.60000W	40:10:24.49265N	70:11:27.32569W	36:50:12.16424N	70:10:16.11397W	-1.0	-2.0	38:04:35.80000N	72:12:34.70000W
	Outputs	88.48154	96.22417	38:06:05.77988N	70:10:42.38354W								
test14	Inputs	40:10:24.50000N	70:12:45.60000W	37:58:59.08359N	73:26:32.36055W	40:11:56.48089N	70:14:26.26527W	37:59:43.69324N	73:27:23.18593W	2.0	1.0	38:04:35.80000N	72:12:34.70000W
	Outputs	318.44031	35.88843	38:31:24.84927N	72:42:54.95851W								
test15	Inputs	40:10:24.50000N	70:12:45.60000W	40:05:30.77099N	74:33:27.97842W	40:08:24.41100N	70:12:45.60000W	40:04:30.79747N	74:33:24.15824W	-2.0	-1.0	38:04:35.80000N	72:12:34.70000W
	Outputs	358.99772	123.10364	40:07:47.67496N	72:15:23.10907W								
test16	Inputs	20:10:24.50000N	70:12:45.60000W	22:47:42.88332N	67:59:32.62915W	20:11:01.57566N	70:13:35.86376W	22:48:20.61693N	68:00:23.22901W	-1.0	-1.0	22:04:35.80000N	68:12:34.70000W
	Outputs	308.72881	18.49323	22:16:11.68878N	68:28:07.95660W								
test17	Inputs	20:10:24.50000N	70:12:45.60000W	22:47:42.88332N	67:59:32.62915W	20:09:47.42031N	70:11:55.34284W	22:47:05.14519N	67:58:42.03703W	1.0	1.0	22:04:35.80000N	68:12:34.70000W
	Outputs	308.72881	16.49323	22:14:56.50252N	68:26:26.90385W								
test18	Inputs	20:10:24.50000N	70:12:45.60000W	22:47:42.88332N	67:59:32.62915W	20:09:47.42031N	70:11:55.34284W	22:46:27.40256N	67:57:51.45264W	1.0	2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	309.01529	15.69835	22:14:30.29919N	68:25:43.56946W								
test19	Inputs	20:10:24.50000N	70:12:45.60000W	22:47:42.88332N	67:59:32.62915W	20:11:01.57566N	70:13:35.86376W	22:48:58.34604N	68:01:13.83660W	-1.0	-2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	308.44233	19.28768	22:16:37.00430N	68:28:51.98766W								
test20	Inputs	20:10:24.50000N	70:12:45.60000W	21:42:55.04997N	67:03:07.16284W	20:11:17.67400N	70:13:15.54639W	21:44:42.47168N	67:04:05.42224W	-1.0	-2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	152.41757	46.88028	21:22:52.16995N	67:49:19.19587W								
test21	Inputs	20:10:24.50000N	70:12:45.60000W	20:08:16.10563N	66:40:11.24376W	20:08:24.05152N	70:12:45.60000W	20:07:15.89488N	66:40:12.60255W	2.0	1.0	22:04:35.80000N	68:12:34.70000W
	Outputs	180.40439	115.88931	20:08:17.39840N	68:13:26.84791W								

test22	Inputs	20:10:24.50000N	70:12:45.60000W	18:08:16.60075N	67:25:03.87343W	20:12:00.68945N	70:11:28.81766W	18:09:51.63861N	67:23:46.42707W	-2.0	-2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	217.71425	156.60521	19:59:44.51317N	69:54:16.80106W								
test23	Inputs	20:10:24.50000N	70:12:45.60000W	17:16:01.61500N	68:28:18.10827W	20:09:54.38551N	70:13:40.83341W	17:15:02.38476N	68:30:07.30583W	1.0	2.0	20:04:35.80000N	69:12:34.70000W
	Outputs	240.62790	47.41380	19:41:09.80503N	69:56:21.99784W								
test24	Inputs	20:10:24.50000N	70:12:45.60000W	23:26:37.86400N	69:27:33.93765W	20:10:37.01823N	70:13:47.98905W	23:27:03.45735N	69:29:41.45246W	-1.0	-2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	282.46352	87.05417	22:23:01.23192N	69:44:17.95270W								
test25	Inputs	20:10:24.50000N	70:12:45.60000W	23:31:06.93560N	70:12:45.60000W	20:10:24.48716N	70:10:38.03712W	23:31:06.93179N	70:11:40.31639W	2.0	1.0	22:04:35.80000N	68:12:34.70000W
	Outputs	270.46647	110.19089	22:04:46.78090N	70:11:13.20586W								
test26	Inputs	20:10:24.50000N	70:12:45.60000W	23:30:20.06967N	70:31:42.81974W	20:10:19.24793N	70:13:49.13814W	23:30:09.31498N	70:33:52.85078W	-1.0	-2.0	22:04:35.80000N	68:12:34.70000W
	Outputs	265.46611	122.69379	21:53:59.00085N	70:24:06.45107W								
test27	Inputs	20:10:24.50000N	70:12:45.60000W	22:12:35.69228N	73:02:34.77881W	20:11:11.95601N	70:12:06.32892W	22:13:23.79135N	73:01:55.88211W	1.0	1.0	22:04:35.80000N	69:12:34.70000W
	Outputs	218.36943	123.21147	20:27:18.81236N	70:34:01.01617W								
test28	Inputs	20:10:24.50000N	70:12:45.60000W	16:49:37.49349N	70:12:45.60000W	20:10:24.49679N	70:11:41.81856W	16:49:37.48292N	70:10:40.49187W	-1.0	-2.0	18:04:35.80000N	72:12:34.70000W
	Outputs	89.09350	115.76556	18:05:47.86911N	70:11:03.51621W								
test29	Inputs	20:10:24.50000N	70:12:45.60000W	18:00:09.46178N	72:53:29.02106W	20:11:56.76327N	70:14:07.60925W	18:00:55.00817N	72:54:10.22384W	2.0	1.0	18:04:35.80000N	72:12:34.70000W
	Outputs	319.05008	23.26620	18:22:13.64861N	72:28:36.69646W								
test30	Inputs	20:10:24.50000N	70:12:45.60000W	20:08:16.10563N	73:45:19.95624W	20:08:24.05152N	70:12:45.60000W	20:07:15.89488N	73:45:18.59745W	-2.0	-1.0	18:04:35.80000N	72:12:34.70000W
	Outputs	359.59765	123.21213	20:08:16.82998N	72:13:29.86100W								

WGS84PointToArcTangents

Test Identifier	Point Latitude	Point Longitude	Arc Center Latitude	Arc Center Longitude	Arc Radius	Tangent Point 1 Latitude	Tangent Point 1 Longitude	Tangent Point 2 Latitude	Tangent Point 2 Longitude
test1	40:04:35.80000N	68:12:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test2	40:04:35.80000N	67:12:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	38:58:50.99979N	68:42:19.92957W	41:17:02.57149N	68:34:37.49185W
test3	40:04:35.80000N	60:42:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	38:33:51.49399N	69:38:46.59230W	41:48:38.13537N	69:47:36.01065W
test4	40:04:35.80000N	47:18:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	38:32:36.38289N	69:45:21.56093W	41:50:24.89752N	70:17:02.95660W
test5	42:54:35.80000N	70:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	41:10:08.36776N	68:27:18.83665W	41:10:59.53083N	71:57:22.47464W
test6	64:54:35.80000N	70:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	40:15:27.76756N	68:02:23.12392W	40:15:31.95981N	72:23:07.86461W
test7	52:54:35.80000N	70:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	40:21:58.95584N	68:02:59.46118W	40:22:10.22316N	72:22:30.19164W
test8	40:24:35.80000N	75:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	41:43:51.26621N	70:59:57.14126W	38:44:18.56935N	71:18:35.69631W
test9	40:24:35.80000N	85:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	41:50:23.42412N	70:17:57.13255W	38:33:20.77969N	70:44:13.68450W
test10	40:24:35.80000N	80:11:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	41:49:34.92720N	70:30:17.76805W	38:34:51.79348N	70:51:10.47505W
test11	37:09:35.80000N	70:21:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	39:17:29.76121N	72:02:47.41811W	39:11:04.58987N	68:28:26.79906W
test12	30:09:35.80000N	70:21:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	39:53:58.01340N	72:21:11.40785W	39:51:26.97905N	68:04:57.44757W
test13	25:09:35.80000N	70:21:34.70000W	40:10:24.50000N	70:12:45.60000W	100.0	39:59:12.99136N	72:22:13.50689W	39:57:25.86494N	68:03:36.34196W
test14	40:04:35.80000N	72:12:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test15	40:04:35.80000N	73:12:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	38:58:59.31128N	71:43:22.32134E	41:16:52.48137N	71:51:05.39764E
test16	40:04:35.80000N	80:12:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	38:33:38.85748N	70:45:44.00068E	41:48:54.91998N	70:35:56.19986E
test17	40:04:35.80000N	85:12:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	38:32:40.44989N	70:40:33.55927E	41:50:14.09817N	70:21:45.92010E
test18	42:54:35.80000N	70:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	41:10:59.53083N	71:57:22.47464E	41:10:08.36776N	68:27:18.83666E
test19	52:54:35.80000N	70:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	40:22:10.22315N	72:22:30.19164E	40:21:58.95586N	68:02:59.46118E
test20	57:54:35.80000N	70:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	40:18:20.82175N	72:22:56.15166E	40:18:13.61636N	68:02:34.42092E
test21	40:24:35.80000N	65:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	41:43:58.89962N	69:26:00.45951E	38:44:06.31619N	69:07:22.38700E
test22	40:24:35.80000N	55:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	41:50:23.55695N	70:07:38.55861E	38:33:20.46158N	69:41:19.14594E
test23	40:24:35.80000N	60:11:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	41:49:35.71820N	69:55:21.25651E	38:34:50.41383N	69:34:26.43627E
test24	37:09:35.80000N	70:21:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	39:11:04.58989N	68:28:26.79904E	39:17:29.76123N	72:02:47.41812E
test25	32:09:35.80000N	70:21:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	39:47:00.76207N	68:06:16.51285E	39:50:03.52790N	72:20:10.72389E
test26	27:09:35.80000N	70:21:34.70000E	40:10:24.50000N	70:12:45.60000E	100.0	39:55:34.77439N	68:03:58.36606E	39:57:35.60852N	72:21:56.65907E
test27	40:04:35.80000S	72:12:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	N/A	N/A	N/A	N/A
test28	40:04:35.80000S	73:12:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	41:16:52.48137S	71:51:05.39763E	38:58:59.31128S	71:43:22.32134E
test29	40:04:35.80000S	83:12:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	41:49:55.55059S	70:26:29.37475E	38:32:53.74966S	70:41:49.38811E
test30	40:04:35.80000S	80:12:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	41:48:54.91998S	70:35:56.19985E	38:33:38.85748S	70:45:44.00069E
test31	38:04:35.80000S	70:11:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	38:49:55.28970S	71:29:33.42172E	38:50:48.30732S	68:54:26.10830E
test32	28:04:35.80000S	70:11:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	39:55:27.43830S	72:21:31.28285E	39:55:44.66533S	68:03:56.29379E
test33	33:04:35.80000S	70:11:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	39:45:36.78731S	72:18:46.32802E	39:46:03.95424S	68:06:35.51577E
test34	40:24:35.80000S	65:51:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	38:48:24.38501S	68:58:41.71027E	41:41:16.63837S	69:17:31.03298E
test35	40:24:35.80000S	60:51:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	38:35:16.36317S	69:32:41.49524E	41:49:20.73591S	69:53:01.97091E
test36	40:24:35.80000S	55:51:34.70000E	40:10:24.50000S	70:12:45.60000E	100.0	38:33:26.36693S	69:40:49.11846E	41:50:20.97633S	70:06:20.58405E
test37	43:09:35.80000S	69:38:25.30000E	40:10:24.50000S	70:12:45.60000E	100.0	40:52:32.16687S	68:13:48.41601E	41:16:01.63700S	71:52:03.48811E
test38	48:09:35.80000S	69:38:25.30000E	40:10:24.50000S	70:12:45.60000E	100.0	40:25:12.33606S	68:03:29.94912E	40:34:39.67829S	72:19:42.54233E
test39	53:09:35.80000S	69:38:25.30000E	40:10:24.50000S	70:12:45.60000E	100.0	40:19:08.92651S	68:02:39.52957E	40:24:28.22924S	72:22:08.94257E
test40	40:04:35.80000S	68:12:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	N/A	N/A	N/A	N/A
test41	40:04:35.80000S	66:47:25.30000W	40:10:24.50000S	70:12:45.60000W	100.0	41:26:06.94082S	68:46:38.84215W	38:51:27.83161S	68:53:19.53080W
test42	40:04:35.80000S	56:47:25.30000W	40:10:24.50000S	70:12:45.60000W	100.0	41:50:00.49059S	70:00:06.82169W	38:32:50.15608S	69:44:01.95578W
test43	40:04:35.80000S	59:47:25.30000W	40:10:24.50000S	70:12:45.60000W	100.0	41:49:07.32741S	69:51:10.22069W	38:33:29.54331S	69:40:33.17198W
test44	38:04:35.80000S	70:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	38:50:48.30732S	68:54:26.10830W	38:49:55.28969S	71:29:33.42171W

test45	28:04:35.80000S	70:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	39:55:44.66533S	68:03:56.29379W	39:55:27.43828S	72:21:31.28285W
test46	33:04:35.80000S	70:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	39:46:03.95424S	68:06:35.51577W	39:45:36.78730S	72:18:46.32802W
test47	40:24:35.80000S	74:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	38:51:54.10807S	71:32:55.13292W	41:39:02.49151S	71:13:58.65781W
test48	40:24:35.80000S	84:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	38:33:30.19485S	70:45:01.28168W	41:50:19.19941S	70:19:56.15761W
test49	40:24:35.80000S	80:11:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	38:34:51.79347S	70:51:10.47504W	41:49:34.92720S	70:30:17.76806W
test50	43:09:35.80000S	70:21:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	41:02:16.59197S	72:05:02.69299W	41:08:20.56609S	68:25:37.35380W
test51	48:09:35.80000S	70:21:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	40:28:45.82853S	72:21:17.78853W	40:31:11.70040S	68:04:49.12313W
test52	53:09:35.80000S	70:21:34.70000W	40:10:24.50000S	70:12:45.60000W	100.0	40:21:08.09707S	72:22:38.37153W	40:22:30.13116S	68:03:03.81110W

WGS84PerpTangentPoints Test Results

Test Identifier	Geodesic Start Latitude	Geodesic Start Longitude	Geodesic Azimuth (degrees)	Arc Center Latitude	Arc Center Longitude	Arc Radius	Intercept 1 Latitude	Intercept 1 Longitude	Intercept 2 Latitude	Intercept 2 Longitude	Tangent Point 1 Latitude	Tangent Point 1 Longitude	Tangent Point 2 Latitude	Tangent s Point 2 Longitude
test1	40:04:35.80000N	65:12:40.70000W	350.0	40:10:24.50000N	70:12:45.60000W	50.0	41:45:15.42301N	65:36:23.05394W	40:06:32.80959N	65:13:07.57044W	40:59:04.91370N	70:27:57.32812W	39:21:40.43861N	69:58:02.47943W
test2	40:04:35.80000N	65:12:40.70000W	200.0	40:10:24.50000N	70:12:45.60000W	50.0	38:14:05.43205N	66:03:35.08024W	39:48:31.53705N	65:20:15.65454W	39:22:29.68372N	70:31:27.94338W	40:58:17.46091N	69:53:43.69995W
test3	40:04:35.80000N	68:12:40.70000W	325.0	40:10:24.50000N	70:12:45.60000W	100.0	42:13:23.37083N	70:14:57.87719W	39:30:24.62906N	67:41:50.28458W	41:30:34.37380N	71:31:37.17040W	38:49:17.65513N	68:57:04.57474W
test4	40:04:35.80000N	65:12:40.70000W	270.0	40:10:24.50000N	70:12:45.60000W	50.0	39:55:02.92066N	71:16:44.98301W	40:00:38.90564N	69:06:53.45783W	40:07:17.85127N	71:17:50.28392W	40:12:54.82728N	69:07:35.57088W
test5	40:04:35.80000N	65:12:40.70000W	300.0	40:10:24.50000N	70:12:45.60000W	50.0	42:06:05.22048N	70:09:48.79496W	41:20:00.99595N	68:11:12.42020W	40:32:38.56283N	71:11:21.28560W	39:47:38.67195N	69:14:49.94129W
test6	40:04:35.80000N	65:12:40.70000W	240.0	40:10:24.50000N	70:12:45.60000W	50.0	37:57:45.76917N	69:38:55.15062W	38:51:12.13212N	67:51:14.22782W	39:42:50.60770N	71:07:01.04721W	40:37:35.17545N	69:17:48.54937W
test7	44:54:35.80000N	70:11:34.70000W	180.0	40:10:24.50000N	70:12:45.60000W	50.0	39:20:22.07307N	70:11:34.70000W	41:00:26.50523N	70:11:34.70000W	39:20:22.06721N	70:12:44.75738W	41:00:26.49902N	70:12:46.49381W
test8	44:54:35.80000N	70:11:34.70000W	148.0	40:10:24.50000N	70:12:45.60000W	50.0	40:44:55.03008N	66:49:02.96925W	42:11:35.30495N	67:55:46.12774W	39:27:50.18529N	69:38:39.28546W	40:52:46.19633N	70:47:39.16449W
test9	44:54:35.80000N	70:11:34.70000W	211.0	40:10:24.50000N	70:12:45.60000W	50.0	40:39:20.90907N	73:30:31.26204W	42:06:51.06530N	72:25:51.03824W	39:27:22.55669N	70:45:52.63953W	40:53:14.53640N	69:38:52.20992W
test10	40:24:35.80000N	75:11:34.70000W	90.0	40:10:24.50000N	70:12:45.60000W	50.0	40:15:00.17740N	69:06:59.49277W	40:20:38.68482N	71:17:28.91405W	40:07:17.14968N	69:07:40.97872W	40:12:55.02357N	71:17:55.61784W
test11	40:24:35.80000N	75:11:34.70000W	71.0	40:10:24.50000N	70:12:45.60000W	50.0	41:42:40.03737N	69:38:05.90758W	41:14:59.29549N	71:45:59.60155W	40:23:40.58611N	69:09:45.81981W	39:56:32.34252N	71:15:19.64207W
test12	40:24:35.80000N	75:11:34.70000W	117.0	40:10:24.50000N	70:12:45.60000W	50.0	38:21:19.52582N	70:19:44.57750W	39:10:39.07842N	72:11:03.63508W	39:45:02.93329N	69:16:42.08956W	40:35:20.61719N	71:09:29.12730W
test13	37:09:35.80000N	70:21:34.70000W	0.0	40:10:24.50000N	70:12:45.60000W	50.0	41:00:26.84065N	70:21:34.70000W	39:20:22.39722N	70:21:34.70000W	41:00:26.49479N	70:12:38.92986W	39:20:22.07107N	70:12:51.88818W
test14	37:09:35.80000N	70:21:34.70000W	34.0	40:10:24.50000N	70:12:45.60000W	50.0	39:57:02.53883N	67:53:34.67323W	38:35:09.95589N	69:07:43.83953W	40:51:46.48176N	69:35:52.67111W	39:28:52.04803N	70:48:56.68220W
test15	37:09:35.80000N	70:21:34.70000W	331.0	40:10:24.50000N	70:12:45.60000W	50.0	40:07:42.80472N	72:30:57.33906W	38:41:00.31862N	71:26:24.86130W	40:54:09.57283N	70:44:34.61853W	39:26:31.66858N	69:41:34.39676W
test16	40:04:35.80000N	75:12:34.70000E	350.0	40:10:24.50000N	70:12:45.60000E	50.0	41:45:12.67315N	74:48:53.01070E	40:06:30.07882N	75:12:08.45696E	40:59:04.94944N	69:57:34.06882E	39:21:40.40510N	70:27:28.53420E
test17	40:04:35.80000N	75:12:34.70000E	200.0	40:10:24.50000N	70:12:45.60000E	50.0	38:14:08.75549N	74:21:41.80893E	39:48:34.82983N	75:05:01.29260E	39:22:29.72463N	69:54:03.08054E	40:58:17.41786N	70:31:47.68622E
test18	40:04:35.80000N	72:12:34.70000E	315.0	40:10:24.50000N	70:12:45.60000E	100.0	42:02:53.59978N	69:31:25.90082E	39:43:08.75530N	72:40:17.05485E	41:18:51.03968N	68:36:46.64551E	39:00:35.86938N	71:45:27.62796E
test19	40:04:35.80000N	73:12:34.70000E	270.0	40:10:24.50000N	70:12:45.60000E	50.0	40:00:17.63529N	69:08:04.99603E	40:03:39.33076N	71:18:12.14247E	40:08:25.20509N	69:07:35.90168E	40:11:47.29572N	71:17:58.51179E
test20	40:04:35.80000N	73:12:34.70000E	300.0	40:10:24.50000N	70:12:45.60000E	50.0	41:28:31.69569N	69:52:44.13264E	40:40:49.88638N	71:49:00.24598E	40:33:41.08619N	69:14:51.20890E	39:46:37.81172N	71:09:59.27305E

test21	40:04:35.80000N	73:12:34.70000E	240.0	40:10:24.50000N	70:12:45.60000E	50.0	38:39:26.28959N	70:09:47.67412E	39:31:32.39864N	71:59:30.22696E	39:43:45.18199N	69:17:44.08525E	40:36:38.84939N	71:08:28.77660E
test22	42:54:35.80000N	70:11:34.70000E	180.0	40:10:24.50000N	70:12:45.60000E	50.0	39:20:22.07307N	70:11:34.70000E	41:00:26.50523N	70:11:34.70000E	39:20:22.06721N	70:12:44.75738E	41:00:26.49902N	70:12:46.49381E
test23	42:54:35.80000N	70:11:34.70000E	148.0	40:10:24.50000N	70:12:45.60000E	50.0	40:12:21.71012N	72:22:44.76027E	41:38:14.00626N	71:14:56.56898E	39:27:51.50743N	70:46:54.69271E	40:52:45.72705N	69:37:51.05930E
test24	42:54:35.80000N	70:11:34.70000E	211.0	40:10:24.50000N	70:12:45.60000E	50.0	40:10:13.49744N	68:03:47.64473E	41:36:57.43421N	69:09:38.18678E	39:27:25.16505N	69:39:32.86210E	40:53:12.66240N	70:46:43.04537E
test25	40:24:35.80000N	65:11:34.70000E	90.0	40:10:24.50000N	70:12:45.60000E	50.0	40:14:52.70121N	71:18:31.30185E	40:20:33.87049N	69:08:02.27516E	40:07:15.81920N	71:17:50.10192E	40:12:56.35847N	69:07:35.65928E
test26	40:24:35.80000N	65:11:34.70000E	71.0	40:10:24.50000N	70:12:45.60000E	50.0	41:43:07.73081N	70:47:18.27558E	41:15:29.46607N	68:39:22.65865E	40:23:39.25925N	71:15:45.84597E	39:56:33.64852N	69:10:11.05812E
test27	40:24:35.80000N	65:11:34.70000E	117.0	40:10:24.50000N	70:12:45.60000E	50.0	38:20:32.33083N	70:05:08.22153E	39:09:53.57178N	68:13:51.51407E	39:45:01.83231N	71:08:48.26146E	40:35:21.75120N	69:16:02.91762E
test28	37:09:35.80000N	70:21:34.70000E	0.0	40:10:24.50000N	70:12:45.60000E	50.0	41:00:26.84065N	70:21:34.70000E	39:20:22.39722N	70:21:34.70000E	41:00:26.49479N	70:12:38.92986E	39:20:22.07107N	70:12:51.88818E
test29	37:09:35.80000N	70:21:34.70000E	31.0	40:10:24.50000N	70:12:45.60000E	50.0	40:01:09.54385N	72:36:33.75760E	38:36:16.81276N	71:28:10.67923E	40:53:16.92717N	70:46:33.80034E	39:27:23.36126N	69:39:36.80041E
test30	37:09:35.80000N	70:21:34.70000E	331.0	40:10:24.50000N	70:12:45.60000E	50.0	40:13:21.86911N	68:07:53.03613E	38:46:42.27396N	69:12:35.67163E	40:54:04.71013N	69:40:45.15677E	39:26:36.29194N	70:44:07.71534E
test31	40:14:35.80000S	76:12:34.70000E	350.0	40:10:24.50000S	70:12:45.60000E	40.0	38:52:44.97680S	75:54:07.21038E	40:11:52.39692S	76:11:57.12656E	39:30:36.53650S	70:07:10.29772E	40:50:12.39327S	70:18:21.70242E
test32	40:04:35.80000S	75:12:34.70000E	200.0	40:10:24.50000S	70:12:45.60000E	50.0	42:16:12.64050S	74:07:57.72436E	40:42:17.22780S	74:54:32.53991E	40:56:18.37182S	69:46:38.66583E	39:24:22.40493S	70:38:11.32653E
test33	40:04:35.80000S	72:12:34.70000E	315.0	40:10:24.50000S	70:12:45.60000E	100.0	38:09:45.50471S	69:49:01.12662E	40:32:44.31824S	72:49:35.77432E	38:57:32.89527S	68:44:05.92033E	41:22:09.83417S	71:44:30.08384E
test34	40:04:35.80000S	73:12:34.70000E	270.0	40:10:24.50000S	70:12:45.60000E	50.0	40:00:17.63529S	69:08:04.99603E	40:03:39.33076S	71:18:12.14247E	40:08:25.20509S	69:07:35.90168E	40:11:47.29572S	71:17:58.51179E
test35	40:04:35.80000S	73:12:34.70000E	300.0	40:10:24.50000S	70:12:45.60000E	50.0	38:39:26.28959S	70:09:47.67412E	39:31:32.39864S	71:59:30.22696E	39:43:45.18199S	69:17:44.08525E	40:36:38.84939S	71:08:28.77660E
test36	40:04:35.80000S	73:12:34.70000E	240.0	40:10:24.50000S	70:12:45.60000E	50.0	41:28:31.69569S	69:52:44.13264E	40:40:49.88638S	71:49:00.24598E	40:33:41.08619S	69:14:51.20890E	39:46:37.81172S	71:09:59.27305E
test37	38:04:35.80000S	70:11:34.70000E	180.0	40:10:24.50000S	70:12:45.60000E	50.0	41:00:26.50523S	70:11:34.70000E	39:20:22.07307S	70:11:34.70000E	41:00:26.49902S	70:12:46.49381E	39:20:22.06721S	70:12:44.75738E
test38	38:04:35.80000S	70:11:34.70000E	148.0	40:10:24.50000S	70:12:45.60000E	50.0	40:17:07.13084S	72:00:20.55877E	38:52:56.85946S	70:50:18.83964E	40:52:45.70508S	70:47:40.18638E	39:27:53.54845S	69:38:32.22868E
test39	38:04:35.80000S	70:11:34.70000E	211.0	40:10:24.50000S	70:12:45.60000E	50.0	40:18:46.00666S	68:25:41.54164E	38:53:38.70009S	69:33:47.56507E	40:53:14.02637S	69:38:51.10513E	39:27:25.77604S	70:45:59.66955E
test40	40:24:35.80000S	65:51:34.70000E	90.0	40:10:24.50000S	70:12:45.60000E	50.0	40:16:52.78726S	71:18:36.57794E	40:21:48.85747S	69:08:01.28224E	40:07:38.35059S	71:17:52.01922E	40:12:33.75700S	69:07:34.45828E
test41	40:24:35.80000S	65:51:34.70000E	71.0	40:10:24.50000S	70:12:45.60000E	50.0	38:59:21.92563S	70:45:28.67998E	39:36:03.21874S	68:45:36.55313E	39:51:34.97299S	71:13:03.49121E	40:28:43.60957S	69:11:55.38110E
test42	40:24:35.80000S	65:51:34.70000E	117.0	40:10:24.50000S	70:12:45.60000E	50.0	42:01:19.14270S	70:19:39.19192E	41:19:26.82819S	68:18:23.75678E	40:30:35.82765S	71:12:35.50340E	39:49:40.20801S	69:13:32.78935E
test43	43:09:35.80000S	69:38:25.30000E	0.0	40:10:24.50000S	70:12:45.60000E	50.0	39:20:27.07217S	69:38:25.30000E	41:00:31.67824S	69:38:25.30000E	39:20:22.12663S	70:12:21.11372E	41:00:26.43381S	70:13:11.57361E
test44	43:09:35.80000S	69:38:25.30000E	34.0	40:10:24.50000S	70:12:45.60000E	50.0	40:10:58.21027S	72:13:54.61283E	41:35:13.91157S	71:02:44.04238E	39:28:37.32353S	70:48:27.91118E	40:51:59.02911S	69:36:16.97478E

test45	43:09:35.80000S	69:38:25.30000E	335.0	40:10:24.50000S	70:12:45.60000E	50.0	40:06:15.66891S	67:47:39.73289E	41:37:39.92668S	68:41:26.00208E	39:25:07.21618S	69:45:10.03499E	40:55:33.61492S	70:41:01.20850E
test46	40:24:35.80000S	65:12:40.70000W	350.0	40:10:24.50000S	70:12:45.60000W	40.0	38:58:11.44004S	65:32:11.35937W	40:17:14.24083S	65:14:22.36760W	39:30:39.49061S	70:18:54.59385W	40:50:09.33911S	70:06:34.13853W
test47	40:04:35.80000S	67:12:40.70000W	200.0	40:10:24.50000S	70:12:45.60000W	50.0	41:43:04.52714S	68:00:35.08875W	40:09:08.86953S	67:14:50.23285W	40:56:45.65430S	70:37:27.46544W	39:23:56.63322S	69:48:40.85141W
test48	40:04:35.80000S	68:12:40.70000W	315.0	40:10:24.50000S	70:12:45.60000W	100.0	38:09:39.42011S	70:36:21.58383W	40:32:38.43897S	67:35:47.44055W	38:57:32.70200S	71:41:25.01247W	41:22:10.04449S	68:41:01.39841W
test49	40:04:35.80000S	66:47:19.30000W	270.0	40:10:24.50000S	70:12:45.60000W	50.0	39:59:20.91374S	71:17:19.47416W	40:03:11.27515S	69:07:15.00811W	40:08:10.83970S	71:17:54.39452W	40:12:01.69154S	69:07:33.13622W
test50	40:04:35.80000S	66:47:19.30000W	300.0	40:10:24.50000S	70:12:45.60000W	50.0	38:30:35.82998S	70:08:06.75040W	39:22:59.34750S	68:18:50.55549W	39:43:33.42333S	71:07:37.37083W	40:36:50.98023S	69:17:12.16414W
test51	40:04:35.80000S	66:47:19.30000W	240.0	40:10:24.50000S	70:12:45.60000W	50.0	41:36:36.30412S	70:27:37.90336W	40:49:14.86902S	68:30:52.22885W	40:33:27.89443S	71:10:48.90600W	39:46:50.64641S	69:15:22.88056W
test52	38:04:35.80000S	70:11:34.70000W	180.0	40:10:24.50000S	70:12:45.60000W	50.0	41:00:26.50523S	70:11:34.70000W	39:20:22.07307S	70:11:34.70000W	41:00:26.49902S	70:12:46.49381W	39:20:22.06721S	70:12:44.75738W
test53	38:04:35.80000S	70:11:34.70000W	148.0	40:10:24.50000S	70:12:45.60000W	50.0	40:16:18.90281S	68:23:29.95567W	38:52:08.17125S	69:33:30.08556W	40:52:46.41906S	69:37:52.49907W	39:27:52.86878S	70:46:57.54788W
test54	38:04:35.80000S	70:11:34.70000W	211.0	40:10:24.50000S	70:12:45.60000W	50.0	40:19:33.41765S	71:58:06.74176W	38:54:26.53851S	70:49:59.19702W	40:53:13.33180S	70:46:41.59808W	39:27:26.43690S	69:39:30.09147W
test55	40:24:35.80000S	74:11:34.70000W	90.0	40:10:24.50000S	70:12:45.60000W	50.0	40:17:53.93865S	69:06:53.05426W	40:22:24.75464S	71:17:31.47355W	40:07:50.95861S	69:07:38.20443W	40:12:21.11411S	71:17:57.31644W
test56	40:24:35.80000S	74:11:34.70000W	71.0	40:10:24.50000S	70:12:45.60000W	50.0	39:05:20.87464S	69:36:38.15858W	39:41:42.34805S	71:36:49.98435W	39:51:46.35643S	69:12:21.64904W	40:28:31.97625S	71:13:41.67519W
test57	40:24:35.80000S	74:11:34.70000W	117.0	40:10:24.50000S	70:12:45.60000W	50.0	41:54:54.96618S	70:02:37.71975W	41:12:42.82714S	72:03:28.17431W	40:30:47.80049S	69:13:02.54949W	39:49:28.51990S	71:11:51.36671W
test58	43:09:35.80000S	70:21:34.70000W	0.0	40:10:24.50000S	70:12:45.60000W	50.0	39:20:22.39722S	70:21:34.70000W	41:00:26.84065S	70:21:34.70000W	39:20:22.07107S	70:12:51.88818W	41:00:26.49479S	70:12:38.92986W
test59	43:09:35.80000S	70:21:34.70000W	34.0	40:10:24.50000S	70:12:45.60000W	50.0	40:20:09.24057S	67:53:40.37644W	41:44:20.61162S	69:05:11.16171W	39:28:45.24018S	69:36:47.75179W	40:51:50.71125S	70:49:30.38048W
test60	43:09:35.80000S	70:21:34.70000W	331.0	40:10:24.50000S	70:12:45.60000W	50.0	40:10:21.52153S	72:30:11.26250W	41:38:48.88727S	71:28:25.57541W	39:26:35.31407S	70:44:05.41422W	40:54:03.53921S	69:40:42.41911W

United States Standard for

Performance Based Navigation (PBN)

Volume 2

Helicopter Area Navigation (RNAV)

RESERVED

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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).

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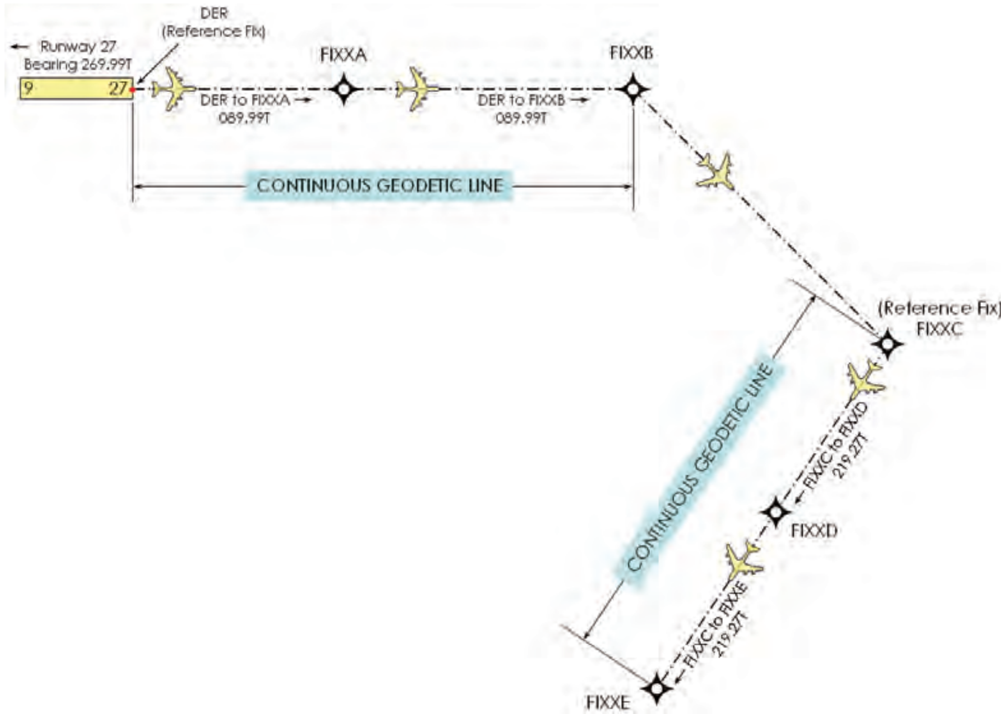
Figure 1-1. Fix Definition Example



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).

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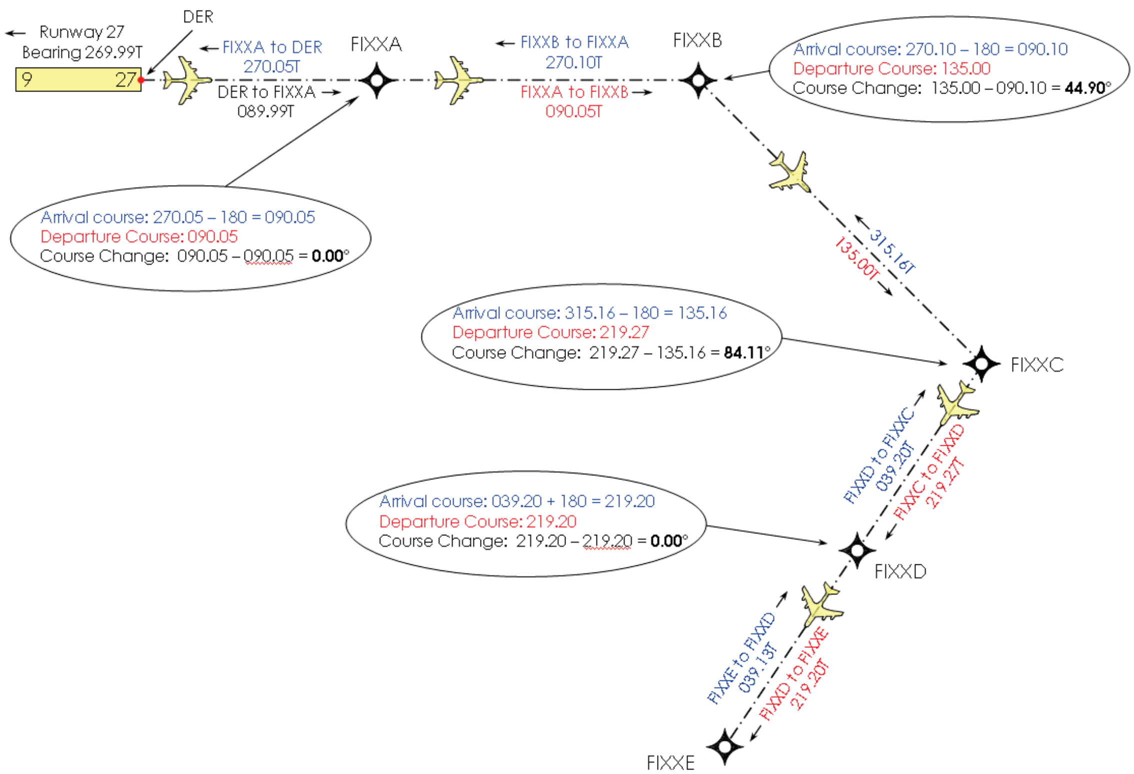
Figure 1-2. Course Change Example



1.4 VA and VI Leg Length Standards.

1.4.1 For LNAV engagement, VA legs must be designed to end at least 500 ft above the airport elevation.

1.4.2 The minimum allowable VI leg length is the greater of 1 NM from DER or 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.

1.4.3 The maximum allowable VA or VI leg length is 10 NM.

1.5 Additional Leg Length Standards.

1.5.1 For segment length considerations, turns of 10 degrees 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) $d_{500} = round[d_{500}, 0]$ $d_{350} = round[d_{350}, 0]$

(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** $(alt$ 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*): $ROC = \text{ceiling}\left[\frac{h}{0.76} - h\right]$

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

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

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

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

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Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 3. Area Construction

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.

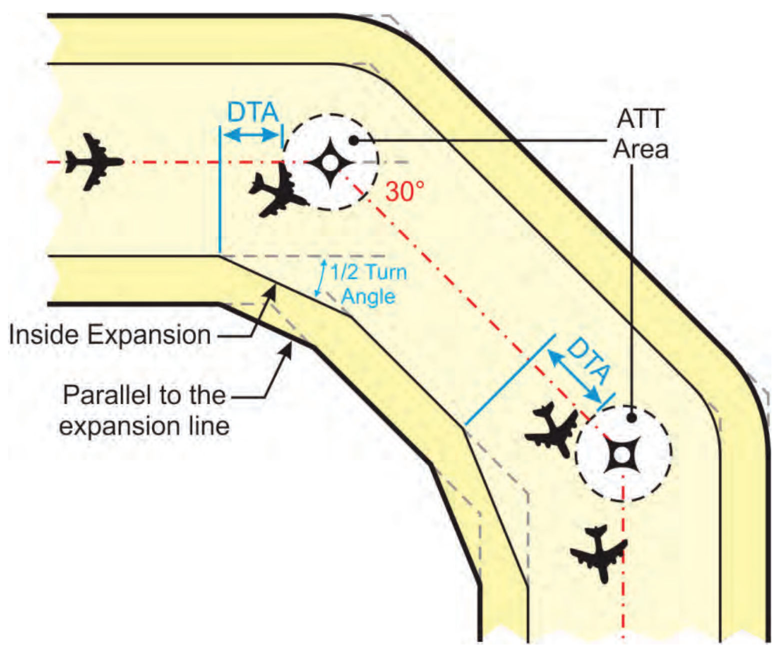
3.1 **Course Change Limitations.** For turns to join a CF or TF leg, the maximum allowable course change or magnitude of heading change below FL 195 is 90 degrees; course changes at or above FL 195 must not exceed 70 degrees.

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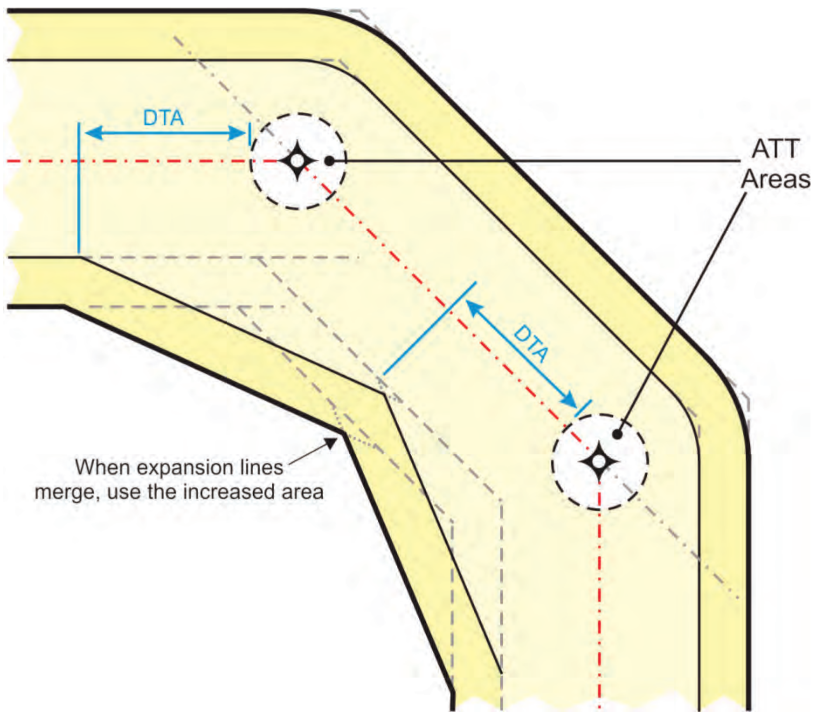
3.2.1 **b. In some cases, the calculated DTA** may cause the expansion lines to merge, increasing the size of the expanded areas. This construction is permissible; utilize the increased area (see figure 3-2).

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.

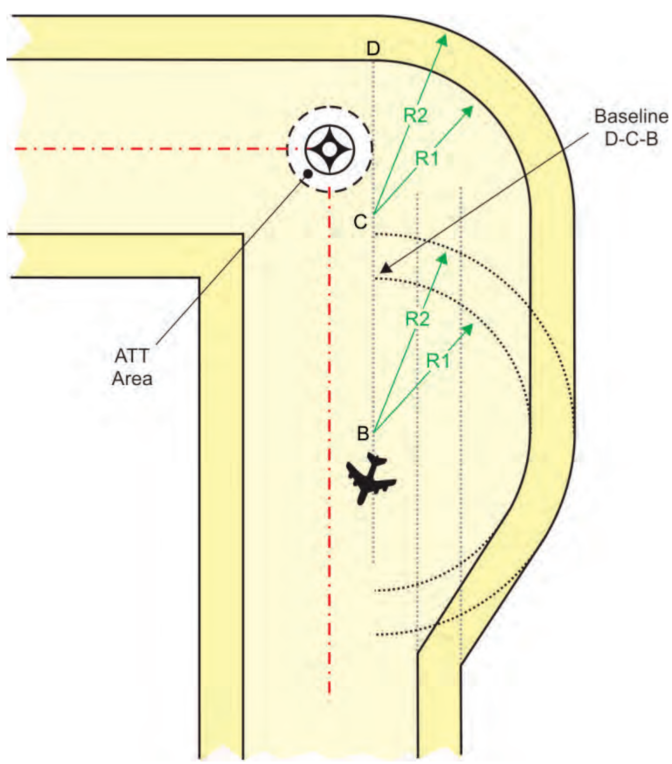
3.3.2 **Outside Expansion Area, TF, or CF Legs.** The primary area boundary (R1) is the calculated Turn Radius, Volume 6 calculator 1-3c, based on the altitude at the fix. The secondary area boundary (R2) is the calculated Turn Radius value plus 1 NM or, where beyond 30 NM from the ARP, the calculated 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.

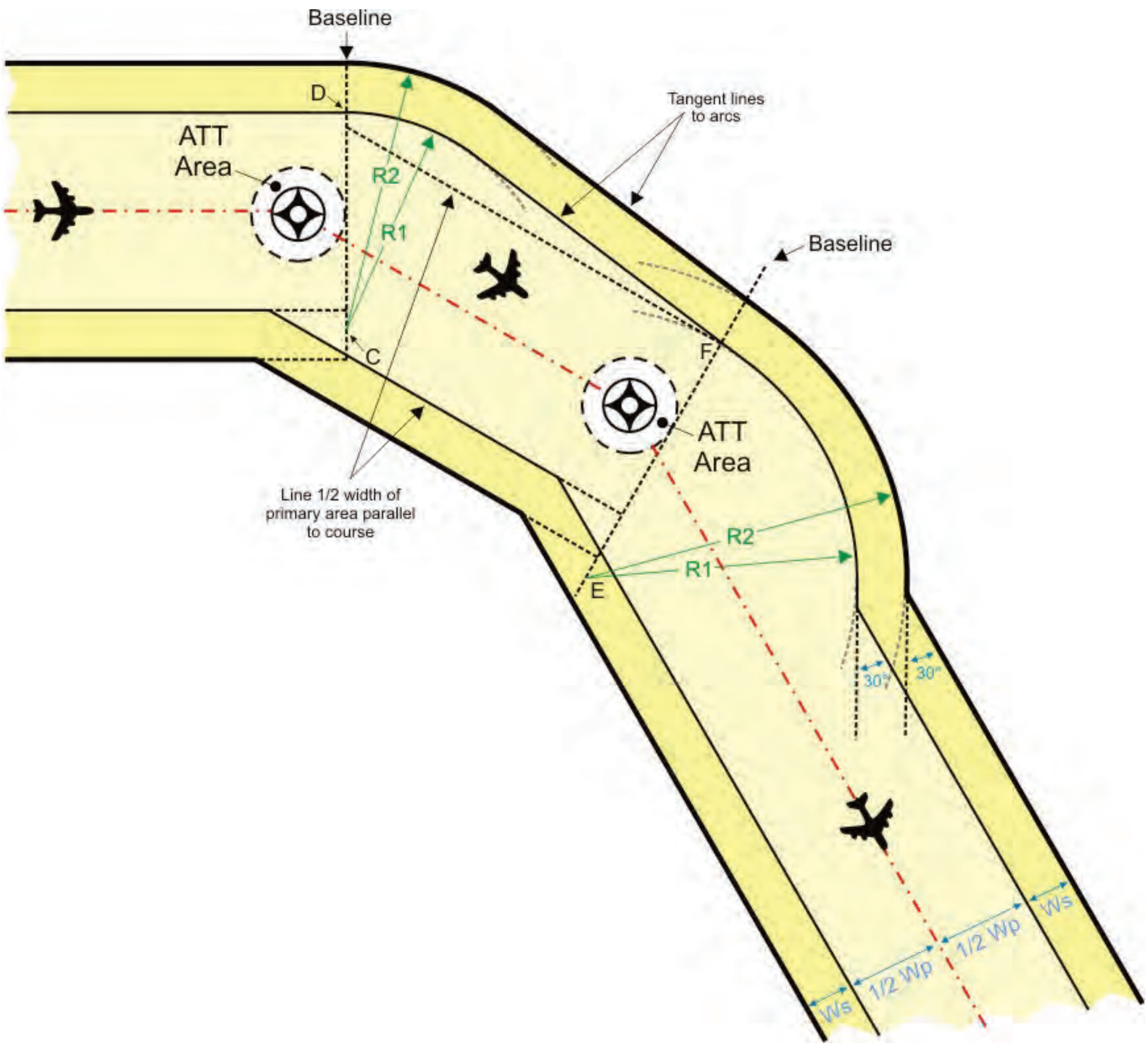
3.3.2 **b. 90 degree turns.** Construct R1 and R2 arcs from point C as defined in paragraph 3.3.2a. From where the inbound primary boundary would intersect the baseline, locate point B on the baseline at a distance equal to the R2 value. Draw another set of R1 and R2 arcs for additional outside turn 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**



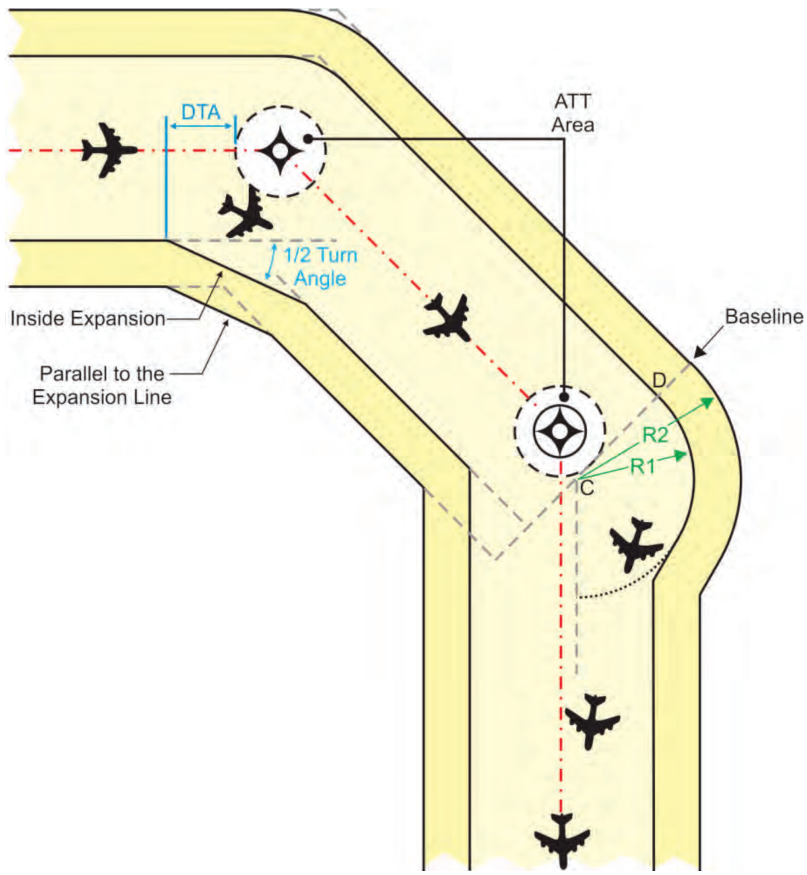
3.3.2 **c. Successive FO Fixes.** Applicable to successive FO fixes in close proximity, construct another baseline after the ATT area of the subsequent fix for the outside expansion boundaries. Construct a line on the outside of the turn, parallel to the course, offset by a distance one-half the segment 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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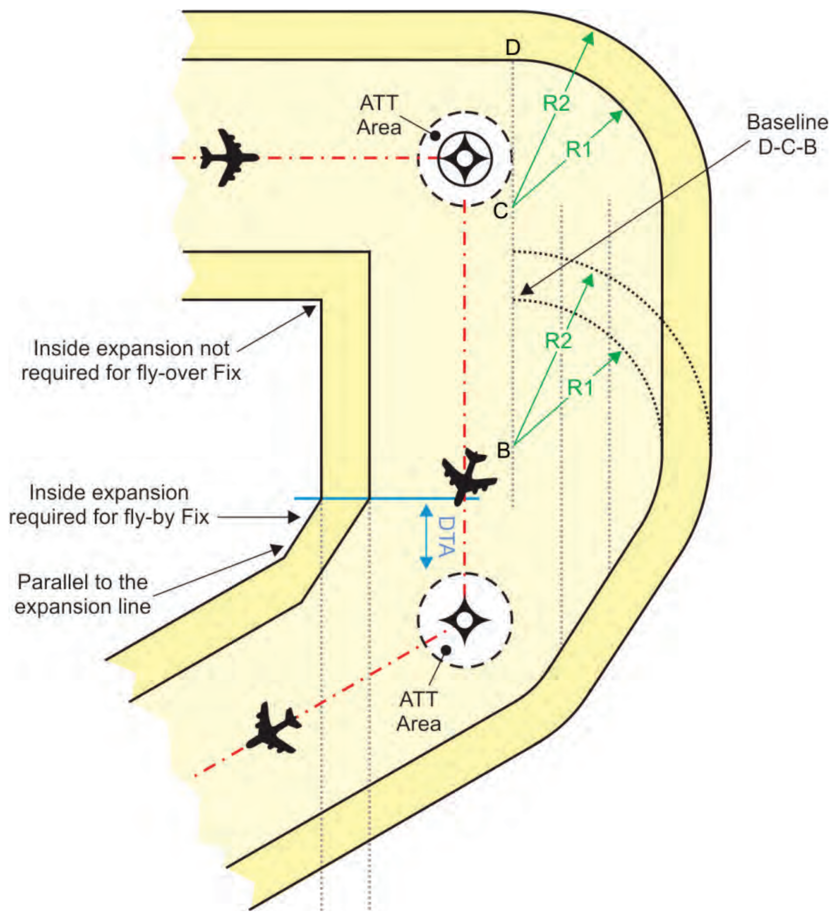
Figure 3-6. FO Fix to FB Fix Turns



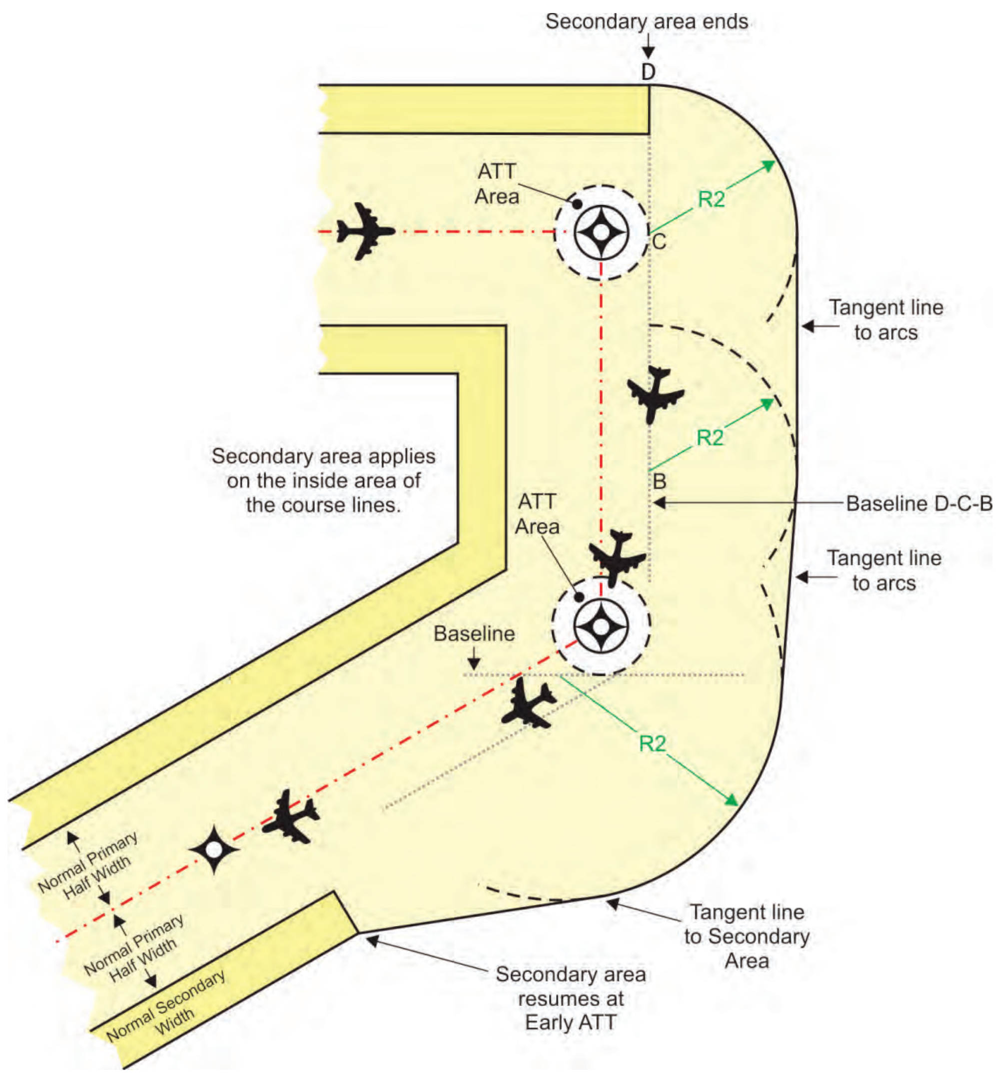
3.3.5 DF Leg FO Turn Construction.

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

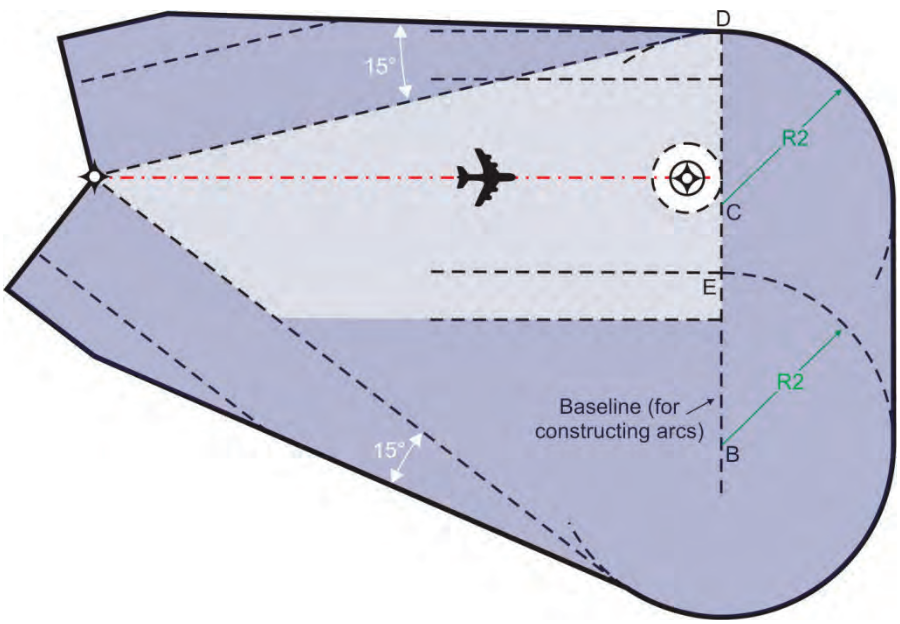


3.3.5 **d. For turns more than 90 degrees,** all inbound primary and secondary boundaries continue until the ATT area baseline. Locate point B at the same R2 distance from the inbound leg primary area width on the baseline (point E). Draw another R2 arc, using point B as the center point, from point 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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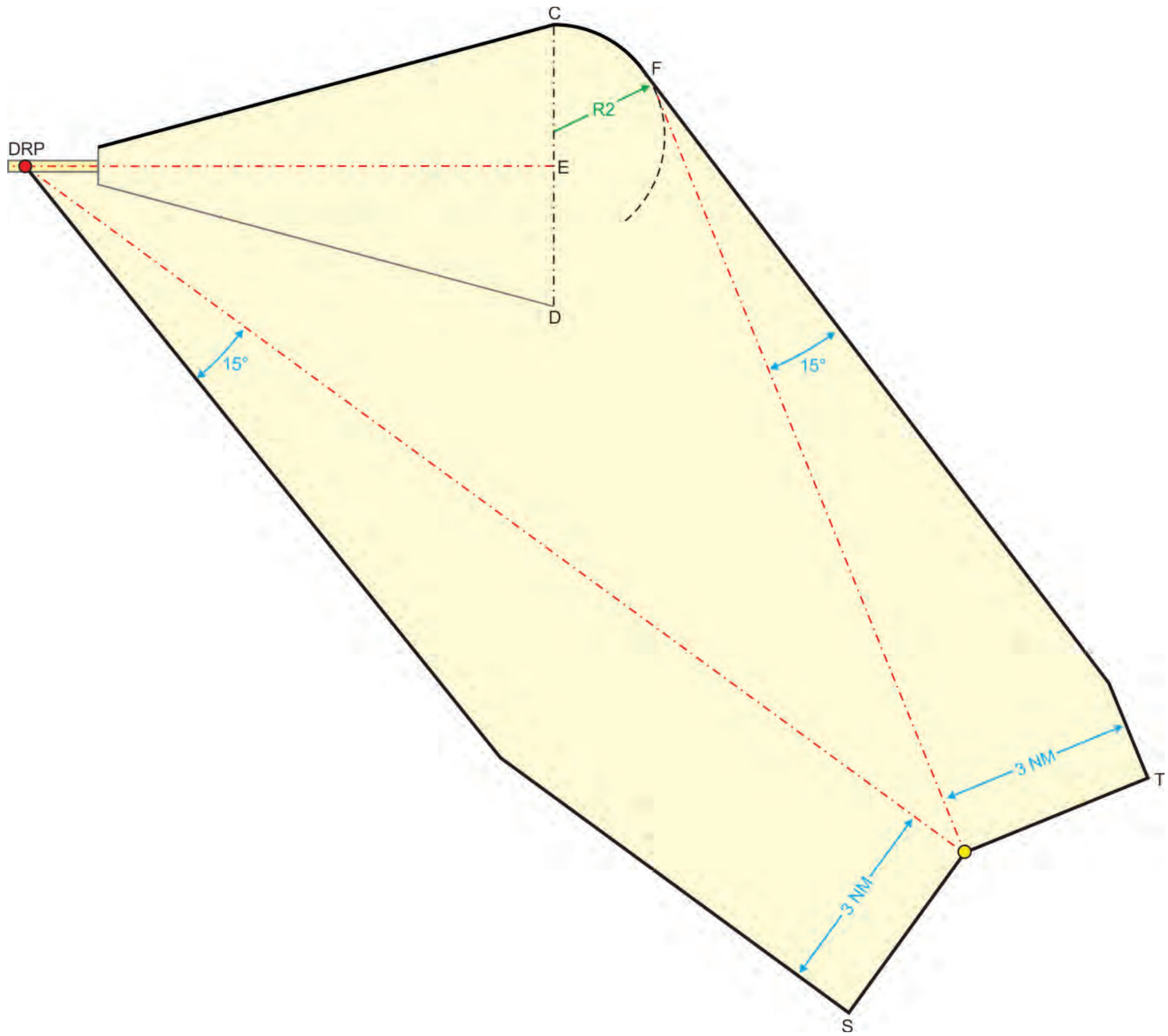
**Figure 3-9. VA-DF Construction –
Turn less than 90 degrees, DRP Inside Boundary Line**



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**

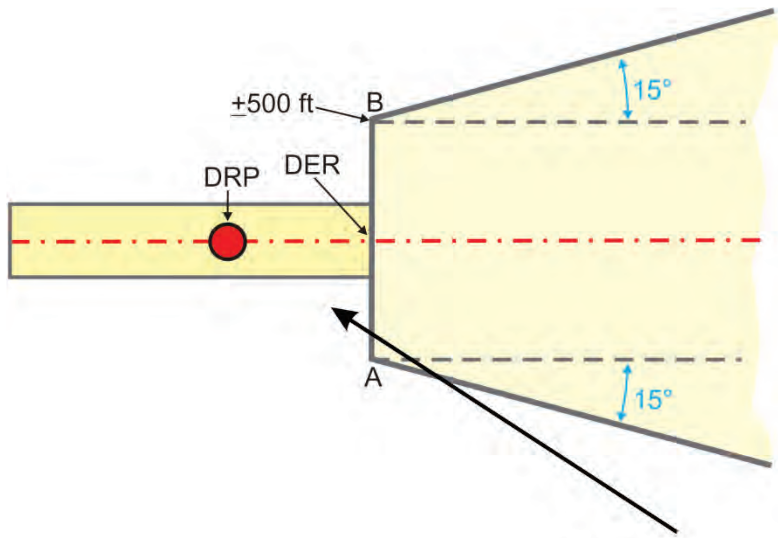
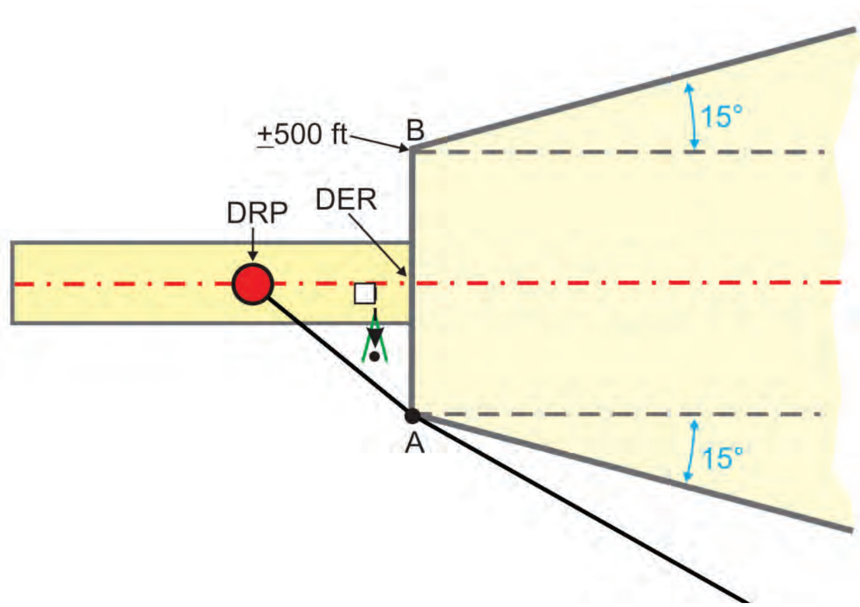


**Figure 3-10B. VA Leg Construction
Alternate Inside Boundary**



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).

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

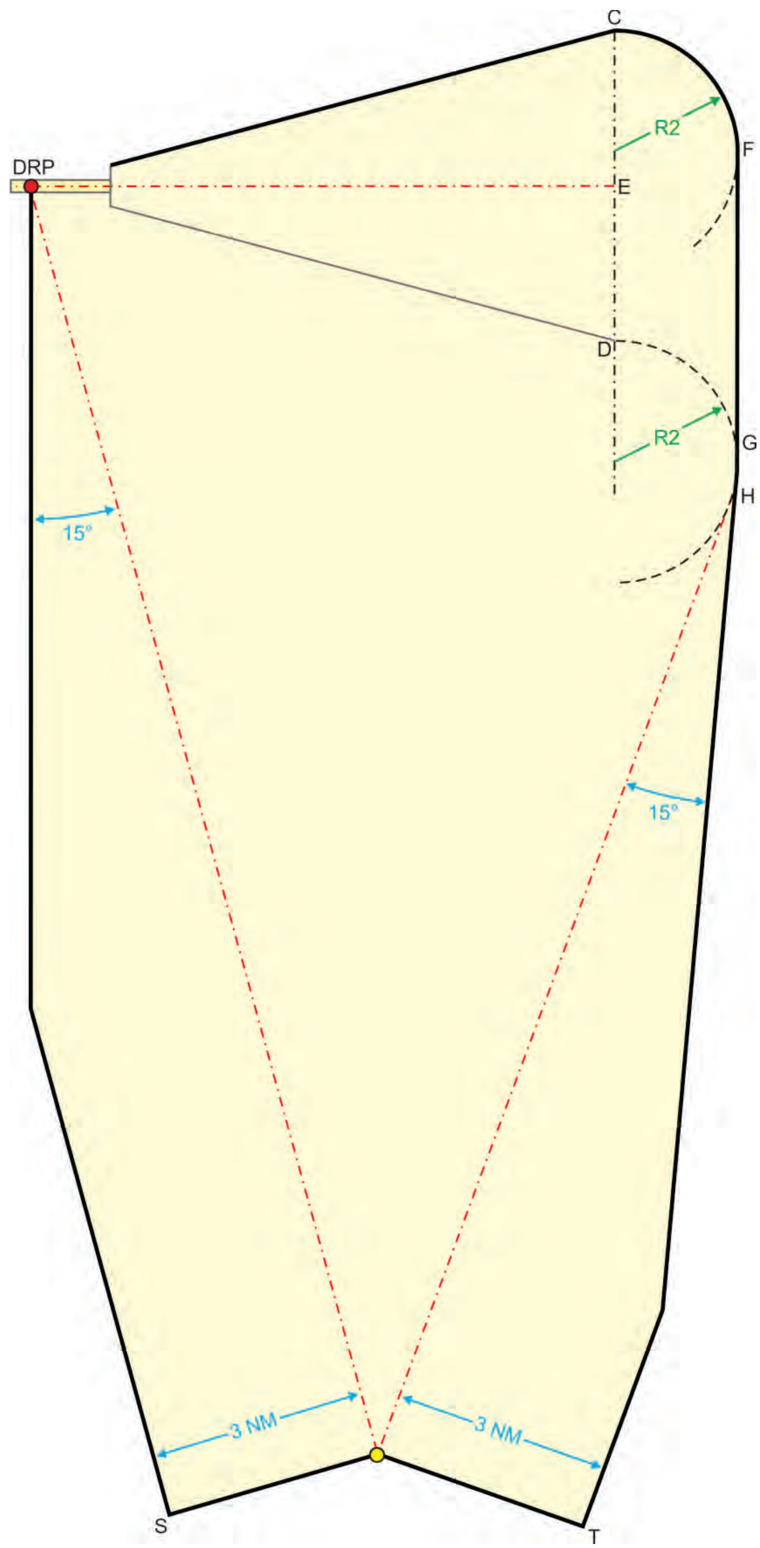
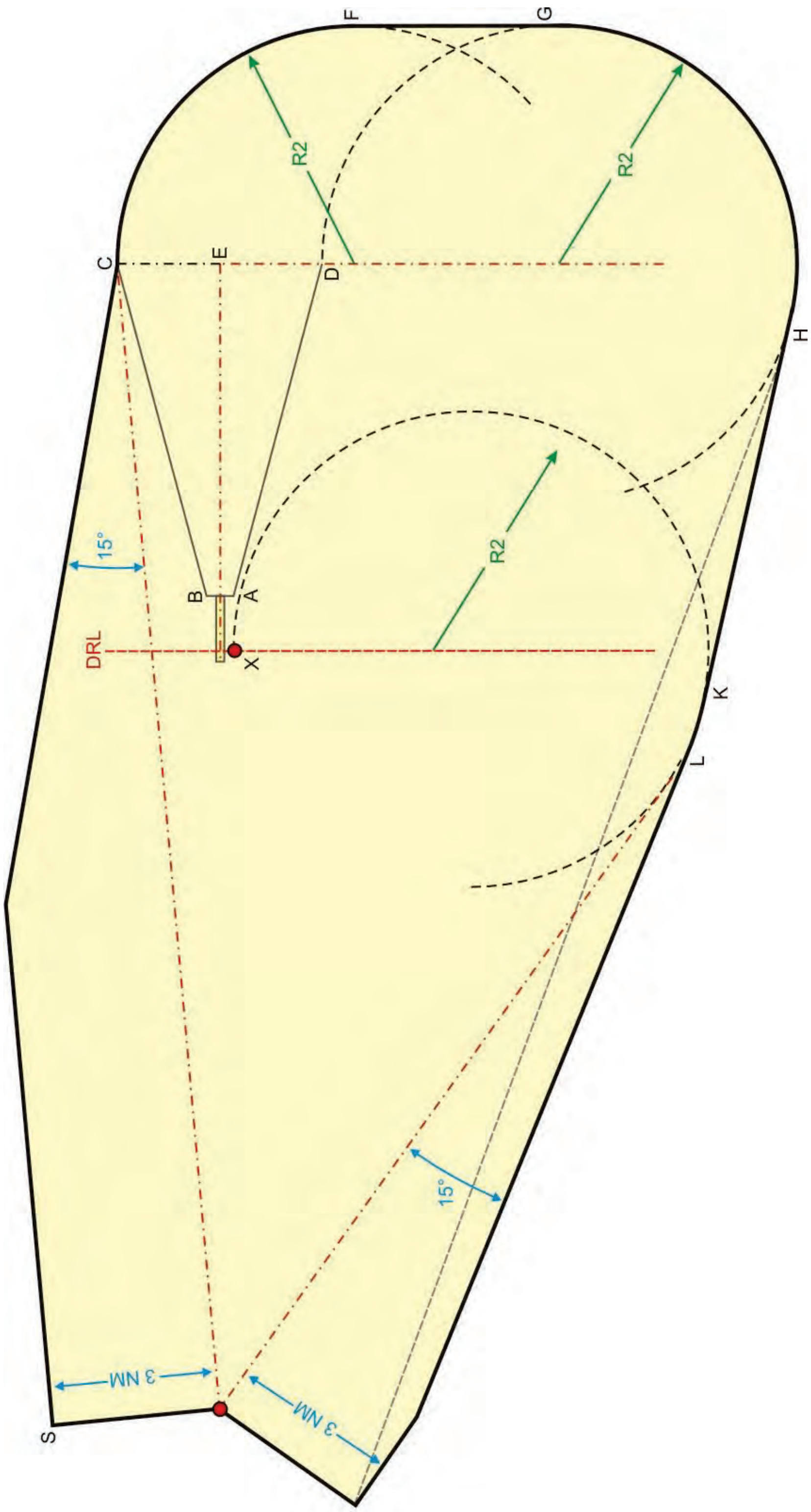


Figure 3-12.VA-OF Construction
180 degree Right Turn



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.

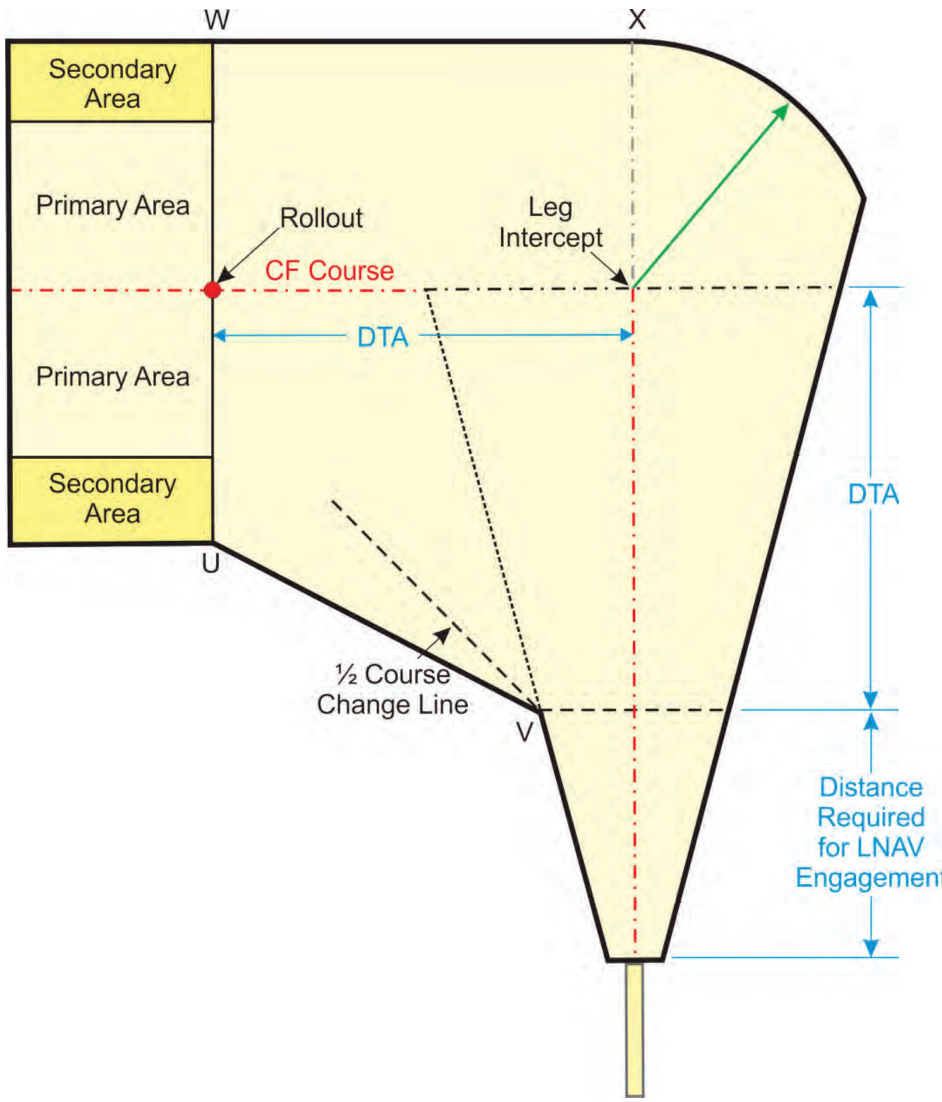
3.9.1 **Inside Expansion Area.** Inside expansion starts where the VI DTA area begins (point V) with an angle drawn at one-half of the course change at leg intercept and ends where the angle converges with the CF leg secondary boundary. Where the angle does not converge with the secondary boundary, draw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



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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.

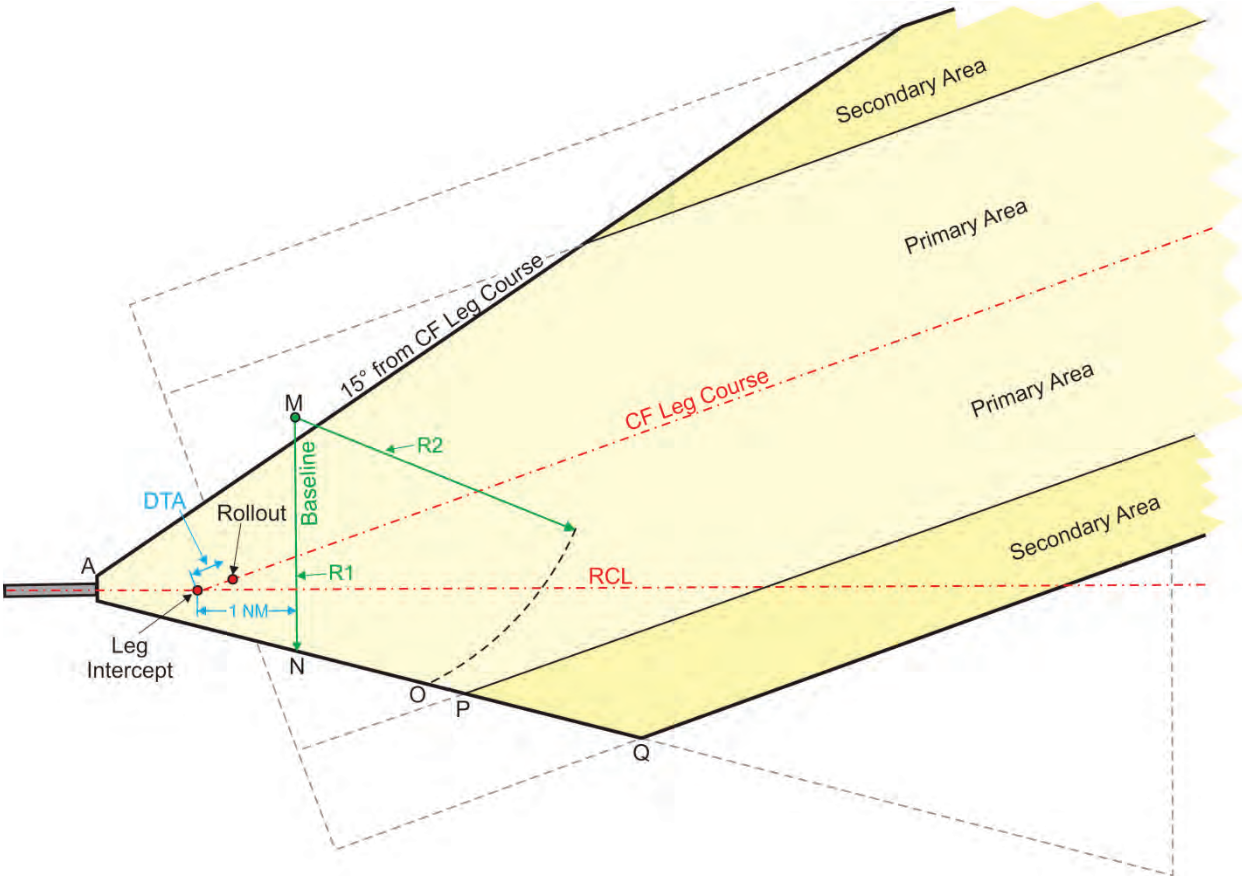
3.10.3 Outside Expansion Area.

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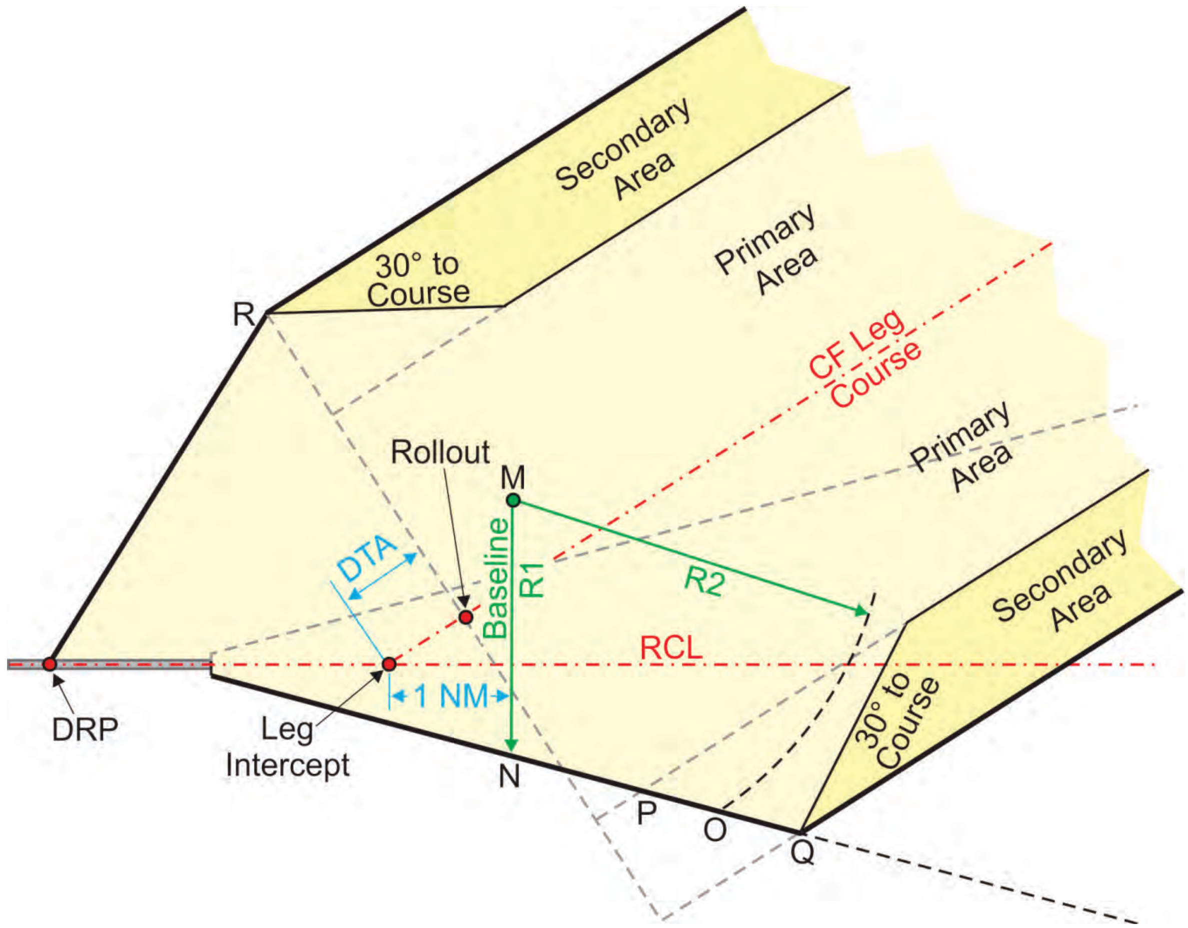
Figure 3-15. Minimum VI-CF Construction, Greater than 30 degree Turn



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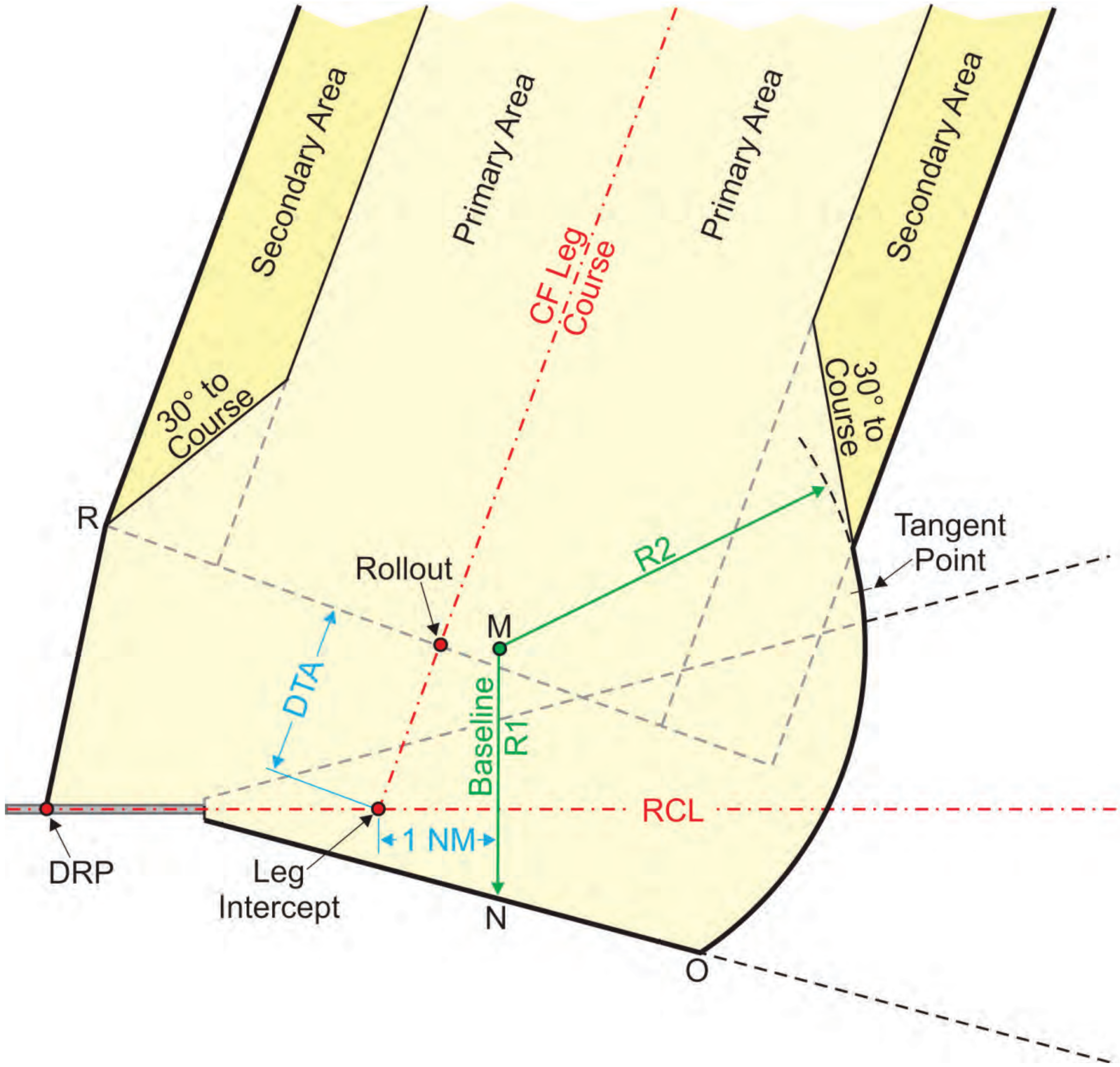
Figure 3-16. Minimum VI-CF Construction, 75 degree Turn



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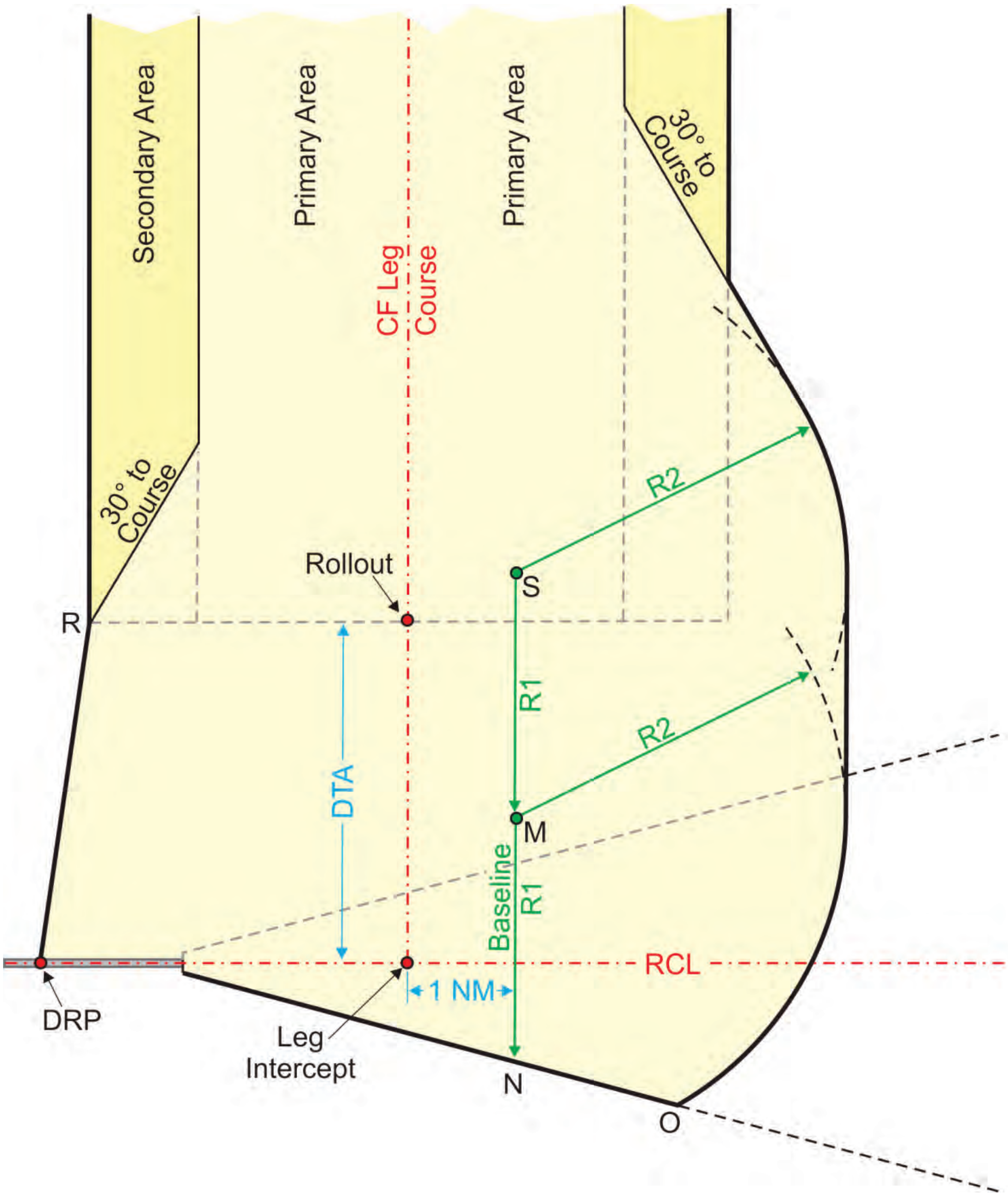
Figure 3-17. Minimum VI-CF Construction, 90 degree Turn



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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

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.

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Figure 4-1. VA-DF Construction OEA Assessment

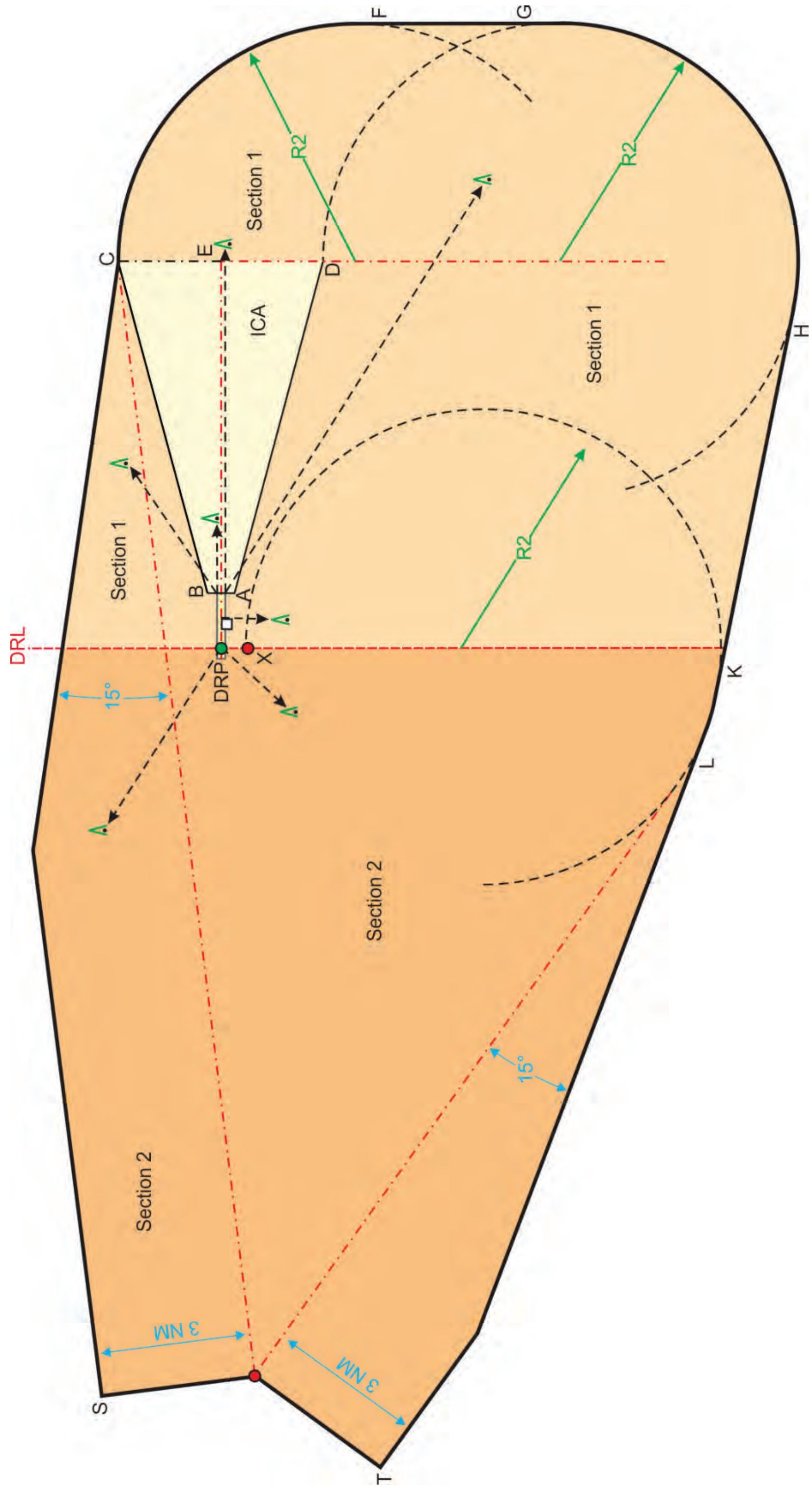

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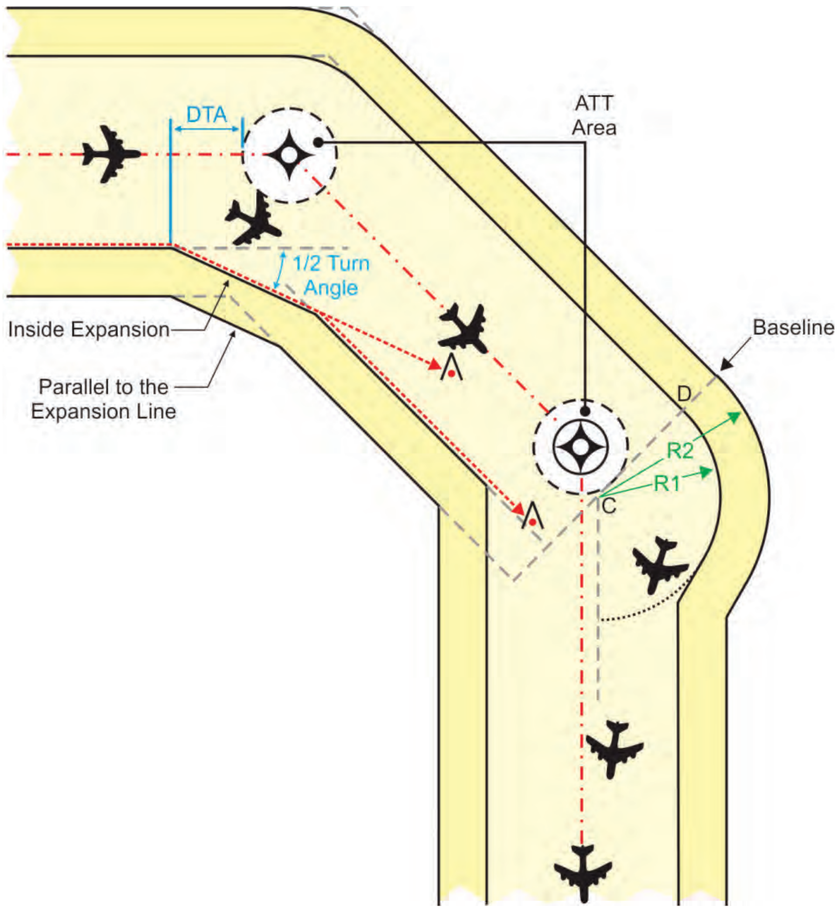
Figure 4-2. Fix Turn Construction OEA Assessment



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Volume 3. RNAV and RNP 1 Departure Procedures

Chapter 5. VA-DF Leg Length Analysis

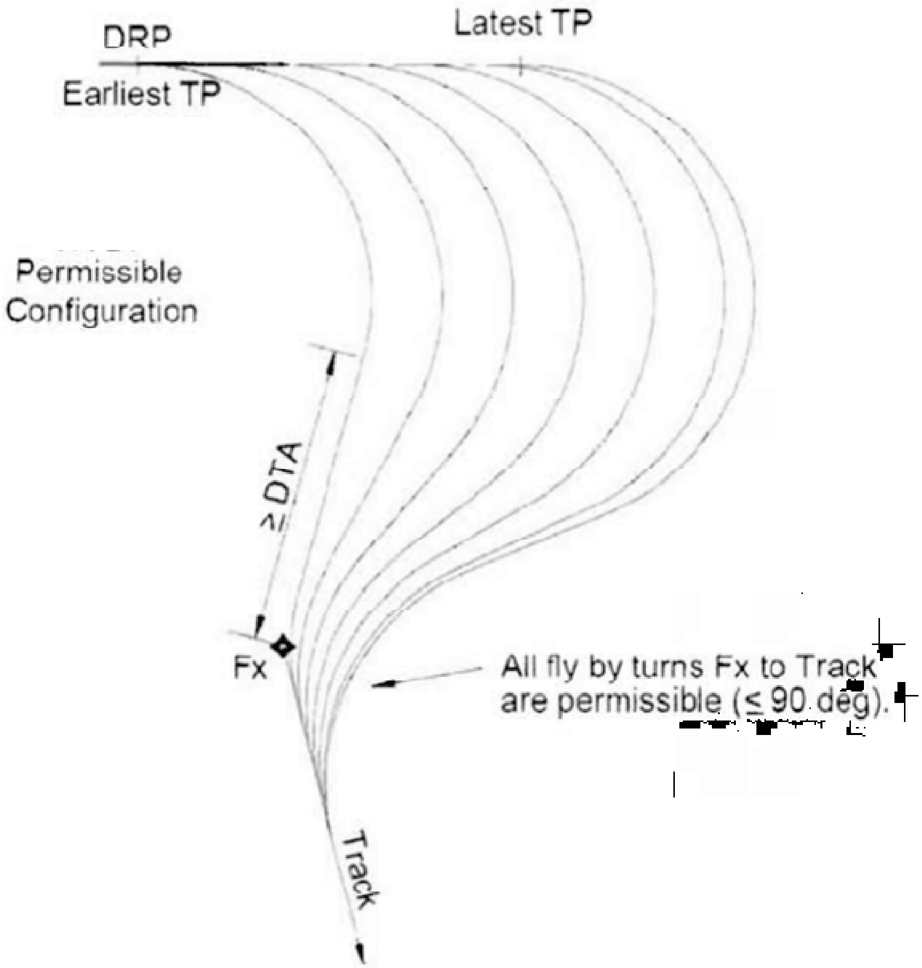
5.0 **Purpose.** This analysis is created to provide guidance for evaluating the DF maneuver but does not mirror OEA construction. In this assessment, the VA leg Earliest TP and Latest TP are treated as a FO fix.

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.

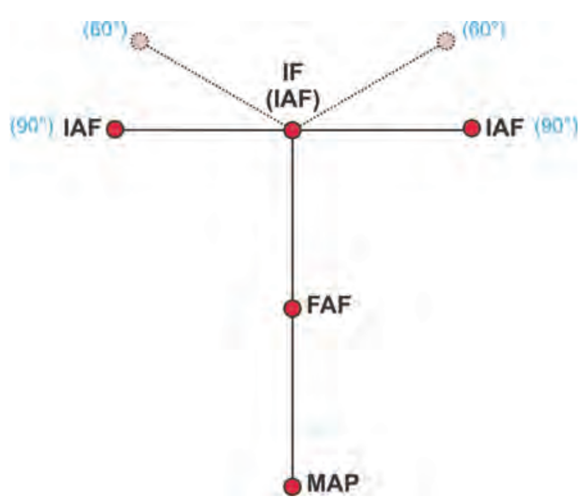
1.1 Initial, Intermediate, Final and Missed Approach Segments.

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.

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

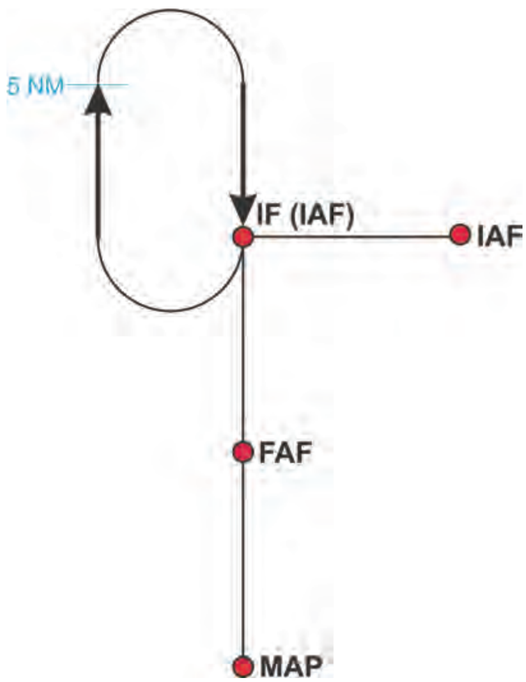


Figure 1-1C. Basic T Parallel Runway Application

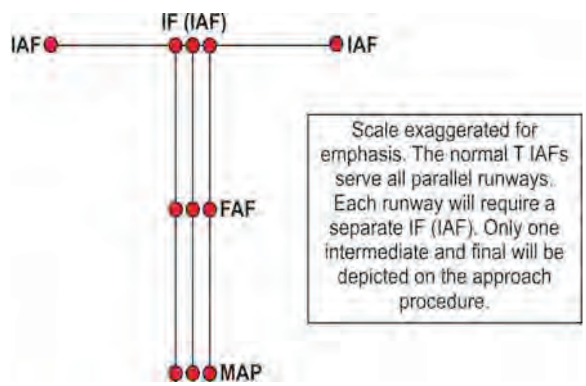


Table 1-1. Minimum Initial Segment Length for TAA Construction

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

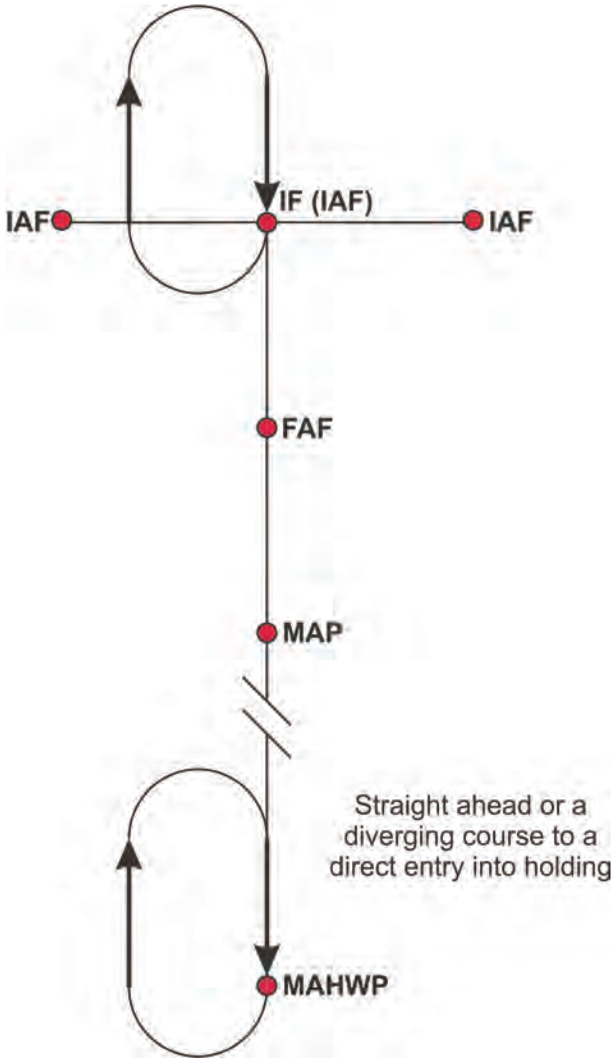
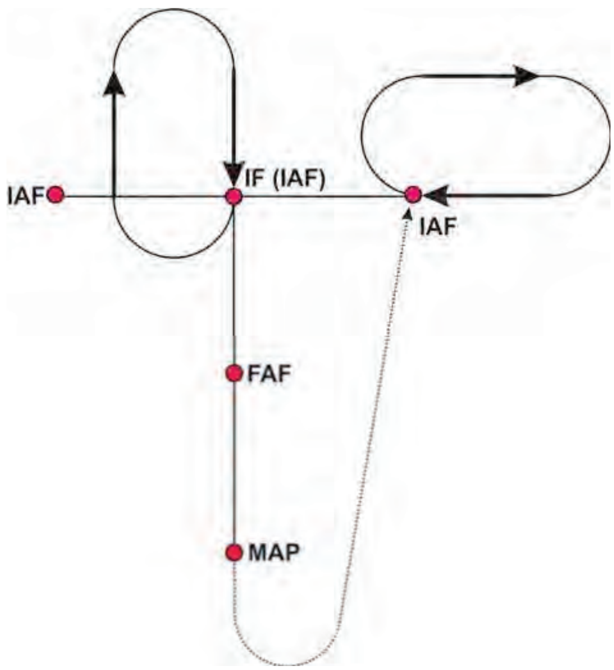


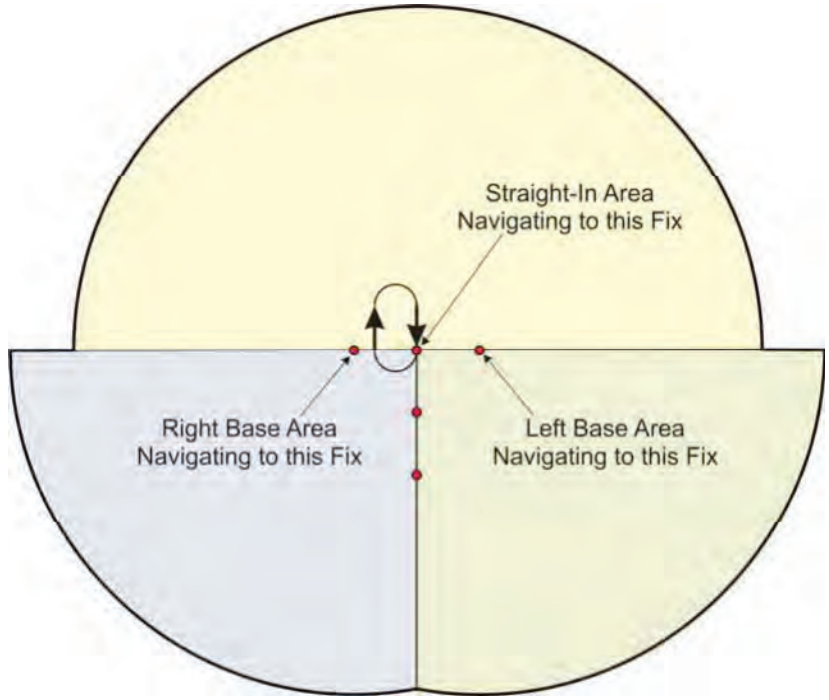
Figure 1-2B. Missed Approach Holding at an IAF



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.

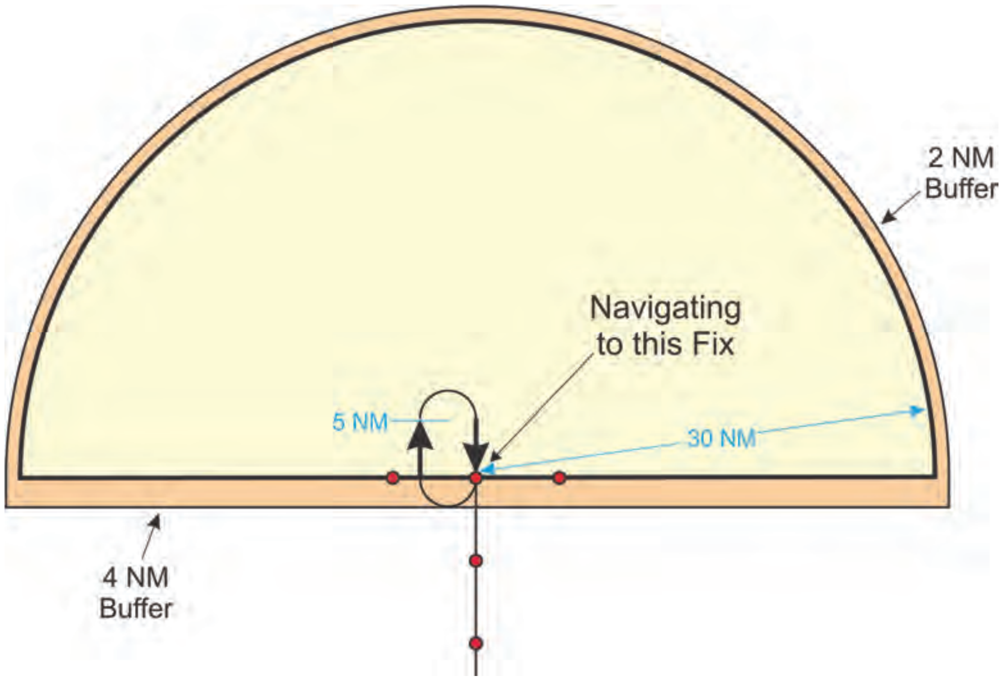
The arc boundary of the straight-in area is equivalent to a feeder fix. When crossing the boundary or when released by ATC within the straight-in area, the pilot can maneuver as necessary within the TAA sector to enter at a given IAF at an airspeed and intercept angle to correctly fly the procedure (assume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



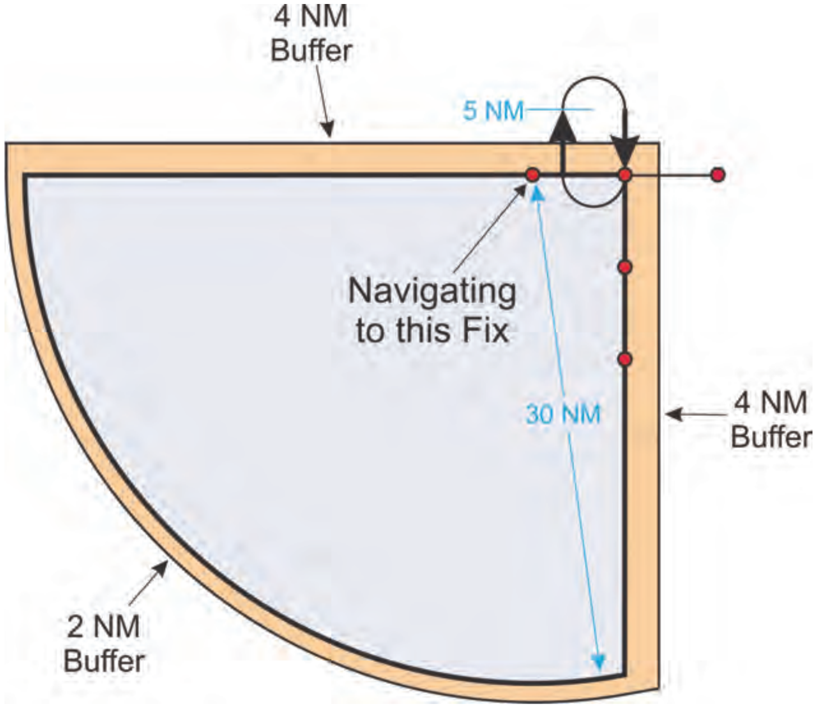
1.2.2 Right Base Area.

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



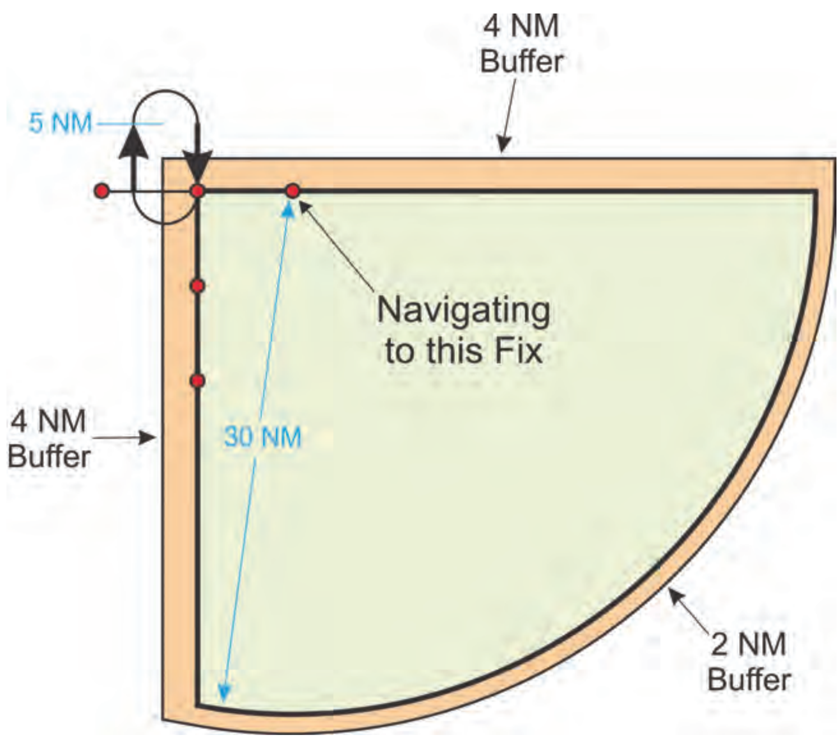
1.2.3 Left Base Area.

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

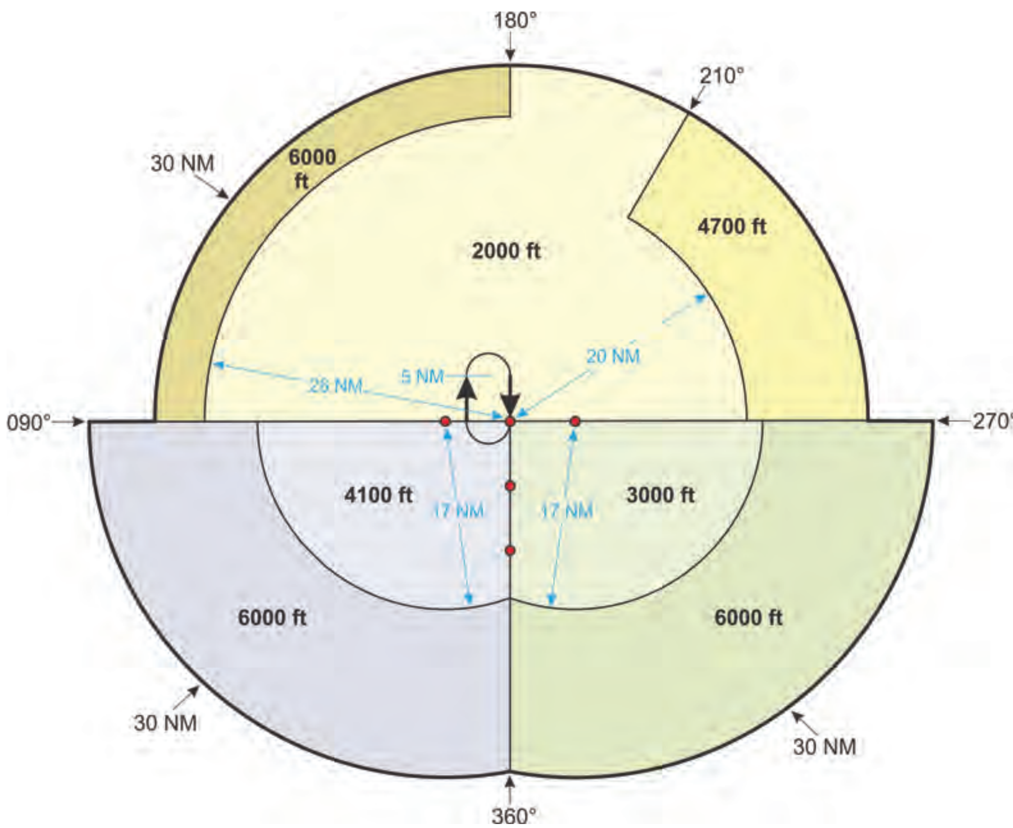


Figure 1-4B. TAA Maximum Sectorization with Maximum Stepdown Arcs

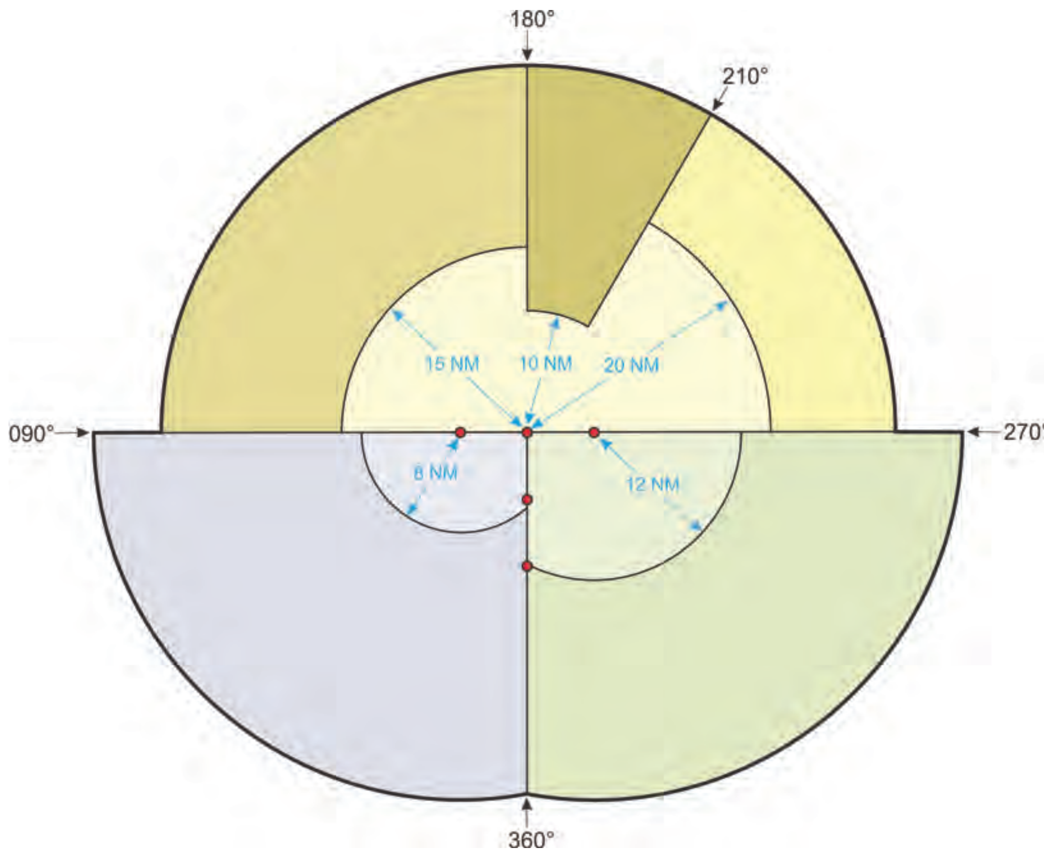


Figure 1-4C. TAA Maximum Sectorization with Maximum Stepdown Arcs

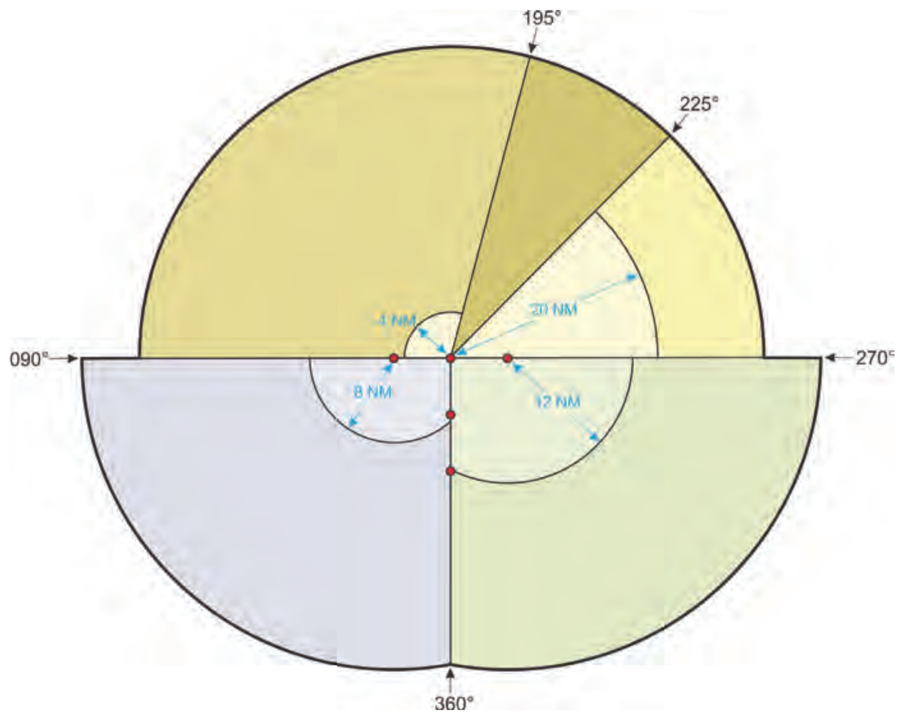
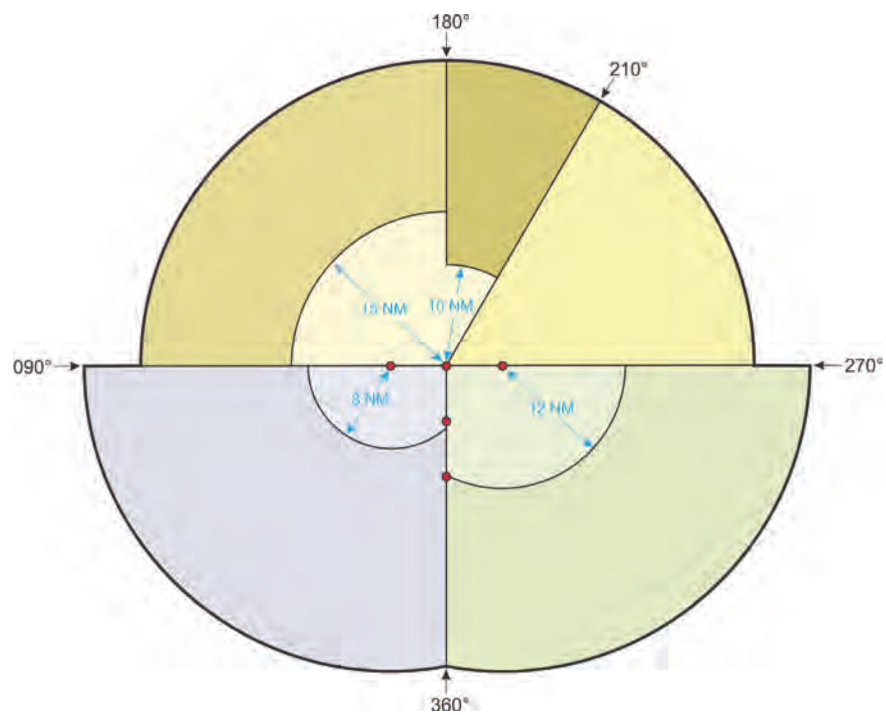


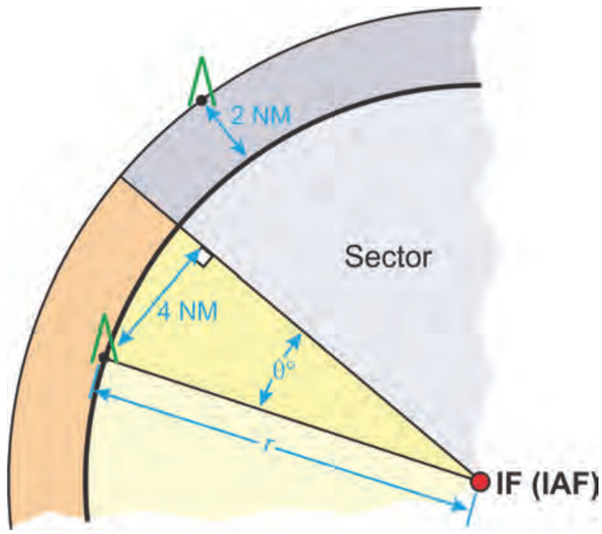
Figure 1-4D. TAA Maximum Sectorization with Maximum Stepdown Arcs



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

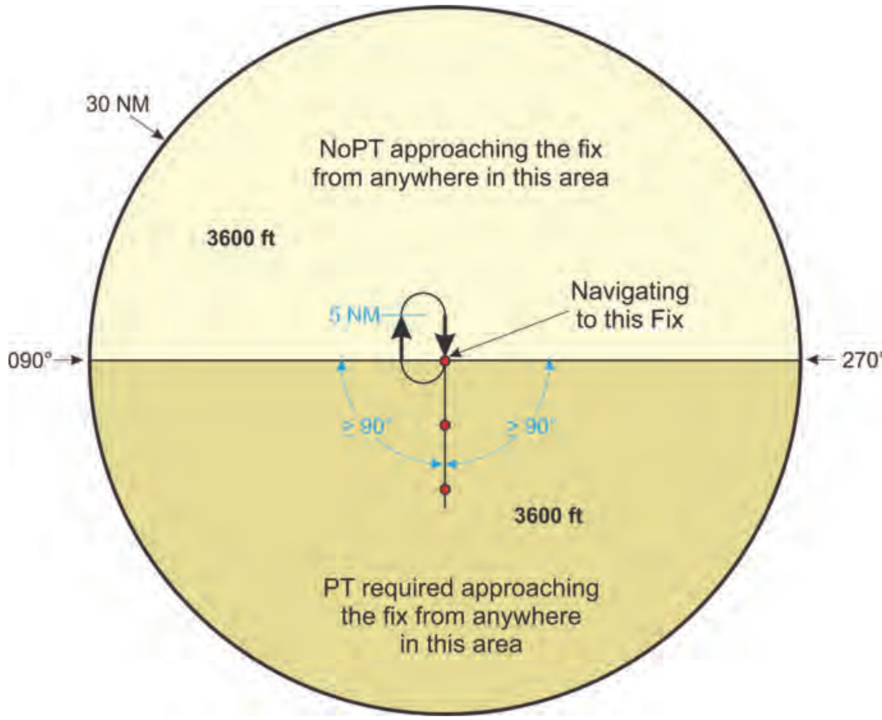


Figure 1-5B. TAA with Right Base Eliminated

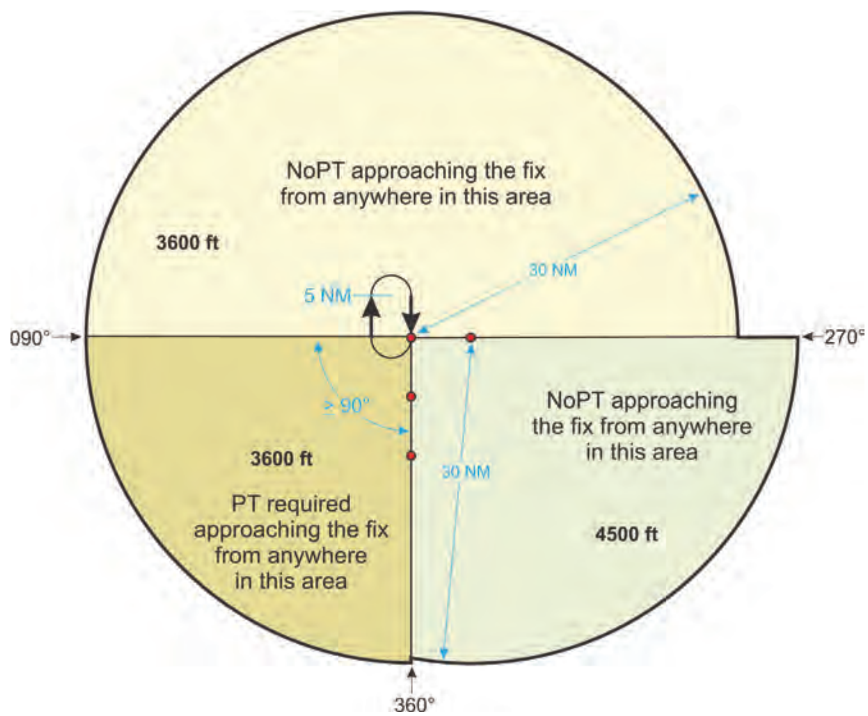


Figure 1-5C. TAA with Left Base Eliminated

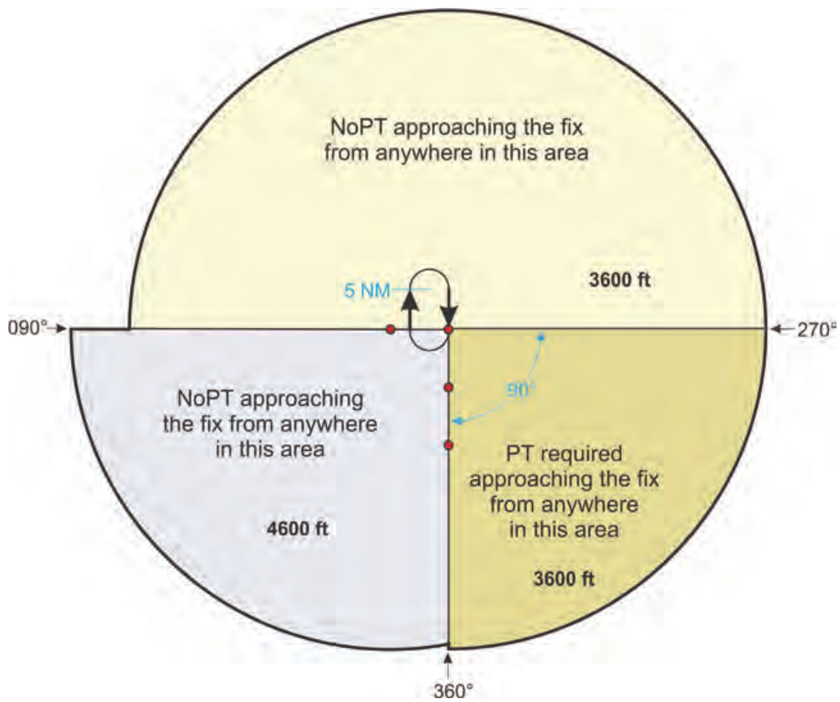


Figure 1-5D. TAA with Part of Straight-In Area Eliminated

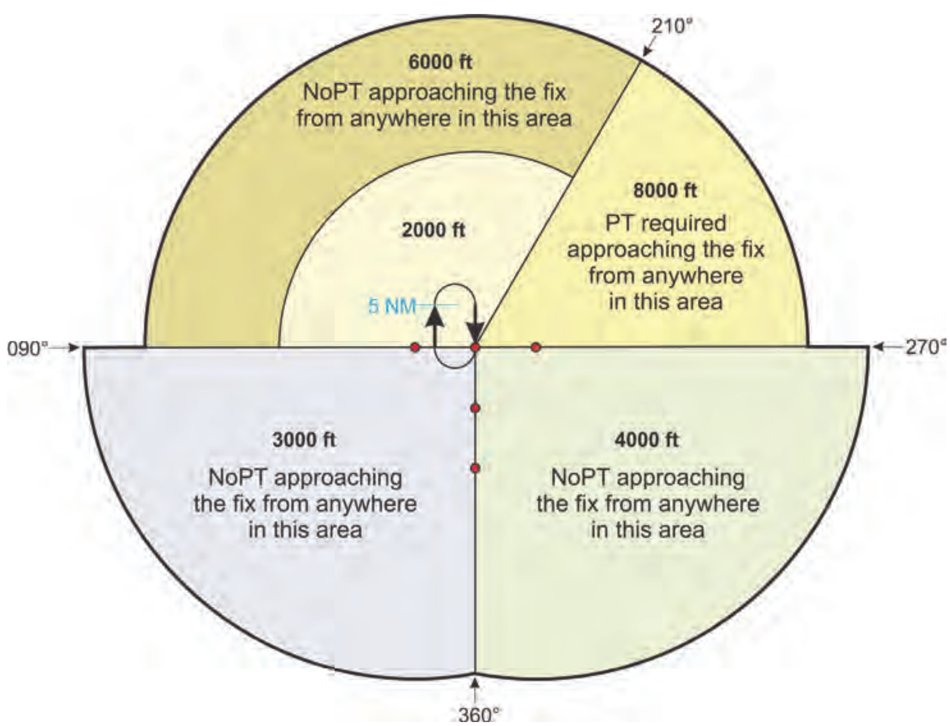
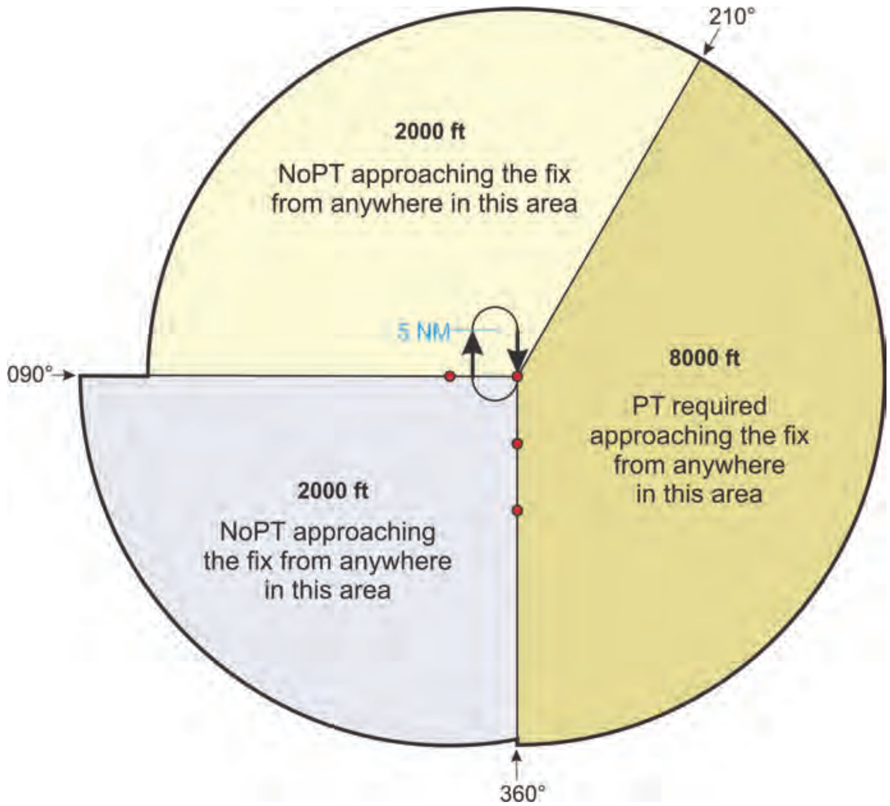


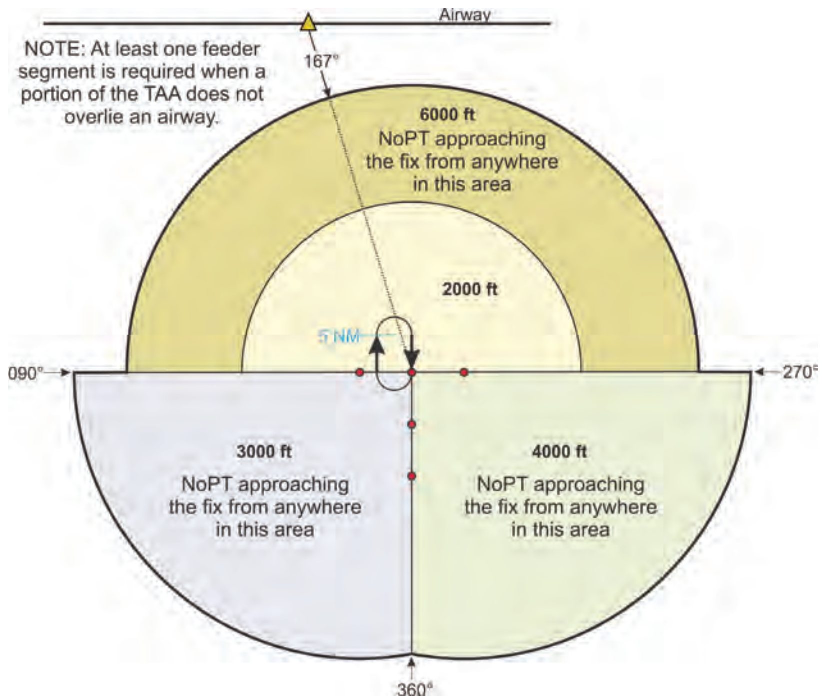
Figure 1-5E. TAA Example with Left Base and Part of Straight-In Area Eliminated



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: / 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 2-1B. 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

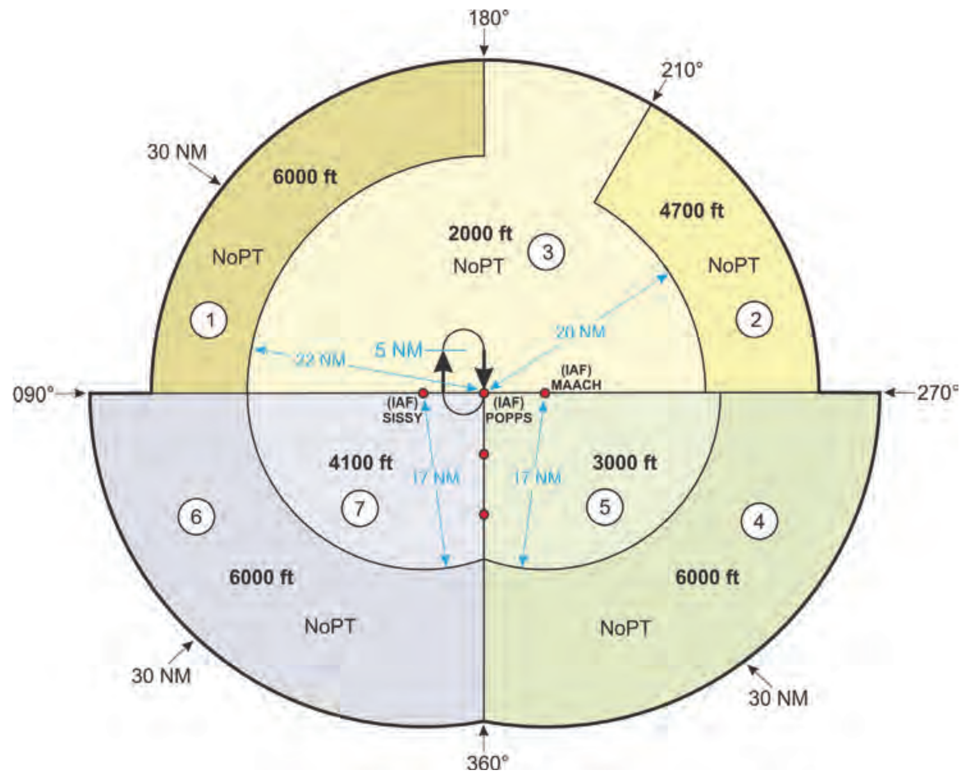
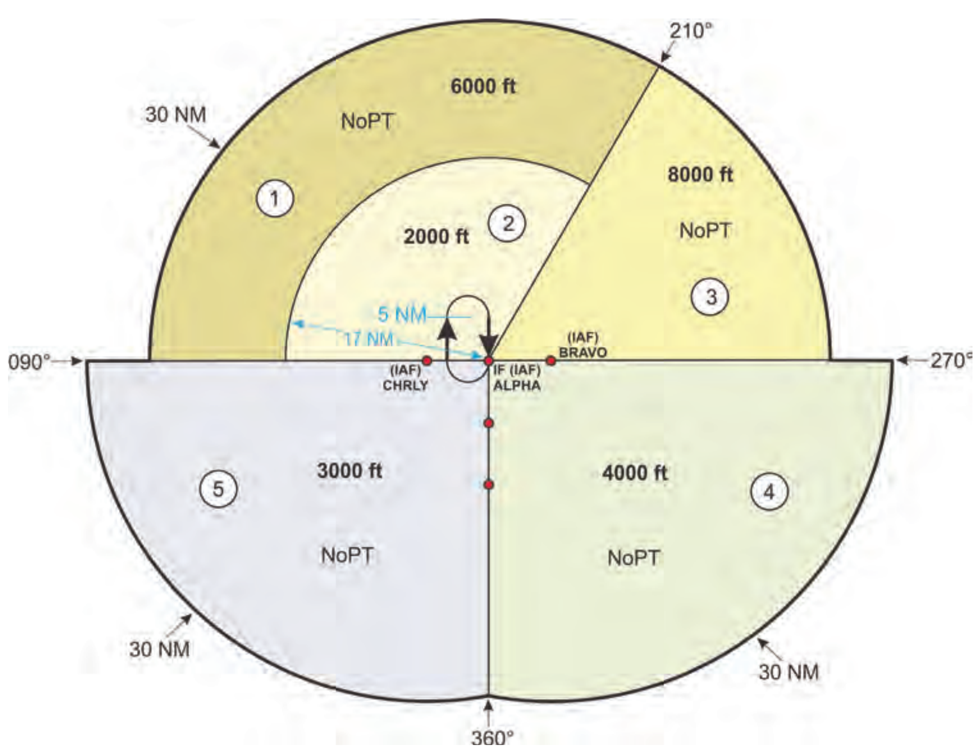


Figure 2-2B. Example 2



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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

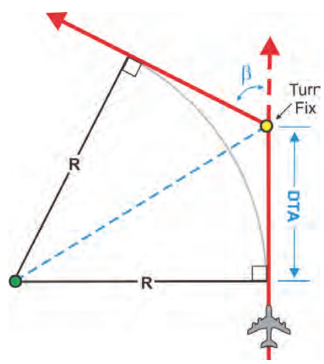
FROP. However, this does not negate the requirement to publish RNP 0.3 minimums with the standard RNP or alternative RNAV missed approach.

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

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

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

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

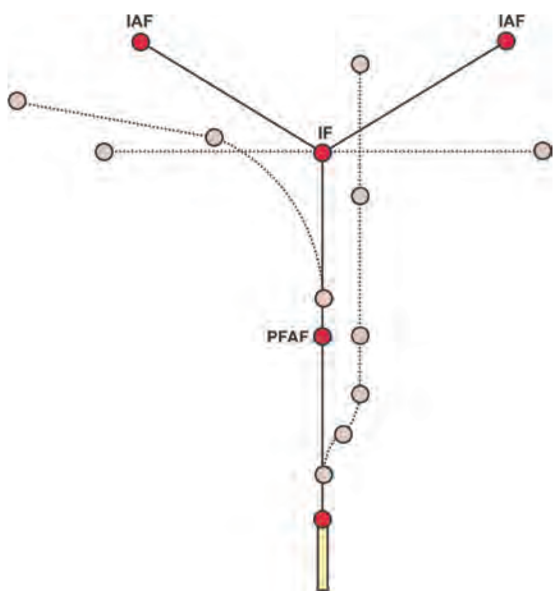
2.0 General.

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.

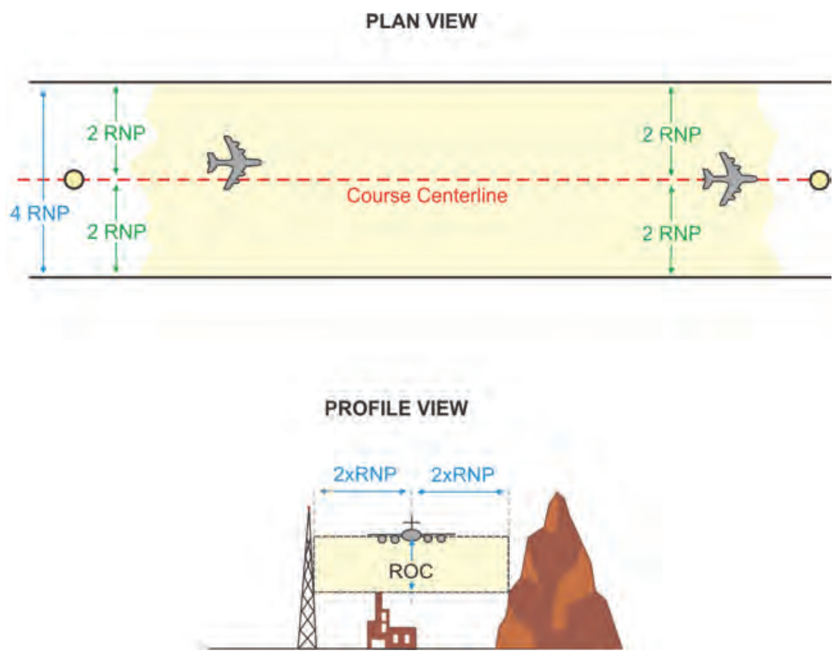
Figure 2-1. Optimum Configuration



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

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.

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.

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

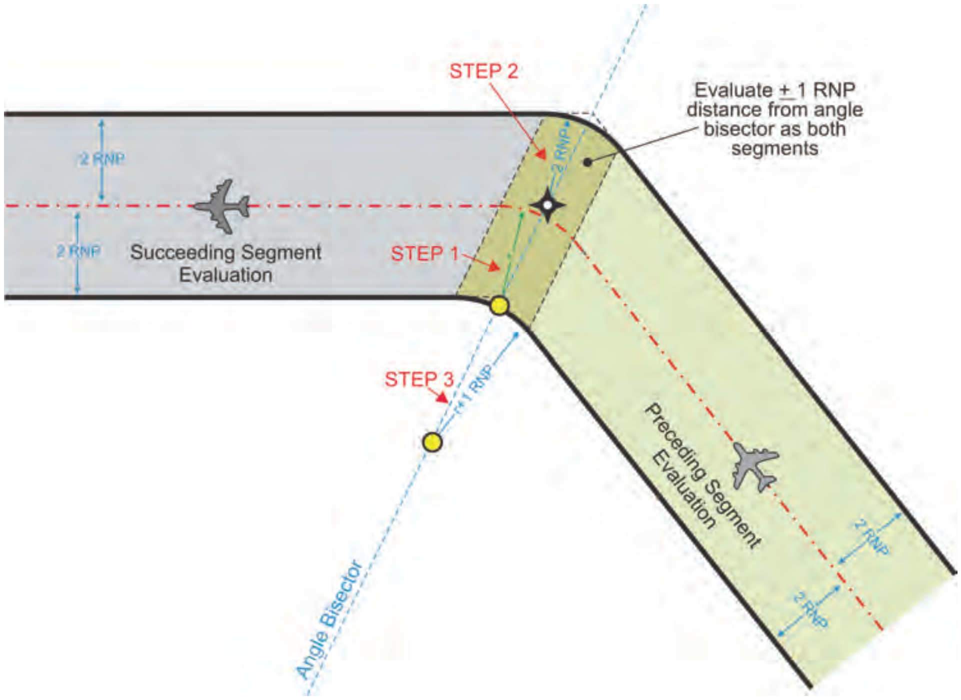
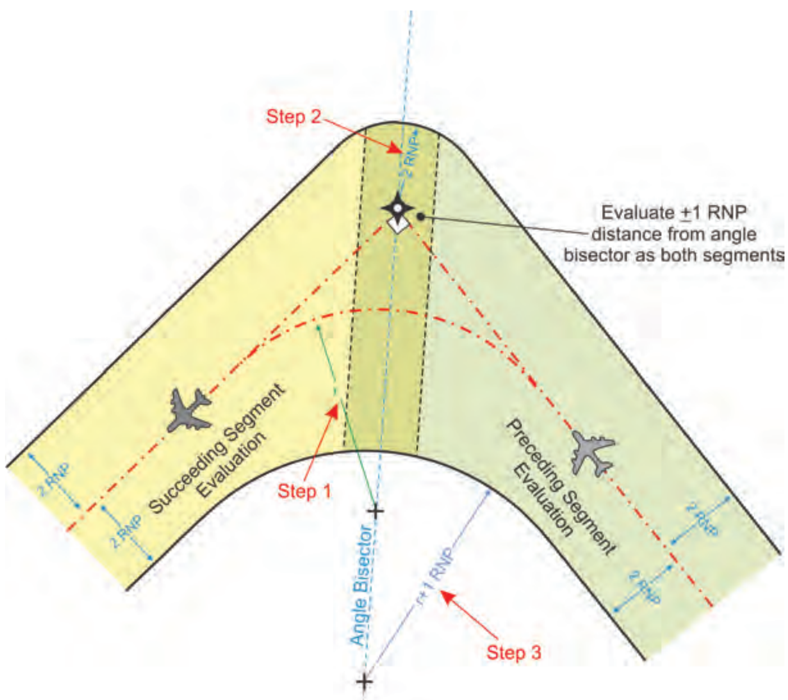


Figure 2-4B. Large Turn at a Fly-by Fix



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)

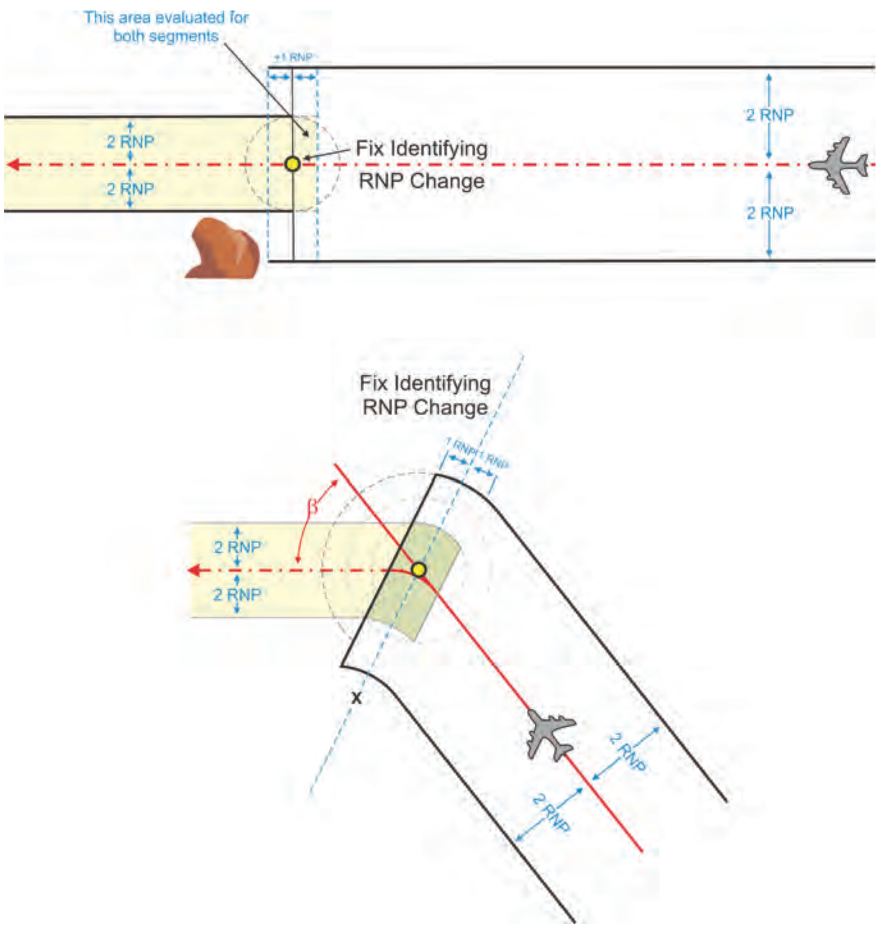


Figure 2-6B. RNP Increase (After Crossing the LTP/FTP)

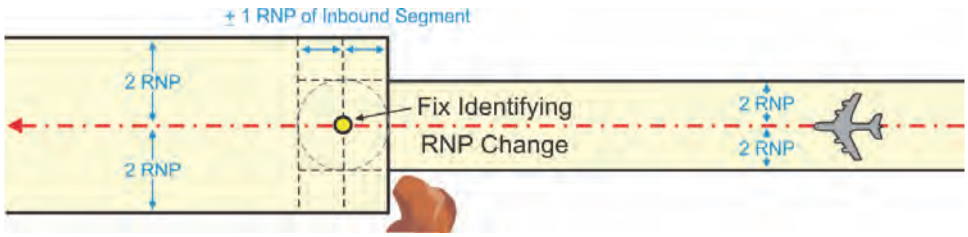
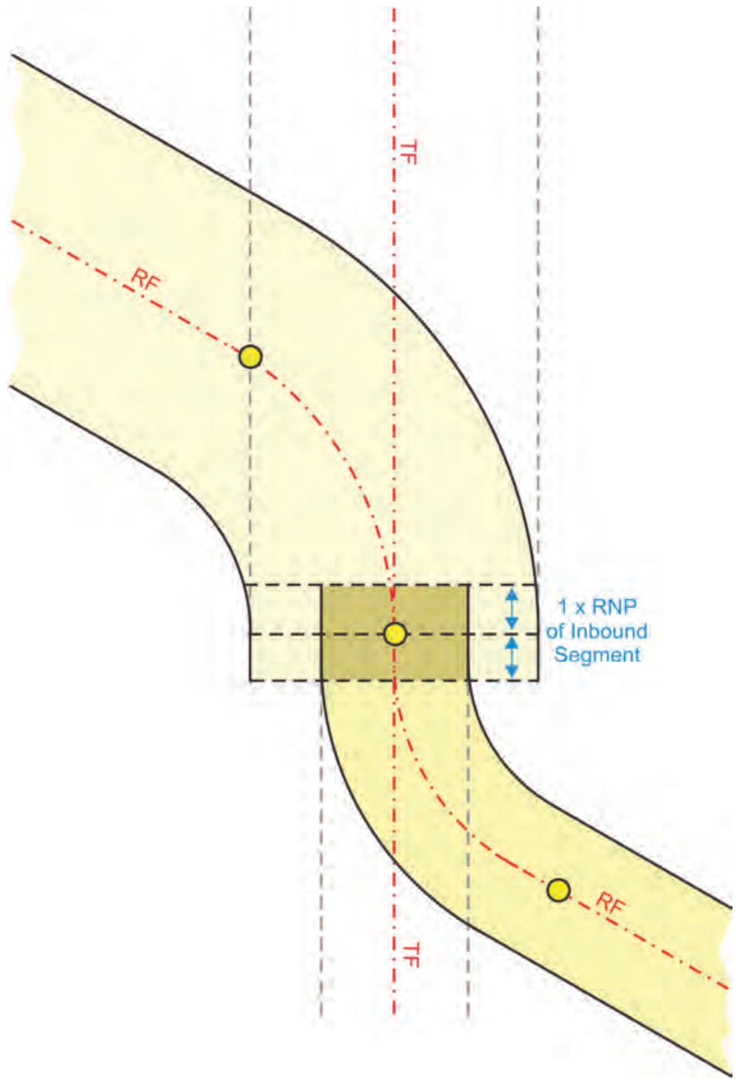


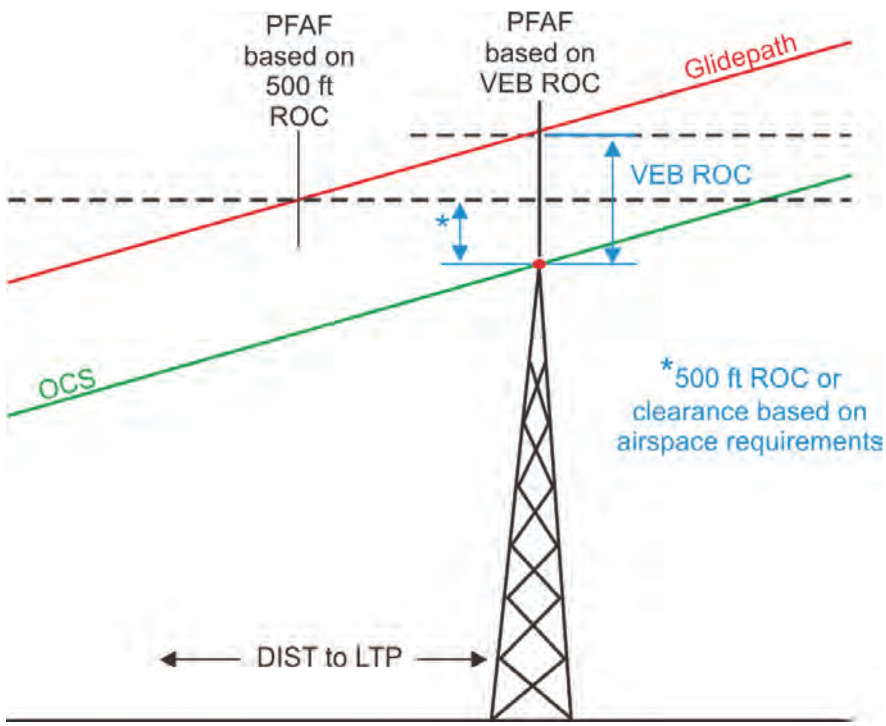
Figure 2-6C. RNP Change Involving RF Legs
(increase and decrease)



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.

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). Volume 6 table 1-4b 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.

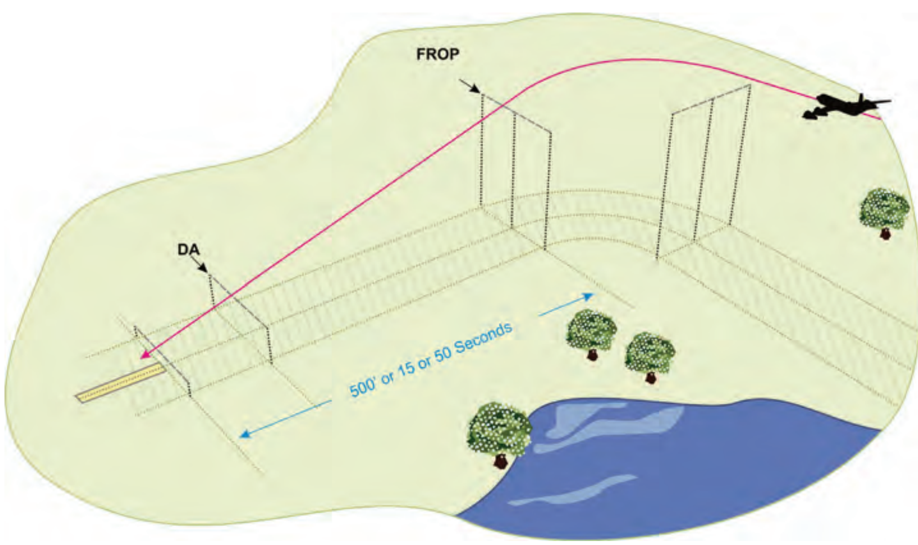
3.2.2 Low Temperature Limitation.

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

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

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

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

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

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

where RNP_{IMAS} = *Initial MAS RNP value*

Calculator 3 1		
θ°		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.

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		
$\alpha°$		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

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

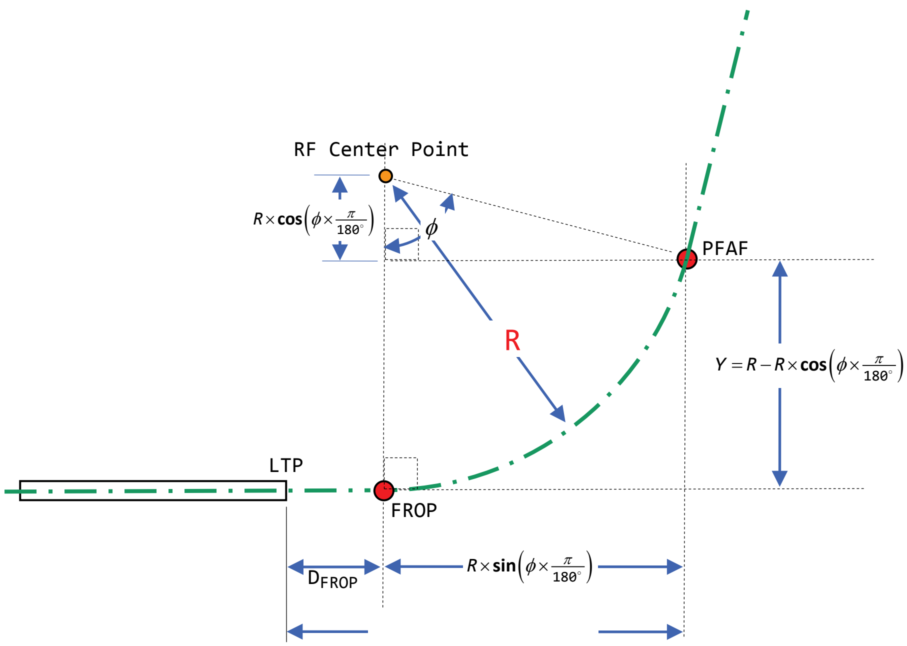
$$Y = R - \left[R \times \cos\left(\alpha° \times \frac{\pi}{180°}\right)\right]$$

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.

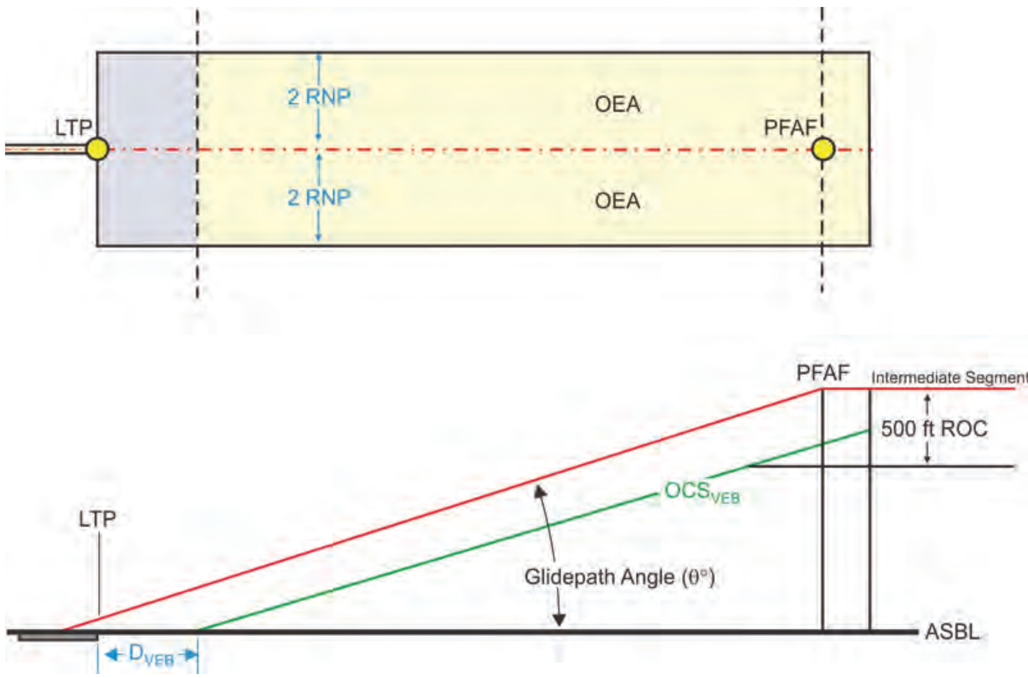
Calculate D_{VEB} and the OCS slope using Calculator 3-8.

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

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.

Calculator 3-10. DA

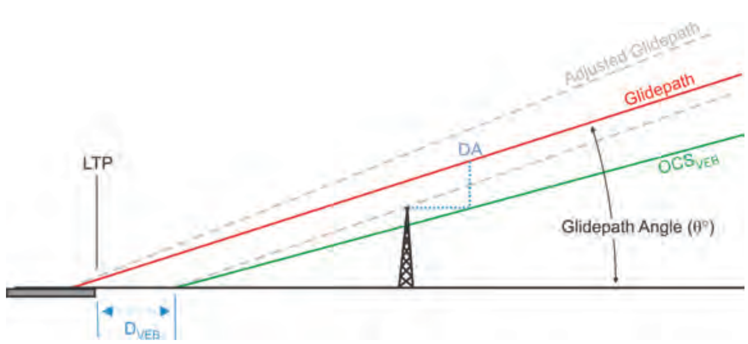
(1) $DA = HATh + LTP_{elev}$

(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}		
θ^{o}		
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)

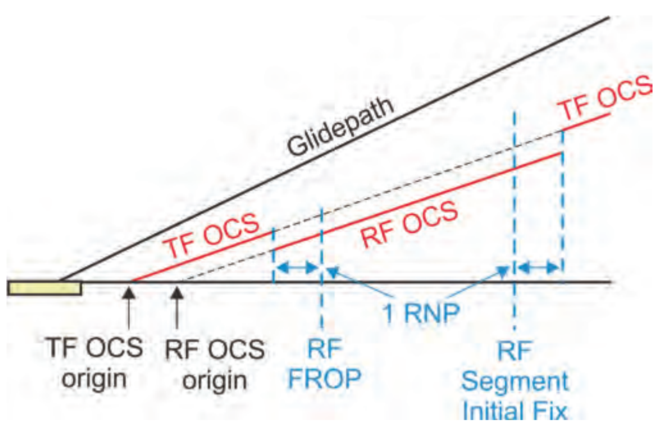
OCS_{VEB} = Slope of VEB OCS

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).

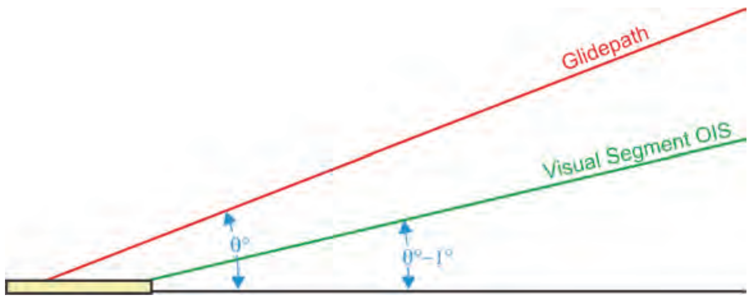
Figure 3-6. RF Final Segment OCS Evaluation



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

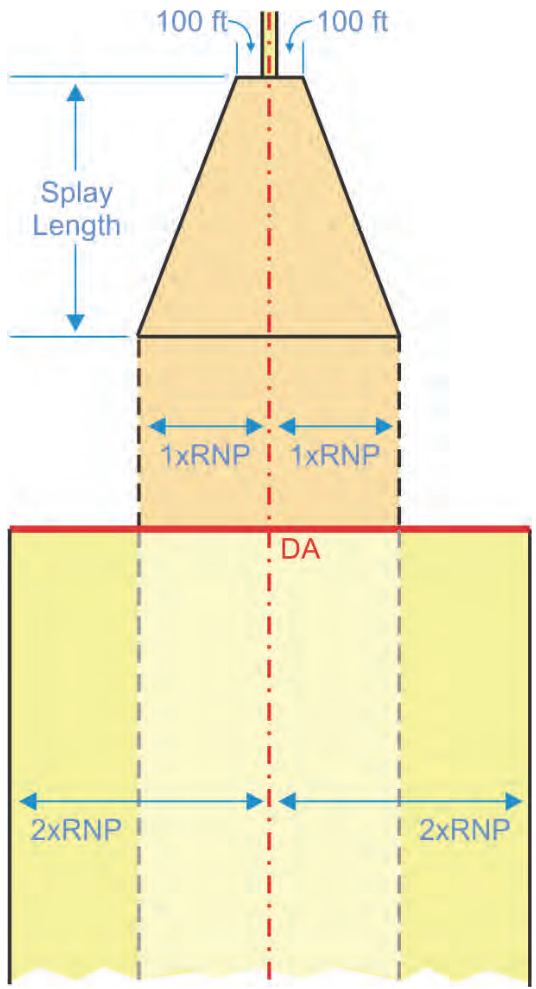
$$Splay_{Length} = \frac{(1 \times RNP \times fpnm) - \left(100 + \frac{Rwy\ Width}{2}\right)}{\tan\left(10^\circ \times \frac{\pi}{180^\circ}\right)}$$

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.

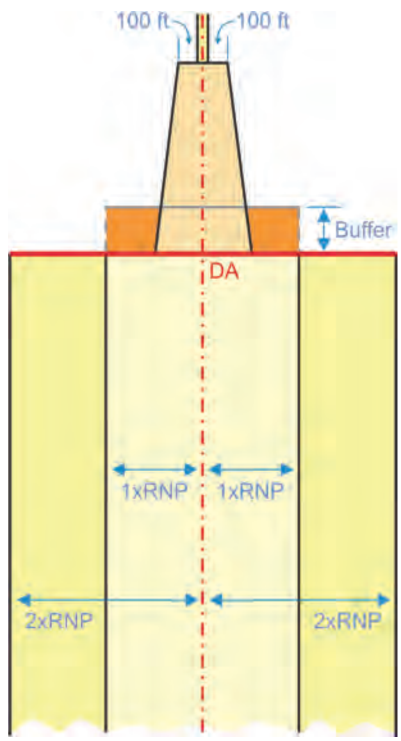
Calculator 3-13. Buffer Area Distance

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

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

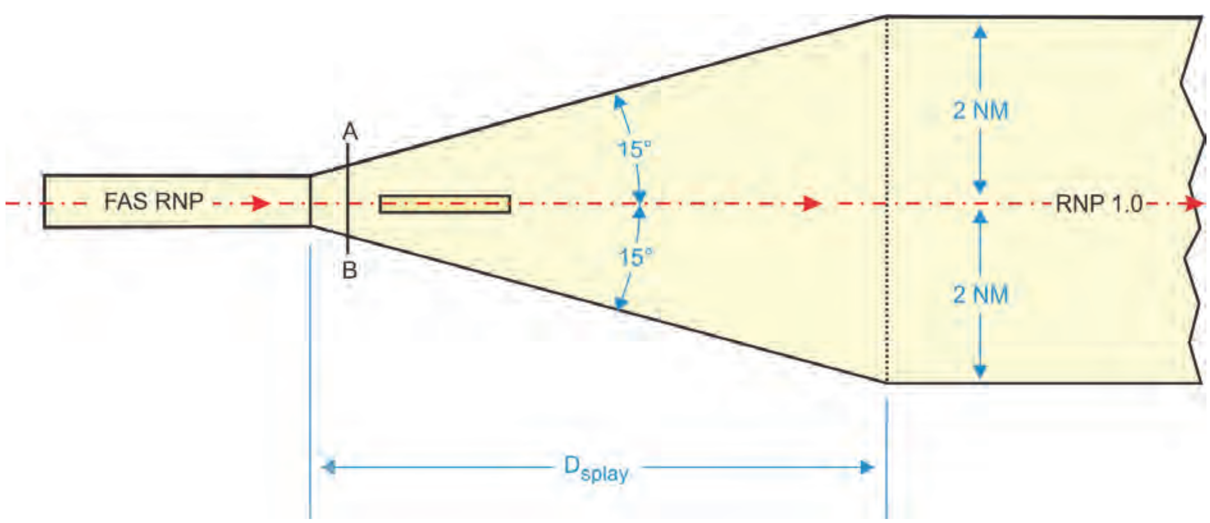
Additionally, if the RF leg RNP value is <1.0, the RF leg length must comply with paragraph 4.2.1.

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

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

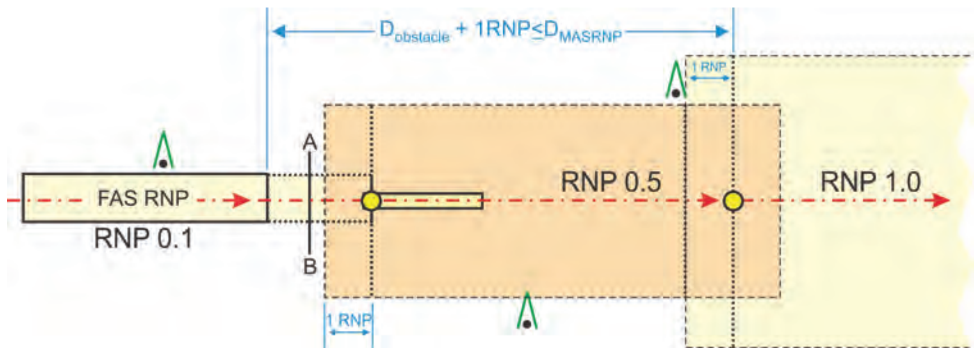
Calculator 4 2		
V_{KIAS}		Calculate
DA		
$D_{MASturn}$		Clear

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

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

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.

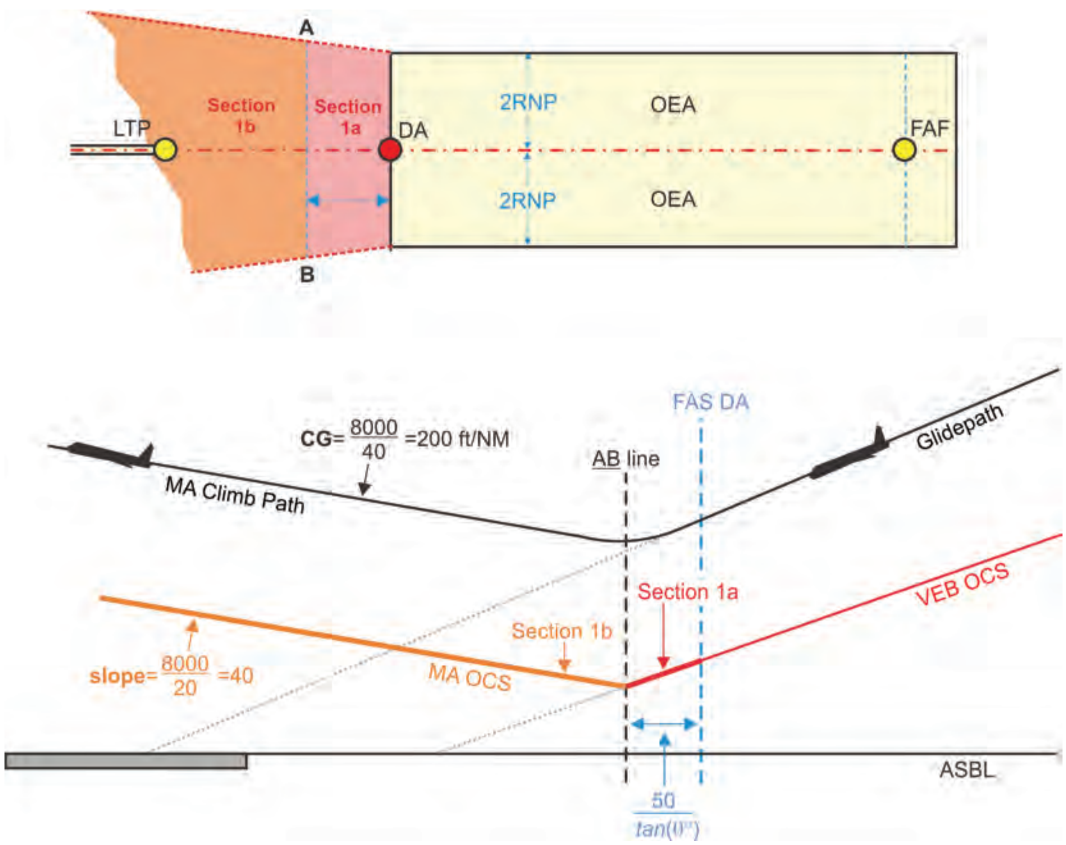
The MAS is composed of OCS sections 1a and 1b (see figure 4-2). Sections 1a and 1b are separated by the AB line. Section 1a OCS extends from the DA point downward at the VEB OCS slope ratio for a distance of $D_{heightloss}$ (calculated using calculator 4-4) measured along the final course track to the AB line. From the AB 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
$HMAS_{AB}$		

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
$H_{section1b}$		

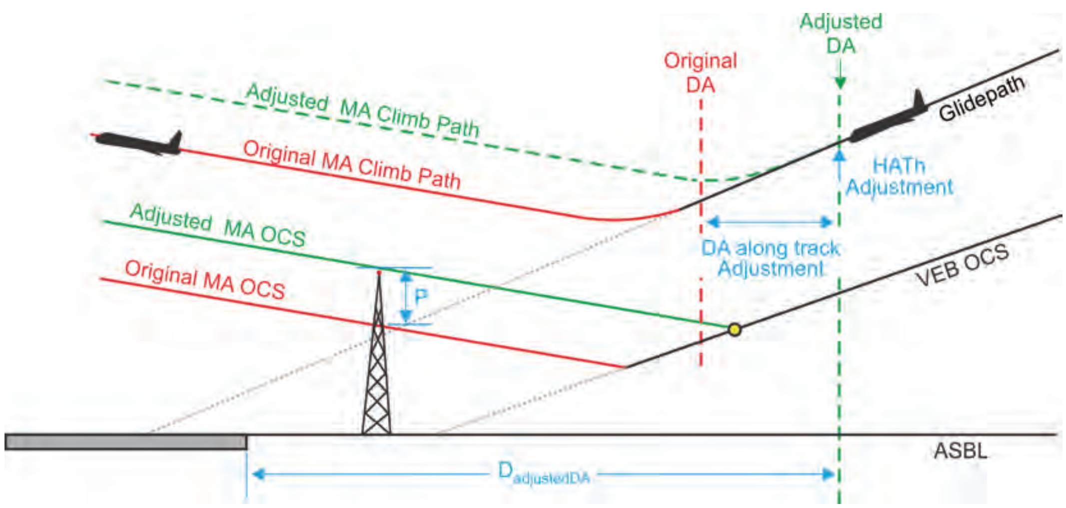
4.3.1 OCS Penetrations.

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°		
$VEB_{OCSslope}$		Clear
$MA_{OCSslope}$		
$HATh_{adjustment}$		

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

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

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

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

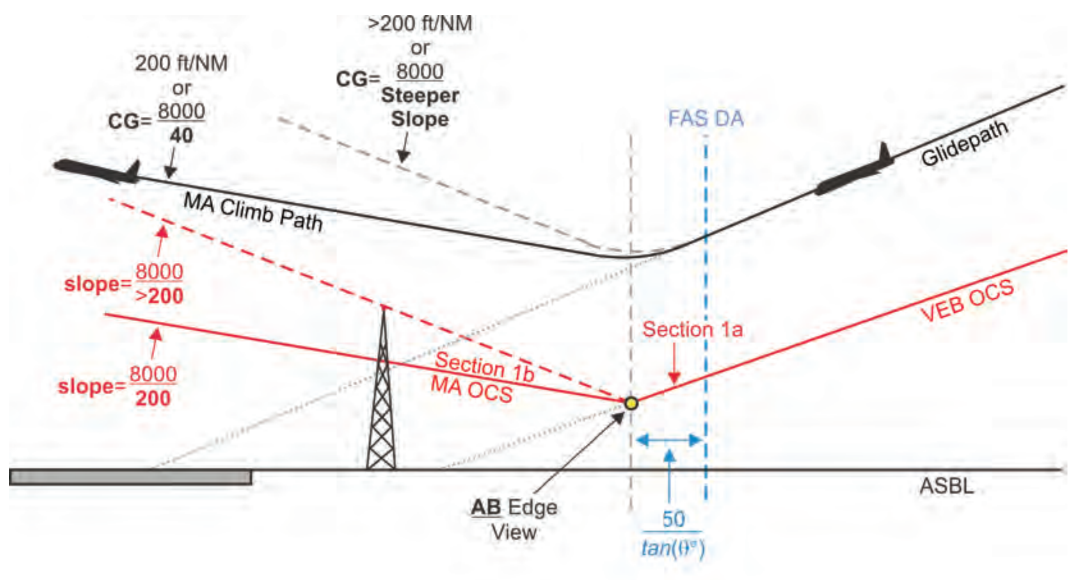
$$DA_{adjusted} = \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times D_{adjustedDA} + \left(LTP_{elev} + TCH\right)$$

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

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

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

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

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: $(4{,}500 ft)$

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:

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

The wpr:

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

The fte: $fte = 75$

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

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

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

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}:

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

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.

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

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United States Standard for

Performance Based Navigation (PBN)

<u>Volume 6</u>

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).

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

Figure 1-1. Segment Width Variables

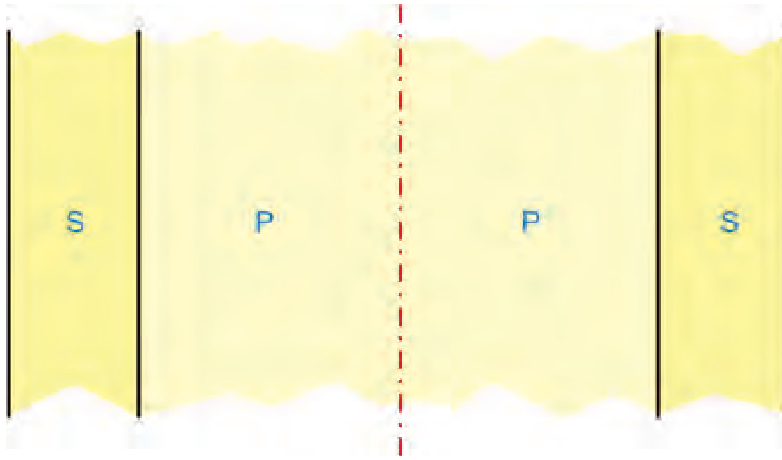
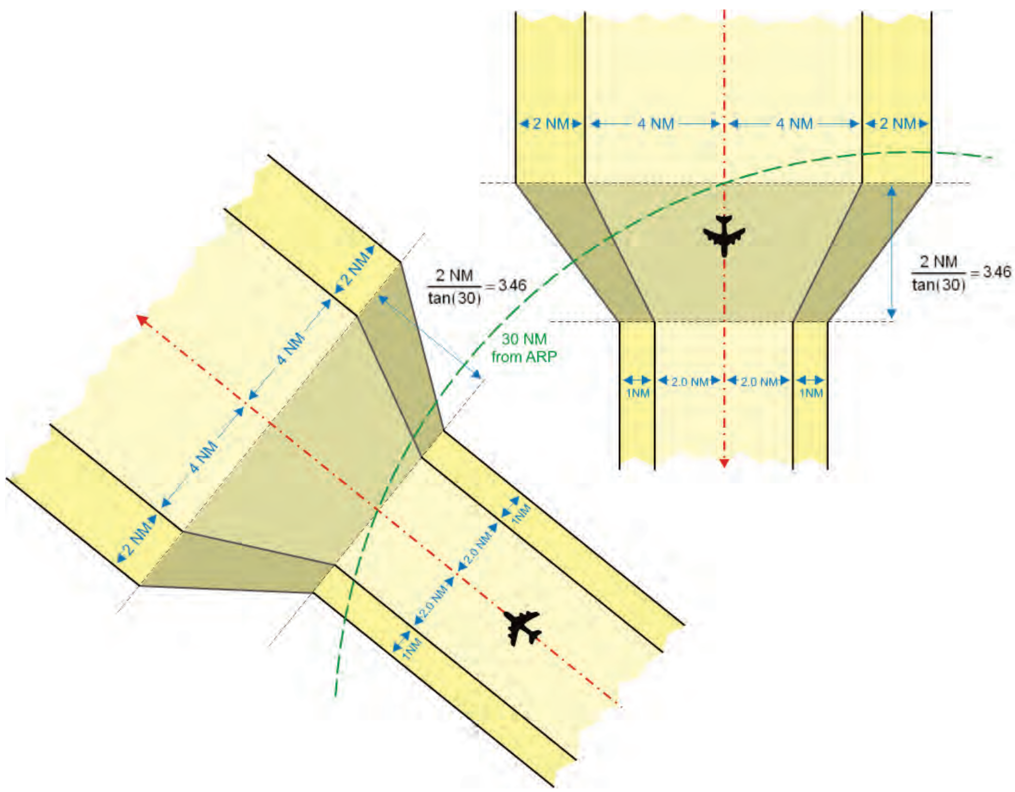


Figure 1-2A. Segment Width Changes at 30 NM



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

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

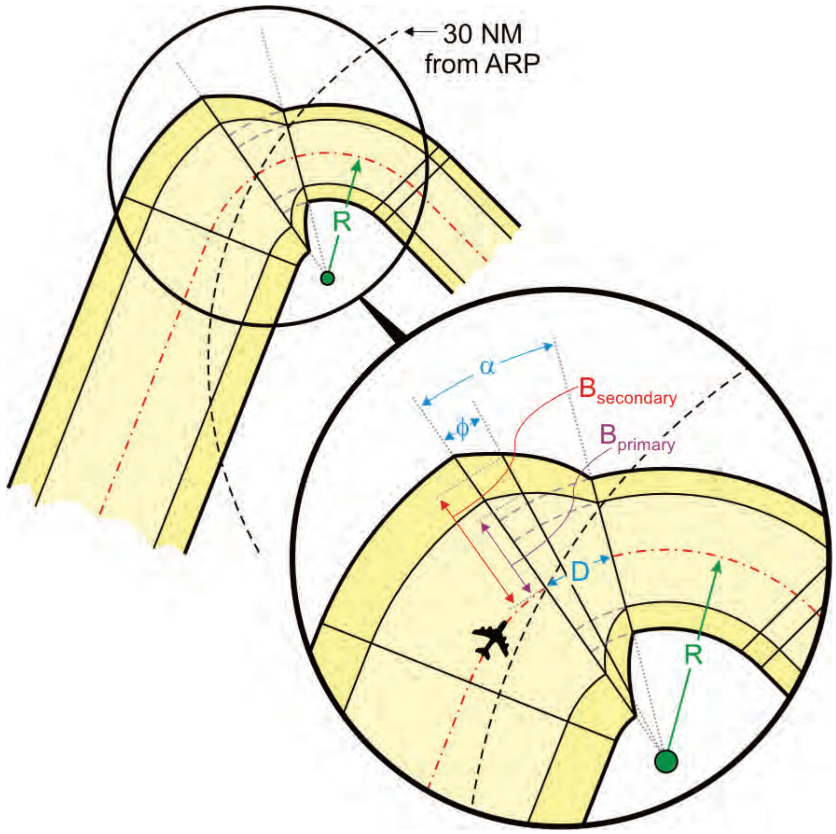
$$(2)\quad B_{primary} = 4 - 2 \times \frac{\phi^\circ \times \pi \times R}{180^\circ \times D}$$

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

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°		Calculate
R		
D		
α°		
$B_{primary}$		Clear
$B_{secondary}$		

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



1.2 Turns.

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.

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.

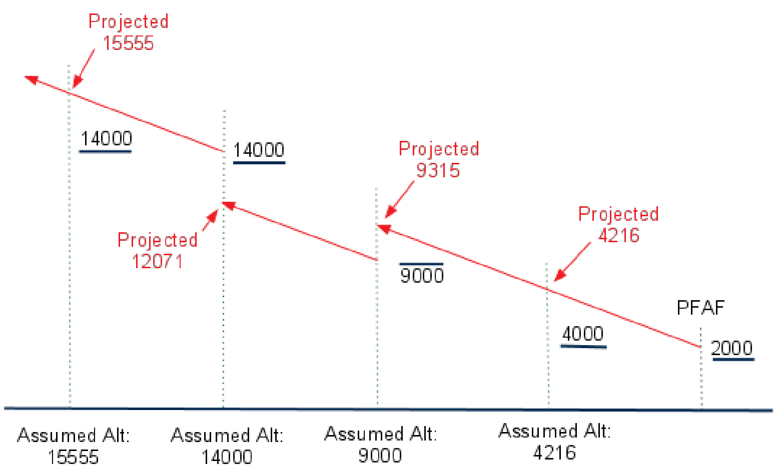
*15 degrees for CAT A and B-only procedures

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

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

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

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

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

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

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

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

STEP 2: Determine rr (see calculator 1-4).

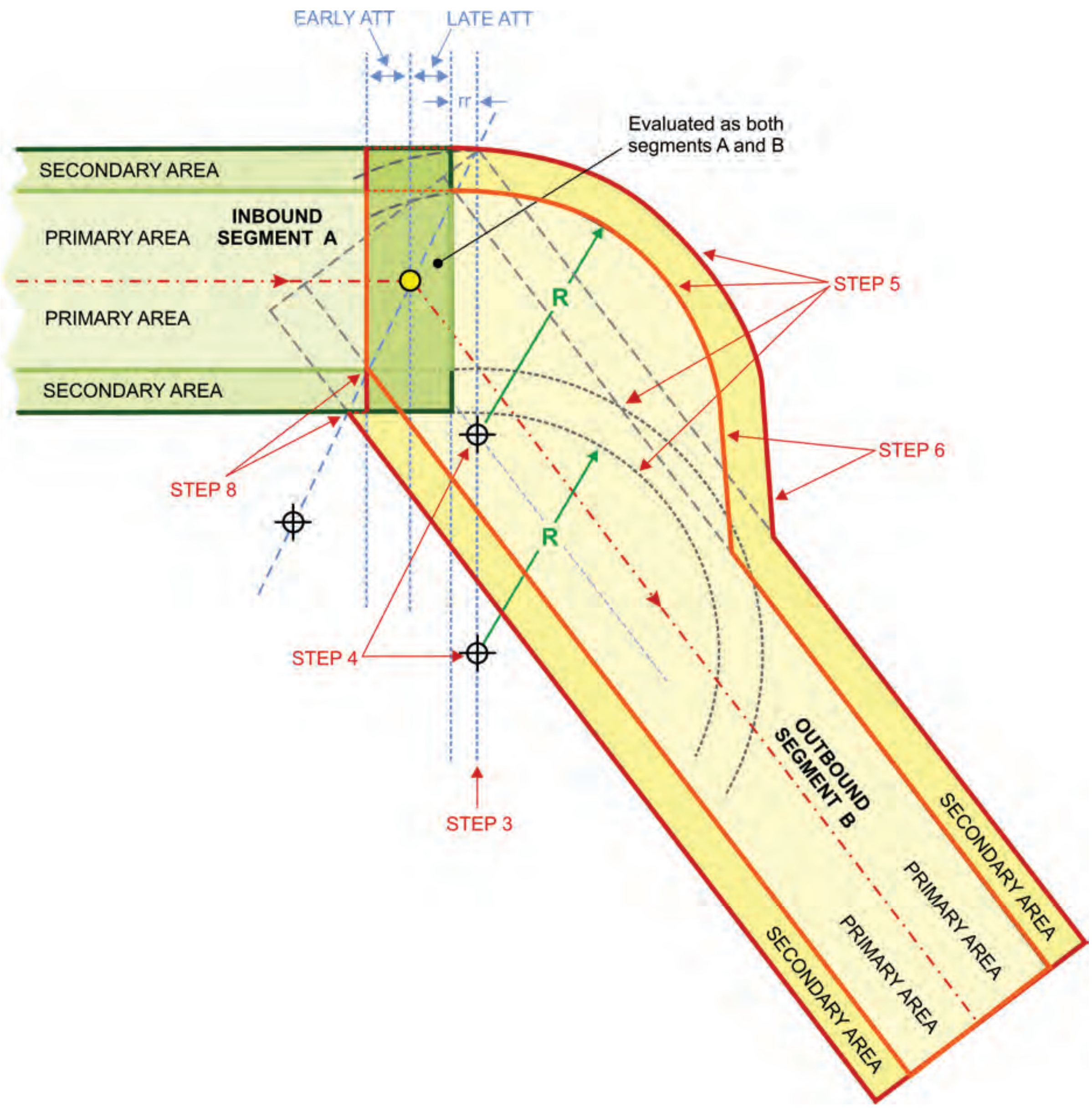
STEP 3: Establish the baseline for construction of the turn expansion area as the line perpendicular to the inbound track at a distance past the turn fix equal to (ATT+rr).

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

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

<u>STEP 6</u>: 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.

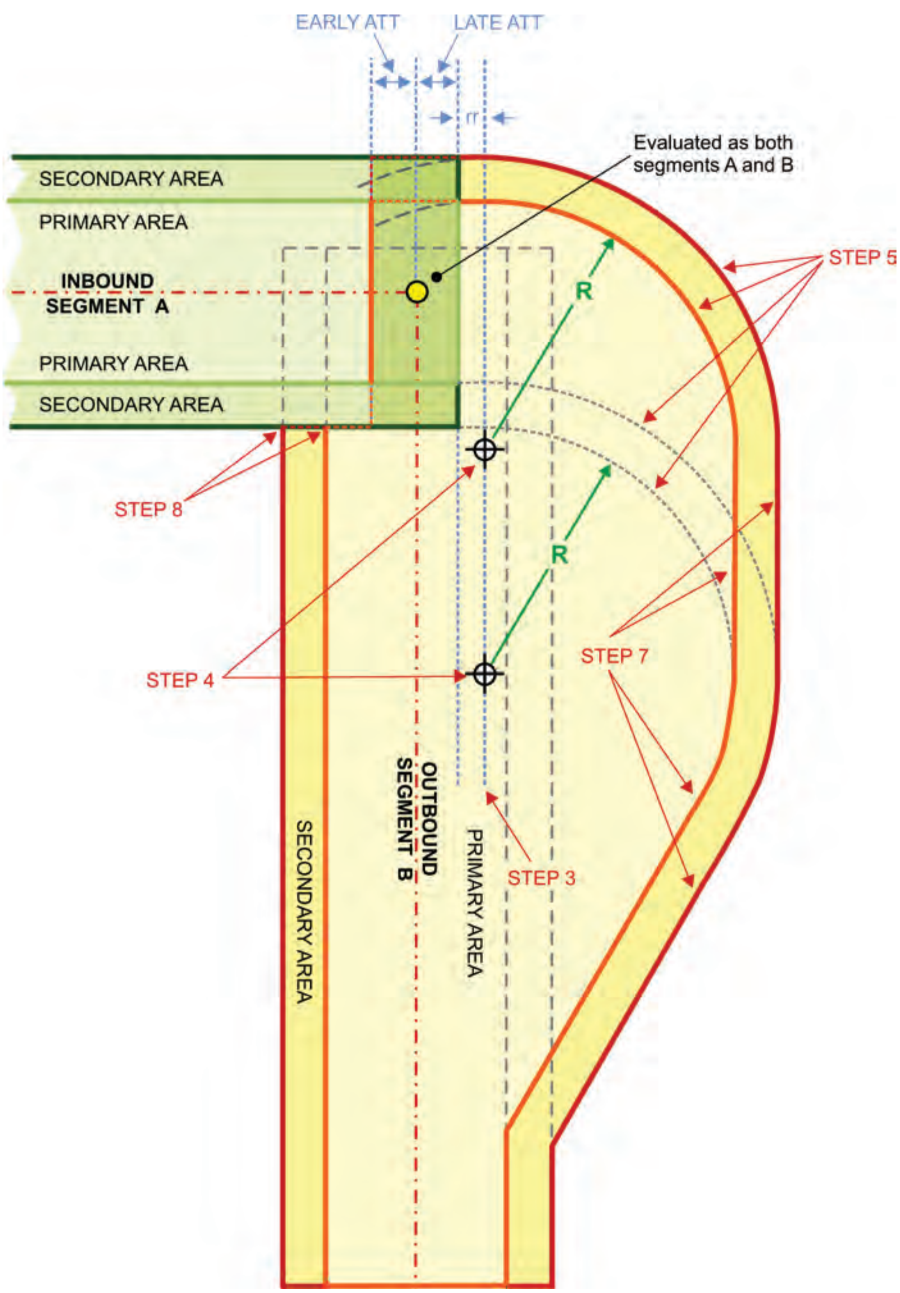
Figure 1-4. Fly-Over with No Second Arc Expansion



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

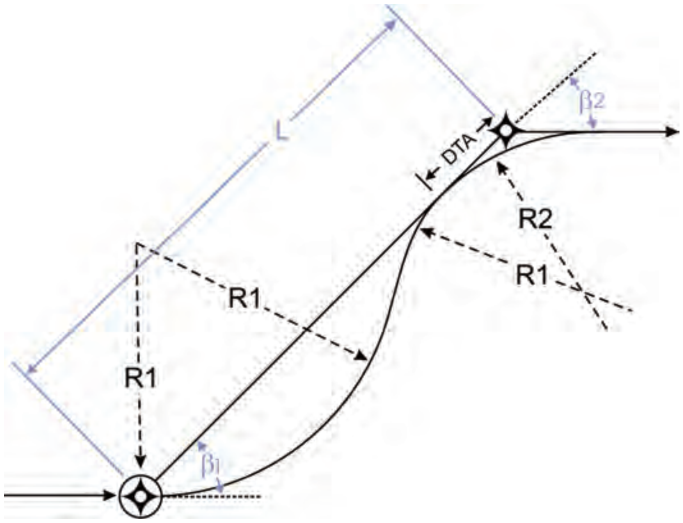
case $\left(\beta 1^\circ < \text{acos}\left(\sqrt{3}-1\right)\times\frac{180^\circ}{\pi}\right)$:

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

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

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

where R1 = turn radius (NM) from calculator 1-3c at first fix
R2 = turn radius (NM) from calculator 1-3c at second fix
$\beta 1^\circ$ = degrees of track change at fix 1
$\beta 2^\circ$ = 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.

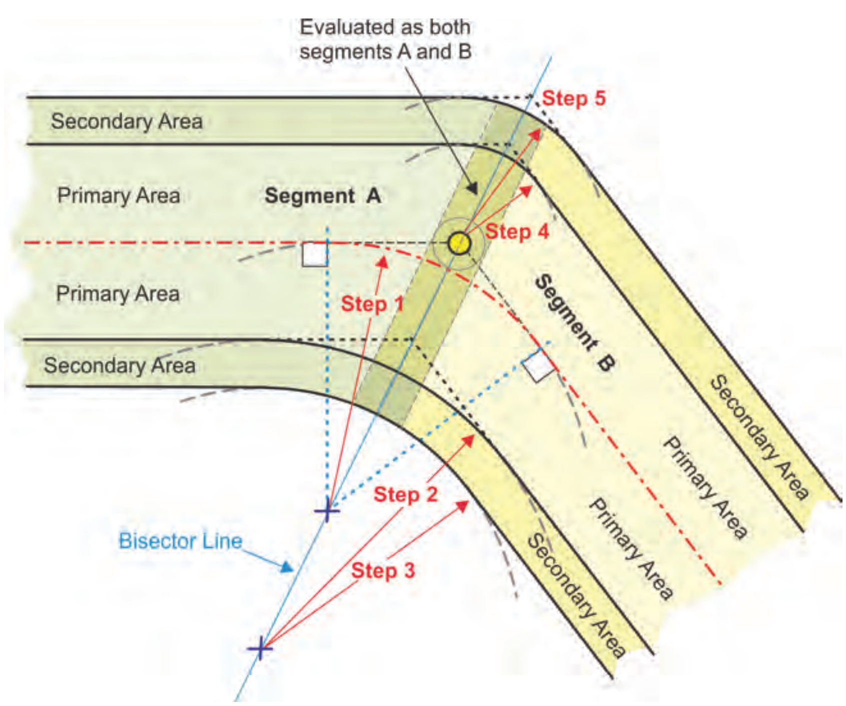
STEP 2: Scribe an arc (with origin on bisector line) that is tangent to the inner primary boundaries of the two segment legs with a radius equal to $R + \frac{\textit{Primary Area Half-width}}{2}$ (example: half width of 2 NM, the radius would be R+1.0 NM).

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



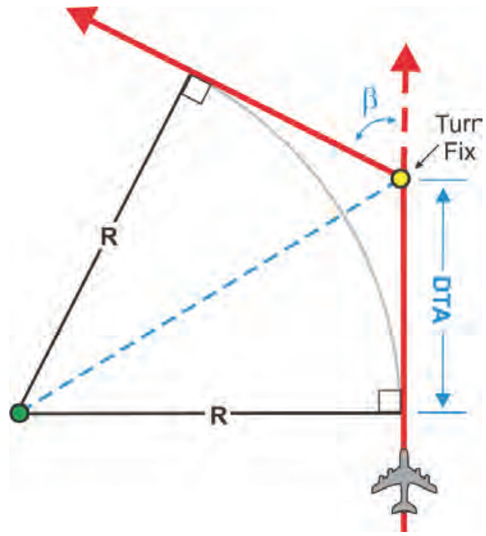
The minimum length must not be less than the total of DTAs for the leg. Calculate DTA using calculator 1-6.

Calculator 1-6. Distance of Turn Anticipation

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

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

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 $\beta 2^\circ$ is fly-over
$\beta 1^\circ$ = degrees of heading change at initial fix
$\beta 2^\circ$ = 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."

<u>STEP 1</u>: 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

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

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

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

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

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

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.

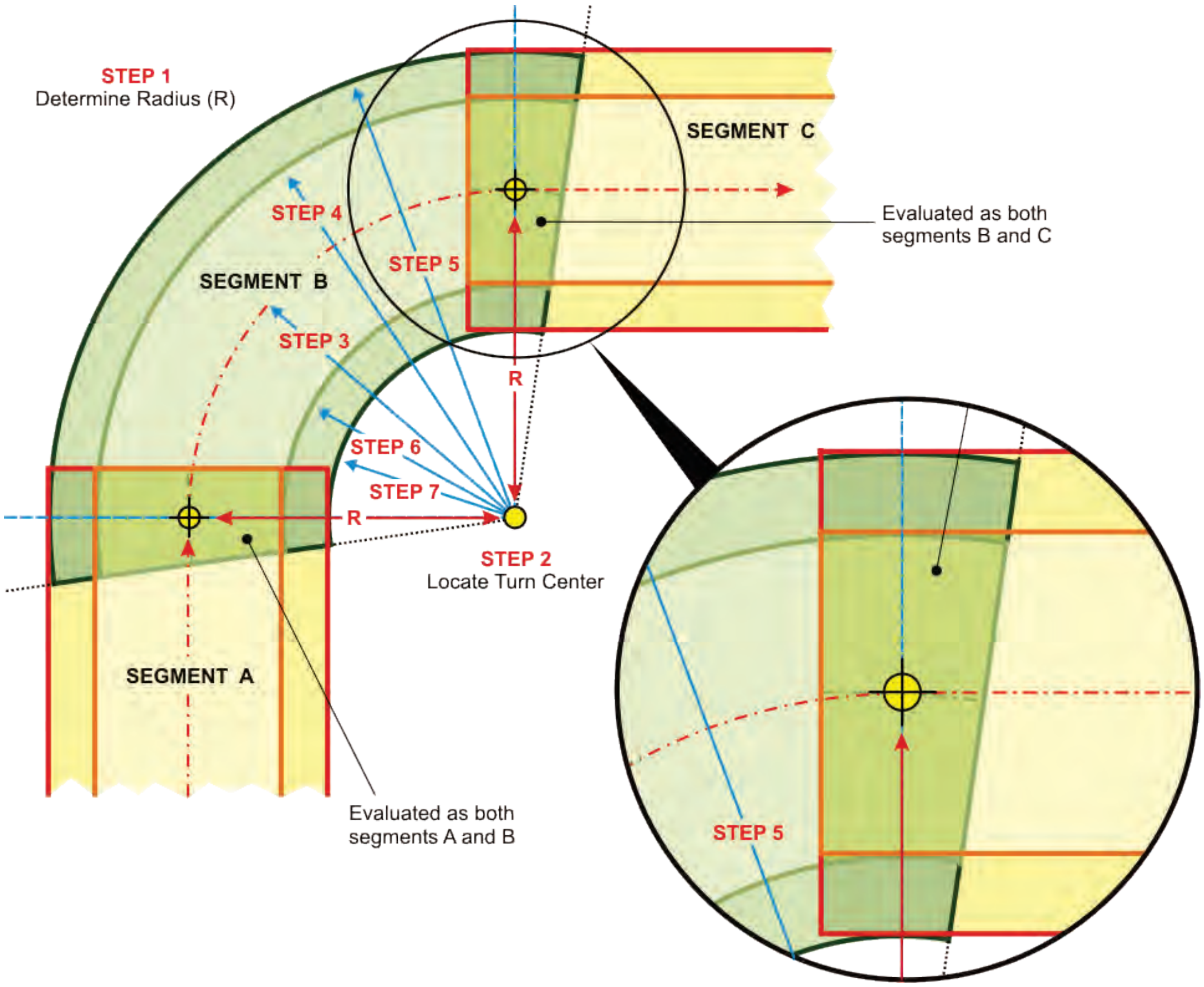
<u>STEP 4</u>: <u>Primary area outer boundary</u>. Construct an arc of radius R+*Primary area half-width* from the tangent point on the preceding segment primary area outer boundary to the tangent point on the following course primary area outer boundary.

<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).

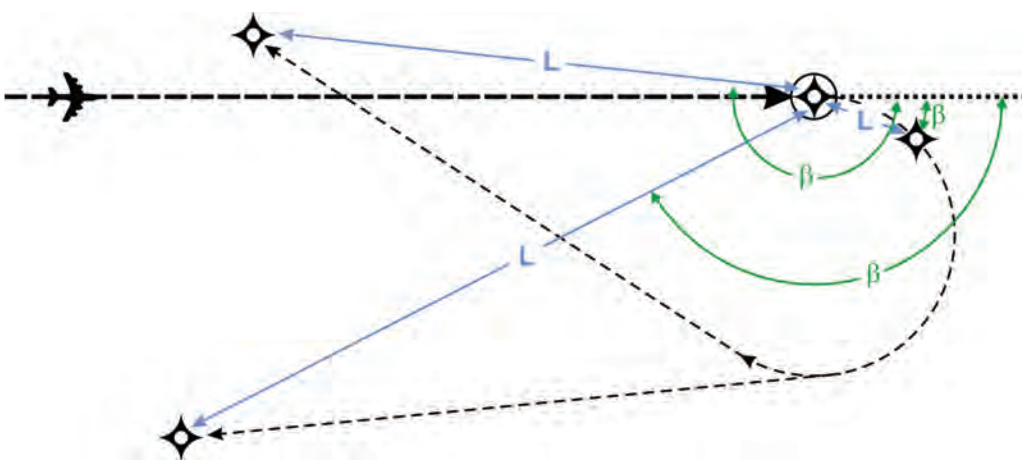
Calculator 1-10. TF/CF Leg Followed by a DF Leg

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

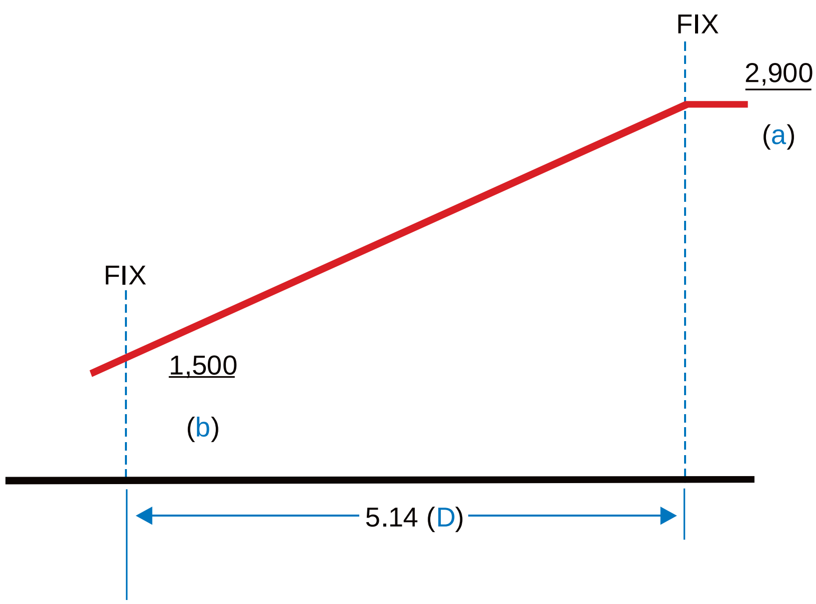
1.4 Descent Gradient.

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).

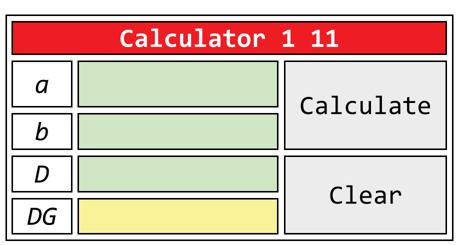
Figure 1-8. Calculating Descent Gradient



Calculator 1-11. Descent Gradient

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

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



1.5 Feeder, Q, and T Route Segments.

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.

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)

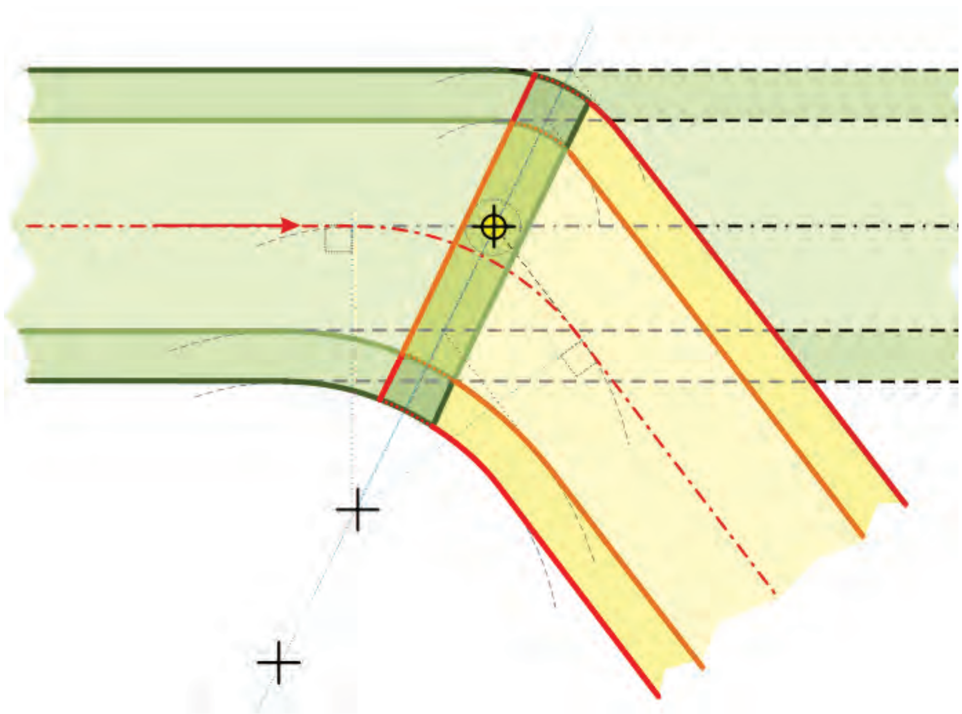
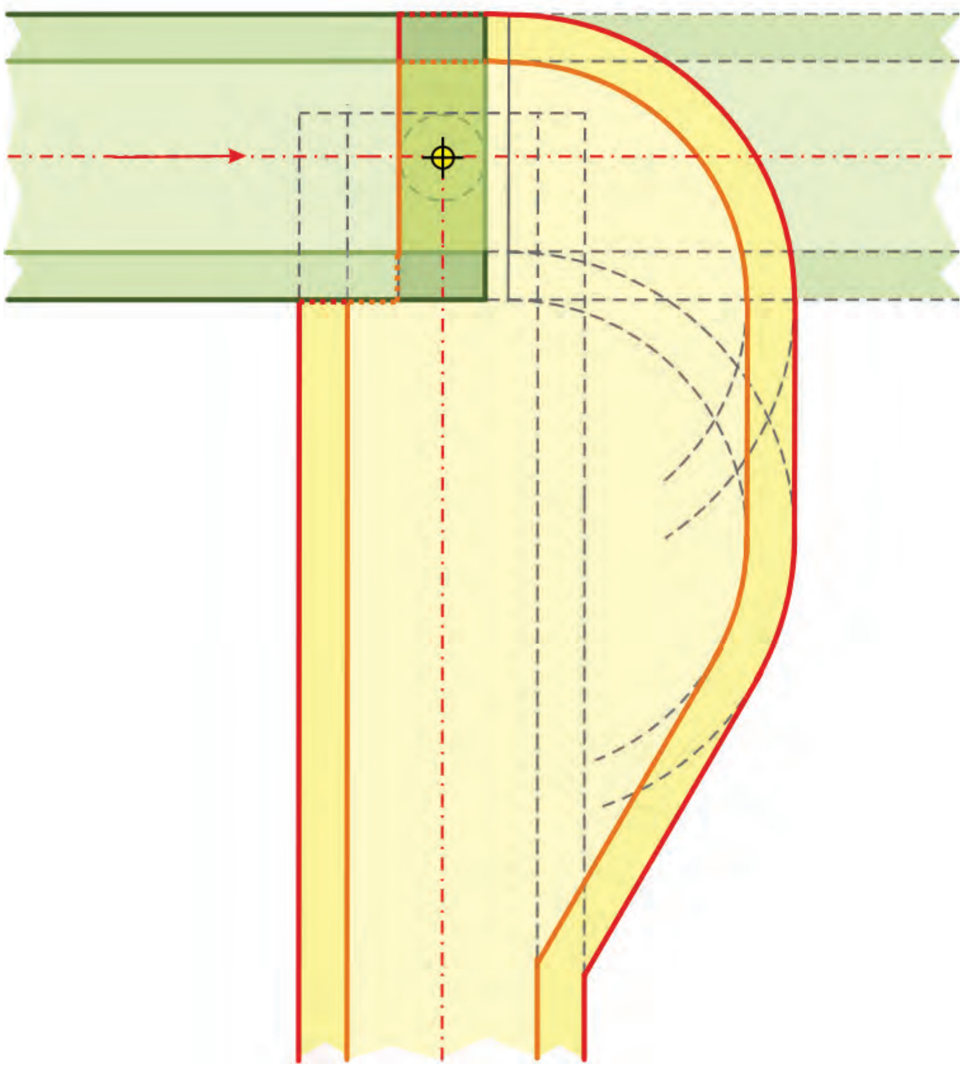


Figure 1-9B. Feeder Route (Fly-over Protection)



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

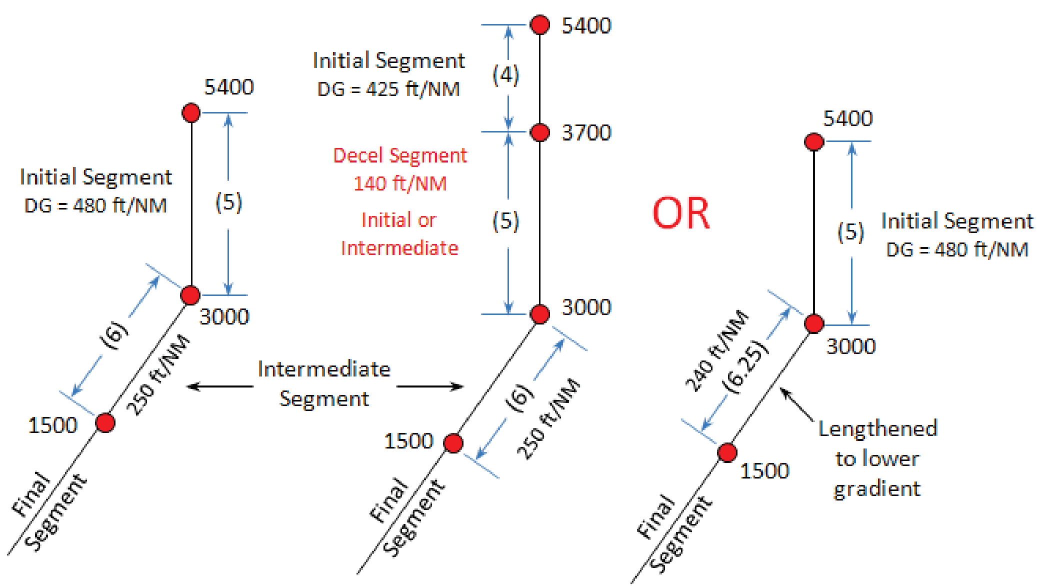
(13.17%, 7.5 degrees); **maximum** is 1000 ft/NM (16.46%, 9.35 degrees).

- 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).

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)

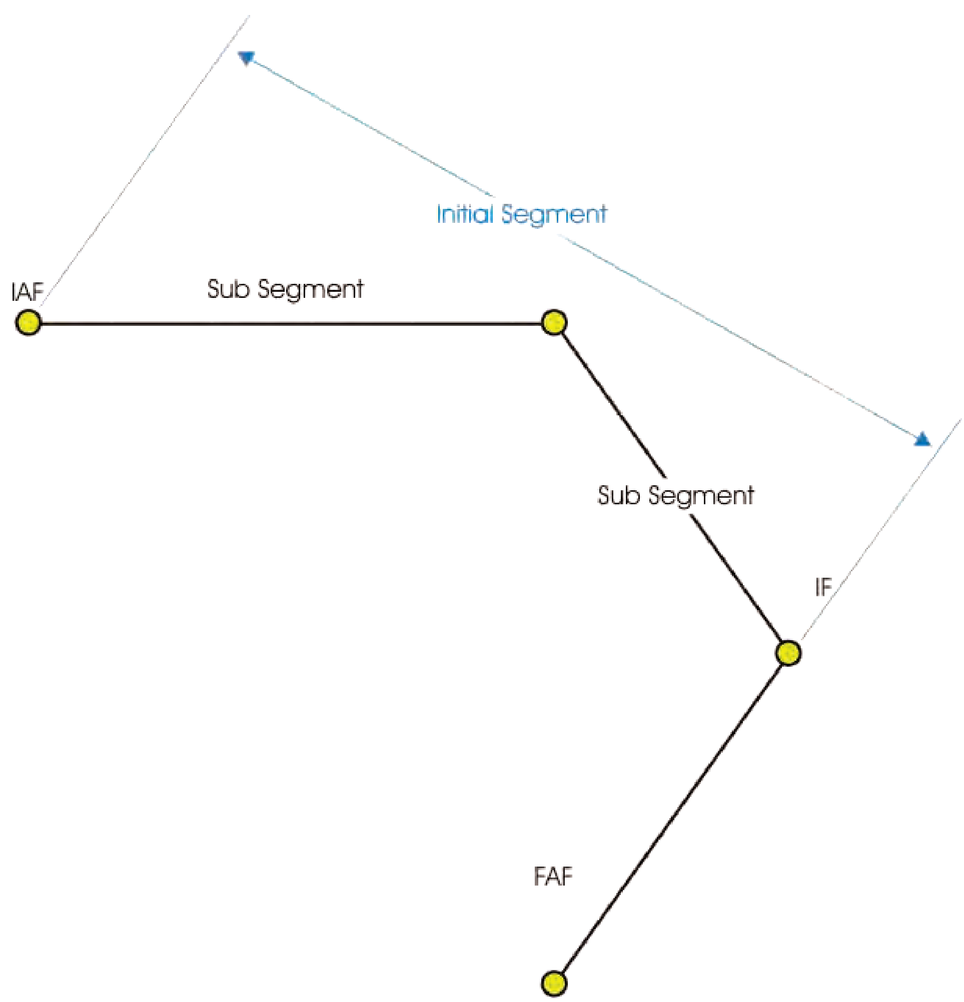
Chapter 1. General Criteria

Section 2. Terminal Segments

1.8 Initial Segment.

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.

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.

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.

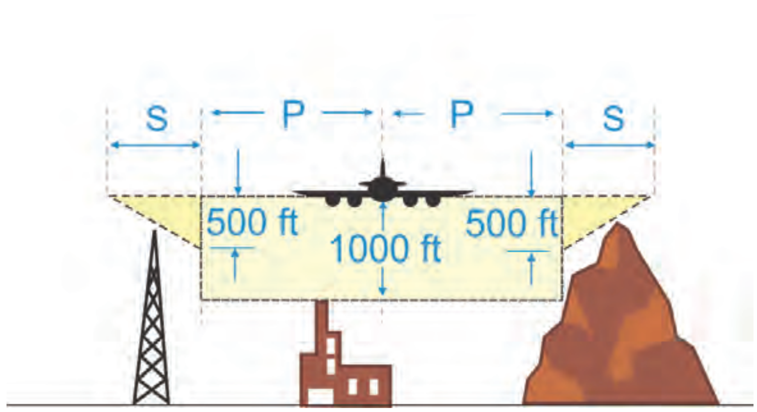
The **maximum** segment length (total of sub segments) is 50 NM. Minimum length of sub segments is determined as described in paragraphs 1.3.1, 1.3.2, or 1.3.3 as appropriate.

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).

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

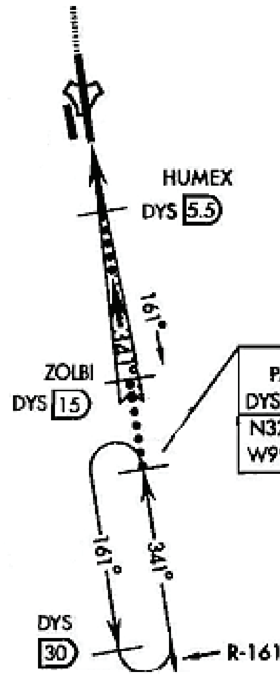
Calculator 1 12a		
$d_{primary}$		Calculate
W_S		Clear
$ROC_{secondary}$		

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.

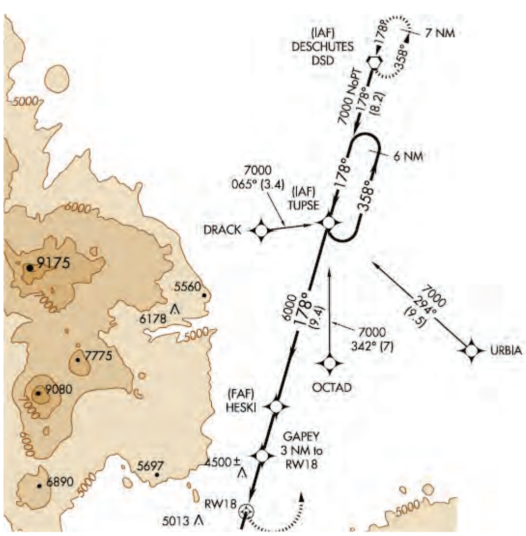
1.8.6 **a. Arrival Holding.** Ideally, the holding pattern inbound course should be aligned with the subsequent TF leg segment (tangent to course at the initial fix of the subsequent RF segment), see figure 1-13A. If the pattern is offset from the subsequent TF segment course, the subsequent segment 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.

Figure 1-13A. Arrival Holding Example



1.8.6 **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)

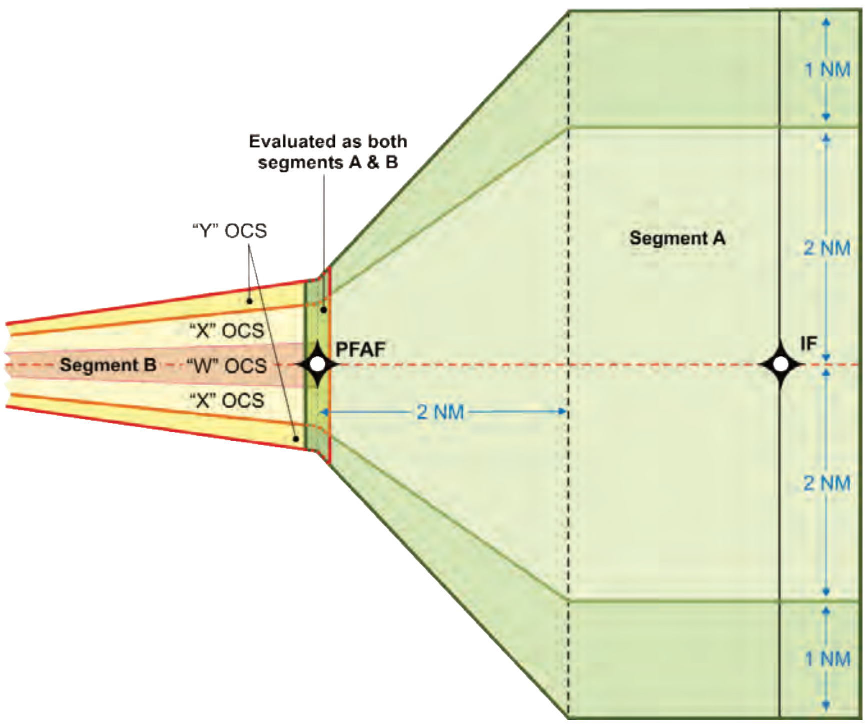
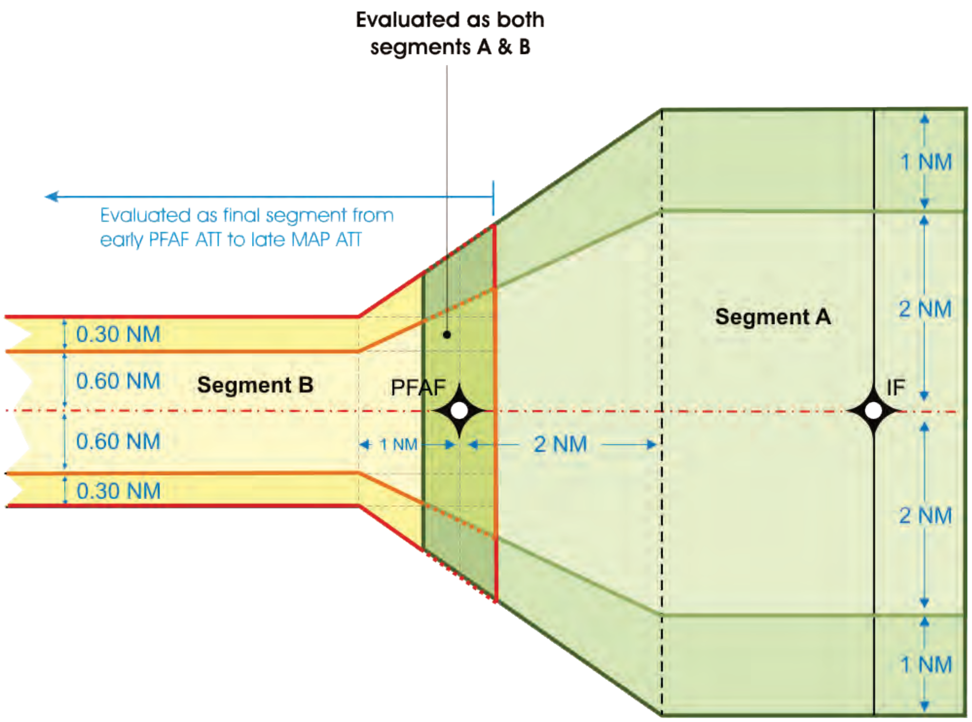


Figure 1-14B. RNAV Intermediate Segment (LNAV and LNAV/VNAV)



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

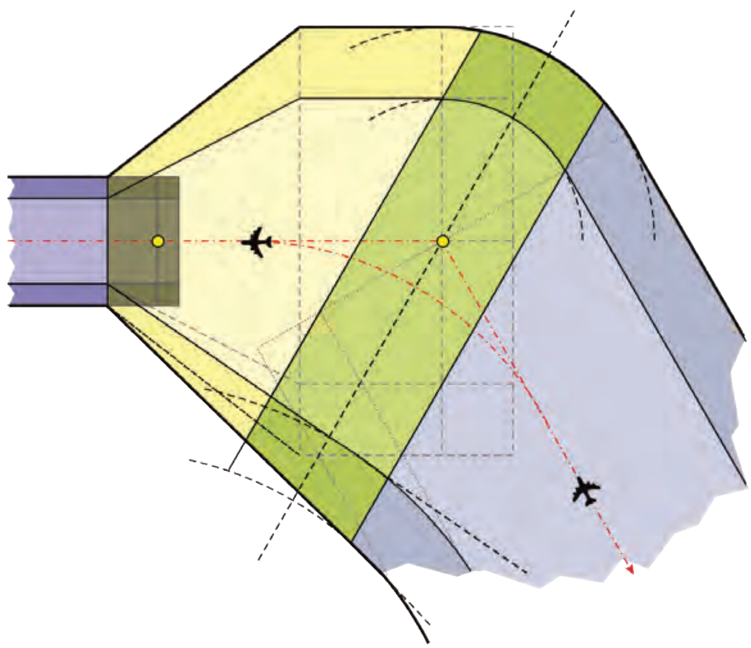
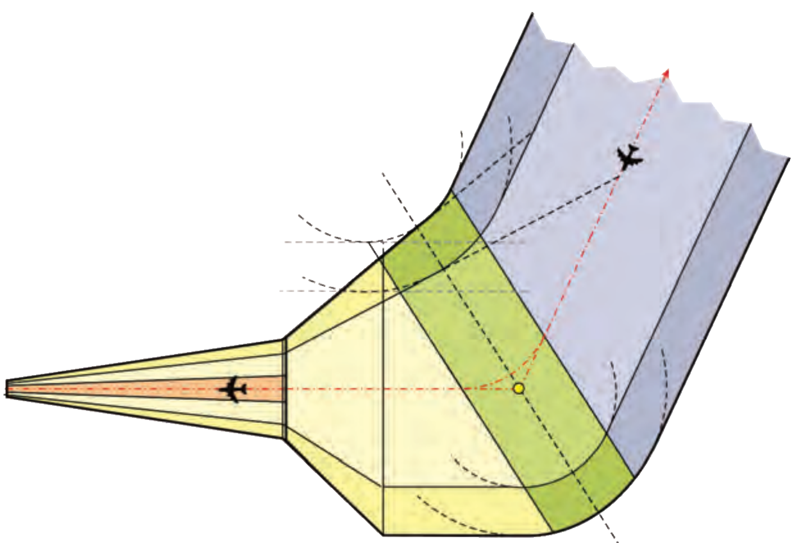


Figure 1-14D. LP, LPV Example



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.

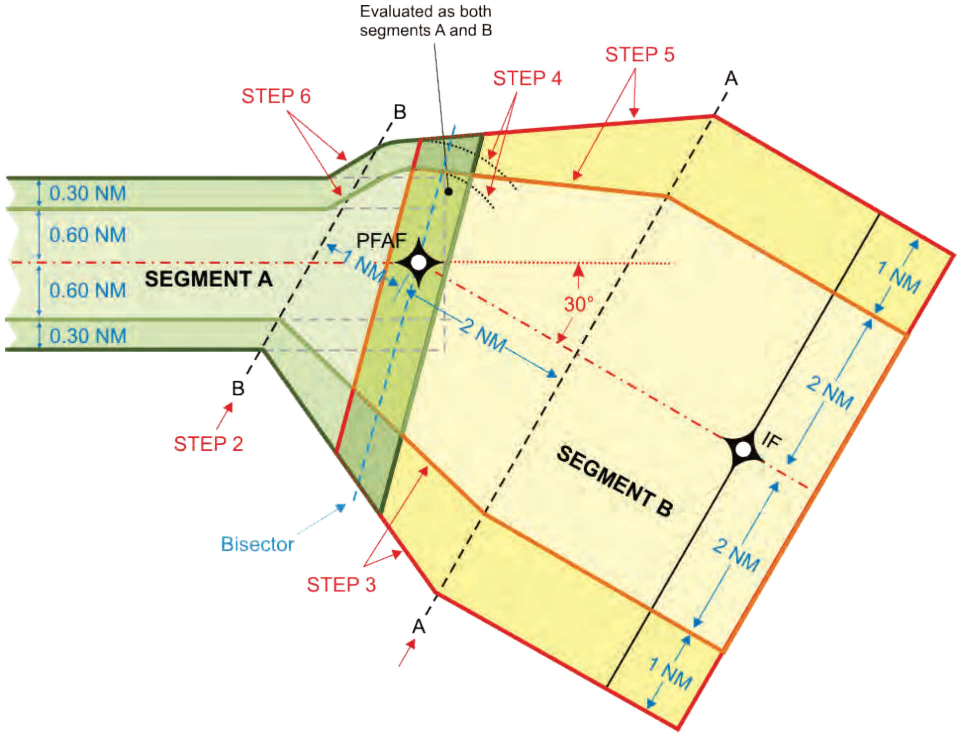
STEP 4: Construct arcs centered on the PFAF of 1 NM and 1.3 NM radius on the non-turn side of the fix.

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.

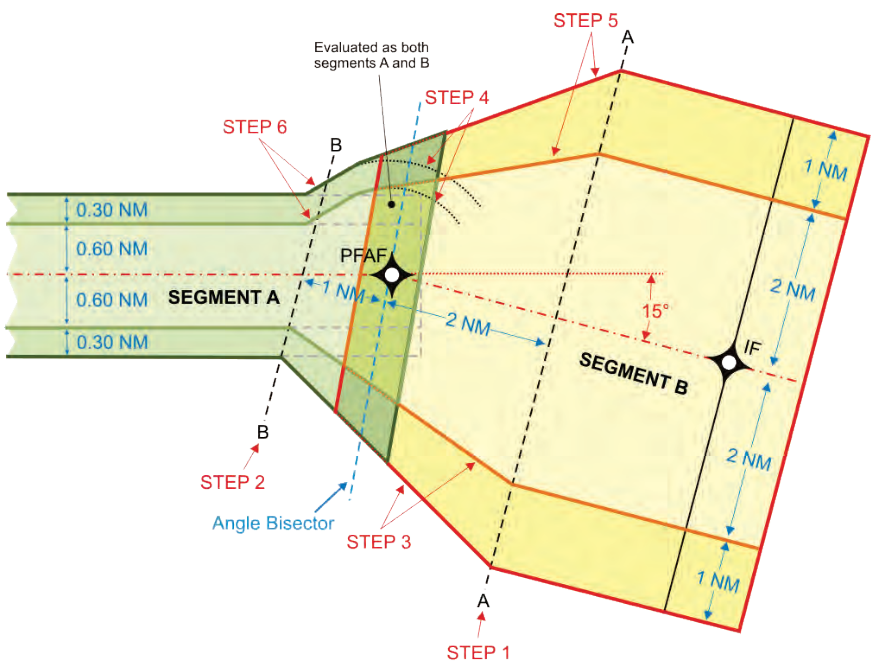
STEP 6: Connect lines tangent to the arcs created in step 4 that taper inward at 30 degrees relative to the FAC to intersect the primary and secondary final segment boundaries as appropriate.

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.

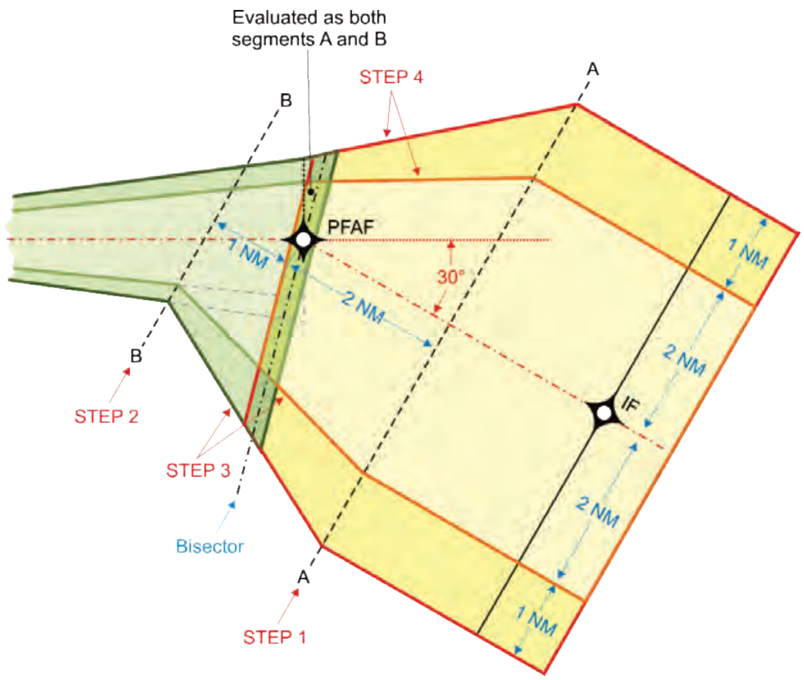
<u>STEP 2</u>: Construct line B perpendicular to the intermediate course extended 1 NM past the PFAF.

<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.

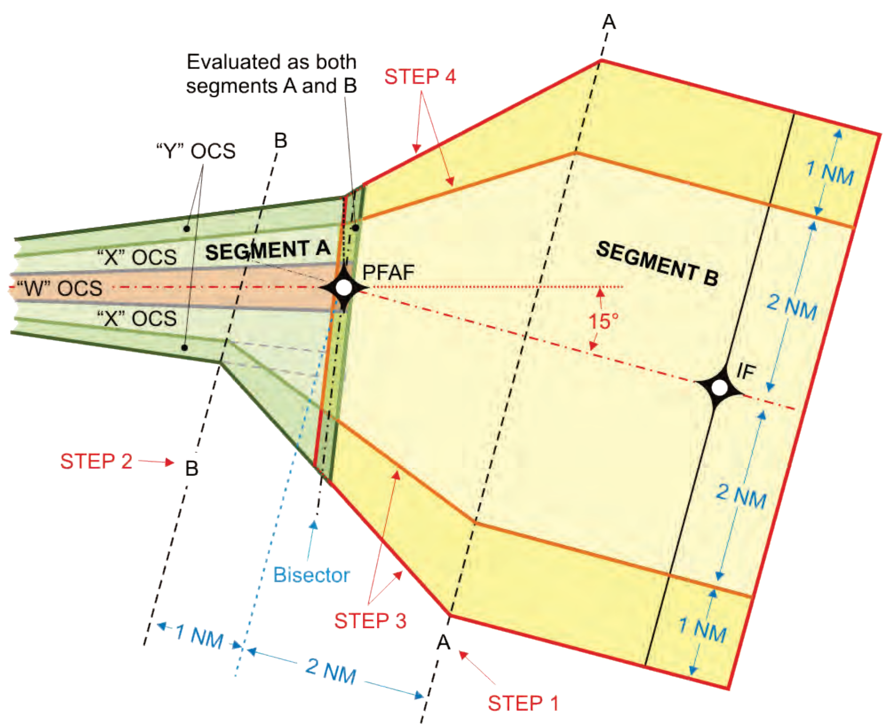
<u>STEP 4</u>: Connect lines from the point of intersection of line A and the outside primary and secondary intermediate segment boundaries to the final segment primary and secondary final segment lines at a point perpendicular to the final course at the PFAF.

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

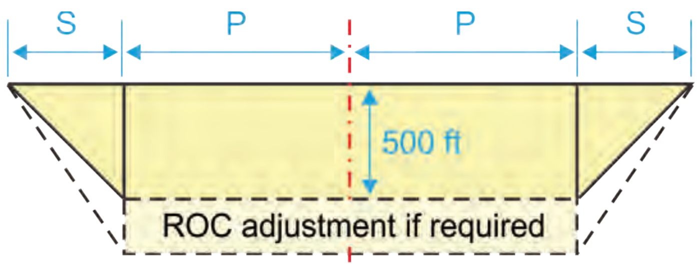


1.9.3 **c. RF intermediate segments.** Locate the intermediate leg's RF segment's terminating fix at least 2 NM outside the PFAF.

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

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

$$d_{IF} = 0.3 \times \frac{d}{350} - \frac{d}{fpnm}$$

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*

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.

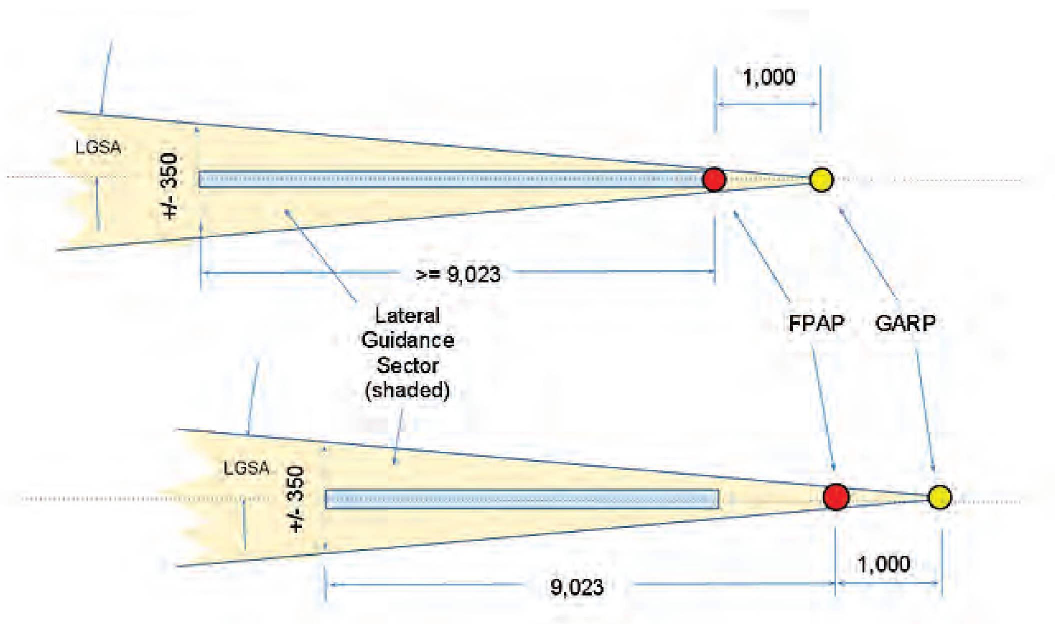
2: To determine the maximum allowable TCH, add 50 ft to the glidepath-to-wheel height.

3: Maximum LPV TCH is 60 ft.

1.12 Determining the Flight Path Alignment Point (FPAP) Location (LPV and LP only).

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.

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) $d_{FPAP} = \mathbf{max}\left(RWY_{Length}, 9023\right)$

(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) $case \ \left(RWY_{Length} > 12366\right):$

$LGSA = 1.5$

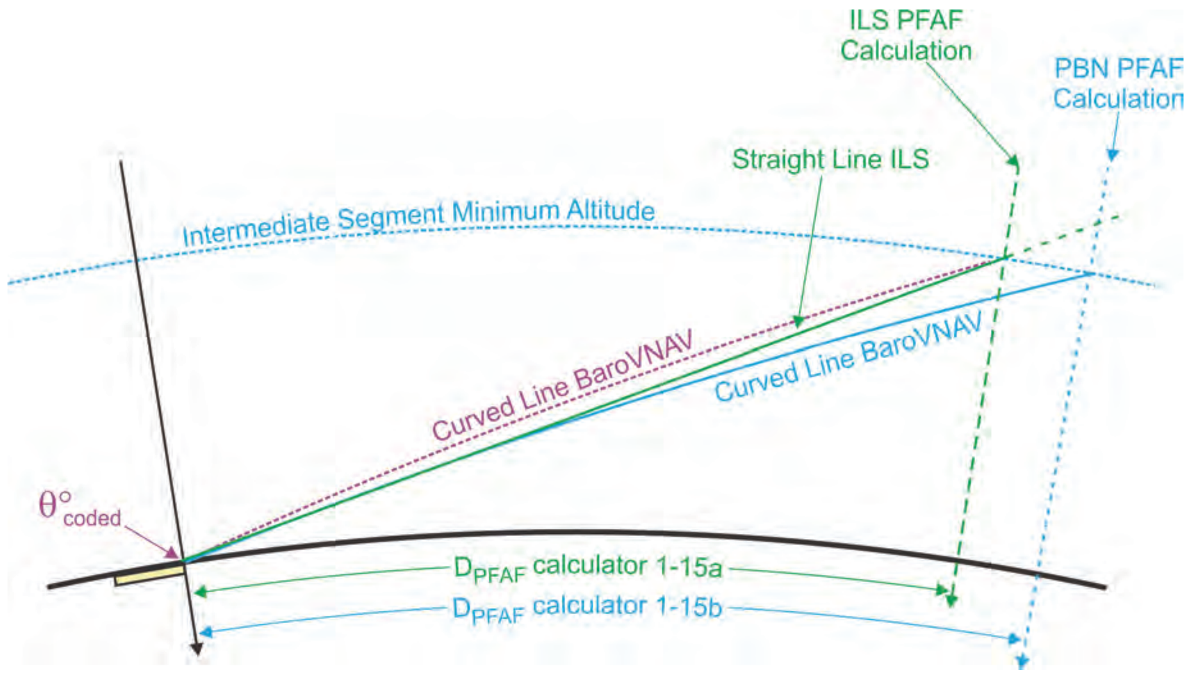
$Width_{feet} = \mathbf{round}\left[\mathbf{tan}\left(1.5° \times \frac{\pi}{180°}\right) \times d_{GARP}, 0\right]$

$Width_{meters} = \frac{\mathbf{round}\left[4 \times Width_{feet} \times 0.3048, 0\right]}{4}$

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

$$D_{PFAF}/D_{GPIP}=\textbf{round}\left[r\times\left(\frac{\pi}{2}-\theta^{\circ}\times\frac{\pi}{180^{\circ}}-a\,\textbf{sin}\left(\frac{\textbf{cos}\left(\theta^{\circ}\times\frac{\pi}{180^{\circ}}\right)\times\left(r+LTP_{elev}+TCH\right)}{r+alt}\right)\right),0\right]$$

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

$$PFAF(ft)=\textbf{round}\left[\frac{\textbf{ln}\left(\frac{r+alt}{r+LTP_{elev}+TCH}\right)\times r}{\textbf{tan}\left(\theta^{\circ}\times\frac{\pi}{180^{\circ}}\right)},0\right]$$

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

$$\theta_{BVNAV} = \mathbf{round}\left[\mathbf{atan}\left(\mathbf{ln}\left(\frac{r+PFAF_{alt}}{r+LTP_{elev}+TCH}\right)\times\frac{r}{D_{PFAF}}\right)\times\frac{180^\circ}{\pi},2\right]$$

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

$$Z_{glidepath} = \mathbf{round}\left[\frac{(r+LTP_{elev}+TCH)\times\mathbf{cos}\left(\theta^\circ\times\frac{\pi}{180^\circ}\right)}{\mathbf{cos}\left(\frac{D_Z}{r}+\theta^\circ\times\frac{\pi}{180^\circ}\right)}-r,0\right]$$

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

$$Z_{glidepath} = \textbf{round}\left[e^{\frac{D_Z \times \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}{r}} \times \left(r + LTP_{elev} + TCH\right) - r, 0 \right]$$

where LTP_{elev} *= LTP MSL elevation*
TCH = Threshold crossing height
θ° = 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)

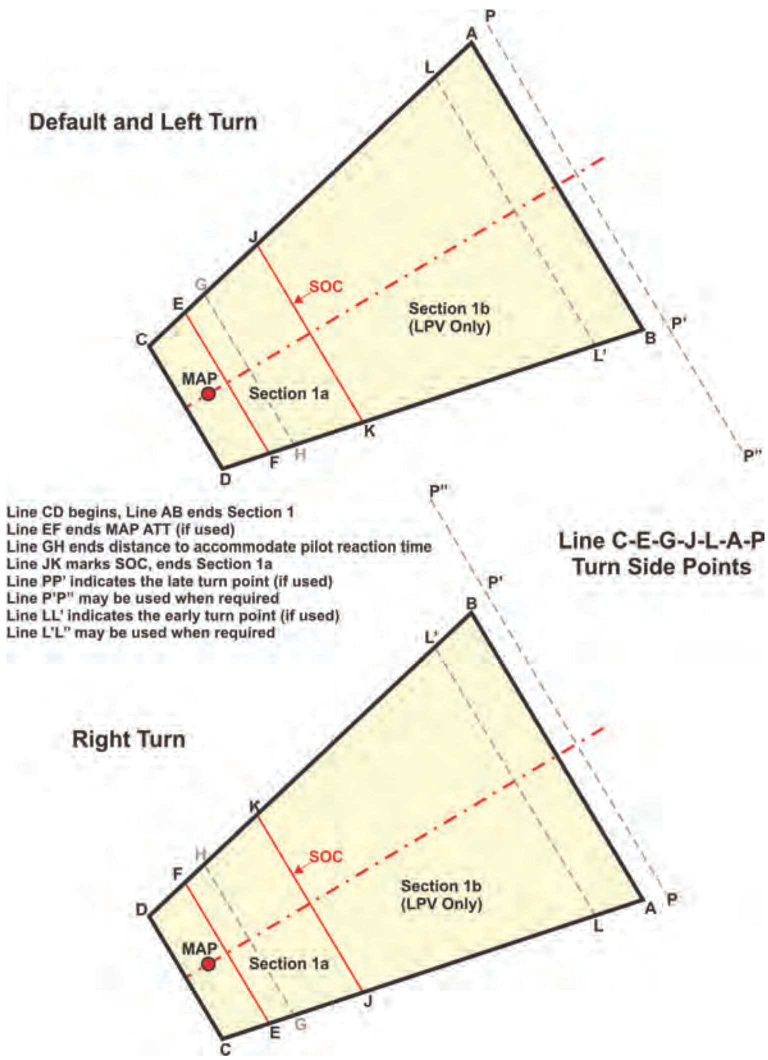
Chapter 1. General Criteria

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.

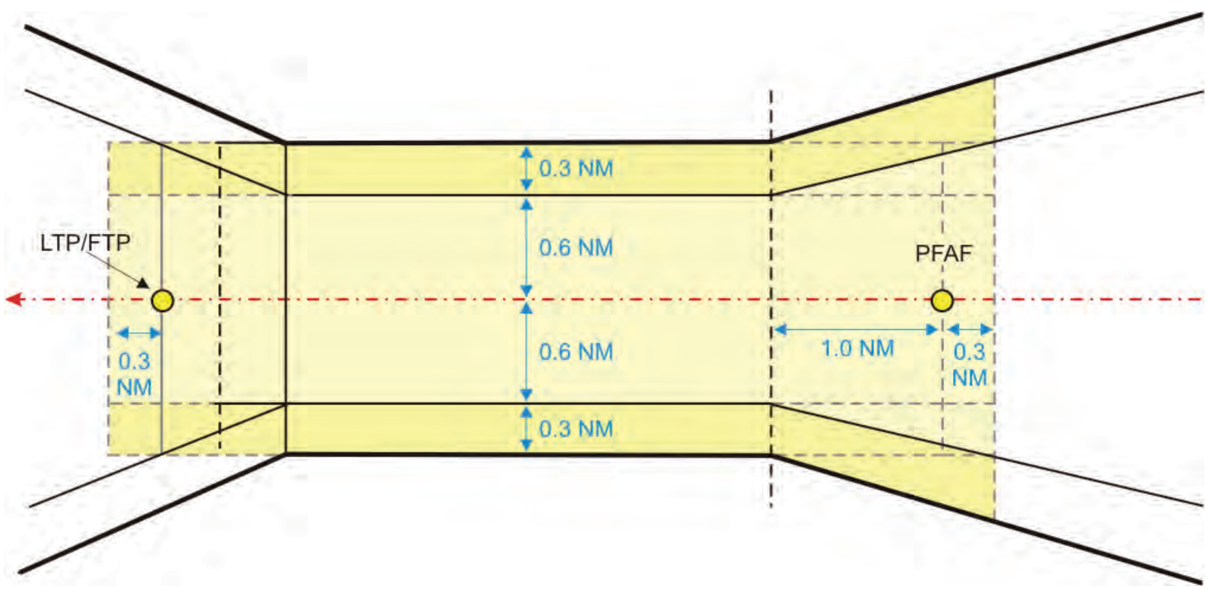
2.1.2 Circling.

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.

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

$$(1)\quad \tfrac{1}{2}W_p = \frac{1.4 \times d}{3} + 0.6$$

$$(2)\quad W_s = \frac{0.7 \times d}{3} + 0.3$$

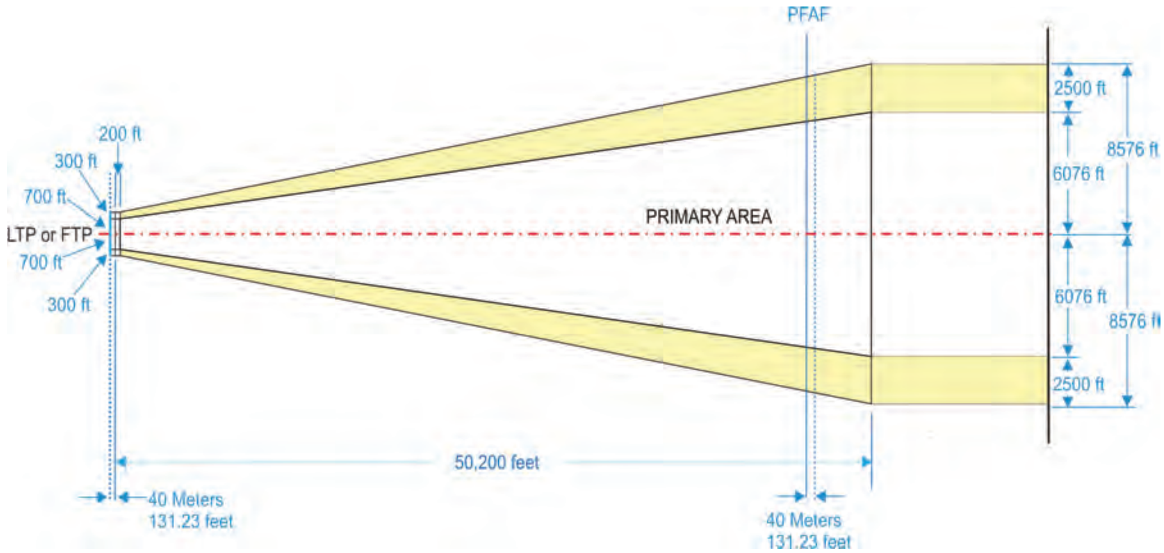
where d = along-track distance from line "B" (see figure 1-13E)

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



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

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.

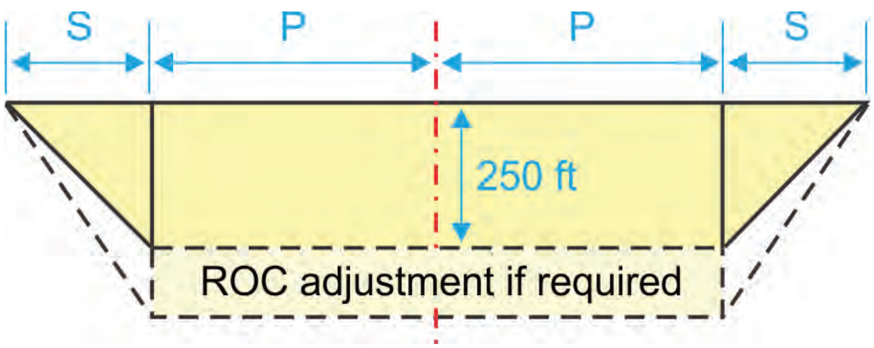
2.4.1 Primary Area.

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.

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

$$(1)\quad OIS_Z = a - c - \frac{O_X}{7}$$

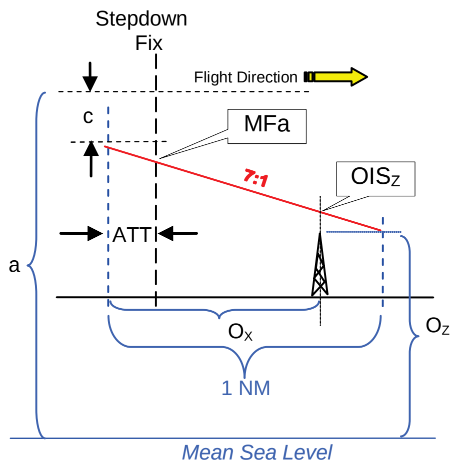
$$(2)\quad MFa = O_Z + c + \frac{O_X}{7}$$

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.

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 ≥ 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).

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.

Calculator 2-7a. LNAV Primary & Secondary Width

$$(1)\quad MAS_{Y primary} = d \times \frac{\tan\left(15° \times \frac{\pi}{180°}\right) \times 1.4 \times fpnm}{2.1 \times fpnm} + 0.6 \times fpnm$$

$$(2)\quad MAS_{Y secondary} = d \times \tan\left(15° \times \frac{\pi}{180°}\right) + 0.9 \times fpnm$$

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

$$(1)\quad MAS_{Yprimary} = d \times \frac{\tan\left(15° \times \frac{\pi}{180°}\right) \times \left(2 \times fpnm - W_P\right)}{3 \times fpnm - W_S} + W_P$$

$$(2)\quad MAS_{Ysecondary} = d \times \tan\left(15° \times \frac{\pi}{180°}\right) + W_S$$

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 $MAS_{Ysecondary}$		

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

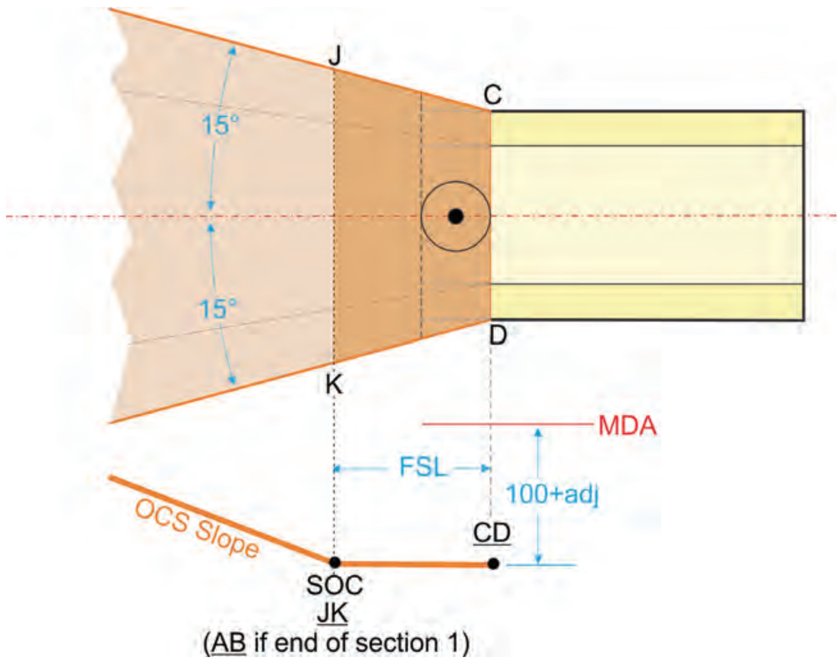
$$HMAS = MDA - (100 + adj)$$

*where adj = final segment precipitous terrain,
remote altimeter (only if full time),
and excessive length of final adjustments*

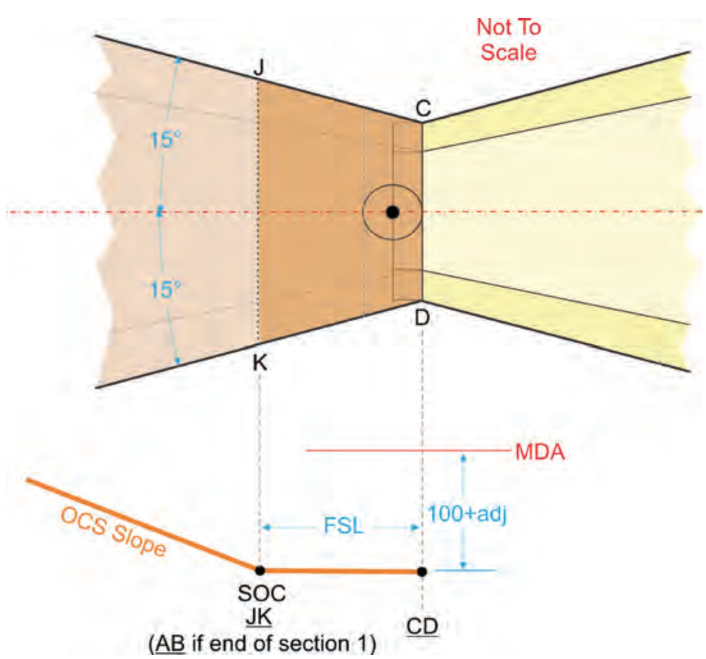
Calculator 2 8		
MDA		Calculate
adj		
HMAS		Clear

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

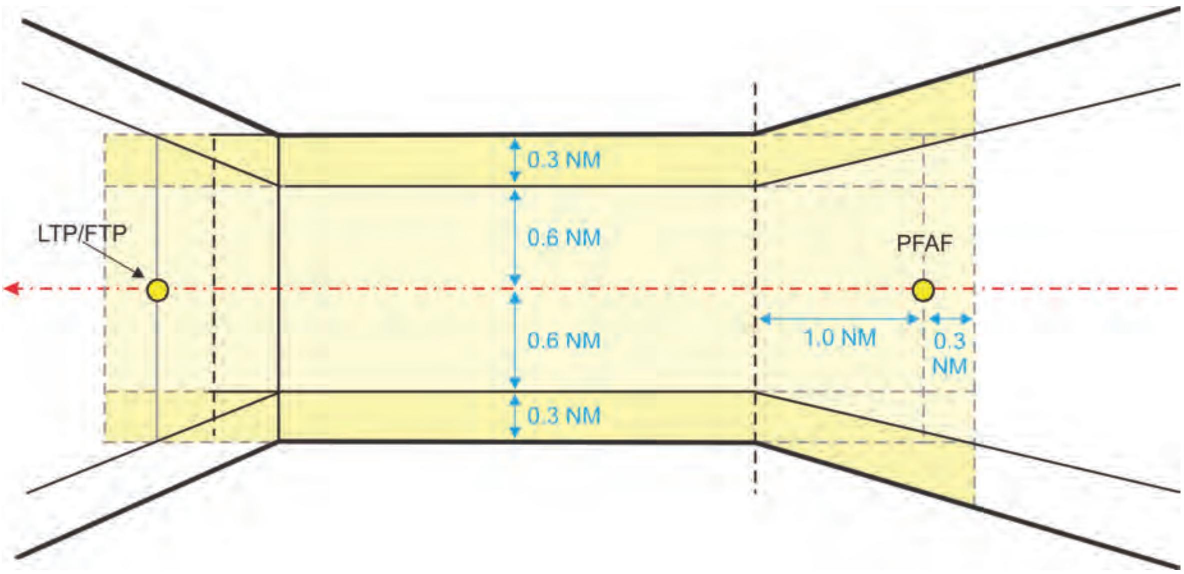
d1 = value from paragraph 3.1.1b/c as appropriate

Calculator 3 1		
d1		Calculate
α°		
V_{KIAS}		
θ°		
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

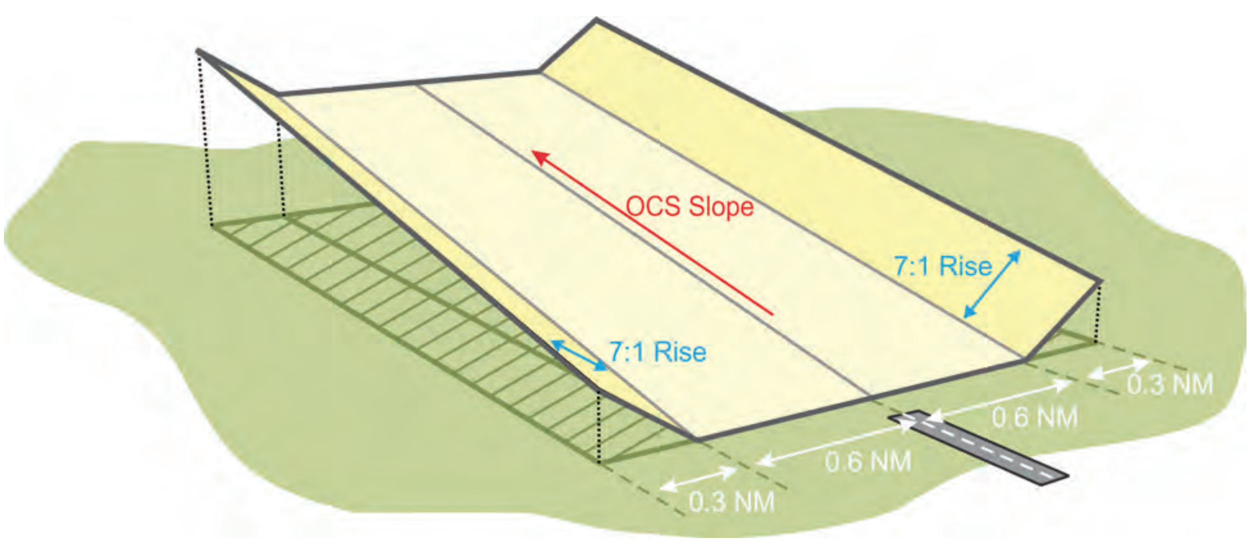
$$D_{origin(ft)} = \frac{250 - TCH}{\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right)}$$

where
θ° = *glidepath angle*

Calculator 3 2		
TCH		Calculate
θ°		
Dorigin		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 <u>temperature spread</u> 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*$\}$

$$(1)\ \Delta ISA_{ACT} = ACT - (15 - 0.00198 \times airport_{elev})$$

$$(2)\ \Delta DA_{alt\_ACT} = \frac{250 \times \Delta ISA_{ACT}}{288 + \Delta ISA_{ACT} - 0.5 \times 0.00198 \times (LTP_{elev} + 250)}$$

$$(3)\ d_{DA\_ft} = \textbf{ceiling}\left[\frac{r \times \ln\left(\frac{r + LTP_{elev} + 250}{r + LTP_{elev} + TCH}\right)}{\tan\left(\theta \times \frac{\pi}{180}\right)}\right]$$

$$(4)\ \theta_{effective} = \frac{180}{\pi} \times \textbf{atan}\left(\frac{r}{d_{DA\_ft}} \times \ln\left(\frac{r + LTP_{elev} + 250 + \Delta DA_{alt\_ACT}}{r + LTP_{elev} + TCH}\right)\right)$$

$$(5)\ \Delta DA_{alt\_2.5} = (r + LTP_{elev} + TCH) \times e^{\frac{d_{DA\_ft}}{r} \times \tan\left(2.5 \times \frac{\pi}{180}\right)} - (r + LTP_{elev} + 250)$$

$$(6)\ \Delta ISA_{2.5} = \frac{\Delta DA_{alt\_2.5} \times (288 - 0.5 \times 0.00198 \times (LTP_{elev} + 250))}{250 - \Delta DA_{alt\_2.5}}$$

$$(7)\ ACT_{2.5} = ISA_{airport} + \Delta ISA_{2.5}$$

$$(8)\ \textbf{case}\ \theta_{effective} \geq 2.5^\circ \quad NA_{below°C} = \textbf{ceiling}[ACT]$$

$$NA_{below°F} = \textbf{ceiling}[ACT \times 1.8 + 32]$$

$$\Delta ISA_{Low°C} = \Delta ISA_{ACT}$$

$$\textbf{case}\ \theta_{effective} < 2.5^\circ \quad NA_{below°C} = \textbf{ceiling}[ACT_{2.5}]$$

$$NA_{below°F} = \textbf{ceiling}[ACT_{2.5} \times 1.8 + 32]$$

$$\Delta ISA_{Low°C} = \Delta ISA_{2.5}$$

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 }- - - - - -

$$(1)\quad MDR_{angle} = 1.13 \times \alpha \times \frac{\pi}{180}$$

$$(2)\quad DR_{high\_temp} = \mathbf{ceiling}\left[\sin\left(MDR_{angle}\right) \times \left(\frac{\left(V_{KIAS}\right) \times 171233 \times \sqrt{303 - 0.00198 \times \left(LTP_{elev} + 250\right)}}{\left(288 - 0.00198 \times \left(LTP_{elev} + 250\right)\right)^{2.628}} + 10\right) \times 101.26859\right]$$

$$(3)\quad DR_{standard\_temp} = \mathbf{ceiling}\left[\sin\left(\theta \times \frac{\pi}{180}\right) \times \left(\frac{\left(V_{KIAS}\right) \times 171233 \times \sqrt{303 - 0.00198 \times \left(LTP_{elev} + 250\right)}}{\left(288 - 0.00198 \times \left(LTP_{elev} + 250\right)\right)^{2.628}} + 10\right) \times 101.26859\right]$$

- - - - - - - - - - - - - - - - - -{ 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) $$d_{DA\_ft} = \textbf{ceiling}\left[\frac{r \times \ln\left(\frac{r + LTP_{elev} + 250}{r + LTP_{elev} + TCH}\right)}{\tan\left(\theta \times \frac{\pi}{180}\right)}\right]$$

(6) $$\Delta DA_{alt} = e^{\frac{d_{DA\_ft}}{r} \times \tan(MDR_{angle})} \times (r + LTP_{elev} + TCH) - (r + LTP_{elev} + 250)$$

(7) $$\Delta ISA_{high} = \frac{\Delta DA_{alt} \times (288 - 0.5 \times 0.00198 \times (LTP_{elev} + 250))}{250 - \Delta DA_{alt}}$$

(8) $temp_{high°C} = ISA_{airport} + \Delta ISA_{high}$

$temp_{high°F} = temp_{high°C} \times 1.8 + 32$

(9) case $temp_{high°C} \geq 54$ $NA_{above°C} = 54$

$NA_{above°F} = 130$

case $temp_{high°C} < 54$ $NA_{above°C} = \textbf{floor}[temp_{high°C}]$

$NA_{above°F} = \textbf{floor}[temp_{high°F}]$

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.

Calculator 3-6. OCS Slope

$$OCS_{slope} = \frac{1}{\tan\left(\theta° \times \frac{\pi}{180°}\right) \times \left(0.928 + 0.0038 \times \left(ACT°C - ISA°C\right)\right)}$$

Where

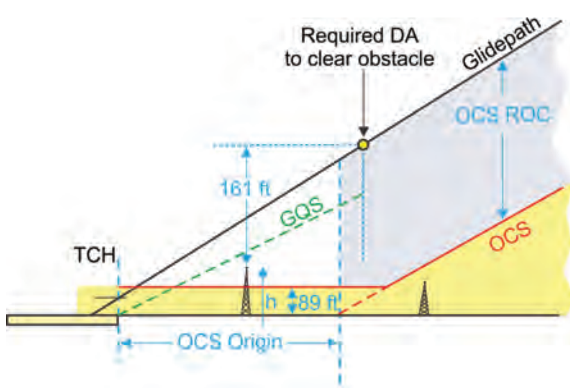
θ° = glidepath angle (degrees)
ISA°C = Airport ISA from calculator 3-3
ACT°C = Value from paragraph 3.3.1

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

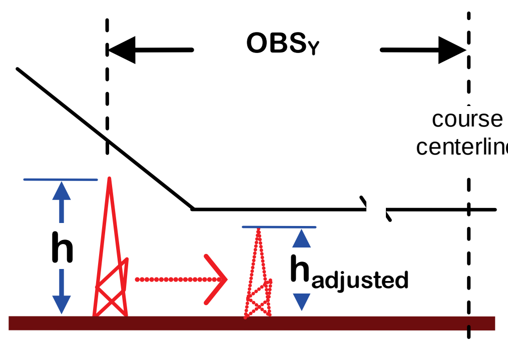
$$h_{adjusted} = h - \frac{OBS_Y - Width_{primary}}{7}$$

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*

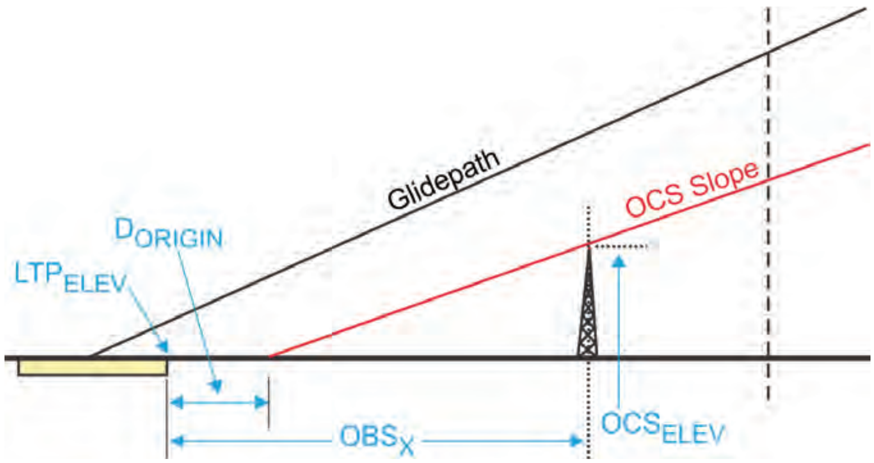
Calculator 3 9a		
LTP_{elev}		Calculate
OCS_{slope}		
D_{origin}		Clear
D_{OCS}		

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

$$(1)\quad d=(r+LTP_{elev})\times OCS_{slope}\times \ln\left(\frac{r+O_{MSL}}{r+LTP_{elev}}\right)+D_{origin}$$

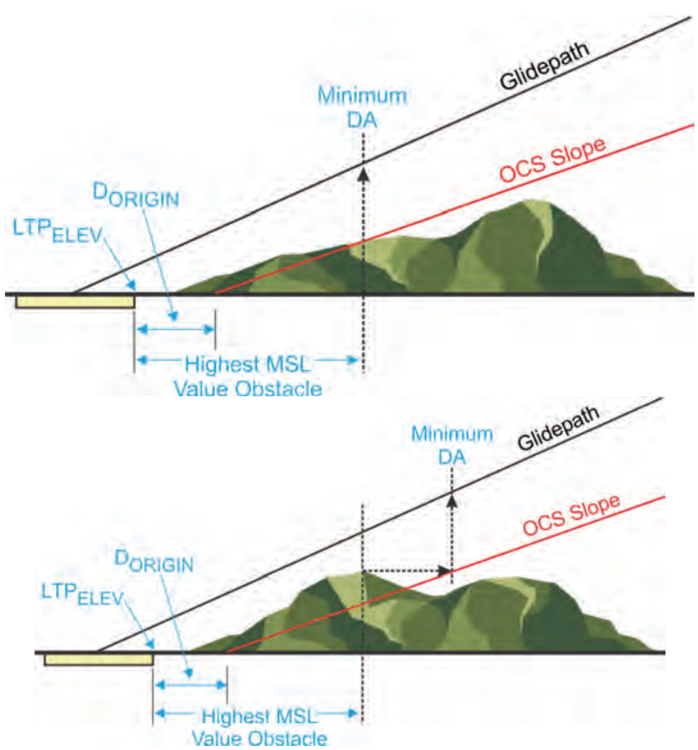
$$(2)\quad DA_{OCS}=e^{\frac{d\times \tan\left(\theta^\circ\times\frac{\pi}{180^\circ}\right)}{r}}\times(r+LTP_{elev}+TCH)-r$$

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.

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^o		
DA		Clear
D_{DA}		

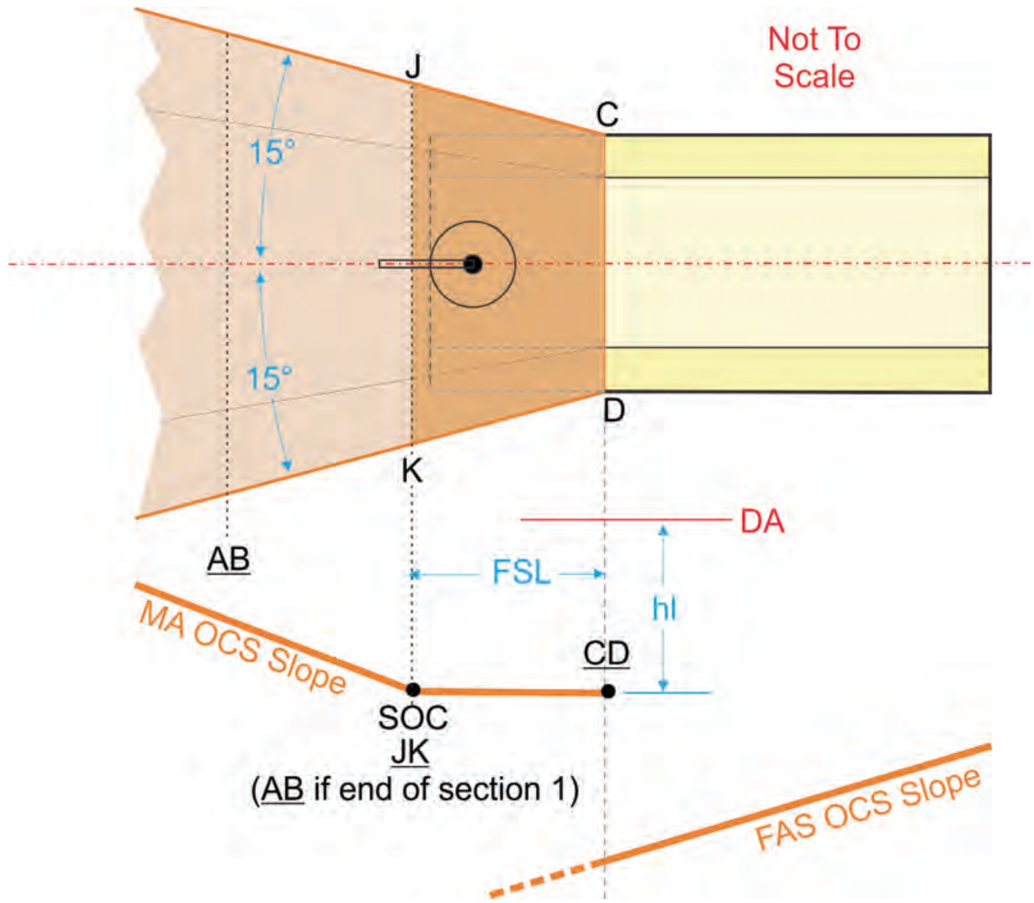
3.4 MA Section 1.

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

$$\Delta DA = r \times e^{\frac{p \times \frac{MA_{slope} \times \tan\left(\theta° \times \frac{\pi}{180°}\right)}{1 + MA_{slope} \times \tan\left(\theta° \times \frac{\pi}{180°}\right)}}{r}} - r$$

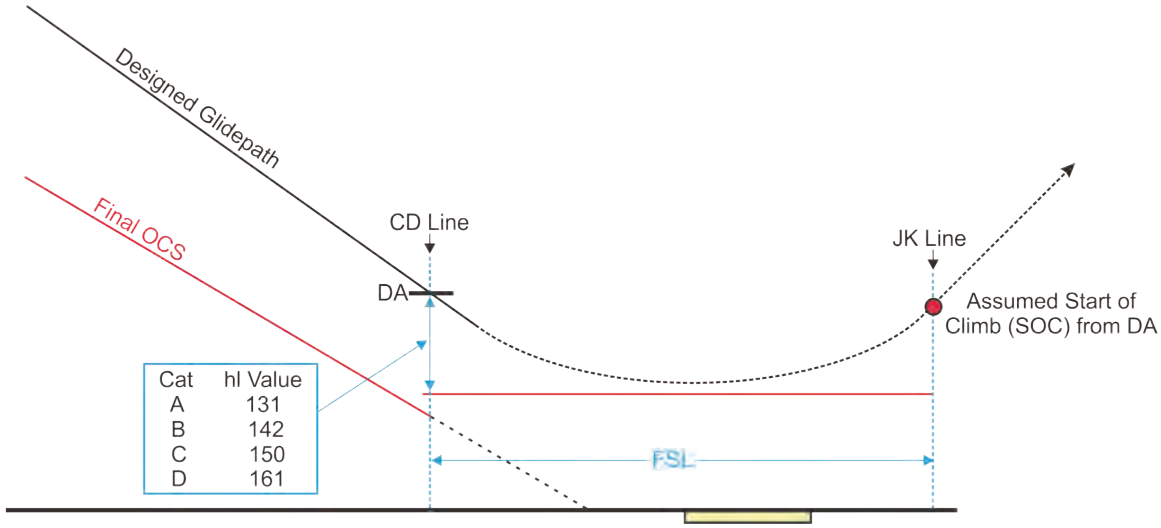
where

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.

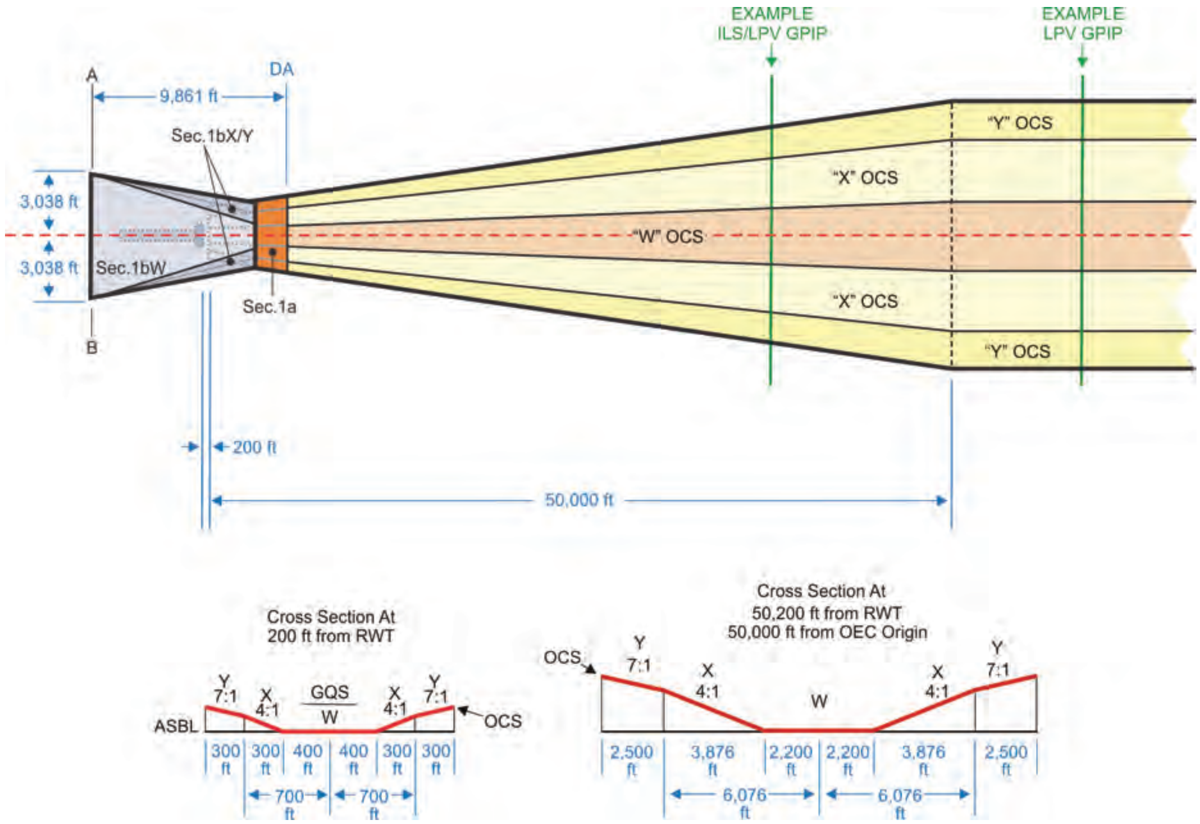
The OEA and associated OCSs are applicable to LPV final approach segments. These criteria may also be applied to construction of an RNAV transition to an ILS final segment where the GPIP is located within 50200 ft of the LTP. For an RNAV transition to an ILS/GLS final, use LPV criteria to evaluate the 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.

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

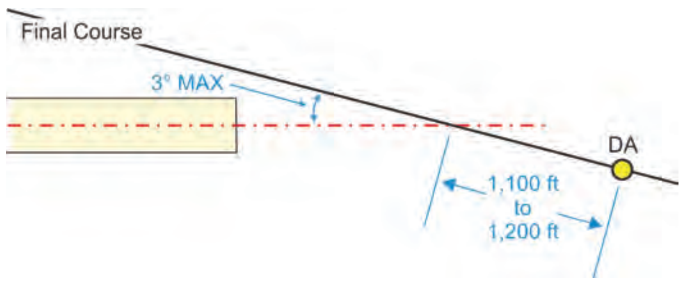


4.1.1 OEA Alignment.

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.

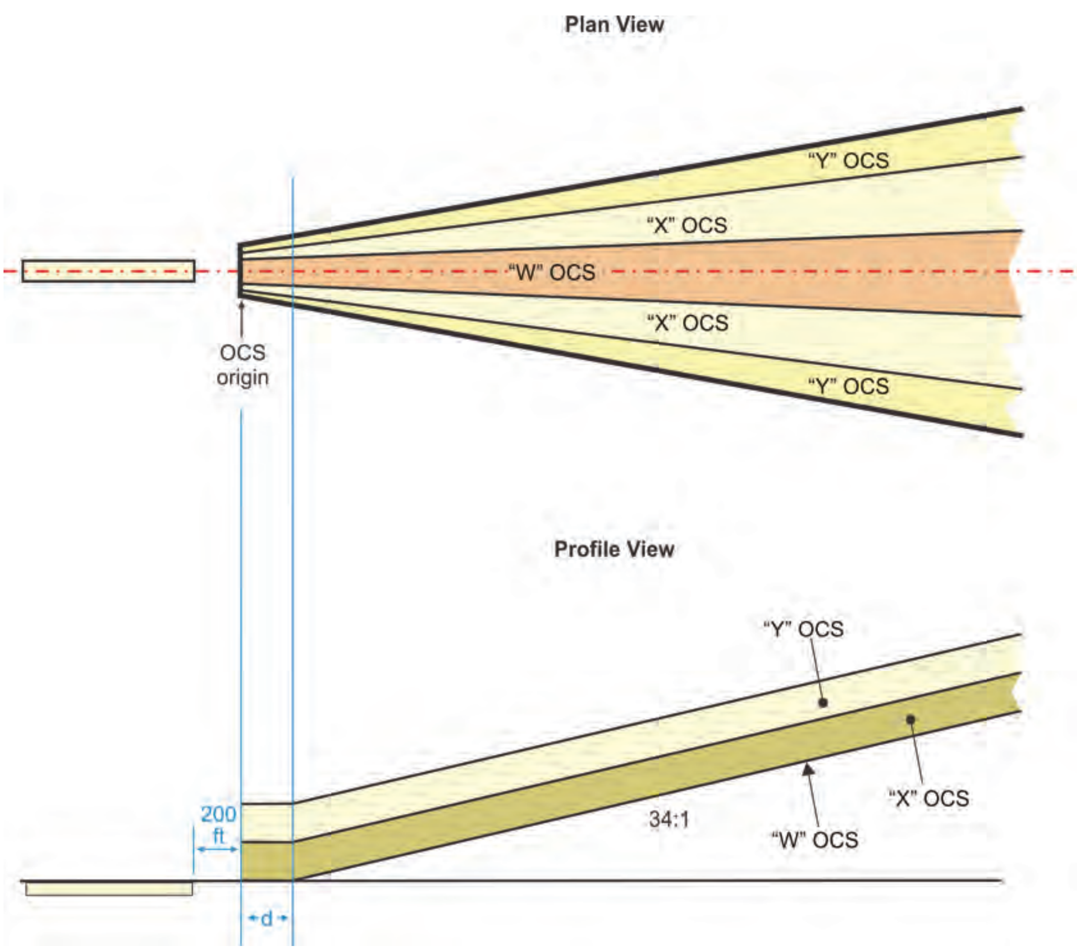
Figure 4-2. Offset Final Course



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

$$S = \frac{102}{\theta°}$$

Calculator 4 1		
$\theta°$		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 $\frac{TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)} \geq 954$, *d equals 0.*

Where $\frac{TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)} < 954$, calculate the value of d using calculator 4-2.

Calculator 4-2. Slope Origin Distance (d)

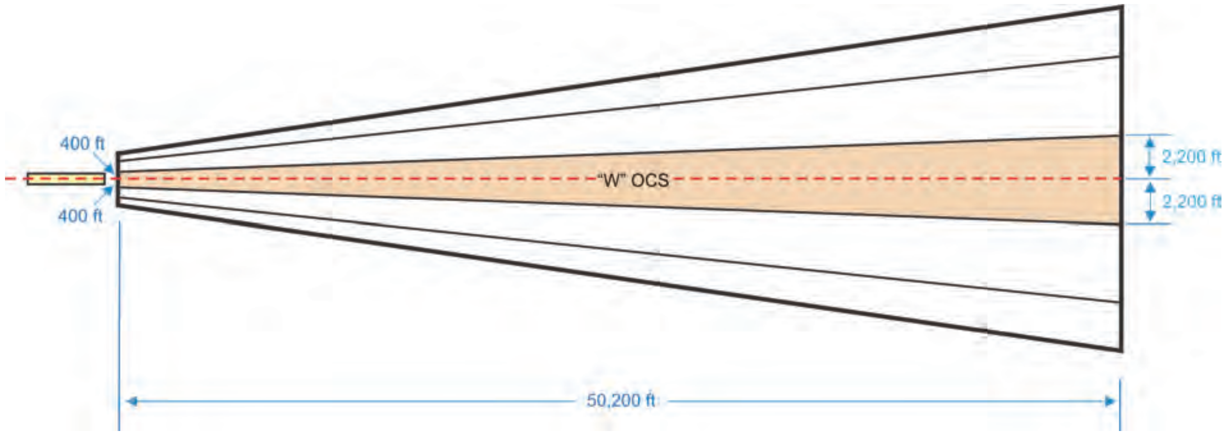
$$d = 954 - \frac{TCH}{\tan\left(\theta° \times \frac{\pi}{180°}\right)}$$

Calculator 4 2		
TCH		Calculate
$\theta°$		
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.**

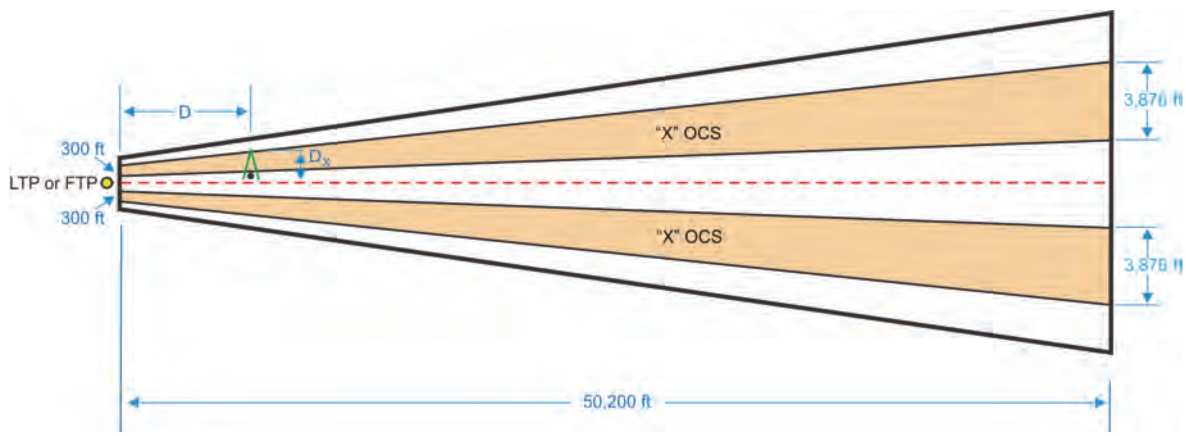
4.2.3 **c. Raise the GPA** (see paragraph 4.6) within the limits of table 1-5.

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

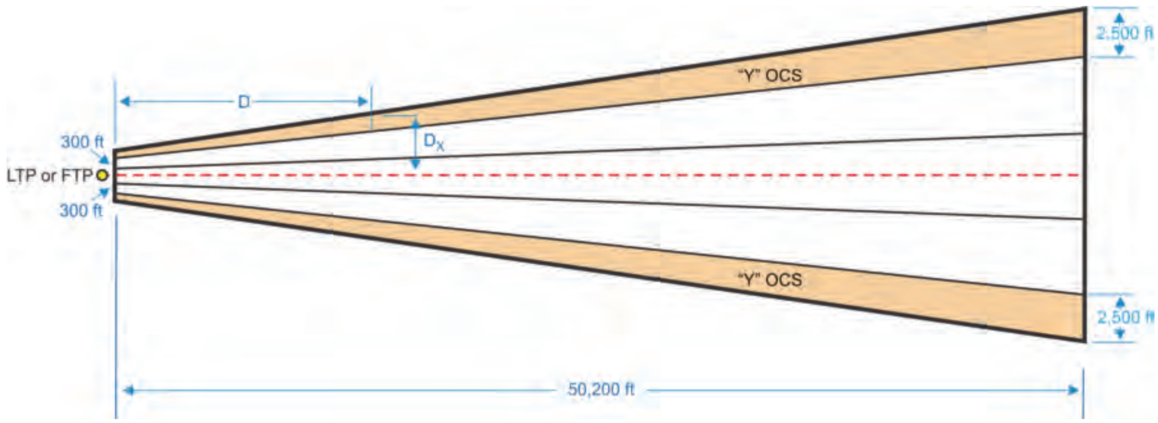
OBS_Y = *perpendicular distance (ft) from course centerline to obstacle*

$W_{boundary}$ = *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.

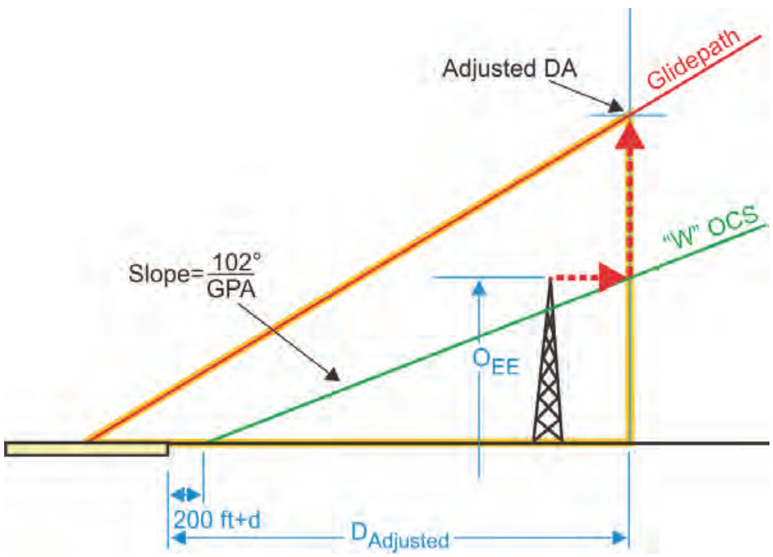
Calculator 4-11. Distance LTP to DA

$$X_{DA} = r \times \left(\frac{\pi}{2} - \theta° \times \frac{\pi}{180°} - \text{asin}\left(\frac{\cos\left(\theta° \times \frac{\pi}{180°}\right) \times (r + LTP_{elev} + TCH)}{r + DA} \right) \right)$$

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) $$D_{adjusted} = r \times \left(\frac{\pi}{2} - \operatorname{atan}\left(\frac{\theta°}{102°} \right) - \operatorname{asin}\left(\frac{\cos\left(\operatorname{atan}\left(\frac{\theta°}{102°} \right) \right) \times \left(r + LTP_{elev} - \frac{\theta° \times (200 + d)}{102°} \right)}{r + O_{EE}} \right) \right)$$

(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

$$(1) \quad SRD = \sqrt{(r+O_{EE})^2 + (r+LTP_{elev})^2 - 2\times(r+O_{EE})\times(r+LTP_{elev})\times\cos\left(\frac{OBS_X-(200+d)}{r}\right)}$$

$$(2) \quad RS = \frac{1}{\tan\left(\operatorname{acos}\left(\frac{SRD^2+(r+LTP_{elev})^2-(r+O_{EE})^2}{2\times SRD\times(r+LTP_{elev})}\right)-\frac{\pi}{2}\right)}$$

$$(3) \quad \theta°_{required} = \frac{102°}{RS}$$

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
$\theta°_{required}$		

4.7 Adjusting TCH to Reduce/Eliminate OCS Penetrations.

This paragraph is applicable ONLY 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) [$p \le Z$]

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 (<u>CD</u> line) and ends at the <u>AB</u> 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

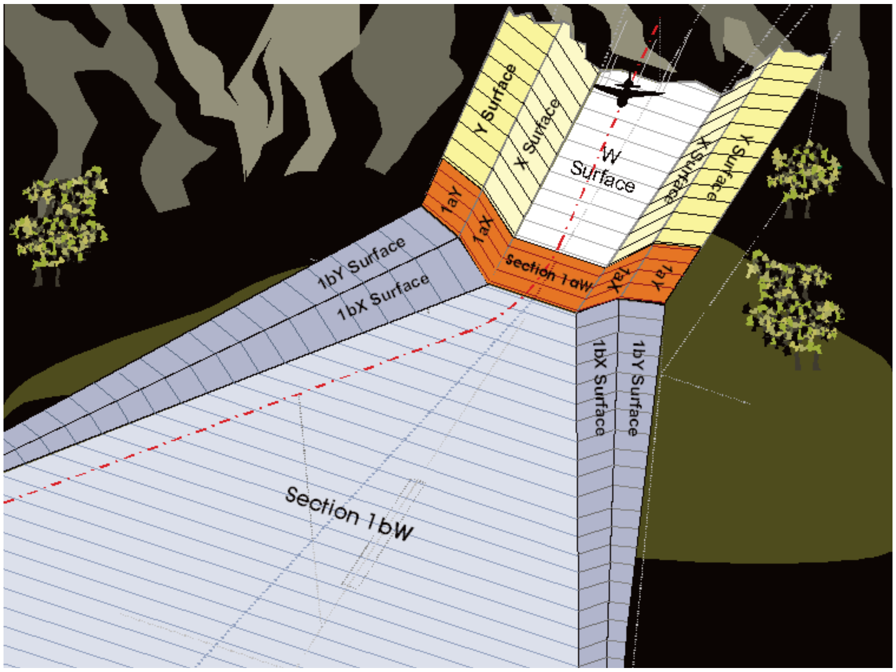
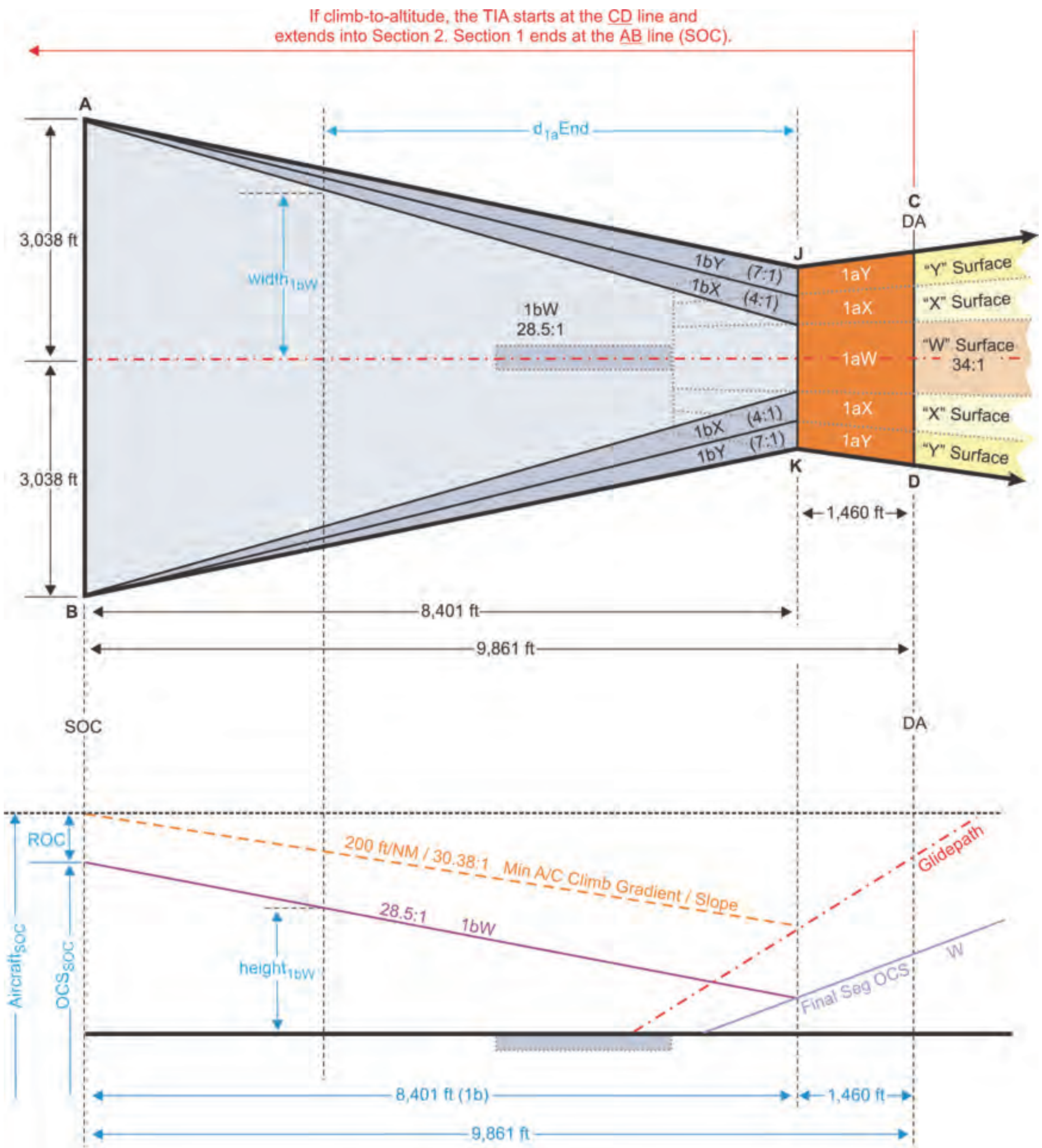


Figure 4-8B. Section 1 (a/b) 2D Perspective



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 <u>JK</u> line at the end of section 1a as an up-sloping surface for a distance of 8401 ft to the <u>AB</u> 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

$$\Delta X_{DA} = \frac{2907 \times p}{28.5 \times \theta^\circ + 102^\circ}$$

where

p = amount of penetration (ft)

Calculator 4 23		
θ^o		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

$$DA_{adjusted} = \text{ceiling}\left[\tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times \left(X_{DA} + \Delta X_{DA}\right) + LTP_{elev} + TCH\right]$$

where

ΔX_{DA} = *from calculator 4-23*
X_{DA} = *from calculator 4-11*

Calculator 4 24		
LTP_{elev}		Calculate
TCH		
θ^o		
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

$$(1)\quad Aircraft_{SOC} = DA - \tan\left(\theta^\circ \times \frac{\pi}{180^\circ}\right) \times 1460 + 276.525$$

$$(2)\quad OCS_{SOC} = \left(r + elev_{1aEnd}\right) e^{\left(\frac{8401}{28.5 \times r}\right)} - r$$

$$(3)\quad ROC_{SOC} = Aircraft_{SOC} - OCS_{SOC}$$

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
θ°		
$elev_{1aEnd}$		
$Aircraft_{SOC}$		Clear
OCS_{SOC}		
ROC_{SOC}		

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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).

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 (≥ 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)		

<u>STEP 2 (LNAV/LP)</u>: 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)		

<u>STEP 2 (LNAV/VNAV)</u>: 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 (≥ 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).

$$EarlyTP = Fix - ATT$$

$$LateTP = Fix + ATT + rr$$

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.

STEP 1: 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).

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 $D_{early_{TP}}$ (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 $D_{early_{TP}}$ (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).

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)

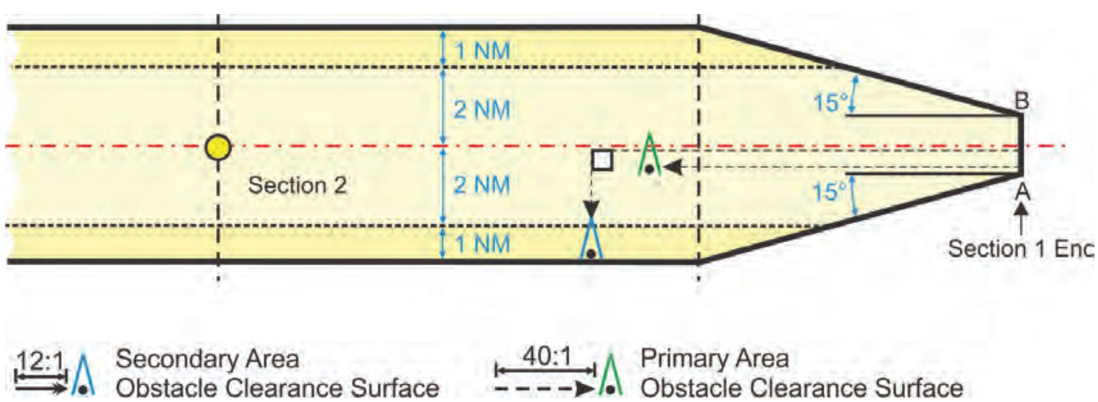


**Figure 5-2. Turn at Altitude –
Direct to Waypoint Small Angle Turn**

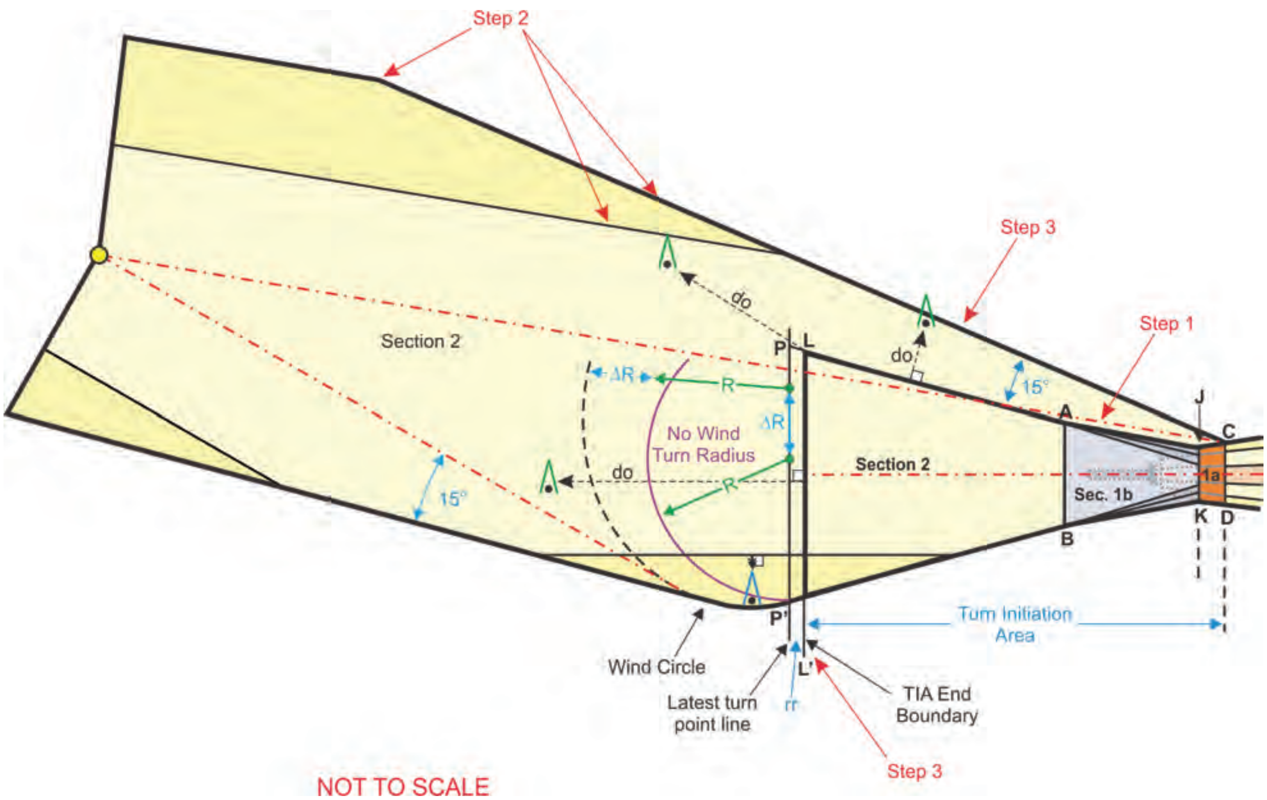


Figure 5-3. Turn at Altitude, TIA must Extend to the End of Section 1B

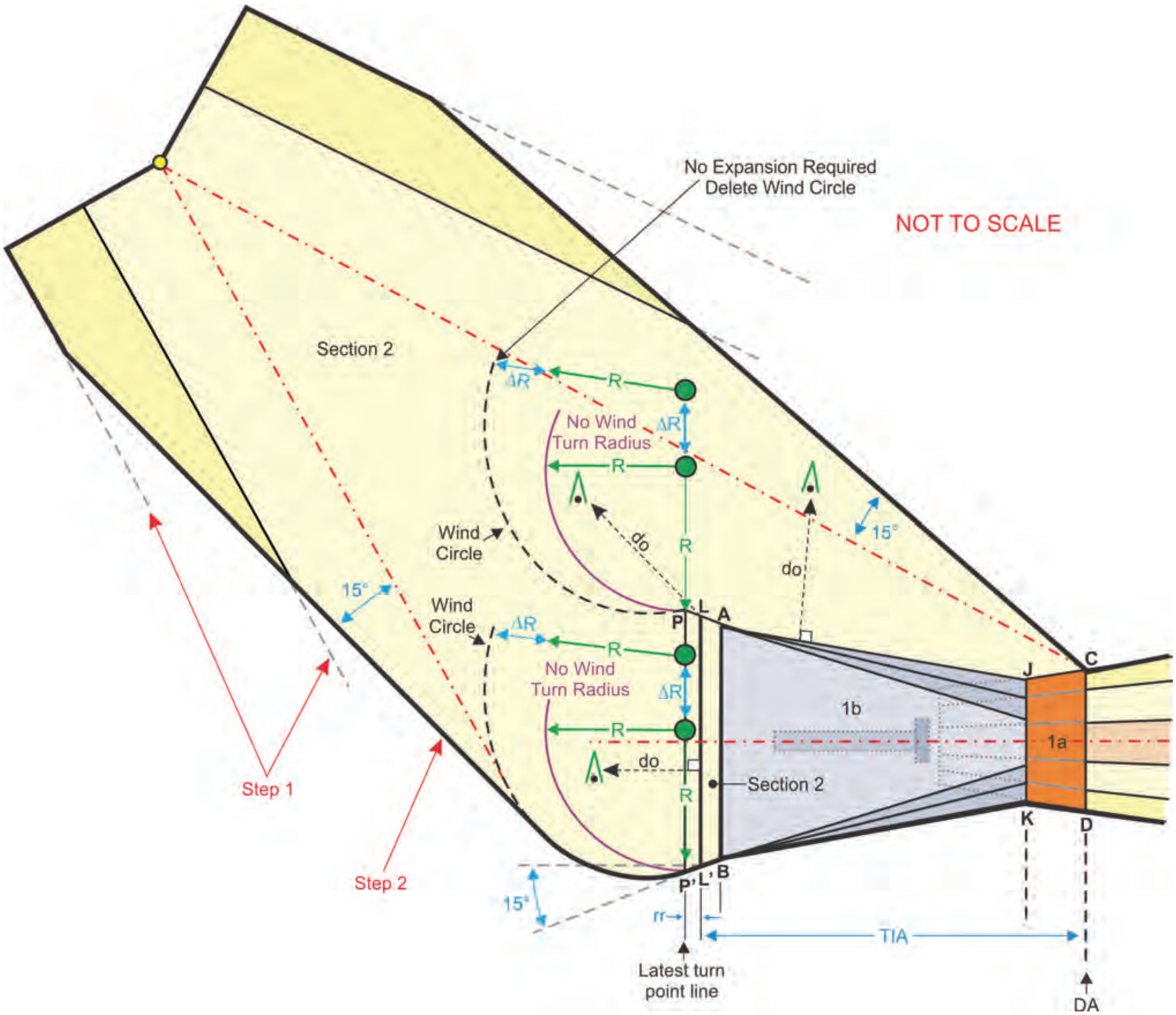


Figure 5-4. Turn at Altitude (Minimum Straight Segment)

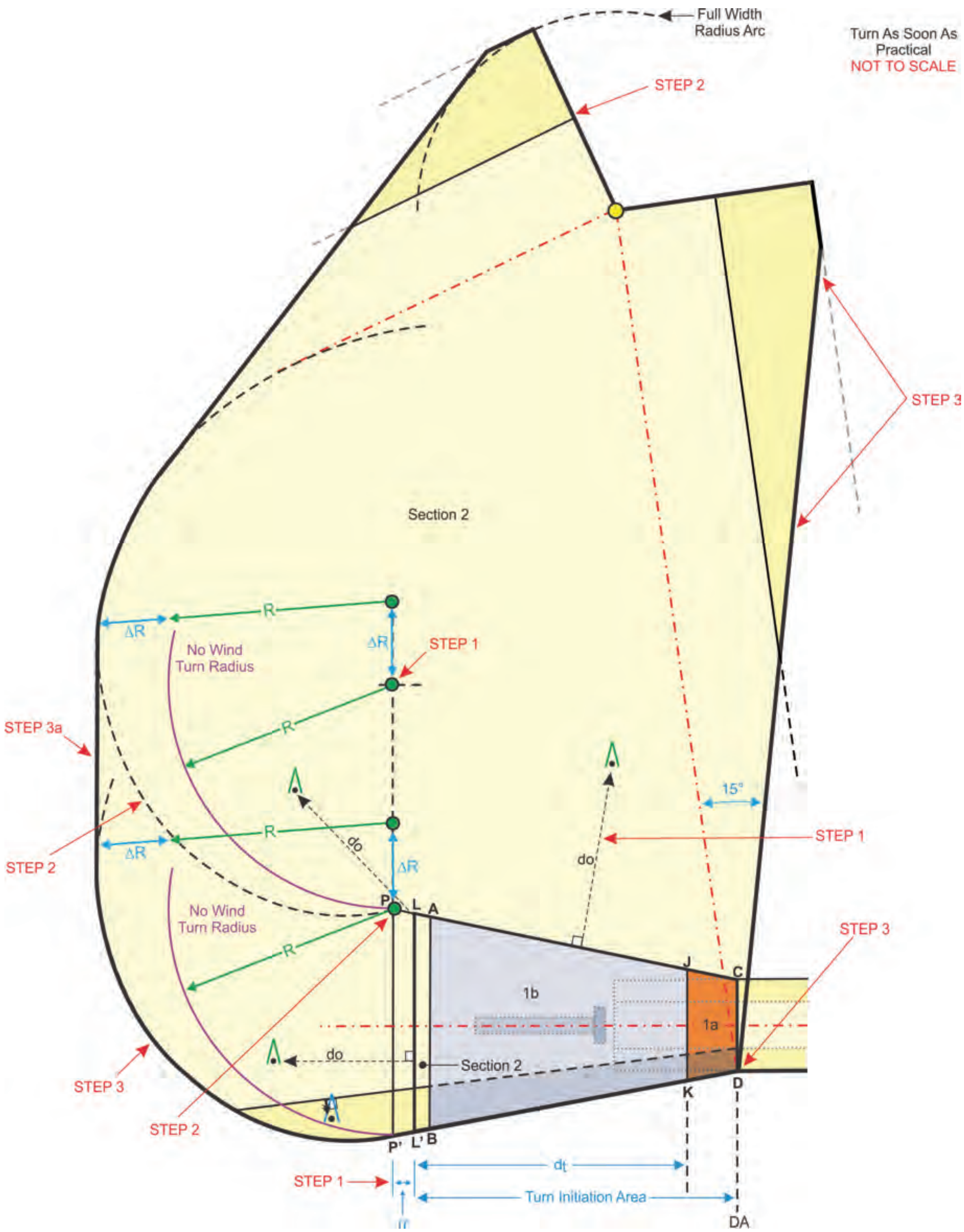


Figure 5-5. Turn at Altitude ≥ 180 degrees

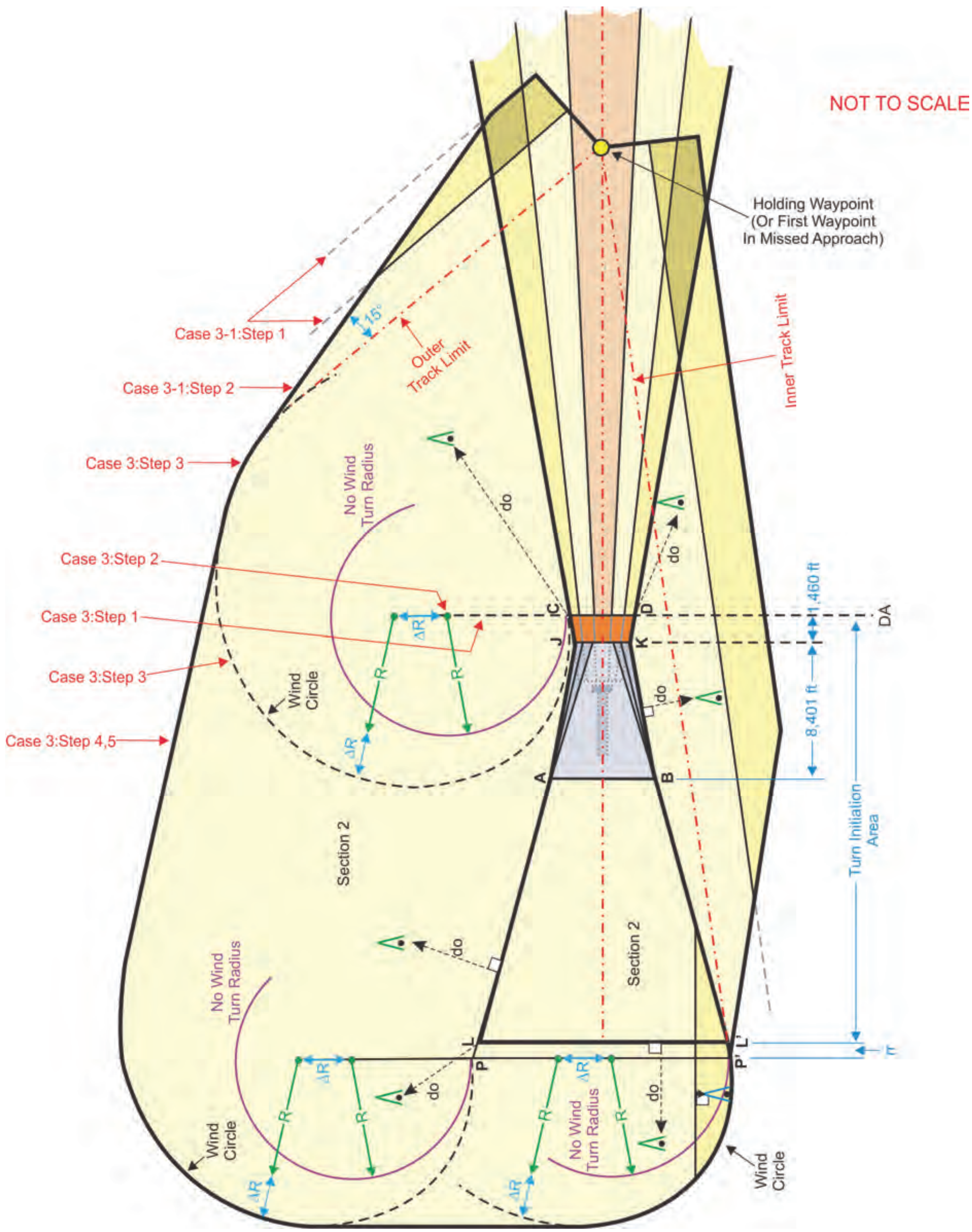


**Figure 5-6. FB DF-TF Turn
Following Turn at Altitude**

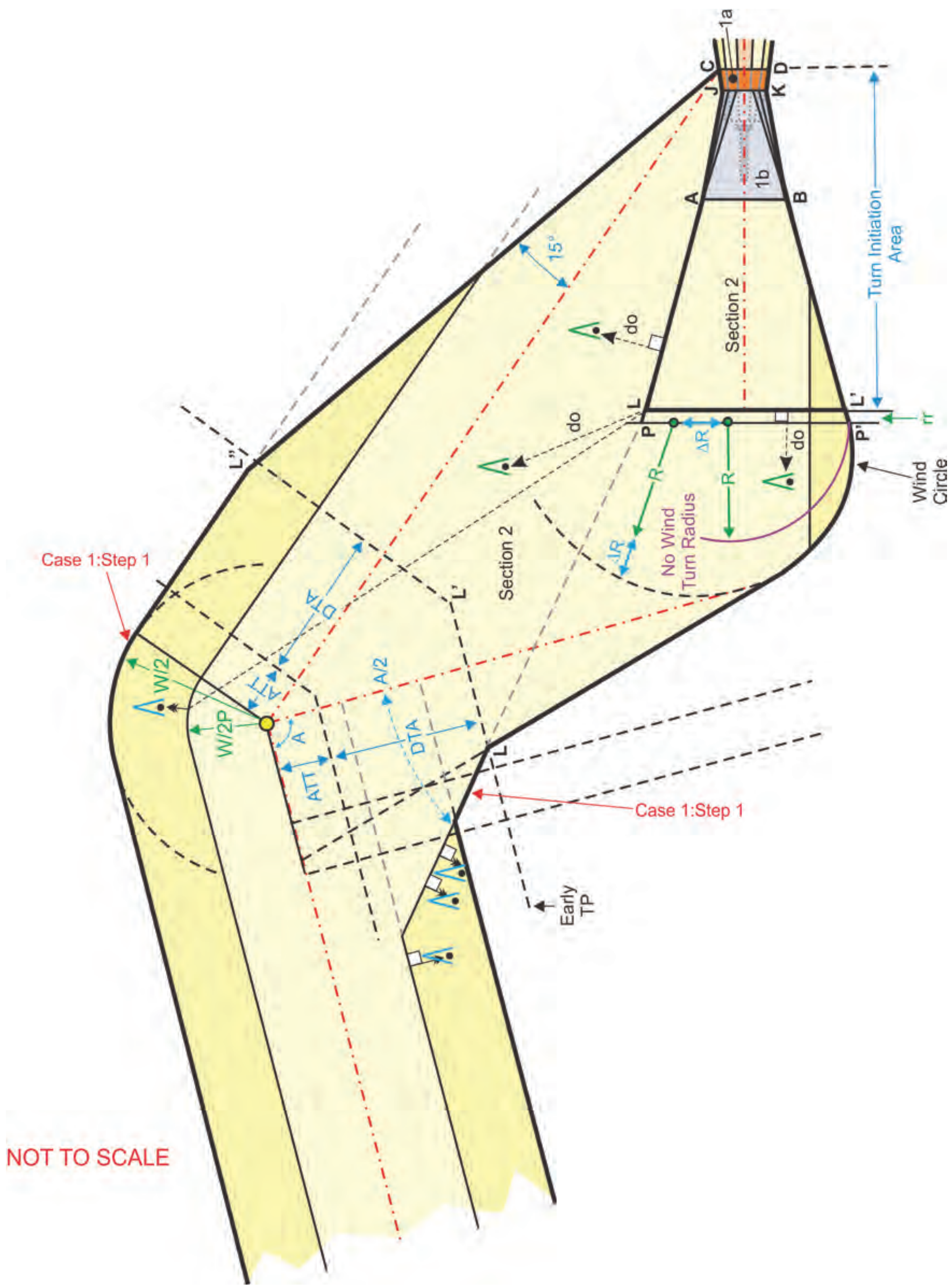
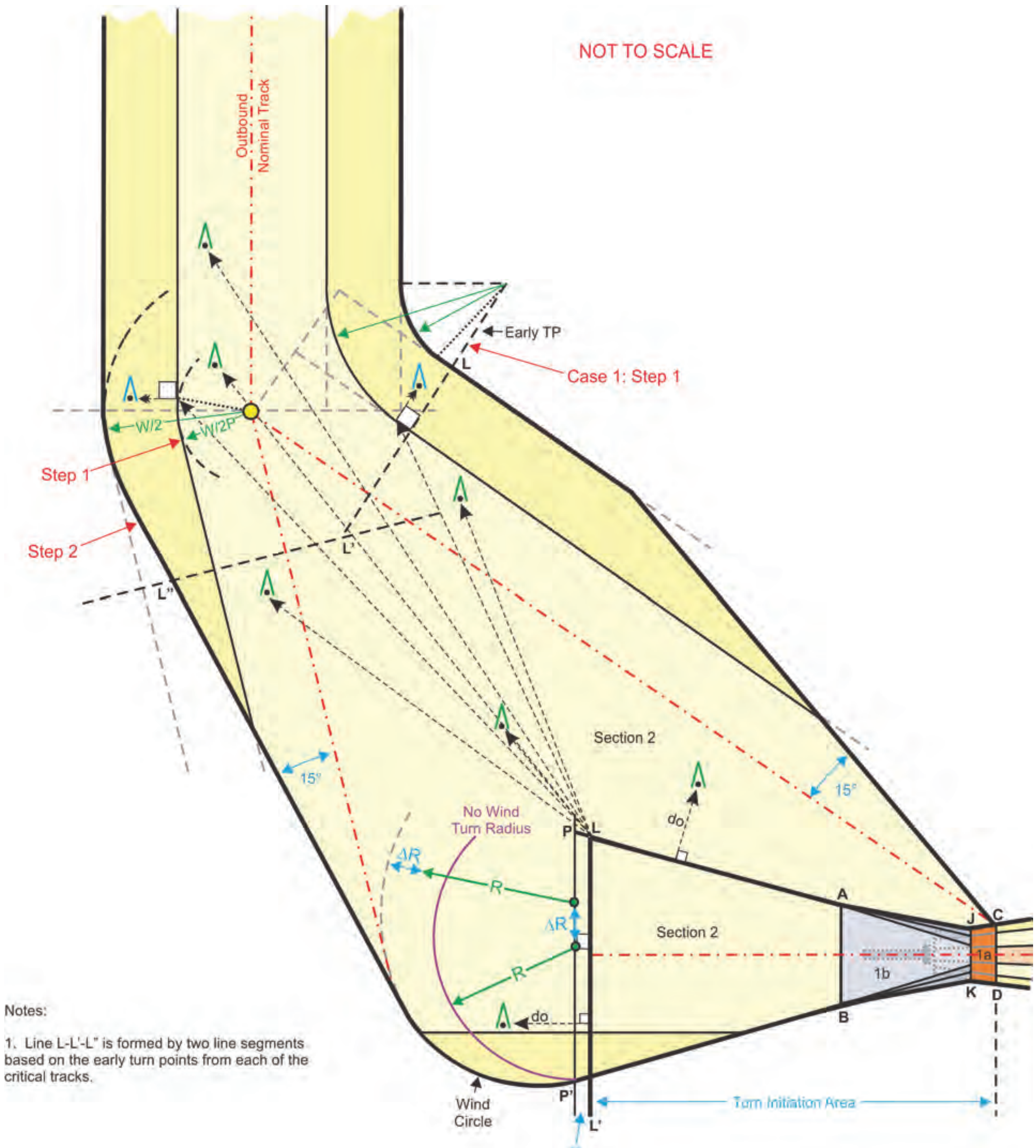


Figure 5-7. Turn at Altitude to FB Waypoint



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

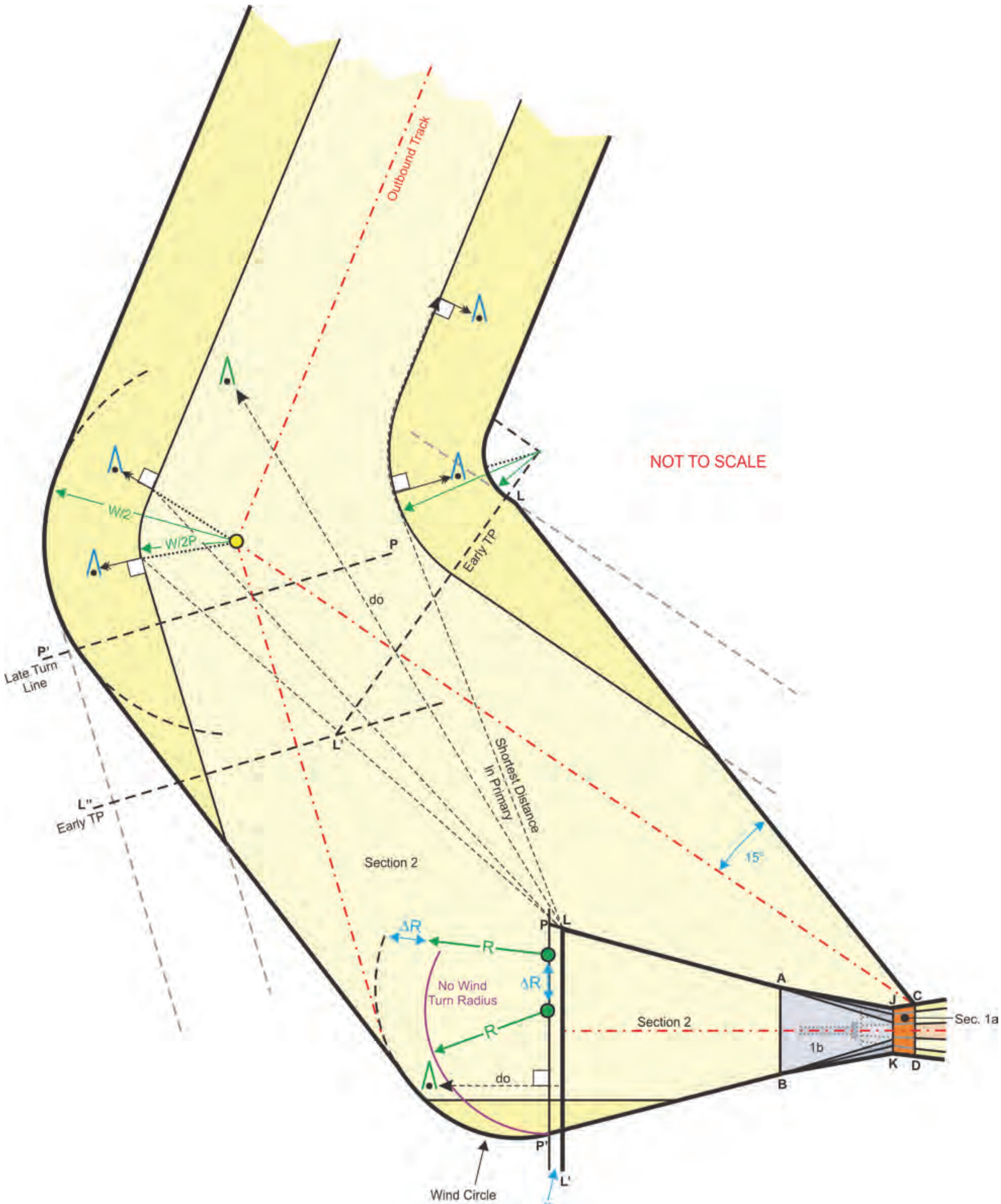


Figure 5-9. Turn at Altitude to a FO Waypoint

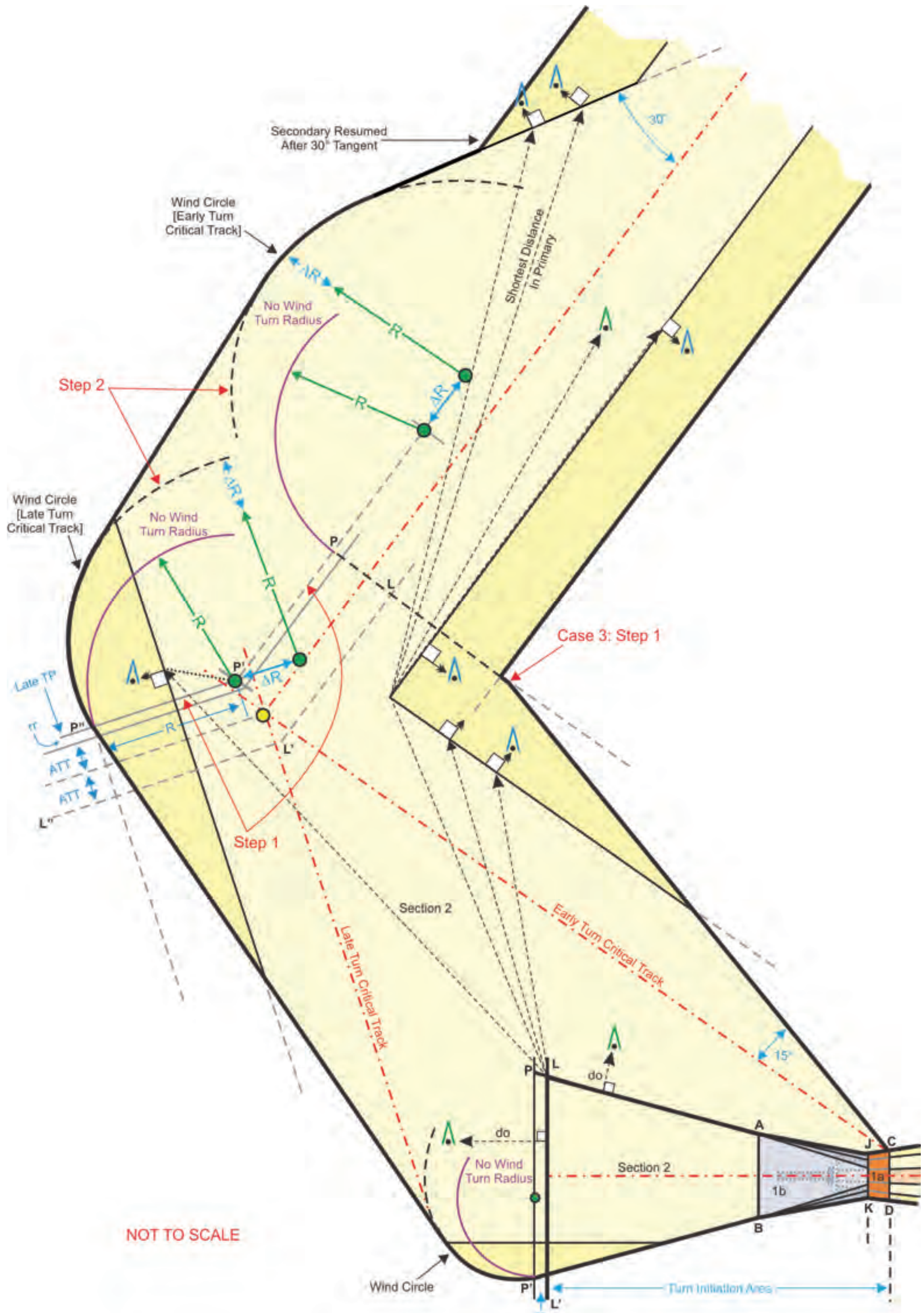
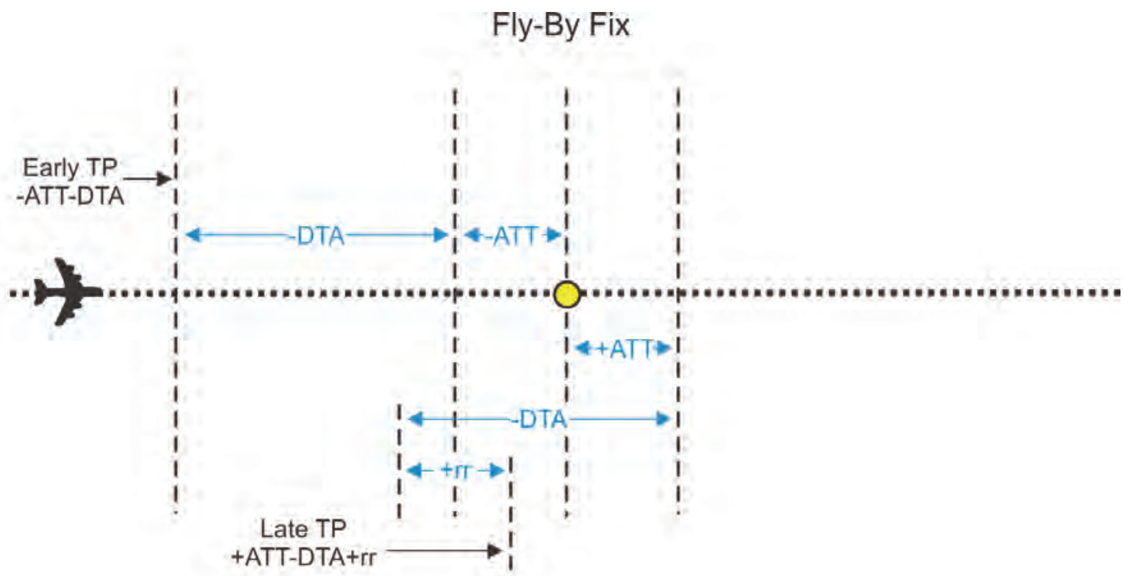


Figure 5-10. FO/FB Fix Diagrams



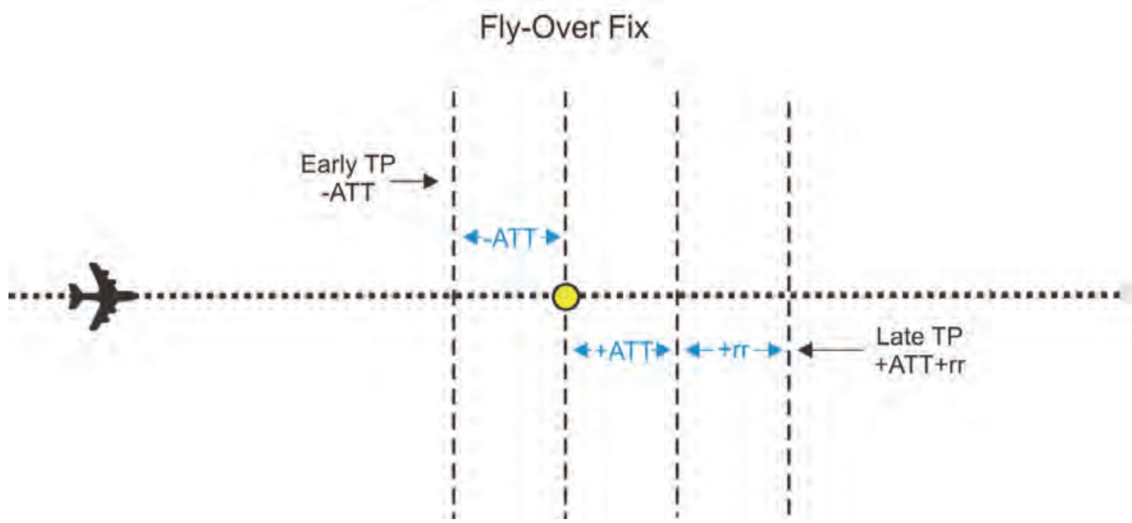


Figure 5-11A. Turn at Waypoint (FB)

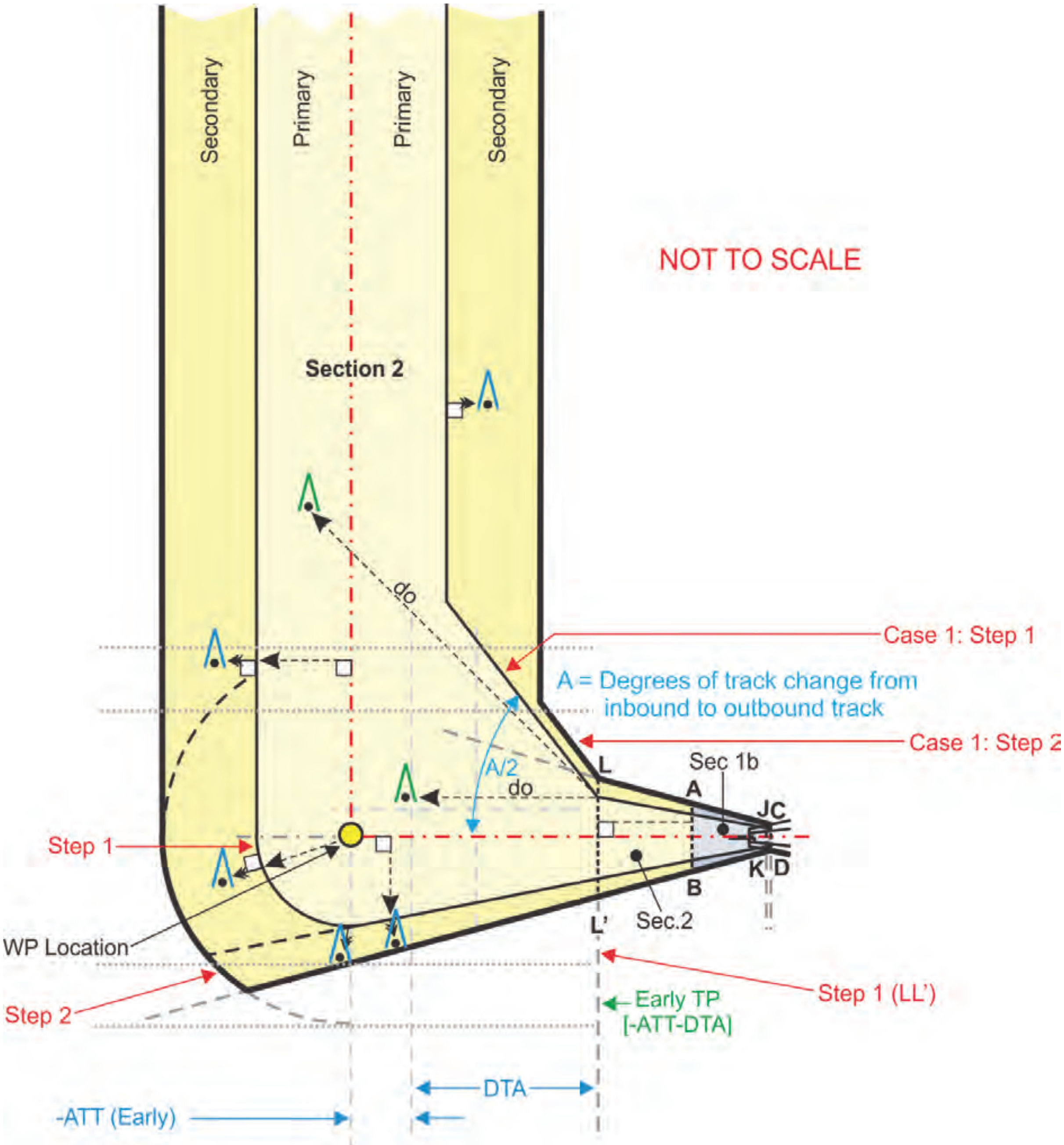


Figure 5-11B. Turn at Waypoint (FB)

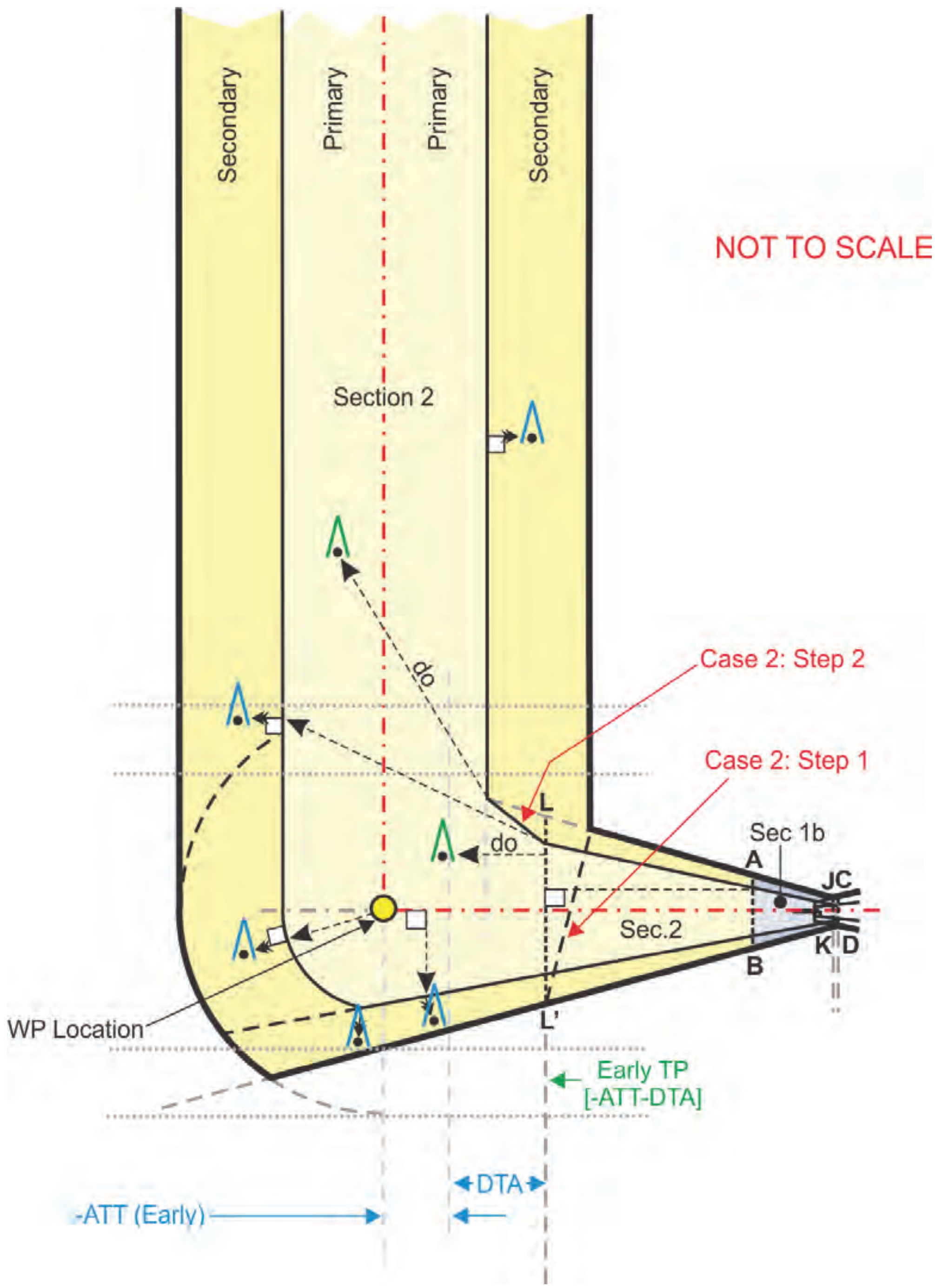


Figure 5-11C. Turn at Waypoint (FB)

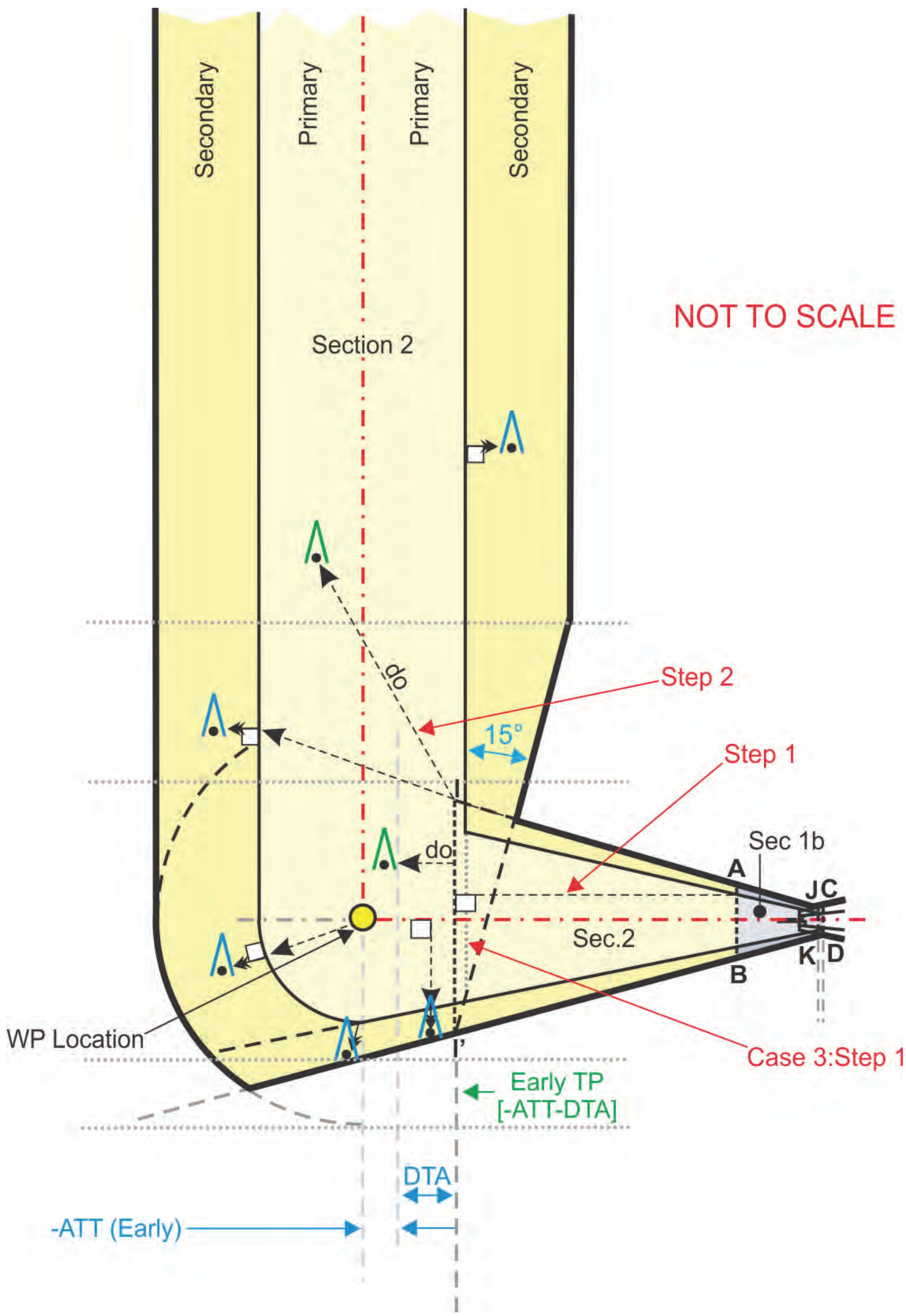


Figure 5-12. Turn at Waypoint (FO), < 75°

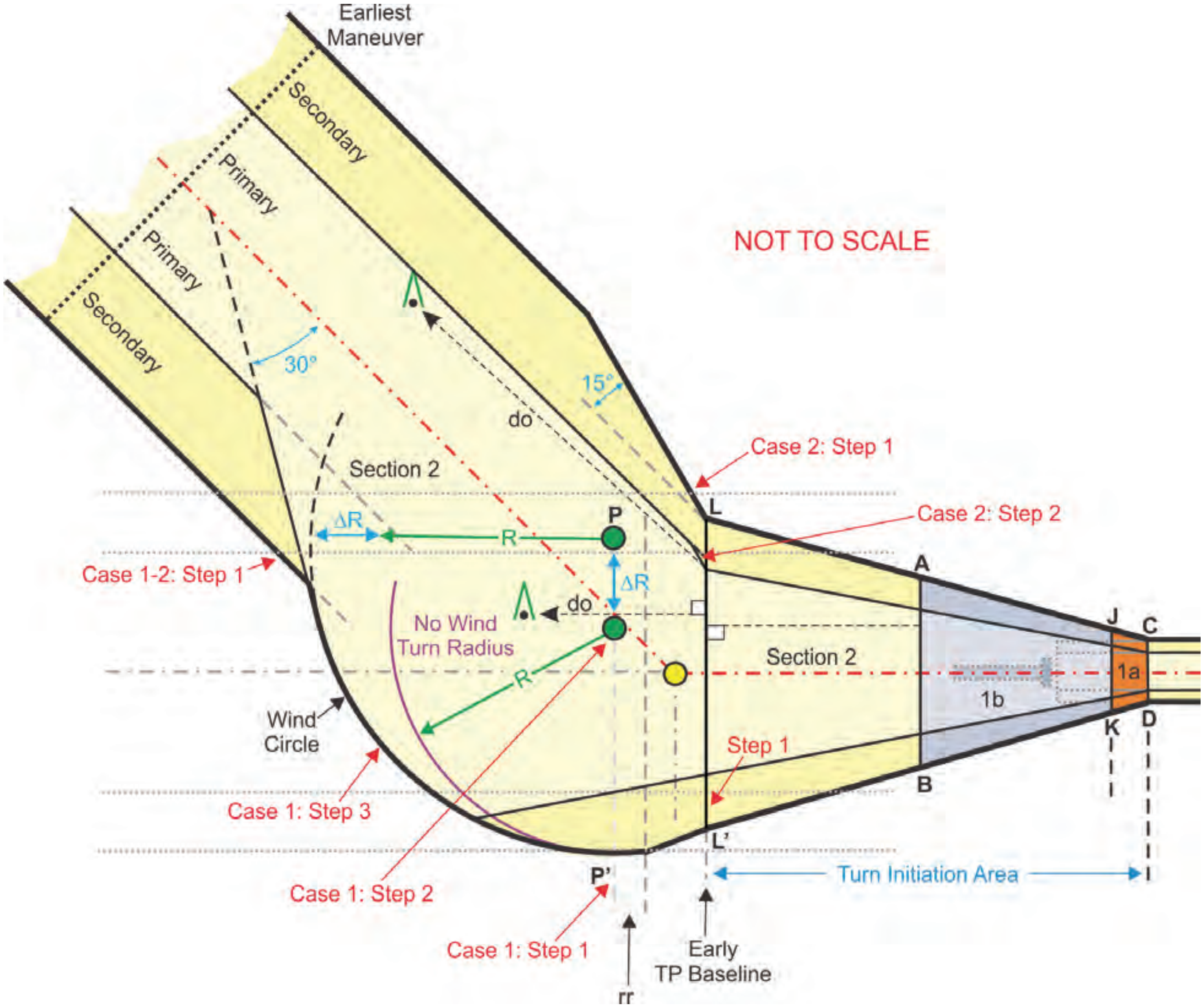


Figure 5-13. Turn at Waypoint (FO), 90°

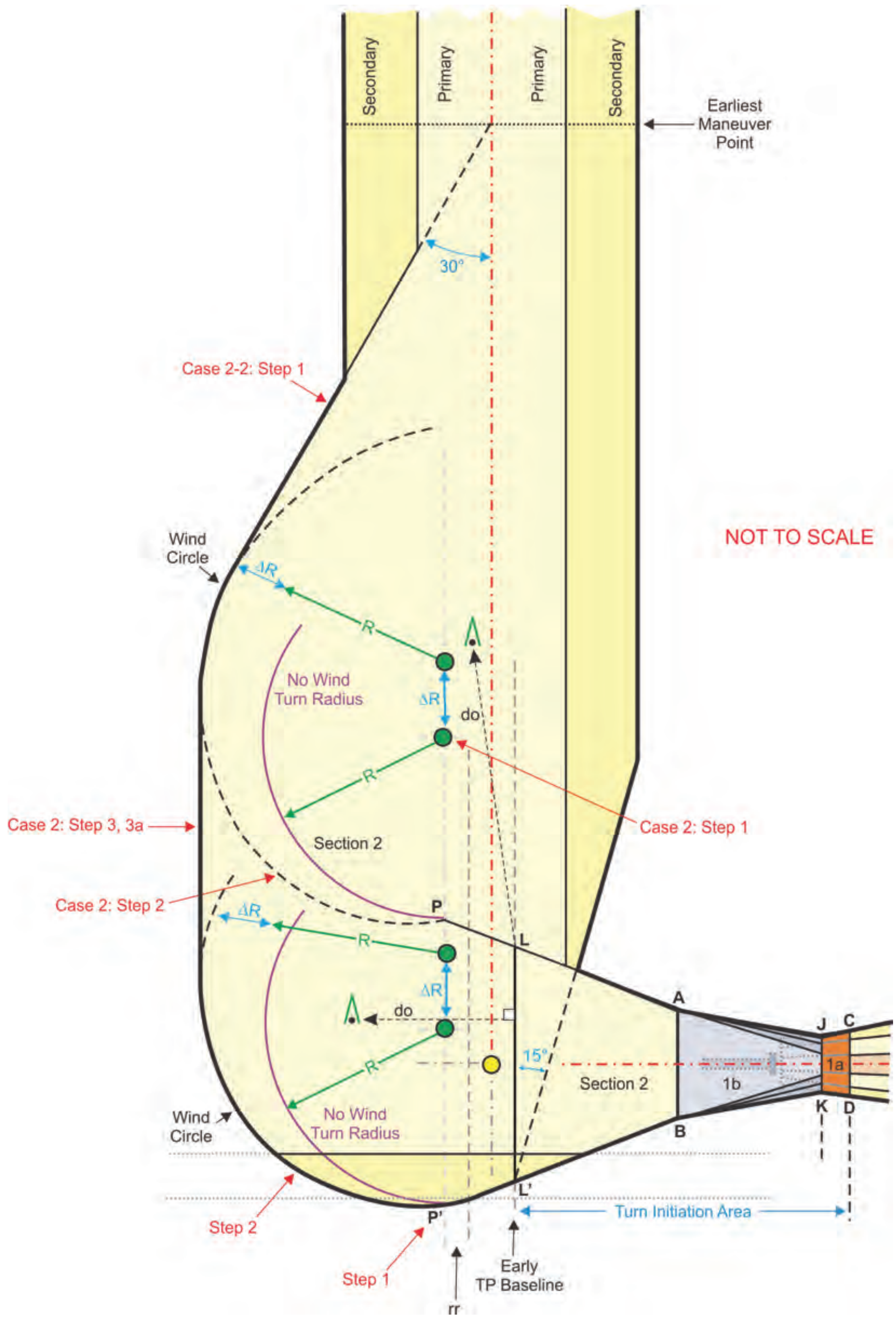


Figure 5-14A. WS Outer Boundary Connections

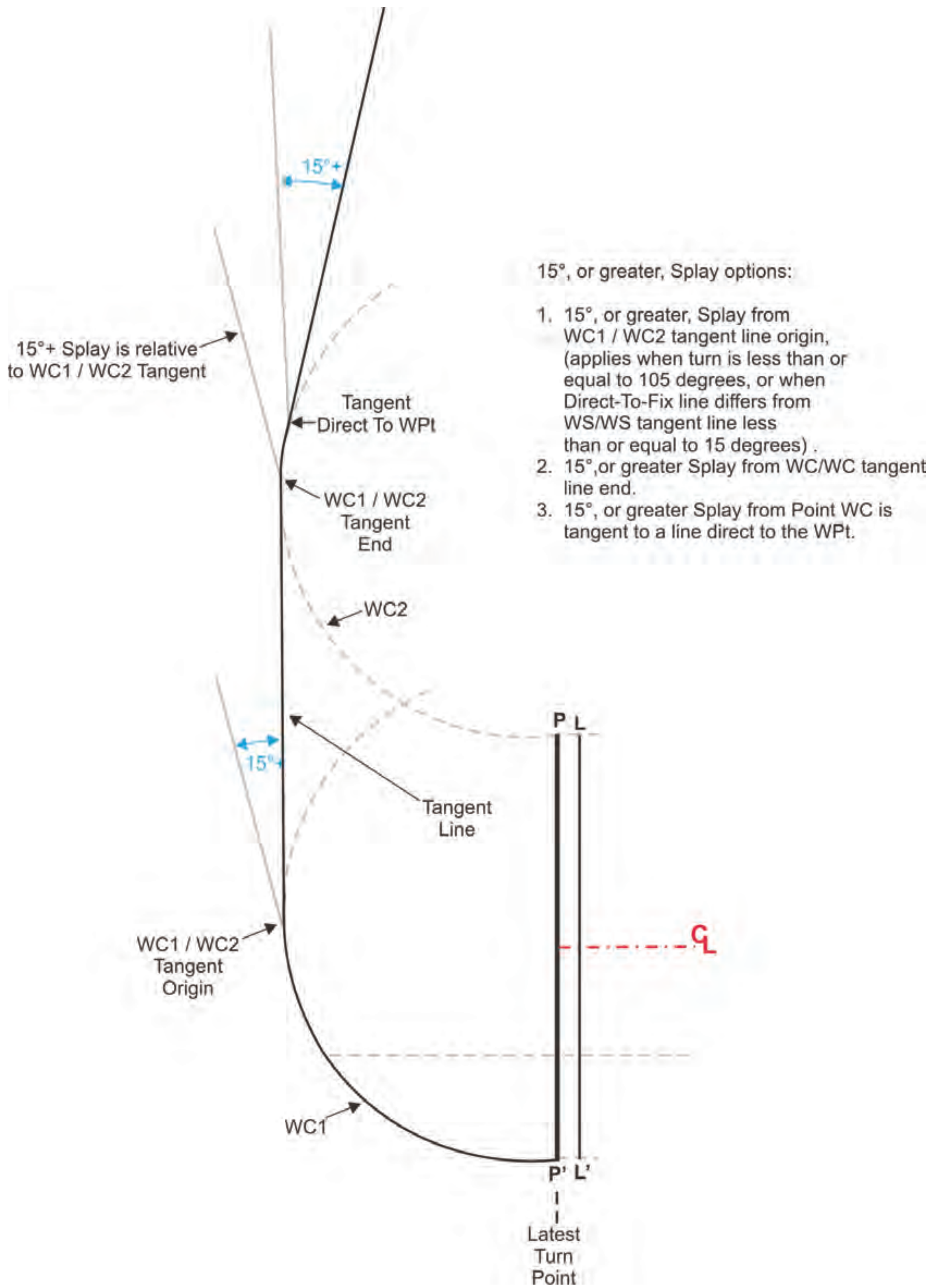


Figure 5-14B. WS1 Outer Boundary Connection

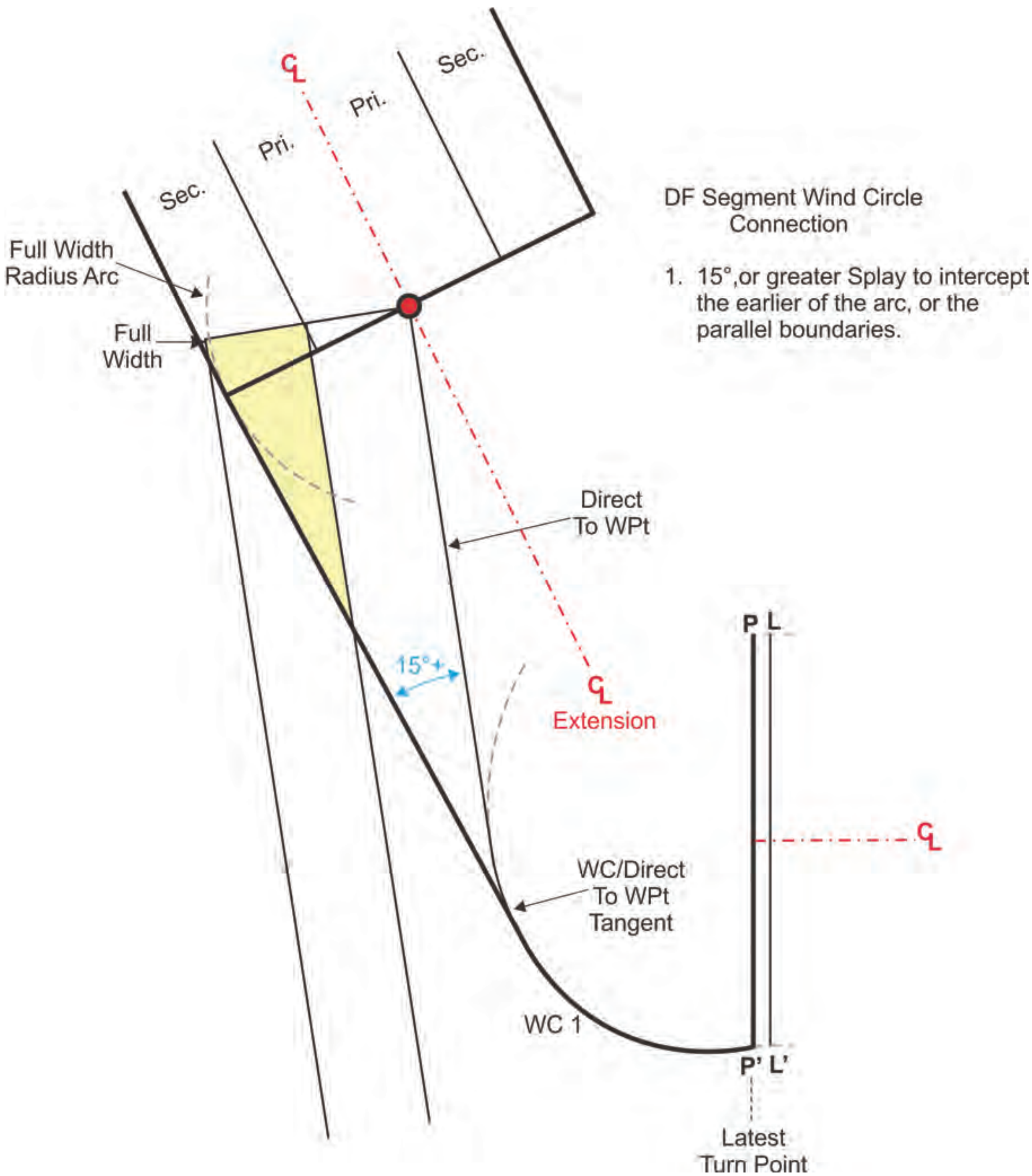
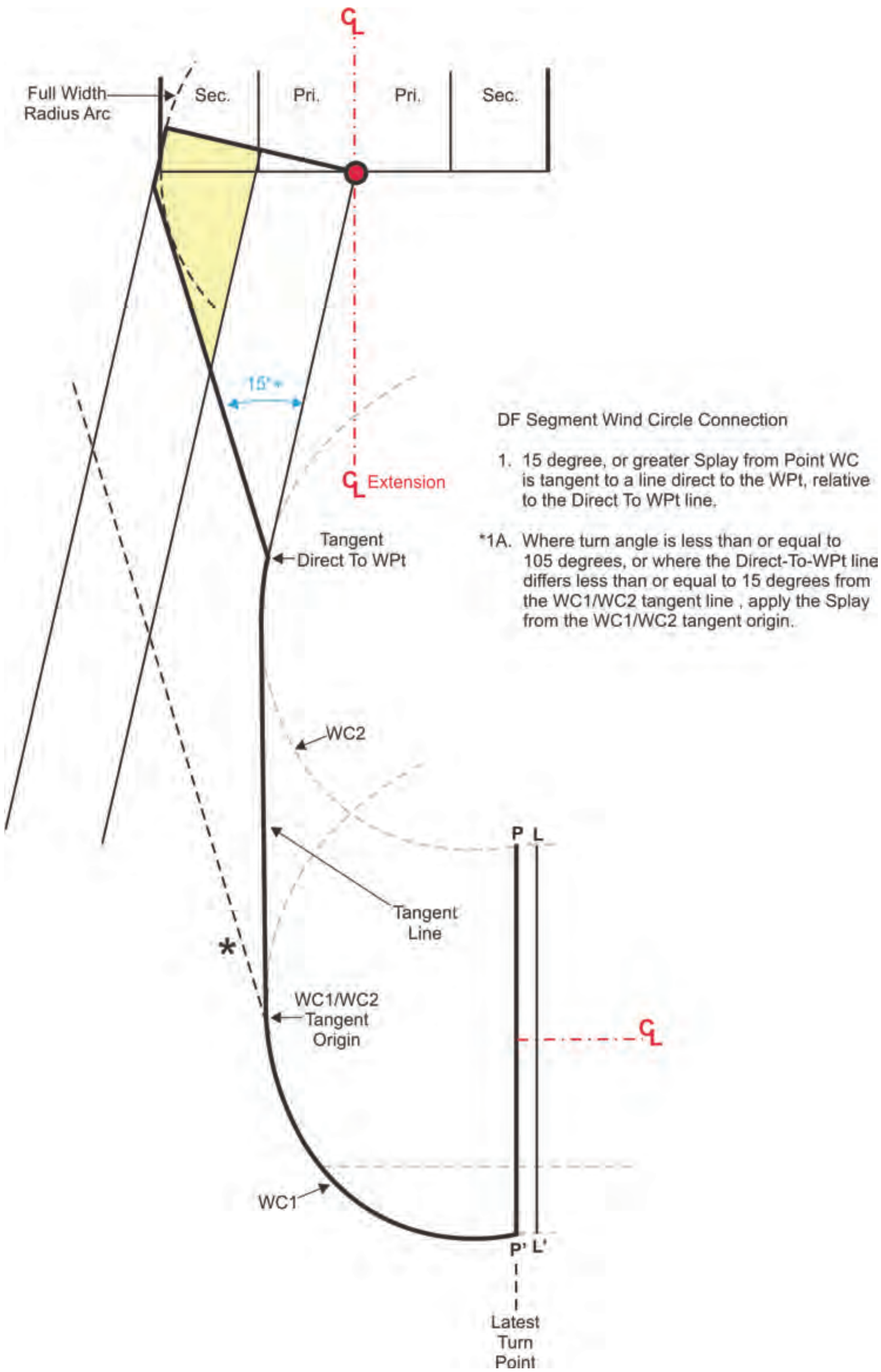


Figure 5-14C. WS Outer Boundary Connection (Multiple)



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Please submit any written comments or recommendation for improving this directive, or suggest new items or subjects to be added to it. Also, if you find an error, please tell us about it.

Subject: Order 8260.58, U.S. Standard for PBN Instrument Procedure Design

To: Manager, Flight Procedure Standards Branch (AFS-420)

(Please check all appropriate line items)

☐ An error (procedural or typographical) has been noted in paragraph __ on page ____________

☐ Recommend paragraph ______ on page _____ be changed as follows: *(attached separate sheet if necessary)*

☐ In future change to this order, please include coverage on the following subject *(briefing describe what you want added)*

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

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