U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

National Policy

ORDER
8260.3F

Effective Date:
09/07/2023

SUBJ: United States Standard for Terminal Instrument Procedures (TERPS)

This order prescribes standardized methods for designing and evaluating instrument flight procedures (IFPs) in the United States and its territories. It is to be used by all personnel responsible for the preparation, approval, and promulgation of IFPs. These criteria are predicated on normal aircraft operations and performance.

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Chapter 1. Administrative

Section 1-1. Scope

1-1-1. Purpose of This Order. This order prescribes standardized methods for designing and evaluating IFPs prescribed under Title 14, Code of Federal Regulations (14 CFR) part 95 and part 97. It also contains design guidance related to other IFPs and Air Traffic Control (ATC) charts not specified under parts 95 or 97. It is to be used by all personnel responsible for the preparation, approval, and promulgation of IFPs. The criteria contained within this order are predicated on normal aircraft operations and performance. This order contains guidance that is pertinent to 14 CFR part 97.

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

1-1-3. Where To Find This Order. You can find this order on the Federal Aviation Administration's (FAA) web site.

1-1-4. What This Order Cancels. Order 8260.3E, United States Standard for Terminal Instrument Procedures (TERPS), dated September 17, 2020.

1-1-5. Explanation of Changes. Significant areas of new direction, guidance, policy, and criteria as follows:

a. Updated administrative changes throughout the document.

b. Updated page and paragraph numbers in the Table of Contents.

c. Added a process and calculations to compensate for high-temperature effects in a new appendix.

d. Removed criteria for the evaluation of the initial climb area (ICA) when clearways are established.

e. Updated criteria in chapter 13, Departure Procedure (DP) Construction:

(1) Added criteria for the evaluation of changeover points (COP).

(2) Updated and added criteria for determination of turn radii.

(3) Added criteria for inside and outside turn protection.

1-1-6. Types of Procedures. Criteria are provided for the following types of IFPs:

a. Precision approach (PA). An instrument approach based on a navigation system that provides course and glidepath deviation information meeting the precision standards of International Civil Aviation Organization (ICAO) Annex 10 is considered a PA procedure. Precision Approach Radar (PAR) and Instrument Landing System (ILS) are examples of PA procedures.

b. Approach with vertical guidance (APV). An instrument approach based on a navigation system that is not required to meet the PA standards of ICAO Annex 10 but provides course and glidepath deviation information is considered an APV procedure. Localizer performance with vertical guidance (LPV), lateral navigation/vertical navigation (LNAV/VNAV), and localizer type directional aid (LDA) with glidepath, are examples of APV procedures.

c. Non-precision approach (NPA). An instrument approach based on a navigation system that provides course deviation information, but no glidepath deviation information is considered an NPA procedure. Very high frequency omnidirectional range (VOR), tactical air navigation (TACAN), very high frequency omnidirectional radio range collocated with tactical air navigational aid (VORTAC), LNAV, localizer performance (LP), nondirectional radio beacon (NDB), localizer (LOC), and airport surveillance radar (ASR) approaches are examples of NPA procedures.

d. Departure procedures (DP). Procedures designed to provide obstacle clearance during instrument departures.

e. Standard terminal arrival (STAR). A procedure that provides obstacle clearance and routing from the en route structure to a fix in the terminal area.

f. En route Air Traffic Service (ATS) routes. Routes including VOR and L/MF-based airways, which provide obstacle clearance.

1-1-7. Word Meanings. Word meanings as used in this order:

a. Must. This means that application of the criteria is mandatory.

b. Should. This means that application of the criteria is recommended.

c. May. This means that application of the criteria is optional.

1-1-8. Formulas. Refer to appendix D, Mathematics Convention, for definitions and abbreviations of formula inputs that are commonly used throughout this document.

1-1-9. Geospatial Standards. IFPs may be evaluated geodetically (see appendix F). Design criteria is stipulated in this order; however, actual construction of obstacle evaluation areas (OEAs) and connection of segments may vary due to constraints within automated software. For precise construction parameters, refer to the software documentation for the appropriate automated software.

Section 1-2. Eligibility, Approval, and Retention

1-2-1. Eligibility.

a. Military airports. IFPs at military airports must be established as required by the directives of the appropriate military service.

b. Civil airports. IFPs at civil airports are established as required by Order 8260.43, Flight Procedures Management Program.

c. Joint-use airports (civil and military). IFPs at joint-use airports are established as specified in paragraph 1-2-1.a when the military is responsible for IFP development, and as specified in paragraph 1-2-1.b when the FAA is responsible for IFP development.

d. Instrument flight rules (IFR) heliports. IFPs at IFR heliports (not applicable to point-in-space (PinS) procedures) are deferred pending development of applicable IFR heliport design standards.

1-2-2. Requests for Procedures. Refer to Order 8260.43 and Order 8260.19, Flight Procedures and Airspace.

1-2-3. Approval. The following minimum standards must be met to approve a request for an IFP:

a. An airport or heliport airspace analysis conducted under Order JO 7400.2, Procedures for Handling Airspace Matters, or appropriate military directives, as applicable must find the airport or heliport acceptable for instrument flight rules (IFR) operations. Acceptability for IFR operations is not required at landing areas for PinS procedures.

b. The airport or heliport (not applicable to PinS Proceed VFR procedures) infrastructure must be adequate to accommodate the aircraft expected to use the procedure (see AC 150/53401, Standards for Airport Markings, and AC 150/5300-13, Airport Design, paragraph 317, and table 3-4, or AC 150/5390-2, Heliport Design, as appropriate).

c. Limit the addition of category (CAT) E minimums for new IFPs to locations where a military requirement exists.

d. Navigation facilities. All instrument and visual navigation facilities used must successfully pass flight inspection.

e. Obstacle marking and lighting. Obstacles that penetrate 14 CFR part 77 imaginary surfaces are obstructions and; therefore, should be marked and lighted per AC 70/7460-1, Obstruction Marking and Lighting. Those penetrating the 14 CFR part 77 approach and transitional surfaces should be removed or made conspicuous under AC 70/7460-1 (or military equivalent). Do not deny instrument approach procedures due to inability to mark and light or remove obstacles that violate 14 CFR part 77 surfaces (see exception in paragraph 3-3-2.c).

f. Weather information. Terminal weather observation and reporting facilities must be available for the airport to serve as an alternate airport. Destination minimums may be approved when a general area weather report is available prior to commencing the approach and approved altimeter settings are available to the pilot prior to and during the approach consistent with communications capability.

g. Communications.

(1) Instrument approach procedure. Air-to-ground communications must be available at the initial approach fix (IAF) minimum altitude and where an aircraft executing the missed approach is expected to reach the missed approach altitude. At lower altitudes, communications are required where essential for the safe and efficient use of airspace.

(2) STAR. Communications with ATC must be available over the entire route at the minimum altitude for each segment.

1-2-4. Cancellation of Procedures. Refer to Order 8260.43.

Section 1-3. Responsibility and Jurisdiction

1-3-1. Responsibility.

a. Military airports. The military services establish and approve IFPs at airports under their respective jurisdictions. IFPs established in accordance with this order are considered equivalent to 14 CFR part 97 procedures and are normally authorized for civil use. The FAA must be informed when IFPs are canceled (see Order 8260.43). The FAA may accept responsibility for the development and/or publication of military IFPs when requested to do so by the appropriate military service through an interagency agreement.

b. Civil airports. The FAA establishes and approves IFPs for civil airports.

c. Military procedures at civil airports. Where existing FAA IFPs at civil airports do not meet user needs, the military may request the FAA to develop IFPs to meet military requirements. Modification of an existing FAA IFP or development of a new IFP may meet these requirements. The FAA must formulate, coordinate with the military and industry, and publish and maintain such procedures. The military must inform the FAA when such IFPs are no longer required.

1-3-2. Jurisdiction. The military or FAA office having jurisdiction over an airport may initiate action under these criteria to establish or revise IFPs when a reasonable need is identified, or where:

a. New navigation facilities or airport infrastructure are installed.

b. Changes to existing facilities/airport infrastructure necessitate a change to an approved IFP.

c. Additional IFPs are necessary.

d. New obstacles or operational uses require a revision to the existing IFP.

Section 1-4. IFP Establishment

1-4-1. Formulation. Proposed IFPs are prepared under the applicable chapter of this order as determined by the phase of flight and navigation source. To permit use by aircraft with limited navigational equipment, an IFP should be formulated using a single navigation source whenever possible. The use of multiple navigation sources of the same or different types may be permitted to gain an operational advantage.

1-4-2. Nonstandard IFPs. The standards contained in this order are based on reasonable assessment of the factors, which contribute to errors in aircraft navigation and maneuvering. They are designed primarily to assure that safe flight operations for all users result from their application. Every effort must be made to formulate IFPs in accordance with these standards; however, obstacles, navigation information, or traffic congestion may require special consideration where justified by operational requirements. In such cases, nonstandard IFPs that deviate from these criteria may be approved, provided they are documented and an equivalent level of safety exists. A nonstandard IFP is not substandard; it has been approved after special study demonstrated that no derogation of safety is involved.

a. See Order 8260.19 for authority and processing of nonstandard civil IFPs.

b. The U.S. Military Service responsible for procedure development is the approving authority for nonstandard military IFPs; see applicable Military Service directive for approval and processing requirement. Military IFPs that deviate from standards because of operational necessity, and in which an equivalent level of safety is not achieved, must be marked "**NOT FOR CIVIL USE.**"

1-4-3. Amendments. Process in accordance with Order 8260.19 (or appropriate directives).

Section 1-5. Coordination

1-5-1. Coordination. Coordinate IFPs to avoid conflicts and to protect the rights of all airspace users.

a. ATC facilities. All new or revised IFPs must be coordinated with the affected military or civil ATC facilities and other related airspace users.

b. Airspace. Where action to designate controlled airspace for an IFP is planned, the airspace action should be initiated sufficiently in advance so that effective dates of the IFP and the airspace action will coincide (see Order 8260.19).

c. Notices to Air Missions (NOTAM). See Order 8260.19 and Order JO 7930.2, Notices to Air Missions (NOTAM), for coordination and processing requirements related to IFP NOTAMs.

1-5-2. Coordination Conflicts. Coordination conflicts that cannot be resolved with the FAA organization responsible for IFP development will be submitted to the IFP Validation Team for resolution. Make every effort to thoroughly evaluate the comments/objections, determine the validity and scope of each issue, and if necessary determine the appropriate course of action to resolve the conflict. For issues other than the application and/or interpretation of IFP design criteria, the IFP Validation Team will forward conflicts that cannot be resolved to the IFP Oversight Committee. Conflicts concerning the application and/or interpretation of IFP design criteria should be forwarded to Flight Technologies and Procedures Division for resolution. Take parallel actions through military channels if a problem involves a military procedure.

Section 1-6. Identification of IFPs

1-6-1. General. IFPs must be uniquely identified to permit differentiation on charts/publications, airborne equipment displays, and during ATC communications. This section specifies IFP identification (procedure naming) only and is not intended for other uses.

1-6-2. Straight-in Approach Procedures. Identification includes the following elements (as applicable) in the following sequence:

a. Navigation system. The first element is the navigation system (and area navigation (RNAV) sensor in some cases) used to provide lateral navigation guidance within the final approach segment.

(1) Non-RNAV. Identify the applicable ground-based system and use the applicable abbreviation, such as, ASR, PAR, NDB, VOR, TACAN, LOC, LDA, or ILS. For localizer back course (BC) procedures, identify as "LOC BC."

Examples: ASR RWY 17, ILS RWY 17, LOC RWY 27, LOC BC RWY 31

(2) RNAV.

(a) Procedures with LNAV, LP, LNAV/VNAV, or LPV minimums use "RNAV (GPS)."

(b) Required Navigation Performance (RNP) procedures with Authorization Required (AR) use "RNAV (RNP)."

(c) Ground Based Augmentation System (GBAS) Landing System (GLS) procedures, use "GLS."

Examples: RNAV (GPS) RWY 17, RNAV (RNP) RWY 17, GLS RWY 17

b. Exception. High altitude approaches, prefix the navigation system with "HI-." This prefix does not eliminate the requirement to use an alphabetical suffix when more than one procedure uses the same navigational guidance to the same runway (see paragraph 1-6-2.d).

Examples: HI-TACAN RWY 31, HI-ILS X RWY 13

c. Precision runway monitor (PRM) modifier. This element is applicable to ILS, GLS, RNAV (GPS), and LDA procedures authorized for closely spaced parallel approach operations including Simultaneous Offset Instrument Approach (SOIA) operations. Include "PRM" following the navigation system (and RNAV sensor if applicable) when requested by ATC to support closely spaced parallel operations.

Examples: ILS PRM RWY 35L, RNAV (GPS) PRM RWY 35L, LDA PRM RWY 28R, GLS PRM RWY 17

d. Alphabetical suffix. When more than one procedure to the same runway uses the same type of navigation system for lateral guidance within the final approach segment, differentiate each procedure by adding a non-repeating alphabetical suffix using the letters "S" through "Z." Suffixes are normally assigned in reverse order starting with "Z," but may be assigned as needed to meet operational needs (for example, all RNAV (RNP) approaches at an airport assigned "Z" suffix, all RNAV (GPS) approaches assigned "Y" suffix, etc.).

Examples: ILS Z RWY 17, ILS Y RWY 17, COPTER ILS X RWY 17

(1) "V" suffix. "V" is reserved for ILS, RNAV, and GLS procedures designated to support simultaneous converging approach operations.

(2) Category I ILS, Special Authorization (SA) Category I ILS, Category II ILS, SA Category II ILS, and/or Category III ILS approaches to the same runway with the same ground tracks, altitudes (landing minimums excluded), and missed approach instructions are not considered duplicates of each other and do not require separate alphabetical identification suffixes. For example, no suffix is required for either the "ILS RWY 16R" or "ILS RWY 16R (SA CAT I)", but if the CAT I ILS has a suffix, then assign the same suffix to the SA ILS, for example, "ILS Y RWY 16R" and "ILS Y RWY 16R (SA CAT I)."

(3) PRM. Assign the same identification suffix to the PRM approach as is assigned to the non-PRM approach it is based on. For example, title the PRM, "RNAV (GPS) PRM Y RWY 28L" when based on the "RNAV (GPS) Y RWY 28L." Do not assign a suffix if the non-PRM approach is published without one. For example, title the PRM, "ILS PRM RWY 17" when based on the "ILS RWY 17."

(4) RNAV (GPS) and RNAV (RNP). Alphabetical suffixes are required for each procedure with "RNAV" in the title when there are two or more such procedures to the same runway.

Examples: RNAV (GPS) Z RWY 28L, RNAV (GPS) Y RWY 28L, RNAV (RNP) X RWY 28L
High altitude procedures and other procedures using the same final approach guidance to the same runway require a suffix unless all tracks and altitudes are identical. For example, title the high ILS as, "HI-ILS Z RWY 32" and the low ILS as, "ILS Y RWY 32."

e. Runway numbers, which the final approach course (FAC) is aligned and to which straight-in minimums are authorized. Describe as "RWY" followed by the runway designator(s).

Examples: ILS RWY 17, RNAV (GPS) RWY 18L, HI-TACAN Y RWY 13. Where approaches meet straight-in alignment criteria to more than one runway: VOR RWY 14L/R, VOR RWY 5/7.

f. Point-in-space (PinS) procedures apply the type of navigation followed by the published final approach course.

Examples: LOC 353, RNAV (GPS) 025, COPTER RNAV (GPS) 247, VOR 221, COPTER VOR 243

g. Helicopter procedures to IFR heliports apply PinS naming.

1-6-3. Circling Approach Procedures. When the approach does not meet criteria authorizing straight-in landing minimums, identification includes the following elements:

a. The navigation system (and sensor when applicable) as specified in paragraph 1-6-2.a.

b. A non-repeating alphabetical suffix assigned sequentially.

(1) The first approach established uses the suffix “A” even though there may be no intention to establish additional procedures. Only suffixes “A” through “H” may be used.

(2) Do not duplicate the alphabetical suffix where there are multiple circling procedures at the same airport, even when the procedures use different navigation systems; if additional procedures are established, they must be identified alphabetically in sequence. A revised approach procedure will use its original identification.

Examples: NDB-A, VOR-B, LDA-C

(3) The alphabetical suffix must not be duplicated at airports with identical city names within the same state, regardless of the airport name/navigation system guidance.

Example:

State	City	Airport	Procedure name
GA	Atlanta	KFTY	VOR-A
GA	Atlanta	KCCO	NDB-B
GA	Atlanta	KPDK	LDA-C

1-6-4. Combined Charting of Approach Procedures. A VOR approach may be combined with a TACAN approach if they share common tracks, fixes, fix altitudes, and missed approach instructions. An ILS approach may be combined with a LOC approach if they share common tracks, fixes and fix altitudes (excluding the precise final approach fix (PFAF), missed approach point (MAP) and any final segment step down fixes), and missed approach instructions. Identify as specified in paragraph 1-6-2, except the runway number element (single suffix for circling) is included only with the last approach listed, and identifications are connected by the word “or.”

Examples: ILS or LOC RWY 36L, VOR or TACAN RWY 31, ILS Z or LOC Z RWY 18, ILS Z or LOC RWY 36, ILS Z or LOC Y RWY 28, VOR or TACAN-A

1-6-5. Non-part 97 Approach Procedure Naming. Non-part 97 straight-in approach procedures will be designated with the suffixes “M,” “N,” “P,” or “Q.” Circling-only approach procedures will be designated with the suffixes “J” or “K.”

a. The first approach established uses the suffix “M” (or “J” if circling-only) even though there may be no intention to establish additional procedures.

b. Do not duplicate the alphabetical suffix where there are multiple non-part 97 approach procedures at the same airport, even when the procedures use different navigation systems; if additional procedures are established, they must be identified alphabetically in sequence. A revised approach procedure will use its original identification.

c. The alphabetical suffix must not be duplicated at airports with identical city names within the same state, regardless of the airport name/navigation system guidance.

Examples: ILS M or LOC M RWY 36L, VOR N RWY 31, NDB-J

1-6-6. DP Identification. For named departures, see Order 8260.46, Departure Procedures (DP) Program.

1-6-7. En Route Procedure Identification. ATS routes are identified with names or letter designators associated with specific route types.

a. Low/Medium Frequency (L/MF) routes are identified by color names: Amber, Blue, Green, or Red.

b. VOR routes are identified by the letter "V."

c. Jet routes (Flight Level (FL) 180 through FL 450) are identified by the letter "J."

d. RNAV routes are identified by their usage.

(1) Low altitude (below FL 180) RNAV routes are identified by the letter "T."

(2) High altitude (FL 180 through FL 450) RNAV routes are identified by the letter "Q."

(3) Helicopter RNAV routes are identified by a letter supplemented with a suffix: "TK."

e. Non-part 95 routes are identified by their usage.

(1) Low altitude (below FL 180) RNAV routes are identified by the letter "Z."

(2) Helicopter RNAV routes are identified by a letter supplemented with a suffix: "ZK."

1-6-8. Standard Terminal Arrival Identification. See Order 8260.19.

Section 1-7. IFP Publication

1-7-1. Submission. IFPs must be submitted by the approving authority on forms provided by the originating agency. IFPs must be routed under current orders or directives of the originating agency.

1-7-2. Issuance. The FAA Administrator (or designee) is responsible for issuing civil instrument procedures. The military approving authorities are responsible for issuing military instrument procedures.

1-7-3. Effective Date. See Orders 8260.19 and 8260.26, Establishing Submission Cutoff Dates for Civil Instrument Flight Procedures, or applicable military directive(s). FAA policy does not permit the issuance of complete civil instrument approach procedures by NOTAM.

Chapter 2. General Criteria

Section 2-1. Common Information

2-1-1. Scope. This chapter contains only that information common to all types of TERPS. Criteria, which do not have general application, are located in the individual chapters concerned with the specific types of facility, navigation source, or application.

2-1-2. Required Obstacle Clearance (ROC). This order specifies the minimum measure of obstacle clearance considered by the FAA to supply a satisfactory level of vertical protection. The validity of the protection is dependent, in part, on assumed aircraft performance. In the case of TERPS, it is assumed that aircraft will perform within certification requirements.

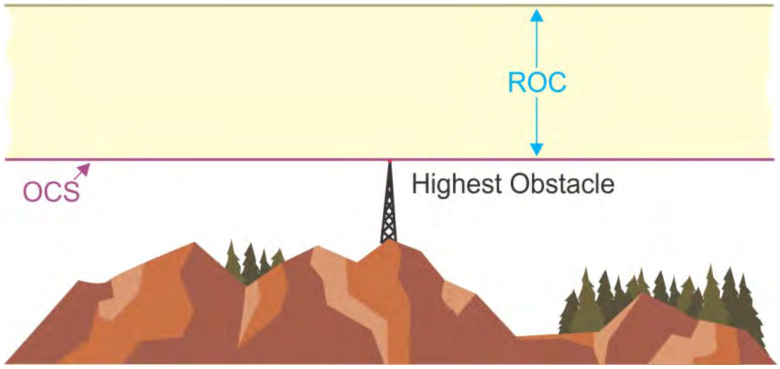
a. These criteria are predicated on normal aircraft operations for considering obstacle clearance requirements. Normal aircraft operation means all aircraft systems are functioning normally, all required navigation systems are performing within flight inspection parameters, and the pilot is conducting instrument operations utilizing IFPs based on the TERPS standard to provide ROC.

b. While the application of TERPS criteria indirectly addresses issues of flyability and efficient-use of navigation systems, the major safety contribution is the provision of obstacle clearance standards. This facet of TERPS allows aeronautical navigation in instrument meteorological conditions (IMC) without fear of collision with unseen obstacles. ROC is provided through application of level and sloping obstacle clearance surface (OCS).

2-1-3. Level OCS. The level OCS concept is applicable to “level flight” segments. These segments are level flight operations intended for en route, STAR, feeder, initial, intermediate, and NPA final approach segments. A single ROC value is applied over the length of the segment. These values were determined through testing and observation of aircraft and pilot performance in various flight conditions. Typical ROC values are: 1000 feet (2000 over designated mountainous terrain) for en route, STAR, and feeder segments, 1000 feet for initial segments, 500 feet for intermediate segments, and 250-500 feet for final segments.

a. This method of applying ROC results in a horizontal band of airspace that cannot be penetrated by obstacles. The bottom surface of the ROC band is mathematically placed on top of the highest obstacle within the segment. The depth (ROC value) of the band is added to the obstacle height to determine the minimum altitude authorized for the segment. The bottom surface of the ROC band is referred to as the level OCS. Therefore, level flight segments are evaluated by the level OCS application standard (see figure 2-1-1).

Figure 2-1-1. Minimum Segment Altitude



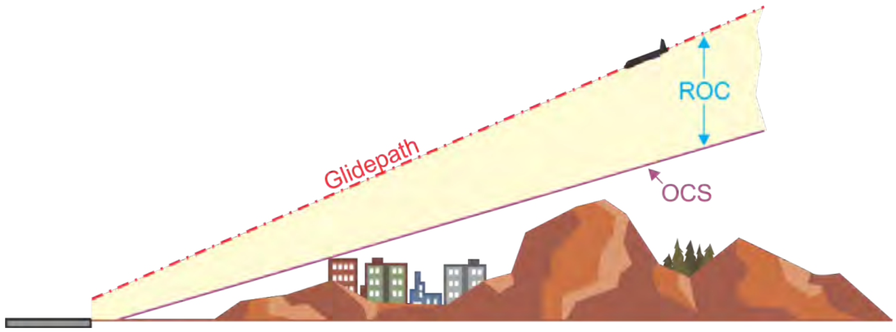
2-1-4. Sloping OCS. The method of applying ROC, in segments dedicated to descending on a glidepath or climbing in a departure or missed approach segment, requires a different obstacle clearance concept than the level OCS because the ROC value must vary throughout the segment. The value of ROC near the runway is relatively small and increases throughout the segment.

Note: While slope ratios are normally expressed in terms of rise over run in engineering and professional technical jargon, TERPS has traditionally expressed slope ratios in terms of run over rise; for example, 34:1, 40:1 (see figure 2-1-2).

Figure 2-1-2. TERPS Slope Ratio

a. Descending on a PA/APV glidepath. The obstacle evaluation method for descent on a glidepath is the application of a descending OCS below the glidepath. The vertical distance between the glidepath and the OCS is the ROC; thus ROC = (glidepath height) - (OCS height). The ROC decreases with distance from the PFAF as the OCS and glidepath are converging towards the landing surface (see figure 2-1-3). The OCS slope and glidepath angle (GPA) values are interdependent: OCS Slope = 102/GPA; or GPA = 102/OCS slope.

Figure 2-1-3. PA/APV Glidepath Descent



(1) If the OCS is penetrated, the OCS slope may be adjusted upward, thereby increasing the glidepath angle. The glidepath angle would increase because it is dependent on the required slope.

(2) Descent on an ILS/LPV glidepath and descent on other types of glidepaths such as barometric vertical navigation (baro-VNAV) provide ROC through application of a descending sloping surface based on standards using differing formulas, but the concept is the same.

b. Climbing on DP or missed approach. The concept of providing obstacle clearance in the climb segment of an IFP is based on the aircraft maintaining a minimum climb gradient (CG). The CG must be sufficient to increase obstacle clearance along the flight path so that the minimum ROC for the subsequent segment is achieved prior to leaving the climb segment. The minimum CG that will provide adequate ROC in the climb segment is 200 ft/nautical mile (NM) (400 ft/NM for helicopters), also referred to as the "standard CG." A higher gradient may be specified as defined in this order.

(1) The obstacle evaluation method for a climb segment is the application of a rising OCS below the minimum climbing flight path. Whether the climb is for departure or missed approach is immaterial. The vertical distance between the climbing flight path and the OCS is ROC. ROC for a departure segment is defined as ROC = 0.24 × CG. This concept is often called the "24 percent rule." Altitude gained is dependent on CG expressed in ft/NM.

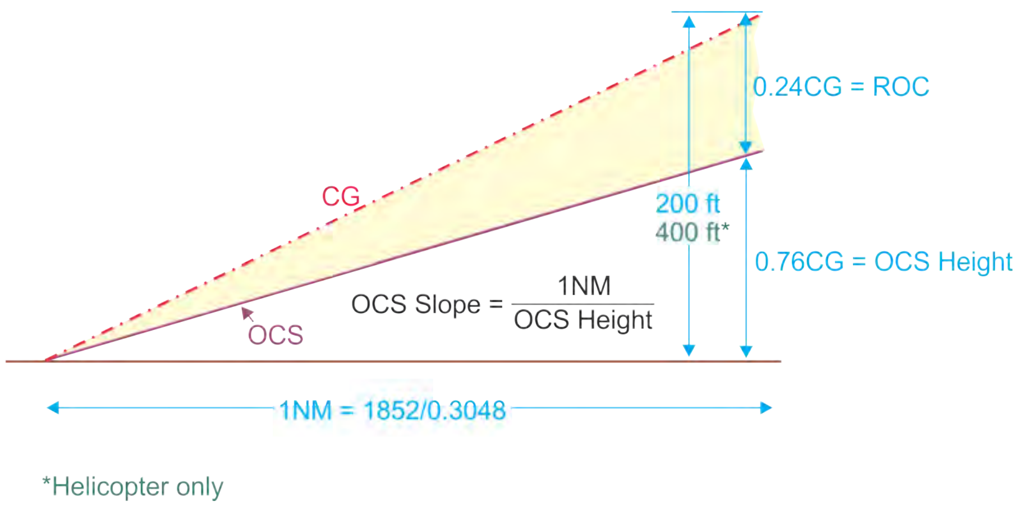
(a) The minimum ROC supplied by the standard CG is 48 ft/NM ($0.24 \times 200 = 48$). Since 48 of the 200 feet gained in 1 NM is ROC, the OCS height at that point must be 152 feet ($200 - 48 = 152$), or 76% of the CG ($152/200 = 0.76$). The slope of a surface that rises 152 feet over 1 NM is 40:1[1] (see figure 2-1-4).

(b) Helicopter minimum ROC supplied by the standard CG of 400 ft/NM is 96 ft ($0.24 \times 400 = 96$). Since 96 of the 400 feet gained in 1 NM is ROC, the OCS height at that point

[1] $\frac{1852}{152}/0.3048 \approx 39.97$, rounded to 40.

is 304 feet ($400 - 96 = 304$), or 76% of the CG ($304/400 = 0.76$). The slope of a surface that rises 304 feet over 1 NM is 20:1[2] (see figure 2-1-4).

Figure 2-1-4. Climb Segment



(2) Where an obstruction penetrates the sloping OCS, a CG greater than standard CG is required to provide adequate ROC. Departure CGs greater than standard will have ROC greater than 48 ft/NM (96 ft/NM for helicopters) since ROC is equal to 24% of the CG. The ROC expressed in ft/NM can be calculated using formula 2-1-1. However, instead of calculating the ROC value, the required CG is normally calculated directly using formula 2-1-2. Refer to chapter 10 for ILS missed approach CGs.

Formula 2-1-1. Departure Sloping Segment ROC

$$ROC = \frac{(0.24 \times h)}{(0.76 \times D)}$$

Where:
h = Height of obstacle above the altitude from which the climb is initiated
D = Distance in NM from the initiation of the climb to the obstacle

Formula 2-1-2. Departure CG

$$CG = \frac{h}{(0.76 \times D)}$$

Where:
h = Height of obstacle above the altitude from which the climb is initiated
D = Distance in NM from the initiation of the climb to the obstacle

[2] $\frac{1852}{304}/0.3048 \approx 19.99$, rounded to 20.

c. In the case of an instrument departure, the sloping OCS is applied during the climb until en route ROC is attained. The OCS begins at the departure end of runway, at the elevation of the runway end. ROC is zero at the runway end, and increases along the departure route until the appropriate ROC value is attained to allow en route flight to commence.

d. In the case of a missed approach procedure, the climbing flight path starts at the height of the minimum descent altitude (MDA) or decision altitude (DA) minus height loss. The OCS starts approximately at the MAP/DA at an altitude of MDA/DA minus the final segment ROC and adjustments (see paragraph 3-2-2). Therefore, the final segment ROC is assured at the beginning of the OCS and increases as the missed approach route progresses. The OCS is applied until at least the minimum en route or holding value of ROC is attained (as appropriate).

e. Extraordinary circumstances, such as a mechanical or electrical malfunction, may prevent an aircraft from achieving the minimum CG assumed by TERPS. In these cases, adequate obstacle clearance may not be provided by published IFPs. Operational procedures contained outside TERPS guidelines are required to cope with these abnormal scenarios.

2-1-5. Units of Measurement. Units of measurement must be expressed as set forth below:

a. Bearings, courses, and radials. Bearings and courses must be expressed in degrees magnetic. Radials must also be expressed in degrees magnetic, and must further be identified as radials by prefixing the letter “R” to the magnetic bearing from the facility. For example, R-027 or R-010.

b. Altitudes. The unit of measure for altitude in this publication is feet. Published heights below the transition level (18000 feet) must be expressed in feet above mean sea level (MSL); for example, 17900 feet. Published heights at and above the transition level (18000 feet) must be expressed as flight levels; for example, FL 180, FL 190, etc.

c. Distances. Develop all distances in NM and hundredths, except where feet are required (1 NM = 1852/0.3048 feet). When applied to visibilities, distances must be expressed in statute miles (SM) (5280 feet/SM) and the appropriate fractions thereof (see section 3-3). Runway visual range (RVR) must be expressed in feet.

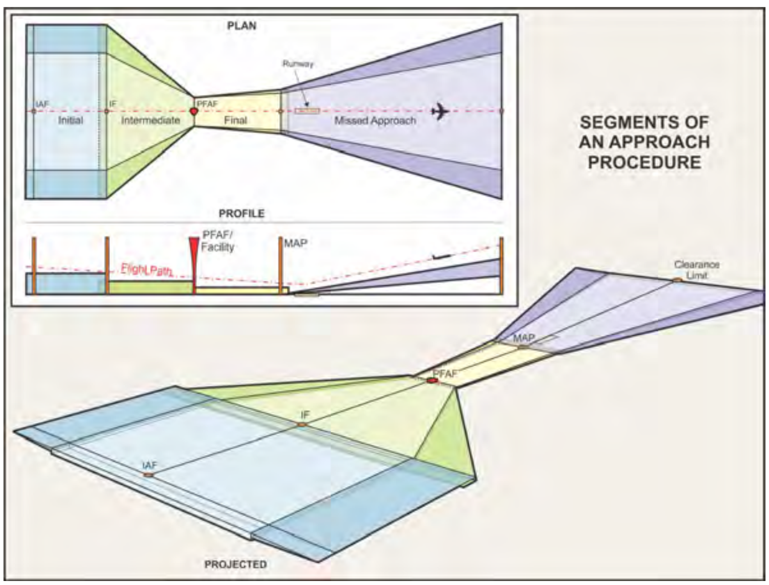
d. Speeds. Aircraft speeds must be expressed in knots indicated airspeed (KIAS).

2-1-6. Positive Course Guidance (PCG). PCG is achieved where pilots receive a continuous display of navigation data, which enable the aircraft to be flown along a specific course line or track. For courses based on a ground-based navigation facility, PCG is possible only within the standard or expanded service volume of the facility. PCG must be provided for feeder routes, initial (except as provided for in paragraph 2-4-4), intermediate, and final approach segments.

2-1-7. Approach Categories. Aircraft performance differences have an effect on the airspace and visibility needed to perform certain maneuvers. Because of these differences, aircraft manufacturer/operational directives assign an alphabetical category to each aircraft (see 14 CFR part 97). The categories used and referenced throughout this order are CAT A, B, C, D, and E. For helicopter-only approaches, COPTER is an authorized category. The authorized CAT must be used to determine OEAs for circling and missed approaches and used to establish landing minimums.

2-1-8. Procedure Construction. An instrument approach procedure (IAP) may have as many as four separate segments. They are the initial, intermediate, final, and missed approach segments. In addition, an area for circling the airport under visual conditions is considered when circling is authorized. An approach segment begins and ends at the plotted position of the fix; however, under some circumstances certain segments may begin at specified points where no fixes are available. The fixes are named to coincide with the associated segment. For example, the intermediate segment begins at the intermediate fix (IF) and ends at the PFAF. The order in which this chapter discusses the segments is the same order in which the pilot would fly them in a completed procedure; that is from an initial, through an intermediate, to a final approach. In constructing the procedure, the FAC should be identified first because it is the least flexible and most critical of all the segments. Then establish the other segments to produce an orderly maneuvering pattern responsive to the local traffic flow and to conserve controlled airspace to the maximum extent possible (see figure 2-1-5).

Figure 2-1-5. Segments of an Approach Procedure



2-1-9. Continuous Descent Approach (CDA). CDA is a procedure that optimizes the aircraft approach from the beginning of its descent to touch-down. With CDA, noise and emission levels are substantially reduced and significant fuel cost savings can be realized by participating aircraft. CDA procedures do not require special instrument approach design criteria; they can be flown using existing instrument approach procedures where “at or above” altitudes are established based on the minimum ROC required for the segment. This allows pilots to descend at the optimum profile for their aircraft while maintaining a safe altitude. Mandatory and/or maximum altitude restrictions severely restrict the use of CDA and should only be implemented where absolutely necessary.

2-1-10. Aircraft Speed. Do not establish speed restrictions that require an aircraft to exceed the restrictions in 14 CFR part 91.117 (a) and (c).

Section 2-2. Standard Terminal Arrival Procedures

2-2-1. Standard Terminal Arrival. A STAR is a preplanned route designed to facilitate the transition from the en route environment to the terminal environment for landing at one or more airports.

2-2-2. Origination and Termination.

a. A STAR must originate from a fix (see appendix B). The distance between the origination fix and any airport served by the STAR should not exceed 200 NM.

b. A STAR must terminate at a fix. The fix may be:

(1) A point-in-space.

(2) A fix that is also charted on an IAP.

(a) When charted on an instrument approach procedure, the termination fix must be a feeder fix, IAF, or IF. The termination fix must be the first fix that is common to both the STAR and the IAP (the STAR and the IAP must not share more than one common fix, and that fix must be the last fix on the STAR).

(b) When charted as an IAF or IF on an IAP and the approach procedure contains a course reversal, the approach segment following the STAR termination fix must be designated as "no procedure turn" (NoPT).

c. Specify a heading or course to fly after the termination fix when requested by ATC.

2-2-3. Routes and Transitions. A STAR serving a single airport consists of a common route, with optional en route and/or runway transitions. A STAR without a common route (such as a STAR with only a common point) may also be established if it contains at least two en route transitions or at least two runway transitions. STARs serving multiple airports may consist of separate common routes to each airport; however, all common routes must begin at a fix that serves all airports.

a. En route transitions. En route transitions are established prior to the first fix of a common route. An en route transition must terminate at a fix common to all en route transitions on the same STAR.

b. Runway transitions. Runway transitions may only be established for a single airport served by the STAR. They are established between the last fix of a common route and a fix that serves a runway (or multiple runways at the same airport).

c. Positive course guidance. Positive course guidance is required for all segments of a conventional (non-RNAV) STAR from origination to the termination fix.

2-2-4. Alignment.

a. The angle of intersection between the initial routing of a ground-based STAR and the ATS route where it begins (if applicable) must not exceed 120 degrees. For RNAV STARs, apply Order 8260.58, United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design.

b. When a STAR terminates at a fix located on an approach procedure, the maximum angle of intersection is 90 degrees.

c. The approach procedure segment following a STAR termination fix must meet the minimum length standards required for the magnitude of turn necessary to transition from the STAR.

2-2-5. Area. For routes based on a ground-based navigational aid (NAVAID), apply chapter 14. For RNAV routes, apply Order 8260.58.

2-2-6. Obstacle Clearance. Apply criteria in chapter 14.

2-2-7. Altitudes.

a. Minimum en route altitudes (MEAs) and published altitudes must:

(1) Provide at least the minimum ROC. ROC must be provided from each fix with an altitude restriction to the previous altitude restriction except maximum altitude restrictions.

(2) Meet communication and navigational facility requirements.

(3) Be established in 100-foot increments; when necessary round to the next higher 100-foot increment (for example, when obstacle elevation plus ROC equals 3001, round up to 3100).

b. Altitude restrictions above FL 200 should only be published to support an operational requirement.

c. When altitude restrictions are necessary, establish in the following order of preference (see exceptions in paragraphs 2-2-7.e and 2-2-7.f):

(1) Minimum altitudes. Example: AT/ABOVE 9000

(2) Block altitudes. Example: AT/ABOVE 9000 AT/BELOW 12000

(3) Mandatory altitudes. Example: AT 6000. **Exception:** A mandatory altitude is the first preference for the last fix on a STAR if the fix is not shared with an approach procedure.

(4) Maximum altitudes. Example: AT/BELOW 12000

d. En route transitions.

(1) Establish an MEA between fixes on the transition.

(2) Establish a minimum obstruction clearance altitude (MOCA) between fixes on a transition.

(3) Do not apply minimum crossing altitude (MCA) criteria. An MEA or a MOCA must not be higher than the previous MEA or MOCA (as applicable); increase previous MEAs/MOCAs as necessary to comply.

(4) Do not raise an MEA to support ATC operational requirements. An altitude restriction must be used if ATC has an operational requirement for an altitude higher than the MEA.

e. Common route and runway transitions. Establish a mandatory, minimum or block altitude restriction at a fix that represents the lowest altitude authorized by the STAR or STAR runway transition.

(1) Establish additional altitudes as required for obstacle clearance or to support an ATC operational requirement.

(2) When a maximum altitude restriction is established, also establish a minimum altitude at the same fix (a block altitude) or at a subsequent fix to ensure obstacle clearance. The subsequent minimum altitude (or minimum altitude of a block) must also provide obstacle clearance to the previous fix(es) with a maximum altitude. For example, publishing a maximum altitude at CHRLY (as shown in figure 2-2-1) requires the addition of a minimum altitude at CHRLY or the minimum altitude at DELTA must provide obstacle clearance back to the previous minimum altitude (in this example, the minimum altitude of a block) at BRAVO.

(3) Do not establish MEAs or MOCAs for common routes or runway transitions.

f. STAR termination altitude.

(1) An altitude restriction must be established at the termination fix of the STAR if the same fix is charted on an approach procedure. If the approach procedure fix has an altitude restriction associated with it, then the STAR termination altitude restriction must be identical to it. For example, if the approach procedure’s fix is a mandatory altitude, then the STAR must end with an identical mandatory altitude. If the approach procedure’s fix is a minimum altitude, then the STAR must end with an identical minimum altitude.

(2) If the STAR authorizes radar vectors after the termination fix, an altitude is required at the termination fix and that altitude must be at or above the minimum vectoring altitude (MVA) and/or minimum IFR altitude (MIA) (as applicable). If the STAR authorizes radar vectors after the termination fix and does not join an approach, then the altitude authorized at the termination fix should be a mandatory altitude. Flight Standards approval is required if no altitude is established due to an operational need (see paragraph 1-4-2).

(3) If the STAR termination fix will be authorized for either joining an approach or for radar vectors, the altitude must be above the MVA/MIA and comply with paragraph 2-2-7.f(1).

(4) A STAR termination altitude may be no lower than any instrument approach procedure fix altitude to be flown after the STAR termination. If the approach procedure has no altitude charted at that approach procedure fix, the STAR termination altitude may be no lower than any approach procedure minimum segment altitude following that fix.

2-2-8. Descent Gradient (DG). Calculate DGs between fixes with an altitude restriction by using the guidance in this paragraph and the calculation methods in section 2-9. When deceleration is required, also use paragraphs 2-2-9 and 2-2-10. The DG past the termination fix of the STAR is not calculated as part of the STAR design; the overall airspace design should optimize the location and altitude for the STAR termination fix and that becomes an input to the STAR design.

a. The maximum DG (see figure 2-2-1) is based on altitude, deceleration, and airspeed constraints, as follows:

(1) The maximum permissible DG 10000 feet MSL and above is 330 ft/NM (approximately 3.11 degrees).

(2) The maximum permissible DG below 10000 feet MSL is 318 ft/NM (approximately 3.0 degrees).

(3) When a STAR contains a descent between fixes that passes through 10000 feet MSL, the maximum permissible DG is between 318 ft/NM and 330 ft/NM and is in proportion to the amount of the altitude change that is below/above 10000 feet MSL. Use formula 2-2-1 to determine the maximum DG (DG_{max}) between fixes that contain a descent that passes through 10000 feet MSL.

Formula 2-2-1. Maximum DG Passing Through 10000 Feet MSL (ft/NM)

$$DGmax = \frac{(Alt_1 - 10000) \times 12}{(Alt_1 - Alt_2)} + 318$$

Where:
Alt_1 = Altitude at the fix prior to crossing 10000 feet MSL
Alt_2 = Altitude at the fix after crossing 10000 feet MSL

Example 1: From BRAVO to CHRLY in figure 2-2-1, the altitude of 11000 minimum at BRAVO and 9000 maximum at CHRLY, will have 1/2 of the gradient at 330 ft/NM and 1/2 at 318 ft/NM, Maximum DG $= (11000 - 10000) \times 12 / (11000 - 9000) + 318 = 324$.

Example 2: In the previous example if there were no altitude restrictions at BRAVO, the gradient applies from ALPHA to CHRLY. Maximum DG $= (19000 - 10000) \times 12 / (19000 - 9000) + 318 = 328.8$.

Example 3: From GOLFF to HOTEL in figure 2-2-2, the mandatory altitude of 15000 at GOLFF and a mandatory altitude of 4000 at HOTEL, will have 5/11 of the gradient at 330 ft/NM and 6/11 at 318 ft/NM, Maximum DG = (15000 – 10000) × 12 / (15000 – 4000) + 318 = 323.45.

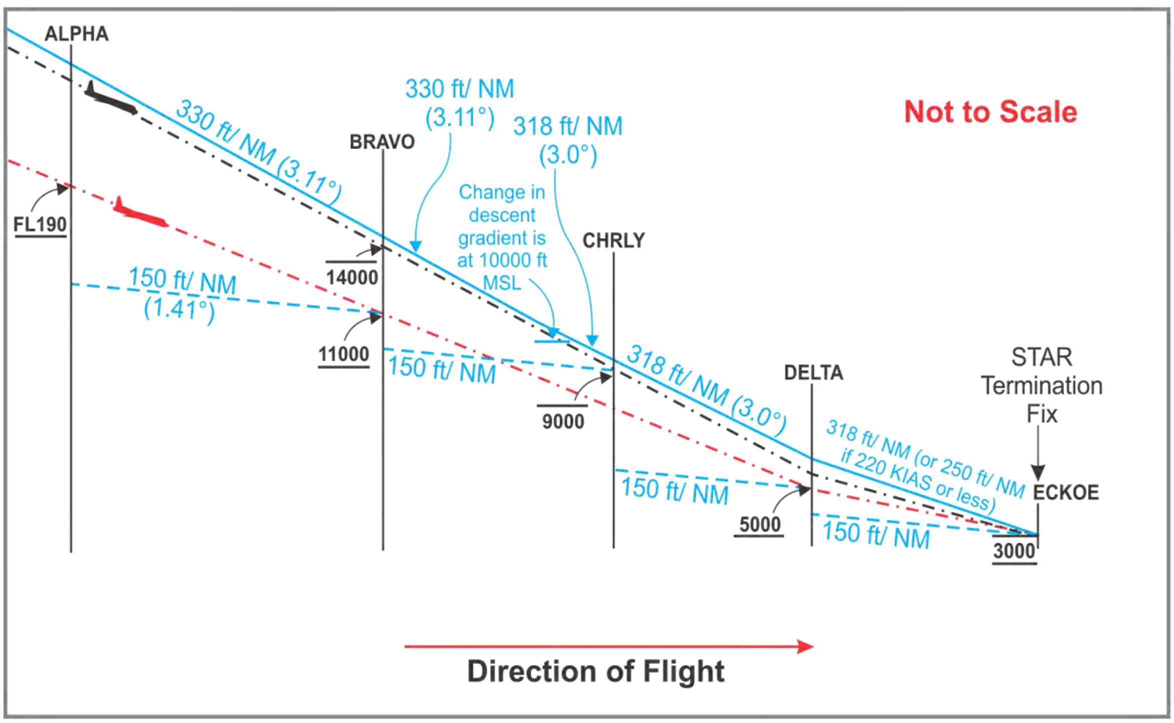
Note: Descent below 10000 feet MSL requires a deceleration calculation unless an airspeed restriction of 250 KIAS or less exists prior to the point where the descent below 10000 feet MSL occurs.

(4) Gradient after deceleration to 220 KIAS. After a speed restriction of 220 KIAS or less is used, for subsequent fixes along the route of the STAR the maximum permissible descent gradient is 250 ft/NM (approximately 2.36 degrees).

(5) Evaluation of a fix with no altitude restriction. The evaluation is done from the previous fix that has an altitude restriction to the subsequent fix that has an altitude restriction using the overall distance between the fixes with the restrictions.

(6) If more than one of paragraphs 2-2-8.a(1) through 2-2-8.a(5) applies, use the lower of the resulting values for the maximum DG.

Figure 2-2-1. Altitude Restrictions and Maximum Descent Gradient

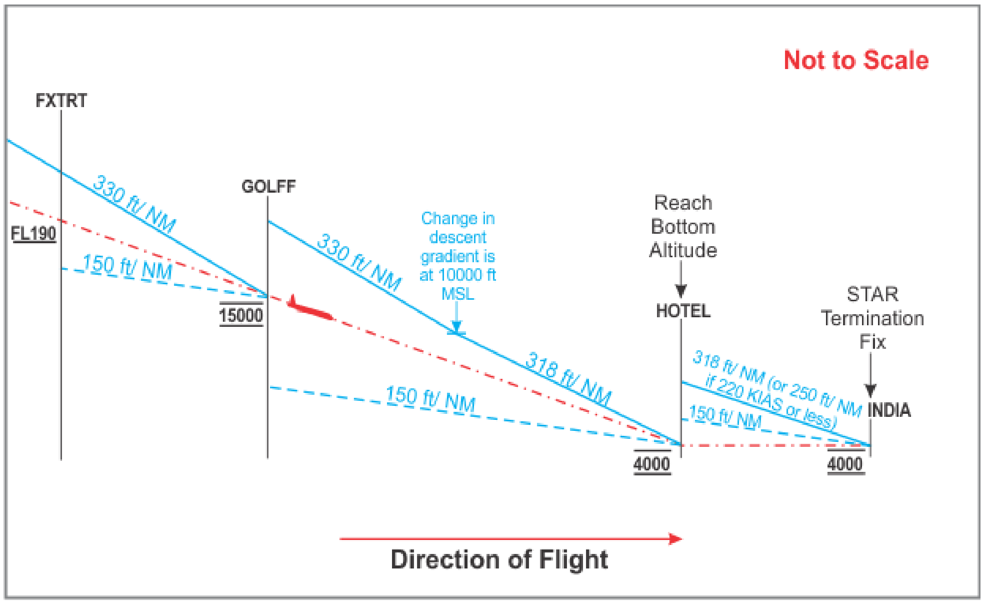


b. When a gradient exceeds the maximum DG allowed in paragraph 2-2-8.a, the STAR requires approval (see paragraph 1-4-2).

c. The descent gradient between any two consecutive fixes with an altitude restriction should be at least 150 ft/NM (approximately 1.41 degrees). Descent gradients of less than 150 ft/NM (or no descent as depicted between HOTEL and INDIA in figure 2-2-2) should not be used except to support an operational requirement.

d. Figure 2-2-1 and figure 2-2-2 illustrate examples of STAR design. Figure 2-2-1 shows different flight paths to illustrate the recommended design of allowing some flexibility in the descent, preferably through the use of minimum altitudes. Figure 2-2-1 shows the recommended design of all altitude constraints being on or above the 150 ft/NM line; an ATC and/or airspace requirement is shown in figure 2-2-2 with no descent between HOTEL and INDIA. The solid blue line, depicting the maximum descent gradient, depicts the upper design limit for fixes prior to an altitude constraint. As shown in figure 2-2-2, the use of mandatory altitude constraints reduces the range of altitudes allowed at previous fixes and may result in an inefficient descent for aircraft on the STAR.

Figure 2-2-2. Altitude Restrictions With Mandatory Altitudes



2-2-9. Speed Restrictions. Minimize the use of speed restrictions as much as practicable. Optimum values are 280 KIAS at 10000 feet MSL or above and 240 KIAS below 10000 feet MSL.

a. Speed restrictions above FL 200 should only be published to support an operational requirement. When published, the restriction must allow for Mach transition (see Order 8260.19, chapter 4).

b. Do not establish more than one speed restriction per fix (for example, one speed applicable to jets and one applicable to props).

c. If a STAR terminates at a fix charted on an approach procedure, and the fix has a charted speed restriction, then establish a speed restriction on the STAR with the same numerical airspeed value. The STAR's speed restriction must be a mandatory ("at") speed restriction and the approach procedure must be a maximum ("at or below") speed restriction. For example, if the approach procedure's speed restriction is a maximum airspeed of 210 KIAS, then the STAR's speed restriction at the same fix must indicate a mandatory airspeed of 210 KIAS.

d. If a STAR terminates at a fix charted on an instrument approach procedure, and the fix does not have a speed restriction, then verify if the approach procedure contains a speed restriction located prior to the fix. If the approach procedure contains a speed restriction, then establish a mandatory speed restriction with the same numerical airspeed at or prior to the termination of the STAR.

e. For the portion of a STAR underlying a Class B airspace area, do not establish a speed restriction that requires aircraft to exceed 200 KIAS.

2-2-10. Deceleration. A deceleration evaluation is required prior to any fix with a speed restriction or when required for 14 CFR part 91.117 (a) or (c). STARs not meeting the requirements of this paragraph may be authorized with Flight Standards approval unless required for 14 CFR part 91.117 (a) or (c) (see paragraph 1-4-2).

a. Where deceleration is required but descent is not permitted (for example, between two fixes with the same mandatory altitudes) or is not required (for example, between two fixes with the same minimum altitudes), provide a minimum distance of at least 4 NM prior to a fix with a speed reduction of 40 KIAS or less. For deceleration greater than 40 KIAS, allow 1 NM between fixes for every 10 knots of deceleration required. For example, a deceleration of 10, 20, 30, or 40 KIAS requires a minimum length of 4 NM; a deceleration of 50 KIAS requires a minimum length of 5 NM; a deceleration of 60 KIAS requires 6 NM.

b. When descent is permitted, the descent gradient leading to the fix with the speed restriction must be reduced. Apply formula 2-2-2 to determine the minimum deceleration distance ($Decel_D$) required before the fix; the greater distance leads to a reduced descent gradient.

(1) In determining the applicable formula gradient value, "G," use 330 ft/NM (approximately 3.11 degrees) when the ending speed restriction is greater than or equal to 250 KIAS; use 318 ft/NM (approximately 3.0 degrees) when the ending speed restriction is less than 250 KIAS but greater than 220 KIAS; use 250 ft/NM (approximately 2.36 degrees) when the ending speed restriction is 220 KIAS or less.

(2) In determining "K," use 310 KIAS, or the previous speed restriction if less than 310 KIAS, as the reference speed at or above 10000 feet MSL. For the reference speed below 10000 feet MSL, use 250 KIAS or the previous speed restriction if less. For a block altitude, use the minimum altitude when selecting 310 or 250 to use to determine the "K" value.

(3) The first altitude restriction that is below 10000 feet MSL requires a deceleration evaluation unless an airspeed restriction of 250 KIAS or less exists prior to the point where descent below 10000 feet MSL occurs [14 CFR part 91.117 (a)]. If no speed is published at the first altitude restriction that is below 10000 feet MSL, then use the lower of 250 KIAS or the previous speed restriction (if applicable). When the first fix that allows descent below 10000 feet MSL has no charted speed restriction and the altitude constraint allows continued flight above 10000 feet MSL, the calculation is extended to the subsequent fix using the total descent and total distance for the applicable fixes.

(4) When an altitude restriction exists at a fix that could place an aircraft below Class B airspace [14 CFR part 91.117 (c)] a deceleration evaluation is required to ensure sufficient

distance for the aircraft to comply with the 200 KIAS airspeed restriction even though it is not charted.

(5) Some examples are as follows: If deceleration from a fix with no speed restriction to 280 KIAS is required above 10000 feet MSL, then "K" is equal to 3 NM($K = 310\text{-}280 / 10$). If an aircraft is decelerating from a fix with a speed restriction of 280 KIAS to a fix with no speed restriction that is below 10000 feet MSL, use 250 KIAS as the reference airspeed; then "K" is equal to 3 NM($K = 280\text{-}250 / 10$). If an aircraft is decelerating from a fix with no speed restriction that is below 10000 feet MSL, use 250 KIAS as the reference airspeed for the deceleration to the next fix; if the deceleration is to a fix with a speed restriction of 230 KIAS, then "K" is equal to 2 NM($K = 250\text{-}230 / 10$).

Formula 2-2-2. Minimum Deceleration Distance (NM)

$$Decel_D = \frac{Alt_1 - Alt_2}{G} + K$$

Where:
Alt_1 = Minimum altitude at the fix prior to the speed restriction
Alt_2 = Minimum altitude at the fix with the speed restriction
$G =$ Applicable gradient value (330/318/250)
K = 1 NM for every 10 KIAS of deceleration required

Example 1: If the termination fix has a mandatory altitude of 3000 and a published speed restriction of 210 KIAS and is preceded by a fix with a minimum altitude of 7500 and a published speed restriction at or before that fix of 230 KIAS, the values are:
Alt_1 - Alt_2 = 4500 (7500-3000); G = 250, based on an ending speed of 220 KIAS or less;
K = 2 NM (K = 230-210 / 10); $Decel_D$ = 20 NM ($Decel_D$ = 4500/250 + 2) and the resulting descent gradient will be no more than 225.0 ft/NM (DG = 4500 / 20).

Example 2: In example 1, if the preceding fix has no speed restriction, use 250 KIAS based on the altitude of 7500 being below 10000 feet MSL (or previous speed restriction if less than 250 KIAS). The values are: Alt_1 - Alt_2 = 4500; G = 250, K = 4 NM (K = 250-210 / 10);
$Decel_D$ = 22 NM ($Decel_D$ = 4500/250 + 4). The resulting descent gradient will be no more than 204.5 ft/NM (DG = 4500 / 22).

Section 2-3. Feeder Routes/Emergency Areas

2-3-1. Feeder Routes. Establish non-radar feeder routes where the IAF is not part of the en route structure and where preferred over other options [for example, radar vectors, terminal arrival area (TAA)]. Limit the number of feeder routes where radar vectoring is provided on a 24-hour basis, but where practical provide at least one route per location to account for radar/communications failure. Feeder routes originate at a navigation facility or named fix on an airway and terminate at another feeder fix or at an IAF. The feeder route must not extend beyond the operational service volume of the facility which provides navigational guidance.

a. Alignment.

(1) The angle of intersection between a ground-based feeder route course and the en route structure must not exceed 120 degrees. For RNAV routes, apply Order 8260.58.

(2) The angle of intersection between a ground-based feeder route course and the next segment (feeder/initial) course must not exceed 120 degrees except when connecting to a course reversal segment. For RNAV routes, apply Order 8260.58.

(3) Do not establish a feeder route that terminate at a course reversal fix if both the angle of intersection between the route and the segment that follows the course reversal fix is 120 degrees or less (90 degrees or less for RNAV), and if the required descent is within initial segment limitations (see paragraph 2-4-3). Under these conditions, the route must be developed as an initial segment based on straight course criteria.

b. Area. For routes based on ground-based NAVAIDs, apply chapter 14. When connecting to a course reversal segment, the area terminates at a line perpendicular to the feeder course through the course reversal fix. For RNAV routes, apply Order 8260.58.

c. Obstacle clearance. Apply criteria in sections 14-2 or 14-5 as appropriate. 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. Establish minimum altitudes in 100-foot increments; when necessary round to the next higher 100-foot increment (for example, when obstacle elevation plus ROC equals 3001, round up to 3100).

d. Descent gradient. The optimum descent gradient in the feeder route is 250 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 500 ft/NM. The optimum descent gradient for feeder routes associated with high altitude procedures is 800 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 1000 ft/NM.

2-3-2. Minimum Safe Altitude (MSA). Establish an MSA for all approach procedures, graphic obstacle departure procedures (ODPs), and standard instrument departures (SIDs) within a 25-NM radius of a specified point for use during emergency situations (see figure 2-3-1).

a. Altitude selection. Specify altitudes in 100-foot increments; when necessary round to the next higher 100-foot increment (for example, when obstacle elevation plus ROC equals 1501, round up to 1600).

b. Area.

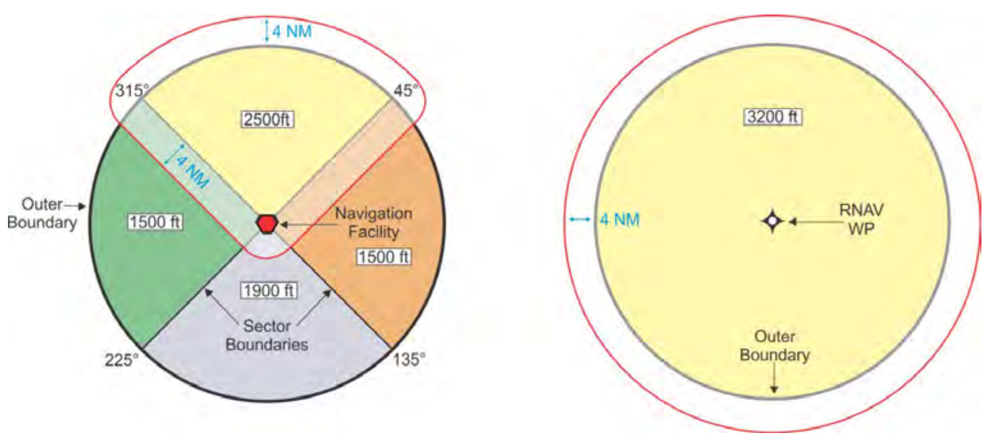
(1) Non-RNAV procedures. Center the MSA on the omni-directional facility upon which the procedure is based. When the distance from the facility to the airport exceeds 25 NM, extend the radius to include the airport or heliport landing surfaces up to a maximum distance of 30 NM. When the procedure does not use an omnidirectional facility (for example, an ILS or vector SID), use the primary omnidirectional facility in the area. If a graphic OPD or SID utilizes more than one omni-directional facility, use the facility nearest the airport or heliport. If no omni-directional NAVAID is located within 30 NM of the airport landing surfaces, then center the MSA on the airport reference point (ARP) or heliport reference point (HRP). Establish a common area (no sectors) around the facility or ARP/HRP. If necessary to offer relief from obstacles, sector divisions may be established for an MSA based on a facility. Sectors must not be less than 90 degrees in spread.

(2) RNAV procedures. For RNAV straight-in approach procedures, establish a common safe altitude within the specified radius of the runway threshold (preferred) or the MAP waypoint (WP); for RNAV circling and RNAV DPs use the airport waypoint (APT WP). For approaches to or departures from a heliport, use the heliport waypoint.

(3) PinS procedures. For PinS approach procedures, establish a common safe altitude within the specified radius of the MAP WP. For PinS DPs, use the initial departure fix (IDF).

c. Obstacle clearance. Common safe altitudes and sector altitudes must provide 1000 feet of obstacle clearance to include a 4-NM buffer area beyond the 25-NM radius, and a 4-NM buffer area in any adjacent sector. Sector altitudes should be raised and combined with adjacent higher sectors when the altitude difference is 300 feet or less.

Figure 2-3-1. MSA



2-3-3. Emergency Safe Altitude (ESA). ESAs are applicable to military procedures at the option of the approving authority. Establish ESAs within a 100-NM radius of the navigation facility or WP used as the ESA center, with a common altitude for the entire area. Where ESAs are located in designated mountainous areas, provide at least 2000 feet of obstacle clearance. Paragraph 2-3-2.a applies.

Section 2-4. Initial Approach

2-4-1. Initial Approach Segment. The instrument approach commences at the IAF. In the initial approach, the aircraft has departed the en route phase of flight and is maneuvering to enter an intermediate segment. An initial approach may be made along an arc DME, radial, course, heading, radar vector, or a combination thereof. PCG is required except when dead reckoning (DR) courses can be established over limited distances. Although more than one initial approach may be established for a procedure, the number should be limited to that which is justified by traffic flow or other operational requirements. Where practical, establish at least one initial segment that does not require a course reversal. Where alignment and/or descent gradient cannot be met and/or where otherwise operationally advantageous, initial segments requiring a course reversal may be established such as a procedure turn (PT), holding pattern descent, or high altitude teardrop turn.

a. When the IAF is part of the en route structure, the angle of intersection between the en route structure and a ground-based initial approach segment course must not exceed 120 degrees. For RNAV routes, apply Order 8260.58.

b. When the IF is part of the en route structure, it may not be necessary to establish an initial approach segment. In this case, the fix is designated as an IF/IAF and intermediate segment standards apply (see section 2-5).

c. When the IAF is collocated with an IF (for example, in the case of a course reversal over the IF), the fix is also designated as an IF/IAF. The course reversal is considered to be the initial segment.

d. Where holding is required prior to entering the initial approach segment, the holding fix and IAF should coincide. When this is not possible, the IAF must be located within the holding pattern on the inbound holding course.

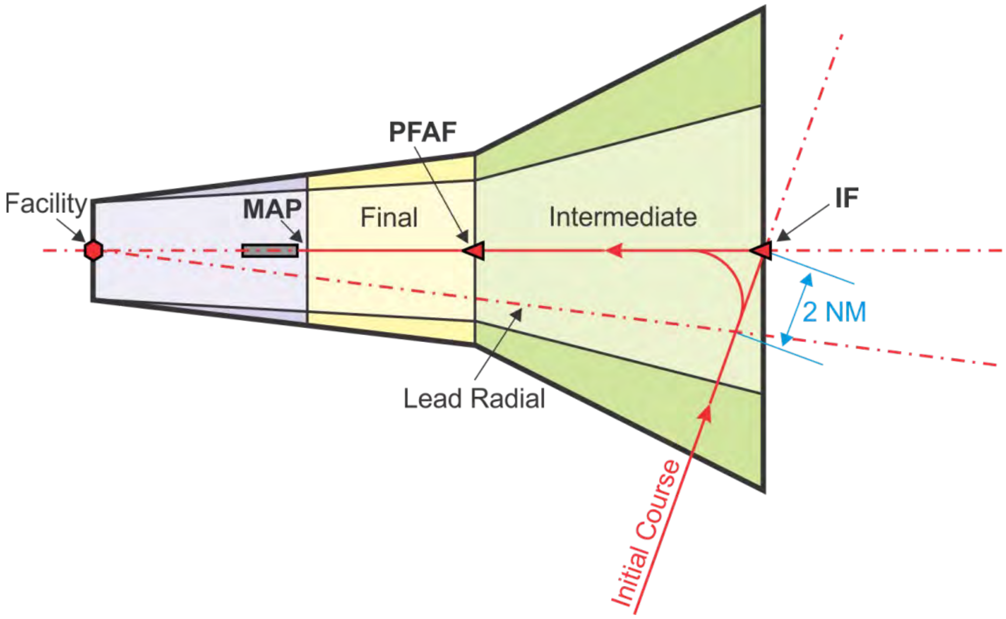
2-4-2. Altitude Selection. Minimum altitudes in the initial approach segment must be established in 100-foot increments. The selected altitude must provide the minimum ROC (plus adjustments as specified by paragraph 3-2-2); for example, when obstacle elevation plus ROC equals 1501, round up to 1600. The altitude selected must not be below the PT altitude where a PT is required. In addition, altitudes specified in the initial approach segment must not be lower than any altitude specified for any portion of the intermediate or final approach segment.

2-4-3. Initial Approach Segments Based on Straight Courses and Arcs with PCG.

a. Alignment.

(1) Straight courses. The angle of intersection between two successive initial approach courses and the angle of intersection between an initial approach course and an intermediate course must not exceed 120 degrees. When the angle between an initial approach course and intermediate course exceeds 90 degrees, a radial or bearing which provides at least 2 NM of lead must be identified to assist in leading the turn onto the intermediate course (see figure 2-4-1).

Figure 2-4-1. Initial Approach Interception Angle Greater than 90 degrees

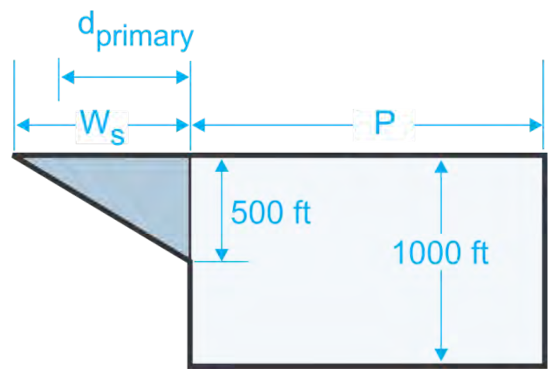


(2) Arcs. A DME arc may provide course guidance for all or a portion of an initial approach. The minimum arc radius is 7 NM. The radius for high altitude procedures should be at least 15 NM unless a reduced descent gradient is used (see paragraph 2-4-3.d). An arc may join a course at or before the IF. When joining a course at or before the IF, the angle of intersection of the arc and the course must not exceed 120 degrees. When the angle exceeds 90 degrees, a radial which provides at least 2 NM of lead must be identified to assist in leading the turn on to the intermediate course. DME arc courses must be predicated on DME collocated with a facility providing omnidirectional course information.

b. Area. The initial approach segment has no standard length. The length must be sufficient to permit the altitude change required by the procedure and must not exceed 50 NM unless an operational requirement exists. The total width of the initial approach segment is 6 NM on each side of the initial approach course. This width is divided into a primary area, which extends laterally 4 NM on each side of the course, and a secondary area, which extends laterally 2 NM on each side of the primary area (see figure 2-4-1). When any portion of the initial approach is more than 50 NM from the navigation facility, the criteria for en route airways applies to that portion.

c. Obstacle clearance. The minimum ROC in the primary area is 1000 feet. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 2-4-2). The minimum ROC at any given point in the secondary area is determined by formula 2-4-1. Adjustments for precipitous terrain must be applied as specified in paragraph 3-2-2 (see also paragraph 2-4-2).

Figure 2-4-2. Straight/Arc Initial Segment Minimum ROC



Formula 2-4-1. Straight/Arc Initial Segment Minimum Secondary ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_s}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge
W_S = Total width of the secondary area (feet)

d. Descent gradient. The optimum descent gradient in the initial approach is 250 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 500 ft/NM. The optimum descent gradient for high altitude procedures is 800 ft/NM. Where a higher descent gradient is necessary, the maximum gradient is 1000 ft/NM. When an arc of less than 15 NM is used in high altitude procedures, the descent gradient along the arc must not exceed the values in table 2-4-1 (values may be interpolated).

Table 2-4-1. Descent Gradient on High Altitude Procedure Arcs 15 NM and Less

ARC RADIUS (NM)	MAX FEET/NM
≥15	1000
14	720
13	640
12	560
11	480
10	400
9	320
8	240
7	160

2-4-4. Initial Approach Segment Based on DR.

a. Alignment. Each DR course must intercept the extended intermediate course. For low altitude procedures, the intercept point must be at least 1 NM from the IF for each 2 NM of DR flown. For high altitude procedures, the intercept point may be 1 NM for each 3 NM of DR flown. The intercept angle must:

(1) Not exceed 90 degrees.

(2) Not be less than 45 degrees except when DME is required for the approach and is used to identify the IF, or the DR distance is 3 NM or less.

b. Area. The maximum length of the DR portion of the initial segment is 10 NM (except paragraph 2-4-3.b applies for high altitude procedures where DME is available throughout the DR segment). Where the DR course begins, the width is 6 NM on each side of the course, expanding by 15 degrees outward until joining the points shown in figure 2-4-3 through figure 2-4-7.

c. Obstacle clearance. The minimum ROC in the DR initial approach segment is 1000 feet. There is no secondary area. Adjustments for precipitous terrain must be applied as specified in paragraph 3-2-2 (see also paragraph 2-4-2).

d. Descent gradient. The optimum descent gradient in the initial approach is 250 ft/NM. Where a higher descent gradient is necessary, the maximum permissible gradient is 500 ft/NM. The optimum descent gradient for high altitude procedures is 800 ft/NM. Where a higher descent gradient is necessary, the maximum permissible gradient is 1000 ft/NM.

Figure 2-4-3. Example DR Segment

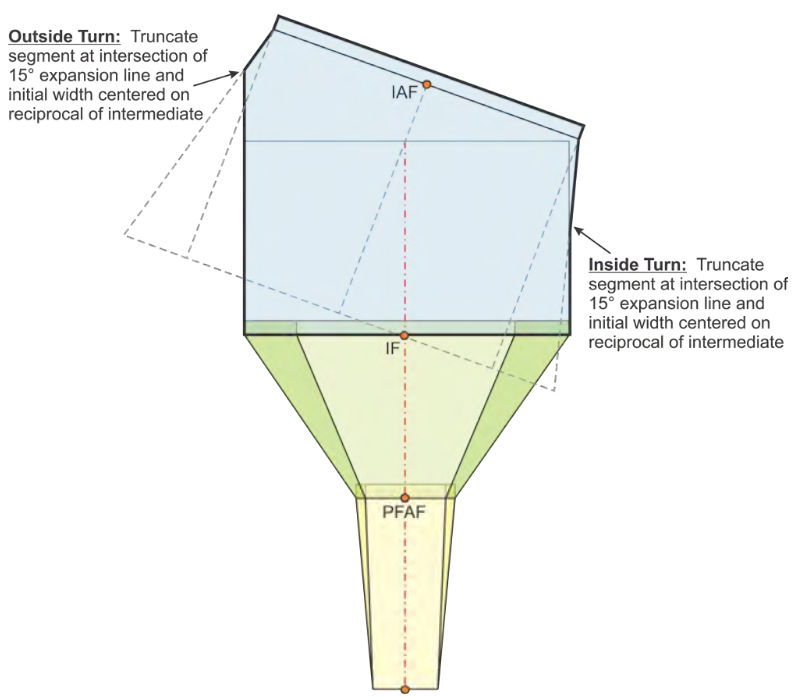


Figure 2-4-4. Example DR Segment

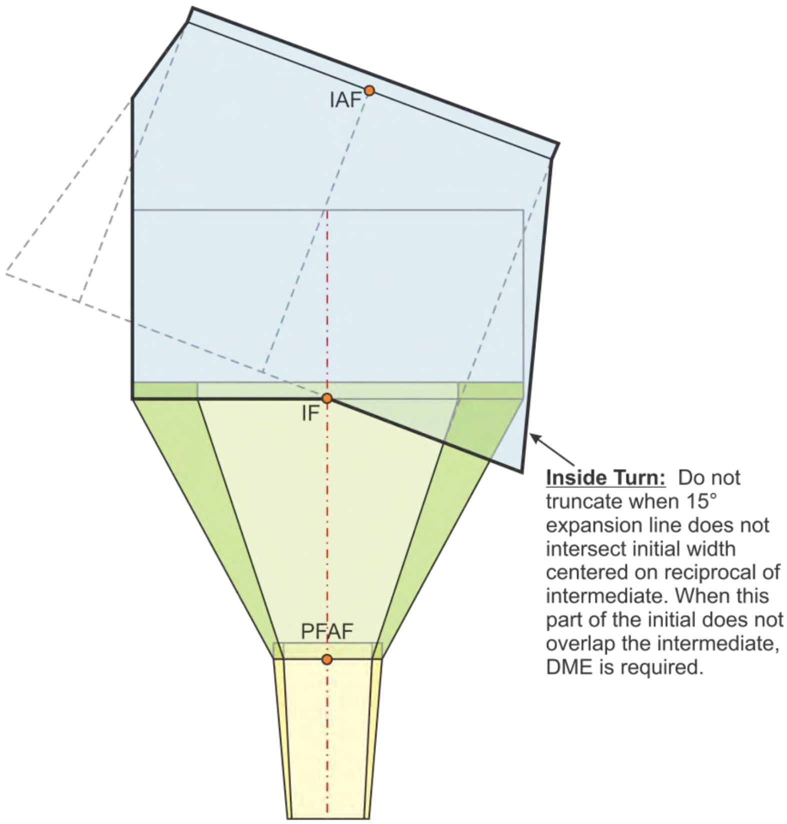


Figure 2-4-5. Example DR Segment

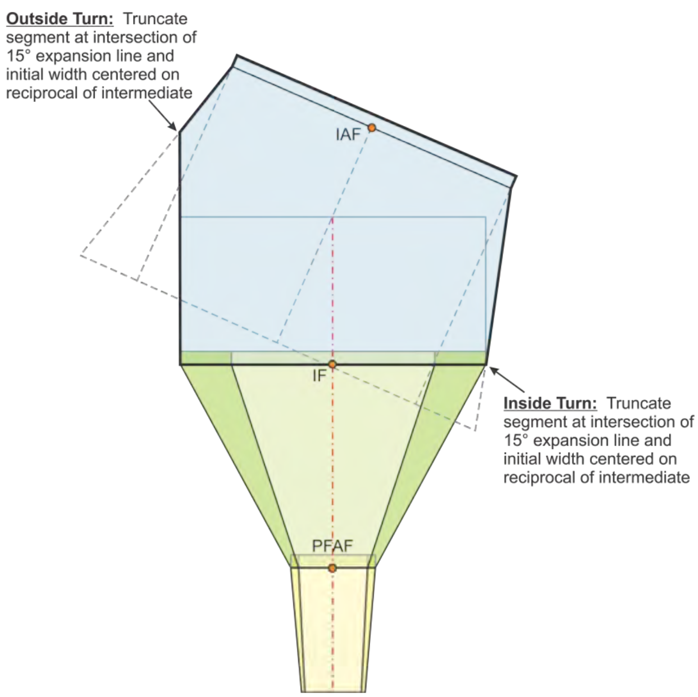


Figure 2-4-6. Example DR Segment

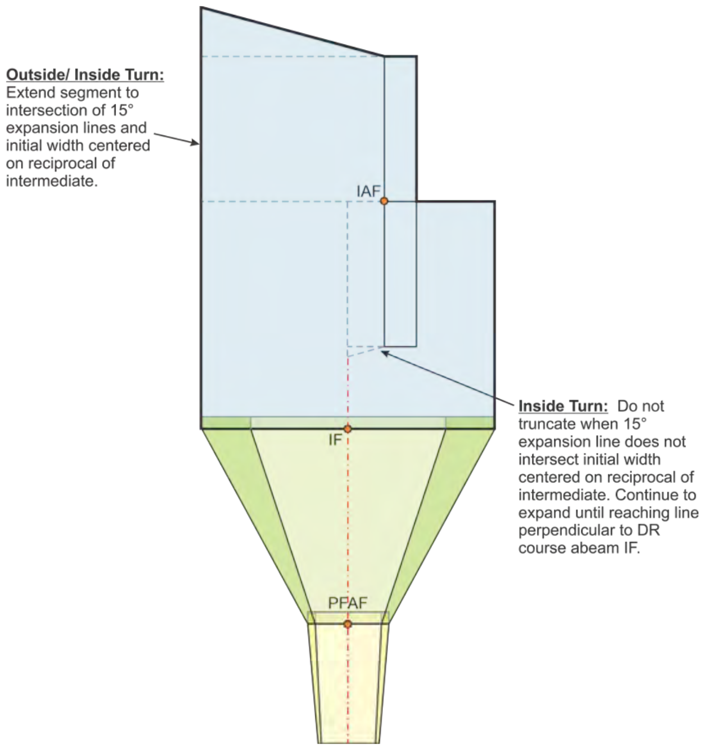
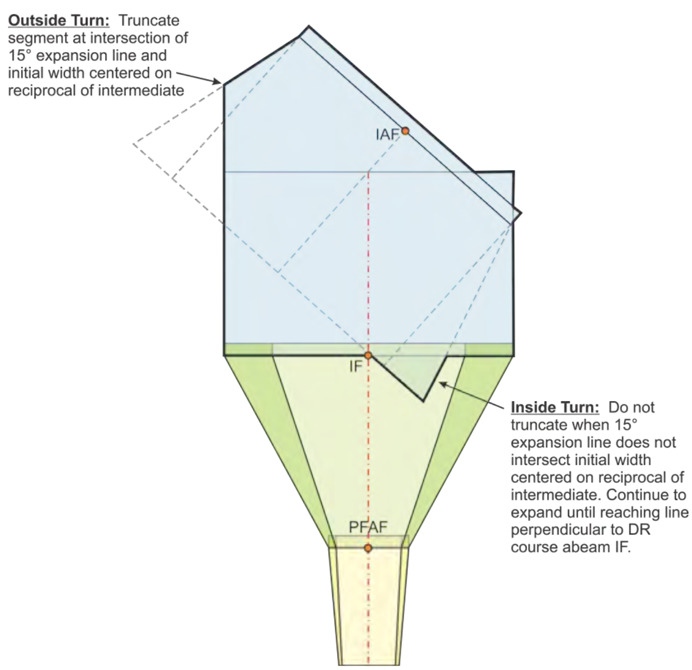


Figure 2-4-7. Example DR Segment



2-4-5. Initial Approach Segment Based on a PT. Establish a PT when it is necessary to reverse direction to establish the aircraft on an intermediate or FAC, except as specified in paragraph 2-4-5.e. A PT begins by overheading a facility, or a fix which meets either the criteria for a holding fix (see paragraph 2-9-8.b) or for a PFAF (see paragraph 2-9-8.c). A PT must not be established over a 75 MHz marker beacon. The procedure must specify the PT fix, the outbound and inbound courses, the distance within which the PT must be completed, and the direction of the PT. When a teardrop turn is used, the angle of divergence between the outbound courses and the reciprocal of the inbound course must be a minimum of 15 degrees or a maximum of 30 degrees (see paragraph 2-4-6.a for high altitude teardrop turn). When the beginning of the intermediate or final approach segment associated with the PT is not marked by a fix, the segment is deemed to begin on the inbound PT course at the maximum distance specified in the procedure. Where neither segment is marked by a fix, the final segment begins at the maximum distance specified in the procedure.

a. Alignment. When the inbound course of the PT becomes the intermediate course, it must meet the intermediate course alignment criteria (see paragraph 2-5-3.a). When the inbound course becomes the FAC, it must meet the FAC alignment criteria (see paragraph 2-6-1). The wider side of the PT area must be oriented in the same direction as that prescribed for the PT.

b. Area. The PT areas are depicted in figure 2-4-8. The minimum PT distance is 10 NM when CAT B, C, or D minimums are authorized. Decrease this distance to 5 NM where only CAT A aircraft or helicopters are to be operating, and increase to 15 NM to accommodate operational requirements, or as specified in paragraph 2-4-5.d. No extension of the PT is permitted without a PFAF. When a PT is authorized for use by approach CAT E aircraft, use a 15-NM PT distance. The PT segment is made up of the entry and maneuvering zones. The entry zone terminates at the inner boundary which extends perpendicular to the PT inbound course at the PT fix. The remainder of the PT segment is the maneuvering zone. The entry and maneuvering zones are made up of primary and secondary areas. The PT primary area dimensions are based on the highest authorized PT entry altitude or the highest feeder route altitude, whichever is greater. To allow additional maneuvering area as the true airspeed increases at higher altitudes, the dimensions of the PT primary area increase; see table 2-4-2 through table 2-4-4. The PT secondary area is 2 NM on the outside of the primary area.

Figure 2-4-8. PT Area
(See table 2-4-2 to Determine Radius Values)

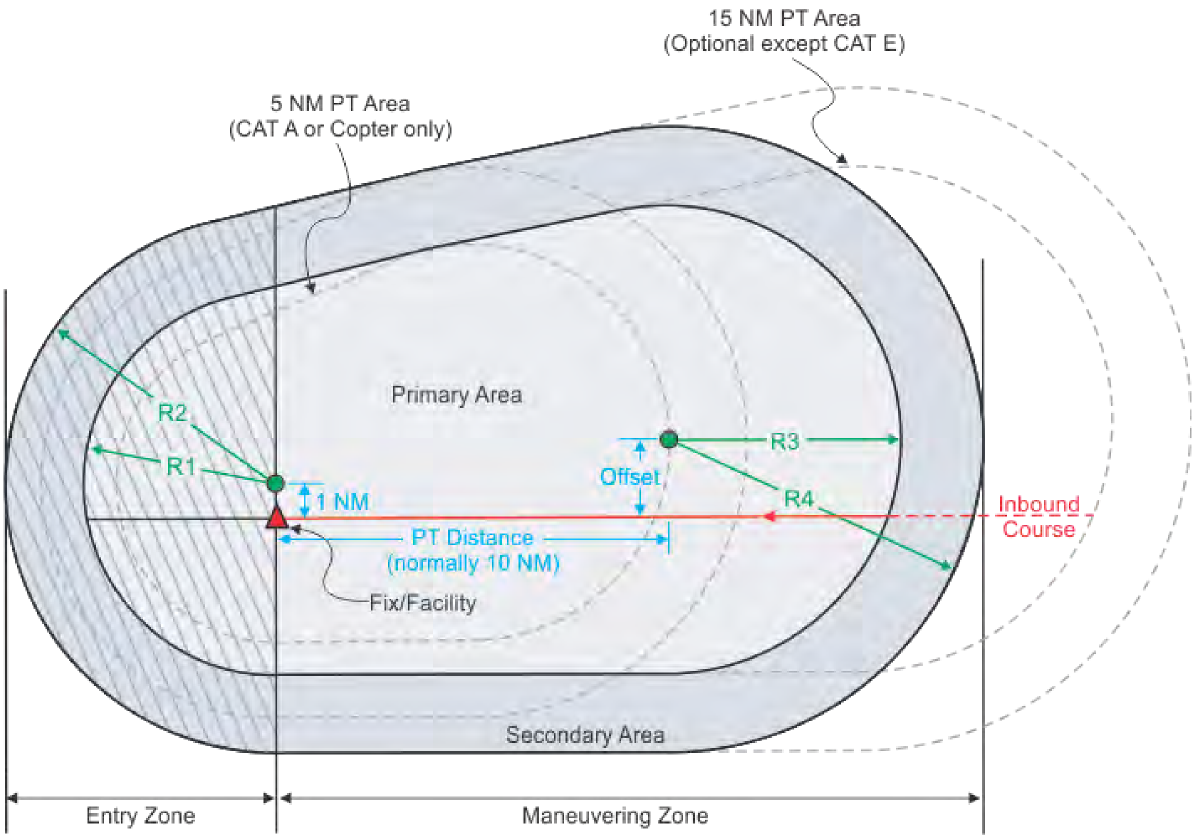


Table 2-4-2. PT Variables (NM) by Altitude ≤ 6000

PT LENGTH	OFFSET	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	5	7	6	8
>10-15	a - 4	5	7	a	a + 2

Where:
$a = 0.1 \times (b - 10) + 6$
b = Specified PT length

Table 2-4-3. PT Variables (NM) by Altitude > 6000 to ≤ 10000

PT Length	Offset	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	6	8	7	9
>10-15	a - 5	6	8	a	a + 2

Where:
$a = 0.1 \times (b - 10) + 7$
b = Specified PT length

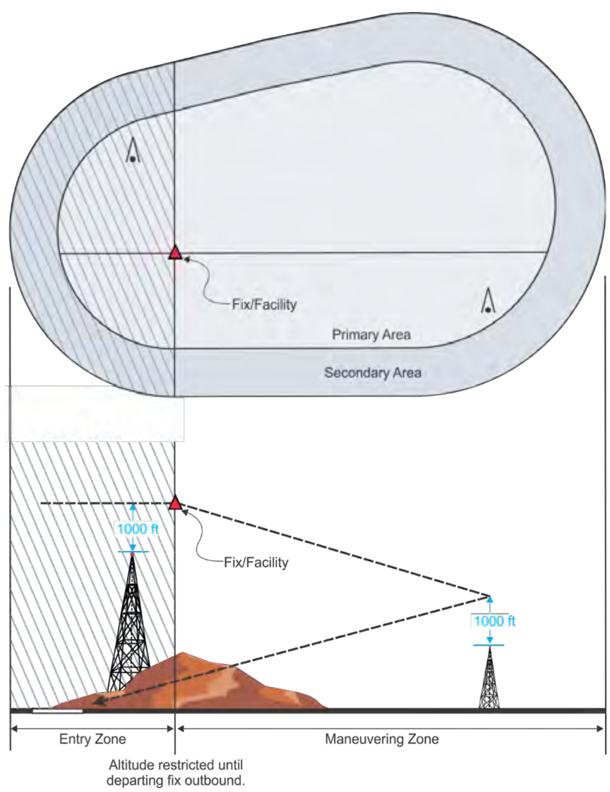
Table 2-4-4. PT Variables (NM) by Altitude > 10000

PT Length	Offset	R_1	R_2	R_3	R_4
5	2	4	6	5	7
>5-10	2	7	9	8	10
>10-15	a - 6	7	9	a	a + 2

Where:
$a = 0.1 \times (b - 10) + 8$
b = Specified PT length

c. Obstacle clearance. Apply paragraph 2-4-3.c. In addition, the primary and secondary areas determine obstacle clearance in both the entry and maneuvering zones. The use of entry and maneuvering zones provides further relief from obstacles. The entry zone is established to control the obstacle clearance prior to proceeding outbound from the PT fix/facility. The maneuvering zone is established to control obstacle clearance after proceeding outbound from the PT fix/facility (see figure 2-4-9).

Figure 2-4-9. PT Initial Approach Area



d. Descent gradient. The optimum descent gradient in the initial approach is 250 ft/NM. Where a higher descent gradient is necessary, the maximum permissible gradient is 500 ft/NM. Where a PT is established over a PFAF, the PT completion altitude should be as close as possible to the PFAF altitude. The difference between the PT completion altitude and the altitude over the PFAF must not be greater than those shown in table 2-4-5. If greater differences are required for a 5-NM or 10-NM PT, the PT distance limits and maneuvering zone must be increased at the rate of 1 NM for each 200 feet of required altitude.

Table 2-4-5. PT Completion Altitude Difference

Type of PT	Altitude Difference
15 NM PT from PFAF	≤ 3000 feet over PFAF altitude
10 NM PT from PFAF	≤ 2000 feet over PFAF altitude
5 NM PT from PFAF	≤ 1000 feet over PFAF altitude
15 NM PT, no PFAF	Not Authorized
10 NM PT, no PFAF	≤ 1500 feet over MDA
5 NM PT, no PFAF	≤ 1000 feet over MDA

e. Elimination of PT. A PT is not required when an approach can be made direct from a specified IF to the PFAF provided the alignment of the initial segment complies with paragraph 2-4-3.a. A PT need not be established when an approach can be made from a properly aligned holding pattern (see paragraph 16-9-2). In this case, the holding pattern in lieu of a PT must be established over a final or intermediate approach fix and the following conditions apply:

(1) If the holding pattern is established over the PFAF (not applicable to RNAV procedures), an intermediate segment is not constructed. Ideally, establish the minimum holding altitude at the PFAF altitude. In any case, the published holding altitude must not be more than 300 feet above the PFAF altitude.

(2) If the holding pattern is established over the IF, the minimum holding altitude (MHA) must permit descent to the PFAF altitude within the descent gradient tolerances prescribed for the intermediate segment (see paragraph 2-5-3.d).

2-4-6. Initial Approach Based on High Altitude Teardrop Turn. A high altitude teardrop turn consists of departure from an IAF on an outbound course, followed by a turn toward and intercepting the inbound course at or prior to the IF or point used in lieu of an IF when no IF exists (see paragraph 2-4-6.c). Its purpose is to permit an aircraft to reverse direction and lose considerable altitude within reasonably limited airspace. Where no IF is available to mark the beginning of the intermediate segment, it must be assumed to commence at a point 10 NM prior to the PFAF. When the facility is located on the airport, and no fix is available to mark the beginning of the final approach segment, the criteria in paragraph 4-3-4 apply.

a. Alignment. The outbound course must be between 18 and 26 degrees to the left or right of the reciprocal of the inbound course. The actual angular divergence between the courses will vary inversely with the distance from the facility at which the turn is made (see table 2-4-6).

b. Area.

(1) Size. The size of the turn area must be sufficient to accommodate both the turn and the altitude loss required by the procedure. The turn distance must not be less than 20 NM from the facility. The turn distance depends on the altitude to be lost in the procedure and the point at

which the descent is started (see table 2-4-6). The aircraft should lose half the total altitude or 5000 feet, whichever is greater, outbound prior to starting the turn. The turn area has a width of 6 NM on both sides of the flight track up to the IF (or point used in lieu of the IF), and must encompass all the areas within the turn (see figure 2-4-10).

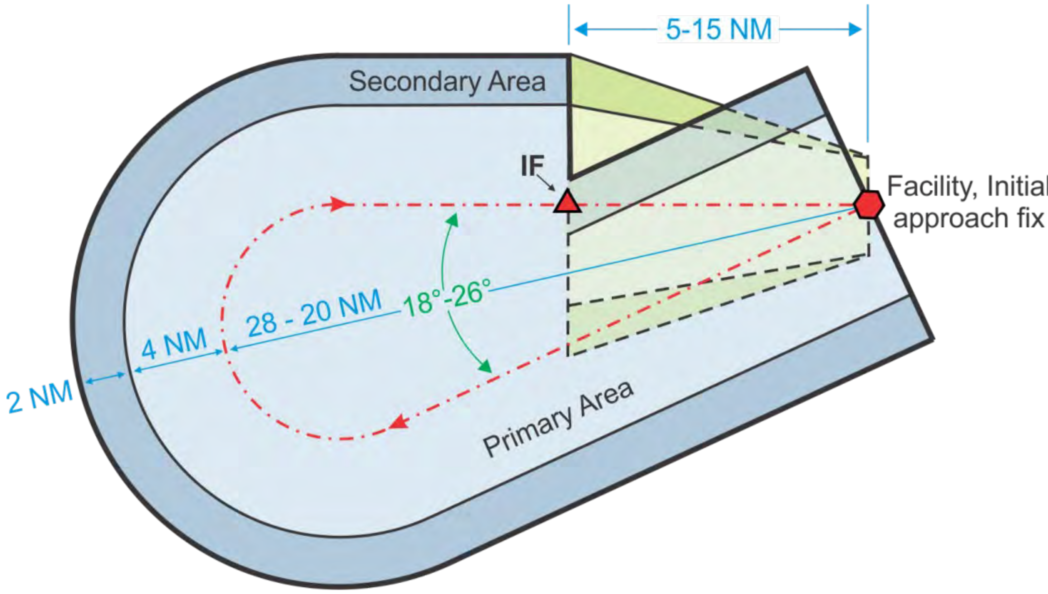
(2) Turn distance table. Use table 2-4-6 to compute the desired course divergence and turn distances which apply when a specific altitude loss outbound is required. It is assumed that the descent begins at the plotted position of fix. When the procedure requires a delay before descent of more than 5 NM, add the distance in excess of 5 NM to the distance the turn commences. Then adjust the course divergence and teardrop turn distance to correspond to the adjusted turn distance. Extrapolations may be made from the table.

(3) Primary and secondary areas. All of the turn area, except the outer 2 NM of the 6-NM obstacle clearance area on the outer side of the turn teardrop track is primary area (see figure 2-4-10). The outer 2 NM is secondary area. The outer 2 NM on both sides of the inbound course should be treated as secondary area (see figure 2-4-12).

Table 2-4-6. High Altitude Turn Distance/Divergence

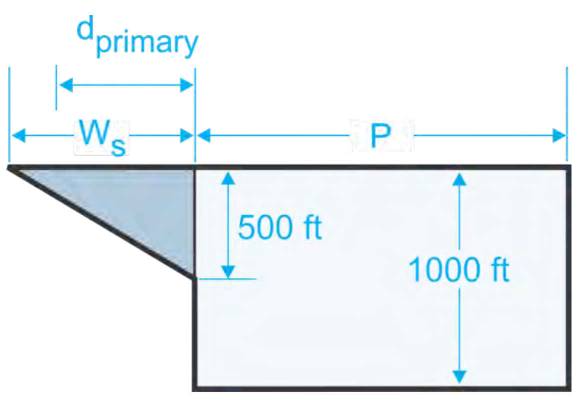
ALT to be Lost Prior to Commencing Turn (feet)	Distance Turn Commences (NM)	Course Divergence (Degrees)	Specified Turn Distance (NM)
12000	24	18	28
11000	23	19	27
10000	22	20	26
9000	21	21	25
8000	20	22	24
7000	19	23	23
6000	18	24	22
5000	17	25	21
5000	16	26	20

Figure 2-4-10. Typical High Altitude Teardrop Turn Initial Approach Area



c. Obstacle clearance. The minimum ROC in the primary area is 1000 feet. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 2-4-11). The minimum ROC at any given point in the secondary area is determined by formula 2-4-2. Adjustments for precipitous terrain must be applied as specified in paragraph 3-2-2. Where no IF is available, a 10-NM intermediate segment is assumed and intermediate segment ROC is applied (see paragraph 2-5-3.c). The controlling obstacle, as well as the minimum altitude selected for the intermediate segment, may depend on the availability of an IF (see figure 2-4-12).

Figure 2-4-11. High Altitude Teardrop Initial Segment Secondary ROC



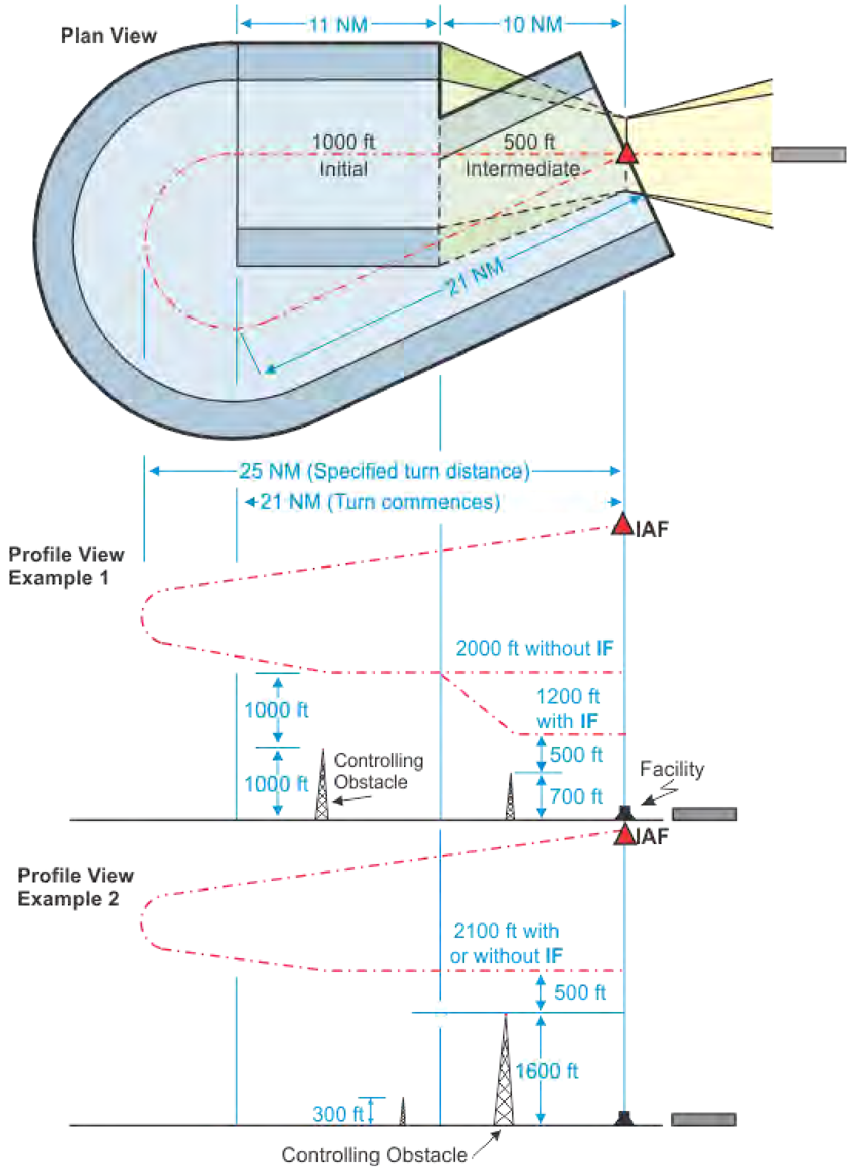
Formula 2-4-2. PT Initial Segment Secondary ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_s}\right)$$

Where:

$d_{primary}$= Perpendicular distance (feet) from primary area edge
W_S = Total width of the secondary area (feet)

Figure 2-4-12. High Altitude Teardrop Turn Initial Approach Obstacle Clearance



d. Descent gradient. The optimum descent gradient is 800 ft/NM. The maximum gradient is 1000 ft/NM.

e. Turn altitude. When an IF is not provided, the turn completion altitude must not be more than 4000 feet above the PFAF altitude.

2-4-7. Initial Approach Course Reversal Using Noncollocated Facilities and a Turn of 120 Degrees or Greater to Intercept the Inbound Course. See figure 2-4-13, figure 2-4-14, and figure 2-4-15.

a. Common criteria.

(1) A turn point fix must be established as shown in the figures. The fix error must meet section 2-9 criteria and must not exceed ± 2 NM.

(2) A flight path radius (R) of 2.8 NM must be used for procedures where the altitude at the turn point fix is at or below 10000 feet, or 4 NM for procedures where the altitude at the turn point fix is above 10000 feet MSL.

(3) Construct the primary boundary (and secondary if applicable) of the turn by swinging an arc(s) from the intersection of the bisector line and the turn point's fix error line.

(4) Descent gradient. Apply criteria in paragraph 2-4-3.d.

(5) Obstacle clearance. Apply criteria in paragraph 2-4-6.c.

(6) When the course reversal turn intercepts the extended intermediate course, or when the course reversal turn intercepts a straight segment prior to intercepting the extended intermediate course, the minimum distance between the rollout point and the PFAF is 10 NM.

(7) ROC reduction. No reduction of secondary ROC is authorized in the course reversal area unless the turn point fix is DME.

b. Figure 2-4-13 and figure 2-4-14. The rollout point must be at or prior to the IF/point.

(1) Select the desired rollout point on the inbound course.

(2) Place the appropriate flight path arc tangent to the rollout point.

(3) From the outbound facility**,** place the outbound course tangent to the flight path arc. The point of tangency must be the turn point fix.

Figure 2-4-13. Example Initial Approach Course Reversal Using Noncollocated Facilities and Turn Greater than 120 Degrees

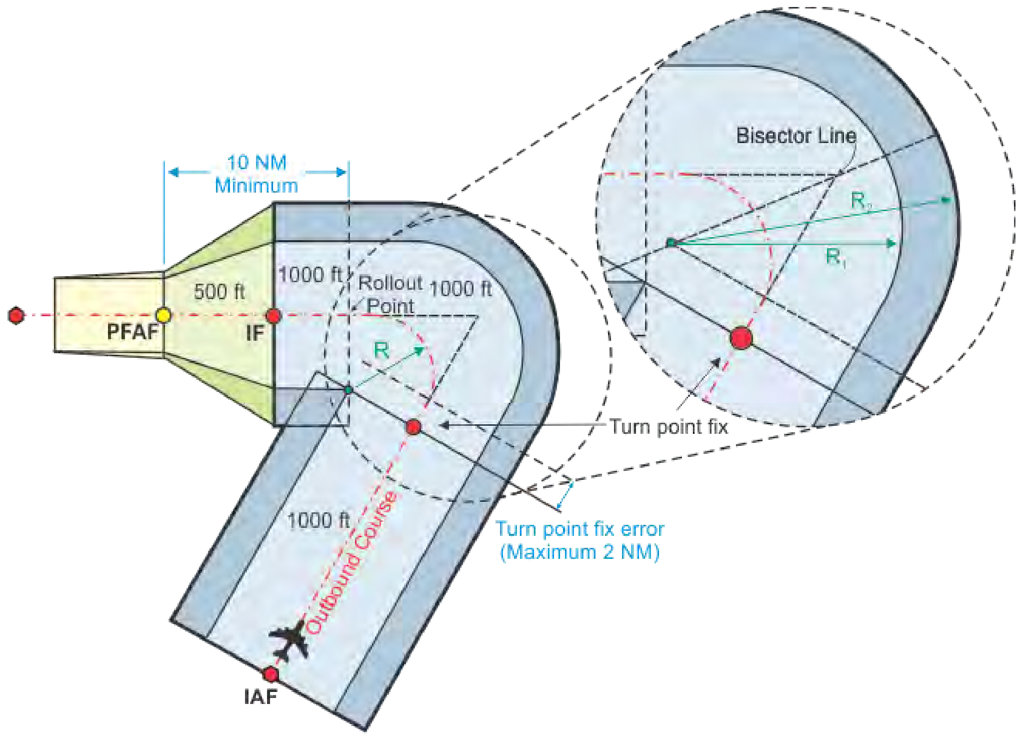
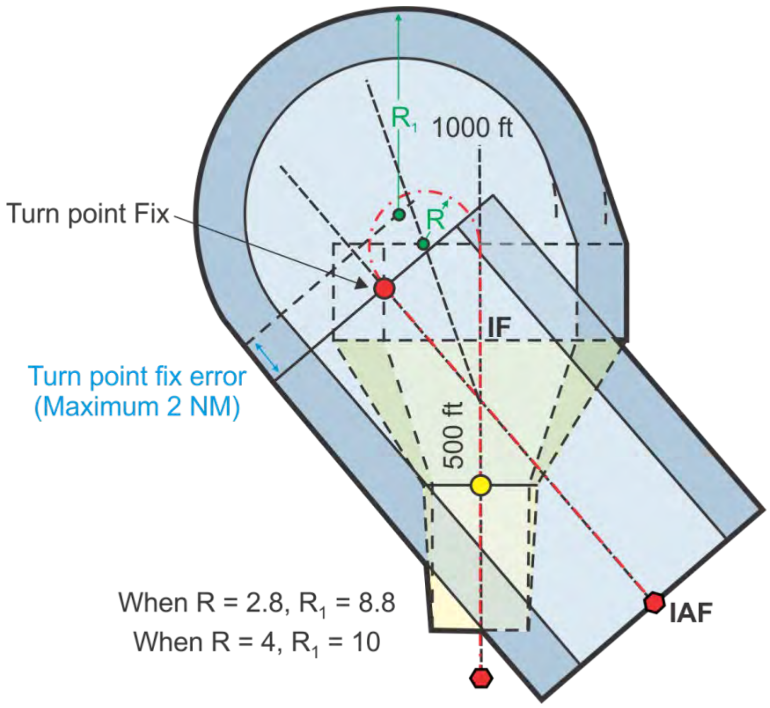


Figure 2-4-14. Example Initial Approach Course Reversal Using Noncollocated Facilities and Turn Greater than 120 Degrees



c. Figure 2-4-15.

(1) The point of intersection must be at or prior to the IF/point (paragraph 2-5-3 applies). The angle must be 90 degrees or less.

(2) The distance between the roll-out point and the point of intersection must be no less than the distance shown in table 2-4-7.

Figure 2-4-15. Example Initial Approach Course Reversal Using Noncollocated Facilities and Turn Greater than 120 Degrees

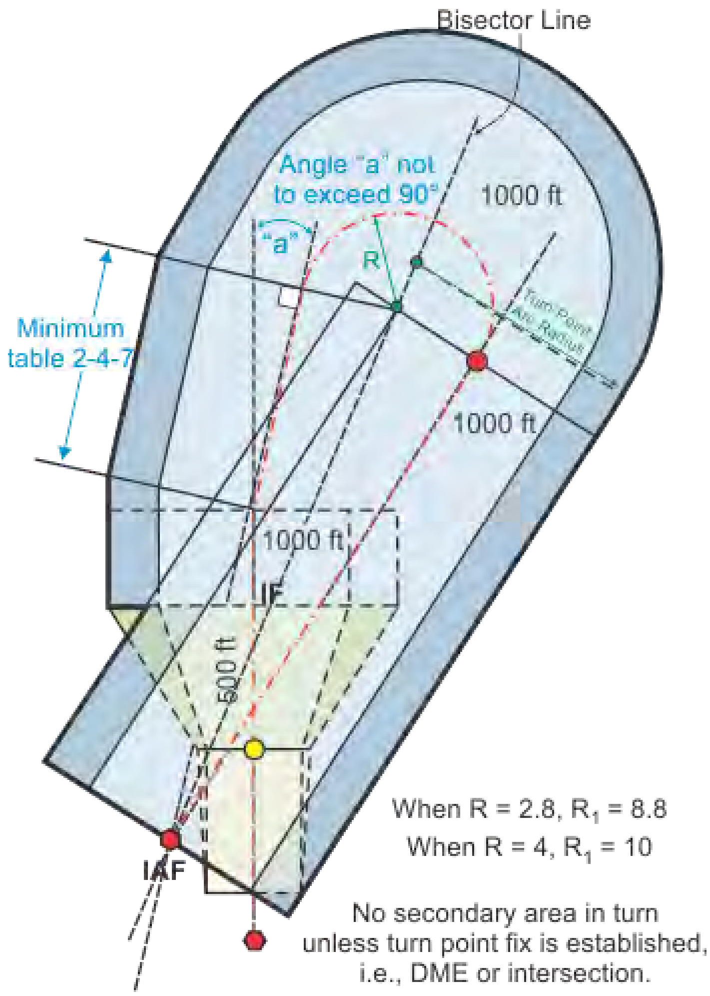


Table 2-4-7. Minimum Distance from Roll Out Point to Point of Intersection

Angle "a" (Degrees)	NM
0 - 15	1
>15 - 30	2
>30 - 45	3
>45 - 60	4
>60 - 75	5
>75 - 90	6

Note: For high altitude procedures, use paragraph 2-4-6 and table 2-4-7 up to the point of intersection of the two inbound courses.

(3) Select the desired point of intersection. From the outbound facility draw a line through the point of intersection.

(4) At the outbound facility, measure the required number of degrees course divergence (may be either side of the line through the point of intersection) and draw the outbound course out the required distance. Connect the outbound course and the line through the point of intersection with the appropriate arc.

(5) Determine the desired rollout point on the line through the point of intersection.

(a) Place the appropriate flight path arc tangent to the rollout point.

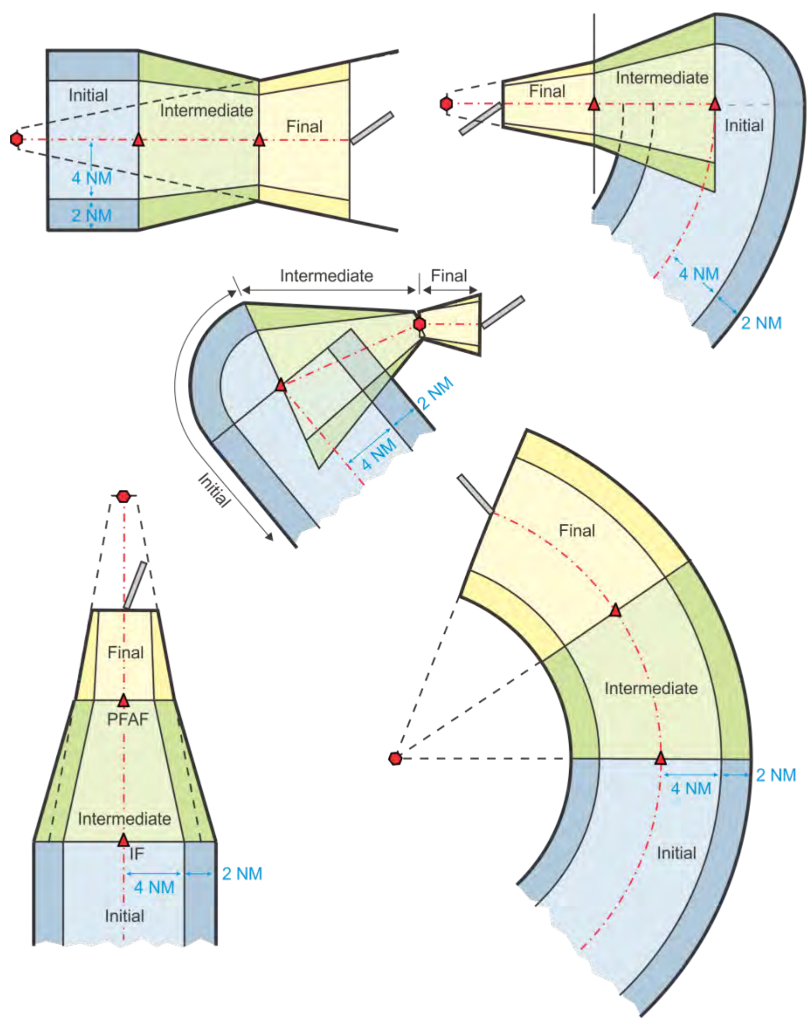
(b) From the outbound facility draw the outbound course tangent to the flight path arc. The point of tangency is the turn point fix.

Section 2-5. Intermediate Approach

2-5-1. Intermediate Approach Segment. This is the segment which blends the initial approach segment into the final approach segment. It is the segment in which aircraft configuration, speed, and positioning adjustments are made for entry into the final approach segment. The intermediate segment begins at the IF (or point used in lieu of) and ends at the PFAF. There are two types of intermediate segments; the “radial” or “course” intermediate segment, and the “arc” intermediate segment. In either case, PCG must be provided. For typical approach segments, see figure 2-5-1.

2-5-2. Altitude Selection. Minimum altitudes in the intermediate segment must be established in 100-foot increments. The selected altitude must provide the minimum ROC (plus adjustments as specified by paragraph 3-2-2); for example, when obstacle height plus ROC and adjustments equals 701, round up to 800 feet. The altitude selected for arrival over the PFAF must be low enough to permit descent from the PFAF to the airport for a straight-in landing whenever possible. In addition, the altitude selected for the PFAF must not be lower than the highest straight-in or circling MDA (CMDA).

Figure 2-5-1. Typical Approach Segments



2-5-3. Intermediate Approach Segment Based on Straight Courses.

a. Alignment. The course to be flown in the intermediate segment must be the same as the FAC, except when the PFAF is the navigation facility and it is not practical for the courses to be identical. In such cases, the intermediate course must not differ from the FAC by more than 30 degrees.

b. Area.

(1) Length. The length of the intermediate segment is measured along the course to be flown. Where the initial segment joins the intermediate segment at angles up to and including 96 degrees, the minimum length is 5 NM for CAT A/B and 6 NM for CAT C/D/E (see chapters 8, 10, 11, and 12 for exceptions). Table 2-5-1 lists the minimum segment length where the initial approach course joins the intermediate course at angles greater than 96 degrees. The maximum segment length is 15 NM. The optimum length is 10 NM. A distance greater than 10 NM should not be used unless an operational requirement justifies a greater distance.

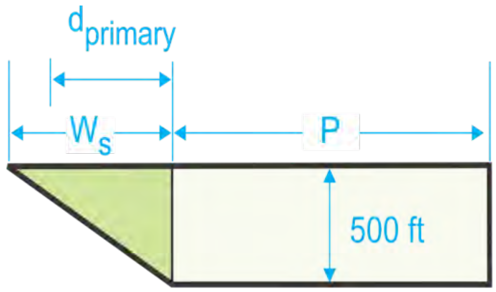
(2) Width. The width of the intermediate segment is the same as the width of the segment it joins. When the intermediate segment is aligned with initial or final approach segments, the width of the intermediate segment is determined by joining the outer edges of the initial segment with the outer edges of the final segment. When the intermediate segment is not aligned with the initial or final approach segments, the resulting gap on the outside of the turn is a part of the preceding segment and is closed by the appropriate arc (see figure 2-5-1). For obstacle clearance purposes, the intermediate segment is divided into a primary and a secondary area.

Table 2-5-1. Minimum Intermediate Course Length

Angle (Degrees)	Minimum Length (NM) based on CAT	
	A/B	C/D/E
0 - 96	5	6
> 96 - 102	6	7
>102 - 108	6	8
>108 - 114	6	9
>114 - 120	7	10

c. Obstacle clearance. The minimum ROC in the primary area is 500 feet. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 2-5-2). The minimum ROC at any given point in the secondary area is determined by formula 2-5-1. Apply adjustments as specified in paragraph 3-2-2.

Figure 2-5-2. Intermediate Segment Secondary ROC



Formula 2-5-1. Intermediate Segment Secondary ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:
$d_{primary}$ = Perpendicular distance (feet) from primary area edge
W_S = Total width of the secondary area (feet)

d. Descent gradients. Because the intermediate segment is used to prepare the aircraft speed and configuration for entry into the final approach segment, the gradient should be as flat as possible. A descent gradient no greater than 150 ft/NM is optimum. The maximum gradient between the IF and the PFAF is 318 ft/NM. When one or more stepdown fixes are established, ensure the gradient from each stepdown fix to the PFAF does not exceed 318 ft/NM. Higher gradients resulting from arithmetic rounding are permissible.

2-5-4. Intermediate Approach Segment Based on an Arc. DME Arcs with a radius of less than 7 NM or more than 30 NM from the navigation facility must not be used. Arc courses must be predicated on DME collocated with a facility providing omnidirectional course information.

a. Alignment. The same arc must be used for the intermediate and the final approach segments. No turns are permitted over the PFAF.

b. Area.

(1) Length. The intermediate segment must not be less than 5 NM or more than 15 NM in length, measured along the arc. The optimum length is 10 NM. A distance greater than 10 NM should not be used unless an operational requirement justifies the greater distance.

(2) Width. The total width of an arc intermediate segment is 6 NM on each side of the arc. For obstacle clearance purposes, this width is divided into a primary and a secondary area. The primary area extends 4 NM laterally on each side of the arc segment. The secondary areas extend 2 NM laterally on each side of the primary area (see figure 2-5-1).

c. Obstacle clearance. Apply criteria in paragraph 2-5-3.c.

d. Descent gradients. Apply criteria in paragraph 2-5-3.d.

2-5-5. Intermediate Approach Segment Within a PT.

a. PT over a PFAF when the PFAF is a facility (see figure 2-5-3).

(1) The maximum intermediate length is 15 NM, the optimum is 10 NM, and the minimum is 5 NM. Its width is the same as the final segment at the facility and expanding uniformly to 6 NM on each side of the course at 15 NM from the facility.

(2) The intermediate segment considered for obstacle clearance must be the same length as the PT distance; for example, if the procedure requires a PT to be completed within 5 NM, the intermediate segment must be 5 NM long, and the intermediate approach must begin on the intermediate course 5 NM from the PFAF.

(3) When establishing a stepdown fix within an intermediate/initial segment underlying a PT area:

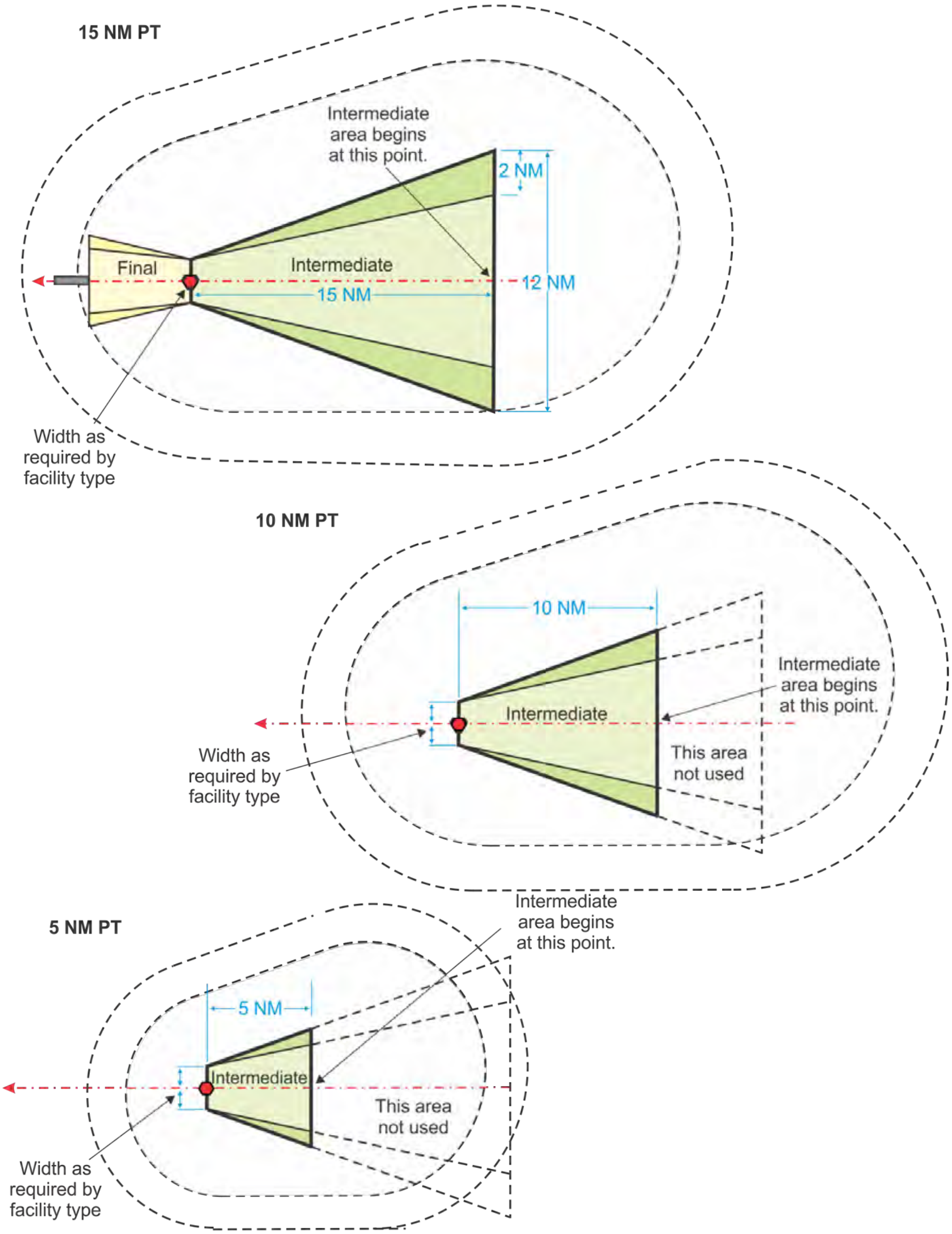
(a) Table 2-4-5, PT Completion Altitude Difference, must be applied.

(b) Only one stepdown fix is authorized within the intermediate segment that underlies the PT maneuvering area.

(c) The distance between the PT fix/facility and a stepdown fix underlying the PT area must not exceed 4 NM.

(d) The maximum descent gradient from the IF point to the stepdown fix is 200 ft/NM. The maximum descent gradient from the stepdown fix to the PFAF is 318 ft/NM.

Figure 2-5-3. Intermediate Area Within a PT Area, PFAF is the Facility



b. PT over a PFAF when the PFAF is not a facility (see figure 2-5-4).

(1) The intermediate segment must be 6 NM wide each side of the intermediate course at the PT distance.

(2) When establishing a stepdown fix within an intermediate/initial segment underlying a PT area:

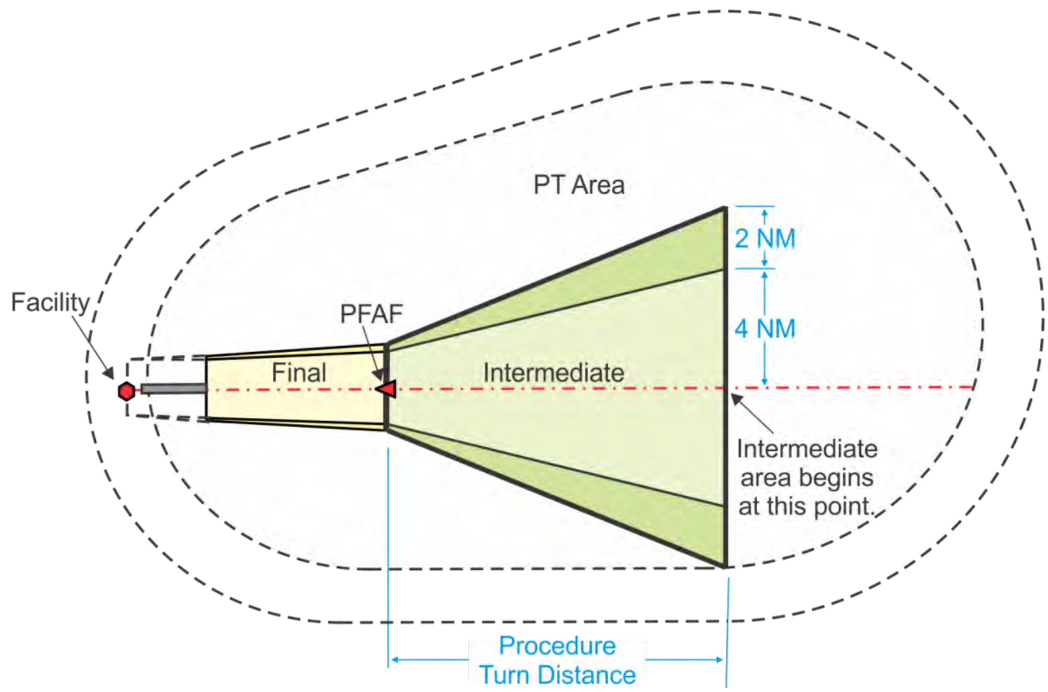
(a) Table 2-4-5, PT Completion Turn Altitude, must be applied.

(b) Only one stepdown fix is authorized within the intermediate segment that underlies the PT maneuvering area.

(c) The distance between the PT fix/facility and a stepdown fix underlying the PT area must not exceed 4 NM.

(d) The maximum descent gradient from the IF point to the stepdown fix is 200 ft/NM. The maximum descent gradient from the stepdown fix to the PFAF is 318 ft/NM.

Figure 2-5-4. Intermediate Area Within the PT Area, PFAF is not the Facility



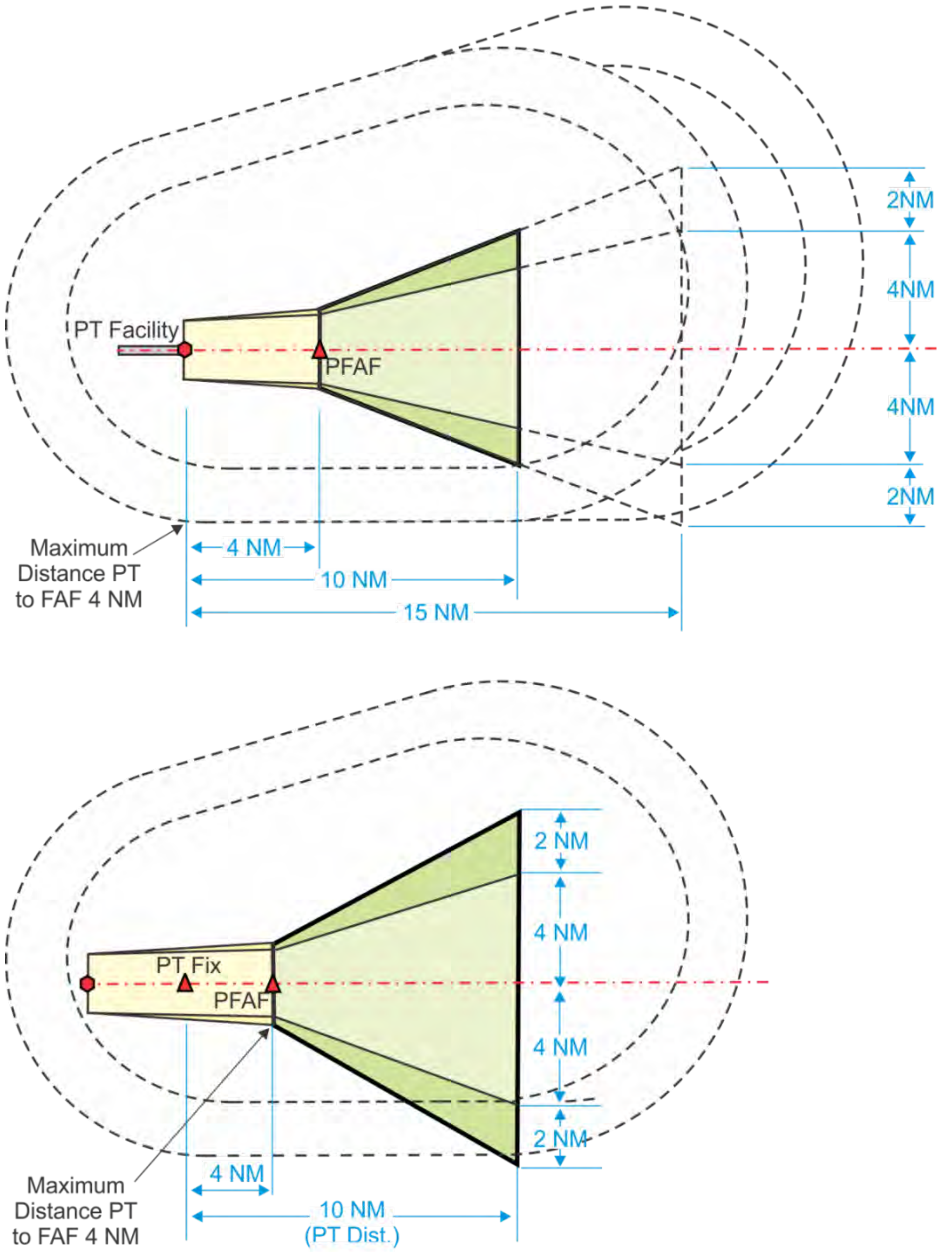
c. PT over a facility/fix after the PFAF (see figure 2-5-5).

(1) The PT facility/fix to PFAF distance must not exceed 4 NM.

(2) The maximum PT distance is 15 NM.

(3) The length of the intermediate segment is from the start of the PT distance to the PFAF and the minimum length must be 5 NM.

Figure 2-5-5. Intermediate Area Within the PT Area, PT Over the Facility/Fix After the PFAF



(4) Intermediate segment area.

(a) PT over a facility. The intermediate segment starts 15 NM from the facility at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the PFAF. The area considered for obstacle clearance is from the start of the PT distance to the PFAF.

(b) PT over a fix (not a facility). The intermediate segment starts at the PT distance at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the PFAF. The area considered for obstacle clearance is from the start of the PT distance to the PFAF.

(5) The maximum descent gradient in the intermediate segment is 200 ft/NM. The PT distance may be increased in 1-NM increments up to 15 NM to meet descent limitations.

(6) When establishing a stepdown fix within an intermediate/initial segment underlying a PT area:

(a) Only one stepdown fix is authorized within the intermediate segment that underlies the PT maneuvering area.

(b) The distance between the PT fix/facility and a stepdown fix underlying the PT area must not exceed 4 NM.

(c) The maximum descent gradient from the IF point to the stepdown fix is 200 ft/NM. The maximum descent gradient from the stepdown fix to the PFAF is 318 ft/NM.

d. PT over a facility/fix prior to the PFAF (see figure 2-5-6 and figure 2-5-7).

(1) The minimum PT distance is 5 NM.

(2) The length of the intermediate segment is from the start of the PT distance to the PFAF and the maximum length is 15 NM.

(3) Intermediate segment area.

(a) PT over a facility. The intermediate segment starts 15 NM from the facility at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the PFAF. The area considered for obstacle clearance is from the start of the PT distance to the PFAF.

(b) PT over a fix (not a facility). The intermediate segment starts at the PT distance at a width of 6 NM each side of the inbound course and connects to the width of the final segment at the PFAF. The area considered for obstacle clearance is from the start of the PT distance to the PFAF.

Figure 2-5-6. Intermediate Area Within the PT Area, PT Over the Facility/Fix Prior to the PFAF

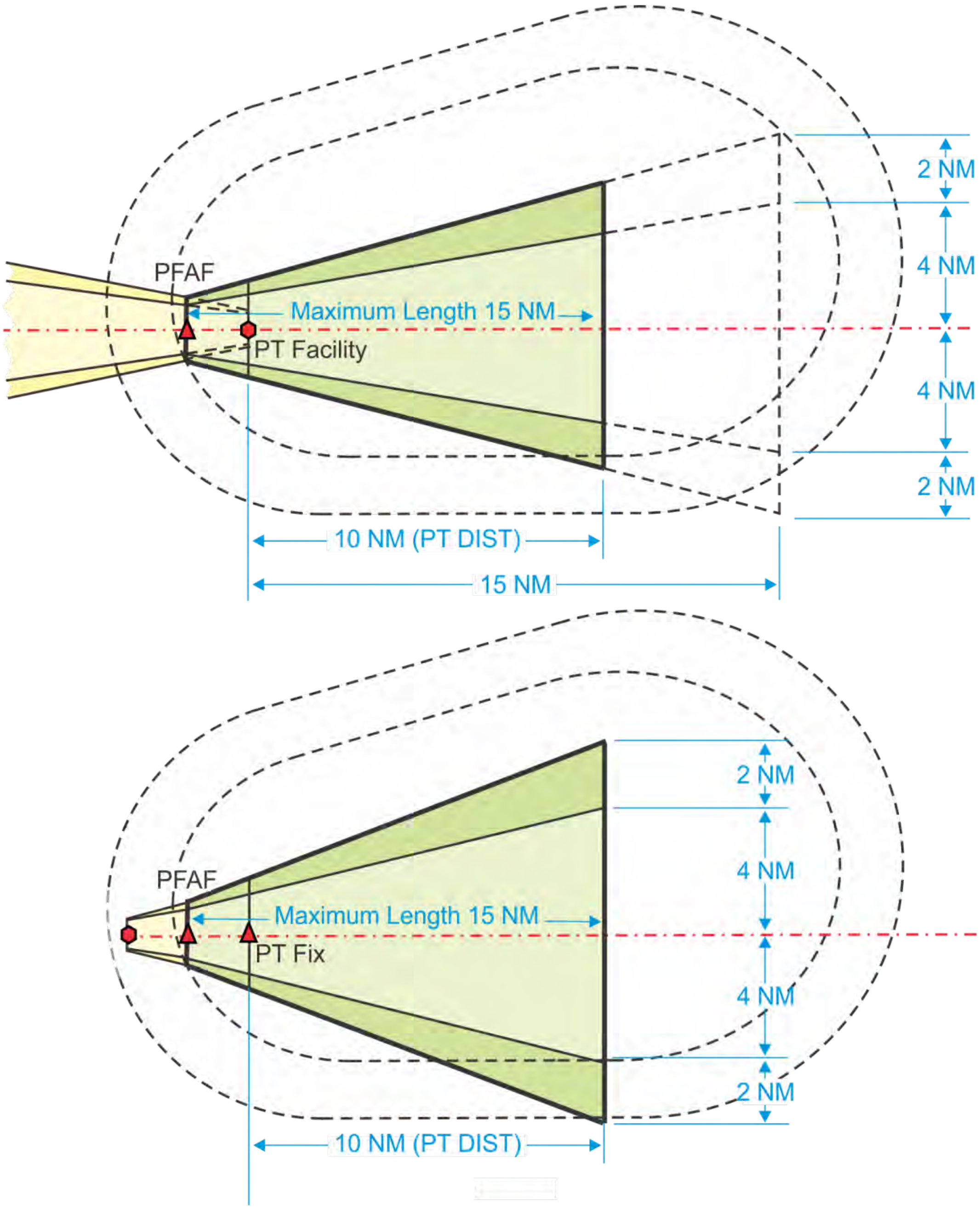
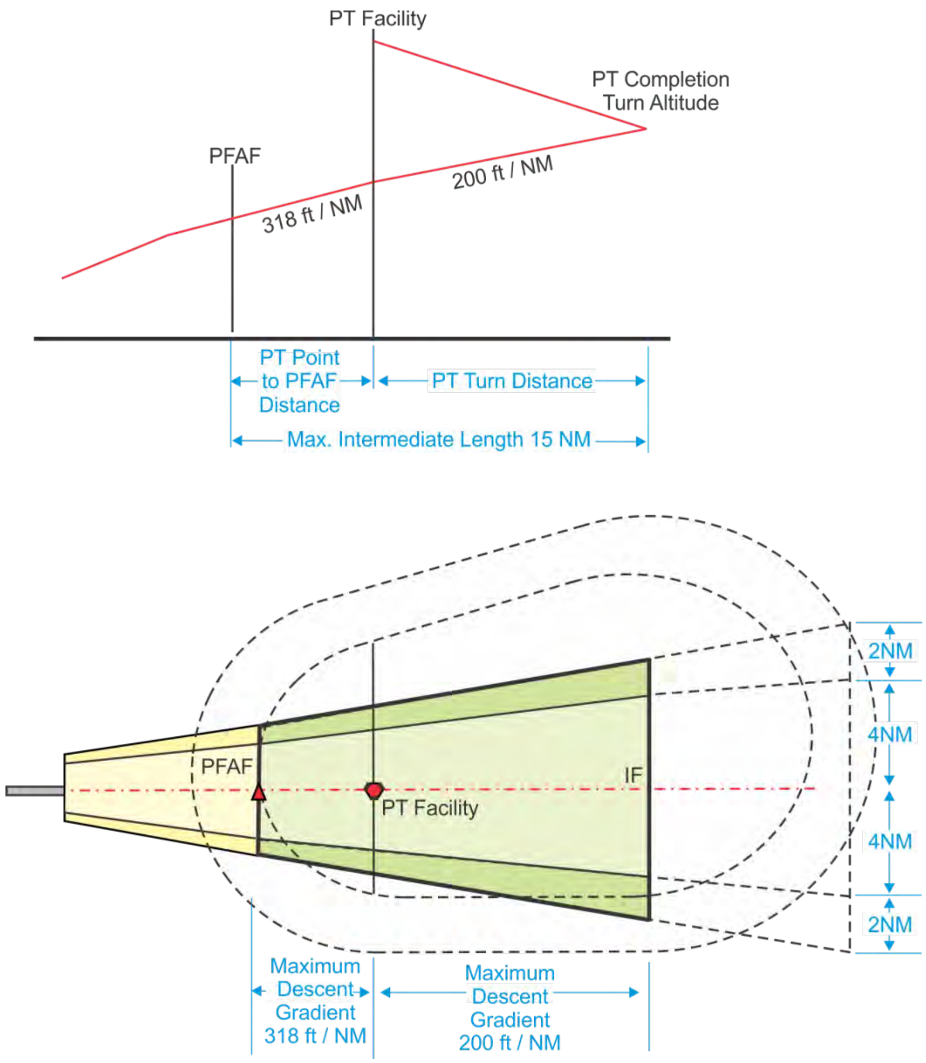


Figure 2-5-7. Intermediate Area Within PT Area, PT Facility/Fix Used as a Stepdown Fix



(4) The maximum descent gradient is 200 ft/NM. If the PT facility/fix is a stepdown fix, the descent gradient from the stepdown fix to the PFAF may be increased to a maximum of 318 ft/NM (see figure 2-5-7). The PT distance may be increased in 1-NM increments up to 15 NM to meet descent limitations.

(5) When establishing a stepdown fix within an intermediate/initial segment underlying a PT area:

(a) When the PT fix is over a facility/fix prior to the PFAF, the facility/fix is the stepdown fix in the intermediate/initial area, and another stepdown fix within this segment is not authorized.

(b) The maximum descent gradient from the IF point to the stepdown fix is 200 ft/NM. The maximum descent gradient from the stepdown fix to the PFAF is 318 ft/NM.

e. PT facility fix used as an IF (see figure 2-5-8).

(1) When the PT inbound course is the same as the intermediate course, either paragraph 2-5-5.d may be used, or a straight initial segment may be used from the start of the PT distance to the PT fix.

(2) When the PT inbound course is not the same as the intermediate course, an intermediate segment within the PT area is not authorized; only a straight initial segment may be used from the start of the PT distance to the PT fix.

(3) When a straight initial segment is used, the maximum descent gradient within the PT distance is 318 ft/NM; the PT distance may be increased in 1-NM increments up to 15 NM to meet descent limitations.

(4) When establishing a stepdown fix within an intermediate/initial segment underlying a PT area:

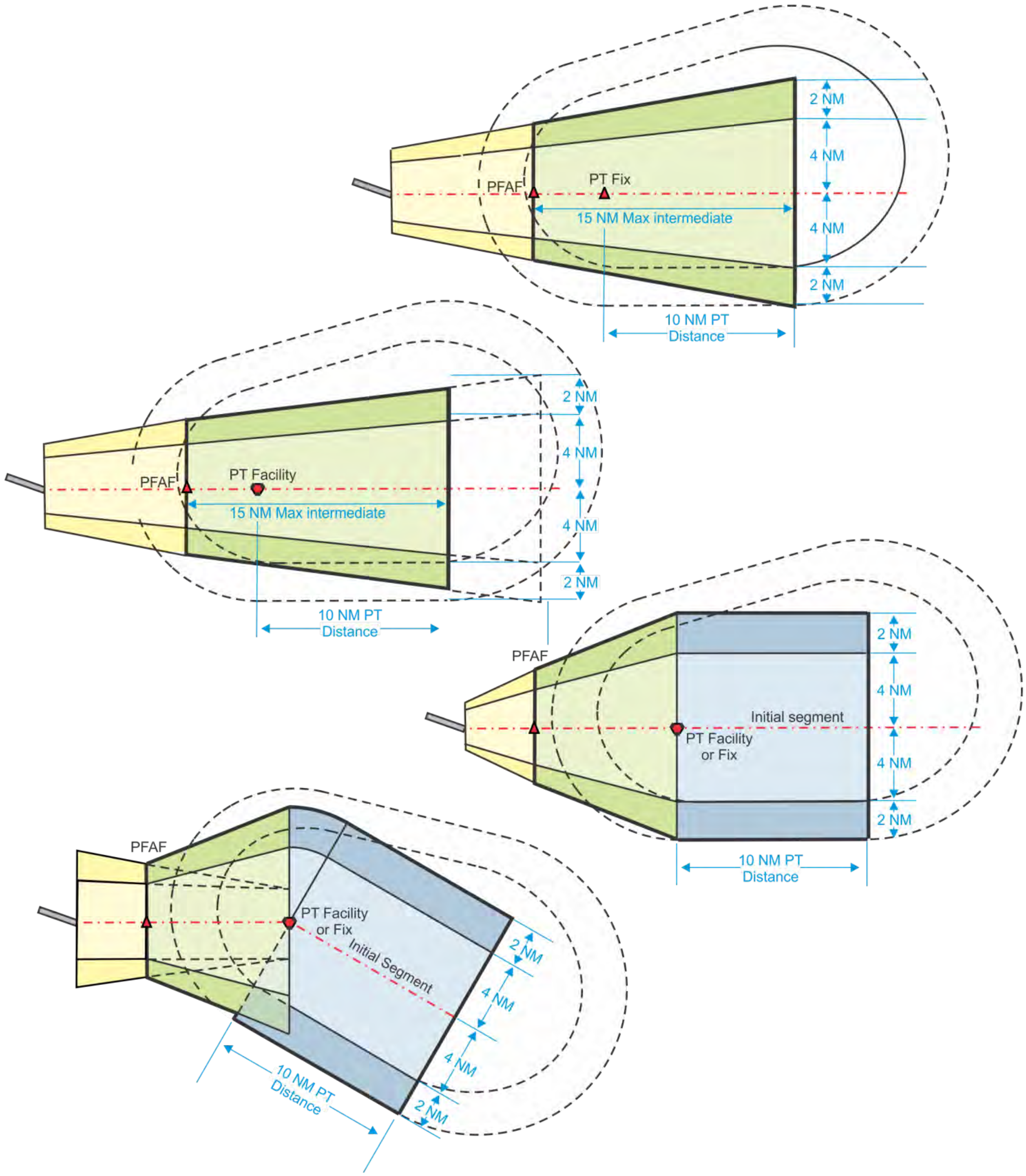
(a) Only one stepdown fix is authorized within the initial segment that underlies the PT maneuvering area.

(b) The distance from the PT facility/fix and a stepdown fix underlying the PT area must not exceed 4 NM.

(c) The maximum descent gradient from the PT completion point (turn distance) to the stepdown fix, and from the stepdown fix to the IF, is 318 ft/NM.

f. When a PT from a facility is required to intercept a localizer course, the PT facility is considered on the localizer course when it is located within the commissioned localizer course width.

Figure 2-5-8. Use of PT Fix for IF



Section 2-6. Final Approach

2-6-1. Final Approach Segment. This is the segment in which alignment and descent for landing are accomplished. Final approach may be made to a runway for a straight-in landing or to an airport for a circling approach. The segment begins at the PFAF and ends at the MAP and/or DA. Criteria for alignment, length, OEA, and OCS evaluation are contained in the chapters/directives specific to the facility/system providing navigation guidance. A visual portion within the final approach segment is also assessed for all approaches (see section 3-3).

2-6-2. Glidepath Angle (GPA) and Vertical Descent Angle (VDA).

a. Approval is required to establish a GPA or a VDA (of a procedure where the FAC is straight-in aligned) that is more than 0.20 degrees greater than the glidepath angle of a visual glide slope indicator (VGSI) installed on the same runway (see paragraph 1-4-2).

b. Approval is required to establish a VDA (of a procedure where the FAC is straight-in aligned) that is less than the angle of a VGSI installed to the same runway (see paragraph 1-4-2).

c. GPA/VDA must not exceed the values specified in table 2-6-1.

Table 2-6-1. Maximum VDAs

CAT	Maximum Angle
A (80 knots or less)	6.40
A (81-90 knots)	5.70
B	4.20
C	3.77
D	3.50
E	3.10*

* USAF/USN CAT E maximum is 3.50 degrees.

2-6-3. GPA. Use a standard 3.00 degree GPA where possible. A GPA greater than 3.00 degrees but not more than the maximum (see table 2-6-1) is authorized without approval when needed to provide obstacle clearance or to meet simultaneous parallel approach standards. Other cases or a GPA less than 3.00 degrees requires approval (see paragraph 1-4-2). U.S. Air Force (USAF) and U.S. Navy (USN) minimum GPA is 2.50 degrees.

2-6-4. VDA. Determine a VDA for all NPA procedures except those published in conjunction with vertically-guided minimums or no-FAF procedures that do not contain a stepdown fix in the final segment. Optimum VDA is 3.00 degrees. Minimum VDA for a procedure with straight-in minimums is 2.75 degrees (2.50 degrees for USAF and USN); no minimum VDA applies to a procedure with only circling minimums or PinS procedures.

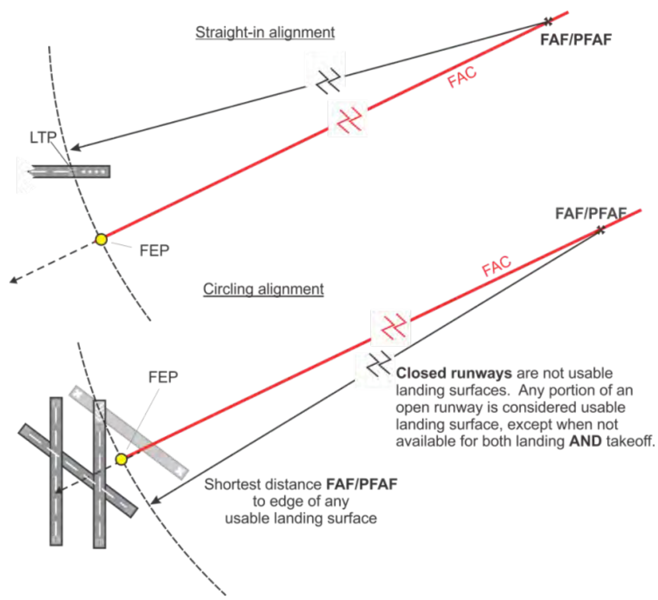
a. Where the FAC is straight-in aligned, design with a VDA equal to or higher than the lowest PA/APV glidepath angle established to the same runway. If no PA/APV procedure is established but a VGSI to the same runway is installed, then design with a VDA that is at least equal to, but not more than 0.20 degrees greater than the VGSI angle (see paragraph 2-6-2.a).

(1) If the final is circling aligned, or if a VGSI is not installed, then design the procedure at the optimum VDA when possible.

(2) If Flight Inspection determines the VDA is unsatisfactory due to obstacles, redesign the procedure using the highest allowable VDA within table 2-6-1. If the highest VDA is still unsatisfactory to flight inspection, then do not publish a VDA (see Order 8260.19).

b. Calculate VDA based on the distance from the plotted position of the PFAF or stepdown fix to the plotted position of the final end point (FEP) (see figure 2-6-1). The FEP is a point on the FAC equal to the distance from the PFAF to the landing threshold point (LTP) or from PFAF to the edge of first usable landing surface for circling only aligned procedures.

Figure 2-6-1. Final End Point



c. VDA for procedures meeting straight-in alignment.

(1) Calculate the VDA from the PFAF altitude (or stepdown fix altitude per paragraphs 2-6-4.e(1) or 2-6-4.f) to threshold crossing height (TCH) using formula 2-6-1. Round results to the nearest 0.01 degrees.

Formula 2-6-1. VDA Calculation for Procedure Meeting Straight-in Alignment

$$VDA = atan\left(\ln\left(\frac{r + alt}{r + THRe + TCH}\right) \times \frac{r}{D_{FIX}}\right)$$

Where:
alt = PFAF altitude in feet (stepdown altitude if applicable)
THRe = Threshold elevation
TCH = Use value that meets minimum and maximum TCH requirements
D_{FIX} = PFAF (stepdown fix if applicable) to FEP distance (feet)

(2) When the maximum VDA calculated in accordance with formula 2-6-1 is exceeded and altitudes/fix locations cannot be modified, straight-in minimums are not authorized. The procedure may be approved when restricted to circling minimums provided the maximum VDA calculated in accordance with paragraph 2-6-4.d is not exceeded. In this case, when VDA is published, specify the VDA calculated in accordance with formula 2-6-1 (published angle may exceed the maximum).

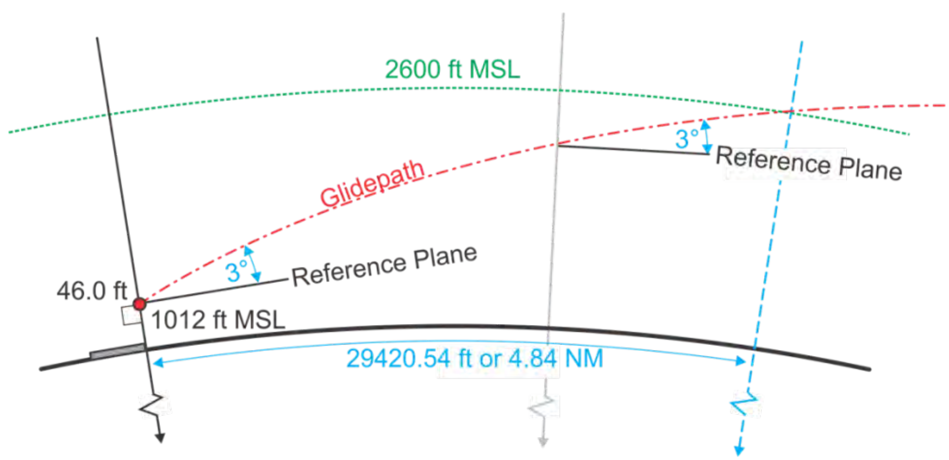
(3) Use formula 2-6-2 to determine a PFAF or stepdown fix location to achieve a specified design angle. Where a VGSI is installed and within the range of minimum/maximum VDAs, select a fix location which permits a VDA equivalent with the VGSI angle. When it is not feasible to achieve equivalency (for example, VGSI is not within the range of acceptable angles, or VGSI is not installed), select a fix location to achieve an optimum VDA when possible or within standard VDA range (see figure 2-6-2).

Formula 2-6-2. Determining PFAF or Stepdown Fix Location

$$D_{FIX} = \frac{\ln\left(\frac{r + alt}{r + THRe + TCH}\right) \times r}{\tan(\theta)}$$

Where:
D_{FIX}= PFAF (stepdown fix if applicable) to FEP distance (feet)
alt = PFAF altitude in feet (stepdown altitude if applicable)
THRe = Threshold elevation
TCH = Use table 10-1-1 value that meets minimum and maximum TCH requirements
θ = VGSI or specified VDA

Figure 2-6-2. Straight-In FAF/PFAF or Stepdown Fix Distance Based on Altitude and Angle



d. VDA for procedures not meeting straight-in alignment or for straight-in aligned procedures not authorized straight-in minimums.

(1) Procedures designed to circling alignment standards are not normally flown using a stabilized descent from the PFAF to landing. Therefore, PFAF location is not predicated on VDA; however, the achieved angle must not exceed the maximum VDA. Establish the PFAF

location in accordance with the alignment and segment length criteria applicable to the final approach NAVAID or system and calculate the circling VDA.

(2) Calculate the VDA from the PFAF (or stepdown fix altitude per paragraphs 2-6-4.e(2) or 2-6-4.f) to the lowest CMDA using formula 2-6-3. When the maximum VDA is exceeded, relocate the PFAF/stepdown fix and/or raise the CMDA until the angle is compliant.

Formula 2-6-3. VDA Calculation for Procedures Not Authorized Straight-In Minimums

$$VDA = atan\left(\ln\left(\frac{r + alt}{r + CMDA}\right) \times \frac{r}{D_{FIX}}\right)$$

Where:
alt = PFAF altitude in feet (stepdown altitude if applicable)
CMDA = Lowest published circling minimum descent altitude
D_{FIX}= PFAF (stepdown fix if applicable) to FEP distance (feet)

e. Stepdown fixes (with PFAF procedures and/or procedures published w/out PA/APV minimums). Establish stepdown fixes at the lowest altitude possible that also provides obstacle clearance. Determine the altitude of the vertical path at a stepdown fix using formula 2-6-4. When a minimum fix altitude is above the vertical profile of a VDA calculated in accordance with paragraph 2-6-4.c, adjust the stepdown fix location(s) if feasible. When stepdown fix location(s) cannot be modified, change the FAF/PFAF location or raise the FAF/PFAF altitude until stepdown fix(es) are at or below the vertical path of the VDA (must not exceed the maximum angle).

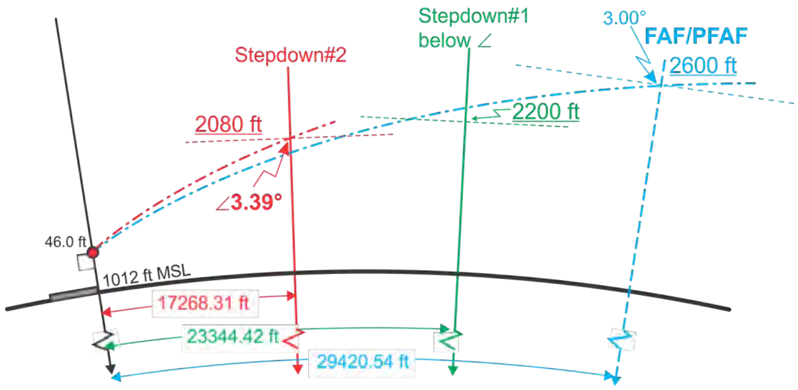
Formula 2-6-4. Vertical Path Elevation at Stepdown Fix

$$Z_{vertpath} = e^{\frac{D_{FIX} \times tan(\theta)}{r}} \times (r + base_{alt}) - r$$

Where:
D_{FIX} = PFAF (stepdown fix if applicable) to FEP distance (feet)
θ = Angle calculated in accordance with paragraph 2-6-4.c or 2-6-4.d
$base_{alt}$ = (THRe + TCH) for paragraph 2-6-4.c calculations; CMDA for paragraph 2-6-4.d calculations

(1) For straight-in aligned procedures only, when no other option is practical, calculate a VDA from each stepdown fix altitude above the vertical path (apply paragraph 2-6-4.c). Publish the greatest VDA and associate it with the applicable stepdown fix (see figure 2-6-3).

Figure 2-6-3. VDA with Stepdown Fixes



(2) For circling aligned procedures, when no other option is practical, calculate a VDA from each stepdown fix altitude above the vertical path (apply paragraph 2-6-4.d) and ensure each angle is less than or equal to the maximum angle.

(3) Do not raise stepdown fix altitudes higher than needed for obstacle clearance solely to achieve coincidence with the VDA vertical path (USN not applicable).

f. Stepdown fixes (no-PFAF procedures). Apply paragraph 2-6-4.c or 2-6-4.d to calculate the VDA from the stepdown fix. When there are multiple stepdown fixes, also apply paragraph 2-6-4.e, except the vertical path is calculated from the first stepdown fix (farthest from LTP) instead of from the PFAF.

g. Do not establish maximum, mandatory, or block altitudes at any final segment fix (including PFAF) except for where operationally required and approved (see paragraph 1-4-2).

2-6-5. Visual Descent Point (VDP). The VDP defines a point on an NPA procedure from which normal descent from the MDA may be commenced provided the required visual references have been acquired.

a. Establish a VDP for all straight-in NPA procedures (to include those combined with a PA/APV procedure), with the following exceptions/limitations:

(1) Do not publish a VDP when the primary altimeter setting comes from a remote source.

(2) Do not publish a VDP located prior to a stepdown fix.

(3) If the VDP is between the MAP and the runway do not publish a VDP.

(4) Do not publish a VDP when the visual area 20:1 surface is penetrated (see section 3-3).

(5) The VDP should be ≥ 1 NM from any other final segment fix (for example, MAP, stepdown). When not feasible, the VDP must be at least 0.5 NM from any other final segment

fix. If < 0.5 NM and the other fix cannot be relocated, do not publish a VDP. Do not increase the MDA to achieve the ≥ 0.5 NM distance.

(6) Do not publish a VDP on PinS procedures.

b. Determine VDP distance (in feet) using formula 2-6-5. When dual or multiple lines of NPA minimums are published, use the lowest MDA from any CAT to calculate the VDP distance.

(1) For runways served by a VGSI (regardless of coincidence with final VDA), using the VGSI TCH, establish the distance from LTP to a point where the lowest published VGSI glidepath angle reaches the appropriate MDA.

(2) For runways not served by a VGSI, using an appropriate TCH from table 10-1-1, establish the distance from LTP to a point where the greater of a three degree or the final segment VDA reaches the appropriate MDA. Apply this paragraph to establish a VDP for a non-PinS procedure to a landing area that supports IFR procedures, using the helipoint crossing height (HCH) in place of TCH.

Formula 2-6-5. VDP Distance

$$d_{VDP} = \frac{r \times \pi}{180} \times \left(90 - \theta - asin\left(\frac{\cos(\theta) \times (r + THRe + TCH)}{r + MDA}\right)\right)$$

Where:
MDA = Lowest published MDA
THRe = Threshold elevation (helipad elevation for non-PinS procedures to landing areas that support IFR procedures)
TCH = VGSI TCH or TCH from table 10-1-1 (HCH for non-PinS procedures to landing areas that support IFR procedures)
θ = VGSI or specified VDA

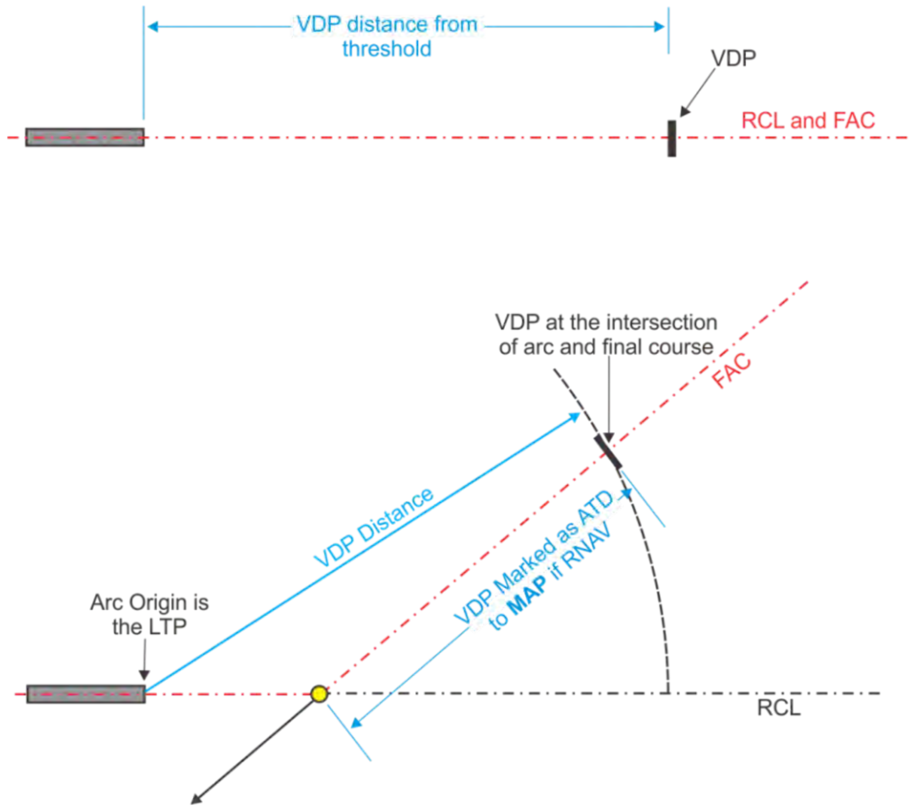
c. Marking VDP location.

(1) For Non-RNAV procedures, mark the VDP location with a DME fix. The DME source must be the same as for other DME fixes in the final segment. If suitable DME is not available, do not publish a VDP. Maximum fix error is ± 0.5 NM.

(2) For RNAV procedures, mark the VDP location with an along track distance (ATD) fix to the MAP. Maximum fix error is ± 0.5 NM.

(3) If the final course is not aligned with the runway centerline (RCL), using the LTP as an arc center, swing an arc of a radius equal to the VDP distance across the final approach course (see figure 2-6-4). The point of intersection is the VDP. For RNAV procedures, the distance from the point of intersection to the MAP is the ATD for the VDP.

Figure 2-6-4. VDP Location



2-6-6. Vertical Guidance Surface (VGS). The VGS must be evaluated for all PA and APV approach procedures (except helicopter APV PinS procedures).

a. If evaluation results in a penetration of the VGS, eliminate the penetration by increasing the GPA or TCH until it no longer penetrates. Offsetting the FAC to achieve a lower DA (and therefore a shorter VGS) may also be an option to eliminate the penetration. Penetrations caused by airport lighting, airport signage, and their associated equipment may be disregarded when installed in accordance with FAA (or military) standards.

Once the VGS is clear, refer to table 2-6-1 to determine the highest CAT that may be authorized based on the required GPA to clear the penetration.

b. Length.

(1) The VGS begins at the LTP and extends to the DA point (highest DA). See figure 2-6-5.

(2) For approaches to a heliport, the VGS begins at the center of the touchdown and lift-off area (TLOF) and extends to the DA point (highest DA).

Note: For VGS purposes, the DA point must be calculated using primary altimeter minimums only.

c. Width.

(1) The beginning width is 100 feet each side of the runway edge. It expands towards the DA point. Calculate the beginning half-width ("k") by applying formula 2-6-6. Calculate the half-width at the DA point using formula 2-6-7. Apply formula 2-6-8 to calculate the half-width for any other distance from LTP.

(2) For approaches to a heliport, the beginning width is the width of the safety area, or the diameter of the safety area for a circular final approach and takeoff area (FATO).

Formula 2-6-6. VGS Half-Width at Origin for Approach to a Runway

$$k = \frac{runway\ width}{2} + 100$$

Formula 2-6-7. VGS Half-Width at DA Point

$$E = 0.036 \times d + 392.8$$

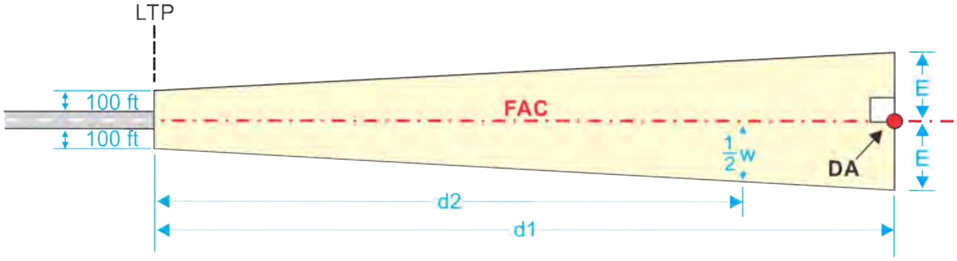
Where:
d = distance (feet) from LTP or center of TLOF to DA point

Formula 2-6-8. VGS Half-Width at Specified Distance

$$\frac{1}{2}w = \left(\frac{E - k}{d1} \times d2\right) + k$$

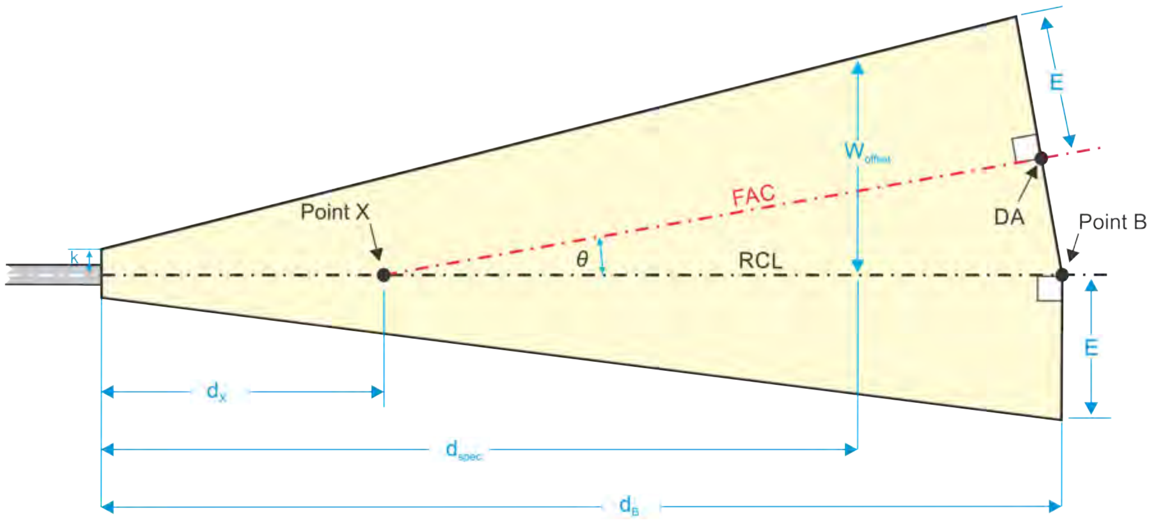
Where:
E = VGS half-width at DA point (feet) (see formula 2-6-7)
k = VGS half-width at origin (feet) (see formula 2-6-6 for approach to a runway, or paragraph 2-6-6c(2) for approach to a heliport)
$d1$ = Distance (feet) from LTP (or center of TLOF) to DA point
$d2$ = Specified distance (feet) from LTP (or center of TLOF) as measured along RCL (or final approach course for approach to a heliport)

Figure 2-6-5. VGS Area



d. Offset area. Expand the VGS area when the FAC is offset from the RCL by more than three degrees. The area at the DA point extends perpendicularly from the FAC on the side of the offset for distance "E" (see formula 2-6-7). On the side closest to the RCL, the area extends perpendicularly to the FAC until intersecting the RCL. It then extends perpendicularly to the RCL for distance "E" (see figure 2-6-6). Apply formula 2-6-9 to determine the offset side width from RCL for a specified distance from LTP.

Figure 2-6-6. Offset VGS Area Construction



Formula 2-6-9. VGS Offset Side Width at Specified Distance

$$W_{Offset} = d_{spec} \times \left(\frac{\cos(\theta) \times [\sin(\theta) \times (d_B - d_X) + E] - k}{d_B - \sin(\theta) \times [\sin(\theta) \times (d_B - d_X) + E]} \right) + k$$

Where:
d_{spec} = Specified distance (feet) from LTP as measured along RCL
θ = FAC offset in degrees
d_B = Distance (feet) from LTP to point B
d_X = Distance (feet) from LTP to intersection of RCL and FAC (point X)
E = VGS half-width at DA point (feet) (see formula 2-6-7)
k = VGS half-width at origin (feet) (see formula 2-6-6)

e. VGS Slope Origin. The VGS slope origin and starting elevation is based on TCH (see figure 2-6-7). For helicopter procedures, the starting elevation will be the TLOF elevation.

(1) Where the TCH is greater than 50 feet, the slope origin is the beginning of the VGS area. Starting elevation is V_{Offset} above THRe. Calculate V_{Offset} by applying formula 2-6-10.

(2) Where the TCH is at least 40 feet but not more than 50 feet, the slope origin is the beginning of the VGS area. Starting elevation is THRe.

(3) Where the TCH is less than 40 feet, the slope origin is X_{Offset} distance from the beginning of the VGS area. Calculate X_{Offset} by applying formula 2-6-11. The VGS area within X_{Offset} distance is a level surface equal to THRe which must be clear of obstacles (see exceptions in paragraph 2-6-6.a).

Formula 2-6-10. V_{Offset} Height for TCH Greater Than 50 Feet

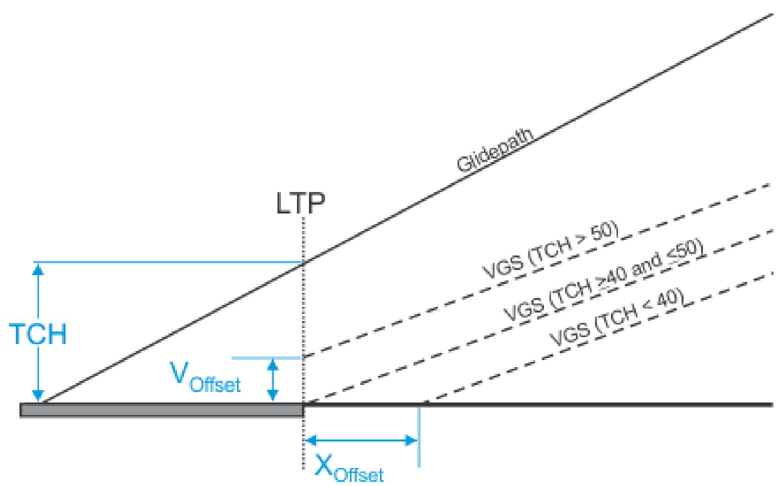
$$V_{Offset} = TCH - 50$$

Formula 2-6-11. X_{Offset} Distance for TCH Less than 40 Feet

$$X_{Offset} = \frac{40 - TCH}{tan\,(\theta)}$$

Where:
θ = GPA

Figure 2-6-7. VGS Slope Origin



f. VGS slope elevation. The VGS slope is based on 2/3 x GPA. Apply formula 2-6-12 to determine the VGS elevation.

Formula 2-6-12. VGS Elevation

$$VGS_{Elev} = tan\left(\theta \times \frac{2}{3}\right) \times \left(d - X_{Offset}\right) + THRe + V_{Offset}$$

Where:
θ = GPA
d = Distance (feet) from LTP
X_{Offset} = formula 2-6-11 result for TCH less than 40 feet, else 0.
V_{Offset} = formula 2-6-10 result for TCH greater than 50, else 0.

Example:

$$\mathrm{VGS_{Elev}} = \tan\left(3.1 \times \frac{2}{3}\right) \times (4991.01 - 0) + 1125.4 + 5$$

$$\mathrm{VGS_{Elev}} \approx 1310.5$$

Section 2-7. Circling Approach and Sidestep Maneuvers

2-7-1. Circling Approach Area. Where circling is authorized, evaluate the circling approach OEA for each CAT published on the procedure. The CMDA is based on the results of the circling approach OEA evaluation and the evaluation of the final segment OEA (also see paragraph 3-2-1.g).

a. Obstacle evaluation area.

(1) The OEA for each CAT is based on true airspeed (V_{KTAS}). The minimum altitude used for true airspeed conversion is 1000 feet above airport elevation. Use formula 2-7-1 to convert indicated airspeed (V_{KIAS}) to true airspeed (V_{KTAS}).

Formula 2-7-1. True Airspeed

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

Where:
V_{KIAS} = Indicated airspeed (see table 2-7-1)
alt = Airport elevation (MSL)
k = Height above airport (minimum 1000 feet)

(2) Calculate the circling approach radius (CAR) based on true airspeed, bank angle, and straight segment using formula 2-7-2. The minimum CAR is 1.30 NM.

Formula 2-7-2. Circling Approach Radius

$$CAR = 2 \times \frac{(V_{KTAS} + 25)^2}{\tan\left(bank_{angle}\right) \times 68625.4} + S$$

Where:
V_{KTAS} = True airspeed from formula 2-7-1
$bank_{angle}$ = Bank angle (see table 2-7-1)
S = Straight segment length in NM (see table 2-7-1)

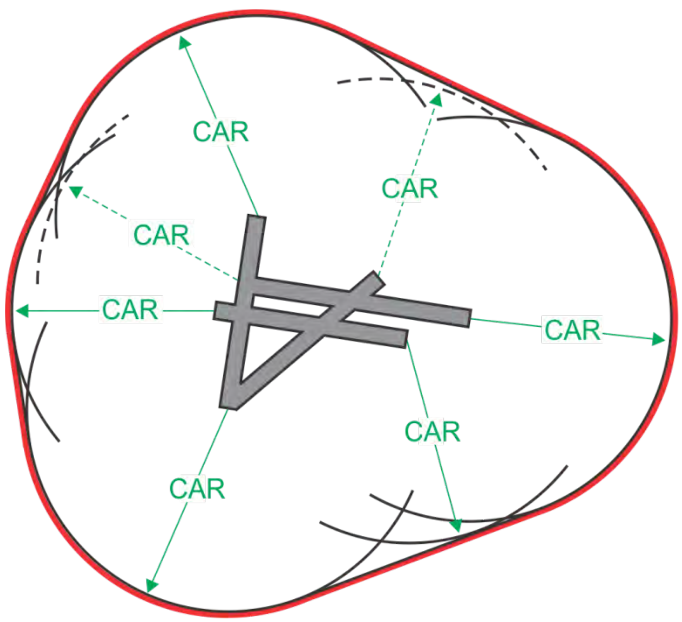
Table 2-7-1. Circling Approach Area Parameters

CAT	V_{KIAS}	$Bank_{angle}$	Straight Segment Length (S)
A	90	25	0.4
B	120	25	0.4
C	140	20	0.5
D	165	20	0.6
E	200	22	0.7

(3) Construct the OEA by drawing arcs equal to the CAR for each CAT from the LTP of each runway to which circling will be authorized. However, when only one end of the runway

is not authorized for circling, the OEA is based on the CAR from both LTPs. Join the outermost arcs with tangential lines. The resulting enclosed area is the circling OEA [(no secondary area) see figure 2-7-1].

Figure 2-7-1. Construction of Circling Approach OEA



b. Obstacle clearance. The minimum ROC in the circling approach OEA is 300 feet. Adjustments must be applied as specified in paragraph 3-2-2.c.

c. Circling minimum descent altitude. Paragraph 3-2-1.g applies. Where the CMDA results in a height above airport (HAA) greater than 1000 feet, recalculate V_{KTAS} by increasing the “k” value within formula 2-7-1 to equal the actual HAA, then recalculate the CAR using formula 2-7-2 and re-evaluate the OEA. If the resulting HAA value increases, recalculate and re-evaluate using the higher value.

Example:

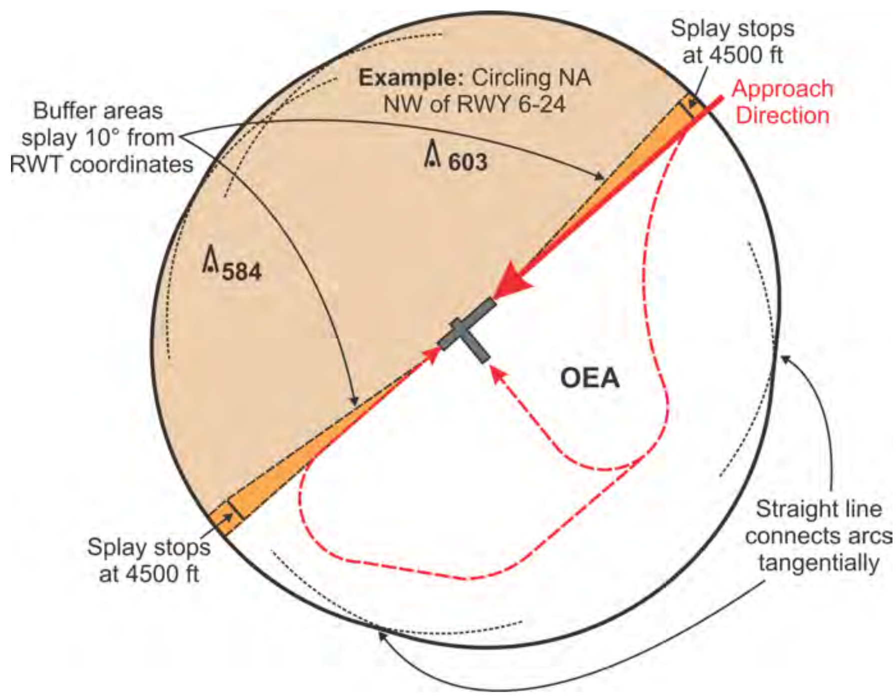
<u>Given</u>
CAT A controlling obstacle: 623 feet
Airport Elevation: 600 feet

<u>Determine CMDA</u>
CMDA based on ROC = 623 feet + 300 feet = 923 feet (rounds to 940)
CMDA based on minimum HAA for CAT A = 600 feet + 350 feet = 950 feet (rounds to 960)
Published CMDA = 960 feet

2-7-2. Restricted Circling Area. The circling OEA may be modified to gain relief from obstacles by establishing a restricted area. This option is only authorized where the restriction can clearly be described as a portion of the airspace where circling is not authorized and the chart is properly annotated. The OEA excludes the restricted area except the portion defined by a line originating at the LTP of each runway used to define the area splaying 10 degrees relative to RCL towards the restricted area. Discontinue the splay when it reaches 4500 feet in width from RCL extended (see figure 2-7-2).

a. Simple restricted area. Establish the restricted area as the right or left half of the OEA relative to RCL(s) extended to the CAR boundary. The chart annotation must include the runway identification number (both ends) and the area's cardinal or intercardinal magnetic direction from RCL [(as in, N, NE, E, SE, S, SW, W, or NW) see figure 2-7-2 and Order 8260.19, chapter 8].

Figure 2-7-2. Simple Restricted Circling Area, Straight-in Aligned Approach



b. Complex restricted area. Establish the restricted area as a single contiguous sector bounded by the extended centerlines of intersecting runways, continued outward to the OEA boundary, and truncated (see figure 2-7-3 through figure 2-7-6) or expanded (see figure 2-7-7) by a direct line from each LTP. The chart annotation must include the runway identification numbers and the area's general magnetic or intercardinal magnetic direction from each identified runway (see also Order 8260.19, chapter 8).

Figure 2-7-3. Complex Restricted Circling Area, Straight-in Aligned Approach (<180 Degrees)

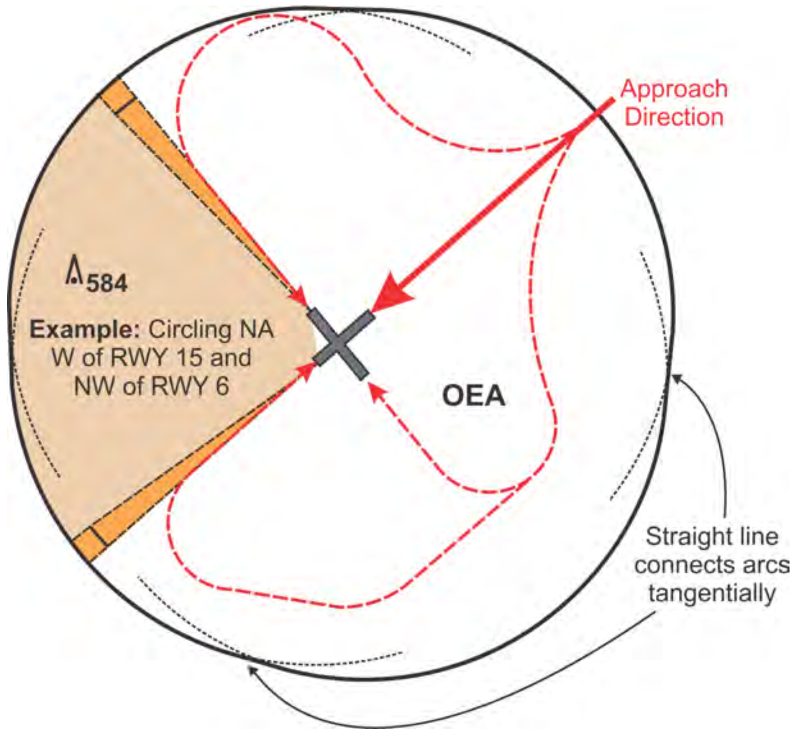


Figure 2-7-4. Complex Restricted Circling Area, Circling Aligned Approach (<180 Degrees)

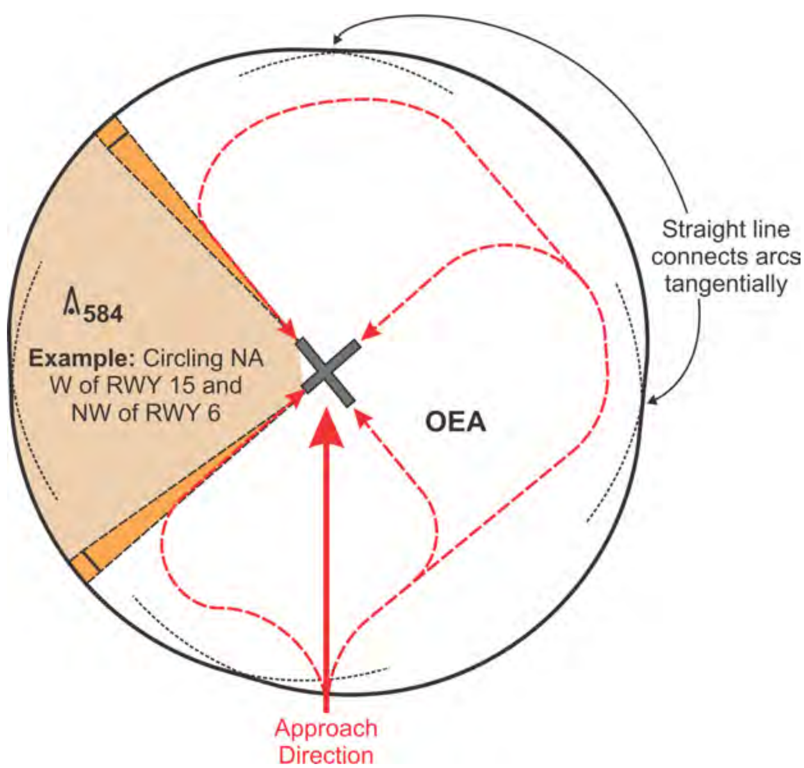


Figure 2-7-5. Complex Restricted Circling Area, Straight-in Aligned Approach (<180 Degrees, Intersecting Runways)

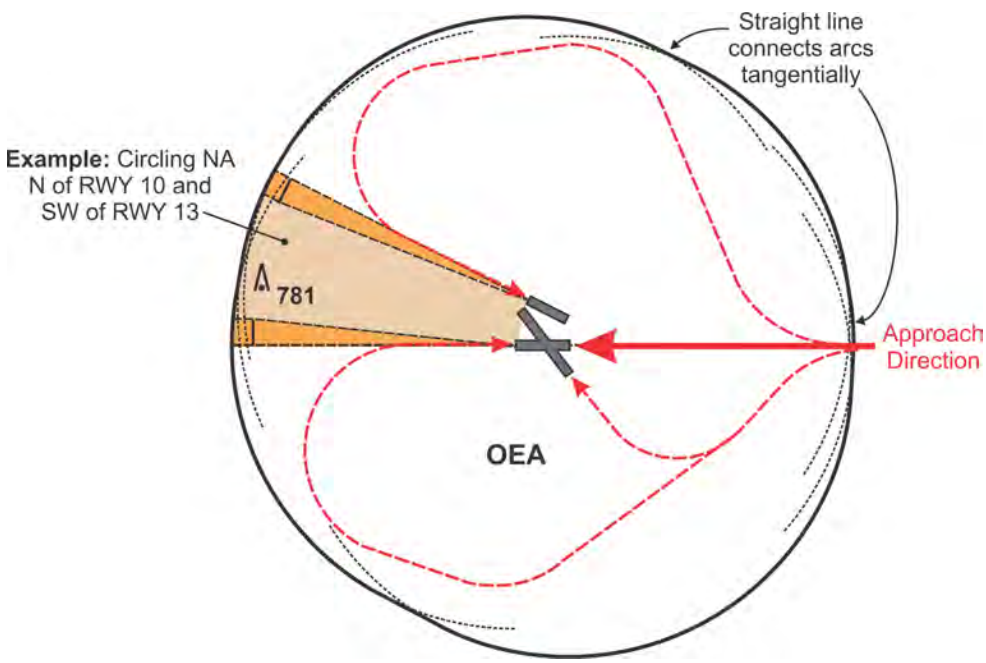


Figure 2-7-6. Complex Restricted Circling Area, Straight-in Aligned Approach (<180 Degrees, Parallel Runways)

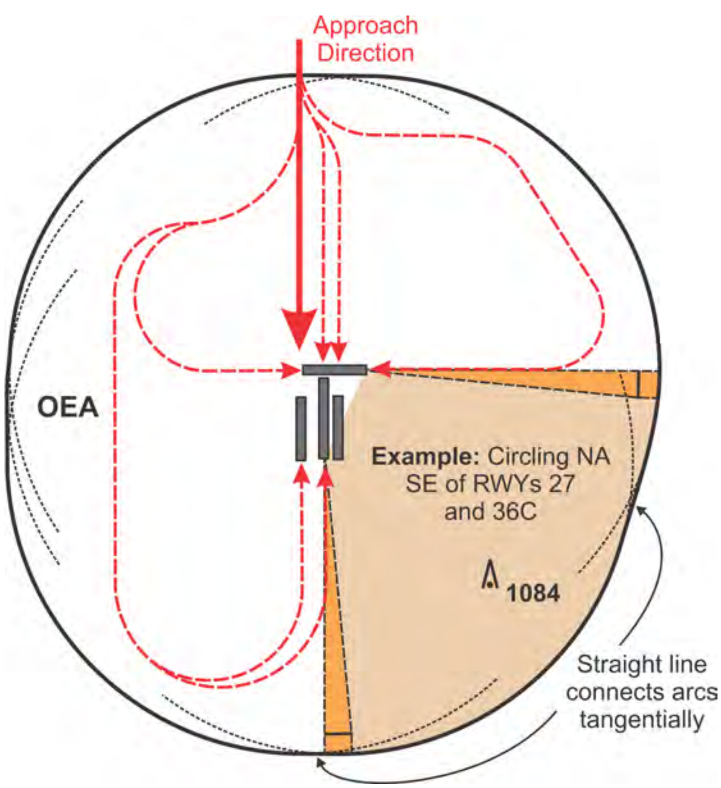
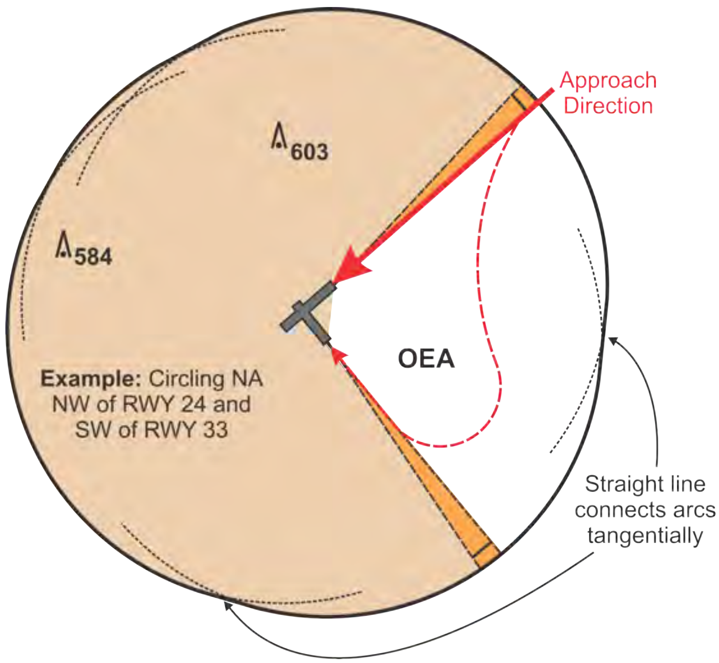


Figure 2-7-7. Complex Restricted Circling Area, Expanded Restricted Area, Straight-in Aligned Approach



2-7-3. Sidestep Maneuvers. A sidestep maneuver is a visual alignment maneuver, required by a pilot executing a straight-in approach to one runway, and cleared to land on a parallel runway. The following conditions must exist:

a. RCLs are separated by 1200 feet or less.

b. Only one final approach course is published.

c. The final approach course is aligned within three degrees of the RCL of the primary runway.

d. The procedure is identified in accordance with section 1-6.

e. Establish a nonprecision final approach area (using the same navigational guidance as is used on the primary approach) to the sidestep runway extending from the runway threshold to a point abeam the beginning of the primary runway's nonprecision final approach area. The area is longitudinally centered on the sidestep runway's extended centerline.

(1) The width of the localizer or SDF final approach area is as specified in chapter 8 (chapter 9 for SDF).

(2) For all other conventional final approach areas; where the approach facility is on the airport, base the width of the sidestep final approach area as if the navigation facility were located on the sidestep threshold. Where the facility is off airport, assume the facility is located abeam the beginning of the primary runway's nonprecision final approach area.

(3) For RNAV final approach areas, the width is as specified in the applicable chapter of Order 8260.58. Evaluate both LP and LNAV final approach areas when the procedure contains both lines of minimums. The higher minimums apply for the sidestep maneuver.

f. Utilize the same nonprecision obstacle clearance used for the primary runway to determine the published MDA for the sidestep maneuver. Include adjustments for RASS when determining the sidestep MDA; do not apply adjustments for precipitous terrain and excessive length of final (see paragraphs 3-2-2.b and 3-2-2.c). Publish a single MDA to the sidestep runway. The published MDA must not be less than the highest MDA and/or DA for the approach and must provide obstacle clearance throughout the entire sidestep final approach area(s). When a stepdown fix is incorporated into the procedure, the sidestep MDA must only provide obstruction clearance between the last stepdown fix and the sidestep threshold. All stepdown fixes must provide appropriate obstruction clearance within the sidestep final approach area.

g. Calculate the descent angle from the approach PFAF directly to the TCH of the sidestep runway's VGSI. When a VGSI is not installed on the sidestep runway, use an appropriate TCH from table 10-1-1. Calculate descent angles from stepdown fixes as measured along the sidestep runway's extended centerline to the sidestep LTP. The sidestep procedure must not be authorized if any angle exceeds the maximum values within table 2-6-1. Minimum angles do not apply to sidestep maneuvers.

h. See chapter 3 to establish published visibility.

Section 2-8. Missed Approach

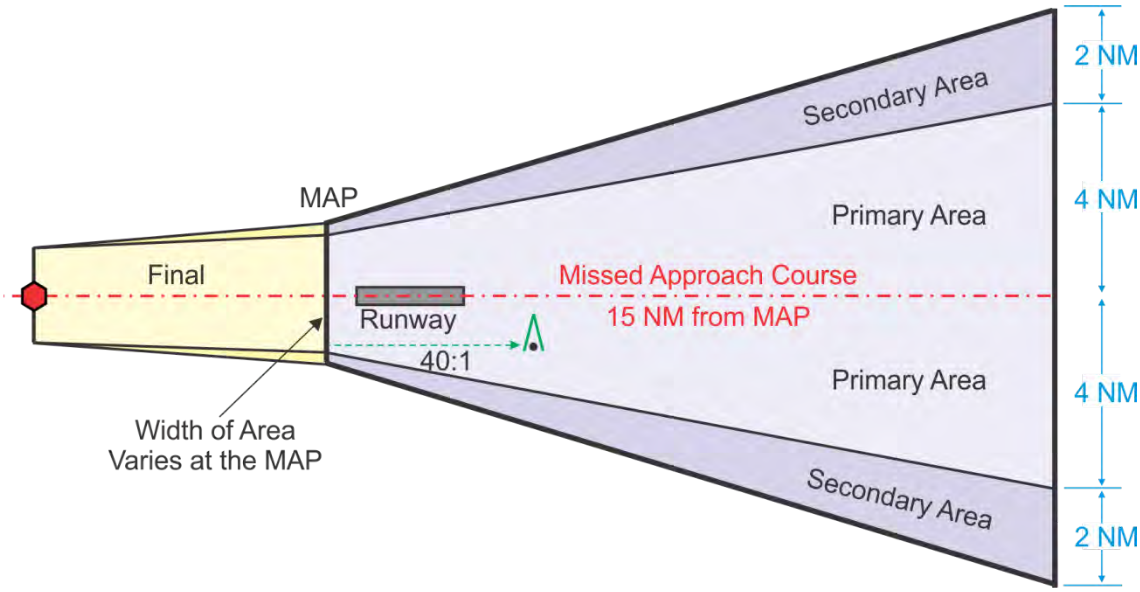
2-8-1. Missed Approach Segment. A missed approach procedure must be established for each instrument approach procedure. The missed approach begins at the DA for PA/APV procedures, and the MAP for NPA procedures. The missed approach procedure must be simple, specify a charted missed approach altitude (altitude at clearance limit), and a clearance limit fix/facility. When required by obstacles or deemed operationally advantageous, the missed approach may also specify an interim "climb-to" altitude to identify a turn point. Any other interim altitude restriction is not permitted. The charted missed approach altitude must not be lower than the highest DA/MDA (including adjustments) and be sufficient to permit holding or en route flight. Design alternate missed approach procedures using the criteria in this section. The area considered for obstacles has a width equal to that of the final approach area at the MAP or DA point and expands uniformly to the width of the initial approach segment at a point 15 NM from the MAP (as measured along flight path). When PCG is available, a secondary area for the reduction of obstacle clearance is identified within the missed approach area. It has the same width as the final approach secondary area at the MAP and expands uniformly to a width of 2 NM at a point 15 NM from the MAP (see figure 2-8-1). Where PCG is not available beyond this point, expansion of the area continues until PCG is achieved or the segment terminates. Where PCG is available beyond this point, the area tapers at a rate of 30 degrees inward relative to the course until it reaches initial segment width.

2-8-2. Missed Approach Alignment. Wherever practical, the missed approach course should be a continuation of the FAC. Turns are permitted, but should be minimized in the interest of safety and simplicity.

2-8-3. MAP. The MAP specified in the procedure may be the point of intersection of a specific glidepath with a DA, a navigation facility, a fix, or a specified distance from the PFAF. A specified distance may not be more than the distance from the PFAF to the usable landing surface. The MAP must not be located prior to a VDP. Specific criteria for the MAP are contained in the appropriate chapters.

2-8-4. Straight Missed Approach Area. When the missed approach course is within 15 degrees of the final approach course, it is considered a straight missed approach (see figure 2-8-1). The area considered for obstacle evaluation is specified in paragraph 2-8-1.

Figure 2-8-1. Straight Missed Approach Area



2-8-5. Straight Missed Approach Obstacle Clearance. Within the primary missed approach area, no obstacle may penetrate the missed approach surface. This surface begins over the MAP at a height determined by subtracting the required final approach ROC and any adjustments to minimums, per paragraph 3-2-2 from the MDA. It rises uniformly at a rate of one-foot vertically for each 40-foot horizontally (40:1) (see figure 2-8-2). Where the 40:1 surface reaches a height of 1000 feet below the missed approach altitude (see paragraph 2-8-1), further application of the surface is not required. In the secondary area, no obstacle may penetrate a 12:1 slope that extends outward and upward from the 40:1 surface at the inner boundaries of the secondary area (see figure 2-8-3). Evaluate the missed approach segment to ensure obstacle clearance is provided.

a. Evaluate the 40:1 surface from the MAP to the clearance limit (end of the missed approach segment). The height of the missed approach surface over an obstacle is determined by measuring the straight-line distance from the obstacle to the nearest point on the line defining the origin of the 40:1 surface. If obstacles penetrate the surface, take action to eliminate the penetration; for example, increase the MDA, adjust the MAP location, etc.

b. The preliminary charted missed approach altitude is the highest of the minimum missed approach obstruction altitude, minimum holding altitude (MHA) established in accordance with paragraph 16-9-5, or the lowest airway MEA at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identify the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in the secondary area. Then add the appropriate ROC (plus adjustments) for holding or en route to the highest obstacle elevation. If the resultant altitude is not in a 100-foot increment, then round upward to the next 100-foot value.

c. Determine if a climbing in holding pattern (climb-in-hold) evaluation is required (see section 16-7). If a climb in holding is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation of the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. Compute the 40:1 rise from a point on the line defining the origin of the 40:1 surface in the shortest distance and perpendicular to the end-of-segment line at the clearance limit.

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb-in-hold evaluation is not required.

(b) If the computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. Section 16-7 specifies higher speed groups; therefore, larger template sizes, are usually necessary for the climb-in-hold evaluation. These templates may require an increase to the MHA under paragraph 16-2-4. If this evaluation requires an increase to the MHA, evaluate the new altitude using the higher speed group specified in section 16-7. This sequence of review must be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

(4) The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under paragraph 2-8-5.c(3).

Figure 2-8-2. Straight Missed Approach Obstacle Clearance

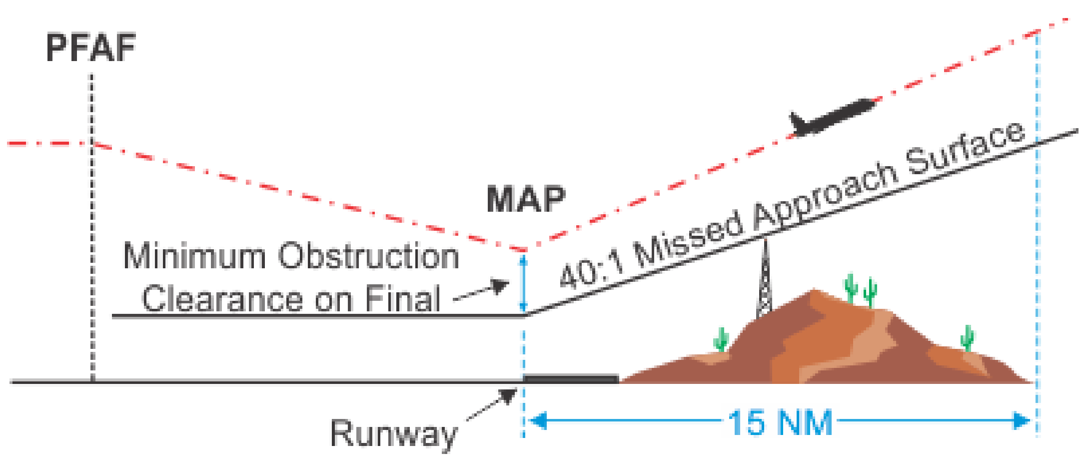
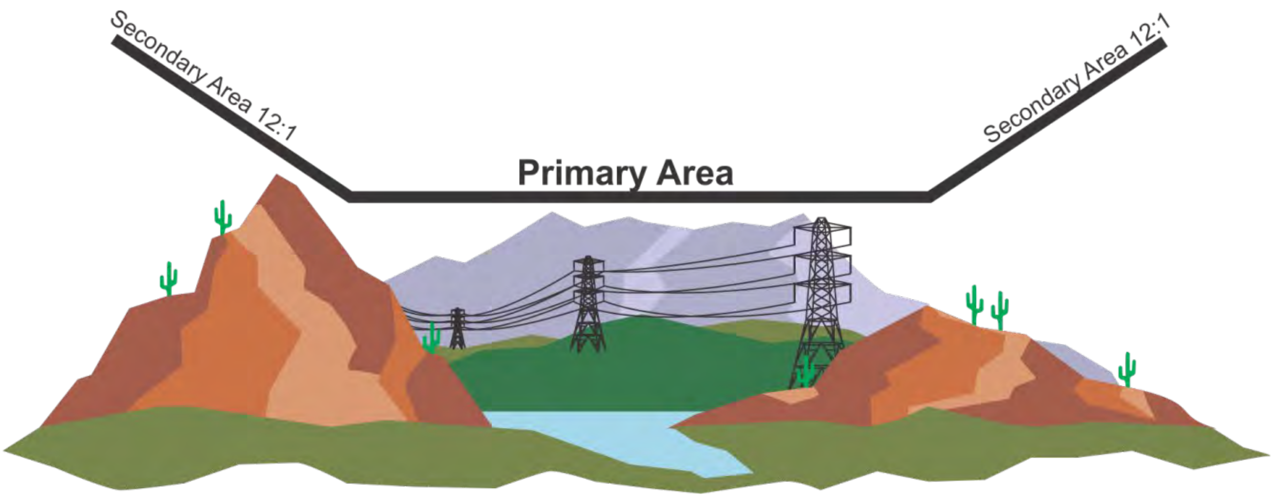


Figure 2-8-3. Missed Approach Cross Section



2-8-6. Turning Missed Approach Area. If a turn of more than 15 degrees from the FAC is required, a turning or combination straight and turning missed approach area must be constructed. If the HAT or HAA value associated with the DA/MDA/CMDA is less than 400 feet, construct a combination straight and turning missed approach (see paragraph 2-8-8). The minimum turn altitude is 400 feet above touchdown zone elevation (TDZE)/airport elevation, rounded to the nearest foot increment.

a. The dimensions and shape of this area are affected by three variables:

(1) Width of final approach area at the MAP.

(2) Approach categories of aircraft authorized to use the procedure.

Note: Turning areas must be constructed for each CAT. Plotting only the highest CAT will not assure proper OEA protection for lower CATs.

(3) Number of degrees of turn required by the procedure.

b. Secondary areas for the reduction of obstacle clearance are permitted when PCG is provided. The secondary area begins where a line perpendicular to the straight flight path, originating at the point of completion of the turn, intersects the outer boundaries of the missed approach segment. The width of the secondary area expands uniformly from zero to 2 NM at the 15 NM point (measured along flight path).

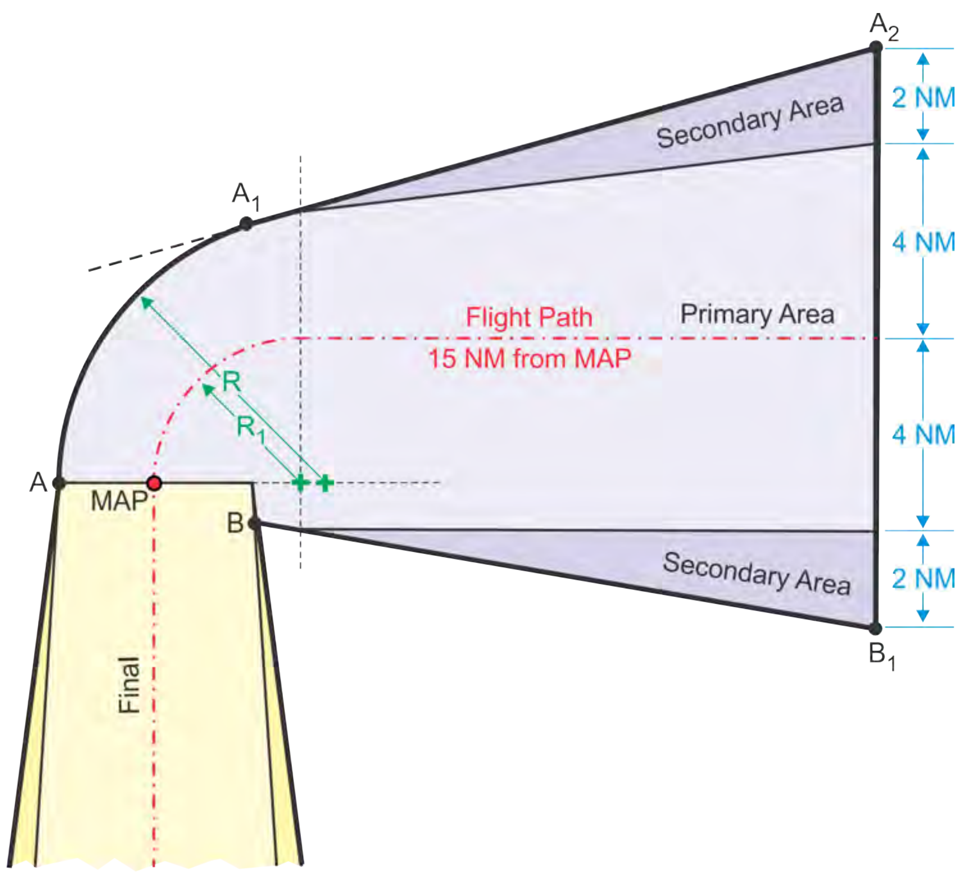
c. Primary areas. Figure 2-8-4 through figure 2-8-9 show the manner of construction of some typical turning missed approach areas. The radii specified in table 2-8-1 are used in the construction of these areas:

Table 2-8-1. Turning Missed Approach Radii (NM)

CAT	Obstacle Clearance Radius (R)	Flight Path Radius (R_1)
A	2.6	1.30
B	2.8	1.40
C	3.0	1.50
D	3.5	1.75
E	5.0	2.50

(1) 90-degree turn or less, narrow final approach area at MAP (see figure 2-8-4). To construct the area:

Figure 2-8-4. Turning Missed Approach Area, 90-Degree Turn or Less, Narrow Final Approach Area at MAP



(a) Draw an arc with the radius (R_1) from the MAP. This line is then extended outward to a point 15 NM from the MAP, measured along the line. This is the assumed flight path (see table 2-8-1).

(b) Establish points "A_2" and "B_1" measuring 6 NM perpendicular to the flight path at the 15 NM point.

(c) Connect "A_2" and "B_1" with a straight line.

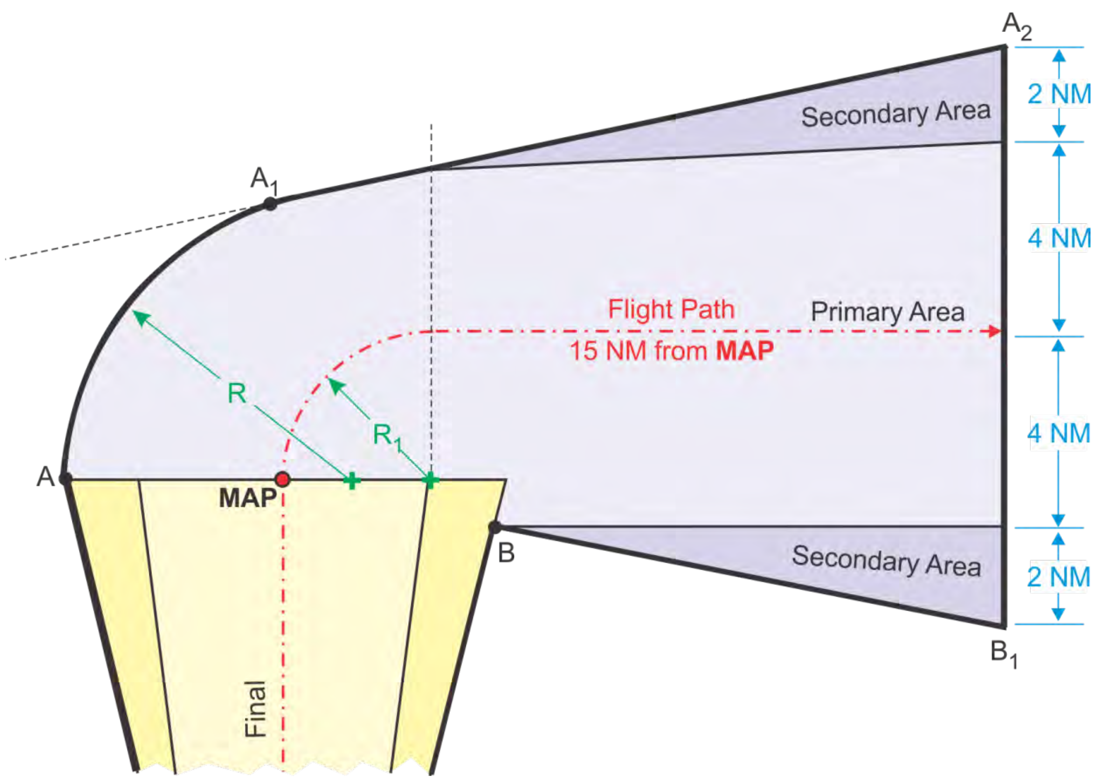
(d) Draw an arc with the radius (R) from point "A" to "A_1." This is the edge of the obstacle clearance area.

(e) Establish point "B" by measuring backward on the edge of the final approach area a distance of 1 NM or a distance equal to the fix error prior to the PFAF, whichever is greater.

(f) Connect point "A_1" with point "A_2," and connect point "B" with point "B_1" using straight lines.

(2) 90-degree turn or less, wide final approach area at MAP (see figure 2-8-5). To construct the area:

Figure 2-8-5. Turning Missed Approach Area, 90-Degree Turn or Less, Wide Final Approach Area at MAP



(a) Draw an arc with the appropriate radius (R_1) from the MAP. This line is then extended outward to a point 15 NM from the MAP, measured along the line. This is the assumed flight path.

(b) Establish points "A_2" and "B_1" by measuring 6 NM perpendicular to the flight path at the 15 NM point.

(c) Connect points "A_2" and "B_1" with a straight line.

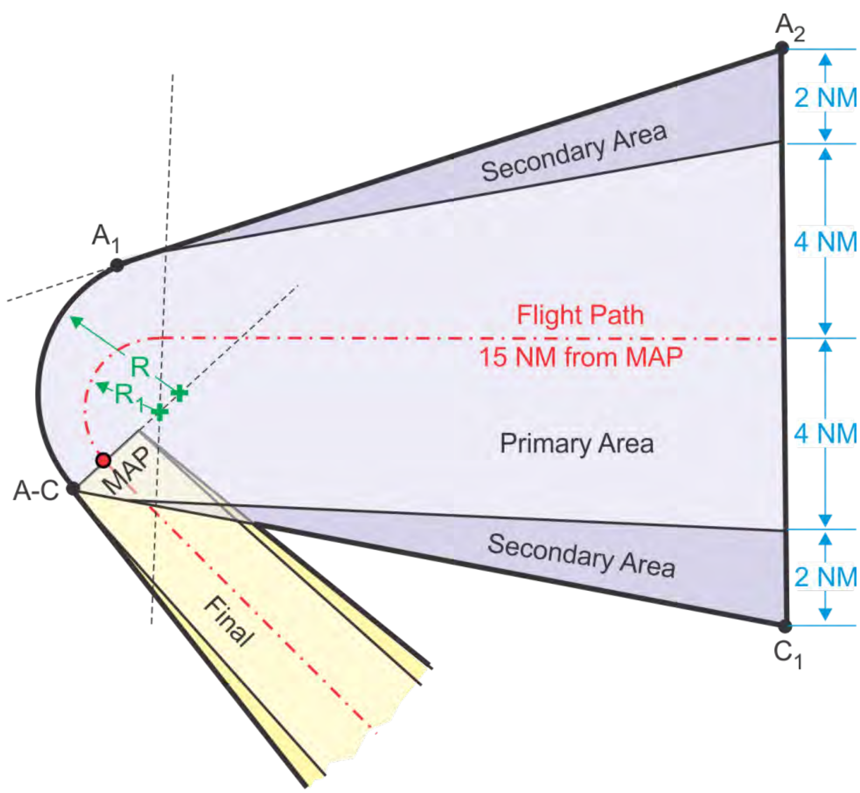
(d) Draw an arc with the appropriate radius (R) from point "A" to point "A_1." This is the edge of the obstacle clearance area.

(e) Establish point "B" by measuring backward on the edge of the final approach area a distance of 1 NM or a distance equal to the fix error prior to the PFAF, whichever is greater.

(f) Connect point "A_1" with point "A_2," and connect point "B" with point "B_1" using straight lines.

(3) More than 90-degree turn, narrow final approach area at MAP (see figure 2-8-6). To construct the area:

Figure 2-8-6. Turning Missed Approach Area, More Than 90-Degree Turn, Narrow Final Approach Area at MAP



(a) Draw an arc with the radius (R_1) from the MAP through the required number of degrees and then continue outward to a point 15 NM from the MAP, measured along this line, which is the assumed flight path.

(b) Establish points "A_2" and "C_1" by measuring 6 NM on each side of the assumed flight path and perpendicular to it at the 15-NM point.

(c) Connect points “A_2” and “C_1” with a straight line.

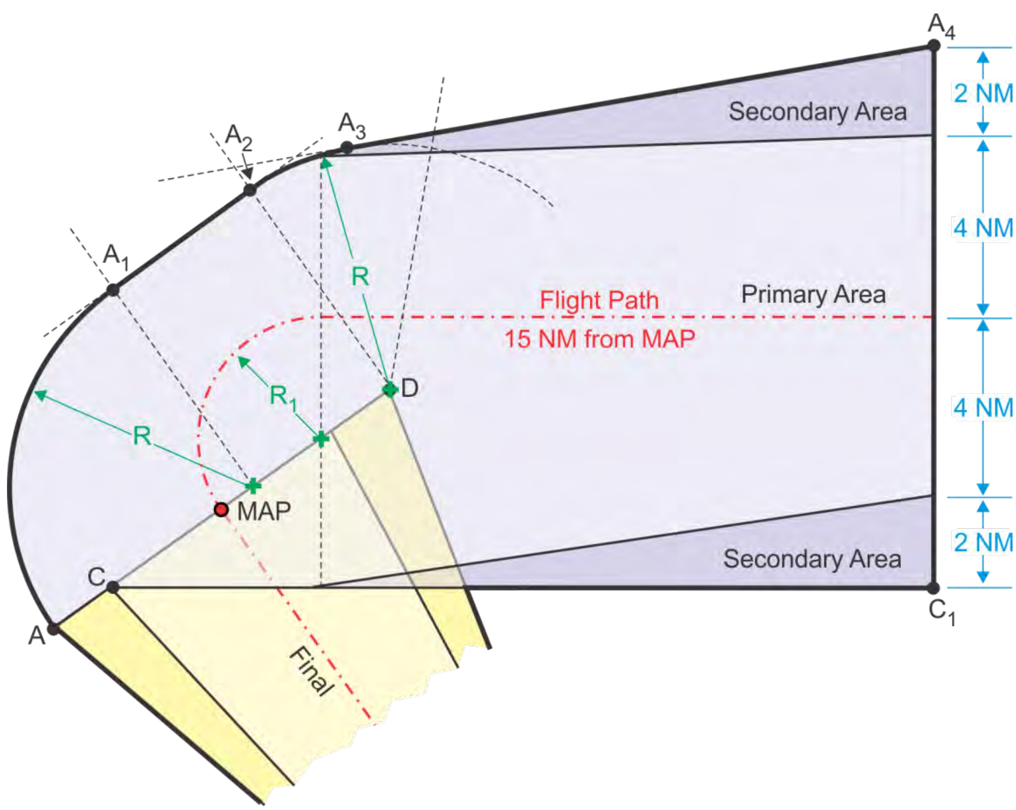
(d) Draw an arc with the radius (R) from point “A” to point “A_1” (figure 2-8-6 uses 135 degrees). This is the outer edge of the obstacle clearance area.

(e) Locate point “C” at the inner edge of the final approach secondary area opposite the MAP. Point “A” and point “C” will be coincident when the MAP is the facility.

(f) Connect point “A_1” with point “A_2” and connect point “C” with “C_1” using straight lines.

(4) More than 90-degree turn, wide final approach area at MAP (see figure 2-8-7). To construct the area:

Figure 2-8-7. Turning Missed Approach Area, More Than 90 Degree Turn, Wide Final Approach Area at MAP



(a) Draw the assumed flight path arc with the radius (R_1) from the MAP the required number of degrees to the desired flight path or course.

(b) Establish points “A_4” and “C_1” by measuring 6 NM on each side of the assumed flight path and perpendicular to it at the 15-NM point.

(c) Connect points “A_4” and “C_1” with a straight line.

(d) Draw a 90-degree arc with the appropriate radius (R) from point "A" to "A_1." Note that when the width of the final approach area at the MAP is greater than the appropriate radius (R), the turn is made in two increments when constructing the obstacle clearance area.

(e) Draw an arc with the radius (R) from point "D" (edge of final approach secondary area opposite MAP) the required number of degrees from point "A_2" to point "A_3." Compute the number of degrees by subtracting 90 degrees from the total turn magnitude.

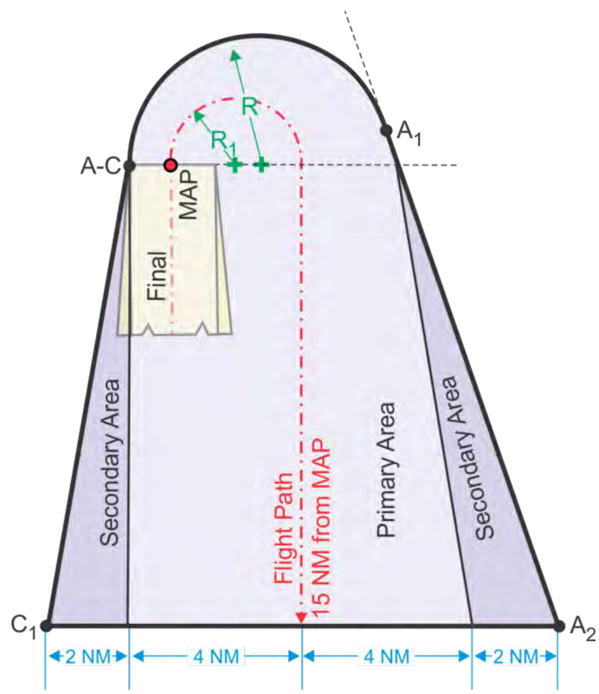
(f) Connect points "A_1" and "A_2" with a straight line.

(g) Locate point "C" at the inner edge of the final approach secondary area opposite the MAP.

(h) Connect point "A_3" with point "A_4" and connect point "C" with point "C_1" using straight lines.

(5) 180-degree turn, narrow final approach area at MAP (see figure 2-8-8). To construct the area:

Figure 2-8-8. Turning Missed Approach Area, 180-Degree Turn, Narrow Final Approach Area at MAP



(a) Draw an arc with the radius (R_1) from the MAP through 180 degrees, and then continue outward to a point 15 NM from the MAP, measured along this line, which is the assumed flight path.

(b) Establish points "A_2" and "C_1" by measuring 6 NM on each side of the assumed flight path, and perpendicular to it at the 15 NM point.

(c) Connect points "A_2" and "C_1" with a straight line.

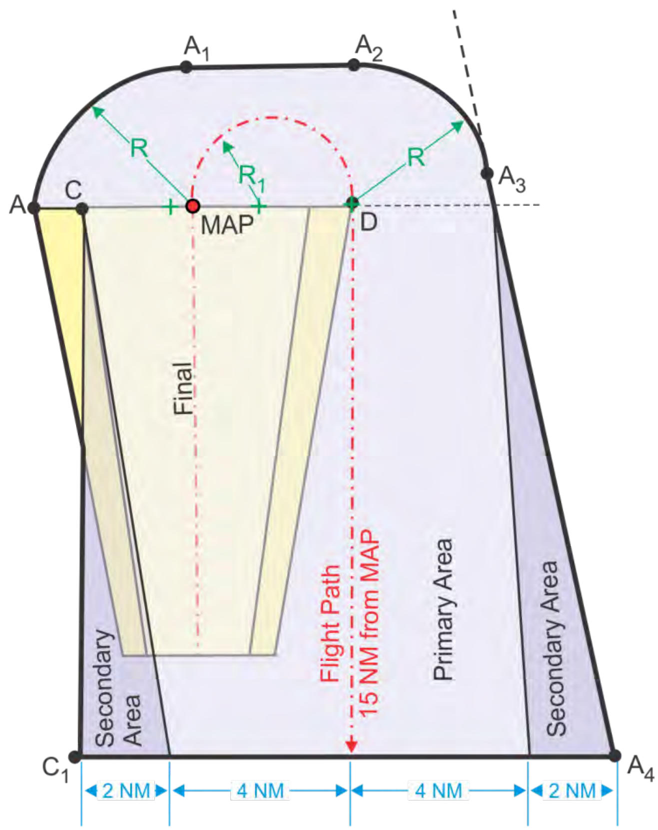
(d) Locate point "C" at the inner edge of the final approach secondary area opposite the MAP. (Point "A" and point "C" will be coincident when the MAP is the facility.)

(e) Draw an arc with the radius (R) from point "A" to point "A_1" (180 degrees). This is the outer edge of the obstacle clearance area.

(f) Connect point "A_1" with point "A_2" and connect point "C" with point "C_1" using straight lines. (The line "A_1-A_2" joins the arc tangentially.)

(6) 180-degree turn, wide final approach area at MAP (see figure 2-8-9). To construct the area:

Figure 2-8-9. Turning Missed Approach Area
180-Degree Turn, Wide Final Approach Area at MAP



(a) Draw the flight path arc with radius (R_1) from the MAP and then continue the line outward to a point 15 NM from the MAP, measured along the assumed flight path.

(b) Establish points “A_4”and “C_1” by measuring 6 NM on each side of the flight path and perpendicular to it at the 15 NM point.

(c) Connect points “A_4” and “C_1” with a straight line.

(d) Draw a 90-degree arc with the appropriate radius (R) from point “A” to point “A_1.” Note that when the width of the final approach area at the MAP is greater than the appropriate radius (R), the turn is made in two increments when constructing the obstacle clearance area.

(e) Draw an arc with the radius (R) from point “D” (edge of final approach secondary area opposite MAP) the required number of degrees from point “A_2” to point “A_3.” Compute the number of degrees by subtracting 90 degrees from the total turn magnitude.

(f) Connect points “A_1” and “A_2,” with a straight line.

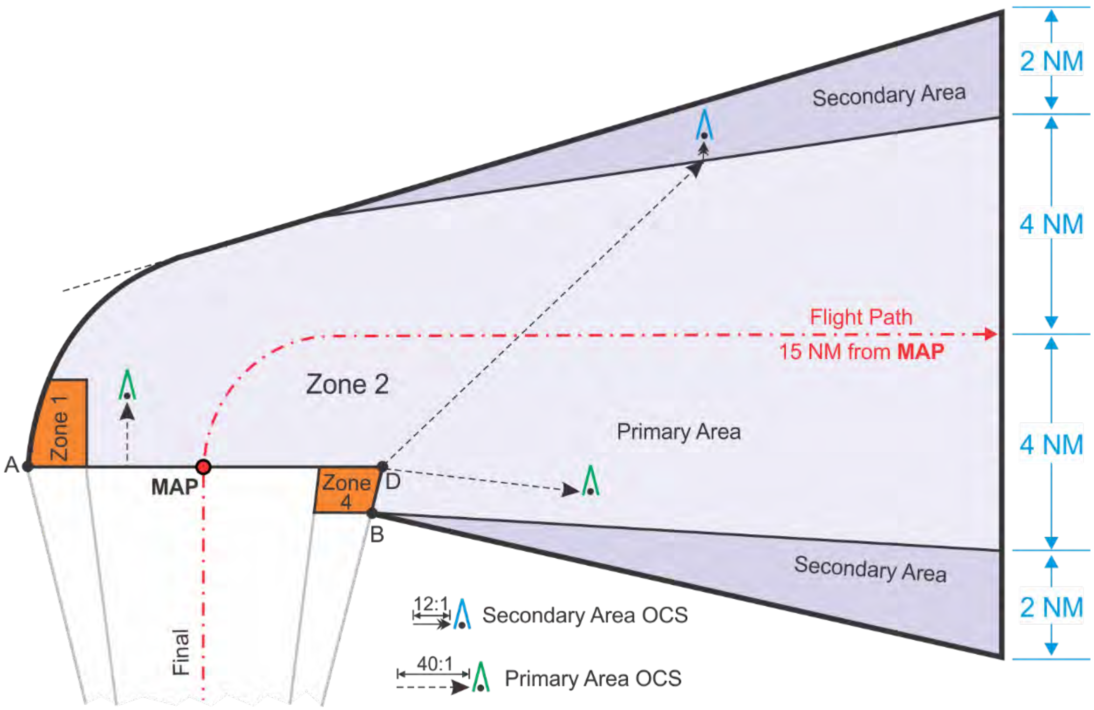
(g) Locate point “C” at the inner edge of the final approach secondary area opposite the MAP.

(h) Connect point “A_3” with point “A_4” and connect point “C” with point “C_1” using straight lines. The line “A_3-A_4” joins the arc tangentially.

2-8-7. Turning Missed Approach Obstacle Clearance. The methods of determining the height of the 40:1 missed approach surface over obstacles in the turning missed approach area varies with the amount of turn involved. Evaluate the missed approach segment to ensure the 40:1 OCS is not penetrated.

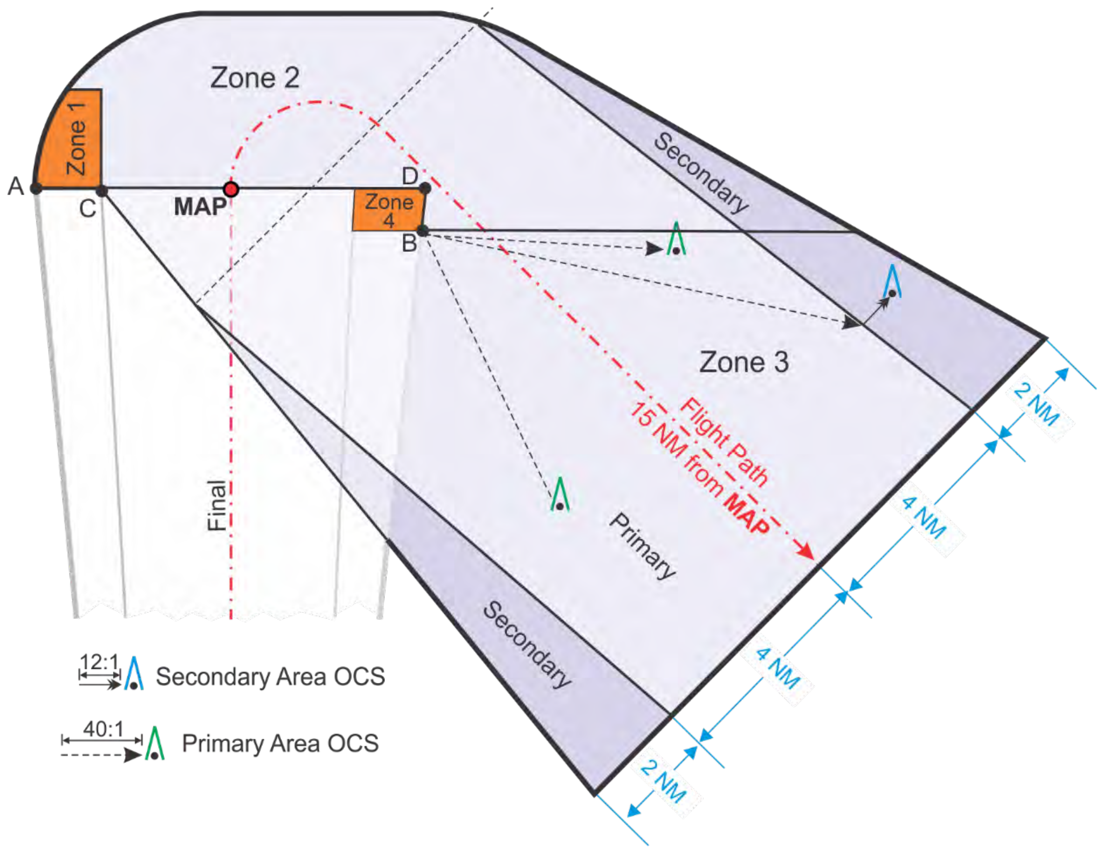
a. 90-degree turn or less (see figure 2-8-10). The height of the missed approach surface over the MAP is the same as specified in paragraph 2-8-5. Zone 1 is a 1.6 NM continuation of the final approach secondary area. The height of the missed approach surface over an obstacle in zone 1 is equal to the height of the missed approach surface over the MAP plus the secondary rise defined for the final approach segment. Zone 2 is the area in which the height of the missed approach surface over an obstacle must be determined. To do this, first identify line “A-D-B.” To protect for the short turning aircraft point “B” is located by measuring backward on the edge of the final approach area a distance of 1 NM or a distance equal to the fix error prior to the PFAF, whichever is greater. Zone 4 is part of the missed approach equivalent to a portion of the final secondary OEA on the side of the turn between point “B” and the MAP. The height of the missed approach surface over an obstacle in zone 4 is equal to the height of the missed approach surface over the MAP. Obstacles in zones 1 and 4 need not be evaluated by zone 2. The height of the missed approach surface over an obstacle in zone 2 is determined by measuring the straight-line distance from the obstacle to the nearest point online “A-D-B” and computing the height based on the 40:1 ratio. When an obstacle is in a secondary area, measure the straight-line distance from the nearest point on the line “A-D-B” to the point on the inner edge of the secondary area which is nearest the obstacle. Compute the height of the missed approach surface at this point, using the 40:1 ratio. Then apply the 12:1 secondary area ratio from the height of the surface for the remaining distance to the obstacle.

Figure 2-8-10. Turning Missed Approach Obstacle Clearance, 90 Degree Turn or Less



b. More than 90-degree turn (see figure 2-8-11). In this case another zone becomes necessary. Zone 3 is defined by extending a line from point "B" to the extremity of the missed approach area perpendicular to the FAC. Zone 3 will encompass all of the missed approach area not specifically within zones 1, 2, and 4. All distance measurements in zone 3 are made from point "B." The height of the missed approach surface over point "B" for zone 3 computations is equal to the height of the MDA less any RASS and precipitous terrain adjustments. The height of the missed approach surface over an obstacle in zone 3 is determined by measuring the distance from the obstacle to point "B" and computing the height based on the 40:1 ratio. For an obstacle in the secondary area, use the same measuring method prescribed in paragraph 2-8-7.a, except that the original measuring point must be point "B."

Figure 2-8-11. Turning Missed Approach Obstacle Clearance, More Than a 90-Degree Turn



c. Secondary area. In the secondary area no obstacles may penetrate a 12:1 slope which extends outward and upward from the 40:1 surface from the inner to the outer boundary lines of the secondary area.

d. Evaluate the missed approach segment from the MAP to the clearance limit. Terminate the 40:1 OCS at an elevation corresponding to the en route ROC below the missed altitude.

(1) If the 40:1 OCS terminates prior to the clearance limit, continue the evaluation using a level obstacle identification surface (OIS) at the height that the 40:1 OCS was terminated.

(2) If the clearance limit is reached before the 40:1 OCS terminates, continue a climb-in-hold evaluation at the clearance limit.

e. The preliminary charted missed approach altitude is the highest of the minimum missed approach obstruction altitude, MHA established in accordance with paragraph 16-2-4, or the lowest airway MEA at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identify the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in the secondary area. Then add the appropriate ROC (plus adjustments) for holding or en route to the highest obstacle elevation. If the resultant altitude is not in a 100-foot increment, then round upward to the next 100-foot value.

f. Determine if a climb-in-hold evaluation is required (see section 16-7). If a climb in holding is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation of the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. Compute the 40:1 rise from a point on the "A-D-B" line in the shortest distance to the end-of-segment line at the clearance limit.

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb-in-hold evaluation is not required.

(b) If the computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. Section 16-7 specifies higher speed groups, and; therefore, larger template sizes are usually necessary for the climb-in-hold evaluation. These templates may require an increase in MHA under paragraph 16-2-4. If this evaluation requires an increase in the MHA, evaluate the new altitude using the higher speed group specified in section 16-7. This sequence of review must be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

g. The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under paragraph 2-8-5.c(3)(b).

2-8-8. Combination Straight and Turning Missed Approach Area. If a straight climb to a specific altitude followed by a turn is necessary to avoid obstacles, a combination straight and turning missed approach area must be constructed. The straight portion of this missed approach area is section 1. The portion in which the turn is made is section 2. Evaluate the missed approach segment to ensure obstacle clearance is provided.

a. Straight portion. Section 1 is a portion of the normal straight missed approach area and is constructed as specified in paragraph 2-8-4. Obstacle clearance is provided as specified in paragraph 2-8-5 except that secondary area reductions do not apply. The length of section 1 is determined as shown in figure 2-8-12 and relates to the need to climb to a specified altitude prior to the turn. Point A_1 marks the end of section 1.

b. Turning portion. Section 2 is constructed as specified in paragraph 2-8-6 except that point "A" is replaced by point "A_1" and unless a fix does not exist at the end of section 1, or if positive course guidance is not provided in section 2, point "B" is replaced by a point 1 NM from the end of section 1 (point "B_1") (see figure 2-8-12). Obstacle clearance requirements in section 2 are the same as those specified in paragraph 2-8-7 with the following exemptions:

(1) Zone 1 is not considered.

(2) The height of the missed approach surface over point "B_1" or "B" for zone 3 computations is equal to the turn altitude less any RASS and precipitous terrain adjustments for final.

(3) Zone 4 may begin at either point "B_1" or "B," if either are found prior to the MAP. The height of zone 4 is equal to the height of the OCS at the end of section 1.

Figure 2-8-12. Combination Missed Approach Area

EXAMPLE:

***Given*:**
1. MDA 360 MSL
2. Obstacle height: 1098 MSL
3. Obstacle in section 2 = 3 NM from near edge of section 1

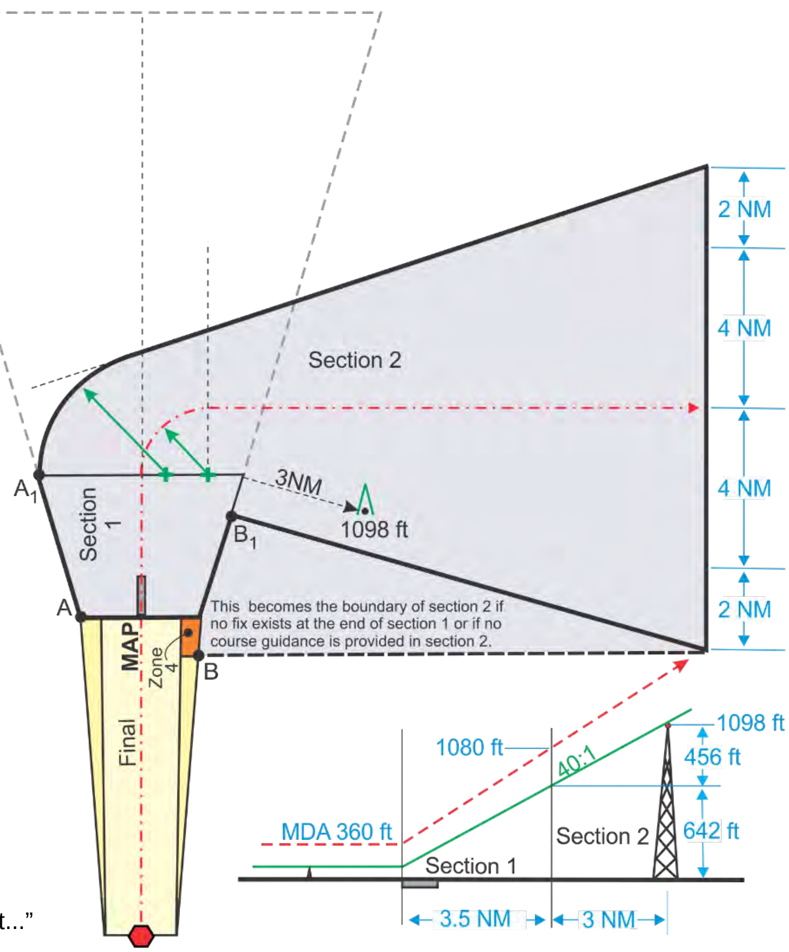
***Determine*:**
1. Section 1 length.
2. Minimum turn altitude.
3. Missed approach instructions.

***Solution*:**

1. Section 1 length.
   a. 3 NM (18228 ft) ÷ 40 = 456 ft.
   b. 1098 MSL – 456 ft = 642 MSL required section 1 end height.
   c. MDA-(ROC+ADJ)= 110 MSL section 1 start height
   d. 642 - 110 = 532 required section 1 rise
   e. 532 ft x 40 = 21280 ft (3.50 NM)

2. Minimum turn altitude.
   a. (21280 ÷ 30.38)+MDA = 1060.5
   b. Round to higher 20-ft increment = 1080 MSL

3. Missed approach instructions.
   a. "Climb to 1080 then right turn direct..."



c. Evaluate the 40:1 surface from the MAP to the clearance limit (end of the missed approach segment). If obstacles penetrate the surface, take action to eliminate the penetration.

d. The preliminary charted missed approach altitude is the highest of the minimum missed approach obstruction altitude, MHA established in accordance with paragraph 16-2-4, or the lowest airway MEA at the clearance limit. To determine the minimum missed approach obstruction altitude for the missed approach segment, identify the highest obstacle in the primary area; or if applicable, the highest equivalent obstacle in the secondary area. Then add the appropriate ROC (plus adjustments) for holding or en route to the highest obstacle elevation. If the resultant altitude is not in a 100-foot increment, then round upward to the next 100-foot value.

e. Determine if a climb-in-hold evaluation is required (see section 16-7). If a climb in holding is intended at the clearance limit, a climb-in-hold evaluation is mandatory.

(1) Calculate the elevation of the 40:1 surface at the end of the segment (clearance limit). The 40:1 surface starts at the same elevation as it does for obstacle evaluations. First, compute the 40:1 rise from a point on the line defining the origin of the 40:1 surface at the MAP, in the shortest distance and perpendicular to the end-of-section 1. If there is a RASS adjustment and the missed approach instructions do not include a parenthetical climb to altitude then the elevation at the end of section 1 is adjusted by subtracting the altitude difference between the RASS adjustments when two remote altimeter sources are used; or subtracting the RASS adjustment for a part-time altimeter source. The resulting altitude at the end of section 1 must not be lower than the 40:1 surface height at the MAP. Second, compute the 40:1 rise from a point on the nearest edge of section 1, in the shortest distance to the end-of-segment line at the clearance limit. Add the two values together and this is the 40:1 surface height at the end of the segment (clearance limit).

(2) Compute the ROC surface elevation at the clearance limit by subtracting the appropriate ROC (plus adjustments) from the preliminary charted missed approach altitude.

(3) Compare the ROC surface elevation at the clearance limit with the 40:1 surface elevation.

(a) If the computed 40:1 surface elevation is equal to or greater than the ROC surface elevation, a climb-in-hold evaluation is not required.

(b) If the computed 40:1 surface elevation is less than the ROC surface elevation, a climb-in-hold evaluation is required. Section 16-7, specifies higher speed groups, and therefore larger template sizes, and are usually necessary for the climb-in-hold evaluation. These templates may require an increase in MHA under paragraph 16-2-4. If this evaluation requires an increase in the MHA, evaluate the new altitude using the higher speed group specified in section 16-7. This sequence of review must be used until the MHA does not increase, then the 40:1 surface is re-evaluated. If obstacles penetrate the 40:1 surface, take action to eliminate the penetration.

f. The charted missed approach altitude is the higher of the preliminary charted missed approach altitude or the MHA established under paragraph 2-8-5.c(3)(b).

2-8-9. Climb-in-Hold at the MAP Missed Approach Area. A climb-in-hold at the MAP is a missed approach that occurs when the aircraft reaches the missed approach point and immediately turns to enter holding while climbing. The missed approach turn direction must be to the holding side of the holding pattern, and the MAP will be the holding fix. The missed approach will include Zone 4 (see figure 2-8-13) which is evaluated as described in paragraph 2-8-7.a. See section 16-7 for climb-in-hold obstacle evaluation. This type of missed approach is only allowed for VOR and NDB procedures and is permitted for both straight-in and circling procedures.

a. The following requirements must be met:

(1) The MAP must be the final approach course facility, and it must also be the clearance limit.

(2) The missed approach holding pattern must be aligned with (and overlie) the final approach course.

(3) Obstacles in the holding pattern are measured from the closest distance to the OCS origin as described in chapter 2, except for those in Zone 4, which are evaluated as described in paragraph 2-8-7.a.

b. The following limitations apply:

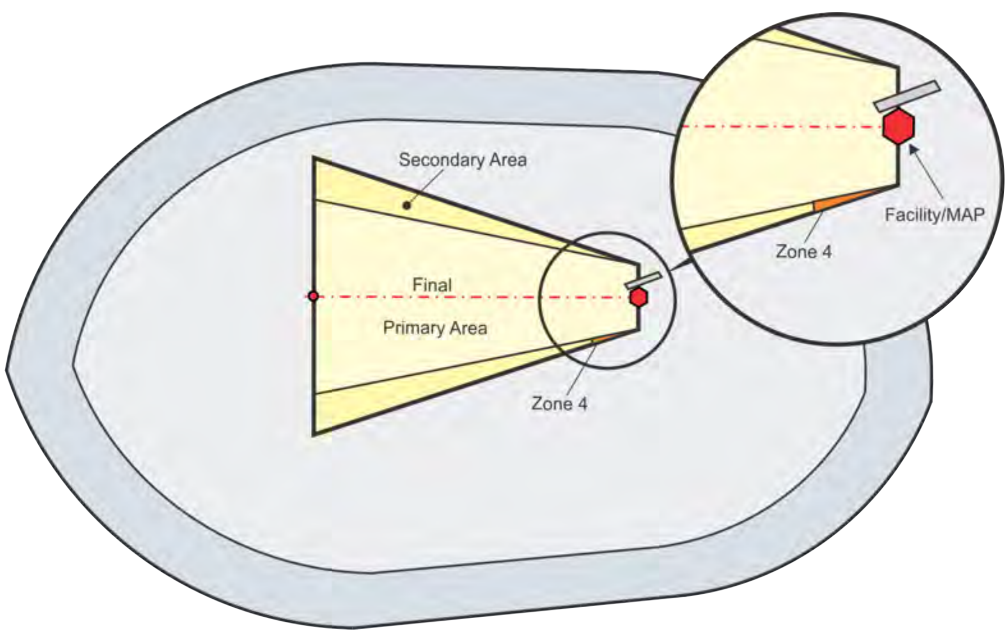
(1) A climb-in-hold at the MAP must not be used in conjunction with a climb-to altitude before turning, or any other instructions that would delay entry into the holding pattern.

(2) A climb-in-hold at the MAP is not authorized if the MDA/CDMA is less than 400 feet above TDZE/airport elevation rounded to the nearest foot increment.

(3) Penetrations of the 40:1 OCS may only be eliminated/mitigated by an increase in MDA/CMDA. CGs greater than standard are not authorized.

(4) The 310-knot pattern must be used for the climb-in-hold evaluation.

Figure 2-8-13. Climb-in Hold at MAP



2-8-10. End of Missed Approach. Aircraft are assumed to be in the initial approach or en route environment upon reaching MOCA or MEA. Thereafter, the initial approach or the en route clearance criteria apply.

Section 2-9. Terminal Area Fixes

2-9-1. General. Terminal area fixes include, but are not limited to the PFAF, the IF, the IAF, the holding fix, and when possible, a fix to mark the MAP. Each fix is a geographical position on a defined course. Terminal area fixes should be based on similar navigation systems. For example, TACAN, VORTAC, and VOR/DME facilities provide radial/DME fixes. NDB facilities provide bearings. VOR facilities provide VOR radials. The use of integrated (VHF/NDB) fixes must be limited to those intersection fixes where no satisfactory alternative exists.

2-9-2. Fixes Formed By Intersection. A geographical position can be determined by the intersection of courses or radials from two stations. One station provides the course the aircraft is flying and the other provides a crossing indication which identifies a point along the course which is being flown. Because all stations have accuracy limitations, the geographical point which is identified is not precise, but may be anywhere within a quadrangle which surrounds the plotted point of intersection. Figure 2-9-1 illustrates the intersection of an arc and a radial from the same DME facility and the intersection of two radials or courses from different navigation facilities. The area encompassed by the sides of the quadrangle formed in these ways is referred to in this publication as the “fix displacement area.”

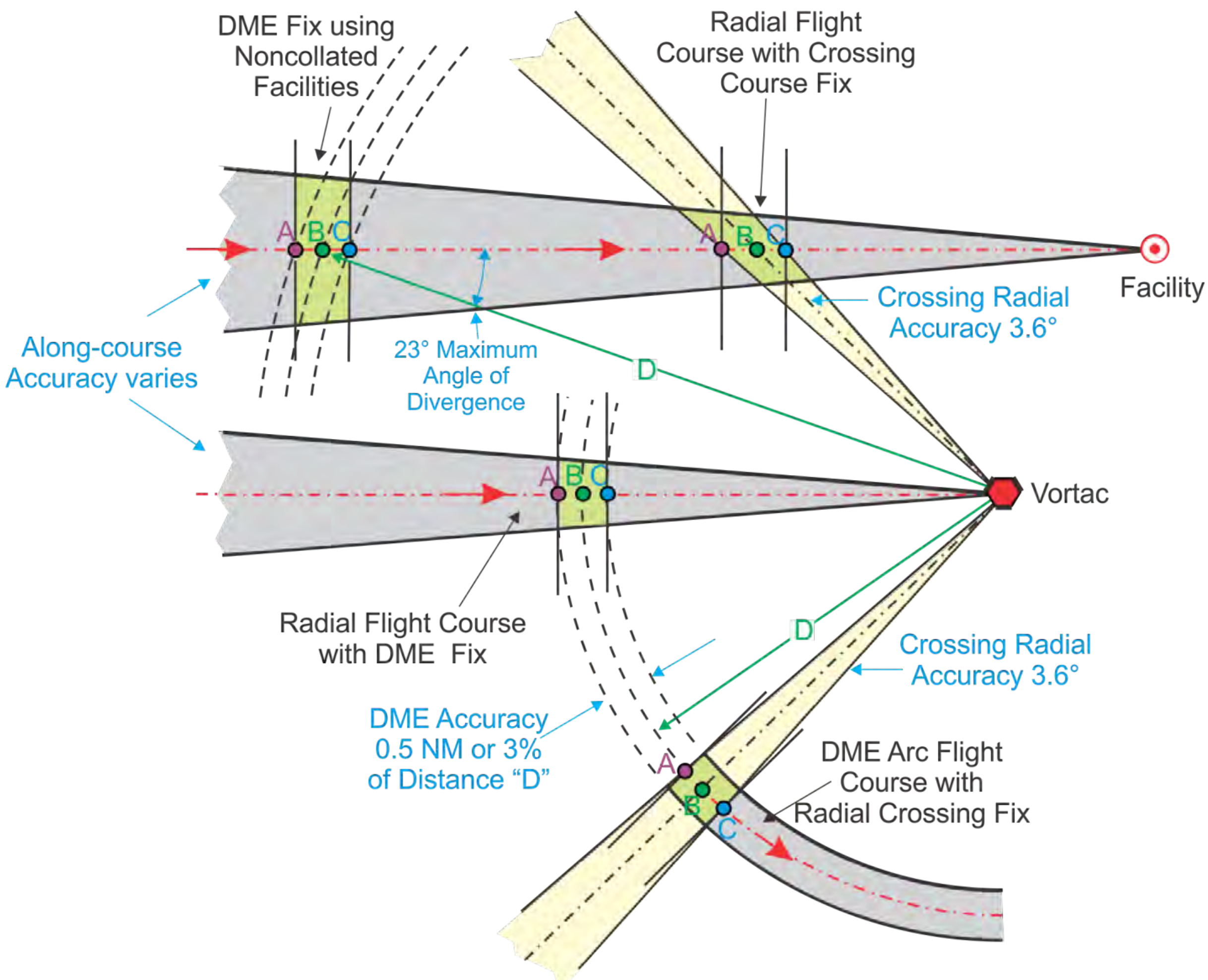
2-9-3. Course/Distance Fixes.

a. DME fixes. A DME fix is formed by a DME reading on a positive navigational course. The information should be derived from a single facility with collocated azimuth and DME antennas. Collocation parameters are defined in Order 6050.32, Spectrum Management Regulations and Procedures Manual. Where operationally required, DME information from a non-collocated facility may be used to identify a fix provided the angular divergence between the signal sources at the fix does not exceed 23 degrees (see figure 2-9-1).

b. ATD fixes. An ATD fix is an along track position defined as a distance in NM, with reference to the next WP along a specified course.

c. Fixes formed by marker beacons. Marker beacons are installed to support certain NAVAIDs that provide course guidance. A marker beacon is suitable to establish a fix only when it marks an along course distance from the NAVAID it is associated with; for example, a localizer and outer marker.

Figure 2-9-1. Fix Displacement



2-9-4. Fixes Formed By Radar. Where ATC can provide the service, ASR may be used for any terminal area fix. PAR may be used to form any fix within the radar coverage of the PAR system. Air Route Surveillance Radar (ARSR) may be used for initial approach and intermediate approach fixes. Coordinate with the appropriate ATC facility before establishing a radar fix to ensure the facility agrees to provide the radar fix service.

2-9-5. Fix Displacement Area. The areas portrayed in figure 2-9-1 extend along the flight course from point "A" to point "C." The fix error is a plus-or-minus value, and is represented by the lengths from "A" to "B" and "B" to "C." Each of these lengths is applied differently. The fix error may cause the fix to be received early (between "A" and "B"). Because the fix may be received early, protection against obstacles must be provided from a line perpendicular to the flight course at point "A."

2-9-6. Intersection Fix Displacement Factors. The intersection fix displacement area is determined by the system use accuracy of the navigation fixing systems. The system use accuracy in VOR and TACAN type systems is determined by the combination of ground station error, airborne receiving system error, and flight technical error (FTE). En route VOR data have shown that VOR system use accuracy along radial courses of ± 4.5 degrees, 95 percent of occasions, is a realistic, conservative figure. Thus, in normal use of VOR or TACAN intersections, fix displacement factors may conservatively be assessed as follows:

a. Along-course accuracy.

(1) VOR/TACAN radials, plus-or-minus 4.5 degrees.

(2) Localizer course**,** plus-or-minus 1 degree.

(3) NDB courses or bearing, plus-or-minus 5 degrees.

Note: The plus-or-minus 4.5 degrees (95 percent) VOR/TACAN figure is achieved when the ground station course signal error, the FTE, and the VOR airborne equipment error are controlled to certain normal tolerances. Where it can be shown that any of the three error elements is consistently different from these assumptions (for example, if flight inspection shows a consistently better VOR signal accuracy or stability than the one assumed, or if it can be shown that airborne equipment error is consistently smaller than assumed), VOR fix displacement factors smaller than those shown above may be utilized under paragraph 1-4-2.

b. Crossing course accuracy.

(1) VOR/TACAN radials, plus-or-minus 3.6 degrees.

(2) Localizer course**,** plus-or-minus 0.5 degrees.

(3) NDB bearings**,** plus-or-minus 5 degrees.

Note: The plus-or-minus 3.6 degrees (95 percent) VOR/ TACAN figure is achieved when the ground station course signal error and the VOR airborne equipment error are controlled to certain normal tolerances. Since the crossing course is not flown, FTE is not a contributing element. Where it can be shown that either of the error elements is consistently different, VOR displacement factors smaller than those shown above may be utilized under paragraph 1-4-2.

c. Calculate intersection fix displacement along the track to be flown using formula 2-9-1 and formula 2-9-2 (see figure 2-9-2).

Formula 2-9-1. Fix Displacement Calculations

$$E = \frac{1852 \times D \times \sin(B)}{0.3048 \times \sin([A + B])}$$

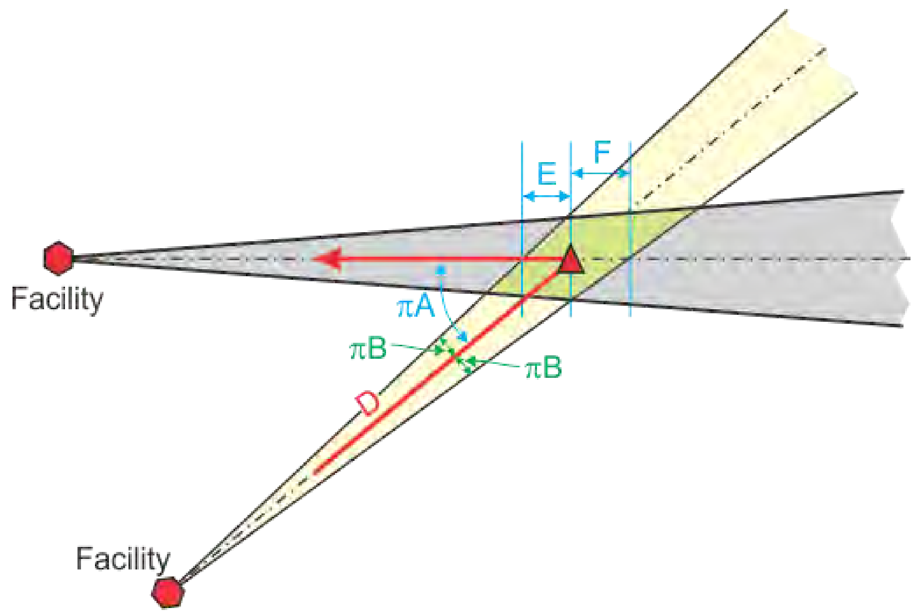
Where:
E = Fix displacement on turn side (feet)
A = Angle between along course track and crossing course
B = Crossing course accuracy
D = Distance (NM) from crossing facility to intersection

Formula 2-9-2. Fix Displacement Calculations

$$F = \frac{1852 \times D \times \sin(B)}{0.3048 \times \sin([A - B])}$$

Where:
F = Fix displacement opposite of turn side (feet)
A = Angle between along course track and crossing course
B = Crossing course accuracy
D = Distance (NM) from crossing facility to intersection

Figure 2-9-2. Fix Displacement



2-9-7. Other Fix Displacement Factors.

a. Radar. Plus-or-minus 500 feet or three percent of the distance to the antenna, whichever is greater.

b. DME. Plus-or-minus 0.5 NM or three percent of the distance to the antenna, whichever is greater.

c. 75 MHz marker beacon.

(1) Normal powered fan marker**,** plus-or-minus 2 NM.

(2) Bone-shaped fan marker**,** plus-or-minus 1 NM.

(3) Low powered fan marker, plus-or-minus 0.5 NM.

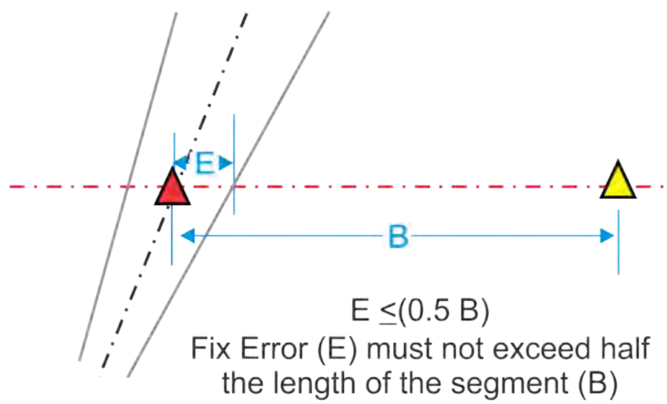
Note: Where these 75 MHz marker values are restrictive, the actual coverage of the fan marker (2 milliamp signal level) at the specific location and altitude may be used instead.

d. Overheading a station. The fix error involved in station passage is not considered significant in terminal applications. The fix is therefore considered to be at the plotted position of the navigation facility. The use of TACAN station passage as a fix is not acceptable for holding fixes or high altitude IAFs.

2-9-8. Satisfactory Fixes.

a. Intermediate, initial, or feeder fix. To be satisfactory as an intermediate, initial, or feeder approach fix, the fix error must not be larger than 50 percent of the appropriate segment distance that follows the fix. Measurements are made from the plotted fix position (see figure 2-9-3).

Figure 2-9-3. Intermediate, Initial, or Feeder Approach Fix Errors



b. Holding fixes. Any terminal area fix, except overheading a TACAN or a 75 MHz marker beacon, may be used for holding. The following conditions must exist when the fix is an intersection formed by courses or radials:

(1) The angle of divergence of the intersecting courses or radials must not be less than 45 degrees.

(2) If the facility which provides the crossing courses is not an NDB, it may be as much as 45 NM from the point of intersection.

(3) If the facility which provides the crossing course is an NDB, it must be within 30 NM of the intersection point.

(4) If distances stated in paragraphs 2-9-8.b(2) or 2-9-8.b(3) are exceeded, the minimum angle of divergence of the intersecting courses must be increased at the following rate:

(a) If an NDB facility is involved, 1 degree for each NM over 30 NM.

(b) If an NDB facility is not involved, 0.5 degree for each NM over 45 NM.

c. PFAF. For a fix to be satisfactory for use as a PFAF, the fix error should not exceed plus-or-minus 1 NM (see figure 2-9-4). It may be as large as plus-or-minus 2 NM when:

(1) The MAP is marked by overheading an air navigation facility (except 75 MHz markers); or

(2) Where DME is required for identification of the MAP (FAF to MAP timing is not published); or

(3) Where DME is not required for identification of the MAP (FAF to MAP timing is either required or optional for identification of the MAP), a buffer of equal length to the excessive fix error after the PFAF is provided between the published MAP and the point where the missed approach surface begins. The area between the MAP and the start of the 40:1 (20:1 for helicopters) surface rise is considered missed approach primary area. When PCG is available, the 12:1 secondary area may begin where the 40:1 (20:1 for helicopters) surface rise starts (see figure 2-9-5).

Figure 2-9-4. Measurement of PFAF Error

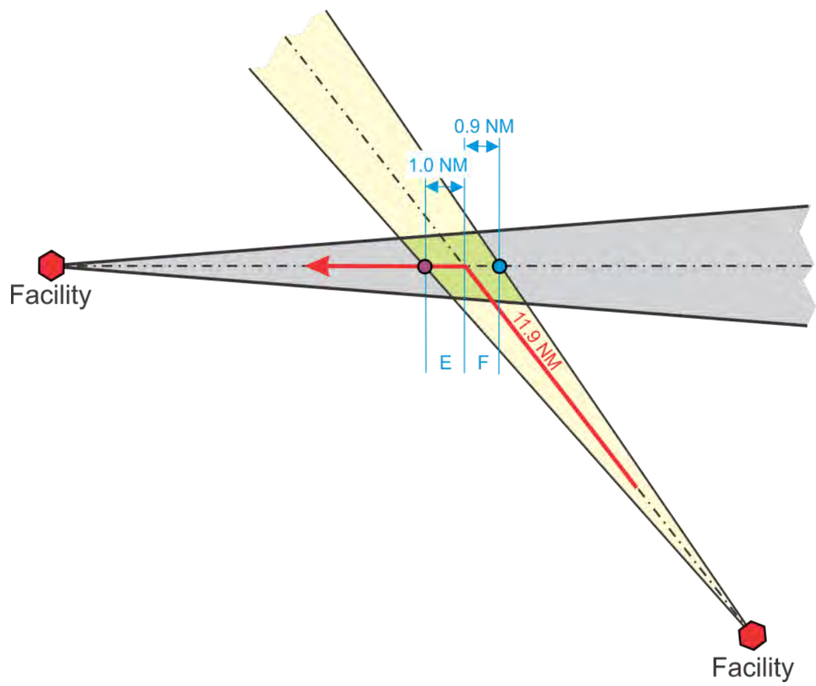
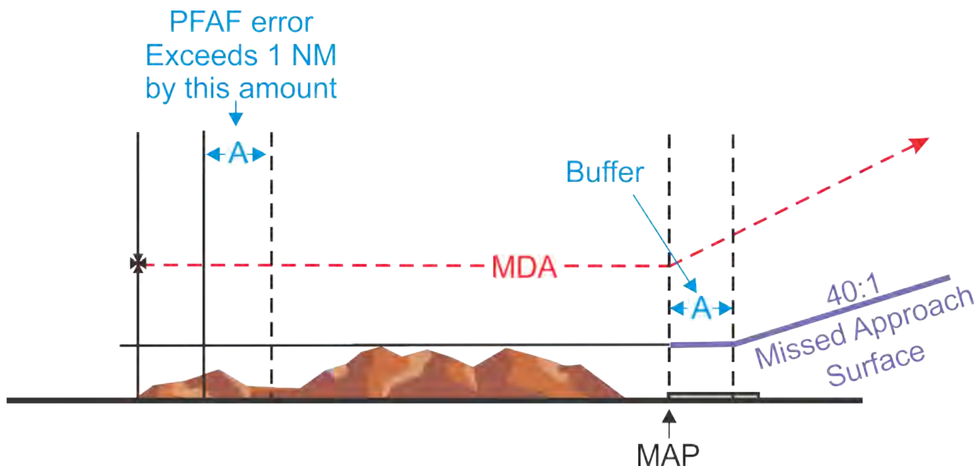


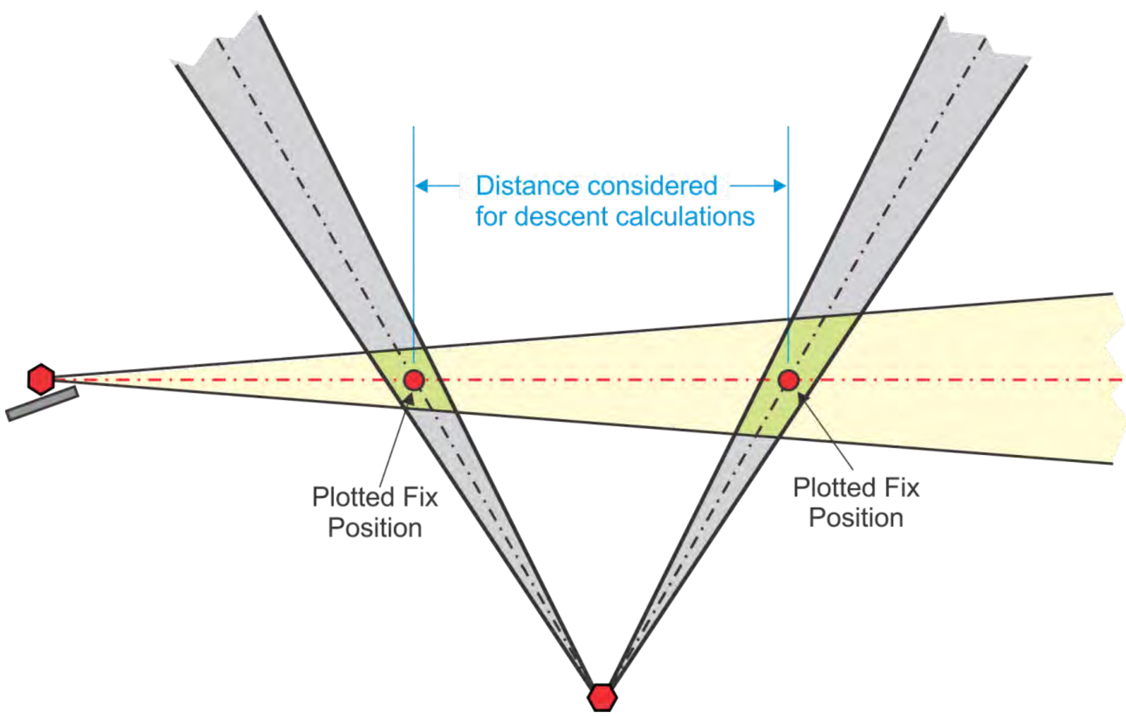
Figure 2-9-5. PFAF Error Buffer



2-9-9. Using Fixes for Descent.

a. Descent gradients. When applying descent gradient criteria applicable to a STAR, feeder, or approach segment (initial, intermediate, or final approach), the measuring points are the plotted position of the fix (see figure 2-9-6) with the lower altitude restriction, and the plotted position of the fix with the higher altitude restriction. Fixes without an altitude restriction are ignored for descent gradient calculations. Calculate using the minimum altitude authorized at each fix for a minimum, mandatory, or block altitude restriction. For maximum altitude restrictions, calculate using the maximum altitude authorized at the fix.

Figure 2-9-6. Distance for Descent Gradient Application



b. Obstacle clearance after passing a fix. Descent is assumed to occur at the earliest point a fix can be received. Full obstacle clearance must be provided from this point to the plotted point of the next fix. Therefore, the altitude to which descent is to be made at the fix must provide the same clearance over obstacles in the fix error area as it does over those in the approach segment which is being entered (see figure 2-9-7 and figure 2-9-8).

Figure 2-9-7. Obstacle Clearance Area Between Fixes

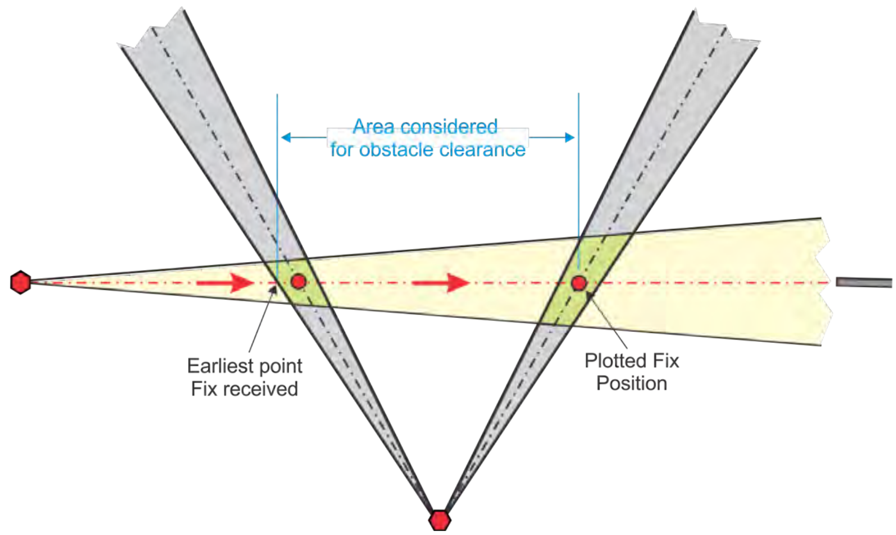
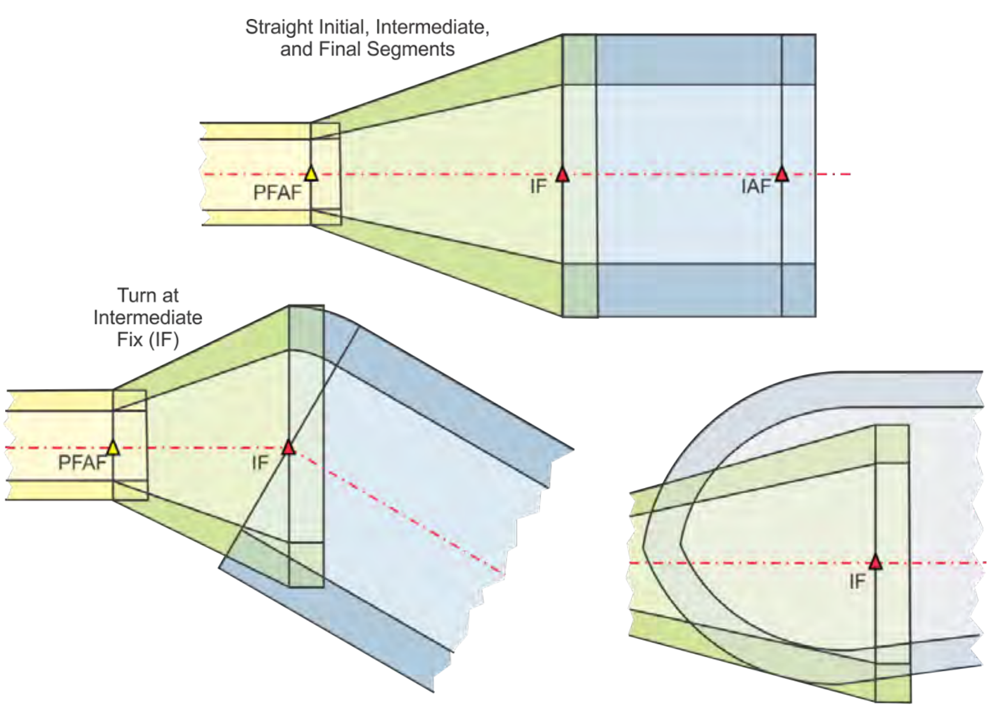


Figure 2-9-8. Construction of Fix Displacement Area for Obstacle Clearance



c. Stepdown fixes (see figure 2-9-9).

(1) DME, ATD, RNAV WP, or radar fixes. Except in the intermediate segment within a PT (see paragraph 2-5-5), there is no maximum number of stepdown fixes in any segment when DME, an RNAV WP, an ATD fix, or radar is used. DME and ATD fixes may be denoted in tenths of a NM. The distance between fixes must not be less than 1 NM.

(2) Intersection fixes.

(a) Only one stepdown fix is permitted in the final and intermediate segments.

(b) If an intersection fix forms a PFAF, IF, or IAF:

1. The same crossing facility must be used for the stepdown fix(es) within that segment.

2. All fixes from the IF to a stepdown fix in final must be formed using the same crossing facility.

(c) Table 2-9-1 must be used to determine the number of stepdown fixes permitted in the initial segment. The distance between fixes must not be less than 1 NM.

(3) Altitude at the fix. The minimum altitude at each stepdown fix must be specified in 100-foot increments, except the altitude of a stepdown fix in the final segment may be specified in a 20-foot increment.

(4) In the final segment:

(a) The altitude at a stepdown fix published in conjunction with vertically-guided minimums (for example, an RNAV with LPV and LNAV minimums or an ILS combined with a LOC) must not exceed the calculated altitude of the glide slope/glidepath at the fix. Calculate the maximum permissible altitude for a stepdown fix by applying formula 2-6-4.

(b) A stepdown fix must not be established unless a decrease of at least 60 feet in MDA or a reduction in visibility minimums is achieved.

(c) The last stepdown fix error must not exceed plus-or-minus 2 NM or the distance to the MAP, whichever is less. The fix error for other stepdown fixes in the FAS must not exceed 1 NM.

(d) Minimums must be published both with and without the stepdown fix, except for procedures requiring DME or NDB procedures which use a VOR radial to define the stepdown fix.

Figure 2-9-9. Final Segment Stepdown Fix

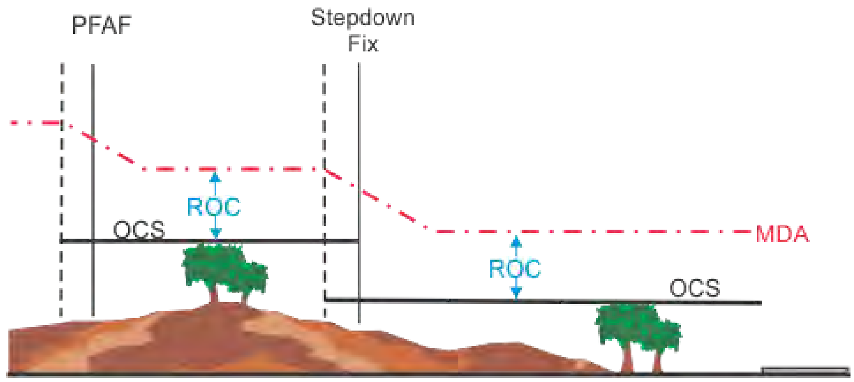


Table 2-9-1. Stepdown Fixes in Initial Segment

Length of Segment	Number of Fixes
5-10 NM	1 stepdown fix
over 10-15 NM	2 stepdown fixes
over 15 NM	3 stepdown fixes

2-9-10. Obstacles Close to a PFAF or a Final Approach Segment Stepdown Fix. Obstacles close to the PFAF/Stepdown Fix (located within the FAS) may be eliminated from consideration if the following conditions are met:

a. The obstacle is in the final approach trapezoid within 1 NM past the point the PFAF/stepdown fix can first be received, and

b. The obstacle does not penetrate a 7:1 (fixed-wing) or 3.5:1 (helicopter) OIS. The surface begins at the earliest point the fix can be received and extends toward the MAP 1 NM. The beginning surface height is determined by subtracting the final segment ROC (and adjustments from paragraph 3-2-2 as applicable) from the minimum altitude required at the fix. The surface slopes downward 1-foot vertically for each seven-feet horizontally (fixed-wing) or one-foot vertically for each 3.5-feet horizontally (helicopter) toward the MAP (see figure 2-9-10).

c. Formula 2-9-3 and formula 2-9-4 may be used to determine the OIS height at the obstacle or the minimum fix altitude based on applying the surface to an obstacle which must be eliminated. To determine fix error, see paragraphs 2-9-5, 2-9-6, and 2-9-7.

Formula 2-9-3. OIS Height Calculation

$$OIS_{height} = FixAlt - ROC - \left(\frac{d}{s}\right)$$

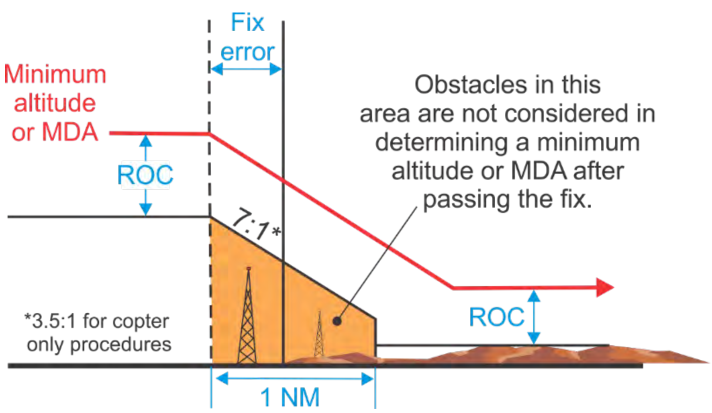
Where:
$FixAlt$ = Published MSL fix altitude
ROC = Required obstacle clearance plus adjustments
d = Distance from earliest fix reception to obstacle (feet)
s = 7 for fixed-wing, 3.5 for helicopter-only

Formula 2-9-4. Minimum Fix Altitude Calculation

$$MinFix_{alt} = ObstElev + ROC + \left(\frac{d}{s}\right)$$

Where:
$ObstElev$ = Obstacle elevation
ROC = Required obstacle clearance plus adjustments
d = Distance from earliest fix reception to obstacle (feet)
s = 7 for fixed-wing, 3.5 for helicopter-only

Figure 2-9-10. Obstacles Close-In to a Fix



Chapter 3. Landing and Takeoff Minimums

Section 3-1. Landing Minimums General Information

3-1-1. Application. The minimums specified in this chapter are the lowest *that can be approved through TERPS application* at any location for the type of navigation facility/system concerned. Category (CAT) II/III visibility minima calculation methods and elements are located in chapter 10.

3-1-2. Establishment. Establish the lowest minimums permitted by the criteria contained in this order. Specify minimums for each condition indicated in the procedure; such as straight-in, circling, alternate, and takeoff, as required. List the following minima elements: DA, decision height (DH), MDA, HAT, HAA, height above landing (HAL), or height above surface (HAS) as appropriate, and RVR or visibility. Specify alternate minimums (when required) as a ceiling and visibility. Specify takeoff minimums when required, as visibility only, except where the need to see and avoid an obstacle requires the establishment of a ceiling value.

Note: Ceiling is specified in 100-foot increments and is equal to DA/MDA/CMDA minus airport elevation. When necessary, round to the next higher 100-foot value. For example, DA 1242-Airport Elevation 214 = 1028 = Ceiling 1100 feet.

a. Publication.

(1) Publish minimums for each approach category accommodated at the airport.

Note: The set of approach category minimums to publish is made on a case-by-case basis through the IFP Validation Team or by the appropriate military authority, and must accommodate the approach speed (straight-in and circling) of all aircraft expected to use the procedure.

(2) Annotate the chart appropriately when one or more approach categories are not authorized. Publish minimums for each approach category except those not authorized (for example, publish only CAT A and B straight-in minimums when CAT C and D are not authorized).

b. Runway visual range (RVR). Reported RVR values are determined by instruments located alongside of a runway. It represents the horizontal distance a pilot can expect to see down the runway, based on sighting either the high intensity runway lights (HIRL) or the visual contrast of other targets, whichever yields the greater visual range. RVR may be published with straight-in landing minima when:

(1) RVR equipment is installed to (or shared with) the runway in accordance with the applicable FAA standard (for example, Order 6560.10, Runway Visual Range, or appropriate military directive). Installations must always include a touchdown zone sensor.

(2) HIRLs are installed to the runway in accordance with appropriate FAA or military standards.

(3) Instrument runway markings are available. When required runway markings are not available but touchdown zone (TDZ) and centerline lights (CL) are available, RVR equal to the visibility minimum appropriate for the approach light configuration is authorized.

c. Approach lighting systems. Approach lighting systems extend visual cues to the approaching pilot and make the runway environment apparent with less visibility than when such lighting is not available. For this reason, lower straight-in (not applicable to circling) visibility minimums may be established when standard or equivalent approach lighting systems are present.

(1) Standard lighting systems. Table 3-1-1 provides the types of standard approach and runway lighting systems, as well as the operational coverage for each type. Table 3-1-2 provides lighting system classifications.

Table 3-1-1. Standard Lighting Systems

	APPROACH LIGHTING SYSTEMS	Operational Coverage (°)	
		Lateral (±)	Vertical (above horizon)
ALSF-1	Standard Approach Lighting System with Sequenced Flashers	21.0* 12.5#	12.0* 12.5#
ALSF-2	Standard Approach Lighting System with Sequenced Flashers & CAT II Modification	21.0* 12.5#	12.0* 12.5#
SALS	Short Approach Lighting System	21.0*	12.0*
SALSF	Short Approach Lighting System with Sequenced Flashers	21.0* 12.5#	12.0* 12.5#
SSALS	Simplified Short Approach Lighting System	21.0*	12.0*
SSALF	Simplified Short Approach Lighting System with Sequenced Flashers	21.0* 12.5#	12.0* 12.5#
SSALR	Simplified Short Approach Lighting System with Runway Alignment Indicator Lights	21.0* 12.5#	12.0* 12.5#
MALS	Medium Intensity Approach Lighting System	10.0*	10.0*
MALSF	Medium Intensity Approach Lighting System with Sequenced Flashers	10.0* 12.5#	10.0* 12.5#
MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights	10.0* 12.5#	10.0* 12.5#
ODALS	Omni-Directional Approach Lighting System	360#	2.0-10.0#

***** Steady-burning # Sequenced flashers

Note: Order JO 6850.2, Visual Guidance Lighting Systems, contains descriptions of various approach lighting systems.

Table 3-1-2. Lighting System Classification

Facility Class	Approach Lighting Systems (ALS)
Full (FALS)	ALSF-1, ALSF-2, SSALR, MALSR High or medium intensity and/or flashing lights.
Intermediate (IALS)	MALSF, MALS, SSALF, SSALS, SALS/SALSF High or medium intensity and/or flashing lights.
Basic (BALS)	ODALS High or medium intensity lights and/or flashing lights.
Nil (NALS)	No approach lights or length less than 700 feet.

(2) Operational conditions. In order to apply approach light credit to straight-in landing minimums and publish visibility from the FALS, IALS, or BALS column from table 3-3-1, table 3-3-3, or table 3-3-4, the following conditions must exist:

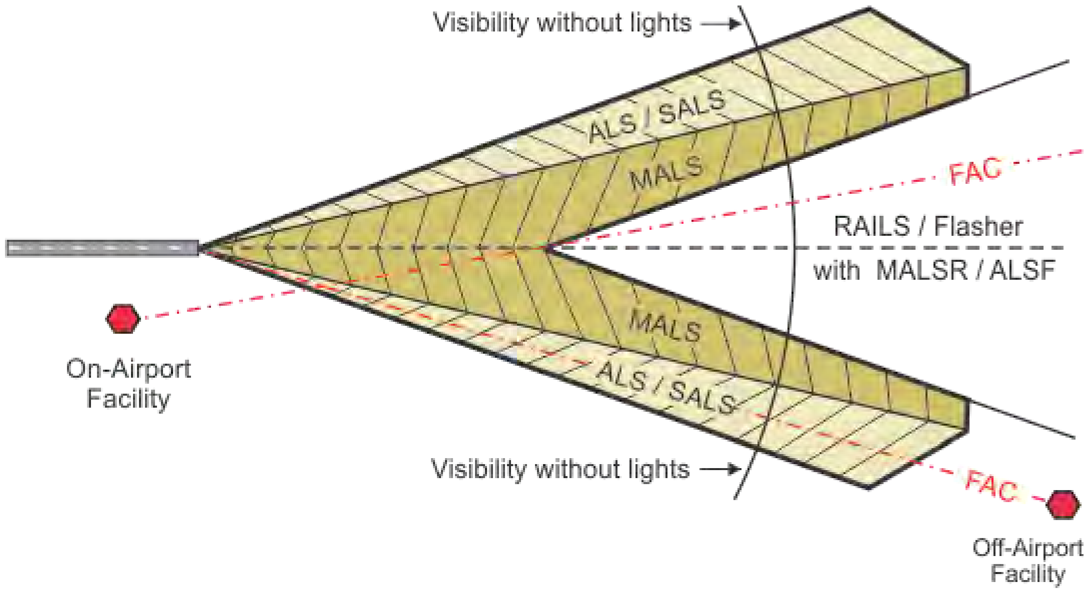
(a) The distance from the MAP/DA to LTP must be less than or equal to 3 SM.

(b) For PA and APV procedures, the TCH must not exceed the upper limit value specified by table 3-1-3.

(c) The runway must have NPA or PA runway surface marking schemes or both touchdown zone and centerline lights as specified in directives of the appropriate approving authority. Runway marking effectiveness may be degraded when obscured by surface water, snow, ice, or tire marks. All procedures to the affected runway must revert to no-light minimums when required markings are removed, or when it is determined the markings are inadequate for reduced visibility credit. Operational TDZ and CL lights may be substituted for removed, deteriorated, or obscured runway markings to authorize a visibility minimum appropriate for the applicable approach light configuration.

(d) The FAC must place the aircraft within the operational coverage of the approach lighting system at a distance from the landing threshold equal to the standard visibility required *without* lights (NALS column). For example, in figure 3-1-1 the FAC to the on-airport facility transits all approach light operational areas at the limit of the visibility arc and may therefore be authorized light credit for ALS/SALS and MALS. However, the FAC from the off-airport facility transits the operational area for ALS/SALS but not the area for MALS and may therefore be authorized light credit for ALS/SALS only.

Figure 3-1-1. Application of Lateral Coverage Angles



(3) Other lighting systems. Variations of standard systems, and other systems not included in this chapter, must meet the specified operational conditions in paragraph 3-1-2.c(2) to receive visibility reduction credit. The provisions of paragraph 1-4-2, Nonstandard IFPs, govern light credit for civil airport lighting systems which do not meet known standards or for which standards do not exist.

Table 3-1-3. PA/APV TCH Upper Limits for Allowing Approach Lighting Credit

HAT (Feet)	Glidepath Angle (Degrees)	TCH upper limit (Feet)	HAT (Feet)	Glidepath Angle (Degrees)	TCH Upper Limit (Feet)
*200 to 249	# 2.50 - 3.20	75	300 to 349	# 2.50 - 4.90	75
	3.21 - 3.30	70		4.91 - 5.00	71
	3.31 - 3.40	66		5.01 - 5.10	66
	3.41 - 3.50	63		5.11 - 5.20	61
	3.51 - 3.60	59		5.21 - 5.30	56
	3.61 - 3.70	55		5.31 - 5.40	52
	3.71 - 3.80	50		5.41 - 5.50	48
	3.81 - 3.90	47		5.51 - 5.60	43
	3.91 - 4.00	43		5.61 - 5.70	39
	4.01 - 4.10	39			
	4.11 - 4.20	35	350 and above	# 2.50 - 5.60	75
				5.61 - 5.70	70
250 to 269	# 2.50 - 4.10	75		5.71 - 5.80	65
	4.11 - 4.20	71		5.81 - 5.90	60
	4.21 - 4.30	67		5.91 - 6.00	55
	4.31 - 4.40	62		6.01 - 6.10	50
	4.41 - 4.50	58		6.11 - 6.20	45
	4.51 - 4.60	54		6.21 - 6.30	40
	4.61 - 4.70	50		6.31 - 6.40	35
	4.71 - 4.80	45			
	4.81 - 4.90	41			
	4.91 - 5.00	37			
270 to 299	# 2.50 - 4.40	75			
	4.41 - 4.50	73			
	4.51 - 4.60	68			
	4.61 - 4.70	64			
	4.71 - 4.80	59			
	4.81 - 4.90	55			
	4.91 - 5.00	51			

***** 100 feet – 199 feet HAT for DoD PAR only

Approval required for angles less than 3 degrees [(see paragraph 1-4-2) (USAF & USN NA)]

Section 3-2. Establishing Minimum Altitudes/Heights

3-2-1. Establish Minimum Altitudes/heights for Each Authorized Approach Category. Minimum altitudes/height types are:

a. Decision altitude (DA). A DA is a specified minimum altitude (feet MSL) in a PA or APV instrument approach procedure at which a decision is made to either continue the approach or to initiate a missed approach. Determine the DA using the appropriate criteria and specify in a one-foot increment (for example, 234.10 rounds to 235).

b. Decision height (DH). A DH serves the same purpose as a DA for CAT II ILS, but is expressed as a radio altimeter height above terrain.

c. Height above touchdown (HAT). Calculate by subtracting the TDZE (rounded to the nearest foot) from the DA/MDA. For example, if TDZE is 632.6 and MDA is 1040, then the HAT is 407 (1040 – 633 = 407). The minimum HAT for a PA/APV procedure is specified in table 3-2-2 unless otherwise specified in the applicable design chapter. The minimum HAT for an NPA is equal to the minimum ROC applicable to the final approach segment primary area as specified in the applicable design chapter (for example, 300 feet for VOR no FAF, 250 feet for VOR/DME and LOC, etc.).

d. Height above airport (HAA). Calculate by subtracting the airport elevation (rounded to the nearest foot) from the CMDA. For example, if airport elevation is 437.4 and CMDA is 920, then the HAA is 483 (920 – 437 = 483). The HAA specified for each aircraft CAT must not be less than those specified in table 3-2-1.

Table 3-2-1. Minimum Authorized HAA

CAT	A	B	C	D	E
HAA	350	450		550	

e. PinS Approaches. HAL is used for Proceed Visual approaches. Calculate HAL by subtracting the appropriate elevation (rounded to the nearest foot) from DA/MDA. For a Proceed Visual approach to a heliport, use the heliport elevation. For all other Proceed Visual approaches, use the elevation of the intended landing point. For example, if the heliport elevation is 403.4 and the MDA is 620, the HAL is 217 (620 – 403 = 217). HAS is used for Proceed VFR approaches. Calculate HAS by subtracting the surface elevation (see paragraph 12-2-4.c(1)(a)) (rounded to the nearest foot) from DA/MDA.

f. Radio altimeter (RA). When necessary to establish an RA height, first determine the elevation of the terrain directly beneath the DA point along the FAC. The RA is the difference between the DA and the terrain elevation and is calculated by applying formula 3-2-1. Determine the distance from LTP to the DA point by applying formula 3-2-2 (see example in figure 3-2-1).

Formula 3-2-1. Calculating RA

$$RA = DA - terrain_{elev}$$

Where:

$terrain_{elev}$ = Terrain elevation on FAC at DA point

Formula 3-2-2. DA Point Distance from LTP (feet)

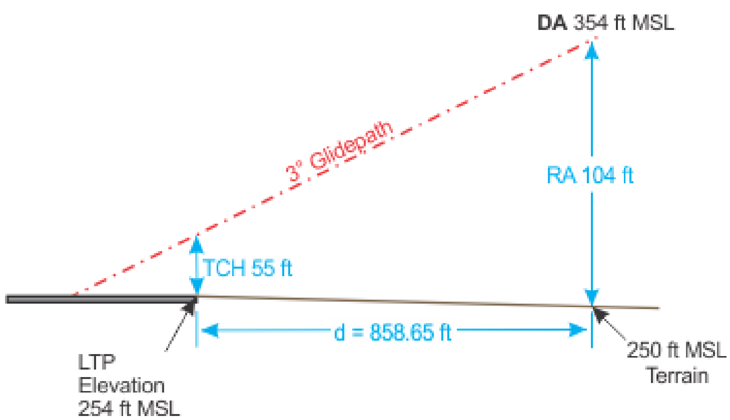
$$d_{LTP} = \frac{DA - (LTP_{elev} + TCH)}{\tan \theta}$$

Where:

LTP_{elev} = LTP elevation

θ = Glidepath angle

Figure 3-2-1. RA Example



g. Minimum descent altitude (MDA). MDA represents the final approach segment minimum altitude for NPA procedures. Each MDA must provide at least the minimum final approach segment (FAS) and missed approach segment (MAS) ROC as specified by the applicable chapter/standard. Express MDAs in 20-foot MSL increments; round upwards when necessary (for example, 820 remains 820, 821 rounds to 840). The MDA must not be higher than the PFAF altitude.

h. Circling MDA (CMDA). In addition to the requirements of paragraphs 3-2-1.d and 3-2-1.g, each CMDA must provide the minimum ROC in the circling maneuvering area and must not be lower than the highest straight-in or sidestep MDA (same CAT) published on the same chart.

Note: When dual minimums are authorized, the CMDA is compared against the straight-in MDA associated with the corresponding minima set (for example, circling with stepdown minimums checked against straight-in with stepdown minimums).

3-2-2. Adjustments to Minimum Altitudes/Heights. The MDA or DA may require an increase under the conditions described below:

a. PA/APV approaches. Determine the minimum HAT based on glidepath angle and aircraft category using table 3-2-2.

Table 3-2-2. Minimum HAT for PA and APV Approach Procedures

	CAT				
Glidepath Angle	**A**	**B**	**C**	**D**	**E**
2.50° - 2.99°[1]	200[2,3]				
3.00° - 3.10°	200[2,3]				
3.11° - 3.30°	200[3]		250		NA[5]
3.31° - 3.50°	200[3]		270		NA[6]
3.51° - 3.77°	200[3,4]		300	NA	
3.78° - 3.80°	200[3,4]		NA		
3.81° - 4.20°	200[3,4]	250	NA		
4.21° - 5.00°	250	NA			
5.01° - 5.70°	300	NA			
5.71° - 6.40° Airspeed NTE 80 knots	350	NA			

1. Approval required for angles less than three degrees (see paragraph 1-4-2) (DoD NA)
2. PAR minimum HAT = 100 (DoD only)
3. LNAV/VNAV, RNP AR, and LDA with GS minimum HAT = 250
4. LPV w/GPA > 3.5° = 250
5. USN and USAF only = 250
6. USN and USAF only = 270

b. Precipitous terrain. In areas characterized by precipitous terrain (in or outside of designated mountainous areas) consideration must be given to induced altimeter errors and pilot control problems.

(1) Precipitous terrain adjustments must be accomplished using software implementing the algorithms in appendix C paragraph 1 for instrument approach procedure segments and level holding associated with a DP.

(a) Precipitous terrain identified in the final segment**.**

<u>1.</u> NPA. Increase ROC values by the amount specified by the software.

<u>2.</u> PA and APV. For approaches that permit precipitous terrain in the final segment, increase the HAT by 10 percent of the value determined by evaluation of the final and

missed segments; for example, 200-foot HAT increases to 220 feet, 350-foot HAT increases to 385 feet. Do not include adjustments for RASS before determining the precipitous terrain adjustment.

(b) Precipitous terrain identified in initial, intermediate, missed approach OEA (applicable to the missed approach obstruction altitude), and missed approach and departure holding segments. Increase ROC by the amount specified by the software. Precipitous terrain adjustments are not applied to the missed approach sloping OCS.

(2) Determination of precipitous terrain should be accomplished using the algorithms in appendix C or other methods for other evaluations such as radar vectoring altitude charts, STAR, feeder routes, TAA, and ATS routes.

(3) Where operationally advantageous, results from the Precipitous Point Value (PPV) algorithms in appendix C paragraph 2 may be used with approval.

c. Remote altimeter setting source (RASS). Not applicable to MSAs, initials, en route, feeder routes, or segment/areas based on en route criteria. When the altimeter setting is obtained from a source more than 5 NM from the ARP for an airport, heliport reference point (HRP) for a heliport, or the MAP for a Proceed VFR PinS approach, a RASS adjustment must be considered. A RASS is not authorized for a remote distance greater than 75 NM or for an elevation differential between the RASS and the landing area that is greater than 6000 feet. To determine which formula applies, evaluate the terrain between the RASS and the airport/heliport/PinS MAP for adverse atmospheric pressure pattern effect. Solicit the best available climatological information from the Aviation Weather Center, National Weather Service (NWS), and/or the Center Weather Service Unit (CWSU).

Note: When a secondary altimeter source must be specified and either the primary or secondary altimeter source (or both) is considered remote (more than 5 NM from the ARP), establish separate landing minima. If establishing separate minima is impractical, publish a chart note specifying the difference between the MDA/DA for primary and secondary sources.

Where intervening terrain does not adversely influence atmospheric pressure patterns, use formula 3-2-3 to compute the basic RASS adjustment in feet (see figure 3-2-2).

Formula 3-2-3. Basic RASS adjustment (no intervening terrain)

$$Adjustments = 2.30 \times D_r + 0.14 \times E_1$$

Where:

D_r = Horizontal dist (NM) altimeter source to ARP/HRP*

E_1 = Elevation differential (feet) between RASS elevation and airport/heliport/ elevation (use heliport elevation for helicopter PinS approaches; if multiple landing areas are utilized by the approach procedure, use the landing area elevation with the greatest differential to the RASS elevation)

***** Copter PinS Approaches/Departures. When annotated "Proceed Visually": D_r = Horizontal distance from altimeter source to HRP. When annotated "Proceed VFR": D_r = Horizontal distance from altimeter source to MAP/IDF.

Examples:

Airport

D_r = 10.8 NM

E_1 = 1000 - 800 = 200 feet

$(2.30 \times 10.8) + (0.14 \times 200) = 52.84$ feet basic RASS adjustment

In intermediate segment: $52.84 \times 0.6 < 200$ (no ROC increase)

In PA/APV final segment: DA = 200 + 52.84 = increase DA to 253

In NPA final segment: 1225 (Controlling obs) + 250 ROC + 52.84 = 1540 MDA

Heliport

D_r = 6.4 NM

E_1 = 1200 - 1000 = 200 feet

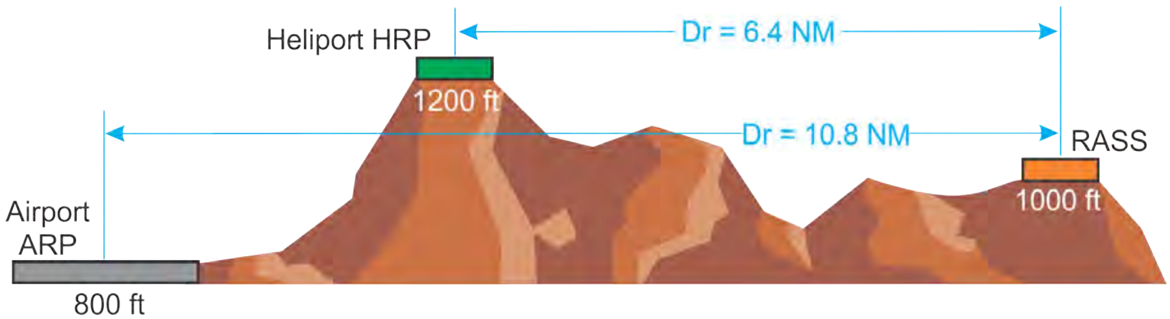
$(2.30 \times 6.4) + (0.14 \times 200) = 42.72$ feet basic RASS adjustment

In intermediate segment $42.72 \times 0.6 < 200$ (no ROC increase)

In PA/APV final segment: DA = 200 + 42.72 = increase DA to 243

In NPA final segment: 1225 (Controlling obs) + 250 ROC + 42.72 = 1520 MDA

Figure 3-2-2. Basic RASS adjustment (no intervening terrain)



(1) Where intervening terrain adversely influences atmospheric pressure patterns, an Elevation Differential Area (EDA) must be evaluated. The EDA is defined as an area 5 NM each side of a line connecting the ARP/HRP (or MAP/IDF for "Proceed VFR" PinS approaches/ departures) and the RASS, and includes a circular area enclosed by a 5 NM radius at each end of this line. Use formula 3-2-4 to compute the basic adjustment in feet (see figure 3-2-3).

Formula 3-2-4. RASS Adjustment Adverse Terrain

$$Adjustments = 2.30 \times D_r + 0.14 \times E_2$$

Where:

D_r = Horizontal dist (NM) altimeter source to ARP/HRP*

E_2 = The elevation differential (feet) between lowest and highest elevation points within the EDA

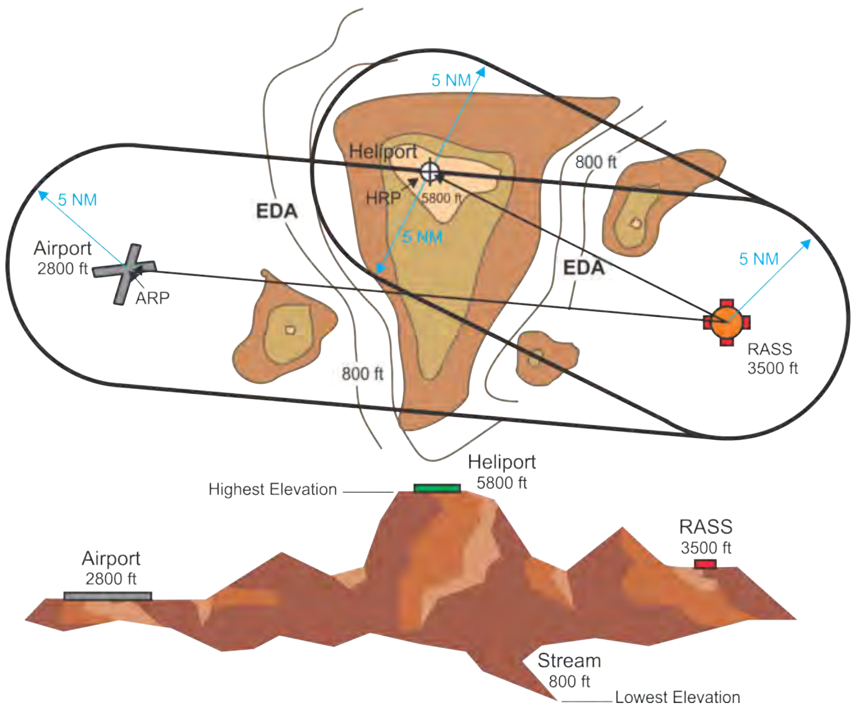
* Copter PinS Approaches/Departures. When annotated "Proceed Visually": D_r = Horizontal distance from altimeter source to HRP. When annotated "Proceed VFR": D_r = Horizontal distance from altimeter source to MAP/IDF.

Examples:

Airport
D_r = 25 NM
E_2 = 5800 - 800 = 5000 feet
$(2.30 \times 25) + (0.14 \times 5000) = 757.5$ feet basic RASS adjustment
In intermediate segment $757.5 \times 0.6 = 454.5 - 200$ (254.5 feet ROC increase)
In PA/APV final segment: DA = 350 + 757.5 = increase DA to 1108
In NPA final segment: 3052.2 (Controlling obs) + 250 ROC + 757.5 = 4060 MDA

Heliport
D_r = 15 NM
E_2 = 5800 - 800 = 5000 feet
$(2.30 \times 15) + (0.14 \times 5000) = 734.5$ feet basic RASS adjustment
In intermediate segment $734.5 \times 0.6 = 440.7 - 200$ (240.7 feet ROC increase)
In PA/APV final segment: DA = 294 + 734.5 = increase DA to 1029
In NPA final segment: 6000 (Controlling obs) + 250 ROC + 734.5 = 7000 MDA

Figure 3-2-3. Elevation Differential Area (EDA) Intervening Terrain Influences Atmospheric Pressure Patterns



(2) Final approach segment adjustments.

(a) NPA final segments (including the circling maneuvering area). Increase primary area ROC by the full basic RASS adjustment.

(b) PA/APV final segments. Increase the DA (prior to rounding) by the full basic RASS adjustment.

(c) To determine separate landing minima for a secondary altimeter source, or to determine the increase for a secondary altimeter RASS by chart note:

1. If the primary altimeter source is local (not remote), the MDA/DA adjustment will be the full secondary source RASS adjustment, rounded up to the next publishable increment.

Example:
Secondary altimeter RASS: 72.3 feet
Value for secondary MDA adjustment: 80 feet
Value for secondary DA adjustment: 73 feet

Primary MDA calculation:
1832 (obs. elev.) + 250 (ROC) = 2082 feet (round to 2100 for publication)
Secondary MDA calculation:
2100 (primary MDA) + 80 (secondary RASS adjustment) = 2180

<u>2.</u> If the primary altimeter source is remote, the MDA/DA adjustment from the primary landing minima is the difference between the secondary source RASS adjustment and the primary source RASS adjustment rounded up to the next publishable increment.

<u>Example</u>:
Primary altimeter RASS (remote): 43.7 feet
Secondary altimeter RASS: 72.3 feet
Difference: 72.3 – 43.7 = 28.6 feet
Value for secondary MDA adjustment: 40 feet
Value for secondary DA adjustment: 29 feet

Primary MDA calculation:
1832 (obs. elev.) + 250 (ROC) + 43.7 (RASS) = 2125.7 feet (round to 2140 for publication)
Secondary MDA calculation:
2140 (primary MDA) + 40 (secondary RASS adjustment) = 2180

(3) For the intermediate segment, use 60 percent of the basic RASS adjustment from formula 3-2-3 or formula 3-2-4, and increase the intermediate segment primary area ROC by the amount this value exceeds 200 feet.

(4) When the missed approach design utilizes a turn at altitude prior to the clearance limit and a part-time altimeter source is specified, decrease the turning section OCS starting height by the difference between RASS adjustments for the two remote altimeter sources. Where one altimeter source is local, subtract the full raw RASS adjustment. Do not decrease these surface starting heights to less than the OCS at the MAP. If this results in an OCS penetration that cannot be resolved by other methods, provide a second climb-to-altitude determined by adding the difference between the RASS adjustments to the climb-to-altitude and rounding to the next higher appropriate increment. This application must not produce a turn altitude above the missed approach clearance-limit altitude.

Example: "MISSED APPROACH: Climb to 6000 (6100 when using Denver Intl altimeter setting) then…"

Note: Combination straight-portion length extension is not required to accommodate the worst-case altimeter source.

(5) Minimum reception altitude (MRA). Where a minimum altitude is MRA based, increase the MRA by the required RASS adjustment.

(6) Where the altimeter setting is based on a remote source(s), annotate the procedure and/or publish the appropriate minima lines in accordance with Order 8260.19.

d. Excessive length, non-precision final approach. When a procedure incorporates a PFAF, and the PFAF-to-MAP length exceeds 6 NM (plotted positions), increase the final segment primary area ROC five feet for each one-tenth NM over 6 NM.

Exception: If a stepdown fix exists and the remaining segment length is less than 6 NM, the basic ROC may be applied between the stepdown fix and the MAP (see formula 3-2-5).

Formula 3-2-5. Excessive Length Adjustment

$$Adjustments = 50\left(Length_{final} - 6\right)$$

Where:

$length_{final}$ = Horizontal distance (NM) from PFAF to MAP (plotted position)

Example:
Distance PFAF to MAP = 6.47
Adjustment = 50(6.47- 6) = 23.5
250 ROC + 23.5 = 273.5 adjusted ROC

e. Multiple adjustment sources. When multiple adjustments are required, the resulting MDA/DA will be the sum of the raw values of the adjustments, rounded to the next higher altitude increment for publication.

Example:
For an airport with both remote primary and secondary source, with both precipitous terrain and excessive length of final adjustments:

Primary altimeter RASS (remote):	43.7 feet
Secondary altimeter RASS:	72.3 feet
Difference (72.3 – 43.7):	28.6 feet

Primary MDA

Nonprecision approach controlling obstruction elevation	1250.3	MSL
ROC	250	feet
Primary RASS	43.7	feet
Precipitous terrain adjustment	25.1	feet
Excessive length of final adjustment	23.5	feet
	1592.6	MSL
Published rounded value	**1600**	**MSL**

Secondary MDA

Primary published MDA	1600	MSL
RASS adjustment difference (rounded)	40	feet
Published secondary MDA	**1640**	**MSL**

Section 3-3. Visibility Minimums

3-3-1. Visibility Minimums Authorization.

a. Straight-in visibility minimums are authorized when:

(1) Applicable straight-in alignment standards are met, and

(2) The final approach segment VDA (when applicable) does not exceed tolerances (see paragraphs 2-6-2 and 2-6-4).

b. Circling visibility minimums are authorized when:

(1) Straight-in alignment requirements cannot be met, or

(2) Straight-in alignment requirements are met, but descent angle precludes publication of straight-in minimums (see paragraph 2-6-2.c), or

(3) Published in conjunction with straight-in NPA minimums.

Note: Do not establish circling minimums when PA or APV procedures are established without accompanying straight-in NPA minimums.

3-3-2. Establishing Straight-in Visibility Minimums. Establish as RVR where applicable, otherwise as a statute mile (SM) value. Meter (M) values are for locations outside the U.S.

a. Visibility without approach lights. Determine visibility without approach lights as the highest of:

(1) The value specified in the applicable row and the NALS column of table 3-3-1, table 3-3-2, table 3-3-3, or table 3-3-4 (as applicable) for the type approach and CAT.

(a) Use table 3-3-1 for all procedures and CATs except for CAT A and B NPA, CAT II/III ILS, Special Authorization (SA) CAT I/II ILS and helicopter approaches.

(b) Use table 3-3-3 for CAT A straight-in NPA procedures.

(c) Use table 3-3-4 for CAT B straight-in NPA approaches.

(2) The MAP-to-LTP distance (NPA only, and only if MAP is located prior to LTP) (see figure 3-3-1).

(a) Determine the MAP-to-LTP distance in feet.

(b) Regardless of approach CAT for which visibility is being determined, convert the distance to a SM or M value contained within the NALS column of table 3-3-1; round upwards when necessary. For example, if the MAP-to-LTP distance is 5121.44 feet (converts to 0.97 SM), select 1 SM from table 3-3-1 since it is the next value contained on the table greater than 0.97 SM.

(c) For RVR minimums, use the RVR value associated with the SM visibility selected in paragraph 3-3-2.a(2)(b). Use RVR 5000 for 1 SM.

(d) If the MAP-to-LTP distance is greater than 3 SM, then round to the next whole mile increment (1000 M increments when meters are applicable).

(3) The DA point-to-LTP distance (PA/APV only and only if greater than 3 SM).

(a) Determine the DA point-to-LTP distance in feet by applying formula 3-2-2.

(b) Convert the distance to a SM value (or M when applicable); if not in a whole SM increment, then round upwards to the next whole SM (1000 M increment for meters). For example, use 4 SM if the DA point-to-LTP distance is 19694 feet (converts to 3.73 SM).

(4) The minimum visibility based on evaluation of the visual area (see paragraph 3-3-2c(4)).

(5) The minimum visibility based on runway requirements (see paragraph 3-3-2.d).

b. Visibility with approach lights. When authorized approach light credit (see paragraph 3-1-2.c(2)), determine visibility with approach lights as the highest of:

(1) The value specified in the applicable row and column of table 3-3-1, table 3-3-2, table 3-3-3, table 3-3-4, and table 3-3-5 (as applicable) for the type approach and CAT.

(a) Use table 3-3-1 for all procedures and CATs except for CAT A and B NPA, CAT II/III ILS, Special Authorization (SA) CAT I/II ILS and helicopter approaches.

(b) Use table 3-3-3 for CAT A straight-in NPA procedures. Use table 3-3-4 for CAT B straight-in NPA approaches.

(c) Use table 3-3-5 for CAT C/D/E straight-in NPA procedures to runways with FALS after determining the visibility minimums prescribed by table 3-3-1.

(2) The MAP-to-LTP distance [(NPA only, and only if MAP is located prior to LTP) (see figure 3-3-1)].

(a) Determine the MAP-to-LTP distance in feet, then subtract 2400 feet for a FALS, 1400 feet for an IALS, or 700 feet for a BALS.

(b) Convert the distance to a SM or M value (as appropriate) contained within the appropriate ALS column of table 3-3-1 (regardless of approach CAT for which visibility is being determined); round upwards when necessary. For example, if the MAP-to-LTP distance is 5186.23 feet, and a FALS system is applicable, subtract 2400 feet for the FALS to arrive at 2786.23 feet (converts to 0.53 SM). Then select 5/8 SM from table 3-3-1 since it is the next incremental value greater than 0.53 SM found on the table.

(c) For RVR minimums, use the RVR value associated with the SM visibility selected in paragraph 3-3-2.b(2)(b). Use RVR 2400 for ½ SM, RVR 3000 for 5/8 SM, and RVR 5000 for 1 SM.

(3) The minimum visibility based on evaluation of the visual area (see paragraph 3-3-2c(4)).

(4) The minimum visibility based on runway requirements (see paragraph 3-3-2.d).

Table 3-3-1. Minimum Visibility Values, All Procedures/CATs (except CAT A and B NPA, SA CAT I/II, CAT II/III, and helicopters)

HAT Range			FALS			IALS			BALS			NALS		
			RVR	SM	M	RVR	SM	M	RVR	SM	M	RVR	SM	M
		200	1800[1], 2400	1/2	550[1], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1200
201	-	210	1800[2], 2400	1/2	550[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1200
211	-	220	1800[2], 2400	1/2	550[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1200
221	-	230	1800[2], 2400	1/2	550[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1200
231	-	240	1800[2], 2400	1/2	550[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1200
241	-	250	1800[2], 2400	1/2	550[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1300
251	-	260	1800[2], 2400	1/2	600[2], 750	4000	3/4	1200	4000	3/4	1200	4000	3/4	1300
261	-	280	2000[2], 2400	1/2	600[2], 750	4000	3/4	1200	4000	3/4	1200	4500	7/8	1300
281	-	300	2200[2], 2400	1/2	650[2], 750	4000	3/4	1200	4000	3/4	1200	4500	7/8	1400
301	-	320	2400	1/2	700[2], 750	4000	3/4	1200	4000	3/4	1200	4500	7/8	1400
321	-	340	2600	1/2	800	4000	3/4	1200	4500	7/8	1300	5000	1	1500
341	-	360	3000	5/8	900	4000	3/4	1200	4500	7/8	1400	5500	1	1600
361	-	380	3500	5/8	1000	4000	3/4	1300	5000	1	1500	5500	1	1700
381	-	400	3500	5/8	1100	4500	7/8	1400	5000	1	1600	6000	1 1/8	1800
401		420	4000	3/4	1200	5000	1	1500	5500	1	1700	6000	1 1/8	1900
421	-	440	4000	3/4	1300	5000	1	1600	6000	1 1/8	1800		1 1/4	2000
441	-	460	4500	7/8	1400	5500	1	1700	6000	1 1/8	1900		1 3/8	2100
461	-	480	5000	1	1500	6000	1 1/8	1800		1 1/4	2000		1 3/8	2200
481	-	500	5000	1	1500	6000	1 1/8	1800		1 1/4	2100		1 3/8	2300
501	-	520	5500	1	1600		1 1/4	1900		1 3/8	2100		1 3/8	2400
521	-	540	5500	1	1700		1 1/4	2000		1 3/8	2200		1 1/2	2400
541	-	560	6000	1 1/8	1800		1 3/8	2100		1 3/8	2300		1 5/8	2500
561	-	580		1 1/4	1900		1 3/8	2200		1 1/2	2400		1 5/8	2600
581	-	600		1 1/4	2000		1 3/8	2300		1 5/8	2500		1 3/4	2700
601	-	620		1 3/8	2100		1 1/2	2400		1 5/8	2600		1 3/4	2800
621	-	640		1 3/8	2200		1 1/2	2500		1 3/4	2700		1 3/4	2900
641	-	660		1 3/8	2300		1 5/8	2600		1 3/4	2800		1 7/8	3000
661	-	680		1 1/2	2400		1 3/4	2700		1 3/4	2900		1 7/8	3100
681	-	700		1 1/2	2500		1 3/4	2800		1 7/8	3000		2	3200
701	-	720		1 5/8	2600		1 3/4	2900		1 7/8	3100		2	3300
721	-	740		1 5/8	2700		1 3/4	3000		2	3200		2	3400
741	-	760		1 3/4	2700		1 7/8	3000		2	3300		2	3500
761	-	800		1 3/4	2900		2	3200		2	3400		2 1/2	3600
801	-	850		1 7/8	3100		2	3400		2 1/2	3600		2 1/2	3800
851	-	900		2	3300		2 1/2	3600		2 1/2	3800		2 1/2	4000
901	-	950		2	3600		2 1/2	3900		2 1/2	4100		2 1/2	4300
951	-	1000		2 1/2	3800		2 1/2	4100		2 1/2	4300		3	4500
1001	-	1100		2 1/2	4100		2 1/2	4400		3	4600		3	4900
1101	-	1200		3	4600		3	4900		3	5000		3	5000
1201	-	Above		3	5000		3	5000		3	5000		3	5000

Notes:

[1] ILS, LPV, GLS with both TDZ and CL lights, or ILS, LPV, or GLS without both TDZ and CL lights but when authorized by Order 8400.13, Procedures for the Evaluation and Approval of Facilities for Special Authorization Category I Operations and All Category II and III Operations.

[2] ILS, LPV, or GLS with both TDZ and CL lights. If FAC is offset, then minimum RVR is 2400.

Table 3-3-2. U.S. Military Standard Minimums PAR with HAT < 200 feet (all CATs)

ALSF TDZ and CL			ALSF/SSALR/SALS/SSALS			MALSR/MALS/ODALS			NO LIGHTS		
RVR	SM	M	RVR	SM	M	RVR	SM	M	RVR	SM	M
1200	-	350	1600	1/4	500	2400	1/2	750	2400	1/2	750

Table 3-3-3. CAT A Straight-in NPA, Authorized RVR/Visibility

	FALS			IALS			BALS			NALS		
HAT/HAA	RVR	SM	M	RVR	SM	M	RVR	SM	M	RVR	SM	M
250-880	2400[1]	1/2 [1]	750[1]	4000	3/4	1200	4000	3/4	1200	5500	1	1600
881-above	4000	3/4	1200	5500	1	1600	5500	1	1600		1 1/4	2000

1. RVR 4000, 3/4 SM, 1200m (NDB)

Table 3-3-4. CAT B Straight-in NPA, Authorized RVR/Visibility

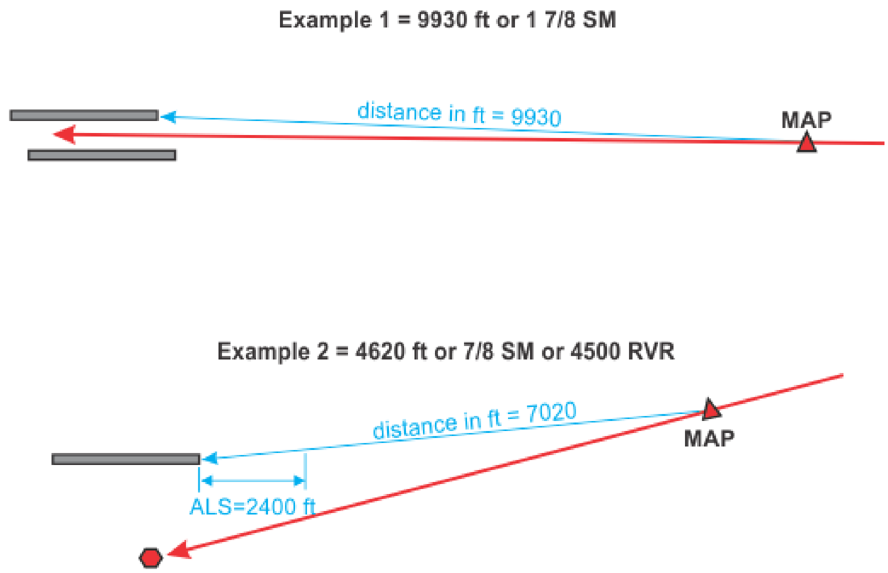
	FALS			IALS			BALS			NALS		
HAT/HAA	RVR	SM	M	RVR	SM	M	RVR	SM	M	RVR	SM	M
250-740	2400[1]	1/2[1]	750[1]	4000	3/4	1200	4000	3/4	1200	5500	1	1600
741-950	4000	3/4	1200	5500	1	1600	5500	1	1600		1 1/4	2000
951-above	5500	1	1600		1 1/4	2000		1 1/4	2000		1 1/2	2400

1. RVR 4000, 3/4 SM, 1200m (NDB)

Table 3-3-5. Minimum Straight-in RVR/Visibility NPA Procedures CAT C/D/E

Procedure Design					
- Final approach guidance is not NDB, AND - Final Course-RWY C/L offset: ≤ 5°, AND - Final Approach segment ≥ 3 NM, AND - With PFAF procedure, AND- *PFAF to LTP ≤ 8 NM (*If time/distance table is published)			ALL OTHERS		
RVR	**SM**	**M**	**RVR**	**SM**	**M**
2400	1/2	750	4000	3/4	1200

Figure 3-3-1. MAP to LTP Distance Straight-in Aligned



c. Determine visibility based on evaluation of the visual portion of the final approach segment. Apply the circling visual area to runways to which an aircraft is authorized to circle (either in association with a straight-in procedure or a circling only approach) and to runways to which a sidestep maneuver is authorized. Apply the straight-in visual area to runways with approach procedures aligned with the runway centerline (less than or equal to ± 0.03 degrees). Apply the offset visual area to evaluate the visual portion of a straight-in approach that is not aligned with the runway centerline (more than ± 0.03 degrees). These evaluations determine if visibility minimums and/or night operations must be restricted.

Note: Assess the appropriate visual area separately for each line of minima on the same approach plate.

(1) Circling visual area (see figure 3-3-2).

(a) Alignment. Align with the RCL extended.

(b) Width. The beginning width is ± 200 feet either side of RCL. The sides splay outward relative to RCL. Calculate the half-width of the area at any distance "d" from its origin using formula 3-3-1.

(c) Length. The area begins 200 feet from LTP and extends 10000 feet out RCL.

(2) Straight-in visual area. Procedure need not meet straight-in descent criteria (see figure 3-3-2). Straight-in visual areas are also applied to helicopter procedures to landing areas that support IFR procedures.

(a) Alignment. Align with the RCL for approaches to a runway, and the FAC for approaches to landing areas that support IFR procedures.

(b) Width. Calculate the half-width of the area at any distance "d" from its origin using formula 3-3-1.

1. For approaches to a runway, the beginning width is ± 200 feet either side of RCL. The sides splay outward relative to RCL.

2. For approaches to a landing area that supports IFR procedures, the beginning width is the width of the heliport safety area.

(c) Length. The area begins 200 feet from LTP (or leading edge of the heliport safety area for landing areas that support IFR procedures) and extends to the calculated DA point for each PA or APV procedure, and to the VDP location (even if one is not published) for NPA procedures (see paragraph 2-6-5).

Note: When multiple NPA minimums are published on the same chart (such as dual minimums or applicable RNAV procedures), use the lowest MDA to determine VDP location and to determine the length of the visual area. For PA/APV approaches, calculate the DA point based on the primary altimeter source.

Formula 3-3-1. Visual Area ½ Width

$$^1/_2\, W = (0.15 \times d) + 200 \text{ (for runways)}$$
$$^1/_2\, W = (0.15 \times d) + w_h \text{ (for landing areas that support IFR procedures)}$$

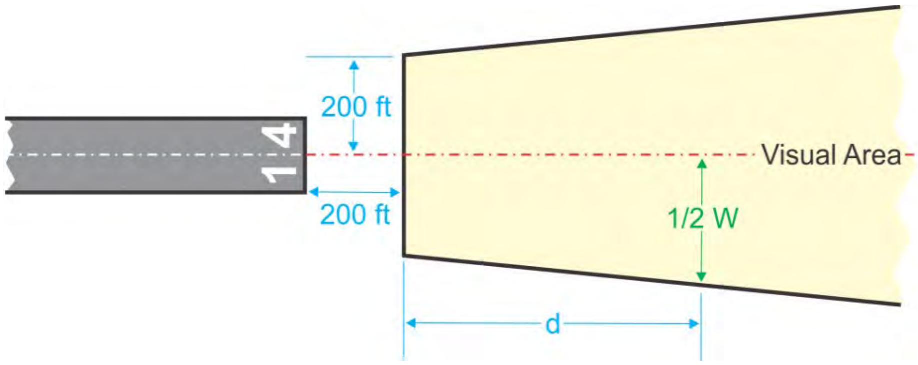
Where:

½W = Perpendicular distance (feet) from RCL (FAC for landing areas that support IFR procedures) to area edge

d = Distance (feet) measured along RCL (FAC for landing areas that support IFR procedures) from area origin

w_h = one-half the width of the safety area (feet)

Figure 3-3-2. Circling and Straight-In Visual Area for Approach to a Runway



(3) Offset visual areas. Procedure need not meet straight-in descent criteria.

(a) When the final course is not aligned within ± 0.03° of the RCL (FAC for IFR heliports) or is not within ± 5 feet of LTP (± 5 feet of the center of the heliport safety area for IFR heliports), modify the straight-in visual area as follows (see figure 3-3-3):

1. *Step 1*. Draw the straight-in area aligned with the RCL (FAC for IFR heliports) as previously described.

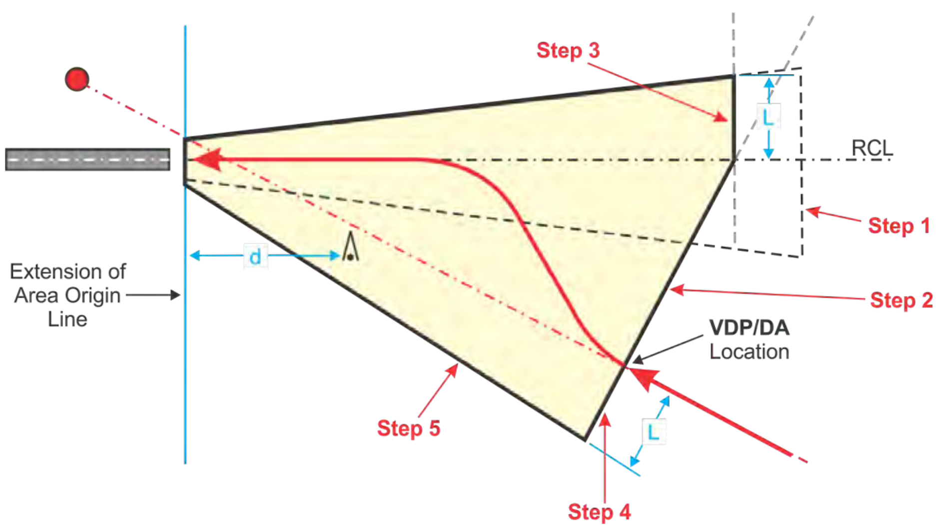
2. *Step 2*. Extend a line perpendicular to the FAC from the DA point or VDP (even if one is not published) to the point it crosses the RCL (FAC for IFR heliports).

3. *Step 3*. Extend a line from this point perpendicular to the RCL (FAC for IFR heliports) to the outer edge of the straight-in area, noting the length (L).

4. *Step 4*. Extend a line in the opposite direction of the line in *step 2* from the DA/VDP perpendicular to the FAC for distance (L).

5. *Step 5*. Connect the end of the line constructed in *step 4* to the end of the inner edge of the area origin line 200 feet from LTP (edge of the heliport safety area for IFR heliports).

Figure 3-3-3. Offset Visual Area



(b) In cases where the FAC does not intercept the extended RCL, but lies within 500 feet laterally of the extended RCL at a point 3000 feet outward from the LTP and is within ± 5 feet of LTP, apply the straight-in visual area from paragraph 3-3-2.c(2).

(4) OIS. When evaluating a straight-in or offset visual area, apply both a 34:1 and a 20:1 OIS. When evaluating the circling visual area or helicopter procedures to an IFR heliport, apply a 20:1 surface only. Calculate the OIS height above LTP elevation (TLOF elevation for helicopter approaches to an IFR heliport) at any distance “d” from an extension of the area origin line using formula 3-3-2:

Formula 3-3-2. Visual Area OIS Height Above LTP Elevation

$$20{:}1\ OIS\ Height = \frac{d}{20}$$
$$34{:}1\ OIS\ Height = \frac{d}{34}$$

Where:
d = Dist. (feet) measured along RCL from area origin extended

(a) 34:1 OIS. If penetrated, limit visibility to no lower than 4000 RVR or ¾ SM.

(b) 20:1 OIS. If penetrated, limit visibility to no lower than 5000 RVR or 1 SM, do not publish a VDP, and if the obstacle is unlighted, annotate the chart to deny the approach or the applicable minimums at night.

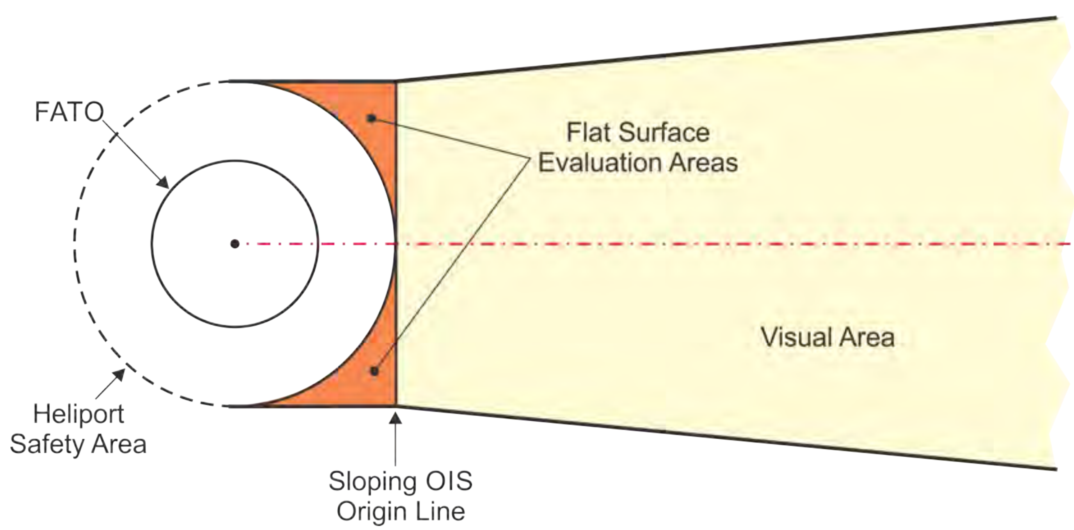
1. A VGSI may be used in lieu of obstruction lighting with approval (see paragraph 1-4-2).

2. If a straight-in approach is restricted at night due to a 20:1 OIS penetration, deny circling at night to the same runway on all approach procedures.

(5) Light units and associated support hardware of an approach lighting system and runway and taxiway guidance signs, installed in accordance with FAA (or military) standards may be disregarded if they penetrate the 34:1 or 20:1 OIS.

(6) For helicopter approaches to IFR heliports with a circular FATO, the VGS origin line will be perpendicular to the FAC and tangent to the circular heliport safety area (see figure 3-3-4). The origin width will be equal to the diameter of the safety area. The OIS evaluation will be the same as paragraph 3-3-2.c(4). If any obstacles are located in the areas between the origin line and the edge of the safety area abeam the center of the TLOF, the limitations of paragraph 3-3-2.c(4). will be applied.

Figure 3-3-4. Helicopter Visual Area with Circular FATO



d. Runway Requirements. Table 3-3-6 specifies minimum visibility based on runway characteristics.

Table 3-3-6. Minimum Visibility Based on Runway Characteristics

Runway Characteristics	RVR	SM	M
Runway does not have a full length parallel taxiway[1]	5000	1	1500
Edge lighting is not HIRL or MIRL	NA	1	1500
Surface is not asphalt or concrete	4000	3/4	1200
Does not have precision runway markings	4000	3/4	1200
Length is less than 4200 feet	4000	3/4	1200
Runway survey type does not support vertical guidance[2]	4000	3/4	1200

1. This line is not applicable if:
   a. The airport is serviced by a full time ATC control tower.
   b. The airport is serviced by a part-time ATC control tower and the chart is annotated to increase the visibility when the tower is closed.
   c. Taxiway(s) are available that permit entry/exit along the full extent of the runway without requiring back-taxi operations.
2. Refer to AC 150/5300-18, General guidance, and Specification for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards, for a description of survey types.

e. Inoperative Lighting Components. Where an ALS is installed, determine the applicability of the U.S. Terminal Procedures Publication (TPP) “Inoperative Components and Visual Aids” table. This step is not applicable to the USAF.

(1) Compare the visibility without approach lights (see paragraph 3-3-2.a) with the visibility with approach lights (paragraph 3-3-2.b) for each approach CAT.

(2) If there is no difference between the “without lights” and the “with lights” values, or if the difference is not equal to the required increase found in the “Increase Visibility” column of the Inoperative Components and Visual Aids table, then annotate the procedure in accordance with Order 8260.19, paragraph 8-6-5.

(3) If the difference between the “without lights” and the “with lights” values is equal to the required increase found in the “Increase Visibility” column of the Inoperative Components and Visual Aids table, then no action or annotation is required.

3-3-3. Establishing Circling Visibility Minimums. Establish as a statute (SM) value. Meter (M) values are for locations outside the United States only. Determine circling visibility as the highest of:

a. The value specified in the applicable row and column of table 3-3-7.

b. The distance from the MAP to the nearest surface authorized for landing by a circling aligned procedure [(only if MAP is located prior to the nearest landing surface) (see figure 3-3-5)]. For procedures meeting straight-in alignment, use the distance from the MAP to the LTP (see figure 3-3-1).

(1) Determine the distance in feet and then convert to SM or M (as appropriate).

(2) The converted value must be in an incremental value contained within table 3-3-7; round upwards when necessary. For example, if the MAP distance is 10664.81 feet (2.02 SM), select 2 1/4 SM (3600 M if applicable) from table 3-3-7 since it is the next value contained on the table.

(3) If the MAP distance is greater than 3 SM, then round to the next whole mile increment (1000 M increments when meters are applicable).

c. Evaluation of the visual portion of the final approach segment (see paragraph 3-3-2.c).

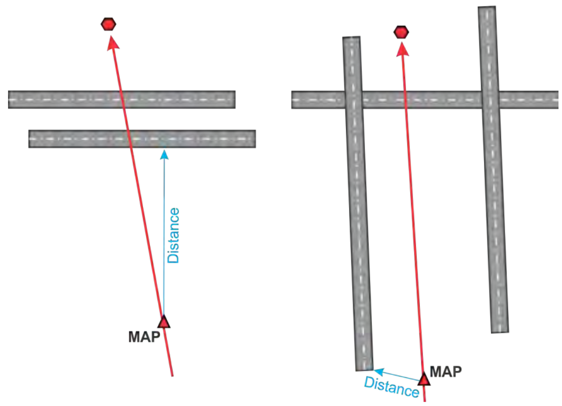
d. The "without approach lights" (see paragraph 3-3-2.a) visibility of the highest straight-in or sidestep line of minima (same CAT) published on the same chart.

Note: For dual minimums, the circling visibility is compared to the corresponding straight-in visibility set (for example, "UKENE FIX MINIMUMS" circling visibility compared to "UKENE FIX MINIMUMS" straight-in visibility).

Table 3-3-7. Authorized Circling Visibility Minimums

CAT →	A		B		C		D		E	
HAA	**SM**	**M**	**SM**	**M**	**SM**	**M**	**SM**	**M**	**SM**	**M**
350 - 449	1	1600								
450 - 549	1	1600	1	1600	1 1/2	2400				
550 - 600	1	1600	1	1600	1 1/2	2400	2	3200	2	3200
601 - 670	1	1600	1	1600	1 3/4	2800	2	3200	2 1/4	3600
671 – 740	1	1600	1	1600	2	3200	2 1/4	3600	2 1/2	4000
741 - 810	1	1600	1	1600	2 1/4	3600	2 1/2	4000	2 3/4	4400
811 - 880	1 1/4	2000	1 1/4	2000	2 1/2	4000	2 3/4	4400	3	4800
881 - 950	1 1/4	2000	1 1/4	2000	2 3/4	4400	3	4800	3	4800
951 and above	1 1/4	2000	1 1/2	2400	3	4800	3	4800	3	4800

Figure 3-3-5. MAP to Nearest Landing Surface, Circling Aligned



3-3-4. Establishing Sidestep Visibility Minimums. Apply the circling visual area (see paragraph 3-3-2.c(1)) to the sidestep runway and assess the 20:1 surface. If penetrated, publish a note denying the sidestep maneuver at night unless the obstacle is lighted. Use of VGSI may be used in lieu of obstruction lighting with approval (see paragraph 1-4-2).

a. Establish published visibility as follows:

(1) Determine visibility without approach lights by applying table 3-3-7.

(a) Substitute the sidestep height above touchdown (HAT) for HAA.

(b) If the HAT is less than 450 feet for CAT B and C, then the minimum visibility is 1 SM for CAT B, and 1 ½ SM for CAT C. If the HAT is less than 550 feet for CAT D and E, then the minimum visibility is 2 SM for both CATs.

(2) One-half SM visibility reduction is authorized when a full approach light system (FALS) is installed to the sidestep runway (see table 3-1-2). The minimum visibility after applying this reduction must not be less than 1 SM.

(3) When the sidestep runway threshold is offset/staggered, and is more than 1000 feet closer to the PFAF than the runway with course guidance, increase the published visibility by an additional 1/4 SM, or by the actual offset distance, whichever is greater.

(4) The published sidestep visibility must not be less than the highest straight-in visibility for the primary approach (for each CAT).

(5) Publish 1 SM visibility as RVR 5500 when the provisions of paragraph 3-1-2.b are met.

3-3-5. Fly Visual to Airport. Where the DA/MAP-to-LTP distance (straight-in procedures) or the MAP-to-nearest landing surface distance (circling procedures) exceeds 3 SM, and the DA/MDA is greater than 900 feet above airport elevation, 3 SM visibility may be established with approval (see paragraph 1-4-2). Such procedures must be annotated with "Fly Visual to Airport."

Section 3-4. Alternate Airport Minimums

3-4-1. Establishing Alternate Minimums. Publish alternate minimums at eligible airports and for eligible procedures whenever the ceiling and/or visibility (without approach lights) values are greater than the values specified in table 3-4-1 (see also Order 8260.19, paragraph 8-6-11). Publish PA alternate minimums separately from NPA alternate minimums when both types of procedures are published on the same chart.

Table 3-4-1. Standard Alternate Airport Minimums

Approach Type	Ceiling	Visibility
NPA or APV	800	2
PA	600	2

a. Determine the applicable ceiling and visibility (without approach lights) for comparison to table 3-4-1.

(1) Base alternate minimums on local altimeter setting minimums only.

(2) PA. For each approach CAT, select the PA's ceiling and the PA's visibility (without approach lights). When more than one line of PA minimums is published on the same chart, use the line with the higher HAT.

(3) NPA and APV. For each approach CAT, select the highest NPA or APV ceiling, and the highest NPA or APV visibility (without approach lights) for the procedure (including circling and/or sidestep minimums if applicable).

b. Establish the alternate ceiling minimum as the higher of the table 3-4-1 value or the ceiling selected in paragraph 3-4-1.a.

c. Establish the alternate visibility minimum as the higher of the table 3-4-1 value or the visibility selected in paragraph 3-4-1.a.

d. Publish both the alternate ceiling minimum and alternate visibility minimum if either of the values established in paragraph 3-4-1.b or 3-4-1.c exceed the standard values in table 3-4-1. For example, if the highest CAT A ceiling is 1000 feet, and the highest CAT A visibility is 1 ¾ SM, then the published CAT A alternate minimums would be 1000-2. If neither value exceeds the table 3-4-1 values, then do not publish alternate minimums for that approach CAT. Additional examples follow.

Examples:

ILS or LOC RWY 28L

Lines of Minimums	Ceiling and Visibility (no light)
S-ILS RWY 28L#	200 - 3/4[1]
S-ILS RWY 28L	800 - 2 3/4[2]
S-LOC 28L#	500 - 1 3/8[3]
S-LOC 28L	800 - 2[3]
CIRCLING	1600 - 3[4]
Alternate Minimums	
ILS	800 - 2 ¾
LOC	1600 – 3

1. Do not use this line of minimums since it is not the highest line of PA minimums.
2. Both the ceiling and visibility exceed table 3-4-1 (PA) values and must be published.
3. Neither the ceiling nor visibility is the highest LOC or Circling value published on the procedure.
4. Both the ceiling and visibility exceed table 3-4-1 NPA values and must be published as the LOC Alternate minimums.

RNAV (GPS) Y RWY 30

Lines of Minimums	Ceiling and Visibility (no light)
LPV DA	200-3/4[1]
LNAV/VNAV DA	300 – 7/8[1]
LNAV MDA	600 – 2 1/2[1]
CIRCLING	900 – 2 3/4[2]
Alternate Minimums	900 – 2 3/4[2]

1. Neither the ceiling nor visibility values are the highest values published on the procedure.
2. Both the ceiling and visibility exceed table 3-4-1 NPA values and must be published as the procedure's alternate minimums.

Section 3-5. Takeoff Minimums

3-5-1. Civil Standard Takeoff Minimums. Title 14 CFR part 91.175(f) defines civil takeoff minimums for aircraft operating under part 121, 125, 129, or 135 as shown in table 3-5-1. A ceiling value may also be required to see and avoid an obstacle. In this case, the published procedure must identify the location of the obstacle(s) that must be avoided. See Order 8260.46, Departure Procedure (DP) Program, for guidance on how and when other than standard takeoff minimums and/or obstacles are defined.

Table 3-5-1. Standard Civil Takeoff Minimums

Number of Engines	Visibility (SM)
1 or 2	1
3 or more	1/2
Helicopter	1/2

Chapter 4. On-Airport VOR (No PFAF)

Section 4-1. General Information

4-1-1. General. These criteria apply to procedures based on a VOR facility located on an airport in which no PFAF is established. This chapter divides criteria into a section for low altitude procedures and a section for high altitude teardrop turn procedures. These procedures must incorporate a PT or a teardrop turn. An on-airport facility is one which is located:

a. For straight-in approach. Within 1 NM of the nearest portion of the landing runway.

b. For circling approach. Within 1 NM of the nearest portion of the usable landing surface of the airport.

Section 4-2. Low Altitude Procedures

4-2-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

4-2-2. Initial Approach Segment. The IAF is received by overheading the navigation facility. The initial approach is a PT. Apply criteria in paragraph 2-4-5.

4-2-3. Intermediate Segment. This type of procedure has no intermediate segment. Upon completion of the PT, the aircraft is on final approach.

4-2-4. Final Approach Segment. The final approach begins where the PT intersects the FAC.

a. Alignment. The alignment of the FAC with the runway centerline determines whether a straight-in or circling-only approach may be established.

(1) Straight-in. The angle of convergence of the FAC and the extended runway centerline must not exceed 30 degrees. The FAC should be aligned to intersect the extended runway centerline 3000 feet outward from the LTP. When an operational advantage can be achieved, this point of intersection may be established at any point between the LTP and a point 5200 feet outward from the LTP. Also, where an operational advantage can be achieved, a FAC which does not intersect the runway centerline or intersects it at a distance greater than 5200 feet from the LTP may be established, provided that such course lies within 500 feet laterally of the extended runway centerline at a point 3000 feet outward from the LTP. Straight-in category C, D, and E minimums are not authorized when the final approach course intersects the extended runway centerline at an angle greater than 15 degrees and a distance less than 3000 feet (see figure 4-2-1).

(2) Circling approach. When the FAC alignment does not meet the criteria for straight-in landing, only a circling approach is authorized. Course alignment should be made to the center of the landing area; however, the use of any radial is permitted when an operational advantage can be achieved. It is not a requirement for the final approach course radial to pass through a portion of the useable landing surface (see figure 4-2-2).

Figure 4-2-1. Alignment Options for Final Approach Course, On-Airport VOR, No PFAF, Straight-in Approach Procedure

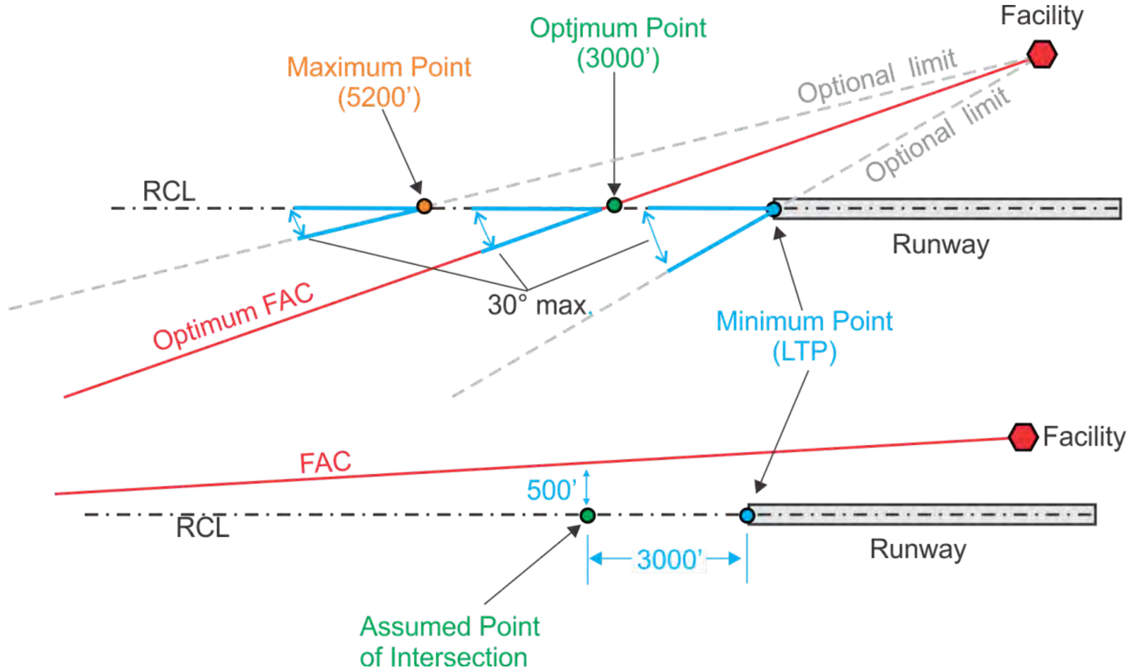
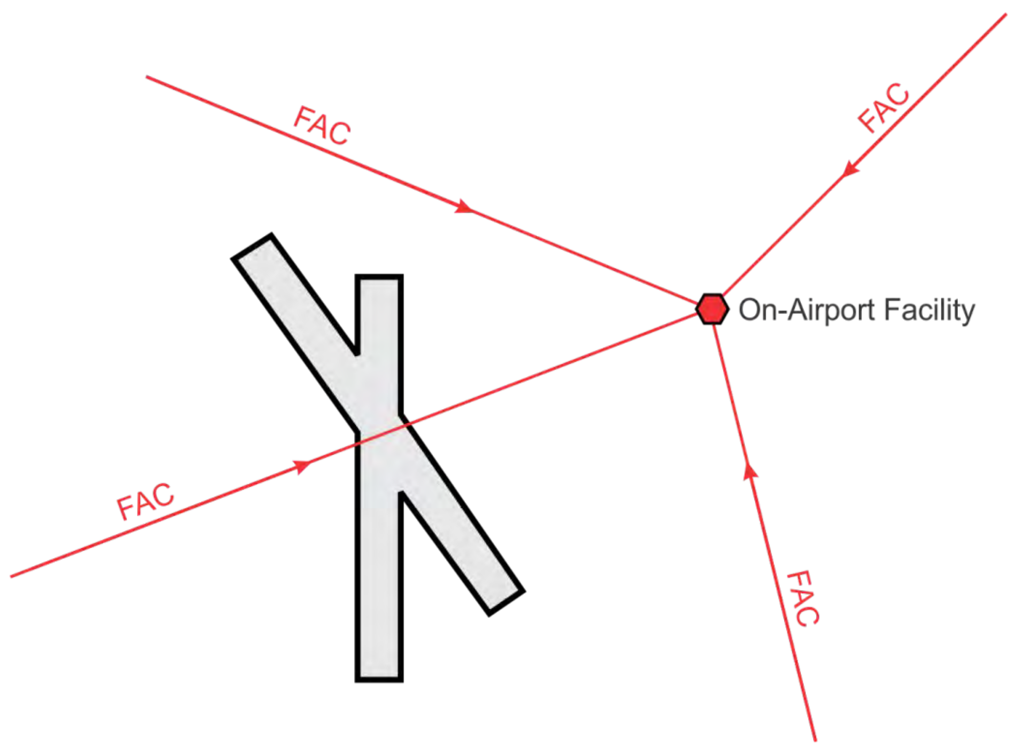
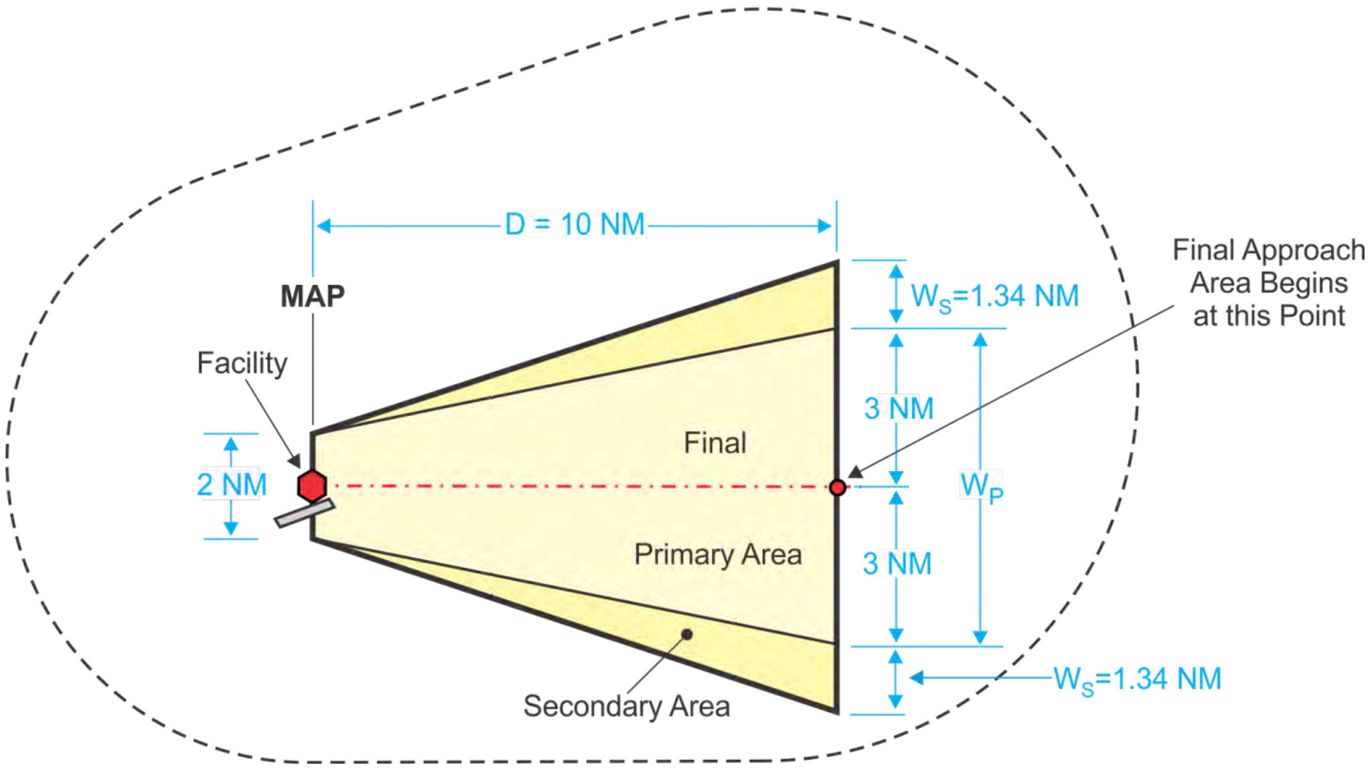


Figure 4-2-2. Alignment Options for Final Approach Course, On-Airport VOR, No PFAF, Circling Approach Procedure



b. Area. Figure 4-2-3 illustrates the final approach primary and secondary areas. The primary area is longitudinally centered on the FAC and is 10 NM long. The primary area is 2 NM wide at the facility and expands uniformly to 6 NM at 10 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility and expands uniformly to 1.34 NM on each side of the primary area at 10 NM from the facility. When the 5-NM PT is used, only the inner 5 NM of the final approach area need be considered. Apply formula 4-2-1 and formula 4-2-2 to determine primary and secondary widths (as applicable).

Figure 4-2-3. Final Approach Primary and Secondary Areas. On-Airport VOR, No PFAF



Formula 4-2-1. Final Approach Primary Area Half Width

$$\frac{1}{2}W_P = 0.2 \times D + 1.0$$

Where:
D = Distance (NM) from facility measured along FAC

Formula 4-2-2. Final Approach Secondary Area Width

$$W_S = 0.134 \times D$$

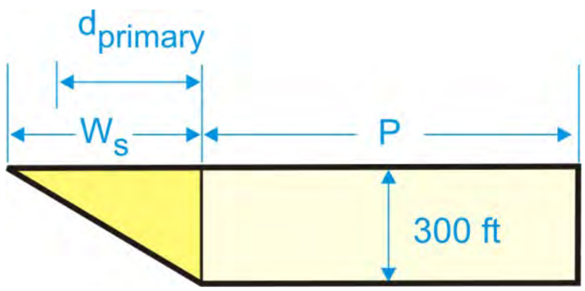
Where:
D = Distance (NM) from facility measured along FAC

c. Obstacle clearance.

(1) Straight-in. The minimum ROC in the primary area is 300 feet. The minimum ROC in the secondary area is 300 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 4-2-4). The minimum ROC at any given point in the secondary area is determined by formula 4-2-3. Adjustments must be applied as specified in paragraph 3-2-2.

(2) Circling approach. In addition to the minimum requirements specified in paragraph 4-2-4.c(1), apply obstacle clearance criteria in section 2-7.

Figure 4-2-4. Final Approach Area ROC



Formula 4-2-3. Final Approach Secondary Area ROC

$$ROC_{secondary} = 300 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge
W_S = Total width of the secondary area (feet)

d. PT altitude.

(1) Straight-in. The PT completion altitude must be within 1500 feet of the MDA (1000 feet with a 5-NM PT), provided the distance from the facility to the point where the final approach course intersects the runway centerline does not exceed 2 NM. When this distance exceeds 2 NM, the maximum difference between the PT completion altitude and the MDA must be reduced at the rate of 25 feet for each one-tenth of a NM in excess of 2 NM (see figure 4-2-5).

Note: For straight-in procedures in which the final approach does not intersect the extended runway centerline within 5200 feet of the runway threshold [see paragraph 4-2-4.a(1)] the assumed point of intersection for computing the distance from the facility is 3000 feet from the runway threshold (see figure 4-2-1).

(2) Circling. For a circling only procedure, the PT completion altitude must be within 1500 feet of the MDA (1000 feet with a 5-NM PT), provided the distance from the facility to a point where the final approach course intersects the first usable portion of the landing surface does not exceed 2 NM. Where the final approach course does not intersect the landing surface, the 2-NM distance limitation applies as measured from the facility to a point on the FAC equal to

the distance from the PT completion point (start of the final segment) to the nearest landing surface authorized for landing (see figure 4-2-6). In all cases, when the applicable distance exceeds 2 NM, the maximum difference between the PT completion altitude and the MDA must be reduced at the rate of 25 feet for each one-tenth of a NM in excess of 2 NM.

Note: If the distance from the PT completion point and the nearest landing surface exceeds the PT distance, then no reduction between the PT completion altitude and MDA is necessary.

Figure 4-2-5. PT Altitude, On-Airport VOR, No PFAF

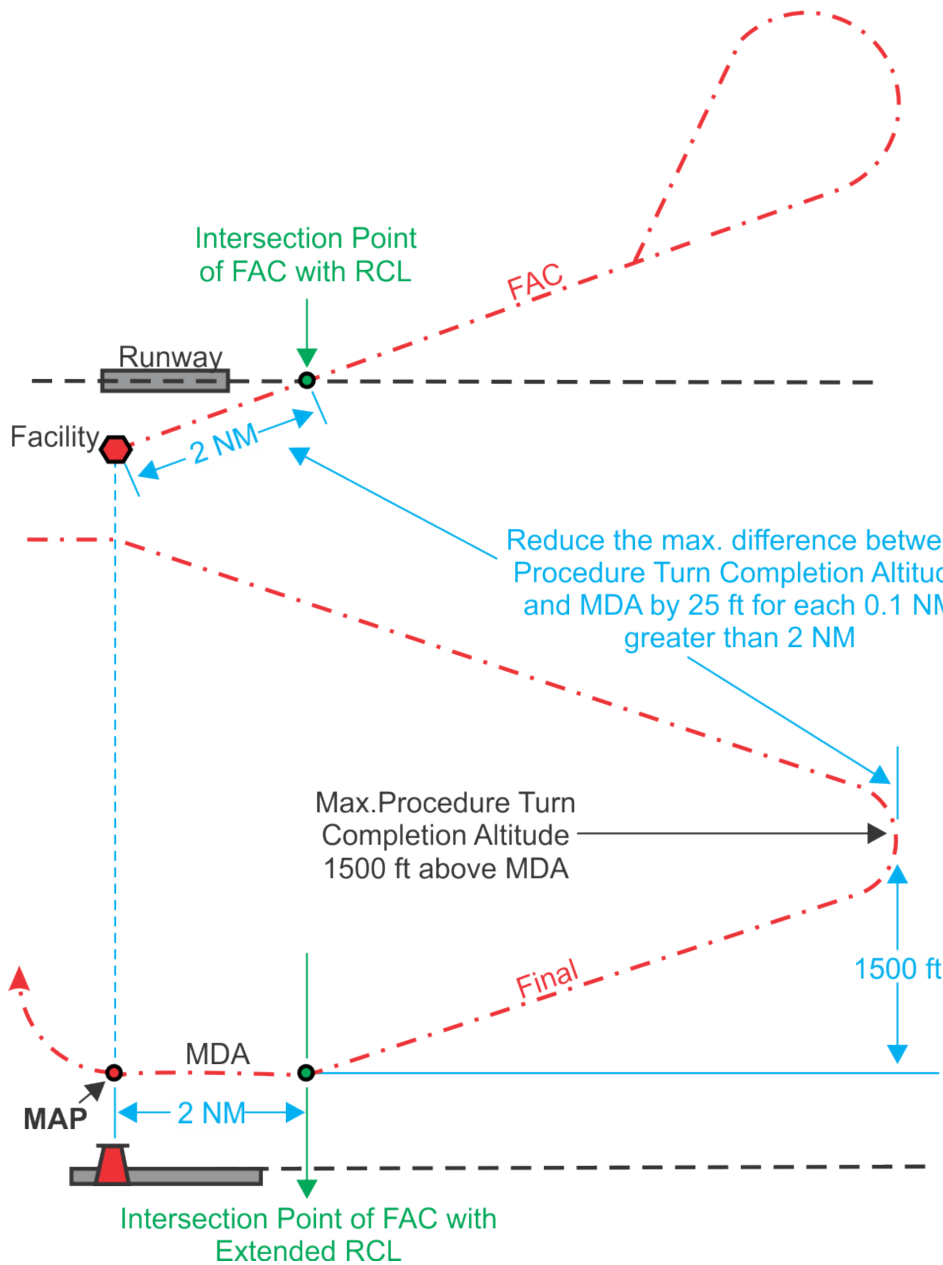
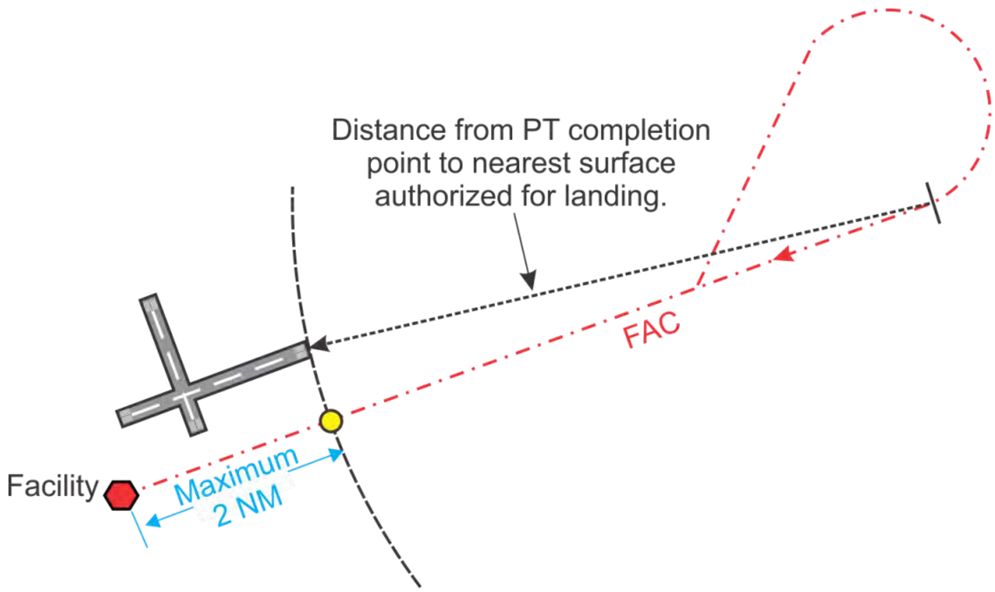
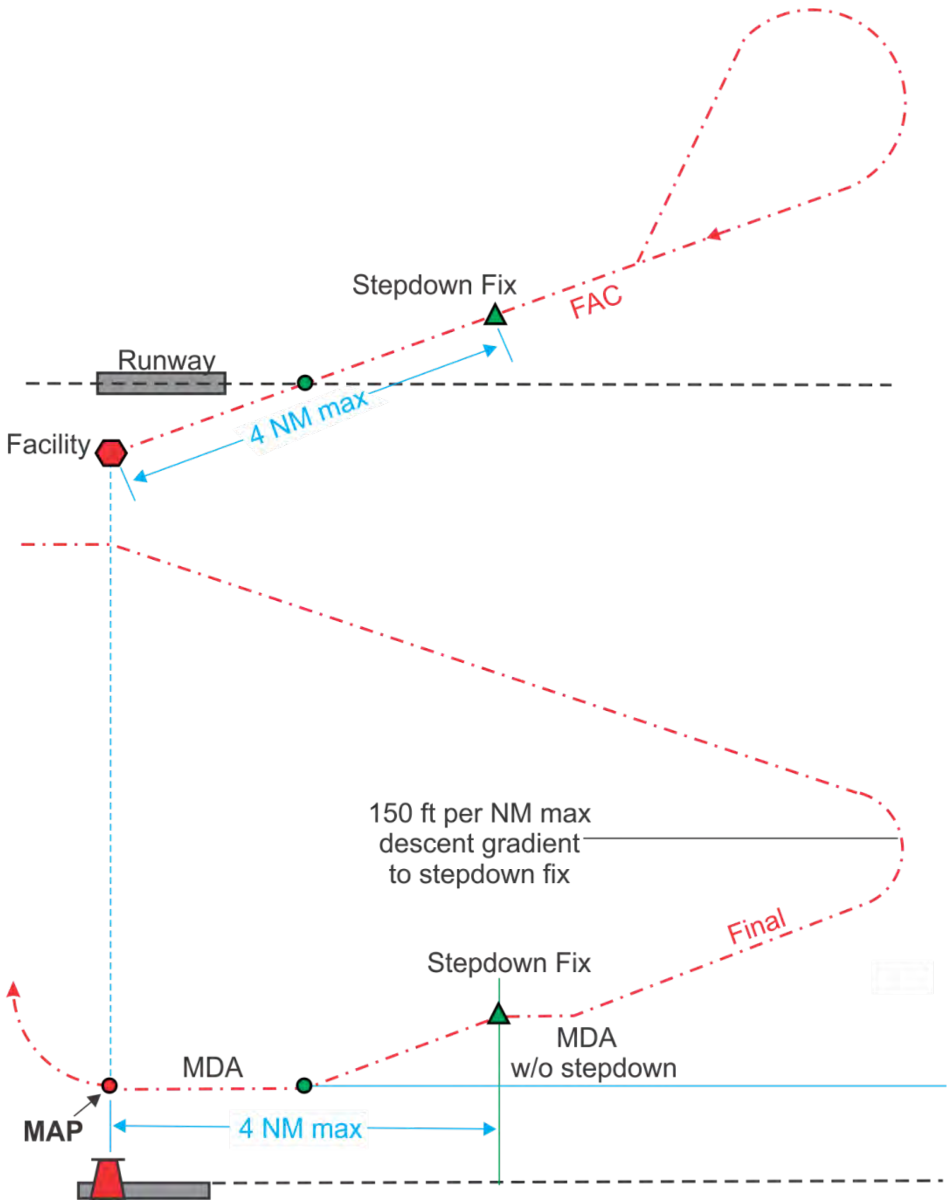


Figure 4-2-6. PT Altitude, Circling



e. Use of a stepdown fix. Use of a stepdown fix (see paragraph 2-9-9.c) is permitted provided the distance from the facility to the stepdown fix does not exceed 4 NM. The descent gradient between the PT completion altitude and stepdown fix altitude must not exceed 150 ft/NM. Calculate the descent gradient based upon the difference in PT completion altitude minus stepdown fix altitude, divided by the specified PT distance, minus the facility to stepdown fix distance (see figure 4-2-7). Minimum ROC between the stepdown fix and the MAP/FEP is 250 feet plus adjustments as specified in paragraph 3-2-2.

Figure 4-2-7. Use of Stepdown Fix, On-Airport VOR, No PFAF



f. MDA. Apply criteria in section 3-2.

4-2-5. Missed Approach Segment. Apply criteria in section 2-8. The MAP is the facility (see figure 4-2-5). The missed approach surface commences over the facility at the required height (see paragraph 2-8-5).

Section 4-3. High Altitude Teardrop Turn

4-3-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

4-3-2. Initial Approach Segment. The IAF is received by overheading the navigation facility. The initial approach is a teardrop turn. Apply criteria in paragraph 2-4-6.

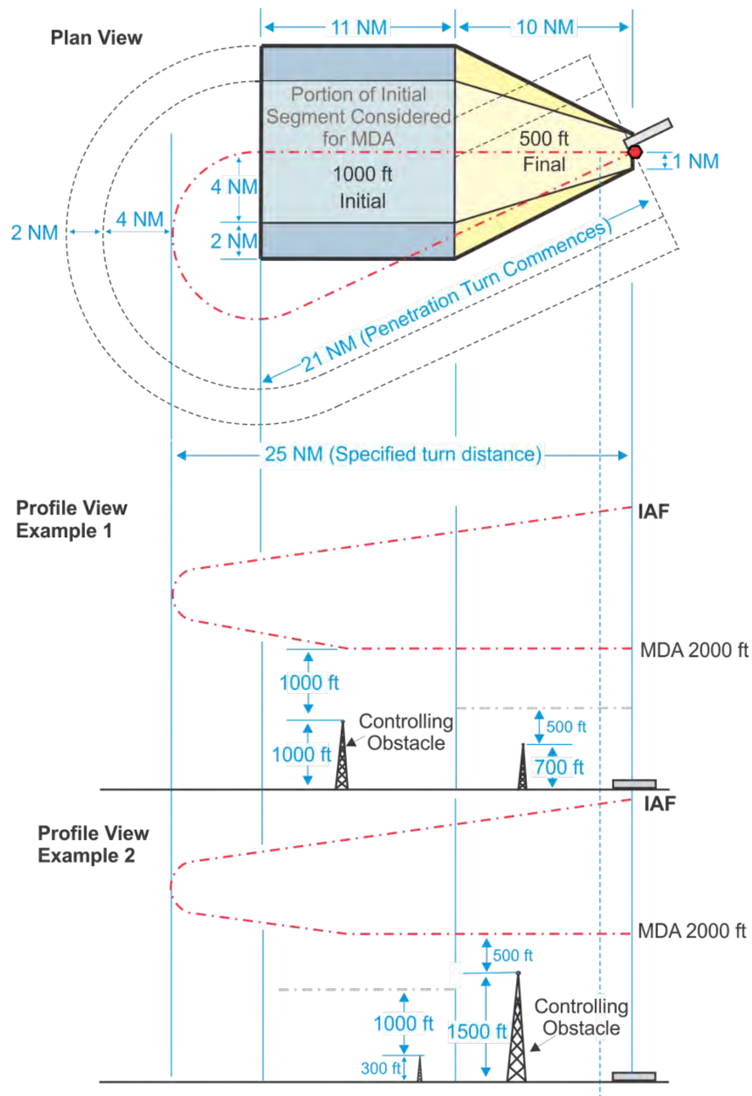
4-3-3. Intermediate Segment. This procedure has no intermediate segment. Upon completion of the teardrop turn, the aircraft is on final approach.

4-3-4. Final Approach Segment. An aircraft is considered to be on final approach upon completion of the teardrop turn. However, the final approach segment begins on the FAC 10 NM from the facility. That portion of the teardrop turn procedure prior to the 10-NM point is treated as the initial approach segment (see figure 4-3-1).

a. Alignment. Apply paragraph 4-2-4.a.

b. Area. Figure 4-3-1 illustrates the final approach primary and secondary areas. The primary area is longitudinally centered on the FAC and is 10 NM long. The primary area is 2 NM wide at the facility and expands uniformly to 8 NM at a point 10 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility, and expands uniformly to 2 NM each side of the primary area at a point 10 NM from the facility.

Figure 4-3-1. Teardrop Turn, On-Airport VOR, No PFAF



c. Obstacle clearance.

(1) Straight-in. The minimum ROC in the primary area is 500 feet. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge. Use formula 2-4-1 to determine obstacle clearance at any given point in the secondary area. Adjustments must be applied as specified in paragraph 3-2-2.

(2) Circling approach. In addition to the minimum requirements specified in paragraph 4-3-4.c(1), apply obstacle clearance criteria in section 2-7.

d. Teardrop turn altitude (descent gradient). The teardrop turn completion altitude must be at least 1000 feet, but not more than 4000 feet above the MDA on final approach.

e. Use of a stepdown fix. The use of the stepdown fix (see paragraph 2-9-9.c) is permitted, provided the distance from the facility to the stepdown fix does not exceed 10 NM.

f. MDA. In addition to the normal obstacle clearance requirement of the final approach segment (see paragraph 4-3-4.c), the MDA specified must provide at least 1000 feet of clearance over obstacles in the portion of the initial approach segment between the final approach segment and the point where the assumed teardrop turn track intercepts the inbound course (see figure 4-3-1).

4-3-5. Missed Approach Segment. Apply criteria in section 2-8. The MAP is the facility (see figure 4-3-1). The missed approach surface must commence over the facility at the required height (see paragraph 2-8-5).

Chapter 5. TACAN, VOR/DME, and VOR with PFAF

General Information

5-1-1. General. This chapter applies to approach procedures that incorporate a PFAF where final approach guidance is based on a VOR, TACAN, or VORTAC facility. Section 5-2 provides criteria for VOR procedures which do not use DME as the primary method for establishing fixes. Section 5-3 provides criteria for VOR and TACAN procedures which use collocated, frequency paired DME as the sole method of establishing fixes. When both the VOR and TACAN azimuth elements of a VORTAC station will support it, publish a single procedure identified as a, "VOR or TACAN" (see paragraph 1-6-4). Such a procedure may be flown using either a VOR/DME or TACAN airborne receiver and must satisfy TACAN terminal area fix requirements (see paragraph 2-9-7.d).

Section 5-2. VOR with PFAF

5-2-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

5-2-2. Initial Approach Segment. Apply criteria in section 2-4 (see figure 5-2-1 and figure 5-2-2).

5-2-3. Intermediate Approach Segment. Apply criteria in section 2-5 (see figure 5-2-1 and figure 5-2-2).

5-2-4. Final Approach Segment. The final approach may be made either “FROM” or “TOWARD” the facility. The final approach segment begins at the PFAF and ends at the FEP or MAP, whichever is encountered last.

a. Alignment. The alignment of the FAC with the runway centerline determines whether a straight-in or circling-only approach may be established. The alignment criteria differ depending on whether the facility is OFF or ON the airport (see paragraph 4-1-1 for determination of an on-airport facility).

(1) Off-airport facility.

(a) Straight-in. The angle of convergence of the FAC and the extended runway centerline must not exceed 30 degrees. The FAC should be aligned to intersect the LTP. However, when an operational advantage can be achieved, the point of intersection may be established as much as 3000 feet outward from the LTP (see figure 5-2-3).

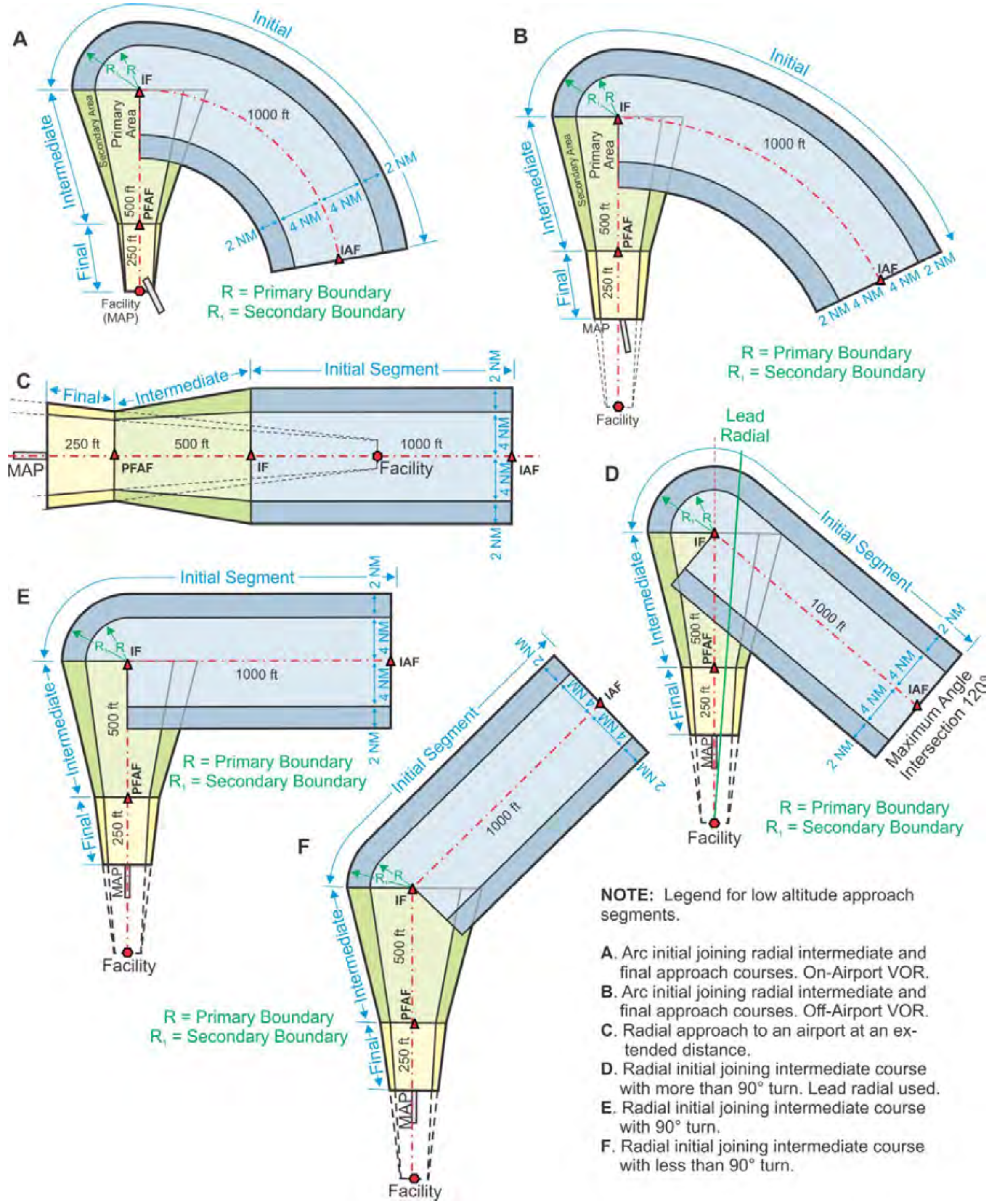
(b) Circling approach. When the FAC alignment does not meet the criteria for a straight-in landing, only a circling approach is authorized, and the course alignment should be made to the center of the landing area. When an operational advantage can be achieved, the FAC may be aligned to any portion of the usable landing surface (see figure 5-2-4).

(2) On-airport facility.

(a) Straight-in. The angle of convergence of the FAC and the extended runway centerline must not exceed 30 degrees. The FAC should be aligned to intersect the extended runway centerline 3000 feet outward from the LTP. When an operational advantage can be achieved, this point of intersection may be established at any point between the LTP and a point 5200 feet outward from the LTP. Also, where an operational advantage can be achieved a FAC which does not intersect the runway centerline, or which intersects it at a distance greater than 5200 feet from the LTP, may be established, provided that such a course lies within 500 feet laterally of the extended runway centerline at a point 3000 feet outward from the LTP (see figure 5-2-5).

(b) Circling approach. When the FAC alignment does not meet the criteria for a straight-in landing, only a circling approach is authorized. Course alignment should be made to the center of the landing area; however, the use of any radial is permitted when an operational advantage can be achieved. It is not a requirement for the final approach course radial to pass through a portion of the useable landing surface (see figure 5-2-4).

Figure 5-2-1. Typical Low Altitude Approach Segments. VOR with PFAF



NOTE: Legend for low altitude approach segments.

A. Arc initial joining radial intermediate and final approach courses. On-Airport VOR.
B. Arc initial joining radial intermediate and final approach courses. Off-Airport VOR.
C. Radial approach to an airport at an extended distance.
D. Radial initial joining intermediate course with more than 90° turn. Lead radial used.
E. Radial initial joining intermediate course with 90° turn.
F. Radial initial joining intermediate course with less than 90° turn.

Figure 5-2-2. Typical High Altitude Segments. VOR with PFAF

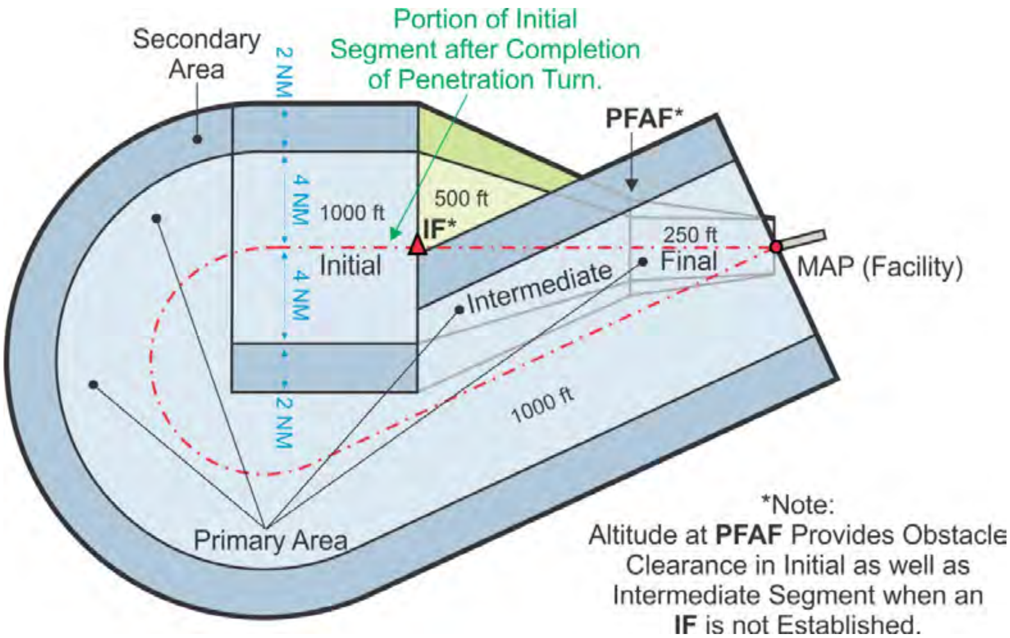


Figure 5-2-3. Alignment Options for Final Approach Course. Off-Airport VOR with PFAF. Straight-In Approach

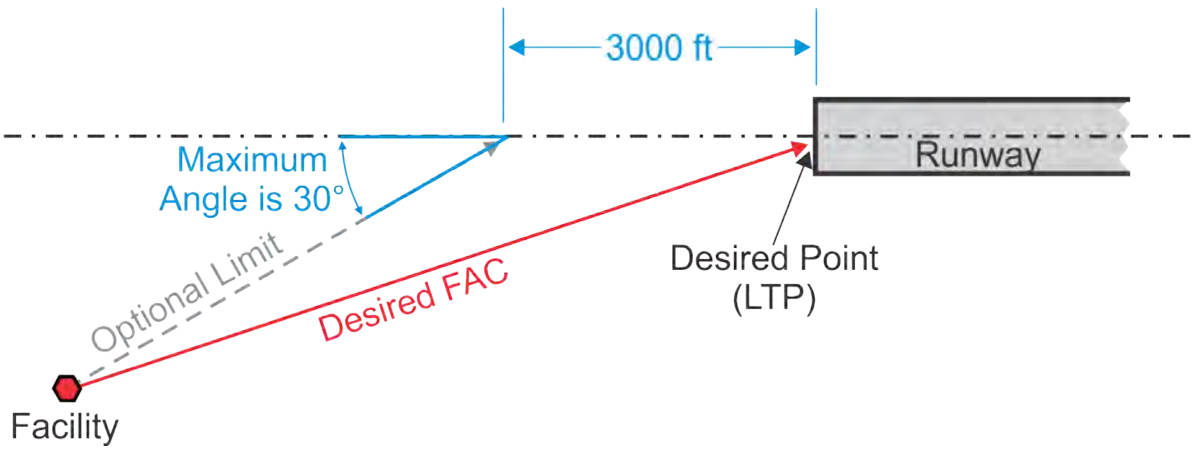


**Figure 5-2-4. Alignment Options or Final Approach Course.
On- and Off-Airport VOR with PFAF. Circling Approach**

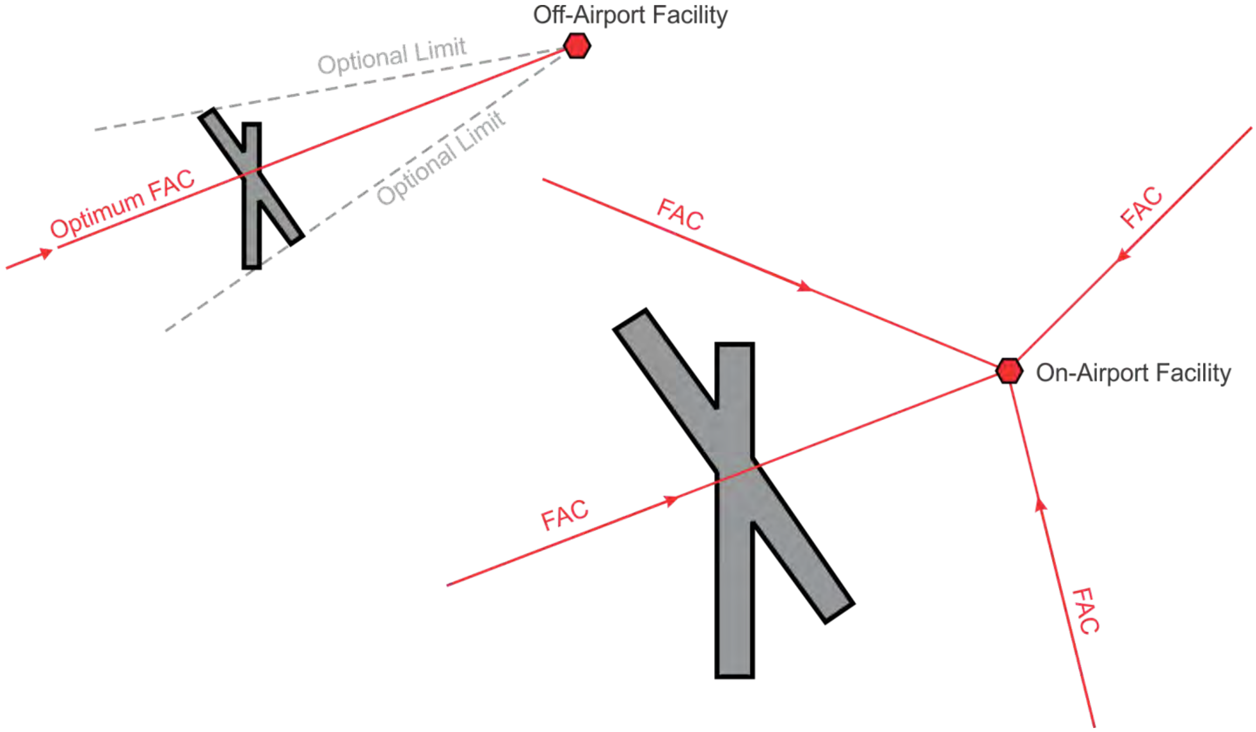
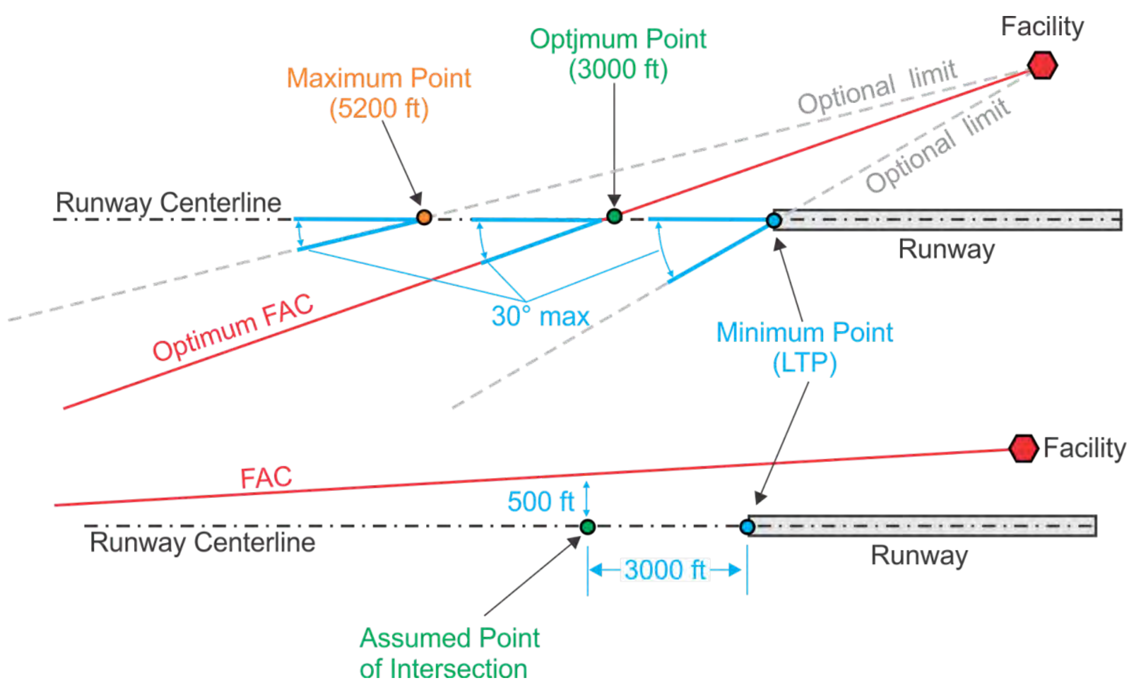
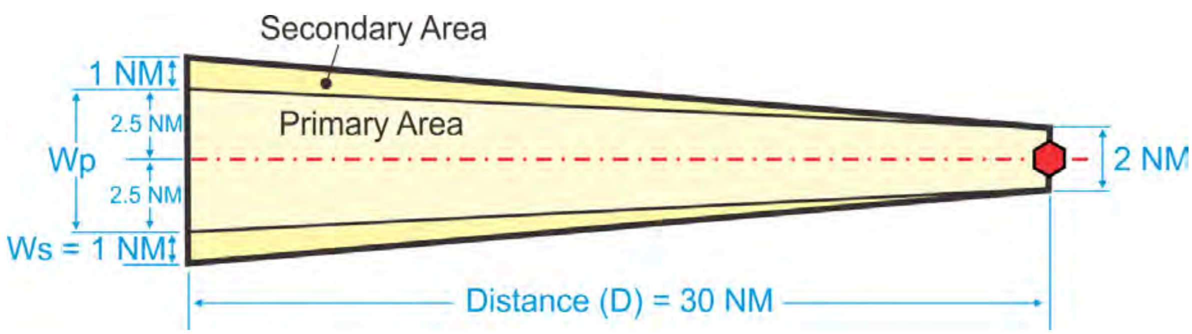


**Figure 5-2-5. Alignment Options for Final Approach Course.
On-Airport VOR with PFAF. Straight-In Approach**



b. Area. The area considered for obstacle clearance in the final approach segment starts at the earliest point the PFAF can be received, and ends at the FEP or MAP, whichever is encountered last. It is a portion of a 30-NM long trapezoid (see figure 5-2-6) which is made up of primary and secondary areas. The primary area is centered longitudinally on the FAC. It is 2 NM wide at the facility, and expands uniformly to 5 NM wide at 30 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility and expands uniformly to 1 NM on each side of the primary area at 30 NM from the facility (formula 5-2-1 and formula 5-2-2 apply). Final approaches may be made to airports a maximum of 30 NM from the facility (see figure 5-2-7). The optimum length of the final approach segment is 5 NM. The maximum length is 10 NM. The minimum length of the final approach segment must provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the facility. Table 5-2-1 must be used to determine the minimum length to regain the course.

Figure 5-2-6. Final Approach Trapezoid. VOR with PFAF



Formula 5-2-1. Final Approach Primary Area Half Width

$$\frac{1}{2}W_P = 0.05 \times D + 1$$

Where:

D = Distance (NM) from facility

Formula 5-2-2. Final Approach Secondary Area Width

$$W_S = 0.0333 \times D$$

Where:

D = Distance (NM) from facility measured along FAC

Figure 5-2-7. Typical Straight-in Final Approaches VOR with PFAF

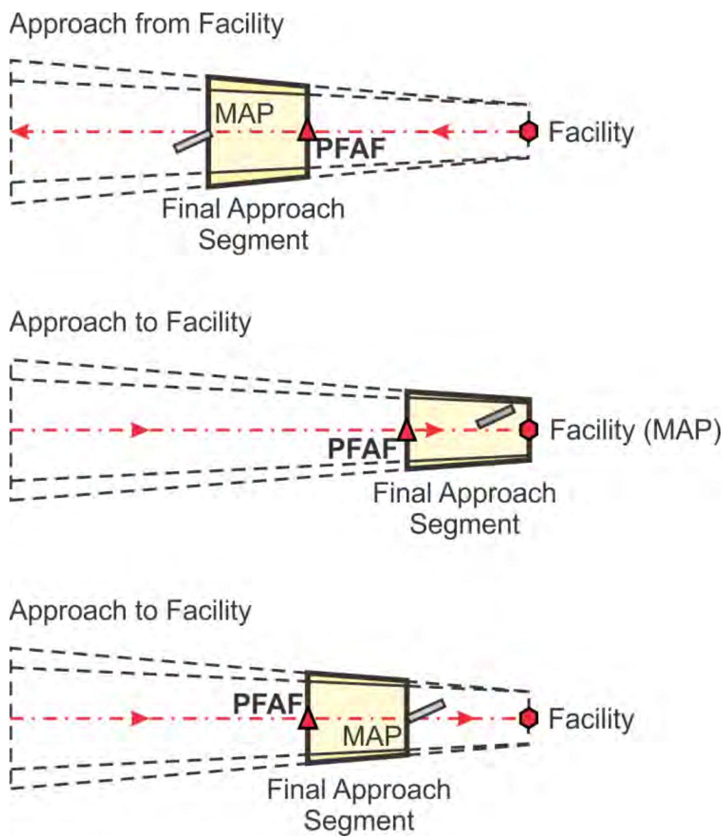


Table 5-2-1. Minimum Length of Final Approach Segment-VOR (NM)

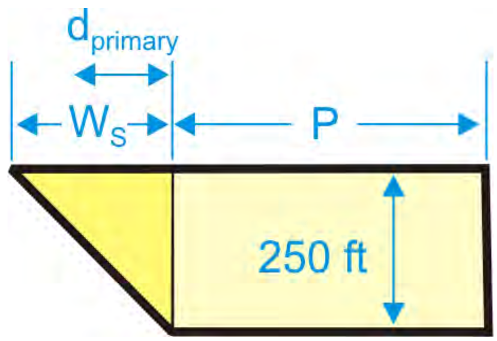
CAT	MAGNITUDE OF TURN OVER FACILITY (DEGREES)		
	10	**20**	**30**
A	1.0	1.5	2.0
B	1.5	2.0	2.5
C	2.0	2.5	3.0
D	2.5	3.0	3.5
E	3.0	3.5	4.0

Note: This table may be interpolated. If the minimum length specified in the table is not available, straight-in minimums are not authorized (see figure 5-2-7 for typical final approach areas).

c. Obstacle clearance.

(1) Straight-in landing. The minimum obstacle clearance in the primary area is 250 feet. The ROC in the secondary area is 250 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 5-2-8). The minimum ROC at any given point in the secondary area is determined by formula 5-2-3. Apply adjustments as specified in paragraph 3-2-2.

Figure 5-2-8. Final Approach Area ROC



Formula 5-2-3. Final Approach Secondary Area ROC

$$ROC_{secondary} = 250 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

(2) Circling Approach. In addition to the minimum requirements specified in paragraph 5-2-4.c(1), apply obstacle clearance criteria in section 2-7.

d. Vertical descent angle. Apply criteria in paragraphs 2-6-2 and 2-6-4.

e. Use of fixes. Apply criteria in section 2-9. Where a procedure is based on a PT and an on-airport facility is the PT fix, the distance from the facility to the PFAF must not exceed 4 NM.

f. MDA. Apply criteria in section 3-2.

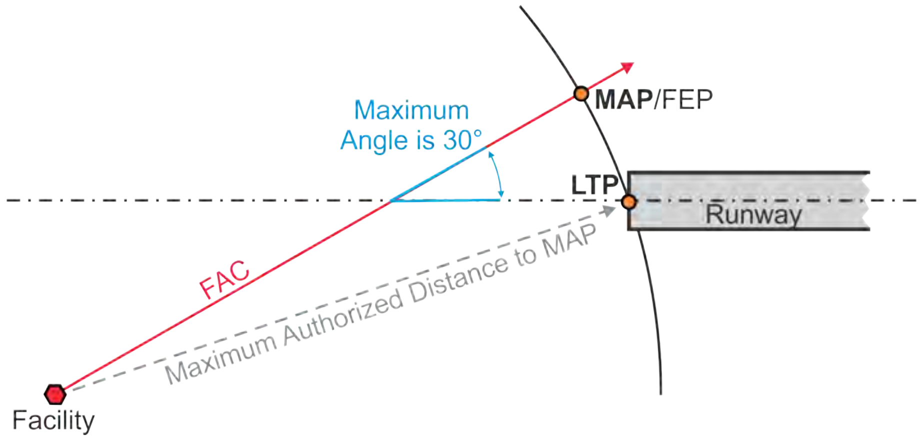
5-2-5. Missed Approach Segment. Apply criteria in section 2-8. For VOR procedures, the MAP and surface must be established as follows:

a. Off-airport facilities.

(1) Straight-in. The MAP is a point on the FAC which is not farther from the PFAF than the FEP (see figure 5-2-9). The missed approach surface must commence over the MAP at the required height (see paragraph 2-8-5).

(2) Circling approach. The MAP is a point on the FAC which is not farther from the PFAF than the FEP. The missed approach surface must commence over the MAP at the required height (see paragraph 2-8-5).

Figure 5-2-9. MAP, Off-Airport VOR with PFAF



b. On-airport facilities. The MAP is a point on the FAC which is not farther from the PFAF than the facility. The missed approach surface must commence over the MAP at the required height (see paragraph 2-8-5).

Section 5-3. TACAN and VOR/DME

5-3-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

5-3-2. Initial Segment. Due to the fixing capability of TACAN and VOR/DME, a PT initial approach may not be required. Apply criteria in section 2-4.

5-3-3. Intermediate Segment. Apply criteria in section 2-5.

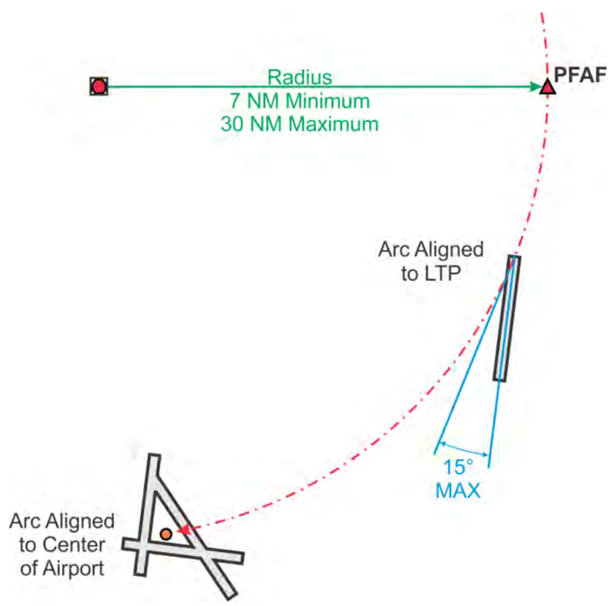
5-3-4. Final Approach Segment. TACAN and VOR/DME final approaches may be based either on arcs or radials. The final approach begins at a PFAF and ends at the MAP. The MAP is always marked with a fix.

a. Radial final approach. Apply criteria in paragraph 5-2-4.

b. Arc final approach. The final approach arc must be a continuation of the intermediate arc. It must be specified in NM and tenths thereof. The minimum arc distance from the facility is 7 NM (15 NM for high altitude procedures) and the maximum is 30 NM. No turns are permitted over the PFAF.

(1) Alignment. For straight-in approaches, the final approach arc must pass through the LTP when the angle of convergence of the runway centerline and the tangent of the arc does not exceed 15 degrees. When the angle exceeds 15 degrees, the final approach arc must be aligned to pass through the center of the airport and only circling minimums are authorized (see figure 5-3-1).

Figure 5-3-1. Final Approach Alignment. Arc Aligned to Threshold/Center of Airport. TACAN or VOR/DME



(2) Area. The area considered for obstacle clearance in the arc final approach segment starts at the earliest point the PFAF can be received and ends at the FEP or MAP, whichever is encountered last. It should not be more than 5 NM long; apply formula 5-3-1 to calculate the length. The area is divided into primary and secondary areas. The primary area is 8 NM wide, and extends 4 NM on either side of the arc. A secondary area is on each side of the primary area. The secondary areas are 2 NM wide on each side of the primary area (see figure 5-3-2).

Formula 5-3-1. Length of an Arc Final Approach Segment (NM)

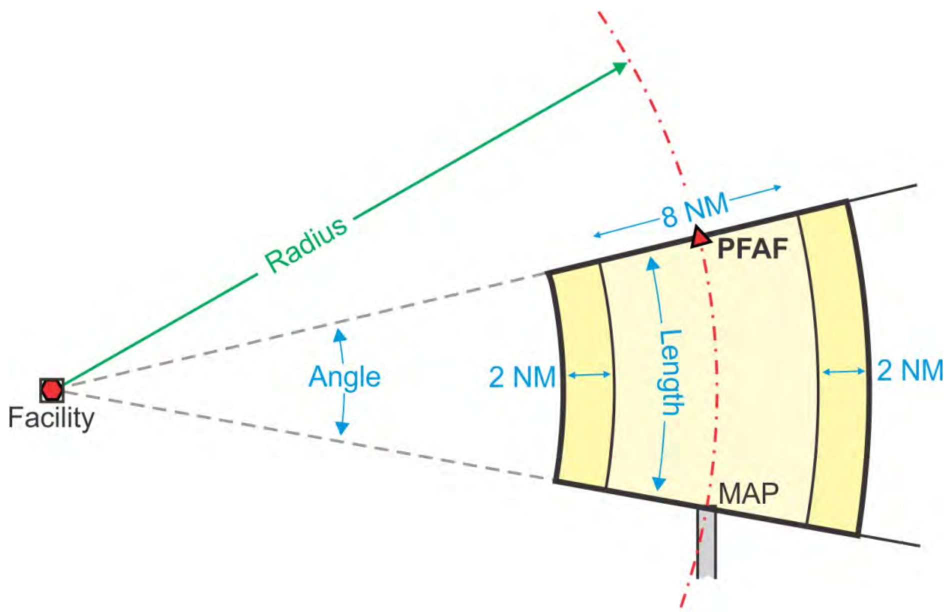
$$L = \frac{R}{57.3} \times \theta$$

Where:

R = Arc radius (NM)

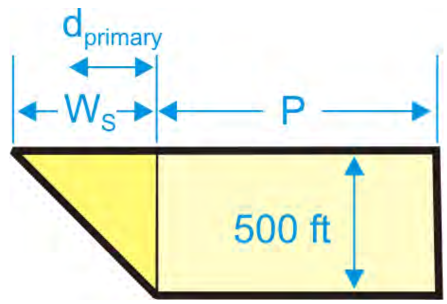
θ = Angle between start and end points

Figure 5-3-2. Arc Final Approach Area. TACAN or VOR/DME



(3) Obstacle clearance. The minimum obstacle clearance in the primary area is 500 feet. The ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 5-3-3). The minimum ROC at any given point in the secondary area is determined by formula 5-3-2. Adjustments must be applied as specified in paragraph 3-2-2.

Figure 5-3-3. Arc Final Approach Area ROC. TACAN or VOR/DME



Formula 5-3-2. Arc Final Approach Secondary Area ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

(4) Vertical descent angle. Apply criteria in paragraphs 2-6-2 and 2-6-4, with the following exceptions.

(a) For straight-in approaches, determine the distance as measured along the FAC from the PFAF (stepdown fix if applicable) to the LTP and use in place of D_{FIX} within formulas 2-6-1, 2-6-2, and 2-6-4.

(b) For circling approaches, determine the distance as measured along the FAC from the PFAF (stepdown fix if applicable) to the point where a line drawn perpendicular to the FAC passes through the nearest landing surface authorized for landing and use in place of D_{FIX} within formula 2-6-3.

(5) Use of fixes. Fixes along an arc are restricted to those formed by radials from the VORTAC facility which provides the DME signal. Apply criteria in section 2-9.

(6) MDA. Straight-in MDAs must not be specified lower than circling for arc procedures. Apply criteria in section 3-2.

5-3-5. Missed Approach Segment. Apply criteria in section 2-8. The MAP must be a radial/DME fix. The missed approach surface must commence over the fix and at the required height. Apply criteria in paragraph 5-2-5, except the MAP for a straight-in approach and for a circling approach is a point on the FAC which is not farther from the PFAF than the "D_{FIX}" distance as determined in paragraph 5-3-4.b(4).

Note: The arc missed approach course may be a continuation of the final approach arc.

Chapter 6. NDB Procedures On-Airport Facility (No PFAF)

Section 6-1. General Information

6-1-1. General. These criteria apply to NDB procedures based on a facility located on the airport in which no PFAF is established. This chapter divides criteria into a section for low altitude procedures and a section for high altitude teardrop turn procedures. These procedures must incorporate a PT or a teardrop turn. For determination of an on-airport facility, see paragraph 4-1-1.

Section 6-2. Low Altitude Procedures

6-2-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

6-2-2. Initial Approach Segment. The IAF is received by overheading the navigation facility. The initial approach is a PT. Apply criteria in paragraph 2-4-5.

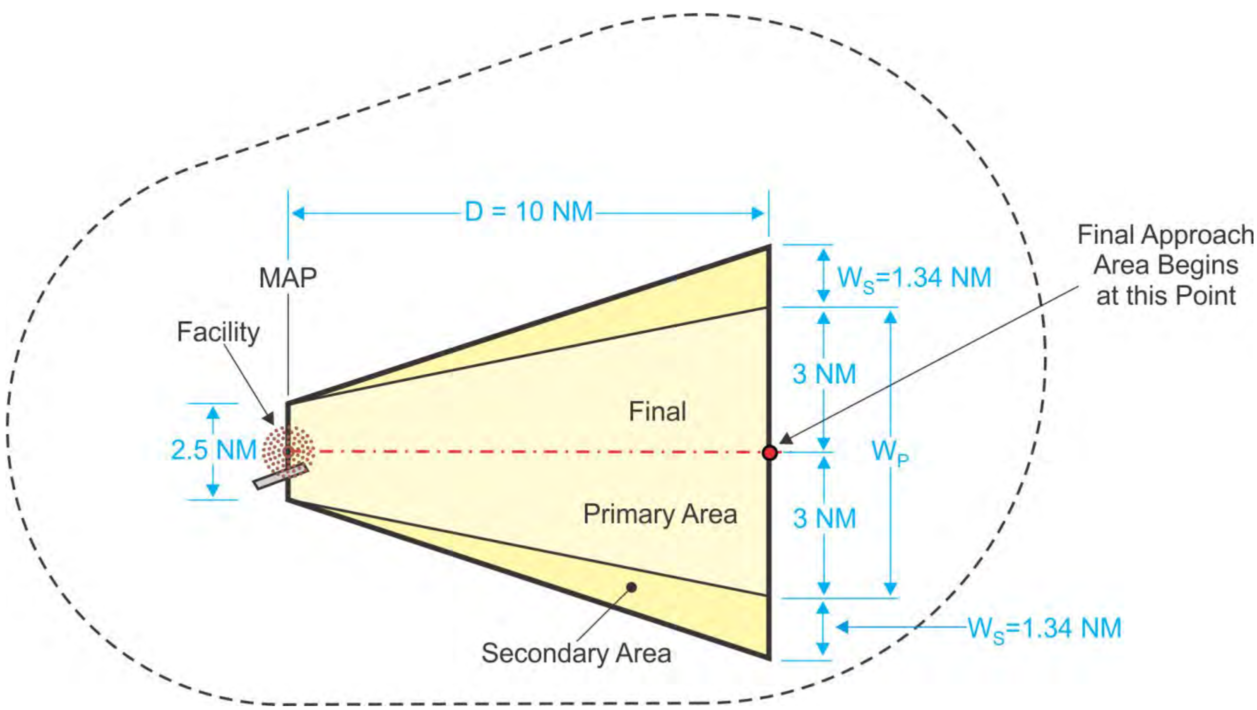
6-2-3. Intermediate Segment. This type of procedure has no intermediate segment. Upon completion of the PT, the aircraft is on final approach.

6-2-4. Final approach segment. The final approach begins where the PT intersects the FAC.

a. Alignment. The alignment of the FAC with the runway centerline determines whether a straight-in or circling-only approach may be established. Apply criteria in paragraphs 4-2-4.a(1) and 4-2-4.a(2).

b. Area. Figure 6-2-1 illustrates the final approach primary and secondary areas. The primary area is longitudinally centered on the FAC and is 10 NM long. The primary area is 2.5 NM wide at the facility and expands uniformly to 6 NM wide at 10 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility, and expands uniformly to 1.34 NM on each side of the primary area at 10 NM from the facility. When the 5-NM PT is used, only the inner 5 NM of the final approach area need be considered. Formula 6-2-1 and formula 6-2-2 apply.

Figure 6-2-1. Final Approach Primary and Secondary Areas. On-Airport NDB. No PFAF.



Formula 6-2-1. Final Approach Primary Area Half Width

$$\frac{1}{2}W_P = 0.175 \times D + 1.25$$

Where:

D = Distance (NM) from facility measured along FAC

Formula 6-2-2. Final Approach Secondary Area Width

$$W_S = 0.134 \times D$$

Where:

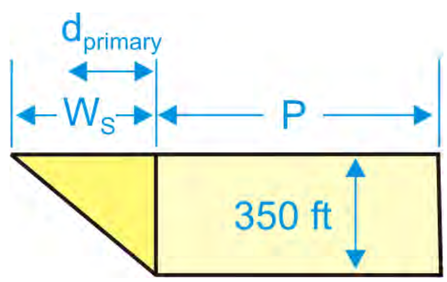
D = Distance (NM) from facility measured along FAC

c. Obstacle clearance.

(1) Straight-in. The minimum ROC in the primary area is 350 feet. The minimum ROC in the secondary area is 350 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 6-2-2). The minimum ROC at any given point in the secondary area is determined by formula 6-2-3. Adjustments must be applied as specified in paragraph 3-2-2.

(2) Circling approach. In addition to the requirements specified in paragraph 6-2-4.c(1), apply obstacle clearance criteria in section 2-7.

Figure 6-2-2. Low Altitude Final Approach Area ROC



Formula 6-2-3. Final Approach Secondary Area ROC

$$ROC_{secondary} = 350 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

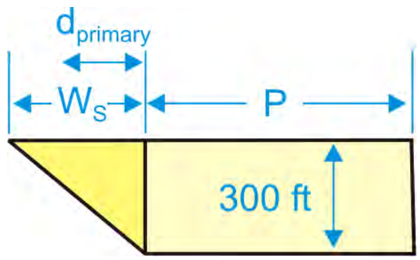
Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

Exception: Military procedures annotated “Not For Civil Use” may apply 300 feet of ROC in the primary area and 300 feet at the inner edge tapering uniformly to zero feet at the outer edge in the secondary area (see figure 6-2-3). Use formula 6-2-4 to determine obstacle clearance at any given point in the secondary area.

Figure 6-2-3. Low Altitude Military Final Approach Area ROC



Formula 6-2-4. Low Altitude Military Final Approach Secondary Area ROC

$$ROC_{secondary} = 300 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

d. PT altitude. Apply criteria in paragraph 4-2-4.d.

e. Use of a stepdown fix. Apply criteria in paragraph 4-2-4.e except minimum ROC between the stepdown fix and the MAP/FEP is 300 feet (250 feet for Military procedures annotated “Not For Civil Use”).

f. MDA. Apply criteria in section 3-2.

6-2-5. Missed Approach Segment. Apply criteria in paragraph 4-2-5.

Section 6-3. High Altitude Teardrop Turn

6-3-1. Feeder Routes. Apply criteria in paragraph 2-3-1.

6-3-2. Initial Approach Segment. The IAF is received by overheading the navigation facility. The initial approach is a teardrop turn. Apply criteria in paragraph 2-4-6.

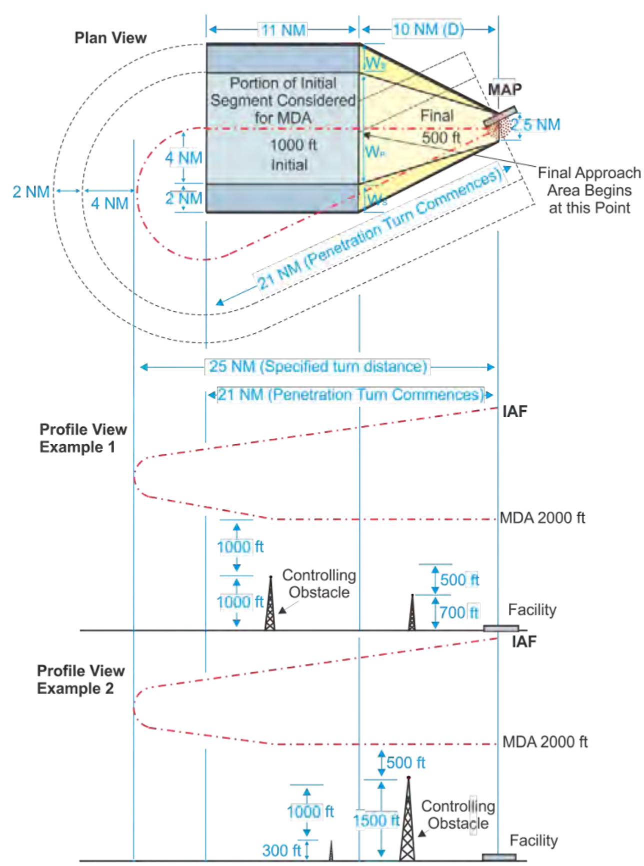
6-3-3. Intermediate Segment. The procedure has no intermediate segment. Upon completion of the teardrop turn, the aircraft is on final approach.

6-3-4. Final Approach Segment. An aircraft is considered to be on final approach upon completion of the teardrop turn. However, the final approach segment begins on the FAC 10 NM from the facility. That portion of the teardrop turn procedure prior to the 10-NM point is treated as the initial approach segment (see figure 6-3-1).

a. Alignment. Apply paragraph 4-2-4.a.

b. Area. Figure 6-3-1 illustrates the final approach primary and secondary areas. The primary area is longitudinally centered on the FAC, and is 10 NM long. The primary area is 2.5 NM wide at the facility, and expands uniformly to 8 NM at 10 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility and expands uniformly to 2 NM each side of the primary area at 10 NM from the facility.

Figure 6-3-1. Teardrop Turn. On-Airport NDB, No PFAF



c. Obstacle clearance.

(1) Straight-in. The minimum ROC in the primary area is 500 feet. The minimum ROC in the secondary area is 500 feet at the primary boundary, tapering uniformly to zero feet at the outer edge. Use formula 2-4-1 to determine obstacle clearance at any given point in the secondary area.

(2) Circling approach. In addition to the minimum requirements specified in paragraph 6-3-4.c(1), apply obstacle clearance criteria in section 2-7.

d. Teardrop turn altitude (descent gradient). The teardrop turn completion altitude must be at least 1000 feet, but not more than 4000 feet above the MDA on final approach.

e. Use of a stepdown fix. The use of a stepdown fix (see paragraph 2-9-9.c) is permitted, provided the distance from the facility to the stepdown fix does not exceed 10 NM.

f. MDA. In addition to the normal obstacle clearance requirements of the final approach segment (see paragraph 6-3-4.c), the MDA specified must provide at least 1000 feet of clearance over obstacles in that portion of the initial approach segment between the final approach segment and the point where the assumed teardrop turn track intercepts the inbound course (see figure 6-3-1).

g. Missed approach segment. Apply criteria in section 2-8. The MAP is the facility (see figure 6-3-1). The missed approach surface must commence over the facility at the required height (see paragraph 2-8-5).

Chapter 7. NDB with PFAF

Section 7-1.

7-1-1. General. This chapter prescribes criteria for NDB procedures which incorporate a PFAF. NDB procedures must be based only on facilities which transmit a continuous carrier.

7-1-2. Feeder Routes. Apply criteria in paragraph 2-3-1.

7-1-3. Initial Approach Segment. Apply criteria in section 2-4.

7-1-4. Intermediate Approach Segment. Apply criteria in section 2-5.

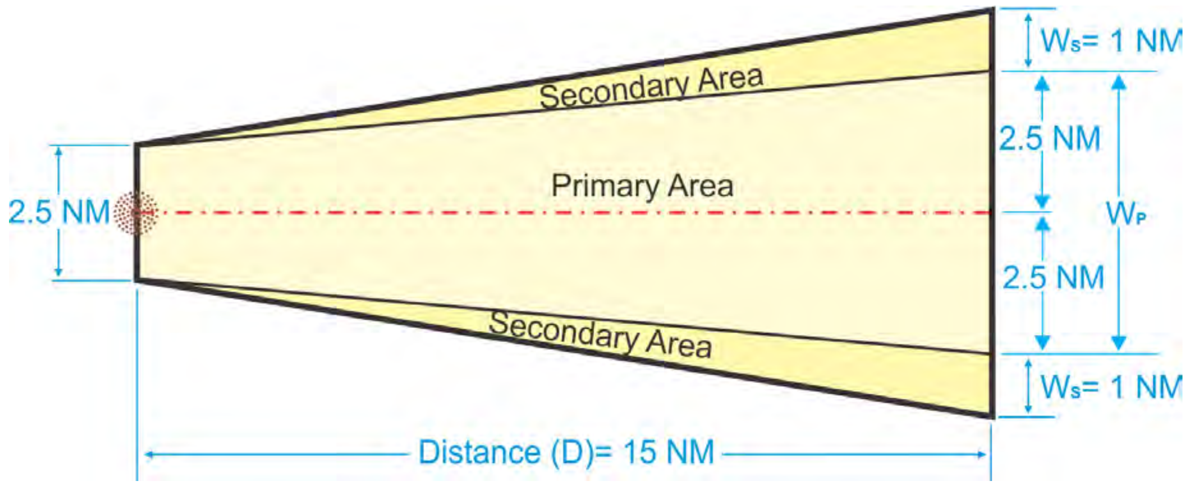
7-1-5. Final Approach Segment. The final approach may be made either “FROM” or “TOWARD” the facility. The final approach segment begins at the PFAF and ends at the FEP or MAP, whichever is encountered last.

Note: Apply criteria in paragraph 5-3-4.b for the establishment of arc final approaches.

a. Alignment. Apply criteria in paragraph 5-2-4.a.

b. Area. The area considered for obstacle clearance in the final approach segment starts at the earliest point the PFAF can be received and ends at the FEP or MAP, whichever is encountered last. It is a portion of a 15-NM long trapezoid (see figure 7-1-1) which is made up of primary and secondary areas. The primary area is centered longitudinally on the FAC. It is 2.5 NM wide at the facility and expands uniformly to 5 NM at 15 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility, and expands uniformly to 1 NM each side of the primary area at 15 NM from the facility. Formula 7-1-1 and formula 7-1-2 apply. Final approaches may be made to airports which are a maximum of 15 NM from the facility. The optimum length of the final approach segment is 5 NM. The maximum length is 10 NM. The minimum length of the final approach segment must provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the facility. Use table 7-1-1 to determine the minimum length needed to regain course.

Figure 7-1-1. Final Approach Trapezoid. NDB with PFAF



Formula 7-1-1. Final Approach Primary Area Half Width

$$\frac{1}{2}W_P = 0.08333 \times D + 1.25$$

Where:
D = Distance (NM) from facility measured along FAC

Formula 7-1-2. Final Approach Secondary Area Width

$$W_S = 0.0666 \times D$$

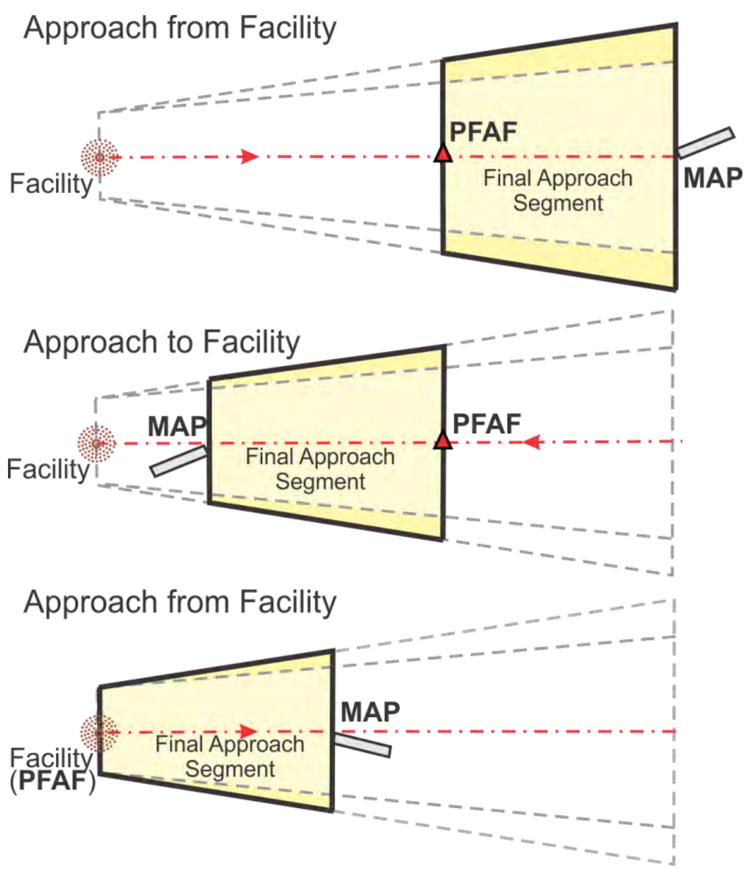
Where:
D = Distance (NM) from facility measured along FAC

Table 7-1-1. Minimum Length of Final Approach Segment (NM)

CAT	Magnitude of Turn over Facility (Degrees)		
	10	20	30
A	1.0	1.5	2.0
B	1.5	2.0	2.5
C	2.0	2.5	3.0
D	2.5	3.0	3.5
E	3.0	3.5	4.0

Note: This table may be interpolated. If turns of more than 30 degrees are required, or if the minimum lengths specified in table 7-1-1 are not available for the procedure, straight-in minimums are not authorized. For typical final approach areas, see figure 7-1-2.

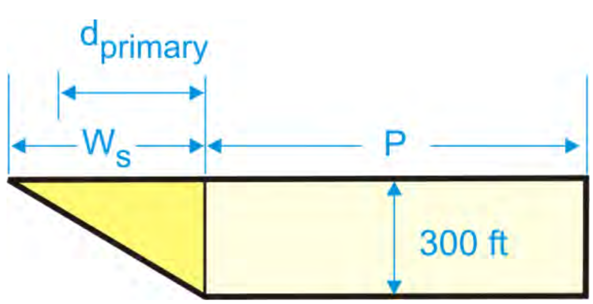
Figure 7-1-2. Typical Final Approach Areas. NDB with PFAF.



c. Obstacle clearance.

(1) Straight-in. The minimum ROC in the primary area is 300 feet. The minimum ROC in the secondary area is 300 feet at the primary boundary, tapering uniformly to zero feet at the outer edge (see figure 7-1-3). The minimum ROC at any given point in the secondary area is determined by formula 7-1-3. Apply adjustments as specified in paragraph 3-2-2.

Figure 7-1-3. Final Approach Area ROC



Formula 7-1-3. Final Approach Secondary Area ROC

$$ROC_{secondary} = 300 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

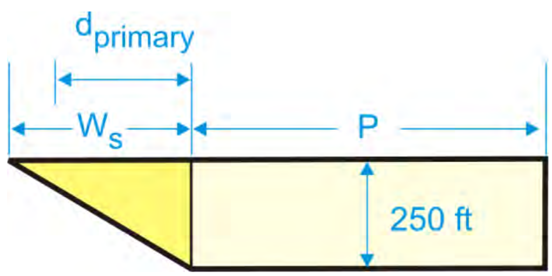
Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

Exception: Military procedures annotated "NOT FOR CIVIL USE" may apply 250 feet obstacle clearance in the primary area and 250 feet at the inner edge tapering uniformly to zero feet at the outer edge in the secondary area. Utilize the following formula to determine obstacle clearance at any given point in the secondary area:

Figure 7-1-4. Military Final Approach ROC



Formula 7-1-4. Military Final Approach Secondary Area ROC

$$ROC_{secondary} = 250 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = Perpendicular distance (feet) from primary area edge

W_S = Total width of the secondary area (feet)

(2) Circling approach. In addition to the minimum requirements specified in paragraph 7-1-5.c(1), apply obstacle clearance criteria in section 2-7.

d. Vertical descent angle. Apply criteria in paragraphs 2-6-2 and 2-6-4.

e. Use of fixes. Apply criteria in section 2-9. Where a procedure is based on a PT and an on-airport facility is the PT fix, the distance from the facility to the PFAF must not exceed 4 NM.

f. Minimum Descent Altitude (MDA). Apply criteria in section 3-2.

7-1-6. Missed Approach Segment. Apply criteria in paragraph 5-2-5.

Chapter 8. Localizer (LOC) and Localizer Type Directional Aids (LDA)

Section 8-1.

8-1-1. Feeder Routes, Initial Approach, and Intermediate Segments. Apply criteria in sections 2-3 thru 2-5. When a LOC is associated with an ILS procedure, apply paragraph 10-1-3.

8-1-2. Final Segment.

a. PFAF. The procedure must include a PFAF located within 10 NM of the LTP/FTP.

(1) If the PFAF is a DME fix, then the distance from the DME facility to the PFAF must not exceed 16.66 NM.

(2) If the PFAF is formed by DME from a facility that is not collocated with the LOC/LDA, then the angular divergence between the DME and LOC/LDA signal sources at the PFAF must not exceed six degrees (DoD 23 degrees).

b. Alignment. Localizers aligned within three degrees of the RCL are identified as localizers. If the alignment exceeds three degrees, they will be identified as LDA facilities. An LDA procedure must meet the final approach alignment criteria for VOR on-airport facilities (see paragraph 5-2-4 and figure 5-2-5).

c. Back Course Procedures. A back course LOC approach may only be approved if the back course is aligned within 0.03 degrees of the RCL and if the course width is six degrees or less. A back course LDA approach must not be approved.

8-1-3. Area. Figure 8-1-1 illustrates the final approach primary and transitional areas out to 50200 feet from LTP/FTP. For LDA procedures, the final approach area commences at the facility. Extend the boundaries symmetrically beyond 50200 feet when necessary. Apply formula 8-1-1 and formula 8-1-2 to determine the area widths. Only that portion of the final approach area that is between the earliest point the PFAF can be received and the LTP/FTP need be considered as the final approach segment for obstacle clearance purposes. The optimum length of the final approach segment is 5 NM. The minimum length of the final approach segment must be sufficient to provide adequate distance for an aircraft to make the required descent. The area must be centered on the FAC.

Formula 8-1-1. Primary Area Half Width Formula

$$\frac{1}{2}W_P = 0.10752 \times (d - 200) + 700$$

Where:

d = Distance (feet) from LTP/FTP measured along FAC

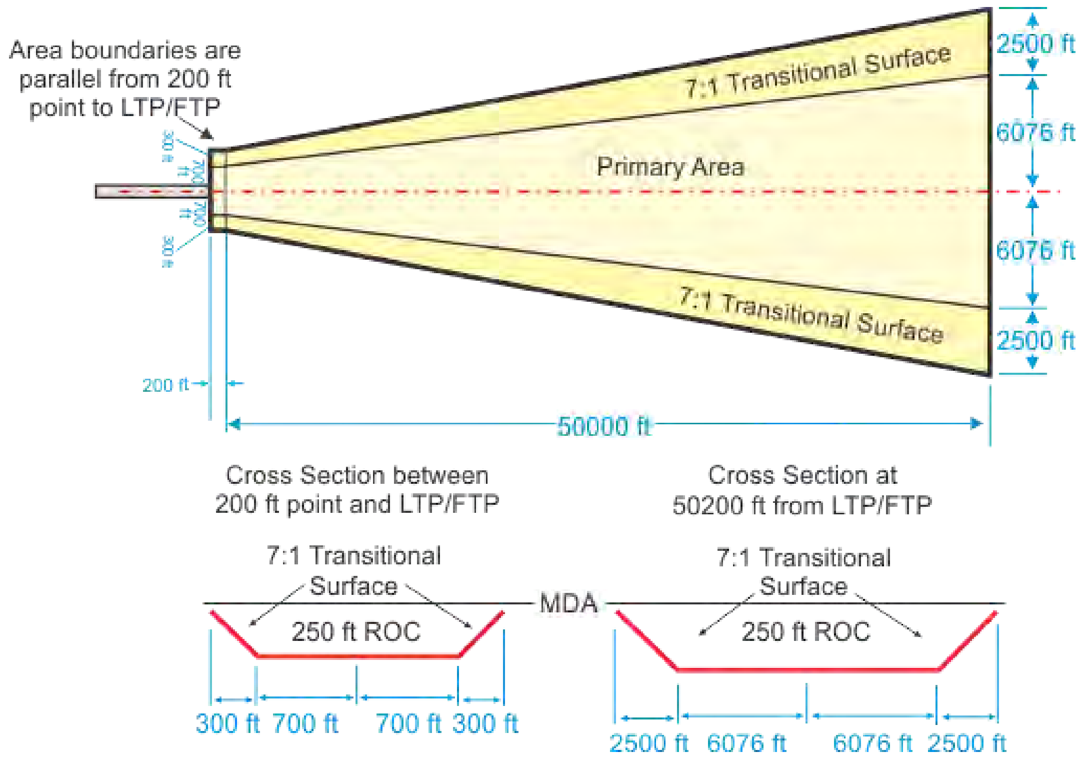
Formula 8-1-2. Perpendicular Width from RCL to Edge of Transitional Surface

$$Transitional\ Sfc = 0.15152 \times (d - 200) + 1000$$

Where:

d = Distance (feet) from LTP/FTP measured along FAC

Figure 8-1-1. Final Approach Area



8-1-4. Obstacle Clearance. The minimum ROC in the final approach area is 250 feet plus adjustments as specified in paragraph 3-2-2. In addition, the MDA established for the final approach area must assure that no obstacles penetrate the 7:1 transitional surfaces.

8-1-5. Vertical Descent Angle. Apply criteria in paragraphs 2-6-2 and 2-6-4.

8-1-6. Minimum Descent Altitude. The lowest altitude on final approach is specified as an MDA. Apply criteria in section 3-2.

8-1-7. Missed Approach Segment. Apply criteria in section 2-8. The MAP is on the FAC not farther from the PFAF than the LTP/FTP (first usable portion of the landing area for circling approach), and must be at least 3000 feet from the LOC/LDA facility. The missed approach surface must commence over the MAP at the required height (see paragraph 2-8-5). When a LOC (stand alone or associated with an ILS) has an RNAV-based missed approach, apply the LP missed approach criteria specified in Order 8260.58.

Chapter 9. Simplified Directional Facilities (SDF) Procedures

Section 9-1.

9-1-1. General. This chapter applies to approach procedures based on SDF. SDF is a directional aid facility providing only lateral guidance (front or back course) for approach from a PFAF.

9-1-2. Feeder Routes, Initial Approach, and Intermediate Segments. Apply criteria in sections 2-3 through 2-5.

9-1-3. Final Segment. The final approach must be made only "TOWARD" the facility because of system characteristics. The final approach segment begins at the PFAF and ends at the MAP.

a. Alignment. The alignment of the final approach course with the runway centerline determines whether a straight-in or circling-only approach should be established.

(1) Straight-in. Apply criteria in paragraph 5-2-4.a(2)(a).

(2) Circling approach. Apply criteria in paragraph 5-2-4.a(2)(b).

b. Area. The area considered for obstacle clearance in the final approach segment starts at the earliest point the PFAF can be received and ends at the LTP/FTP. It is a portion of a 10-NM long trapezoid that is centered longitudinally on the final approach course (see figure 9-1-1).

(1) For six-degree course width facilities, it is 1000 feet wide at the LTP/FTP and expands uniformly to 19228 feet at 10 NM from the LTP/FTP.

(2) For 12-degree course width facilities, it is 2800 feet wide at the LTP/FTP and expands uniformly to a width of 21028 feet at 10 NM from the LTP/FTP.

(3) For course widths between six and 12 degrees, the area considered for obstacle clearance may be extrapolated from the six-degree and 12-degree figures to the next intermediate whole degree. For example, the width of the obstacle clearance area for a 9-degree course width would start at 1900 feet and expands to 20128 feet.

(4) The optimum length of the final approach segment is 5 NM. The maximum length is 10 NM. The minimum length of the final approach segment must provide adequate distance for an aircraft to make the required descent.

c. Transitional surfaces. Transitional surfaces are inclined planes with a slope of 7:1 that extend upward and outward 5000 feet from the edge of the final approach area. The transitional surfaces begin at a height no less than 250 feet below the MDA.

d. Obstacle clearance.

(1) Straight-in landing. The minimum ROC in the final approach area is 250 feet plus adjustments as specified in paragraph 3-2-2. In addition, the MDA established for the final approach area must assure that no obstacles penetrate the transitional surfaces.

(2) Circling approach. In addition to the minimum requirements specified in paragraph 9-1-3.d(1), obstacle clearance in the circling area must be as prescribed in section 2-7.

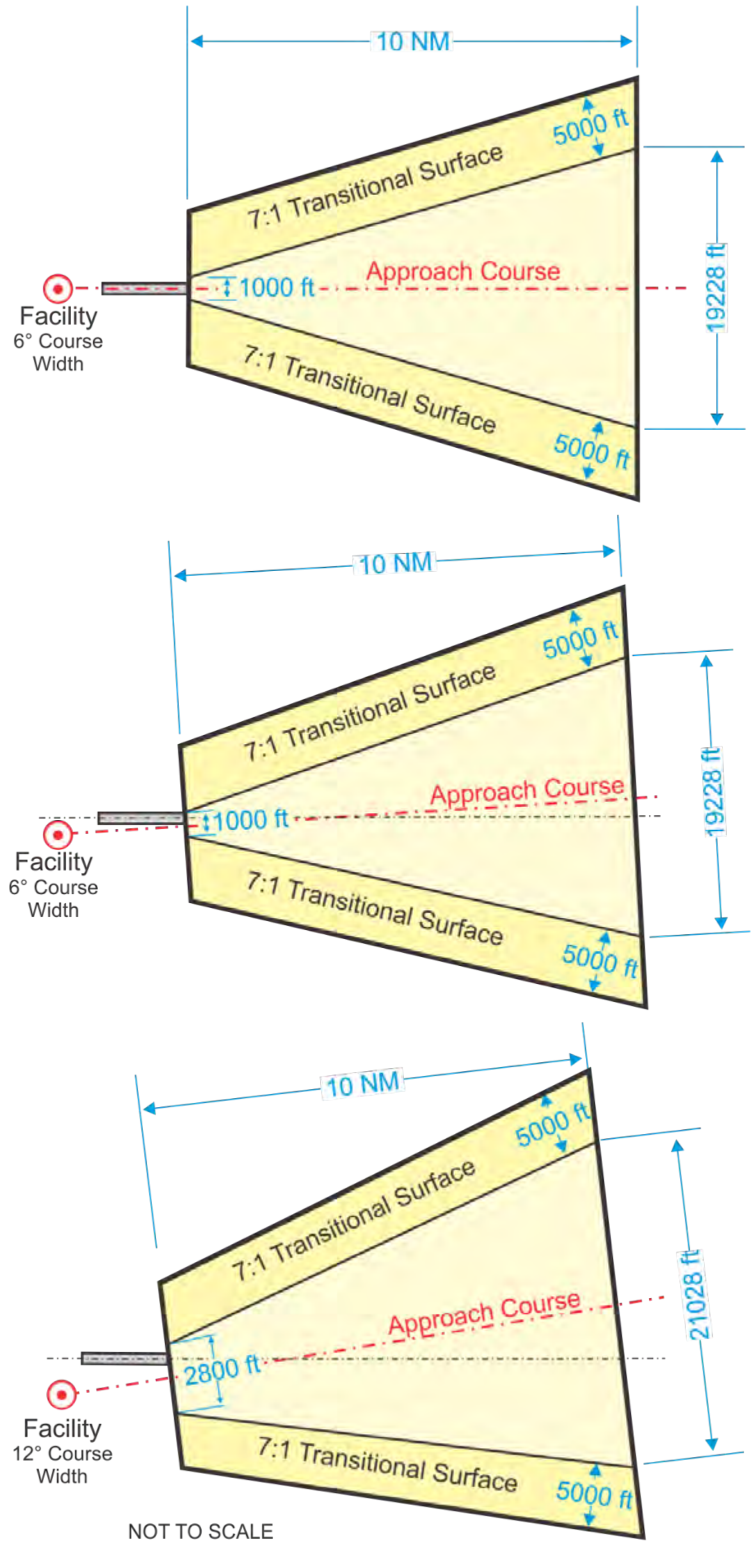
e. Vertical descent angle. Apply criteria in paragraphs 2-6-2 and 2-6-4.

f. Use of fixes. Apply criteria in section 2-9.

g. Minimum descent altitudes. The lowest altitude on final approach is specified as an MDA. Apply criteria in section 3-2.

9-1-4. Missed Approach Segment. Apply criteria in section 2-8 except the MAP is a point on the final approach course that is not farther from the PFAF than the LTP/FTP (first usable portion of the landing area for circling) and must be at least 3000 feet prior to the SDF. The missed approach surface must commence over the MAP at the required height (see paragraph 2-8-5).

Figure 9-1-1. Final Approach Areas



Chapter 10. Precision Approach and LDA with Glide Slope

Section 10-1. General Information and Criteria

10-1-1. Purpose. This chapter contains criteria applicable to conventional instrument approach procedures with vertical guidance. Apply these criteria to approaches based on ILS, mobile microwave landing system (MMLS), PAR, and LDA with glide slope.

10-1-2. Background. ILS meets the PA performance standard and may be authorized CAT I, II, or III landing minimums. LDA with glide slope only qualifies for APV minimums. PAR and MMLS meet the PA performance standard, but may be authorized CAT I landing minimums only.

10-1-3. MSA, Feeder, Initial, and Intermediate Segments. For RNAV based feeder, initial and intermediate segments, apply criteria in Order 8260.58. Otherwise apply criteria in sections 2-3 thru 2-5 of this order except as follows:

a. MSA. Procedures that require GPS may apply paragraph 2-3-2.b(2) in lieu of 2-3-2.b(1).

b. Initial segment.

(1) Procedure turn. The PT completion altitude must not be lower than the glidepath intercept altitude or more than 500 feet above the PFAF altitude.

(2) High altitude teardrop turn. The teardrop turn completion altitude must not be lower than the PFAF altitude or more than 4000 feet above the PFAF altitude.

c. Intermediate segment. The intermediate segment begins at the IF and extends along the FAC extended to the PFAF. Where a turn from the initial course to the FAC extended is required, the initial course must intercept at or before the IF.

(1) Length. The minimum length of the intermediate segment is 2 NM. Minimum segment length varies where a turn is required at the IF (see figure 10-1-1).

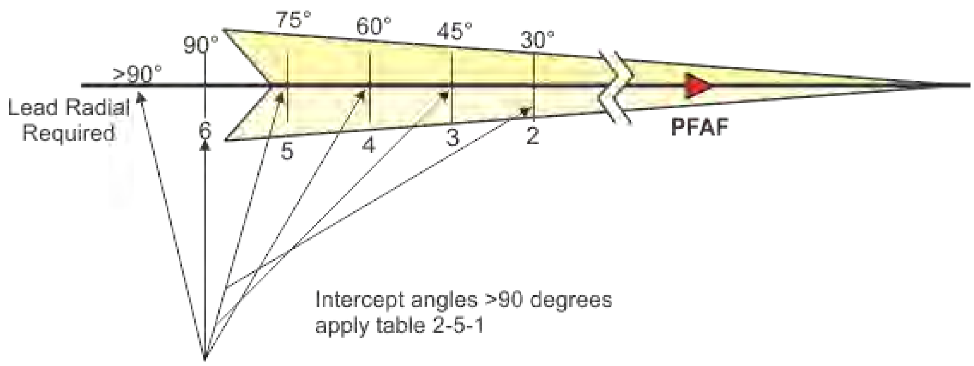
(a) Length is determined by the magnitude of heading change in the turn on to the FAC extended. Use formula 10-1-1 or formula 10-1-2 to determine the minimum length. The maximum angle of intersection is 90 degrees unless a lead radial as specified in paragraph 2-4-3.a, is provided and the length of the intermediate segment is increased as specified in table 2-5-1.

(b) Where the initial segment is based on an arc and the DME source is not collocated with the FAC facility, determine the intercept initial/intermediate segment intercept angle on approach procedures using formula 10-1-3 or formula 10-1-4 (see figure 10-1-2).

1. Use formula 10-1-3 where the DME source is on the arc side of the FAC extended.

2. Use formula 10-1-4 where the DME source is not on the arc side of the FAC extended.

Figure 10-1-1. Minimum Intermediate Segment Length, CAT C, D, E



Formula 10-1-1. Minimum Intermediate Segment Length, CAT A, B

$$CAT\ AB\ MIN_{Length} = \frac{\theta}{18}$$

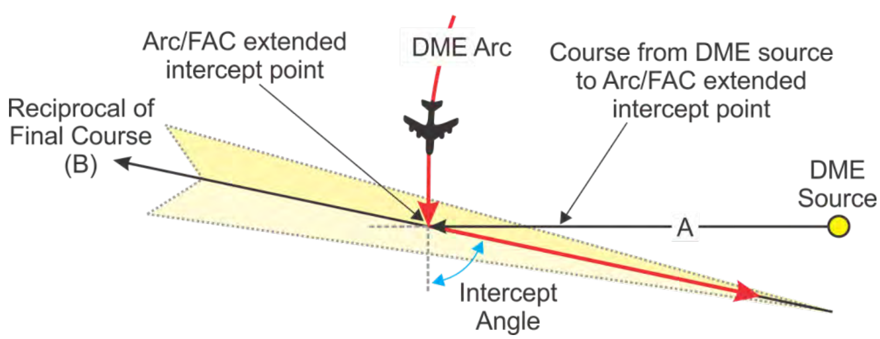
Where:
θ = Intercept angle

Formula 10-1-2. Minimum Intermediate Segment Length, CAT C, D, E

$$CAT\ CDE\ MIN_{Length} = \frac{\theta}{15}$$

Where:
θ = Intercept angle

Figure 10-1-2. DME Source on Arc Side



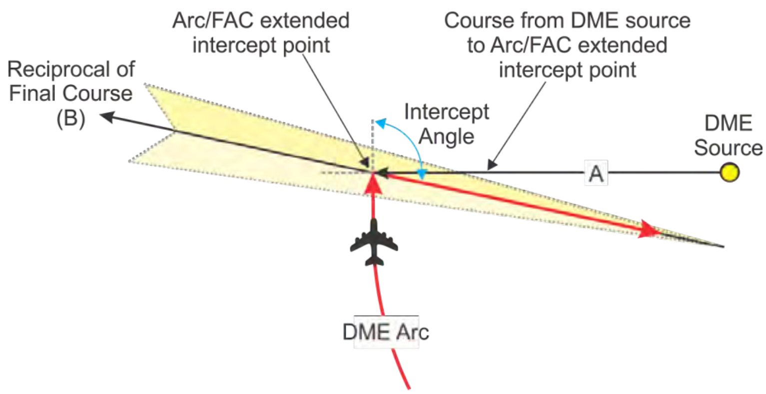
Formula 10-1-3. FAC intercept angle, DME Source on Arc Side

$$90 - |A - B| = Intercept\ Angle$$

Where:

A = Course from DME source to intercept point
B = Reciprocal of FAC

Figure 10-1-3. DME Source Opposite the Arc Side



Formula 10-1-4. FAC Intercept Angle, DME Source Opposite the Arc Side

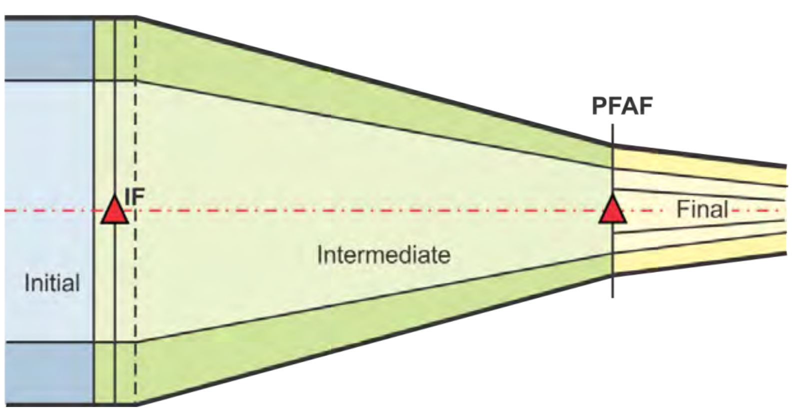
$$90 + |A - B| = Intercept\ Angle$$

Where:

A = Course from DME source to intercept point
B = Reciprocal of FAC

(2) Width. The intermediate trapezoid begins at the width of the initial segment at the earliest point the IF can be received, and beginning at the latest point the IF can be received it tapers to the width of the final segment at the plotted position of the PFAF (see figure 10-1-4).

Figure 10-1-4. Intermediate Segment Width



(3) Altitude selection. The intermediate altitude must not be lower than the PFAF altitude.

10-1-4. General Requirements.

a. GPA (see paragraphs 2-6-2 and 2-6-3).

b. TCH. The TCH (nearest whole foot) should accommodate the largest aircraft height group normally expected to use the runway and must not be less than the minimum or exceed the maximum TCH.

(1) The maximum TCH is 60 feet regardless of height group.

(2) CAT I. The TCH is based on achieving an acceptable wheel crossing height (WCH). The WCH is the difference between the TCH and the approximate glidepath antenna-to-wheel height (see table 10-1-1).

(a) The optimum TCH provides a 30 foot WCH. The minimum WCH is 20 feet and the maximum WCH is 50 feet.

(b) Displaced Threshold. The TCH over a displaced threshold may result in a WCH of not less than 10 feet provided:

<u>1.</u> Pavement equivalent to the strength of the landing runway is present prior to the displaced threshold.

<u>2.</u> The calculated height of the glide slope over the beginning of the pavement prior to the displaced threshold is within the minimum/maximum TCH values.

(3) CAT II/III. The optimum TCH is 55 feet. The minimum TCH is 50 feet regardless of height group.

(4) For the purposes of this chapter, the TCH is the design TCH designated within the appropriate data source.

Table 10-1-1. TCH Requirements

Representative Aircraft Type	Glidepath-to-Wheel Height (approximate)	Recommended TCH	Remarks
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate Turbojets, T-38, C-12, C-20, C-21, T-1, Fighter Jets, UC-35, T-3, T-6	10 ft or less	40 ft	Normally runways < 6000 long with reduced widths and/ or limited weight bearing, limiting larger aircraft use.
HEIGHT GROUP 2 F-28, B-737, C-9, DC-9, C-130, T-43, B-2	15 ft	45 ft	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-135, C-141, C-17, E-3, P-3, E-8, C-32	20 ft	50 ft	Runways not normally used by aircraft with ILS glidepath-to-wheel heights > 20 feet.
HEIGHT GROUP 4 B-747/767/777, DC-10, A-300, B-1, KC-10, E-4, C-5, VC-25	25 ft	55 ft	Most primary runways at major airports.

Note: To determine the minimum allowable TCH, add 20 feet to the glidepath-to-wheel height and to determine the maximum allowable TCH, add 50 feet to the glidepath-to-wheel height (not to exceed 60 feet).

c. PFAF. Calculate the along-track distance in feet from the LTP/FTP to the PFAF using formula 10-1-5.

Formula 10-1-5. Distance LTP/FTP to PFAF

$$D_{PFAF} = r \times \frac{\ln\left(\frac{r + PFAF_{alt}}{r + LTP_{elev} + TCH}\right)}{\tan(GPA)}$$

Where:

LTP_{elev} = LTP/FTP MSL elevation

$PFAF_{alt}$ = Minimum intermediate segment altitude

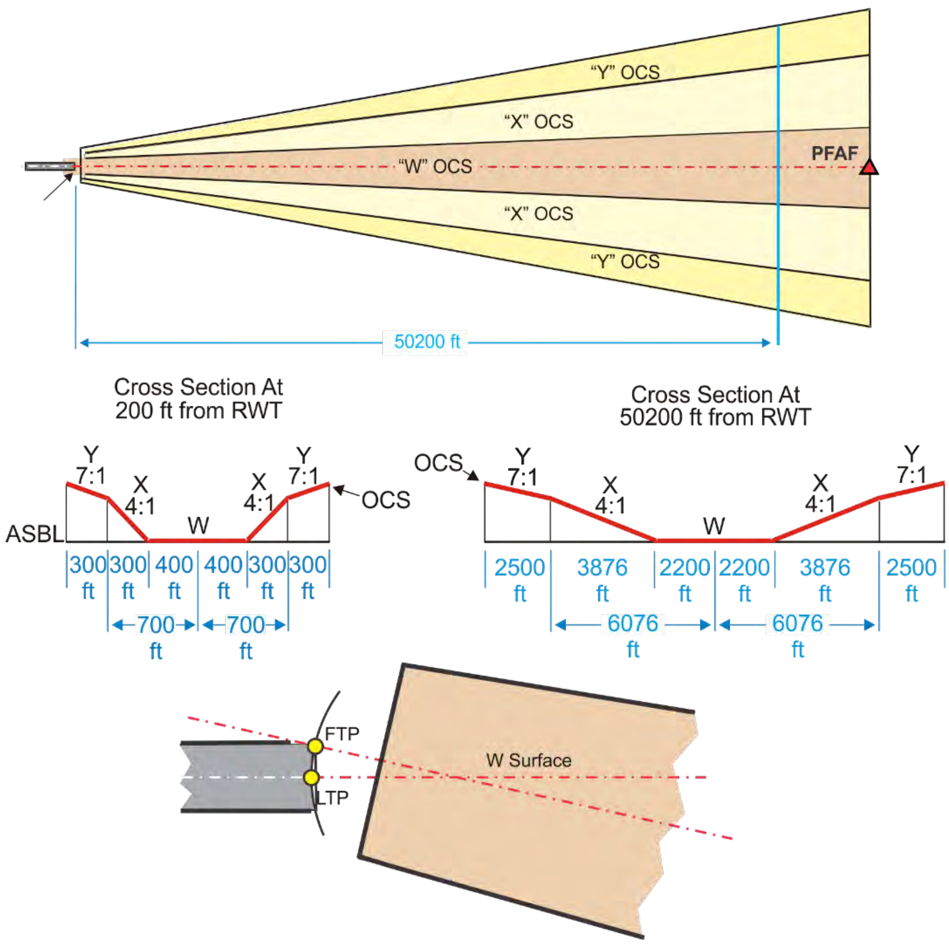
Note: Appendix H may be utilized to adjust the PFAF location to compensate for high-temperature effects.

Section 10-2. Final Approach Segment

10-2-1. Final Segment.

a. Area. The area originates 200 feet from LTP or FTP and extends to the PFAF. The primary area consists of the “W” and “X” OCS, and the secondary area consists of the “Y” OCS (see figure 10-2-1).

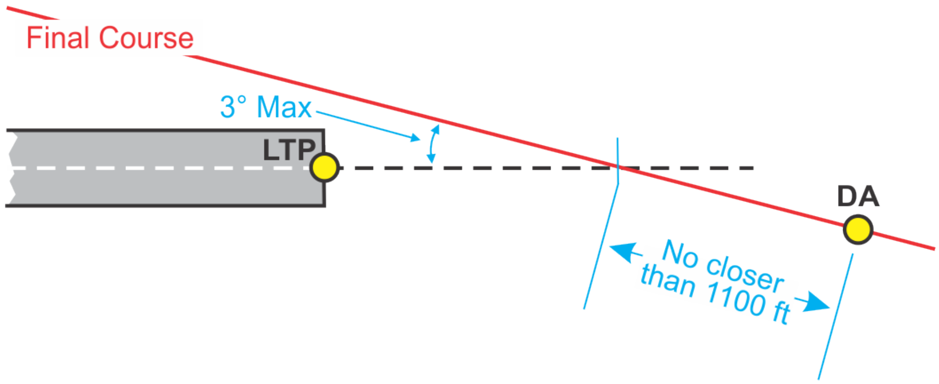
Figure 10-2-1. Final Segment OEA/OCS



b. Alignment.

(1) ILS. The final course is normally aligned with the RCL extended (±0.03 degrees) through the LTP (± 5 feet). Where a unique operational requirement indicates a need to offset the course from RCL, the offset must not exceed three degrees. The offset course must intersect the runway centerline at a point no closer than 1100 feet inside the DA point (see figure 10-2-2). The DA point for this evaluation is the point on the glideslope where the altitude is equal to the published DA less any RASS and precipitous terrain adjustments. For offset courses the minimum HAT is 250 feet and the minimum RVR is 2400.

Figure 10-2-2. ILS Offset Final



(2) LDA with GS. The final course maximum offset from RCL extended is 15 degrees. The final course must cross the RCL extended at least 3000 feet from LTP, but no more than 5200 feet from LTP.

10-2-2. OCS Slope.

a. Determine the OCS slope associated with a specific GPA using formula 10-2-1.

Formula 10-2-1. OCS Slope

$$OCS_{Slope} = \frac{102}{GPA}$$

Example:

$\mathrm{OCS}_{\mathrm{Slope}} = \frac{102}{3.1}$

$\mathrm{OCS}_{\mathrm{Slope}} \approx 32.90$

b. Origin. The OEA (all OCS surfaces) originates from LTP elevation at a point 200 feet from LTP (see figure 10-2-3) measured along course centerline and extends toward the PFAF. The longitudinal (along-track) rising W surface slope begins at a calculated distance "d_{origin}" feet from the LTP (use formula 10-2-2).

Formula 10-2-2. Slope Origin Distance

$$d_{origin} = greater\ of\ 200\ or\ 1154 - \frac{TCH}{\tan(GPA)}$$

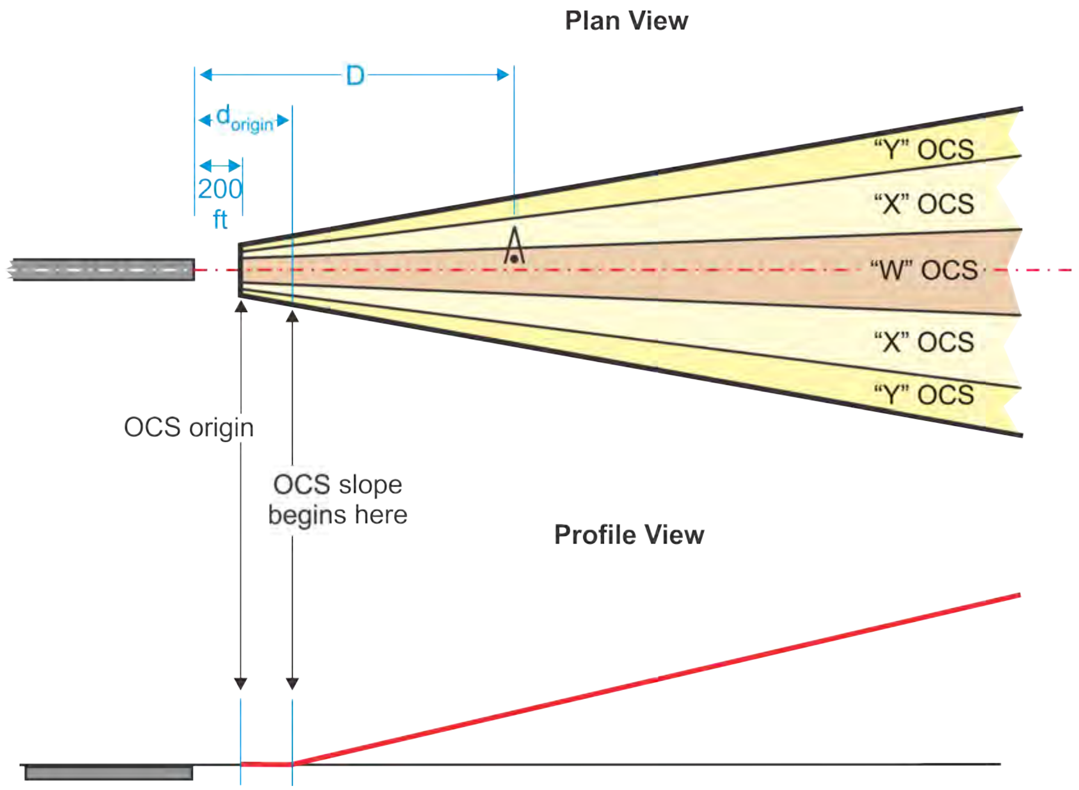
Example:

$d_{\mathrm{origin}} = 1154 - \frac{55}{\tan(3.1)}$

$d_{\mathrm{origin}} \approx 138.45$ feet

$d_{\mathrm{origin}} = 200$ feet

Figure 10-2-3. OCS Slope Origin When "d_{origin}" Greater than 200



c. Obstacle effective elevation (O_{EE}). Because the earth curves away from the OCS as distance from course centerline increases, the MSL elevation of an obstacle is reduced to account for this. Use formula 10-2-3 to calculate O_{EE}.

Formula 10-2-3. Obstacle Effective Elevation

$$O_{EE} = O_{MSL} - \left[(r + LTP_{elev}) \times \left(\cos \left[\frac{OBS_Y \times 180}{r \times \pi} \right]^{-1} - 1 \right) + Q \right]$$

Where:

O_{MSL} = Obstacle MSL elevation
OBS_Y = Perpendicular distance (feet) from course centerline to obstacle
Q = Obstacle adjustment (feet) for X or Y surface rise. Zero (0) if in the W surface.

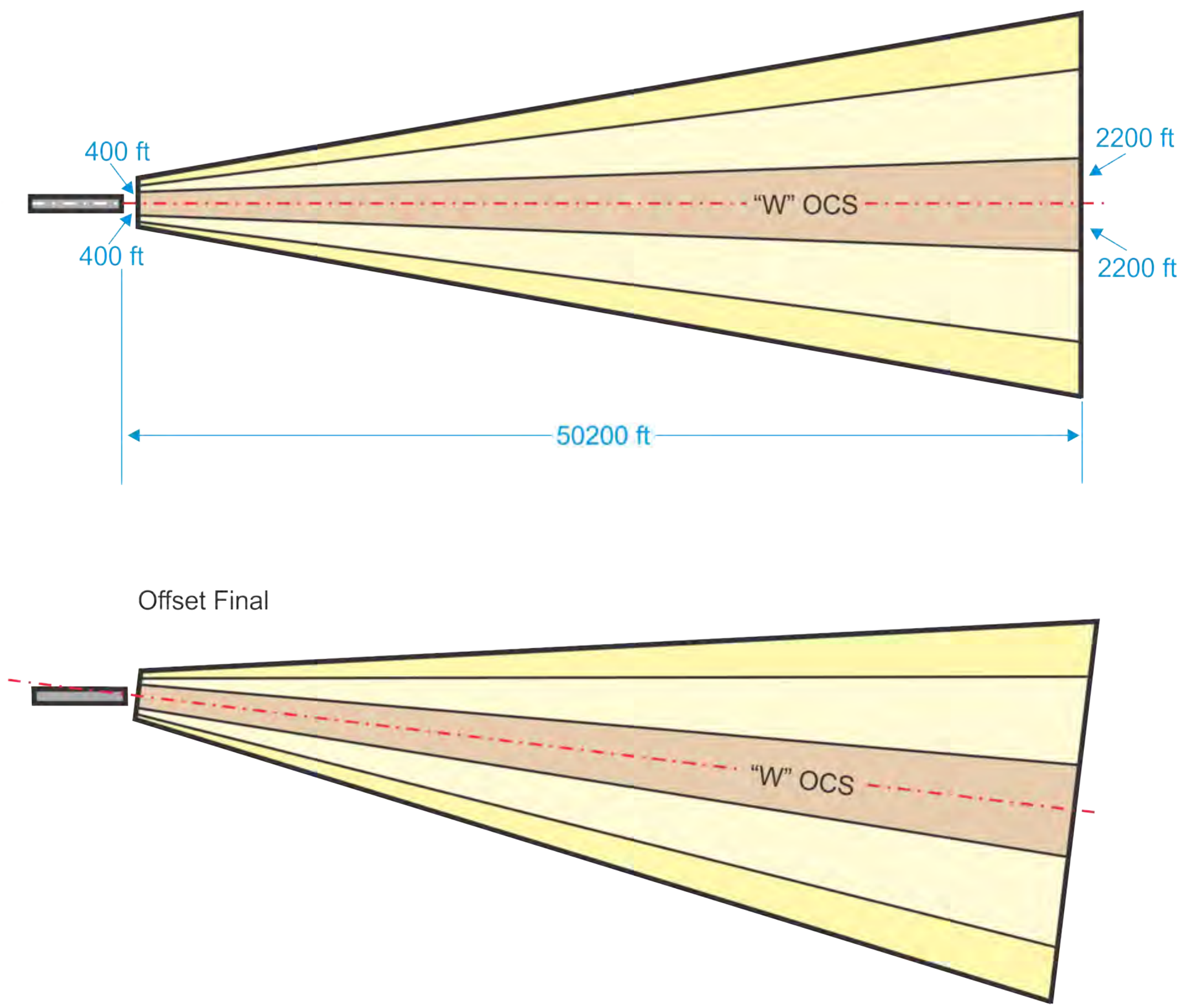
Example:

$$\mathrm{O_{EE}} = 2768.9 - \left[(\mathrm{r} + 1125.4) \times \left(\cos \left[\frac{1432.5 \times 180}{\mathrm{r} \times \pi} \right]^{-1} - 1 \right) + 192.90 \right]$$

$$\mathrm{O_{EE}} \approx 2575.95$$

10-2-3. "W" OCS (see figure 10-2-4).

Figure 10-2-4. “W” OCS



a. Width. The width is 400 feet on each side of course at the beginning, and expands uniformly to 2200 feet on each side of course at 50200 feet from LTP/FTP. Use formula 10-2-4 to calculate the “W” OCS half-width at a specified distance.

Formula 10-2-4. "W" OCS Half-Width at Specified Distance

$$W_{boundary} = 0.036 \times d_{LTP} + 392.8$$

Where:

d_{LTP} = distance (feet) from LTP/FTP as measured along FAC

$W_{boundary}$ = perpendicular distance (feet) from course centerline to "W" surface outer boundary

Example:

$W_{boundary} = 0.036 \times 5462.03 + 392.8$

$W_{boundary} \approx 589.43$ feet

b. Elevation. Use formula 10-2-5 to calculate the "W" OCS angle and formula 10-2-6 to calculate the "W" OCS elevation for any specified distance beyond the OCS origin.

Formula 10-2-5. "W" OCS Angle

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

Example:

$OCS_{angle} = atan\left(\frac{3.1}{102}\right)$

$OCS_{angle} \approx 1.74^{\circ}$

Formula 10-2-6. "W" OCS Elevation

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

Where:

OCS_{angle} = Formula 10-2-5 result

d_{LTP} = Distance (feet) from LTP (FTP if applicable) to point of interest as measured along FAC

d_{origin} = Distance (feet) from LTP/FTP to OCS slope origin (formula 10-2-2 result)

Example:

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

W $OCS_{elev} \approx 1280.35$

c. OCS evaluation. Compare the "W" OCS evaluation abeam the obstacle location with the O_{EE}. Lowest minimums are achieved when the "W" surface is clear. If the surface is penetrated by an obstacle take one or more of the following actions:

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

(2) Raise the GPA (see paragraph 10-2-7).

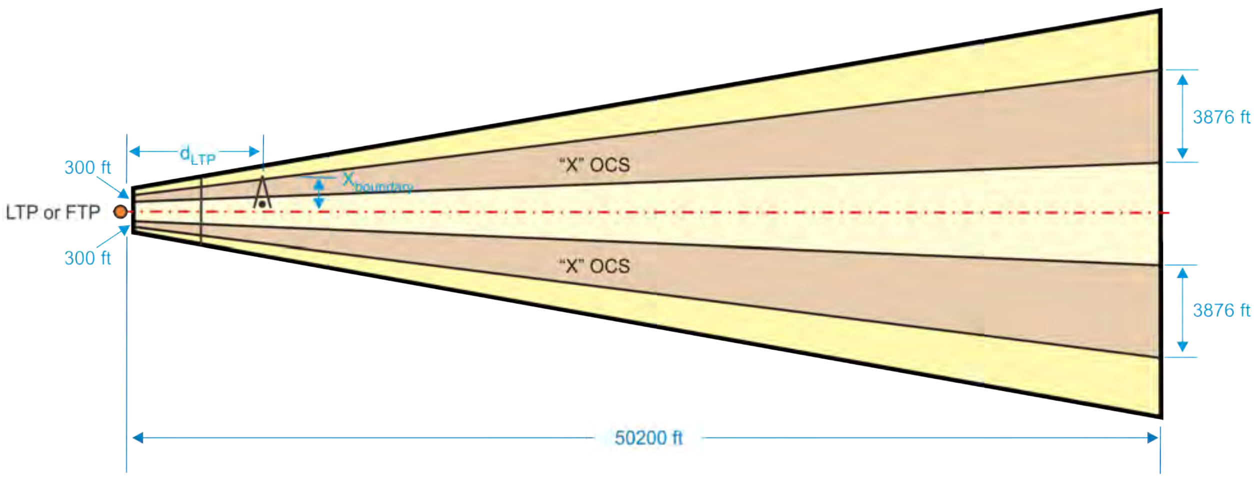
(3) Displace the RWT to eliminate the penetration.

(4) If the penetration cannot be eliminated, adjust the DA (see paragraph 10-2-7).

(5) Raise the TCH. Coordination must be accomplished with appropriate agencies due to the cost of moving ILS equipment.

10-2-4. "X" OCS (see figure 10-2-5).

Figure 10-2-5. "X" OCS



a. Width. Use formula 10-2-7 to calculate the perpendicular distance ($X_{boundary}$) from the course to the outer boundary of the "X" OCS at a specified distance.

Formula 10-2-7. Perpendicular Distance to X Boundary

$$X_{boundary} = 0.10752 \times d_{LTP} + 678.496$$

Where:

d_{LTP} = Distance (feet) from LTP (FTP if applicable) to point of interest as measured along FAC

Example:

$X_{boundary} = 0.10752 \times 5462.03 + 678.496$

$X_{boundary} \approx 1265.77$ feet

b. Elevation. 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 reduced by the amount of surface rise. Use formula 10-2-8 to determine the obstacle height adjustment "Q" for use in formula 10-2-3. Evaluate the obstacle in accordance with paragraph 10-2-2.d.

Formula 10-2-8. "X" OCS Obstacle Adjustment

$$Q = \frac{OBS_Y - W_{boundary}}{4}$$

Where:
OBS_Y = Perpendicular distance (feet) from the course centerline to the obstacle
$W_{boundary}$ = Perpendicular distance (feet) between FAC and the "W" surface boundary

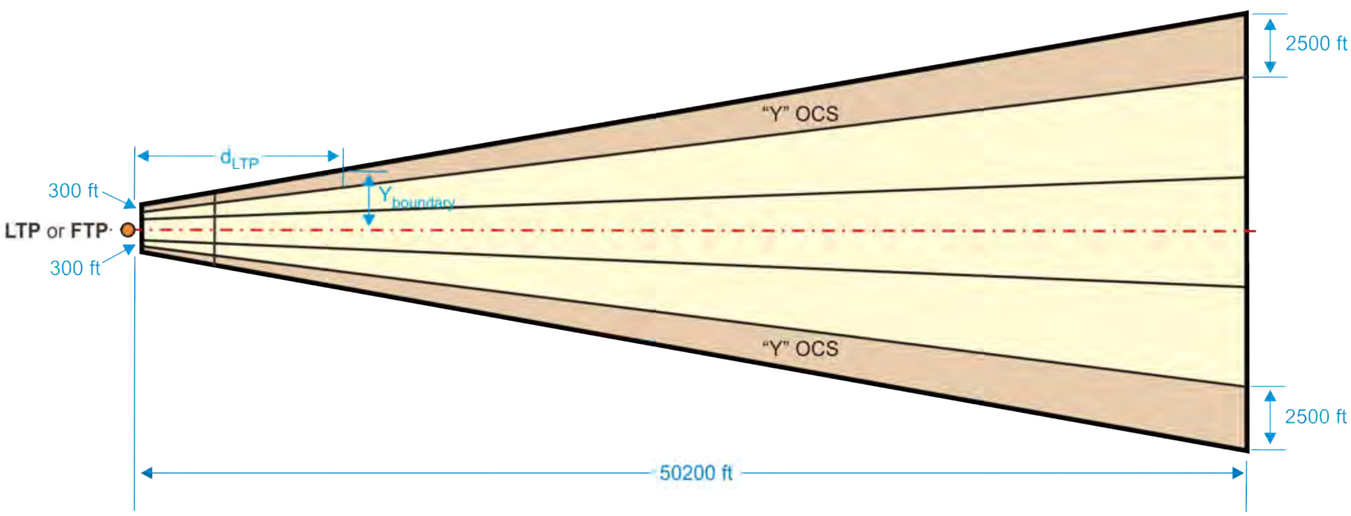
Example:

$$Q = \frac{1265.77 - 589.43}{4}$$

Q≈169.09 feet

10-2-5. "Y" OCS (see figure 10-2-6).

Figure 10-2-6. "Y" OCS



a. Width. Use formula 10-2-9 to calculate the perpendicular distance ($Y_{boundary}$) from the course to the outer boundary of the "Y" OCS at a specified distance.

Formula 10-2-9. Perpendicular Distance to Y Boundary

$$Y_{boundary} = 0.15152 \times d_{LTP} + 969.696$$

Where:
d_{LTP} = Distance (feet) from LTP (FTP if applicable) to point of interest as measured along FAC

Example:
$Y_{boundary} = 0.15152 \times 5462.03 + 969.696$
$Y_{boundary} \approx 1797.30$ feet

b. Obstacle Adjustment. 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 reduced by the amount of “X” and “Y” rise. Use formula 10-2-10 to determine the obstacle height adjustment “Q” for use in formula 10-2-3. Evaluate the obstacle in accordance with paragraph 10-2-2.d.

Formula 10-2-10. “Y” OCS at Specified Distance

$$Q = \frac{X_{boundary} - W_{boundary}}{4} + \frac{OBS_Y - X_{boundary}}{7}$$

Where:

$X_{boundary}$ = Perpendicular distance (feet) between FAC and the “X” surface boundary
$W_{boundary}$ = Perpendicular distance (feet) between FAC and the “W” surface boundary
OBS_Y = Perpendicular distance (feet) from the course centerline to the obstacle

Example:

$$Q = \frac{1265.77 - 589.43}{4} + \frac{1432.5 - 1265.77}{7}$$

$Q \approx 192.90$ feet

10-2-6. DA and Height Above Touchdown (HAT). The DA value may be derived from the HAT. The minimum HAT for PA CAT I is 200 feet. The minimum HAT for LDA with GS is 250 feet. Calculate DA using formula 10-2-11; calculate HAT using formula 10-2-12.

Formula 10-2-11. DA

$$DA = HAT + TDZE$$

Formula 10-2-12. HAT

$$HAT = DA - TDZE$$

10-2-7. Raising GPA for OCS Penetrations. Raising the GPA may eliminate OCS penetrations. Apply formula 10-2-13 to determine the revised minimum GPA.

Formula 10-2-13. GPA Adjustment

$$\theta_{\text{ adjusted}} = \tan\left[\text{acos}\left(\frac{\text{SRD}^2 + (\text{r} + \text{LTP}_{\text{elev}})^2 - (\text{r} + \text{O}_{\text{EE}})^2}{2 \times \text{SRD} \times (\text{r} + \text{LTP}_{\text{elev}})}\right) - 90\right] \times 102$$

Where:

SRD = Formula 10-2-14 result

O_{EE} = Formula 10-2-3 result

Example:

$$\theta_{\text{ adjusted}} = \tan\left[\text{acos}\left(\frac{3795.85^2 + (\text{r} + 1125.4)^2 - (\text{r} + 1274.5)^2}{2 \times 3795.85 \times (\text{r} + 1125.4)}\right) - 90\right] \times 102$$

$$\theta_{\text{ adjusted}} \approx 4.00^\circ$$

Formula 10-2-14. Square Root Distance (SRD)

$$\text{SRD} = \sqrt{(\text{r} + \text{O}_{\text{EE}})^2 + (\text{r} + \text{LTP}_{\text{elev}})^2 - 2 \times (\text{r} + \text{O}_{\text{EE}}) \times (\text{r} + \text{LTP}_{\text{elev}}) \times \cos\left[\frac{(\text{d}_{\text{LTP}} - \text{d}_{\text{origin}}) \times 180}{\text{r} \times \pi}\right]}$$

Where:

O_{EE} = Formula 10-2-3 result

d_{LTP} = Along track distance (feet) from LTP to penetrating obstacle

d_{origin} = Distance (feet) from LTP to OCS origin

Example:

$$\text{SRD} = \sqrt{(\text{r} + 1274.5)^2 + (\text{r} + 1125.4)^2 - 2 \times (\text{r} + 1274.5) \times (\text{r} + 1125.4) \times \cos\left[\frac{3992.7 - 200) \times 180}{\text{r} \times \pi}\right]}$$

$$\text{SRD} \approx 3795.85$$

10-2-8. Adjustment of DA for Final Approach OCS Penetrations. The DA may be increased to provide sufficient obstacle clearance (see figure 10-2-7).

a. DA distance from LTP/FTP. Use formula 10-2-15 to determine the distance from LTP/FTP to the adjusted DA point (d_{DA}).

Formula 10-2-15. Distance from LTP/FTP To Adjusted DA Point

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - OCS_{angle} - asin\left[\frac{\cos(OCS_{angle}) \times (r + LTP_{elev})}{r + O_{EE}}\right]\right) + d_{origin}$$

Where:

OCS_{angle} = Formula 10-2-5 result

d_{origin} = Distance (feet) from LTP/FTP to OCS origin

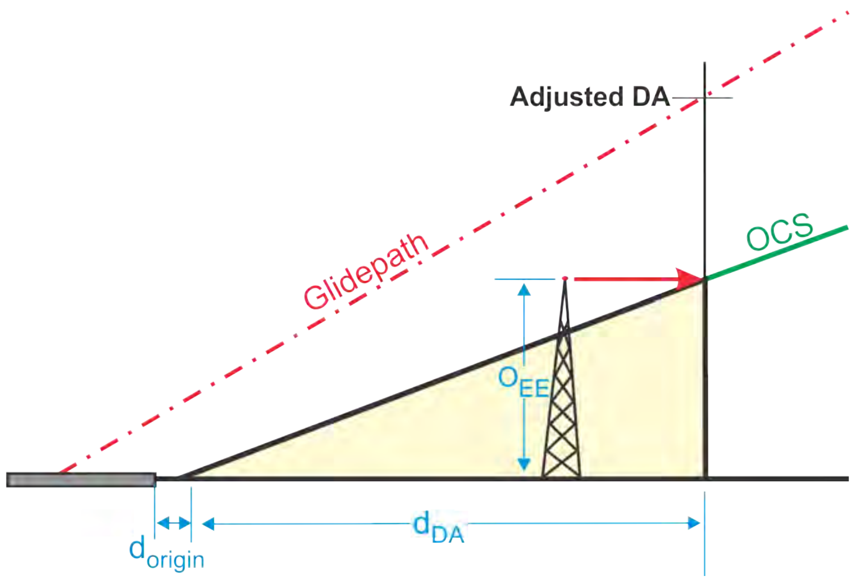
O_{EE} = Formula 10-2-3 result

Example:

$$d_{DA} = \frac{r \times \pi}{180} \times \left(90 - 1.74 - asin\left[\frac{\cos(1.74) \times (r + 1125.4)}{r + 1271.5}\right]\right) + 200$$

$d_{DA} \approx 4991.01$ feet

Figure 10-2-7. DA Adjustment



b. Use formula 10-2-16 to calculate the adjusted DA.

Formula 10-2-16. Adjusted DA

$$DA_{adj} = \frac{(r + LTP_{elev} + TCH) \times \cos(GPA)}{\cos\left(\frac{d_{DA} \times 180}{r \times \pi} + GPA\right)} - r$$

Where:

d_{DA} = Formula 10-2-15 result

Example:

$$\mathrm{DA_{adj}} = \frac{(\mathrm{r} + 1125.4 + 55) \times \cos(3.1)}{\cos\left(\frac{42041.91 \times 180}{\mathrm{r} \times \pi} + 3.1\right)} - \mathrm{r}$$

$$\mathrm{DA_{adj}} \approx 3500$$

c. Use formula 10-2-17 to calculate the revised minimum HAT and maximum ROC.

Formula 10-2-17. Minimum HAT and Maximum ROC

$$MinHAT/MaxROC_{Revised} = \frac{GPA}{3} \times 250$$

d. Compare HAT based on adjusted DA and the minimum HAT based on formula 10-2-17. Publish the DA associated with the higher of the two.

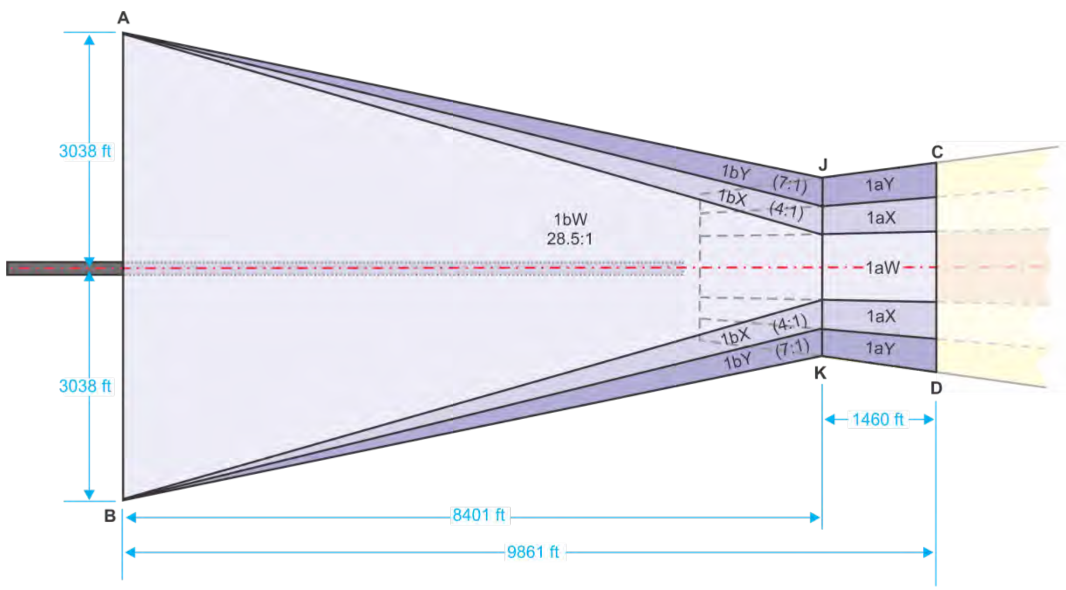
Section 10-3. CAT I Missed Approach Segment

10-3-1. General Information. This section applies to missed approach segments based on conventional (non-RNAV) guidance. Apply the LPV missed approach criteria specified in Order 8260.58 when the missed approach is based on RNAV guidance. The missed approach segment begins at DA and ends at the clearance limit. It is comprised of section 1 (initial climb) and section 2 (from end of section 1 to the clearance limit). The MA procedure is limited to two turns.

10-3-2. Section 1.

a. Section 1 is aligned with the final approach course and no turn is allowed before the end of this section. It is comprised of two subsections, 1a and 1b. Section 1 begins at a point where DA is achieved, less any RASS and precipitous terrain adjustments (line C-D). For example, if the published DA is 500 feet and incorporates a 100-foot RASS adjustment, then section 1 would begin at the point where a 400 foot DA point would be located. Section 1 extends 9861 feet from line C-D and terminates at line A-B (see figure 10-3-1).

Figure 10-3-1. Missed Approach Area Section 1



b. Section 1a.

(1) Area. Section 1a begins at line C-D and overlies the final segment OEA. It extends 1460 feet in the direction of the missed approach to line J-K. Section 1a is subdivided into section 1aW, sections 1aX, and sections 1aY. Each of the subsections corresponds to the underlying FAS "W," "X," and "Y" surfaces.

(2) OCS. The elevations of the section 1a surfaces are equal to the underlying "W," "X," or "Y" surface as appropriate. The section 1a surfaces must not be penetrated.

c. Section 1b.

(1) Area. Section 1b begins at line J-K at the end of section 1a and is aligned with the final approach course extended. It extends 8401 feet to line A-B. This section is subdivided into sections 1bW, sections 1bX, and sections 1bY. Apply formula 10-3-1 to calculate the distance from course centerline to the boundary of these areas.

(a) Section 1bW. This section extends from the end of section 1aW for a distance of 8401 feet. Its lateral boundaries splay from the ending width of section 1aW to a width of 3038 feet each side of the extended FAC.

(b) Sections 1bX. These sections extend from the end of sections 1aX for a distance of 8401 feet. The inner boundaries are shared with the lateral boundaries of section 1bW. The outer boundaries taper to points 3038 feet each side of the extended FAC.

(c) Sections 1bY. These sections extend from the end of sections 1aY for a distance of 8401 feet. The inner boundaries are shared with the outer boundaries of section 1bX. The outer boundaries taper to points 3038 feet each side of the extended FAC.

Formula 10-3-1. Section 1b Boundary Distances

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

Where:

$1b_{boundary}$ = The boundary of interest (that is, 1bW, 1bX, or 1bY)
d_{1aEnd} = Distance (feet) as measured along section 1 centerline from line J-K
$1a_{boundary}$ = Distance (feet) as measured along line J-K from centerline of section 1 to respective ending 1a boundary. For example, if calculating 1bX width, then use 1aX distance.

Example:

$$1\mathrm{b}_{\mathrm{boundary}} = \frac{2591.8 \times (3038 - 481.06)}{8401} + 481.06$$

$1\mathrm{b}_{\mathrm{boundary}} \approx 1269.90$ feet

(2) OCS elevation.

(a) Section 1bW. The OCS begins at an elevation equal to the ending elevation of section 1aW and rises in the direction of the extension of the FAC at a slope of 28.5:1. Apply formula 10-3-2 to determine the section 1bW elevation at any distance from line J-K.

(b) Sections 1bX. The OCS begins at the boundary with section 1bW and rises perpendicularly from the extended FAC at a slope of 4:1. Use formula 10-2-8 to calculate the adjustment “Q” for “X” surface obstacles.

(c) Sections 1bY. The OCS begins at the boundary with section 1bX and rises perpendicularly from the extended FAC at a slope of 7:1. Use formula 10-2-10 to calculate the adjustment "Q" for "Y" surface obstacles.

Formula 10-3-2. Section 1bW OCS Elevation

$$OCS_{Section1bW} = e^{\left(\frac{d_{OCS}}{r \times 28.5}\right)} \times \ (r + OCS_{start}) - r$$

Where:

d_{OCS} = Distance from end of section 1a (line J-K) as measured along FAC extension
OCS_{start} = Ending elevation of section 1aW

Example:

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

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

(3) OCS evaluation. The section 1bW, 1bX, and 1bY surfaces must not be penetrated. Use formula 10-3-3 to determine the amount of section 1b surface penetration.

Formula 10-3-3. Section 1b Surface Penetration

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

Where:

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

Example:

$\mathrm{p} = 1325.8 - 24.22 - 1282.70$
$\mathrm{p} \approx 18.88$ feet

(4) OCS penetration. If any section 1b surface is penetrated, take one or more of the following actions:

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

(b) Raising GPA within categorical limits.

(c) Adjusting DA. For a surface 1b penetration of p feet, the DA point must move Δd_{DA} feet further from the LTP to raise the surface above the penetration (see formula 10-3-4 and figure 10-3-2).

Formula 10-3-4. DA Adjustment

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

Where:

p = Penetration (feet) of the 1b OCS

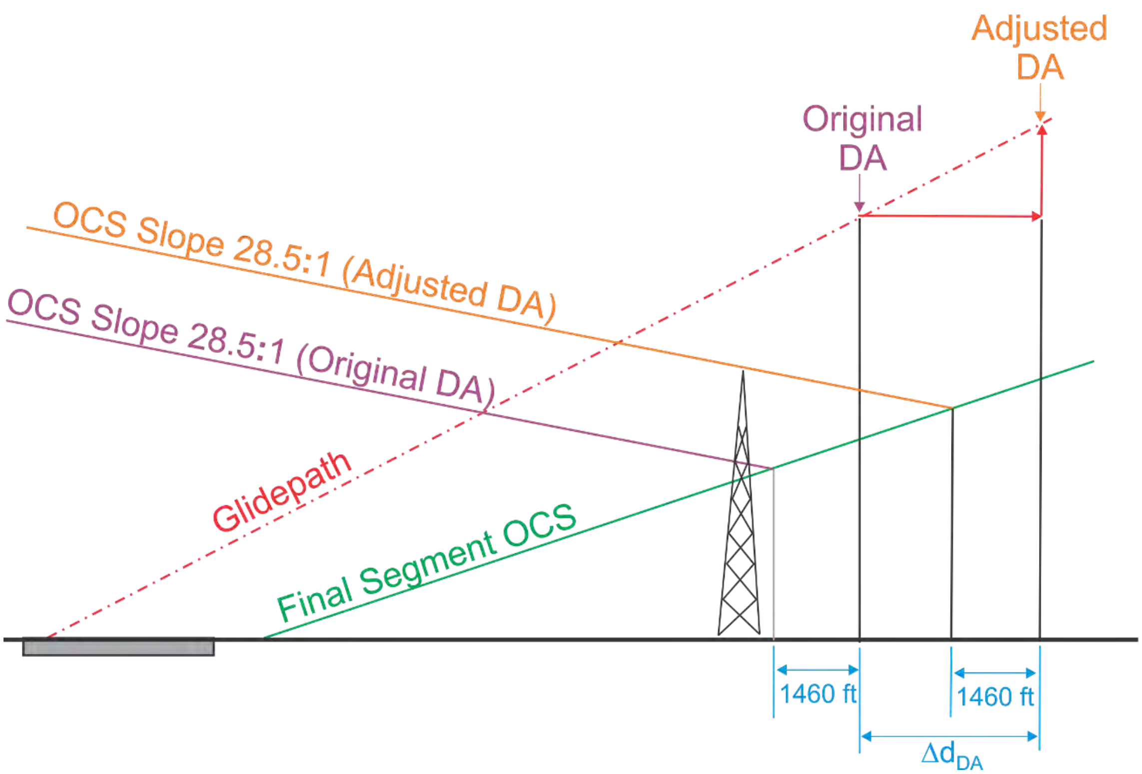
FAS_{slope} = Final approach segment OCS slope ratio

Example:

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

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

Figure 10-3-2. Penetration of Section 1b OCS



d. Apply formula 10-3-5 to calculate aircraft elevation at the end of section 1.

Formula 10-3-5. Aircraft Elevation at End of Section 1

$$AC_{Section1End} = DA - \tan(\theta) \times 1460 + \frac{8401 \times 0.3048 \times 200}{1852}$$

Where:
θ = GPA

Example:

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

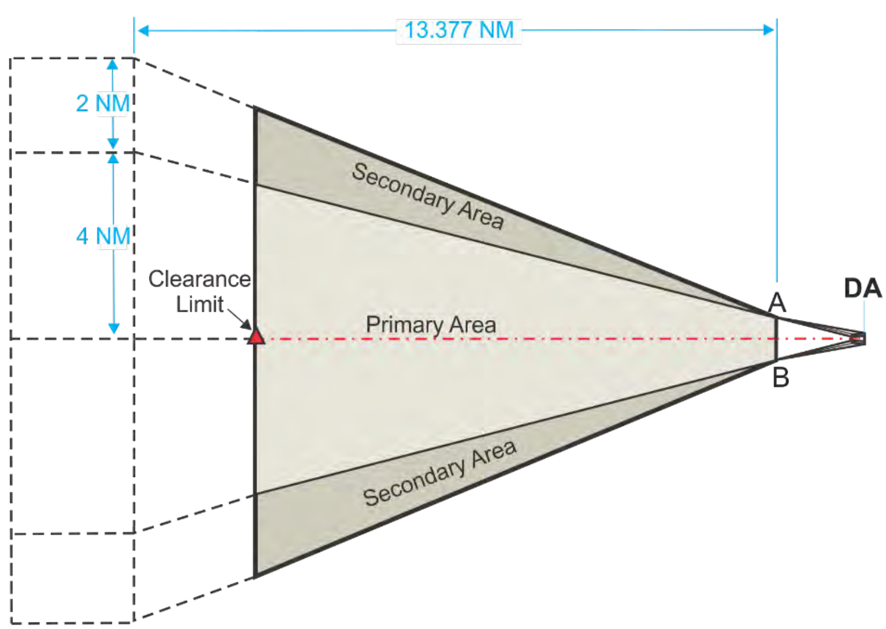
$$\text{Section 2 start altitude} \approx 1422.45 \text{ feet}$$

10-3-3. Section 2. Section 2 starts at the end of section 1 centered on the published missed approach course and ends at the clearance limit. Secondary areas may be established where PCG is available. Apply paragraph 2-8-8.d to determine the preliminary charted missed approach altitude, paragraph 2-8-8.e to assess the need for a climb-in-holding evaluation, and paragraph 2-8-8.f to determine the charted missed approach altitude.

a. Straight. Apply to turns of 15 degrees or less from continuation of the FAC.

(1) Straight area. The width increases from ± 3038 feet at line A-B to reach ± 6 NM at a point 13.377 NM from the beginning. Where applicable, secondary areas begin at 0 NM wide and expand to reach 2 NM on both sides of the primary area at 13.377 NM (see figure 10-3-3).

Figure 10-3-3. Section 2, Straight Missed Approach Area with PCG



(2) Obstacle clearance. Within the primary area, obstacles are measured shortest distance to line A-B. The section 2 OCS start height is the section 1 OCS end elevation. The standard OCS in the primary area is a 40:1 slope. For obstacles located in the secondary area,

apply the primary OCS slope to a point abeam the obstacle, then apply a 12:1 secondary OCS (perpendicular to course) from the primary boundary to the obstacle.

b. Combination straight and turning. Apply when a turn fix is established on a course 15 degrees or more from continuation of the FAC or when it is necessary to specify a turn initiation area (TIA) before beginning a turn (see figure 10-3-4).

(1) Straight portion ending at turn fix. Apply paragraph 10-3-3a for the straight portion, extended to the turn fix. Secondary areas are not permitted in the straight section.

(2) Straight portion ending at a TIA. Specify a minimum turn altitude in a 20-foot increment that is at least 400 feet above TDZE rounded to the nearest foot, and is greater than the aircraft elevation at the end of section 1 (see formula 10-3-6). Apply paragraph 10-3-3.a until reaching Line A'- B', which is the point the minimum turning altitude is expected to be reached.

(3) Turning portion. The area begins at the end of the straight portion. The flight track and outer boundary radii are specified in paragraph 2-8-6 and table 2-8-1. The outer and inner boundaries expand to reach ± 6 NM at a point 13.377 NM from the beginning of section 2. Where applicable, secondary areas begin after completion of the turn at 0 NM wide and expand to reach 2 NM on both sides of the primary area at 13.377 NM (see figure 10-3-4). The secondary area begins where a line perpendicular to the straight flight path, originating at the point of completion of the turn, intersects the outer boundaries of the missed approach segment. For turning obstacle clearance, apply paragraph 2-8-7, except zones 1 and 4 are not applicable. Other exceptions are noted below.

(a) When a fix denotes the turn point and PCG is available following the turn, connect the inside turn boundary to point B,' D, or T (when it can be determined, is the point of tangency between the outer boundary radii and the inner boundary expansion line) whichever results in the larger area. Point B' is located on the outside turn edge at the end of the straight portion. Establish point D on the inside boundary of either section 2 or section 1, measured 9000 feet prior to point A' along the boundaries of the straight portion and if necessary, section 1. In zone 2, obstacles are measured shortest distance to the boundary of section 1 or the straight portion of section 2 on the side of the turn. The zone 2 OCS start height is equivalent to the OCS elevation at the turn fix. Zone 3 obstacles are measured shortest distance to point D. The zone 3 OCS start height is the aircraft altitude at the turn fix calculated using formula 10-3-6 (see figure 10-3-4).

Formula 10-3-6. Calculated Aircraft Altitude at Turn Fix

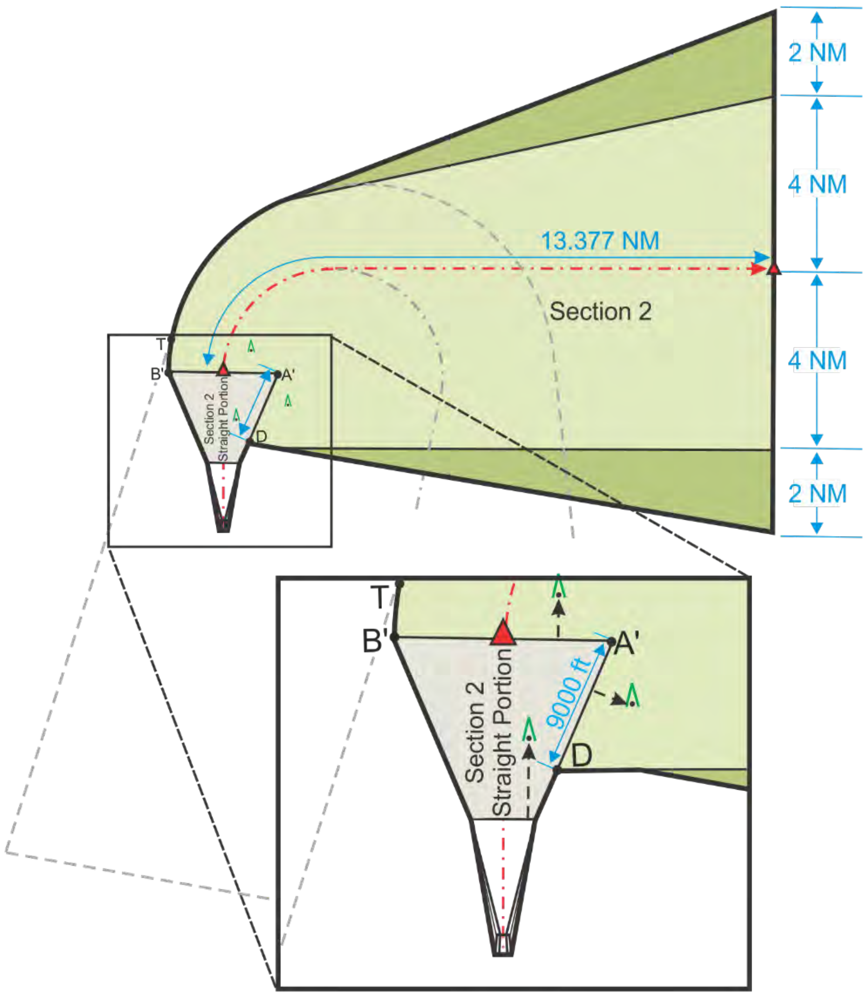
$$turnfix_{MSL} = \frac{d_{straight} \times 0.3048 \times CG}{1852} + AC_{Section1End}$$

Where:

$turnfix_{MSL}$ = Aircraft altitude at turn fix (MSL)
$d_{straight}$ = Distance (feet) from end of section 1 to turn point
CG = Standard or as specified
$AC_{Section1End}$ = Formula 10-3-5 result

(b) When the turn is based on a TIA, or when PCG is not available following the turn, the inside turn boundary connects to point B,' C, or T (when it exists) whichever results in the larger area. Point B' is located on the outside turn edge at the end of the straight portion. In zone 2, obstacles are measured shortest distance to the boundary of section 1 or to the boundary of the straight portion of section 2. The zone 2 OCS start height is equivalent to the end OCS elevation of the straight portion of section 2, less any RASS and precipitous terrain adjustments for the final segment. Zone 3 obstacles are measured shortest distance to point C. The zone 3 OCS start height is the specified turn altitude, less any RASS and precipitous terrain adjustments for the final segment.

Figure 10-3-4. Combination Straight and Turning Missed Approach Area



10-3-4. Missed Approach CG. Where the section 2 OCS is penetrated and the lowest HAT is required, a missed approach CG greater than standard may be specified. Gradients greater than 425 ft/NM require a waiver. Calculate the required climb gradient termination altitude (CGTA) and the CG by applying formula 10-3-7 and formula 10-3-8.

Formula 10-3-7. Required CGTA

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

Where:

D = Shortest distance (NM) section 2 origin to obstacle or secondary measurement point
O_{MSL} = Obstacle elevation (MSL)
AC_{start} = Starting altitude (feet) of the aircraft
OCS_{start} = Starting altitude (feet) of the OCS
RASS = Greatest RASS adjustment (feet) for final if applicable (either primary remote or secondary)

Formula 10-3-8. Required CG

$$CG = \frac{CG_{term} - AC_{start} - RASS}{D}$$

Where:

CG_{term} = Result from formula 10-3-7
AC_{start} = Starting altitude (feet) of the aircraft
D = Shortest distance (NM) section 2 origin to obstacle or secondary measurement point
RASS = RASS adjustment used in formula 10-3-7

Section 10-4. Special Authorization (SA) CAT I ILS Missed Approach

10-4-1. General Information. This section describes criteria for the evaluation of SA CAT I ILS procedures established under Order 8400.13.

10-4-2. Final Approach Segment. The CAT I ILS final approach segment obstacle evaluation applies to the SA CAT I approach authorization. The CAT I procedure must support a 200-foot HAT and lowest possible visibility (no restrictions incurred by lack of infrastructure or obstacle surface penetrations).

10-4-3. Approach Minimums.

a. The lowest SA CAT I HAT is 150 feet. Do not establish an SA CAT I procedure if the required HAT value is greater than 185 feet.

b. SA CAT I procedures require radio altimeter (RA) minimums. If flight inspection determines the procedure RA is unsatisfactory, then an SA CAT I procedure is not authorized.

c. Determine the published RVR using table 10-4-1 (see exception in paragraph 10-4-4.a(2)).

Table 10-4-1. Minimum RVR Values

HAT Range	RVR
150-170	1400
171-185	1600

10-4-4. Missed Approach Evaluation.

a. On runways with established CAT II approaches, evaluate the missed approach segment by applying paragraph 10-5-5 except:

(1) Obstacle penetrations of missed approach surface “A” do not require a HAT adjustment unless the obstacle penetrates the surface by more than 50 feet. When the amount of penetration exceeds 50 feet, adjust the HAT one foot for each foot of surface penetration in excess of 50 feet. For example, if the object penetrates the surface by 58 feet, then increase the HAT from 150 feet to 158 feet.

(2) Do not increase HAT for penetrations of the missed approach surface “B,” “C,” or “D,” however if the penetration exceeds the surface height by more than 70 feet, then increase runway visual range (RVR) from 1400 to 1600.

(3) Table 10-4-2 is provided as a quick-reference for assessing each missed approach surface area.

Table 10-4-2. CAT II Missed Approach Surface Penetration Disposition

Surface A	Surface A1	Surface B, C, or D
1. Adjust HAT upward one foot for each foot of penetration as if the HAT was adjusted, but do not publish a revised HAT until the adjustment exceeds 50 feet; in this case, the amount of HAT adjustment is equal to the amount of penetration that exceeds 50 feet. 2. Increase RVR by applying table 10-4-1 as appropriate. 3. An adjusted HAT greater than 185 feet is not authorized.	Penetration not authorized unless deemed acceptable in accordance with the CAT II missed approach standard.	1. Adjust HAT upward one foot for each foot of penetration in excess of 50 feet as if the HAT was adjusted, but **do not** publish a revised HAT. 2. Increase RVR by applying table 10-4-1 based on the adjusted HAT. 3. An adjusted HAT greater than 185 feet is not authorized.

b. On runways without a CAT II ILS procedure, apply section 10-3 with the following exceptions.

(1) Aircraft are assumed to be 200 feet above the DA at the end of section 1 (9860.69 feet from the DA point).

(2) Minimum turn altitude is 400 feet above the TDZE rounded to the nearest foot; therefore, a combination straight and turning missed approach must always be constructed to accommodate a climb to at least 400 feet above TDZE before a turn can commence.

(a) Straight Portion. Do not extend section 1. Construct the straight portion by applying 10-3-3.a (section 2, straight missed approach construction) from the end of section 1 through the necessary distance for the aircraft to reach the specified turn altitude. The straight portion is considered part of section 2. Secondary areas are not permitted in the straight portion.

(b) Turning Portion. The area begins at the end of the straight portion.

(3) Any obstacle located within section 1 of the missed approach that would qualify to be eliminated from TERPS consideration under the CAT II missed approach standard may also be eliminated from consideration using the CAT I standard.

c. SA CAT I ILS procedures with obstacle driven missed approach CGs of up to 425 ft/NM may be established as public-use procedures without waiver approval when evaluated under paragraph 10-4-4.b. Consider this option prior to adjusting the HAT.

Section 10-5. CAT II/III ILS Evaluation

10-5-1. General Information. This section describes criteria for the evaluation of CAT II and III ILS procedures.

10-5-2. Final Approach Segment. The CAT I ILS final approach segment obstacle evaluation applies to the CAT II/III approach authorization. The CAT I procedure must support a 200-foot HAT and lowest possible visibility (no restrictions incurred by lack of infrastructure or obstacle surface penetrations). The GPA must be 3.0 degrees unless approved (see paragraph 1-4-2).

10-5-3. Approach Light Area. Obstructions must not penetrate the approach light plane or the inner-approach OFZ in accordance with AC 150/5300-13.

10-5-4. Approach Minimums. The lowest CAT II HAT is 100 feet. Apply table 10-5-1 to determine the minimum RVR associated with the lowest authorized CAT II HAT (see paragraph 10-5-6 for CAT III RVR requirements).

Table 10-5-1. Minimum Authorized CAT II RVR

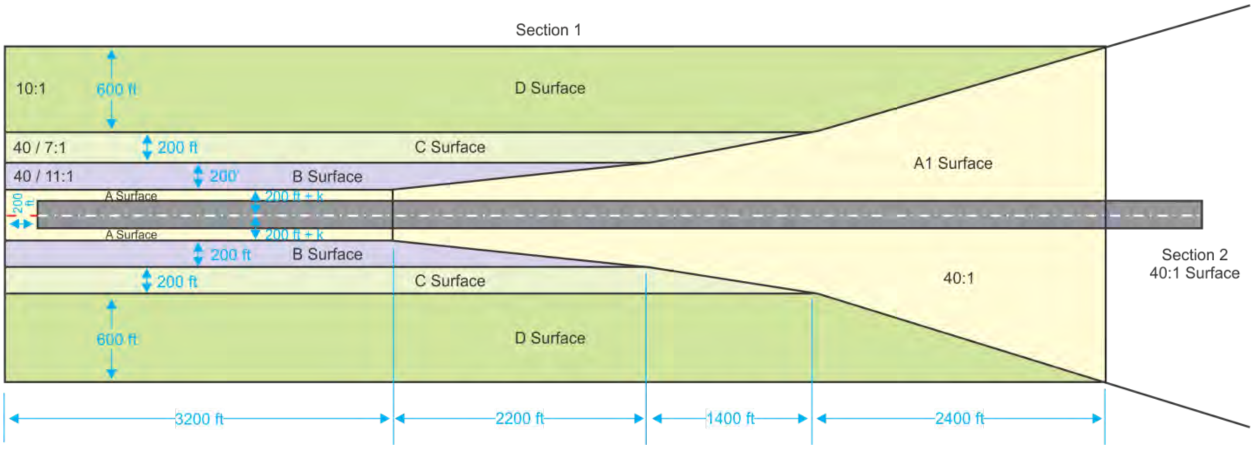
HAT (feet)	RVR
100 - 140	1200
141- 180	1600
181 - 199	1800

10-5-5. Missed Approach Segment. The CAT II/III missed approach area is comprised of two sections.

a. Section 1 (see figure 10-5-1).

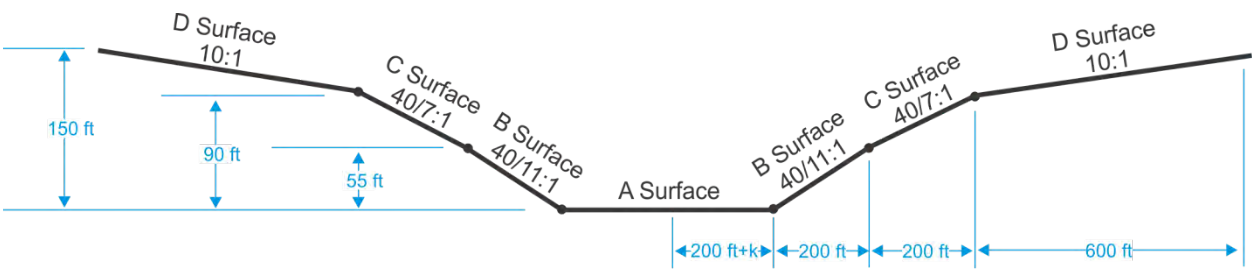
(1) The section 1 area begins at the end of the final approach OCS and is aligned with a continuation of the FAC, continuing in the direction of landing for a distance of 9200 feet excluding extensions. It is comprised of five surfaces: A, B, C, D, and A1.

Figure 10-5-1. Section 1 Plan View



(2) The OCS slopes associated with surface A, B, C, and D are depicted in figure 10-5-2. Surface A1 has a slope of 40:1 rising in the direction of the missed approach.

Figure 10-5-2. Section 1 Profile View and OCS Slopes



Where airport elev ≤ 1000 ft, k = 0
Where airport elev > 1000 ft, k = .01(airport elev - 1000 ft)

(a) Apply formula 10-5-1 to calculate the MSL height of the surface A, B, C, or D OCS at any given distance (X) from the LTP and (Y) from the runway centerline when X is 3000 feet or less.

Formula 10-5-1. Surface A, B, C, D Surface Height Where X ≤ 3000 and Y:

$Y < (200 + k)$: $h = e$ A surface

$Y \geq (200 + k)$:

$h = \frac{11(Y-(200+k))}{40} + e$ B surface

$Y > (400 + k)$: $h = \frac{7\times(Y-(400+k))}{40} + 55 + e$ C surface

$Y > (600 + k)$: $h = \frac{Y-(600+k)}{10} + 90 + e$ D surface

Where:
h = MSL height of OCS
X = Distance (feet) from LTP measured parallel to runway centerline
Y = Perpendicular distance (feet) from runway centerline
e = MSL elevation of the runway centerline at distance X
k = 0 if airport elevation ≤ 1000 MSL, otherwise k = 0.01(airport elevation – 1000)

(b) Apply formula 10-5-2 to calculate the MSL height of the B, C, D, or A1 OCS at any given distance (X) from the LTP and (Y) from the runway centerline when X is greater than 3000 feet but equal to or less than 9000 feet.

Formula 10-5-2. Surface B, C, and D Surface Height Where X > 3000 and Y:

$Y > (200 + k)$: $h = \frac{11\times(Y-(200+k))}{40} + f$ B surface

$Y > (400 + k)$: $h = \frac{7\times(Y-(400+k))}{40} + 55 + f$ C surface

$Y > (600 + k)$: $h = \frac{Y-(600+k)}{10} + 90 + f$ D surface

Where:
h = MSL height of OCS
X = Distance (feet) from LTP measured parallel to runway centerline
Y = Perpendicular distance (feet) from runway centerline
f = MSL elevation of the runway centerline 3000 feet from threshold
k = 0 if airport elevation ≤ 1000 MSL, otherwise k = 0.01(airport elevation – 1000)

(c) Apply formula 10-5-3 to calculate the MSL height of the surface A1 at any given distance (X) from the LTP and (Y) from the runway centerline when X is greater than 3000 feet but equal to or less than 9000 feet.

Formula 10-5-3. Surface A1 Surface Height

$$h = \frac{X - 3000}{40} + f$$

Where:
h = MSL height of OCS
X = Distance (feet) from LTP measured parallel to runway centerline
f = MSL elevation of the runway centerline 3000 feet from LTP

(3) An obstacle must not penetrate the OCS of surface A, B, C, D, or A1 unless the obstacle is either deemed acceptable under table 10-6-1, or the minimums are adjusted as follows:

(a) Surface A or inner approach OFZ. Adjust the HAT upward one foot for each foot of surface penetration. A CAT II procedure is not authorized if the resultant HAT is greater than 199 feet.

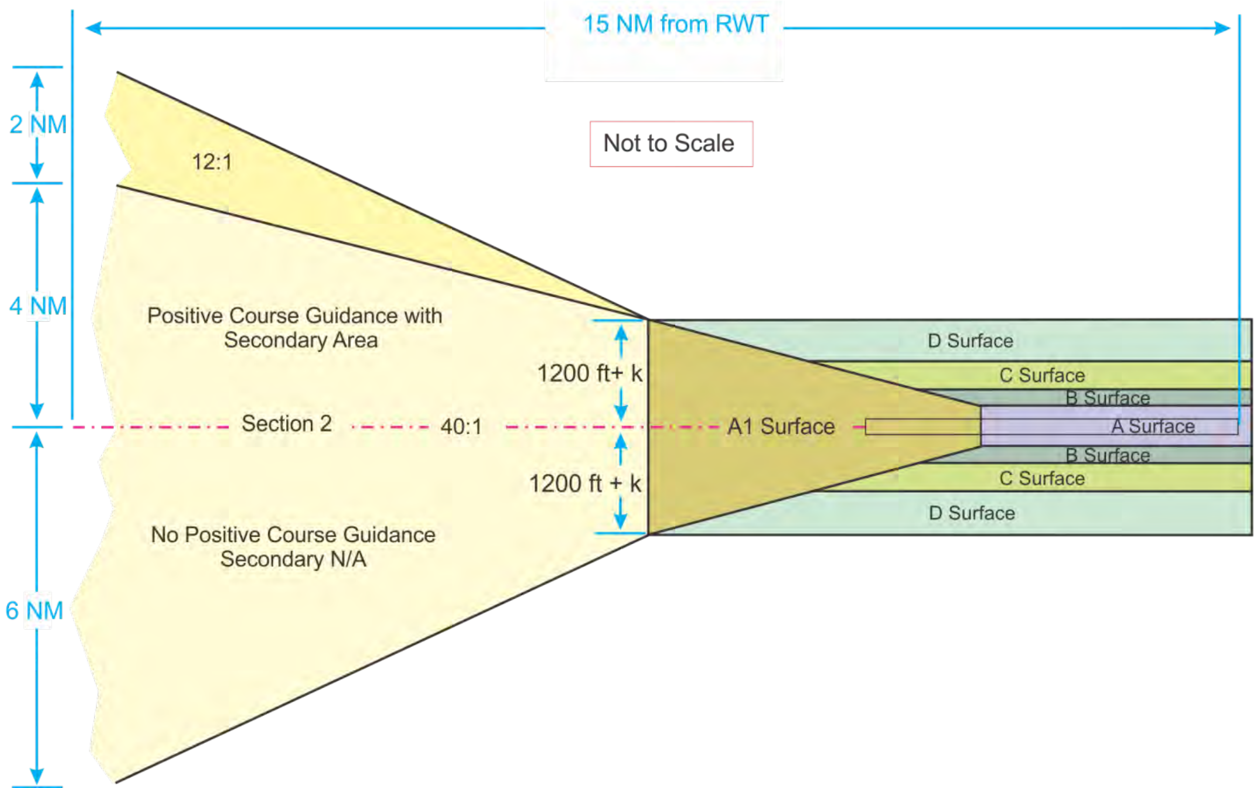
(b) Surface B, C, or D. Increase RVR as specified in table 10-5-1 as if the HAT was adjusted, but do not raise the HAT.

(c) Surface A1. This surface must not be penetrated unless the obstacle is deemed acceptable under table 10-6-1.

b. Section 2 (see figure 10-5-3).

(1) Straight-ahead missed approach area (applies to turns 15 degrees or less). This area starts at the end of the A1 surface and is centered on the specified missed approach course. The width increases uniformly from +/- (1200 + k) feet at the beginning to en route width at a point 15 NM from the LTP. When PCG is provided for the missed approach procedure, secondary areas that are zero miles wide at the point of beginning and which increase uniformly to initial secondary width may be added to section 2.

Figure 10-5-3. Straight Missed Approach Area



(2) Turning Missed Approach Area (applies to turns of more than 15 degrees) (see figure 10-5-4). Design the procedure to accommodate an aircraft turning at least 400 feet above the TDZE rounded to the nearest foot. Aircraft are assumed to be 200 feet above the runway elevation at the end of the A1 surface; therefore, an extension to the A1 surface must be constructed (referred to as $A1_{extended}$). Determine the length of $A1_{extended}$ by applying formula 10-5-4.

Formula 10-5-4. $A1_{extended}$ Length

$$d = (T_{MSL} - (f + 200)) \times \left(\frac{1852}{0.3048 \times CG}\right)$$

Where:

d = Length of $A1_{extended}$ from end of surface A (feet)
T_{MSL} = Aircraft MSL turn height (minimum is TDZE elevation + 400)
f = MSL elevation of the runway centerline 3000 feet from LTP
CG = Standard or as specified

(a) The $A1_{extended}$ surface area splays outward at 15 degrees from the missed approach course until reaching the turn altitude/point (see figure 10-5-5).

(b) The flight track and outer boundary radii of the turn are specified in paragraph 2-8-6 and table 2-8-1 both originating on a line marking the end of the $A1_{extended}$

surface. Unless a fix/facility identifies the turn point, the inner boundary line commences at the inside turn edge of the D surface opposite the end of the touchdown area (A surface). When the turn point is marked by a fix/facility, the inside tieback may be constructed relative to the end of the $A1_{extended}$ surface. When the point on the inside turn side of section 2 area abeam the clearance limit is past an imaginary line extended perpendicular to the edge of section 1 abeam the end of the touchdown zone on inside turn side, the inner boundary line commences on the outside turn edge of the D surface opposite the end of the touchdown area [(A surface) (see figure 10-5-6)]. The outer and inner boundary lines extend to points each side at flight track at the clearance limit at a rate that achieves initial segment width 15 NM from the LTP. Where secondary areas are required, they must commence after completion of the turn at the point where PCG is achieved.

(3) Section 2 OCS is a 40:1 inclined plane originating at the end of section 1.

(a) Beginning height is equivalent to the end of the A1 surface height on centerline.

(b) The beginning height of the section 2 OCS outside of the $A1_{extended}$ surface is equivalent to the ending height of the $A1_{extended}$ surface on centerline. Obstacles outside of the $A1_{extended}$ surface are measured to the nearest edge of section 1 (or to the $A1_{extended}$ surface).

(c) Section 3 is necessary for turns more than 90 degrees as described in paragraph 2-8-7.b, except point "B" is defined as the point of the inside of turn edge of section 1 abeam the end of the A surface regardless of the location of the inside tieback point (see paragraph 10-5-5b(2)(b)).

(d) The 40:1 OCS within section 2 (to include $A1_{extended}$) and section 3 must not be penetrated by an obstacle.

Figure 10-5-4. Turning Missed Approach Area

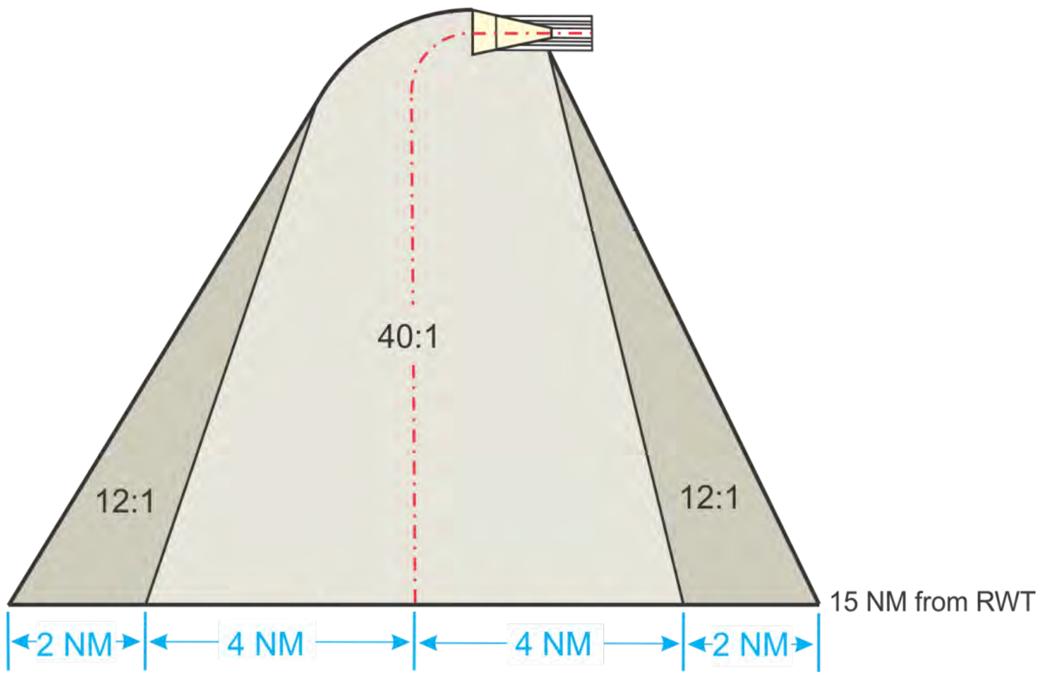


Figure 10-5-5. Turning Missed Approach OCS Detail

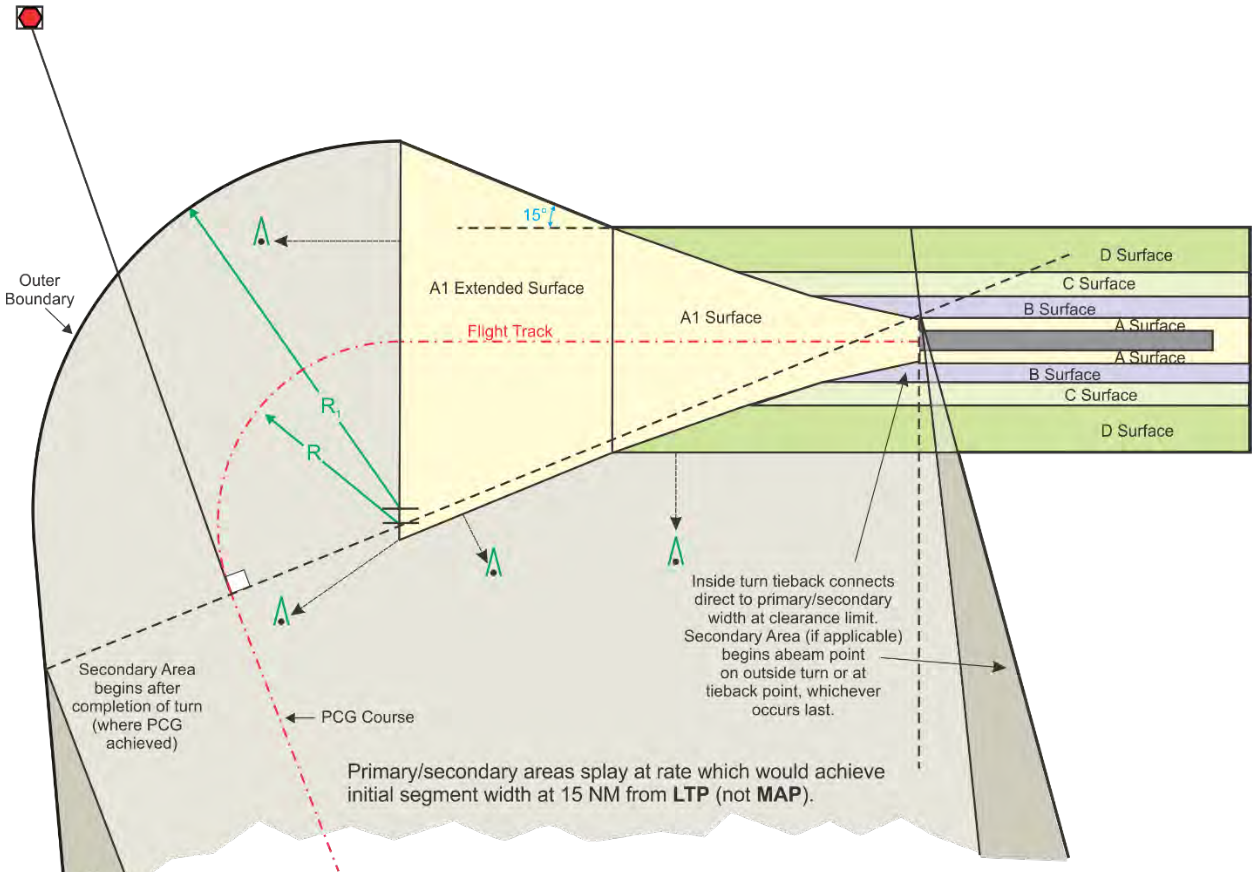
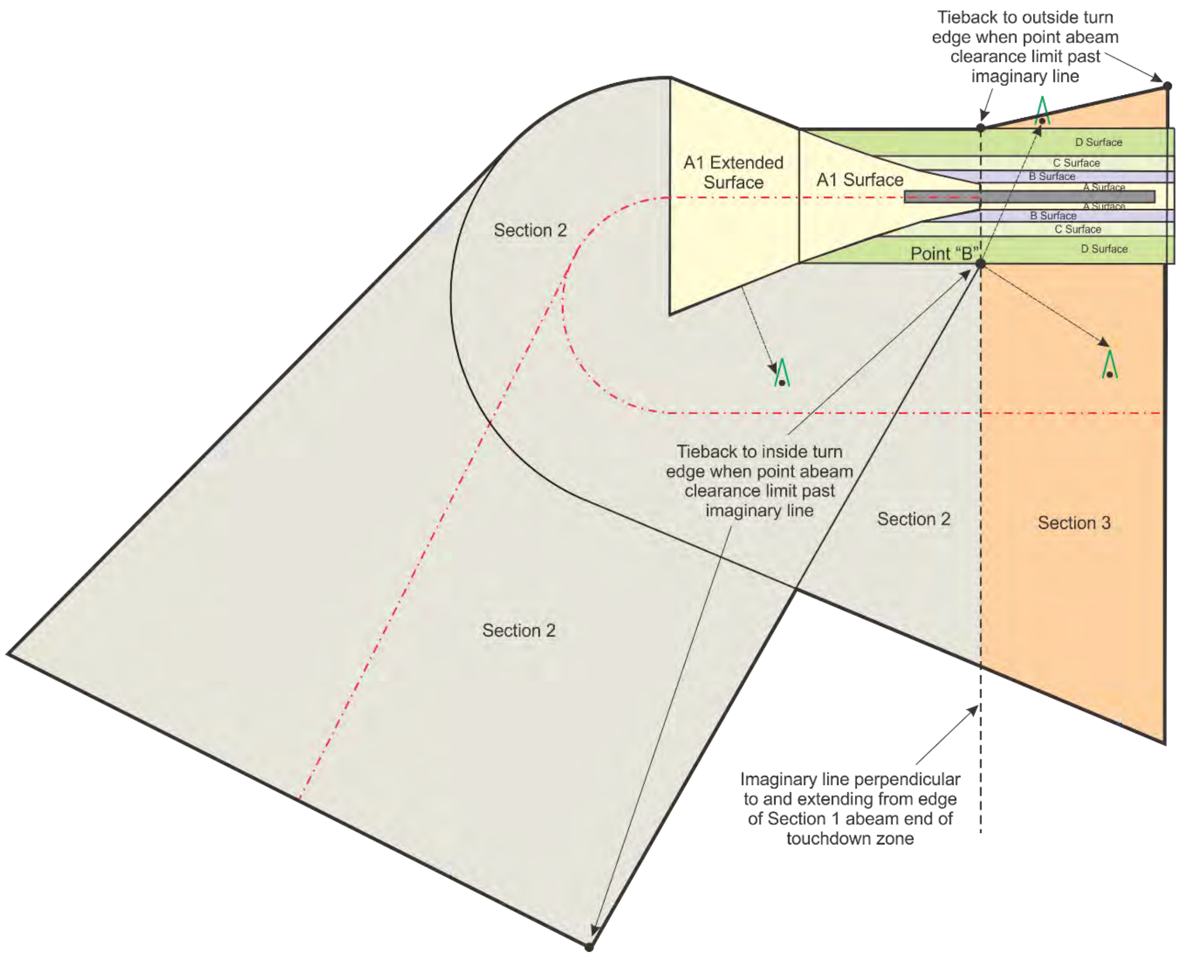


Figure 10-5-6. Turning Missed Approach OCS Detail (Continued)



10-5-6. Requirements for CAT III ILS. Except as noted within this paragraph, the requirements for CAT II ILS applies.

a. Minimums.

(1) Publish the lowest authorized CAT III RVR when the runway supports unrestricted CAT II operations (100-foot HAT and RVR 1200).

(2) The following CAT III minimum RVR standards are applicable based on equipment performance class:

(a) III/D/3 for RVR $\geq$ 700

(b) III/E/3 for RVR $\geq$ 600

(c) III/E/4 for RVR < 600

Section 10-6. PA and APV Obstacle Assessment

10-6-1. Acceptable Obstacles. Certain equipment essential to flight operations may penetrate PA and APV final approach and missed approach surfaces without impacting the procedure. Refer to table 10-6-1 to determine if an obstacle is permitted to be excluded from obstacle clearance consideration based on its type and location. If an obstacle is permitted to be excluded, then no adjustment to the procedure is required.

Table 10-6-1. Acceptable Obstacles

Obstacle Type	Location
VGSI[1] (PAPI, VASI, etc.)	CAT II/III Section 1 Missed Surface A, B, A1
Approach Lights[1]	Final Segment OCS
REIL[1] Runway and taxiway lights[2]	CAT II/III Section 1 Missed Surface A, B
Airport Signs[3]	Final Segment OCS CAT II/III Section 1 Missed Surface A, B
End-fire glide slope antenna[4]	CAT II/III Section 1 Missed Surface A, B
PAR components[5] Radar reflectors[5] (frangible mounted)	CAT II/III Section 1 Missed Surface B
Aircraft and Vehicles	Final segment OCS[6] CAT II/III Section 1 Missed Surface B, C, A1[7]

[1] When installed in accordance with Order JO 6850.2, Visual Guidance Lighting Systems.
[2] When installed in accordance with AC 150/5340-30, Design and Installation Details for Airport Visual Aids.
[3] When installed in accordance with AC 150/5340-18, Standards for Airport Sign Systems.
[4] When installed in accordance with Order 6750.16, Siting Criteria for Instrument Landing Systems & AC 150/5300-13, Airport Design.
[5] Must be at least 400 feet from RCL and no higher than 15 feet above the closest point on the RCL.
[6] Only when the requirements of paragraph 10-6-2.b are met.
[7] Only when the requirements of paragraph 10-6-2.c are met.

10-6-2. Aircraft and Ground Vehicles as Obstacles. Taxiing, holding, parked aircraft and ground vehicles are considered obstacles for instrument procedure obstacle clearance except as permitted by application of table 10-6-1.

a. Evaluation. When evaluating aircraft as obstacles, consider the location of the taxiway or ramp and consider the highest aircraft surface that falls within the area. For ground vehicles, consider the road/taxiway/ramp with routine vehicle traffic and apply the appropriate height from Order 8260.19 Section 2-11, Obstacle Data.

b. Final segment obstacles. Taxiing, holding, and parked aircraft/ground vehicles are considered obstacles in the final segment OCS unless positive controls have been established to keep the surfaces clear when aircraft on approach to the same runway are within 2 NM of the LTP when the ceiling is less than 800 feet and/or the prevailing visibility is less than 2 SM. Positive controls include proper placement of hold markings/signage as specified by FAA Airports Engineering Division and/or establishment of ATC operating procedures. Private roads and airport access roads are considered acceptable when positive controls are established to either keep the surface clear when the reported weather is less than 800-2, or when access is restricted to vehicles of less than 10 feet in height that are necessary for the maintenance of the airport/navigation facilities. Controls must also prevent vehicles that penetrate the OCS from parking in the surface without being in direct contact with ATC.

c. CAT II/III Section 1 Missed Surface B, C, A1 obstacles. Aircraft and vehicles may be excluded from obstacle clearance consideration provided they are operating on a taxiway that is distanced appropriately from the runway. Appropriate runway-to-parallel taxiway distances are specified within AC 150/5300-13. Entry and exit taxiways are considered compliant if the hold line-to-runway centerline distances meet the airport design standards specified in AC 150/5300-13 (normally 250-280 feet).

Chapter 11. Radar Approach Procedures and Vectoring Charts

Section 11-1. General Information

11-1-1. General. This chapter applies to radar approach procedures and vectoring charts utilizing ground-based radar or other approved surveillance systems (such as satellite-based). The types of systems supported are:

a. PAR is a system that graphically displays lateral course, glidepath, and distance from touchdown information of sufficient accuracy, continuity, and integrity to provide precision approach capability to a runway/landing area.

b. Surveillance radar is a system that displays direction and distance information with suitable accuracy, continuity, and integrity to safely provide radar vectoring capability for departures, arrivals, en route operations, and ASR approaches to an airport.

(1) Within this chapter, the term “single sensor” applies to configurations authorized to use 3-NM lateral separation, and the term “multi-sensor” applies to those that require 5 NM as specified in Order JO 7110.65, paragraph 5-5-4. Where both single sensor and multi-sensor separation standards apply, either establish a separate procedure/chart for each sensor configuration, or establish one procedure/chart to accommodate the larger standard.

Note: Within 60 NM of the antenna, single sensor separation applies to full time reinforced Monopulse Secondary Surveillance Radar (MSSR) systems.

(2) FUSION describes adaptations based on the input of all available surveillance sources such as ASR, ARSR, automatic dependent surveillance – broadcast (ADS-B), and any future surveillance source, into the display of a single tracked target for air traffic control separation services.

(a) When the aircraft target symbol can be used for 3-NM separation, minimum lateral obstacle clearance is 3 NM.

(b) When the aircraft target symbol can be used for 5-NM separation (Increased Separation Required (ISR) is displayed), minimum lateral obstacle clearance is 5 NM.

c. ADS-B. Apply paragraph 11-1-1.b, except not authorized for conducting ASR approaches.

Section 11-2. Radar Approaches

11-2-1. General. Both ASR and PAR approach procedures may be established where the applicable Order 8200.1, U.S. Standard Flight Inspection Manual, coverage, and alignment tolerances are met. ASR approaches may be established when the final segment is adapted for Single Sensor operations and the radar antenna is not more than 20 NM from:

a. The LTP when the procedure is designed to meet straight-in alignment.

b. The ARP when the procedure is designed to meet circling-only alignment.

11-2-2. Feeder Routes and Initial Approach Segments.

a. Feeder and initial segments do not need to be established when navigation guidance and obstacle clearance are provided by ATC radar vectors during the transition from the en route to the terminal phase of flight.

b. Feeder/Initial segments based on routes (Military Only). When operationally required, establish feeder routes and/or initial segments based on conventional navigation, RNAV, or radar routes.

(1) Conventional/RNAV Feeder/Initial. Develop in accordance with chapter 2 or Order 8260.58 as appropriate.

(2) Radar Feeder/Initial. The route/segment begins at an established fix that permits positive radar identification and ends at the appropriate termination fix for the segment. Display the course centerline on a radar video map as a “special use” track per Order 7210.3, Facility Operation and Administration, chapter 3, section 7.

(a) Alignment. Design feeder/initial and initial/initial segment intersections with the smallest amount of course change necessary for the procedure. The maximum allowable course change between segments is 90 degrees.

(b) Area. The OEA begins at the applicable radar fix displacement prior to the route/segment start fix and extends to the segment termination fix. Primary area half-width is equal to the minimum lateral clearance applicable to the radar configuration/adaptation (see paragraph 11-1-1.b) from course centerline. There is no secondary area. The area has no specified maximum or minimum length; however, the segment must be long enough to permit the required altitude loss without exceeding the maximum authorized descent gradient.

Note: When the minimum lateral clearance changes within a segment, the OEA half-width also changes without the need to “splay” or “taper.” For example, when transitioning from a Multi-sensor to Single Sensor configuration, the lateral clearance changes from 5 NM to 3 NM. Likewise lateral clearance changes from 5 NM to 3 NM when the distance to the sensor reduces to less than 40 NM and the configuration qualifies for 3-NM clearance at that point (see paragraph 11-1-1.b(1) and Order JO 7110.65 paragraph 5-5-4).

(c) Obstacle clearance. Apply the chapter 2 standard applicable to the segment.

(d) Descent gradient. Apply the chapter 2 standard applicable to the segment.

(e) Altitude selection. Apply the chapter 2 standard applicable to the segment. Do not publish fix altitudes higher than the minimum required for obstacle clearance or airspace to achieve an "*optimum*" descent gradient.

11-2-3. Intermediate Approach Segment. Establish an intermediate segment when necessary (for example, ATC radar vectors not available, or MVA too high to support desired PFAF altitude). The intermediate segment begins at the intermediate fix and extends to the PFAF. When there is a preceding conventional/RNAV route segment, the applicable conventional/ RNAV intermediate segment standards apply, except as specified in paragraph 11-2-3.b(2).

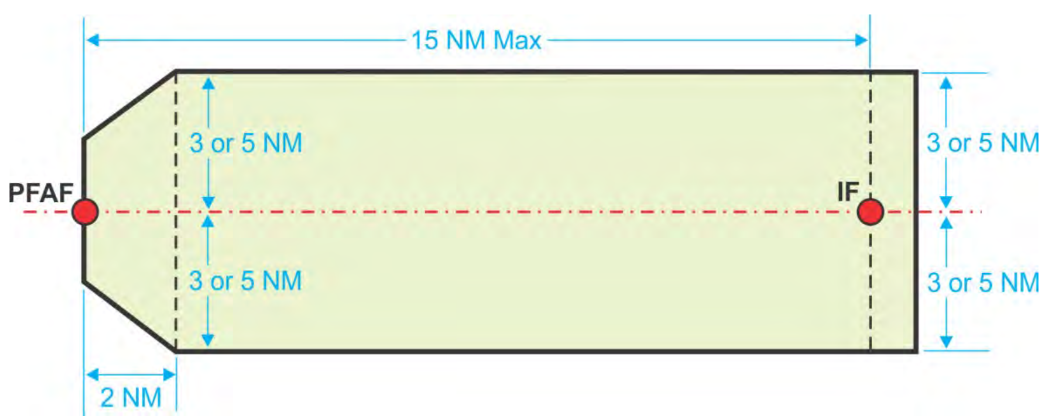
a. Alignment. The intermediate course is an extension of the final approach course (no course change permitted at the PFAF).

b. Area.

(1) Radar intermediate. When radar is used for course guidance (route or vector), the OEA begins at the applicable radar fix displacement prior to the IF and extends to the PFAF. Primary area half-width is equal to the minimum lateral clearance applicable to the radar configuration/adaptation (see paragraph 11-1-1.b) until reaching a point 2 NM prior to the PFAF, then tapers to the width of the ASR/PAR/PAR without glide slope final approach segment (FAS) primary OEA width abeam the PFAF (see paragraphs 10-2-1, 11-2-4, and 11-2-5) (USN NA). There are no intermediate secondary areas (see figure 11-2-1).

Note: When the minimum lateral clearance changes within a segment (for example, when transitioning from a multi- to single-sensor configuration, or at the applicable distance for a single sensor configuration), the OEA half-width also changes without the need to "splay" or "taper."

Figure 11-2-1. Intermediate Segment Area



(2) Non-radar intermediate. When conventional/RNAV navigation is used for course guidance, apply the intermediate OEA criteria from the applicable 8260-series order with the following exceptions:

(a) Connection to PAR final. Connect the outer edges of the intermediate primary area abeam the IF to the outer edges of the precision “X” OCS and the intermediate secondary area to the precision “Y” OCS abeam the PFAF.

(b) Connection to ASR final. Connect the outer edges of the intermediate primary and secondary areas abeam the IF to the outer edge of the ASR area abeam the PFAF.

c. Length. The intermediate segment length is normally 6 NM. The minimum length varies based on course guidance but must always accommodate the required altitude loss. The maximum length is 15 NM. For conventional/RNAV and radar route course guidance, apply paragraph 2-5-3.b(1) for ASR approaches and paragraph 10-1-3.b for PAR approaches. Radar intermediate segments may not be less than 2 NM.

d. Obstacle clearance. The minimum ROC is 500 feet. Apply paragraph 3-2-2 adjustments. For conventional/RNAV course guidance, apply secondary area ROC criteria from the applicable 8260-series directive.

e. Descent gradient. Apply paragraph 2-5-3.d.

11-2-4. PAR Final Approach Segment.

a. Inoperative/unused components. Failure of the azimuth component renders the entire PAR system inoperative. When the elevation component (glidepath) fails or is not used (for example, to support pilot or controller training) the PAR azimuth may be used to provide an ASR approach. A stand-alone PAR azimuth without glide slope procedure is not required when ASR minimums are established to the same runway and used during the approach, the missed approach instructions are the same, and the ASR missed approach point is identifiable on the PAR scope. Alternatively, a separate PAR azimuth without glide slope procedure may be established when required and/or operationally advantageous. Evaluate using the localizer area and obstacle clearance requirements specified in chapter 8. NPA visibility minimums are established according to section 3-3 and documented in accordance with applicable directives.

b. General. Apply the final segment general criteria applicable ILS for GPA, TCH, and PFAF.

(1) Use the highest applicable MVA to determine the PFAF to LTP distance when there is no preceding segment.

(2) ILS HAT and DA standards apply (to include paragraph 3-2-2), except the minimum HAT may be 100 feet for DoD-only approaches when the OCS is clear. Adjusting TCH to reduce/eliminate OCS penetrations is not applicable to PAR FAS evaluations.

c. OEA/OCS. Apply the ILS FAS criteria for alignment, OCS slope, width, height, and OEA/OCS evaluation except the OEA extends to the PFAF (no radar fix tolerance applied). Also, where the PFAF must be located more than 50200 feet from the RWT coordinates, the OEA continues to splay to the PFAF or until reaching the minimum lateral clearance applicable to the radar configuration (see paragraph 11-1-1.b).

11-2-5. ASR FAS. Use the highest applicable MVA to determine the PFAF location when there is no preceding segment.

a. General. Apply the current non-vertically guided final segment general criteria.

b. Alignment. Align the FAC with the extended runway centerline for a straight-in approach, or to the ARP for a circling approach. When an operational advantage can be achieved, the FAC for circling approaches may be aligned to pass through any portion of the usable landing surface.

c. Area. The final approach begins at the applicable radar fix displacement prior to the PFAF and ends at the FEP or the appropriate radar fix displacement beyond the MAP, whichever is encountered last. Determine the primary area half-width (½W_P) using formula 11-2-1. When the distance of any point on FAC centerline is greater than 20 NM, the primary area ½W_P is 3 NM. Connect the width calculated at the PFAF to the width calculated at the FEP (straight line connection). The width at the early or late fix displacement points is equal to the width at the PFAF and FEP (see figure 11-2-2).

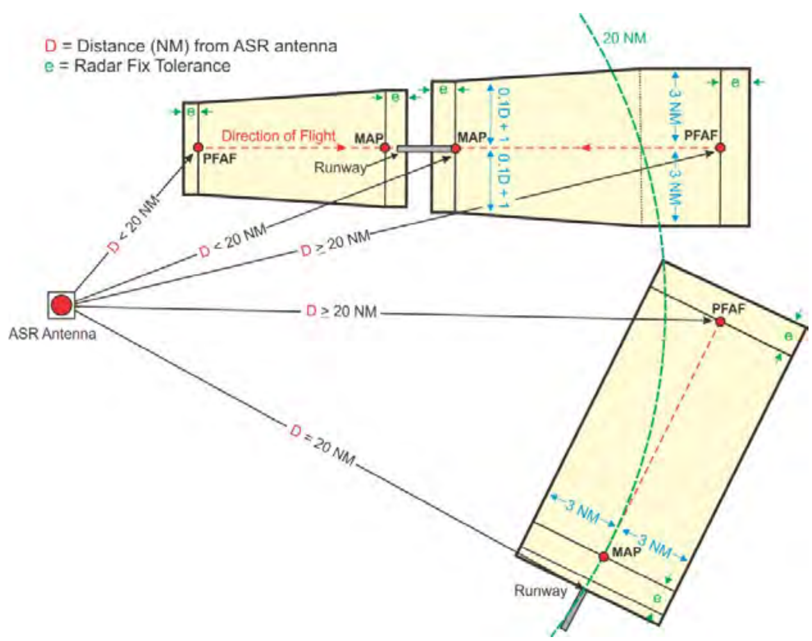
Formula 11-2-1. Final Area Half-Width at PFAF and RWT/FEP

$$\frac{1}{2}W_P = 0.1 \times D + 1$$

Where:
D = Distance, FAC point to Antenna (NM)

Note: ½ W_P = 3 NM where D > 20 NM

Figure 11-2-2. ASR Final Approach Segment



d. Length. The segment must provide sufficient length to accommodate required altitude loss. The minimum length is 3 NM and maximum length is 10 NM.

e. Obstacle clearance. The minimum ROC is 250 feet. Apply paragraph 3-2-2 adjustments.

f. Vertical Descent Angle (VDA). Apply paragraphs 2-6-2 and 2-6-4 criteria, except do not publish the VDA.

g. Recommended altitudes (RecAlt). Determine recommended altitudes at each mile on final approach for ATC use. RecAlt values below the MDA are not issued. Round recommended altitudes to the nearest 20-foot increment. Determine RecAlt values using formula 11-2-2.

Formula 11-2-2. Recommended Altitudes (RecAlt)

$$RecAlt = A - DG$$

Where:
A = PFAF altitude or last RecAlt (unrounded)
DG = (1852/0.3048) x tan(VDA calculated per paragraph 2-6-4)

Example:

PFAF altitude = 2000 ft MDA = 660 ft, VDA = 3.00 (318.436/NM)
6 NM (PFAF) = 2000 ft
5 NM recommended altitude: 2000 - 318.436 = 1681.564 (1680)
4 NM recommended altitude: 1681.564 - 318.436 = 1363.128 (1360)
3 NM recommended altitude: 1363.128 - 318.436 = 1044.692 (1040)
2 NM recommended altitude: 1044.692 - 318.436 = 726.256 (720)
1 NM recommended altitude: 726.256 - 318.436 = 407.82 (Not issued)

Note: RecAlt with Stepdown Fix above the VDA. When the minimum altitude at a stepdown fix is above the vertical path of the VDA, calculate RecAlt using the appropriate VDA for each sub-segment (VDA from PFAF to stepdown altitude prior to stepdown fix, and VDA from stepdown altitude to TCH after the stepdown fix).

Example:

PFAF altitude = 3300 ft, MDA = 1400 ft, VDA PFAF to stepdown fix = 3.00 (318.436/NM), VDA at 4 NM stepdown fix to TCH = 3.39° (359.924/NM)
6 NM (PFAF) = 3300
5 NM recommended altitude: 3300 - 318.436 = 2981.564 (2980)
4 NM recommended altitude: 2981.564 - 318.436 = 2663.128 (2660)
3 NM recommended altitude: 2663.128 - 359.924 = 2303.204 (2300)
2 NM recommended altitude: 2303.204 - 359.924 = 1943.280 (1940)
1 NM recommended altitude: 1943.280 - 359.924 = 1583.356 (1580)

11-2-6. Missed Approach Segment.

a. PAR. Apply the CAT I ILS missed approach criteria to approaches with HAT values greater than or equal to 200 feet. Apply the CAT II ILS missed approach criteria for approaches with HAT values lower than 200 feet.

b. ASR. Apply section 2-8 missed approach criteria. The MAP is located on the final approach course not farther from the PFAF than the FEP.

Section 11-3. Minimum Vectoring Altitude Charts

11-3-1. Sectors. The MVAC may be subdivided into sectors to gain relief from obstacles. There is no prescribed limit on the size, shape, or orientation of MVAC sectors. Where small contiguous sectors with different altitudes do not serve an operational need, consider combining them.

a. OEA. Adjacent sectors share common boundaries; however, each sector OEA is stand-alone and evaluated separately. The sector OEA includes the volume of airspace contained within its defined boundaries. Except for isolation areas (see paragraph 11-3-2.b), each sector includes a buffer equal to the minimum required lateral clearance for the applicable radar configuration/adaptation.

(1) Single sensor configuration. An OEA buffer expands outward at least 3 NM from those portions of the boundary within 40 NM of the radar antenna and at least 5 NM outward from those portions of the boundary equal to or greater than 40 NM from the radar antenna. When a contiguous sector crosses 40 NM from the radar antenna, the sector is effectively divided into sub-sectors at the 40 NM arc and normal OEA/buffers applied to each, except buffers expanding INTO the sector may be truncated at the boundary. The highest altitude from each sub-sector applies (see figure 11-3-3 and figure 11-3-4).

Note: For full time reinforced MSSR systems use 60 NM instead of 40 NM in all instances within the above paragraph.

Figure 11-3-1. Sector Buffer Areas (Single Sensor, w/out reinforced MSSR)

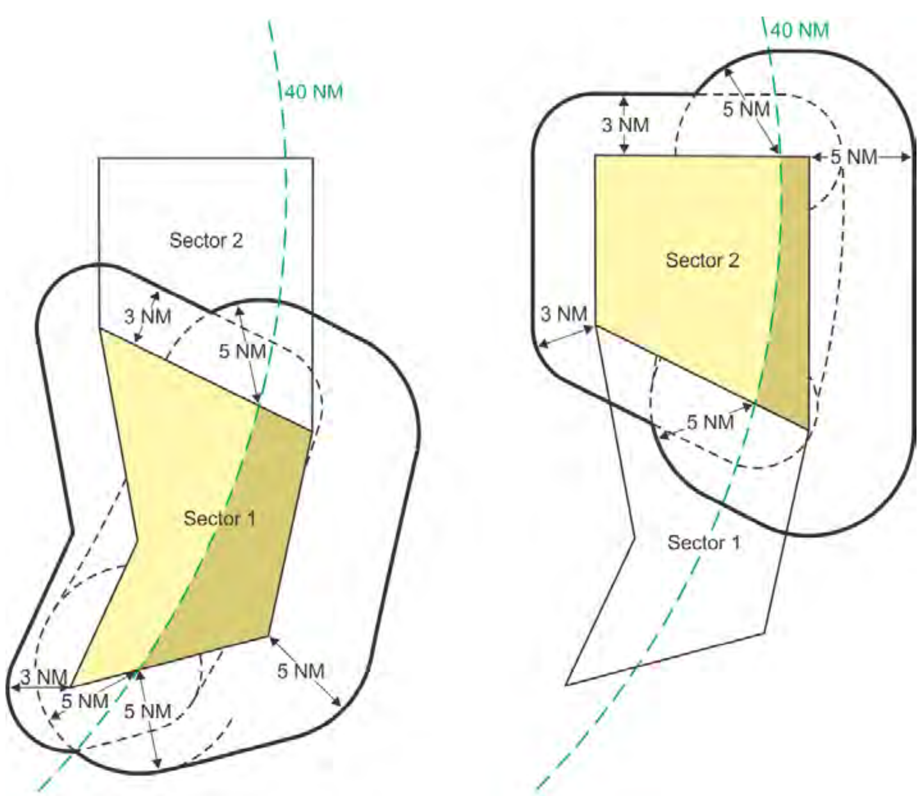
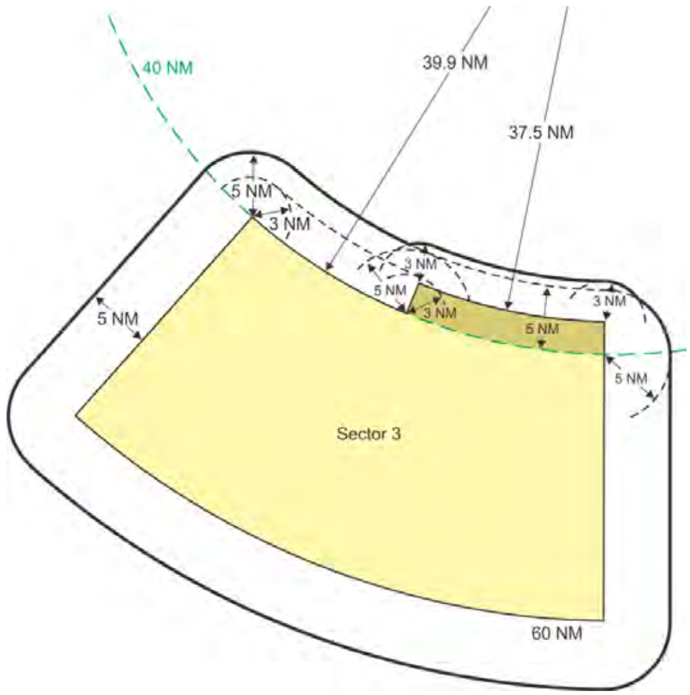
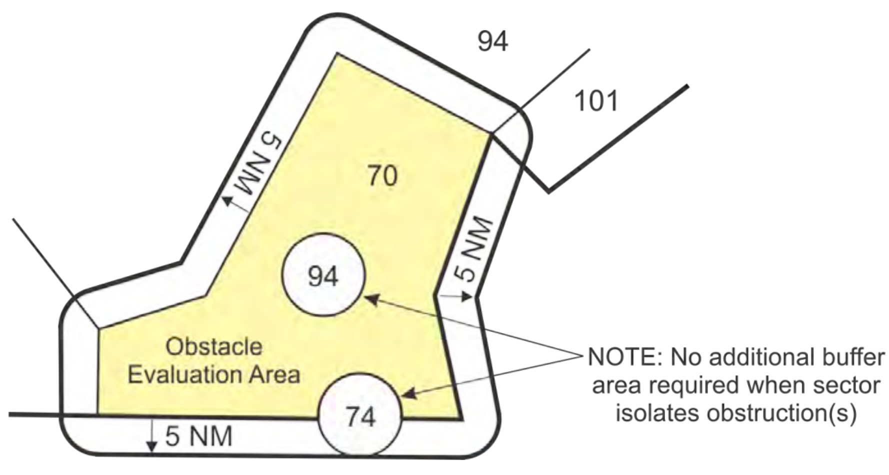


Figure 11-3-2. Buffer Area, Contiguous Sector crossing 40 NM. (Single Sensor, w/out reinforced MSSR)



(2) Multi-sensor configuration. The OEA includes a buffer extending at least 5 NM outward from the boundary, regardless of distance to radar antenna or MVAC center (see figure 11-3-5).

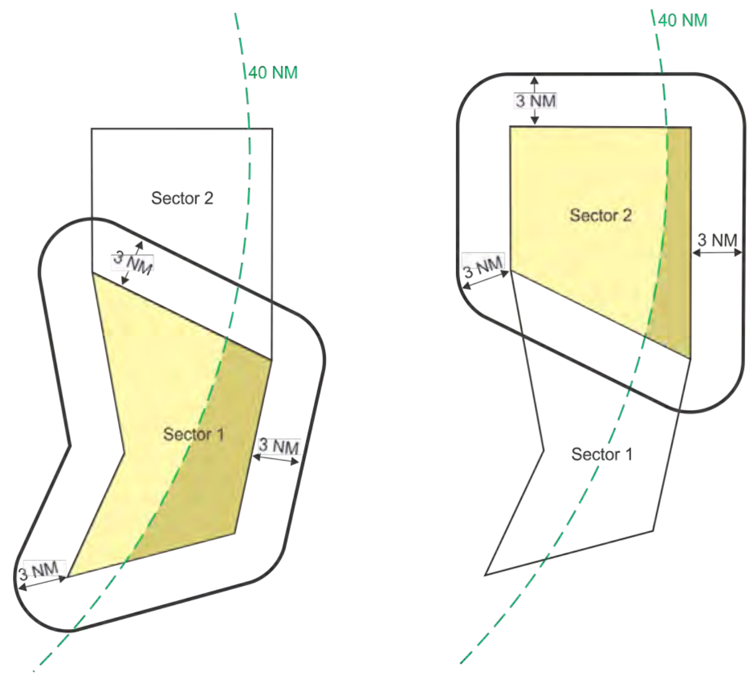
Figure 11-3-3. Multi-Sensor Buffer Areas



(3) FUSION adaptation:

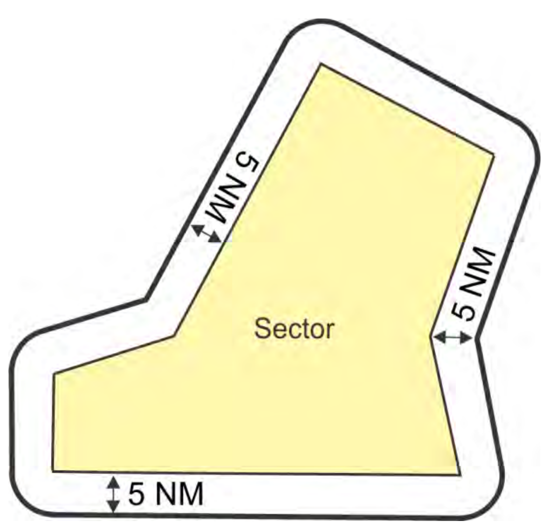
(a) The OEA includes a buffer extending at least 3 NM outward from the boundary, regardless of distance to radar antenna or MVAC center for the 3-NM separation minima chart (see figure 11-3-6).

Figure 11-3-4. Fusion Adaptation Sector Buffer Areas (3-NM Separation Minima Chart)



(b) The OEA includes a buffer extending at least 5 NM outward from the boundary, regardless of distance to radar antenna or MVAC center for the 5-NM minima separation chart (see figure 11-3-7).

Figure 11-3-5. Fusion Adaptation Sector Buffer Areas (5-NM Separation Minima Chart)



b. Isolating obstacles. Any obstacle may be isolated to lower the MVA in one or more standard sectors. The OEA buffers of neighboring sectors still apply in the isolation area, but exclude the specific feature being isolated (all other obstacles must be considered). Truncate an isolation area at the sector boundary when it expands into a sector requiring a higher MVA. The dimensions of the isolation area otherwise depend on the feature type and whether single sensor configuration, multi-sensor configuration, or a FUSION adaptation applies.

(1) Point feature (antennas, towers, high-rise buildings, etc.). The isolation area is based on a radius centered on the feature that provides at least the minimum lateral clearance applicable to the radar configuration/adaptation (see paragraph 11-1-1.b). Apply Order 8260.19 Section 2-11, Obstacle Data. Isolation areas for multiple point features (such as antenna or wind farms, etc.) may be combined; however, the minimum required lateral clearance must be provided from each feature and the MVA must equal the highest required for any individual feature.

(a) Single sensor configuration. The isolation area boundary is a 3-NM radius when the feature is 35 NM or less from the radar antenna, and a 5-NM radius when the feature is more than 35 NM from the radar antenna (see figure 11-3-8). When operationally advantageous, the boundary may be reduced to less than 5 NM for those portions of the isolation area within 40 NM from the antenna, but not less than the minimum required lateral clearance (see figure 11-3-9).

Note: For full time reinforced MSSR systems use a 3-NM radius when the feature is 55 NM or less from antenna (instead of 35 NM). Boundaries may also be reduced to less than 5 NM for those portions of an isolation area within 60 NM of these system antennas (instead of 40 NM).

Figure 11-3-6. Isolation Area, Point Feature

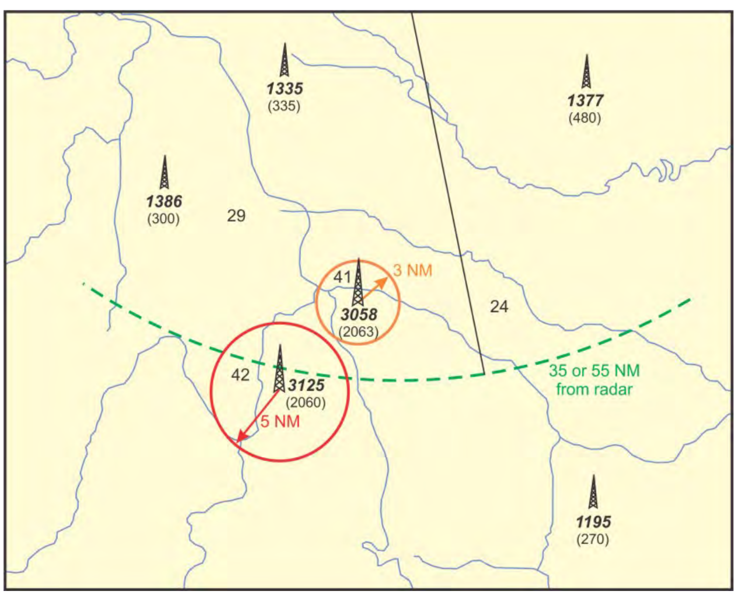
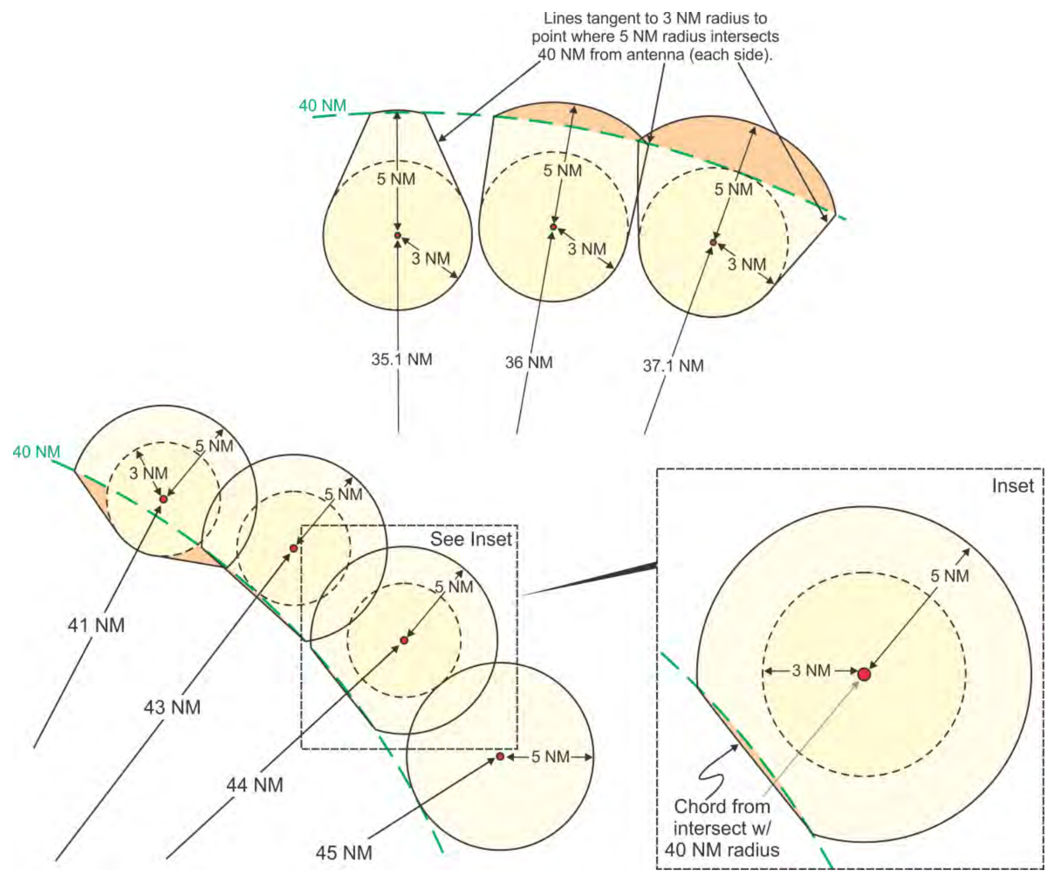


Figure 11-3-7. Isolation Area, Point Feature, Example Construction > 35 NM from Radar (Single Sensor, w/out Reinforced MSSR)



(b) Multi-sensor configuration. Isolation area boundary is a 5-NM radius, regardless of distance from radar antenna.

(c) FUSION adaptation.

1. The isolation area boundary is a 3-NM radius, regardless of distance from radar antenna for the 3-NM minima separation chart (see figure 11-3-6).

2. The isolation area boundary is a 5-NM radius, regardless of distance from radar antenna for the 5-NM minima separation chart (see figure 11-3-7).

(2) Zone feature (for example, distinct terrain, topographical contours, etc.). When determining the sector boundary, first define the dimensions of the feature to be isolated (for example, mountain from 4700-foot contour and above).

(a) Single sensor configuration. Establish the isolation area boundary 3 NM from the feature for points 35 NM or less from the radar antenna and 5 NM from the feature for points more than 35 NM from the radar antenna. When operationally advantageous, the boundary may be reduced to less than 5 NM for those portions of the isolation area within 40 NM from the antenna, but not less than the minimum required lateral clearance (see figure 11-3-10 and figure 11-3-11).

Figure 11-3-8. Isolation Area, Zone Feature > 35 NM from Radar (Single Sensor, w/out Reinforced MSSR)

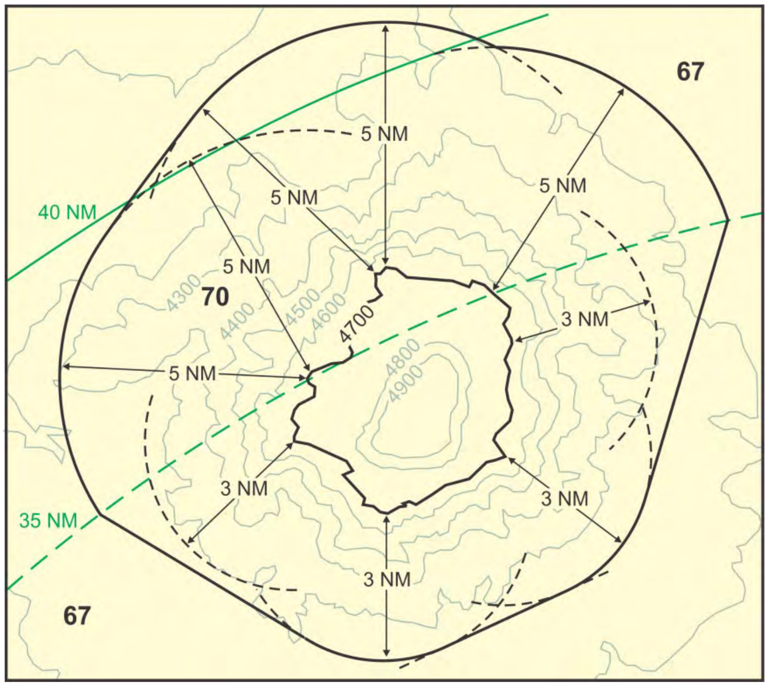
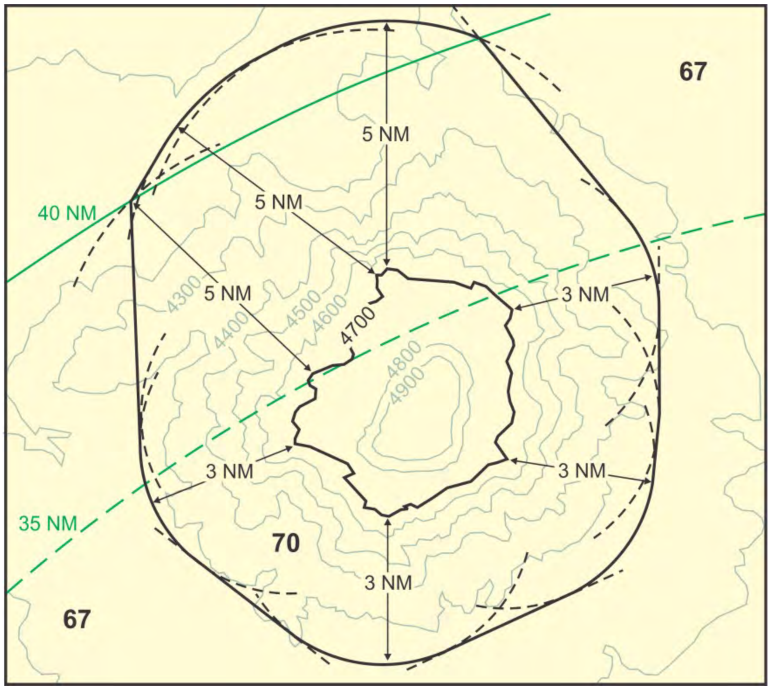


Figure 11-3-9. Isolation Area, Zone Feature, Example Construction > 35 NM from Radar (Single Sensor, w/out Reinforced MSSR)



(b) Multi-sensor configuration. Isolation area boundary is 5 NM from the feature, regardless of distance from radar antenna.

(c) FUSION adaptation.

1. The isolation area boundary is a 3-NM radius from the feature, regardless of distance from radar antenna for the 3-NM minima separation chart.

2. The isolation area boundary is a 5-NM radius from the feature, regardless of distance from radar antenna for the 5-NM minima separation chart.

11-3-2. Minimum Vectoring Altitude Chart (MVAC). An MVAC is used by air traffic facilities when providing terminal service. An MVAC may be developed by En Route facilities in selected areas where the MIA chart does not meet operational needs. An MVAC specifies the lowest MSL altitude at or above the floor of controlled airspace that provides at least the minimum ROC over obstacles. The MVAC may be used in lieu of feeder, initial, and intermediate approach segment(s) for radar approaches (see Orders JO 7210.3 or 7210.37, En Route Instrument Flight Rules (IFR) Minimum IFR Altitude (MIA) Sector Charts).

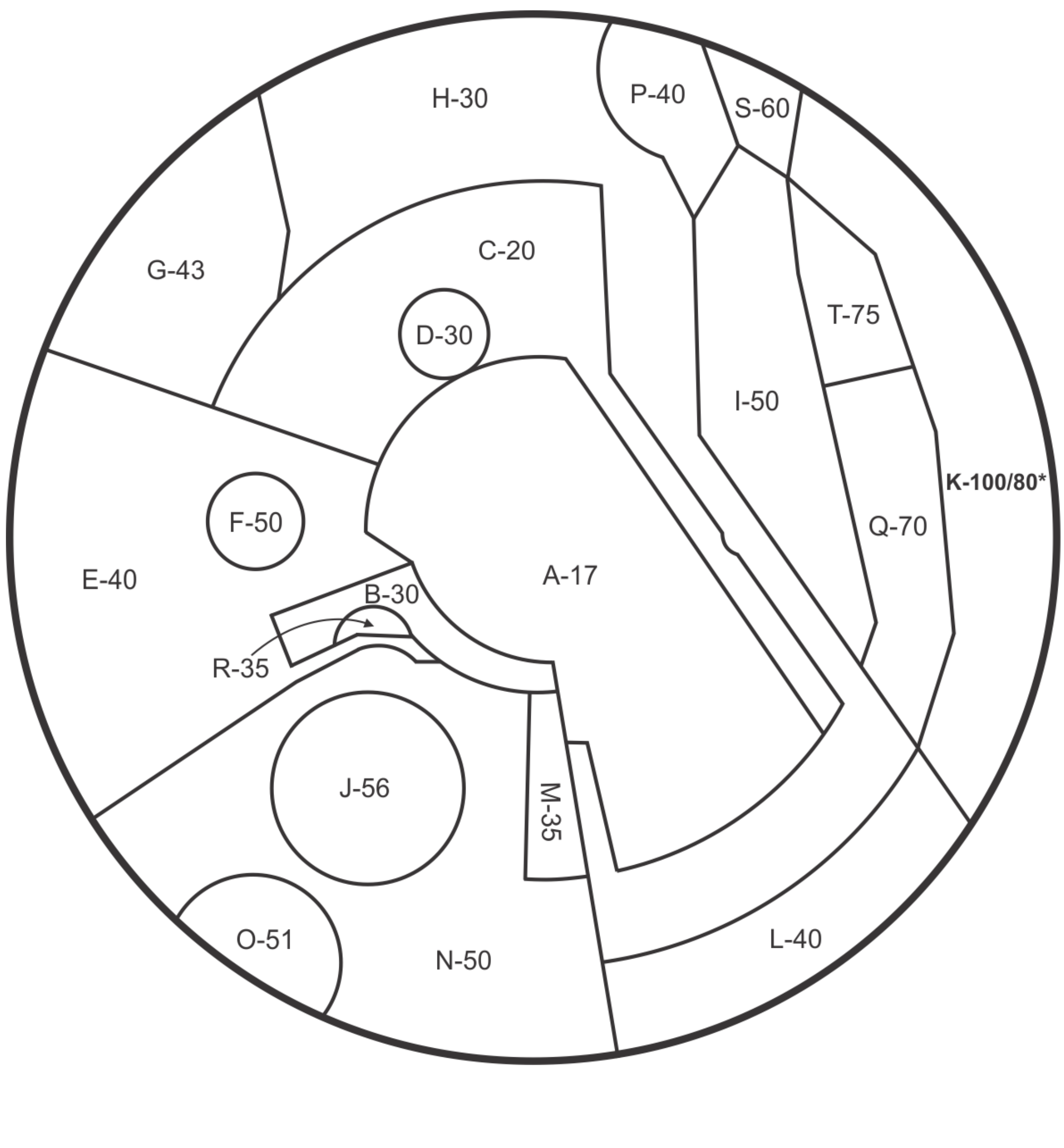
a. General. Apply current Order JO 7210.3 criteria (or applicable military directive) to determine when an MVAC is required, the range/coverage of the chart(s) and the lateral obstacle clearance applicable to the chart and/or specific sectors. When the area of responsibility is beyond the radar system limits but a vectoring chart is still operationally necessary, apply Order JO 7210.37 for the non-radar area.

b. Apply the vertical and horizontal obstacle accuracy standards in Order 8260.19.

c. FUSION-based MVACs must be developed to provide both 3-NM separation minima or more and 5-NM separation minima or more from obstacles. The MVAC(s) must depict obstacle clearances outward to the lateral limits of the associated approach control airspace and an appropriate buffer outside the lateral approach control airspace boundaries.

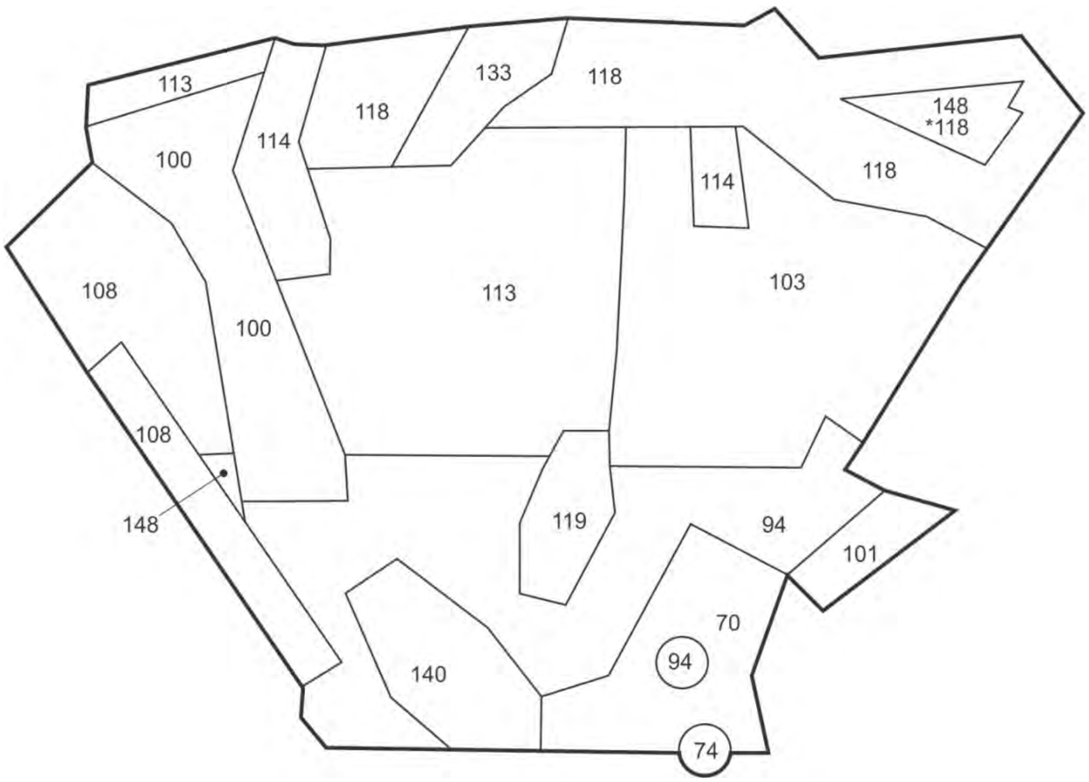
d. Single sensor configuration or FUSION adaptation. Center the MVAC on the radar sensor or designated point of tangency for FUSION MVA Charts. Define sector boundaries by bearings, point-to-point lines, arcs, and/or circles relative to a specified point or points; such as a radar antenna, NAVAID, fix, latitude/longitude coordinate, etc. (see figure 11-3-1).

Figure 11-3-10. MVAC for Single Sensor Configuration or FUSION Adaptation



e. Multi-sensor configuration. Sector boundaries may be defined by any combination of bearings, point-to-point lines, arcs, and/or circles relative to a specified point or points, such as a radar antenna, NAVAID, fix, latitude/longitude coordinate, etc. (see figure 11-3-2).

Figure 11-3-11. MVAC for Multi-Sensor Configuration



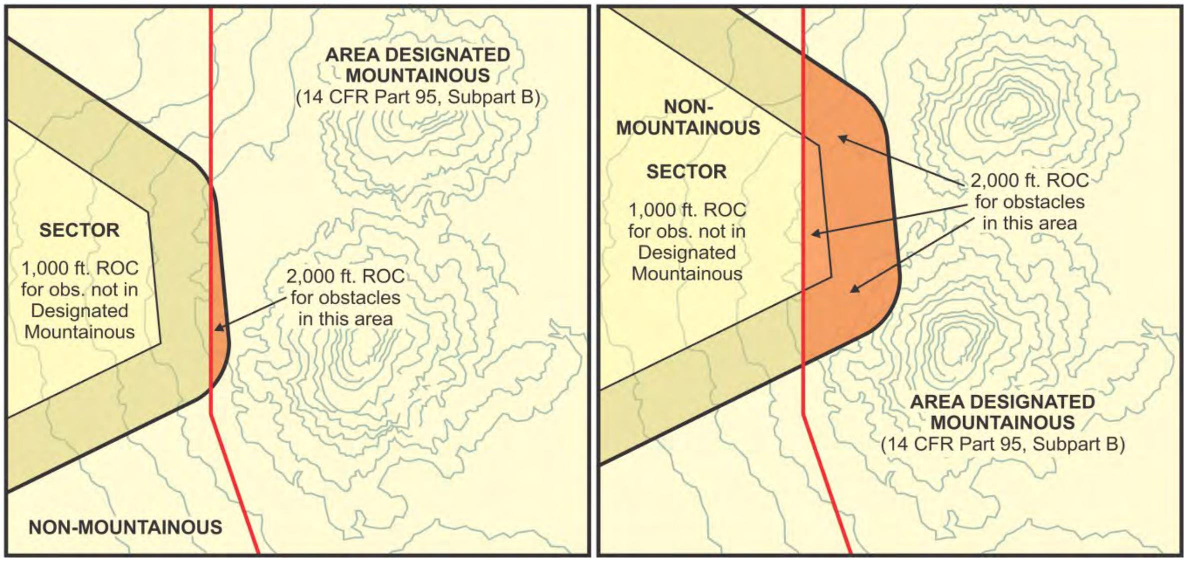
11-3-3. Obstacle Clearance. ROC depends on the relationship of the obstacle to those areas designated mountainous per 14 CFR part 95 Subpart B.

a. Non-mountainous areas. The minimum ROC is 1000 feet.

b. Mountainous areas. The minimum ROC is 2000 feet unless a reduction has been requested, approved, and documented in accordance with current Order JO 7210.3. ROC must not be reduced to less than 1000 feet.

c. When a sector/buffer/isolation area overlies both non-mountainous and mountainous terrain, consider revising sector boundaries. Otherwise, apply the appropriate ROC based on the location of the obstacle (see figure 11-3-12).

Figure 11-3-12. Sector/Buffer Overlying Both Mountainous and Non-Mountainous Areas



11-3-4. Adverse Assumption Obstacle (AAO) Considerations. Apply AAO to terrain except those areas around primary/satellite airports exempted by Order 8260.19 and/or when applying 2000 feet of unreduced ROC.

11-3-5. Airspace. Establish sector altitudes (to include isolation areas) that provide at least a 300-foot buffer above the floor of controlled airspace. When operationally required, altitudes may be reduced not lower than the floor of controlled airspace. When consideration of floor of controlled airspace results in an exceptionally high altitude; such as in areas where the floor of controlled airspace is 14500 MSL and operationally required to vector aircraft in underlying Class G (uncontrolled) airspace, two sector altitudes may be established. The first must be based on obstacle clearance and the floor of controlled airspace. A second lower altitude that provides obstacle clearance only may be established. The obstacle clearance only altitude must be uniquely identified (by an asterisk (*) for example). Do not consider sector buffer areas for controlled airspace evaluations.

11-3-6. Altitude Selection. Specify sector altitudes (to include isolation areas) in the 100-foot increment that provides ROC over all obstacles within the OEA.

a. Sector altitudes may be rounded to the nearest 100-foot increment over AAO obstacles when operationally required.

b. For non-AAO obstacles, sector altitudes may be rounded to the nearest 100-foot increment where the entire sector (excluding buffer) or isolation area is;

(1) In the contiguous United States (not authorized in Alaska, Hawaii, or any other territory or possession).

(2) Documented to be within 65 NM of an altimeter setting source which is issued by ATC in accordance with Order JO 7110.65 chapter 2, section 7 and either;

(a) Outside of any area designated mountainous by 14 CFR part 95, or;

(b) In an area designated mountainous where ROC is not reduced, or;

(c) In an area designated mountainous where for this purpose the terrain is considered not to be precipitous (no significant elevation changes greater than 1500 feet) and at least 951 feet ROC is provided or;

(d) In an area designated mountainous where rounding provides ROC in accordance with table 11-3-1. Interpolation of this table permitted.

Table 11-3-1. Minimum Obstacle Clearance (feet) Based on ACT/distance from Altimeter Source

ACT (°C/°F)	Distance ≤ 65 NM
-40/-40	1851
-30/-22	1651
-20/-4	1451
-10/14	1251
0/32	1051
2/36	1051*
7/45	951

* 951 within 35 NM

Example: The ACT is determined to be -30 degrees C. The controlling obstacle is a 2549 MSL tower, and ROC is reduced to 1800 feet. The minimum sector altitude may be rounded to 4300 feet since it provides at least 1651-foot clearance.

Chapter 12. Helicopter Procedures

Section 12-1. Administrative

12-1-1. General. This chapter contains criteria for application to "helicopter only" procedures. These criteria are based on the premise that helicopters are capable of special maneuvering characteristics. Refer to Order 8260.58 for specific guidance related to RNAV helicopter procedures. Helicopter criteria may be utilized for lighter-than-air aircraft procedure development without special consideration or minimum speed limitations.

a. A procedure intended as "helicopter only" must be identified by a "COPTER" designation (see paragraph 1-6-2). These procedures may use any combination of criteria within this, or any associated order. A procedure may be designated as "helicopter only" even if no unique helicopter criteria is utilized in the design and evaluation of the procedure.

b. Circling approach and high altitude teardrop turn criteria do not apply to helicopter procedures.

12-1-2. Type of Procedure. Helicopter only procedures are designed to meet low altitude straight-in requirements only. The type of approach procedure allowed depends on the qualification of the landing area. The allowable types of approaches are:

- IFR to an IFR heliport (Deferred pending development of applicable IFR heliport design standards. See paragraph 1-2-1.d.)
- IFR to a VFR heliport – PinS
- IFR to an IFR runway/IFR runway with a designated helipad
- IFR to a VFR runway – PinS
- IFR to an unmarked landing area – PinS

Section 12-2. General Criteria

12-2-1. Application. These criteria are based on the unique maneuvering capability of the helicopter at airspeeds not exceeding 90 knots.

12-2-2. PinS Approach. Where the center of the landing area is not within 2600 feet of the MAP, an approach procedure to a PinS may be designed using any of the facilities for which criteria are provided in this chapter. PinS approach procedures will not contain alternate minima. PinS are designed to allow IFR operations to VFR landing areas. The 8:1 VFR approach surface may not be penetrated as described in AC 150/5390-2, Heliport Design, without Flight Standards approval. The optimum location of the MAP will be within 1 NM of the FATO. When designing PinS procedures, consideration must be given to the type of aircraft flying the procedure and the specific flight characteristic limitations that aircraft may have. For approaches to landing areas other than runways, final approach airspeed is limited to a maximum of 90 knots when the MAP is at least 0.9 NM from the landing area to allow for deceleration. If the MAP is less than 0.9 NM from the landing area, restrict the final approach airspeed to 70 knots.

a. PinS procedures are categorized into two types, Proceed Visually and Proceed VFR.

(1) Proceed Visually PinS requirements:

(a) Course change at the MAP between the final approach course and the course to the landing area shall not exceed 30 degrees.

(b) The MAP may not be closer than 3342 feet (.55 NM) from the landing area.

(c) A visual segment evaluation is required.

(2) Proceed VFR PinS requirements:

(a) MAP must be within 10 NM of the landing area.

(b) VFR transition area evaluation is required.

b. PinS procedures may only be developed using certain types of final approach course navigation (see table 12-2-1).

Table 12-2-1. Final Approach Segment Navigation for PinS Procedures

Final Approach Segment Navigation Source	Allowed?
VOR/TACAN	Yes
NDB	Yes
LOC	Yes
ILS	No
LDA	N/A
LDA w/GS	No
SDF	Yes
ASR	Yes
PAR	No
LNAV	Yes
LNAV/VNAV	No
LP	Yes
LPV/GLS	Yes
RNP AR APCH	No

12-2-3. Approach Categories. When helicopters use instrument flight procedures designed for fixed-wing aircraft, CAT “A” approach minima apply regardless of helicopter weight.

12-2-4. Procedure Construction. Apply paragraph 2-1-8 except for the reference to circling. Procedure construction should be allowed to provide the best benefit for the procedure while ensuring maximum safety.

a. For procedures designed to an IFR heliport, the FAC should be aligned with the helipad on the designated ingress/egress course with the MAP/DA no closer than 0.55 NM from the helipad for NPA, APV, and PA.

b. For procedures designed to a runway, the alignment of the FAC should be to the threshold on RCL, or a designated helipad on the runway with the MAP on the RCL or RCL extended no more than 2600 feet from the threshold. A PinS procedure not aligned with the RCL may be developed to a helipoint if an obstacle evaluation based on the helipoint is conducted.

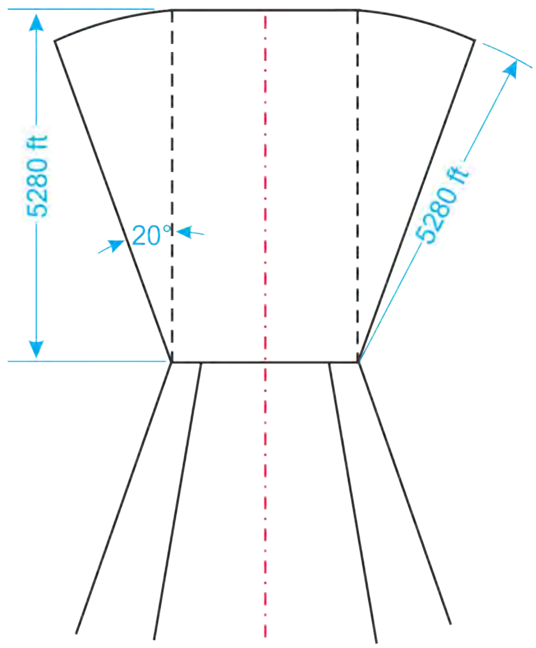
c. The type of PinS visual evaluation depends on the type of PinS approach (see appendix G).

(1) Proceed VFR:

(a) A VFR surface elevation is established within a 5200-foot radius around the MAP. The HAS is determined by subtracting the highest terrain elevation within the area (adverse vegetation assumptions are not applied) from the DA/MDA.

(b) A VFR transition area extends 5280 feet beyond the end of the final approach segment OEA. The lateral boundaries of the area are established on either side of the area as a 20-degree splay from the final approach course, beginning at the end of the secondary area boundary. On each side of the area, an arc with radius 5280 feet, with arc-center at the end of the primary boundary is drawn to the lateral boundary. The two arcs are connected by a line segment perpendicular to the final approach course. The elevation of the evaluation surface is determined by subtracting 250 feet plus any adjustments for RASS and precipitous terrain from the DA/MDA. If penetrations of this surface exist, either raise the MDA until the surface is clear of penetrations, or the penetrations must identified (see Order 8260.19 paragraph 8-6-10.q).

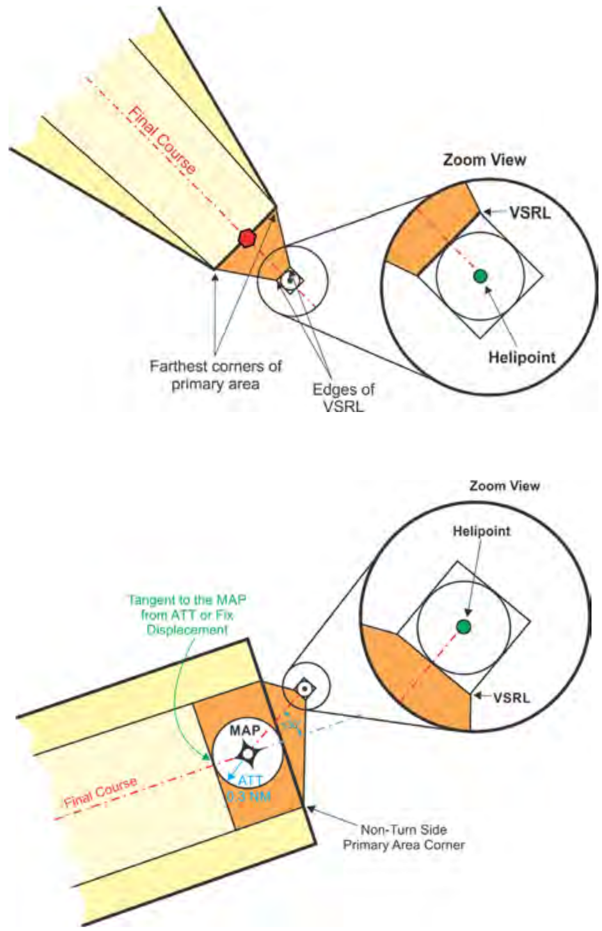
Figure 12-2-1. VFR Transition Area



(2) Proceed visually:

(a) A visual segment extends from the earlier reception of the MAP to the closest edges of the FATO identified by the visual segment reference line (VSRL). If the helipoint is not located on final approach course extended beyond the MAP, evaluate from the closest MAP abeam point to the VSRL. If the path from the visual segment to the FATO is not aligned with the helipad layout, rotate the VSRL to be perpendicular to the path.

Figure 12-2-2. Visual Segment Area



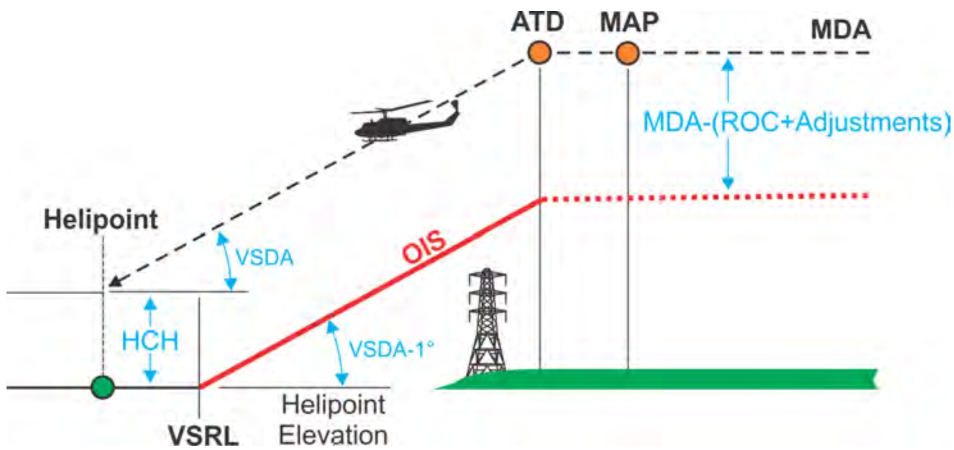
(b) A visual segment descent angle (VSDA) is established from the MAP to the center of the helipad at the desired HCH/hover height. The optimum HCH/hover height is five feet, but may be increased up to 20 feet if necessary to mitigate penetrations of the visual segment surface. The optimum VSDA is six degrees, but may not exceed 7.5 degrees. A VSDA greater than 7.5 degrees may be used with Flight Standards approval.

(c) The proceed visually OEA begins at the earliest MAP fix error (ATT for RNAV) and ends at the VSRL. The proceed visually OEA maximum length is 10,560 ft (2 SM), measured from the MAP plotted position to the helipoint. The optimum MAP/Fix (ATD fix for RNAV) to helipoint distance is 3,949 ft (0.65 NM). The minimum distance from the MAP/fix (ATD fix for RNAV) to the helipoint is 3,342 ft (0.55 NM).

(d) An OIS (identified as VSDA-1) is associated with the VSDA. The VSDA-1 angle is 1 degree less than the VSDA angle. The VSDA-1 extends from the VSRL at helipoint elevation to the earliest reception point of the MAP at an elevation of MDA/DA minus 250 feet plus adjustments. Where the MAP is beyond this point, the OIS becomes a level surface to the MAP plotted position. Measure obstacles using the shortest distance to the VSRL. The VSDA-1 must not be penetrated. If penetrated, remove, or adjust the location above the helipoint elevation by the amount of the obstacle, raise the VSDA to achieve an OIS angle that clears the obstacle, (7.5 degrees maximum without Flight Standards Service approval), or adjust the HCH/hover height to ≤ 20 feet provided the height is consistent with the helicopter's ability to hover out of ground effect. When the procedures is applied, raise the OIS origin above the helipoint elevation by the amount that the helipoint crossing height is increased, or raise the MDA the penetration amount and round to the next higher 20 foot increment, or identify that the pilot must remain at a specific altitude until clear of the obstacle (see Order 8260.19 paragraph 8-6-10.q).

(e) The slope of the missed approach OCS is 20:1.

Figure 12-2-3. VSDA and Associated OIS



12-2-5. Descent Gradient/Vertical Descent Angle. The descent gradient/VDA criteria specified in other chapters of this order do not apply. The optimum descent gradient in all segments of helicopter approach procedures is 400 ft/NM. Where a higher descent gradient is necessary, the recommended maximum is 600 ft/NM. However, where an operational requirement exists, a gradient up to 800 ft/NM may be authorized with Flight Standards approval, provided the gradient used is depicted on approach charts (see special procedure turn criteria in paragraph 12-2-7).

12-2-6. Initial Approach Segments Based on Straight Courses and Arcs with Positive Course Guidance. Apply paragraph 2-4-3 except as follows:

a. Alignment.

(1) Courses. The 2-NM lead radial specified in paragraph 2-4-3.a(1) is reduced to 1 NM.

(2) Arcs. The minimum arc radius specified in paragraph 2-4-3.a(2) is reduced to 4 NM. The 2-NM lead radial may be reduced to 1 NM.

12-2-7. Initial Approach Based on Procedure Turn. Apply paragraph 2-4-5, except for all of paragraph 2-4-5.d. Within paragraph 2-4-5.e(1), 300 feet is changed to 600 feet.

a. Area. Since helicopters operate at CAT A speeds the 5 NM-procedure turn will normally be used (see figure 12-2-4). However, the larger 10 NM and 15 NM areas may be used if considered necessary.

b. Descent gradient. Because the actual length of the track will vary with environmental conditions and pilot technique, it is not practical to specify a descent gradient solely in feet per NM for the procedure turn. Instead, the descent gradient is controlled by requiring the procedure turn completion altitude to be as close as possible to the PFAF altitude. The difference between the procedure turn completion altitude and the altitude over the PFAF must not be greater than those shown in table 12-2-2.

Figure 12-2-4. Helicopter Procedure Turn Area

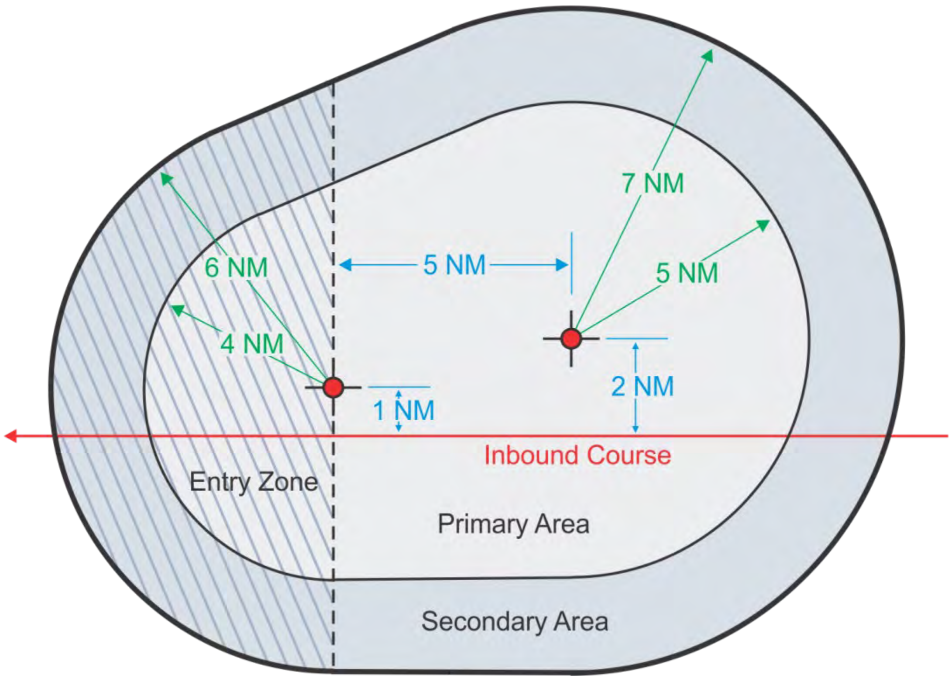


Table 12-2-2. Procedure Turn Completion Altitude Difference

Type Procedure Turn	Altitude Difference
15 NM PT from PFAF	Within 6000 ft of alt over PFAF
10 NM PT from PFAF	Within 4000 ft of alt over PFAF
5 NM PT from PFAF	Within 2000 ft of alt over PFAF
15 NM PT, no PFAF	Not Authorized
10 NM PT, no PFAF	Within 4000 ft of MDA on Final
5 NM PT, no PFAF	Within 2000 ft of MDA on Final

12-2-8. Intermediate Approach Segment Based On Straight Courses. Apply paragraph 2-5-3 except as follows:

a. Alignment. The intermediate course must not differ from the FAC by more than 60 degrees.

b. Length. The optimum length of the intermediate approach segment is 2 NM. The minimum length is 1 NM and the recommended maximum is 5 NM. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance. The minimum length specified in table 12-2-3 applies when the angle at which the initial approach course joins the intermediate course exceeds 30 degrees (see figure 2-4-1).

12-2-9. Intermediate Approach Segment Based on an Arc. Apply paragraph 2-5-4 except as follows: Arcs with a radius of less than 4 NM or more than 30 NM from the navigation facility must not be used. The optimum length of the intermediate segment is 2 NM. The minimum length is 1 NM and the recommended maximum is 5 NM. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance. The minimum length specified in table 12-2-3 applies when the angle at which the initial approach course joins the intermediate course exceeds 30 degrees (see figure 2-4-1).

Table 12-2-3. Minimum Intermediate Course Length (Not applicable to PAR and ILS)

Angle (degrees)	Minimum Length (NM)
0 – 30	1.0
> 30 – 60	2.0
> 60 – 90	3.0
> 90 – 120	4.0

Note: This table may be interpolated.

12-2-10. Intermediate Segment within a Procedure Turn Segment. Apply paragraph 2-5-5 except as follows: The normal procedure turn distance is 5 NM from the fix or from the facility. This produces an intermediate segment 5 NM long. The portion of the intermediate segment considered for obstacle clearance will always have the same length as the procedure turn distance. A distance greater than 5 NM should not be used unless an operational requirement justifies the greater distance.

12-2-11. Final Approach. Paragraph 2-6-1 applies except that the word runway is understood to include landing area and the reference to circling approach does not apply. The FAC of a PA procedure must be aligned as indicated in paragraphs 12-9-3 and 12-10-3. FAC alignment for NPA procedures is as follows:

a. Approach to a landing area. The FAC (or its extension) should be aligned so as to pass through the landing area. Where an operational advantage can be achieved, a FAC which does not pass through the landing area may be established, provided such a course lies within 2600 feet of the landing area at the MAP.

b. PinS approach. The FAC should be aligned to provide for the most effective operational use of the procedure consistent with safety.

12-2-12. Missed Approach Point. Apply paragraph 2-8-3 except the specified distance may not be more than the distance from the PFAF to a point not more than 2600 feet from the center of the landing area. The MAP may be located more than 2600 feet from the landing area provided the minimum visibility agrees with the increased distance; for example, if the MAP is

3800 feet from the landing area, then the minimum visibility (NALS) is ¾ SM (see figure 12-5-1). For PinS approaches, the MAP is on the FAC at the end of the final approach area. For procedures designed to a landing area that supports IFR procedures, the MAP should be no closer than 2400 feet to the HRP.

12-2-13. Straight Missed Approach Area. Apply paragraph 2-8-4 except that the missed approach area expands uniformly to the width of an en route airway at a point 7.5 NM from the MAP.

12-2-14. Straight Missed Approach Obstacle Clearance. Apply paragraph 2-8-5 except that the slope of the missed approach surface is changed from 40:1 to 20:1; and the secondary area slope is changed from 12:1 to 4:1.

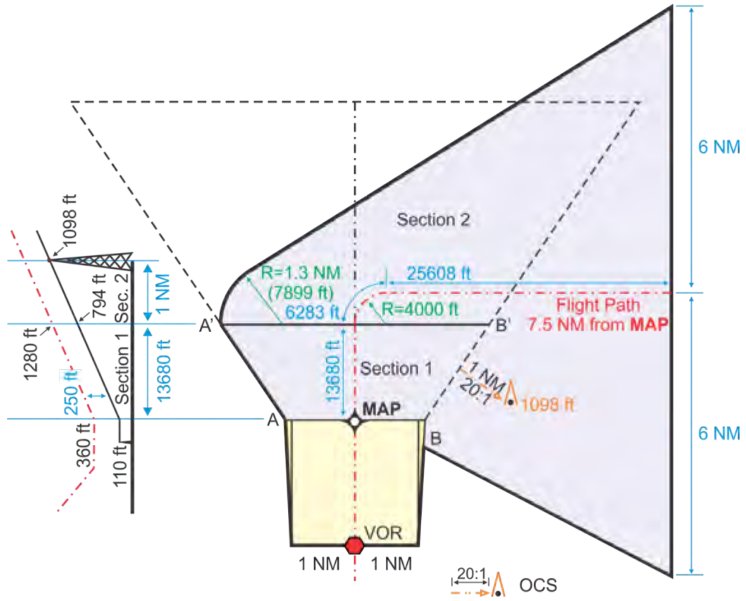
12-2-15. Turning Missed Approach Area. Apply paragraph 2-8-6 except that when applying missed approach criteria shown in figure 2-8-4 thru figure 2-8-9, and table 2-8-1, change all flight path lengths to 7.5 NM, missed approach surface slope to 20:1, secondary slopes to 4:1, obstacle clearance radius to 1.3 NM, and flight path radius (R_1) to 4000 feet (0.66 NM). The area width will expand uniformly to the width of an en route airway.

12-2-16. Turning Missed Approach Obstacle Clearance. All missed approach areas described in paragraph 2-8-7 and depicted in figure 2-8-10 and figure 2-8-11 will be adjusted for helicopter operation using the values shown in paragraph 12-2-15. The area width will expand uniformly to the appropriate en route airway width.

12-2-17. Combination Straight and Turning Missed Approach. Apply paragraph 2-8-8 except that the values in paragraph 12-2-15 must be used and point B is relocated to a position abeam the MAP. The area width will expand uniformly to the width of an en route airway (see figure 12-2-5).

12-2-18. Holding. Apply chapter 16, except within paragraph 16-9-2, when the PFAF is a facility, the inbound holding course must not differ from the final approach course by more than 90 degrees.

Figure 12-2-5. Combination Missed Approach Area



Example:

Given:

1. MDA is 360 feet MSL based on obstacles in the approach area
2. 1098 feet MSL obstacle is 1 NM from the near edge of section 1

Determine:

1. Section 1 length
2. Minimum turn altitude
3. Missed approach instructions

Solution:

1. Section 1 length
   a. $\frac{1\,NM}{20\,feet} = \frac{1852}{20 \times 0.3048} \approx 304\,ft$
   b. 1098 feet - 304 feet = 794 feet MSL, required section 1 end height
   c. MDA – (ROC + Adjustments) = 110 feet MSL, section 1 start height
   d. 794 feet – 110 feet = 684 feet, required section 1 rise
   e. 684 feet x 20 = 13680 feet, required length of section 1

2. Minimum turn altitude
   a. $\left(\frac{13680}{15.19}\right) + MDA = 1261$
   b. Round to next higher 20-foot increment = 1280 feet MSL

3. Missed approach instructions "Climb to 1280 then turn right direct…"

Section 12-3. Takeoff and Landing Minimums

12-3-1. Application. The minimums specified in this section apply to helicopter-only procedures.

12-3-2. Altitudes. Apply section 3-2, except do not establish a CMDA for helicopter only procedures.

12-3-3. Visibility. Apply section 3-3, except as follows:

a. Non-precision approaches.

(1) Approach to a runway. The minimum visibility may be one-half the computed straight-in value from table 3-3-3, but not less than 1/4 SM/1200 RVR.

(2) Approach to a landing area that supports IFR procedures (landing area within 2600 feet of MAP). The minimum visibility required prior to applying credit for lights may not be less than the visibility associated with the HAL, as specified in table 12-3-1. Do not apply paragraph 3-3-2.

b. Precision and APV approaches.

(1) Approach to runway. The minimum visibility may be one-half the computed value specified in table 3-3-1, but not less than 1/4 SM/1200 RVR.

(2) Approach to a landing area that supports IFR procedures (landing within 2600 feet of MAP). The minimum visibility required prior to applying credit for lights may not be less than the visibility associated with the HAL, as specified in table 12-3-1. Do not apply paragraph 3-3-2.

c. PinS approaches. No credit for lights will be authorized. Alternate minimums are not authorized. Do not apply table 12-3-1.

(1) Proceed VFR. The minimum visibility is 3/4 SM day / 1 SM night. If the HAS exceeds 800 feet, the minimum visibility is 1 SM.

(2) Proceed Visually. The minimum visibility is the greater of 3/4 SM or the distance from the MAP to the landing area.

Table 12-3-1. Effect of HAL Height on Visibility Minimums

HAL	200-600 feet	601-800 feet	More than 800 feet
Visibility Minimum (SM)	1/2	3/4	1

d. When aligned to a runway, apply paragraph 3-3-2.c(4) and apply visibility adjustments as applicable.

12-3-4. Visibility Credit. Where visibility credit for lighting facilities is allowed for fixed-wing operations, the same type of credit should be considered for helicopter operations. The approving authority will grant credit on an individual case basis, until such time as a standard for helicopter approach lighting systems is established. Apply the concepts stated in paragraph 3-1-2.c(2), except heliport markings may be substituted for the runway marking requirements specified therein.

12-3-5. Takeoff Minimums. Apply section 3-5 for departures from an IFR heliport. Apply appropriate FAA/DoD directives when departing VFR heliports, VFR runways, or unmarked landing areas.

Section 12-4. On-Airport/Heliport VOR (No PFAF)

12-4-1. General. Do not apply paragraph 4-1-1. Those criteria apply to procedures based on a VOR facility located within 2600 feet of the center of the landing area in which no PFAF is established. These procedures must incorporate a procedure turn.

12-4-2. Initial and Intermediate Segments. Apply criteria contained in section 12-2.

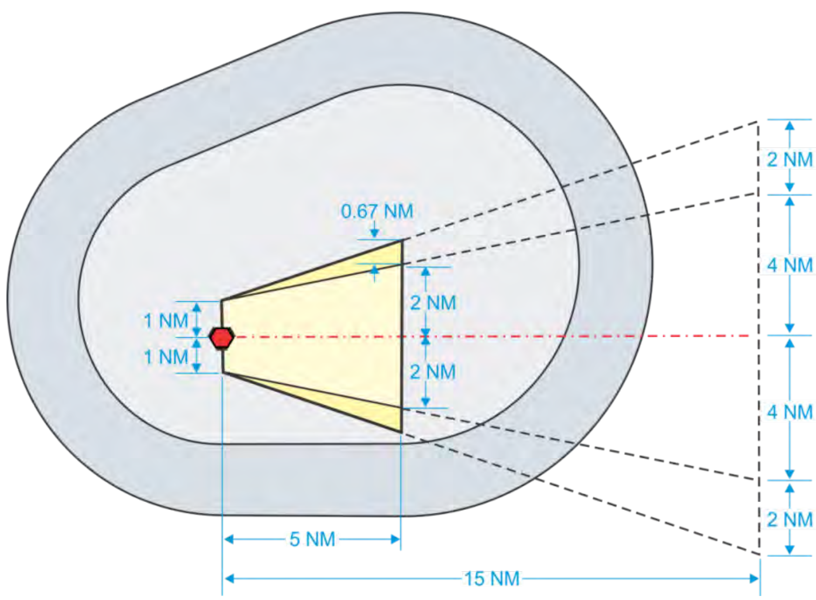
12-4-3. Final Approach Segment. Do not apply paragraph 4-2-4, except as noted below. The final approach begins where the PT intersects the FAC inbound.

a. Alignment. Apply paragraphs 12-2-11.

b. Area. The primary area is longitudinally centered on the final approach course. The minimum length is 5 NM. This may be extended if an operational requirement exists. The primary area is 2 NM wide at the facility and expands uniformly to 4 NM wide at 5 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility and expands uniformly to 0.67 NM on each side of the primary area at 5 NM from the facility (see figure 12-4-1).

c. Obstacle clearance. Apply paragraph 4-2-4.c(1).

Figure 12-4-1. Final Approach Primary and Secondary area On-Airport/Heliport VOR, No PFAF



d. Procedure turn altitude. The procedure turn completion altitude must be in accordance with table 12-2-2.

e. Use of stepdown fix. Apply paragraph 4-2-4.e, except that 4 NM is changed to 2.5 NM.

f. MDA. Apply criteria for determining MDA contained in sections 12-3 and 3-2.

Section 12-5. TACAN, VOR/DME, and VOR with PFAF

12-5-1. Final Approach Segment. Do not apply paragraph 5-2-4, except as noted below.

a. Alignment. Apply paragraph 12-2-11.

b. Area. Apply paragraph 5-2-4.b, except when the PFAF is the facility providing course guidance, the minimum length specified in table 12-5-1 applies.

c. Obstacle clearance. Apply paragraph 5-2-4.c(1).

Table 12-5-1. Minimum Length of Final Approach Segment When PFAF is the Facility

Turn Magnitude Over Facility	0 – 30 Degrees	60 Degrees	90 Degrees
Minimum Length	1.0 NM	2.0 NM	3.0 NM

Note: This table may be interpolated.

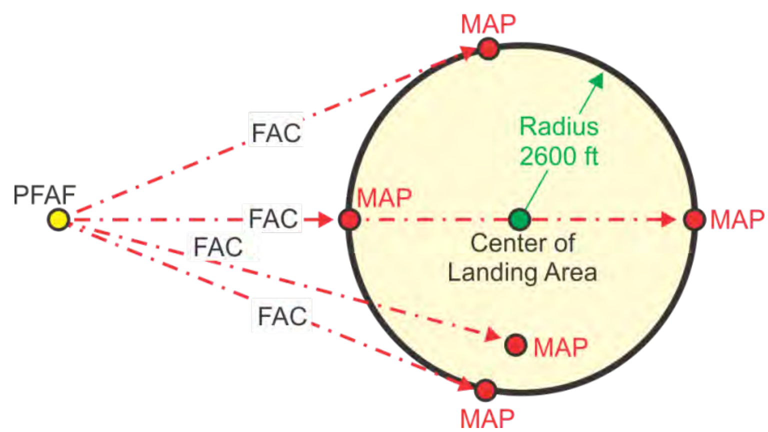
12-5-2. Missed Approach Point. Apply paragraph 5-2-5, except the MAP is a point on the FAC which is not farther than 2600 feet from the center of the landing area (see figure 12-5-1). For PinS approaches the MAP is on the FAC at the end of the final approach area.

12-5-3. Arc Final Approach Segment. Paragraph 5-3-4.b(1) does not apply. The final approach arc should be a continuation of the intermediate arc. It must be specified in NM and tenths thereof.

a. Radius. The minimum arc radius on final approach is 4 NM.

b. Alignment. The final approach arc should be aligned so as to pass through the landing area. Where an operational advantage can be achieved, a final approach arc which does not pass through the landing area may be established provided the arc lies within 2600 feet of the landing area at the MAP.

Figure 12-5-1. Missed Approach Points, Off-Airport/Heliport VOR With PFAF



Section 12-6. On-Airport/Heliport NDB, No PFAF

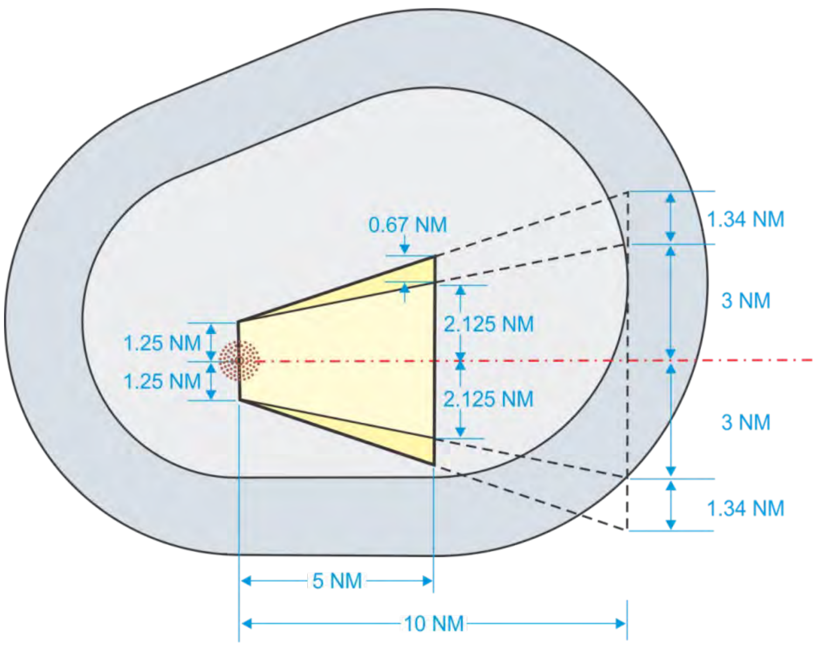
12-6-1. General. Do not apply paragraph 6-1-1 These criteria apply to procedures based on an NDB facility located within 2600 feet of the center of the landing area in which no PFAF is established. These procedures must incorporate a procedure turn.

12-6-2. Final Approach Segment. Do not apply paragraph 6-2-4, except as noted below. The final approach begins where the PT intersects the FAC inbound.

a. Alignment. Apply paragraph 12-2-11.

b. Area. The primary area is longitudinally centered on the final approach course. The minimum length is 5 NM. This may be extended if an operational requirement exists. The primary area is 2.5 NM wide at the facility, and expands uniformly to 4.25 NM wide at 5 NM from the facility. A secondary area is on each side of the primary area. It is 0 NM wide at the facility, and expands uniformly to 0.67 NM wide on each side of the primary area at 5 NM from the facility. Figure 12-6-1 illustrates the primary and secondary areas.

Figure 12-6-1. Final Approach Primary and Secondary Areas, On-Airport/Heliport NDB, No PFAF



c. Obstacle clearance. Apply paragraph 6-2-4.c(1).

d. Procedure turn altitude. The procedure turn completion altitude must be in accordance with table 12-2-2.

e. Use of stepdown fix. Apply paragraph 6-2-4.e, except that 4 NM is changed to 2.5 NM.

f. MDA. Apply criteria for determining the MDA contained in sections 12-3 and 3-2.

Section 12-7. NDB Procedures with PFAF

12-7-1. General. These criteria apply to procedures based on an NDB facility which incorporates a PFAF.

12-7-2. Final Approach Segment. Do not apply paragraph 7-1-5, except as noted below:

a. Alignment. Apply paragraph 12-2-11.

b. Area. Apply paragraph 7-1-5.b, except when the PFAF is the facility providing course guidance, the minimum length specified in table 12-5-1We applies.

c. Obstacle clearance. Apply paragraph 7-1-5.c(1).

12-7-3. Missed Approach Point. Apply paragraph 5-2-5, except the MAP is a point on the FAC which is not farther than 2600 feet from the center of the landing area (see figure 12-5-1). For PinS approaches the MAP is on the FAC at the end of the final approach area.

Section 12-8. Localizer and LDA Procedures

12-8-1. Localizer and LDA. Apply chapter 8, except as noted in this paragraph.

a. Alignment. Apply paragraph 8-1-2 for localizer alignment. Apply paragraph 12-2-11 for LDA alignment.

b. Area. Apply paragraph 8-1-3, except the minimum length specified in table 12-5-1 applies.

c. MAP. Apply paragraph 8-1-7, except the MAP is a point on the FAC which is not farther than 2600 feet from the center of the landing area (see figure 12-5-1). For PinS approaches the MAP is on the FAC at the end of the final approach area. The MAP must be at least 3000 feet from the LOC/LDA facility.

Section 12-9. ILS Procedures

12-9-1. General. Apply chapter 10 except as noted in this section.

12-9-2. Intermediate Approach Segment. Table 12-10-1 specifies the minimum length of the intermediate segment based on the angle of intersection of the initial approach course with the localizer course.

12-9-3. Final Approach Segment.

a. The optimum length of the final approach course is 3 NM. The minimum length is 2 NM. A distance in excess of 4 NM should not be used unless a special operational requirement exists.

b. Final approach termination. The final approach must terminate at a landing point (runway) or at a hover point between the decision height and the GPI. Where required, visual hover/taxi routes will be provided to the terminal area.

12-9-4. Missed Approach Area. Normally existing missed approach criteria will be utilized for helicopter operations. However, if an operational advantage can be gained, the area described in paragraphs 12-10-11 through 12-10-14 may be substituted.

Section 12-10. Precision Approach Radar (PAR)

12-10-1. Intermediate Approach Segment. Apply paragraph 11-2-3 with the exception that table 12-10-1 specifies the minimum length of the intermediate segment based on the angle of intersection of the initial approach course with the intermediate course.

Table 12-10-1. Intermediate Segment Angle of Intercept VS. Segment Length

Angle of Intercept	0 – 30 Degrees	60 Degrees	90 Degrees
Minimum Length	1.0 NM	2.0 NM	3.0 NM

Note: This table may be interpolated.

12-10-2. Final Approach Segment. Apply paragraph 11-2-4, except that the minimum distance from the glide slope intercept point to the GPI is 2 NM.

12-10-3. Final Approach Alignment. The final approach course must be aligned to a landing area. Where required, visual hover/taxi routes must be established leading to terminal areas.

12-10-4. Final Approach Area.

a. Length. The final approach area is 25000 feet long, measured outward along the final approach course from the GPI. Where operationally required for other procedural considerations or for existing obstacles, the length may be increased or decreased symmetrically, except when glide slope usability would be impaired or restricted (see figure 12-10-1).

b. Width. The final approach area is centered on the final approach course. The area has a total width of 500 feet at the GPI and expands uniformly to a total width of 8000 feet at a point 25000 feet outward from the GPI. The widths are further uniformly expanded or reduced where a different length is required as in paragraph 12-10-4.a (see figure 12-10-1). The width either side of the centerline at a given distance from the point of beginning can be found by using the formula 12-10-1.

Formula 12-10-1. PAR Final Approach Area ½ Width

$$250 + .15 \times D = \frac{1}{2} width$$

Where:

The width either side of the centerline at a given distance "D" from the point of beginning.

12-10-5. Final Approach Obstacle Clearance Surface. The final approach obstacle clearance surface is divided into two sections.

a. Section 1. This section originates at the GPI and extends for a distance of 775 feet in the direction of the PFAF. It is a level plane, the elevation of which is equal to the elevation of the GPI.

b. Section 2. This section originates 775 feet outward from the GPI. It connects with section 1 at the elevation of the GPI. The gradient of this section varies with the glidepath angle used. To identify the glide slope angle and associated final approach surface gradient to clear obstacles in section 2:

(1) Determine the distance "D" from the GPI to the controlling obstacle and the height of the controlling obstacle above the GPI.

Figure 12-10-1. PAR Final Approach Area

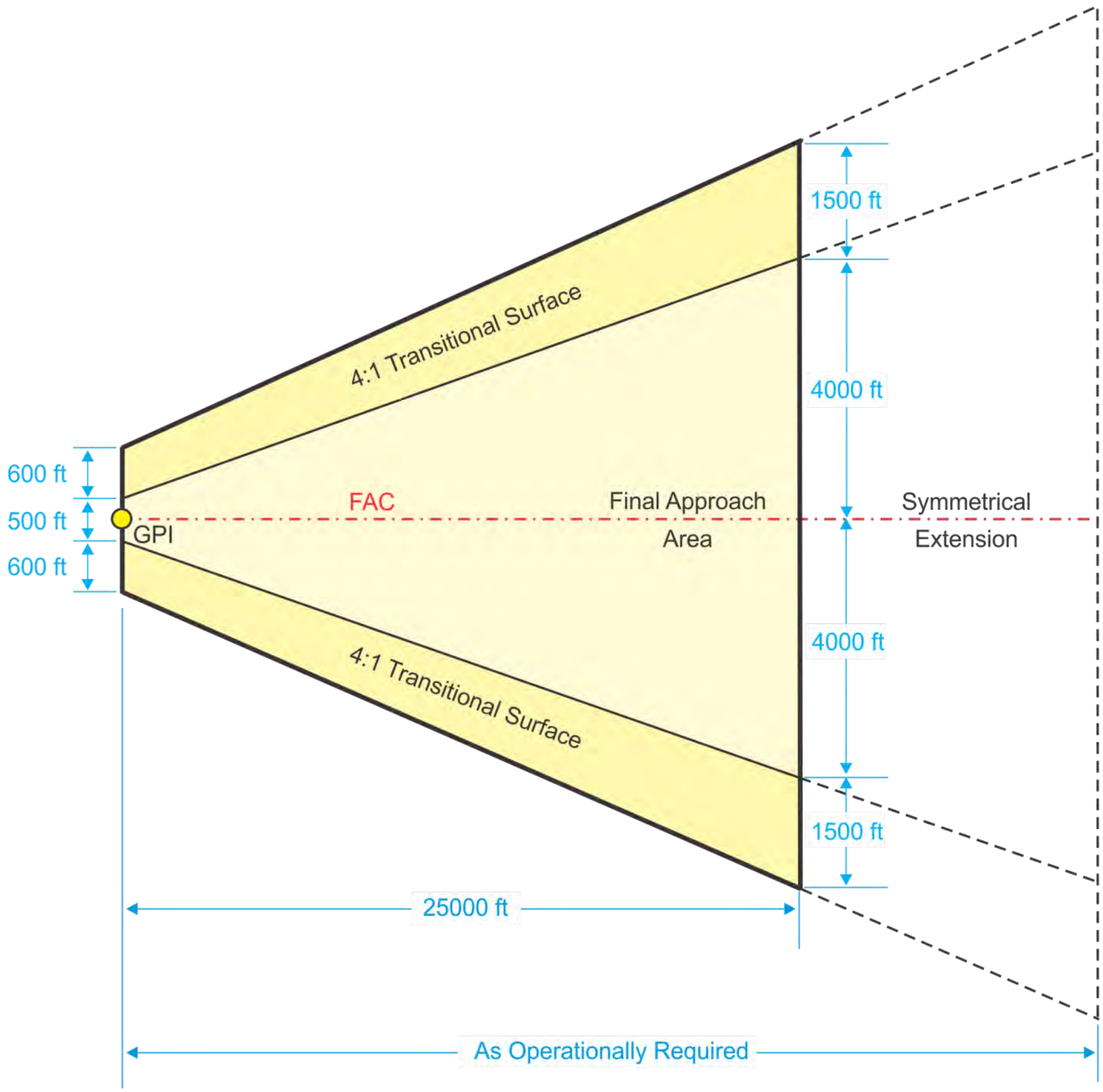


Table 12-10-2. Final Approach Glide Slope – Surface Slope Angles

Glide Slope Angle (Degrees)	Less Than 3	3	4	5	6
Section 2 obstacle clearance surface gradient (degrees)	NA	1.65	2.51	3.37	4.23

Note: This table may be interpolated.

(2) Enter these values in formula 12-10-2:

Formula 12-10-2. PAR Section 2 Approach Surface Gradient

$$\text{TanAngle} = \frac{\text{ObstacleHeight}}{\text{D} - 775}$$

(3) Convert the tangent angle. This is the angle of the section 2 approach surface gradient measured at the height of the GPI.

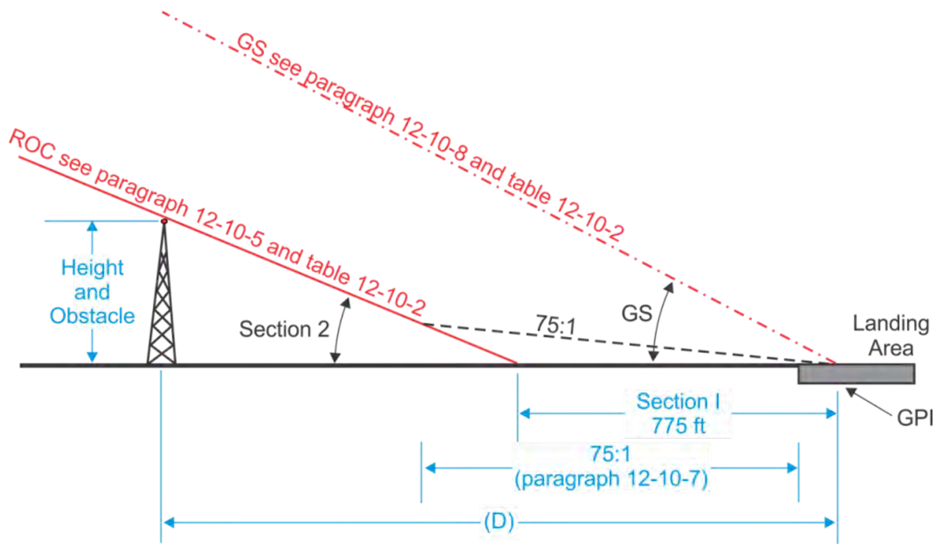
(4) The minimum glide slope angle required is found in table 12-10-2.

12-10-6. Transitional Surfaces. Transitional surfaces for PAR are inclined planes with a slope of 4:1 which extend outward and upward from the edges of the final approach surfaces. They start at the height of the applicable final approach surface and are perpendicular to the final approach course. They extend laterally 600 feet at the GPI and expand uniformly to a width of 1500 feet at 25000 feet from the GPI.

12-10-7. Obstacle Clearance. No obstacle may penetrate the applicable final approach surfaces specified in paragraphs 12-10-5 and 12-10-6. Obstacle clearance requirements greater than 500 feet need not be applied unless required in the interest of safety due to precipitous terrain or radar system peculiarities (see figure 12-10-2).

Note: The terrain in section 1 may rise at a gradient of 75:1 without adverse effect on minimums provided the surface is free of obstacles.

Figure 12-10-2. Final Approach Area Surface and Obstacle Clearance



12-10-8. Glide Slope. Required obstacle clearance is specified in paragraph 12-10-7. In addition, consideration must be given to the following in the selection of the glide slope angle:

a. Angles less than three degrees are not authorized.

b. Angles greater than six degrees must not be established without authorization of the approving authority. The angle selected should be no greater than that required to provide obstacle clearance.

c. Angles selected should be increased to the next higher tenth of a degree, for example, 4.71 degrees becomes 4.8; 4.69 degrees becomes 4.7.

12-10-9. Relocation of the Glide Slope. The GPI must normally be located at the arrival edge of the landing area. If obstacle clearance requirements cannot be satisfied, or if other operational advantages will result, the GPI may be moved into the landing area provided sufficient landing area is available forward of the displaced or relocated GPI.

12-10-10. Adjustment of DH. An adjustment is required whenever the angle to be used exceeds 3.8 degrees (see table 12-10-3). This adjustment is necessary to provide ample deceleration distance between the DH point and the landing area.

Table 12-10-3. Minimum –H - GS Angle Relationship

GS Angle (degrees)	up to 3.80	3.81 to 5.70	Over 5.70
Minimum DH (feet)	100	150	200

12-10-11. Missed Approach Obstacle Clearance. No obstacle may penetrate a 20:1 missed approach surface which overlies the missed approach areas illustrated in figure 12-10-5, figure 12-10-6, and figure 12-10-7. The missed approach surface originates at the GPI. However, to gain relief from obstacles in the missed approach area the point at which the surface originates may be relocated as far backward from the GPI as a point on the final approach course which is directly below the MAP. In such cases the surface originates at a height below the DH as specified in table 12-10-4 (see figure 12-10-3 and figure 12-10-4).

Note: When penetration of the 20:1 surface originating at the GPI occurs, an upward adjustment to the DH equal to the maximum penetration of the surface should be considered.

12-10-12. Straight Missed Approach Area. The straight missed approach (maximum of 15-degree turn from final approach course) area starts at the MAP and extends to 7.5 NM.

a. Primary area. This area is divided into three sections.

(1) Section 1a is a continuation of the final approach area. It starts at the MAP and ends at the GPI. It has the same width as the final approach area at the MAP.

(2) Section 1b is centered on the missed approach course. It begins at the GPI and extends to a point 1 NM from the MAP outward along the missed approach course. It has a beginning width the same as the final approach area at the MAP and expands uniformly to 4000 feet at 1 NM from the MAP.

Table 12-10-4. Beginning Point of Missed Approach Surface

GS Angle (Degrees)	3	6	9
Dist. below DH point (feet)	100	150	200

Note: This table may be interpolated.

Figure 12-10-3. Missed Approach Surface at GPI

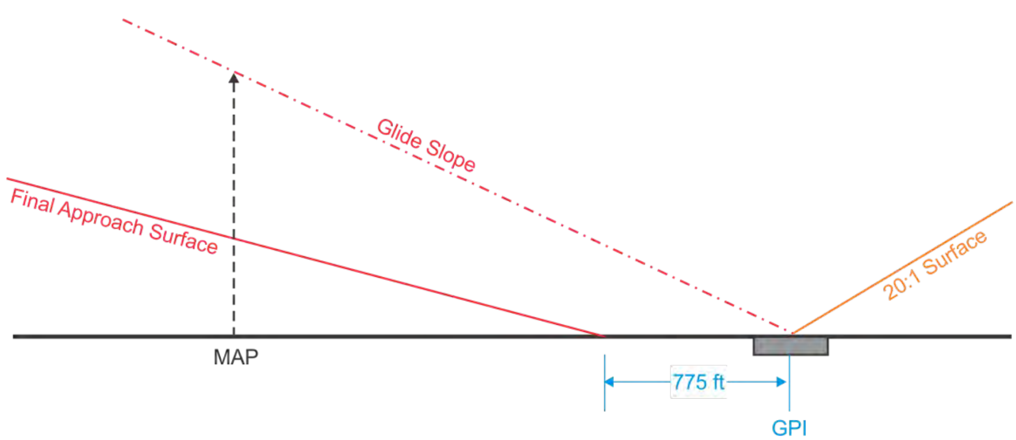
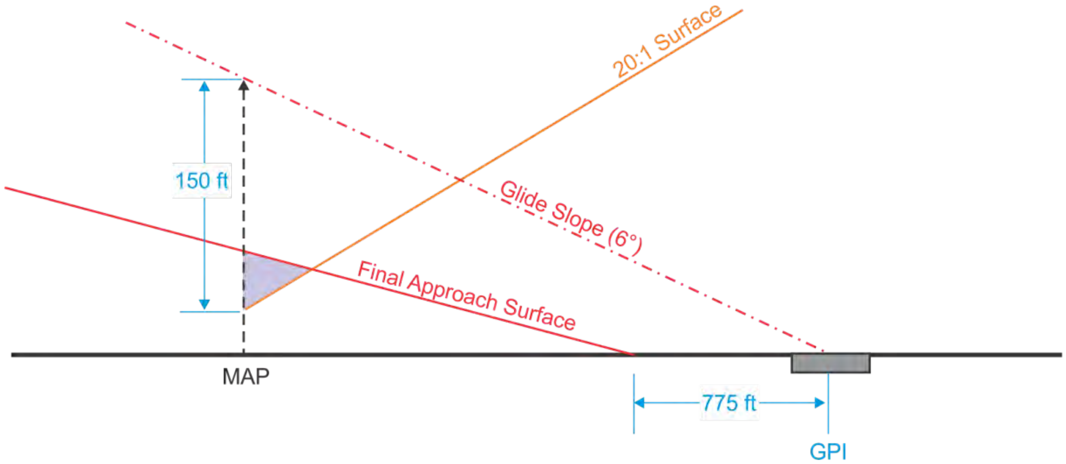


Figure 12-10-4. Missed Approach Surface at MAP

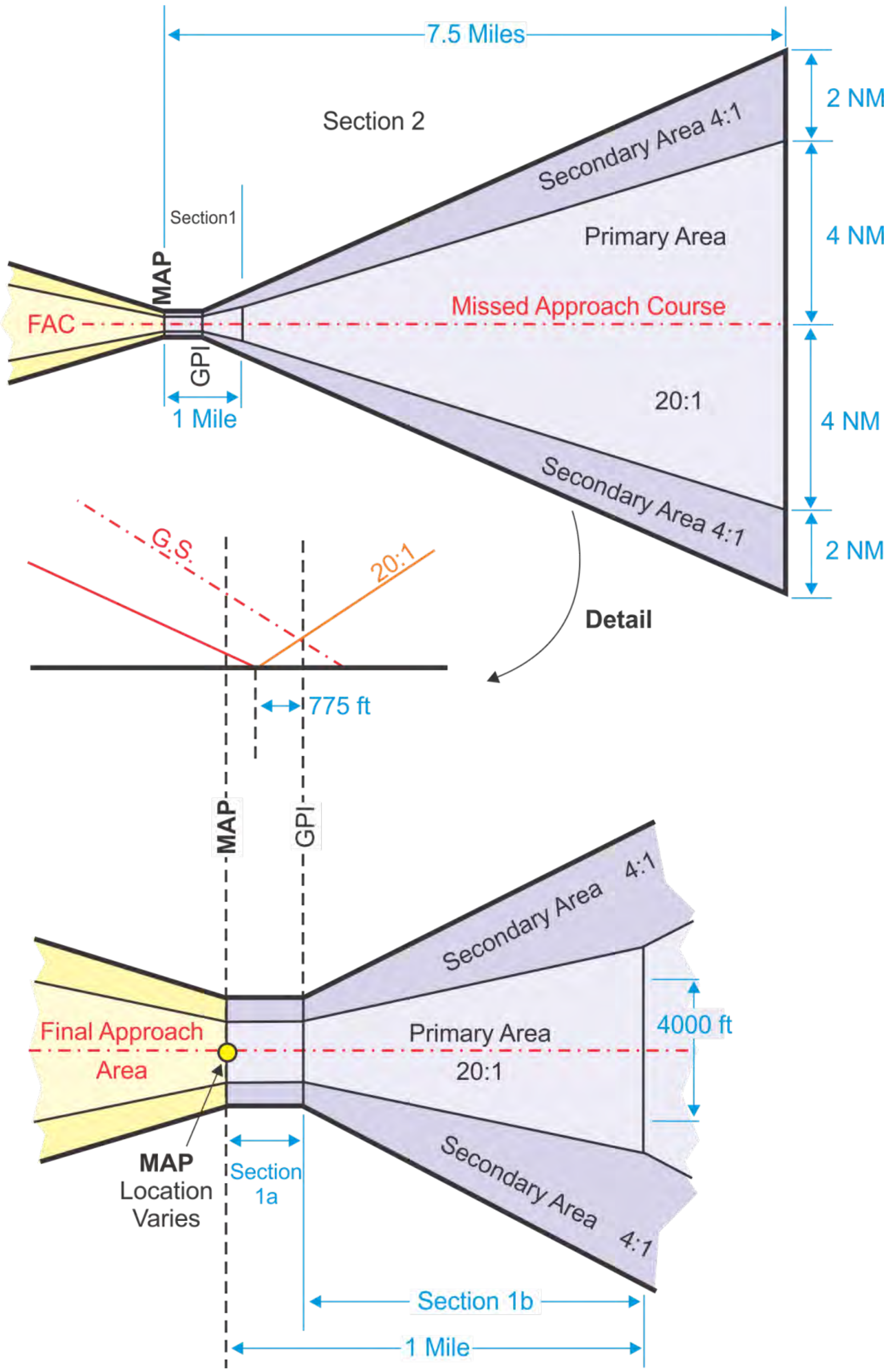


Note: Obstacles in shaded area not considered.

(3) Section 2 is centered on the continuation of the section 1b course. It begins 1 NM from the MAP and ends 7.5 NM from the MAP. It has a beginning width of 4000 feet, expanding uniformly to a width equal to that of an initial approach area at 7.5 NM from the MAP.

b. Secondary area. The secondary area begins at the MAP, where it has the same width as the final approach secondary area. In section 1a the width remains constant from the MAP to the GPI, after which it increases uniformly to the appropriate airway width at 7.5 NM from the MAP (see figure 12-10-5).

Figure 12-10-5. Straight Missed Approach

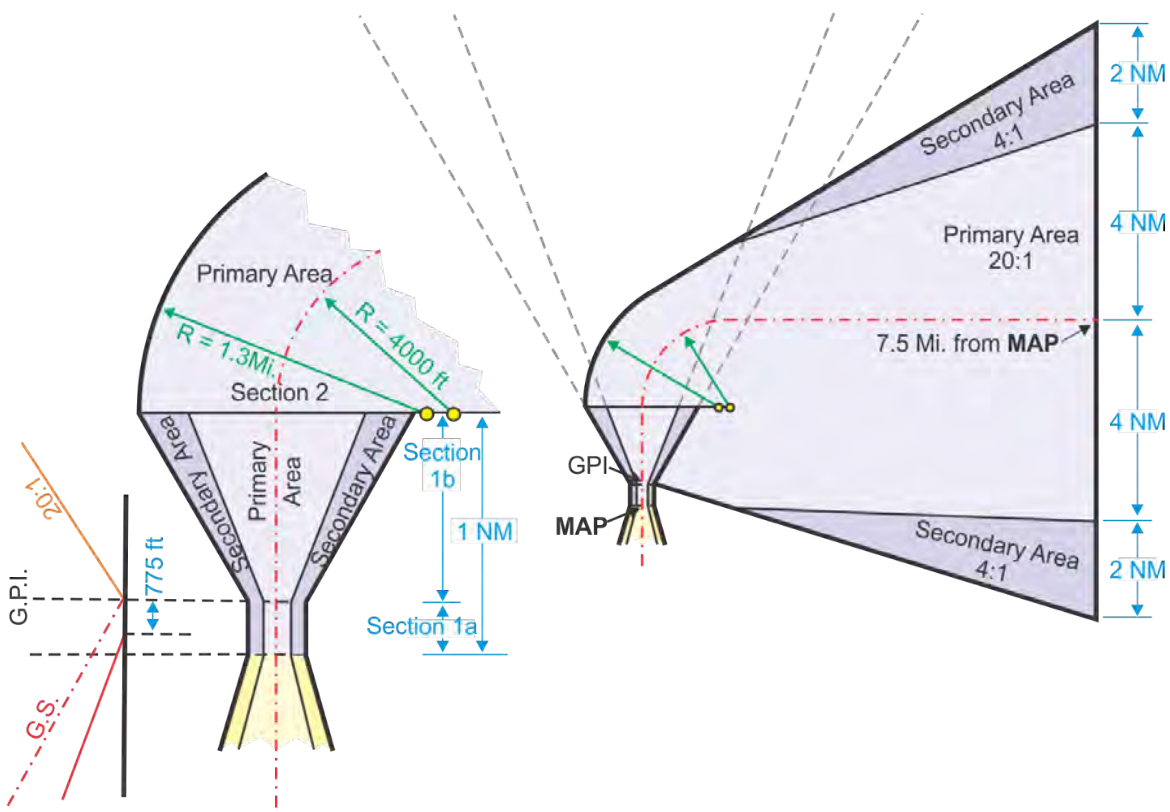


12-10-13. Turning Missed Approach Area. Where turns of more than 15 degrees are required in a missed approach procedure, they must commence at an altitude which is at least 400 feet above the elevation of the landing area rounded to the nearest foot. Such turns are assumed to commence at the point where section 2 begins. The turning flight track radius must be 4000 feet (0.66 NM).

a. Primary areas. The outer boundary of the section 2 primary area must be drawn with a 1.3-NM radius. The inner boundary must commence at the beginning of section 1b. The outer and inner boundaries expand uniformly to the width of an initial approach area 7.5 NM from the MAP.

b. Secondary area. Secondary areas for reduction of obstacle clearance are identified with section 2. The secondary areas begin after completion of the turn. They are 0 NM wide at the point of beginning and increase uniformly to the appropriate airway width at the end of section 2. Positive course guidance is required to reduce obstacle clearance in the secondary area (see figure 12-10-6).

Figure 12-10-6. Turning Missed Approach Area



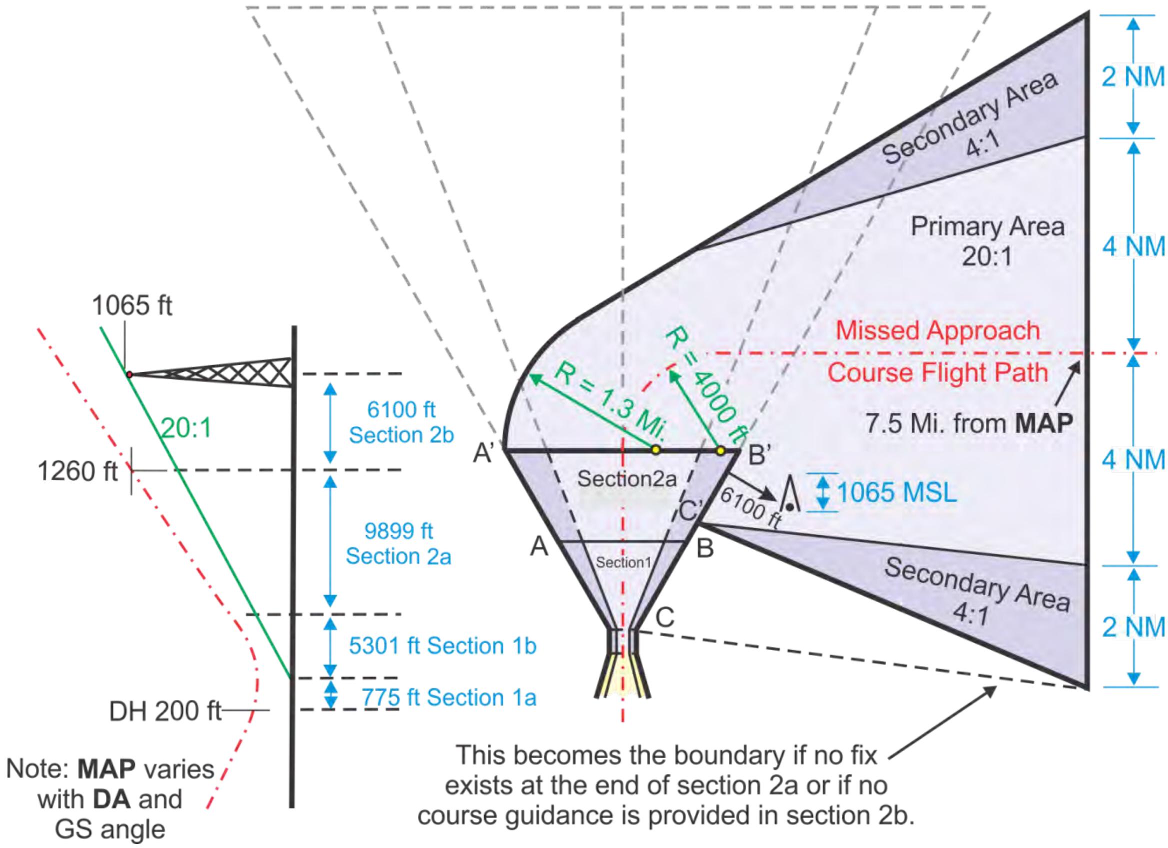
12-10-14. Combination Straight And Turning Missed Approach Area. If a straight climb to an altitude greater than 400 feet is necessary prior to commencing a missed approach turn, a combination straight and turning missed approach area must be constructed. The straight portion of this missed approach area is divided into sections 1 and 2a. The portion in which the turn is made is section 2b.

a. Straight portion. Sections 1 and 2a correspond respectively to sections 1 and 2 of the normal straight missed approach area and are constructed as specified in paragraph 12-10-12 except that section 2a has no secondary areas. Obstacle clearance is provided as specified in paragraph 12-2-14. The length of section 2a is determined as shown in figure 12-10-7, and relates to the need to climb to a specified altitude prior to commencing the turn. The line A’-B' marks the end of section 2a. Point C' is 5300 feet from the end of section 2a.

b. Turning portion. Section 2b is constructed as specified in paragraph 12-10-12 except that it begins at the end of section 2a instead of the end of section 1. To determine the height which must be attained before commencing the missed approach turn, first identify the controlling obstacle on the side of section 2a to which the turn is to be made. Then measure the distance from this obstacle to the nearest edge of the section 2a area. Using this distance as illustrated in figure 12-10-7, determine the height of the 20:1 slope at the edge of section 2a. This height plus 250 feet (rounded off to the next higher 20-foot increment) is the height at which the turn should be started. Obstacle clearance requirements in section 2b are the same as those specified in paragraph 12-10-7 except that section 2b is expanded to start at point C if no fix exists at the end of section 2a or if no course guidance is provided in section 2 (see figure 12-10-7).

Note: The missed approach areas expand uniformly to the appropriate airway width.

Figure 12-10-7. Combination Straight and Turning Missed Approach



Example:

Given:

1. DA/DH is 200 feet
2. Obstacle height: 1065 MSL
3. Obstacle in section 2 = 6100 feet from the near edge of section 2a
4. Missed approach surface begins at GPI

Determine:

1. Distance from DA point to end of section 2a
2. Minimum turn altitude
3. Missed approach instructions

Solution:

1. Distance from DA point to end of section 2a
   a. $\frac{6100}{20} = 305\,ft$
   b. $10–5$ - $305 = 760$ MSL, required section 2a end OCS height
   c. $760 – 0$ (20:1 origin height) $= 760$ feet of total rise in sections 1 and 2a
   d. $760 \times 20 = 15200$ feet, distance from 20:1 origin to end of section 2a
   e. $15200\ + 775$ (distance from DA point to 20:1 origin) = 15975 feet

2. Minimum turn altitude
   a. $\frac{15975}{15.19} + DA = 1251.68$
   b. Round to next higher 20-foot increment = 1260 MSL

3. Missed approach instructions "Climb to 1260 then turn right…"

Section 12-11. Airport Surveillance Radar (ASR)

12-11-1. Initial Approach Segment. Apply paragraph 11-2-2, except that 90 degrees is changed to 120 degrees.

12-11-2. Intermediate Approach Segment. Apply paragraph 11-2-3. The maximum angle of interception between the intermediate and initial segment is 120 degrees. Table 12-2-3 is used to determine the required minimum length of the intermediate segment.

12-11-3. Final Approach Segment. Apply paragraph 11-2-5, except for paragraphs 11-2-5.a and 11-2-5.f. Apply paragraph 12-2-11.

12-11-4. Missed Approach Point. The MAP is a point on the FAC which is not farther than 2600 feet from the center of the landing area (see figure 12-5-1). For PinS approaches the MAP is on the FAC at the end of the final approach area.

Chapter 13. DP Construction

Section 13-1. General Criteria

13-1-1. General. IFR DPs may be designed and published for all runways authorized by the approving authority. For civil procedures, runway/taxiway separations, and airport obstacle free zones (OFZ) must meet the standards in AC 150/5300-13 or appropriate military directives for military procedures for specified departure visibility minimums. Criteria for RNAV-equipped aircraft are provided in Order 8260.58.

13-1-2. Helicopter Departures. Development of departures depends on the certification of the departure area. RNAV or non-RNAV departures may be developed based on the departure location as defined below:

a. Departures from an IFR heliport are developed from the helipad. (Deferred pending development of applicable IFR heliport design standards. See paragraph 1-2-1.d.)

b. Departures from IFR airports will utilize the developed IFR procedure(s) from the airport. Copter DPs will not be developed from airports with established ODPs unless an obstacle survey of the departure route is accomplished.

c. PinS DPs are authorized from VFR helipads, VFR runways, or unmarked landing areas in accordance with section 13-7.

d. Throughout this chapter, the following references are modified for helicopter DPs:

(1) 200 ft/NM is replaced by 400 ft/NM,

(2) 40:1 primary slope is replaced by 20:1 slope,

(3) Runway centerline is replaced by departure course, and

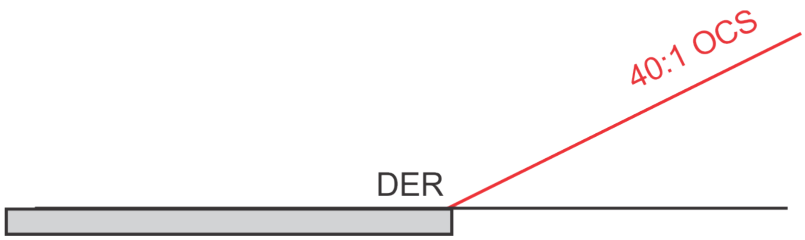
(4) Departure end of runway (DER) is replaced by heliport departure reference point (HDRP). The HDRP is the point of intersection of the FATO and departure course.

e. The standard CG for helicopters is 400 ft/NM, resulting in a 20:1 OCS slope. ROC is 96 ft/NM as described in paragraph 2-1-4.b(1)(b).

13-1-3. Departure Criteria Application. Evaluate runways or heliports for IFR departure operations (see Order 8260.46). At locations served by radar with an operational control tower, air traffic control may request development of diverse vector areas to aid in radar vectoring departure traffic (see section 13-5).

13-1-4. Departure OCS Application. Evaluate the 40:1 departure OCS originating at the DER at DER elevation (see figure 13-1-1). For helicopter departures from a takeoff area that supports IFR procedures, evaluate the 20:1 OCS originating at the HDRP at TLOF elevation. Departure operations are unrestricted if the OCS is clear. Where obstructions penetrate the OCS, see Order 8260.46 for required actions.

Figure 13-1-1. OCS Starting Elevation



a. Low, close-in OCS penetrations. Do not publish a CG to a height of 200 feet (400 feet for helicopters) or less above the OCS start elevation.

b. Calculating OCS height. Apply paragraph 13-1-7.b(3) for measuring obstacles located within the ICA. For obstacles outside the ICA apply applicable section based on the DP design.

(1) Primary area. The OCS slope is 40:1 (20:1 for helicopters). Use formula 13-1-1 to calculate the OCS elevation.

Formula 13-1. Primary OCS Elevation

$$h_{OCS} = \frac{d}{s} + e$$

Where:
d = shortest distance (feet) from OCS origin to obstacle
s = 40 (20 for helicopters)
e = OCS origin elevation

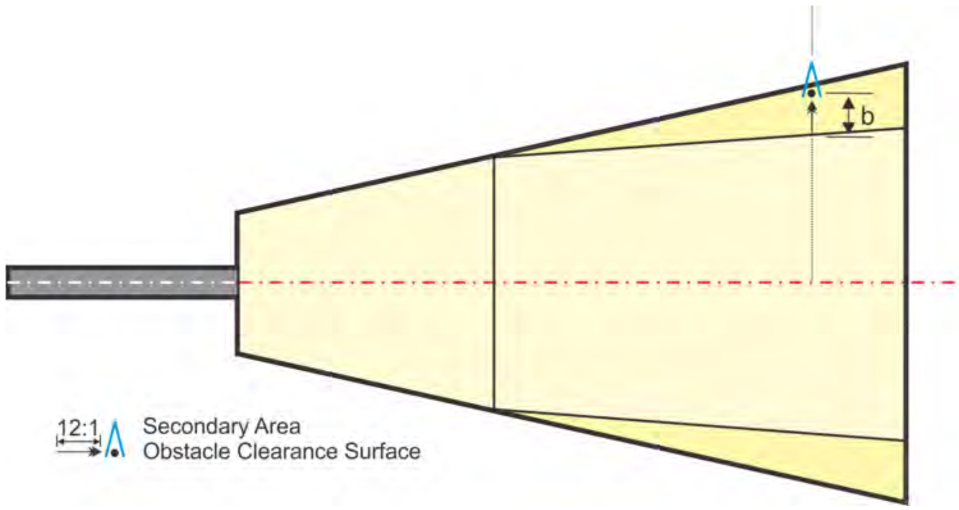
(2) Secondary area. (Applicable only when PCG is identified.) The OCS slope is 12:1. The secondary OCS elevation is the sum of the 40:1 (20:1 for helicopters) OCS rise in the primary area to a point the obstacle is perpendicular to the departure course, and the secondary OCS rise from the edge of the primary OCS to the obstacle (see figure 13-1-2). Use formula 13-1-2 to calculate the secondary OCS elevation.

Formula 13-1-1. Secondary OCS Elevation

$$h_{SECONDARY} = h_{OCS} + \frac{b}{12}$$

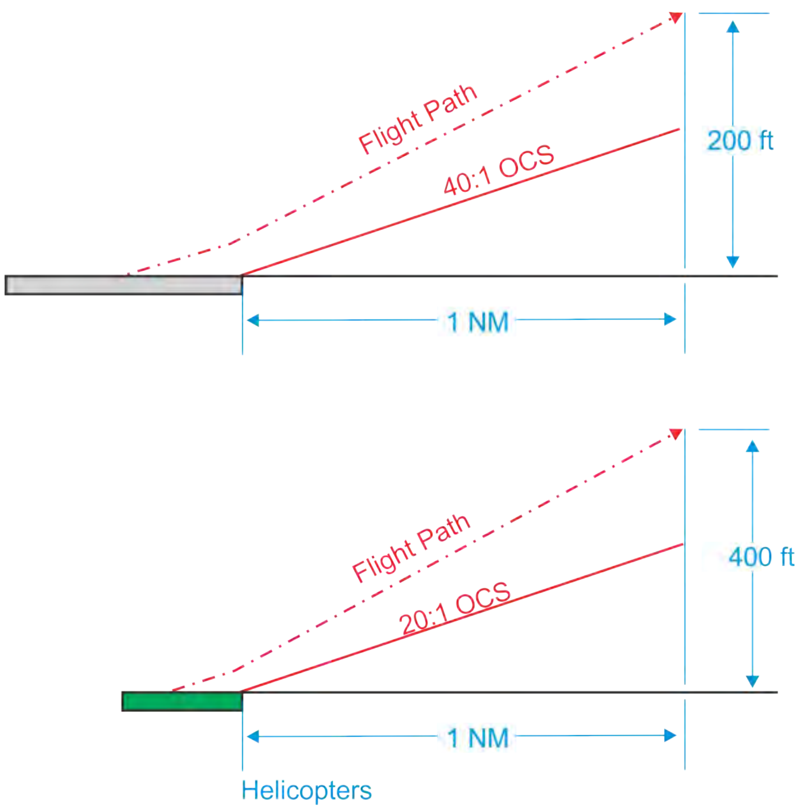
Where:
h_{OCS} = primary OCS height
b = perpendicular distance (feet) from edge of primary

Figure 13-1-2. Secondary OCS



13-1-5. CGs. DP obstacle clearance is based on a minimum CG performance of 200 ft/NM [(400 ft/NM for helicopters), see figure 13-1-3].

Figure 13-1-3. Standard CG



a. Calculating CGs to clear obstacles. CGs in excess of 500 ft/NM (600 ft/NM for helicopters) require approval (see paragraph 1-4-2). Calculate CGs using formula 13-1-3.

Formula 13-1-2. Standard/Military Option CG

Standard Formula	Military Option*
$CG = \frac{O-E}{0.76 \times D}$	$CG = \frac{(48 \times D + O) - E}{D}$

Where:
O = Obstacle MSL elevation
E = OCS start elevation
D = Distance (NM) OCS origin to obstacle
* For use by military aircraft only. Not for civil use.

b. Calculating the CGTA. When the aircraft achieves an altitude that provides the required obstacle clearance, the CG restriction may be lifted. This altitude is called "climb to" altitude (A). Calculate the climb to altitude using formula 13-1-4.

Formula 13-1-3. Climb to Altitude

$$A = E + (CG \times D)$$

Where:
E = CG starting elevation (MSL)
D = Distance (NM) from OCS origin to obstacle

Example: 1221 + (352 x 3.1) = 2312.20 round to 2400

c. CGs to altitudes for other than obstacles. Calculate the CG to the stated “climb to” altitude using formula 13-1-5.

Formula 13-1-4. Climb to Altitude for Other than Obstacles

$$CG = \frac{A - E}{D}$$

Where:
A = CGTA
E = CG starting elevation (MSL)
D = Distance (NM) from OCS origin to point where altitude is required

Example: $CG = \frac{3000-1221}{5}$ = 355.8 round to 356 ft/NM

Note: The CG must be equal to or greater than the gradient required for obstacles along the route of flight.

d. Reduced Takeoff Runway Length (RTRL). Where required to provide an option to reduce takeoff runway length (see Order 8260.46, table 2-1-1), calculate the RTRL by applying formula 13-1-6. An RTRL may only be used to mitigate a penetration within the initial climb area (extended); see paragraph 13-1-7.b(1). The RTRL value must be rounded up to the next higher 100-ft increment.

Formula 13-1-5. Reduced Takeoff Runway Length

$$RWY_{reduction} = 30.38 \times (p + 35)$$

Where:
p = OCS penetration (feet)

e. Effect of DER-to-obstacle distance (see Order 8260.46).

13-1-6. Ceiling and Visibility. A ceiling and visibility may be specified to see and avoid penetrating obstacles within the ICA (extended) 3 SM or less from the DER.

a. Ceiling. Specify a ceiling value equal to or higher than the height of the obstruction above the airport elevation. Ceilings must be specified in 100-foot increments, round upwards when necessary. Do not specify ceilings of 200 feet or less.

b. Visibility. Specify a visibility value equal to the distance measured directly from the DER to the obstruction, rounded to the next higher reportable value. The minimum value that may be specified is 1 SM (1/2 for helicopters); the maximum value that may be specified is 3 SM.

13-1-7. Initial Climb Area (ICA). The ICA is an area centered on the runway centerline extended used to evaluate obstacle clearance during the climb to 400 feet above DER rounded to the nearest foot, with a minimum CG of 200 ft/NM (400 ft/NM for helicopters).

a. ICA terms.

(1) ICA baseline (ICAB). The ICAB is a line extending perpendicular to the RCL ± 500 feet at DER (departure course ± 250 feet at HDRP for helicopters). It is the origin of the ICA (see figure 13-1-4 or figure 13-1-5 for helicopters).

(2) ICA end-line (ICAE). The ICAE is a line at the end of the ICA perpendicular to the RCL extended (departure course for helicopters). The splay of 15 degrees and length of the ICA determine its width (see figure 13-1-4 or figure 13-1-5 for helicopters).

b. Area.

(1) Length. The ICA length is normally 2 NM (1 NM for helicopters), measured from the ICAB to the ICAE along RCL extended (departure course for helicopters). It may be less than 2 NM (1 NM for helicopters) in length for early turns by publishing a CG. The ICA may be extended to maximum length of 10 NM. A specified altitude (typically 400 feet above DER) or the interception of PCG route must identify the ICAE.

(2) Width. The ICA origin width is 1000 feet (± 500 feet perpendicular to RCL) for departures from a runway and 500 feet (± 250 feet perpendicular to the departure course) for helicopter departures. The area splays outward at a rate of 15 degrees relative to the departure course (normally RCL extended or departure course for helicopters).

Figure 13-1-4. Initial Climb Area: Standard

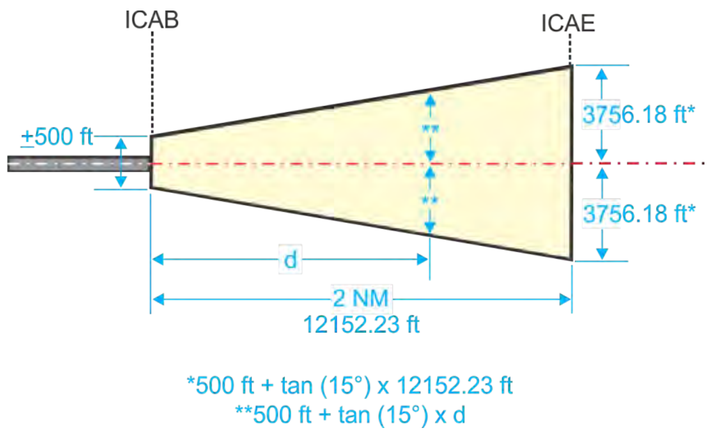
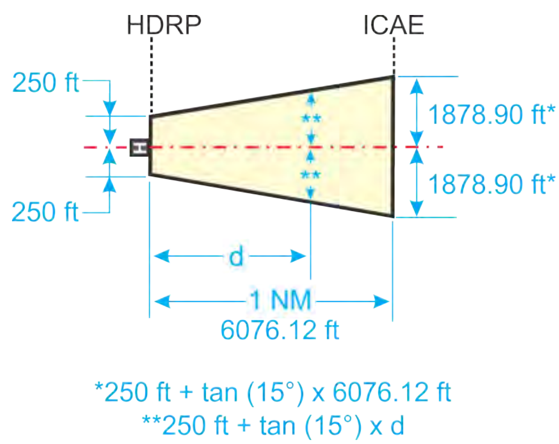


Figure 13-1-5. Initial Climb Area: Helicopters



(3) OCS. The OCS originates at the ICAB, at the OCS start elevation (see paragraph 13-1-4). Apply the OCS by measuring along the RCL from the ICAB to a point where the obstacle is perpendicular to the RCL and evaluate per paragraph 13-1-4. The MSL elevation of the ICAE is calculated using formula 13-1-7.

Formula 13-1-6. ICAE Elevation

$$ICAE_{elev} = a + \left(\frac{b}{c}\right)$$

Where:

a = OCS start elevation
b = ICA length (feet)
c = OCS slope (normally 40:1 for other than helicopters; 20:1 for helicopters)

Section 13-2. Diverse Departure Assessment

13-2-1. General. Assess diverse "A" and "B" areas to a distance of 25 NM. Extend the assessment to a distance of 46 NM if any part of the assessment area includes mountainous areas (see figure 13-2-1 or figure 13-2-2 for helicopters).

a. Area. The diverse departure assessment covers three areas.

Figure 13-2-1. Diverse Departure Assessment Areas

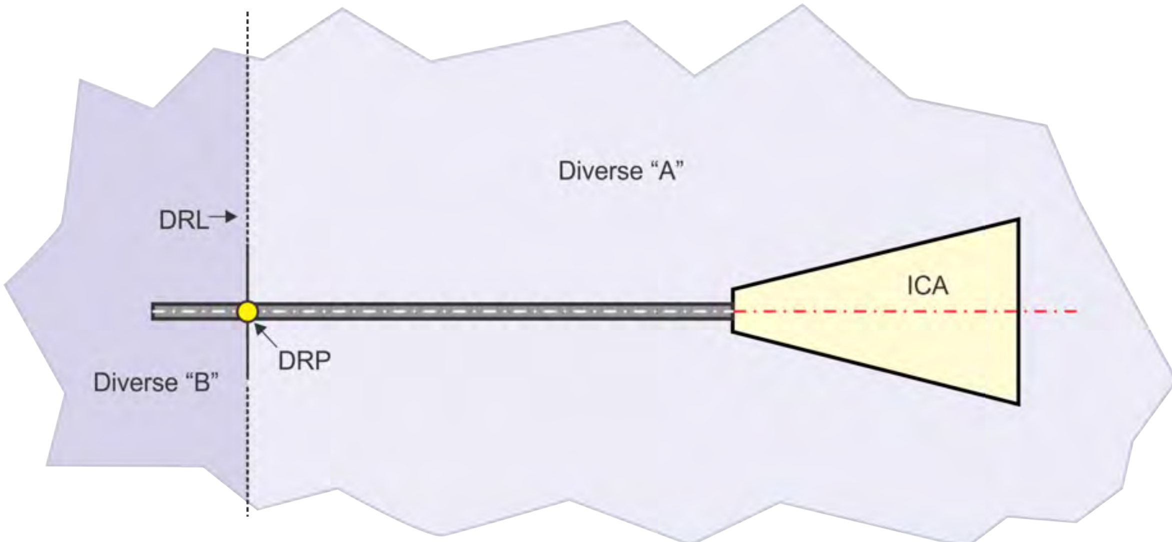
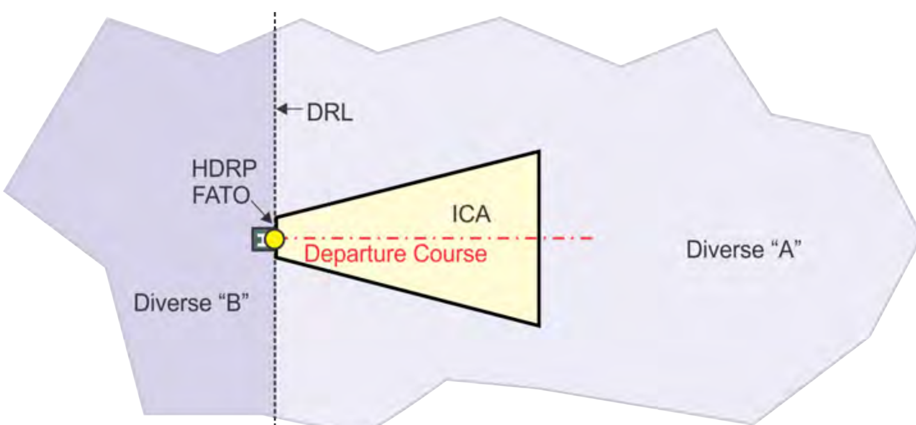


Figure 13-2-2. Heliport Diverse Departure Assessment Areas



(1) ICA. Apply paragraph 13-1-7 to evaluate the ICA using a 40:1 OCS slope (see figure 13-2-1).

(2) Diverse area. Diverse "A" consists of all area on the DER side of the departure reference line (DRL), excluding the ICA. The DRL is a line perpendicular to the RCL that passes through the departure reference point (DRP) which is established on RCL 2000 feet from the start end of the runway (collocated with the FATO for helicopters). Calculate the elevation of the

OCS at any given location in the diverse area by applying formula 13-2-1. Measure the distance from the obstacle to the closest point on the centerline of the runway between the DRP and ICAB, or the closest point on ICA boundary lines as appropriate (see figure 13-2-3 or figure 13-2-4 for helicopters). The beginning OCS elevation is equal to the MSL elevation of the ICAE.

Formula 13-2-1. OCS Height Diverse "A" Area

$$h = a + \frac{d}{s}$$

Where:

h = OCS MSL elevation at obstacle
d = distance (feet) from obstacle to closest point
a = ICAE MSL elevation
s = 40 (20 for helicopters)

Figure 13-2-3. Diverse "A" Area Evaluation

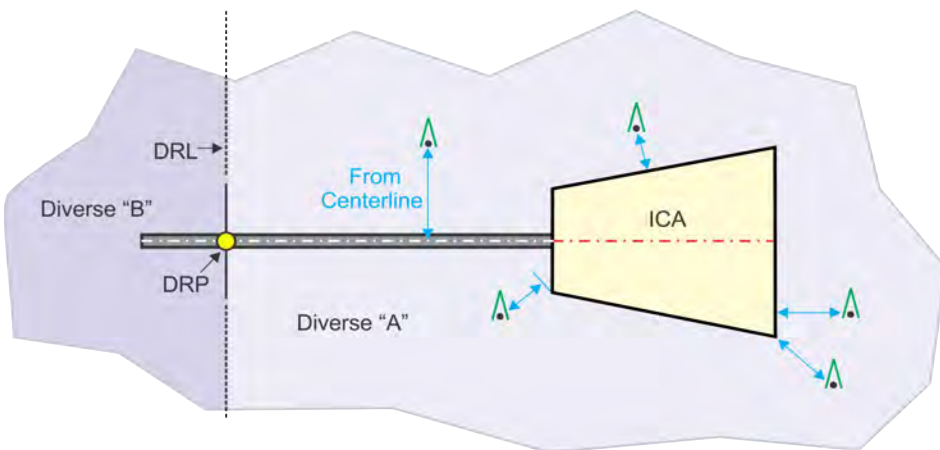
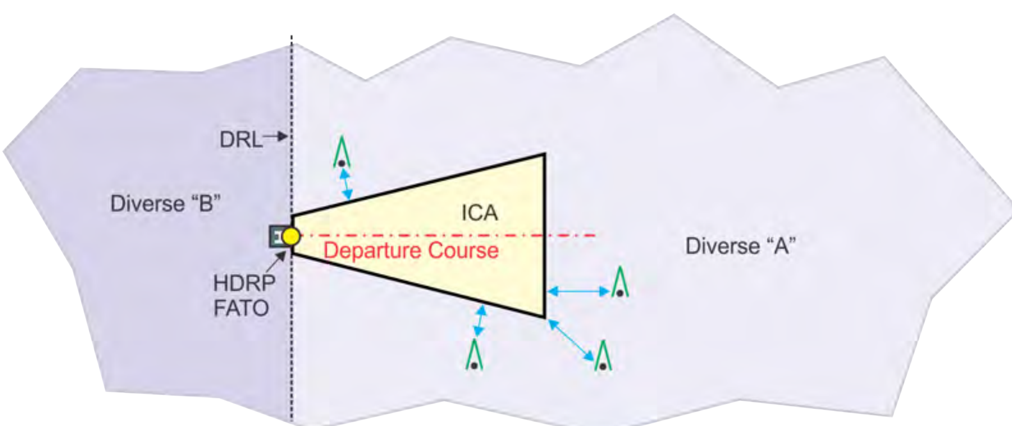


Figure 13-2-4. Heliport Diverse "A" Area Evaluation



(3) Diverse "B" area. All areas on the start end of runway side (non-departure side for helicopters) of the DRL. Evaluate obstacles in the Diverse "B" area by measuring the distance in

feet from the obstacle to the DRP (see figure 13-1-5 or figure 13-2-6 for helicopters). Calculate the OCS MSL elevation at the obstacle using formula 13-2-2.

Formula 13-2-2. OCS Height Diverse "B" Area

$$h = \frac{d}{s} + (b + 400)$$

Where:

h = OCS MSL elevation at obstacle
d = distance (feet) from obstacle to DRP
b = Airport MSL elevation
s = 40 (20 for helicopters)

Figure 13-2-5. Diverse "B" Area

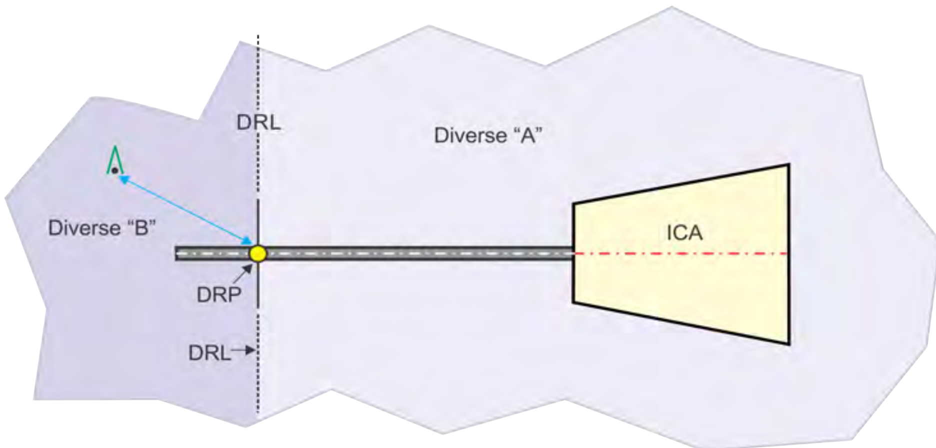
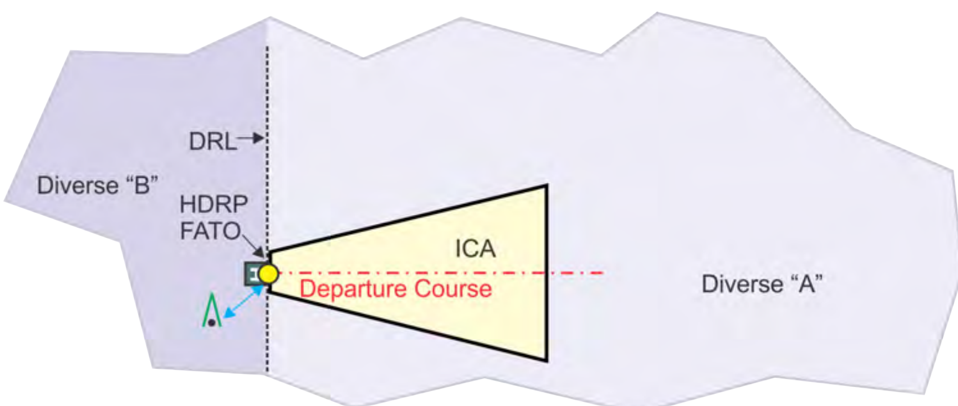


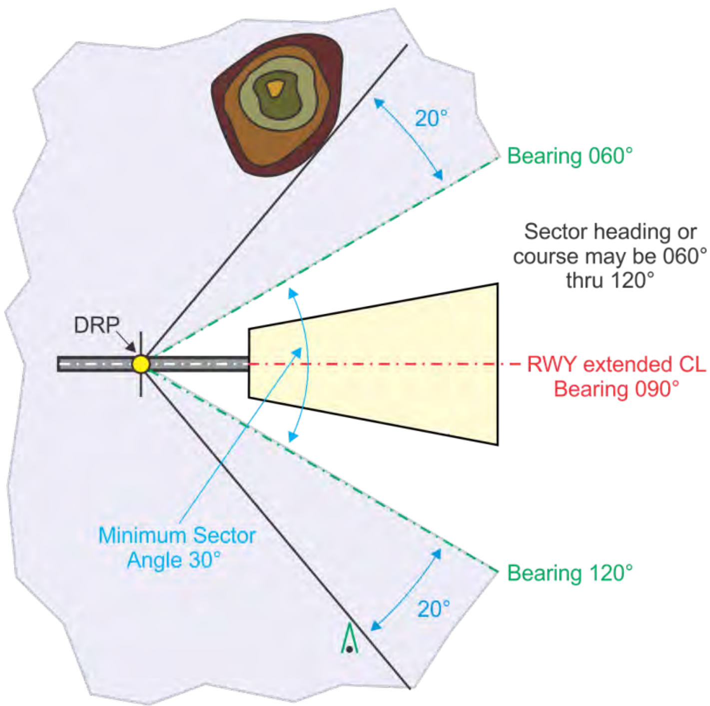
Figure 13-2-6. Heliport Diverse "B" Area



(4) Evaluation of the diverse area for helicopters may be conducted from the helipad in all directions from the FATO utilizing the 20:1 slope from the helipad elevation. If the evaluation reveals all surfaces clear in all directions, then the diverse area is considered clear and standard minimums apply and no departure course will be required. In this case, there is no distinction of Diverse "A" and "B" areas.

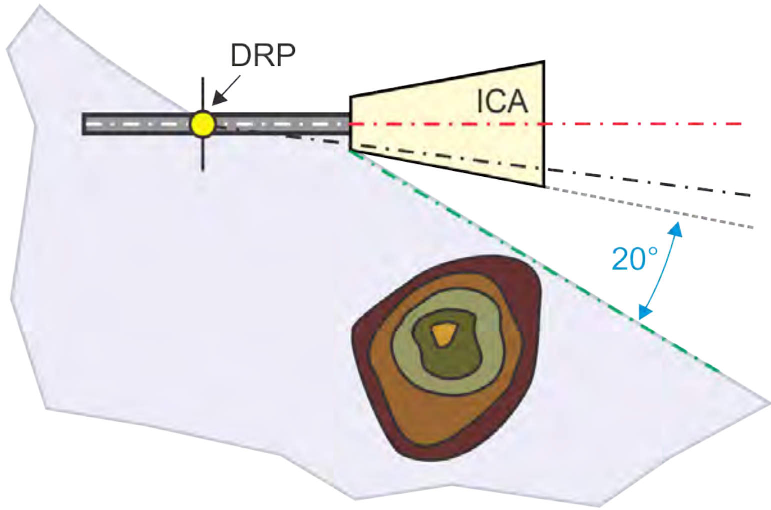
13-2-2. Departure Sectors. Where OCS penetrations prevent unrestricted diverse departure, consider constructing sectors within the diverse areas where departure flight is prohibited. Departure sectors may not be applied to helicopter departures from an IFR heliport. Departure instructions must assure the aircraft will maneuver clear of the prohibited sector boundaries. Separate sector boundaries from obstacles via a buffer established by a 20-degree splay from the DRP. The minimum angle between sector boundaries is 30 degrees. The ICA must be protected at all times (see figure 13-2-7).

Figure 13-2-7. Minimum Sector Area



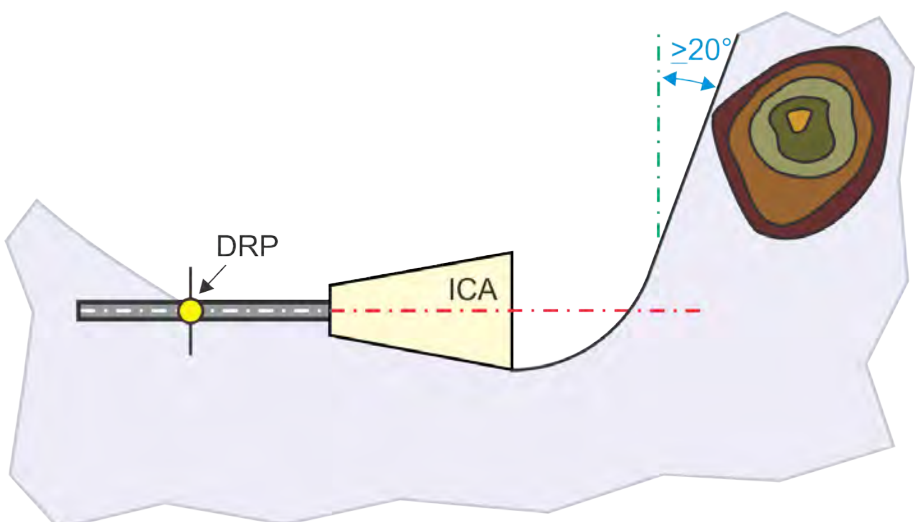
a. Boundary based on the ICA. When the 20-degree splay from the DRP cuts across the ICA, construct a line 20 degrees relative to the side of the ICA. To protect the ICA, no obstacle may lie inside this line (see figure 13-2-8).

Figure 13-2-8. Boundary Based on ICA



b. Outer boundary involving a turn. Locate the turn point on runway centerline (extended) and establish the ICAE. Construct the outer boundary from the ICAE, using table 13-3-2 for selection of the outer boundary radius. Construct a line from the obstacle tangent to the outer boundary radius. Establish the outer boundary buffer 20 degrees from this line on the maneuvering side. Begin the 20-degree buffer at the tangent point where the obstacle line intercepts the arc (see figure 13-2-9).

Figure 13-2-9. Outer Boundary



c. Defining sector boundaries. Construct boundaries to define each sector. Sector boundaries originate at the DRP, or are defined tangentially from the outer boundary radius (see figure 13-2-10). Define and publish sector boundaries by reference to aircraft magnetic headings. Sector "headings" must be equivalent to the magnetic bearing of the sector boundaries from their origins.

d. CGs. A departure sector that uses a standard CG is preferred; however, operational requirements may necessitate a higher CG. When an obstacle penetrates the 40:1 OCS within the departure sector OEA, establish a CG and CGTA in accordance with paragraph 13-1-5.

13-2-3. Sector Limitations.

a. The maximum turn from the takeoff runway in any one direction is 180 degrees relative to takeoff runway heading (see figure 13-2-10). Figure 13-2-11 shows a sector of 360 degrees clockwise, 270 degrees could be assigned; however, the maximum turn to the right is a heading not in excess of the reciprocal of the takeoff runway heading.

Figure 13-2-10. Sector Limitations

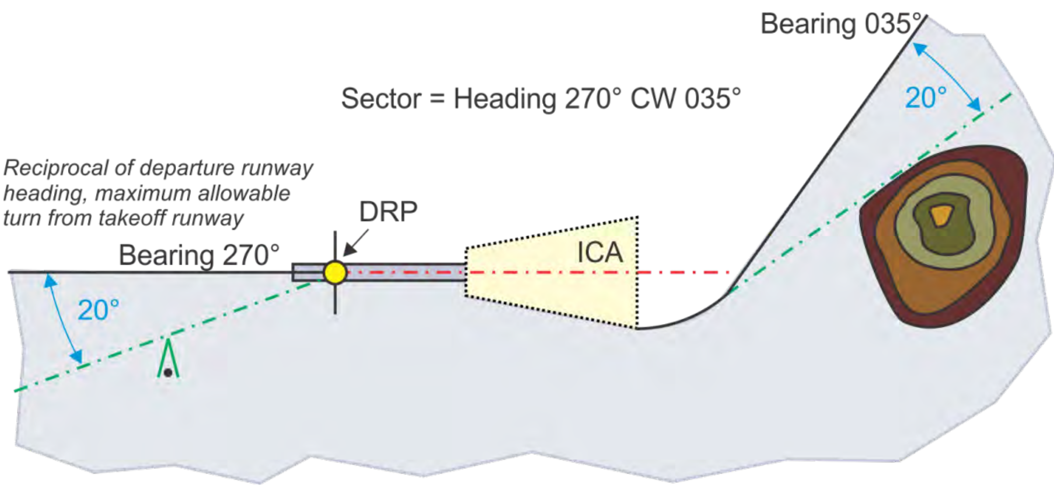
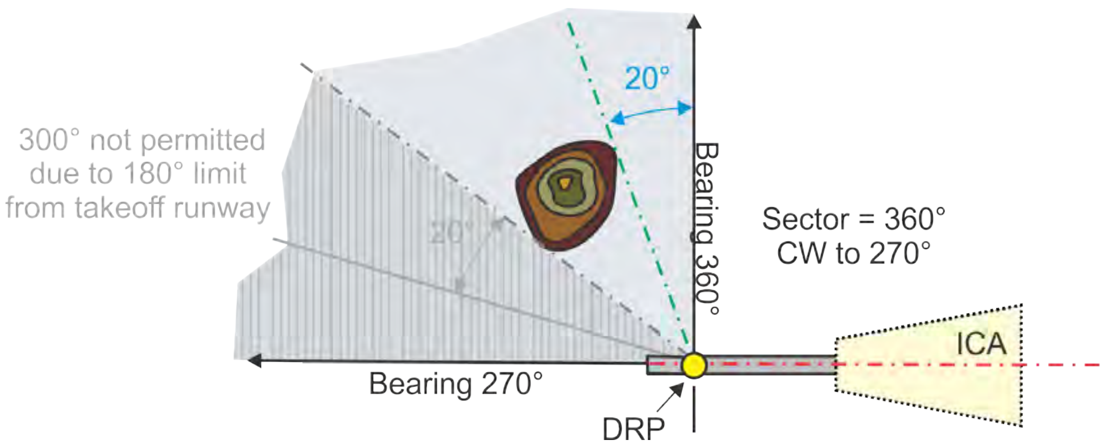
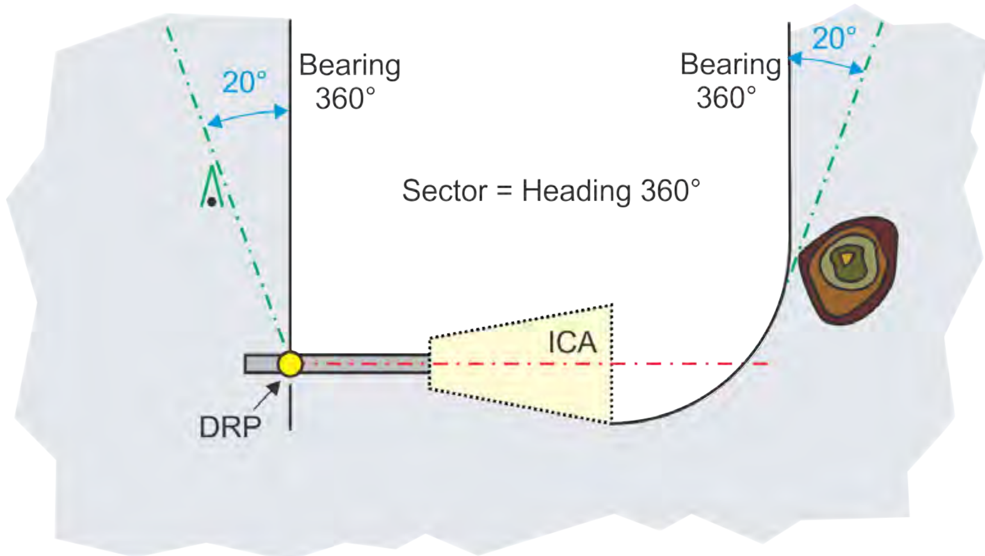


Figure 13-2-11. Maximum Heading Limitation



b. Assign a single heading for a sector which has parallel boundaries. The heading must parallel the boundaries. Figure 13-2-12 shows heading 360 degrees as the only heading allowable.

Figure 13-2-12. Parallel Boundaries



c. Do not establish a sector if the boundaries converge.

Example: In figure 13-2-12, if the bearing from the DRP had been .001 degrees or greater or the outer bearing 359 degrees or less, the sector could not be established.

Section 13-3. Departure Routes

13-3-1. General Information. DP routes are defined as either straight or turning as described below.

a. The ICA must be aligned along the runway centerline for at least 2 NM (1 NM for helicopters). Apply paragraph 13-1-7 to evaluate the ICA.

b. Limit the DR segment to a maximum distance of 10 NM from the DER to the PCG intercept along the intended flight track of the aircraft.

c. Secondary areas may be constructed and obstacles evaluated where PCG is provided.

d. Apply section 2-9, excluding paragraph 2-9-9 and 2-9-10, for terminal area fixes used in DP design.

e. The CG applied to the departure route must be sufficient to increase obstacle clearance along the flight path so that the minimum ROC for the subsequent segment is achieved prior to the end of the departure route climbing segment.

f. Apply section 16-7 for climb-in-holding requirement and evaluation when 1,000 feet of ROC is not achieved. Level holding pattern altitude must have a 1,000 feet of ROC per paragraph 16-2-4.

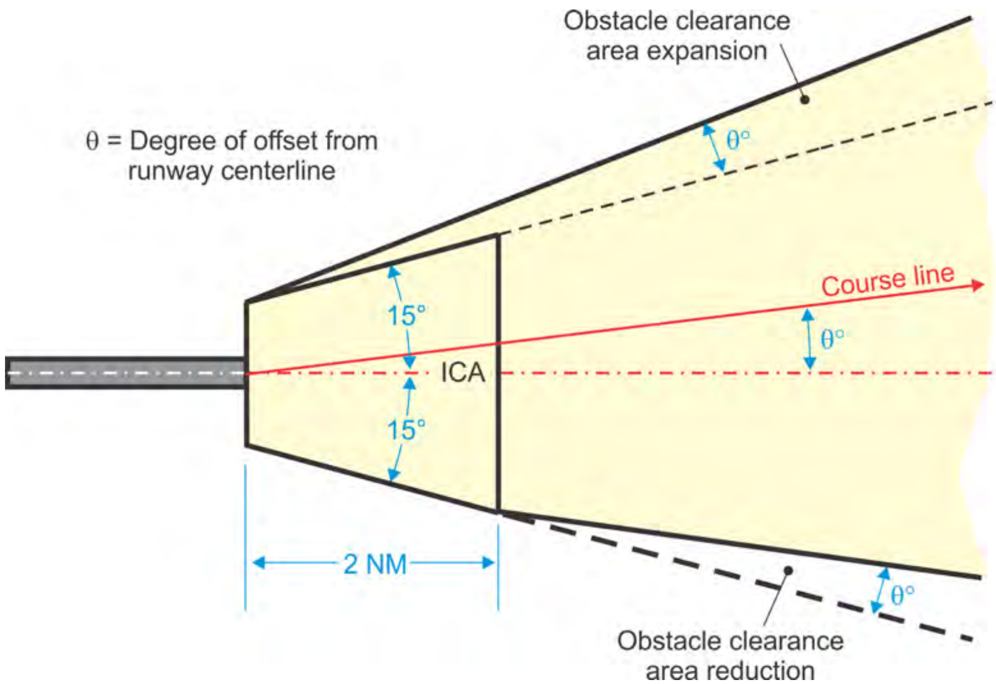
g. Do not exceed 120 degree turn over a fix or facility.

h. Do not apply COP criteria to the terminal area segments of the DP. The bearing, radial, or DME used to establish PCG must be contained within the service volume of the NAVAID used for course/arc guidance and the signal used for the course/arc must not be restricted from use.

13-3-2. Straight DP Segments. DP routes aligned within 15 degrees of the runway centerline (require a turn less than or equal to 15 degrees) are considered straight DP routes.

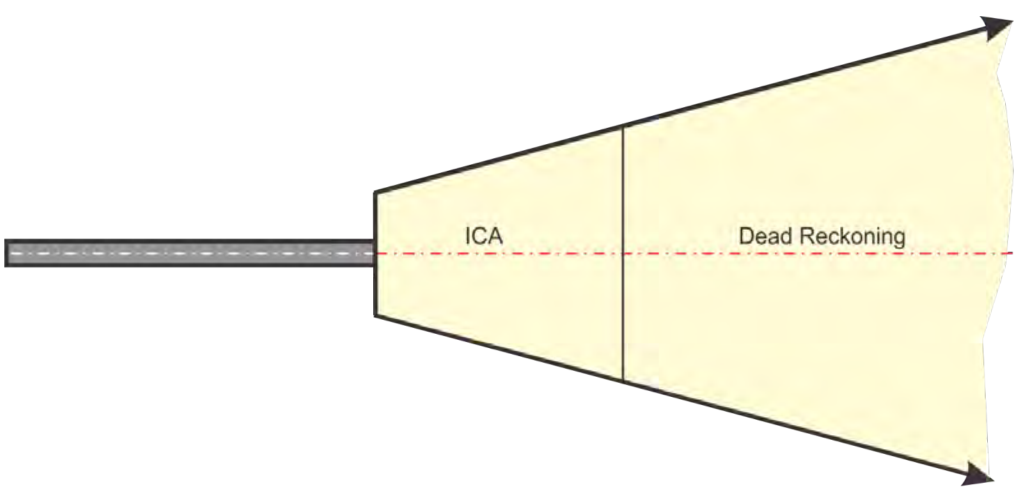
a. Turn 15 Degrees or Less at DER. If a turn at the DER (HDRP for helicopters) is needed, the aircraft is expected to have climbed to 400 ft above the DER elevation before beginning the turn. To account for reaching 400 ft above DER elevation at DER expand the obstacle clearance area in the direction of the turn an amount equal to the departure course degree of offset from runway centerline (departure course for helicopters) (see figure 13-3-1). To account for the aircraft reaching 400 ft at the end of the ICA reduce the obstacle clearance area following the ICA on the side opposite the turn an amount equal to the expansion on the opposite side.

Figure 13-3-1. Turn ≤15 degrees at DER



b. DR, No Turn. The boundary lines of the departure OEA splay outwards 15 degrees relative to the departure course from the end of the ICA (see figure 13-3-2).

Figure 13-3-2. DR, No Turn



c. Intercept PCG, Turn 15 Degrees or Less. Apply the values from table 13-3-1 to formula 13-3-1 and formula 13-3-2 to calculate the obstruction primary area half width (½W_P), and the width of the secondary area (W_S). Refer to table 13-3-1 for the values of k_P, D, A, and k_S. A DR segment must be used after the ICA to intercept PCG when applicable. The ICAE line must be contained in the primary OEA or the PCG NAVAID and must not be intersected by the secondary OEA.

Formula 13-3-1. Half Width of the Primary Area

$$\frac{1}{2}W_P = k_P \times D + A$$

Formula 13-3-2. Width of the Secondary Area

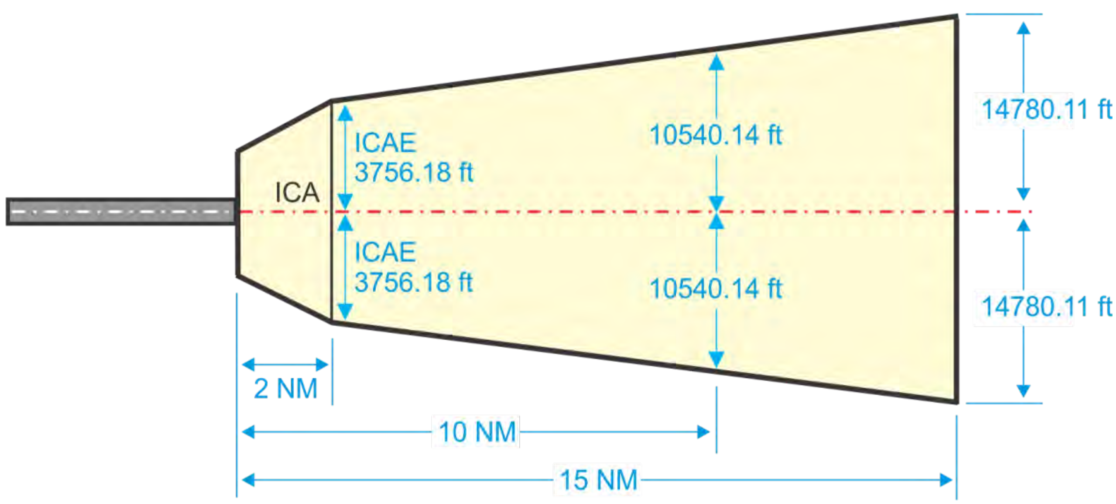
$$W_S = k_S \times D$$

Table 13-3-1. Obstruction Area Values

½ Width	k_p	k_s	D	A
DR	0.267949	none	Distance (feet) from DER	500 feet
Localizer	0.139562	none	Distance (feet) from ICAE	3756.18 feet
NDB	0.0833	0.0666	Distance (NM) from facility	1.25 NM
VOR / TACAN	0.05	0.0333	Distance (NM) from facility	1 NM

(1) Localizer OEA guidance. The OEA begins at the ICAE. The maximum length of the segment is 15 NM from DER. Evaluate in accordance with paragraph 13-1-5.a. If necessary, calculate the required minimum CG using formula 13-1-4 where D is the shortest distance to the ICAB (see figure 13-3-3).

Figure 13-3-3. Localizer Area



(2) NDB OEA guidance. Evaluate in accordance with paragraph 13-1-5.a. If necessary, calculate the required minimum CG using figure 13-1-4. Figure 13-3-4 through figure 13-3-6 illustrate possible facility area configurations for similar NAVAIDs.

(3) VOR/TACAN OEA guidance. Evaluate in accordance with paragraph 13-1-5.a. If necessary, calculate the required minimum CG using figure 13-1-4. Figure 13-3-4 through figure 13-3-6 illustrate possible facility area configurations.

Figure 13-3-4. Facility Area and DR Area Relationship

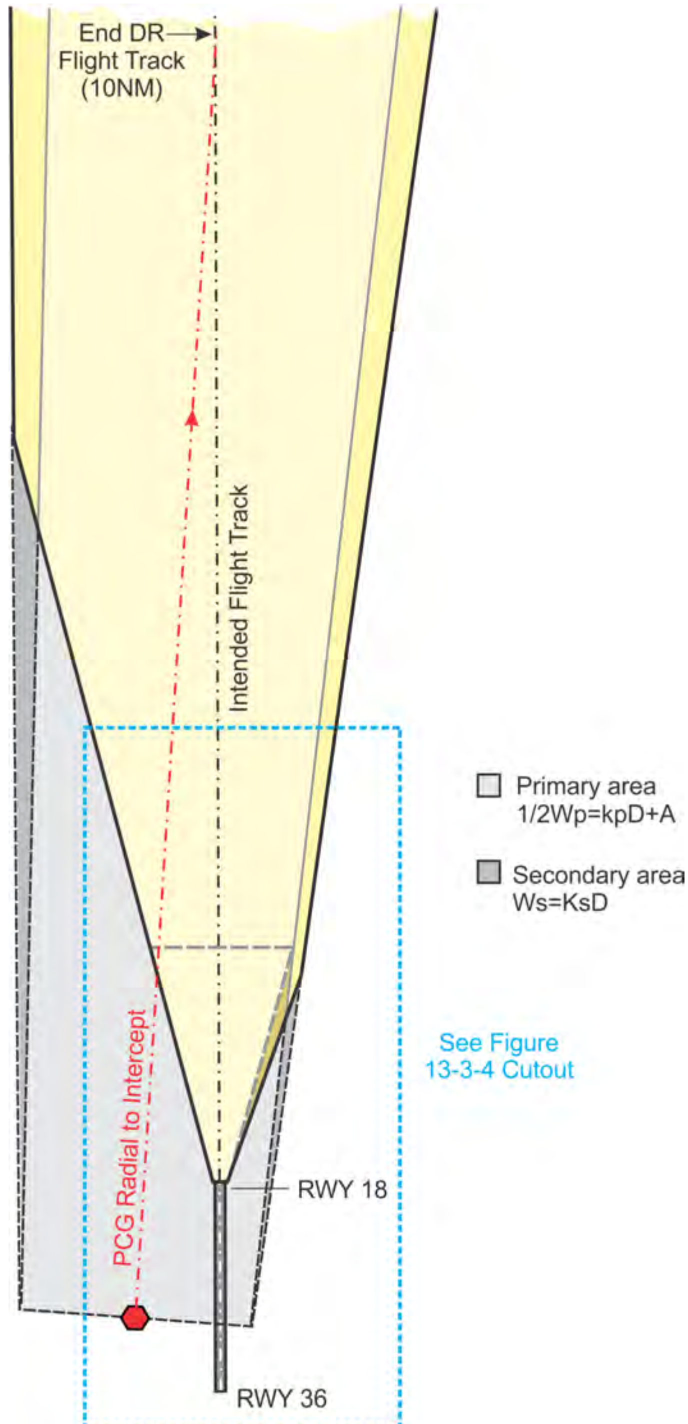


Figure 13-3-4. Cutout

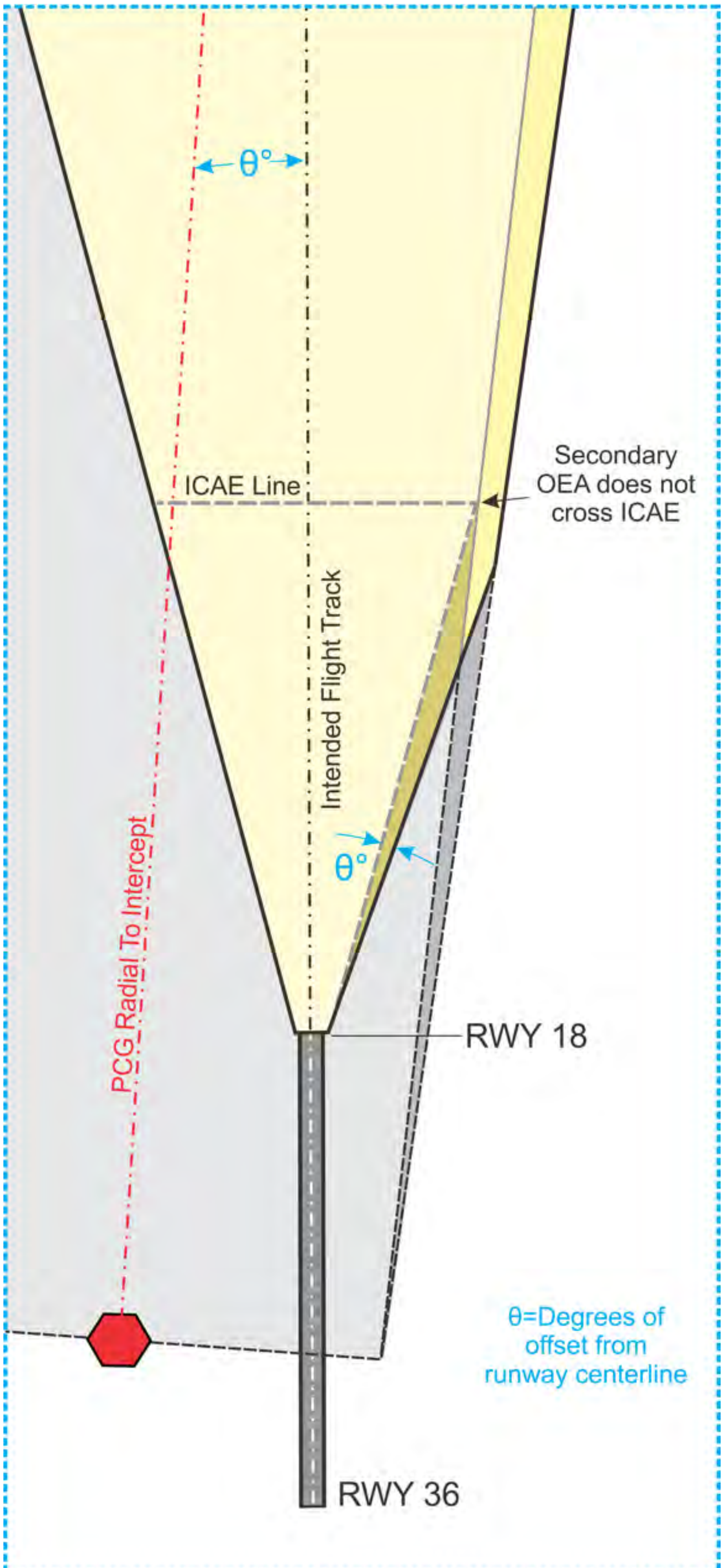


Figure 13-3-5. DER within Primary Area Facility, On Airport NAVAID

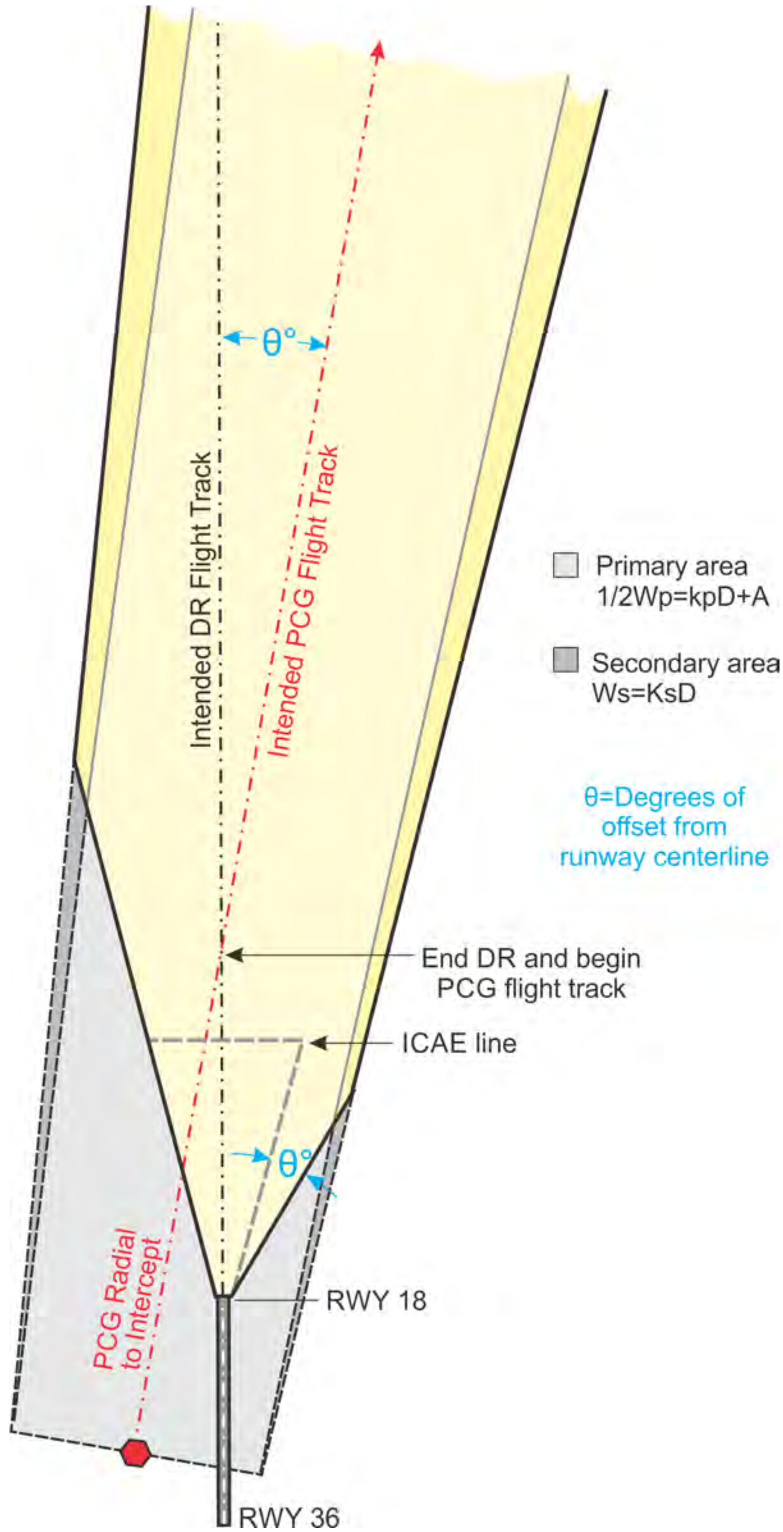
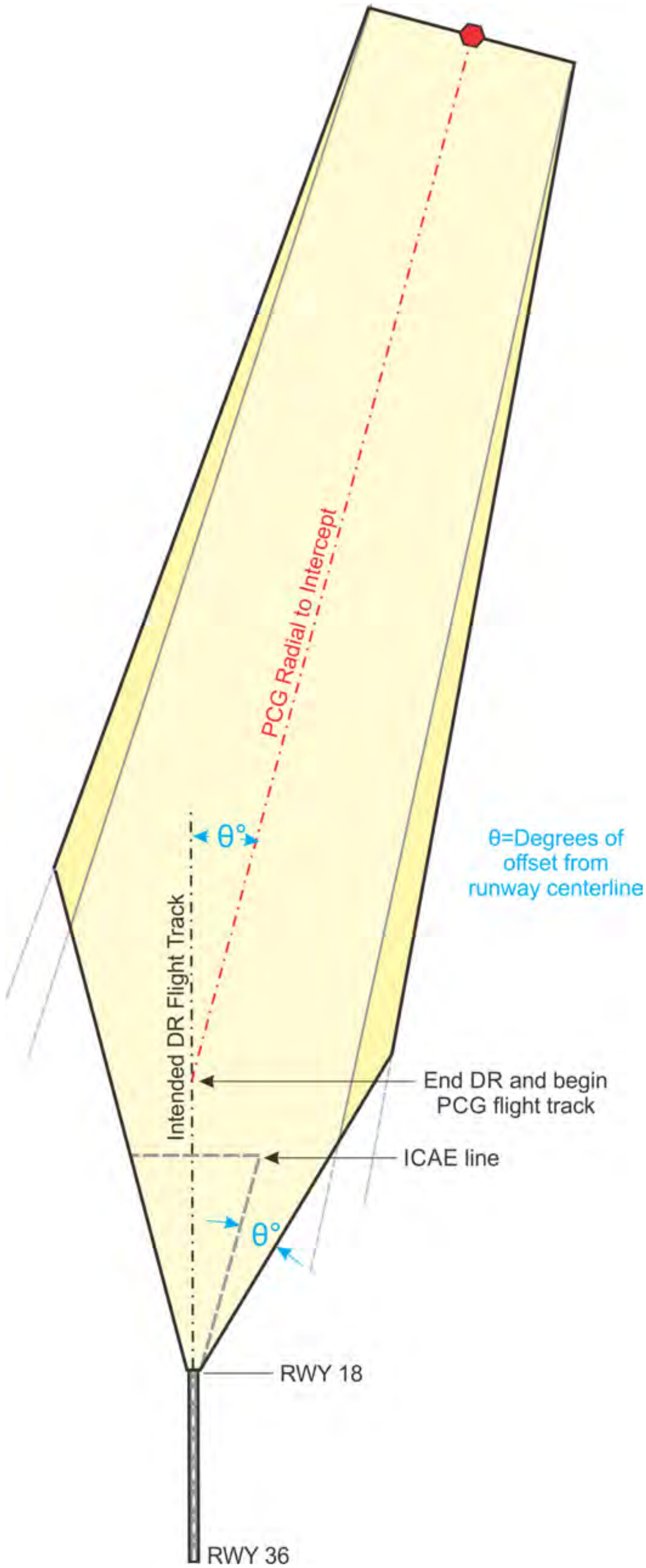


Figure 13-3-6. Facility Area Relationship, Off Airport NAVAID



13-3-3. Turning DP Segments. DP routes not aligned within 15 degrees of the runway centerline (require a turn greater than 15 degrees) are considered turning DP routes.

a. Turning Segment General Information.

(1) To account for reaching 400 ft at the DRP and beginning the turn the turning segment will tie back to the DRP.

(2) When specifying a mandatory climb to altitude before the initial turn to PCG, increase the length of the ICA per paragraph 13-1-6 then apply paragraphs 13-3-1.b. or 13-3-1.c. as applicable.

(3) For turn radii use table 13-3-2 and apply paragraphs 13-3-3.a(3)(a) through 13-3-3.a(3)(f), as appropriate. Use next higher airspeed in table 13-3-2 if specific speed is not provided.

(a) Turns below 10000 feet MSL. Use 250 KIAS unless a speed restriction other than 250 KIAS is noted on the procedure for that turn. Use 200 KIAS for a minimum speed for CAT C and 230 KIAS for CAT D aircraft.

(b) Turns at 10000 feet and above. Use 310 KIAS unless a speed restriction not less than 250 KIAS above 10000 through 15000 feet is noted on the procedure for that turn. Above 15000 feet, speed reduction below 310 KIAS is not permitted.

(c) When speeds greater than 250 KIAS are authorized below 10000 feet MSL and speeds greater than 310 KIAS are authorized at or above 10000 feet MSL, use the appropriate speed in table 13-3-2.

(d) Use the following standard note to publish a speed restriction: “Do not exceed (speed) until BRONI (fix).”

(e) For helicopter departures, use table 13-3-2 radii for 90 KIAS with turns below 10000 feet MSL until intercepting the NAVAID course. Once established on the NAVAID course, use radii for 140 KIAS with subsequent turns unless a speed restriction other than 90 KIAS is noted.

(f) Determine the aircraft turn altitude at the fix or radio facility assuming a CG of 500 ft/NM below 10000 feet MSL and 350 ft/NM above 10000 feet MSL for all fixed-wing aircraft, 400 ft/NM for helicopters. If a published CG is higher than those assumed, use the higher CG to determine the altitude at the fix or radio facility. If the projected fix altitude based on a default CG causes operational issues and ATC Facility Operating Procedures prevent a continuous climb due to airspace the highest altitude of the airspace may be used as an altitude restriction for evaluation and it is not required to be published. The distance used for the calculation will be the distance along the path of flight beginning at the end of the ICA to each subsequent fix or radio facility. Once the altitude is determined, use table 13-3-2 to determine the turn and boundary radii. If a speed restriction exists at or beyond the evaluation fix or radio facility, use that speed to determine the radii, otherwise, use 250 KIAS if the altitude is below 10000 MSL, and 310 KIAS if the altitude is above 10000 MSL.

Table 13-3-2. Turn Radii

Radii (turn radius / outer boundary radius) (NM)		
Airspeed (KIAS)	**Below 10000 feet MSL**	**At and above 10000 feet MSL**
90	0.8 / 0.9	1.2 / 1.4
120	1.2 / 1.4	1.6 / 2.0
140	1.4 / 1.7	1.9 / 2.5
150	1.6 / 1.9	2.0 / 2.7
175	2.0 / 2.4	2.5 / 3.3
180	2.0 / 2.5	2.6 / 3.4
210	2.6 / 3.2	3.1 / 4.3
240	3.1 / 3.9	3.8 / 5.2
250	3.4 / 4.2	4.0 / 5.5
270	3.8 / 4.7	4.5 / 6.2
300	4.5 / 5.6	5.3 / 7.3
310	4.8 / 6.0	5.6 / 7.7
350	5.8 / 7.3	6.7 / 9.3

Note: The table depicts common airspeeds used to determine turn radius (see Pilot's Handbook of Aeronautical Knowledge, chapter 5 for radius of a turn calculations) based on radius of turn calculations accounting for omni winds. Speeds include 60-knot omni winds below 10000 feet MSL; 90-knot omni winds at 10000 feet and above; bank angle 23 degrees.

(4) The computed start point of the turn is the distance of turn anticipation (DTA) for the radio facility or fix (see formula 13-3-3).

Formula 13-3-3. Distance Turn Anticipation

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

Where:

R = turn radius from table 13-3-2

β = magnitude of heading change (degrees)

b. DR to Intercept PCG Radial or Bearing, Turn Greater Than 15 Degrees (see figure 13-3-7 through figure 13-3-11). For turn radii apply paragraph 13-3-3 as applicable. Apply the values from table 13-3-1 to formula 13-3-1 and formula 13-3-2 to calculate the obstruction primary area half width (½WP), and the width of the secondary area (WS). Refer to table 13-3-1 for the values of k_P, D, A, and k_S.

(1) The PCG intercept point (the intercept point is where the intended DR flight track ends and the PCG course begins) must not be located in the ICA or on a line from the DRP to the DER.

(2) The intended flight track will begin at the DER and extend through the appropriate part of the ICAE line. At the ICAE line or the extended flight track beyond the ICAE where it intercepts the PCG course as appropriate, use the selected radius from table 13-3-2 to continue the flight track until the desired intercept angle can be formed between the intended flight track and the PCG line. The intercept point of the intended flight track and PCG line must occur prior to the fix displacement or NAVAID as applicable. The minimum intercept angle from the intended flight track to the PCG line is 15 degrees, optimum is 30-45 degrees. Where an

operational advantage exist up to 60-degree intercept maybe used with flight standards approval (see paragraph 1-4-2). A heading for the intercept must be defined unless the heading is unable to intercept the PCG course staring on a line from the DRP to the DER and along the intended flight track to the intercept point. When a heading is not defined use the optimum intercept angle.

(a) Outside turn protection starts from the outside edge of the ICAE line using the outside boundary radius from table 13-3-2 to a tangent point relative the intercept course or ends when intercepting the primary boundary of the PCG NAVAID. When the tangent point is available, continue a splay plus-or-minus 15 degree the intercept course as appropriate from the tangent point to the intended PGC course until it intercepts the appropriate OEA boundary. The splay or outer boundary arc must intersect the primary OEA boundary prior to the fix displacement or NAVAID as applicable. When a intercept heading cannot be specified and the radial/bearing to intercept crosses the outside boundary arc from the ICAE, then the start point of the arc must be delayed on an extended line from the outside edge of the ICAE to account for system accuracy of the PCG NAVAID.

(b) Inside turn protection begins at the DRP and either splays plus-or-minus 15 degrees relative the intercept course or relative the PCG course as appropriate until it intercepts the appropriate OEA boundary of the PCG course.

Figure 13-3-7. Turn to Intercept Radial (Off Airport NAVAID)

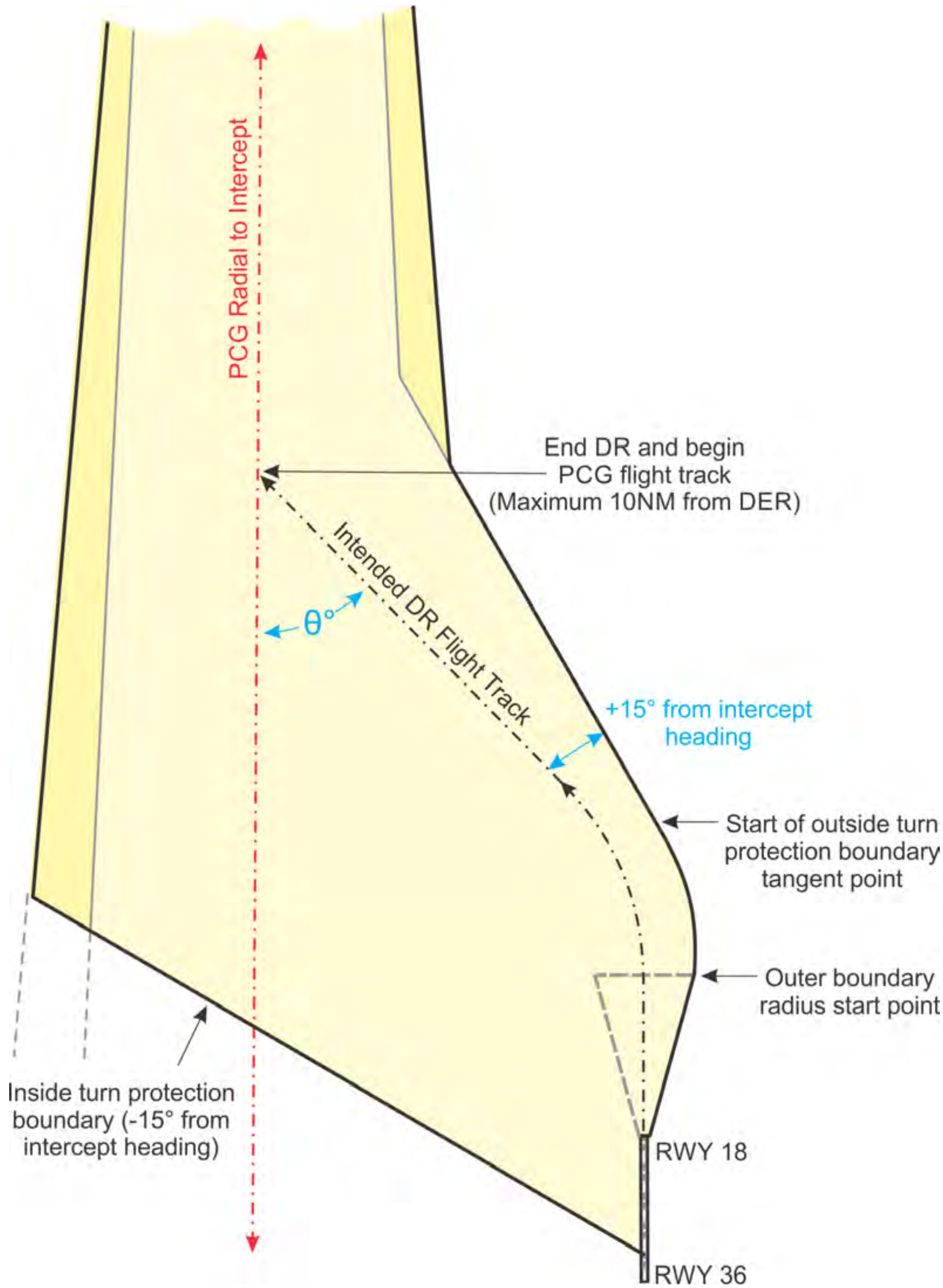


Figure 13-3-8. Turn to Intercept Radial, Example 1 (On Airport NAVAID)

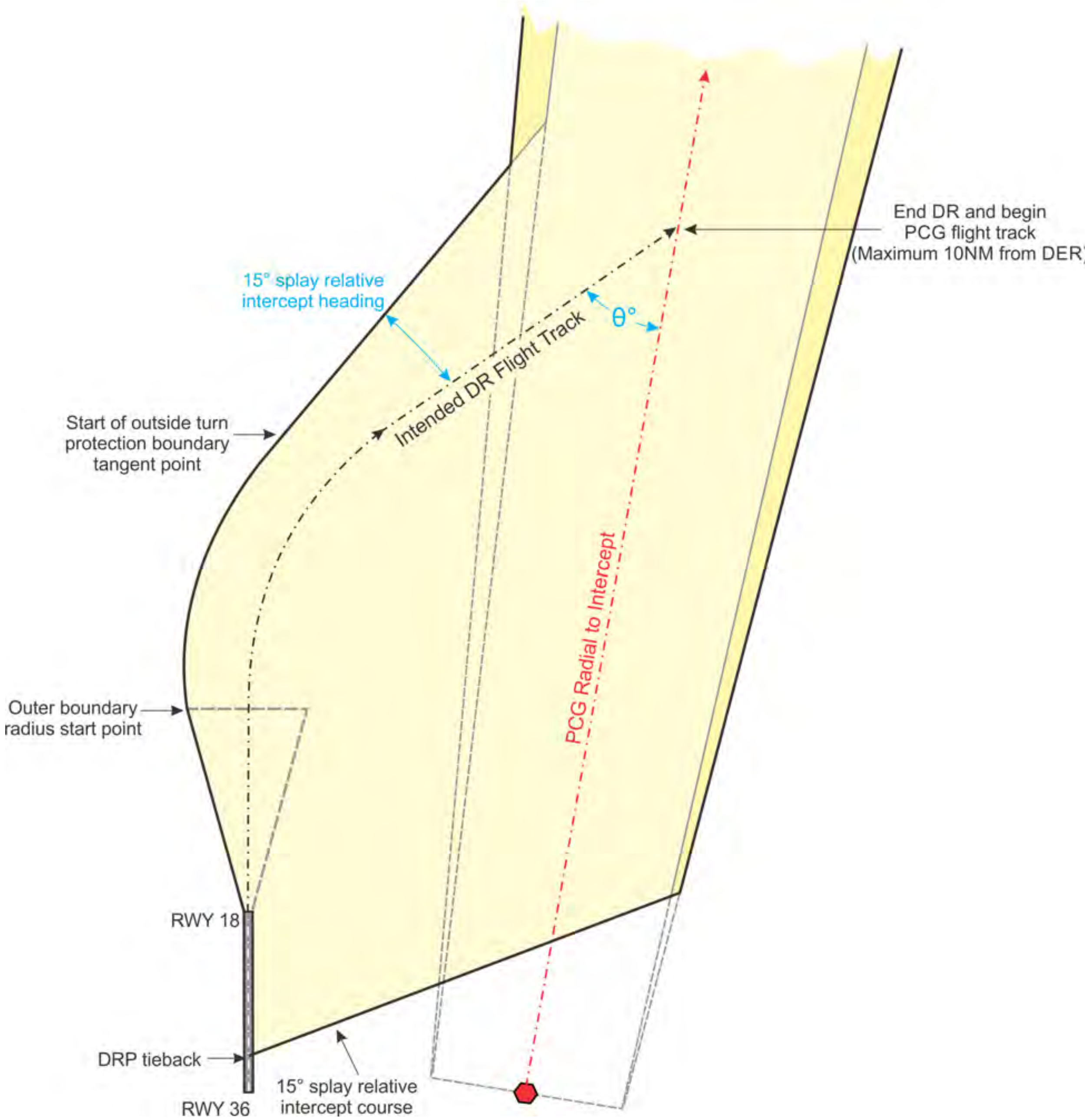


Figure 13-3-9. Turn to Intercept Radial, Example 2 (On Airport NAVAID)

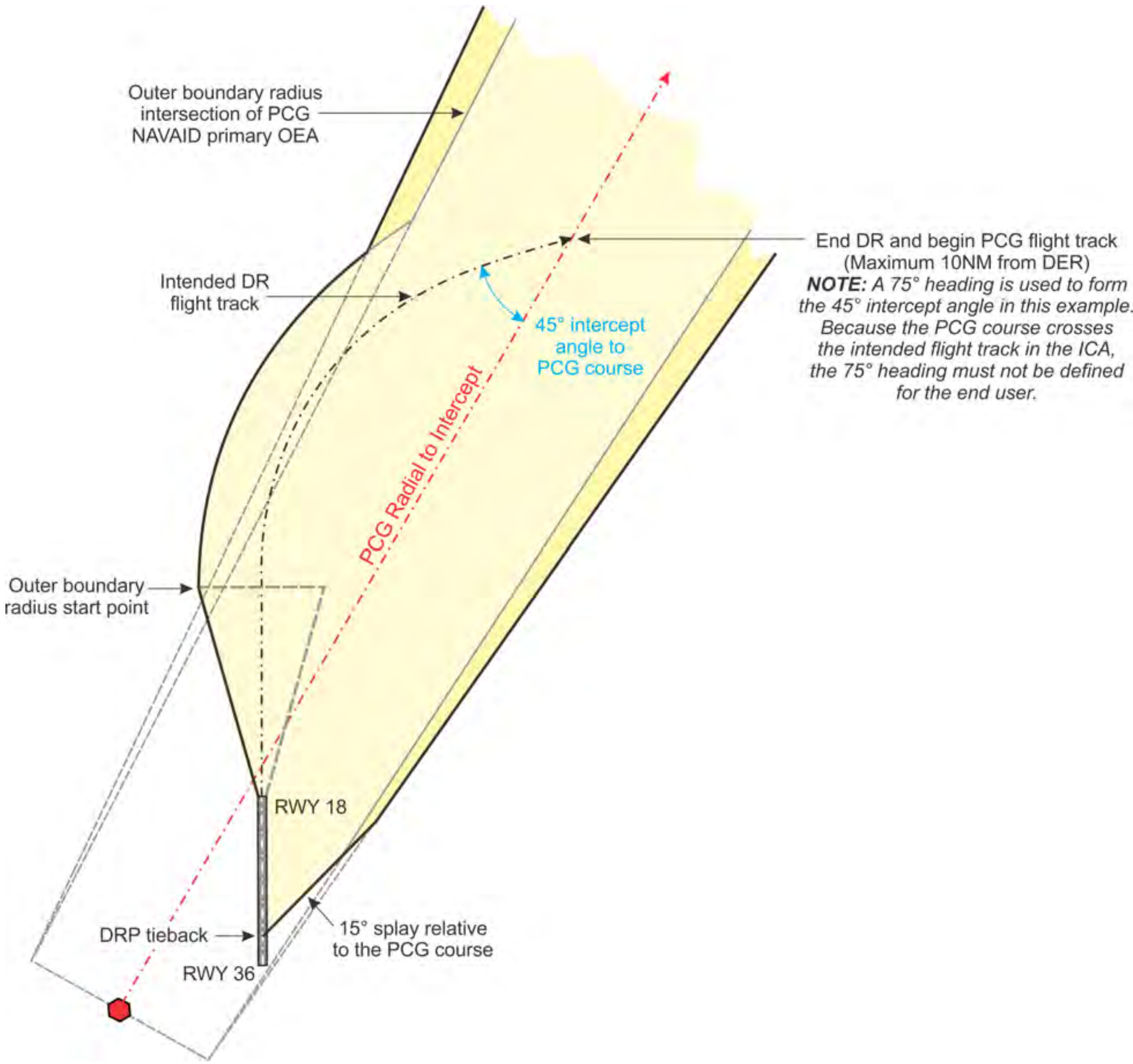
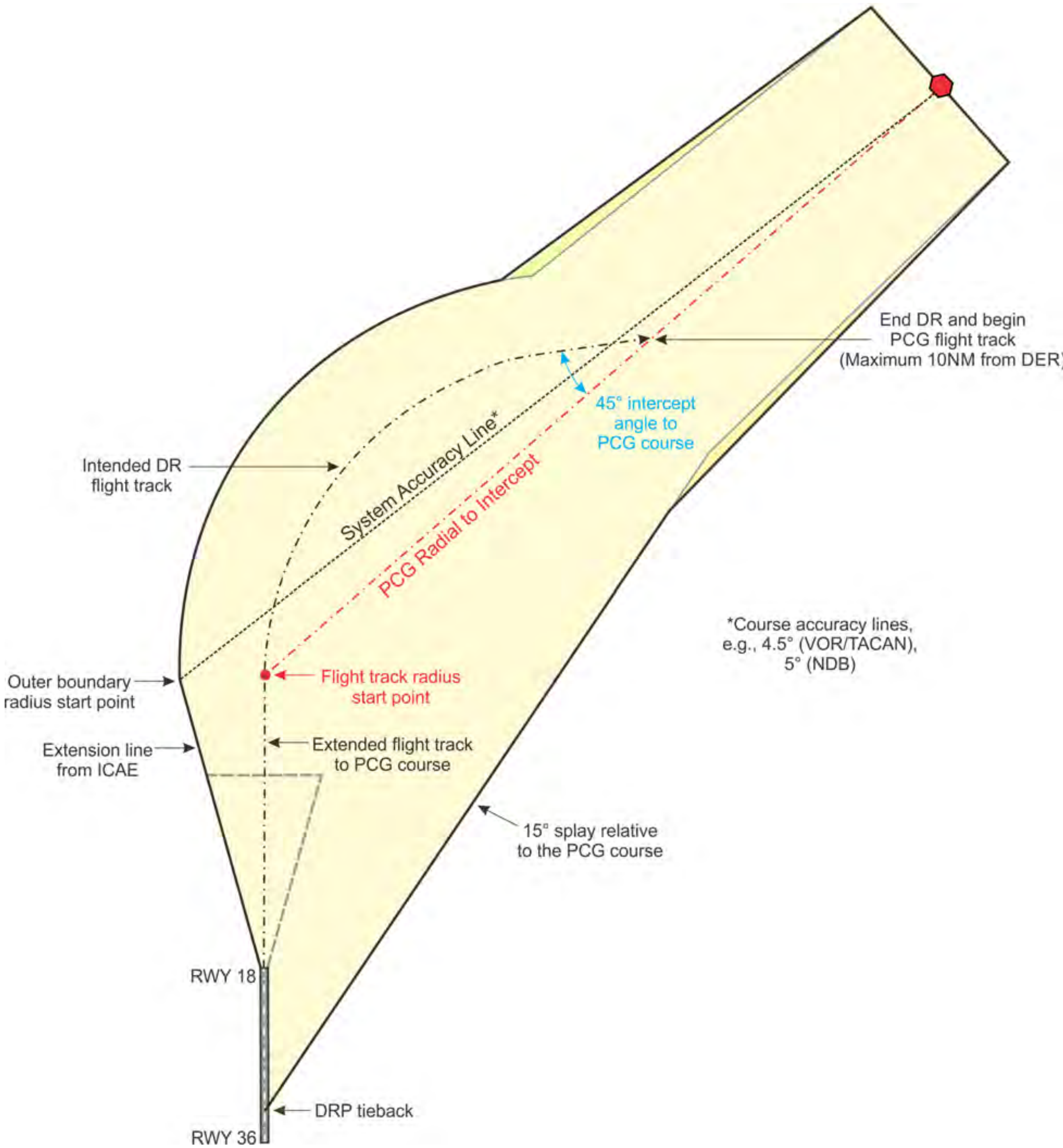


Figure 13-3-10. Turn to Intercept Radial with Arc Extension (Off Airport NAVAID)



(3) If specifying a crossing radial or bearing before the turn to intercept PCG apply the following exception to paragraph 13-3-3b(2).

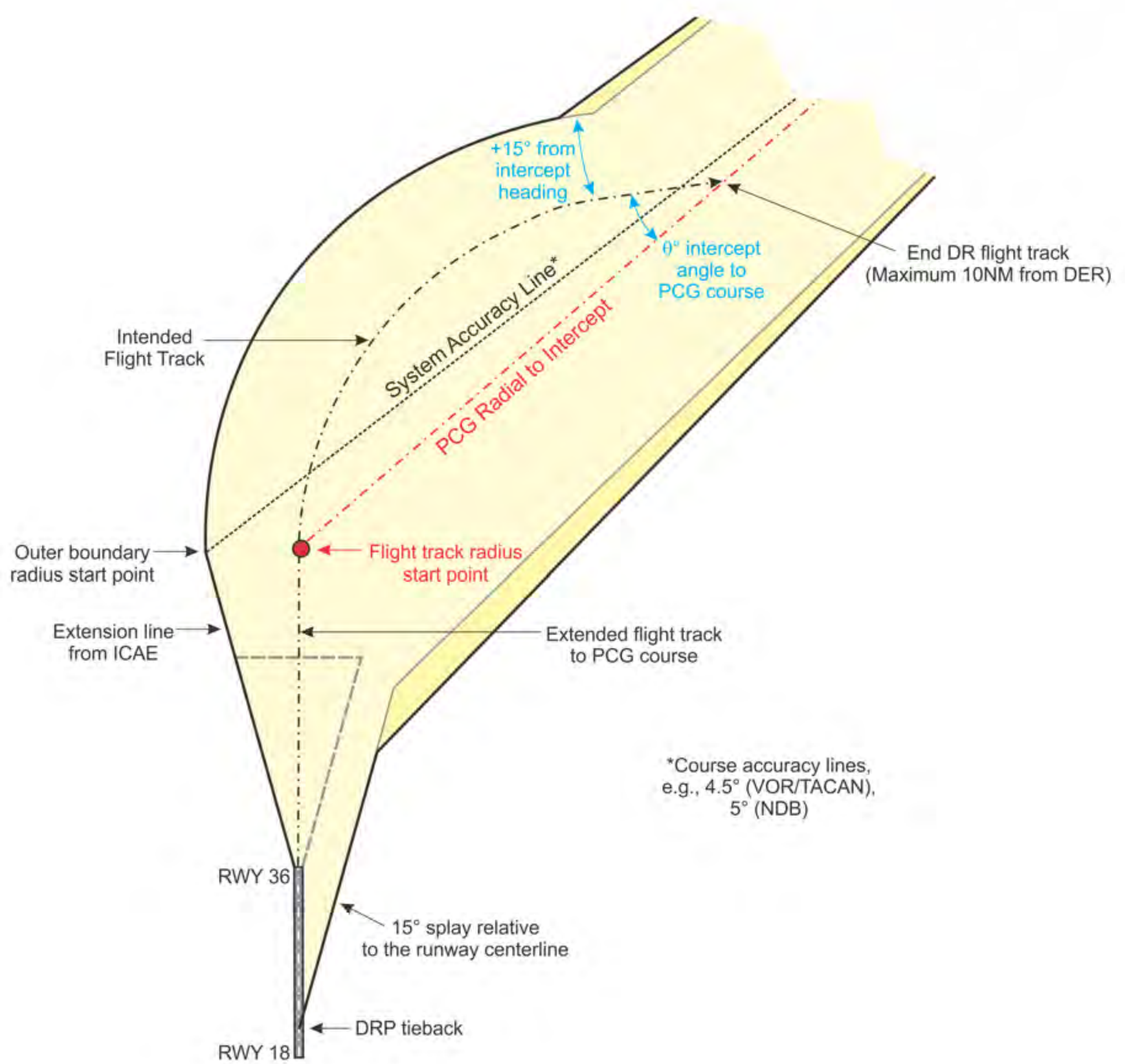
(a) A heading that forms the intercept angle to PCG must be defined as outline in paragraph 13-3-3b(2) regardless of heading usability from the intended flight track prior to the crossing radial/bearing.

(b) The outside turn protection must be designed relative to the intercept course as defined in paragraph 13-3-3b(2)(a).

(c) If the radial/bearing system accuracy line crosses the outside boundary arc from the ICAE, then the start point of the outside turn protection arc must be delayed on an extended line from the outside edge of the ICAE to account for system accuracy of the PCG radial/bearing.

(d) The Inside turn protection will splay at 15 degrees relative to the intended flight track heading from the DRP to the appropriate OEA boundary.

Figure 13-3-11. Turning at a Specified Radial/Bearing Prior to PCG Intercept



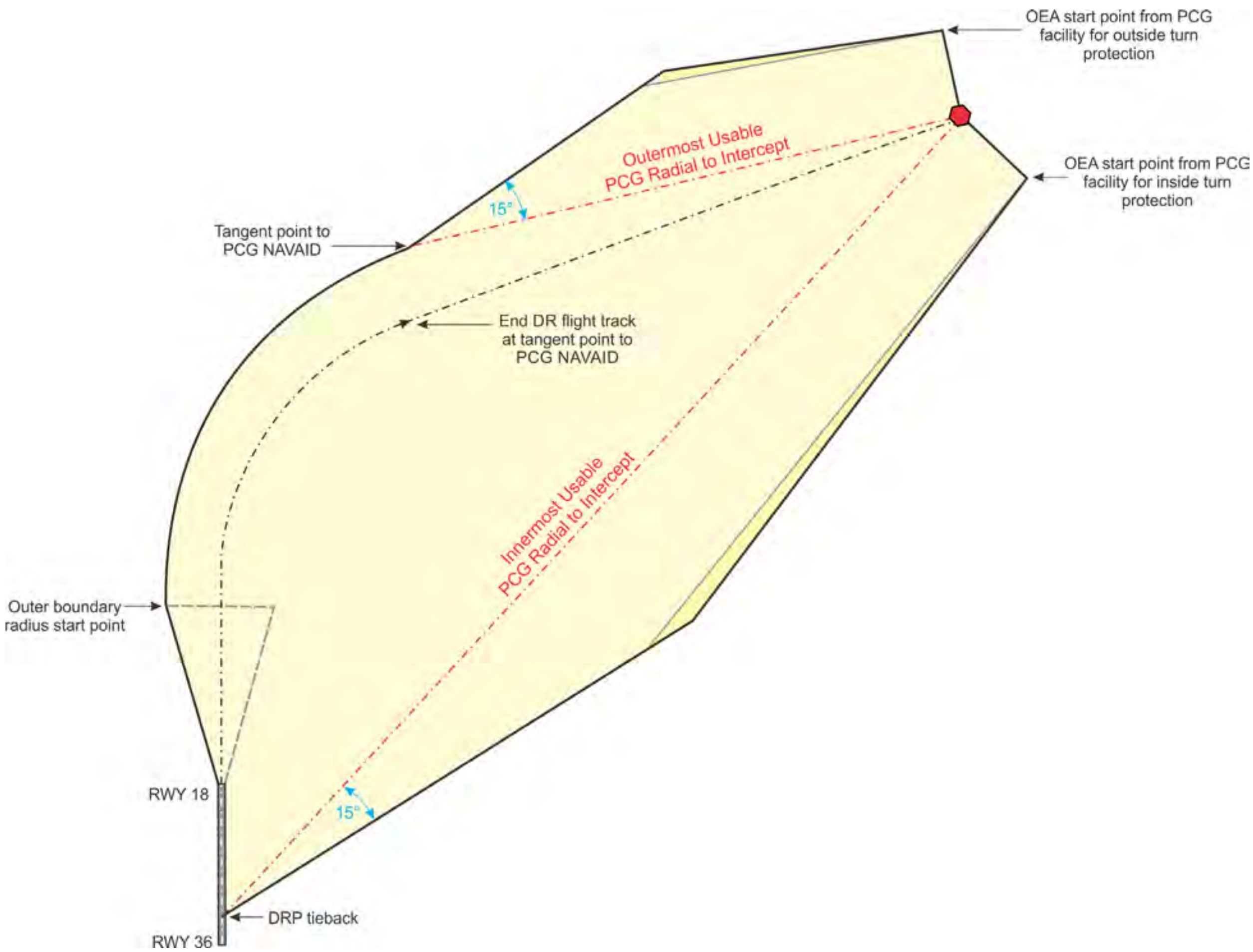
c. Direct to Facility, General Information. The intended flight track will begin at the DER and extend through the appropriate part of the ICAE line. At the ICAE line, use the appropriate radius from table 13-3-2 to continue a flight track until the radial/bearing from the facility can be connected tangent to the arc. The DR leg starts at the DER and ends at this point.

(1) Turn Greater Than 15 Degrees but Less Than or Equal to 90 Degrees, OEA Construction (see figure 13-3-12).

(a) Start the outside turn protection at the outside edge of the ICAE line using the appropriate outside boundary radius from table 13-3-2. Then continue the outside turn protection until a radial/bearing can be connected tangent from the PCG facility. Then from the facility tangent point on the arc, the outside turn protection OEA will splay at 15 degrees relative the radial/bearing until it intercepts the outer most OEA boundary developed from the facility.

(b) Develop inside turn protection base on a radial/bearing directly from the facility to the DRP. Then from the DRP, the inside turn protection OEA will splay at 15 degrees relative this radial/bearing until it intersects the outer most OEA boundary developed from the facility.

Figure 13-3-12. Direct to Facility, Turn Greater Than 15 Degrees but Less Than or Equal to 90 Degrees

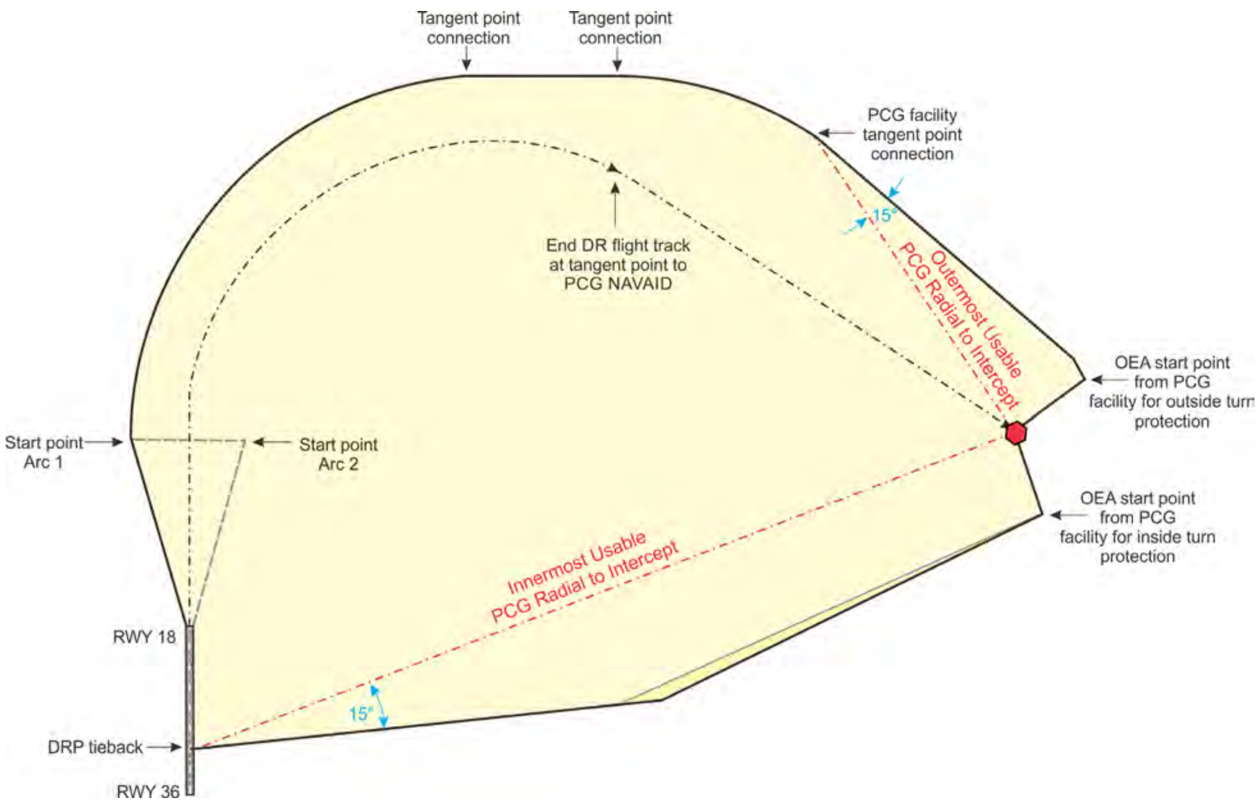


(2) Turn Greater Than 90 Degrees but Less Than or Equal to 180 Degrees, OEA Construction (see figure 13-3-13).

(a) Start the outside turn protection by constructing an arc at the outside edge of the ICAE line using the appropriate outside boundary radius from table 13-3-2 to a 90 degrees outbound course relative the intended flight track course at the ICAE. Then construct a second arc at the inside edge if the ICAE using the appropriate outside boundary radius from table 13-3-2 and connect the two arcs with a tangent line. Then continue the second arc until a radial/bearing can be connected tangent from the PCG facility. Then from the facility tangent point on the second arc, the outside turn protection OEA will splay at 15 degrees relative the radial/bearing until it intercepts the outer most OEA boundary developed from the facility and must do so prior to the OEA start point abeam the facility.

(b) Develop inside turn protection base on a radial/bearing directly from the facility to the DRP. Then from the DRP, the inside turn protection OEA will splay at 15 degrees relative this radial/bearing until it intersects the outer most OEA boundary developed from the facility and must do so prior to the OEA start point abeam the facility.

Figure 13-3-13. Direct to Facility, Turn Greater Than 90 Degrees but Less Than or Equal to 180 Degrees



13-3-4. Multiple PCG Turn Segments. The bearing, radial, or DME used to establish PCG must be contained within the service volume of the NAVAID used for course guidance and the signal used for the course must not be restricted from use. Use the following criteria for OEA construction:

a. Inside Turn Protection. Inside turn protection is provided for turns with a heading change by truncating the preceding segment OEA or calculating a DTA or identifying a 2-NM lead point turn area. The beginning of the 2-NM lead point turn area must be defined by a radial, bearing or DME in that order of precedence. Every effort must be made to formulate lead areas for all users and as such a lead DME must only be used when required.

(1) Turning over a radio fix. A turnover a radio fix must be a minimum of 1 but not exceed 120 degrees. When constructing a 2-NM lead area it must be predicated on facilities defining the preceding or succeeding segment.

(a) Inside turn OEA truncation of the preceding segment (see figure 13-3-14 and figure 13-3-15).

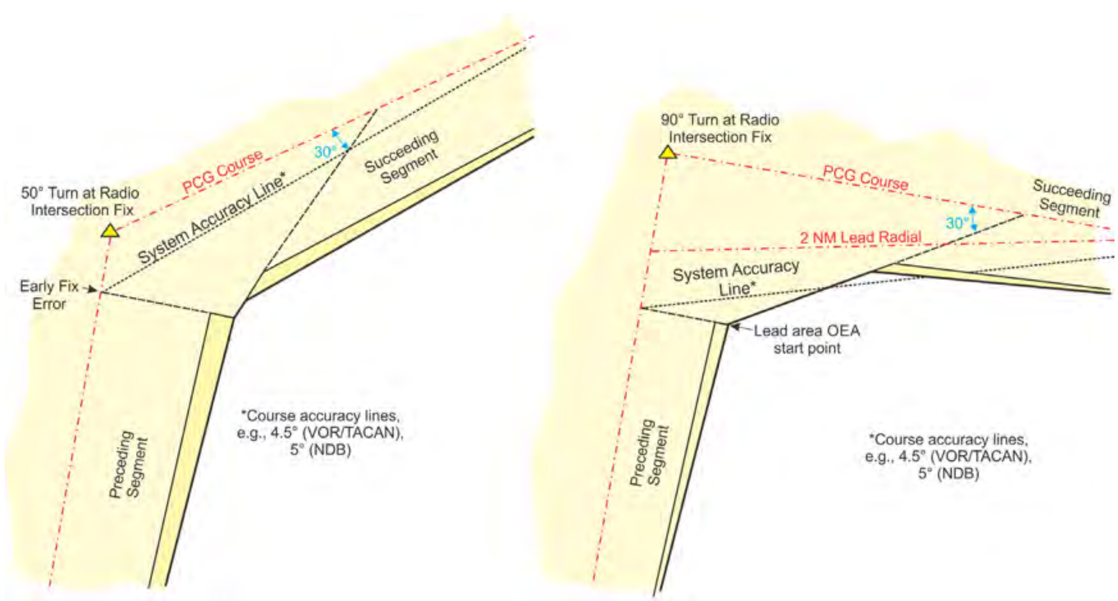
1. For a turn 1 degree but less than 30 degrees, truncate the secondary OEA abeam the DME fix error only.

2. For a turn greater than or equal to 30 degrees but less than 60 degrees, truncate the secondary OEA abeam the early fix error.

3. For turns greater than or equal to 60 degrees but less than or equal to 120 degrees, use a lead radial, bearing or DME to construct the inside turn protection. Truncate the secondary OEA in the preceding segment abeam 2-NM lead radial/bearing plus system accuracy or fix error prior to the radio fix.

(b) Lead point turn area construction. Connect a line to the succeeding primary and secondary OEAs from the truncated point by tapering 30 or splaying 15 degrees relative the outbound course as applicable for evaluation. For small angle turns less than 30 degrees, use half the magnitude of turn angle in lieu of the 30-degree taper as appropriate.

Figure 13-3-14. Inside Turn Area Construction Over a Radio Fix



(2) Turning over a radio facility. A turnover a radio facility may be a minimum of one but must not exceed 120 degrees.

(a) Inside turn OEA truncation of the preceding segment.

1. For turns greater than 90 degrees, use a lead radial, bearing or DME to construct the inside turn protection. Truncate the secondary OEA in the preceding segment abeam 2 NM plus system accuracy as appropriate prior to the radio facility.

2. For turns 60 to 90 degrees use either a DTA, or a lead radial, bearing, DME to construct the inside turn protection. Truncate the secondary OEA in the preceding segment abeam the calculated DTA point using formula 13-3-3 unless the identified 2 NM plus system accuracy abeam point, as appropriate, in the preceding segment is closer to the turn. If the turn is shallow enough that the radial/bearing plus system accuracy is fully within the primary areas of both adjoining trapezoids, truncate the preceding secondary area abeam the radio facility used for the turn.

3. For turns less than 60 degrees use a DTA to construct the inside turn protection. Truncate the secondary OEA in the preceding segment abeam the calculated DTA using formula 13-3-3.

(b) Lead point turn area construction. Connect a line to the succeeding primary and secondary OEAs from the preceding outer OEA boundary of the truncated point by tapering 30 or splaying 15 degrees relative the outbound course as applicable for evaluation. For small angle turns less than 30 degrees, use half the magnitude of turn angle in lieu of the 30-degree taper as appropriate.

Figure 13-3-15. Inside Turn Area Construction, 75º Turn Over Radio Facility

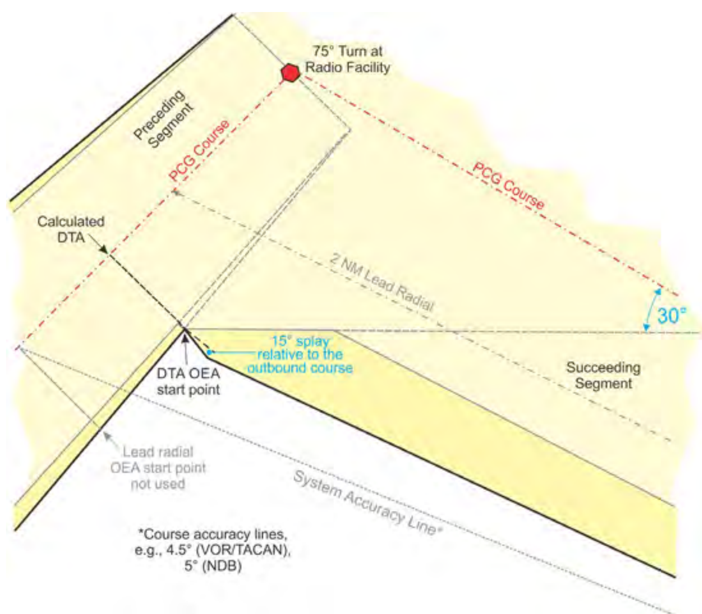
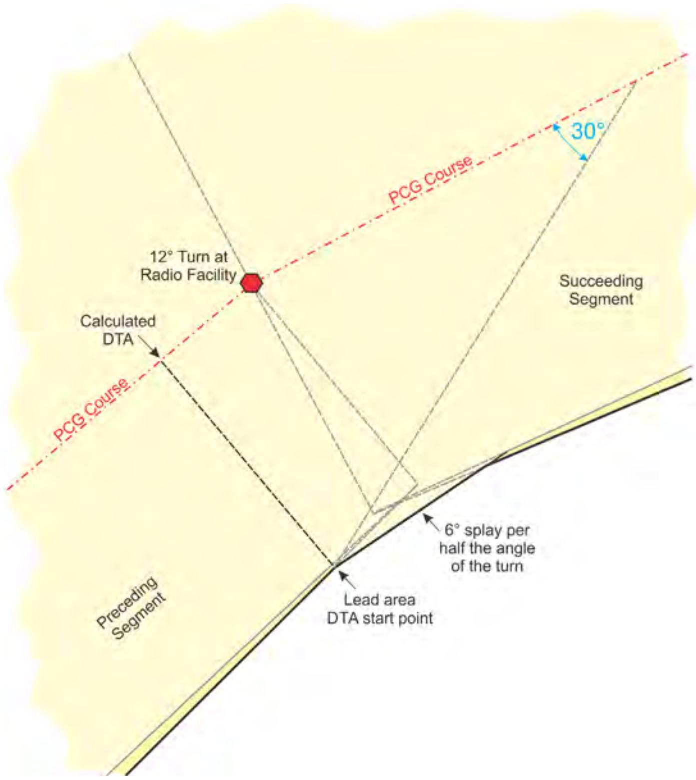


Figure 13-3-16. Inside Turn Area Construction, 12° Turn Over Radio Facility



b. Outside Turn Protection (see figure 13-3-17 through figure 13-3-19).

(1) Altitude determination.

(a) Calculate the projected fix altitude by applying the vertical path rise from the start point or altitude along the course centerline to the subsequent fix or point applying paragraph 13-3-3.a(3)(f). The start point for subsequent legs is the end fix or point of the preceding leg at the assumed altitude of the fix or point.

(b) If the projected fix altitude based on a default CG causes operational issues and ATC Facility Operating Procedures prevent a continuous climb due to airspace the highest altitude of the airspace may be used as an altitude restriction for evaluation and it is not published.

(2) The outside turn protection must intersect the corresponding OEA of the outbound leg prior to the fix error at the end of the outbound leg. Determine outer boundary radii from table 13-3-2. Construct the outside turn protection as follows:

(a) First arc construction for turns 90 degrees or less.

1. *Step 1.* For a turn at a NAVAID, the start point of the arc is the end of the outside boundary of the inbound leg OEA. For a turn at a radio fix, the start point of the arc is the intersection of the error boundary of the outbound leg OEA with the extended outer boundary of the inbound leg OEA.

2. *Step 2.* Project a line from the start point of the arc along the end of the inbound leg OEA boundary.

3. *Step 3.* Locate the arc center point on the projection line from *Step 2*, at a distance from the start point equal to the outer boundary radius determined from table 13-3-2.

4. *Step 4.* Construct the arc from the arc start point with center point as established in *Step 3*.

5. *Step 5.* If a second arc is not needed, tangent to the outbound course line construct a convergence line tapering 30 or splaying 15 degrees relative the outbound course line to the succeeding primary and secondary OEAs, or end the arc at the primary OEA if a 30-dergee angle tangent line cannot be constructed.

(b) Second arc construction for turns greater than 90 degrees to 120 degrees.

1. *Step 1.* For a turn at a NAVAID, the start point of the arc is the end of the inside boundary of the inbound OEA, and whichever occurs earliest along the route of flight of either: abeam the start point of the first arc with respect to the extended inbound path; or the intersection of the outbound NAVAID error splay with the extended inbound secondary boundary.

2. *Step 2.* Project a line from the start point of the arc onto the extended inbound leg OEA boundary.

3. *Step 3.* Locate the arc center point on the projection line from *Step 2*, at a distance from the start point equal to the outer boundary radius determined from table 13-3-2.

4. *Step 4.* Connect the first and second arcs with a line tangent to both.

5. *Step 5.* Tangent to the out bound course line construct a convergence line tapering 30 or splaying 15 degrees relative the outbound course line to the succeeding primary and secondary OEAs, or end the arc at the primary OEA if a 30-degee angle tangent line cannot be constructed.

Figure 13-3-17. Turn at NAVAID to NAVAID

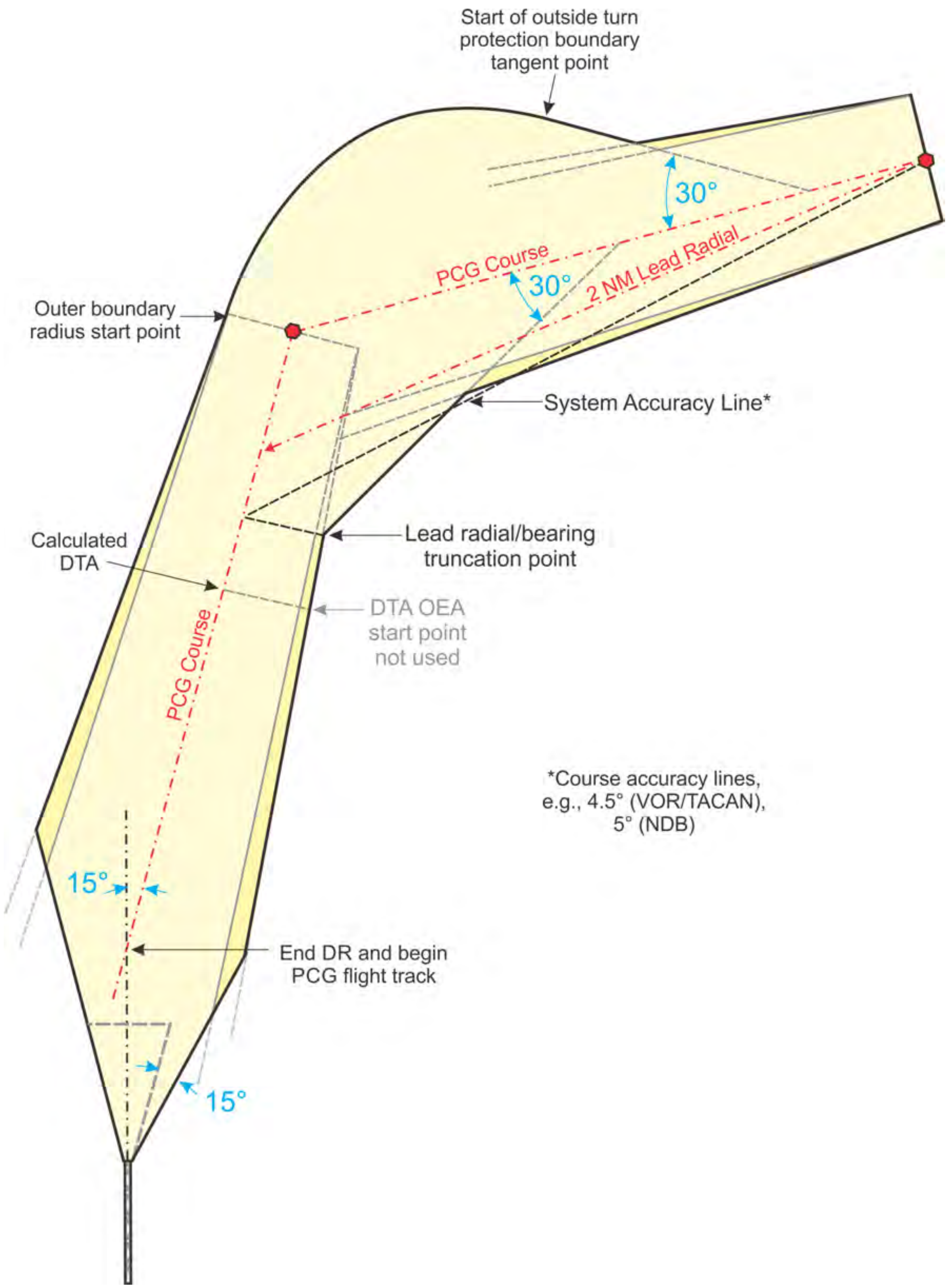


Figure 13-3-18. Turn at Fix to NAVAID

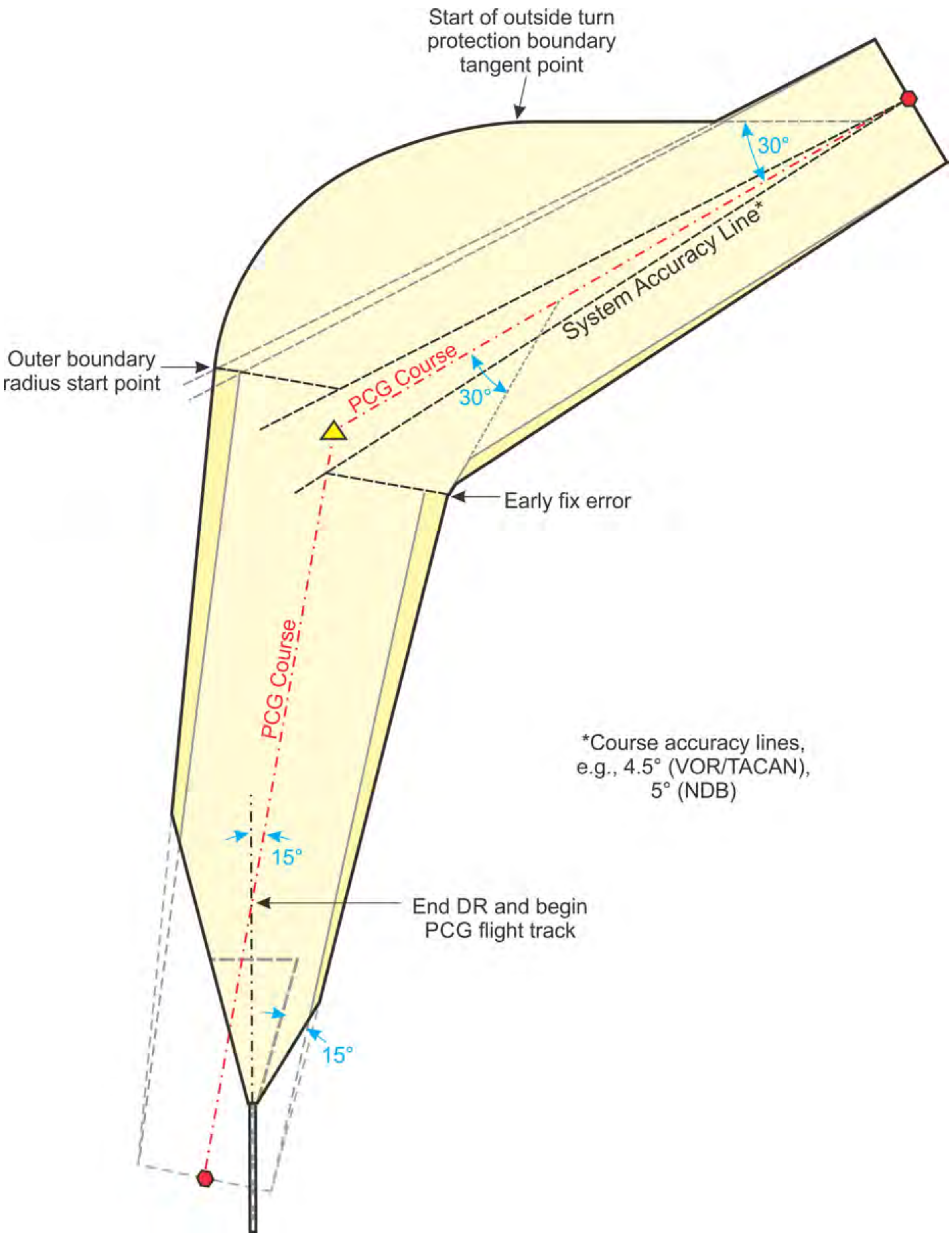
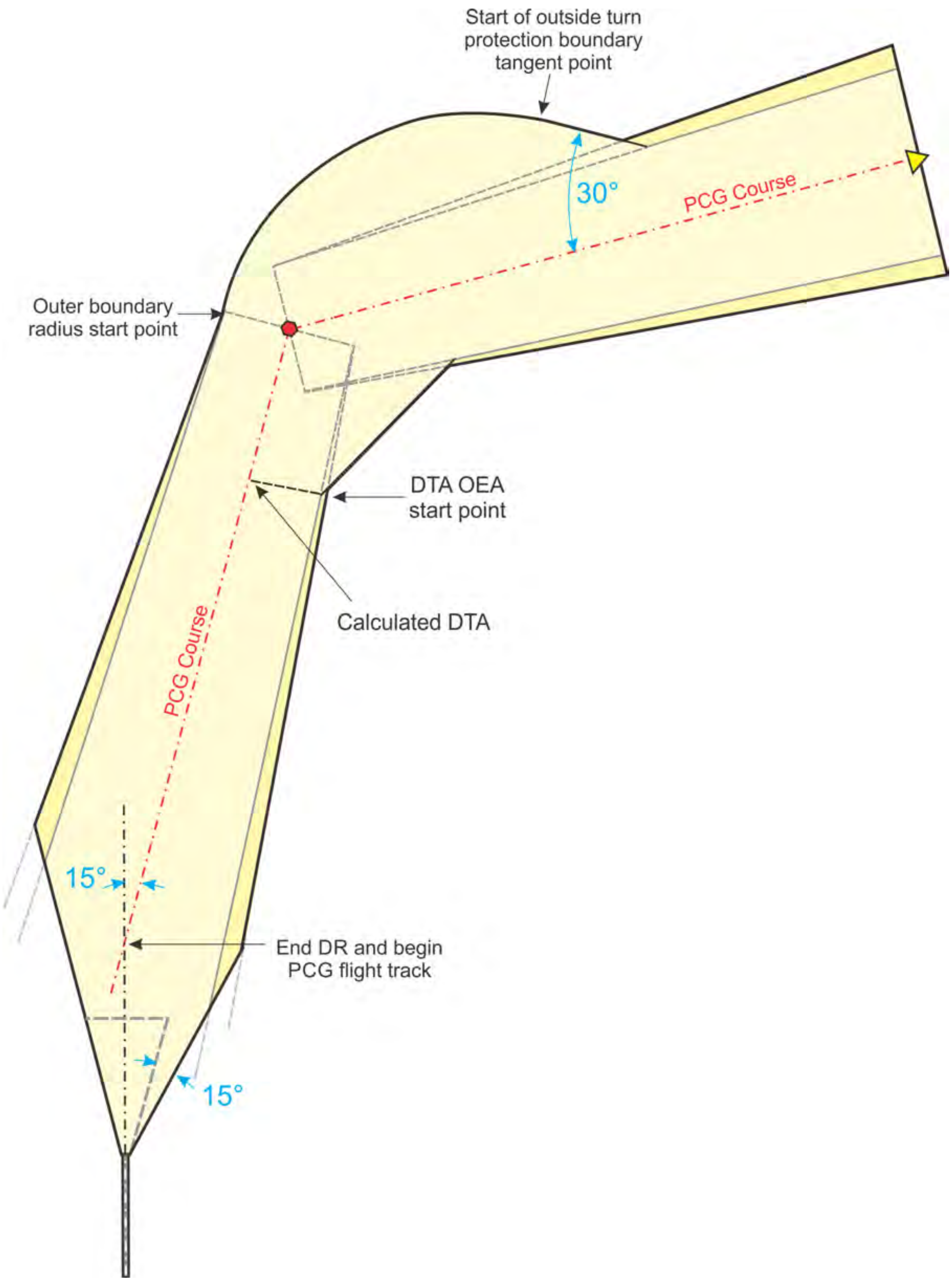


Figure 13-3-19. Turn at NAVAID to Fix



13-3-5. Routed Departure Obstacle Evaluation. Obstacles must not penetrate the OCS. Evaluate obstacle against the OCS along the routed DP using either a 40:1 or 12:1 slope until the terminal portion of the DP ends (see figure 13-3-20 though figure 13-3-22, formula 13-1-1 and formula 13-1-2).

a. Primary OEA. Starting at the ICAE OCS elevation, continue the OCS to the obstacle using the shortest 40:1 straight-line distance from either the boundary lines of the ICA or along the RCL from the DRP to the ICAB for the primary area of the route.

b. Secondary OEA. Measure 12:1 into secondary area from edge of primary area perpendicular to the segment's course to the obstacle. Convert the secondary area obstacles to primary equivalent at edges of primary area. Then apply paragraph 13-3-5.a to the obstacle's primary equivalent elevation at a point on the edge of the primary area perpendicular to the segment's course to the obstacle.

Figure 13-3-20. OCS Evaluation Along Departure Route (OEA Example 1)

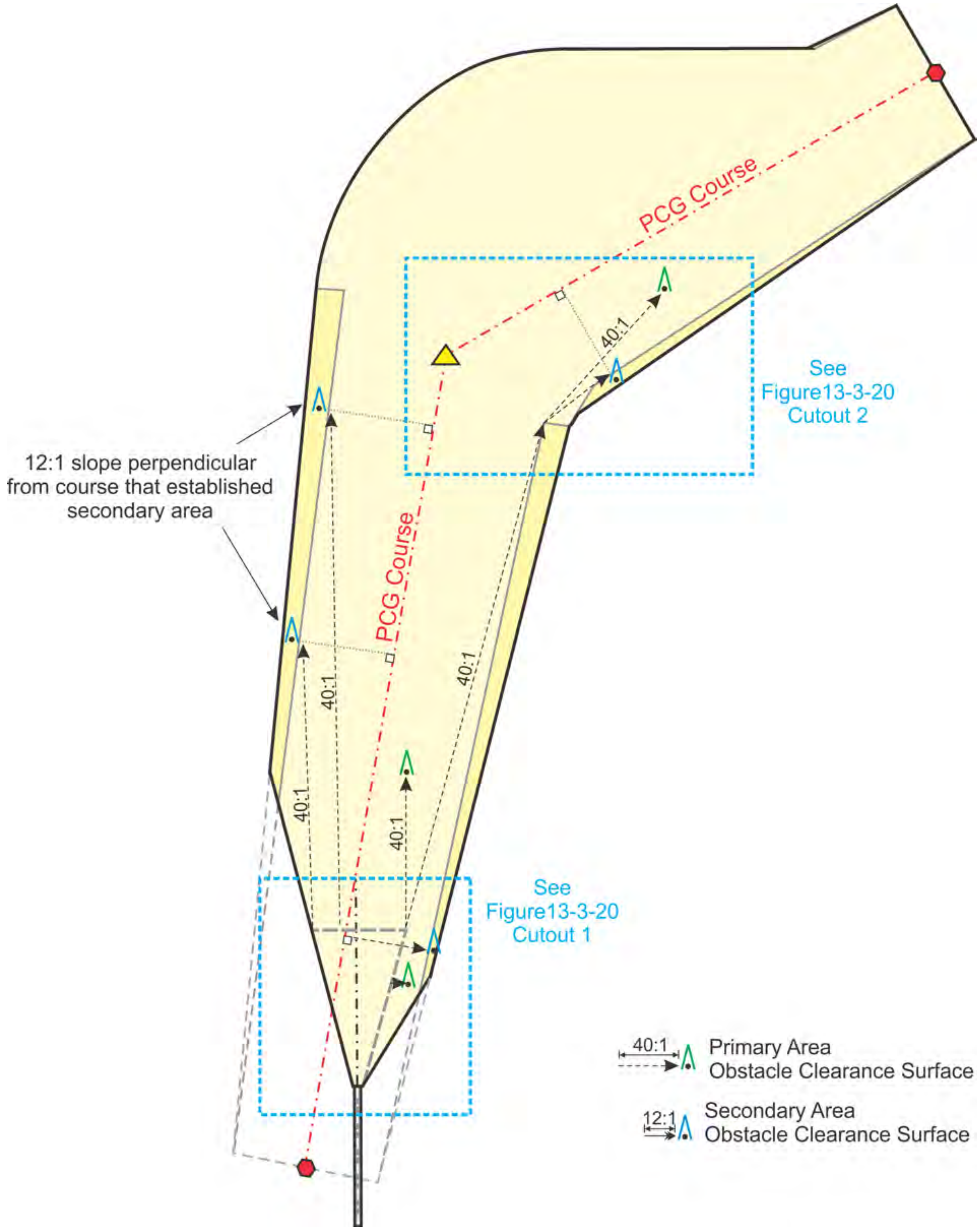


Figure 13-3-20. OEA Example 1, Cutout 1

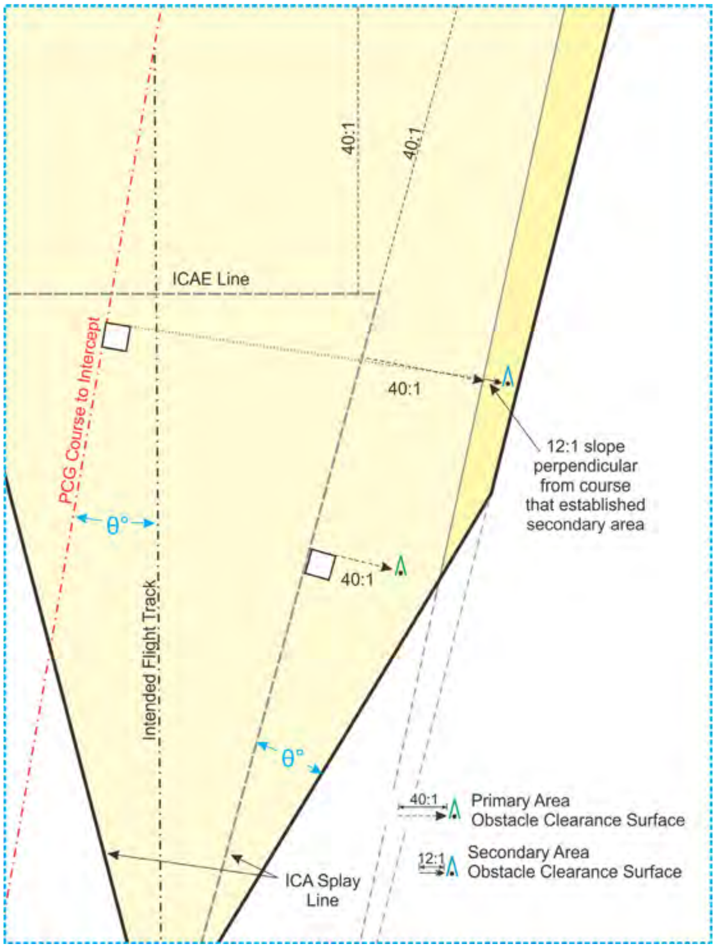


Figure 13-3-20. OEA Example 1, Cutout 2

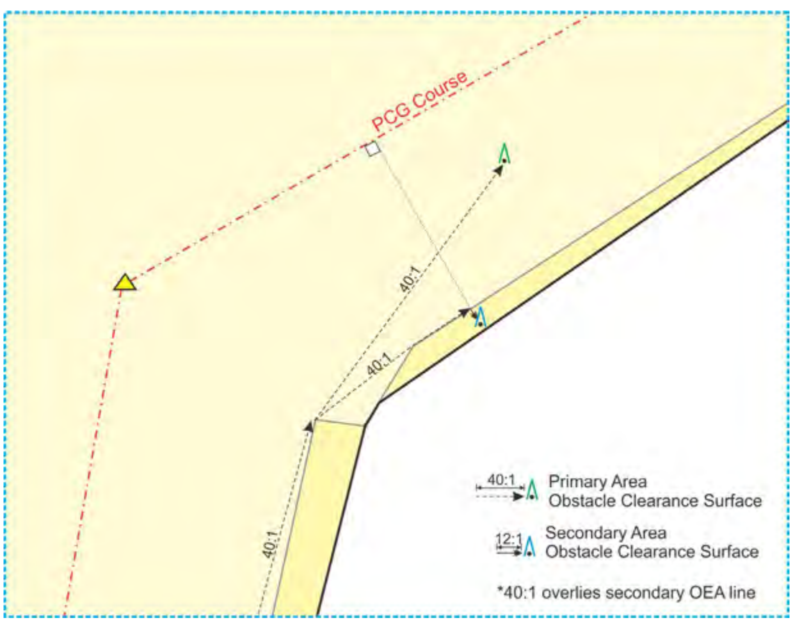
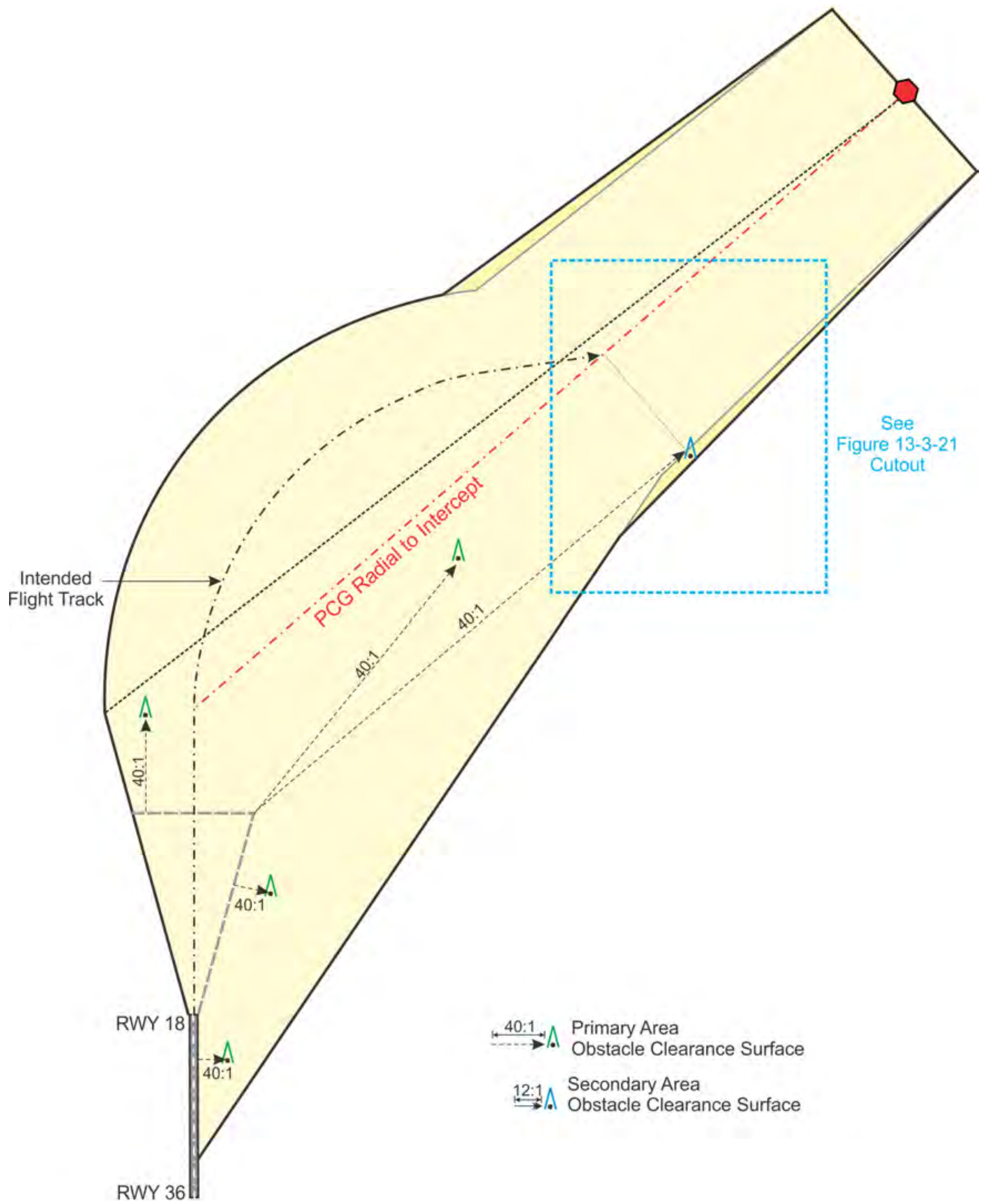


Figure 13-3-21. OCS Evaluation Along Departure Route (OEA Example 2)



13-3-21. OEA Example 2, Cutout

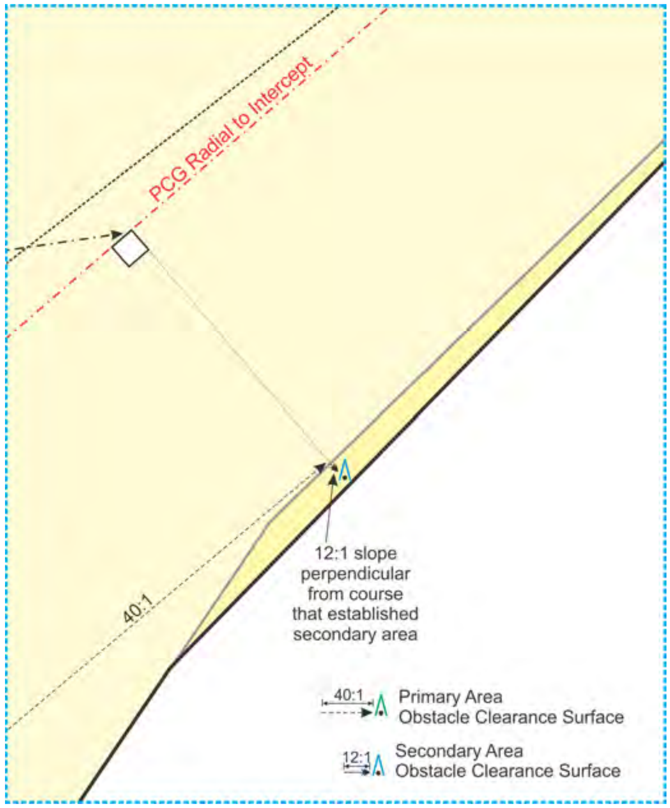


Figure 13-3-22. OCS Evaluation Along Departure Route (Example 3)

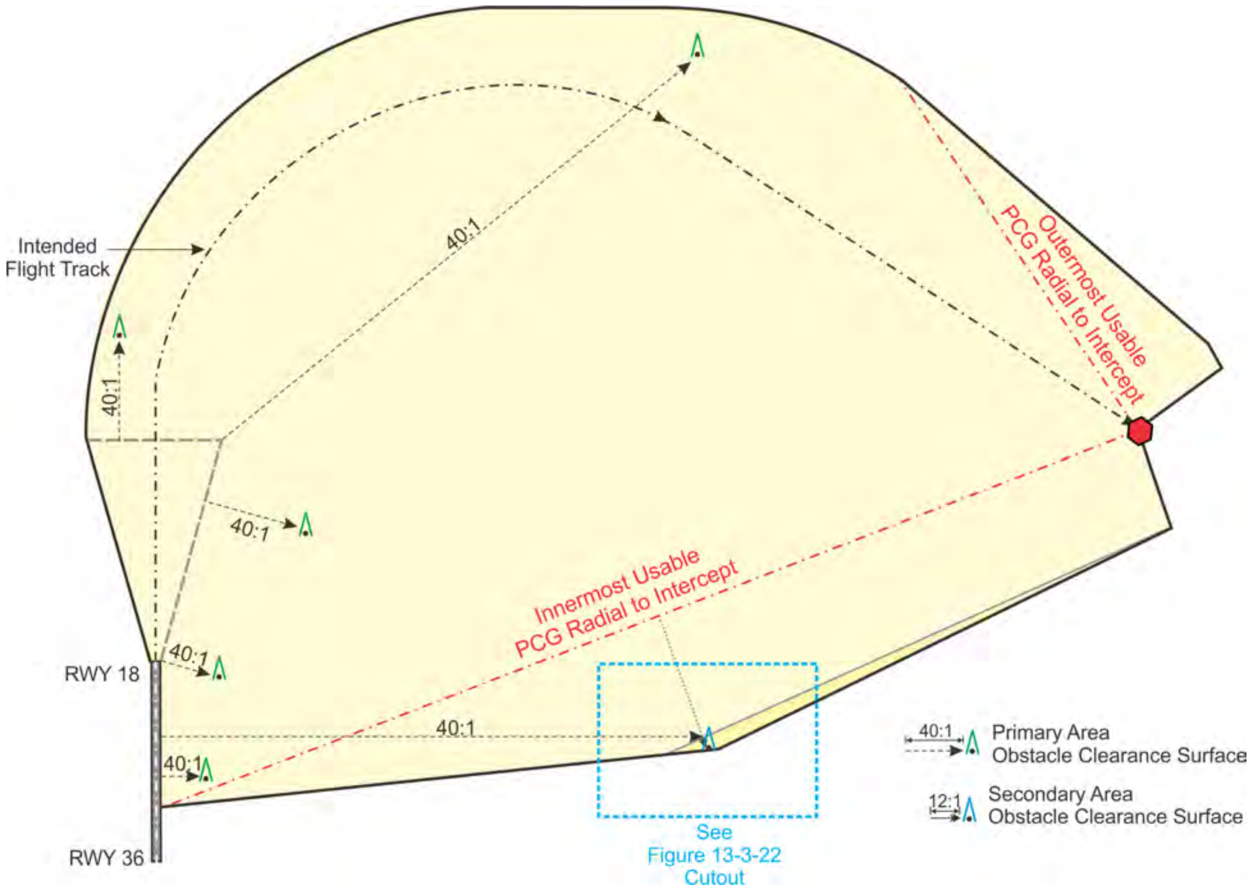
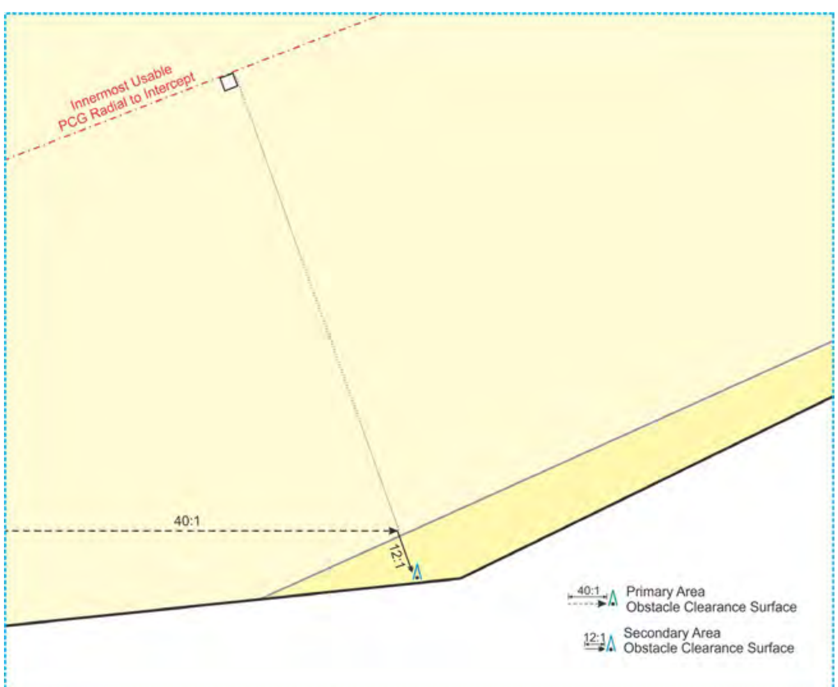
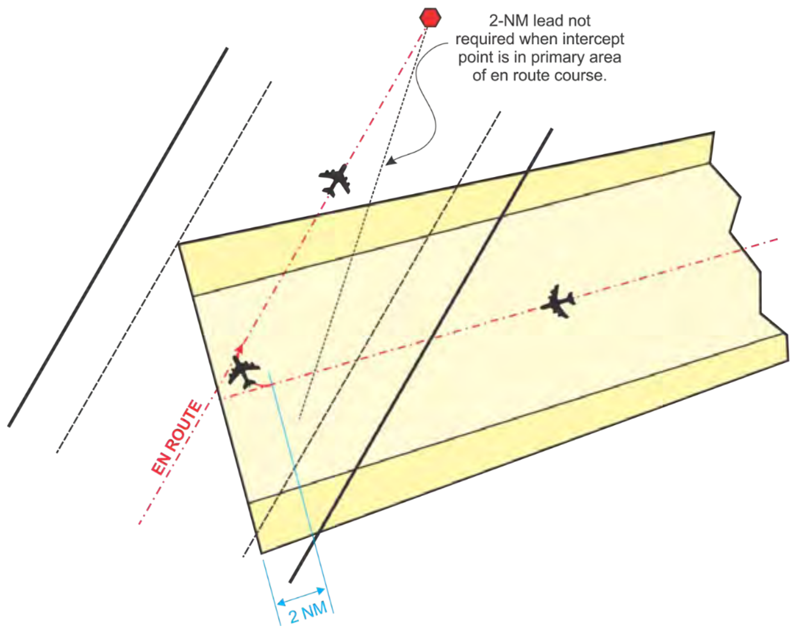


Figure 13-3-22. Example 3, Cutout



13-3-6. Connecting Terminal Departure to the En Route Structure: The 2-mile lead is not required when lead point is within primary area of en route course (see figure 13-3-23).

Figure 13-3-23. Turn onto En Route Course



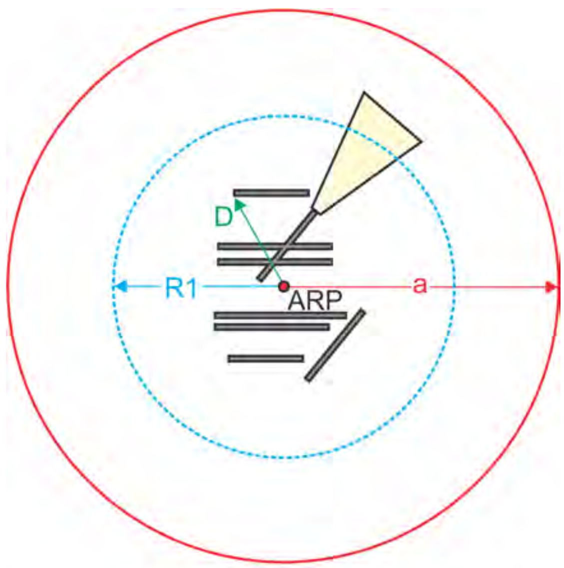
Section 13-4. Visual Climb Over Airport (VCOA)

13-4-1. General. VCOA is an alternative method for pilots to depart the airport where aircraft performance does not meet the specified CG. VCOA is not authorized for departures from heliports.

13-4-2. Basic Area.

a. Construct a visual climb area (VCA) over the airport using ARP as the center of a circle (see figure 13-4-1). Use R1 in table 13-4-1 plus the distance the ARP to the most distant runway end as the radius for the circle.

Figure 13-4-1. VCA



a = radius used to establish VCA via Formula 13-4-1. This example used 1,000 feet MSL and 250 KIAS to establish the VCA.

Formula 13-4-1. VAC Radius Calculation

$$a = R1 + D$$

Where:

R1 = radius from table 13-4-1

D = NM distance from ARP to furthest DER on airport

b. Select 250 KIAS as the standard airspeed and apply the appropriate MSL altitude to determine the R1 value. Use other airspeeds in table 13-4-1, if specified on the procedure, using the appropriate radius for the selected airspeed. Altitude must equal or exceed field elevation. The VCA must encompass the area of the ICA from the departure runway(s). Expand the VCA radius if necessary to include the ICA (see figure 13-4-2).

Figure 13-4-2. VCA Expanded

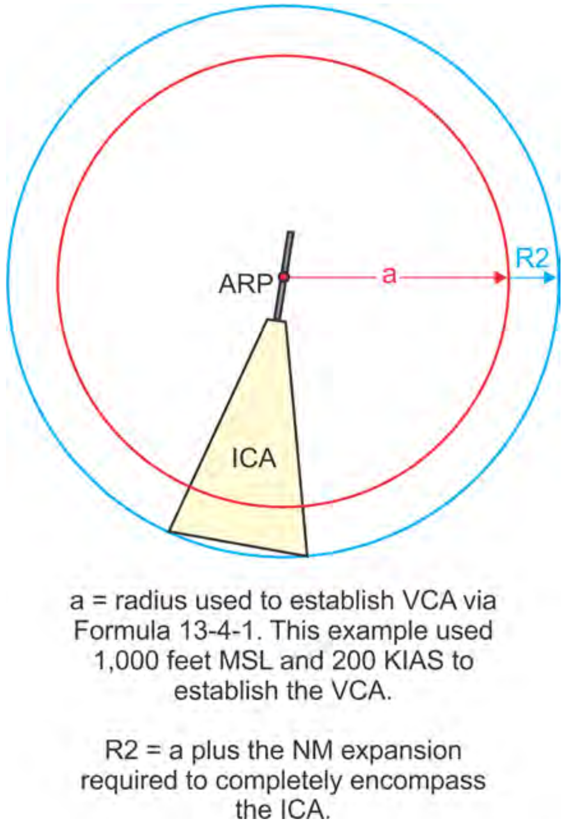


Table 13-4-1. Radius Values

Altitudes MSL	Below 2000 feet	Below 5000 feet	Below 10000 feet	10000 feet And above
Speed KIAS				
90	2.0	2.0	2.0	2.0
120	2.0	2.0	2.0	2.0
180	2.0	2.0	2.5	3.4
210	2.1	2.5	3.2	4.3
250	2.8	3.4	4.2	5.5
310	4.2	4.9	6.0	7.7
350	5.2	6.0	7.3	9.3

Note: Table 13-4-1 speeds include 30-knot tail winds below 2000 feet MSL, 45-knot tail winds below 5000 feet MSL, and 60-knot tail winds below 10000 feet MSL, 90 knot winds at 10000 feet and above; bank angle: 23 degrees.

13-4-3. VCOA Assessment.

a. Diverse VCOA.

(1) Identify the highest obstacle within the VCA. This is the preliminary height of the VCA level surface.

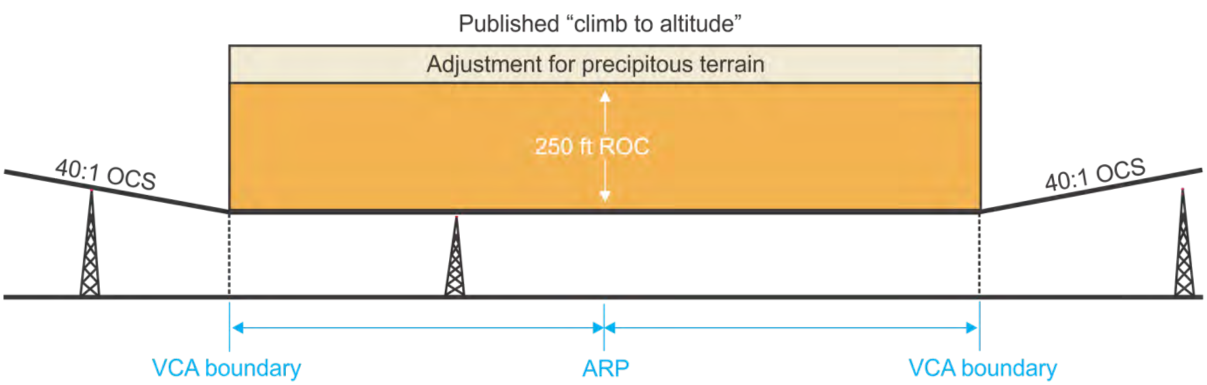
(2) Assess a 40:1 OCS outward from the VCA boundary using the preliminary height of the VCA level surface as the starting OCS height. The 40:1 surface must be evaluated to a minimum distance of 19 NM; expand the assessment to a distance of 40 NM if any part of the assessment area within 19 NM includes designated mountainous terrain.

(3) If the 40:1 OCS is penetrated, increase the VCA level surface by the amount of the greatest penetration.

(4) Add 250 feet of ROC to the final elevation of the VCA level surface. Adjustments for precipitous terrain located within the VCA must be applied as specified in paragraph 3-2-2. Express the resultant altitude in a 100-foot increment; round upward if necessary. This altitude is published as the “climb to altitude” for the VCOA procedure (see figure 13-4-3).

Note: Rounding upward would not be required if the sum of the obstacle’s height, ROC, and required adjustment was in a 100-foot increment (such as 500 feet). Rounding would be required for any other value (for example, 501 feet rounds to 600 feet).

Figure 13-4-3. Diverse VCOA Assessment



Example:

Highest obstacle within VCA :	151 ft
Precipitous terrain adjustment:	70 ft
ROC:	250 ft
Climb to altitude:	471 ft (rounds to 500)

b. Departure routes. Where VCOA diverse departure is not feasible, construct a VCOA departure route based on NDB, VOR, or TACAN guidance.

(1) Construct the VCA by applying paragraph 13-4-2.

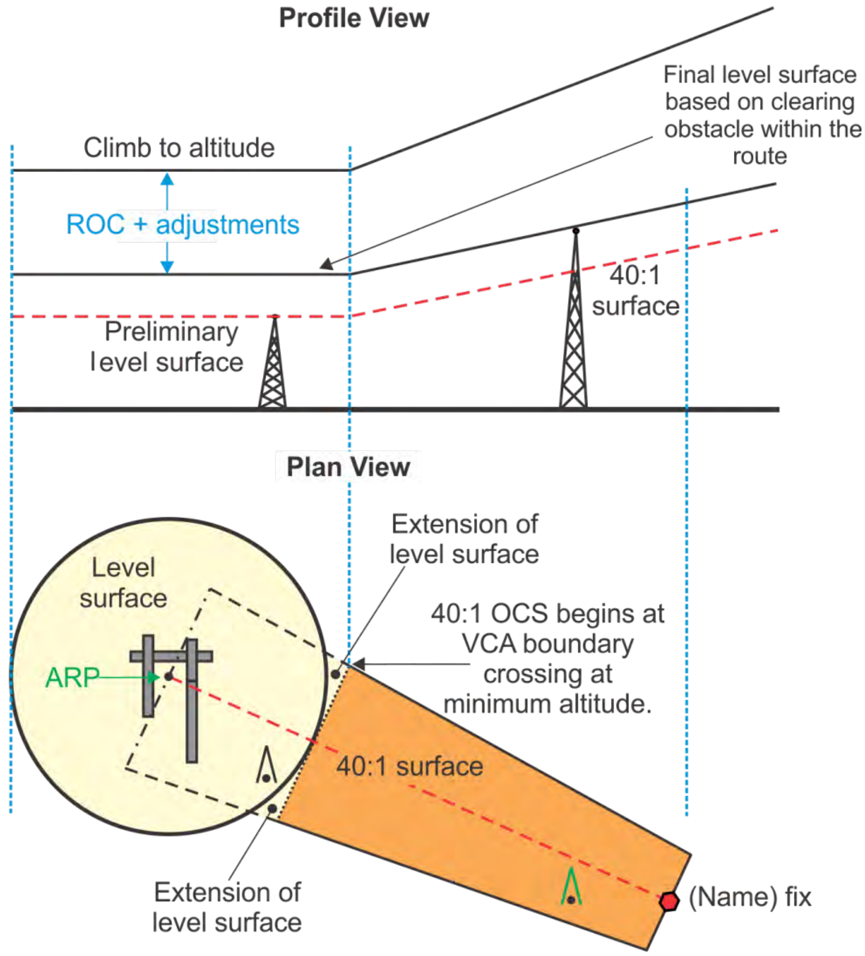
(2) Determine the preliminary level surface height by applying paragraph 13-4-3.a(1).

(3) Locate, within the VCA, the beginning point of the route. Construct the route using criteria for the navigation system desired.

(4) The 40:1 surface rise begins along a line perpendicular to the route course and tangent to the VCA boundary (see figure 13-4-4). If the 40:1 OCS is penetrated, increase the VCA level surface by the amount of the greatest penetration.

(5) Determine the climb to altitude by applying paragraph 13-4-3.a(4).

Figure 13-4-4. Route Out of VCA



13-4-4. Ceiling and Visibility.

a. Publish visibility as 3 SM. Publish visibility as 5 SM when the climb to altitude is 10000 feet MSL or greater.

b. Publish a ceiling which is at least 100 feet above the "climb to altitude" expressed as a height above the airport elevation. The ceiling must be published in a 100-foot increment; round upward when necessary. The minimum ceiling that may be specified is 1000 feet.

13-4-5. Published Annotations. The procedure must include instructions to climb in visual conditions to cross a location/fix at or above the climb to altitude determined during the evaluation of the procedure.

a. For a VCOA diverse departure, include the term, "before proceeding on course" following the climb to altitude.

Example: "Climb in visual conditions to cross Castle Airport at or above 2200 before proceeding on course."

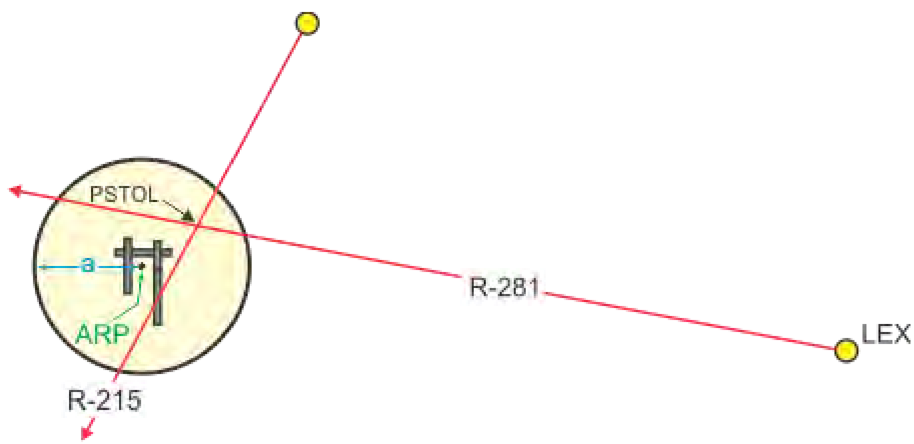
b. For a VCOA route departure, specify the intended direction of flight to cross the first fix of the route, followed by the climb to altitude, and then specify the route.

Example: "Climb in visual conditions to cross PSTOL eastbound at or above 5000, then via LEX R-281 to LEX"

c. Detail the makeup of any fix specified in the VCOA instructions that is not published on an en route or graphical ODP chart.

Example: "Climb in visual conditions to cross PEETE (AGC 040/2 DME) northbound at or above 2000…"

Figure 13-4-5. VCOA Departure Route



Section 13-5. Diverse Vector Area (DVA) Assessment

13-5-1. General. DVA is utilized by ATC radar facilities pursuant to Order JO 7210.3 to allow the radar vectoring of aircraft below the MVA, or for en route facilities, the MIA. A DVA consists of designated airspace associated with a runway where the utilization of applicable departure criteria have been applied to identify and avoid obstacles that penetrate the departure OCS. Avoidance of obstacles is achieved through the application of a sloping OCS within the boundaries of the DVA. Since a sloping OCS is applicable to climb segments, a DVA is valid only when aircraft are permitted to climb uninterrupted from the departure runway to the MVA/MIA (or higher). A DVA is not applicable once an aircraft's climb is arrested. A DVA is not authorized for a departure from a heliport.

a. Assess a single DVA at the request of an ATC facility for any candidate runway. Candidate runways are those runways where a diverse departure assessment has identified obstacles that penetrate the 40:1 OCS that require a CG greater than 200 ft/NM to an altitude more than 200 feet above the DER elevation. Do not establish a DVA when obstacles do not penetrate the departure 40:1 OCS, or when the only penetrations are those that require a CGTA of 200 feet or less above the DER elevation (low, close-in obstacles).

b. A DVA is only applicable to the ATC facility (or facilities) that requested it. A maximum of two ATC facilities may use a DVA. When two facilities are authorized use of a DVA, ensure the OEA and all restrictions (such as range of headings, area, CGs, etc.) are identical.

c. No obstacles (except low, close-in) may penetrate OCS of the DVA unless isolated in accordance with paragraph 13-5-3.a (see paragraph 13-5-4).

DoD Only: DoD radar facilities may require the establishment of a DVA even in the absence of any 40:1 OCS penetrations.

13-5-2. Initial Departure Assessment. Assess the runway from which ATC desires to vector departing aircraft below the MVA/MIA using paragraph 13-2-1 to determine the location of 40:1 OCS penetrations which are not considered as low, close-in obstacles. The length of the ICA is based on a climb to 400 feet above the DER rounded to the nearest foot. When requested, provide the requesting ATC facility a graphical depiction of the departure penetrations to assist facility managers in visualizing the departure obstacle environment (not applicable to the USN).

13-5-3. Select a DVA Method. Establish a DVA that either: (a) isolates penetrating obstacles; (b) uses a range of authorized headings to define a sector; (c) climbs to an initial MVA/MIA within a range of headings, (d) defines an area which avoids penetrating obstacles; or (e) uses a combination of these methods.

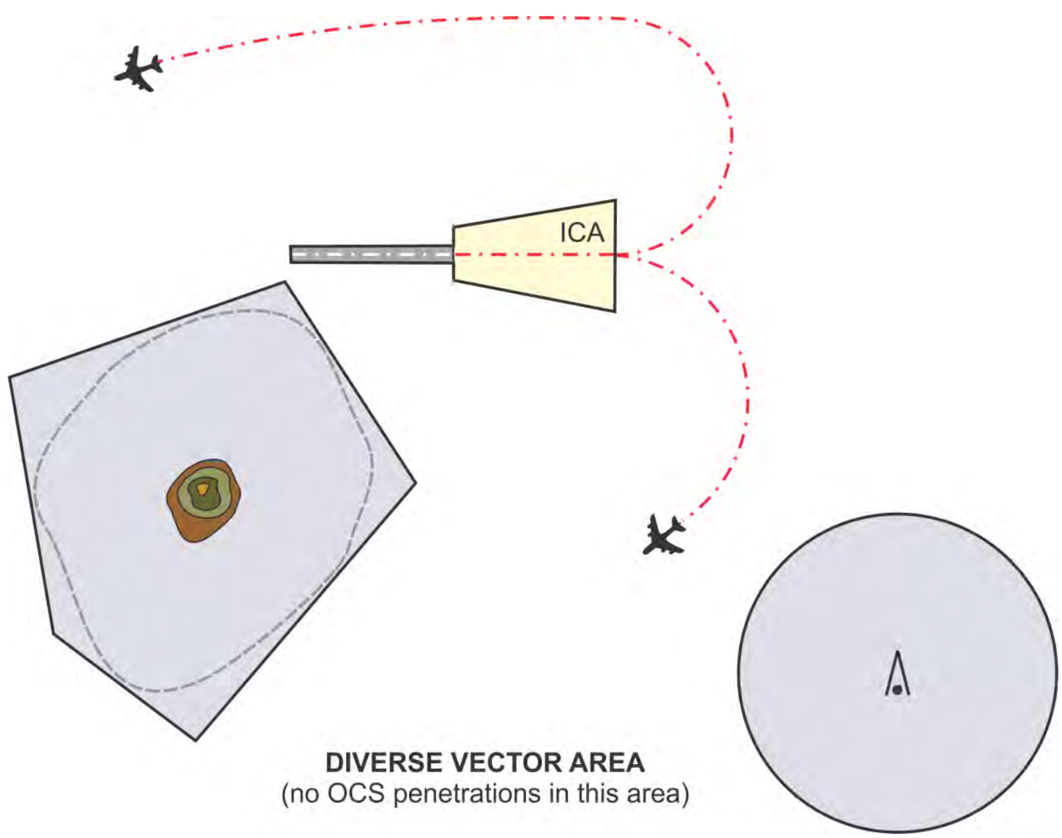
a. Isolate penetrating obstacles. This method is generally suitable for isolating single obstacles, or a group of obstacles in proximity to each other. Boundaries surrounding obstacles that penetrate a departure runway's OCS are established that define an area where vectors below the MVA/MIA are prohibited. Vectors below the MVA which avoid the isolation areas are permitted within the diverse departure evaluation area (25/46 NM from DRP as applicable), minus 5 NM to account for worst case radar separation requirements.

(1) Construct isolation area boundaries around all penetrating obstacles using the MVA sector construction specified in paragraph 11-3-2.b, except a DVA for an ARTCC must use an isolation boundary that provides 5 NM of separation from an obstacle. Consider the ease in constructing and documenting isolation area boundaries when determining the shape of an isolation area which surrounds multiple obstacles or terrain points (zone feature). For example, to simplify construction, documentation, and radar video mapping of an isolation area, it may be preferable to construct the area using only a circle or by using only a minimal series of points and lines. Figure 13-5-1 depicts an example with two isolation areas; one is a circle around a single obstacle and the other is defined by points and lines to define the prohibited area around a terrain contour of irregular shape.

(2) Isolation areas must not overlie any part of the departure runway between the DRP and the DER, nor any part of the ICA associated with the departure runway.

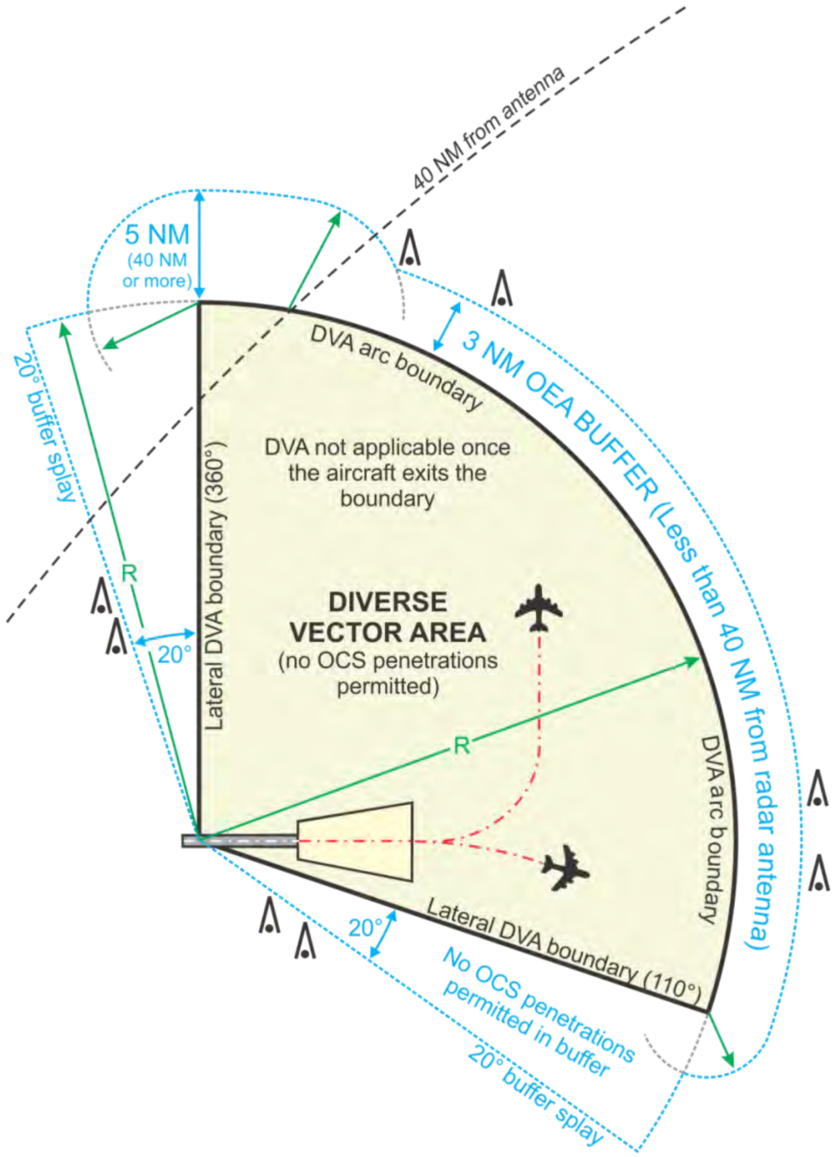
(3) Isolation areas must be located so that sufficient room to vector departing aircraft is provided which would allow ATC to issue vectors as necessary to avoid the areas. This determination must be made in collaboration with the air traffic facility.

Figure 13-5-1. Isolation Areas



b. Define a range of authorized headings. An ATC facility may desire the establishment of a DVA sector which is comprised of a range of authorized headings from the departure runway. For example, the DVA may permit the assignment of headings 360 clockwise through 110 within the DVA evaluation area. The assignment of radar vectors that exceed the authorized range of headings is not permitted until the aircraft reaches the MVA/MIA (see figure 13-5-2).

Figure 13-5-2. Range of Headings Sector



(1) Construct lateral sector boundaries from the DRP which correspond to the desired headings using the Departure Sectors criteria of paragraphs 13-2-2 and 13-2-3, except the sector boundaries must diverge by a minimum of 30 degrees.

(2) Connect each lateral boundary with an arc centered on the DRP using radius "R" which is equivalent to the desired distance for the DVA.

(3) An OEA buffer expands outward from the DVA boundaries. The buffer of the DVA arc boundary must meet the distance requirements of paragraph 11-3-2.a, except a 5-NM buffer

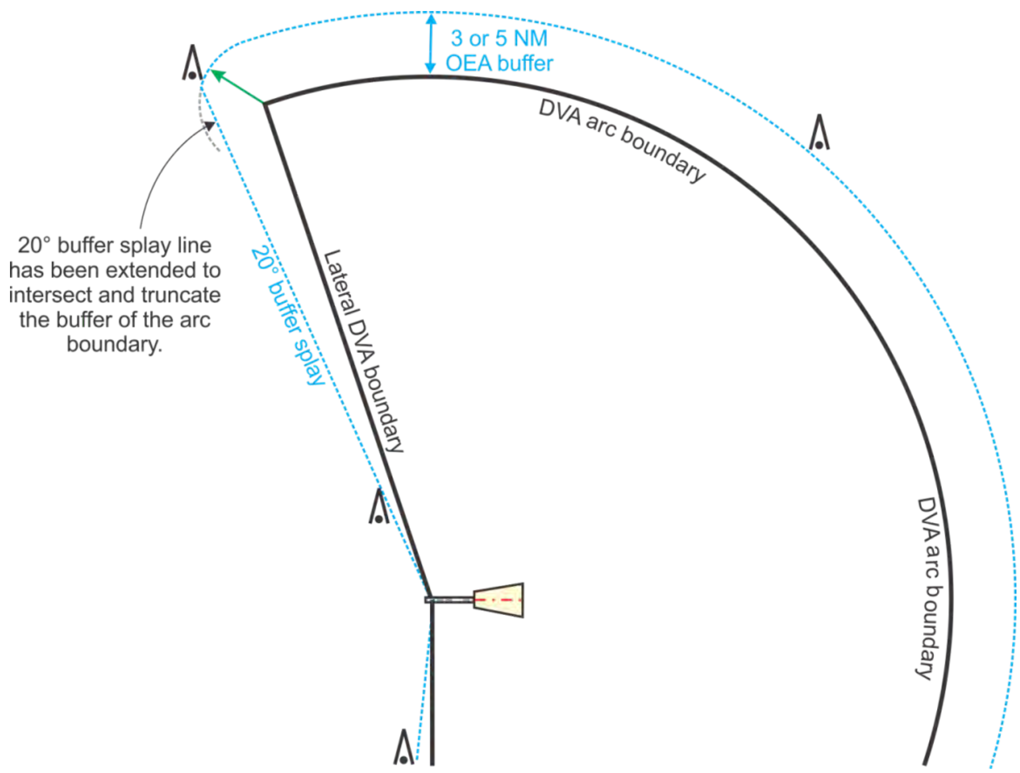
always applies to a DVA that will be used by an ARTCC. The lateral buffers begin at DRP and splay outward from the lateral boundaries by 20 degrees.

(4) Connect the 20-degree buffer splay lines with the buffer of the arc boundary as follows:

(a) When the 20-degree splay line is outside the buffer of the arc boundary, join the two buffers with an arc centered on the DRP using radius “R” (see figure 13-5-2).

(b) When the 20-degree splay line is inside the buffer of the arc boundary, extend the splay line until it intersects and truncates the buffer of the arc (see figure 13-5-3).

Figure 13-5-3. Truncation of Lateral Boundary Buffer



(5) The DVA boundaries must provide sufficient maneuvering area to permit ATC to vector an aircraft to remain within the DVA until the aircraft can climb to the MVA/MIA. Determination of sufficient maneuvering area must be made in collaboration with the ATC facility.

c. Climb to an Initial MVA/MIA. ATC may request a DVA based on a clockwise (CW) range of headings to an initial MVA/MIA. For example, ATC may request a DVA in the form of, “009 CW 190 to 3500 ft.” For a DVA of this type, it is necessary to obtain and refer to the currently approved MVA/MIA chart which depicts the sector boundaries and minimum altitudes (see figure 13-5-4 through figure 13-5-8).

Note: "Initial MVA/MIA" is defined as the altitude at which the DVA terminates and the MVA/MIA is used to provide radar vector service. It will be identified by the requesting ATC facility.

(1) Determine the preliminary 40:1 search boundary's radii (in feet); R_A and R_B.

(a) $R_A = (Initial\ MVA/MIA\ - DER\ Elevation - 951 - 304) \times 40$

(b) $R_B = (Initial\ MVA/MIA - Airport\ Elevation - 951 - 400) \times 40$

Note: 951 represents the least amount of ROC possible (after rounding) within an MVA sector.

Example calculation where MVA is equal to 3500 and DER equal to 618:

$$\begin{aligned} R_A &= (3500 - 618 - 951 - 304) \times 40 \\ &= 1627\ \times 40 \\ &= 65080 \end{aligned}$$

(2) Construct a preliminary search area on the diverse A side of the departure reference line (DRL). Establish point Y and point Z at distance R_A from each corner of the ICAE in the direction of the departure along a line which is parallel to the runway centerline. Swing an arc with radius R_A centered on each corner of the ICAE from points Y and Z away from the runway centerline until it intersects the DRL. If the distance from the DRP to the intersection of the arc and the DRL is less than R_A, then the preliminary search area must be expanded. Expand the area by establishing Points W and X along the DRL at a distance equal to R_A and tangentially connect each arc to each respective point (see figure 13-5-5). Complete the search area with a line that connects point Y to point Z (see figure 13-5-4 and figure 13-5-5).

(3) Construct a preliminary search area on the diverse B side of the DRL using the radius R_B. Swing a 180-degree arc centered on the DRP beginning at the DRL to encompass the start end of the runway (see figure 13-5-4).

Figure 13-5-4. Preliminary Search Area Boundary

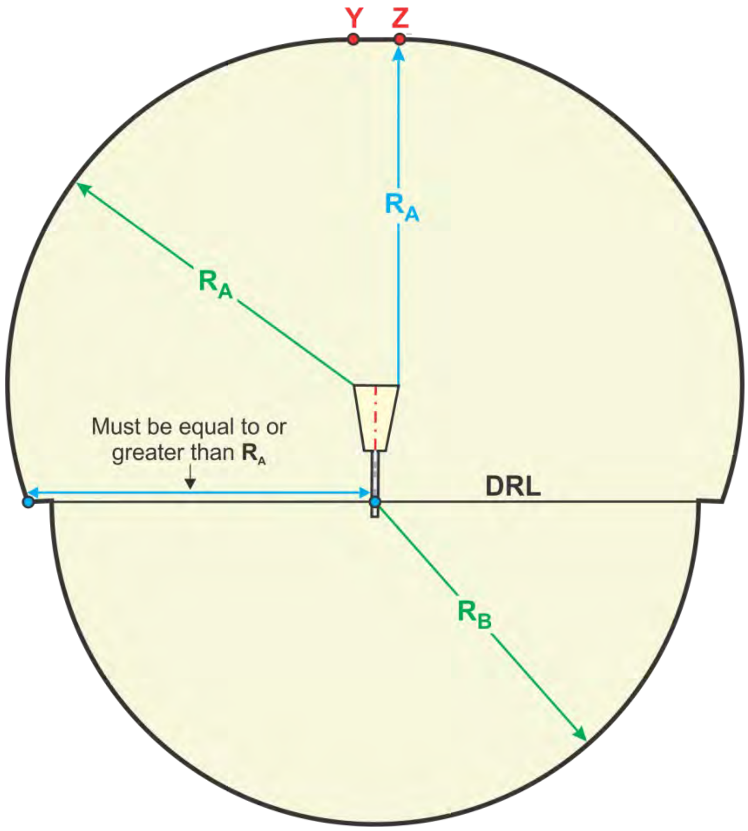
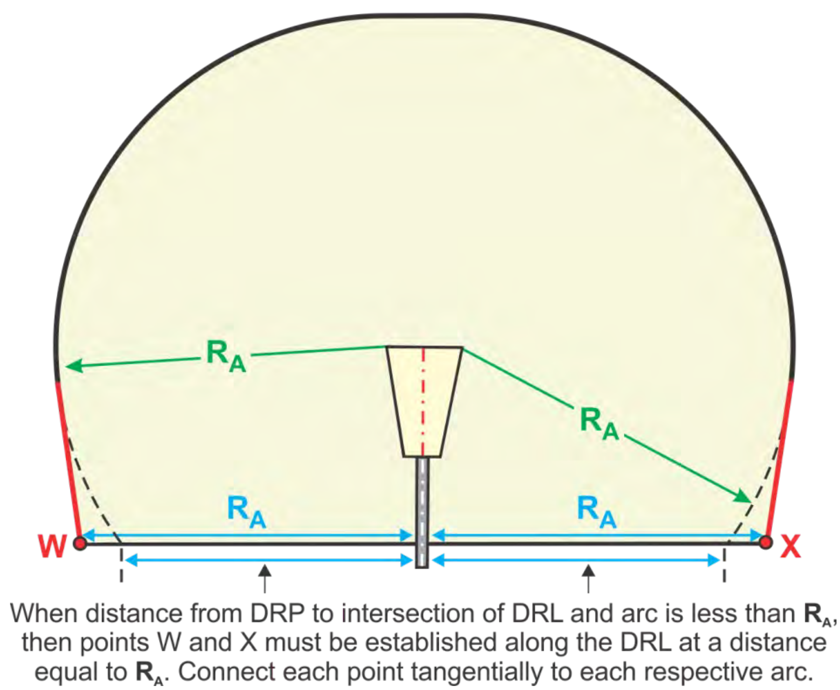


Figure 13-5-5. Construction with Points W and X



(4) Identify all 40:1 OCS penetrations (other than low, close-in) located within the preliminary search area boundaries, or 3/5 NM (appropriate MVA buffer distance per chapter 11, or 5 NM for an MIA) beyond the next higher MVA/MIA sector boundary, whichever is encountered first (see figure 13-5-6 and figure 13-5-7).

(5) Establish lateral boundaries and associated buffers that avoid the 40:1 penetrations using the departure sectors criteria of paragraph 13-2-2. The maximum range of permitted headings (for example, 310 CW to 050) corresponds to the lateral boundaries. All headings are available when no 40:1 penetrations are located within the search area boundaries. The final OEA includes those areas within the boundaries of the search area located between the 20-degree splay lines (see figure 13-5-8).

Figure 13-5-6. MVA Chart With Applicable Buffer Areas

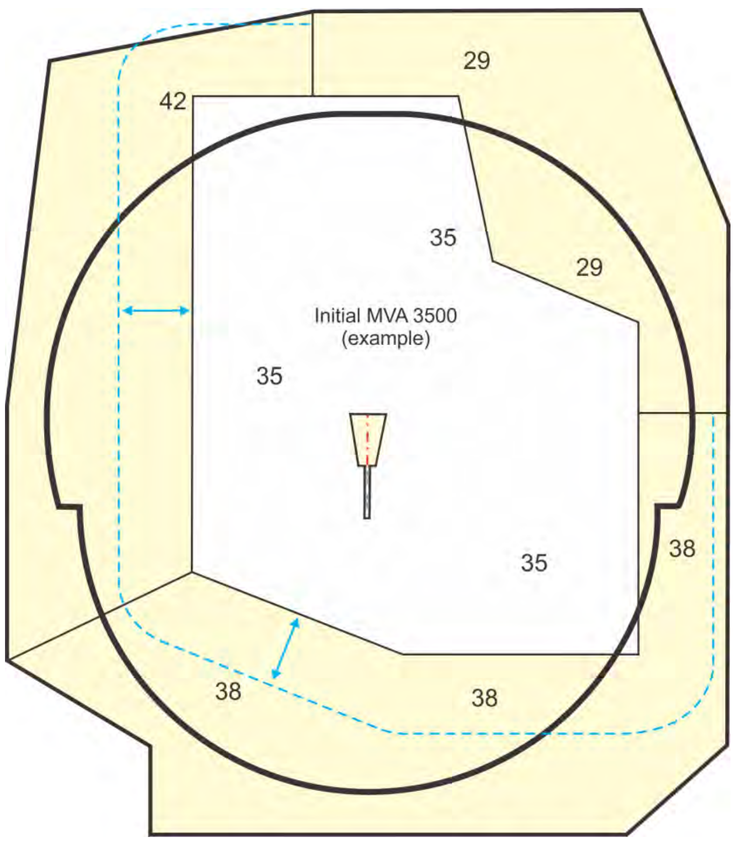


Figure 13-5-7. Obstacle Search Area

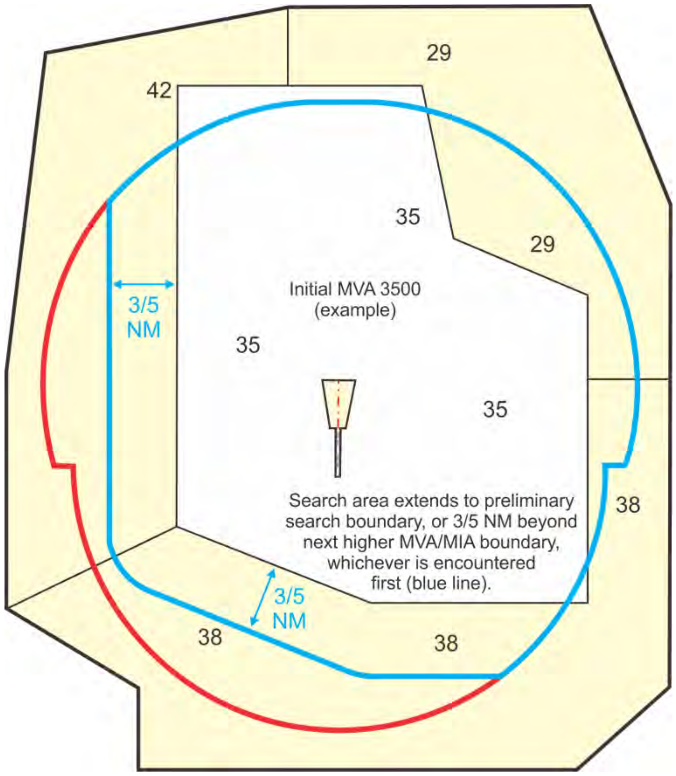
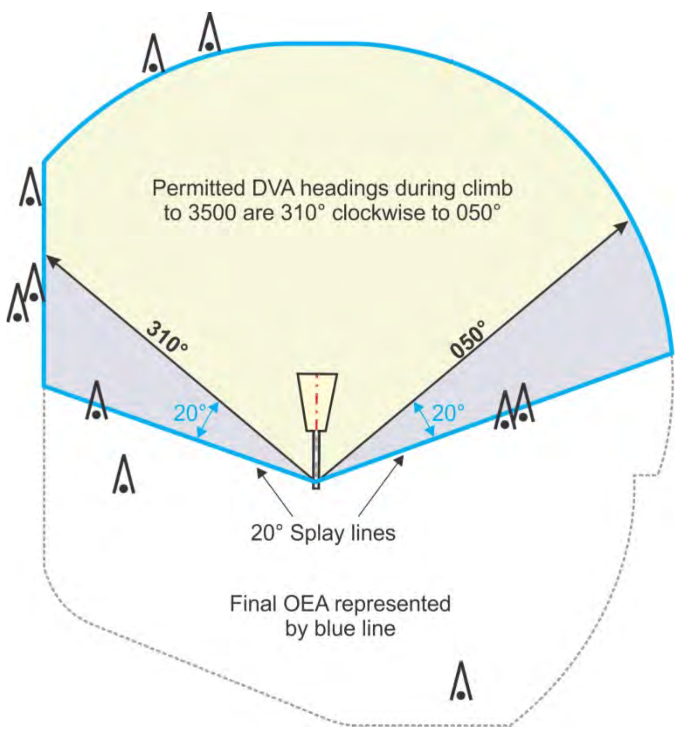


Figure 13-5-8. Permitted DVA Headings Based on Obstacles

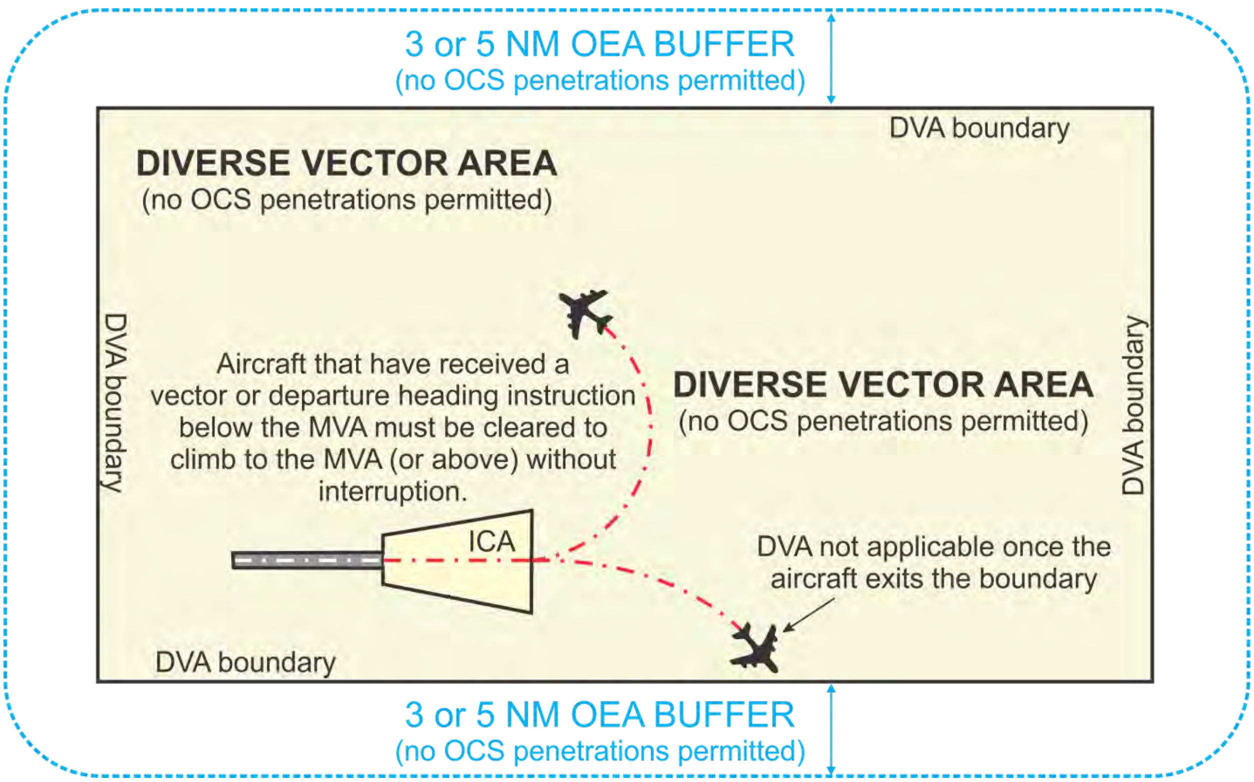


d. Define an area. An area may be defined which excludes all obstacles (low, close-in obstacles are permitted) that penetrate the departure OCS (see figure 13-5-9).

(1) Construct the area boundary and an OEA buffer using the MVA sector construction specified in section 11-3. The defined area may take the form of any shape; however, it must be determined in consultation with the ATC facility to ensure it meets their operational needs and to ensure it provides sufficient maneuvering area for ATC to vector an aircraft to remain within the DVA until the aircraft can climb to the MVA/MIA.

(2) The area boundary must fully encompass the entire width of the departure runway from the DRP towards the DER, as well as the entire ICA associated with the departure runway.

Figure 13-5-9. Defined Area



13-5-4. CGs. A DVA that uses a standard CG is preferred; however, operational requirements may necessitate a higher CG. When an obstacle penetrates the 40:1 OCS within the DVA OEA, establish a CG and CGTA in accordance with paragraph 13-1-5.

Note: Do not establish CGs for low, close-in obstacles or for obstacle that have been isolated in accordance with paragraph 13-5-3.a.

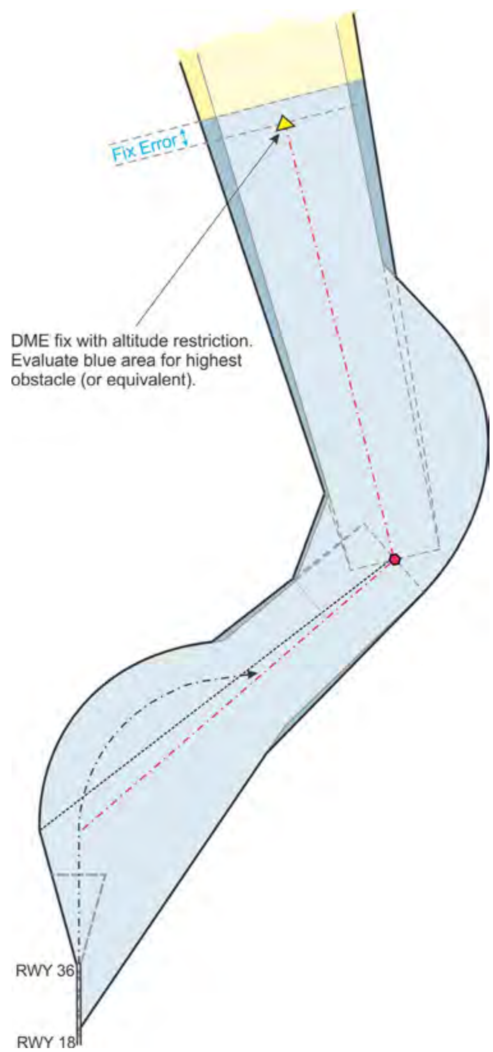
Section 13-6. Obstacle Clearance Requirements for SID Containing ATC Altitude Restrictions

13-6-1. Maximum Altitude Restrictions. A level surface obstacle evaluation must be conducted whenever a maximum, mandatory, or block altitude restriction is charted on a SID. The maximum altitude, the mandatory altitude, and the upper limit of a block altitude must provide the en route ROC specified in paragraph 14-2-1.

a. Identify the highest obstacle in the primary area, or if applicable, the highest equivalent obstacle in the secondary area, within the OEA located prior to the latest point the fix with the altitude restriction could be received.

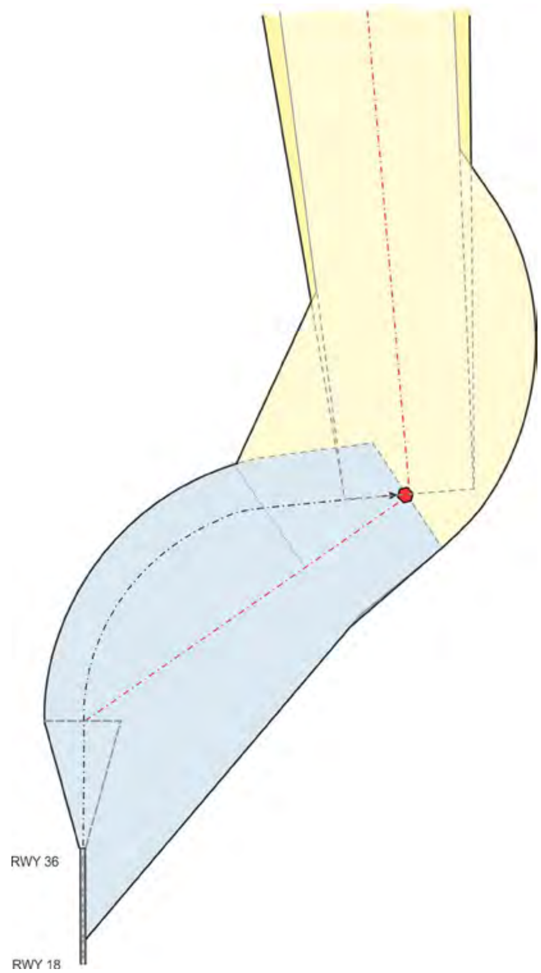
(1) When no turn is required at the fix with the altitude restriction, evaluate the OEA prior to a line drawn perpendicular to the latest point the fix could be received (see figure 13-6-1).

Figure 13-6-1. No Turn Required at Fix



(2) When a turn is required at the fix with the altitude restriction, the evaluation area includes the trapezoid leading to the turn fix as well as any expansion areas (see figure 13-6-2).

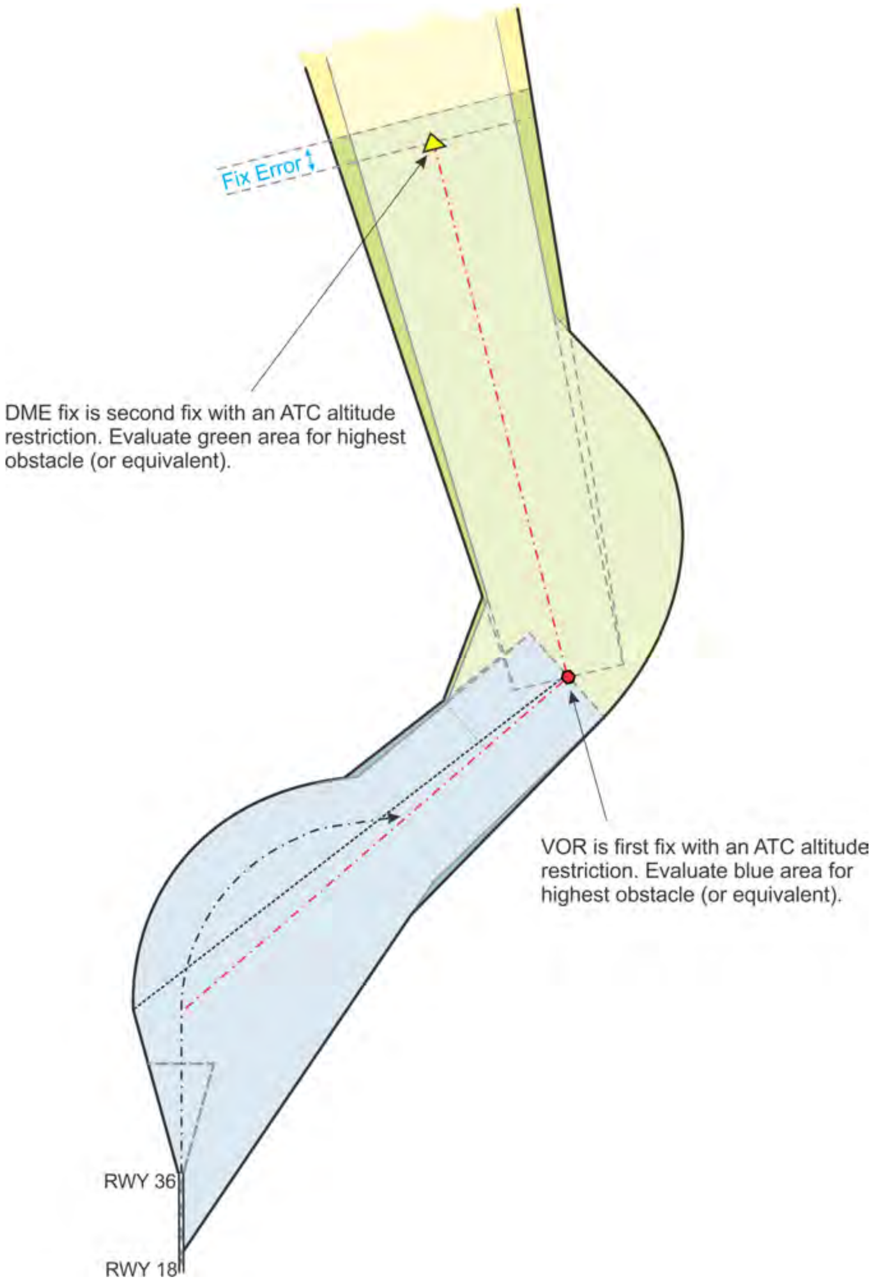
Figure 13-6-2. Turn Required at Fix



b. Determine the level flight OCS elevation by subtracting the appropriate en route ROC from the maximum altitude authorized at the fix. The maximum altitude authorized for a fix is the singular altitude specified for either a maximum altitude restriction or a mandatory altitude restriction, and the upper limit of a block altitude restriction. The obstacle identified through application of paragraph 13-6-1.a must not penetrate the level OCS.

c. Where multiple maximum, mandatory, or block altitude restrictions are necessary, each maximum altitude authorized at a fix must be equal to or higher than the maximum altitude authorized at a proceeding fix. Evaluate additional altitude restrictions in the same manner as the first, by applying a level OCS to the OEA until the latest point at which the fix with the altitude restriction could be received. Those portions of the OEA previously assessed in association with a preceding altitude restriction need not be assessed again (see figure 13-6-3).

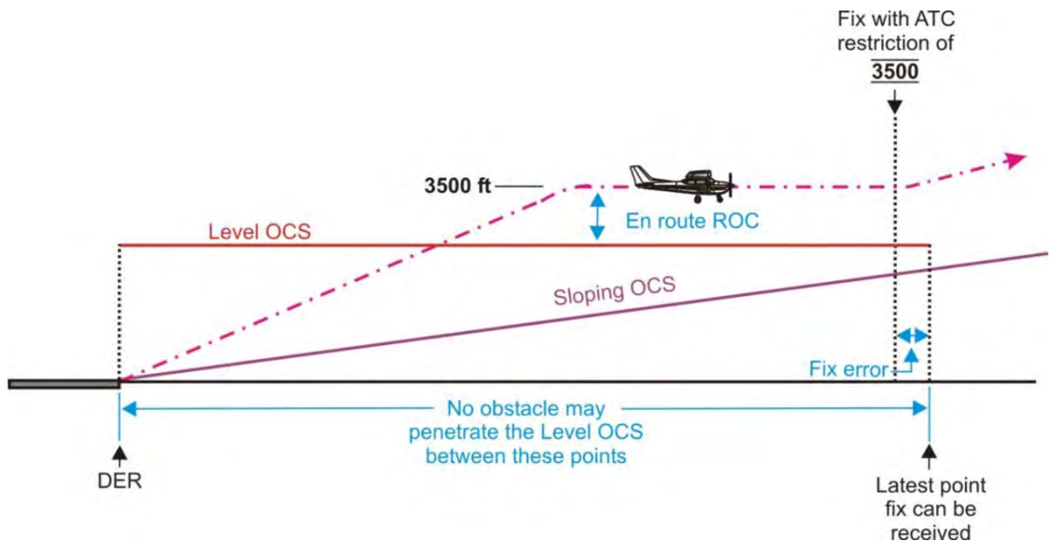
Figure 13-6-3. Multiple Altitude Restrictions



d. Sloping OCS. Compare the height of the level surface and height of the sloping OCS at the plotted position of the fix with the maximum altitude restriction.

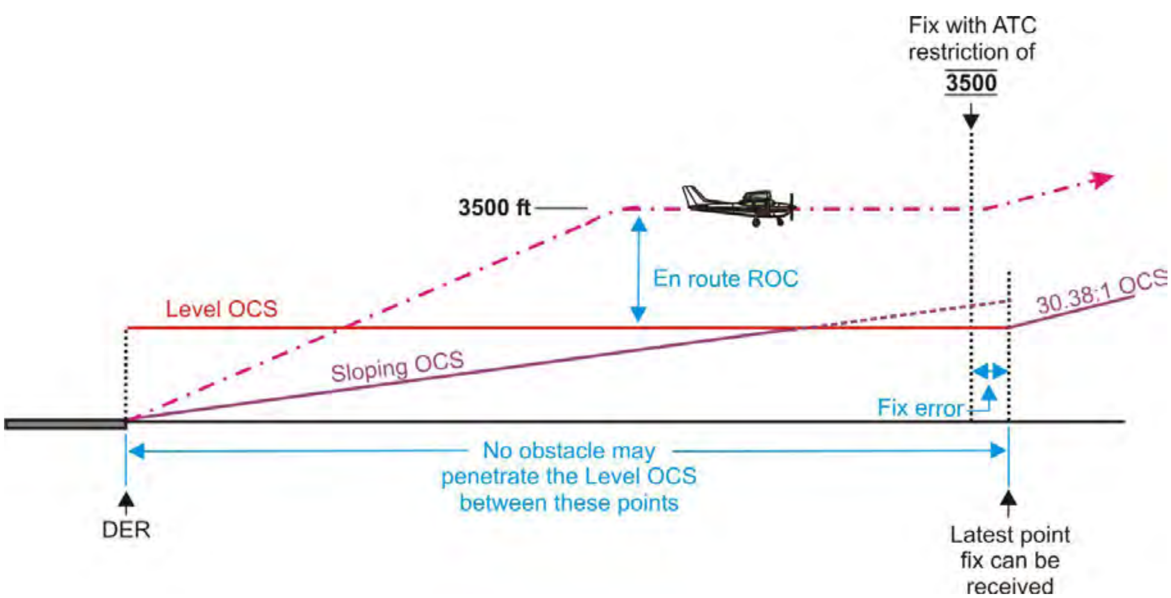
(1) Where the height of the level OCS is equal to or greater than the height of the sloping OCS, continue the sloping surface uninterrupted into the next segment of the departure (see figure 13-6-4).

Figure 13-6-4. Continuation of Sloping OCS



(2) Where the height of the level OCS is less than the height of the sloping OCS, apply a 30.38:1 sloping OCS into the next segment from the primary area boundary of the level OEA. The 30.38:1 OCS originates at the same height as the level OCS. Penetrations may not be mitigated by a CG; if penetrations exist, the maximum altitude authorized at the fix with the altitude restriction must be increased until the penetration is eliminated (see figure 13-6-5).

Figure 13-6-5. Sloping OCS Applied from Level OCS



13-6-2. Minimum Altitudes. When ATC requests the establishment of a minimum altitude, either stand-alone or as part of a block altitude, ensure the minimum CG for the procedure is sufficient to either meet or exceed the restriction.

Section 13-7. Helicopter Point-in-Space (PinS) Departures

13-7-1. General. PinS departures may be conducted from VFR heliports, unmarked landing areas, and VFR runways not served by an ODP. PinS departures are designed to allow a pilot to navigate to a point where IFR flight may commence. For RNAV PinS departures, refer to Order 8260.58.

a. Only proceed VFR departures are authorized for non-RNAV ground-based PinS departures. IFR obstruction clearance does not begin until reaching the IDF flat surface.

b. An IDF must be established no more than 10 NM from the helipad. PCG and obstruction clearance is not provided from the helipad to the IDF. The dimensions of the flat surface area are dependent on the navigation system being flown (see table 13-3-1).

c. The DP consists of an IDF flat surface area, which is a level surface area to initiate the DP. Section 1 begins from the IDF flat surface area in the direction of flight at full width utilizing primary and secondary areas. Section 2 begins at the end of section 1 and continues until the DP is terminated or transition segments begin.

d. When developing routes with multiple segments or more than one navigation system, apply section 13-3 development standards.

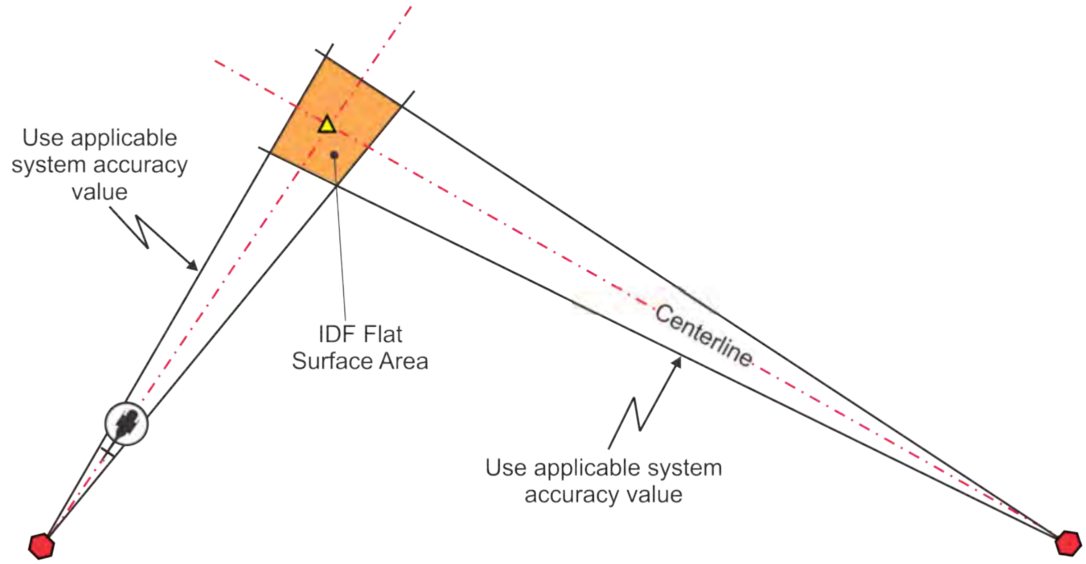
e. The DP must join the en route structure at an altitude that permits en route flight to include airspace and obstacle clearance. It is not mandatory that the DP join an airway, but the DP altitude must allow for continued level flight in all directions. If unable, raise the DP altitude or place restrictions on the DP.

13-7-2. Procedure Design Standards. Utilize the following standards for procedure design.

a. Utilize standard climb airspeed of 80 KIAS and bank angle of 13 degrees until reaching the desired target altitude. After reaching the desired target altitude, evaluate at an airspeed of 140 KIAS and bank angle of 15 degrees.

b. IDF flat surface area dimensions are based on the type of non-RNAV ground based navigation system being flown. Use the appropriate width from table 13-3-1, to include both primary and secondary areas. The length is based on the governing facility obstruction area values or 1/2 NM for DME.

Figure 13-7-1. IDF Flat Surface



c. Standard ROC of 250 plus adjustments (altimeter, precipitous terrain) is applied in level surface areas.

d. Precipitous terrain evaluation is applied in the IDF flat surface area.

e. Altimeter setting adjustments are applied for altimeter sources more than 5 NM from the IDF fix to the altimeter source.

f. A 20:1 slope for the primary area and a 12:1 slope for the secondary area are applied after the flat surface area.

13-7-3. Obstacle Evaluation Area (OEA). Apply obstacle evaluation as shown in figure 13-3-13 or figure 13-3-14. The starting OIS is the IDF flat surface area OIS elevation. Continue the evaluation utilizing a 20:1 slope throughout the procedure.

Chapter 14. En Route Criteria

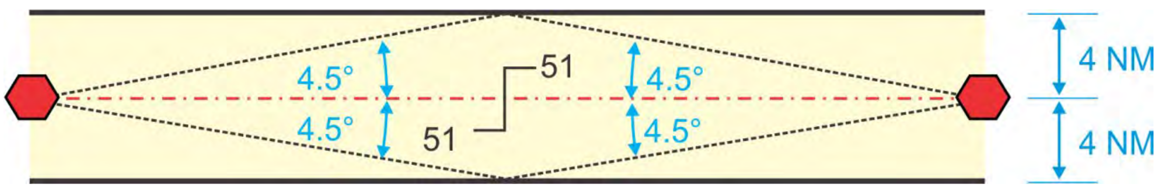
Section 14-1. VHF Obstacle Clearance Areas

14-1-1. En Route Obstacle Clearance Areas. Obstacle clearance areas for en route planning are identified as "primary," "secondary," and "turning" areas.

14-1-2. Primary Areas.

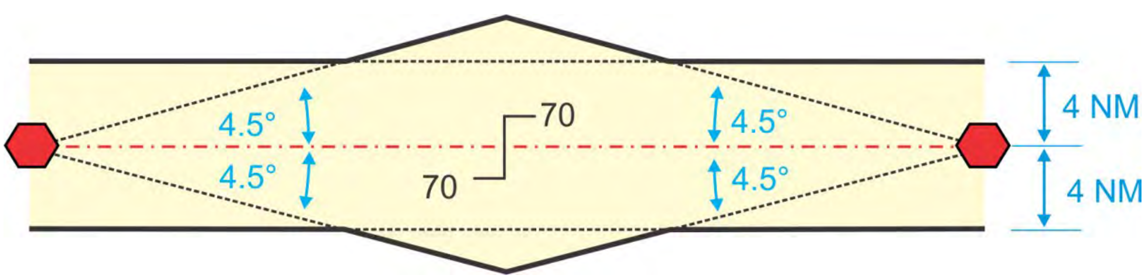
a. Basic area. The primary en route obstacle clearance area extends from each radio facility on an airway or route to the next facility. It has a width of 8 NM; 4 NM on each side of the centerline of the airway or route (see figure 14-1-1).

Figure 14-1-1. Primary Obstacle Clearance Area



b. System accuracy. System accuracy lines are drawn at a 4.5-degree angle on each side of the course or route (see figure 14-1-1). The apexes of the 4.5-degree angles are at the facility. These system accuracy lines will intersect the boundaries of the primary area at a point that is approximately 50.82 NM from the facility (normally 51 NM is used). If the distance from the facility to the changeover point (COP) is more than 51 NM, the outer boundary of the primary area extends beyond the 4 NM width along the 4.5-degree line (see figure 14-1-2). These examples apply when the COP is at midpoint. Paragraph 14-1-7 covers the effect of offset COP or dogleg segments.

Figure 14-1-2. Primary Obstacle Clearance Area Application of System Accuracy

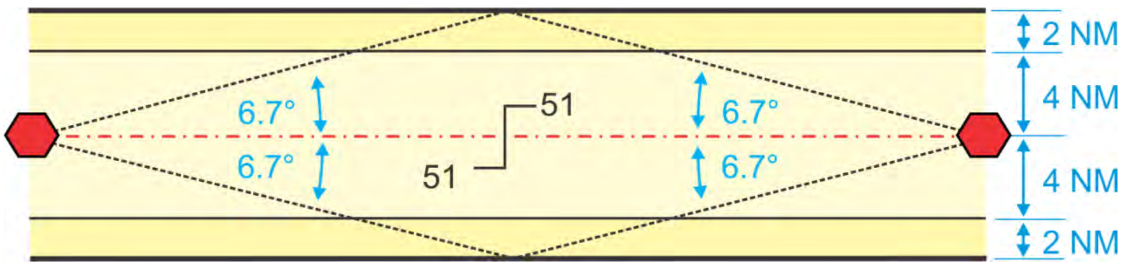


c. Termination point. When the airway or route terminates at a navigational facility or other radio fix, the primary area extends beyond that termination point. The boundary of the area may be defined by an arc which connects the two boundary lines. The center of the arc is, in the case of a facility termination point, located at the geographic location of the facility. In the case of a termination at a radial or DME fix, the boundary is formed by an arc with its center located at the most distant point of the fix displacement area on course line. Figure 14-1-8 and its inset show the construction of the area at the termination point.

14-1-3. Secondary Areas.

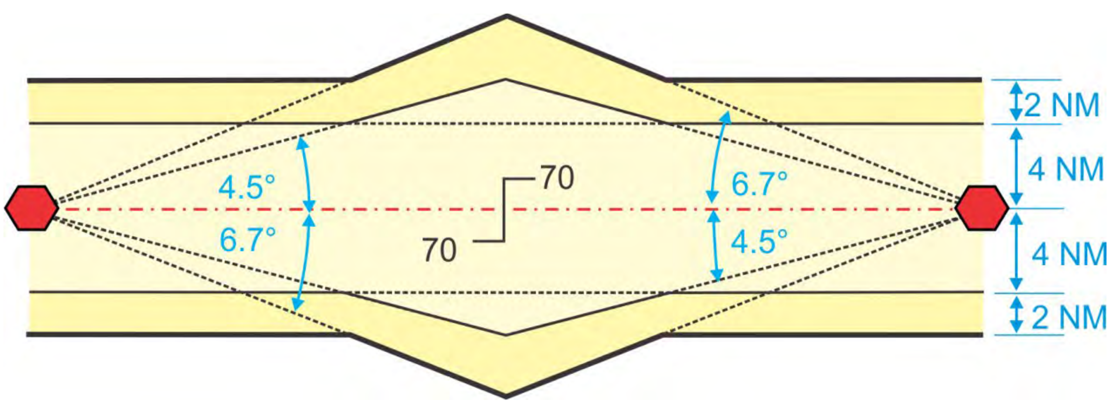
a. Basic area. The secondary obstacle clearance area extends along a line drawn 2 NM on each side of the primary area (see figure 14-1-3).

Figure 14-1-3. Secondary Obstacle Clearance Areas



b. System accuracy. Secondary area system accuracy lines are drawn at a 6.7-degree angle on each side of the course or route (see figure 14-1-3). The apexes are at the facility. These system accuracy lines will intersect the outer boundaries of the secondary areas at approximately the same point as primary lines, 51 NM from the facility. If the distance from the facility to the COP is more than 51 NM, the secondary area extends along the 6.7-degree line (see figure 14-1-4). For offset COP or dogleg airway (see paragraphs 14-1-7.c and 14-1-7.d).

Figure 14-1-4. Secondary Obstacle Clearance Areas Application of System Accuracy Lines



c. Termination point. Where the airway or route terminates at a facility or radio fix the boundaries are connected by an arc in the same way as those in the primary area. Figure 14-1-8 and its inset shows termination point secondary areas.

14-1-4. Turning Area.

a. Definition. The en route turning area may be defined as an area which may extend the primary and secondary obstacle clearance areas when a change of course is necessary. The dimensions of the primary and secondary areas will provide adequate protection where the aircraft is tracking along a specific radial, but when the pilot executes a turn, the aircraft may go beyond the boundaries of the protected airspace. The turning area criteria supplement the airway and route segment criteria to protect the aircraft in the turn.

b. Requirement for turning area criteria. Because of the limitation on aircraft indicated airspeeds below 10000 feet MSL (see 14 CFR part 91.117); some conditions do not require the application of turning area airspace criteria.

(1) The graph in figure 14-1-5 may be used to determine if the turning area should be plotted for airways/routes below 10000 feet MSL. If the point of intersection on the graph of the "amount of turn at intersection" versus "VOR facility to intersection distance" falls outside the hatched area of the graph, the turning area criteria need not be applied.

(2) If the "amount of turn" versus "facility distance" values fall within the hatched area or outside the periphery of the graph, then the turning area criteria must be applied as described in paragraph 14-1-5.

c. Track. The flight track resulting from a combination of turn delay, inertia, turning rate, and wind effect is represented by a parabolic curve. For ease of application, a radius arc has been developed which can be applied to any scale chart.

d. Curve radii. A 250 KIAS, which is the maximum allowed below 10000 feet MSL, results in radii of 2 NM for the primary area and 4 NM for the secondary area up to that altitude. For altitudes at or above 10000 feet MSL up to but not including 18000 feet MSL the primary area radius is 6 NM and the secondary area radius is 8 NM. At or above 18000 feet MSL the radii are 11 NM for primary and 13 NM for secondary.

e. System accuracy. In drawing turning areas it will be necessary to consider system accuracy factors by applying them to the most adverse displacement of the radio fix or airway/route boundaries at which the turn is made. The 4.5- and 6.7-degree factors apply to the VOR radial being flown, but since no pilot or aircraft factors exist in the measurement of an intersecting radial, a navigation facility factor of plus-or-minus 3.6 degrees is used (see figure 14-1-6).

Note: If a radio fix is formed by intersecting signals from two low frequency (LF), or one LF and VOR facility, the obstacle clearance areas are based upon accuracy factors of 5.0 (primary) and 7.5 (secondary) degrees each side of the course or route centerlines of the LF facilities. If the VOR radial is the intersecting signal, the 3.6-degree value stated in paragraph 14-1-4.e applies.

Figure 14-1-5. Turn Angle VS Distance

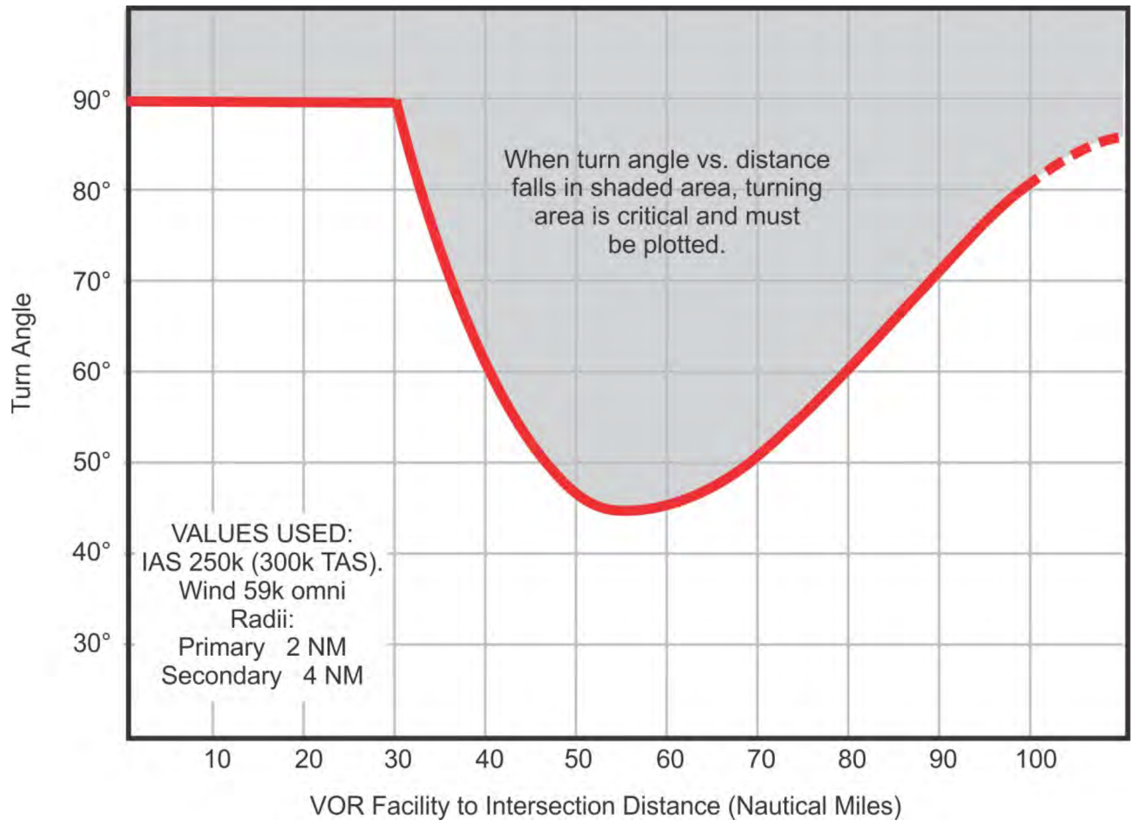
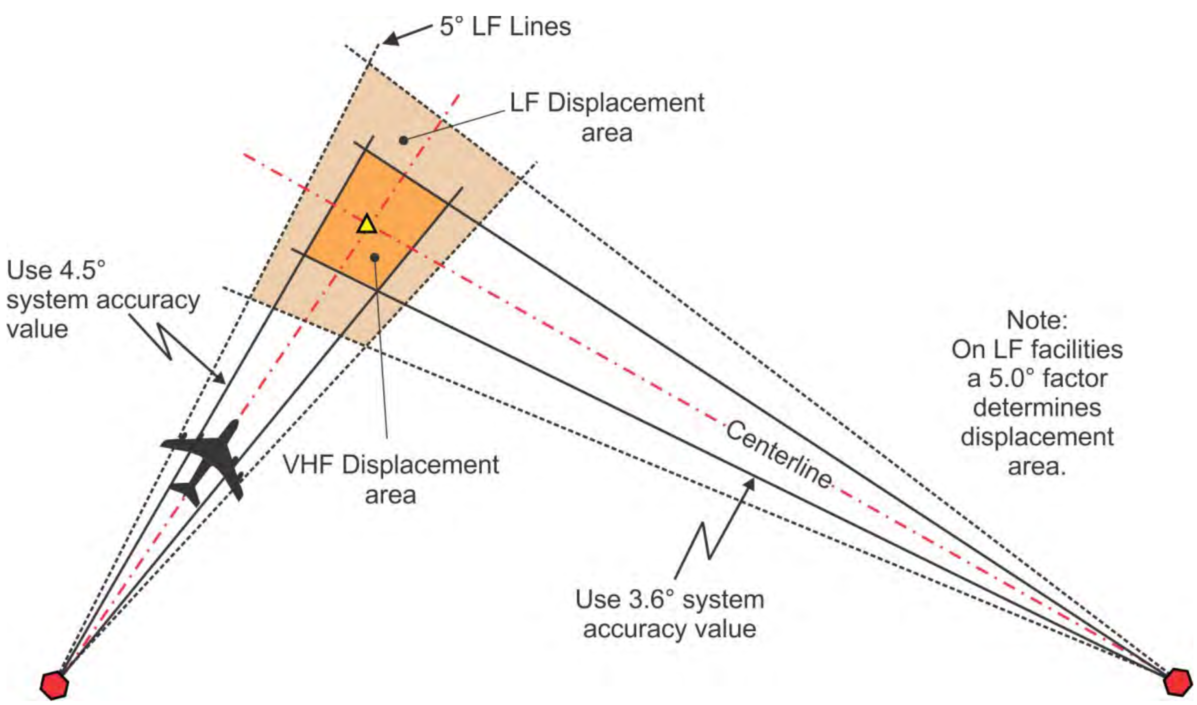


Figure 14-1-6. Fix Displacement



14-1-5. Application of Turning Area Criteria.

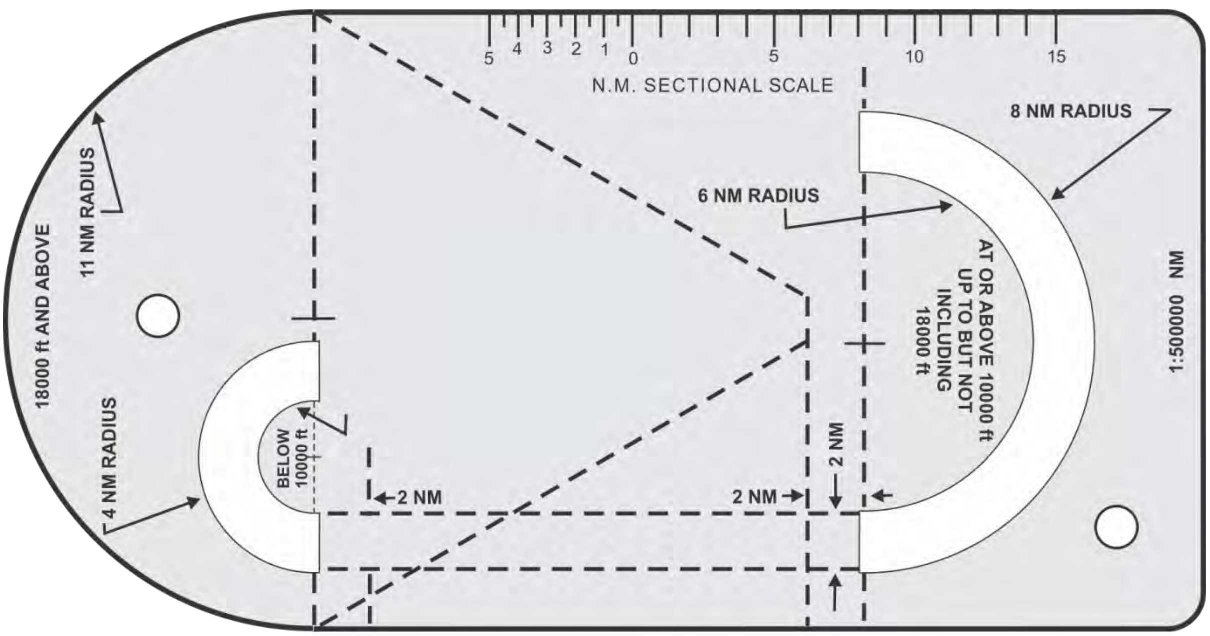
a. Techniques. Figure 14-1-8, figure 14-1-9, and figure 14-1-10 illustrate the application of the criteria. They also show areas which may be deleted from consideration when obstacle clearance is the deciding factor for establishing MEAs on airways or route segments.

b. Computations. Computations due to obstacles actually located in the turning areas will probably be indicated only in a minority of cases. These methods do; however, add to the flexibility of procedures specialists in resolving specific obstacle clearance problems without resorting to the use of waivers.

c. Minimum turning altitude (MTA). Where the application of the turn criteria inhibits the use of an MEA with a cardinal altitude, the use of an MTA for a special direction of flight may be authorized.

14-1-6. Turn Area Template. A turn area template has been designed for use on charts scaled at 1:500,000; it is identified as "TA-1" (see figure 14-1-7).

Figure 14-1-7. Turning Area Template



a. Use of template-intersection fix.

(1) Primary area. At an intersection fix the primary obstacle clearance area arc indexes are placed at the most adverse points of the fix displacement area as determined by the outer intersections of the en route radial 4.5-degree lines (VOR) and the cross-radial 3.6-degree lines [(VOR) (see figure 14-1-8 and figure 14-1-9)]. If LF signals are used, the 5.0-degree system accuracy lines apply. The parallel dashed lines on the turn area template are aligned with the appropriate system accuracy lines and the curves are drawn.

(2) Secondary area "outside" curve. The outside curve of the secondary turning area is the curve farthest from the navigation facility which provides the intersecting radial. This curve is indexed to the distance from the fix to the en route facility as follows:

(a) Where the fix is less than 51 NM from the en route facility, the secondary arc is started at a point 2 NM outside the primary index with the parallel dashed lines of the template aligned on the 4.5-degree line (see figure 14-1-8).

(b) Where the fix is farther than 51 NM from the en route station, the arc is started at the point of intersection of the 3.6 and 6.7-degree lines with the parallel dashed lines of the template aligned on the 6.7-degree line (see figure 14-1-9).

(3) Secondary area "inside" curve. The inside curve is the turning area arc which is nearest the navigation facility which provides the intersecting radial. This arc is begun 2 NM beyond the primary index and on the 3.6-degree line. The parallel dashed lines on the turning area template are aligned with the 4.5-degree line from the en route station.

Figure 14-1-8. Turning Area, Intersection Fix (Facility Distance Less than 51 NM)

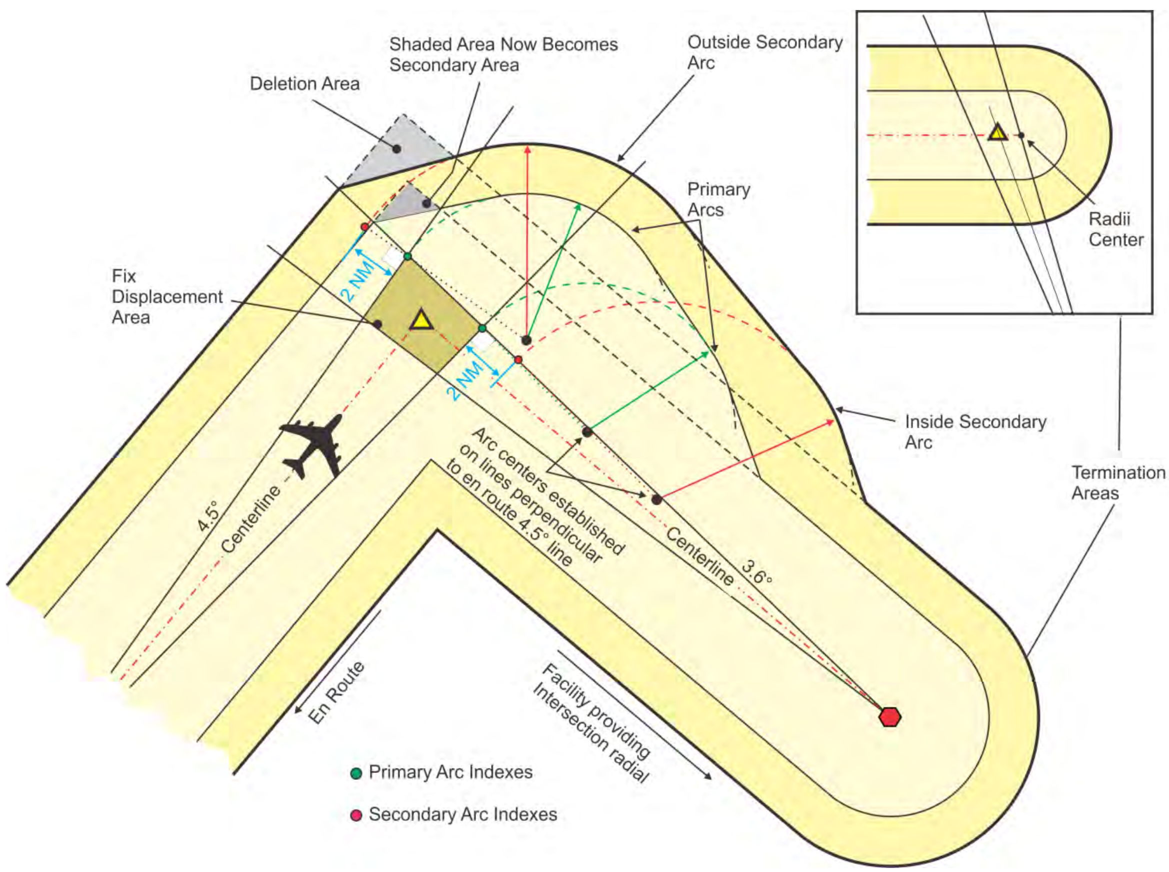
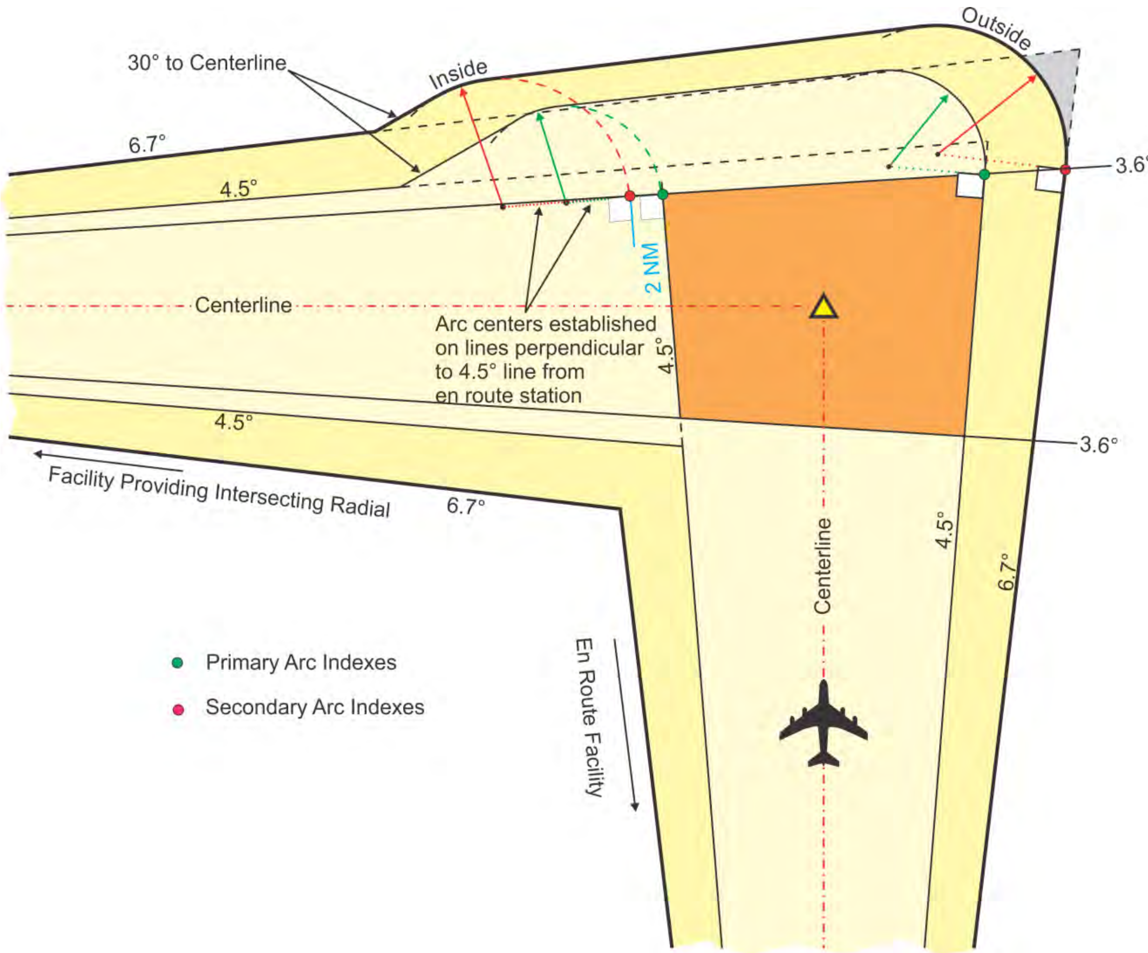


Figure 14-1-9. Turning Area, Intersection Fix (Facility Distance Beyond 51 NM)



(a) Where the fix is less than 51 NM from the en route facility and the magnitude of the turn is less than 30 degrees, the "inside" curves do not affect the size of the secondary area.

(b) Where the distance from the en route facility to the fix is more than 51 NM but the magnitude of the turn is less than 45 degrees, the "inside" curves do not increase the size of the secondary area.

(c) Where the magnitude of the turn is greater than those stipulated in paragraphs 14-1-6.a(3)(a) and 14-1-6.a(3)(b), the "inside" curves will affect the size of the secondary area.

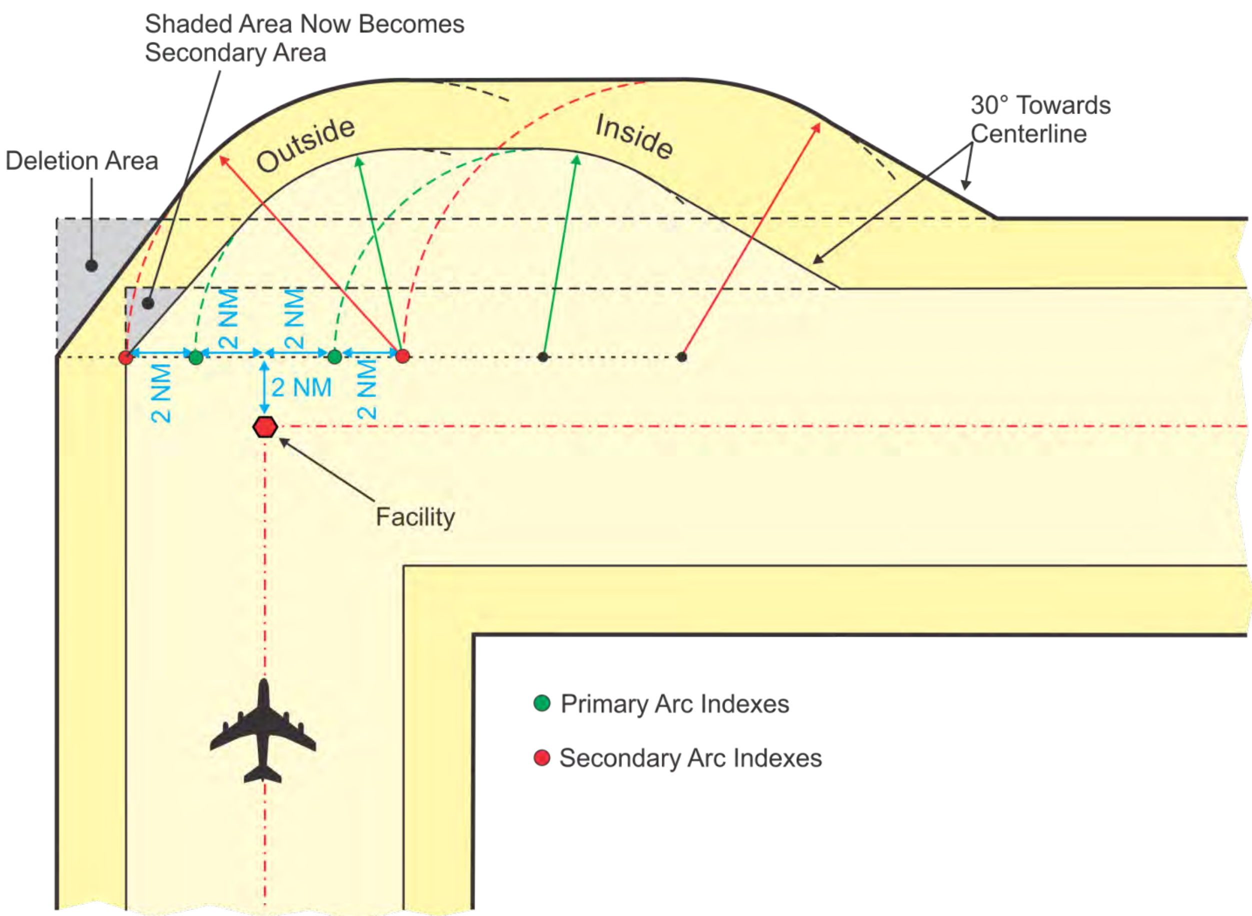
(d) Whether the secondary area curves affect the size of the secondary obstacle clearance area or not, they must be drawn to provide reference points for the tangential lines described in paragraph 14-1-6.a(4).

(4) Connecting lines. Tangential straight lines are now drawn connecting the two primary arcs and the two secondary arcs. The outer limits of both curves are symmetrically connected to the respective primary and secondary area boundaries in the direction of flight by

lines drawn at a 30-degree angle to the airway or route centerline (see figure 14-1-8 and figure 14-1-9).

b. Use of template when fix overheads a facility (see figure 14-1-10). The geographical position of the fix is considered to be displaced laterally and longitudinally by 2 NM at all altitudes.

Figure 14-1-10. Turning Area Overhead the Facility



(1) Primary arcs. The primary arcs are indexed at points 2 NM beyond the station and 2 NM on each side of the station. The parallel dotted lines on the template are aligned with the airway or route boundaries and the curves drawn.

(2) Secondary arcs. The secondary arcs are indexed 2 NM outside the primary points, and on a line with them. The parallel dotted lines on the template are aligned with the airway or route boundaries, and the curves drawn.

(3) Connection lines. Tangential straight lines are now drawn connecting the two primary and the two secondary arcs. The outer limits of both curves are connected to the primary and secondary area boundaries by intercept lines which are drawn 30 degrees to the airway or route centerline. The 30-degree lines on the template may be used to draw these intercept lines.

c. Deletion areas. Irregular areas remain on the outer corners of the turn areas (see figure 14-1-8, figure 14-1-9, and figure 14-1-10). These are the areas identified in paragraph 14-1-5 which may be deleted from consideration when obstacle clearance is the deciding factor for determination of MEA on an airway or route segment.

(1) Where the “outside” secondary area curve is started within the airway or route secondary area boundary (see figure 14-1-8), the area is blended by drawing a line from the point where the 3.6-degree (5.0 with LF facility) line meets the line which forms the en route secondary boundary tangent to the “outside” secondary arc. Another line is drawn from the point where the same 3.6- (or 5.0-) degree line meets the line which forms the primary boundary, tangent to the matching primary arc. These two lines now enclose the secondary area at the turn. The corner which was formerly part of the secondary area may be disregarded; the part which was formerly part of the primary area may now be considered secondary area. These areas are shaded in figure 14-1-8.

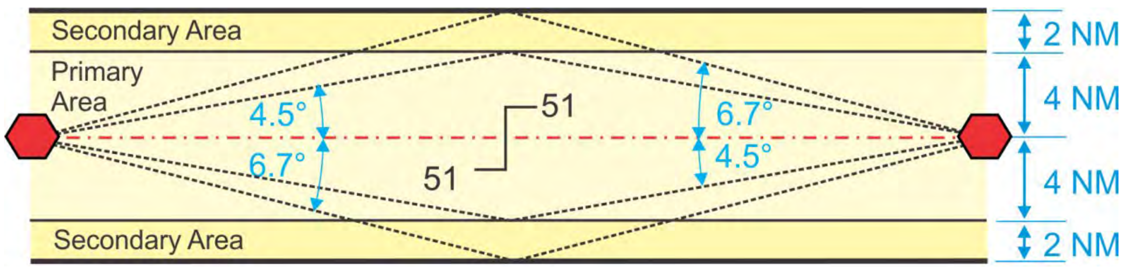
(2) Where the secondary curve is indexed on the secondary area boundary formed by the 6.7-degree lines, the arc itself cuts the corner and prescribes the deleted area (see figure 14-1-9). This condition occurs when the radio fix is over 51 NM from the en route navigation facility.

(3) When overheading the facility, the secondary area corner deletion area is established by drawing a line from a point opposite the station index at the secondary area boundary, tangent to the secondary “outside” curve (see figure 14-1-10). A similar line is drawn from a point opposite the station index at the primary area boundary, tangent to the primary turning arc. The corner formerly part of the primary area now becomes secondary area. The deletion areas are shown in figure 14-1-10 by shading.

14-1-7. Changeover Points (COPs). Points have been defined between navigation facilities along airway/route segments which are called “changeover points (COPs).” These points indicate that the pilot using the airway/route should “changeover” his navigation equipment to receive course guidance from the facility ahead of the aircraft instead of the one behind. These COPs divide a segment and assure continuous reception of navigation signals at the prescribed MEA. They also assure that aircraft operating within the same portion of an airway or route segment will not be using azimuth signals from two different navigation facilities. Where signal coverage from two facilities overlaps at the MEA, COPs will normally be designated at the midpoint. Where radio frequency interference or other navigation signal problems exist, COPs will be at the optimum location, taking into consideration the signal strength, alignment error, or any other known condition which affects reception. The effect of COPs on the primary and secondary obstacle clearance areas is as follows:

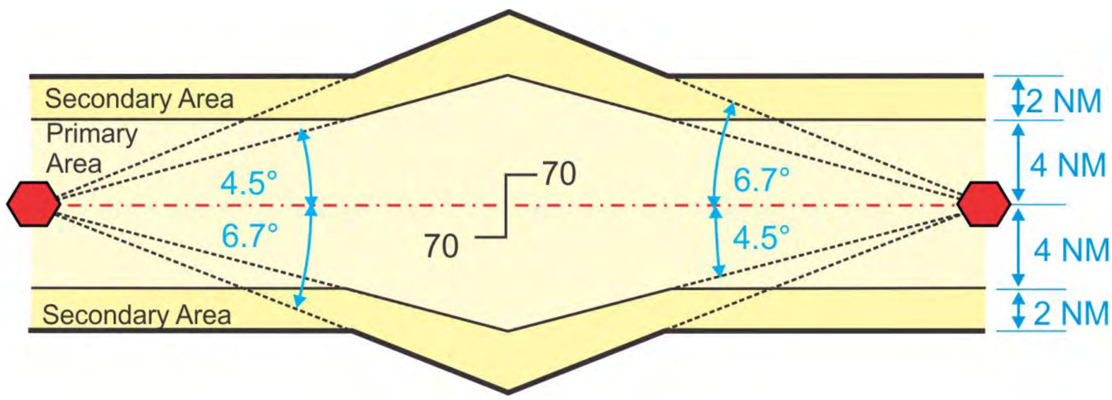
a. Short segments. If the airway or route segment is less than 102 NM long and the COP is placed at the midpoint, the obstacle clearance areas are not affected (see figure 14-1-11).

Figure 14-1-11. COP Effect Short Airway or Route Segment



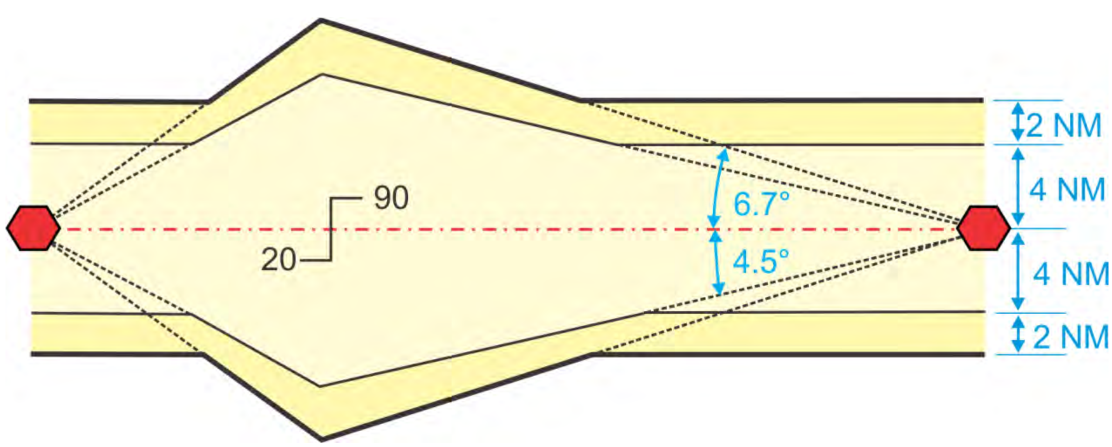
b. Long segments. If the distance between two facilities is over 102 NM and the COP is placed at the midpoint, the system accuracy lines extend beyond the minimum widths of 8 NM and 12 NM, and a flare results at the COP (see figure 14-1-12).

Figure 14-1-12. COP Effect Long Airway or Route Segment



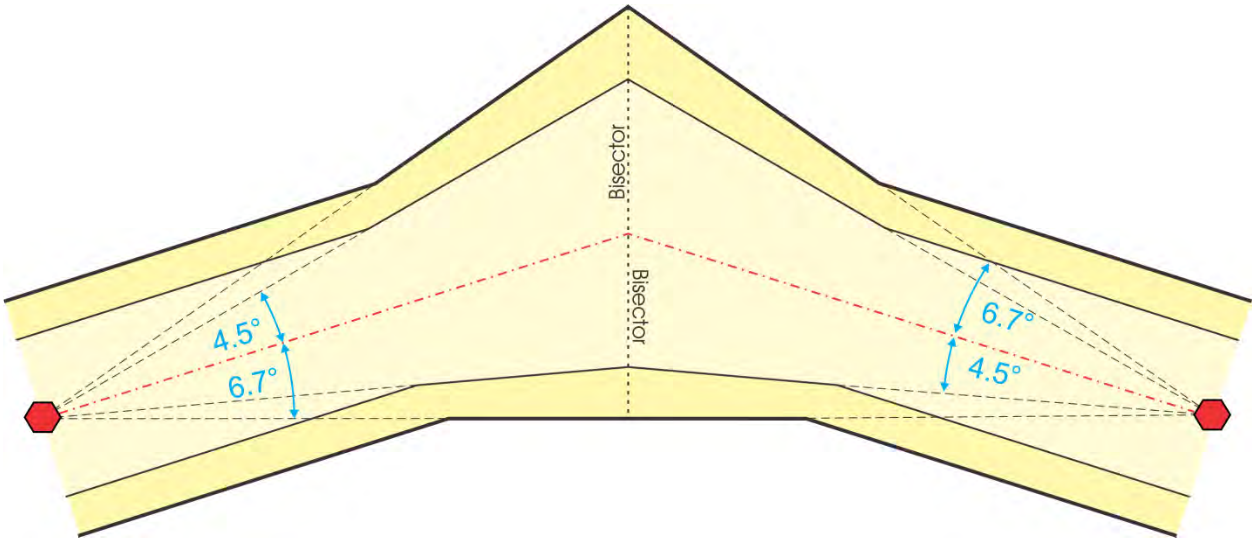
c. Offset COP. If the changeover point is offset due to facility performance problems, the system accuracy lines must be carried from the farthest facility to a position abeam the changeover point, and these lines on each side of the airway or route segment at the COP are joined by lines drawn directly from the nearer facility. In this case the angles of the lines drawn from the nearer facility have no specific angle (see figure 14-1-13).

Figure 14-1-13. Offset COP



d. Dogleg segment. A dogleg airway or route segment may be treated in a manner similar to that given offset COP. The system accuracy lines will be drawn to meet at a line drawn as the bisector of the dogleg "bend" angle and the boundaries of the primary and secondary areas extended as required (see figure 14-1-14).

Figure 14-1-14. Dogleg Segment



14-1-8. Course Change Effect. The complexity of defining the obstacle clearance areas is increased when the airway or route becomes more complex. Figure 14-1-15 shows the method of defining the primary area when a radio fix and a COP are involved. Note that the system accuracy lines are drawn from the farthest facility first, and govern the width of the airway or route at the COP. The application of secondary area criteria results in a segment similar to that depicted in figure 14-1-16.

Figure 14-1-15. Course Change Effect

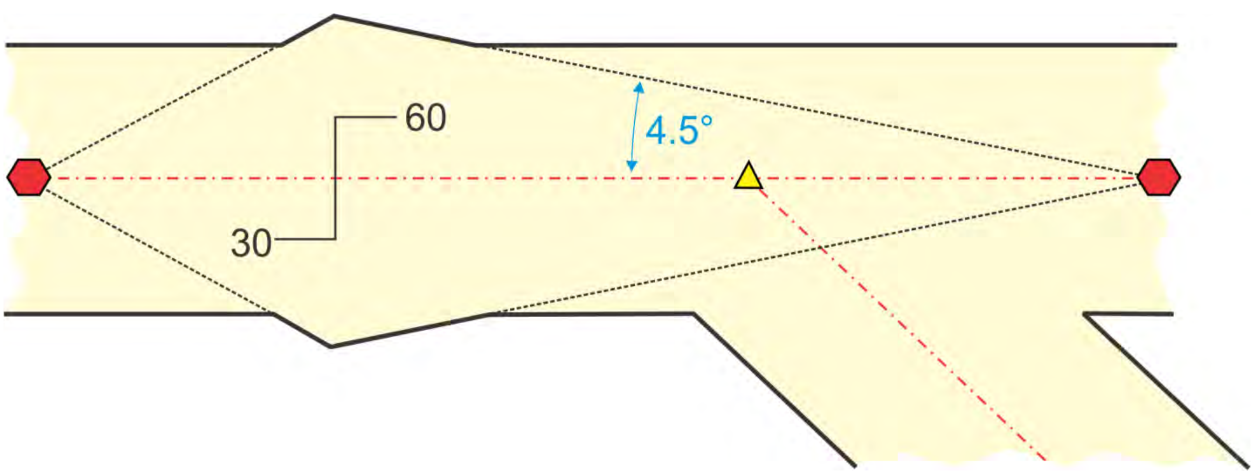
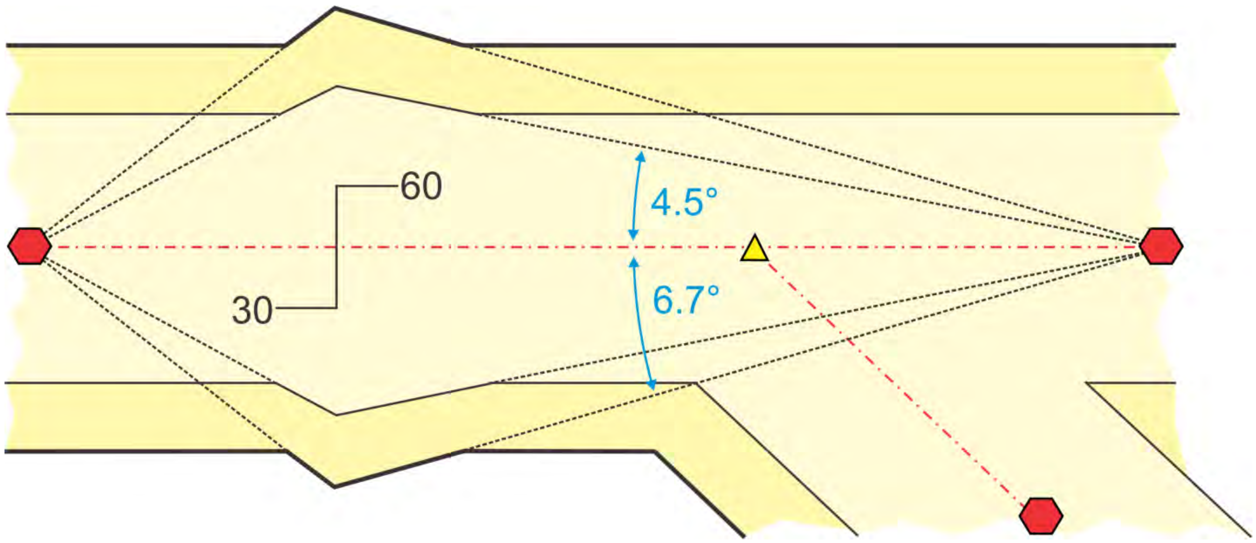


Figure 14-1-16. Application of Secondary Areas



14-1-9. Minimum En Route IFR Altitudes. An MEA will be established for each segment of an airway/route from radio fix to radio fix. The MEA will be established based upon obstacle clearance, adequacy of navigation facility performance, and communications requirements. Segments are designated West to East and South to North. Altitudes must be established in 100-foot increments (for example, 2001 feet becomes 2100).

Note: Care must be taken to ensure that all MEAs based upon fight inspection information have been corrected to and reported as true altitudes above MSL.

14-1-10. Protected En Route Areas. As previously established, the en route areas which must be considered for obstacle clearance protection are identified as primary, secondary, and turn areas. The overall consideration of these areas is necessary when determining obstacle clearances.

Section 14-2. VHF Obstacle Clearance

14-2-1. Obstacle Clearance, Primary Area.

a. Nonmountainous areas. The minimum ROC over areas not designated as mountainous under 14 CFR part 95 is 1000 feet.

b. Mountainous areas. Owing to the action of Bernoulli Effect and of atmospheric eddies, vortices, waves, and other phenomena which occur in conjunction with the disturbed airflow attending the passage of strong winds over mountains, pressure deficiencies manifested as very steep horizontal pressure gradients develop over such regions. Since downdrafts and turbulence are prevalent under these conditions, the hazards to air navigation are multiplied. Except as set forth in paragraphs 14-2-1.b(1) and 14-2-1.b(2), the minimum ROC within areas designated in 14 CFR part 95 as "mountainous" is 2000 feet.

(1) ROC may be reduced to not less than 1500 feet above terrain and vegetation in the designated mountainous areas of the Eastern United States, Commonwealth of Puerto Rico, and the land areas of the State of Hawaii; and may be reduced to not less than 1700 feet above terrain and vegetation in the designated mountainous areas of the Western United States and the State of Alaska. Consideration must be given to the following points before any altitudes providing less than 2000 feet of terrain and vegetation clearance are authorized.

(a) Areas characterized by precipitous terrain.

(b) Weather phenomena peculiar to the area.

(c) Phenomena conducive to marked pressure differentials.

(d) Type of and distance between navigation facilities.

(e) Availability of weather services throughout the area.

(f) Availability and reliability of altimeter resetting points along airways/routes in the area.

(2) Where reduced ROC is applied as described in paragraph 14-2-1.b(1), altitudes providing at least 1000 feet of ROC over towers and/or other manmade obstacles/AAO are authorized.

14-2-2. Obstacle Clearance, Secondary Areas. In all areas, mountainous and nonmountainous, obstacles which are located in the secondary areas will be considered as obstacles to air navigation when they extend above the secondary obstacle clearance plane. This plane begins at a point 500 feet above the obstacles upon which the primary obstacle clearance area MOCA is based, and slants upward at an angle which will cause it to intersect the outer edge of the secondary area at a point 500 feet higher (see figure 14-2-1). Where an obstacle extends above this plane, the normal MOCA must be increased by adding to the MSL height of the highest penetrating obstacle in the secondary area the required obstacle clearance, computed with formula 14-2-1:

Formula 14-2-1. Secondary ROC

$$ROC_{secondary} = 500 \times \left(1 - \frac{d_{primary}}{W_S}\right)$$

Where:

$d_{primary}$ = perpendicular distance(feet) from primary area edge

W_S = total width of the secondary area (feet)

Note 1: Add an extra 1000 feet in mountainous areas except where the primary area ROC has been reduced under the provisions of paragraph 14-2-1. In these cases, where the primary area ROC has been reduced to 1700 feet, add 700 feet to the secondary obstacle clearance, and where the primary area ROC has been reduced to 1500 feet, add 500 feet to the secondary area clearance value.

Note 2: W_S has a total width of 2 NM, or 12152 feet out to a distance of 51 NM from the en route facility, and then increases at a rate of 236 feet for each additional NM.

Figure 14-2-1. Cross Section, Secondary Area Obstacle Clearance

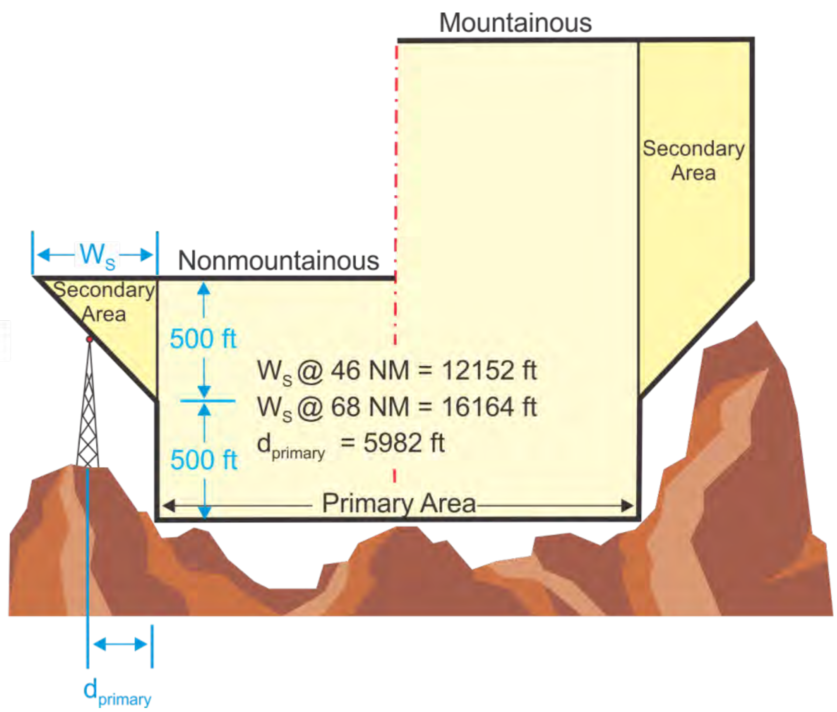
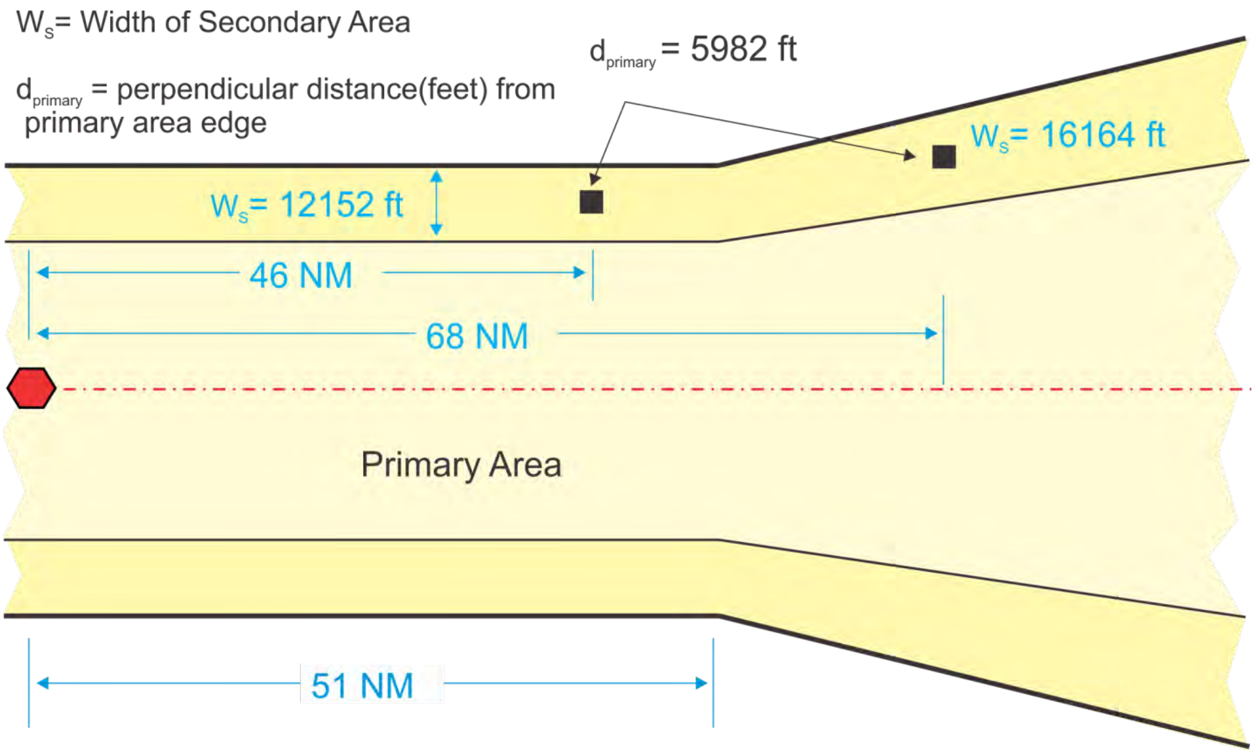


Figure 14-2-2. Plan View, Secondary Area Obstacle Clearances



Example: An obstacle which reaches 1875 feet MSL is found in the secondary area; 5982 feet from the primary area edge, and 46 NM from the facility (see figure 14-2-1 and figure 14-2-2).

Using formula 14-2-1:
$W_S = 12152$ feet
$d_{primary} = 5982$ feet

$$500 \times \left(1 - \frac{5982}{12152}\right) = 253.8\ (254\ \text{feet})$$

Obstacle height $(1875) + 254 = 2129$
MOCA = 2200 feet

Section 14-3. Altitudes

14-3-1. Minimum Crossing Altitude (MCA). It is necessary to establish MCAs in all cases where obstacles intervene to prevent a pilot from maintaining obstacle clearance during a normal climb to a higher MEA after the aircraft passes a point beyond which the higher MEA applies. The same vertical obstacle clearance requirement for the primary and secondary areas must be considered in the determination of the MCA (see paragraph 14-1-9). The standard for determining the MCA must be based upon the following climb rates, and is computed from the flight altitude:

Table 14-3-1. Assumed Climb Rates

0 through 4999 feet MSL	150 ft/NM
5000 through 9999 feet MSL	120 ft/NM
10000 feet MSL and over	100 ft/NM

a. To determine the MCA, the distance from the obstacle to the radio fix must be computed from the point where the centerline of the en route course in the direction of flight intersects the farthest displacement from the fix (see figure 14-1-1 and figure 14-3-2).

Figure 14-3-1. MCA Determination Point

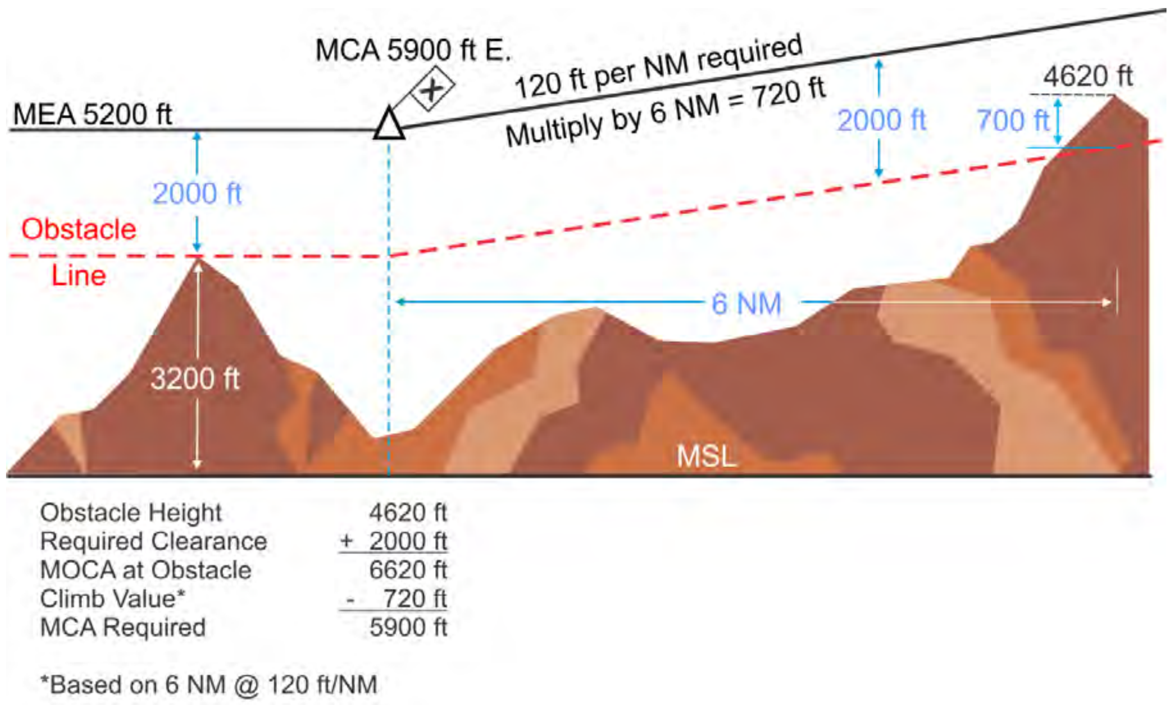
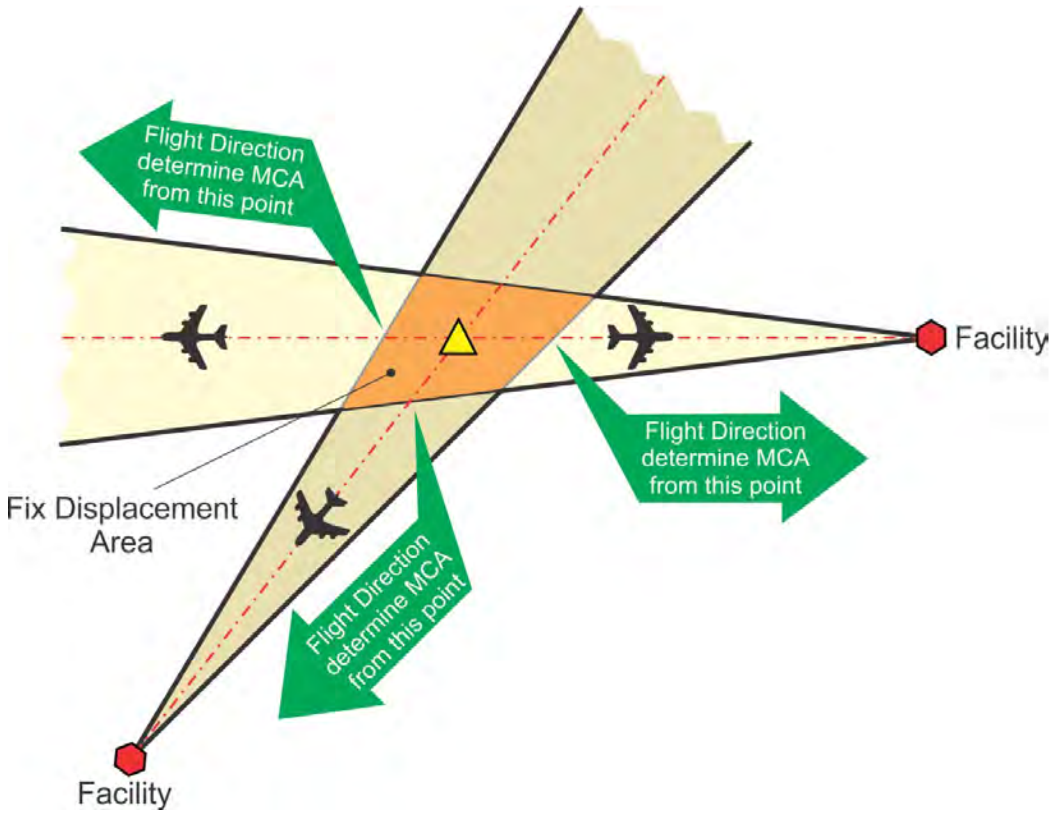


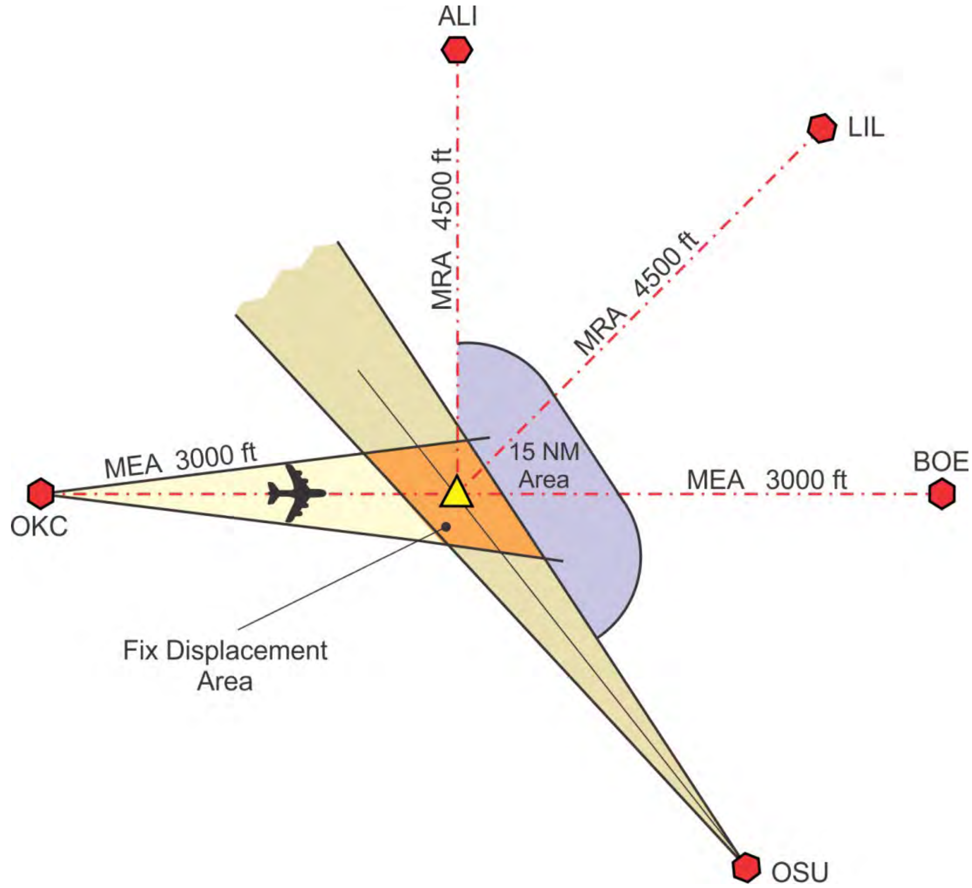
Figure 14-3-2. Determination of MCA



b. When a change of altitudes is involved with a course change, course guidance must be provided if the change of altitude is more than 1500 feet and/or if the course is more than 45 degrees.

Exception: Course changes of up to 90 degrees may be approved without course guidance provided that no obstacles penetrate the established MEA requirement of the previous airway/route segment within 15 NM of the boundaries of the system accuracy displacement area of the fix [see figure 14-3-3 and paragraph 14-4-1.b(2)].

Figure 14-3-3. MEA with Navigation Gap at Turning Point



14-3-2. En Route Minimum Holding Altitudes. Criteria for holding pattern airspace and obstacle clearance are specified in chapter 16.

Section 14-4. Navigational Gaps

14-4-1. Navigational Gap Criteria. Where a gap in course guidance exists, an airway or route segment may be approved in accordance with the criteria set forth in paragraph 14-4-1.c, provided:

a. Restrictions.

(1) The gap may not exceed a distance which varies directly with altitude from 0 NM at sea level to 65 NM at 45000 feet MSL, and

(2) Not more than one gap may exist in the airspace structure for the airway/route segment, and

(3) A gap may not occur at any airway or route turning point, except when the provisions of paragraph 14-4-1.b(2) are applied, and

(4) A notation must be included on Form 8260-16, Transmittal of Airways/Route Data Record, which specifies the area within which a gap exists where the MEA has been established with a gap in navigational signal coverage. The gap area will be identified by distances from the navigation facilities.

b. Authorizations. MEAs with gaps are authorized only where a specific operational requirement exists. Where gaps exceed the distance in paragraph 14-4-1.a(1), or are in conflict with the limitations in paragraphs 14-4-1.a(2) or 14-4-1.a(3), the MEA must be increased as follows:

(1) For straight segments.

(a) To an altitude which will meet the distance requirement of paragraph 14-4-1.a(1), or

(b) When in conflict with paragraph 14-4-1.a(1) or 14-4-1.a(2) to an altitude where there is continuous course guidance available.

(2) For turning segments**.** Turns to intercept radials with higher MEAs may be allowed provided:

(a) The increase in MEA does not exceed 1500 feet, and

(b) The turn does not exceed 90 degrees, and

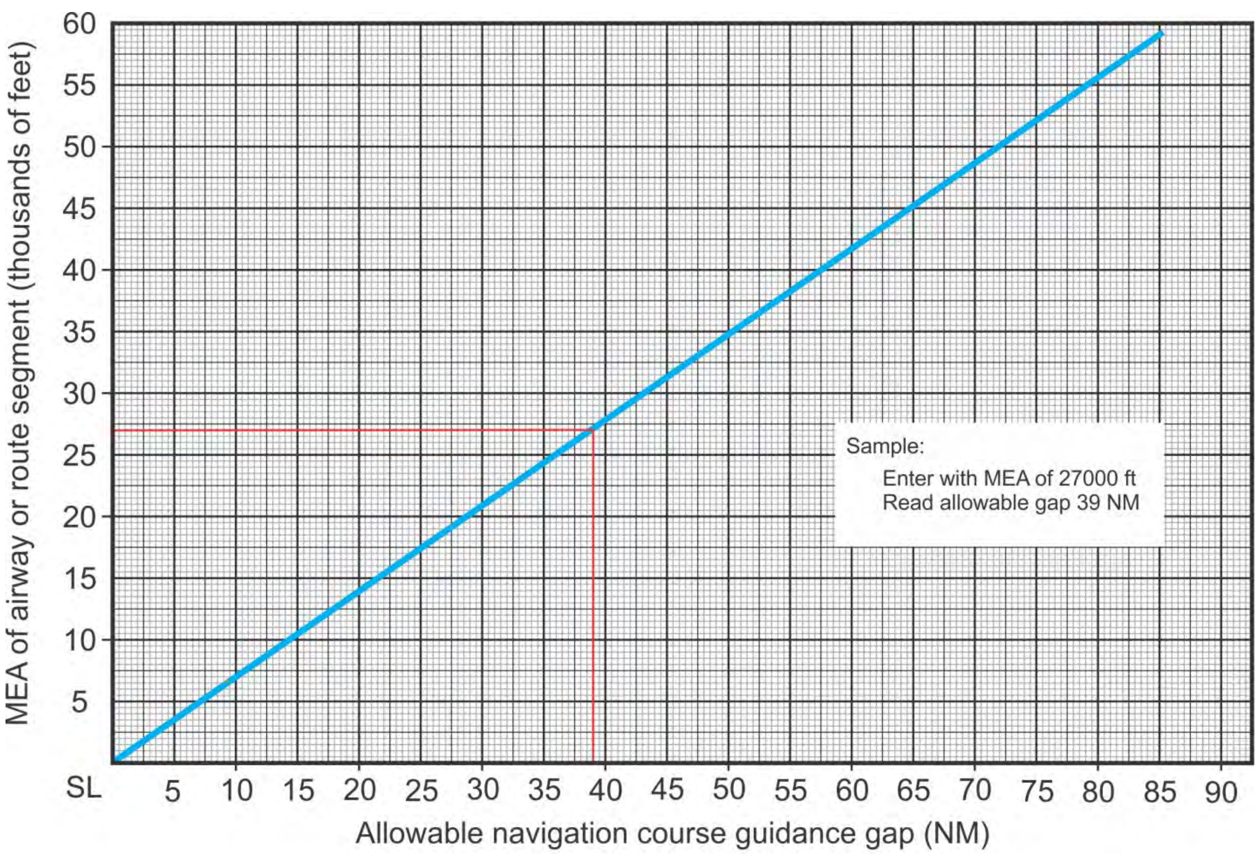
(c) No obstacles penetrate the MEA of the course being flown within 15 NM of the fix displacement area (see figure 14-3-3).

(3) When in conflict with paragraph 14-4-1.b(1) or 14-4-1.b(2) to an altitude where there is continuous course guidance available.

c. Use of steps. Where large gaps exist which require the establishment of altitudes that inhibit the effective use of airspace, consideration may be given to the establishment of MEA "steps." These steps may be established at increments of no less than 2000 feet below 18000 feet MSL, or no less than 4000 feet at 18000 feet MSL and above, provided that a total gap does not exist for the segment within the airspace structure. MEA steps must be limited to one step between any two facilities to eliminate continuous or repeated changes of altitude in problem areas. MEA changes must be identified by designated radio fixes.

d. Gaps. Allowable navigational gaps may be determined by reference to the graph in figure 14-4-1.

Figure 14-4-1. Navigation Course Guidance Gaps



Example: The problem drawn on the chart shows the method used to determine the allowable gap on a route segment with a proposed MEA of 27000 feet. Enter the graph at the left edge with the MEA of 27000 feet. Move to the right to the interception of the diagonal line. Move to the bottom of the graph to read the allowable gap. In the problem drawn, a 39-NM gap is allowable.

Section 14-5. Low Frequency Airways or Routes

14-5-1. LF Airways or Routes.

a. Usage. LF navigation facilities may be used to establish en route airway/route segments. Their use will be limited to those instances where an operational requirement exists.

b. Obstacle clearance areas (see figure 14-5-1 and figure 14-5-2).

(1) The primary obstacle clearance area boundaries of LF segments are lines drawn 4.34 NM on each side of and parallel to the segment centerline. These boundaries will be affected by obstacle clearance area factors shown in paragraph 14-5-1.c.

(2) The LF secondary obstacle clearance areas extend laterally for an additional 4.34 NM on each side of the primary area. The boundaries of the secondary areas are also affected by the obstacle clearance area factors shown in paragraph 14-5-1.c.

Figure 14-5-1. LF Segment Primary Obstacle Clearance Area

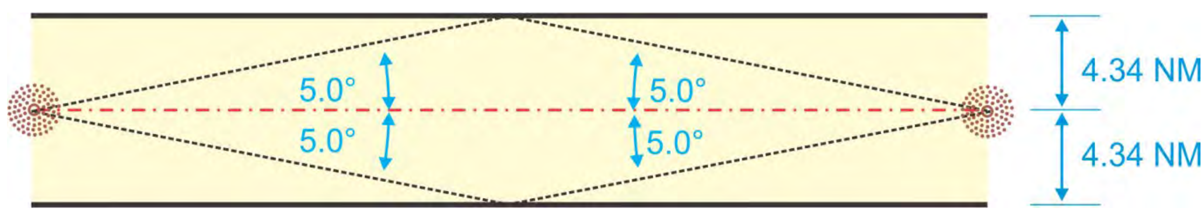
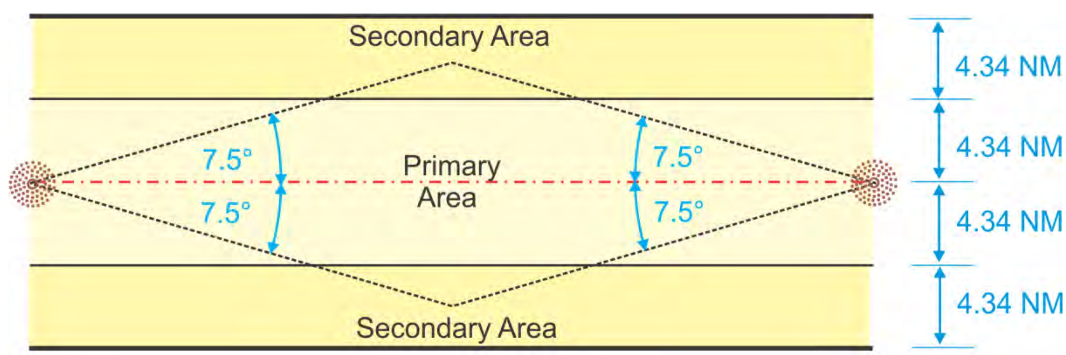


Figure 14-5-2. LF Segment Secondary Obstacle Clearance Area



c. Obstacle clearance area factors (see figure 14-5-1 and figure 14-5-2).

(1) The primary area of LF segments is expanded in the same way as for VHF airways/routes. Lines are drawn at 5 degrees off the course centerline from each facility. These lines meet at the midpoint of the segment. Intersection with the 4.34-NM boundaries occurs approximately 49.61 NM from the facility.

(2) The secondary areas are expanded in the same manner as the secondary areas for VHF airways/routes. Lines are drawn 7.5 degrees on each side of the segment centerline. These

7.5-degree lines will intersect the original 8.68 NM secondary area boundaries approximately 65.93 NM from the facility.

d. Obstacle clearance.

(1) Obstacle clearance in the primary area of LF airways or routes is the same as that required for VOR airways/routes. The areas over which the clearances apply are different, as shown in paragraph 14-5-1.c.

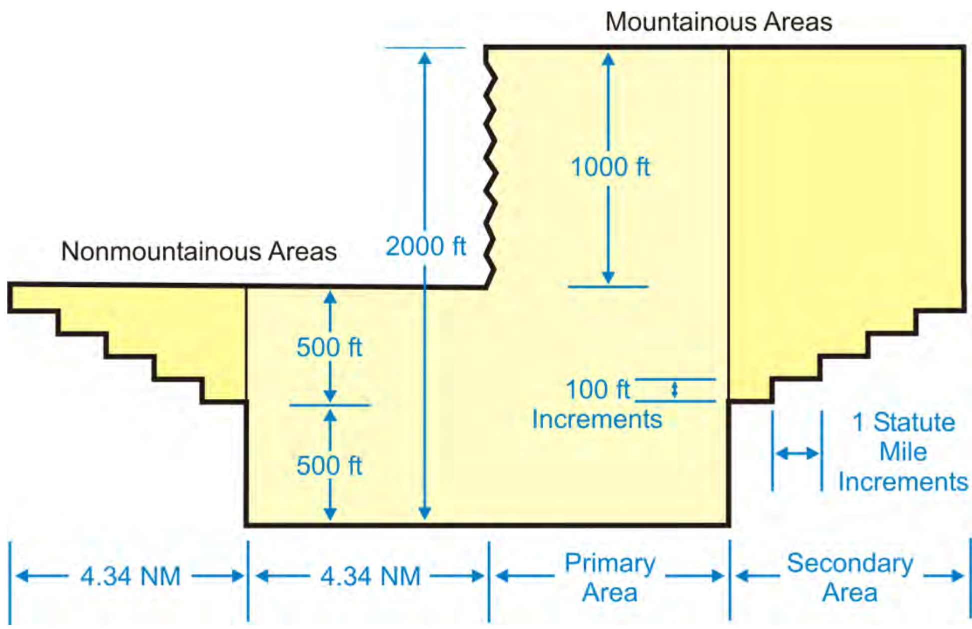
(2) Secondary area obstacle clearance requirements for LF segments are based upon distance from the facility and location of the obstacle relative to the inside boundary of the secondary area.

(a) Within 25 NM of the facility the obstacle clearance is based upon a 50:1 plane drawn from the primary area boundary 500 feet above the obstacle which dictates its MOCA and extending to the edge of the secondary area. When obstacles penetrate this 50:1 plane, the MOCA for the segment will be increased above that dictated for the primary area obstacle as follows (see figure 14-5-3 for cross section view. Also see paragraph 14-5-1.d(2)(c)):

Table 14-5-1. Obstacle Height Increase

Distance from Primary Boundary	Add to Height of Obstacle
0 - 1 SM	500 feet
1 - 2 SM	400 feet
2 - 3 SM	300 feet
3 - 4 SM	200 feet
More than 4 SM	100 feet

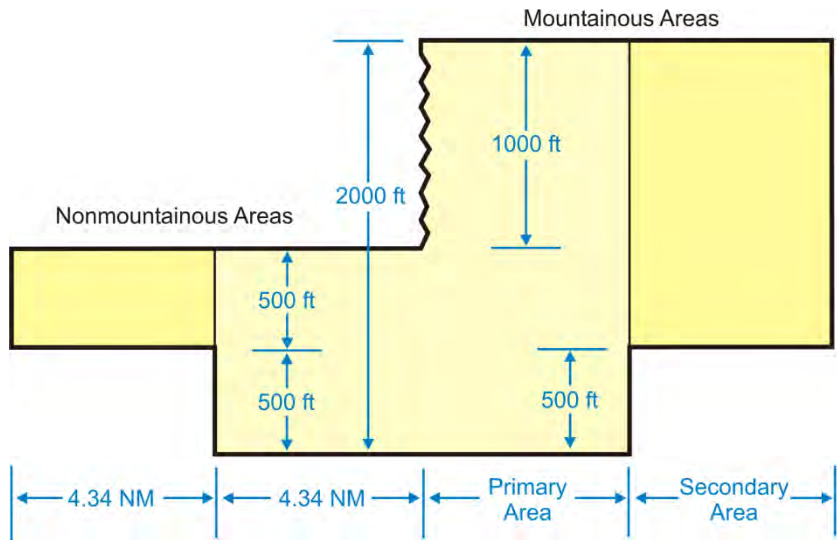
Figure 14-5-3. LG Segment Obstacle Clearance Within 25 NM of En Route Facility



(b) Beyond the 25-NM distance from the facility, the secondary obstacle clearance plane is flat. This plane is drawn from the primary area boundary 500 feet above the obstacle which dictates its MOCA and extending to the edge of the secondary area. If an obstacle penetrates this surface the MOCA for the segment will be increased so as to provide 500 feet of clearance over the obstacle (see Figure 14-5-4 and paragraph 14-5-1.d(2)(c)).

(c) Obstacle clearance values shown in paragraphs 14-5-1.d(2)(a) and 14-5-1d(2)(b) are correct for nonmountainous areas only. For areas designated as mountainous add 1000 feet when the primary obstacle clearance is 2000 feet. Where the primary area MOCA has been reduced to 1700 feet, add 700 feet, and where the primary area MOCA has been reduced to 1500 feet, add 500 feet to the secondary area clearance value.

Figure 14-5-4. LF Segment Obstacle Clearance over 25 NM from En Route Facility



Section 14-6. Minimum Divergence Angles

14-6-1. General.

a. Governing facility. The governing facility for determining the minimum divergence angle depends upon how the fix is determined.

(1) Where the fix is predicated on an off-course radial or bearing, the distance from the fix to the facility providing the off-course radial or bearing is used.

(2) Where the fix is predicated on the radials or bearings of two intersecting airways or routes, the distance between the farthest facility and the fix will be used to determine the angle.

b. Holding. See chapter 16 for minimum divergence angle when holding will be authorized at an intersection.

14-6-2. VHF Fixes.

a. The minimum divergence angles for those fixes formed by intersecting VHF radials are determined as follows:

(1) When both radio facilities are located within 30 NM of the fix, the minimum divergence angle is 30 degrees.

(2) When the governing facility is over 30 NM from the fix, the minimum allowable angle will be increased at the rate of 1 degree per NM up to 45 NM (45 degrees).

(3) Beyond 45 NM, the minimum divergence angle increases at the rate of 1/2 degree per NM.

Example: Distance from fix to governing facility is 51 NM. 51 NM - 45 NM = 6 NM. $6 \times ½ = 3$ additional degrees. Add to the 45 degrees required at 45 NM and get 48 degrees minimum divergence angle at 51 NM.

b. A graph may be used to define minimum divergence angles (see figure 14-6-1). Using the foregoing example, enter the chart at the bottom with the facility distance (51 NM). Move up to the "VHF Fix" conversion line. Then move to the left to read the angle -48 degrees.

14-6-3. LF or VHF/LF Fixes.

a. Minimum divergence angles for LF or integrated (VHF/LF) fixes are determined as follows:

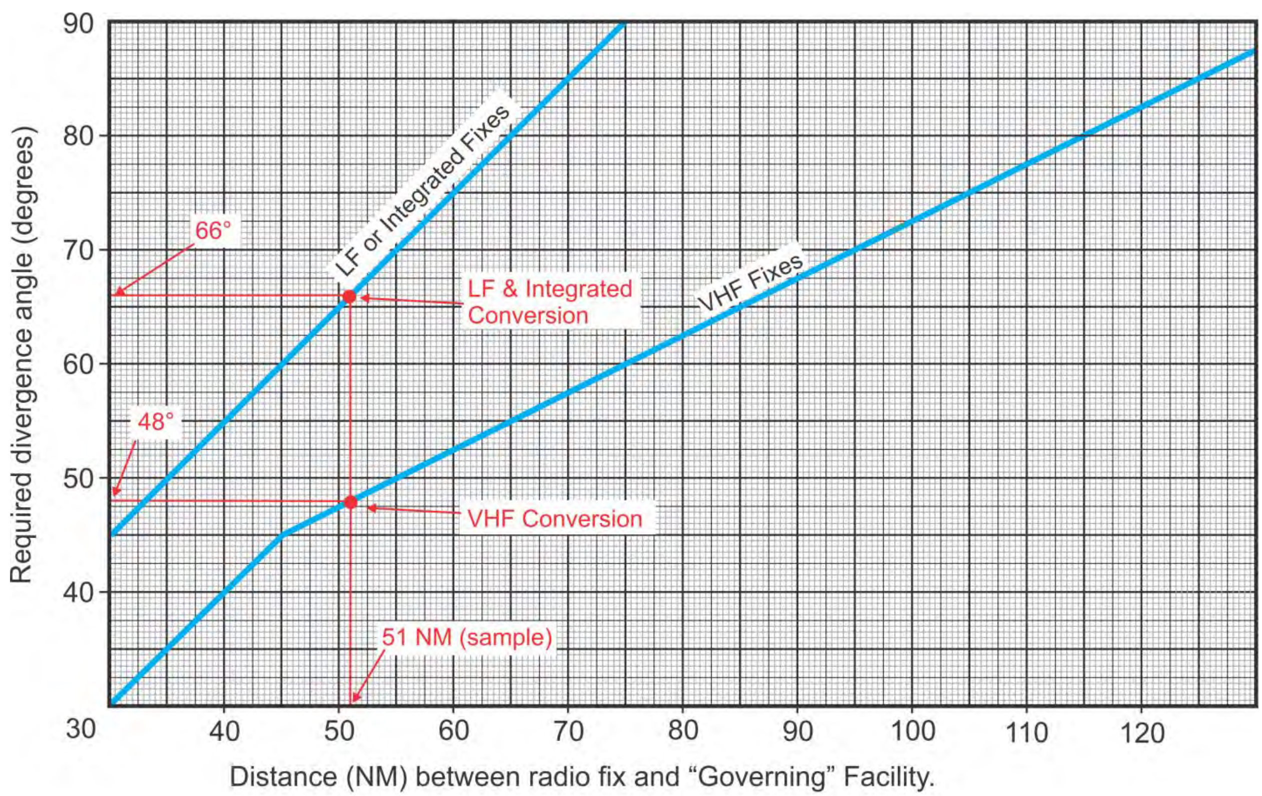
(1) When the governing facility is within 30 NM of the fix, the minimum divergence angle is 45 degrees.

(2) Beyond 30 NM the minimum angle must be increased at the rate of 1 degree for each NM, except for fixes on long overwater routes where the fix will be used for reporting purposes and not for traffic separation.

Example: The distance from the governing facility is 51 NM. 51 NM - 30 NM = 21 NM. 21 × 1 = 21. Add 21 to 45 degrees required at 30 NM to get the required divergence angle of 66 degrees.

b. The graph may be used to define minimum angles for LF or VHF/LF fixes (see figure 14-6-1). Using the foregoing example, enter at the bottom of the chart with the 51 NM distance between facility and fix. Move up to the "LF or INTEGRATED FIX" conversion line, then left to read the required divergence angle, 66 degrees.

Figure 14-6-1. Minimum Divergence Angle for Radio Fix



Chapter 15. Simultaneous Approach Operations

Section 15-1. Simultaneous Independent Approaches Spaced at Least 4300 Feet Apart

15-1-1. Purpose. This section provides TERPS criteria for instrument approaches that are requested for Simultaneous Independent Parallel Instrument Approach (SIPIA) operations. SIPIA operations use approaches, authorized by chart notes, to parallel runways spaced at least 4300 feet apart.

15-1-2. General Guidance. For overview/background for SIPIA, see appendix E.

15-1-3. Types of Approaches. The following types of approaches are authorized to support SIPIA operations.

a. ILS. Include LOC minimums on the same chart unless requested otherwise.

b. GLS.

c. RNAV (GPS) with LPV and/or LNAV/VNAV minimums.

d. RNAV (RNP).

15-1-4. Approach Design. IAPs used for SIPIA operations must comply with the applicable design standards, except as stated in this chapter.

15-1-5. Final Approach Design. Alignment of the FAC should be straight-in along the RCL extended. An offset FAC alignment, as described in paragraph 15-2-5.d, may be used if requested by ATC or a user. No course change is permitted at the FAF/PFAF except as allowed in section 15-5.

15-1-6. Missed Approach Design.

a. Dual widely spaced SIPIA operations. Missed approach courses must have a combined divergence of at least 45 degrees until other means of separation are provided.

b. Triple widely spaced SIPIA operations. The missed approach course for the center runway is a continuation of the FAC. The course for each 'outboard' runway must diverge at least 45 degrees from the center runway in opposite directions. At least one outside parallel must have a turn height specified that is not greater than 500 feet above the airport elevation; this may be rounded up to the next 100-foot MSL increment for the published turn altitude.

c. Quadruple widely spaced SIPIA operations. Missed approach course divergence is as specified by a Flight Research and Analysis Group safety analysis (see appendix E).

d. Alternate missed approach. Where an alternate missed approach has been established for an approach authorized for use during simultaneous operations, it must also comply with the preceding restrictions.

15-1-7. Charting. For additional information see appendix E, section 2, paragraph 6. For charting requirements see Order 8260.19, chapters 4 and 8.

15-1-8. Coordination and Approval.

a. Approval. If a request is received involving any of the following situations, the procedures require approval (see paragraph 1-4-2).

(1) A request for independent approach operation involving runways that are not parallel.

(2) A request for missed approaches with radius-to-fix (RF) turns.

(3) A request for triple or quadruple independent approach operations and one set of parallel runways is closely spaced (see appendix E, sections 2 and 3).

Exception: If the guidance for close spaced runways will be applied to both pairs, then section 15-2 applies and the procedure may be processed without review or approval (see paragraph 1-4-2).

(4) A request for quadruple independent approach operations.

(5) A request to authorize simultaneous independent operations at airport elevations above 6000 feet MSL.

(6) A request for two adjacent airports to have simultaneous independent approach operations.

b. Coordination information. When approach procedures authorize simultaneous operations, the following information must be included in the procedure package as applicable.

(1) Include the type of operation (such as dependent, independent, or both, SCP, SOIA) to be authorized for the approach.

(2) List each simultaneous runway pair/triple/quad and the approaches authorized for simultaneous operations with the approach being submitted.

(3) Indicate the altitude/point where the simultaneous operation will begin (depicted as “Point S” in the figures in the chapter and described in paragraph 15-2-4.b).

(4) Incorrect flight procedure selection information as identified in paragraph 15-5-2.

Section 15-2. Simultaneous Close Parallel (SCP) Approaches Spaced at Least 3000 Feet Apart but Less Than 4300 Feet Apart

15-2-1. Purpose. This section provides TERPS criteria for instrument approaches that are requested for SCP operations to parallel runways spaced less than 4300 feet but at least 3000 feet apart.

15-2-2. General Guidance. IAPs used for SCP operations must comply with the applicable design standards, except as stated in this chapter. For overview/background for SCP, see appendix E.

15-2-3. Types of Approaches. The following types of approaches are authorized to support SCP operations (see appendix E, section 3, paragraph 4 for information on minimums):

a. ILS.

b. GLS.

c. RNAV (GPS) with LPV and/or LNAV/VNAV minimums.

Note: Pilot procedures and flight deck duties for RNP AR operations and PRM have not been evaluated for compatibility, therefore RNP AR is not authorized for these approaches.

15-2-4. Approach Design. Approaches requested to be authorized for simultaneous approach operation to runways spaced at least 3000 feet must have vertical guidance. For GLS and RNAV (GPS) approaches used for SCP, flight director or autopilot and GPS are required.

a. Feeder routes and initial approach segment. The initial approach is normally done by radar vectors, but when requested by ATC may also be made from a NAVAID, fix, or waypoint. SCP approaches are normally published without transition routes (unless requested by ATC). Procedure turn and high altitude teardrop turn procedures must not be included on an SCP approach procedure.

b. Intercept angle/point. If ATC requests a route, instead of or in addition to radar vectors, apply standard design guidance to the initial segment route except the maximum intercept angle between the FAC extended (LOC/RNAV/GLS course/track) and the initial segment (if used) must be limited to reduce the risk of overshooting the FAC extended. The maximum intercept angle for the route is the same (20 degrees or 30 degrees as stated in Order JO 7110.65) as would be used for radar vectors. Also, the intercept point with the FAC extended must be designed to be at or outside the intercept altitude/point (depicted as “Point S” in the figures in this chapter) beyond which ATC no longer provides a minimum of 1000 feet vertical or 3-NM radar separation. Coordinate with ATC if that information is not included in the procedure request.

c. Alignment. No course change between the intermediate segment and final approach segment is permitted at the PFAF except as allowed in section 15-5. This applies to either a straight-in or offset FAC.

15-2-5. Final Approach Design.

a. Alignment of the FAC, for dual runway operations spaced at least 3600 feet. The alignment is recommended to be straight-in along the extended RCL; however, an offset FAC alignment may be used if requested by ATC or a user.

b. Alignment of the FAC, for runways spaced less than 3600 feet. When high update radar is not used, the alignment must have one FAC to be straight-in along the extended RCL and one offset FAC alignment for each runway pair to be authorized for simultaneous operations.

Note: If High Update Radar is used to monitor the no transgression zone (NTZ), the spacing for dual runway operations, the spacing needed for a straight-in FAC alignment and the width of the NTZ may be reduced based on the results of the current NAS-wide studies, or an airport specific study by the appropriate Flight Technologies and Procedure Division's office.

c. Alignment of the FAC, for triple runway simultaneous operations. The center runway FAC must be straight-in along the extended RCL. The outside runway FAC, for runway pairs spaced at least 3900 feet is recommended to be straight-in along the extended RCL, but an offset FAC alignment may be used if requested by ATC or a user. The outside runway FAC, for runway pairs spaced less than 3900 feet, must have the FAC alignment to be offset in the direction away from the center runway FAC. The minimum runway spacing for triples is 3000 feet (the same as for dual runways).

d. Offset FAC. The offset FAC must be aligned at least 2-½ degrees divergent from the other FAC, but not more than 3.0 degrees.

Note: Autopilots with autoland are only used for localizers aligned with the RCL; therefore, Category II and III are not applicable to an offset FAC approach.

e. Obstacle assessment. An obstacle assessment must be performed for all runways using SCP procedures (see section 15-4 and appendix E).

15-2-6. Missed Approach Design. Missed approach procedures for SCP approaches should specify a turn as soon as practical (but not below 400 feet above TDZE, rounded to the nearest foot).

a. Divergence. Missed approach courses, for each pair of SCP procedures, must have a combined divergence of at least 45 degrees until other means of separation are provided.

b. Start of divergence. The 45-degree divergence must be established by 0.5 NM past the most distant DER.

Exception: A distance greater than 0.5 NM is allowed if the NTZ and the controller monitoring (which is established by ATC, not the procedure development specialist) is extended to the point where the 45-degree divergence is achieved (see figure 15-2-1 and figure 15-2-2). Coordinate with ATC, as necessary.

Figure 15-2-1. Missed Approach Divergence Within 0.5 NM of DER

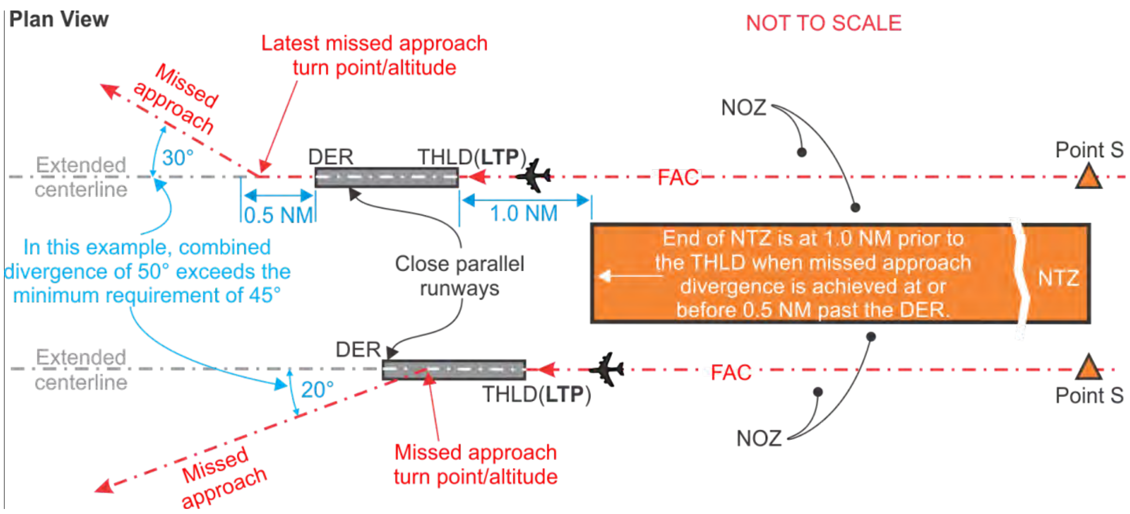
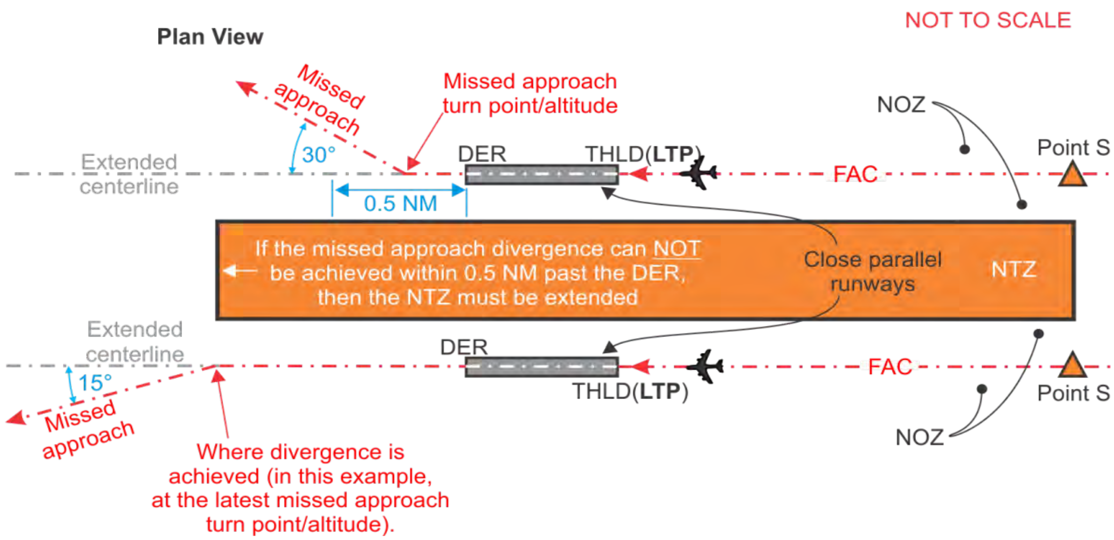


Figure 15-2-2. Missed Approach Divergence Delayed Beyond 0.5 NM



c. Offset FAC design. Where an offset FAC is used, the first missed approach turn point must be established so that the applicable (for the fastest category aircraft expected to utilize the offset FAC) flight track radius must not exceed one tenth of the distance from the landing runway centerline to the adjacent runway centerline (including the extended runway centerlines). The purpose of that requirement is to have the plotted missed approach flight track to not overlap the NTZ or the extension of the edge of the NTZ.

d. Alternate missed approach. Where an alternate missed approach has been established for an approach authorized for use during SCP operations, it must also comply with the preceding restrictions.

15-2-7. Procedure Naming and Charting. A separate instrument approach procedure must be published for each runway in the close parallel pair of runways. Identify SCP procedures by including “PRM” in the title in accordance with paragraph 1-6-2.c. Charting requirements are specified in Order 8260.19, chapters 4 and 8.

15-2-8. Coordination and Approval.

a. Approval. If a request is received involving any of the following situations, the procedures require approval (see paragraph 1-4-2).

(1) A request for independent approach operations involving runways that are not parallel.

(2) Missed approaches with RF turns.

(3) A request to authorize simultaneous operations at airport elevations above 2000 feet MSL.

b. Coordination information. When SCP procedures authorize simultaneous operation, the procedure package must include the information listed in paragraph 15-1-8.b.

c. Attention All Users Page (AAUP). Guidance for developing and processing an AAUP is in Order 8260.19, chapter 8.

d. Obstacle assessment. When an obstacle assessment surface evaluation for breakout situations is available, include that documentation along with the SCP procedure package (see section 15-4 and appendix E for guidance for an obstacle assessment surface evaluation).

Section 15-3. Simultaneous Offset Instrument Approach (SOIA) Runways Spaced at Least 750 Feet Apart but Less Than 3000 Feet Apart

15-3-1. Purpose. This section provides TERPS criteria for SOIA procedures to parallel runways spaced at least 750 feet apart but less than 3000 feet apart.

15-3-2. General Guidance. Apply this section when ATC or the Site Implementation Team (SIT) requests approaches for SOIA operations. Instrument approach procedures used for SOIA operations must comply with the applicable design standard(s), except as stated in this chapter. For overview/background for SOIA, see appendix E.

15-3-3. Types of Approaches. The following types of approaches, with the specified lines of minima, are authorized to support SOIA operations:

a. ILS. For straight-in FAC only.

b. LDA with a glide slope. For offset FAC only.

c. GLS.

d. RNAV (GPS) with LPV and/or LNAV/VNAV minimums.

Note 1: Use of "LOC only" during simultaneous operations has not been evaluated for runways spaced less than 3000 feet; the LOC line of minima is not authorized for SOIA approach procedures.

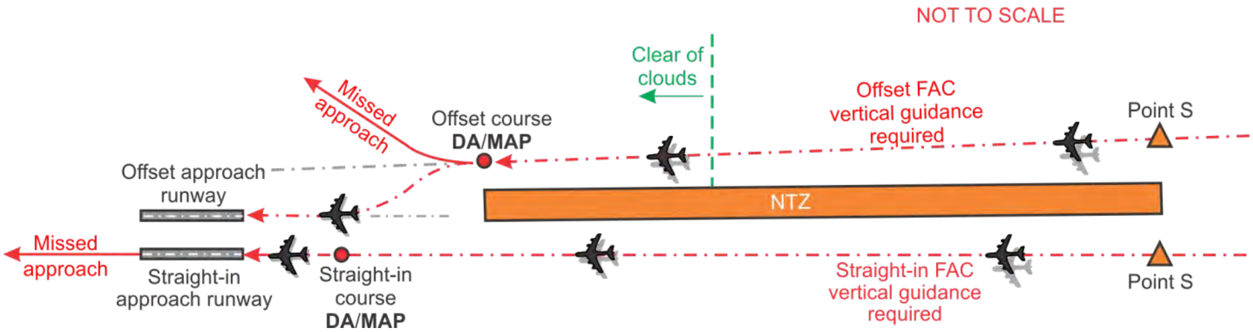
Note 2: LNAV and LP lines of minima are not authorized for SOIA approach procedures.

Note 3: Use of RNAV (RNP) for PRM approaches does not have flight operations authorization and is not authorized for SOIA approach operations.

15-3-4. Approach Design. Approaches designed for SOIA operations must have vertical guidance on final. Flight director or autopilot and GPS is required for approaches used for SOIA; No course change is permitted at the PFAF. For feeder routes, initial approach segment, intercept angle/point and intermediate segment, in a SOIA approach, use the same guidance as for an SCP approach (see paragraph 15-2-4).

15-3-5. Final Approach Segment Design. SOIA approaches contain one straight-in FAC and one offset FAC instrument approach procedure (see figure 15-3-1).

Figure 15-3-1. SOIA Final Approach Segments



a. Straight-in FAC. Alignment must be ± 0.03 degrees of the extended RCL through the LTP (± 5 feet). The option in chapter 10, to offset the course from the RCL, is not allowed for SOIA straight-in approaches. The PFAF must be designed at the same location for all straight-in FAC approaches used for SOIA and the PFAF identified with the same waypoint/fix name. A point abeam the near end of the NTZ must also be identified by a named fix/waypoint. Additionally, for an ILS approach a DME value must be identified for the FAF and a point abeam the near end of the NTZ. For the DME source, use the ILS DME (not from another navigation aid such as a VOR or VORTAC).

b. Offset FAC. Alignment must be at least 2.50 degrees divergent from the procedure with the straight-in FAC, but not more than 3.00 degrees. Localizer-based SOIA offset approach procedures are always identified as "LDA" (instead of ILS) even though the offset may be within three degrees of the RCL extended (see also paragraph 15-3-7.a). The MAP of the offset FAC approach is normally located where the two FACs converge to the minimum distance to conduct simultaneous independent approaches (typically 3000 feet). Note that the lowest SOIA ceiling and visibility minimums are achieved when the DA of the offset FAC is located at the point where the offset and straight-in FACs reach the minimum allowed distance between them. The minimum distance is set by the results of Flight Technologies and Procedures Division safety studies and operational safety assessments and depends on the type of ATC surveillance system used (with or without high update radar, such as PRM) to monitor the NTZ. The TERPS specialist is not responsible for determining the minimum distance; if it is not included with the procedure request, ask the proponent to contact Flight Technologies and Procedures Division.

Exception: The SOIA offset FAC is exempt from the requirement to cross the extended RCL at least 3000 feet from the threshold, but no more than 5200 feet from threshold. The offset FAC extended may intercept the RCL past the threshold and the offset FAC may be more than 500 feet away from the extended RCL at 3000 feet prior to the landing threshold.

Note: Inside of the MAP, the SOIA offset FAC is not used for lateral navigation.

c. Vertical guidance. SOIA instrument procedures must provide vertical guidance on final from the glide slope/glidepath intercept point to the FTP/runway threshold. Exceptions require approval (see paragraphs 1-4-2 and 15-3-7).

d. Offset FAC approach. The approach types that may be used for a SOIA offset FAC PRM approach are LDA DME, RNAV (GPS), and GLS. Use the following design guidance for a SOIA offset FAC approach:

(1) For all approach types, the procedure must be specifically designed for FMC coding purposes. An input should be obtained from Flight Technologies and Procedures Division.

(2) The FAF must be designed at the same location for all offset FAC approaches used for SOIA. Identify each FAF with the same waypoint/fix name. On an LDA approach, a DME value must also be identified for the FAF. For the DME source, use the LDA DME (not from another navigation aid such as a VOR or VORTAC). For all approach types, a fix/waypoint must be identified for the MAP (at the DA point) published on the charted approach. For the LDA approach, the charted MAP must also be identified by an LDA DME distance. For all approach types, the MAP depicted on the instrument procedure is coded on forms (and in the FMC) as a step down fix and the FTP is coded as the MAP. The textual and map descriptions of the missed approach procedure for all approaches commences at the charted MAP (not the FTP). Because the FTP is coded as the MAP, an initial heading is required when executing a missed approach so that the aircraft does not continue toward the FTP. Some FMCs do not code step down fixes. Therefore, ensure that the charted MAP for the approach is identified by a distance from the FTP. The unique nature of the offset SOIA approaches that use an FTP relative to execution of the missed approach procedure should also be addressed as part of the AAUP.

(3) For all types of offset FAC approaches, the following chart note must be added: "When executing a missed approach or go-around, unless otherwise instructed by ATC, initially turn (left/right) to (heading) utilizing heading mode."

(4) The missed approach procedure must initially use a heading. Example: "MISSED APPROACH: Climbing (left/right) turn to (altitude) on heading (degrees), then…"

Note: Beginning at the MAP, the vertical guidance is advisory in nature and may be utilized to assist in conducting a stabilized approach and for wake mitigation purposes while the aircraft is maneuvering visually to align with the runway. The reason for the SOIA design and coding is to achieve vertical guidance to the threshold.

e. Offset FAC approach DA. Determine the published DA for the offset FAC approach using inputs from the Flight Technologies and Procedures Division automated analysis and using the TERPS evaluation steps described below. The Flight Technologies and Procedures Division automated analysis, also called "SOIA Design Program" is performed by the Flight Research and Analysis Group. Determine the DA, as follows:

(1) *Step 1*. Using the offset FAC MAP location and DA, as specified by the automated analysis, identify the corresponding DME fix/distance and waypoint latitude/longitude. The MAP must be designed at the same location for all offset FAC approaches used for SOIA and the MAP identified with the same waypoint/fix name. For an LDA approach, a DME value must also be identified for the MAP. For the DME source, use the LDA DME (not from another navigation aid such as a VOR or VORTAC).

(2) *Step 2*. Evaluate the TERPS final and missed approach segments using the DA from *Step 1*. If any surface is penetrated, resubmit the procedure for further analysis and notify them of the required DA adjustment.

Note: Procedural amendments to the SOIA offset FAC PRM approach (or associated non-SOIA approach) modifying course, revising MAP location, or changing DA/visibility must be resubmitted for an updated automated analysis.

(3) *Step 3*. Use the DA that is the higher of the values derived from the automated analysis or the TERPS obstacle evaluation, as described in steps one and two. Submit the DA (rounded to the upper one foot increment) for publication on the SOIA offset FAC PRM approach and if there is an associated non-SOIA approach, for that approach also.

f. Identical approach. When requested by ATC or the SIT, a separate non-PRM identical approach may also be designed/published for each of the close parallel approaches used for SOIA.

(1) For PRM and non-PRM approaches to be considered identical, approaches to the same runway using the same type of navigation (both use ILS or both use LDA or both use RNAV for example), must contain the same ground tracks, fixes, altitudes, minimums, and missed approach procedures (see examples 1 and 2). Approaches that duplicate those items are considered identical and do not require separate/different identification suffixes. Approaches that do not meet these criteria are not identical and; therefore, require the use of a suffix/different suffix (see examples 3 and 4).

Example 1: (Identical) RNAV (GPS) PRM Rwy 28L and RNAV (GPS) Rwy 28L.

Example 2: (Identical) ILS PRM Y Rwy 28L and ILS Y Rwy 28L.

Example 3: (Not identical) ILS PRM Z Rwy 24R and ILS Rwy 24R.

Example 4: (Not identical) RNAV (GPS) PRM Y Rwy 24R and RNAV (GPS) Z Rwy 24R.

(2) The responsibility of Aeronautical Information Services, when a request is received for identical (SOIA and non-SOIA) approaches, is to use the current criteria for that type of approach with the exceptions indicated in this order. The additional (non-SOIA) approach(es) do not have “PRM” in the identification and do not have the SOIA-related simultaneous operation notes.

g. Visibility minimums for SOIA operations.

(1) Determine the visibility for the offset FAC approach procedure. Note that the distance from the DA (for the offset FAC approach) to the runway threshold (for that approach) is typically the item that limits the visibility value and determines the visibility minimum for SOIA operations.

(2) Determine the visibility for the straight-in approach procedure using standard guidance.

(3) The visibility minimum for conducting SOIA operations will be equal to the higher of the visibility values for the two (straight-in or offset) SOIA approaches. Provide the visibility information to the SOIA SIT so that they can include the higher value as part of the AAUP for each approach.

Process: The procedure specialist receives the output from the SOIA Design Program indicating the distance from the runway to the MAP and the latitude/longitude of the MAP. Using standard visibility guidance, TERPS Specialists calculate the visibility values for both approaches. The TERPS Specialist also provides that information to the SIT so that they can use the higher value for establishing the minimum visibility value in order to conduct SOIA operations. That value goes in the AAUP and to the facility conducting the approach.

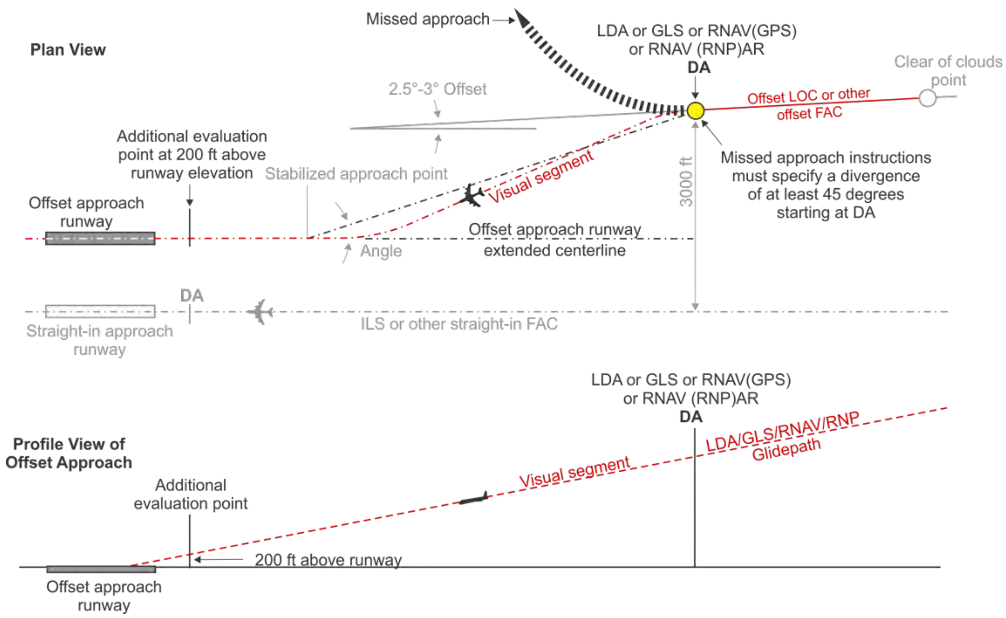
Example: The procedure specialist receives the output from the SOIA Design Program indicating the distance from the LDA DA to the landing runway threshold is 20889 feet. Using standard guidance, the visibility to submit for publication on the LDA PRM approach is 4 SM and the visibility for the ILS PRM approach is 2400 RVR, which the procedure specialist also provides to the SIT. They take the higher visibility value (the higher of 4 SM or 2400 RVR in this example) and submit that value (4 SM in this example) as part of the AAUP as the minimum visibility value for conducting SOIA operations.

h. Visual segment. Evaluate the visual segment using standard guidance (note that the SOIA offset FAC approach visual area will be larger than for a typical approach because of the larger distance from DA to threshold). The offset FAC approach DA must be within the operational coverage of the VGSI. There is no requirement to discontinue SOIA if the VGSI is out of operation; however, night operations will not be possible if the VGSI is used in lieu of obstruction lighting per paragraph 3-3-2.c(4)(b)1.

15-3-6. Missed Approach Design (see figure 15-3-2).

a. Missed approach divergence. For SOIA procedures, an initial divergence of at least 45 degrees until other means of separation are provided. The beginning point for 45-degree divergence must be established at the offset FAC approach MAP. The initial heading of the missed approach (section 2 initial) for the offset FAC approach must be at least 45 degrees divergent from the adjacent (straight-in) FAC.

Figure 15-3-2. Missed Approach Design and Additional Missed Approach Evaluation



b. Offset FAC Approach. Missed approach procedures for SOIA offset FAC approaches must specify a turn to a heading at the MAP (the DA). Use the current TERPS evaluation for the offset FAC type of approach navigation with a turning missed approach.

c. Straight-in Approach. The missed approach procedure for a SOIA straight-in approach is usually straight ahead; it may diverge in a direction away from the offset FAC approach RCL, but must not converge (until other means of separation are provided). The straight-in approach missed approach may use an initial heading/course/track as otherwise allowed by current guidance for missed approach design.

d. Offset FAC approach MAP. The MAP (DA) for the offset FAC approach is determined by the "SOIA design program" (see paragraph 15-3-5.e). If the design program results are not included with the approach procedure request, coordinate with the proponent of the SOIA procedure. Normally the proponent makes the request; but either the proponent or the instrument procedure specialist may submit a request. The request for the SOIA design program must be submitted, in writing, to Flight Technologies and Procedures Division with a copy to Flight Research and Analysis Group.

e. Alternate missed approach. Where an alternate missed approach has been established for an approach authorized for use during SOIA operations, it must also comply with the preceding restrictions.

f. Additional evaluation (for go around). In addition to the missed approach evaluation beginning at the published DA, evaluate an additional missed approach segment from a point on the offset FAC approach runway's extended centerline to determine the impact of obstacles on a go-around executed past the MAP (offset FAC approach DA). For the additional missed approach segment, evaluate an ILS type approach DA on the same glidepath used for the offset FAC approach and on RCL at 200 feet above the TDZE (see figure 15-3-2). Apply the current missed approach TERPS criteria for an ILS approach with a turning missed approach; use the same missed approach heading as is used for the offset FAC approach published missed approach. If such an ILS approach already exists, no additional evaluation is necessary.

Exceptions:

1. If the additional missed approach obstacle evaluation surface is penetrated, calculate the required CG using the current TERPS criteria for an ILS missed approach (from a point on RCL on the glide slope at 200 feet above the touchdown zone elevation). If applicable, specify a CG using the format in Order 8260.19.

   Example: "If go around executed after passing DARNE, go around requires minimum climb of 380 feet per NM to 1800."

2. When the additional missed approach obstacle evaluation surface is penetrated, no DA adjustment calculations are required and no additional automated analysis is needed and no additional lines of minima are required based on this additional evaluation.

   Note: The only mitigation required in this situation is to specify the CG.

15-3-7. Procedure Naming and Charting. Charting requirements are specified in Order 8260.19, chapters 4 and 8.

a. Approach identification. A separate instrument approach procedure must be published for each runway in the SOIA pair of runways. Identify SOIA procedures by including "PRM" in the title in accordance with paragraph 1-6-2.c. Naming is the same as for SCP with the addition that an offset FAC procedure using localizer guidance with glide slope is "LDA PRM Rwy #."

Example 1:	ILS PRM Z RWY 28L (CLOSE PARALLEL)	LDA PRM RWY 28R (CLOSE PARALLEL)
Example 2:	RNAV (GPS) PRM RWY 27L (CLOSE PARALLEL)	RNAV (GPS) PRM Y RWY 27R (CLOSE PARALLEL)

15-3-8. Coordination and Approval.

a. Approval. If a request is received involving any of the following situations, the procedures require approval (see paragraph 1-4-2).

(1) A request for SOIA approach operation involving runways that are not parallel.

(2) Missed approaches with radius-to-fix (RF) turns.

(3) A request for triple or quadruple independent approach operations and any set of runways is to be used for SOIA operation.

(4) A request to authorize simultaneous operations at airport elevations above 2000 feet MSL.

(5) A request for temporary use of a SOIA instrument procedures without vertical guidance on final from the glide slope/glidepath intercept point to the runway threshold. Exceptions for temporary ground equipment outages, airborne equipment limitations, or special circumstances require approval (see paragraph 1-4-2).

(6) Runways spaced less than 750 feet apart require additional analysis and approval (see paragraph 1-4-2).

(7) All SOIA procedures require approval in regard to wake turbulence mitigation (see paragraph 1-4-2).

b. Coordination information. When SOIA procedures authorize simultaneous operation, the procedure package must include the information listed in paragraph 15-1-8.b.

c. AAUP. Guidance for developing an AAUP is in Order 8260.19, chapter 8.

d. Obstacle assessment. When an obstacle assessment surface evaluation for breakout situations has been completed, include that documentation along with the SOIA procedure package (see section 15-4 and appendix E for guidance for an obstacle assessment surface evaluation).

Section 15-4. Breakout Obstacle Assessment for Simultaneous Independent Parallel Instrument Approach Operations

15-4-1. Scope. A breakout obstacle assessment must be completed as part of the planning/evaluation for simultaneous independent approach operations to close parallel runways. For other simultaneous approach operations, this assessment may be used.

15-4-2. Assessment. The breakout obstacle assessment includes the following:

a. Refer to the most recent diverse departure assessment for the reciprocal runway. For example, if the simultaneous approach is to runway 17L, then refer to the diverse departure assessment for runway 35R.

b. Provide the results of the diverse departure assessment (all surfaces clear or a list of all penetrating obstacles) to the procedure requester (typically the SIT or ATC facility). The electronic output from the diverse departure assessment is an acceptable means of documenting the results.

c. The SIT or ATC facility has the option of using all of the obstacle penetrations identified by the diverse departure assessment. If all obstacles are to be used, proceed with paragraph 15-4-3 below, otherwise determine if any of the obstacle penetrations identified in paragraph 15-4-2.b also penetrate any of the parallel approach obstruction assessment surfaces described in appendix E, section 6, paragraph 2. Obstacles that do not penetrate any of the parallel approach obstruction assessment surfaces may be ignored. The remaining (penetrating) obstacles must be considered under paragraph 15-4-3.

15-4-3. Obstacle Penetration Mitigations. Penetrating obstacles must be mitigated by the ATC facility through accomplishment of one or more of the following actions. A safety risk analysis may be helpful in identifying the most appropriate action(s):

a. Remove or lower the obstacles (if practicable).

b. Establish local procedures for avoiding the penetrating obstacles when breakouts occur.

c. Display penetrating obstacles on the controller’s radar display to aid in avoidance during breakouts.

15-4-4. Periodic Review. The breakout obstacle assessment is subject to the periodic review requirements specified within section 2-8 of Order 8260.19.

Section 15-5. Simultaneous Independent Procedures Considered Established on a PBN Segment of a Published Instrument Approach

15-5-1. Purpose. This section provides design criteria for Performance Based Navigation (PBN) instrument approaches intended for simultaneous operations that allows ATC to discontinue 1000 feet or 3-NM separation once the aircraft is established on an approved PBN segment of an approach, in accordance with the Established on RNP (EoR) concept.

15-5-2. Approach Design. Apply Order 8260.58, and 8260.19 and sections 15-1 and 15-2 of this order along with the following requirements.

a. Additional requirements:

(1) Only RNAV (GPS) and RNAV (RNP) procedures are authorized.

(2) Use of GPS is required.

(3) Use of flight director (FD) or auto pilot (AP) is required.

(4) When designing a procedure to an offset FAC or a procedure paired with and offset FAC, the final roll-out point on the offset FAC must be at least 3600 feet for dual operations or 3900 feet for triple operations from the final roll-out point to the FAC extended of the paired approach.

(5) When designing procedures from the same side of the FAC, the paired approach tracks must be no closer than 3 NM from each other until being monitored by a final monitor controller.

(6) Airspeed restrictions.

(a) TF legs. Establish an airspeed restriction not faster than 180 KIAS at or prior to the start fix of the FAC intercept leg.

(b) RF legs. Establish an airspeed restriction for the start waypoint of an RF leg that joins the FAC using along-track distance (see table 15-5-1).

Table 15-5-1. RF Max Airspeed Restriction

RF leg length	Max KIAS
≥ 4NM	210
≤ 4NM ≥ 3NM	200
≤ 3NM ≥ 2NM	190
≤ 2NM	180

15-5-3. Track Separation. The approach design must provide for aircraft to become established on a unique initial or intermediate approach segment associated with the simultaneous approach procedure. A initial or intermediate approach segment is considered unique when separated by at least 0.5 NM from the track of any other RNAV (GPS) or RNAV (RNP) approach. In addition, an initial or intermediate approach segment is considered unique even if it does not have a unique track if latter segments of the approach provide a unique track for at least 50 seconds prior to crossing the first FAC (see formula 15-5-1). The unique track allows ATC adequate time to identify that an aircraft is not flying the expected track due to selection of an incorrect flight procedure. The track separation must be continued until crossing the first FAC. See figure 15-5-1 for a conceptual example of required track separation with TF legs; see figure 15-5-2 for an example with RF legs.

Formula 15-5-1. Incorrect Flight Procedure Separation Distance

$$D = \frac{(V_{KTAS} + V_{KTW}) \times 50}{3600}$$

Figure 15-5-1. Incorrect Flight Procedure Selection (TF Legs)

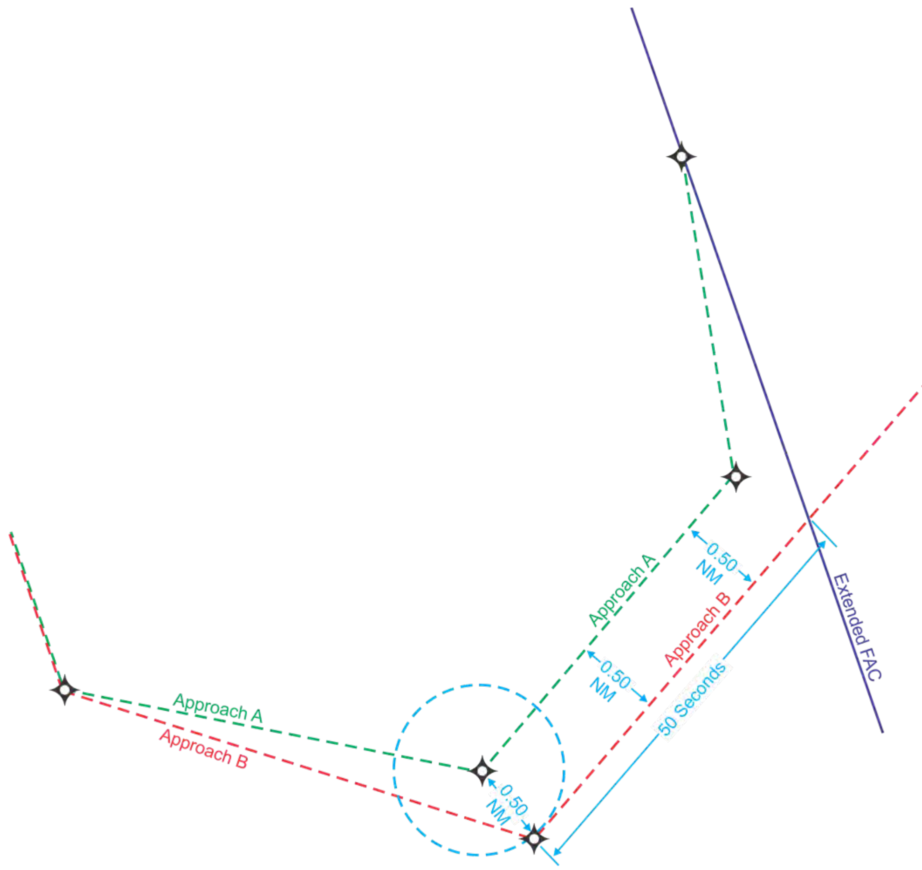
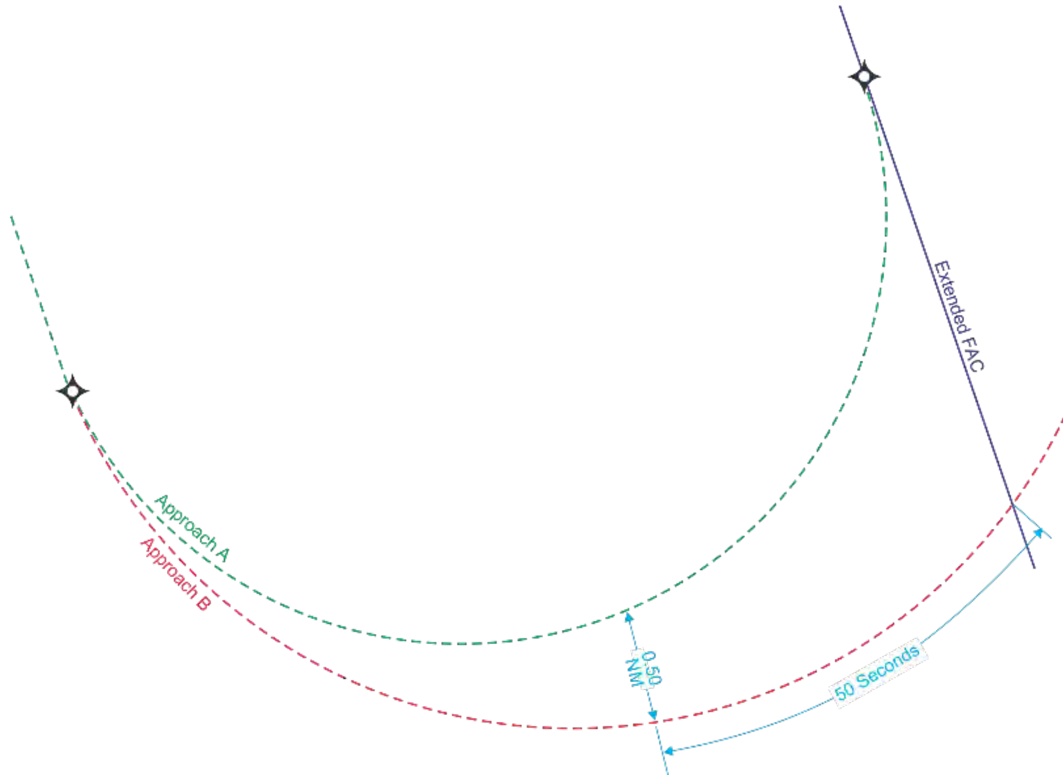


Figure 15-5-2. Incorrect Flight Procedure Selection (RF Legs)



15-5-4. Alignment.

a. FAC offsets. Offsets must be divergent from other paired FAC, regardless of spacing.

b. FAC intercept. To decrease the probability of overshoots and to minimize FMA and TCAS alerts, the following restrictions apply;

(1) TF legs.

(a) The intercept angle of the last leg prior to FAC (intercept leg) must be 10 degrees or less.

(b) The start fix of the intercept leg must be at least 0.2 NM from the closest point on the FAC (extended).

(c) The leg preceding the intercept leg must converge with the FAC (extended) at an angle of 60 degrees or less.

(2) RF legs. For designs using multiple consecutive RF legs to join the FAC, the arc radius of the leg joining the FAC must be the same or larger than the arc radius of any preceding RF leg.

Chapter 16. Basic Holding Criteria
Section 16-1. Pattern Design Assumptions

16-1-1. Development Concept. Efficient and economical use of airspace requires standardization of aircraft entry and holding maneuvers. These criteria incorporate factors which affect aircraft during these maneuvers.

16-1-2. Turn Effect. Pilot procedures contained in the Aeronautical Information Manual specify 30 degrees of bank (or a standard rate turn, whichever requires the least bank) for entry and holding pattern turns. However, due to factors such as instrument precision, pilot technique, ballistic effect, etc., a constant 30 degrees of bank is seldom achieved. To compensate for this, these criteria are based on 25 degrees of bank.

16-1-3. NAVAID Ground and Airborne System Tolerance. The basic holding criteria apply to conventional NAVAIDs such as VOR, a VOR with DME, and/or NDB, TACAN, and LOC/DME. The FAA uses the term VOR/DME generically throughout this chapter for all single DME type systems to avoid confusion with DME/DME. These criteria contain allowances for:

a. Cone of ambiguity: related to altitude, and

(1) System error: ± 5 degrees,

(2) Aircraft Course Indicator: ± 10 degrees for full instrument deflection, and

(3) Total tolerance of (1) and (2): 15 degrees.

b. Intersection disparity: related to system error, and

(1) Distance of the holding point from the furthest NAVAID,

(2) Overhead “to-from” error: 4 degrees, and

(3) Delay in recognizing and reacting to fix passage: six seconds for entry turn, applied in the direction most significant to protected airspace.

16-1-4. Effect of Wind. Analysis of winds recorded at various levels over a five-year period led to the adoption of a scale of velocities beginning with 50 knots at 4000 feet MSL and increasing at a rate of three knots for each additional 2000 feet of altitude to a maximum of 120 knots.

16-1-5. Development. Develop holding to accommodate the performance capabilities of pertinent civil and military aircraft. Evaluate the full size of the holding pattern primary and secondary areas for obstacle clearance, with no fix-end or outbound-end reduction applied. Do not permit the use of smaller pattern number/pattern sizes for “on-entry” procedures.

16-1-6. Application in the National Airspace System (NAS). Holding airspace area dimensions permit use of all types of holding when the operational assumptions for flying the aircraft are complied with.

16-1-7. Uncharted holding. Holding over a fix in the NAS that does not have a charted holding pattern is not addressed in this order.

16-1-8. Air Traffic Operations. ATC assumes responsibility for obstacle clearance when giving authorization for an aircraft to hold at other than a charted holding pattern, above the maximum altitude considered in the holding pattern design, or at airspeeds above those considered in the design. When depicting holding pattern airspace areas ATC will only use the primary area.

Section 16-2. Pattern Components

16-2-1. Area.

a. Primary Area. Dimensions for manual construction, and templates discussed in this document define only the primary area of the holding pattern (see section 16-3).

b. Secondary Area. A secondary area 2 NM wide surrounds the perimeter of the primary area in all cases. (Note: Secondary areas are used for obstacle clearance purposes only.)

c. When paragraph 16-7-3 is used, the primary holding area must encompass the departure or missed approach segment width at the holding fix (see figure 16-7-1).

16-2-2. Outbound Leg Length. Base the outbound leg length on either time or distance. Standard time values are one minute for altitudes from the MHA through 14000 feet and 1- ½ minutes at altitudes above 14000 feet. Establish the distance value of the outbound leg consistent with section 16-13 for VOR/DME, or with section 16-10 for RNAV.

16-2-3. Maximum Holding Airspeed.

a. Develop holding patterns based upon maximum airspeeds of table 16-2-1, with the exception of Increased Airspeed Holding Operations defined in section 16-12. Holding patterns developed at other than the standard airspeeds must be annotated in order for pilots and controllers to know that either slower airspeeds are required, or higher airspeeds are allowed.

Table 16-2-1. Maximum Holding Airspeeds

Maximum Holding Airspeed through 6000 feet	200 KIAS
Above 6000 feet through 14000 feet	230 KIAS
Above 14000 feet	265 KIAS

Note: At USAF airfields, the maximum holding airspeed is 310 KIAS unless otherwise noted. At USN airfields, the maximum holding airspeed is 230 KIAS unless otherwise noted. Annotate procedures at Joint-Use airports, designed to accommodate increased airspeed holding, since military airspeeds cannot be assumed.

b. Where operationally necessary, restrict civil holding patterns to the following speeds when the procedure has the restriction annotated:

(1) 175 KIAS at altitudes from MHA to 18000 feet MSL, as part of an instrument approach procedure that is restricted for use by CAT A and B aircraft only. A 175 KIAS holding pattern is non-standard and is highly discouraged. Development of 175 KIAS holding patterns must only be accomplished to avoid obstacles and terrain.

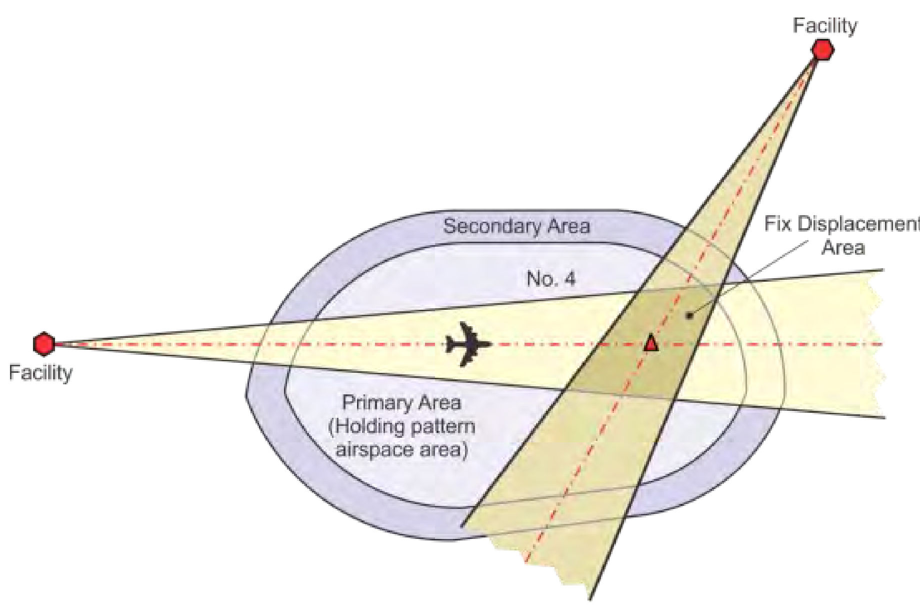
(2) 210 KIAS at altitudes above 6000 feet through 14000 feet MSL.

16-2-4. Obstacle Clearance for Level Holding. Apply criteria in section 14-2 for holding in en route, STAR and feeder segments. Apply criteria in paragraph 2-4-3.c for holding in arrival at IAF, hold-in-lieu, holding associated with a DP, and missed approach holding associated with an IAP. Establish minimum holding altitude in 100-foot increments. The selected altitude must provide the minimum ROC (plus adjustments when applying paragraph 3-2-2.b); for example, when obstacle elevation plus ROC and adjustments equals 1501, round up to 1600 feet (see section 16-7 for climb-in-hold obstacle evaluation).

16-2-5. Communications. Require communications on appropriate ATC frequencies (as determined by Air Traffic Service) throughout the entire holding primary pattern area from the MHA up to and including the maximum holding altitude. Increase the MHA if communications are not satisfactory at the MHA, as set forth in Order 8200.1.

16-2-6. Intersection Fix. When holding at an intersection fix the selected pattern must be large enough for the primary area to contain at least three corners of the fix displacement area (see figure 16-2-1 and paragraphs 2-9-5 and 2-9-6).

Figure 16-2-1. Holding Pattern Number Application

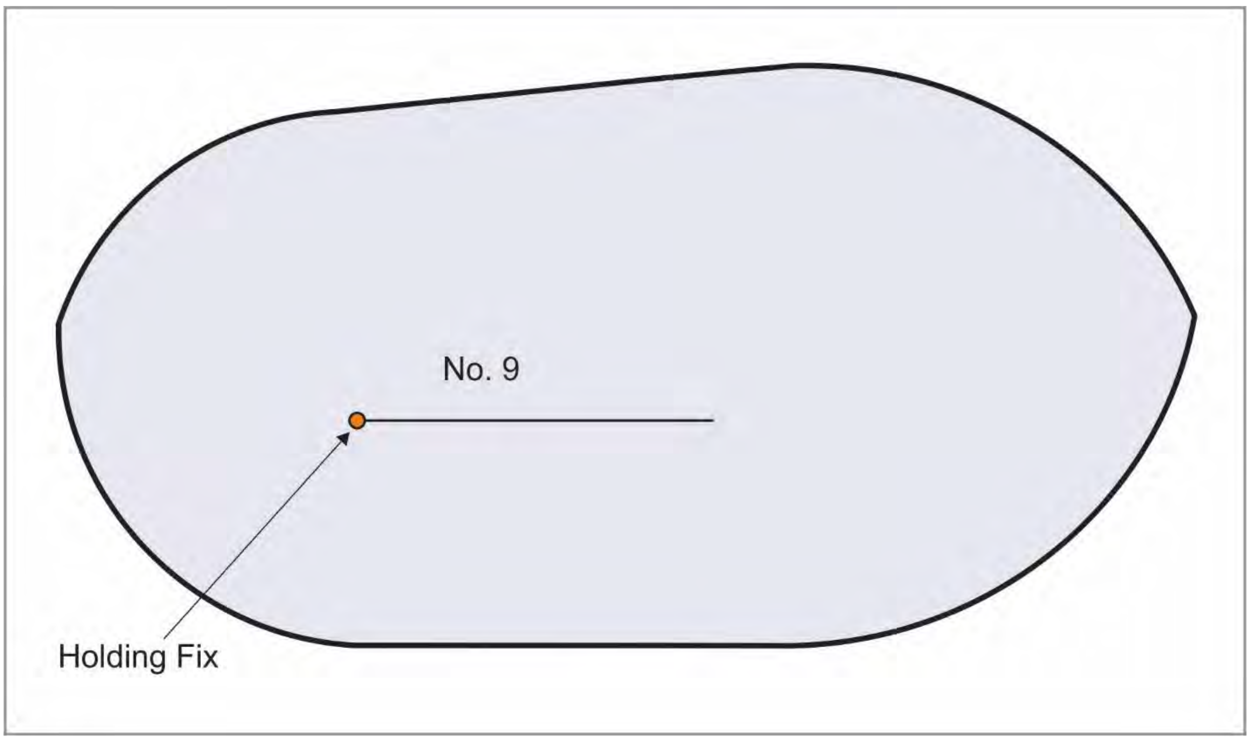


Section 16-3. Primary Area Size Determination

16-3-1. Size and Numbering. Each pattern size is related to one or more even-numbered altitudes/flight levels and is identified by a pattern number for easy reference. There were originally 31 holding pattern sizes defined, which were commonly referred to as templates, since plastic templates were generally used to speed construction. With the change to automated construction in most cases today, the term template has been dropped except in cases specifically referring to the use of the plastic templates. Pattern sizes one to three are no longer in use. The size is fixed for a given pattern number; however, the placement of the protected area varies depending on whether slant-range is a factor in the navigation system or not.

16-3-2. Pattern Numbers. The dimensions provided for each pattern number are used to determine holding airspace obstacle protection. Figure 16-3-1 shows the shape of the protected airspace primary area, the size varies by the pattern number.

Figure 16-3-1. Holding Pattern Primary Area



16-3-3. Altitude Levels. Table 16-3-1, Holding Pattern Selection Chart, provides holding levels from MHA to FL 500 at intervals of 2000 feet. Holding at 2000 feet and below requires use of the appropriate pattern for 2000 feet. Holding at higher even altitudes requires use of appropriate altitude/flight level patterns as listed in table 16-3-1. Holding at odd altitudes above 2000 feet is determined by use of the next higher even altitude/flight level pattern.

Table 16-3-1. Holding Pattern Selection Chart

Fix-to-NAVAID Distance		
0-14.9 NM	**15 - 29.9 NM and RNAV**	**30 NM and Over**
Altitude – Pattern No.	**Altitude – Pattern No.**	**Altitude – Pattern No.**
175 KIAS		
2000 – 4	2000 – 4	2000 – 4
4000 – 4	4000 – 4	4000 – 4
6000 – 4	6000 – 4	6000 – 4
8000 – 4	8000 – 4	8000 – 5
10000 – 4	10000 – 5	10000 – 6
12000 – 5	12000 – 6	12000 – 7
14000 – 6	14000 – 7	14000 – 8
16000 – 7	16000 – 8	16000 – 9
FL 18 – 8	FL 18 – 9	FL 18 – 10
FL 20 – 8	FL 20 – 9	FL 20 – 10
FL 22 – 9	FL 22 – 10	FL 22 – 11
FL 24 – 10	FL 24 – 11	FL 24 – 12
FL 26 – 11	FL 26 – 12	FL 26 – 13
FL 28 – 12	FL 28 – 13	FL 28 – 14
FL 30 – 13	FL 30 – 14	FL 30 – 15
200 KIAS		
2000 - 4	2000 - 4	2000 - 5
4000 - 4	4000 - 5	4000 - 6
6000 - 5	6000 - 6	6000 - 7
210 KIAS		
8000 – 6	8000 – 7	8000 – 8
10000 – 7	10000 – 8	10000 – 9
12000 – 7	12000 – 8	12000 – 9
14000 – 8	14000 – 9	14000 - 10
230 KIAS		
2000 – 5	2000 – 6	2000 – 7
4000 – 6	4000 – 7	4000 – 8
6000 – 7	6000 – 8	6000 – 9
8000 – 8	8000 – 9	8000 – 10
10000 – 9	10000 – 10	10000 – 11
12000 – 9	12000 – 10	12000 – 11
14000 – 10	14000 – 11	14000 – 12
16000 – 12	16000 – 13	16000 – 14
FL 18 – 13	FL 18 – 14	FL 18 – 15
FL 20 – 14	FL 20 – 15	FL 20 – 16
FL 22 – 15	FL 22 – 16	FL 22 – 17
FL 24 – 16	FL 24 – 17	FL 24 – 18
FL 26 – 17	FL 26 – 18	FL 26 - 19

Table 16-3-2 (Continued). Holding Pattern Selection Chart

Fix-to-NAVAID Distance		
0-14.9 NM	**15 - 29.9 NM and RNAV**	**30 NM and Over**
Altitude – Pattern No.	**Altitude – Pattern No.**	**Altitude – Pattern No.**
230 KIAS		
FL 28 – 18	FL 28 – 19	FL 28 – 20
FL 30 – 19	FL 30 – 20	FL 30 – 21
FL 32 – 20	FL 32 – 21	FL 32 – 22
FL 34 – 21	FL 34 – 22	FL 34 – 23
FL 36 – 22	FL 36 – 23	FL 36 – 24
FL 38 – 23	FL 38 – 24	FL 38 – 25
FL 40 – 24	FL 40 – 25	FL 40 – 26
FL 42 – 25	FL 42 – 26	FL 42 – 27
FL 44 – 26	FL 44 – 27	FL 44 – 28
FL 46 – 27	FL 46 – 28	FL 46 – 29
FL 48 – 28	FL 48 – 29	FL 48 – 30
FL 50 – 28	FL 50 – 29	FL 50 – 30
265 KIAS		
2000 – 7	2000 – 8	2000 – 9
4000 – 8	4000 – 9	4000 – 10
6000 – 9	6000 – 10	6000 – 11
8000 – 10	8000 – 11	8000 – 12
10000 – 11	10000 – 12	10000 – 13
12000 – 12	12000 – 13	12000 – 14
14000 – 13	14000 – 14	14000 – 15
16000 – 15	16000 – 16	16000 – 17
FL 18 – 16	FL 18 – 17	FL 18 – 18
FL 20 – 17	FL 20 – 18	FL 20 – 19
FL 22 – 18	FL 22 – 19	FL 22 – 20
FL 24 – 19	FL 24 – 20	FL 24 – 21
FL 26 – 20	FL 26 – 21	FL 26 – 22
FL 28 – 21	FL 28 – 22	FL 28 – 23
FL 30 – 22	FL 30 – 23	FL 30 – 24
FL 32 – 23	FL 32 – 24	FL 32 – 25
FL 34 – 24	FL 34 – 25	FL 34 – 26
FL 36 – 25	FL 36 – 26	FL 36 – 27
FL 38 – 26	FL 38 – 27	FL 38 – 28
FL 40 – 27	FL 40 – 28	FL 40 – 29
FL 42 – 28	FL 42 – 29	FL 42 – 30
FL 44 – 28	FL 44 – 29	FL 44 – 30
FL 46 – 29	FL 46 – 30	FL 46 – 31
FL 48 – 31		

Notes:
1. Columns are used based on the distance column header for conventional holding.
2. Use the 15-29.9 NM column to determine the pattern number used for RNAV patterns.

16-3-4. Fix-to-NAVAID Distances. Fix-to-NAVAID distance is the measured ground distance in nautical miles from the holding fix to the NAVAID. Apply separately slant-range, or DME distance. Pattern number sizes are shown for three ranges of fix-to-NAVAID distances: 0-14.9 NM, 15-29.9 NM, and 30 NM and over. When a fix is based on two NAVAIDs, use the greatest fix-to-NAVAID distance for pattern number determination. This applies to any type or combination of NAVAIDs used to establish a holding fix.

16-3-5. Pattern Applicability. Table 16-3-1, contains fix-to-NAVAID distance columns, airspeed sections, which lead you to the correct altitude level, and pattern number pairing. Additional information concerning special purpose holding patterns for turbulent air/maneuvering speed, climb-in-hold, descend-in-hold, helicopter and RNAV are contained in the appropriate section.

16-3-6. Pattern Selection. Analyze holding patterns incrementally for all altitudes requested by ATC and for all applicable speeds. Apply appropriate obstacle clearance to all obstacles within each pattern number area. Save some time by initially evaluating the patterns for the highest speed. If the same controlling obstruction or minimum holding altitude results, document the obstruction and the associated smaller pattern number; the evaluation is complete. If the minimum holding altitudes differ, a more detailed incremental analysis is necessary.

Example Problems:

1. For crossing radial based holding, assume that civil aircraft are to hold at a fix located 32 NM from the farthest NAVAID used to form the fix. Altitudes involved are 8000 feet through 14000 feet. From table 16-2-1, select airspeed of 230 KIAS. By reference to table 16-3-1, select pattern number 10 to determine the area to be protected for 8000 feet; number 11 for 9000/10000 feet; number 11 for 11000/12000 feet; number 12 for 13000/14000 feet. Apply each pattern number to the fix individually to determine obstacle clearance.

2. For restricted airspeed, assume that a 175 KIAS restricted holding pattern is to be developed at a fix located 12 NM from the farthest NAVAID used to form the fix. Altitudes involved are 2000 feet through 12000 feet. Reference to table 16-3-1, indicates use of pattern number five (12000 feet). When it is applied to the fix, no conflict with obstacles is indicated between 12000 feet and 5000 feet. However, a conflict at 4000 feet and below exists. Reference to table 16-3-1, indicates use of pattern number four for 4000 feet and below. If pattern number four does not conflict with the obstacle, it can be published as requested, otherwise the minimum holding altitude would be restricted to 5000 feet. Chart the holding pattern with the holding speed cartographic icon restriction due to the airspeed.

Section 16-4. DME Applications with Slant-Range

16-4-1. Slant-Range Effect. VOR/DME, TACAN, and other systems using a single DME such as NDB/DME and LOC/DME, measure the distance from the aircraft receiver to the NAVAID; therefore, the horizontal distance from the aircraft to the NAVAID decreases with altitude even though the indicated distance remains the same. An airborne VOR/DME reading of 5 NM at FL 300 would indicate that an aircraft is directly over the NAVAID. The location of an aircraft with the same 5 NM indicated VOR/DME distance at altitudes between overhead the fix and the surface would form an arc beginning over the NAVAID to a point on the surface 5 NM from the NAVAID. Therefore, near the surface, a holding fix could be 5 NM horizontally from the NAVAID, but at 13000 feet, it would be 4.52 NM horizontally from the NAVAID. In this instance, 5 NM is the fix-to-NAVAID distance, which is the distance from the plotted position of the holding fix to the NAVAID, and 4.52 NM is the slant-range/geographical distance, which is the horizontal (geographic) distance from where the aircraft would be located at the maximum holding altitude to the NAVAID. When establishing a VOR/DME holding fix, determine the difference between fix-to-NAVAID and slant-range/geographical distance to ensure the holding fix is not too close to the NAVAID (inside the no-course signal zone). Govern differences by requirements in paragraph 16-4-4.

16-4-2. Determining VOR/DME Distances. Use the slant-range formulas in section 16-14 to accurately determine the height above the NAVAID, slant-range, slant-range/ geographical and fix-to-NAVAID distances, as well as the differences between those values used to determine pattern placement. Figure 16-14-1 illustrates the relationship between the distances. First, use formula 16-14-1 to determine the height of the maximum holding altitude above the NAVAID, since that value is required by most of the other formulas. Multiple formulas are required to determine the final value in many cases.

16-4-3. No-Course-Signal Zone. Calculate no-course-signal zone information using formula 16-14-4 or formula 16-14-5 to determine the minimum fix-to-NAVAID distance at the maximum holding altitude. Do not establish VOR/DME fixes within the no-course-signal zone. Course information may be available at distances less than the minimum derived from the formulas; however, no waiver of these minimums is permitted.

16-4-4. Fix Distance Variances. For the purpose of accurate plotting of holding pattern airspace, differences between fix-to-NAVAID and slant-range/geographical distance can be significant. When establishing or changing the use of a VOR/DME holding fix, use the following guidance to determine how the distance differences are applied:

a. Use whole NM for slant-range distance where possible on non-RNAV procedures. In all cases, do not publish distances less than tenths.

Example: It is desired to hold aircraft at the minimum VOR/DME distance at 10000 feet. Formula 16-14-5 shows the intersection of the 10000 feet altitude line and the edge of the no-course-signal zone occurs at a fix-to-NAVAID distance of 2.35 NM. Using formula 16-14-2 the slant-range is 2.86 NM. Slant-range distance should normally be rounded up for ease of use by aircrews in VOR/DME holding, and to avoid placing the fix in the no signal area. Therefore, holding should be based on a 3 NM VOR/DME fix.

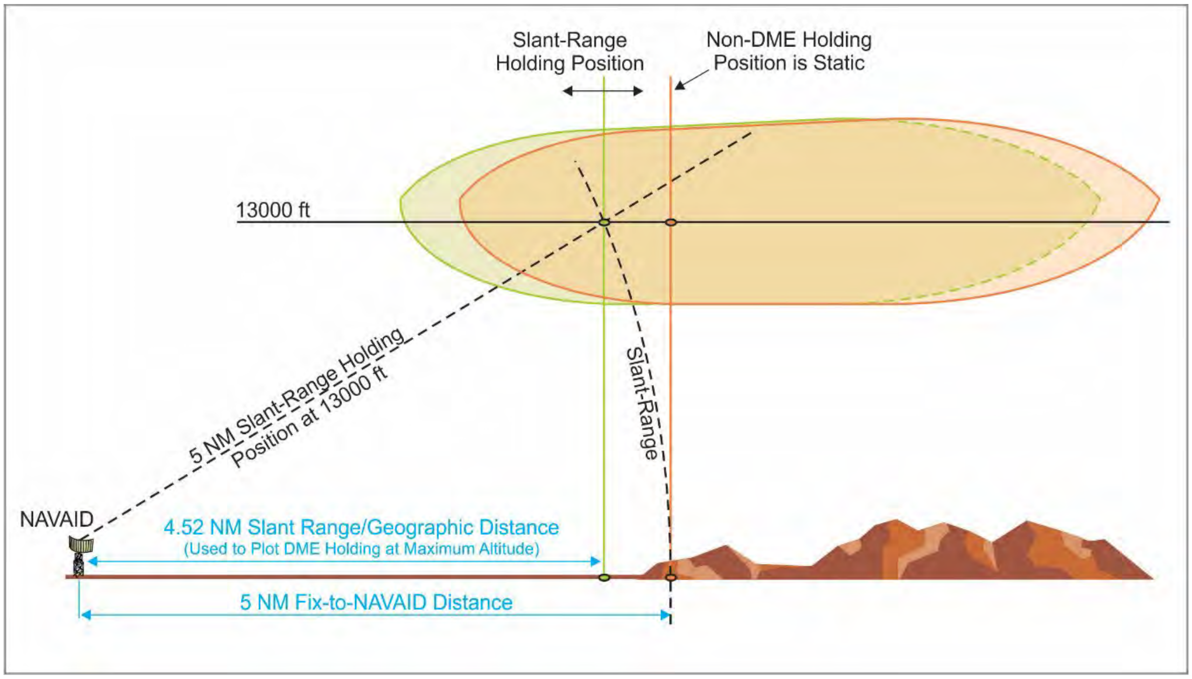
b. When slant-range/geographical distance differs .25 NM or less from fix-to-NAVAID distance, the difference may be disregarded 14000 feet and below. A difference of 0.5 NM or less may be disregarded above 14000 feet (see formula 16-14-8 to compute the difference).

c. When a VOR/DME slant-range holding fix will be collocated with another established fix, which is not based on slant-range, including GPS and RNAV, (see section 16-10) and the distance from the fix to the NAVAID forming the holding course is also used as the VOR/DME slant-range distance, significant variances per paragraphs 16-4-4.a and 16-4-4.b may exist. Plotting of protected holding pattern airspace may be affected. Significant variances must be governed by the following:

(1) Since holding patterns often are used in multiple procedures, and RNAV substitution is allowed in conventional holding, both slant-range and without slant-range operations must be accommodated in holding patterns designed for VOR/DME. Either VOR/DME and VOR intersection holding, or other non-DME protected holding airspace, must be plotted at the VOR intersection/non-DME location and re-plotted at the slant-range/geographical distance. See formula 16-14-7 and formula 16-14-8 to convert the fix-to-NAVAID distance for the non-DME fix to slant-range/geographic distance at the maximum holding altitude, and apply in the proper direction for holding toward or away from the NAVAID. The perimeter of the two plots outlines the primary airspace to be protected (see figure 16-4-1). The published holding distance is the fix-to-NAVAID distance; however, the slant-range/geographic distance must be outside the no-course signal zone. Use formula 16-14-4 or formula 16-14-5 to check that the newly determined slant-range/geographic distance is not inside the no-course signal zone.

Example: Establish a VOR/DME fix for holding at FL 200 and below, at 30 NM fix-to-NAVAID distance. Reference formula 16-14-7 and formula 16-14-8 and compute the slant-range/ geographical distance associated with 30 NM, which is 29.82 NM. The difference of .18 NM may be disregarded in protected airspace plotting. However, if the desired fix-to-NAVAID distance was changed to 10 NM, the slant-range/geographical distance becomes 9.44 NM, which creates .56 NM difference. This difference is significant; therefore, protected airspace would be based on 9.44 NM fix-to-NAVAID distance and a 10 NM fix-to-NAVAID distance as described in paragraph 16-4-4.c.

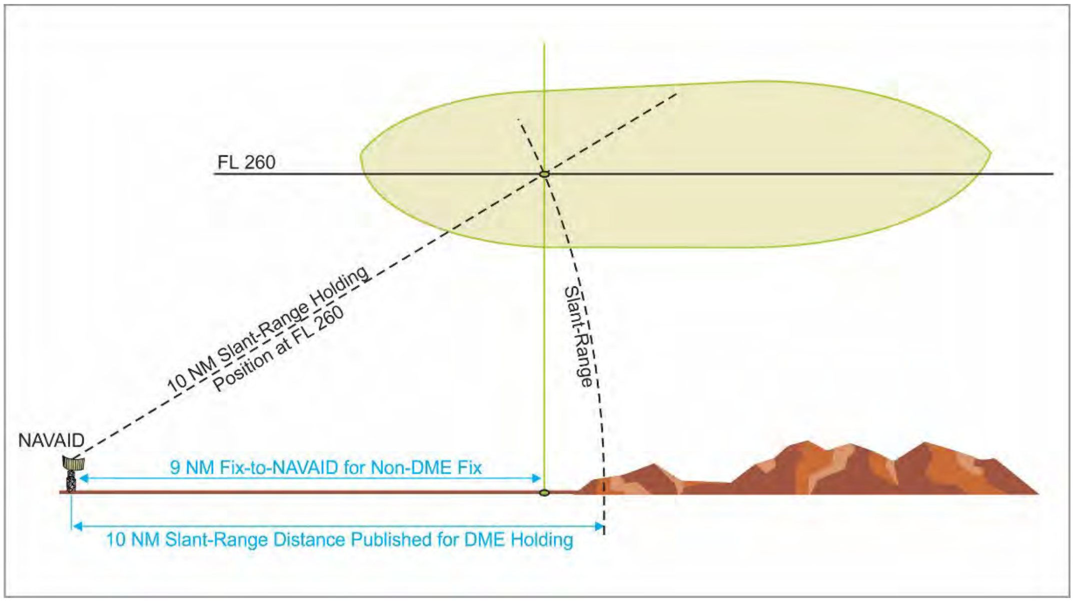
Figure 16-4-1. Collocated VOR/DME and Non-DME Holding Airspace, Inbound Toward NAVAID



Note: Figure 16-4-1 shows holding toward the NAVAID with extended airspace at the fix end when holding away from the NAVAID, the extended airspace would be on the outbound end.

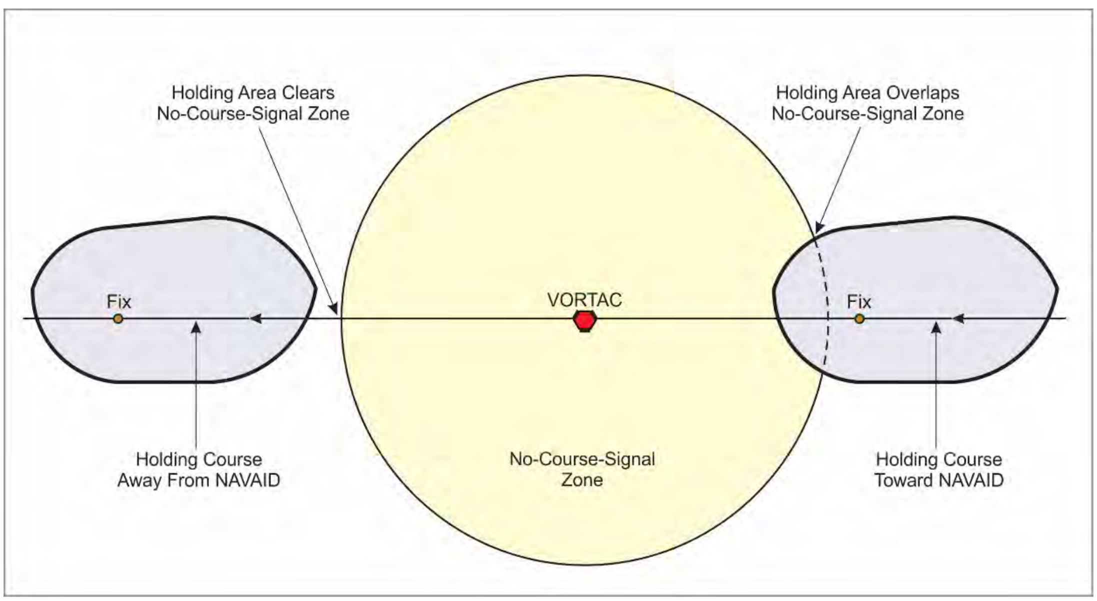
(2) When it is desirable to contain VOR/DME and non-VOR/DME holding within a single pattern size, use a slant-range distance different from the fix-to-NAVAID distance. Use formula 16-14-1 and formula 16-14-2 to select a slant-range distance, which is coincident with the fix-to-NAVAID distance determined, by the non-DME position, at the highest altitude to be used for VOR/DME holding (see figure 16-4-2). If it is desired to publish the holding fix based on a specified slant-range distance, use formula 16-14-3 to convert the slant-range distance to a fix-to-NAVAID distance. The published DME value is the fix-to NAVAID distance and must only be used when the difference is less than 0.25 NM at or below 14000 feet or 0.5 NM above 14000 feet, using formula 16-14-6.

Figure 16-4-2. Collocated Holding Fix Using Single Pattern Number



16-4-5. Holding Toward/Away from the NAVAID. Holding may be accomplished inbound to a VOR/DME fix either toward or away from a NAVAID (see figure 16-4-3).

Figure 16-4-3. VOR/DME Holding



a. Toward the NAVAID. When the VOR/DME holding course is toward the NAVAID, the fix end of the holding area, but not the fix itself, may lie within the no-course-signal zone (see formula 16-14-4 or formula 16-14-5 to determine the edge of the no-course-signal zone at a given altitude).

b. Away from the NAVAID. When the VOR/DME holding course is away from the NAVAID, no part of the pattern area may lie within the no-course-signal zone.

16-4-6. Distance Based Holding Leg Lengths. Table 16-3-1 provides pattern number information applicable to both time and distance based patterns. The outbound leg of a timed pattern is standard according to altitude (see paragraph 16-2-3); however, outbound leg distances for DME patterns vary depending on the fix-to-NAVAID distance and the pattern number being used. Appropriate leg length information can be found in section 16-13; however, to accommodate RNAV substitution, the leg length must not be more than the applicable distance specified in table 16-10-1.

16-4-7. Reduction in area size. No reduction in area size is authorized for obstacle clearance purposes.

16-4-8. VOR/DME Example Problems. Two problems are set forth below with step-by-step solutions. Solution to the first problem is simple and requires one pattern size. The second problem is complex containing two parts. Several pattern sizes and changes to leg length are needed for its solution based on altitude and associated airspeeds. A third problem outlines some additional steps required.

a. Problem 1. The holding course is toward the NAVAID, maximum aircraft holding speed is restricted to 175 knots, on a CAT A and B only procedure, altitudes are MHA through 8000 feet, and fix-to-NAVAID distance is 6 NM.

<u>Solution</u>: Refer to table 16-3-1, speed group 175 knots, distance group 0-14.9 NM, altitude eight, pattern/number four. Refer to section 16-13, fix-to-NAVAID distance 6 NM, pattern number four, four, and five are listed as leg length. Pattern number four with a 5-NM leg length is supported by the obstacle protection.

b. Problem 2. The holding course is toward the NAVAID, maximum aircraft holding speed is 230 knots, and fix-to-NAVAID distance is 30 NM.

(1) <u>Part 1</u>: Find the correct pattern size and related leg length for FL 390.

<u>Solution</u>: At FL 390 and 30 NM fix-to-NAVAID distance, determine slant-range distance using formula 16-14-2, 30.67 NM. The 0.67 NM difference must receive consideration consistent with paragraph 16-4-4. Refer to table 16-3-1, and determine the pattern number/altitude relationship for the 230-knot speed at fix-to-NAVAID distance 30 NM, pattern number 26 is indicated. Refer to section 16-13. For 30 NM and pattern number 26, leg lengths 13, 14, 15, 16, 17, 18, 19, and 20 are listed.

(2) <u>Part 2</u>: Find the correct pattern number size for the MHA of 13000 feet.

<u>Solution</u>: Refer to table 16-3-1, and determine the appropriate pattern, number 12. Refer to section 16-13 and find leg lengths five through nine.

(3) <u>Part 3, Final Solution to Problem 2</u>: The range of leg lengths listed in part one (FL 390) are 13 NM through 20 NM. Compare the findings of part one with part two. Part two

(14000 feet) findings indicate a maximum leg length of 9 NM. Therefore, a 9-NM leg length is selected to serve MHA through FL 390.

c. Problem 3. The holding course is away from the NAVAID. Application of criteria to these situations is handled in the same manner as outlined in paragraphs 16-4-8.a and 16-4-8.b, with two exceptions:

(1) Section 16-13 must be used to determine leg length and numbered area information.

(2) Pattern numbers must be used to determine:

(a) That appropriate numbered areas do not infringe on the no-course-signal zone and/or,

(b) The location of a holding point will keep the holding area from infringing on the no-course-signal zone.

Section 16-5. Template Tracing

16-5-1. Template Usage. Today, most holding pattern construction is accomplished using automation. The existing plastic templates are still valid when used with charts of the appropriate scale. References to templates only apply to users physically using this method of construction. Pattern Numbers directly correspond to template numbers.

16-5-2. Basic Perimeter. The perimeter of the template contains four radii and two straight lines. Position the holding fix grommet hole (see figure 16-3-1) over the fix, align the solid black line with the holding course, and trace the pattern perimeter.

a. Right turn patterns. Trace with imprinted numbers face-up and readable.

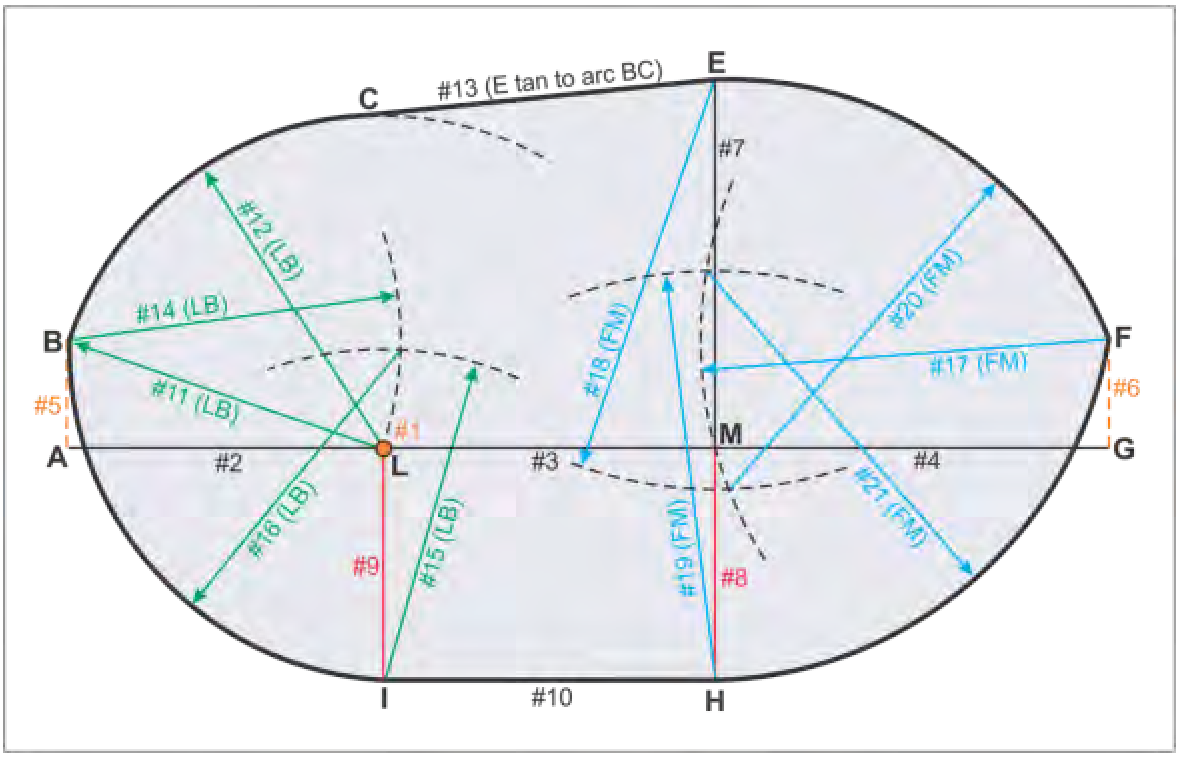
b. Left turn patterns. Trace with imprinted numbers facedown.

Section 16-6. Manual Construction of Patterns

16-6-1. Requirement. Standard plastic holding area templates are available at a scale of 1:500000, Sectional Aeronautical Chart size. When a different scale is desirable/necessary, or automation is not available, holding patterns may be manually constructed as outlined in this section. Dimensions in this section provide the basis for automation of holding construction, and how to derive the distances not provided by the table, which are only established during construction.

16-6-2. Basic Primary Area Construction (right-hand pattern). Each size may be constructed by using figure 16-6-1, dimensions of table 16-6-1, and the following directions (for left-hand pattern reverse the instructions):

Figure 16-6-1. Construction Sequence for Basic Area



Note: All lines that are the same length are the same color. Numbering of the lines represents the order in which the instructions draw the lines and arcs.

a. Line 1. Identify and mark holding fix as letter L.

b. Lines 2 through 4. Draw course line; A to L, L to M, and M to G.

c. Lines 5 through 9. At a 90-degree angle from the course line ALMG locate above A, (B) above G, (F) above M, (E) below M, (H) and below L, (I).

d. Line 10. Connect I and H with a straight line.

e. Line 11 and 12. Place compass center at L, set for distance L-B, and draw an arc from B to beyond C.

f. Line 13. Draw a straight line from E to a point of tangency with the B-C arc.

g. Lines 14 through 16. With the compass still set for distance L-B; place compass center at B and draw a short arc above L; relocate compass center at I and draw a short arc across the first arc; relocate compass center at the intersection of the arcs and connect I-B.

h. Lines 17 through 21. Place compass center at F and set for distance between F-M; draw an arc from above H to below E. Place compass center at E and draw a short arc below M. Place the compass center at H and draw a short arc above M. The arcs formed from E and H intersects the arc formed from F. Place compass center at the appropriate intersection of these arcs and connects E-F; place compass center at the other intersection and connect F-H.

Table 16-6-1. Holding Pattern Dimensions (NM)

Pattern Number	A-L	L-M	M-G	L-I M-H	M-E	A-B G-F (J-K)	(J-L)	Total Length	Total Width
4	4.5	4.3	5.6	3.5	5.3	1.5	3.3	14.4	8.8
5	4.9	4.5	6.1	3.8	5.7	1.7	3.6	15.5	9.5
6	5.6	4.8	6.5	4.2	6.4	2.0	4.1	16.9	10.6
7	6.0	6.6	8.2	4.6	7.2	2.2	4.4	20.8	11.8
8	6.5	6.8	9.3	4.9	7.7	2.3	4.7	22.6	12.6
9	7.0	7.0	9.7	5.3	8.3	2.5	5.1	23.7	13.6
10	7.6	7.3	10.4	5.7	8.9	2.7	5.5	25.3	14.6
11	8.0	7.5	11.1	6.2	9.6	2.9	5.9	26.6	15.8
12	8.7	7.8	11.7	6.5	10.2	3.1	6.3	28.2	16.7
13	9.2	8.6	12.1	7.0	10.9	3.3	6.7	29.9	17.9
14	9.9	8.9	12.8	7.5	11.6	3.6	7.1	31.6	19.1
15	10.4	9.6	13.1	7.7	12.1	3.8	7.5	33.1	19.8
16	11.1	9.9	13.7	8.2	12.8	4.0	7.8	34.7	21.1
17	11.9	10.1	14.8	8.6	13.6	4.3	8.3	36.8	22.2
18	12.7	10.5	15.7	9.2	14.6	4.5	8.9	38.9	23.8
19	13.8	11.1	16.8	9.9	15.7	4.8	9.5	41.7	25.6
20	14.5	11.5	18.0	10.5	16.5	5.2	10.1	44.0	27.0
21	15.5	11.8	18.8	11.2	17.6	5.5	10.7	46.1	28.8
22	16.5	12.1	21.2	11.9	18.8	5.9	11.4	49.8	30.7
23	17.6	12.4	21.6	12.7	20.1	6.3	12.2	51.6	32.8
24	19.2	12.9	23.4	13.7	21.7	6.9	13.1	55.5	35.4
25	21.2	13.3	25.5	14.7	23.4	7.4	14.2	60.0	38.1
26	22.9	13.8	27.6	16.1	25.7	8.1	15.4	64.3	41.8
27	24.6	14.4	29.5	17.3	27.3	8.8	16.5	68.5	44.6
28	26.9	15.2	32.6	18.9	30.2	9.6	18.2	74.7	49.1
29	28.0	15.8	34.6	20.1	32.0	10.0	19.3	78.4	52.1
30	29.2	16.4	35.3	21.3	33.2	10.4	20.2	80.9	54.5
31	30.9	17.0	37.0	22.5	34.5	11.0	21.9	84.9	57.0

Section 16-7. Climb-in-Hold

16-7-1. Climb-in-Hold Evaluations. Applied when it is necessary for aircraft to utilize a holding pattern to reach the en route altitude prior to departing a designated holding fix as part of the DP or missed approach procedure, or with climb-in-hold at the MAP missed approach procedures. Use of the higher airspeeds which may be required to accomplish the maneuver are only authorized when the holding pattern is charted as "Climb-in-Hold." For example, "Proceed direct to XYZ VOR, and hold, continue climb-in-hold to 9000 feet before departing on course." Aircrews must climb continuously until the specified altitude is reached. Where paragraph 16-7-2.a is applied, the holding speed icon must be charted (see Order 8260.19), otherwise 310 KIAS is assumed when the chart is annotated "climb in hold."

16-7-2. Climb-in-Hold Airspeed Determination. Required climb speeds, often exceed the maximum level holding speeds in table 16-2-1. Therefore, the following criteria must be used to provide for such operations.

a. The 200 KIAS pattern for altitudes 6000 feet and below and the 230 KIAS pattern for altitudes above 6000 feet must be used for holding patterns restricted to 175 KIAS.

b. Except as provided in paragraph 16-7-2.a, the 310-knot pattern must be used for climb-in-hold evaluations.

Example: Departing aircraft must climb to FL 180 in a holding pattern. The fix-to-NAVAID distance is 22 NM.

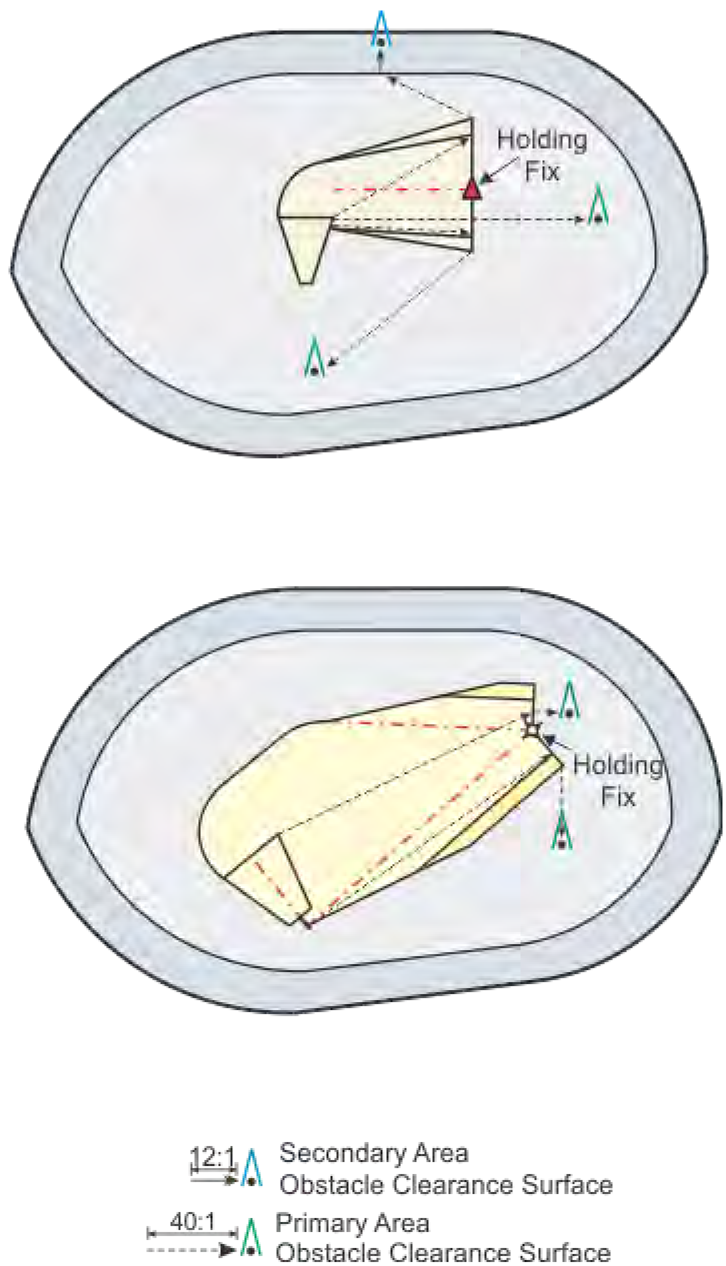
Solution: Refer to table 16-7-1, pattern number 21 is indicated.

Table 16-7-1. Increased Holding Airspeed Holding Pattern Sizes (Altitude-Pattern Number) - Climb-in-Hold

Fix-to-NAVAID Distance		
0-14.9 NM	**15-29.9 NM and RNAV**	**30 NM and Over**
Altitude-Pattern No.	**Altitude-Pattern No.**	**Altitude-Pattern No.**
310 KIAS Climb-in-Hold		
2000 – 11	2000 – 12	2000 – 13
4000 – 12	4000 – 13	4000 – 14
6000 – 13	6000 – 14	6000 – 15
8000 – 14	8000 – 15	8000 – 16
10000 – 15	10000 – 16	10000 – 17
12000 – 17	12000 – 18	12000 – 19
14000 – 18	14000 – 19	14000 – 20
16000 – 19	16000 – 20	16000 – 21
FL18 – 20	FL 18 – 21	FL 18 – 22
FL 20 – 21	FL 20 – 22	FL 20 – 23
FL 22 – 22	FL 22 – 23	FL 22 – 24
FL 24 – 22	FL 24 – 23	FL 24 – 24
FL 26 – 24	FL 26 – 25	FL 26 – 26
FL 28 – 24	FL 28 – 25	FL 28 – 26
FL 30 – 25	FL 30 – 26	FL 30 – 27
FL 32 – 26	FL 32 – 27	FL 32 – 28
FL 34 – 27	FL 34 – 28	FL 34 – 29
FL 36 – 28	FL 36 – 29	FL 36 – 30
FL 38 – 29	FL 38 – 30	FL 38 – 31
FL 40 – 30	FL 40 – 31	

16-7-3. Climb-in-Hold Obstacle Evaluation. When a climb-in-hold is used, on a departure or missed approach due to the required ROC not being achieved at the holding fix, for a climb-in-hold at the MAP missed approach, or when more climb is required prior to departing the holding fix, no obstacle may penetrate the holding surface. This surface begins at the end of the segment leading to the plotted position of the holding fix. It rises at a 40:1 rate to the edge of the primary area, then at a 12:1 rate to the outer edge of the secondary area. The beginning height of the 40:1 surface varies with the ending height of the missed approach/departure OCS at a point on the end of the segment line nearest the obstacle being evaluated. Measurements to obstacles located in the climb-in-hold area (beyond the clearance limit) should be completed in two separate steps: (1) through the previous segment to the closest point to the obstacle on the end of the segment line, and (2) directly to the obstacle (see figure 16-7-1). Precipitous terrain is not applied to the sloping surface of the climb in hold; however, the level holding surface must be evaluated for precipitous terrain.

Figure 16-7-1. Climb-in-Hold Obstacle Evaluation



Section 16-8. Descend-in-Hold Patterns

16-8-1. Descend-in-Hold. Applied when it is necessary for aircraft to utilize a holding pattern, to descend to an altitude prior to departing a designated holding fix, typically for an arrival. The procedure must be annotated “Descend-in-Hold” and the holding pattern must be charted in the plan view.

16-8-2. Descend-in-Hold Airspeed Determination. Standard holding pattern airspeeds for the altitude are used; no increase in airspeed is required.

16-8-3. Descend-in-Hold Criteria. Standard holding criteria is applied where descend in hold is established.

Section 16-9. Operational Applications

16-9-1. Establishing Fixes. Establish holding pattern fixes as follows:

a. Overhead the NAVAID fixes are authorized only for LF and VOR facilities and, when DME is not used, for VOR holding at VORTAC facilities.

b. VOR/DME fixes must not be established overhead the NAVAID from which inbound holding course information would be derived (see formula 16-14-4 or formula 16-14-5 to determine the minimum holding distance from the NAVAID when using VOR/DME).

c. Intersection fixes must be formed by radials/courses/bearings, which are at an angle of not less than 45 degrees to each other.

d. Controlled Airspace. Contain the primary holding areas within controlled airspace, or take action to have controlled airspace designated where uncontrolled airspace is involved, including for turbulent holding and climb-in-hold patterns.

16-9-2. Pattern Alignment. Whenever possible, the holding pattern must be aligned to accommodate entry to the holding area along the inbound holding course, its reciprocal, or at a relatively small angle. However, when the flight path to be flown is along an arc, the holding pattern should be aligned on a radial. When a holding pattern is established at a PFAF and a PT is not used, the inbound course of the holding pattern must be aligned to coincide with the FAC unless the PFAF is a facility. When the PFAF is a facility (non-RNAV holding), the inbound holding course, and the FAC must not differ by more than 30 degrees. Exit from the holding pattern should be as an extension of the inbound holding course where possible. Turns, when exiting holding, may create issues with the length of the inbound leg or the following leg, or with descent or CGs.

16-9-3. VOR/DME Leg Length Selection. Use the <u>longest</u> leg length accommodated by all the pattern numbers being applied to the holding pattern.

16-9-4. VOR/DME Holding Direction. An inbound holding course toward the NAVAID has the following advantages over an inbound holding course away from the NAVAID:

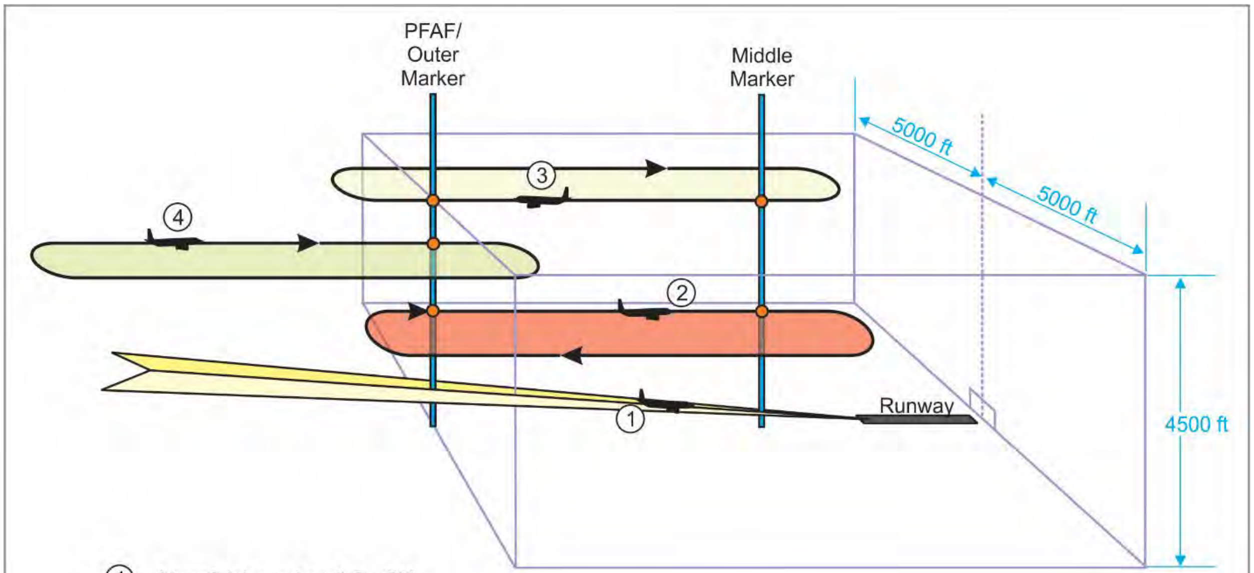
a. It provides a greater choice of leg lengths.

b. When associated with an instrument approach, the aircraft on the inbound holding course will normally be on-course toward the approach NAVAID.

16-9-5. Establishing MHAs. MHAs are determined by service providers during procedure design in accordance with paragraphs 16-2-3 and 16-2-4.

16-9-6. Holding Patterns on or Adjacent to ILS Courses. Do not establish a holding pattern inbound on or adjacent to an ILS localizer between the outer marker/PFAF and the localizer antenna below 5000 feet above the antenna elevation, regardless of the guidance used for the holding pattern. This is to avoid creating unwanted reflected signals (see figure 16-9-1). Holding patterns opposite to the inbound course are acceptable. An outer marker by itself is not acceptable as a holding pattern fix.

Figure 16-9-1. ILS Reflected Signal Area



(1) Aircraft inbound on ILS - OK.

(2) Inbound holding course is coincident with the course of aircraft (1), thus unwanted localizer signals are being reflected - NOT PERMITTED.

(3) Inbound holding course is opposite course of aircraft (1) - OK.

(4) Inbound holding course is outside reflected signal area - OK.

Section 16-10. RNAV Holding Patterns

16-10-1. General Information. This section contains criteria for holding patterns associated with GPS equipment, and other RNAV systems without slant-range using basic holding techniques. For VOR/DME RNAV apply section 16-1.

16-10-2. Criteria Development. Basic holding pattern assumptions in section 16-2 are used for these holding patterns, except paragraph 16-2-6 does not apply.

16-10-3. Restrictions. Do not establish a holding pattern or a hold-in-lieu-of-PT (course reversal) at the FAF of an RNAV procedure.

16-10-4. RNAV Holding Patterns. Use pattern sizes listed in table 16-3-1 (under the fix-to-NAVAID Distance column) for 15-29.9 NM for RNAV holding.

16-10-5. RNAV Leg Length Determination. Distance must be specified on all RNAV holding patterns. Table 16-10-1 contains the maximum leg length, which may be specified for a RNAV holding pattern. Enter table 16-10-1 with the holding pattern number from table 16-3-1 and read the maximum leg length.

Table 16-10-1. RNAV Holding Maximum Outbound Leg Length

Pattern Number	Maximum Outbound Leg Length (NM)
4	4
5	4
6	5
7	6
8	6
9	7
10	7
11	8
12	8
13	9
14	9
15	10
16	10
17	10
18	11
19	11
20	12
21	12
22	12
23	12
24	13
25	13
26	14
27	14
28	15
29	16
30	16
31	16

Section 16-11. Helicopter Holding Patterns

16-11-1. Helicopter (Copter) Holding. Patterns assume at least 90 KIAS while holding.

16-11-2. Copter Holding Procedures. Copter holding published on copter charts is based on pattern number four. If the holding is published on other than a copter chart, or other types of aircraft will hold at the same fix, establish multiple holding patterns, and ensure the copter holding is annotated, or base the pattern used for the copter procedure on standard holding requirements.

Section 16-12. Increased Airspeed Holding Pattern Operations

16-12-1. Turbulent Air Operation. When ATC advises during the design process that turbulent air conditions are known to exist in an area, use table 16-12-1 to determine the required pattern size for evaluation. This is especially critical in a non-RADAR environment.

16-12-2. Maximum Holding Speed in Turbulent Air Conditions. Holding airspace is developed based on 280 KIAS maximum holding speed together with other factors and components listed in sections 16-1 and 16-2. This special speed category provides airspace sizes for holding operations conducted in turbulent air conditions by aircraft whose normal maximum holding speed does not exceed 265 KIAS. Holding patterns are listed in table 16-12-1.

Table 16-12-1. Increased Holding Airspeed Holding Pattern Sizes (Altitude-Pattern number Number) – Turbulent Air

Fix-to-NAVAID Distance		
0-14.9 NM	15-29.9 NM and RNAV	30 NM and Over
Altitude-Pattern No.	Altitude-Pattern No.	Altitude-Pattern No.
280 KIAS Turbulent Air Holding		
2000 - 9	2000 – 10	2000 - 11
4000 - 10	4000 – 11	4000 - 12
6000 - 11	6000 – 12	6000 - 13
8000 - 12	8000 – 13	8000 - 14
10000 - 13	10000 – 14	10000 - 15
12000 - 14	12000 – 15	12000 - 16
14000 - 15	14000 – 16	14000 - 17
16000 - 16	16000 – 17	16000 - 18
FL 18 - 17	FL 18 – 18	FL 18 - 19
FL 20 - 18	FL 20 – 19	FL 20 - 20
FL 22 - 19	FL 22 – 20	FL 22 - 21
FL 24 - 20	FL 24 – 21	FL 24 - 22
FL 26 - 21	FL 26 – 22	FL 26 - 23
FL 28 - 22	FL 28 – 23	FL 28 - 24
FL 30 - 23	FL 30 – 24	FL 30 - 25
FL 32 - 24	FL 32 – 25	FL 32 - 26
FL 34 - 25	FL 34 – 26	FL 34 - 27
FL 36 - 25	FL 36 – 26	FL 36 - 27
FL 38 - 26	FL 38 – 27	FL 38 - 28
FL 40 - 27	FL 40 – 28	FL 40 - 29
FL 42 - 28	FL 42 – 29	FL 42 - 30
FL 44 - 29	FL 44 – 30	FL 44 - 31

16-12-3. Operational Use.

a. Limit the maximum altitude in an existing holding pattern. One method for handling turbulent air holding is to correlate the holding pattern size currently used at individual holding fixes with the information in table 16-7-1. For example, pattern number 20 is being used at a fix 20 NM from the NAVAID (265 KIAS speed group, from MHA through FL 240); correlating pattern number 20 to table 16-7-1 discloses that it is usable from MHA through FL 220 at

280 KIAS. The holding airspace at such a fix would accommodate normal holding at FL 240 and below, or turbulent air holding at FL 220 and below.

b. Develop separate turbulent air holding pattern. Another method of handling turbulent air holding is to establish separate patterns for this purpose at locations where these larger pattern sizes can be accommodated. It may be desirable to do this for each altitude strata in situations where a different holding fix is needed for each stratum.

Note: Crews have no way of knowing if additional obstacle protection has been provided unless turbulent air holding pattern is charted and annotated.

Section 16-13. VOR/DME Leg Length Determination

16-13-1. General. This chapter provides information used to determine the maximum allowable DME leg length, given the fix-to-NAVAID distance, the pattern number, and holding course direction to or from the NAVAID. The longest leg length accommodated by all the pattern numbers used for the entire altitude range of the holding pattern should be published whenever possible.

a. Numbers extending horizontally across the top of each table represent usable fix-to-NAVAID distances (geographical distances).

b. Vertical numbers on the left side of each page represent pattern numbers.

c. Find appropriate leg lengths by first locating the appropriate table for the desired holding direction, toward or away from the NAVAID, then the page of the table containing the desired fix-to-NAVAID distance in the row across the top, and pattern number size in the left column. Determine the usable leg lengths by locating the fix-to-NAVAID distance across the top of the table, then reading vertically down until opposite (horizontally) the selected pattern number(s). Usable leg lengths are listed at the intersection of the column and row, or the first value to the left of this point in the row when a line is used to indicate use at multiple fix-to-NAVAID distances.

Example: Locate fix-to-NAVAID distance 8.5 NM. Read vertically down until opposite pattern number four, then follow the horizontal line to the left until reaching listing “5.” A 5-NM leg length should be selected to maximize level flight between turns.

Table 16-13-1. Holding Course Toward the NAVAID. Usable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	2	3	5	6	7	9	11	12	15	20
4.	6	5							4	
5.	6		5							
6.		6						5		
7.		8						7		

Pattern Number	3	4	5	6	7	8	9	10	12	14	15	17	18	19	20
8.	9		8										7		
9.		9		8						7					
10.		10	9								8				
11.		10						9							
12.			10			9									
13.				11						10					

Pattern Number	4	5	6	7	8	9	11	12	14	15	16	19	20
14.				12			11						
15.	13				12								11
16.		14			13					12			
17.			14					13				12	
18.		15				14						13	

Pattern Number	6	7	8	10	11	13	14	15	19	20
19.	16				15				14	
20.	17			16				15		
21.		18		17			16			
22.			18					17		

Table 16-13-2 (Continued). Holding Course Toward the NAVAID. Usable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	8	9	10	12	13	14	15	17	18	19	20
23.	20			19			18				
24.		21		20				19			
25.		22			21					20	
26.			24			23		22			21

Pattern Number	11	12	13	14	15	16	17	19	20
27.	25			24					23
28.		27			26		25		
29.		28		27					26
30.			29					28	

Pattern Number	14	16	19	20
31.	29		28	

Pattern Number	21	26	30	70
4.	4			
5.	5	4		
6.	5			
7.	7			
8.	7			

Pattern Number	21	24	26	34	50	70
9.	7					
10.	8				7	
11.	9	8				
12.	9			8		
13.	10			9		

Table 16-13-3 (Continued). Holding Course Toward the NAVAID. Usable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	21	22	28	30	38	40	50	55	70
14.	11	10					9		
15.	11					10			
16.	12		11						
17.	12				11				
18.	13			12				11	

Pattern Number	21	23	25	28	30	32	36	40	45	50	55	60	70
19.	14				13					12			
20.	15		14					13					
21.	16	15				14					13		
22.	16			15					14				

Pattern Number	21	23	24	25	28	29	30	32	36	40	45	60	70
23.	17					16				15		14	
24.	18						17				16	15	
25.	20			19				18		17		16	
26.	21				20				19		18	17	

Pattern Number	21	23	24	25	27	28	32	34	36	40	50	60	70
27.	23		22			21				20	19	18	
28.	24			23					22	21	19	18	
29.	26	25			24			23		22	21	20	
30.	26		25					23		22	21	20	

Pattern Number	21	22	26	30	38	45	55	60	70
31.	28	27	26	25	24	23	22	21	20

Table 16-13-4. Holding Course Away From the NAVAID. Useable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	11	12	13	15	16	18	19	23	29
4.		2							
5.		2							
6.		2				3			
7.		2		3				4	
8.			2		3			4	

Pattern Number	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
9.	2			3						4							
10.		2			3						4						
11.			2		3					4							
12.				2		3				4							
13.				2		3					4						
14.					2			3				4					
15.					2		3				4						5
16.						2		3			4						
17.							2		3				4				

Pattern Number	11	20	21	22	23	24	25	26	27	28	29
18.		2		3			4				
19.			2			3			4		
20.				2			3				4
21.					2			3			
22.						2				3	
23.									2		
24.											2

Table 16-13-5 (Continued). Holding Course Away From the NAVAID. Useable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

Pattern Number	30	34	38	40	44	55	80
4.	2	3					
5.	2	3					
6.	3						
7.	4					5	
8.	4				5		
9.	4			5			

Pattern Number	30	31	32	36	37	38	42	44	46	50	55	60	65	70	80
10.	4					5									
11.	4		5											6	
12.	4	5											6		
13.	5										6				
14.	4		5								6				
15.	5							6							
16.	5						6								7

Pattern Number	30	31	32	34	35	36	37	38	40	42	44	48	50	55	60	70	80
17.	4	5								6						7	
18.	5							6							7		
19.	4		5						6					7			
20.	4			5						6				7			
21.	4				5					6				7			
22.	3		4				5				6		7				8
23.	3			4					5			6			7		8

Table 16-13-6 (Continued). Holding Course Away From the NAVAID. Useable DME Leg Lengths

Fix-to-NAVAID (geographical - not DME) Distance in Nautical Miles

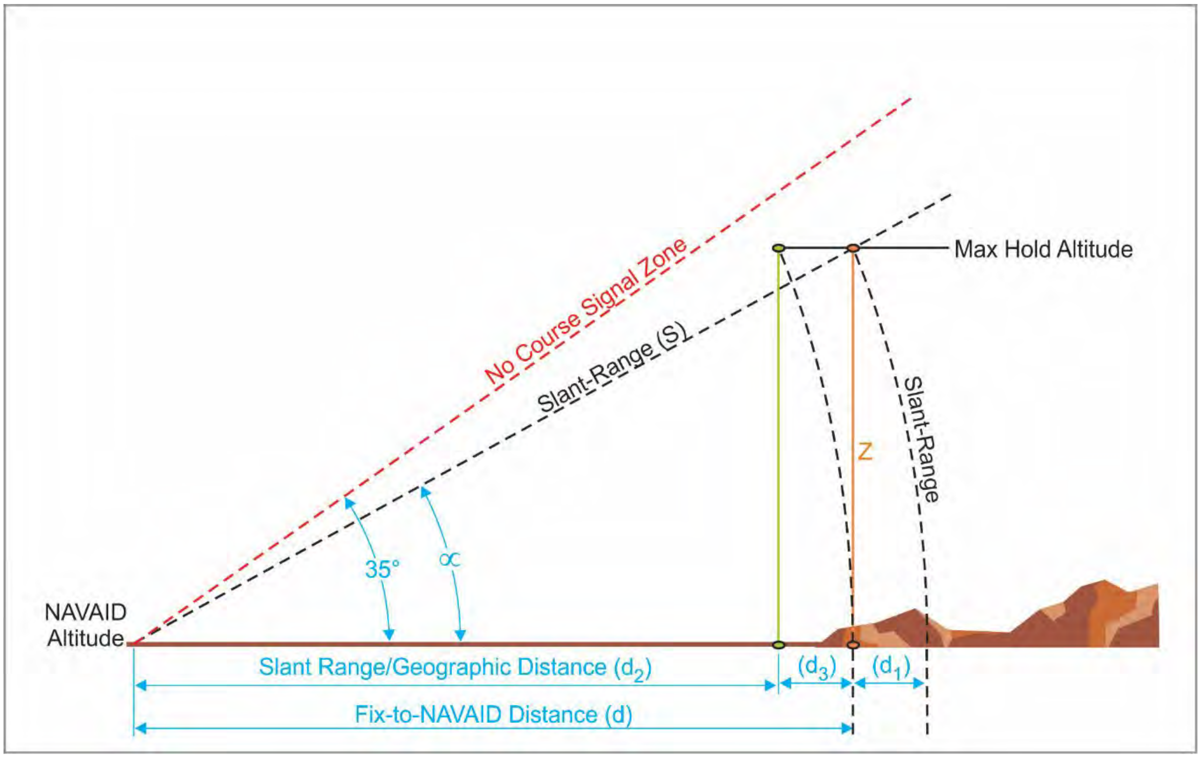
Pattern Number	30	32	34	35	36	37	38	40	42	44	46	48	50	55	60	65	70	80
24.	2	3			4				5				6		7			8
25.		2		3				4			5			6		7		→
26.			2				3		4			5		6		7		→
27.						2			3		4			5	6		7	→
28.									2		3		4		5	6		7
29.										2			3	4	5		6	7
30.										2		3		4	5			7

Pattern Number	30	48	55	60	65	70	80
31.		2	3	4	5	6	7 →

Section 16-14. Formulas for Holding Pattern Placement

16-14-1. General. The formulas in this chapter are used to calculate the values required for evaluating the placement of the holding pattern number and the distances published when charting the holding pattern. More than one formula is required in some calculations. Figure 16-14-1 shows the relationship of the calculations and provides the key to the letters used in the formulas. Formula 16-14-1 through formula 16-14-8 are used as described below and in the previous sections.

Figure 16-14-1. Holding Calculations Relationships



a. Formula 16-14-1 is used to determine the height above the NAVAID at the maximum holding altitude, and converted to NM for use in other calculations.

Formula 16-14-1. Holding Altitude Above the NAVAID (z)

$$z = \frac{(flight_{elev} - NAVAID_{elev}) \times 0.3048}{1852}$$

Where:

$NAVAID_{elev}$ = the elevation of the NAVAID in feet.
$flight_{elev}$ = the maximum holding altitude in feet.

b. Formula 16-14-2 is used to determine the slant-range(s) when the fix-to-NAVAID distance (d) is known.

Formula 16-14-2. Slant-range(s) when fix-to-NAVAID distance (d) is Known.

$$s = \sqrt{d^2 + z^2}$$

Where:

z = Height above the NAVAID in NM using formula 16-14-1
d = The fix-to-NAVAID distance in NM

c. Formula 16-14-3 is used to determine the Fix-to-NAVAID distance (d) when slant-range(s) is known.

Formula 16-14-3. Fix-to-NAVAID Distance (d) When Slant-range is Known

$$d = \sqrt{s^2 - z^2}$$

Where:

z = Height above the NAVAID in NM using formula 16-14-1
s = The slant-range distance in NM

d. Formula 16-14-4 and formula 16-14-5 are used to determine the minimum fix-to-NAVAID distance, at the maximum authorized holding altitude, is calculated based on a 35-degree angle and either the desired slant-range or fix-to-NAVAID distance. Initially calculate this value based on the desired holding location and desired maximum holding altitude (see paragraph 16-4-4.a). When dual plotting of the holding pattern number is required, this calculation must be performed using the closest pattern number location to the NAVAID (see slant-range/geographic distance, paragraph 16-14-1.e), regardless of the published distance to ensure conventional holding is supported. The maximum holding altitude must always be below the 35-degree no-course signal zone.

Formula 16-14-4. No-Course Signal Zone, Desired Slant-range Distance.

$$s = \frac{z}{sin(35°)}$$

Where:

z = Height above the NAVAID in NM using formula 16-14-1

Formula 16-14-5. No-Course Signal Zone, Desired Fix-to-NAVAID Distance.

$$d = \frac{z}{tan(35°)}$$

Where:

z = Height above the NAVAID in NM using formula 16-14-1

e. Formula 16-14-6 identifies the difference between the slant-range distance and fix-to-NAVAID distance, used to determine if a single pattern number can be used for both slant range and non-slant range holding. The fix-to-NAVAID distance (d), the slant-range distance (s), are first calculated using formula 16-14-2 and formula 16-14-3, then the difference (d_1) is calculated using formula 16-14-6 (see paragraph 16-4-4.b). When the value d_1 exceeds the maximum for using a single pattern number, recalculation of the no-course signal zone will be required to determine if the second plotted location (determined by formula 16-14-7 and formula 16-14-8 for slant-range/geographic distance) places the aircraft inside the no-course signal zone.

Formula 16-14-6. Difference Between Slant-range and Fix-to-NAVAID Distance.

$$d_1 = s - d$$

Where:

s = The slant-range distance in NM
d = The fix-to-NAVAID distance in NM

f. Formula 16-14-7 is used to determine the slant-range/geographical distance based on the fix-to-NAVAID distance and maximum holding Altitude (see paragraph 16-4-4.c). The calculated slant-range/geographical distance must be equal or greater than the minimum fix-to-NAVAID distance (d) in formula 16-14-5. Otherwise, the second plotted location, used by conventional aircraft, is above the 35-degree line and therefore, inside the no-course signal zone. The difference between the two plotted locations is computed using formula 16-14-8 to determine d_3.

Formula 16-14-7. Slant-range/Geographic Distance

$$d_2 = \sqrt{d^2 - z^2}$$

Where:

d = The fix-to-NAVAID distance in NM
z = Height above the NAVAID in NM using formula 16-14-1

Formula 16-14-8. Difference Between Plotted Locations

$$d_3 = d - d_2$$

Where:

d = The fix-to-NAVAID distance in NM
d_2 = Slant-range/Geographical Distance in NM from formula 16-14-7

Appendix A. Administrative Information

1. Distribution. This order is distributed electronically only.

2. Acronyms and Abbreviations. Many acronyms and abbreviations for old and new aviation terms are used throughout this order. Definitions can be found in the Aeronautical Information Manual and/or within appendix B of this order. Users of this order can refer to the following alphabetical listing of frequently used acronyms and abbreviations (see table A-1).

Table A-1. Acronyms and Abbreviations

ACT	Average Cold Temperature
ADF	automatic direction finder
AGL	above ground level
ALSF-1	approach lighting system with sequenced flashing lights (CAT I configuration)
ALSF-2	approach lighting system with sequenced flashing lights (CAT II configuration)
APV	approach with vertical guidance
AR	authorization required
ARA	airborne radar approach
ARC	airport reference code
ARP	airport reference point
ARSR	air route surveillance radar
ASOS	automated surface observing system
ASR	airport surveillance radar
ATC	Air Traffic Control
ATD	along track distance
ATRK	along track
ATS	Air Traffic Service
Baro VNAV	barometric vertical navigation
BC	back course
CAT	category
CDA	continuous descent approach
CF	course to fix
CFR	Code of Federal Regulations
CG	climb gradient
COP	changeover point
CVFP	Charted Visual Flight Procedure
CW	clockwise
DA	decision altitude
DER	departure end of runway
DF	direct to fix (RNAV)
DG	descent gradient
DH	decision height
DME	distance measuring equipment
DoD	Department of Defense
DP	departure procedure
DR	dead reckoning
DRL	departure reference line
DRP	departure reference point
DTA	distance turn anticipation
DVA	diverse vector area
ESA	emergency safe altitudes
FAC	final approach course
FAS	final approach segment
FATO	final approach and takeoff area
FAWP	final approach waypoint
FEP	final end point
FL	flight level
FMS	flight management system
FPAP	flight path alignment point
FROP	final roll-out point
FSS	Flight Service Station
FTE	flight technical error
FHP	fictitious helipoint
FTP	fictitious threshold point
GARP	GNSS azimuth reference point
GBAS	Ground Based Augmentation System
GH	geoid height
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GP	glidepath
GPA	glidepath angle
GPI	ground point of intercept
GPS	Global Positioning System
HAA	height above airport
HAE	height above ellipsoid
HAL	height above landing
HAS	height above surface
HCH	helipoint crossing height

HDRP	heliport departure reference point
HF	high frequency
HIRL	high intensity runway lights
HRP	heliport reference point
IAF	initial approach fix
IAP	instrument approach procedure
ICA	initial climb area
ICAB	ICA baseline
ICAE	ICA end-line
ICAO	International Civil Aviation Organization
IDF	initial departure fix
IF	intermediate fix
IAF	initial approach fix
IFP	Instrument flight procedure
IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
INS	inertial navigation system
IRU	inertial reference unit
ISA	International Standard Atmosphere
IVH	IFR to VFR heliport
kHz	kilohertz
KIAS	knots indicated airspeed
LAAS	Local Area Augmentation System
LDA	localizer type directional aid
LF	low frequency
LIRL	low intensity runway lights
LNAV	lateral navigation
LOC	localizer
LOM	locator outer marker
LP	localizer performance
LPV	localizer performance with vertical guidance
LHP	landing helipoint
LTP	landing threshold point
MALS	medium intensity approach lighting system
MALSF	medium intensity approach lighting system with sequenced flashing
MALSR	medium intensity approach lighting system with runway alignment indicator lights
MAP	missed approach point
MCA	minimum crossing altitude
MDA	minimum descent altitude

MEA	minimum en route IFR altitude
MHA	minimum holding altitude
MHz	megahertz
MIA	minimum IFR altitudes
MIRL	medium intensity runway lights
MMLS	mobile microwave landing system
MOCA	minimum obstruction clearance altitude
MRA	minimum reception altitude
MSA	minimum safe altitude
MSL	mean sea level
MSS	Mission Support Services
MTA	minimum turn altitude
MVA	minimum vectoring altitude
MVAC	minimum vectoring altitude chart
NAD	North American Datum
NAS	National Airspace System
NAVAID	navigational aid
NDB	nondirectional radio beacon
NM	nautical mile
NoPT	no procedure turn
NOTAM	Notices to Airmen
NOZ	normal operating zone
NPA	Non-precision approach
NTZ	no transgression zone
NWS	National Weather Service
OCS	obstacle clearance surface
ODALS	omnidirectional approach lighting system
ODP	obstacle departure procedure
OEA	obstruction evaluation area
OIS	obstacle identification surface
PAPI	precision approach path indicator
PAR	precision approach radar
PBN	performance based navigation
PCG	positive course guidance
PFAF	precise final approach fix
PinS	point-in-space
PRM	precision runway monitor
PT	procedure turn
RA	radio altimeter
RAIL	runway alignment indicator lights
RASS	remote altimeter setting source

RCL	runway centerline
REIL	runway end identifier lights
RF	radius-to-fix
RNAV	area navigation
RNP	required navigation performance
ROC	required obstacle clearance
RPI	runway point of intercept
RRP	runway reference point
RTRL	reduced takeoff runway length
RVR	runway visual range
RWY	runway
SA	Special Authorization
SALS	short approach lighting system
SDF	simplified directional facility
SER	start end of runway
SID	standard instrument departure
SOIA	simultaneous offset instrument approach
SM	statute mile
SSALF	simplified short approach lighting system with sequenced flashers
SSALR	simplified short approach lighting system with runway alignment indicator lights
STAR	standard terminal arrival route
TAA	terminal arrival area
TACAN	tactical air navigational aid
TCH	threshold crossing height
TDZ	touchdown zone
TDZE	touchdown zone elevation
TDZL	touchdown zone lights (system)
TERPS	terminal instrument procedures
TF	track to fix

TLOF	touchdown and lift-off area
TP	tangent point
TPD	tangent point distance
UHF	ultra-high frequency
USA	U.S. Army
USAF	U.S. Air Force
USCG	U.S. Coast Guard
USN	U.S. Navy
VASI	visual approach slope indicator
VCA	visual climb area
VCOA	visual climb over airport
VDA	vertical descent angle
VDP	visual descent point
VFR	visual flight rules
VGS	vertical guidance surface
VGSI	visual glide slope indicator
VHF	very high frequency
VMC	visual meteorological conditions
VNAV	vertical navigation
VOR	very high frequency omnidirectional radio range
VOR/DME	very high frequency omnidirectional radio range collocated with distance measuring
VORTAC	very high frequency omnidirectional radio range collocated with tactical air navigational aid
VPA	vertical path angle
VSCA	visual segment climb angle
VSDA	visual segment descent angle
VSDP	visual segment descent point
VSRL	visual segment reference line
WAAS	Wide Area Augmentation System
WCH	wheel crossing height

3. Related Publications.

a. Code of Federal Regulations.

(1) 14 CFR part 1, Definitions and Abbreviations.

(2) 14 CFR part 77, Objects Affecting Navigable Airspace.

(3) 14 CFR part 91, General Operating and Flight Rules.

(4) 14 CFR part 95, IFR Altitudes.

(5) 14 CFR part 97, Standard Instrument Procedures.

(6) 14 CFR part 171, Non-Federal Navigation Facilities.

b. FAA Advisory Circulars.

(1) AC 70/7460-1, Obstruction Marking and Lighting.

(2) AC 150/5300-13, Airport Design.

(3) AC 150/5340-1, Standards for Airport Markings.

c. FAA Directives.

(1) Order 6050.32, Spectrum Management Regulations and Procedures Manual.

(2) Order 6560.10, Runway Visual Range.

(3) Order JO 7210.3, Facility Operations and Administration.

(4) Order JO 7210.37, En Route Minimum Instrument Flight Rule (IFR) Altitude (MIA) Sector Charts.

(5) Order JO 7400.2, Procedures for Handling Airspace Matters.

(6) Order 8200.1, U.S. Standard Flight Inspection Manual.

(7) Order 8260.19, Flight Procedures and Airspace.

(8) Order 8260.43, Flight Procedures Management Program.

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

(10) Order 8260.58, United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design.

(11) Order 9840.1, U.S. National Aviation Handbook for the VOR/DME/TACAN Systems.

4. Forms and Reports. FAA Form 8260-2, Radio Fix and Holding Data Record.

5. Information Update. For your convenience, FAA Form 1320-19, Directives 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 directive. When forwarding your comments to the originating office for consideration, please provide a complete explanation of why the suggested change is necessary.

Appendix B. Definitions

In addition to the definitions common to procedure development contained in various 8260-series FAA orders, the following definitions apply:

1. 3-Dimensional. Approach procedures that provide longitudinal, lateral, and vertical path deviation information are 3D procedures. ILS, PAR, LNAV/VNAV, LPV, and RNP are examples of 3D procedures.

2. Air Traffic Service 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. Airport reference point. The official horizontal geographic location of an airport. It is the approximate geometric center of all usable runways at an airport.

4. Along-track distance. A distance specified in nautical miles, with reference to the next WP.

5. Along-track tolerance. The amount of possible longitudinal fix positioning error on a specified track expressed as a ± value.

6. Angle of divergence (Minimum). The smaller of the angles formed by the intersection of two courses, radials, bearings, or combinations thereof.

7. APT waypoint. A WP located on the FAC at or abeam the first usable landing surface, which is used for construction of the final approach area for a circling-only approach.

8. Area navigation. A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

9. Authorization required. Aircraft may be equipped beyond the minimum standard for public 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.

10. Average coldest temperature. 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.

11. Barometric altitude. A barometric altitude measured above MSL based on atmospheric pressure measured by an aneroid barometer. This is the most common method of determining aircraft altitude.

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.

13. Circling approach area. The area in which aircraft circle to land under visual conditions after completing an instrument approach.

14. Climb gradient. A climb requirement expressed in feet/NM.

15. Common route. The segment(s) of a SID/STAR procedure that provides a single route serving an airport/runway or multiple airports/runways. The common route may consist of a single point.

16. Controlling obstacle. The obstacle on which the design of a procedure or establishment of a minimum altitude or angle is based (see also Order 8260.19).

17. Course. A specified track measured in degrees from magnetic north.

18. Course change. The mathematical difference between the inbound and outbound tracks at a single fix.

19. Course-to-a-fix. A defined, repeatable course (track over the ground) to a specific database fix.

20. Course-to-an-altitude. A defined, repeatable course to a specific altitude at an unspecified position.

21. Course-to-an-intercept. A defined, repeatable course to intercept the subsequent leg.

22. Cross-track tolerance. The amount of possible lateral positioning error expressed as a ± value.

23. Dead reckoning. The estimating or determining of position by advancing an earlier known position by the application of direction and speed data. For example, flight based on a heading from one VORTAC azimuth and distance fix to another is dead reckoning.

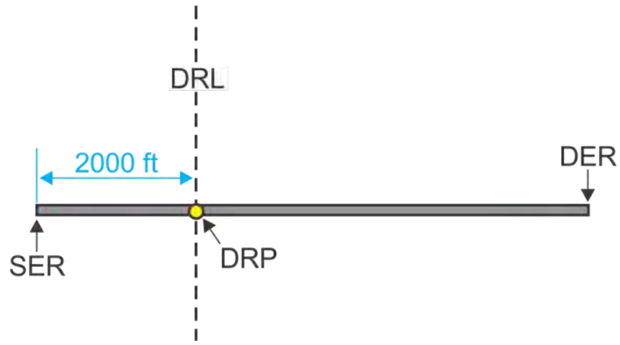
24. Decision altitude. A DA is a specified minimum altitude (feet MSL) in a PA or APV IAP at which the pilot must decide whether to initiate an immediate missed approach if they do not see the required visual references or to continue the approach.

25. Departure end of runway. The end of the runway opposite the landing threshold (see figure B-1).

26. Departure reference line. An imaginary line of indefinite length perpendicular to runway centerline at the DRP (see figure B-1).

27. Departure reference point. A point on the runway centerline 2000 feet from the SER (see figure B-1).

Figure B-1. Runway Terms



28. Departure route. A specified course and altitude along a track defined by positive course guidance (PCG) to a clearance limit, fix, or altitude.

29. Departure sector. Airspace defined by a heading or a range of headings for aircraft departure operations.

30. Direct-to-a-fix. An unspecified non-repeatable track starting from an undefined position to a specific database fix.

31. Descent gradient. Description of aircraft descent profile specified in feet per nautical mile.

32. Distance of turn anticipation. 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.

33. Distance measuring equipment Arc. A course, indicated as a constant DME distance, around a navigation facility which provides distance information.

34. DME distance. The line of sight distance (slant range) from the source of the DME signal to the receiving antenna.

35. Diverse vector area. An area in which a prescribed departure route is not required. Radar vectors may be issued below the minimum vectoring or minimum IFR altitude. It can be established for diverse departure, departure sectors, and/or video map radar areas portraying obstacles and terrain.

36. Early turn point. Represents the earliest location where a flight track turn may commence.

37. En route transition. The segment(s) of a SID/STAR that connect to/from en route flight. Not all SIDs/STARs will contain an en route transition.

38. Fictitious helipoint. The equivalent of the helipoint when the final approach path is not based on the location and elevation of the helipoint.

39. Fictitious threshold point. The equivalent of the LTP when the final approach course is offset from 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 the 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 when appropriate (see figure B-2).

40. Final approach and takeoff area. A defined area over which the final phase of the approach to a hover, or a landing, is completed and from which the takeoff is initiated. A FATO is applicable only at a heliport; guidance for a FATO is published in AC 150/5390-2.

41. Final approach course. Magnetic and/or true heading definition of the final approach lateral path.

42. Final approach segment. The segment of an instrument approach procedure that begins at the PFAF and ends at the MAP or LTP/FTP, whichever is encountered last.

43. Fix. A generic term used to define a predetermined geographical position. A fix may be a ground-based NAVAID, WP or defined by reference to one or more radio NAVAIDs.

44. Fix displacement tolerance. FDT is a legacy term providing 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.

45. Fix-to-NAVAID. Horizontal distance from the plotted position of the holding fix to the NAVAID.

46. Flight control computer. Aircraft computers which process information from various inputs to calculate flight path and flight guidance parameters.

47. Flight management system. 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 flight deck, the FMS is normally controlled through a CDU which incorporates a small screen and keyboard or touchscreen. The FMS sends the flight plan for display on the EFIS, ND or MFD.

48. Flight path alignment point. A point in the same lateral plane as the LTP/FTP that is used to establish the alignment of the FAS. For approaches aligned with the runway centerline, the FPAP is located at or beyond the opposite threshold of the runway. The delta length offset from the opposite threshold defines its location.

49. Fictious helipoint. The FHP is a 3D point defined by the LTP geographic position, MSL elevation, and TCH value. The FHP 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.

50. Final roll-out point. A point in the final approach segment after which no turns are permitted. After the FROP, the FAC must comply with final approach course alignment requirements.

51. Fly-by 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.

52. Fly-over fix. Fly-over fixes/waypoints are used when the aircraft must fly over the point prior to starting a turn.

53. Glidepath angle. 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.

54. Global azimuth reference point. GNSS Azimuth Reference Point. A calculated point 1000 feet 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.

55. Global Navigation Satellite System. 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.

56. Gradient. A slope expressed in feet per mile, or as a ratio of the horizontal to the vertical distance. For example, 40:1 means 40 feet horizontally to one foot vertically.

57. Ground point of intercept. A point in the vertical plane on the runway centerline at which it is assumed that the straight line extension of the glide slope intercepts the runway approach surface baseline.

58. Heading-to-an-altitude. A specified heading to a specific altitude at an unspecified position. The resulting track is not wind corrected.

59. Heading-to-an-intercept. A specified heading to intercept the subsequent leg at an unspecified position. The resulting track is not wind corrected.

60. Height above landing. The height above the landing area elevation.

61. Height above surface. The height of the MDA above the highest terrain/surface within a 5200-foot radius of the MAP in a PinS procedure.

62. Height above touchdown. The height of the DA above TDZE.

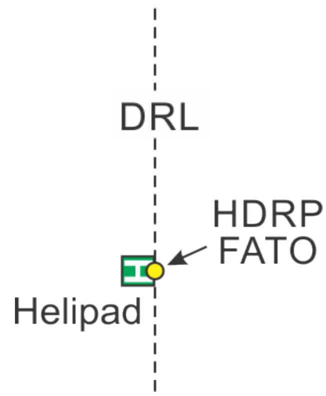
63. Helipoint. For approaches, it is the aiming point for the final approach course. The helipoint is normally centered in the TLOF with an elevation equivalent to the TLOF elevation.

64. Helipoint crossing height. For approaches, it is the height of the vertical path above the helipoint. For departures, it is the hover height above the helipoint.

65. Heliport. An area of land, water, or structure used or intended to be used for helicopter landings and takeoffs and includes associated buildings and facilities**.**

66. Heliport departure reference point. The intersection of the FATO and departure course.

Figure B-2. Heliport Departure Reference Point



67. Heliport elevation. The highest elevation of all landing areas within the heliport, expressed as the distance above mean sea level.

68. Heliport reference point. The official horizontal geographic location of a heliport located at the center of the FATO, or the centroid of multiple FATOs.

69. Initial climb area. A segment variable in length starting at the DER which allows the aircraft sufficient distance to reach an altitude of at least 400 feet above the DER.

70. ICA baseline. A line at DER, perpendicular to runway centerline, denoting the beginning of the ICA.

71. ICA end-line. A line at end of ICA perpendicular to the departure course.

72. Initial approach fix. A fix that identifies the beginning of an initial approach segment.

73. Initial departure fix. The first fix/waypoint used for the departure. The IDF denotes the beginning portion of the SID.

74. Instrument Landing System. A precision instrument approach system which normally consists of a localizer, glide slope, outer marker (or suitable substitute), inner marker for Category II operations (if RA minimums are not authorized), and an approach lighting system.

75. Intermediate fix. The fix that identifies the beginning of the intermediate approach segment of an instrument approach procedure. The fix is normally identified on the instrument approach chart as an IF.

76. International standard atmosphere. A model of standard variation of pressure and temperature.

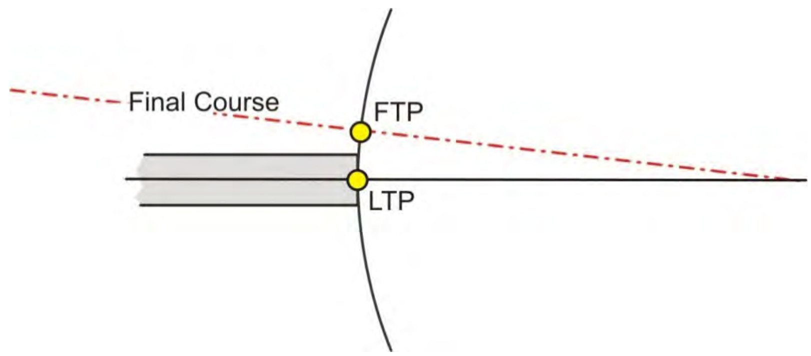
77. Knots indicated airspeed. The speed shown on the aircraft airspeed indicator.

78. Landing area as used in helicopter operations. The portion of the heliport or airport runway used or intended to be used for the landing and takeoff of helicopters.

79. Landing area boundary. The beginning of the landing area of the heliport or runway.

80. Landing threshold point. The LTP is the intersection of the runway centerline and the runway threshold. It is defined by latitude/longitude coordinates, and MSL elevation. LTP elevation applies to the FTP when the final approach course is offset from runway centerline (see figure B-3).

Figure B-3. Landing Threshold Point and Fictitious Threshold Point



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

82. Lateral/Vertical Navigation. An APV evaluated using the Baro VNAV obstacle clearance surfaces conforming to the lateral dimensions of the LNAV OEA.

83. Leg. A subdivision of an RNAV IFP defined by a path and a terminator. Also used in reference to the length of holding patterns.

84. Localizer. The component of an ILS which provides lateral guidance with respect to the runway centerline.

85. Localizer performance. 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.

86. Localizer type directional aid. A facility of comparable utility and accuracy to a LOC, but which is not part of a full ILS and may not be aligned with the runway.

87. Minimum descent altitude. 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.

88. Minimum en route IFR altitude. The lowest published altitude between radio fixes which assures acceptable navigational signal coverage, air-to-ground communications, and which meets obstacle clearance requirements. 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.

89. Minimum obstruction clearance altitude. The lowest published altitude between fixes on an ATS route or STAR which meets obstacle clearance requirements for the entire segment.

90. Non-directional beacon airborne automatic direction finder. A combined term which indicates that an NDB provides an electronic signal for use with ADF equipment.

91. Non-VOR/DME RNAV. It is not dependent upon a reference. It utilizes positioning inputs from DME/DME, DME/DME/IRU, or GNSS. A Multi-Sensor System based on any VOR/DME or non-VOR/DME certified approved system or a combination of certified approved systems may also provide positioning inputs.

92. Obstacle. An object, structure, terrain feature, or vegetation, at a fixed geographical location, or which may be expected at a fixed location within a prescribed area, with reference to which vertical clearance must be provided during flight operation. With reference to mobile objects, a moving vehicle 17 feet high is assumed to be on an Interstate Highway, 15 feet high for any other public roadway, 10 feet high on private roads, and 23 feet high on a railroad track, except where limited to certain heights controlled by use or construction. The tallest point of a watercraft (for example, the mast) is assumed according to the types of watercraft known to use an anchorage or to transit a waterway. Includes taxiing aircraft except where operational restrictions prevent taxi operations during takeoff and landings. Any mobile object may be ignored provided positive controls are applied by the airport authority or by air traffic control to exclude their presence during flight operations.

93. Obstacle clearance. The vertical distance between the lowest authorized flight altitude and a prescribed surface within a specified area.

94. Obstacle clearance surface. A level or sloping surface used for obstacle evaluation. The separation between this surface and specified minimum altitude, glidepath angle or minimum required climb path defines the MINIMUM required obstruction clearance at any given point.

95. Obstacle evaluation area. An area with defined limits that is subjected to obstacle evaluation through the appropriate OCS or OIS application standard.

96. Obstacle identification surface. A surface with an OEA of defined limits used for identification of obstacles that may require mitigation to maintain the required level of safety for the applicable segment.

97. 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.

98. Operational advantage. An improvement which benefits the users of an instrument procedure. Achievement of lower minimums or authorization for a straight-in approach with no derogation of safety is an example of an operational advantage. Many of the options in TERPS are specified for this purpose. For instance, the flexible final approach course alignment criteria may permit the ALS to be used for reduced visibility credit by selection of the proper optional course.

99. Point-in-space approach. A PinS approach is an instrument approach procedure to a point in space, identified as a missed approach point, which is not associated with a specific airport or a specific landing area within 2600 feet of the MAP.

100. Positive course guidance. A continuous display of navigational data which enable an aircraft to be flown along a specific course line.

101. Precipitous terrain. Terrain characterized by steep or abrupt slopes.

102. Precise final approach fix. The PFAF is a calculated WGS84 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.

103. Proceed VFR. Point-in-space procedure which allows an aircraft to fly an IFR approach to a point in which a transition to VFR is conducted. Aircraft are expected to continue from the MAP/IDF under VMC while maintaining VFR minimums. The aircraft is allowed to fly from/to the MAP/IDF to/from the landing area by any route desired by the pilot which will afford obstacle and terrain avoidance. An IFR recovery procedure is not provided between the MAP/IDF and landing area.

104. Proceed Visual. Point-in-space procedure which allows and aircraft to fly an IFR approach to a helipad under IFR conditions. The aircraft is required to be VMC at the MAP/IDF and maintain VMC during flight from/to the landing area. Obstacle evaluation is conducted as part of the procedure evaluation from/to the MAP/IDF to/from the landing area. Aircraft are required to fly the published slope to ensure obstacle avoidance is maintained.

105. Primary area. The area within a segment in which full obstacle clearance is applied.

106. Radio altimeter height. An indication of the vertical distance between a point on the nominal glidepath at DA and the terrain directly beneath this point.

107. Radius to fix leg. An RF leg is a constant radius circular repeatable path about a defined turn center that begins and terminates at a fix.

108. Reduced takeoff runway length. An alternative to a published CG established to mitigate an obstacle that penetrates the departure 40:1 OCS by 35 feet or less. An RTRL establishes a distance prior to DER where takeoff must occur by.

109. Reference facility. A VOR/DME, VORTAC or TACAN facility used for the identification and establishment of an RNAV route, WP, or instrument approach procedure.

110. Reference fix. A point of known location used to geodetically compute the location of another fix.

111. 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.

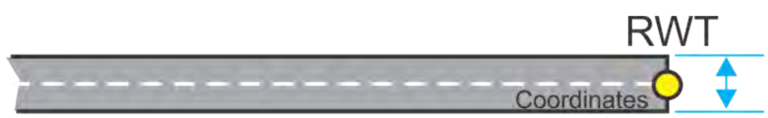
112. Reference navigational aid. A navigational facility required for various leg construction (CF for example) to assign a magnetic variation to the course.

113. Required navigation performance. 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.

114. Required obstacle clearance. The minimum vertical clearance (in feet) that must exist between aircraft and the highest obstacle within the OEA of instrument procedure segments.

115. Runway threshold. The RWT marks the beginning of that part of the runway usable for landing (see figure B-3). It extends the full width of the runway. Threshold elevation is equal to the highest MSL point along the RWT line (see figure B-3).

Figure B-3. Runway Threshold



116. Runway transition. The segment(s) of a SID/STAR between the common route/point and the runway(s). Not all SIDs/STARs will contain a runway transition.

117. Runway WP. A WP located at the runway threshold and used for construction of the final approach area when the FAC meets straight-in alignment criteria.

118. Secondary area. The area within a segment in which ROC is reduced as distance from the prescribed course is increased.

119. Segment. The basic functional division of an instrument approach procedure. The segment is oriented with respect to the course to be flown. Specific values for determining course alignment, obstacle clearance areas, descent gradients, and obstacle clearance requirements are associated with each segment according to its functional purpose.

120. Service volume. That volume of airspace surrounding a VOR, TACAN, or VORTAC facility within which a signal of usable strength exists and where that signal is not operationally limited by co-channel interference. The advertised service volume is defined as a simple cylinder of airspace for ease in planning areas of operation.

121. Slant-range. The actual distance from the aircraft to the DME facility.

122. Slant-range/geographical distance. The slant-range distance at a given altitude converted to geographical distance across the ground.

123. Start end of runway. The beginning of the takeoff runway available.

124. Standard instrument departure. A preplanned IFR ATC DP 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.

125. Standard terminal arrival. A preplanned 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.

126. Start of climb. 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.

127. Tangent point. The point on the VOR/DME RNAV route centerline from which a line perpendicular to the route centerline would pass through the reference facility.

128. Tangent point distance. Distance from the reference facility to the TP.

129. Threshold crossing height. 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.

130. Touchdown and lift-off area. A TLOF is a load bearing, generally paved area, normally centered in the FATO, on which the helicopter touches down or lifts off from.

131. Touchdown zone. The first 3000 feet of runway beginning at the threshold. For helicopter procedures it is identical to the landing area.

132. Touchdown zone elevation. The highest runway centerline elevation in the first 3000 feet of the landing surface (touchdown zone).

133. Track to fix leg. A TF leg is a geodesic path between two fixes. The resulting track is wind corrected.

134. Transition level. The altitude below which heights are expressed in feet MSL and are based on an approved station altimeter setting. The transition level in the United States is 18000 MSL. Altitudes at and above the transition level are expressed in FL. For example, 11000 feet, 17900 feet, FL 180, FL 230, etc.

135. True airspeed. 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.

136. 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.

137. Turn fix. A FB or FO fix denoting a course change.

138. Turn initiation area. The straight portion of a missed approach OEA whose end is identified by a turn at a specified altitude.

139. Turn WP. A WP which identifies a change from one course to another.

140. Unmarked landing area. A designated landing location within the NAS identified by an airport identifier and a set of coordinates. Utilized for helicopter PinS procedures which have no visual reference for the pilot.

141. Vertical descent angle. An advisory angle provided on most nonprecision approach procedures representing the calculated descent angle from the PFAF (or stepdown fix). The VDA is intended to assist the pilot in maintaining a stable vertical path within the final segment.

142. Vertical error budget. 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.

143. Visual climb area. Areas around the ARP to develop a VCOA procedure.

144. Visual climb over airport. Option to allow an aircraft to climb over the airport with visual reference to obstacles to attain a suitable altitude from which to proceed with an IFR departure.

145. Visual descent point. The VDP is a defined point on the final approach course of a non-precision straight-in approach procedure from which normal descent from the MDA to the runway touchdown point may be commenced, provided visual reference is established.

146. Vertical guidance surface. The VGS is a narrow inclined plane centered on the runway centerline that is evaluated for obstructions between the DA/VDP and LTP for all straight-in aligned approach procedures.

147. Visual glide slope indicator. 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.

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

149. Visual segment reference line (VSRL). A line perpendicular to the final course at a distance of 75 ft (22.9 m) from the helipoint for public use heliports and 50 ft (15.27 m) from the helipoint for heliports with special instrument procedures. It extends 75 ft (22.9 m) on each side of the final course centerline for public use heliports and 50 ft (15.27 m) on each side of the final course centerline for heliports with special instrument procedures. For IFR procedures the line is 75 ft (22.9 m) from the helipoint and it extends 75 ft (22.9 m) on each side of the final approach course.

150. WP. A predetermined geographical position used for route definition and progress reporting purposes that is defined by latitude/longitude.

151. WP displacement area. The rectangular area formed around and centered on the plotted position of a WP.

152. Wide Area Augmentation System. 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.

Appendix C. Precipitous Terrain Algorithms

1. Precipitous Terrain Equations, Parameters, Interests, Weights, and Adjustment Values. A digital terrain data base (100 m or 3 arcsecond separation density or better) must be used for the determination of precipitous terrain. The precipitous terrain area will contain the prescribed segment (both primary and secondary, if applicable) and a 2 NM buffer surrounding that segment. For segments that are comprised of multiple legs, each leg should be evaluated separately. The digital terrain data within that defined area will be analyzed electronically to determine the values of five specific parameters [g(1) through g(5)], which will be transformed into interest values [I(1) through I(5)], weighted [W(1) through W(5)] and combined to determine the base precipitous adjustment,

a. *Step 1*. The equations, minimum and maximum thresholds, and weight values for each parameter are:

<u>Average elevation</u>

$g(1) = \frac{\sum h(x,y)}{n}$
$\min(1) = 600\ meters$
$\max(1) = 3000\ meters$
$W(1) = 0.05$

<u>98th percentile – 2nd percentile height differential</u>

$g(2) = h_{98percentile} - h_{2percentile}$
$\min(2) = 250\ meters$
$\max(2) = 2500\ meters$
$W(2) = 0.30$

<u>Slope gradient</u>

$$g(3) = \sqrt{\left(\frac{D_a}{D}\right)^2 + \left(\frac{D_b}{D}\right)^2}$$

$\min(3) = 0.015$
$\max(3) = 0.060$
$W(3) = 0.10$

<u>Standard deviation from plane of best fit</u>

$$g(4) = \sqrt{\frac{\sum \left[h(x,y) - \left(\frac{D_a \times x}{D} + \frac{D_b \times y}{D} + \frac{D_c}{D}\right)\right]^2}{n}}$$

$min(4) = 40 \text{ meters}$
$max(4) = 200 \text{ meters}$
$W(4) = 0.35$

<u>98th percentile max - min height differential within 0.50 NM of each terrain posting.</u>

$g(5) = (h_{max} - h_{min})_{98percentile}$
$min(5) = 100 \text{ meters}$
$max(5) = 1000 \text{ meters}$
$W(5) = 0.20$

b. *Step 2*. The interest values are based on the parameter thresholds and are found via this piecewise function:

$g(i) < min(i)$:
$I(i) = 0$

$min(i) \leq g(i) \leq \max(i)$:

$$I(i) = \frac{g(i) - min(i)}{max(i) - min(i)}$$

$g(i) > \max(i)$:
$I(i) = 1$

c. *Step 3*. The combined interest (CI) is computed as follows:

$$CI = W(1) \times I(1) + W(2) \times I(2) + W(3) \times I(3) + W(4) \times I(4) + W(5) \times I(5)$$

d. *Step 4*. The base precipitous adjustment (BA) is also a piecewise function with a minimum threshold of 0.20 and a maximum of 0.60.

$CI < 0.20$:
$BA = 0$

$0.20 \leq CI \leq 0.60$:
$BA = 500 \times CI - 50$

$CI > 0.60$:
$BA = 250$

e. *Step 5*. Finally, BA is applied and rounded varyingly depending on the evaluated segment to derive the actual adjustment (A) (see note 1).

Rounded to the next higher 1 foot increment:

Precision and APV finals (see note 2)

$A = 0.10 \times HAT$

Rounded to the next higher 10 foot increment:

Nonprecision finals

$A = BA$

Intermediate

$A = 1.25 \times BA$

Initial, holding, and missed approach OEA.

$A = 1.5 \times BA$

Note 1: Precipitous terrain evaluation is not required for the sloping portion of departures and missed approach. Where precipitous terrain evaluation is required, refer to additional guidance provided by criteria.

Note 2: When $BA > 0$, use the HAT output based on final and missed approach assessment, excluding remote altimeter adjustments.

Explanation of variables:

$h(x, y)$ = height (meters) of the selected terrain posting

x = x coordinate of the selected terrain posting

y = y coordinate of the selected terrain posting

n = number of terrain postings in the area

$h_{98percentile}$ = height (meters) of the 98th percentile terrain posting

$h_{2percentile}$ = height (meters) of the 2nd percentile terrain posting

h_{max} = height (meters) of the highest terrain posting within 0.50 NM of the selected post

h_{min} = height (meters) of the lowest terrain posting within 0.50 NM of the selected post

$$D = \begin{vmatrix} \sum x^2 & \sum x \times y & \sum x \\ \sum x \times y & \sum y^2 & \sum y \\ \sum x & \sum y & n \end{vmatrix}$$

$$D_a = \begin{vmatrix} \sum x \times h(x,y) & \sum x \times y & \sum x \\ \sum y \times h(x,y) & \sum y^2 & \sum y \\ \sum h(x,y) & \sum y & n \end{vmatrix}$$

$$D_b = \begin{vmatrix} \sum x^2 & \sum x \times h(x,y) & \sum x \\ \sum x \times y & \sum y \times h(x,y) & \sum y \\ \sum x & \sum h(x,y) & n \end{vmatrix}$$

$$D_c = \begin{vmatrix} \sum x^2 & \sum x \times y & \sum x \times h(x,y) \\ \sum x \times y & \sum y^2 & \sum y \times h(x,y) \\ \sum x & \sum y & \sum h(x,y) \end{vmatrix}$$

To compute the determinant, use the following:

$$Matrix = \begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \end{vmatrix}$$

$$D = A \times E \times I + B \times F \times G + C \times D \times H - A \times F \times H - B \times D \times I - C \times E \times G$$

2. Precipitous Point Value Methodology. A digital terrain data base (100 m or 3 arcsecond separation density or better) must be used for the determination of precipitous terrain. Four parameters are calculated from all terrain points within 1 NM of the geographic location being evaluated (see table C-1).

Table C-1. PPV Parameters

ID	Description	Range (R_{min}-R_{max})	Definition	Weight
P_1	Average Elevation	800-3200	$\sum_{i=1}^{k} \frac{h(x_i, y_i)}{n}$	0.10
P_2	Slope of Plane of Best Fit	0.04-0.15	$\sqrt{a^2 + b^2}$	0.15
P_3	Standard Deviation from Plane of Best Fit	33-165	$\sqrt{\frac{\sum_{i=1}^{k}\left(h(x_i, y_i) - \hat{h}(x_i, y_i)\right)^2}{n}}$	0.55
P_4	Elevation Difference	300-1500	H_s - H_t	0.20

a. These definitions hold when:

(1) $h(x, y)$ is the elevation in meters of the terrain at the geographic location indicated by (x, y).

(2) The plane of best fit using least squares is given by $\hat{h}(x, y) = ax + by + c$.

(3) k is the number of geographic locations within 1 NM of the point being evaluated.

(4) H is the set of $\{H\ (x_i, y_i) | i = 1, 2, \ldots k\}$ ordered least to greatest.

(5) $s = \lceil 0.98\ x\ k \rceil$

(6) $t = \lfloor 0.02 \times k \rfloor$.

b. Each of these parameters is linearly scaled within its respective range, from R_{min} to R_{max} (see formula C-1). These scaled parameters are then combined via their weights (see formula C-2). They are then scaled again (see formula C-3).

Formula C-1. Linearly Scaled Within Respective Range, from R_{min} to R_{max}

$$I_i = \begin{cases} 0 & : P_i < R_{min} \\ \dfrac{P_i - R_{min}}{R_{max} - R_{min}} & : R_{min} \leq P_i < R_{max} \\ 1 & : P_i \geq R_{max} \end{cases}$$

Formula C-2. Scaled Parameters Combined via Their Weights

$$C = \sum_{i=1}^{4} (W_i \; x \; I_i)$$

Formula C-3. Parameters Scaled Again

$$PPV = \begin{cases} 0 & : C \leq 0.2475 \\ \left\lceil 50 + \left(\dfrac{C - 0.25}{0.5} \times 200 \right) \right\rceil & : 0.2475 < C < 0.7475 \\ 250 & : C \geq 0.7475 \end{cases}$$

3. PPV adjustment values are determined as follows (see table C-2).

Table C-2. PPV Adjustment Values

Segment	Adjustment Values
PA/APV Final Approach Segment	Apply paragraph 3-2-2b(1)(a)2. when $PPV_{max} > 0$
Nonprecision Final Approach Segment	$\lceil 0.4 \times PPV_{max} \rceil$ ft
Intermediate Approach Segment	$\lceil 0.5 \times PPV_{max} \rceil$ ft
Initial Approach Segment, Missed Approach OEA, Holding Areas	$\lceil 0.6 \times PPV_{max} \rceil$ ft

Note: PPV_{max} is the maximum PPV value contained within the segment OEA, including secondary areas if applicable.

Appendix D. Mathematics Convention

1. Mathematical Functions and Constants.

a. Functions.

(1) $a + b$ indicates addition.

(2) $a - b$ indicates subtraction.

(3) $a \times b$, ab, a·b, or a*b indicates multiplication.

(4) $\frac{a}{b}$, a/b, or a÷b indicates division.

(5) $(a - b)$ indicates the result of the process within the parenthesis.

(6) $|a - b|$ indicates the absolute value and that result of a-b is assigned a positive sign.

(7) ≈ indicates approximate equality.

(8) $\sqrt{a}$, $a^{0.5}$, or a^0.5 indicates the square root of quantity "a."

(9) a^2 or a^2 indicates a×a.

(10) ln(a) indicates the natural logarithm of "a."

(11) tan(a) indicates the tangent of "a" degrees.

(12) atan(a) indicates the arc tangent of "a."

(13) sin(a) indicates the sine of "a" degrees.

(14) asin(a) indicates the arc sine of "a."

(15) cos(a) indicates the cosine of "a" degrees.

(16) acos(a) indicates the arc cosine of "a."

b. Constants.

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

(2) **r** is the TERPS constant for the mean radius of the earth for spherical calculations in feet. r = 20890537.

2. Operational Precedence (Order of Operation).

a. First. Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.

b. Second. Functions: tangent, sine, cosine, arcsine, and other defined functions

c. Third. Exponentiations: Powers and roots

d. Fourth. Multiplication and Division: Products and quotients

e. Fifth. Addition and Subtraction: sums and differences

Examples:

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

$(5 - 3) \times 2 = 4$ because parentheses takes 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 takes precedence over addition.

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

$sin\left(\frac{30°}{0.5}\right) = 0.8660254$ because parentheses takes 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 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.

3. Conversions by Unit Factors

a. Degree measure to radian measure:

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

b. Radian measure to degree measure:

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

c. Feet to meters:

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

d. Meters to feet:

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

e. Feet to Nautical Miles (NM):

$NM = feet \times \frac{.3048\,NM}{1852\,ft}$ Example: $1.38707\,NM = 8420\,ft \times \frac{.3048\,NM}{1852\,ft}$

f. NM to feet:

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

g. NM to meters:

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

h. Meters to NM:

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

i. Temperature Degrees Celsius (°C) to Degrees Fahrenheit (°F):

$T_{Fahrenheit} = 1.8 \times T_{Celcius} + 32$ Example: $68°F = 1.8 \times 20°C + 32$

j. Temperature Degrees Fahrenheit (°F) to Degrees Celsius (°C):

$T_{Celcius} = \frac{T_{Fahrenheit} - 32}{1.8}$ Example: $20°C = \frac{68°F - 32}{1.8}$

4. Other Conversions.

a. Degrees to a gradient (feet per NM).

$gradient = \tan(degrees) \times \frac{1852\,ft}{.3048\,NM}$

Example: $318.4351719\,ft/NM = \tan(3) \times \frac{1852\,ft}{.3048\,NM}$

b. Gradient (feet per NM) to degrees.

$degrees = \text{atan}\left(\text{gradient} \div \frac{1852\,ft}{.3048\,NM}\right)$

Example: $3° = a\tan\left(318.4351719\,ft/NM \div \frac{1852\,ft}{.3048\,NM}\right)$

c. Slope (run over rise) to degrees.

$degrees = \text{atan}\left(\frac{rise}{run}\right)$ Example: $2.86° = a\tan\left(\frac{1}{20}\right)$

d. Degrees to slope.

$slope = \frac{1}{\tan(degrees)}$ Example: $20{:}1 = \frac{1}{\tan(2.862405)}$

5. Common Equation Terms. These terms/variables are common to all calculations.

Table D-1. Common Equation Terms

Equation Acronym	Equation Terminology
MSL	above mean sea level
ϕ	bank angle
β	Magnitude of heading change in degrees
θ	vertical angle in degrees
DA	decision altitude in feet MSL
alt	altitude in feet MSL
apt_{elev}	published airport elevation in feet MSL
LTP_{elev}	published threshold elevation in feet MSL
TCH	threshold crossing height in feet above threshold
$PFAF_{alt}$	minimum intermediate segment altitude in feet MSL
O_{MSL}	obstacle elevation in feet MSL
OBS_X	along-track distance in feet from LTP to obstacle
HAT	difference between touchdown zone elevation (rounded to the nearest foot) and DA/MDA
HAL	difference between helipoint elevation (rounded to the nearest foot) and DA/MDA

Appendix E. Simultaneous Approach Operations

Section 1. General Information about Simultaneous Approaches.

1. Purpose. This appendix is associated with chapter 15 and provides background information related to simultaneous operations. This information has historically been included in TERPS or other 8260-series documents, but is not directive for IFP developers (it is information only). The primary audience for this appendix is the Site Implementation Team (SIT), or ATC facility that has the responsibility to develop and implement simultaneous approach operations. An additional audience is managers and planners in Flight Operations, Certification, and Air Carrier Operations.

2. Background. Capacity at the nation's busiest airports may be significantly increased by using simultaneous approaches (see figure E-1, figure E-2 and figure E-3). Simultaneous approach operations (dual, triple and quadruple) provide increased capacity without diminishing safety by authorizing reduced ATC separation when appropriate conditions/mitigations are in place to maintain a low level of risk.

a. The Precision Radar Monitor (PRM) is an advanced E-scan radar or multilateration monitoring system intended to increase the use of multiple, closely-spaced parallel runways in IMC weather by use of high resolution displays with alert algorithms and higher aircraft position update rate. Use of PRM for NTZ monitoring is described further in Order JO 7110.65. Based on studies in 2013 and 2014, the use of PRM surveillance is no longer required for most SCP approaches but all other requirements for conducting PRM approaches remain in effect.

b. For current simultaneous operations, ATC applies standard radar separation until participating aircraft are established on parallel FACs. Based on recent studies concerning simultaneous independent PBN procedures considered established on approach, ATC may discontinue standard separation after the aircraft is established on the initial/intermediate approach segment (see figure E-3). It is prudent to review those studies, especially to see the applicable assumptions and conditions of the study, before requesting that type of approach operation. Use of TF legs maximizes fleet participation; however, designs may include TF and/or RF legs. To decrease the probability of overshoots and to minimize FMA and TCAS alerts a 10-degree intercept to the final approach course is used for TF designed legs. Approaches will diverge from other approach paths by 0.5 NM so that the path extends 50 seconds or more before it crosses any other approach path authorized for simultaneous independent operations. For example, extend downwind when transitioning to center and outside runways. This is necessary for ATC to confirm the correct approach is being flown and have time to take appropriate actions to establish appropriate separation (see figure E-3 and section 2, paragraph 6 of this appendix and section 15-5).

Figure E-1. Example of Simultaneous Independent Dual Approaches

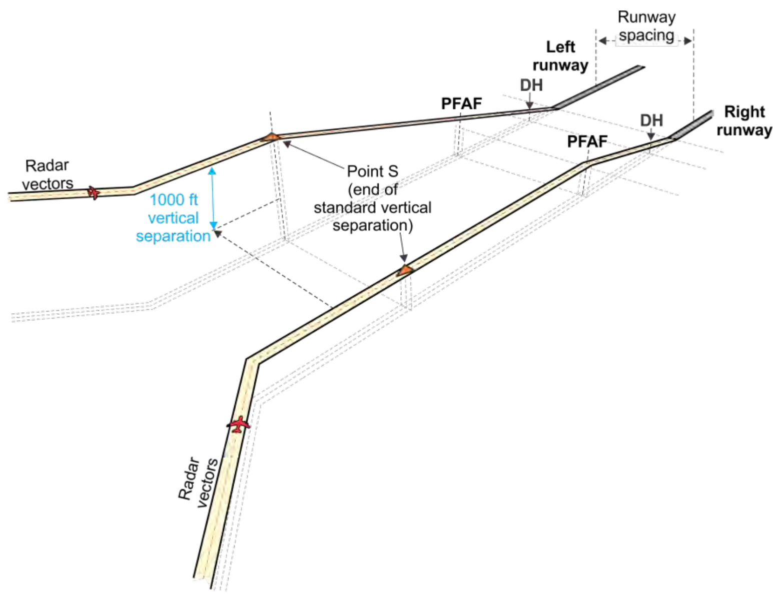


Figure E-2. Example of Triple Independent Simultaneous Approaches

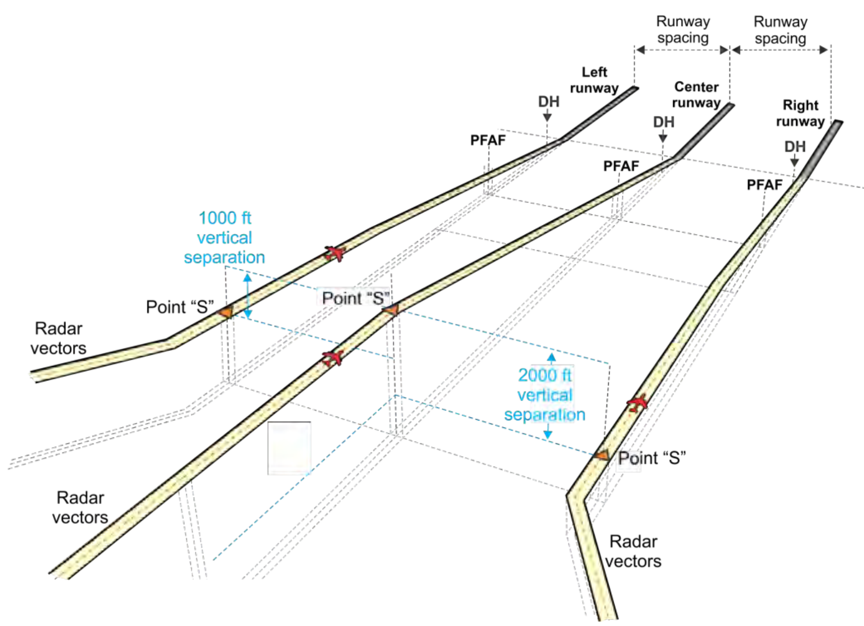
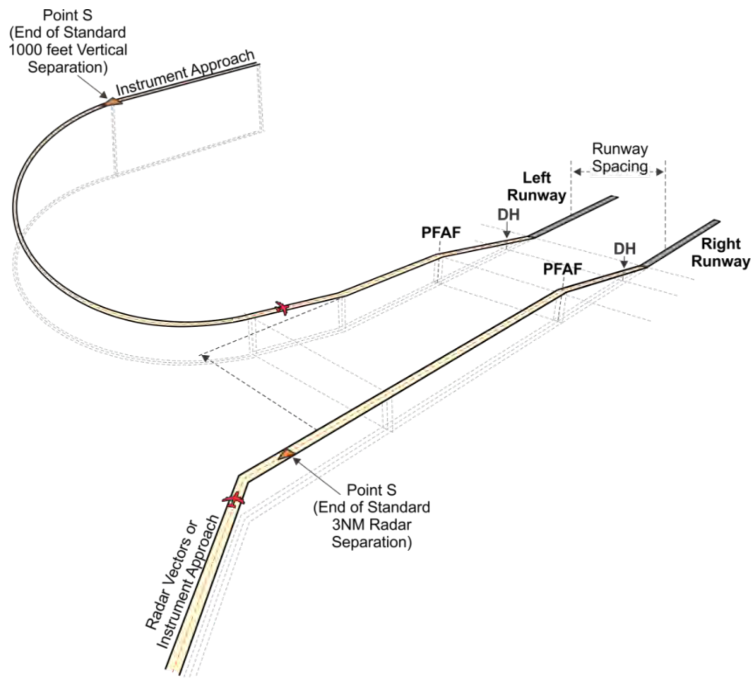


Figure E-3. Example of PBN Simultaneous Independent Procedures Considered Established on Approach Dual Approaches



3. Overview. Simultaneous independent approach operations use reduced air traffic separation and provide a means to maintain near-optimum airport efficiencies in conditions of reduced ceiling and visibilities. A procedure is authorized (by applicable chart notes) if it meets the guidance in this order and other applicable 8260-series criteria and ATC guidance.

4. Safety Studies and Tests. Those conducted by Flight Technologies and Procedures Division and other organizations have shown that a reduction in minimum separation between parallel runways may be achieved by the use of specific air traffic equipment and procedures and precise navigation capabilities. The safety studies that support simultaneous independent approaches, generally, are based on the assumption that standard separation, either 1000 feet vertical or 3-NM radar separation, is maintained until participating aircraft are established on the final approach course (FAC), or the turn on to the extended FAC and that an NTZ begins at the point where 1000 feet vertical or 3-NM radar separation will no longer be provided.

5. Terms, Concepts, and Implementation Considerations.

a. Breakout. This is a technique/procedure to direct an aircraft out of the approach stream. In the context of simultaneous approach operations, when ATC is monitoring aircraft and has an NTZ established, a breakout is used to direct threatened aircraft (sometimes called evading aircraft) away from a deviating aircraft (sometimes called blundering aircraft). A breakout normally is a vector off the FAC, either straight-in FAC or offset course FAC, in response to another aircraft penetrating the NTZ or otherwise being determined as a potential collision threat by ATC. The breakout normally includes a climb, but (under certain conditions including being above the MVA) might include a descent for the evading aircraft. Since the blundering aircraft is assumed not to hear or not to respond to (perhaps repeated) instructions to return to the course, a breakout for the evading aircraft is the standard method assumed in safety studies to mitigate converging paths.

Note: In this appendix, when discussing the straight-in approach/straight-in FAC and the offset approach/offset FAC used for simultaneous operations, those two terms are to be understood to meet the straight-in/offset parameters in chapter 15, not necessarily meeting the parameters in chapters 2, 8, and 10.

b. Missed approach course divergence. The published missed approach heading/course/ track must diverge for each pair of simultaneous procedures by a minimum of 45 degrees. The 45-degree divergence is required until other separation can be applied. Examples of combined divergence of at least 45 degrees are:

Example 1: The missed approach for the right runway is straight ahead and the left runway turns 45 degrees left.

Example 2: The right runway missed approach turns 30 degrees right and the left runway turns 15 degrees left.

Note: For the SOIA offset FAC approach, the initial divergence with the straight in FAC approach is achieved through an assigned heading (see section 15-3).

c. Runway spacing. The required spacing between runways/procedure FAC for dual/triple simultaneous operations is in accordance with this order and Air Traffic Directives, supported by Flight Technologies and Procedures Division safety studies. Some runway spacing requirements (for example spacing and missed approach Quadruple SIPIA operations) require a site-specific safety analysis. For a safety analysis, a written request must be submitted to Flight Technologies and Procedures Division with a copy to Flight Research and Analysis Group.

Note: The runway spacing numbers throughout chapter 15 and this appendix refer to distances to runway centerline rather than to the runway edge.

d. System requirements. The types of instrument procedures that can be used for simultaneous operations are based on safety studies and depend upon airport configuration, aircraft navigation capabilities, and ATC system capabilities. Simultaneous operations are based on radar, communications, and procedures as specified by the applicable ATC directives. System requirements for simultaneous approach procedures typically include:

(1) Final approach guidance (see chapter 15 for permissible types of approach procedures).

(2) DME source. For a SOIA ILS approach, an ILS DME must be installed. For a SOIA LDA approach, an LDA DME must be installed. DME distance is provided not only to identify fixes along the FAC but also to assist the pilot in determining the aircraft’s real time position as it proceeds along the FAC. Other DME sources are not approved because they would provide less continuous positional accuracy along the FAC.

(3) Vertical guidance. Approaches requested to authorize simultaneous operations must have vertical guidance, except as allowed in section 15-1. For approaches designed to support simultaneous operations to runways spaced less than 4300 feet (SOIA and SCP), only vertically guided lines of minimums are allowed. For further information on the use of vertical guidance and the lines of minima allowed, see sections 2, 3, and 4.

(4) NTZ radar monitoring. ASR is generally used but high update surveillance, such as PRM, is used under certain conditions depending on runway spacing and course convergence. See applicable safety studies. The radar or ATC automation system might also require FMA with alert algorithms.

(5) Simultaneous close parallel (SCP) approaches. System requirements for SCP, including SOIA, include monitor controller override of the tower frequency, a secondary PRM frequency for each runway used for SCP, NTZ radar monitoring using FMA with alert algorithms, IAPs with "PRM" in the title and applicable chart notes, pilot training requirements for participating aircrews, and publishing Attention All Users Page (AAUP) information. For guidance on AAUP, see Order 8260.19.

e. List of authorized simultaneous operations. When there are simultaneous operations authorized, it is essential that the local ATC procedures authorizing those operations specifically indicate the authorized/unauthorized runway pairs, specific approaches (if only some approaches are authorized) and the type of operation, such as independent/dependent, duals/trips/quads and routes/IAFs excluded, if any. That is especially important with the recent changes to the publishing requirements that no longer require the approach plate chart notes to state the runway pairs or specific approaches authorized for simultaneous operations.

f. Approach design for fixes on the portion of the approach that is aligned with the FAC. It is highly recommended that the high temperature algorithm (also called temperature compensation) be used when placing fixes on the FAC and extended FAC. The advantage is to allow aircrews to make a stabilized descent, even on days with high temperatures. If the high temperature algorithm is not applied, on high temperature days the pilot might have to shallow out or even briefly level off to meet an altitude restriction instead of being able to follow the glide slope indication. However, since the algorithm results in the fixes being further out, there may be circumstances, such as airspace constraints, that preclude applying the high temperature algorithm. TERPs specialists should coordinate with the affected ATC facility.

6. Related Documentation. See ATC directives such as Order JO 7210.3 and Order JO 7110.65, for operational and equipment requirements. See the Pilot/Controller Glossary for a definition of a parallel runway. Also see the Aeronautical Information Manual (AIM) and Aeronautical Information Publication (AIP) for further operational explanation of simultaneous approach operations.

Section 2. Additional Information for Simultaneous Independent Approaches Spaced at Least 4300 Feet Apart.

1. Purpose. This section is associated with section 15-1 and provides background information related to SIPIA operations to runways spaced at least 4300 feet apart (see section 3 for dual or triple approaches to runways spaced less than 4300 feet apart).

2. Vertical Guidance. The advantage of vertical guidance for instrument approaches is supported by various safety studies. For runways spaced at least 4300 feet, both instrument approach procedures may be designed to have a LOC line of minima to allow flexibility, however vertically-guided procedures must be provided whenever possible.

Note: The operational advantage for including a line of localizer minimums when publishing an ILS approach is that SIPIA operations may continue during an ILS glide slope outage or an equipment failure in the aircraft that denies use of ILS minima but still allows the aircraft to use the LOC line of minima. Limits on the use of approaches for simultaneous operations during glide slope outages are also addressed in Order JO 7210.3 and, when applicable, associated notices.

3. ATC Operations Concept. Simultaneous operations safety studies are based on the ATC operational and equipment requirements stated in Order JO 7110.65. Those requirements include a NTZ established by ATC for each adjacent runway pair used during simultaneous approach operations except where there is sufficient runway spacing that an NTZ is not required, as stated in Order JO 7110.65.

4. NTZ. A 2000 feet wide area is designated equidistant between the FACs for each runway pair, in which flight is normally not allowed (when there is adjacent traffic) during simultaneous independent approach operations. It must begin at or before the farthest point in the adjacent runway pair where any aircraft established on the approach will no longer be provided 1000 feet vertical or 3-NM radar separation (point “S” in figure E-3 and figure E-4). For runways separated by at least 4300 feet, the NTZ ends when abeam the first approach end of runway landing threshold (THLD) also called the landing threshold point (LTP).

Note 1: The NTZ termination point is not changed even when controllers are no longer required to provide aircraft with NTZ radar monitoring (visual separation being applied or aircraft report the runway in sight as examples). The automated alerts, if installed, will continue to be active to the end of the NTZ. Automated alert is a feature that provides visual and/or audible alerts to the monitor controller when an aircraft is projected to enter or has entered the NTZ.

Note 2: Also see the later sections of this appendix concerning the NTZ for runways spaced less than 4300 feet.

5. Normal Operating Zone (NOZ). This is the area remaining between the approach courses and the edge of the NTZ. The NOZ is the operating zone within which aircraft flight remains during normal independent simultaneous parallel approaches (see figure E-4 and figure E-5). The NOZ is used in safety analysis, not in ATC operations.

Figure E-4. Final Approach Courses. No Transgression Zones and Normal Operating Zones (Dual Approach, Non-PRM, Spacing at least 4300 feet)

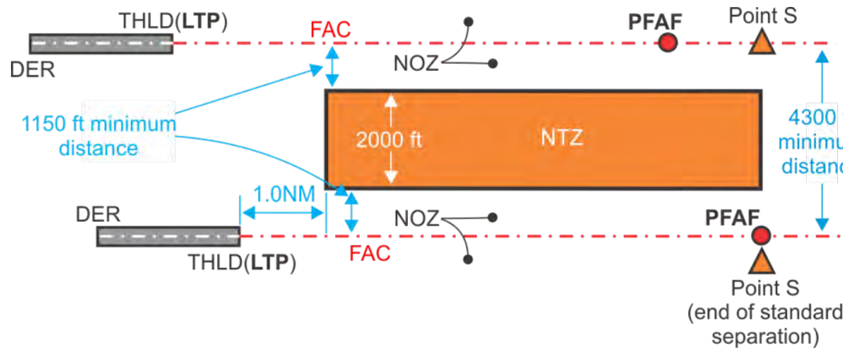
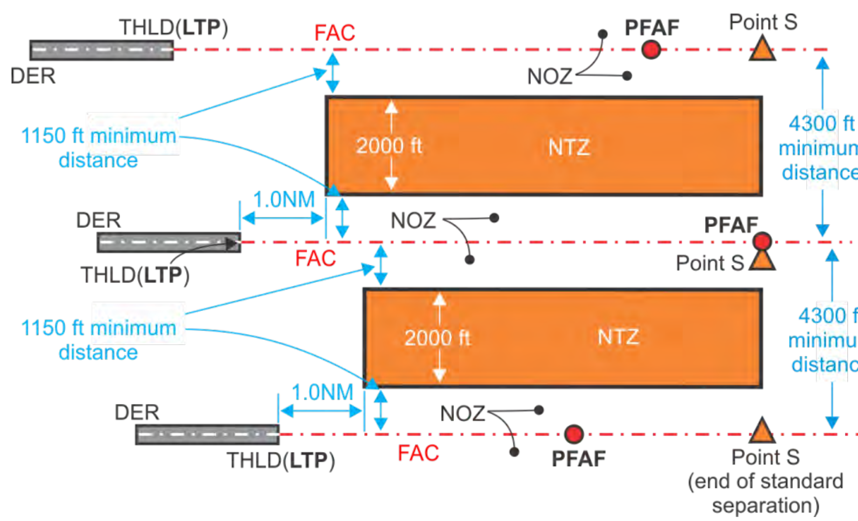


Figure E-5. Final Approach Courses. No Transgression and Normal Operating Zones (Triple Approach, Non-PRM, Spacing at least 4300 feet)



Note: For triple approaches, the highest glide slope intercept altitude should be associated with the approach to the center runway and that intercept point establishes were point S is located for the other two runways.

6. Design Guidelines. The following guidelines, based on safety studies, are to be used:

a. On GLS, RNAV (GPS), and RNAV (RNP) approaches use of flight director (FD) or auto pilot (AP) is required to provide course/track guidance.

b. On ILS approaches, the chart note for FD or AP is required in the situation where RNAV, including RNAV (RNP) is used for a route to transition aircraft to ILS. It would not apply to a procedure that uses only radar vectors to transition aircraft to the ILS (no RNAV routes leading to the localizer course).

c. Results of safety studies indicate that a 10-degree intercept to the final approach course will decrease the probability of overshoots and to minimize FMA and TCAS alerts especially for runways spaced less than 4800 feet apart.

d. GPS is required to be available and included in the aircraft navigation solution for RNAV (GPS), RNAV (RNP), and GLS approaches and where an RNAV route is used to join an ILS or LOC final.

Note: When there are some routes that do not qualify for simultaneous operation, the local ATC procedures authorizing the simultaneous operation must specifically exclude those routes/IAFs (also see section 1, paragraph 4 of this appendix).

Section 3. Additional Information for Simultaneous Close Parallel (SCP) Approaches

1. SIT. At locations that propose the use of simultaneous procedures, particularly for independent close parallel approaches (including SOIA) use of a SIT is recommended to work through the issues of establishing the approach procedures. The team is made up of FAA (including Flight Technologies and Procedures Division) and industry members and the leadership of the team is as designated by Air Traffic.

a. When the ATC facility and Service Area is determining whether to form a SIT, considerations include the complexity of the project and the expressed desire of persons and organizations to participate in the approach/AAUP development. If no team is formed, the ATC facility that controls the airspace in which the procedures are to be conducted must perform the responsibilities of the team.

b. When an ATC facility proposes procedure development from an airport served primarily by air carriers, they should attempt to solicit the assistance of a “lead carrier” in the design and flyability of the proposed approach procedures.

2. Concepts, Terms, and Implementation. SCP applies to simultaneous independent approach operations- dual and triple- spaced at least 3000 feet apart but less than 4300 feet apart.

Note: The runway spacing requirements may change in the future based upon Flight Technologies and Procedures Division studies and/or to changes in surveillance and monitoring systems.

a. AAUP. For SCP approaches, including SOIA, an AAUP must be published to present to the flight crew the various procedures that must be used when conducting the approach, in a form that may be reviewed prior to conducting the procedure. An AAUP is required unless specifically exempted by an Flight Technologies and Procedures Division safety study; however, the establishment of an AAUP should still be considered if ATC or users of the procedures indicate an AAUP would be beneficial. A single AAUP should be developed for all of the “PRM” approaches at an airport; however, within the AAUP, do not combine the instructions for runways that have different aircrew procedures. The AAUP contents must address how an aircraft responds to an ATC “breakout.” An ATC directed “breakout,” for SCP or SOIA, will be manually flown unless otherwise approved by Air Transportation Division. Air Transportation Division must have Flight Technologies and Procedures Division’s concurrence to approve breakout in auto modes. See Order 8260.19 for the AAUP processing, content and for form completion instructions.

b. Close parallel runways. Two parallel runways whose centerlines are separated by less than 4300 feet.

c. High update radar. High update rate surveillance systems, such as PRM, that are approved by air traffic for SCP approach operations.

(1) In this context, “RADAR” is used for systems such as PRM E-scan radar and also for systems that include other types of surveillance inputs such as PRM-A multilateration. The

term “high update radar” is used interchangeably in this appendix and chapter 15 with “high update rate radar”. Both terms apply to the equipment used for NTZ monitoring for (some) SCP approach operations.

(2) PRM is a specialized ATC surveillance system, using E-scan radar or PRM-A multilateration, providing continuous coverage throughout the monitor zone. It includes a high accuracy, high update rate sensor system, and for each runway, a high resolution color Final Monitor Aid (FMA) with automated alerts. The PRM system provides each monitor controller with a precise presentation of aircraft conducting approaches and of the NTZ (also see AIM, AIP, and FAA Pilot/Controller Glossary).

Note 1: The monitor zone, as used in the paragraph above, is the volume of airspace within which the final monitor controllers are monitoring the NTZ during SCP approaches.

Note 2: When the term “PRM” is included in the approach designation, it refers to an SCP operation; however, it no longer indicates whether PRM equipment is being used. PRM, as a specific type of equipment, is no longer required for NTZ monitoring for spacing of at least 3000 feet but less than 4300 feet (with less than 3600 feet spacing for dual or 3900 feet for triple, an offset FAC is required); however, since all other requirements for closely spaced approaches must be adhered to, the SCP approach procedures are still designated as “PRM” to indicate the type of operation. SCP approach procedures are designated as “PRM” regardless of the surveillance system used to monitor the NTZ (requires an update rate no slower than 4.8 seconds). The FAA characterizes training for pilots related to SCP approaches as PRM training.

d. NTZ. The NTZ for SCP (see figure E-6 and figure E-7) is the same as for SIPIA except as follows:

(1) For SCP operations, the NTZ must continue until other means of separation are provided if the missed approach tracks do not achieve a combined 45-degree divergence.

(2) Where an offset FAC is used (possible to be used for SIPIA, but normally associated with SCP or SOIA), the NTZ is also equidistant between the two FACs, but is offset. The NTZ is offset by half as much as the offset course angle; for example, when one FAC is offset 3 degrees, the NTZ is offset 1.5 degrees from both the straight-in FAC and the offset FAC (see figure E-6).

(3) If radar coverage in the portion of the NTZ adjacent to the runways and beyond the runways, is not adequate to provide NTZ monitoring as required by safety determinations/ operational safety assessments by Air Traffic and Flight Technologies and Procedures Division, the decision altitude must be raised to be consistent with the radar coverage. If applicable, the decision altitude (minimum needed for coverage) must be included in the procedure request when sent to Aeronautical Information Services.

Note: NTZ monitoring equipment/procedures are specified in air traffic guidance.

e. NOZ. For parallel straight-in FACs, the NTZ is established equidistant between the two FACs, which are on the parallel extended runway centerlines; the NOZ distance is the same all along the NTZ. When one FAC is offset, the NTZ is also established equidistant between the two FACs. The NTZ remains the same (2000 feet) width; but the NOZ distance is different at each point along the NTZ because the offset course provides greater lateral distance the farther the aircraft is from the threshold (see figure E-6 and figure E-7).

Figure E-6. NTZ, NOZ, and FAC- Straight-In Approaches

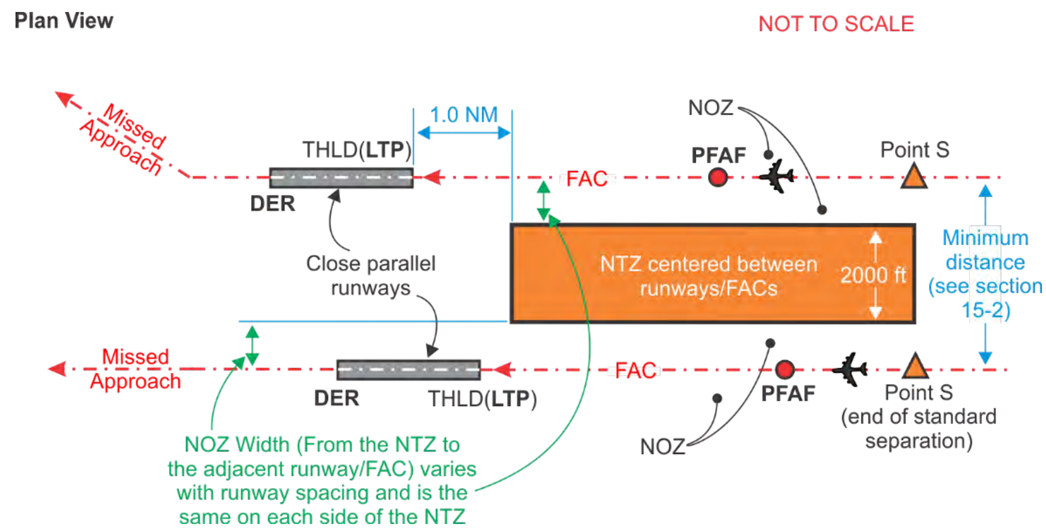
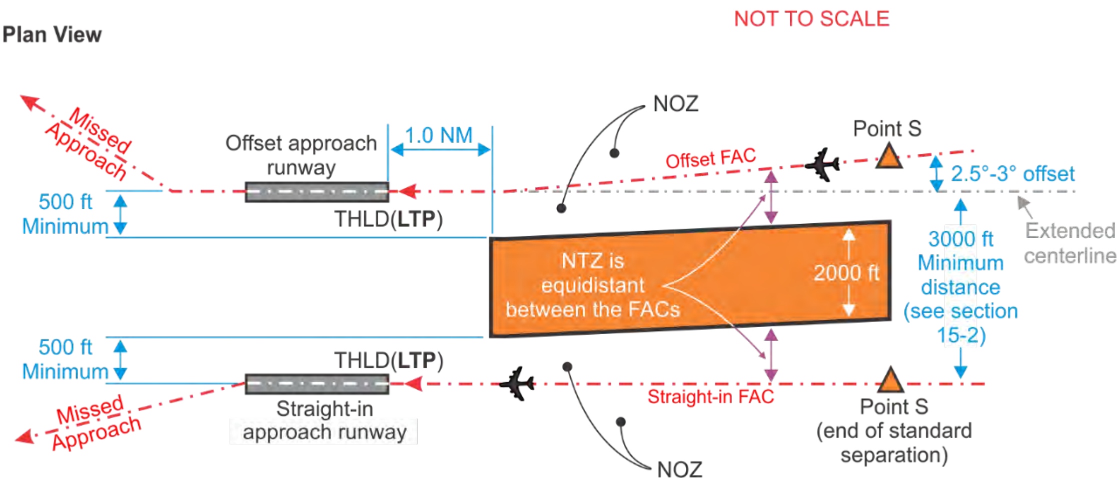


Figure E-7. NTZ, NOZ, and FAC- One Straight-In and One Offset Approach



f. Offset FAC. An angular offset of the FAC from the runway extended centerline in a direction away from the NTZ. An offset course increases the NOZ width as distance increases from the runway (see figure E-7).

3. Approach Design Considerations.

a. Identical approach. A separate instrument approach chart that is identical to the "simultaneous close parallel" procedure is often requested to be published. The identical approach will be exactly like the SCP procedure except that it is not designated for simultaneous operations; it will not include the SCP procedure notes, “PRM” in the title or (Close Parallel) below the title.

Note 1: With the availability of identical approaches, ATC is provided with the flexibility to advertise PRM approaches on the ATIS considerably before traffic density warrants their use and pilots will have ample time to brief the PRM approach.

Note 2: The availability of the non-PRM Approach will permit flight crews that have already briefed the PRM approach procedure, but ATC has yet to begin or has ceased PRM operations, to continue to use the PRM approach chart, during non-PRM operations, without the need to re-brief the non-PRM approach. For that reason, the identical approaches used for simultaneous operations must have the same approach minimums.

Note 3: Also see the discussion of identical approaches for SOIA in section 15-3 and section 4 of this appendix.

b. Extent of simultaneous operations. The point where standard separation is no longer maintained (labeled point S on the figures in this appendix) on independent ILS or LOC SCP approaches should not be authorized at distances greater than 10 NM from threshold. However, if ATC systems and procedures are established which assure minimal probability of NTZ intrusions; this distance may be extended up to 12.5 NM. This limitation should be considered on a site-by-site basis; for example, if the runway spacing is greater than the minimum, a greater distance from threshold (more than 10 NM/12.5 NM) will apply when establishing point S.

Note 1: The reason for limiting the distance for simultaneous parallel ILS procedures is that as the range and splay increases, the likelihood increases of an aircraft that is nominally on course penetrating the NTZ and generating nuisance breakouts. This was found to be a problem at one location that was attempting to use parallel FACs to runways spaced 3380 feet apart.

Note 2: The safety studies that support simultaneous close parallel approaches are based on the assumption that standard separation is maintained until participating aircraft are established on the FAC, or the extended FAC, and that the NTZ begins at the point where standard separation is no longer maintained. When air traffic makes a procedure request, we recommend documenting that point (usually an altitude and/or fix).

Note 3: Where one ILS course is offset, the distance limitation (not to be extended beyond 10 NM/12.5 NM) does not apply regardless of the runway spacing.

Note 4: Where the FAC navigation guidance is based on RNAV (GPS), or GLS, the distance limitation does not apply to either straight-in or offset approaches.

c. Triple approach operation with one set of runways less than 4300 feet spacing. Approach design for *both* sets of runways being at least 4300 feet spacing or for *both* sets of runways being less than 4300 feet spacing is spelled out in sections 15-2 or 15-3 respectively. The combination of one set of runways being less than 4300 feet spacing and one set at least 4300 feet spacing must be evaluated on a case by case basis at this time, pending further safety studies that cover this situation. If the conservative method of applying the close parallel requirements to both sets of runways is done, the exception in paragraph 15-1-8.a allows the procedures to be authorized for simultaneous operations without further approval. If the less demanding method of applying the close parallel requirements only to the closely spaced set of runways is requested, (see paragraph 15-1-8.a) the procedures require approval (see paragraph 1-4-2).

Note: A site specific safety study was done at one location to evaluate this situation on a case by case basis.

4. Authorized Lines of Minimums. SCP approach operations (except SOIA) may use minimums as shown in table E-1 (for SOIA, see paragraph 15-3-3).

Table E-1. Authorized Lines of Minimums for SCP Approach Operations

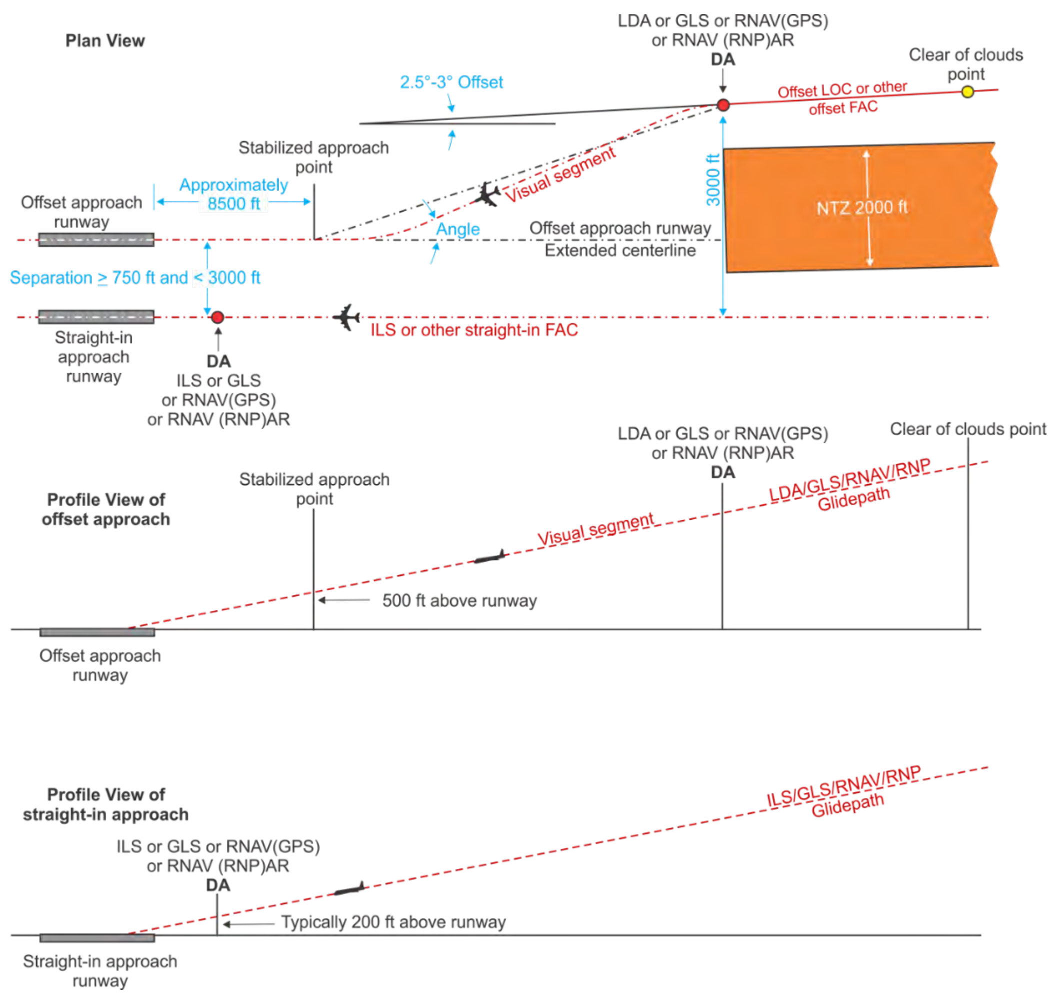
Lines of Minimums for SCP Approaches	Authorized
ILS	Yes
LOC	Not Authorized
GLS	Yes
LPV	Yes
LNAV/VNAV	Yes
LNAV	Not Authorized
LP	Not Authorized
RNP	Not Authorized
LDA, VOR, NDB, etc.	Not Authorized

Note: The approach types that are authorized above may be used in any combination with each other for dual or triple simultaneous approaches. For SCP approaches, the same lines on minima are authorized for either a straight-in or offset FAC. Lines of minima without vertical guidance are not authorized for SCP approach operations. Use of RNP lines of minima for PRM approaches does not have flight operations authorization and is not approved for SCP approach operations.

Section 4. Additional Information for Simultaneous Offset Instrument Approach (SOIA).

1. Concept. SOIA consists of simultaneous independent approaches to close parallel runways utilizing a straight-in approach to one runway and an offset instrument approach to the other runway. SOIA operations are authorized, by applicable chart notes, where simultaneous procedure and instrument approach design meets FAA requirements with conditions to ensure acceptable risk. Safety studies are based on vertical guidance being provided on final. Capacity may be significantly increased to runways spaced less than 3000 feet, when weather conditions will not permit simultaneous visual approaches, by using simultaneous instrument approaches. The use of PRM or other high update rate surveillance systems capable of 1.0-second update interval is recommended for monitoring both aircraft when final approach course spacing at the offset course DA is less than 3000 feet. Implementation of SOIA procedures is done at airports specifically identified by the FAA for SOIA and requires additional analysis and study at most locations (see figure E-8).

Figure E-8. Depiction of the SOIA Concept



Notes:

1. Stabilized approach point. This is a design point along the extended centerline of the intended landing runway on the glide slope/glidepath at 500 feet above the runway threshold elevation. It is used to establish a sufficient distance along the extended runway centerline for the visual maneuver after the offset course approach DA to permit the pilots to conform to approved, stabilized approach criteria. The stabilized approach point is not published on the IAP.

2. Offset course DA. The point along the LDA, or other offset course, where the course separation with the adjacent ILS, or other straight-in course, reaches the minimum distance permitted to conduct closely spaced approaches. Typically, that minimum distance will be 3000 feet without the use of high update radar; with high update radar, course separation of less than 3000 feet may be used when validated by a safety study. The altitude of the glide slope/glidepath at that point determines the offset course approach decision altitude and is where the NTZ terminates. Maneuvering inside the DA is done in visual conditions.

3. Visual segment angle. Angle, as determined by the SOIA design tool, formed by the extension of the straight segment of the calculated flight track (between the offset course MAP/DA and the stabilized approach point) and the extended runway centerline. The size of the angle is dependent on the aircraft approach categories (category D or only selected categories/speeds) that are authorized to use the offset course approach and the spacing between the runways.

4. Visibility. Distance from the offset course approach DA to runway threshold in statute miles.

5. Procedure. The aircraft on the offset course approach must see the runway-landing environment and, if ATC has advised that traffic on the straight-in approach is a factor, the offset course approach aircraft must visually acquire the straight-in approach aircraft and report it in sight to ATC prior to reaching the DA for the offset course approach.

6. Clear of clouds. This is the position on the offset FAC where aircraft first operate in visual meteorological conditions below the ceiling, when the actual weather conditions are at, or near, the minimum ceiling for SOIA operations. Ceiling is defined by the AIM.

2. Design Considerations for Identical Approaches. If an operational advantage can be achieved, the SIT or ATC facility may request an additional approach that is identical to the PRM approach (if one does not exist already) to allow flexibility for controllers and aircrews. The additional (non-SOIA) approach(es) would not have "PRM" in the identification and not have the SOIA related simultaneous operation notes. This additional approach can be used when simultaneous operations are not being conducted, but when it is desirable to have aircraft established on the PRM approach courses prior to or after a SOIA session.

Example: The ATC facility makes a request for the offset LDA PRM RWY 28R approach for SOIA use and an identical (without the simultaneous operation notes) LDA/DME RWY 28R approach for non-SOIA use.

a. Identical approaches. To be considered identical, approaches using the same type of navigation (both approaches using ILS or both LDA or both RNAV for example), must contain the same tracks, fixes, fix crossing altitudes, minimums, and coincident missed approach procedures.

Example: RNAV (GPS) PRM Rwy 28L and RNAV (GPS) Rwy 28L.

b. Non-identical approaches. Approaches that do not meet these criteria are not identical for the purpose of simultaneous operations and require use of a suffix.

Example: RNAV (GPS) PRM Y Rwy 24R and RNAV (GPS) Z Rwy 24R.

c. Design using identical approaches. When SOIA PRM straight-in approaches are designed to a runway that already has a published approach of the same type, the optimum method for designing the PRM approach is to use the existing approach of the same type as a template, only adding “PRM” to the name and adding the required briefing strip and chart notes for SOIA operations.

Example 1: An ILS PRM approach for SOIA (straight-in) use is designed so as to be identical to the existing ILS approaches to runway 28L. Since these approaches are identical, one approach is coded into an FMS; in this example, ILS Rwy 28L in the FMS is used to conduct either the ILS PRM Rwy 28L approach or the ILS Rwy 28L approach.

Example 2: A straight-in RNAV (GPS) PRM approach for SOIA is planned for runway 28L. The existing RNAV (GPS) Rwy 28L approach will be used as the template to produce the SOIA PRM approach. Since the existing approach and the new SOIA approach to Runway 28L will be identical, there is no need to employ suffixes in the approach name. In this example, the RNAV (GPS) Rwy 28L in the FMS is used by aircrews to conduct either the RNAV (GPS) 28L or RNAV (GPS) PRM 28L approach.

d. Design using non-identical approaches. When SOIA PRM approaches are designed to a runway that has other approaches of the same type already published, or planned to be published, and will have different approach courses, fixes, minimums, or missed approaches, suffixes must be used to identify each (non-identical) approach.

Example: An offset course RNAV (GPS) PRM 28R approach for SOIA is planned. There is another published RNAV approach to runway 28R which has a straight-in FAC (and therefore is different from the offset course planned for SOIA). RNAV approaches to 28R must be identified by a suffix (Z, Y for example). If there were already two different approach procedures and the SOIA approach is different from both of them, then each approach must be identified by a suffix (Z, Y, X for example).

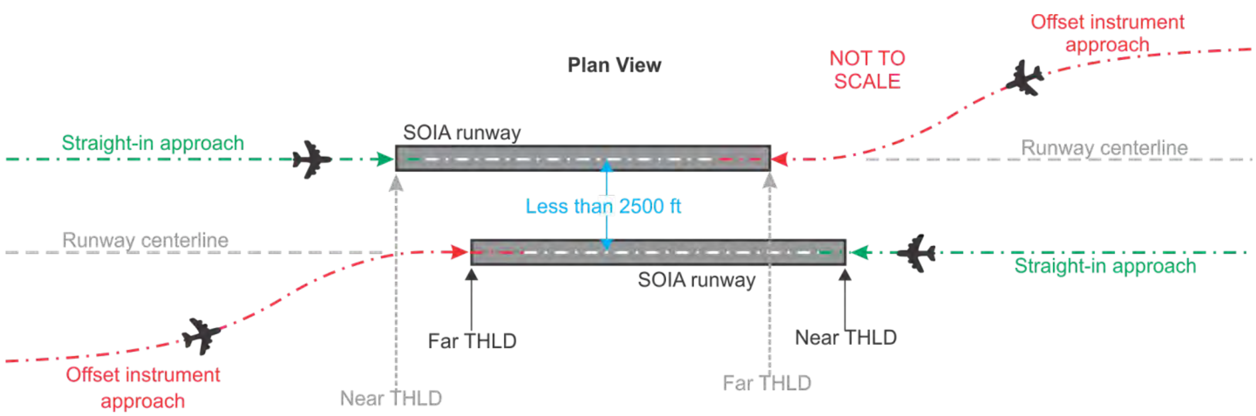
3. Staggered Runway Thresholds. Design considerations for staggered runway thresholds include the following.

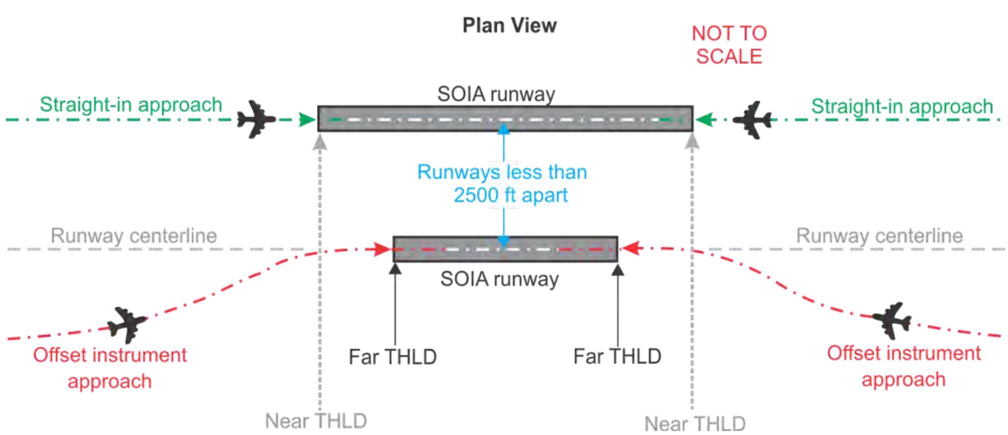
a. Runways separated by less than 2500 feet. For SOIA approach procedures, where there is a stagger between the arrival thresholds on runways separated by less than 2500 feet, you must construct the offset course approach to the runway with the far threshold (see figure E-9), unless an Flight Technologies and Procedures Division study concludes that there is no wake interaction between the two approaches. The offset FAC approach glide slope/glidepath angle must be equal to or greater than the straight-in approach glide slope/glidepath angle. If an exception to this paragraph is needed for site specific circumstances, the SOIA SIT must coordinate with and submit an explanation of the situation to Flight Technologies and Procedures Division with a copy to Flight Operations Group.

Note 1: The intention of this paragraph is to help with wake turbulence mitigation.

Note 2: The terms “far” and “near” are from the approaching aircraft’s point of view.

Figure E-9. Examples of SOIA Design with Staggered Thresholds





b. Runways separated by 2500 feet or more. For runways separated by 2500 feet or more, the design to the far or near threshold is optional; however, it is recommended to be done as stated in paragraph 3a. The SOIA SIT should consider that there may be a benefit, depending on the circumstances at that location, to using the near threshold for the offset course approach.

4. SOIA SIT. At locations that propose the use of SOIA, a SOIA SIT is normally established to work through the issues of establishing the approach procedures. The team is made up of FAA and industry members and the leadership of the team is as designated by ATC. If no Team is established, the FAA facility that controls the airspace in which the approaches are to be conducted is responsible for the functions/tasks of the team. The team (or ATC facility if no team is established) must also ensure the following tasks are completed.

Task 1: Request the SOIA automated analysis; submit a written request to Flight Technologies and Procedures Division.

Task 2: Develop an AAUP (see Order 8260.19, chapter 8).

Note: Since SOIA has only been implemented at a few locations, Flight Technologies and Procedures Division will provide additional guidance and/or assistance to SOIA requesters (typically the SIT/ATC facility) and procedure specialists on a case-by-case basis.

5. AAUP. The guidance for developing AAUPs in section 3 for SCP approaches also applies to AAUPs for SOIA approaches. For the AAUP for SOIA approaches, do not combine the instructions for SOIA straight-in approaches with SOIA offset approaches because the aircrew instructions are different. For all approaches used to conduct the offset approach, the AAUP must address the use of the FTP in the FMC approach coding, including the use of heading for the initial guidance of the missed approach.

Example: "If executing a missed approach or go-around, initially establish a climbing (left/right) turn heading (degrees). *CAUTION:* Missed approach leg from airport to (first missed approach fix name), if depicted on a map display, is for reference only. Follow IAP published missed approach procedure unless otherwise instructed by ATC."

6. SOIA Design Program. The Flight Technologies and Procedures Division SOIA Design Program (also called "SOIA Automated Analysis" or "SOIA tool") is used to design the offset course approach (see section 15-3). The SOIA Design Program provides the location of the DA for the offset course approach.

a. Components of SOIA operations. The SOIA Design Program determines the approach geometry based on a nominal bank angle of 15 degrees, roll-in/roll-out rates of nominally three degrees per second, and airspeeds defined by 14 CFR part 97 aircraft approach category, converted to True Airspeed. The angle of intercept of the offset course approach runway extended centerline is determined by the top-of-category approach speed for the highest category of aircraft certified to fly the approach and the distance between the parallel runways. The offset approach course design includes a stabilized approach point (see the figure E-7 notes). The angle of intercept will be limited so that in case an aircraft does not begin its intercept turn until crossing the extended centerline, it must not fly closer than 400 feet to the straight-in FAC. Roll-in rates of up to five degrees per second and bank angles of 25 degrees may be used to determine the realignment flight track.

b. Visual acquisition. The SOIA design program develops the approach so that there is sufficient time for visual acquisition of the straight-in approach aircraft by the offset course approach flight crew after their aircraft exits the overcast prior to reaching the DA for the offset course approach. Nominally a 30 seconds "clear-of-clouds" time at the highest anticipated approach speed is desirable. For example, if heavy aircraft in Category (CAT) D are authorized for the offset course approach, a ceiling of approximately 450 feet above the DA for the offset course approach is considered adequate. Based on 165 knots IAS, the top of CAT D, 450 feet will provide nominally a 30 seconds “clear-of-clouds” time. For operations restricted to the use of CAT C aircraft and below (and CAT D regional jets with approach speeds of 145 knots or less), a ceiling of approximately 375 feet above the DA, for the offset course approach, is considered adequate. The aircraft in the highest approach category authorized to conduct the approach will determine the approach geometry. Clear-of-clouds time values may be refined with operational experience and scientific analysis.

c. Straight flight segment. The SOIA design program includes a minimum straight flight segment of 1000 feet between the turn at the offset course approach DA and the turn to intercept the extended runway centerline at the stabilized approach point.

7. NTZ. SOIA incorporates a conventional NTZ design that terminates at the location of the DA for the offset FAC approach to protect aircraft on both FACs prior to the extended visual segment.

8. Ceiling for SOIA Operations. The optimum design, when runway centerlines are less than 2500 feet apart, is to have the ceiling value high enough to not require ATC wake turbulence spacing within the pairs.

a. Determine a preliminary ceiling for the offset approach that is at least 450 feet above the procedure’s decision altitude. For example, if the DA is 3130 feet MSL and the airport elevation is 2090 feet MSL, then the preliminary ceiling would be 1500 feet (3130 + 450 – 2090 = 1490; rounds to 1500).

b. The preliminary ceiling value will be used during flight simulator operational evaluations and/or considered during an operational safety assessment.

c. Based on those results and any inputs received from others (such as ATC), the SOIA SIT may choose to increase the ceiling value as necessary. The final ceiling value is submitted as part of the AAUP for each approach.

9. Wake Turbulence Requirements and Considerations. Wake turbulence mitigation techniques employed will be based on each airport’s specific runway geometry and meteorological conditions. Established pilot wake turbulence avoidance procedures will also be considered. A specific wake turbulence simulator evaluation and/or operational safety assessment must be performed by Flight Technologies and Procedures Division for each airport where SOIA implementation is requested. Additionally, if future runway construction changes the relationship of the runways previously approved for SOIA operations, Flight Technologies and Procedures Division must conduct a supplemental wake analysis. For SOIA runway centerlines less than 2500 feet apart, the wake turbulence spacing as described in Order JO 7110.65, paragraph 5-5-4, MINIMA, need not be applied within the pairs if the ceiling for SOIA operations is at least 450 feet above the DA and if the Flight Technologies and Procedures Division flight simulator operational evaluation and/or operational safety assessment is acceptable. Otherwise, the wake turbulence spacing as described in Order JO 7110.65, paragraph 5-5-4, MINIMA, must be applied within the pairs. ATC must issue all wake turbulence advisories when applicable. Separation between the pairs, normally applied between the trailing aircraft on the offset course approach (for example LDA) in the leading pair and the leading aircraft on the straight-in approach (for example ILS) in the subsequent pair, must meet the requirements for standard radar separation unless other approved methods of separation can be applied. Additionally, separation minima in paragraph 5-5-4 of Order JO 7110.65 regarding wake turbulence must be applied as follows: (1) between the straight-in approach (for example ILS) aircraft in the leading SOIA pair and either aircraft in the subsequent SOIA pair as required by paragraph 5-5-4 and (2) between the offset course approach (for example LDA) aircraft in the leading SOIA pair and either aircraft in the subsequent SOIA pair, as required by paragraph 5-5-4 and the SOIA paragraph (currently paragraph 5-9-9).

Note 1: When SOIA runway centerlines are at least 2500 feet apart, there are no wake turbulence requirements between aircraft on adjacent FACs (see Order JO 7100.65).

Note 2: The height of 450 feet above the DA provides at least 30 seconds clear of cloud time for all aircraft through category D. Thirty seconds has been shown to be sufficient for pilots to visually acquire the preceding (straight-in) aircraft prior to reaching the offset course approach DA and prepare to implement a wake avoidance strategy if deemed necessary. The 450 feet height may be reduced, after review by Flight Operations Group, to a height that provides 30 seconds clear of clouds time based on the categories of aircraft authorized for the SOIA procedure (see paragraph 6b).

Note 3: The ceiling may be less than 450 feet above the DA without applying wake turbulence spacing within the pairs, if acceptable mitigating techniques and operational procedures can be documented or developed and verified by a safety management process that involves a safety risk assessment, stakeholder participation, and monitoring the implemented procedures to ensure the mitigations are effective. This requires approval (see paragraph 1-4-2), which will be based on a flight simulator operational evaluation, review by Flight Technologies and Procedures Division Aviation Safety Inspector Pilots and/or an operational safety assessment, and/or review by the Procedure Review Board. Also, air traffic authorization is required as stated in Order JO 7110.65.

10. Crosswind Limits for SOIA. The limiting steady state, direct crosswind component of the reported airport surface wind is 10 knots for runways spaced 750 feet apart, increasing by one knot for each additional 75 feet of centerline separation to a maximum of 15 knots (when centerline spacing is at least 1125 feet). These requirements may be refined based on operational experience and scientific analysis. In addition, these values and their application may be further modified by the FAA wake turbulence study required for each SOIA location.

11. ATC/Flight Crew Coordination. When an aircraft is conducting an offset approach, for example LDA PRM, simultaneously with the adjacent straight-in approach, for example ILS PRM, the offset course approach flight crews must be advised of traffic on the adjacent (straight-in) approach course if pairing with the straight-in aircraft is anticipated. Prior to reaching the DA for the offset course approach, the flight crew must: Visually acquire the leading straight-in approach aircraft, broadcast this acquisition to ATC, and establish and maintain visual contact with the landing runway environment. If visual contact of the straight-in approach aircraft or runway environment is lost, a missed approach must be executed. Broadcasting by the offset course approach aircraft that the straight-in approach traffic is in sight indicates that the offset course approach flight crew has visually acquired the traffic and accepts responsibility for separation and wake turbulence avoidance as applicable. ATC is not required to (and normally does not) respond to this transmission.

a. Pilot responsibility. Pilots accepting a clearance for an offset course approach, for example LDA PRM approach, will remain on the offset course until passing the DA for the offset course approach.

b. Aircraft sequence. During SOIA operations, the offset course approach aircraft should be the trailing aircraft prior to exiting the overcast, and must be in the trailing position prior to reaching the DA for the offset course approach. Aircraft may pass each other as necessary prior to this point as instructed by ATC to achieve the required spacing.

c. AAUP. Pilot responsibilities must be specified on the AAUP (see Order 8260.19).

Note: For additional information regarding SOIA operations, refer to the AIM.

12. SOIA Implementation. The implementation process must include:

a. A national effort by Flight Technologies and Procedures Division. An effort must be made to monitor the operational integrity of SOIA procedures at each site, evaluate PRM-SOIA requirements to ensure consistency with existing standards (including this order and Orders 8260.19 and 8900.1), and oversight and review of issues raised by local SITs.

b. An established local implementation process. The leadership is the responsibility of the SOIA SIT or the air traffic facility at each SOIA site. Tasks include: to assist throughout the SOIA development process, to evaluate and provide support to Flight Technologies and Procedures Division, ATC, and Air Operator Training issues, to monitor local operational integrity issues, a blunder data collection effort (if required by the current air traffic guidance) and to report/refer issues for national consideration as appropriate. Consult Order 8260.43 for core membership and other aviation participants who should be included in this process.

Section 5. Simultaneous Independent Procedures Considered Established on a PBN Segment of a Published Instrument Approach

1. Roles/Responsibilities and Approval Process.

a. Requesting ATC facility will follow PBN implementation process outlined in FAA Order JO 7100.41, Performance Based Navigation Implementation Process.

b. Procedures that meet design requirements are annotated on FAA Form 8260-9 as compliant with section 15-5 in accordance with Order 8260.19.

2. Conclusions. These operations meet the FAA acceptable level of collision risk for dual parallel runway configurations spaced 3600 feet or greater and for triple parallel runway configurations spaced 3900 feet or greater. Operations to runways spaced 9000 feet or less require an FMA with NTZ, while operations to runways spaced more than 9000 feet do not require an FMA. Operations to dual parallel runway configurations based on RNAV (GPS) procedures require a 10-degree intercept of the extended final approach course, and may also be performed adjacent to a straight-in procedure to one of the runways. Triple parallel runway configurations require the 10-degree intercept on either or both outside runways, and a straight-in approach to the center runway. Use GPS based RNAV and RNP procedures with or without vertical guidance using TF fly-by turn procedure design, and may be combined with ILS or GLS straight-in approaches.

3. Key Findings. Consider the following when designing procedures:

a. A 10-degree intercept of the final approach course and an at-or-below 210 KIAS restriction on the downwind leg are required to prevent consistent overshooting of the extended runway centerline.

b. Extending the length of the 10-degree intercept leg, decreasing the angle of the turn prior to the 10-degree intercept leg, or increasing the runway spacing are effective methods to further reduce collision risk.

c. An aircraft should not be considered established on an approach unless the procedure is designed such that the controller can verify that the flight crew is flying the approach for with they were cleared.

d. RNP of 1 NM is acceptable for the turn to the final approach segment, provided GPS and autopilot or flight director are required.

e. VNAV capability may reduce crew workload.

f. Publishing an “at” altitude restriction near the apex of the established on approach turn can improve operational performance and slightly reduce collision risk if this simulates a descent angle between two and three degrees. Compatibility with aircraft automation may impact the suitability of altitude restrictions.

g. Controller intervention is a more effective mitigation when the heading change of the turn immediately preceding the 10-degree intercept leg is 50 degrees or less.

h. An aspect ratio of 3:1, used in less than 4300 feet parallel approach operations, may not be appropriate for curved operations such as established on approach.

i. Modifying the FMA and displays to more closely match the established on approach operating concept may considerably improve the controller reaction time.

j. Controller interventions may better maintain aircraft-to-aircraft separation by issuing a specific heading when directing a go-around, rather than flying the published track.

k. Head-to-head configurations may not be compatible with TCAS, particularly at close runway spacing, and are not preferred by controllers.

l. FMA and TCAS may generate nuisance alerts especially if the length of the 10-degree intercept leg is not sufficient to keep high convergence areas separated.

m. Extending the 10-degree intercept leg, ensuring that the turn-on occurred when the aircraft was below 2350 feet above ground level (sensitivity level 3 or below), or staggering the procedure turn-ons by at least 2 NM were effective for eliminating nuisance TCAS RAs on established on approach operations.

Section 6. Obstacle Assessment Surface Evaluation for Simultaneous Independent Parallel Instrument Approach Operations

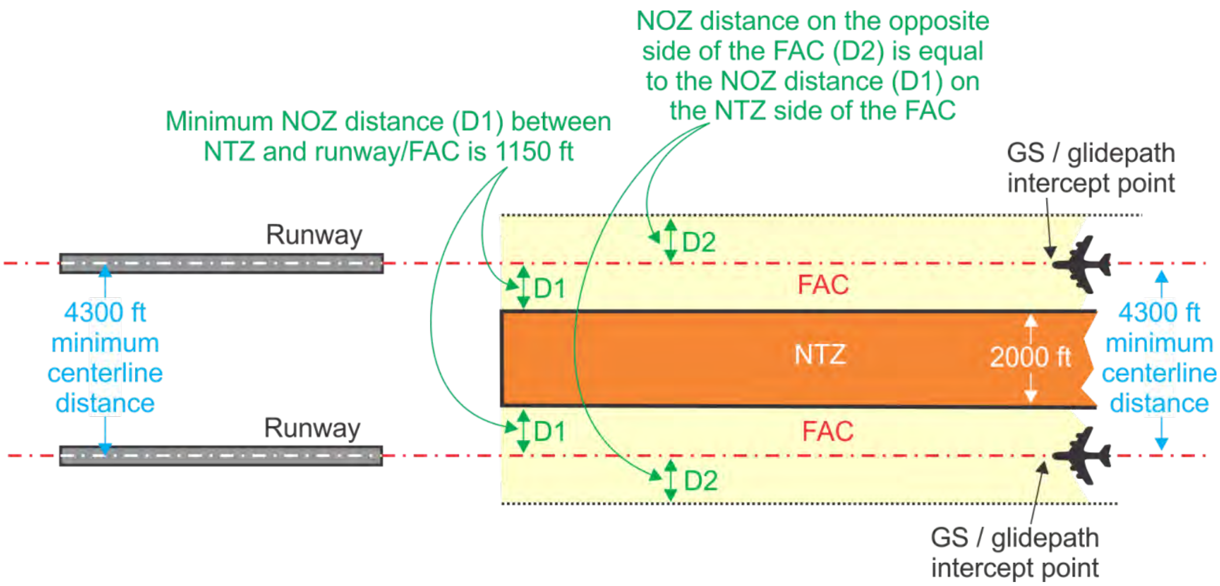
1. Background. The primary purpose for controllers doing radar monitoring during simultaneous independent approach operations is to ensure safe separation of aircraft on close parallel approaches. This separation may be compromised if an aircraft blunders off course toward an aircraft on the adjacent approach. Radar monitoring allows controllers to direct an aircraft off the approach course to avoid a possible collision. Resolution of a blunder is a sequence of events: the monitor alerts and displays the blunder, the controllers intervene, and the pilots comply with controller instructions; thus, increasing the operational safety, flyability, and airport capacity.

a. General. This appendix characterizes criteria used during the interim test phase of evaluating close parallel operations where early turnout obstacle assessments were accomplished by contractual means using terrestrial photometric techniques combined with survey methods of surface evaluation. Although this evaluation is based on the historical use of two ILS approaches, the assessment technique is also used for evaluation of independent simultaneous approach operations using RNAV (GPS), RNAV (RNP), GLS, LDA with glide slope, or LOC. The depictions in this appendix show straight-in FACs an offset course may be evaluated by rotating the areas that are adjacent to the offset course by the amount of the offset and measuring perpendicular to the offset FAC. Only a single evaluation is needed to each runway and should generally be based on primary approach procedure used during simultaneous operations (for example, the ILS approach). Facility information (GPA, TCH, threshold elevations, etc.) may be obtained from ATC planning and automation, flight procedures teams, and/or the systems management organizations for the regions/areas in which independent simultaneous parallel operations are planned.

b. Parallel runway simultaneous approaches. The procedures for airports with multiple parallel runways must ensure that an aircraft approach on one runway is safely separated from those approaching the adjacent parallel runway. An example of such procedures is depicted in figure E-9. Aircraft are directed to the two intermediate segments at altitudes which differ by at least 1000 feet. Vertical separation is required when lateral separation becomes less than 3 NM, as aircraft fly to intercept and stabilize on their respective FAC. This 1000-foot vertical separation is maintained until aircraft begin descent on the glidepath, except for approach operations which allow less than standard separation prior to the extended FAC described in section 15-5.

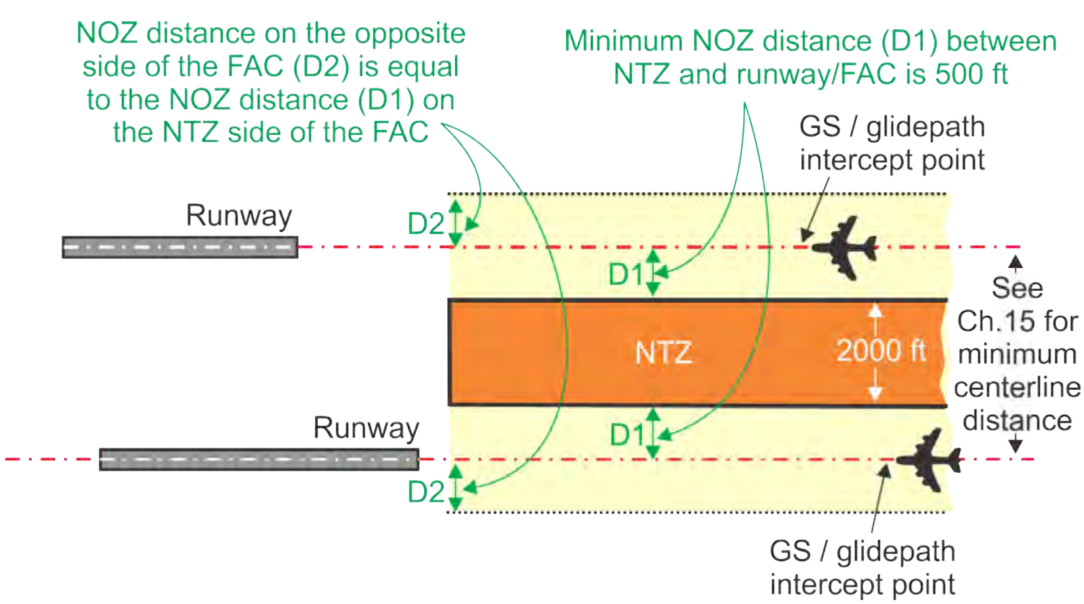
(1) When lateral radar separation is less than the 3 NM and the 1000-foot altitude buffer is lost, the aircraft on adjacent approach courses must be protected by an NTZ and monitored by radar monitor controllers. The controllers will observe the approaches and if an aircraft blunders from the NOZ toward or into a 2000-foot NTZ, the monitor controller can intervene so that threatened aircraft on the adjacent approach(es) are turned away in time to prevent a possible encounter. This maneuver, on the part of the threatened aircraft, is termed a “breakout” because the aircraft is directed out of the approach stream to avoid the transgressor aircraft. A controller for each runway is necessary so that one can turn the transgressing aircraft back to its course centerline while the other directs the breakout (see figure E-10).

Figure E-10. Simultaneous Parallel Runway Approach Zones



(2) The 2000-foot NTZ, flanked by two equal NOZs, provides airspace limitation guidance to the monitor controller and maneuvering room for the aircraft to recover before entering the NTZ. Aircraft are required to operate on or near the approach course within the limits of the NOZ. For runways spaced less than 4300 feet apart, the controllers transmit on both a separate and discrete frequency and on the tower frequency. Pilots only transmit on the tower frequency but listen to both frequencies. If an aircraft strays into the NTZ or turns to a heading that will take it into the NTZ, it is deemed a threat to an aircraft on the adjacent course and appropriate corrective action or breakout instructions are issued (see figure E-11).

Figure E-11. Simultaneous Approach NTZ and NOZ



2. Parallel Approach Obstruction Assessment. The parallel approach obstruction assessment is an examination of obstruction identification surfaces, in addition to the TERPS surfaces, in the direction away from the NTZ and adjacent runway, into which an aircraft on an early breakout could fly. An obstacle evaluation must be conducted to identify penetrating obstacles as part of a coordinated assessment for all independent SCP approach operations. In these criteria, ILS glidepath/localizer terms are synonymous to and may be used interchangeably with RNAV vertical path and lateral track terms. The surface dimensions for the obstacle assessment evaluation are described in the following paragraphs of this appendix.

Note 1: Parallel approach obstruction assessment surfaces are used for identifying obstacles that may impact simultaneous precision operations.

Note 2: A Parallel approach obstruction assessment surface penetration is when one or more obstructions penetrate the parallel approach obstruction assessment surface.

Note 3: A Parallel approach obstruction assessment controlling obstruction is the obstruction within the boundaries of the parallel approach obstruction assessment surface which constitutes the maximum penetration of that surface.

a. Surface 1. A FAC descent surface which is coincident with the glide slope/glidepath beginning at runway threshold with the width point abeam the threshold 350 feet from runway centerline opposite the NTZ, with lateral boundaries at the outer edge of the LOC course width, and ending at the farthest glide slope/glidepath intercept (see figure E-12).

Note: The course width is the angular course deviation required to produce a full scale (+/-) course deviation indication of the airborne navigation instrument. This width is normally tailored to a parameter of not greater than +/- 3 degrees. For precision runways longer than 4000 feet, a linear sector width parameter of +/-350 feet each side of centerline at RWT applies. Few category I localizers operate with a course sector width less than three degrees (+/- 1½ degrees) tailored width may be determined by formula E-1.

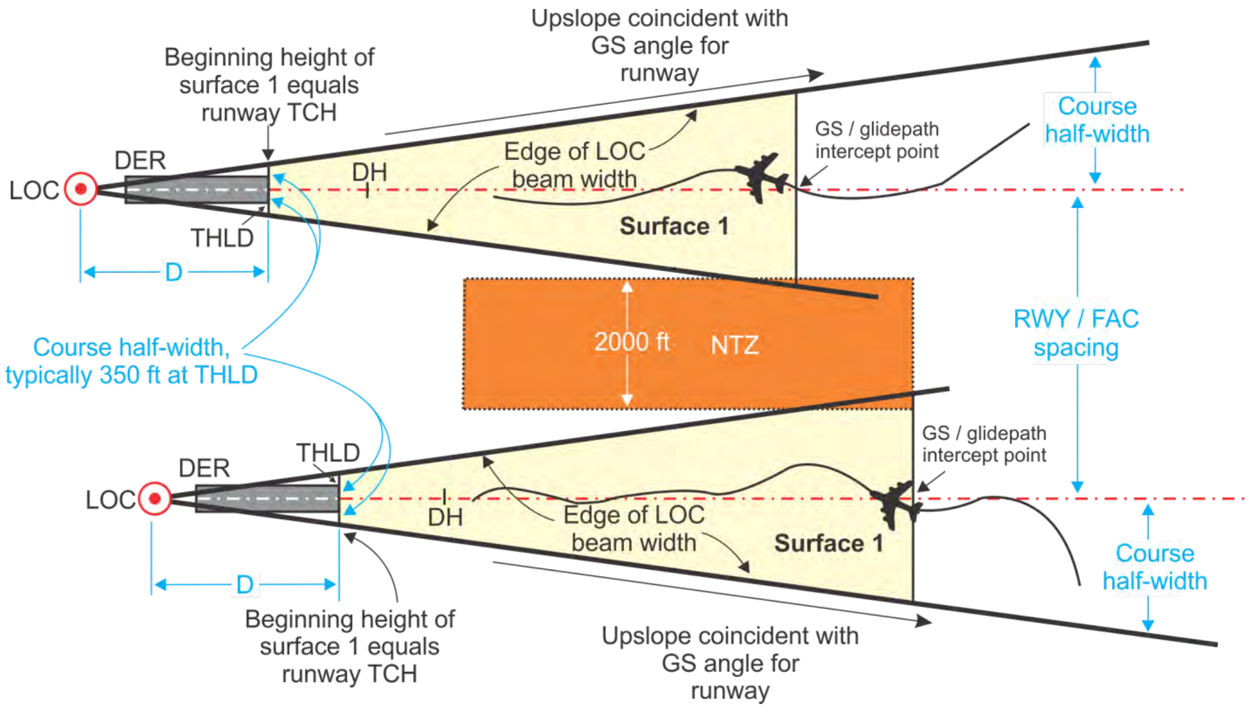
Formula E-1. Tailored LOC Angular Course Width

$$\theta_W = atan\left(\frac{350}{D}\right)$$

Where:

θ_W = Localizer course sector half-width angle
D = Distance from LOC antenna to RWT (in feet)
Total localizer course sector angle = 2 x θ_W

Figure E-12. Final Approach Descent Surface 1



(1) Length. Surface 1 begins over the runway threshold at a height equal to the TCH for the runway, and continues outward and upward at a slope that is coincident with the glide slope/glidepath, to its ending at the GS/vertical path intercept point.

(2) Width. Surface 1 has a width equal to the lateral dimensions of the LOC course width. The surface 1 half-width (see figure E-12) is calculated using formula E-2 or formula E-3.

Formula E-2. Surface 1 Half-width, Part One

$$\frac{1}{2}W = A \times Tan\left(\frac{B}{2}\right) + 350$$

Where:

W = Width of surface 1
A = Distance from RWT measured parallel to course
B = Course Width Beam Angle

OR

Formula E-3. Surface 1 Half-width, Part Two

$$\frac{1}{2}W = L \times Tan\left(\frac{B}{2}\right)$$

Where:
W = Width of surface 1
L = Distance from Azimuth antenna (in feet)
B = Course Width Beam Angle

(3) Height. Surface 1 height at any given centerline distance (d), may be determined in respect to threshold elevation, by adding the TCH to the product of centerline distance in feet from threshold times the tangent of the glide slope/glidepath angle (see formula E-4).

Formula E-4. Surface 1 Height Above LTP Elevation

$$h1 = [d \times Tan(GPA)] + TCH$$

Where:
h1 = Surface 1 height above LTP Elevation

b. Surface 2.

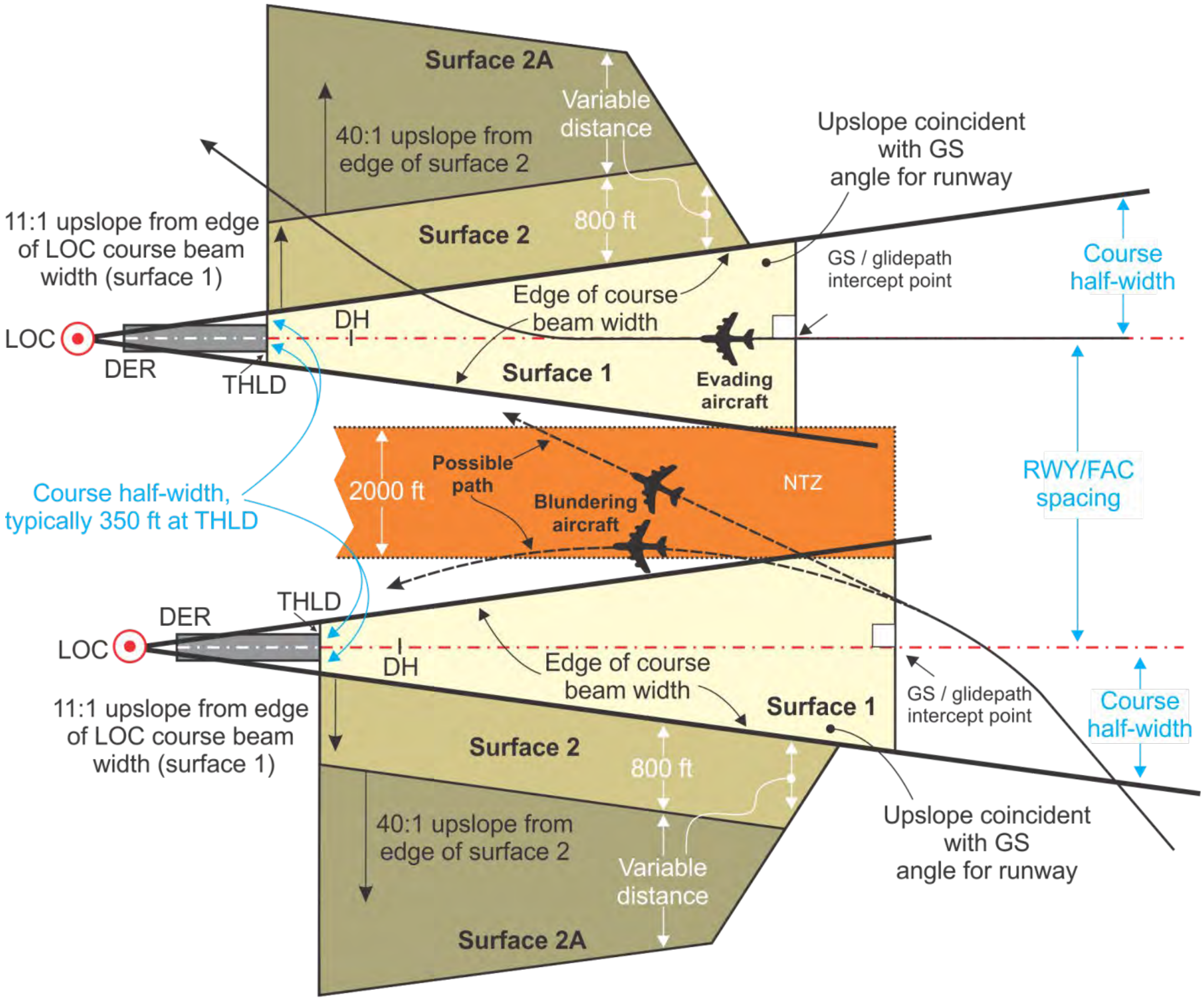
(1) Length [same as paragraph 2a(1)].

(2) Width and height. Surface 2 shares a common boundary with the outer edge of surface 1 on the side opposite the NTZ. Surface 2 begins at the height of surface 1 and slopes upward and outward for 800 feet from the edge of the surface 1 at a slope of 11:1, measured perpendicular to the FAC. After 800 feet, surface 2A uses a slope of 40:1. Further application is not required when the 11:1 or 40:1 surface reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure E-13).

Note 1: If more than one is applicable, use 1000 feet below the lowest applicable MOCA, MSA, or MVA. If an airport is in a designated mountainous area, instead of 1000 feet, use the applicable ROC. This note applies to the use of MOCA, MSA, or MVA throughout section 6 of this appendix.

Note 2: The 40:1 surface provides evaluation for breakout in any direction and is recommended. For locations that limit the amount of turn on the breakout, a higher surface may be used instead of the 40:1 surface with a site specific review by Flight Technologies and Procedures Division.

Figure E-13. Parallel Approach Obstacle Assessment Surface 2



Notes:

1. The outer edges of surfaces 2 and 2A are at a variable distance, as needed to reach the applicable level surface height.

2. Surface 2 height = surface 1 height + rise of 11:1 slope measured from nearest edge of the localizer course beam width (surface 1) to the obstacle measured perpendicular to the FAC.

3. Surface 2A height = surface 2 height + rise of 40:1 slope measured from nearest edge of surface 2 to the obstacle, measured perpendicular to the FAC.

4. An example of an aircraft breakout is illustrated in figure E-12 by the blundering aircraft approaching/entering the NTZ causing the controller to have to issue a vector to the evading aircraft.

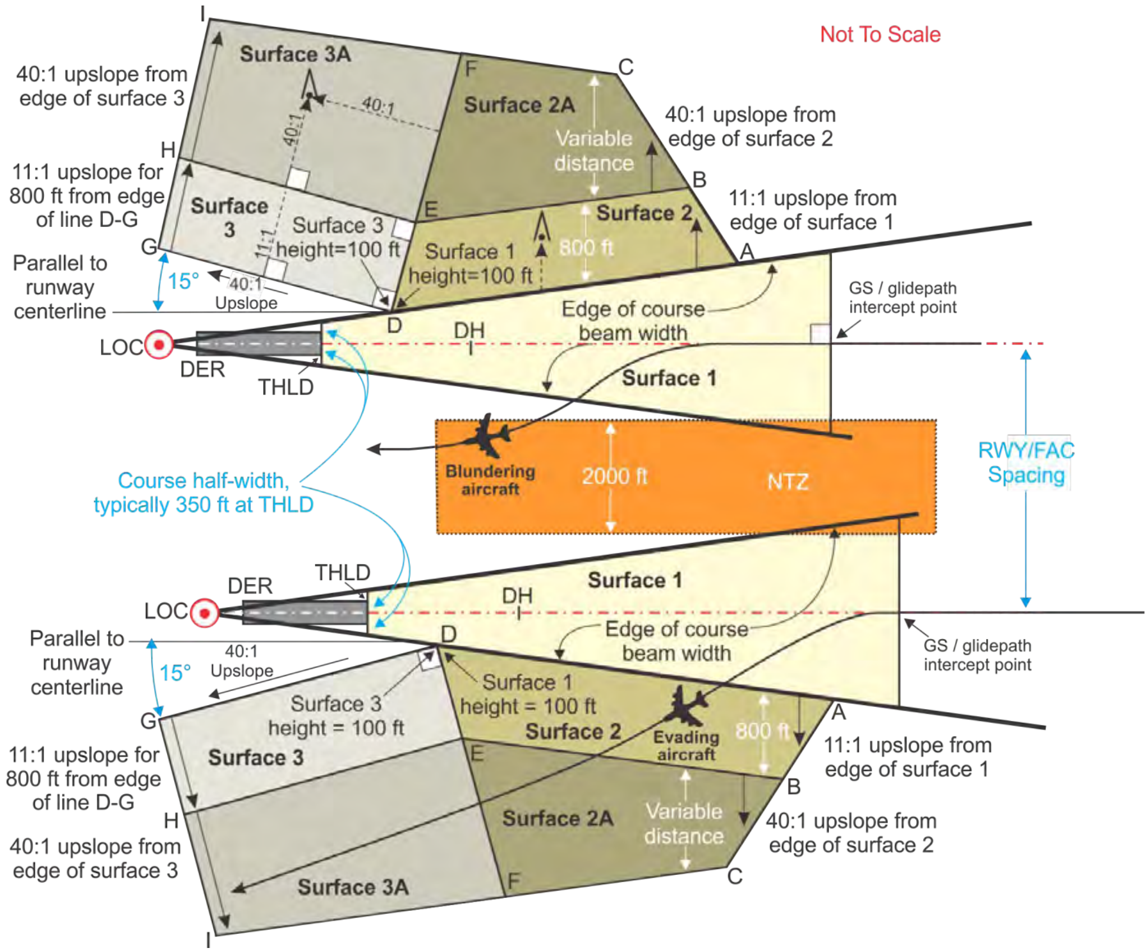
c. Surface 3 (CAT I).

(1) Length. For category I operations, surface 3 begins at the point where surface 1 reaches a height of 100 feet. Use 100 feet above the threshold elevation or use 100 feet above the touchdown elevation (TDZE), whichever was used in the procedure design. Surface 3 slopes upward and outward for 800 feet from the edge of line D-G at a slope of 11:1, measured perpendicular to the line D-G. After 800 feet, surface 3A uses a slope of 40:1. Surface 3 extends to the point where the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable.

(2) Width. From the beginning point, the edge of surface 3 area splays at a 15-degree angle from a line parallel to the runway centerline.

(3) Height. Surface 3 begins at a height of 100 feet above THLDe/TDZE (equal to the height of surface 1 at that point). The surface rises longitudinally at a 40:1 slope along the 15-degree splay line D-G while continuing laterally outward and upward at an 11:1 slope (line D-E is perpendicular to the 15-degree splay line D-G). Surface 3A uses a 40:1 slope. Further application is not required when the 11:1 or 40:1 slope reaches a height at 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure E-14).

Figure E-14. Parallel Approach Obstacle Assessment Surface



Notes:

1. The outer edges of surfaces 2, 2A, 3, and 3A are at a variable distance, as needed to reach the applicable level surface height.

2. Surface 3 height = surface 1 height (100 feet above runway) + rise of 40:1 slope measured along line D-G + rise of 11:1 slope measured from nearest edge of line D-G to the obstacle (measured perpendicular to line D-G).

3. Surface 3A height = surface 3 height + rise of 40:1 slope measured (from obstacle) perpendicular to line D-G.

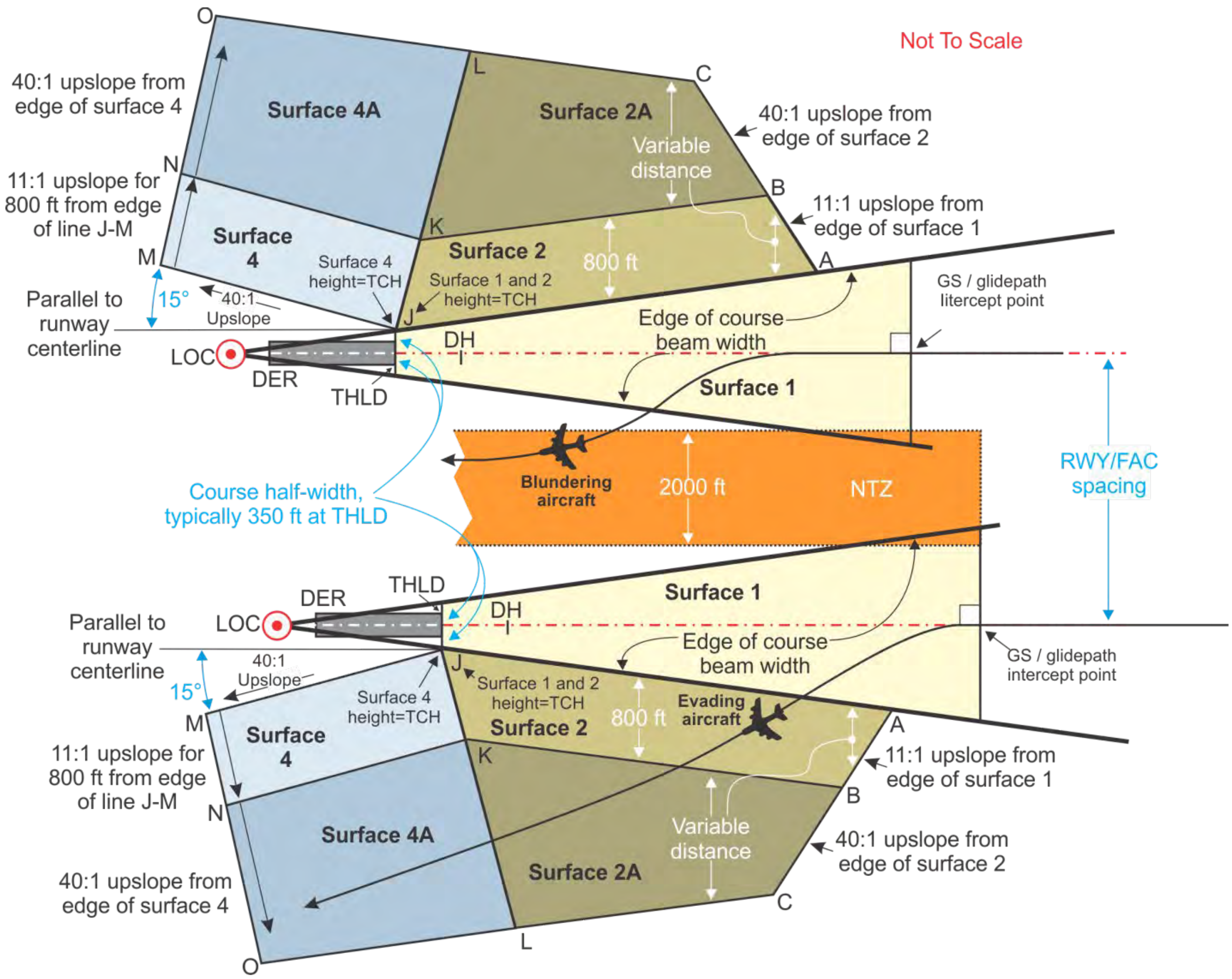
d. Surface 4 (CAT II).

(1) Length. Surface 4 begins at the point where surface 1 reaches the TCH and extends to the point where the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable. Surface 4 slopes upward and outward for 800 feet from the edge of line J-M at a slope of 11:1, measured perpendicular to the FAC. After 800 feet, surface 4A uses a slope of 40:1.

(2) Width. From the point of beginning, the edge of surface 4 area splays at a 15-degree angle from a line parallel to the runway centerline.

(3) Height. Surface 4 begins at the point where surface 1 reaches the TCH and rises longitudinally at a 40:1 slope along the 15-degree splay line J-M, while continuing laterally outward and upward at an 11:1 slope. Further application is not required when the 11:1 or 40:1 slope reaches a height of 1000 feet below the MOCA, MSA, or MVA, whichever is applicable (see figure E-15).

Figure E-15. Parallel Approach Obstacle Assessment Surface 4



Notes:

1. The outer edges of surfaces 2 and 2A or 4 and 4A are at a variable distance, as needed to reach the applicable level surface height.

2. Surface 4 height (above the TCH) = rise of 40:1 slope measured along line J-M + rise of 11:1 slope measured from nearest edge of line J-M to the obstacle (measured perpendicular to line J-M).

3. Surface 4a height = surface 4 height + rise of 40:1 slope measured (from obstacle) perpendicular to line J-M.

Appendix F. Geospatial Standard

Section 1. General

1. Algorithms and methods. Algorithms and methods are described for calculating geodetic locations (latitudes and longitudes) on the World Geodetic System of 1984 (WGS-84) ellipsoid for PBN procedure construction. These algorithms utilize existing distance and azimuth methods to compute intersections and tangent points. The methods apply corrections to an initial spherical approximation until the error is less than the maximum allowable error.

2. Algorithm format and definitions. 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. Because this appendix is intended for computer application, formulas are expressed in radians.

a. Geodetic locations. For convenience, a structure called LLPoint is used to represent both latitude and longitude of a geodetic coordinate.

b. 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.

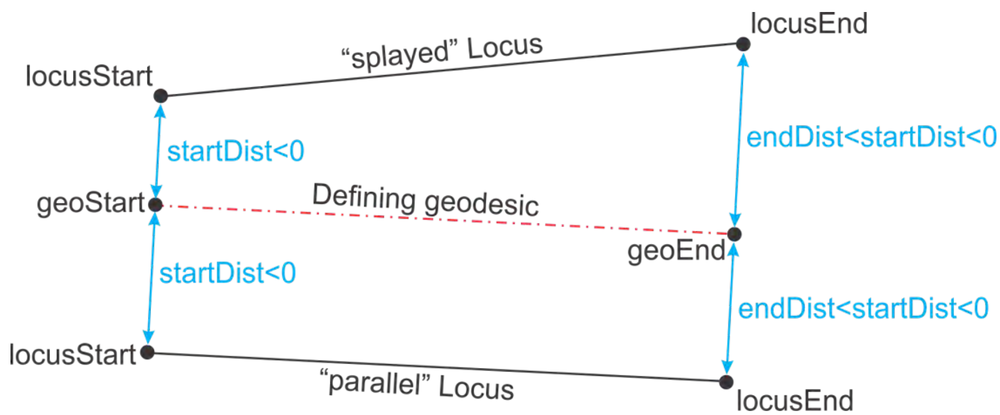
c. Fixed radius arc. A geodetic arc can be defined by a center point and radius distance. The circular arc is then the set (or locus) of points whose distance from the center point is equal to the radius. If an arc subtends an angle of less than 360 degrees, then its start azimuth, end azimuth, and orientation 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.

d. 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;
```

(1) 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 $(endDist \neq startDist)$ 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 appendix 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.

Figure F-1. Two Examples Loci Defined Relative to a Single Geodesic



(2) 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.

(3) The lineType attribute is used to specify the locus' 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.

3. Ellipsoidal formulas. Ellipsoidal formulas must be used in evaluating fixes, courses, and distance between fixes.

a. WGS-84 parameters. The semi-minor axis (b) is derived from the semi-major axis (a) and flattening parameters (f) using the relation $\mathrm{b} = \mathrm{a} \times (1 - \mathrm{f})$.

$$a = 6{,}378{,}137.0 \text{ meters}$$
$$b \approx 6{,}356{,}752.31 \text{ meters}$$
$$f = \frac{1}{298.257223563}$$

b. 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.

4. Spherical Approximations. 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:

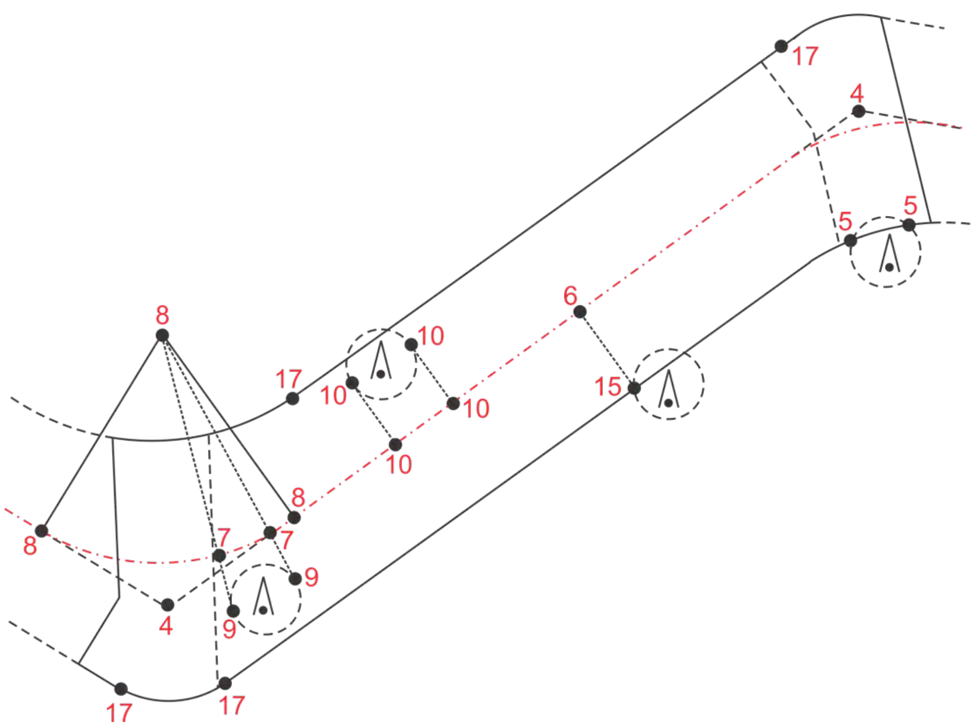
$$SPHERE_{RADIUS} = \sqrt{a \times b}$$

$$SPHERE_{RADIUS} \approx 6{,}367{,}435.68\ meters$$

5. Accuracy. Perform calculations to 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. A locus of points must lie within 30 cm of the true locus to be considered compliant.

6. Geodetic processes. The following are required for evaluating PBN procedures. The numbers in figure F-2 refer to the process used to solve for the point.

Figure F-2. Geodetic Processes



a. 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).

b. 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).

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

d. Process 4. Given two geodesics, find their intersection point(s).

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

f. Process 6. Given a geodesic and a separate point, find the point on the geodesic nearest the given point.

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

h. 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.

i. 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.

j. 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.

k. Process 11. Compute the length of an arc.

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

m. Process 13. Determine whether a given point lies on a particular arc.

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

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

p. Process 16. Given two loci, find their intersection.

q. Process 17. Given two loci and a radius, find the center of the arc tangent to both loci and the points of tangency.

Section 2. Useful Functions

1. 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 $\mathbf{0° = 360°}$. The following algorithm accounts for this case.

a. 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:

(1) double startCrs = Azimuth from center to start point of arc

(2) double endCrs = Azimuth from center to end point of arc

(3) int orientation = Integer that indicates the direction in which the arc is traversed to go from startCrs to endCrs.

(4) orientation = 1 if the arc is traversed counter-clockwise,

(5) orientation = -1 if the arc is traversed clockwise.

(6) double tol = Maximum error allowed in calculations

b. Algorithm steps.

(1) *Step 1*. If $(abs(startCrs - endCrs) < tol)$ then return $2 \times \pi$.

(2) *Step 2*. 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) $endCrs = temp$

(3) *Step 3*. End if.

(4) *Step 4*. If $(startCrs > endCrs)$ then $angle = startCrs – endCrs$.

(5) *Step 5*. Else $angle = 2 \times \pi + startCrs - endCrs$.

(6) *Step 6*. End if.

(7) *Step 7*. If $(orientation < 0)$ then $angle = -angle$.

(8) *Step 8*. Return angle.

2. Converting geodetic latitude/longitude to ECEF coordinates. Geodetic coordinates may be converted to rectilinear ECEF coordinates using the following formulae[3]. Given geodetic latitude ($\boldsymbol{\varphi}$), geodetic longitude ($\boldsymbol{\theta}$), semi-major axis ($\boldsymbol{a}$) and flattening parameter ($\boldsymbol{f}$), calculate the square of the eccentricity $\boldsymbol{e^2 = f \times (2 - f)}$ and the curvature in the prime vertical:

$$N = \frac{a}{\sqrt{1 - e^2 \times \sin{(\varphi)}^2}}$$

The ECEF coordinates are then:

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

3. 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 $[-\boldsymbol{\pi},\ \boldsymbol{\pi}]$:

$$signedAzimuthDifference(a_1, a_2) = mod(a_1 - a_2 + \pi, 2\pi) - \pi$$

a. 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 $signedAzimuthDifference(a_1 a_2) > 0$ azimuth a_2 is to the left when standing at the geodesics' intersection point and facing in the direction of azimuth a_1.

b. The mod function in the definition of signedAzimuthDifference must always return a non-negative value.

Note: 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;  }
```

4. Approximate fixed radius arc length. Section 3 algorithm 7 describes a method for computing the length of an arc to high precision. The following algorithm provides a solution accurate to one 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.

[3] Dana, Peter H., "Coordinate Conversion Geodetic Latitude, Longitude, and Height to ECEF, X, Y, Z>," 11 February 2003

a. 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:

$$e^2 = f \times (2 - f)$$

$$M = \frac{a \times (1 - e^2)}{[1 - e^2 \times \sin(\theta)^2]^{\frac{3}{2}}}$$

$$N = \frac{a}{\sqrt{1 - e^2 \times \sin(\theta)^2}}$$

$$R = \sqrt{M \times N}$$

b. 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:

$$L = A \times R \times \sin\left(\frac{r}{R}\right)$$

Section 3. Basic Calculations

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.

a. 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.

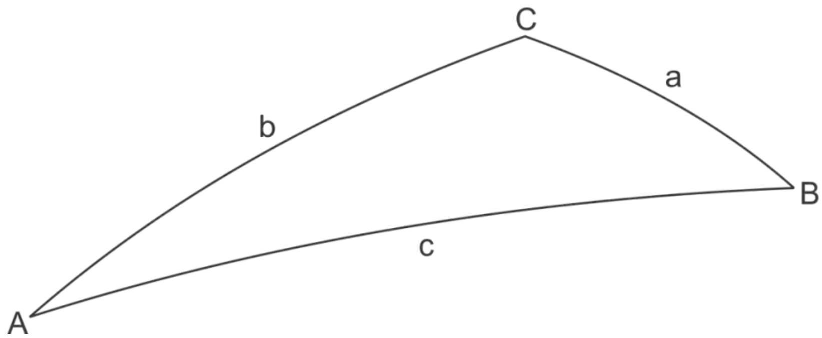
b. The second array (named errarray in the algorithms below) stores the error values corresponding to the two most recent parameter values. Thus, these arrays store a linear representation of the error function. The next solution in each iteration is found by solving for the root of that linear function using the findLinearRoot function. 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.

```
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]
}
```

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.

a. Spherical direction intersection. Given two points A and B and two bearings A to C and B to C, find C.

Figure F-3. Spherical Direction Intersection



(1) *Step 1*. 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.

(2) *Step 2*. Apply the spherical triangle formulas to find the angle C and arc lengths from A to C and from B to C:

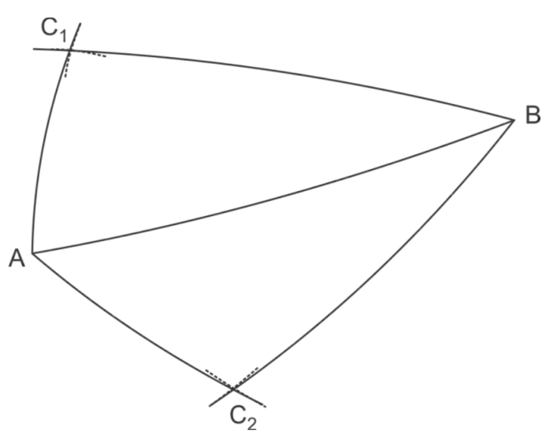
$$C = \cos^{-1}\left[-\cos(A) \times \cos(B) + \sin(A) \times \sin(B) \times \cos\left(\frac{c}{R}\right)\right]$$
$$a = R \times \cos^{-1}\left[\frac{\cos(A) + \cos(B) \times \cos(C)}{\sin(B) \times \sin(C)}\right]$$
$$b = R \times \cos^{-1}\left[\frac{\cos(B) + \cos(A) \times \cos(C)}{\sin(A) \times \sin(C)}\right]$$

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

(3) *Step 3*. Run Direct from A to find C. Use given bearing and computed length b.

b. Spherical distance intersection. Given A, B and distances AC and BC, find C_1 and C_2.

Figure F-4. Spherical Distance Intersection



(1) *Step 1*. Run Inverse to find length and bearings between A and B. Use spherical triangles to find angles $A = BAC_1 = BAC_2, B = ABC_1 = ABC_2, and\ C = BC_1A = BC_2A$:

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

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

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

(2) *Step 2*. Run Direct from A to find C_1 and C_2.

(a) To compute the bearing from A to C_1, start with the bearing from A to B and subtract angle A.

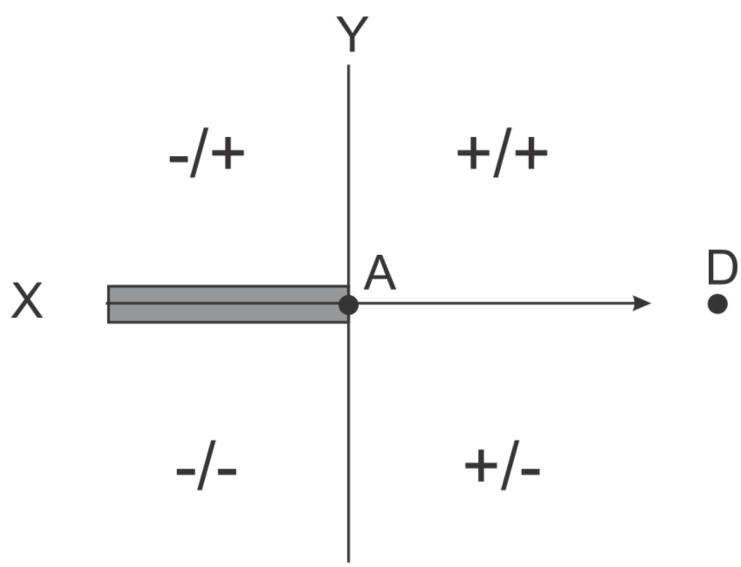
(b) To compute the bearing from A to C_2, start with the bearing from A to B and add angle A.

(3) *Step 3*. Use Inverse and spherical triangle formulas to get remaining bearings.

c. Spherical tangent point.

(1) Distance signs. In both cases of the tangent point, distances are signed according to figure F-5, where the arrow indicates the bearing from the first point A to the target point D.

Figure F-5. Distance Signs



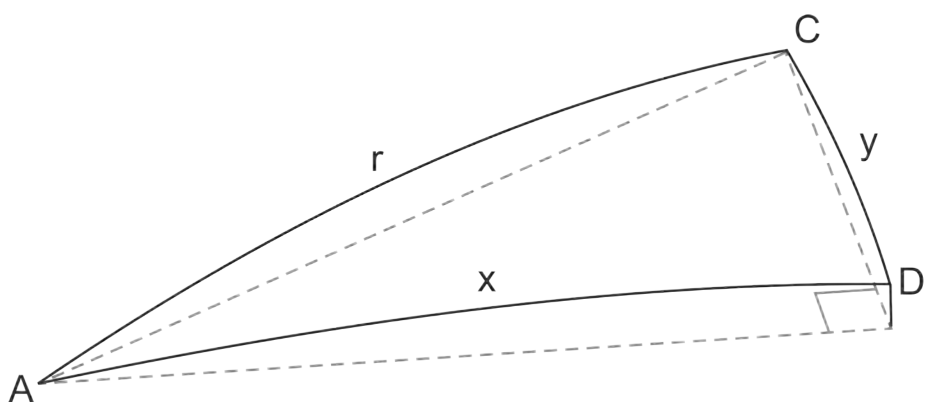
(2) Right spherical triangle. Calculate lengths y and x of the right spherical triangle with the following formulas:

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

$$x = R \times \cos^{-1}\left[\frac{\cos\left(\frac{r}{R}\right)}{\cos\left(\frac{y}{R}\right)}\right]$$

(3) Given two points and a bearing. 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.

Figure F-6. Two Points and a Bearing



(a) *Step 1*. Run Inverse to find length and bearings between A and C.

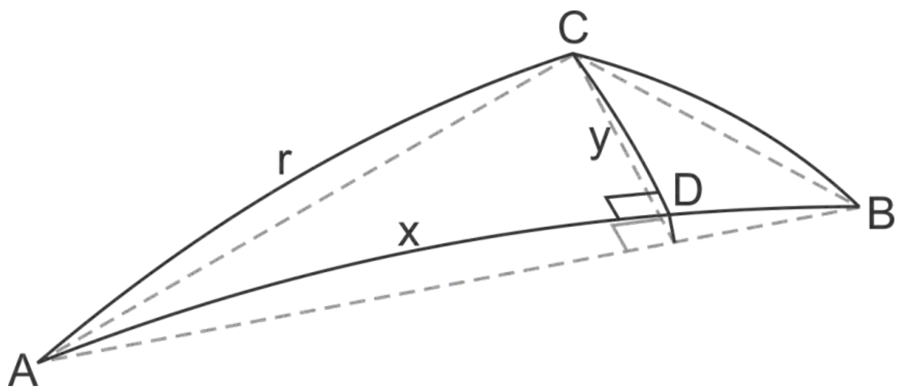
1. Find difference in bearings to compute angle A.

2. Use right spherical triangles to calculate y and x.

(b) *Step 2*. Run Direct from A to find D using given bearing and computed length x.

(4) Given three points. 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.

Figure F-7. Three Points



(a) *Step 1*. Use Inverse to determine bearing from A to B.

(b) *Step 2*. Use Inverse to determine bearing and length from A to C.

(c) *Step 3*. Find the difference in bearings to determine angle A.

(d) *Step 4*. Use right spherical triangles to calculate y and x.

(e) *Step 5*. Use Direct to calculate D from A using the computed bearing from A to B and computed distance x.

3. Tolerances. Two different convergence tolerances must be supplied so that the algorithms cease iterating once the error becomes sufficiently small.

a. Forward and inverse. The first tolerance parameter is used in the forward and inverse routines; it is referred to as eps in the algorithm descriptions. Empirical studies have shown that $eps = 0.5 \times e^{-13}$ works well.

b. Intersection and projection. 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 forward and inverse 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 $tol = 1.0 \times e^{-9}$ works well.

c. Maximum iterations. A maximum iteration count 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.

4. 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.

a. 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:

(1) LLPoint startPt = Coordinates of start point of given geodesic

(2) LLPoint endPt = Coordinates of end point of geodesic

(3) LLPoint testPt = Point at which course of geodesic is to be determined

(4) double* startCrs = Azimuth of geodesic at startPt in radians

(5) double* revCrs = Reciprocal azimuth of geodesic at endPt in radians

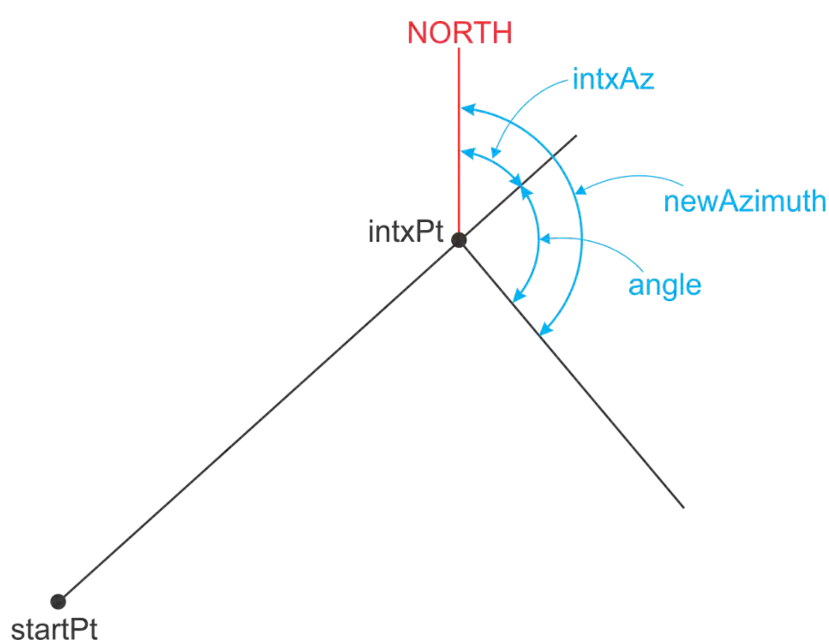
(6) double* distToPt = Distance from startPt to testPt in NM

(7) double tol = Accuracy tolerance for intersection calculation

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-8. Projecting a Geodesic through a Point along the Specified Azimuth



(1) *Step 1*. Use the WGS84PtIsOnLine algorithm to check that testPt actually lies on geodesic defined by startPt and endPt.

(2) *Step 2*. Use Inverse algorithm to determine course and distance from testPt to startPt. Denote course as crsToStart.

(3) *Step 3*. Use Inverse algorithm to determine course and distance from testPt to endPt. Denote course as crsToEnd.

(4) *Step 4*. If testPt lies on geodesic between startPt and endPt, then the correct azimuth is crsToEnd.

(5) *Step 5*. If testPt lies on the geodesic beyond endPt, then the correct azimuth is $crsStart + \pi$.

(6) *Step 6*. Return the calculated azimuth.

Note: If an 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.

5. 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. 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.

a. 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:

(1) LLPoint startPt = Geodetic coordinate of line start point

(2) LLPoint endPt = Geodetic coordinate of line end point

(3) LLPoint testPt = Geodetic coordinate of point to test

(4) LineType lengthCode = Integer that specifies extent of line.

(a) 0: geodesic exists only between startPt and endPt.

(b) 1: geodesic extends beyond endPt.

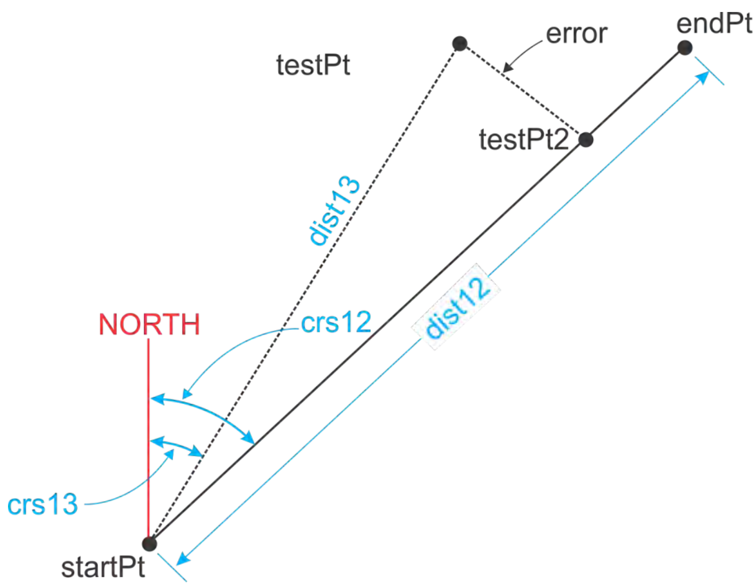
(c) 2: geodesic extends behind startPt.

(5) double tol = Maximum difference allowed in distance

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-9. Entities for Testing Whether a Point Lies on a Geodesic



(1) *Step 1*. Use inverse algorithm to calculate the azimuth and distance from startPt to endPt. Denote these values by crs12 and dist12, respectively.

(2) *Step 2*. Use WGS84PtIsOnCrs algorithm to determine if testPt lies on geodesic given by startPt and endPt:

(a) Use inverse algorithm to calculate the distance from startPt to testPt. Denote this value by tmpDist1Test.

(b) Use direct algorithm to project a point from startPt, along crs12, a distance equal to tmpDist1Test. Denote this point by comparePt.

(c) Use WGS84PointsAreSame algorithm to determine if testPt is equal to comparePt.

(3) *Step 3*. Examine error to determine whether testPt lies on the geodesic within tol as follows:

(a) If $(error \leq tol)$ then,

1. If $(lengthCode > 0)$ or $(dist13 - dist12 \leq tol)$ then $onLine = true$.

2. Else $onLine = false$.

(b) End if.

(c) If $(lengthCode = 2)$,

1. Use the direct algorithm to project point from startPt, along $crs12 + \pi$ a distance dist13. Again, denote this point again by testPt2.

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

3. If $(error \leq tol)$ then $onLine = true$, Else $onLine = false$.

(d) End if.

6. 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 (section 5 algorithms 2, 3, and 6) to determine whether the computed intersections lie within the bounds of the desired arc.

a. 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:

(1) LLPoint center = Geodetic coordinates of arc center

(2) double radius = Arc radius

(3) double startCrs = True azimuth from center to start of arc

(4) double endCrs = True azimuth from center to end of arc

(5) ArcDirection orientation = Orientation of the arc [+1 for counter-clockwise; -1 for clockwise]

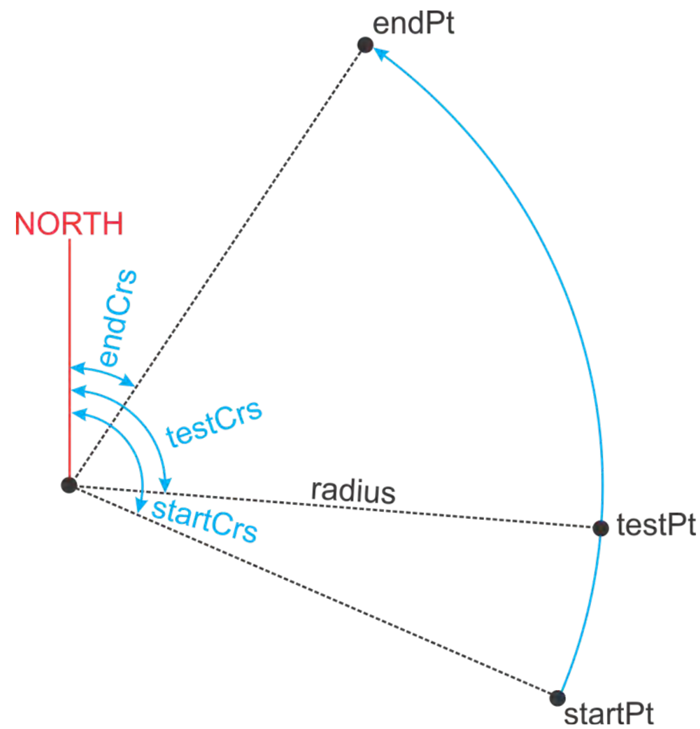
(6) LLPoint testPt = Geodetic coordinate of point to test

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-10. Entities for Testing Whether a Point Lies on an Arc



(1) *Step 1*. Use inverse algorithm to calculate distance and azimuth from center to testPt. Denote values as dist and crs, respectively.

(2) *Step 2*. If $(abs(dist - radius) > tol)$ then testPt is not correct distance from center, onArc = false.

(3) *Step 3*. Else

(a) Use section 2 algorithm 1, Calculate Angular Arc Extent, to calculate the angle subtended by the full arc. Denote this value by arcExtent.

(b) If $(arcExtent = 360°)$ then $onArc = true$.

(c) Else

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

2. Use section 2 algorithm 1, 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 $(-.002 \leq subExtent \leq arcExtent + .002)$ then traversing arc from startCrs to endCrs, one would encounter testPt, so it must lie on arc, $onArc = true$.

(d) End if.

(4) *Step 4*. End if.

7. 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 NM is described in section 2 algorithm 4.

a. 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:

(1) LLPoint center = Geodetic coordinates of arc center

(2) double radius = Arc radius

(3) double startCrs = True azimuth from center to start of arc

(4) double endCrs = True azimuth from center to end of arc

(5) int orient = Orientation of the arc [+1 for counter-clockwise; -1 for clockwise]

(6) int *n = Reference to integer used to return number of steps in discretized arc

(7) double tol = Maximum allowed error

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-11. Calculating Arc Length

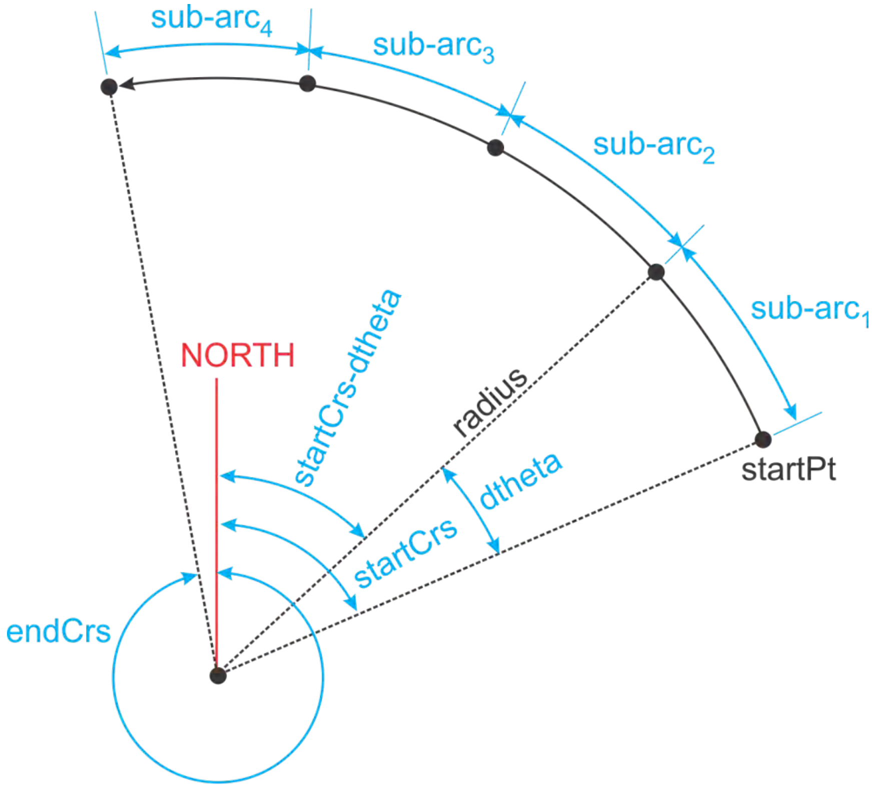
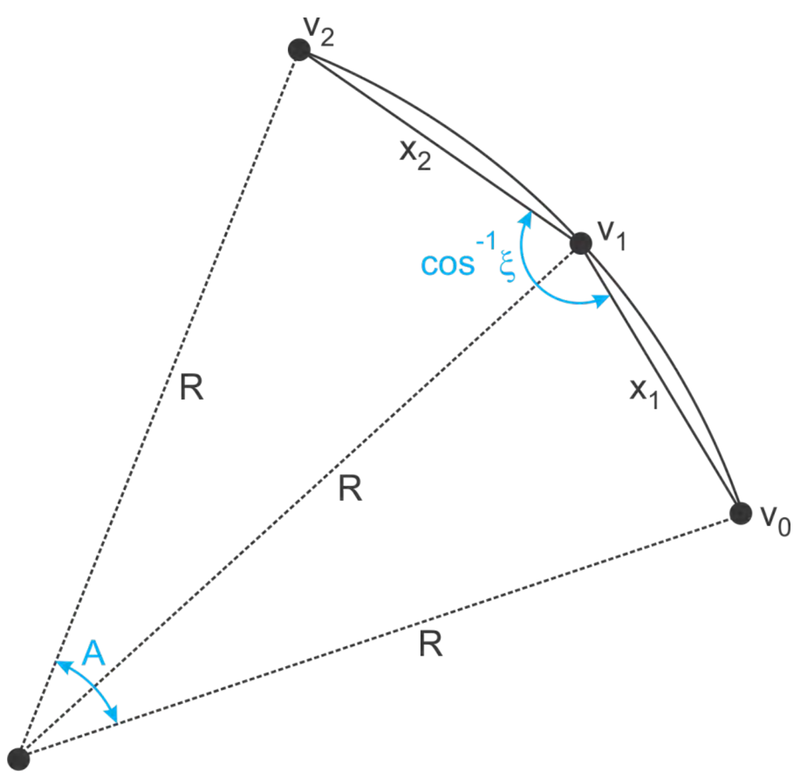


Figure F-12. Calculating the Sub-Arc Length



(1) *Step 1*. 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).

(2) *Step 2*. Convert center point to Earth-Centered, Earth-Fixed (ECEF) coordinates, v0 according to section 2 algorithm 2.

(3) *Step 3*. Compute subtended angle, subtAngle, using section 2 algorithm 1.

(4) *Step 4*. Set iteration count, $k = 0$.

(5) *Step 5*. Do while $k = 0$ or $(error > tol)$ and $(k \leq maximumIterationCount)$

(a) Calculate subtended angle of each sub-arc, $dtheta = \frac{subtAngle}{n}$.

(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: $theta\ = startCrs + i \times dtheta$.

2. Use direct algorithm from center, using azimuth $theta + 0.5 \times dtheta$ 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:

a. $xi = \frac{d}{x1 \times x2}$

b. $sigma = \sqrt{1 - xi^2}$

c. $R = \frac{x2 \times \sqrt{\left(\frac{x1}{x2} - xi\right)^2 + sigma^2}}{2 \times sigma}$

d. $A = 2 \times [\pi - acos\ (xi)]$

e. $L = R \times A$

1 $\xi = \frac{d}{x_1 \times x_2}$

2 $\sigma = \sqrt{1 - \xi^2}$

3 $R = \frac{x_e \times \sqrt{\left(\frac{x_1}{x_2 - \xi}\right)^2 + \sigma^2}}{2 \times \sigma}$

4 $A = 2 \times [\pi - \cos^{-1}(\xi)]$

Note: 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: $n = 2 \times n$.

(j) Save the current length for comparison with the next iteration: $oldLength = length$.

(6) *Step 6*. End while loop.

(7) *Step 7*. Return length.

8. 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.

a. Input/Output.

(1) 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:

(a) Locus loc = Locus of interest

(b) double distance = Distance from locus start point to point where distance is to be computed

(2) 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:

(a) Locus loc = Locus of interest

(b) LLPoint geoPt = Point on defining geodesic

(c) double *faz = Pointer used to return forward azimuth of geodesic at geopt. This is needed if geopt is not between geoStart and geoEnd.

(d) double tol = Maximum allowable error

(e) double eps = Convergence parameter for forward/inverse algorithm

b. 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' line type is 2 and geoPt is farther from geoEnd than it is from geoStart):

(1) *Step 1*. Use the inverse function to compute the length of the locus' defining geodesic. Denote this value as geoLen.

(2) *Step 2*. If $(geoLen = 0)$ then $distToLoc = 0.0$.

(3) *Step 3*. Else.

$$distToLoc = loc.startDist + \frac{distance}{geoLen} \times (loc.endDist - loc.startDist)$$

(4) *Step 4*. End if.

(5) *Step 5*. Return distToLoc.

9. 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' 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.

a. 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' defining geodesic if testPt lies on the locus and NULL otherwise, where the inputs are:

(1) Locus loc = Locus of Interest

(2) LLPoint testPt = Point to test against locus

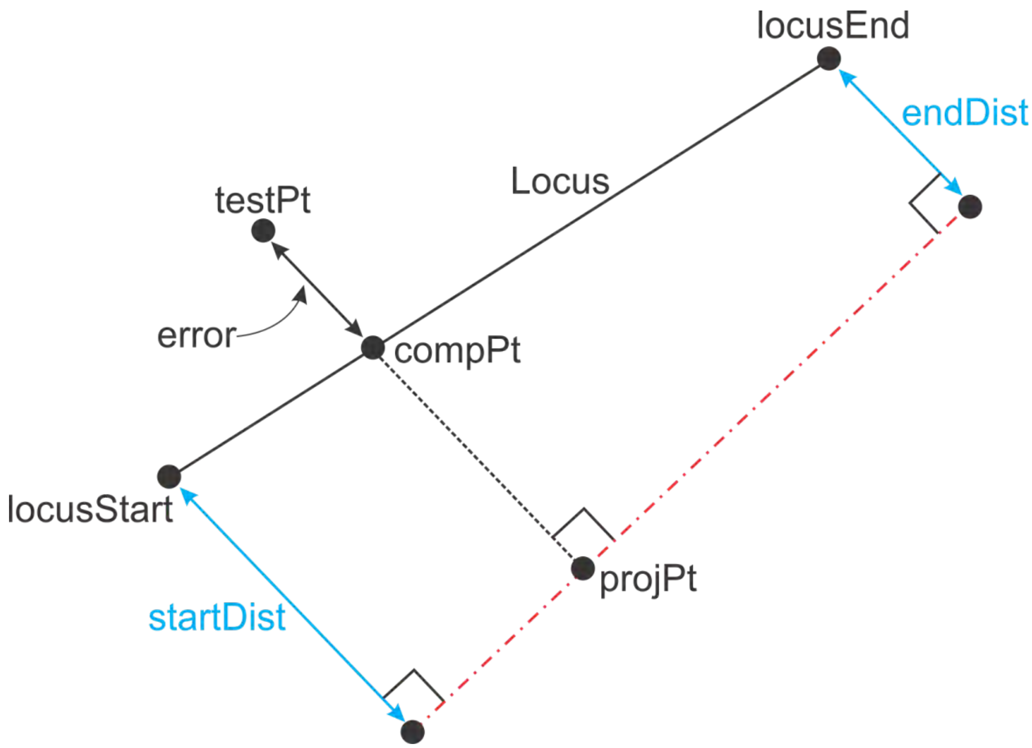
(3) LLPoint* ptOnGeo = Pointer to LLPoint, updated with point on defining geodesic abeam the given point on the locus.

(4) double tol = Maximum allowable error

(5) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-13. Locating a Point Relative to a Locus



(1) *Step 1*. If testPt is the same as loc.geoStart or loc.geoEnd then return a reference to ptOnGeo containing the appropriate point.

(2) *Step 2*. Use section 4 algorithm 1 to project testPt onto the locus' defining geodesic. Denote the projected point as ptOnGeo.

(3) *Step 3*. Use section 3 algorithm 5 to determine whether ptOnGeo lies on the locus' defining geodesic. This will account for an infinite or semi-infinite locus. If it does not, then return 0 (false).

(4) *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.

(5) *Step 5*. Use section 3 algorithm 8 to calculate the correct expected locus distance, locDist.

(6) *Step 6*. If $(abs(distFromPoint - locDist) \leq tol)$ then the point is on the locus. Return a reference to the projection on the defining geodesic.

10. 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.

a. 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' geodesic and the course from the given point toward the geodesic point, where the inputs are:

(1) Locus loc = Locus of Interest

(2) LLPoint testPt = Point at which course will be calculated

(3) LLPoint* geoPt = Projection of testPt on defining geodesic

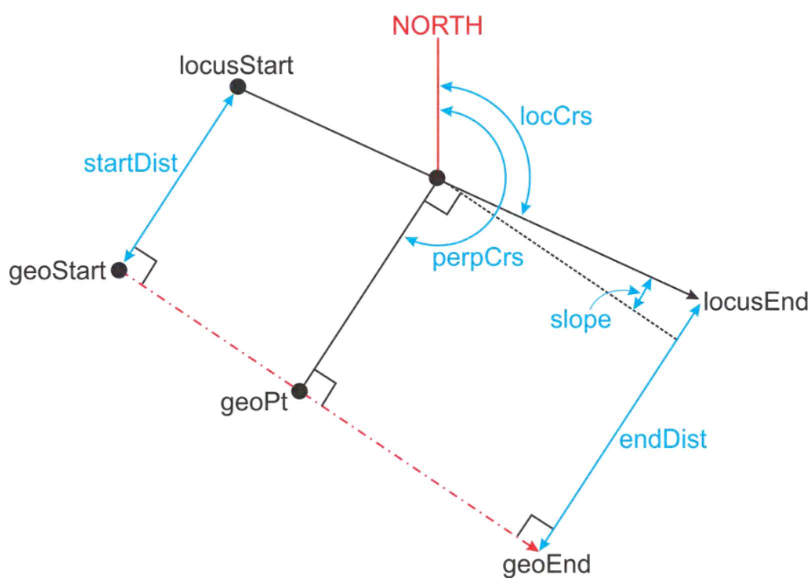
(4) double* perpCrs = Course for testPt to geoPt

(5) double tol = Maximum allowable error

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-14. Angle Used to Calculate the Course of a Locus



(1) *Step 1*. Use section 3 algorithm 9 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.

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

(3) *Step 3*. Use the inverse algorithm to calculate the course and distance from testPt to geoPt, denoted by perpCrs and perpDist, respectively.

(4) *Step 4*. Use section 3 algorithm 8 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.

(5) *Step 5*. Calculate the slope of the locus relative to the geodesic:

$$slope = \frac{loc.endDist - loc.startDist}{geoLen}$$

(6) *Step 6*. Convert the slope to angular measure in radians:

$slope = \text{atan (slope)}$

(7) *Step 7*. Adjust the value of the perpendicular course by slope. This accounts for how the locus is approaching or receding from the geodesic: $perpCrs = perpCrs + slope$

(8) *Step 8*. If (distToLoc < 0) then testPt lies to the left of the geodesic, so perpCrs points to the right of the locus' course: $locCrs = perpCrs - \frac{\pi}{2}$

(9) *Step 9*. Else testPt lies to the right of the geodesic so perpCrs points to the left of the locus' course: $locCrs = perpCrs + \frac{\pi}{2}$

(10) *Step 10*. Return locCrs.

Section 4. Projections

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.

a. 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:

(1) LLPoint pt1 = Coordinates of geodesic start point

(2) double crs13 = Initial azimuth of geodesic at start point

(3) LLPoint pt3 = Coordinates of point to be projected to geodesic

(4) LLPoint* pt2 = Reference to LLPoint that will be updated with coordinates of projected point.

(5) double* crsFromPoint = Reference to azimuth of geodesic from pt3 to projected point, in radians.

(6) double* distFromPoint = Reference to distance from pt3 to projected point, in radians.

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. 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 4(g)* may be modified to return a NULL solution.

Figure F-15. Projecting a Point to a Geodesic

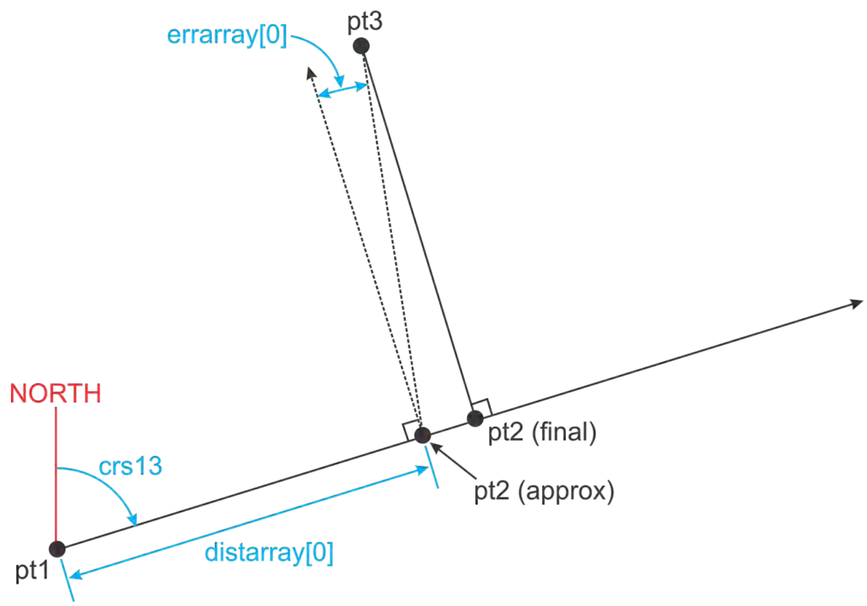
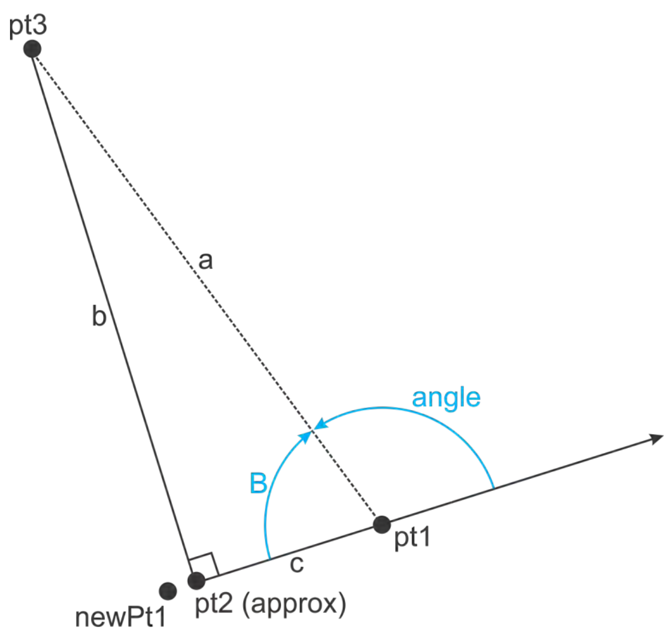


Figure F-16. Elements of Spherical Triangle Used to Determine New Geodesic Starting Point When Projected Point Lies Behind Given Starting Point



(1) *Step 1*. 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.

(2) *Step 2*. Calculate the angle between the given geodesic and the geodesic between pt1 and pt3. This is accomplished using signedAzimuthDifference function (see section 2 algorithm 3): $angle = abs(signedAzimuthDifference(crs13, crs12))$

(3) *Step 3*. If $(dist13 \leq tol)$ then pt2 is the same point as pt1.

(4) *Step 4*. If $(\frac{\pi}{2} - angle < tol)$ 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) $a = \frac{dist13}{SPHERE_{RADIUS}}$

(c) $b = \text{asin}\,[\sin(B) \times \sin(a)]$

(d) $dist12 = 2 \times SPHERE_{RADIUS} \times \text{atan}\,(\tan[0.5 \times (a - b)]) \times \sin[0.5 \times (A - B)]$

(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 $1.1 \times dist12$ for the distance, $crs12 + \pi$ 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, rename newPt1 as pt1: $pt1 = newPt1$.

(5) *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.

(6) *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.

(7) *Step 7*. Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

(8) *Step 8*. Use the inverse algorithm to calculate the azimuth crs23 and distance dist23 from pt3 to pt2.

(9) *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:

$angle = abs\big(signedAzimuthDifference(crs21, crs23)\big)$

(10) *Step 10*. Calculate the error and store it as the first element in the error function array: $errarray[0] = angle - \frac{\pi}{2}$.

(11) *Step 11*. Store the current distance from pt1 to pt2 in the distance function array: $distarray[0] = dist12$.

(12) *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: $distarray[1] = distarray[0] + errarray[0] \times dist23$.

(13) *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.

(14) *Step 14*. Use the inverse algorithm to calculate the azimuth crs21 from pt2 to pt1.

(15) *Step 15*. Use the inverse algorithm to calculate the azimuth crs23 from pt2 to pt3.

(16) *Step 16*. Calculate the error in angle:

$$errarray[1] = abs\big(signedAzimuthDifference(crs21, crs23)\big) - \frac{\pi}{2}$$

(17) *Step 17*. Initialize the iteration count: $k = 0$.

(18) *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:

1. $distarray[0] = distarray[1]$

2. $errarray[0] = errarray[1]$

3. $distarray[1] = dist13$

4. $errarray[1] = abs(signedAzimuthDifference(crs21, crs23)) - \frac{\pi}{2}$

(f) Calculate the difference between the two latest distance values. This serves as the error function for measuring convergence: $error = abs(distarray[1] - distarray[0])$.

(19) *Step 19*. End while.

(20) *Step 20*. Set $crsToPoint = crs32$.

(21) *Step 21*. Set $distToPoint = dist23$.

(22) *Step 22*. Return pt2.

2. Project point to locus from point on defining geodesic. Given a point on the defining geodesic, this algorithm computes the corresponding point on the locus.

a. 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:

(1) Locus loc = Locus of Interest

(2) LLPoint geoPt = Point on defining geodesic

(3) LLPoint* ptonloc = Pointer to LLPoint, updated with coordinates of point on locus abeam given point.

(4) double* perpCrs = Pointer to double, updated with azimuth from point on geodesic to point on locus.

(5) double tol = Maximum allowable error

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

(1) *Step 1*. Use section 3 algorithm 8 (with point input) to determine the distance from geoPt to the locus. Denote this distance as distp.

(2) *Step 2*. If $(distp = 0)$ then return geoPt.

(3) *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.

(4) *Step 4*. If $(distp > 0.0)$ then the locus lies to the right of the geodesic. Let $*perpCrs = fcrs + \frac{\pi}{2}$

(5) *Step 5*. Else the locus lies to the left of the geodesic. Let $*perpCrs = fcrs - \frac{\pi}{2}$.

(6) *Step 6*. End if.

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

(8) *Step 8*. Return ptonLoc.

3. Project point to locus nearest given point. This algorithm returns the point on a locus nearest the given sample point.

a. 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:

(1) Locus loc = Locus structure to which point will be projected

(2) LLPoint pt2 = Coordinates of point to be projected to locus

(3) double* crsFromPoint = Reference to value that will store the course from pt2 to projected point

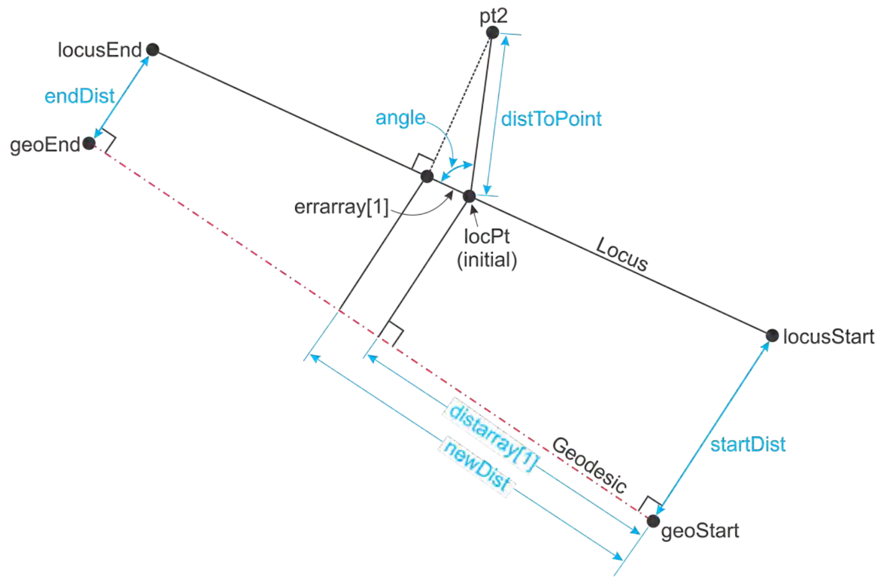
(4) double* distFromPoint = Reference to value that will store the distance from pt2 to projected point

(5) double tol = Maximum error allowed in solution

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-17. Projecting a Point to a Locus



(1) *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) $gdist = loc.geoLength$

(2) *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 section 4 algorithm 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 section 4 algorithm 2 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.

(3) *Step 3*. End if.

(4) *Step 4*. Use the inverse algorithm to compute lcrs, the course from loc.locusStart to loc.locusEnd.

(5) *Step 5*. Use section 4 algorithm 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.)

(6) *Step 6*. Calculate the locus inclination angle, relative to its geodesic: $locAngle = \operatorname{atan}\left(\frac{loc.startDist - loc.endDist}{gdist}\right)$

(7) *Step 7*. Use section 4 algorithm 1 to project locPt onto the locus' defining geodesic. Pass loc.geoStart, gcrs, and locPt as parameters. Denote the computed point as geoPt.

(8) *Step 8*. Use the inverse function to calculate the distance from loc.geoStart to geoPt. Store this value as distarray[1].

(9) *Step 9*. Initialize the iteration count: $k = 0$

(10) *Step 10*. Do while $(k = 0)$ or $abs(errarray[1] > tol)$ and $(< maxIterationCount)$

(a) Use section 4 algorithm 2 with distarray[1] to project a point onto the locus. Reassign locPt as this point.

(b) Use section 3 algorithm 10 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: $errarray[1] = -distToPoint \times \cos(angle)$. 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: $newDist = distarray[1] + errarray[1] \times \cos(locAngle)$

(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:

1. $distarray[0] = distarray[1]$

2. $errarray[0] = errarray[1]$

3. $distarray[1 \; = newDist$

(11) *Step 11*. End while.

(12) *Step 12*. Return locPt.

4. 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.

a. 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:

(1) LLPoint point = Point from which lines will be tangent to arc

(2) LLPoint center = Geodetic centerpoint coordinates of arc

(3) double radius = Radius of arc

(4) LLPointPair tanPt = Two-element array of LLPoint objects that will be updated with tangent point's coordinates

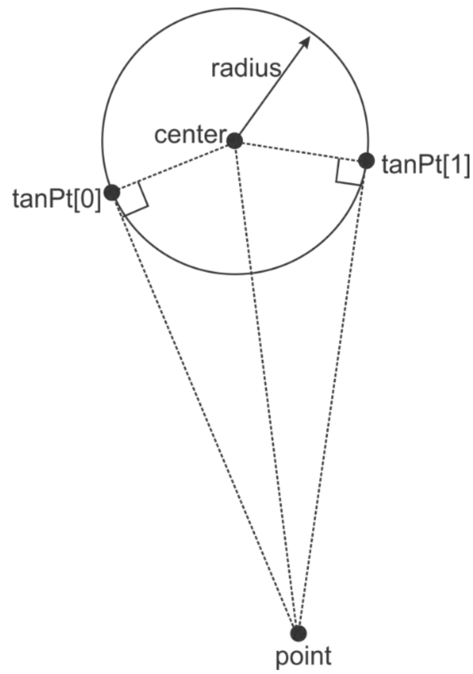
(5) int* n = Reference to number of tangent points found (0, 1, or 2)

(6) double tol = Maximum error allowed in solution

(7) double eps = Convergence parameter for forward/inverse algorithms

b. 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 section 3 algorithm 6 to determine whether they lie within the arc's bounds.

Figure F-18. Projecting Point to Tangent Points on an Arc



(1) *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.

(2) *Step 2*. If $(abs(distToCenter - radius) < tol)$ then point lies on the arc and is a tangent point:

(a) Set $n = 1$.

(b) Return $tanPt = point$.

(3) *Step 3*. Else if $(distToCenter < radius)$ then point lies inside of the arc and no tangent points exist, return no solution.

(4) *Step 4*. End if.

(5) *Step 5*. There must be two tangent points on the circle, so set $n = 2$.

(6) *Step 6*. Use spherical trigonometry to compute approximate tangent points:

(a) $a = \frac{distToCenter}{SPHERE_{RADIUS}}$

(b) $b = \frac{radius}{SPHERE_{RADIUS}}$

(c) $C = \text{acos}\left[\frac{\tan(b)}{\tan(a)}\right]$. This is the approximate angle between the geodesic that joins point with center and the geodesic that joins center with either tangent point.

(7) *Step 7*. Initialize iteration count $k = 0$.

(8) *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 section 2 algorithm 3 to calculate the angle between the two courses and cast it into the range $[-\pi, \pi]$: $diff = signedAzimuthDifference(radCrs, taxCrs)$

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

(f) Adjust the value of C to improve the approximation $C = C + error$.

(g) Increment the iteration count $k = k + 1$.

(9) *Step 9*. End while loop.

(10) *Step 10*. Repeat *Steps 7-9* to solve for tanPt[1]. In each iteration; however, use crsFromPoint–C for azimuth in *Step 8(a)*.

(11) *Step 11*. Return tanPt[0] and tanPt[1].

5. 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.

a. 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:

(1) LLPoint lineStart = Start point of geodesic to which arc tangent points will be projected

(2) double crs = Initial course of geodesic

(3) LLPoint center = Geodetic coordinates of arc center

(4) double radius = Arc radius

(5) LLPointPair linePts = Two-element array of projected points on Geodesic

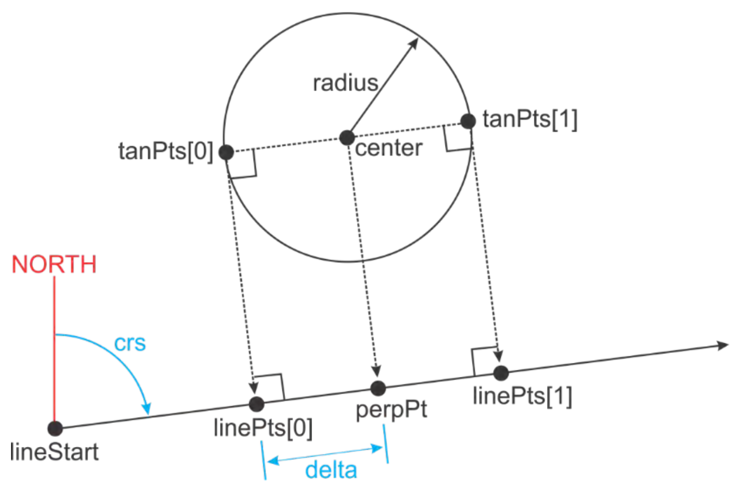
(6) LLPointPair tanPts = Two-element array of tangent points on arc

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-19. Projecting an Arc to a Geodesic



(1) *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.

(2) *Step 2*. Compute the angle between the given geodesic and the geodesic that joins lineStart to center (see section 2 algorithm 3): $angle1 = signedAzimuthDifference(crs, crsStartToCenter)$

(3) *Step 3*. If $(abs(distStartToCenter \times (crsStartToCenter - crs)) < tol)$ 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.

(4) *Step 4*. End if.

(5) *Step 5*. Use section 4 algorithm 1 to project center to the geodesic defined by lineStart and crs. Denote the projected point by perpPt.

(6) *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.

(7) *Step* 7. Set $delta = radius$.

(8) *Step 8*. Initialize iteration count: $k = 0$.

(9) *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 $crs21 + \pi$ 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: $perpCrs = strCrs + \frac{\pi}{2}$.

2. If the circle lies to the left of the line: $perpCrs = strCrs - \frac{\pi}{2}$.

(d) Use section 4 algorithm 1 to project center onto the geodesic passing through linePts[0] at azimuth perpCrs. Section 4 algorithm 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: $k = k + 1$.

(10) *Step 10*. End while loop.

(11) *Step 11*. Repeat *Steps 7-10* to solve for linePts[1] and tanPts[1]. In each iteration; however, use crs21 for azimuth in *Step 9(a)*. Using the final delta value for the first iteration in the search for linePts[1] will make the code more efficient (i.e., do not repeat *Step 7*).

(12) *Step 12*. Return linePts[0], linePts[1], tanPts[0], and tanPts[1].

Section 5. Intersections

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.

a. 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:

(1) LLPoint pt1 = Start point of first geodesic

(2) double crs13 = Azimuth from pt1 to intersection point

(3) double* crs31 = Reference to azimuth from intersection point to pt1

(4) double* dist13 = Reference to distance from pt1 to intersection

(5) LLPoint pt2 = Start point of second geodesic

(6) double crs23 = Azimuth from pt2 to intersection point

(7) double* crs32 = Reference to azimuth from intersection to pt2

(8) double* dist23 = Reference to distance between pt2 and intersection point

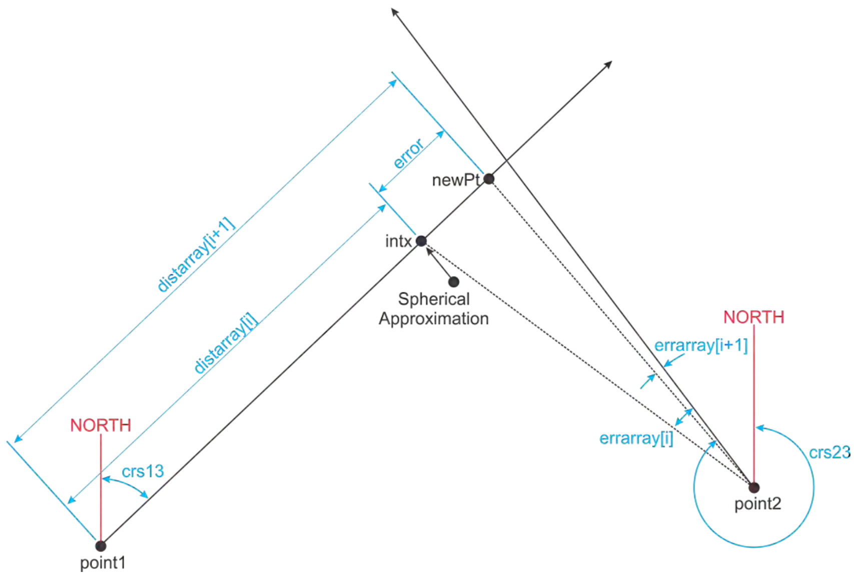
(9) LLPoint* intx = Reference to intersection point

(10) double tol = Maximum error allowed in solution

(11) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-20. Finding the Intersection of Two Geodesics



(1) *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.

2. If pt1 falls on geodesic 2. Return pt1.

3. If pt2 falls on geodesic 1. Return pt2.

(2) *Step 2*. Calculate the signed azimuth difference in angle between crs12 and crs13, denoted by angle1.

(3) *Step 3*. Calculate the signed azimuth difference in angle between crs21 and crs23, denoted by angle2.

(4) *Step 4*. If $(sin(angle1) \times sin(angle2) < 0)$ 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. $angle1 = (crs13 + \pi) - crs12$.

2. Else $angle2 = crs21 - (crs23 + \pi)$.

(5) *Step 5*. End if.

(6) *Step 6*. Locate the approximate intersection point, intx, using a spherical earth model (see section 3 paragraph 2).

(7) *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.

(8) *Step 8*. Use the inverse algorithm to calculate dist13, the distance from pt1 to intx.

(9) *Step 9*. Use the inverse algorithm to calculate dist23, the distance from pt2 to intx.

(10) *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:

(a) Use the direct algorithm to move pt1 from its original coordinates 1 NM along azimuth $crs13 + \pi$.

(b) Use the inverse algorithm to calculate the azimuth acrs13 for the geodesic from the new pt1.

(11) *Step 11*. Repeat *Step*s *10*, *10(a)*, and *10(b)* for pt2 and crs23.

(12) *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.

(13) *Step 13*. End if.

(14) *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.

(15) *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.

(16) *Step 16*. Use the inverse algorithm to measure the azimuth acrs23 from pt2 to intx.

(17) *Step 17*. Initialize the error array:

$errarray[0] = signedAzimuthDifference(acrs23, crs23)$

(18) *Step 18*. Initialize the second element of the distance array using a logical guess: $distarray[1] = 1.01 \times dist13$.

(19) *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.

(20) *Step 20*. Use the inverse algorithm to measure the azimuth acrs23 from pt2 to intx.

(21) *Step 21*. Initialize the error array:

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

(22) *Step 22*. Initialize $k = 0$

(23) *Step 23*. Do while $(k = 0)$ or $(error > tol)$ and $(k \leq MAX_{ITERATIONS})$:

(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:

<u>1.</u> $distarray[0] = distarray[1]$

2. $distarray[1] = dist13$

3. $errarray[0] = errarray[1]$

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

(f) Increment k: $k = k + 1$

(24) *Step 24*. End while loop.

(25) *Step 25*. Check if k reached $MAX_{ITERATIONS}$. If so, then the algorithm may not have converged, so an error message should be displayed.

(26) *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.

(27) *Step 27*. Return intx.

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.

a. 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:

(1) LLPoint center1 = Geodetic coordinates of first arc center

(2) double radius1 = Radius of first arc in nautical miles

(3) LLPoint center2 = Geodetic coordinates of second arc center

(4) double radius2 = Radius of second arc in nautical miles

(5) LLPointPair intx = Two-element array of LLPoint objects that will be updated with intersections' coordinates

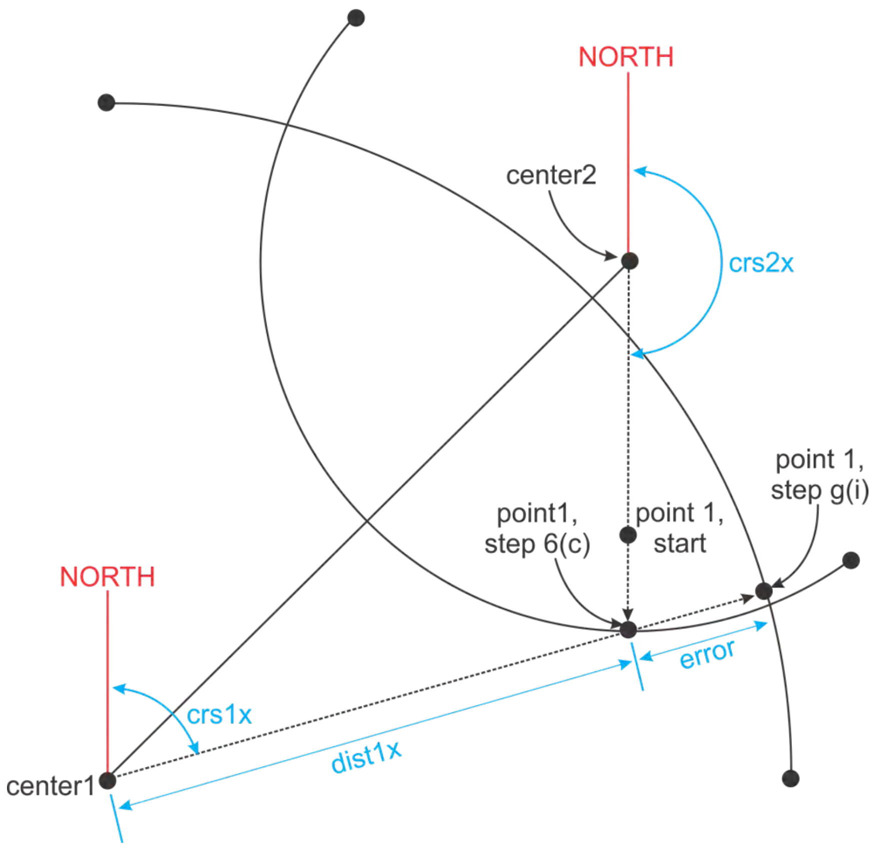
(6) int* n = Reference to integer number of intersection points returned

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. 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.

Figure F-21. Intersection of Two Arcs



(1) *Step 1*. Use inverse algorithm to calculate the distance and azimuth between center1 and center2. Denote these values as dist12 and crs12, respectively.

(2) *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. Return no intersections.

(3) *Step 3*. Else if $(abs(radius1 + radius2 - dist12) \leq tol)$ 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.

(4) *Step 4*. End if.

(5) *Step 5*. Calculate approximate intersection points, intx[0] and intx[1], according to section 3 paragraph 2.

(6) *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:

1. $errarray[1] = error$

2. $crsarray[1] = crs1x$

(g) While ($k \leq maximumIterationCount$) 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:

a. $crsarray[0] = crsarray[1]$

b. $crsarray[1] = crs1x$

c. $errarray[0] = errarray[1]$

d. $errarray[1] = error$

<u>6.</u> Use linear root finder to find the azimuth value that corresponds to zero error. Update the variable crs1x with this root value.

<u>7.</u> Increment k: $k = k + 1$

(h) End while loop.

(7) *Step 7*. Store point in array to be returned: $intx[0] = point$.

(8) *Step 8*. Repeat *Step 6* for approximation intx[1].

(9) *Step 9*. Return array intx.

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.

a. 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:

(1) LLPoint pt1 = Geodetic coordinates of start point of geodesic

(2) double crs1 = Initial azimuth of geodesic at start point

(3) LLPoint center = Geodetic coordinates of arc center point

(4) double radius = Arc radius in nautical miles

(5) LLPointPair intx = Two-element array of LLPoint objects that will be updated with intersections' coordinates

(6) int* n = Reference to number of intersection points returned

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps. This algorithm treats the arc and geodesic as unbounded. Once intersection points are found, they must be tested using section 3 algorithms 5 and 6 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*.

Figure F-22. Locating First Intersection of Geodesic and Arc

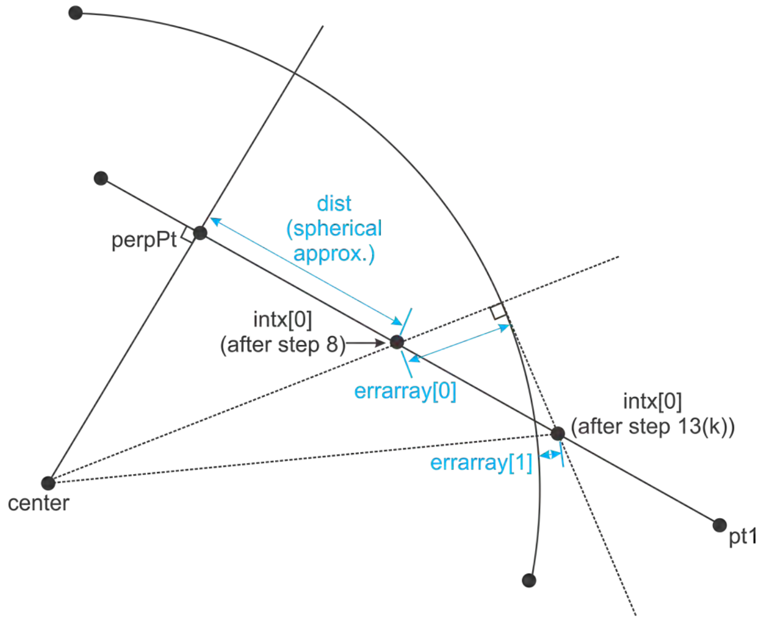
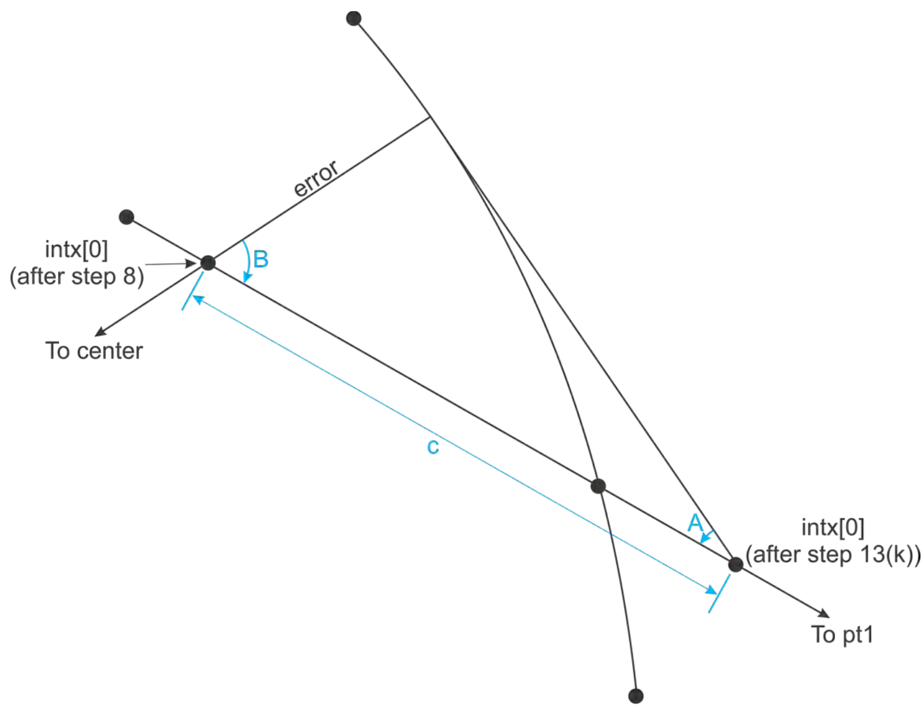


Figure F-23. Near the Appropriate Geodesic-Arc Intersection Point With Spherical Triangle Components That Are Used to Improve the Solution



(1) *Step 1*. Use section 4 algorithm 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.

(2) *Step 2*. Use inverse algorithm to calculate the azimuth of the geodesic at perpPt. Denote the azimuth from perpPt to pt1 as crs.

(3) *Step 3*. If $(abs(perpDist - radius) < tol)$ then the geodesic is tangent to the arc and intersection point is at perpPt, return $intx[0] = perpPt$.

(4) *Step 4*. Else if $(perpDist > radius)$ then geodesic passes too far from center of circle; there is no intersection, return empty array.

(5) *Step 5*. End if.

(6) *Step 6*. 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:

$$dist = SPHERE_{RADIUS} \times \text{acos}\left[\frac{\cos\left(\frac{radius}{SPHERE_{RADIUS}}\right)}{\cos\left(\frac{perpDist}{SPHERE_{RADIUS}}\right)}\right]$$

Note: A test must be performed so that if $(\cos\left(\frac{perpDist}{SPHERE_{RADIUS}}\right) = 0)$ then no solution is returned.

(7) *Step 7*. 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.

(8) *Step 8*. Initialize iteration count $k = 0$.

(9) *Step 9*. 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.

(10) *Step 10.* Calculate error for this iteration: $error = radius - radDist$.

(11) *Step 11*. Initialize arrays that will hold distance and error function values so that linear interpolation may be used to improve approximation:

(a) $distarray[0] = dist$

(b) $errarray[0] = error$

(12) *Step 12*. Do one iterative step using spherical approximation near intersection point:

(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].

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

(c) Calculate the angle opposite the radial error:

$$A = \text{acos}\left(\sin(B) \times \cos\left[\frac{abs(error)}{SPHERE_{RADIUS}}\right]\right)$$

(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:

$$c = \frac{error}{cos(B)}$$

(f) Else use a spherical triangle approximation for c:

$$c = SPHERE_{RADIUS} \times \text{asin}\left[\frac{\sin\left(\frac{error}{SPHERE_{RADIUS}}\right)}{\sin(A)}\right]$$

(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:

1. $distarray[1] = dist$

2. $errarray[1] = radius - radDist$

(13) *Step 13.* 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:

1. $distarray[0] = distarray[1]$

2. $errarray[0] = errarray[1]$

3. $distarray[1] = dist$

4. $errarray[1] = error$

(e) Increment the iteration count: $k = k + 1$

(14) *Step 14*. End while loop.

(15) *Step 15*. Prepare variables to solve for second solution, intx[1]:

(a) Second solution lies on other side of perpPt, so set $crs = crs + \pi$.

(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: $errarray[0] = radius - radDist$.

(16) *Step 16*. Repeat *Steps 13-14* to improve solution for intx[1].

(17) *Step 17*. Return intx[0] and intx[1].

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. 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.

a. 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:

(1) LLPoint pt1 = Geodetic coordinates of start point of first geodesic

(2) double crs12 = Azimuth of first geodesic at pt1

(3) LLPoint pt3 = Geodetic coordinates of end point of second geodesic

(4) double crs3 = Azimuth of second geodesic at pt3

(5) double radius = Radius of desired arc

(6) ArcDirection* dir = Reference to an integer that represents direction of turn.

(a) dir = 1 for left hand turn

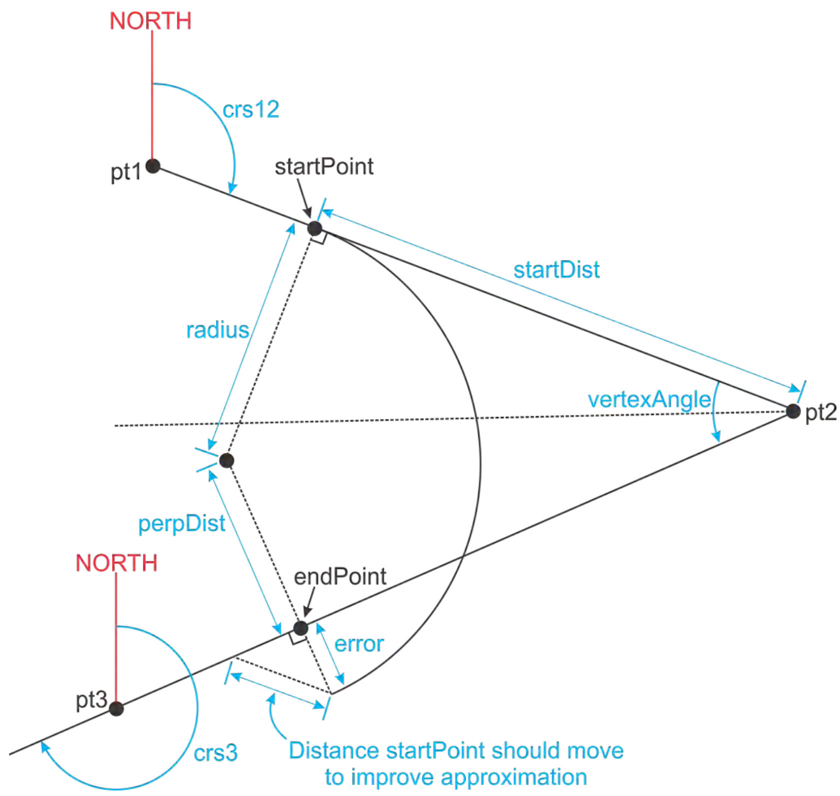
(b) dir = -1 for right hand turn

(7) double tol = Maximum error allowed in solution

(8) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-24. Finding Arc Center and Points at Which Arc is Tangent to Two Geodesics



(1) *Step 1*. Use section 5 algorithm 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.

(2) *Step 2*. If intersection point pt2 is not found, then no tangent arc can be found, return empty array.

(3) *Step 3*. End if.

(4) *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.

(5) *Step 5*. Use the inverse algorithm to compute the azimuth at pt2 to go from pt2 to pt3. Denote this value by crs23.

(6) *Step 6*. Calculate angle between courses at pt2 (see section 2 algorithm 3). Denote this value by vertexAngle: $vertexAngle = signedAzimuthDifference(crs21, crs23)$

(7) *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, return empty array.

(8) *Step 8*. Else if $(vertexAngle > 0)$ then course changes direction to the right: $dir = -1$.

(9) *Step 9*. Else the course changes direction to the left: $dir = 1$

(10) *Step 10*. End if.

(11) *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) $B = \frac{vertexAngle}{2}$

(b) If $(radius > SPHERE_{RADIUS} \times B)$ then no arc of the required radius will fit between the given geodesics, return empty array.

(c) End if.

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

$$distToStart = SPHERE_{RADIUS} \times \text{asin}\left[\frac{\tan\left(\frac{radius}{SPHERE_{RADIUS}}\right)}{\tan(B)}\right]$$

(12) *Step 12*. Initialize the iteration count: $k = 0$

(13) *Step 13*. Initialize the error measure: $error = 0.0$

(14) *Step 14*. Do while $(k = 0)$ or $(abs(error) > tol)$ and $(k \leq maximumIterationCount)$

(a) Adjust the distance to tangent point based on current error value (this has no effect on first pass through, because $error = 0$):

$$distToStart = distToStart + \frac{error}{\sin(vertexAngle)}$$

(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 π/2 to perpCrs to get the azimuth from startPt to center of arc: $perpCrs = perpCrs + \frac{\pi}{2}$

(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: $perpCrs = perpCrs - \frac{\pi}{2}$

(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 section 4 algorithm 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.

(15) *Step 15*. End while.

(16) *Step 16*. 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.

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.

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

(1) LLPoint geoSt = Geodetic coordinates of start point of geodesic

(2) LLPoint geoEnd = Geodetic coordinates of end point of geodesic

(3) Locus loc = Structure defining locus of points

(4) LLPoint* pint = Reference to LLPoint that will be updated with intersection coordinates.

(5) double tol = Maximum error allowed in solution

(6) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-25. Intersection of Geodesic with Locus of Points

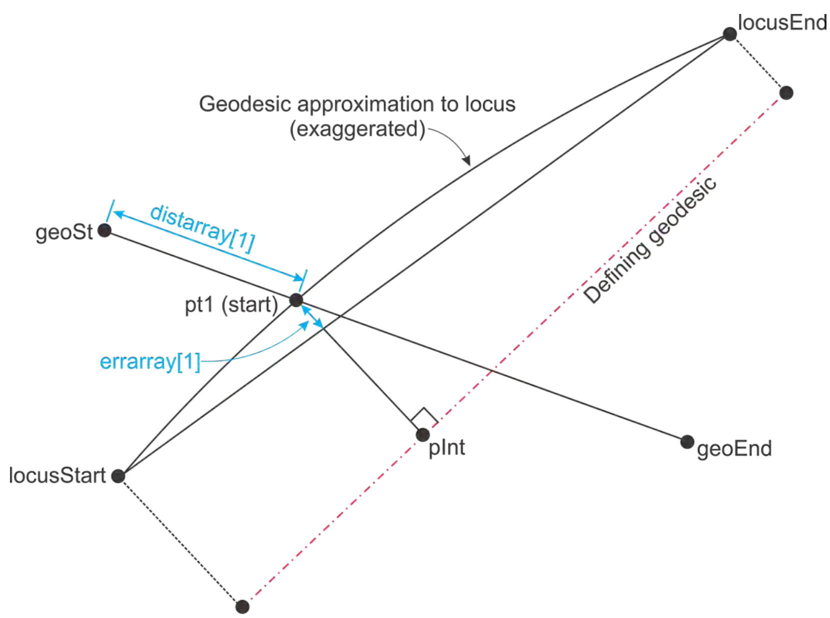
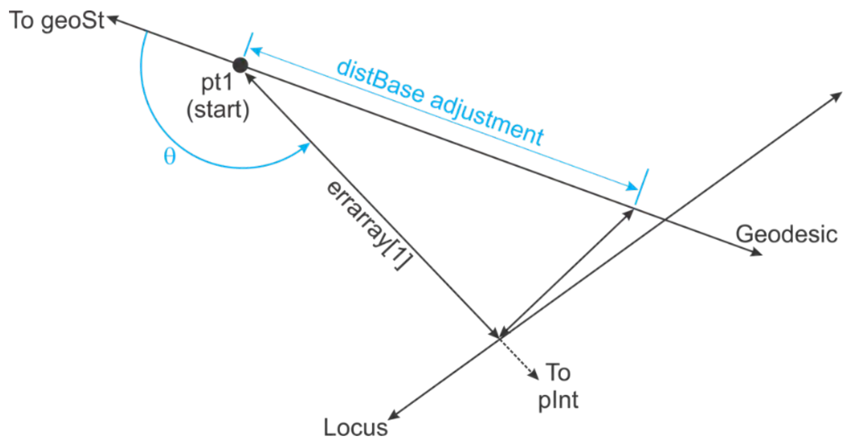


Figure F-26. Computing First Update to Locus-Geodesic Intersection



(1) *Step 1*. Use the geodesic intersection algorithm (see section 5 algorithm 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.

(2) *Step 2*. If pt1 is not found, then the locus and geodesic to not intersect, so return empty point.

(3) *Step 3*. End if.

(4) *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.

(5) *Step 5*. Use the inverse algorithm to calculate the distance and course from pt1 to geoSt. Denote these values as distBase and crsBase, respectively.

(6) *Step 6*. Obtain the forward course of the locus' 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.

(7) *Step 7*. Use section 4 algorithm 1 to project pt1 onto the locus' 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.

(8) *Step 8*. Use section 3 algorithm 8 to calculate the distance from the defining geodesic to the locus at pInt. Denote this value as distLoc.

Note: distLoc may be positive or negative, depending on which side of defining geodesic the locus lays.

(9) *Step 9*. Calculate the distance from pt1 to the locus. This is the initial error:

$errarray[1] = distFromPt - abs(distLoc)$

(10) *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.

(11) *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.

(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:

$$newdistbase = \frac{distbase - errarray[1]}{\cos(theta)}$$

(12) *Step 12*. Initialize the iteration count: $k = 0$.

(13) *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:

1. $errarray[0] = errarray[1]$

2. $geodarray[0] = geodarray[1]$

(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.

(14) *Step 14*. End while.

(15) *Step 15*. Return $pint = pt1$.

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 section 5 algorithm 3, which computes the intersections of an arc and a geodesic. It begins by treating the locus as a geodesic and applying section 5 algorithm 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.

a. 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:

(1) Locus loc = Locus of interest

(2) LLPoint center = Geodetic coordinates of arc

(3) double radius = Arc radius

(4) LLPointPair intx = Two-element array of LLPoint that will be updated with intersection coordinates

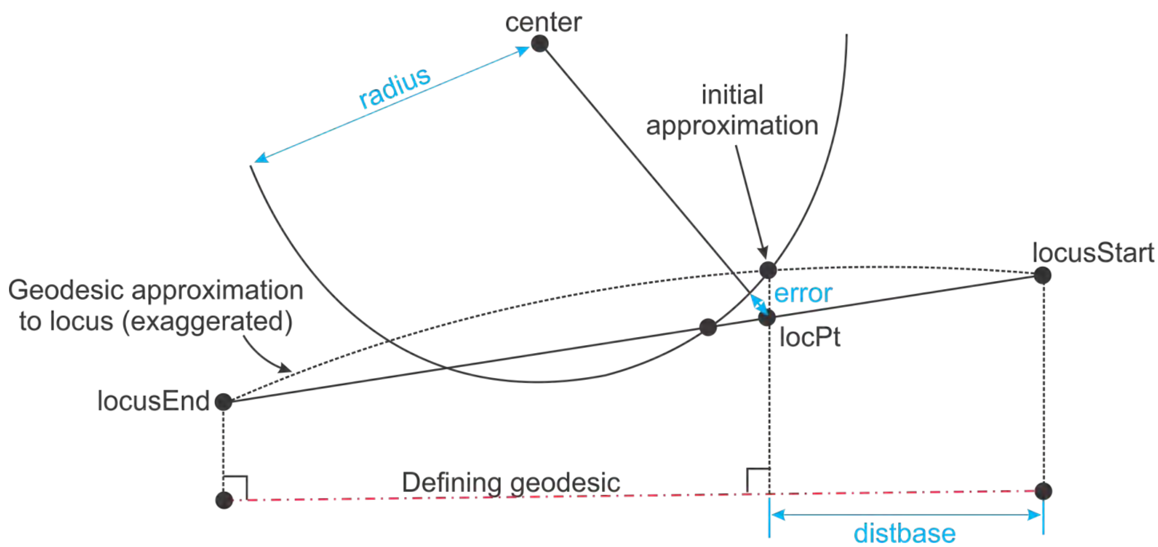
(5) int* n = Number of intersections found

(6) double tol = Maximum error allowed in solution

(7) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-27. Finding the Intersection of an Arc and a Locus



(1) *Step 1*. Initialize number of intersections $n = 0$.

(2) *Step 2*. Use the inverse algorithm to compute the course from loc.locusStart to loc.locusEnd. Denote this value as fcrs.

(3) *Step 3*. Use section 4 algorithm 3 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.

(4) *Step 4*. If $(distFromPoint > radius)$ then no approximate intersections were found. Return NULL.

(5) *Step 5*. End if.

(6) *Step 6*. Else if distFromPoint is equal to radius within tolerance level, then:

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

(b) $intx[0] = locpt$.

(7) *Step 7*. End if.

(8) *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].

(9) *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.

(10) *Step 10*. For $i = 0, i < n1$:

(a) Use section 4 algorithm 1 to project intx[0] to the locus' 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 section 4 algorithm 2 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 (10)(g)* through *(10)(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: $newDistbase = 1.001 \times distbase$

(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 section 4 algorithm 2 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:

a. geodarray[0] = geodarray[1]

b. geodarray[1] = newDistbase

c. errarray[0] = errarray[1]

d. 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 section 3 algorithm 9, then

1. Copy locPt to the output array: $intx[n] = locPt$.

2. Update the count of intersection points found: $n = n + 1$.

(11) *Step 11*. End for loop.

(12) *Step 12*. Return intx.

7. Intersections of two loci.

a. 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:

(1) Locus loc1 = First locus of interest

(2) Locus loc2 = Second locus of interest

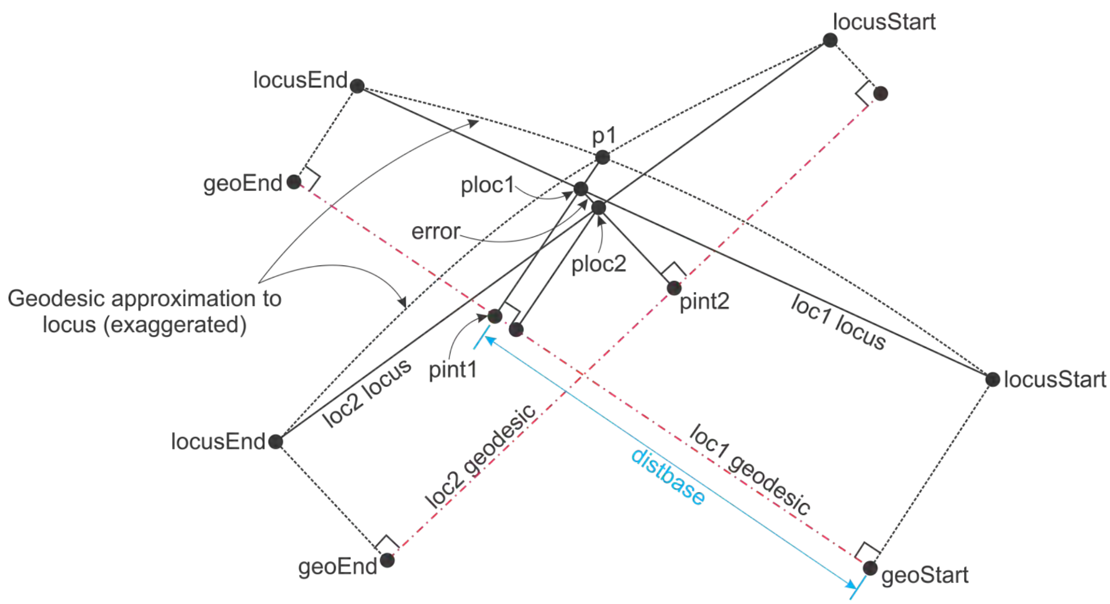
(3) LLPoint* intx = Reference to LLPoint that will be updated with intersection coordinates.

(4) Double tol = Maximum error allowed in solution

(5) Double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-28. Computing the Intersection of Two Loci



(1) *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.

(2) *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.

(3) *Step 3.* Use loc1.locusStart, crs1, loc2.locusStart, and crs2 as input to section 5 algorithm 1 to calculate an approximate solution to the locus intersection. Denote the approximate intersection point at p1.

(4) *Step 4*. If $(p1 = NULL)$ then the loci do not intersect, so return NULL.

(5) *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.

(6) *Step 6*. Project p1 to the geodesic of loc1 using section 4 algorithm 1 with loc1.geoStart and tcrs1 as input parameters. Store the projected point as pint1.

(7) *Step 7*. If $(pint1 = NULL)$ then no projected point was found so return NULL.

(8) *Step 8*. Use the inverse algorithm to calculate distbase, the distance from loc1.geoStart to pint1.

(9) *Step 9*. Initialize iteration counter: $k = 0$

(10) *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 section 4 algorithm 2 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 section 4 algorithm 1 with loc2.geoStart and tcrs2 as input parameters. Store the projected point as pint2.

(d) Use section 4 algorithm 2 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:

1. $errarray[0] = errarray[1]$

2. $errarray[1] = error$

3. $distarray[0] = distarray[1]$

4. $distarray[1] = distbase$

(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 section 4 algorithm 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 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: $k = k + 1$.

(11) *Step 11*. End while.

(12) *Step 12*. Use section 3 algorithm 9 with inputs of loc1 and ploc1 to determine if ploc1 lies on the loc1. Then use section 3 algorithm 9 with inputs of loc2 and ploc1 to determine if ploc1 lies on the loc2. If ploc1 does not lie on both loci, return NULL.

(13) *Step 13*. Return ploc1.

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 section 5 algorithm 4.

a. 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:

(1) Locus loc1 = Structure defining first locus

(2) Locus loc2 = Structure defining second locus

(3) double radius = Radius of desired arc

(4) LLPoint* centerpoint = Reference to LLPoint that will contain arc's center coordinates.

(5) LLPoint* startPoint = Reference to LLPoint that will contain arc's start point coordinates.

(6) LLPoint* endpoint = Reference to LLPoint that will contain arc's endpoint coordinates.

(7) ArcDirection* dir = Reference to an integer that represents direction of turn.

(a) dir = 1 for left hand turn

(b) dir = -1 for right hand turn

(8) double tol = Maximum error allowed in solution

(9) double eps = Convergence parameter for forward/inverse algorithms

b. Algorithm steps.

Figure F-29. Arc Tangent to Two Loci

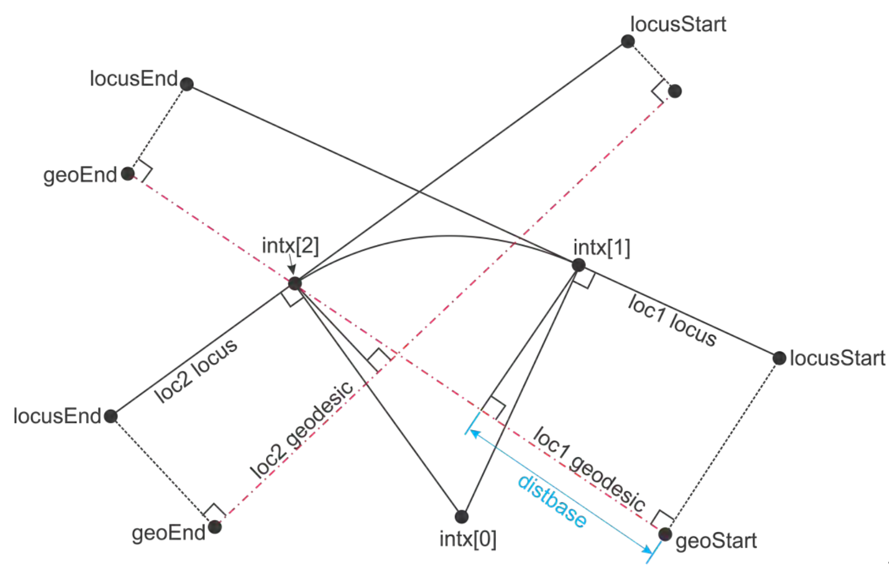
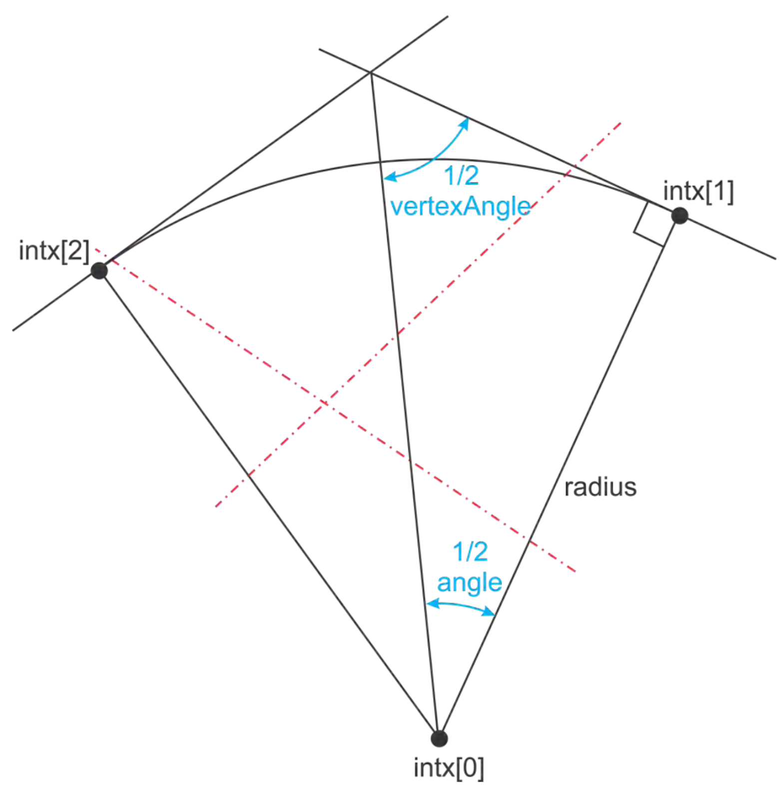


Figure F-30. Spherical Triangle Construction Used for Calculating the Approximate Vertex Angle at the Intersection of Two Loci



(1) *Step 1*. Use inverse algorithm to calculate crs12, the course from loc1.locusStart to loc1.locusEnd.

(2) *Step 2*. Use inverse algorithm to calculate gcrs1 and geoLen1, the course and distance from loc1.geoStart to loc1.geoEnd.

(3) *Step 3*. Use inverse algorithm to calculate crs32, the course from loc2.locusEnd to loc2.locusStart. Convert crs32 to its reciprocal:$crs32 = crs32 + \pi$.

(4) *Step 4*. Apply section 5 algorithm 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.

(5) *Step 5*. If ($intx = NULL$) then there is no tangent arc. Return NULL.

(6) *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:

(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:

$$angle = abs(signedAzimuthDifference(rcrs1, rcrs2))$$

$$vertexAngle = 2 \times \operatorname{acos}\left[\sin\left(\frac{angle}{2}\right) \times \cos\left(\frac{radius}{SPHERE_{RADIUS}}\right)\right]$$

(7) *Step 7*. Calculate the inclination angle of loc1 relative to its geodesic:

$$locAngle = \operatorname{atan}\left(\frac{loc1.endDist - loc1.startDist}{geoLen1}\right)$$

(8) *Step* 8. Initialize$distbase = 0.1$.

(9) *Step 9*. Initialize the iteration count:$k = 0$.

(10) *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 section 4 algorithm 2 to project a point on loc1 from the current geoPt1. Denote the projected point as intx[1].

(c) Use section 3 algorithm 10 to calculate lcrs1, the course of loc1 at intx[1].

(d) Convert lcrs1 into the correct perpendicular course toward the arc center (note that $dir > 0$ indicates a left-hand turn):$lcrs1 = lcrs1 - dir \times \frac{\pi}{2}$.

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

(f) Use section 4 algorithm 3 to project intx[0] onto loc2. Reassign intx[2] as the projected point.

(g) Use the inverse algorithm to calculate r2, the distance from intx[0] to intx[2].

(h) Calculate the error: $error = r2 - radius$.

(i) Update the distance and error function arrays:

1. $distarray[0] = distarray[1]$

2. $distarray[1] = distbase$

3. $errarray[0] = errarray[1]$

4. $errarray[1] = error$

(j) If $(k = 0)$ then estimate better distbase value using spherical approximation and calculated error:

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

(k) 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.

(l) End if.

(11) *Step 11*. End while.

(12) *Step 12*. Return intx.

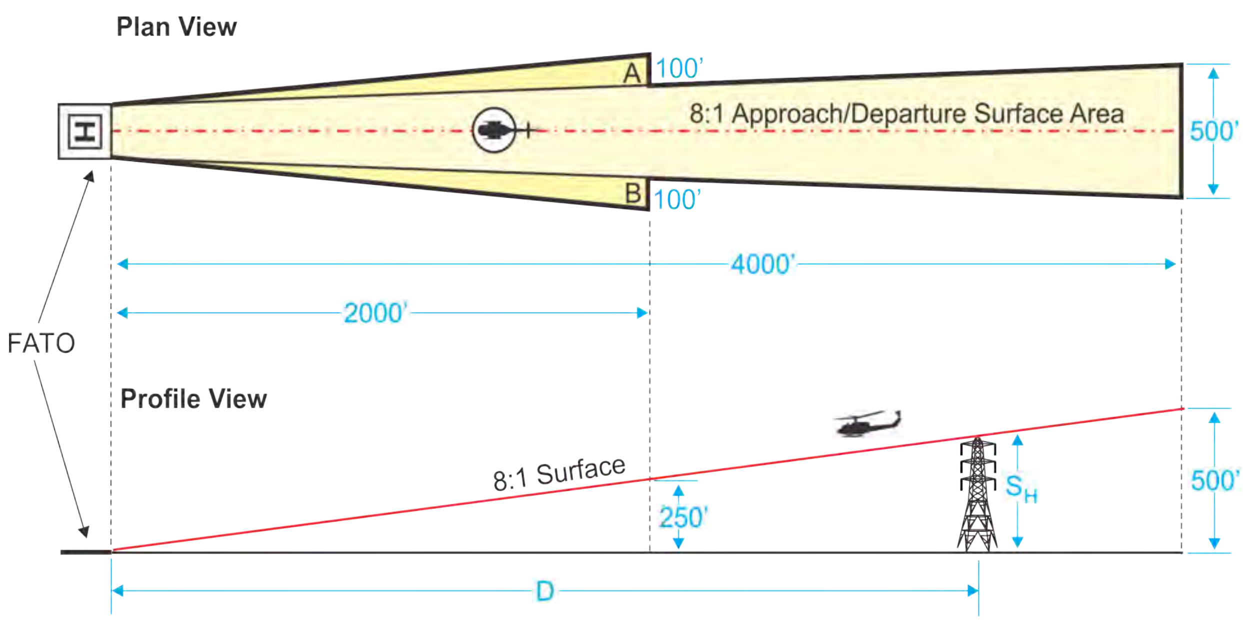
Appendix G. Conditions and Assumptions for IFR to VFR Heliport (IVH) (Proceed Visually) Approach Procedures

Before designing an RNAV (GPS) IVH approach procedure, ensure the heliport meets the following criteria:

1. FAA Form 7480-1, Notice for Construction, Alteration and Deactivation of Airports, has been filed under part 157.

2. No penetration of the 8:1 surface in AC 150/5390-2 is permitted (see figure G-1). Penetrations of either A or B areas but not penetrations of both areas are allowed if the obstructions are charted, and marked or lighted and if not considered a hazard. Use figure G-1 to determine height of the 8:1 surface.

Figure G-1. AC 150-5390-2 8:1 Surface



Formula G-1. 8:1 OCS Height (S_H)

$$S_H = (r + HE) \times e^{\frac{D}{8r}} - r$$

Where:

D = Distance from the FATO edge to obstacle, measured along centerline (feet)
HE = Heliport elevation

3. An acceptable onsite evaluation of the heliport for VFR use is required. Order 8900.1, volume 8, chapter 3, section 3 is to be used for evaluation of the heliport. Based on the FAA determination, a procedure can be developed under the following conditions:

a. No objection.

b. Conditional. Conditions that have been resolved by the proponent (e.g., obstacle penetrations of the 8:1 approach area, transitional and lateral extension areas, or those that pertain to the minimum size of the FATO, TLOF, and safety area). Recommendations made by the inspector when there are no operational safety concerns may not require resolution.

c. Objection. If an objection determination is issued, an IVH approach procedure is not authorized to be developed. A PinS (Proceed VFR) approach procedure may be developed in accordance with paragraph 12-2-2.

4. An acceptable evaluation of the visual segment for flyability, obstacles, and visual references must be completed in both day and night flight conditions. The heliport or heliport visual references must be in clear view at the MAP (e.g., it cannot be completely obscured behind a building). A heliport is the area of land, water or a structure used or intended to be used for the landing and takeoff of helicopters, together with appurtenant buildings and facilities. Buildings and facilities associated with the heliport such as hangers, administration buildings, AWOS equipment, windsock, beacon, etc. located within 500 feet are acceptable visual references. Surrounding buildings and landmarks are not allowable visual references, unless approved by Flight Standards. At least one of the following visual references must be visible or identifiable before the pilot may proceed visually:

a. FATO or FATO lights.

b. TLOF or TLOF lights.

c. Lead-in lights.

d. VGSI.

e. Windsock or windsock light(s).*

f. Heliport beacon.*

g. Other facilities or systems approved by Flight Standards.

*__Note:__ Windsock lights and heliport beacons should be located within 500 feet of the TLOF.

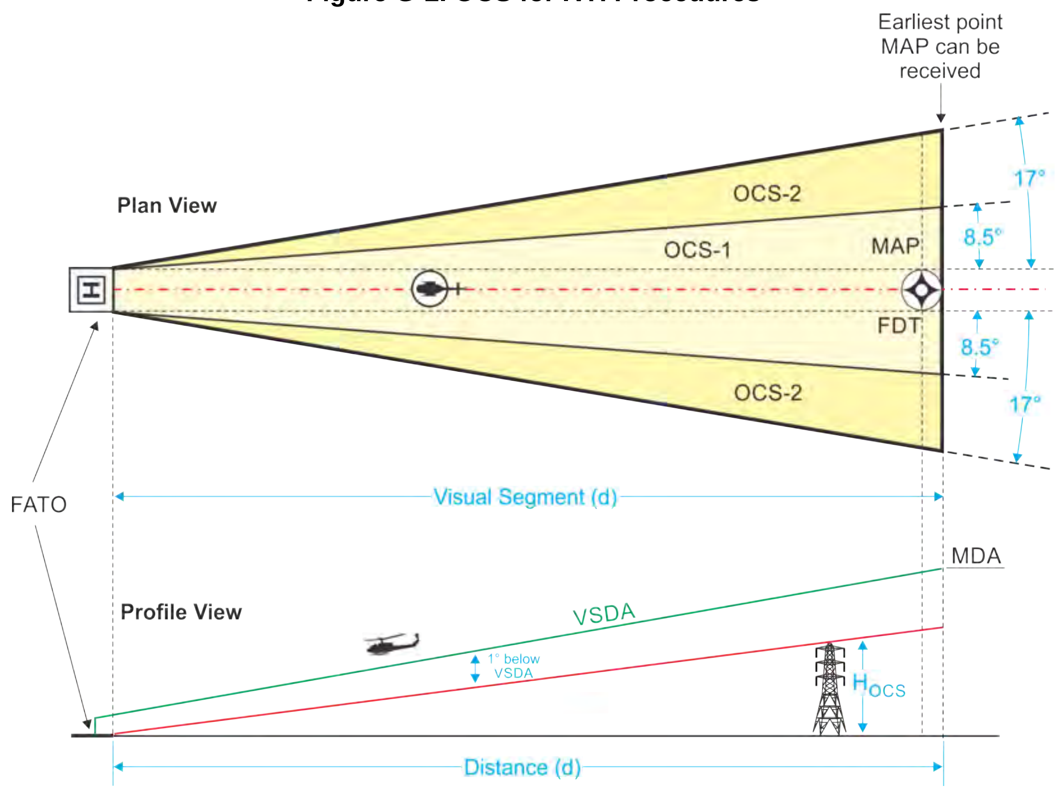
5. IVH Analysis. The following analysis must be performed for authorizing an IVH procedure (see figure G-3). Obstacle clearance surface (OCS) areas are applied using concepts from paragraph 3-3-2.c with the following exceptions:

a. Alignment is always centered on the visual segment centerline

b. Length OCS-1 and OCS-2. The length of OCS-1 and OCS-2 begin from the edge of the FATO and extend to abeam the earliest point the MAP can be received (see figure G-2).

c. Area Width OCS-1 and OCS-2. OCS-1 splays outward 8.5 degrees from the outer edges of the FATO. OCS-2 splays outward 17 degrees from the outer edges of the FATO (see figure G-2).

Figure G-2. OCS for IVH Procedures



(1) *Step 1.* Calculate OCS-1 width (W_{OCS-1}) at distance (d) from the FATO edge using formula G-2.

Formula G-2. OCS-1 Width (W_{OCS-1})

$$W_{OCS-1} = [\tan(8.5) \times d] + 0.5 \times F_w$$

Where:

W_{OCS-1} = Perpendicular distance from the flight path to the edge of OCS-1 (feet)
d = Distance from the FATO edge measured along the flight path (feet)
F_w = FATO width (feet)

(2) *Step 2.* Calculate the OCS-2 width (W_{OCS-2}) at distance (d) from the FATO edge using formula G-3.

Formula G-3. OCS-2 Width (W_{OCS-2})

$$W_{OCS-2} = [\tan(17) \times d] + 0.5 \times F_w$$

Where:

W_{OCS-2} = Perpendicular distance from the flight path to the edge of OCS-2 (feet)

d = Distance from the FATO edge measured along the flight path (feet)

F_w = FATO width (feet)

(3) The slope of OCS-1 and OCS-2 is equal to the VSDA minus one (1) degree measured from the FATO edge elevation. Use formula G-4 to determine the MSL elevation of OCS-1 and OCS-2 at distance (D) from the FATO edge.

Formula G-4.OCS-1 and OCS-2 Slope (H_{OCS})

$$H_{OCS} = (r + HE) \times e^{\frac{D \times [\tan(VSDA-1)]}{r}} - r$$

Where:

$VSDA$ = Visual segment descent angle (degrees)

D = Distance from the FATO edge to obstacle (feet)

HE = FATO edge elevation (feet)

d. If an unlighted obstacle penetrates OCS-1, a VGSI is required to be installed at the heliport.

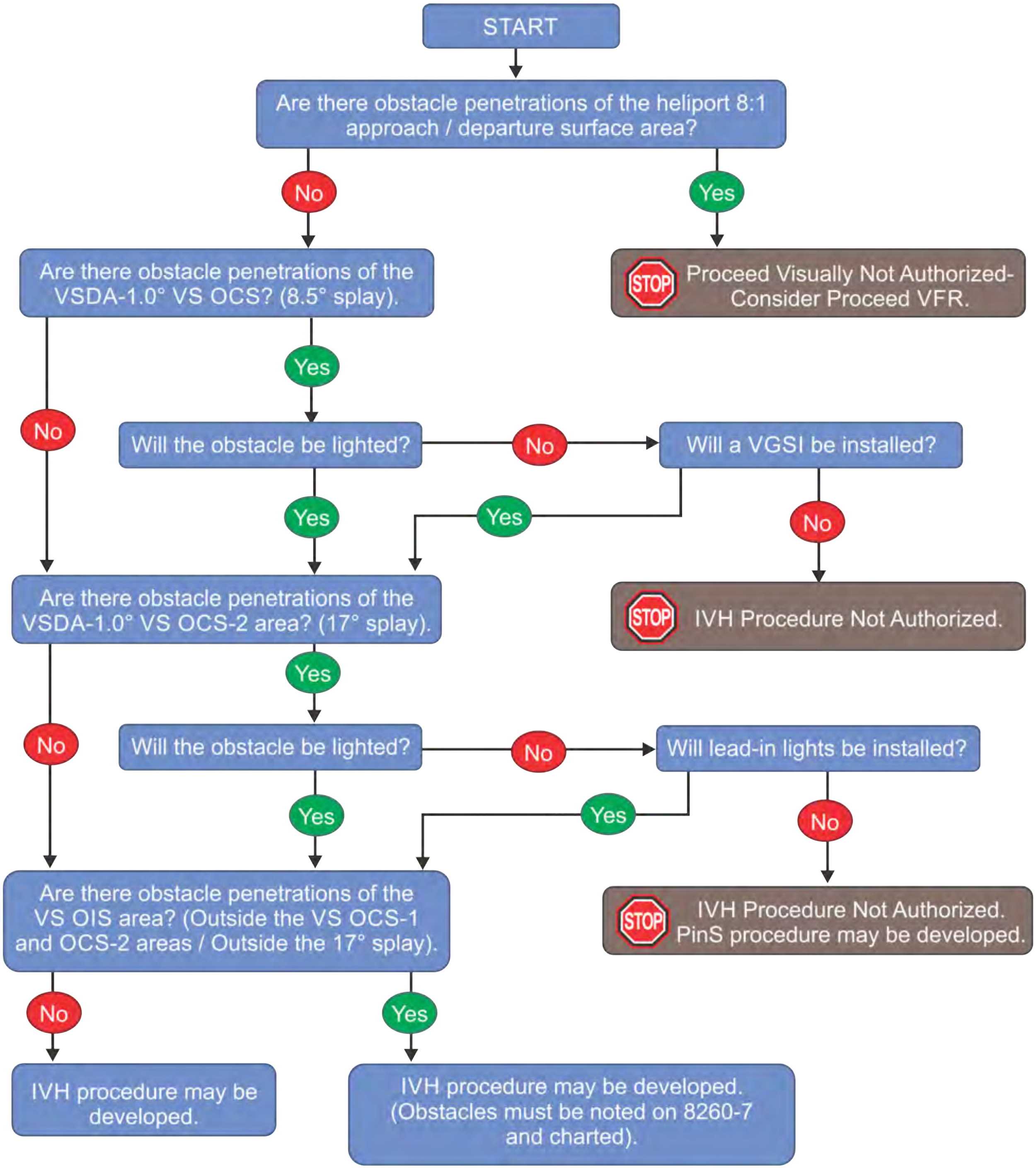
e. If an unlighted obstacle penetration is outside of OCS-1 but within OCS-2, the heliport must have lead-in lights to provide the pilot the visual cues to remain within the IVH OCS area.

f. The operational suitability of the lead-in lights must be evaluated in accordance with appendix G, paragraph 4 during the night evaluation.

g. If there are obstacle penetrations outside of the OCS-1 and OCS-2 areas but within the OES area, these obstacles must be noted on the appropriate 8260-series form and charted.

h. If any of these conditions are not met, a PinS (Proceed VFR) procedure may be developed.

Figure G-3. IVH Procedure Decision Process



Appendix H. Fix Location Adjustment for High Temperature Compensation

At locations where higher than standard temperatures may cause glideslope intercept at a specified altitude to occur prior to the fix or may cause aircraft on the glideslope prior to the PFAF to cross fixes with indicated altitudes below the fix crossing altitudes the following methodology may be used to compensate for those effects by adjusting the fix location to insure intercept does not occur prior to the fix when temperatures are as high as the three to five year average airport high temperature.

1. Airport average high temperature. To determine the three to five year average airport high temperature:

a. Source. The National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC) is the official government source for historical temperature data.

b. Reporting period. Reporting periods are established in calendar years (January through December) and must have a complete temperature record for the airport for the entire period. Ideally use the five full year period prior to the current year. If temperature data is incomplete, use the longest continuous period with complete data starting not more than six years prior to the current year. The minimum reporting period is not less than three full calendar years.

c. Calculate the average airport high temperature as follows:

(1) *Step 1.* For each year in the reporting period, find the month with the highest average temperature. When two or more months have the same average temperature, chose the month with the highest single day temperature.

(2) *Step 2.* Find the highest reported temperature in each of the warmest months.

(3) *Step 3.* When Fahrenheit values are used, convert the results from *Step 2* to Celsius. Average the Celsius temperature values and round the result to the next warmer whole degree Celsius. This result is the average airport high temperature.

2. Determine the adjusted fix location. To determine the location of the temperature-compensated fix location:

a. *Step 1.* Calculate the airport ISA using formula H-1.

Formula H-1. Airport ISA

$$\mathrm{ISA_{airport}} = 15 - 0.00198 \times \mathrm{elev_{apt}}$$

Where:

$\mathrm{elev_{apt}}$ = Airport elevation (feet)

b. *Step 2*. Calculate ISA at the evaluation altitude using formula H-2.

Formula H-2. ISA at Evaluation Altitude

$$\mathrm{ISA_{altitude}} = 15 - 0.00198 \times \mathrm{altitude_{eval}}$$

Where:

$\mathrm{altitude_{eval}}$ = Altitude at which glideslope intercept must be ensured (feet)

c. *Step 3*. Calculate the high temperature at the evaluation altitude using formula H-3 with the three to five year average high temperature.

Formula H-3. ISA at Evaluation Altitude

$$\mathrm{temp_{altitude}} = \mathrm{temp_{high}} - \mathrm{ISA_{airport}} + \mathrm{ISA_{altitude}}$$

Where:

$\mathrm{temp_{high}}$ = Average airport high temperature from paragraph H-1 (degrees Celsius)

d. *Step 4*. Determine the distance to the evaluation altitude using formula H-4.

Note: This is the same as formula 2-6-2, repeated here to aid with calculations.

Formula H-4. Distance to Evaluation Altitude

$$\mathrm{D_{altitude}} = \frac{\ln\left(\frac{\mathrm{r} + \mathrm{altitude_{eval}}}{\mathrm{r} + \mathrm{LTP_{elev}} + \mathrm{TCH}}\right) \times \mathrm{r}}{\tan(\theta)}$$

Where:
$\mathrm{LTP_{elev}}$ = LTP elevation (feet)
Θ = GPA (degrees)

e. *Step 5*. Determine the glideslope elevation at the distance determined in *Step 4* using formula H-5.

Formula H-5. Glideslope Elevation at Evaluation Altitude

$$\mathrm{elev_{glideslope}} = \frac{(\mathrm{r} + \mathrm{LTP_{elev}} + \mathrm{TCH}) \times \cos(\theta)}{\cos\left(\frac{\mathrm{D_{altitude}} \times 180}{\mathrm{r} \times \pi} + \theta\right)} - r$$

f. *Step 6.* Determine the difference between the glideslope elevation and the evaluation altitude using formula H-6.

Formula H-6. Elevation Difference

$$\Delta_{\mathrm{elev}} = \mathrm{elev_{glideslope}} - \mathrm{altitude_{eval}}$$

g. *Step 7.* Determine the vertical error associated with higher than standard temperature at the evaluation altitude using formula H-7.

Formula H-7. Vertical Temperature Error

$$\text{tempErr} = \text{altitude}_{\text{eval}} - \left(\text{elev}_{\text{apt}} + \left(\text{altitude}_{\text{eval}} - \text{elev}_{\text{apt}}\right) \times \frac{273 + \text{ISA}_{\text{altitude}}}{273 + \text{temp}_{\text{altitude}}}\right)$$

h. If Δ_{elev} is greater than or equal to tempErr, the fix distance does not require an adjustment, as the glideslope will be above the desired intercept altitude during periods of high temperature. If Δ_{elev} is less than tempErr, continue to *Step 8*.

i. *Step 8.* Determine the amount of vertical compensation necessary using formula H-8, and the distance to the adjusted fix location using formula H-9.

Formula H-8. Vertical Compensation

$$z = \text{altitude}_{\text{eval}} + (\text{tempErr} - \Delta_{\text{elev}})$$

Formula H-9. Compensated Fix Distance

$$\text{D}_{\text{fix(compensated)}} = \frac{\ln\left(\frac{\text{r} + z}{\text{r} + \text{LTP}_{\text{elev}} + \text{TCH}}\right) \times \text{r}}{\tan(\theta)}$$

3. Example.

a. Calculate a temperature compensated fix location assuming the following:

- Airport elevation = 2000 MSL
- LTP_{elev} = 2000 MSL
- GPA = 3 degrees
- TCH = 50 feet
- Average airport high temperature (5 year) = 43° C
- Evaluation altitude = 5000 MSL

$$\text{ISA}_{\text{airport}} = 15 - 0.00198 \times 2000 \approx 11.04° \text{ C} \quad \text{(Formula H-1)}$$

$$\text{ISA}_{\text{altitude}} = 15 - 0.00198 \times 5000 \approx 5.1° \text{ C} \quad \text{(Formula H-2)}$$

$$\text{temp}_{\text{altitude}} = 43 - 11.04 + 5.1 \approx 37.06° \text{ C} \quad \text{(Formula H-3)}$$

$$\text{D}_{\text{altitude}} = \frac{\ln\left(\frac{\text{r}+5000}{\text{r}+2000+50}\right) \times \text{r}}{\tan(3)} \approx 56279.9 \text{ ft} \quad \text{(Formula H-4)}$$

$$\text{elev}_{\text{glideslope}} = \frac{(\text{r} + 2000 + 50) \times \cos(3)}{\cos\left(\frac{56279.9 \times 180}{\text{r} \times \pi} + 3\right)} - r \approx 5076.0 \text{ ft} \quad \text{(Formula H-5)}$$

$$\Delta_{\text{elev}} = 5076.0 - 5000 \approx 76.0 \text{ ft} \quad \text{(Formula H-6)}$$

$$\text{tempErr} = 5000 - \left(2000 + (5000 - 2000) \times \frac{273+5.1}{273+37.06}\right) \approx 309.2 \text{ ft} \quad \text{(Formula H-7)}$$

b. Since Δ_{elev} (76.0 feet) is less than tempErr (309.2 feet), fix location compensation is necessary.

$$z = 5000 + (309.2 - 76.0) \approx 5233.2\, ft \quad \text{(Formula H-8)}$$

$$D_{fix(compensated)} = \frac{\ln\left(\frac{r+5233.2}{r+2000+50}\right)\times r}{\tan(3)} \approx 60728.4\ ft \qquad \text{(Formula H-9)}$$

c. The LTP to fix distance should be at least 60728.4 feet to ensure the glideslope can be captured at 5000 MSL on days where the airport temperature is as warm as the highest average temperature.

Directive Feedback Information

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:

To: Flight Technologies and Procedures Division, AFS-400 Coordination Mailbox (9-AWA-AFS400-COORD@faa.gov)

(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: *(attach separate sheet if necessary)*

☐ In a future change to this order, please cover the following subject: *(briefly describe what you want added)*

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: **Date:**

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