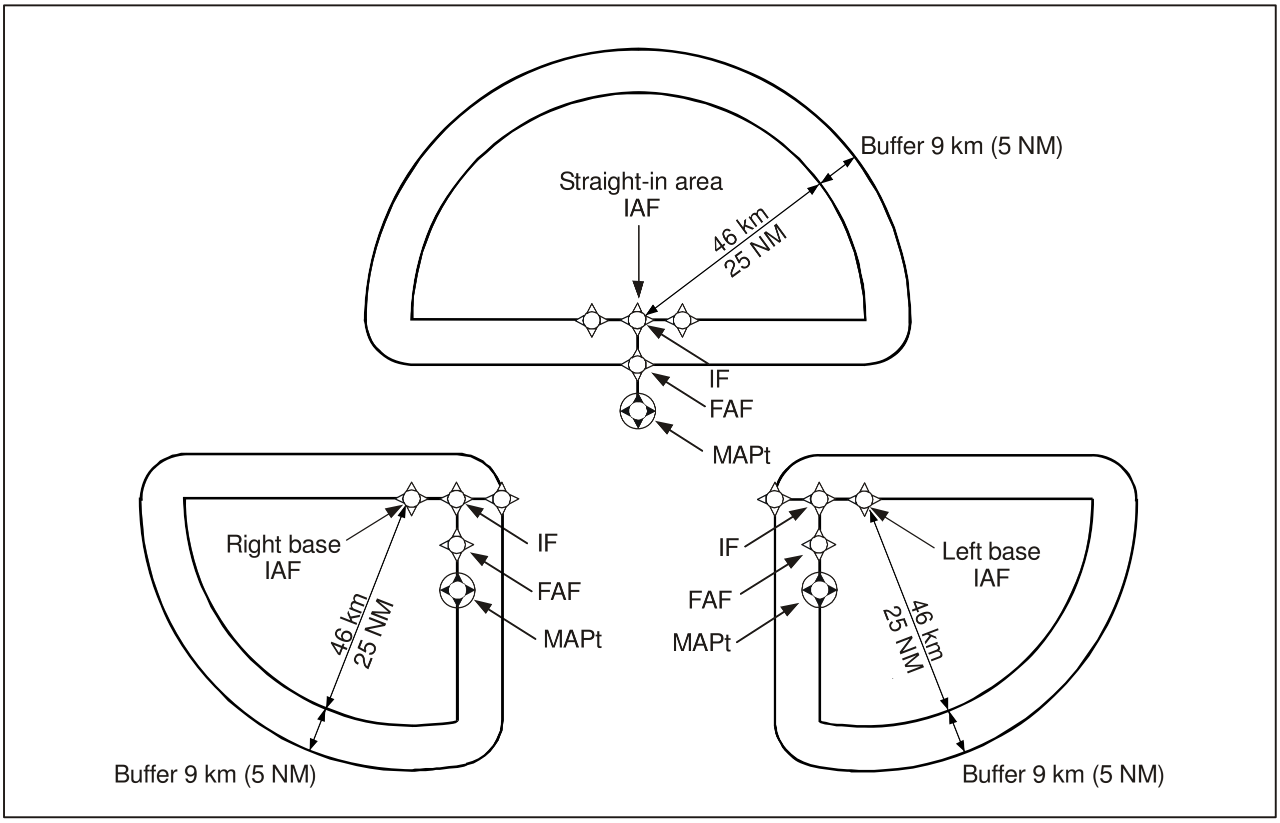


Figure III-2-4-2. TAA T-bar arrangement

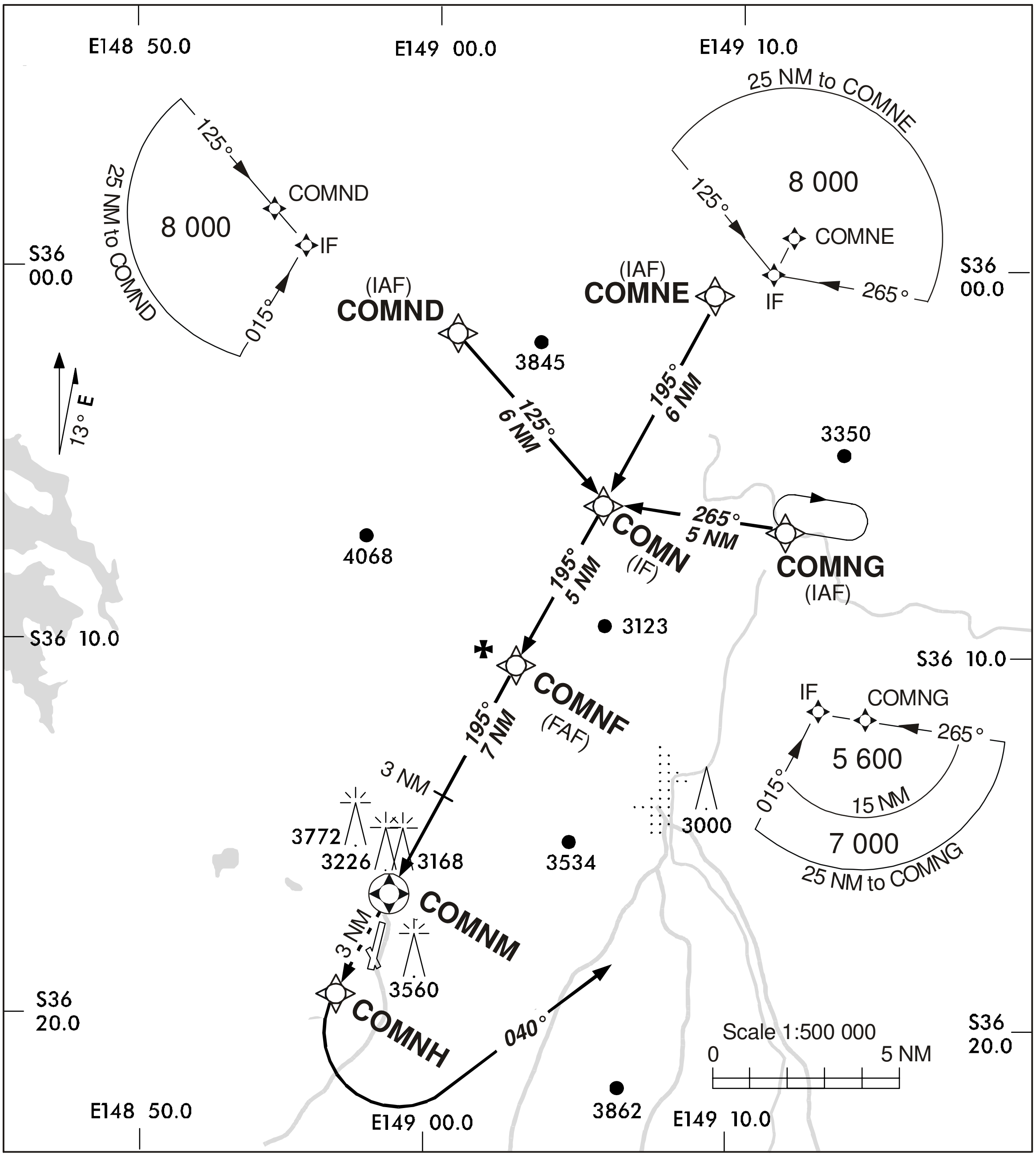


Figure III-2-4-3. TAA Y-bar icon arrangement

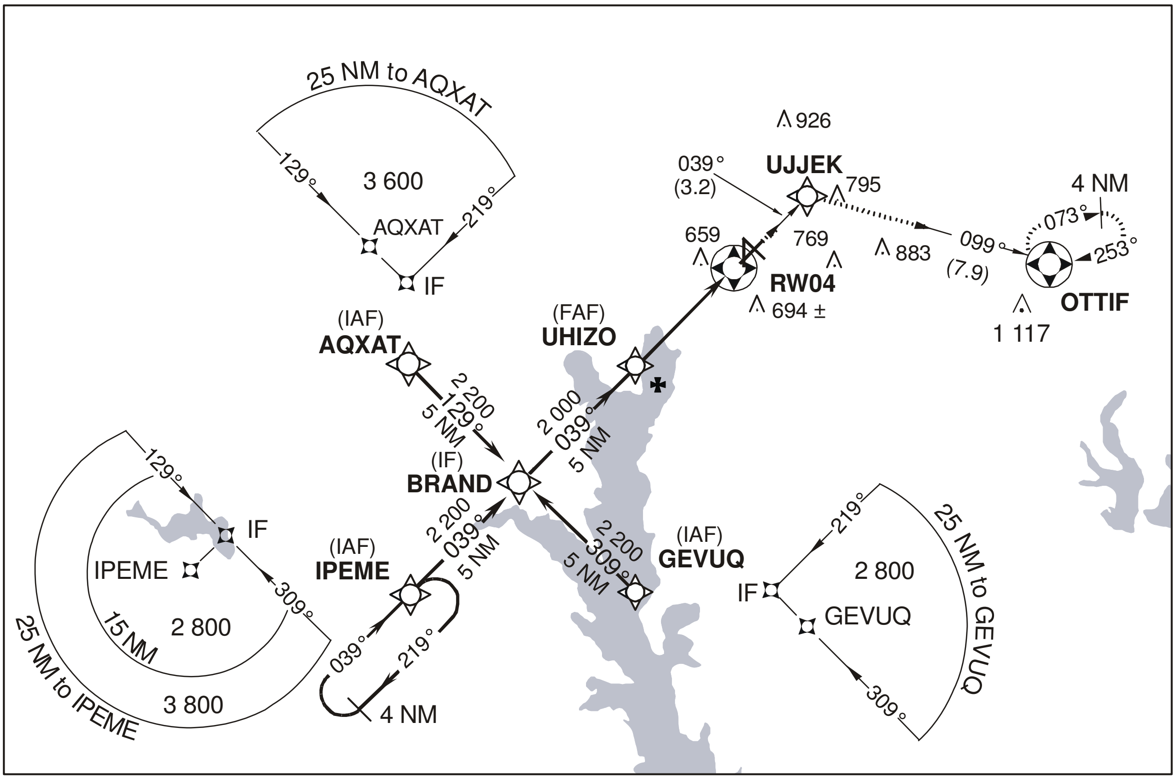


Figure III-2-4-4.   TAA T-bar icon arrangement

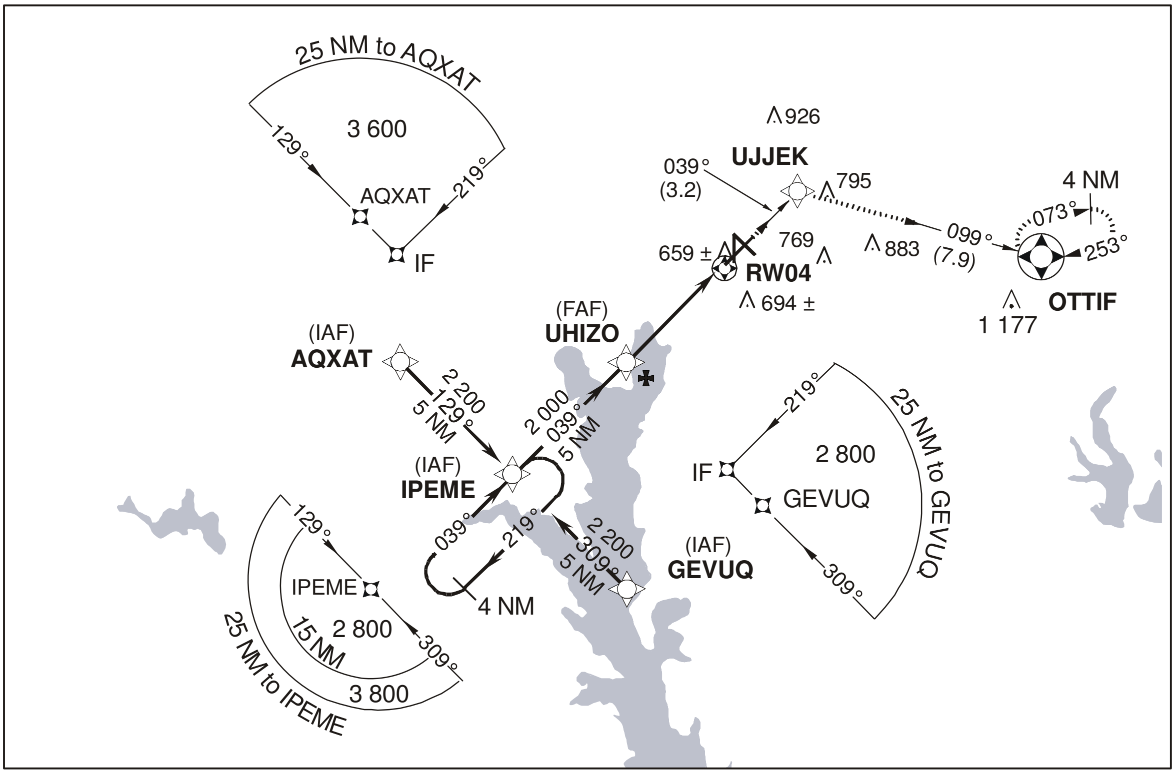


Figure III-2-4-5. TAA T-bar icon arrangement without centre initial

---

Section 3

PROCEDURE CONSTRUCTION

Chapter 1

DEPARTURE PROCEDURES

1.1 GENERAL

1.1.1 Application

1.1.1.1 This chapter describes the departure criteria for RNAV and RNP procedures.

1.1.1.2 The general criteria of Part I, Section 3 and Part III, Sections 1 and 2 as amplified or modified by the criteria in this chapter apply to RNAV and RNP departure procedures.

1.1.2 Secondary areas

The principle of secondary areas applies to straight segments (see Part I, Section 2, Chapter 1, 1.2 and 1.3). Secondary areas are limited to the part of the procedure where the total width of the primary area is at least equal to the area semi-width at the first waypoint, as shown in Table III-3-1-1. See Figure III-3-1-1.

1.1.3 Minimum segment length

Minimum segment length distances are listed in the tables in Section 2, Chapter 1. For construction of the average flight path see Part I, Section 3, Appendix to Chapter 3.

1.1.4 Area widths

1.1.4.1 For RNAV based on VOR/DME, DME/DME or GNSS the total area width results from joining the various area widths at the relevant fixes. For the calculation of area widths and the underlying tolerances involved in these calculations, see the paragraph entitled "XTT, ATT and area semi-width" in Section 1 for the appropriate sensor. These are:

a) VOR/DME, Section 1, Chapter 4, 4.5;

b) DME/DME, Section 1, Chapter 3, 3.6;

c) basic GNSS, Section 1, Chapter 2, 2.5; and

d) SBAS, Section 1, Chapter 5, 5.1.2.

1.1.4.2 For RNAV based on RNP when the promulgated RNP value decreases in a point of a procedure the total area width as defined in Section 1, Chapter 7, 7.5, "XTT, ATT and area semi-width" decreases from the initial value to the final value with a convergence angle of 30° each side of the axis.

1.2 STRAIGHT DEPARTURES

The alignment of the initial departure track ($\alpha \leq 15°$) is determined by the position of the first waypoint located after the departure end of the runway (DER).

1.3 AREA WIDTH AT THE BEGINNING OF THE DEPARTURE

1.3.1 For the construction of the area width at the beginning of the departure, the general criteria apply (see Part I, section 3) until the splaying boundaries reach the outer boundary of the fictitious area (see Figure III-3-1-1) from where it follows the width of the fictitious area until the first waypoint of the departure procedure. The fictitious area begins at the DER and extends to the first waypoint. The area semi-width of this area at the DER and at the first waypoint varies according to sensor type (see Table III-3-1-1).

1.3.2 Basic GNSS area semi-width remains constant after the initial splay at the DER until the distance of 56 km (30 NM) from the reference point of the aerodrome is reached. At 56 km (30 NM), the area splays a second time (at an angle of 15°) until the area semi-width is (14.82 km (8.00 NM)). See Figure III-3-1-3.

1.4 TURNING DEPARTURES

1.4.1 General

1.4.1.1 Four kinds of turns can be prescribed:

a) turn at a “fly-by” waypoint;

b) turn at a “flyover” waypoint (which corresponds to a turn at a designated TP);

c) turn at an altitude/height (avoid with RNP procedures); and

d) fixed radius turn (RNP only).

Note 1.— For some GNSS systems “turns at an altitude/height” cannot be coded in the database, but if there is an operational need, a turn at an altitude/height can be defined and executed manually.

Note 2.— Turns for SBAS can only be specified as fly-by or flyover.

1.4.1.2 Wherever obstacle clearance and other considerations permit, turn at a “fly-by” waypoint is preferred. Whenever possible, use of a turn at an altitude/height should be avoided, in order to preclude dispersion of tracks after the turn.

1.4.1.3 In order for the aircraft to properly execute the turn, each single specified turn should be at least 5° and must not exceed 120°. However, the maximum value of 120° does not apply to the case of a turn (at either altitude/height or at a designated TP) with a free turn back to a waypoint.

1.4.1.4 It is assumed that the navigation equipment is capable of anticipating the turn so that the 3-second allowance for the establishment of bank is not required and that only a pilot reaction time of 3 seconds has to be taken into account.

1.4.1.5 For SBAS the maximum area width on the straight segment on the turn is 11.10 km (6.00 NM).

1.4.2 Turn at a fly-by waypoint

1.4.2.1 *General*

A turn at a fly-by waypoint takes into account turn anticipation by adding a distance rtan (A/2) before the waypoint. This determines point S (see Figure III-3-1-4). The earliest turning point (on the K-line) is located at a distance ATT before point S.

The criteria of 1.3, “Area width at the beginning of the departure” apply until:

a) a distance of ATT + c after point S for the outer side of the turn; and

b) the earliest TP (a distance of ATT before point S) for the inner side of the turn,

where c is a distance corresponding to a 3-second pilot reaction time.

1.4.2.2 *Turn outer boundary*

1.4.2.2.1 On the outside of the turn, turn construction starts from the limits of the primary area at the following distance before the waypoint:

a) rtan (A/2) – ATT – c for turn angles less than or equal to 90 degrees; and

b) r – ATT – c for turn angles more than 90 degrees,

where: c is a distance corresponding to a 3-second pilot reaction time
r is the radius of the turn

1.4.2.2.2 From these points wind spirals or bounding circles are constructed as described in Part I, Section 2, Chapter 3, “Turn area construction “ to define the primary area associated to the turn.

1.4.2.2.3 Additionally, in order to protect the aircraft within the required range of speeds, the outer limit of the primary area is extended until it intersects with that tangent of the wind spiral (or bounding circle) which is parallel to the nominal track after the turn. After the turn, the primary area is connected to the primary area of the subsequent segment by a line converging at an angle of 30° with the nominal track after the turn.

1.4.2.2.4 The secondary area has a constant width during the turn

1.4.2.2.5 If the limit of the primary or the secondary area associated to the turn remains inside the corresponding protection area associated to the subsequent segment, this limit splays at an angle of 15° apart from the nominal track after the turn.

1.4.2.3 *Turn inner boundary*

On the inner edge of the turn, the primary area boundary starts at the K-line. The edges of the primary and secondary areas are connected to their counterparts in the subsequent sections. For these connections, the following rules apply:

a) if the point to connect is outside the protection area associated with the subsequent section, then the boundary converges with the nominal track after the turn at an angle equal to half the angle of turn (A/2); and

b) if the point to connect is inside the protection area associated with the subsequent section, then the boundary diverges from the nominal track at an angle of 15 degrees.

1.4.3 Turn at a flyover waypoint

1.4.3.1 The turning point (TP) is identified by a "flyover" waypoint. The criteria of 1.3, "Area width at the beginning of the departure" apply until:

a) distance of ATT + c after the nominal waypoint for the outer side of the turn; and

b) the earliest TP located at a distance equivalent to the ATT before the nominal waypoint for the inner side of the turn

where c is a distance corresponding to a 3-second pilot reaction time. (See Figure III-3-1-5.)

1.4.3.2 *Turn inner and outer boundary.* On the outside of the turn, wind spirals are constructed from a distance equal to ATT + c(3 s) after the TP. A secondary area with a constant width is applied during the turn, which joins the secondary area of the following waypoint. For inner boundary construction, see 1.4.2.3, "Turn inner boundary".

1.4.4 Turn at an altitude/height

1.4.4.1 This type of turn does not apply to RNP. The general criteria of 1.3, "Area width at the beginning of the departure" apply within the turn initiation area. Then, the general criteria for non-RNAV departures with a turn at an altitude/height apply during the turn.

1.4.4.2 The inner boundary of the turn is constructed as follows:

a) from point (P) located laterally 150 m from the runway centre line and perpendicular to the centre line, 600 m beyond the beginning of the runway, extend a straight line passing through the target waypoint; and

b) from the first point (P) , draw the RNAV width perpendicular to this straight line, on the turn side.

1.4.4.3 From the new point (P') thus obtained, extend a tangent to a circle on the target waypoint. The radius of this circle shall be the ½ A/W which is calculated using the XTT of the next waypoint on the flight path. (See Figure III-3-1-6.)

1.4.5 Radius to fix turn

1.4.5.1 This paragraph only applies to RNP departures. A radius to fix turn (also called an RF leg) is a constant radius circular path (see Figure III-3-1-7) defined by the:

a) tangential point at the end of the turn;

b) centre of the turn; and

c) turn radius.

1.4.5.2 For this kind of turn, the aircraft must be able to make variations of bank angle in order to compensate for wind effects and to follow the pre-determined trajectory with a navigation accuracy related to the RNP. For this reason, the value of the turn radius, r, will be determined as follows:

$$r = \frac{(V+Vw)^2}{68626.\tan\theta} \qquad \text{r in NM; V and Vw in kt}$$

$$r = \frac{(V+Vw)^2}{127094.\tan\theta} \quad \text{r in km; V and Vw in km/h}$$

where: V is the aircraft maximum true airspeed.
Vw is the maximum wind speed.
θ is the maximum bank angle of the phase of flight. (It is assumed that the maximum bank angle is equal to the average achieved bank angle, as defined in the various chapters for the different phases of flight, plus 5°.)

1.4.5.3 *Turn boundary construction.* RF turns are constructed by first delimiting the edges of the primary area, and then adding a secondary area to both sides.

a) *Outer boundary of the primary area.* The outer edge of the primary area is defined by the segment of a circle:

1) centred on point O;

2) having the radius r + [ATT + 0.46 km (0.25 NM)] / cos 45°]; and

3) delimited by the edges of the adjacent straight segments (points J and M) (see Figure III-3-1-7).

b) *Inner boundary of the primary area.* The inner edge of the primary area is defined by the segment of a circle:

1) having the radius r;

2) centred on point I at a distance of [ATT + 0.46 km (0.25 NM)] / cos 45°] from the centre of the turn (point O); and

3) delimited by the edges of the adjacent straight segments (points P and R).

c) *Secondary areas within the turn.* Secondary areas are added to edges of the primary area to establish the turn outer and inner boundaries. The secondary areas maintain a constant width of ATT + 0.46 km (0.25 NM).

Table III-3-1-1. Area semi-width of the fictitious area

Procedure type	*Area semi-width*
RNP	2 × XTT + 0.93 km (0.50 NM)
SBAS	1.85 km (1.00 NM)
Basic GNSS	9.26 km (5.00 NM)
VOR/DME or DME/DME	The greater of these values • 1.5 × XTT + 0.93 km (0.50 NM) • 1.85 km (1.00 NM)

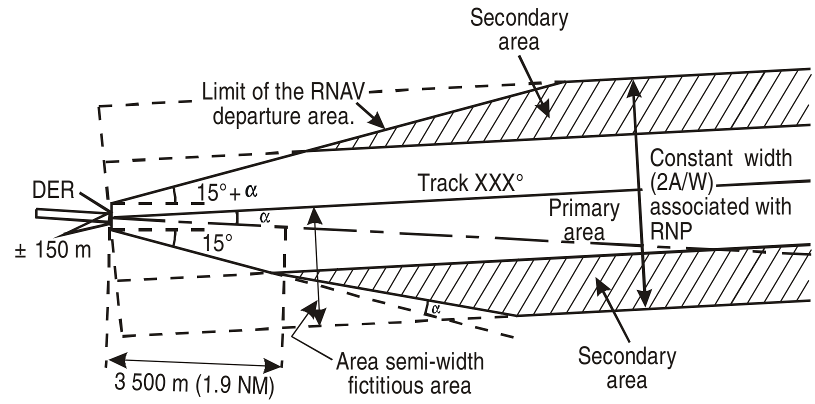


Figure III-3-1-1. Straight departure. Case where the limits of the first part of the area intersect the limits of the fictitious area before the first waypoint

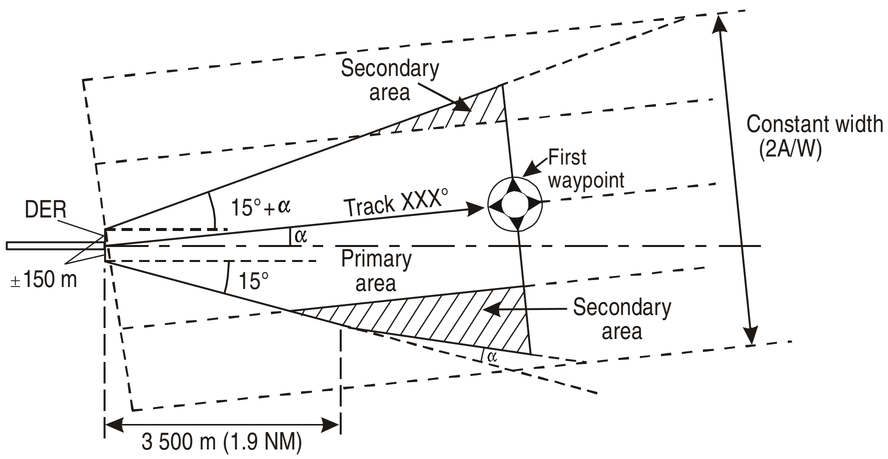


Figure III-3-1-2. Straight departure. Case where the limits of the first part of the area do not attain the limits of the fictitious area before the first waypoint

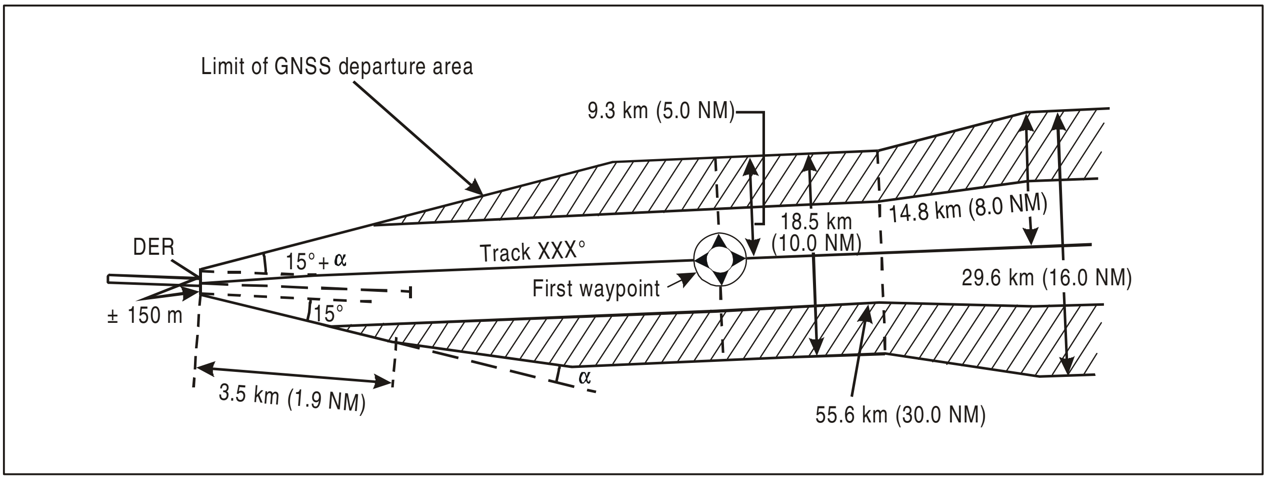


Figure III-3-1-3. GNSS straight departure

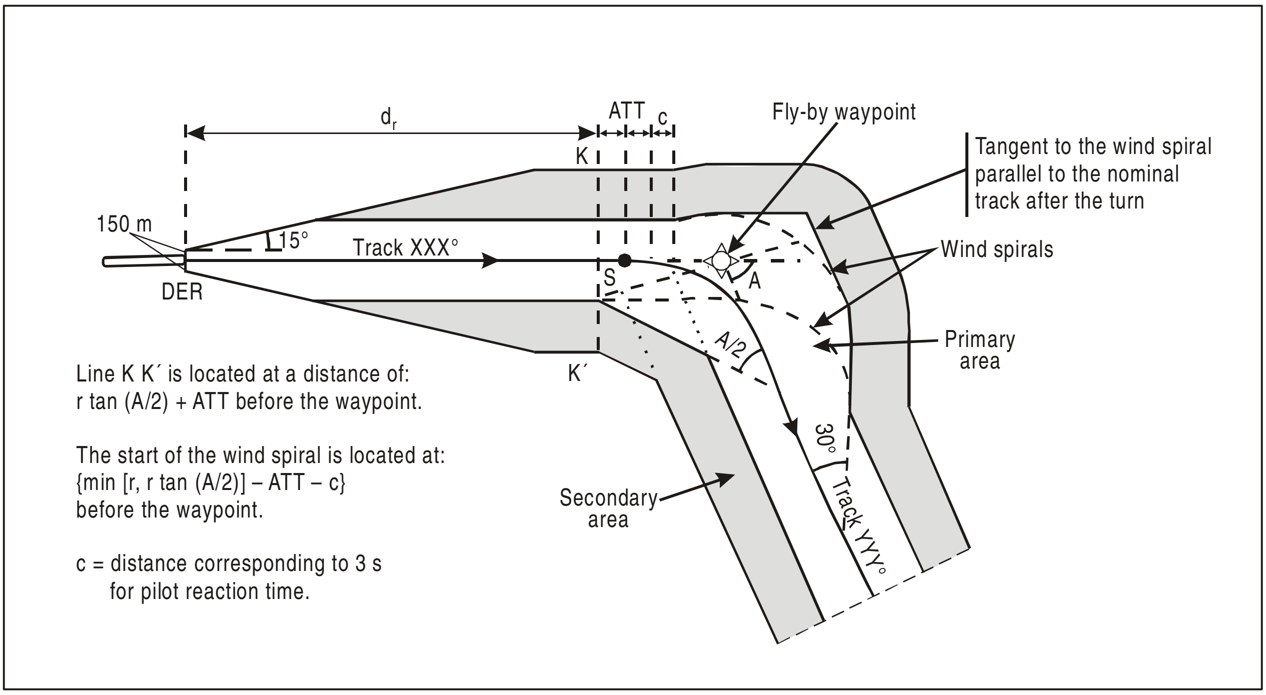


Figure III-3-1-4. Turn at a fly-by waypoint

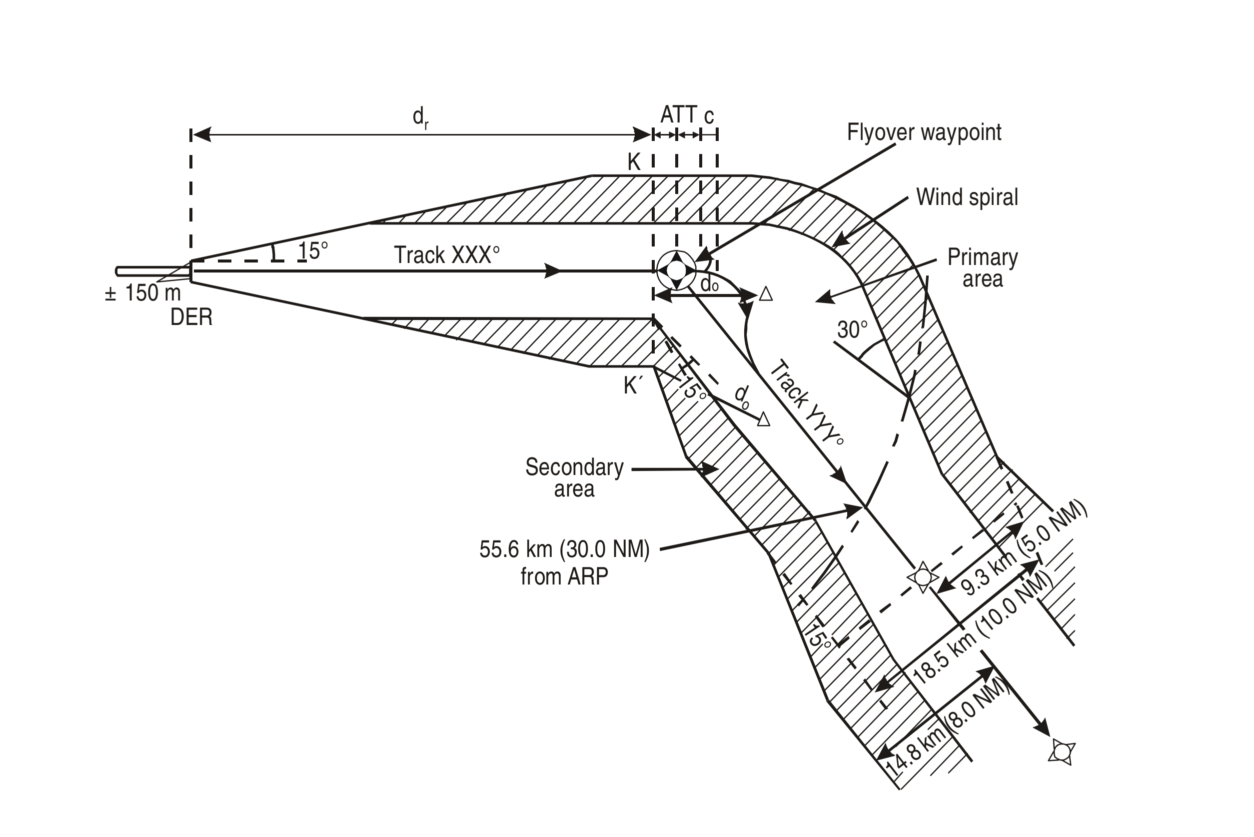


Figure III-3-1-5. Turn at a flyover waypoint

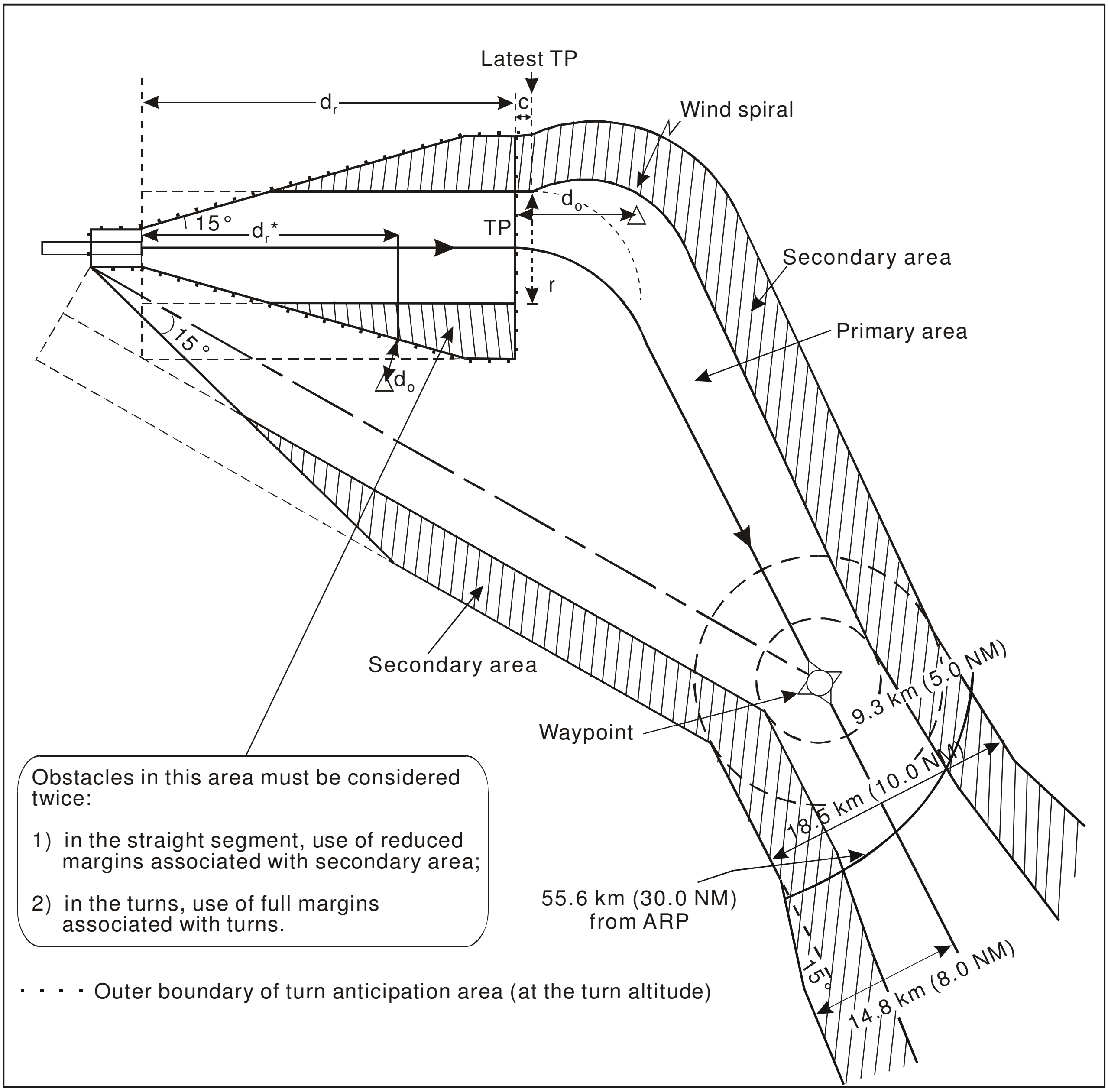


Figure III-3-1-6. Turn at an altitude/height towards a waypoint (Example for Basic GNSS)

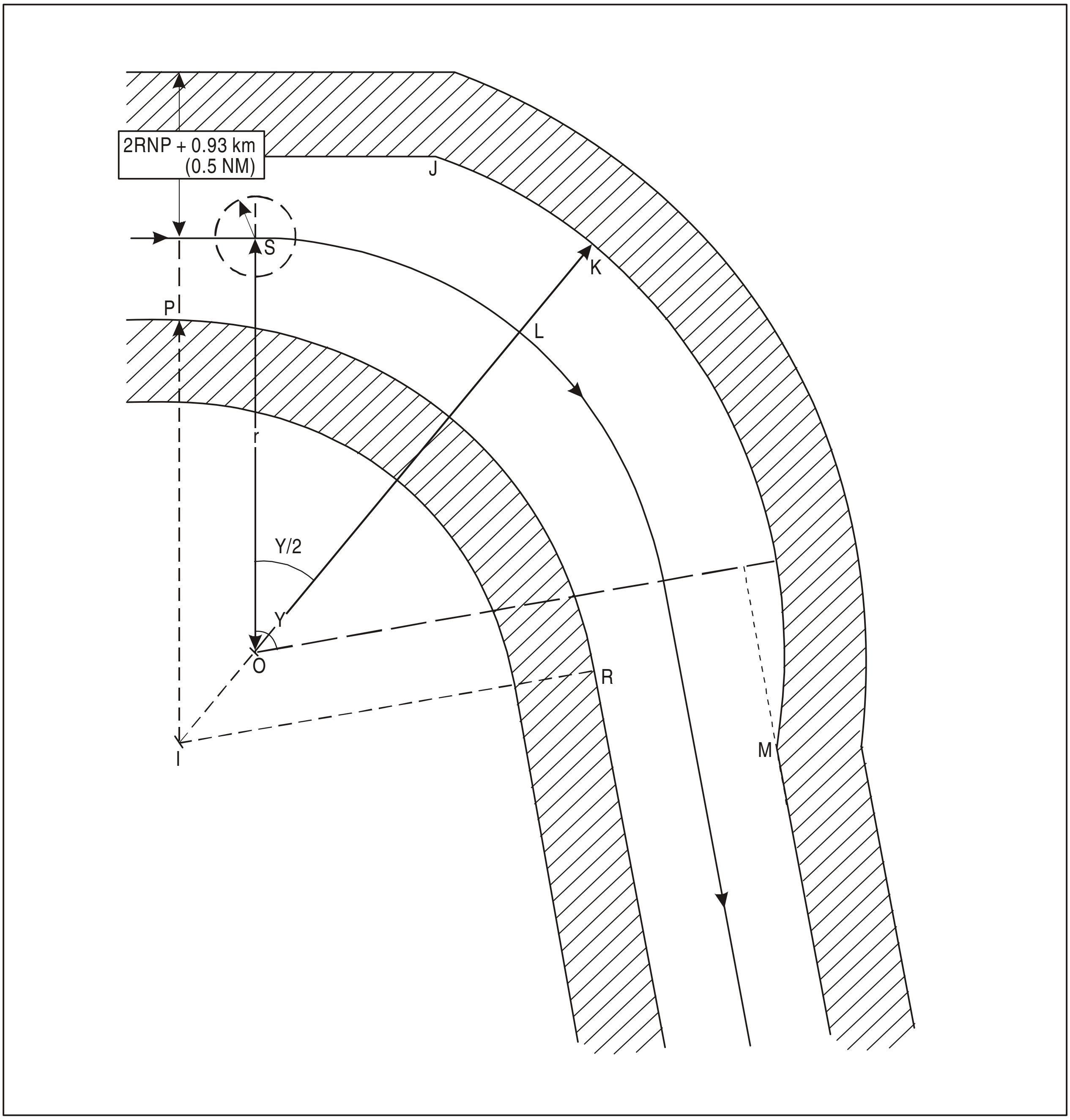


Figure III-3-1-7. Turning departure — radius to fix turn (RF turn)

Chapter 2

ARRIVAL AND APPROACH PROCEDURES

2.1 GENERAL

2.1.1 Application

2.1.1.1 This chapter describes the arrival, approach and final missed approach criteria for RNAV and RNP procedures. The criteria for the final approach, initial and intermediate missed approach are specific to the approach classification (NPA, APV and precision) and are dealt with in separate chapters.

2.1.1.2 The general criteria of Part I and Part III, Sections 1 and 2, as amplified or modified by the criteria in this chapter, apply to RNAV and RNP approach procedures.

2.1.1.3 No more than nine waypoints shall be employed in an RNAV approach procedure, from the initial approach point to the waypoint which concludes the missed approach segment.

2.1.2 Secondary areas

The general criteria for secondary areas apply (see Part I, Section 2, Chapter 1, 1.2 and 1.3).

2.1.3 Minimum segment length

Minimum segment length distances are listed in the tables in Section 2, Chapter 1.

2.1.4 Area widths

For the calculations of area widths and the underlying tolerances involved in these calculations, see the paragraph entitled "XTT, ATT and Area Semi-width" in Section 1 for the appropriate sensor. These are:

a) VOR/DME, Section 1, Chapter 4, 4.5;

b) DME/DME, Section 1, Chapter 3, 3.6;

c) GNSS, Section 1, Chapter 2, 2.5; and

d) for RNAV based on RNP when the promulgated RNP value decreases in a point of a procedure the total area width as defined in Section 1, Chapter 7, 7.5, "XTT, ATT and area semi-width" decreases from the initial value to the final value with a convergence angle of 30° each side of the axis.

2.1.5 Y- or T-bar design concept for RNAV procedures

For a detailed description of non-precision approach procedures based on the Y- or T-bar concept, refer to Section 2, Chapter 3, Y- or T-bar procedure construction".

2.2 ARRIVAL ROUTES

2.2.1 General

Arrival obstacle clearance criteria shall apply up to the initial or intermediate approach fix (see Part I, Section 4, Chapter 2).

2.2.2 Minimum sector altitude/terminal arrival altitude

For terminal arrival altitude see Section 2, Chapter 4, "TAA". Where TAAs are not provided, a minimum sector altitude shall be published. The provisions of Part I, Section 4, Chapter 8, "Minimum sector altitudes (MSA)" apply except that only a single omnidirectional sector shall be established in the case of GNSS. The sector is centred on the latitude and longitude of the aerodrome reference point.

2.2.3 Area width for VOR/DME and DME/DME

2.2.3.1 With VOR/DME, DME/DME the area tapers evenly from the beginning of the arrival segment to the width at the IAF (or IF, as appropriate) at a maximum convergence angle of 30°. See Figure III-3-2-1.

2.2.3.2 The area width at the beginning of the segment differs according to its distance from the IAF (or IF, as appropriate).

a) *Arrival routes which start more than 46 km (25 NM) from the IAF.* The ½ A/W at the beginning of this area is the greater of the following values:

   1) 9.26 km (5.00 NM); or

   2) (1.5 XTT + 3.70 km (2.00 NM)) where XTT is determined with FTT = 3.70 km (2.00 NM).

b) *Arrival routes which start 46 km (25 NM) or less from the IAF.* The ½ A/W at the beginning of this area is the greater of the following values:

   1) 9.26 km (5.00 NM); or

   2) (1.5 XTT + 1.85 km (1.00 NM)) where XTT is determined with FTT = 1.85 km (1.00 NM).

2.2.4 Area width for basic GNSS

In addition to the general arrival criteria, Part I, Section 4, Chapter 2 , the following criteria apply. For basic GNSS area semi-width see Section 1, Chapter 2, 2.5, "XTT, ATT and area semi-width". The area width tapers at an angle of 30° each side of the axis, perpendicular to the point where the 56 km (30 NM) arc from the aerodrome reference point (ARP) intercepts the nominal track. Contrary to the general arrival criteria, the en-route width shall be used when more than 56 km (30 NM) from the ARP. See Figures III-3-2-2 and III-3-2-3.

2.2.5 Area width for RNP

RNP arrivals use:

a) en-route area semi-widths up to a distance of 46 km (25 NM) before the IAF; and

initial approach area semi-widths 46 km (25 NM) and closer to the IAF.

The area semi-width is as shown in Part I, Section 1, Chapter 7, 7.5, "XTT, ATT and area semi-width".

The area width decreases from the "en-route" value to the "initial" value with a convergence angle of 30° each side of the axis. See Figure III-3-2-4 a) and b).

2.3 INITIAL APPROACH SEGMENT

2.3.1 Straight segments

2.3.1.1 *Initial approach alignment.* The angle of interception between an initial approach track and another initial track or with the intermediate track shall not exceed 120°.

2.3.1.2 *Initial approach area length.* For basic GNSS the optimum length of the initial approach segment is 9 km (5 NM) (Cat H, 6 km (3 NM)). If the initial segment is preceded by an arrival route, the minimum length is 11.1 km (6.0 NM) to allow for blending.

2.3.1.3 *Initial approach area width.* The general criteria in Part I, Section 4, Chapter 3, 3.3.3, "Area", apply as modified in this chapter. The total area width results from joining the various area widths at the relevant fixes. The principle of secondary areas applies. For area widths, see 2.1.4, "Area widths".

2.3.2 Turn at a fly-by waypoint (VOR/DME, DME/DME and RNP)

2.3.2.1 For RNP, the general RNAV criteria apply, taking into account the constant area width associated with the straight RNP segments. Where a turn less than or equal to 30° is specified at an IAF or an IF, the outer boundary is defined by an arc equal to the area semi-width of the inbound segment and tangent to the outer boundary of the inbound and the outbound segments. Where a turn greater than 30° is specified at an IAF or an IF, the construction of the protection area is based on the following criteria.

The nominal turn begins r tan (A/2) before the fix, where:

r is the radius of turn and

A is the angle of turn.

Note.—It is assumed that the navigation equipment is capable of anticipating the turn. As a consequence, the 5 seconds allowance for the establishment of bank is not required.

See Figures III-3-2-5 for VOR/DME and DME/DME, Figure III-3-2-6 for RNP.

2.3.2.2 *Turn outer boundary*

2.3.2.2.1 On the outside of the turn, turn construction starts from the limits of the primary area at the following distance before the waypoint:

a) r tan (A/2) – ATT – c for turn angles less than or equal to 90 degrees; and

b) r – ATT – c for turn angles more than 90 degrees

where: c is a distance corresponding to a 6-second pilot reaction time
r is the radius of the turn

2.3.2.2.2 From these points wind spirals or bounding circles are constructed as described in Section 2, Chapter 3, "Turn area construction", to define the primary area associated with the turn.

2.3.2.2.3 Additionally, in order to protect the aircraft within the required range of speeds, the outer limit of the primary area is extended until it intersects with that tangent of the wind spiral (or bounding circle) which is parallel to the nominal track after the turn. After the turn, the primary area is connected to the primary area of the subsequent segment by a line converging at an angle of 30° with the nominal track after the turn.

2.3.2.2.4 The secondary area has a constant width during the turn.

2.3.2.2.5 If the boundary of the primary or the secondary area associated with the turn remains inside the corresponding protection area associated with the subsequent segment, then the boundary splays at an angle of 15° from the nominal track after the turn.

2.3.2.3 *Turn inner boundary*

On the inner edge of the turn, the primary and the secondary area boundaries start at the K-Line. The edges of the primary and secondary areas are connected to their counterparts in the subsequent section.
For these connections the following principles apply:

a) if the point to connect is outside the protection area associated with the subsequent segment, then the boundary converges at an angle of half the angle of turn (A/2) with the nominal track after the turn; and

b) if the point to connect is inside the protection area associated with the subsequent segment then the boundary diverges from the nominal track at an angle of 15 degrees.

2.3.2.4 *Obstacle assessment when descent fix is used*

2.3.2.4.1 To assess an obstacle, reference is made to the earliest descent fix.

2.3.2.4.2 *Fly-by waypoint*. The earliest descent fix is not co-located with the earliest turning point (the K-line). The earliest descent fix is defined by the intersection of the following two lines:

a) Line N-N'. This line is perpendicular to the inbound track, displaced by a distance ATT before point D (see Figure III-3-2-5), where

   D = the intersection of the bisector of the turn with the nominal track; and

Note.— The perpendicular distance from WP to Line N-N' is equal to: ATT + r[tan(A/2) – sin(A/2)].

b) Line N-N'. This line is parallel to the bisector of the turn, displaced by a distance ATT before the bisector of the turn perpendicularly to this bisector (see Figure III-3-2-5).

2.3.2.4.3 Obstacles that are close-in, located at a distance d_o < 9.3 km (5.0 NM), need not be considered in the determination of the minimum altitude/height (MA/H) of the segment after the fly-by waypoint when the elevation of obstacle 0_1 (A_{01}) is less than or equal to:

$$MA/H – (d_0 \times 0.15 + MOC)$$

where: MA/H = minimum altitude/height of the segment preceding the fly-by waypoint
d_0 = distance of the obstacle to the N-N'-N'' line measured perpendicularly to the bisector of the turn
MOC = MOC of the primary area of the earliest segment

2.3.3 Turn at a fly-by waypoint (Basic GNSS)

For turn protection at the IF, see Figure III-3-2-7.

2.3.4 Turn at a fly-over waypoint (VOR/DME, DME/DME, and RNP)

2.3.4.1 The turning point (TP) is identified by a "flyover" waypoint. The turn criteria start at:

a) a distance of ATT + c after the waypoint, for the outer side of the turn; and

b) the earliest TP, located at a distance equivalent to the ATT before the nominal waypoint, for the inner side of the turn,

where c is a distance corresponding to a 3-second pilot reaction time.

(See Figures III-3-2-8 and III-3-2-9 for VOR/DME and DME/DME, Figure III-3-2-10 for RNP.)

2.3.4.2 *Turn inner and outer boundary.* On the outside of the turn, wind spirals are constructed from a distance equal to ATT + c (3 s) after the TP. A secondary area with a constant width is applied during the turn, which joins the secondary area of the following waypoint. For inner boundary construction, see 2.3.2.3, "Turn inner boundary".

2.3.5 Fixed radius turn

2.3.5.1 This paragraph only applies to RNP procedures. A fixed radius turn is a constant radius circular path (see Figure III-3-2-11) designated by:

a) the tangential point at the end of the turn; and

b) the centre of the turn and the turn radius.

2.3.5.2 For this kind of turn, the aircraft must be able to make variations of bank angle to compensate for wind effects and to follow the pre-determined trajectory with a navigation accuracy related to the RNP. For this reason, the value of the turn radius will be determined as follows:

$$r = \frac{(V+w)^2}{68626.\tan \theta} \quad \text{r in NM; V and w in kt}$$

$$r = \frac{(V+w)^2}{127094.\tan\theta} \quad \text{r in km; V and w in km/h}$$

where: V is the aircraft maximum true airspeed.
w is the maximum wind speed.
θ is the maximum bank angle of the phase of flight. (It is assumed that the maximum bank angle is equal to the average achieved bank angle as defined in the various chapters for the different phases of flight, plus 5°.)

2.3.5.3 *Turn boundary construction.* RF turns are constructed by first delimiting the edges of the primary area, and then adding a secondary area to both sides. In the text which follows, BV is the buffer value for the applicable segment as listed in Part I, Section 1, Chapter 7, 7.5, "XTT, ATT and area semi-width".

a) *Outer boundary of the primary area.* The outer edge of the primary area is defined by the segment of a circle:

   1) centred on point O;

   2) having the radius r + [ATT + (BV/2)] / cos 45]; and

   3) delimited by the edges of the adjacent straight segments (points J and M) (See Figure III-3-2-11).

b) *Inner boundary of the primary area.* The inner edge of the primary area is defined by the segment of a circle:

   1) having the radius r;

   2) centred on point I at a distance of [ATT + (BV/2)] / cos 45] from the centre of the turn (point O); and

   3) delimited by the edges of the adjacent straight segments (points P and R).

c) *Secondary areas within the turn.* Secondary areas are added to edges of the primary area to establish the turn outer and inner boundaries. The secondary areas maintain a constant width of ATT + (BV/2).

2.3.6 Reversal procedures

Basic GNSS procedures should be so designed as to avoid the need for reversal procedures. However, when a procedure requires a track reversal, a racetrack pattern shall be established.

2.4 INTERMEDIATE APPROACH SEGMENT

2.4.1 Intermediate approach alignment

The intermediate approach segment should be aligned with the final approach segment whenever possible. If a turn at FAF is considered necessary it shall not exceed:

a) VOR/DME and DME/DME: 45°;

b) Basic GNSS: 30° (Cat H, 60°); and

c) RNP: 30° (Cat H, 60°).

2.4.2 Intermediate approach length

2.4.2.1 The intermediate segment may consist of two components:

a) a turning component (where used) abeam the intermediate waypoint; followed by

b) a straight component immediately before the final approach waypoint.

2.4.2.2 The length of the straight component is variable but will not be less than 3.70 km (2.00 NM). This allows the aircraft to be stabilized prior to overflying the final approach waypoint. The length of the turning component is the minimum stabilization distance for the turn angle at the IF and can be determined from Section 2, Chapter 1, Table III-2-1-3 or III-2-1-9.

2.4.3 Intermediate approach area width

The total area width results from joining the area widths at the IF and the FAF. The principle of secondary areas applies. For area widths see 2.1.4, “Area widths”.

2.4.4 Protection of turns at the FAF

Where a turn at the FAF is greater than 10°, the area should be widened as in 2.3.2 and 2.3.4 using a wind spiral based on the maximum final approach speed.

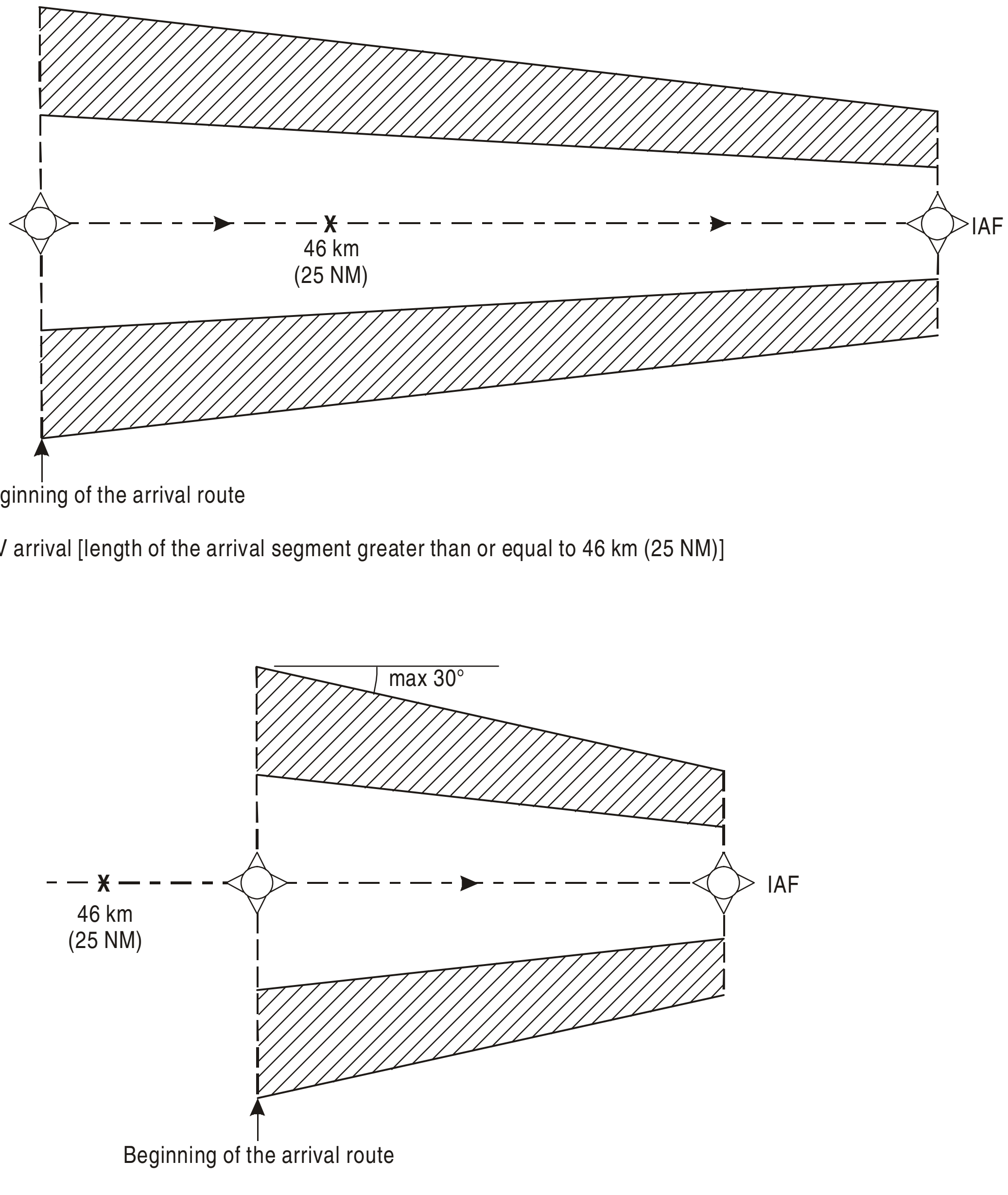
2.5 TURNING MISSED APPROACH

2.5.1 The general criteria in Part I, Section 4, Chapter 6, 6.4.2, “General” and 6.4.3, “Turn parameters” apply, as does Part 1, Section 1, Chapter 3, “Turn area construction”. See also sections 6.4.6, “Turn initiated at a designated turning point (TP)” and 6.4.7, “Turn specified at the MAPt”.

2.5.2 A missed approach with a turn at the MAPt for VOR/DME and DME/DME is shown in Figure III-3-2-5. A missed approach with a turn at the MAPt for basic GNSS is shown in Figure III-3-2-12.

2.6 END OF THE MISSED APPROACH SEGMENT — MAHF

A waypoint (MAHF) defining the end of the missed approach segment shall be located at or after the point where the aircraft, climbing at the minimum prescribed gradient for each segment, reaches the minimum altitude for en route or holding, whichever is appropriate.



a) RNAV arrival [length of the arrival segment greater than or equal to 46 km (25 NM)]

b) RNAV arrival [length of the arrival segment less than 46 km (25 NM)]

Figure III-3-2-1. RNAV arrival

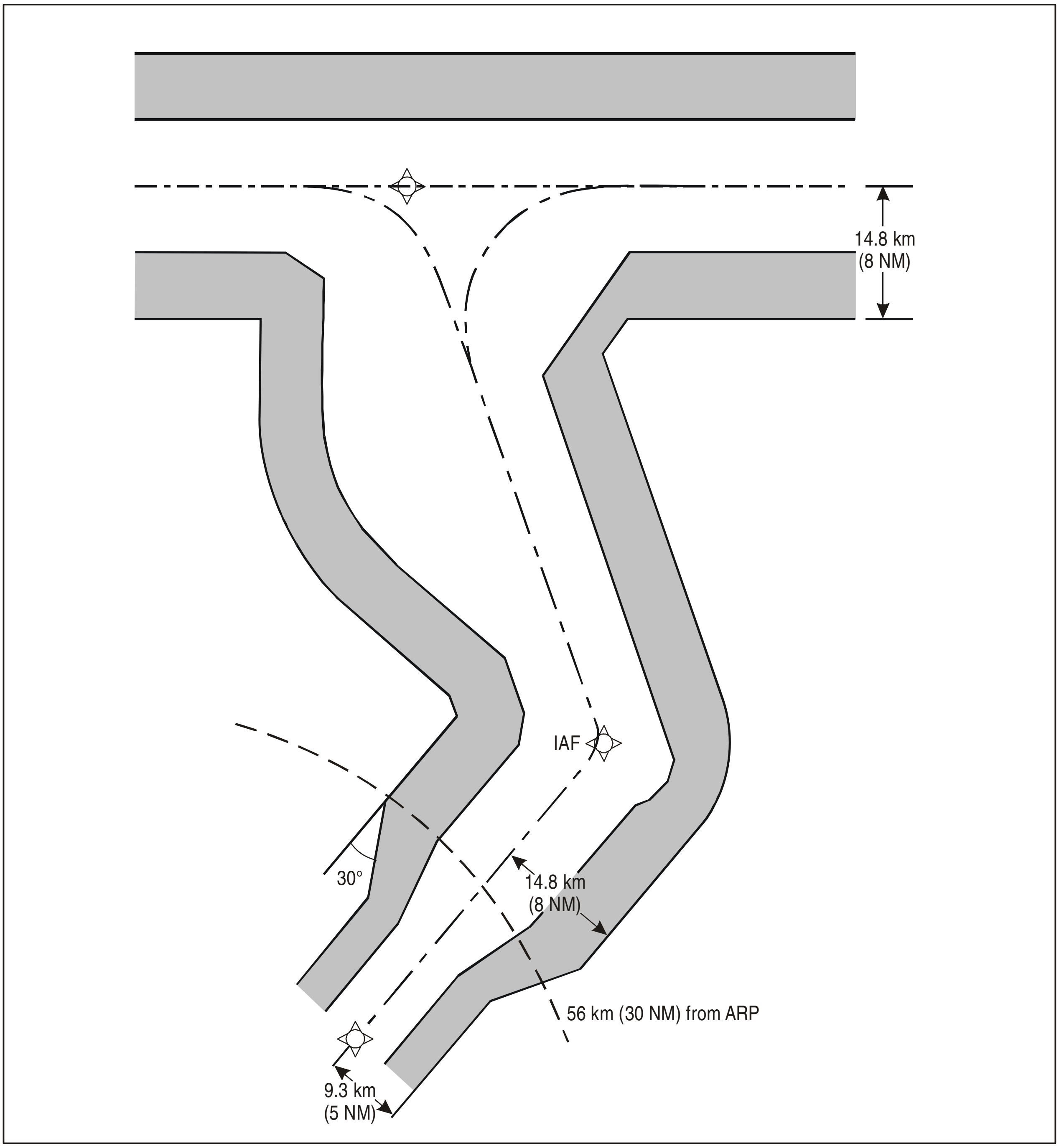


Figure III-3-2-2. GNSS arrival criteria, IAF beyond 30 NM ARP: 8 NM ½ AW prior to 30 NM from ARP then 5 NM ½ AW

Note.— This example is based on 5 seconds roll anticipation 16 000 ft, 300 kt, 15° AOB, ISA + 10°C at en-route waypoint 6 000 ft, 200 kt, 25° AOB, ISA + 10°C at IAF.

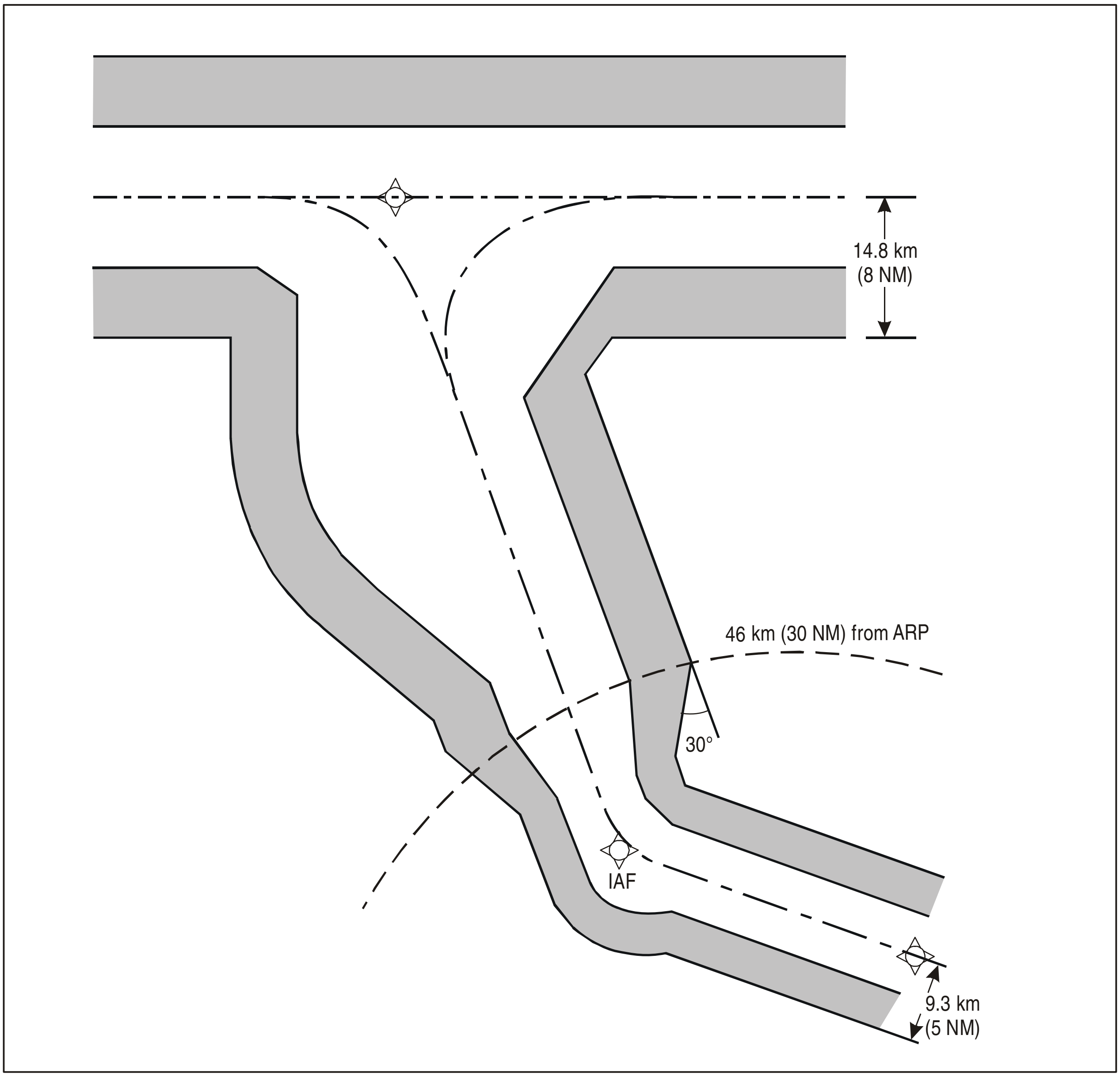


Figure III-3-2-3. GNSS arrival criteria IAF within 30 NM (46 km) ARP : 8 NM ½ AW prior to 30 NM (46 km) from ARP then 5 NM ½ AW

Note.— This example is based on 5 seconds roll anticipation 16 000 ft, 300 kt, 15° AOB, ISA + 10°C at en-route waypoint 15 000 ft, 250 kt, 25° AOB, ISA + 10°C at IAF.

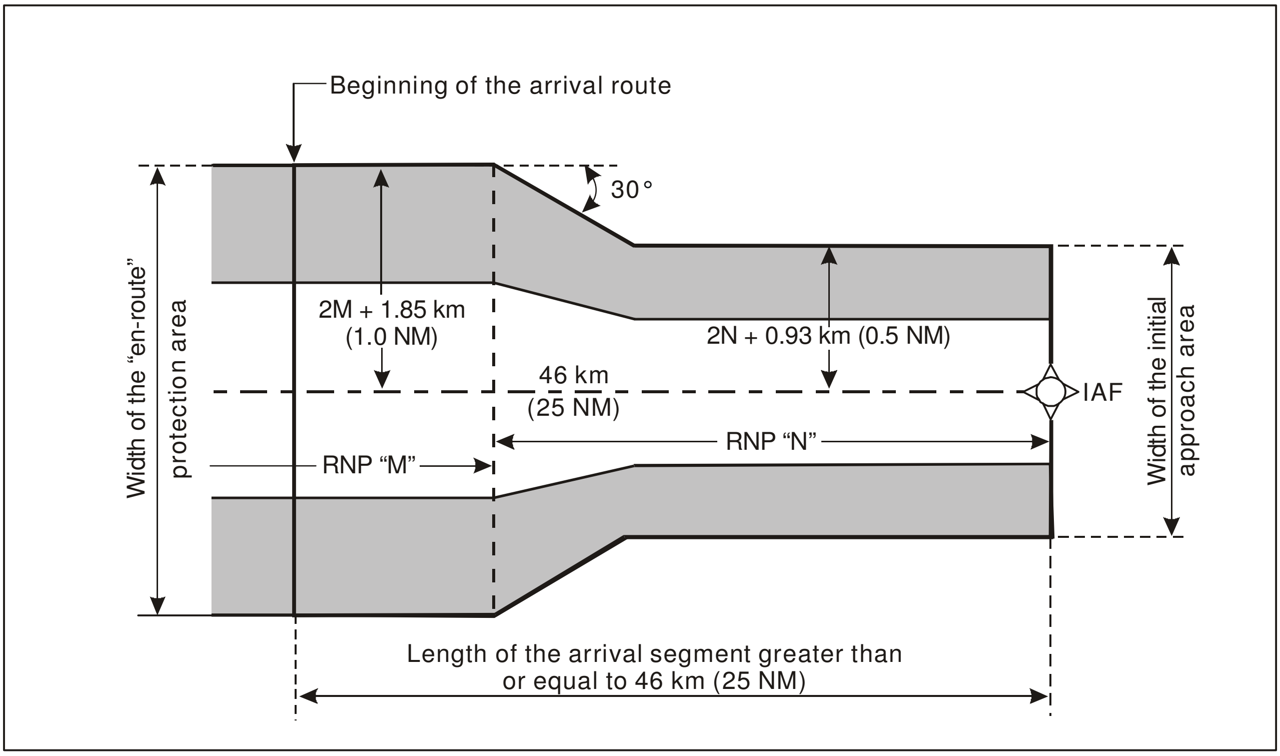


Figure III-3-2-4 a). Arrival segment based on RNP. Protection area.
Length of the arrival segment greater than or equal to 46 km (25 NM)

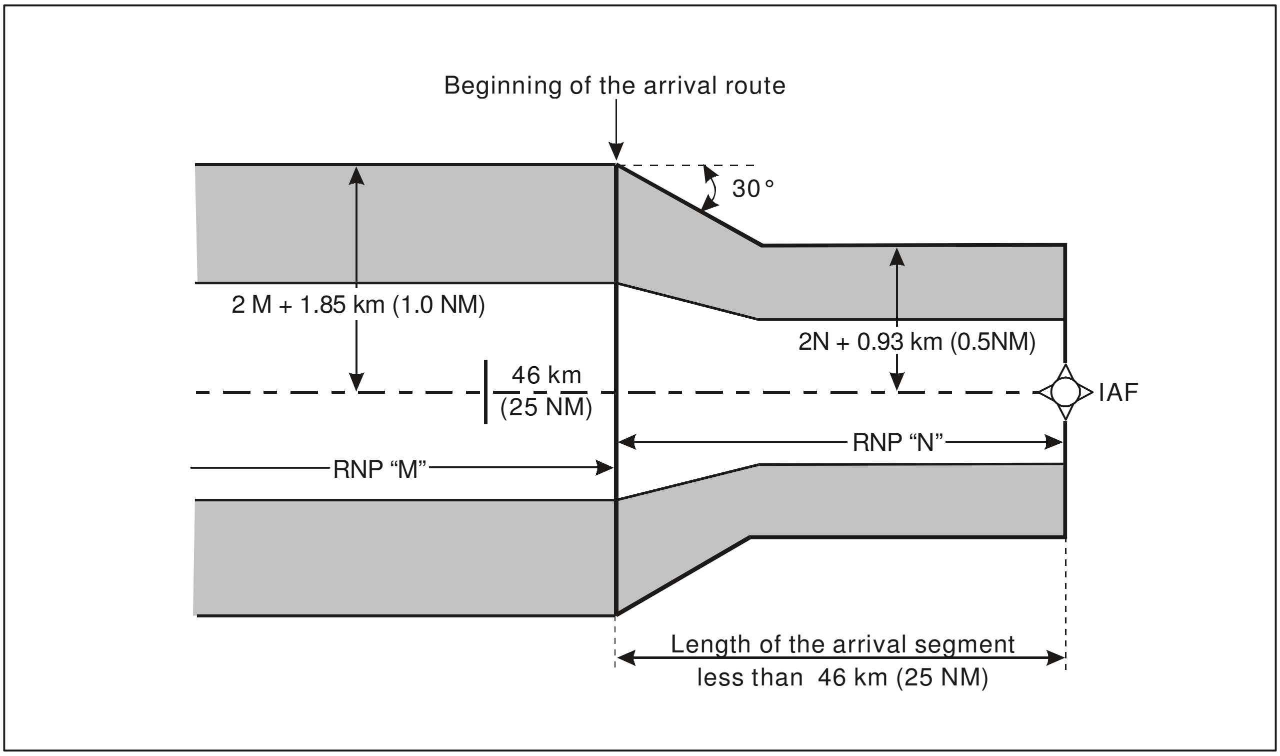


Figure III-3-2-4 b). Arrival segment based on RNP. Protection area.
Length of the arrival segment less than 46 km (25 NM)
(Required RNP: "M" on the en-route segment and "N" on the arrival segment)

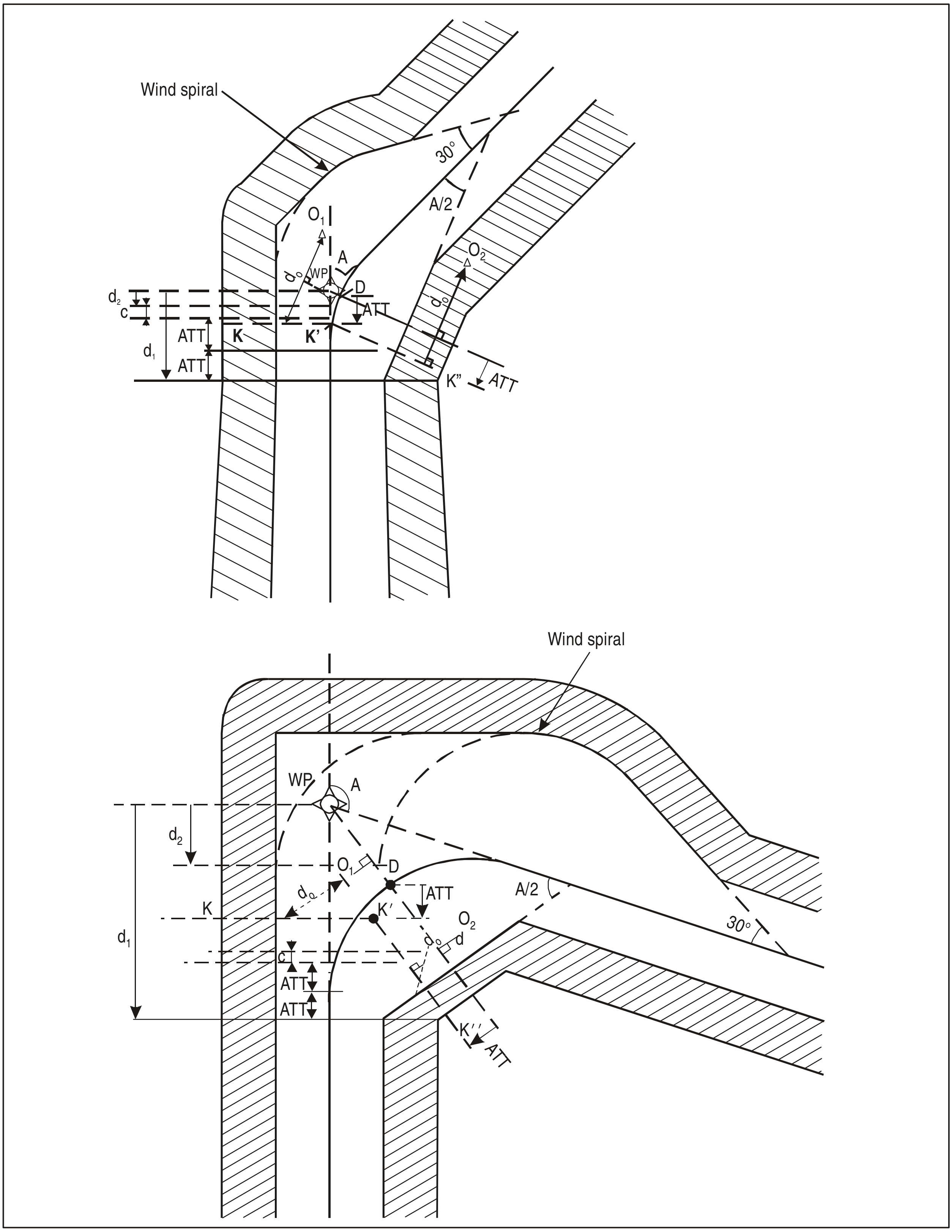


Figure III-3-2-5. Turn at a fly-by waypoint

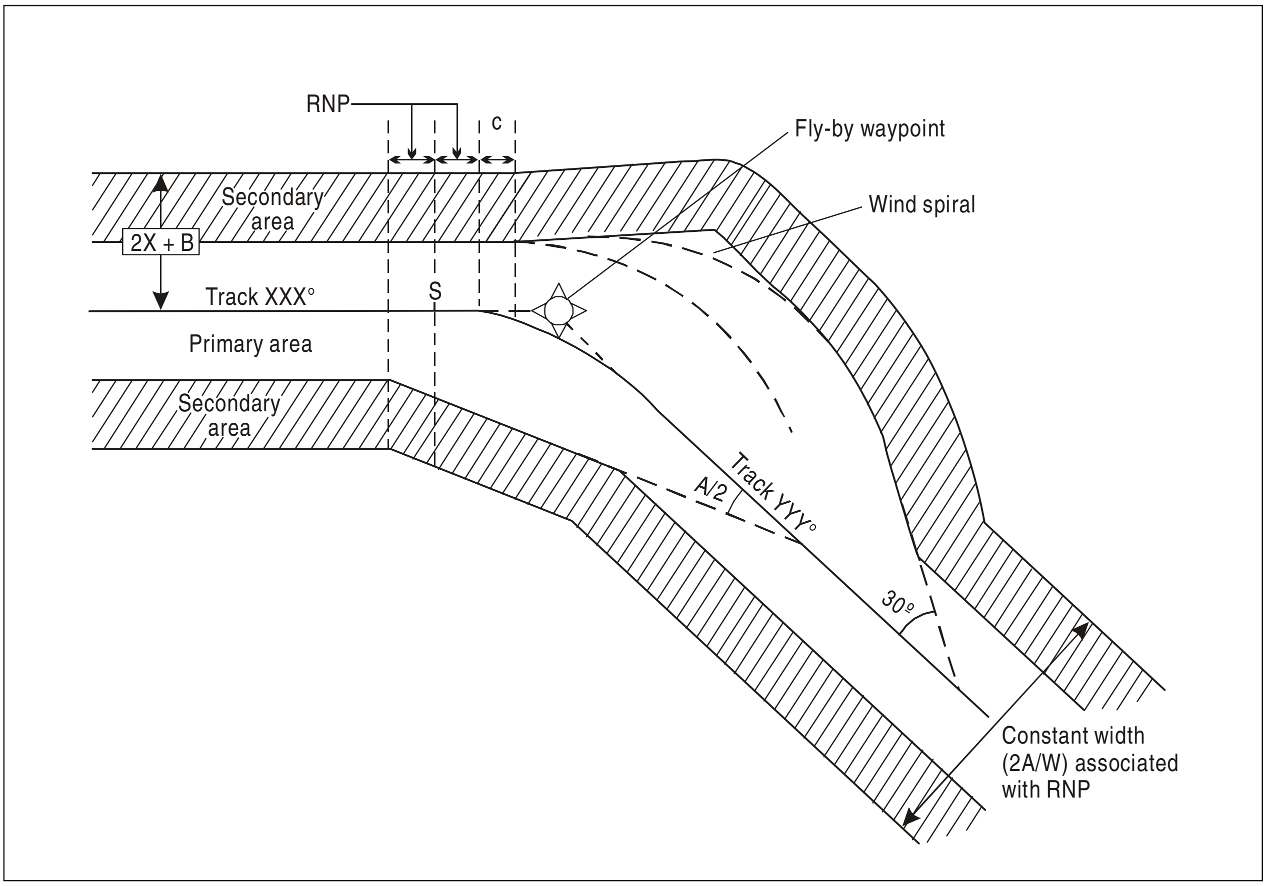


Figure III-3-2-6. Turn at a fly-by waypoint

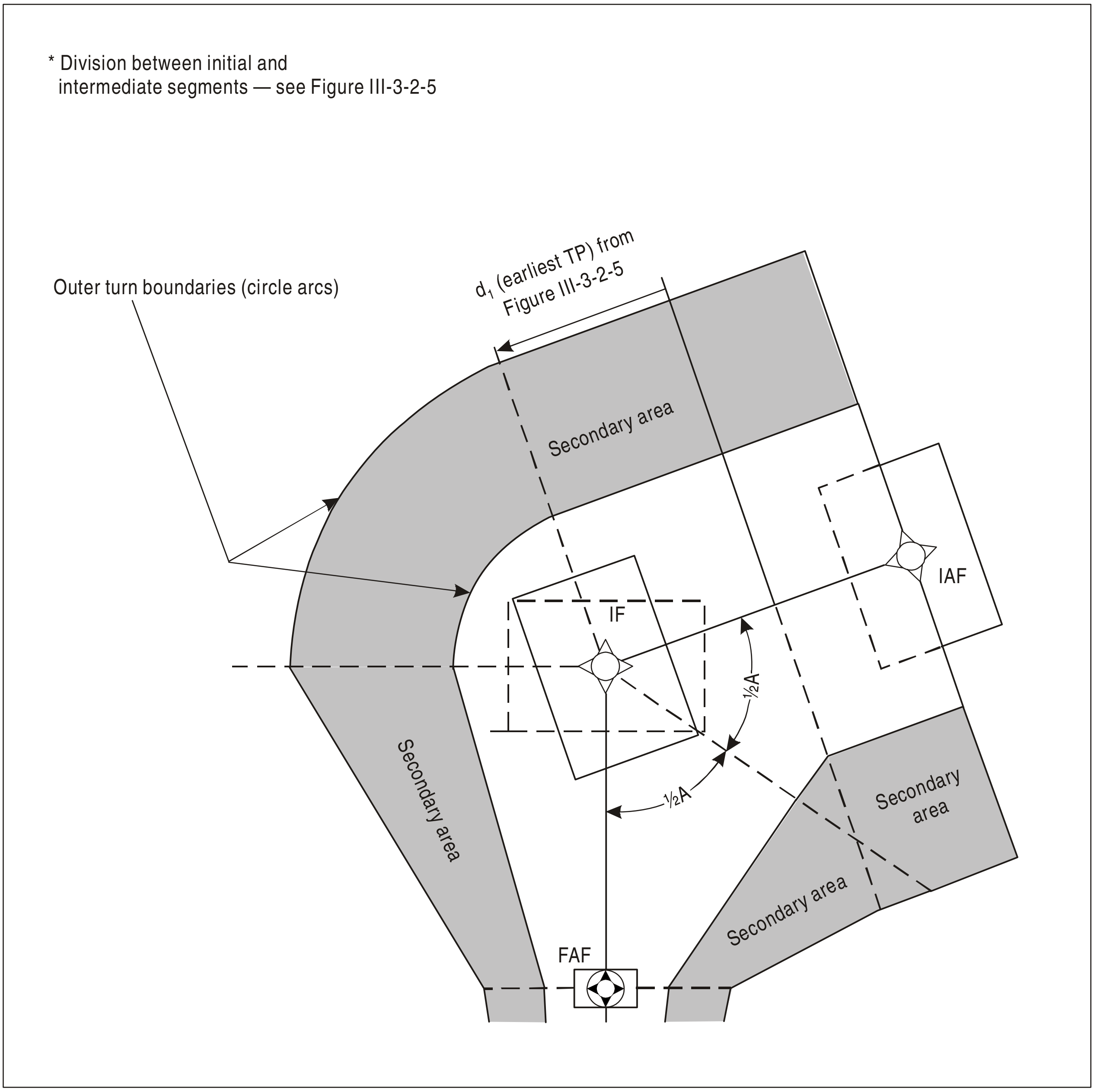


Figure III-3-2-7. Turn protection and area blending at the IWP (offset initial segment)

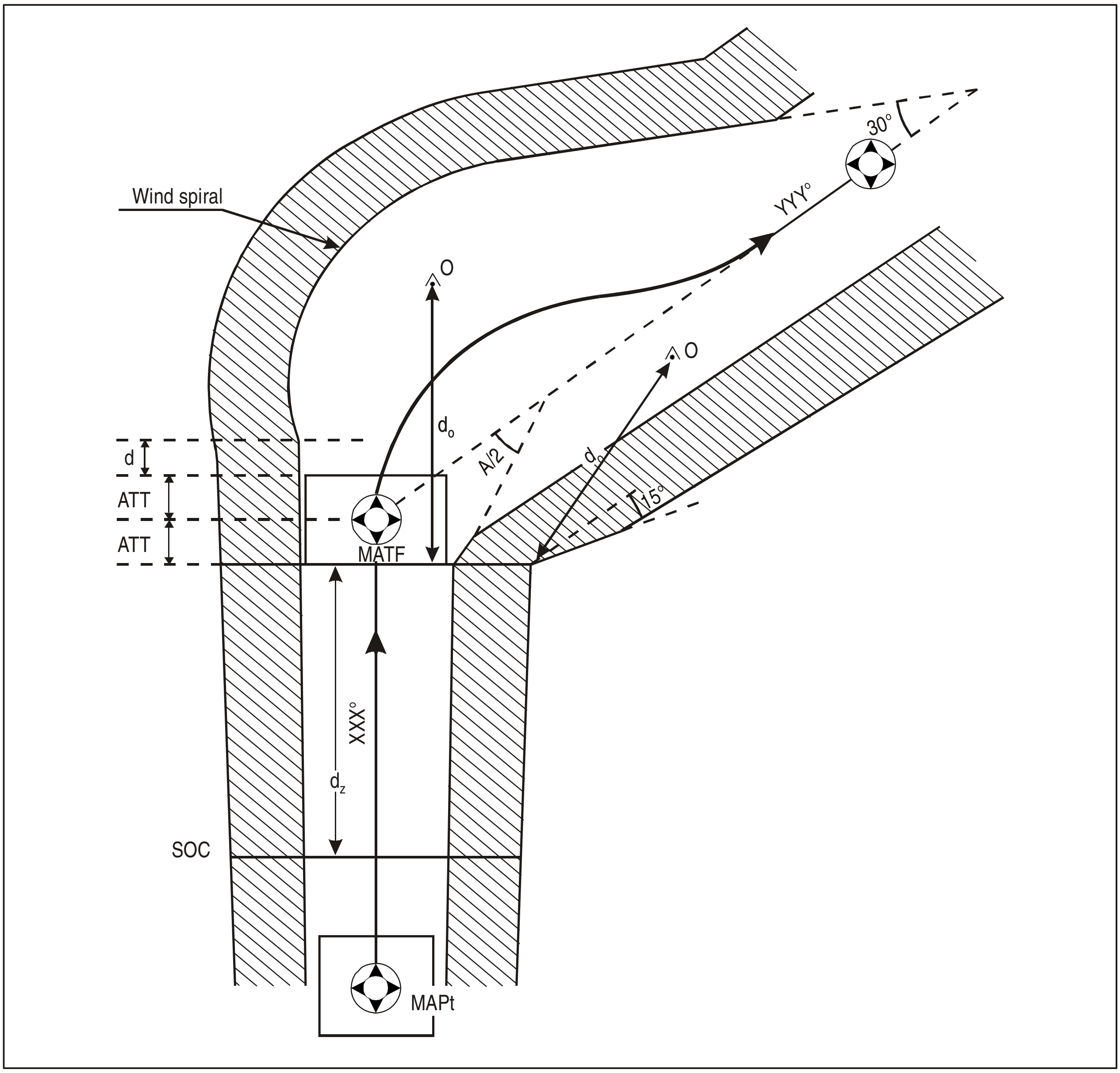


Figure III-3-2-8. Turning missed approach flyover waypoint — turn up to and including 90°

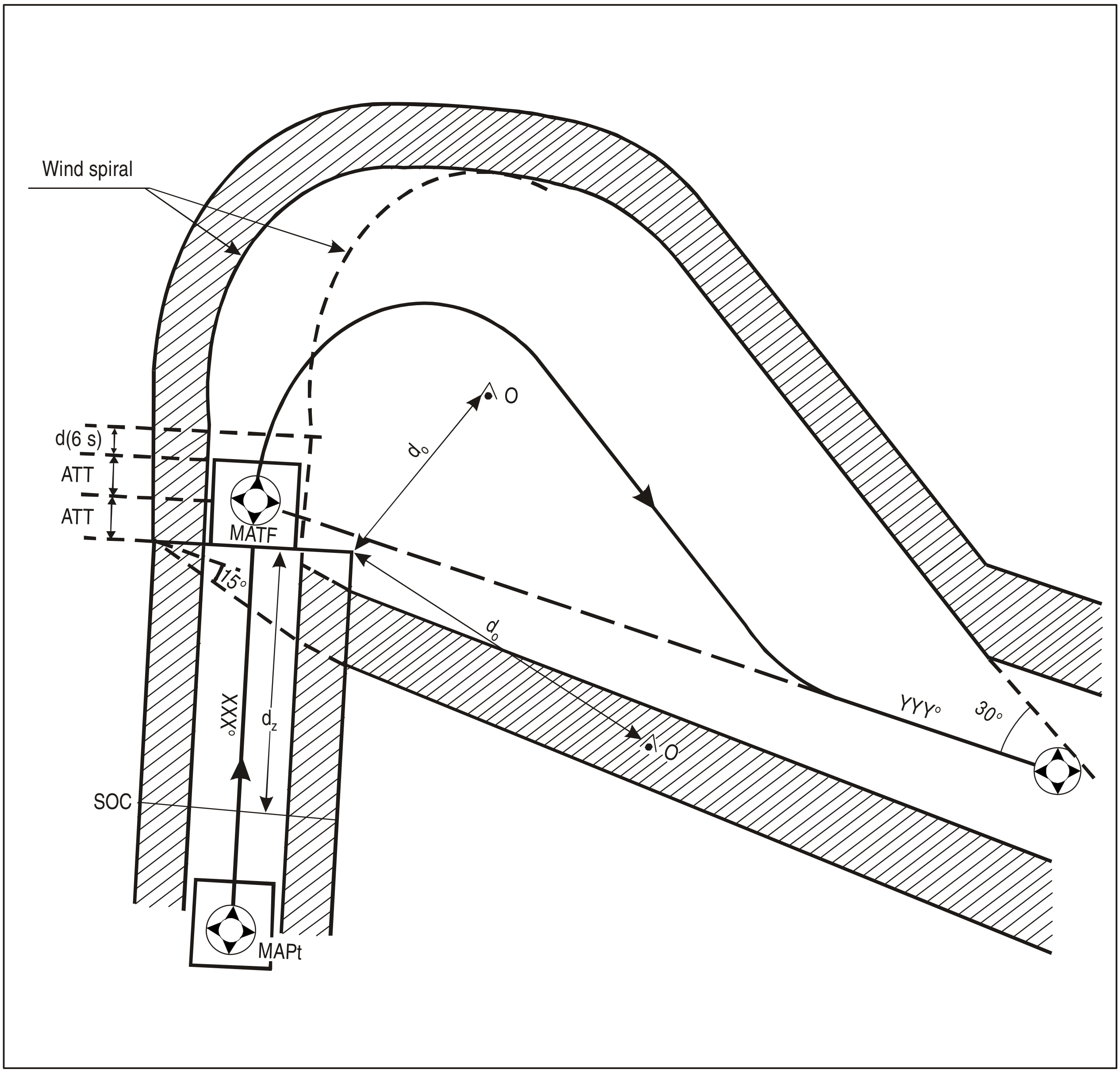


Figure III-3-2-9. Turning missed approach flyover waypoint — turn more than 90°

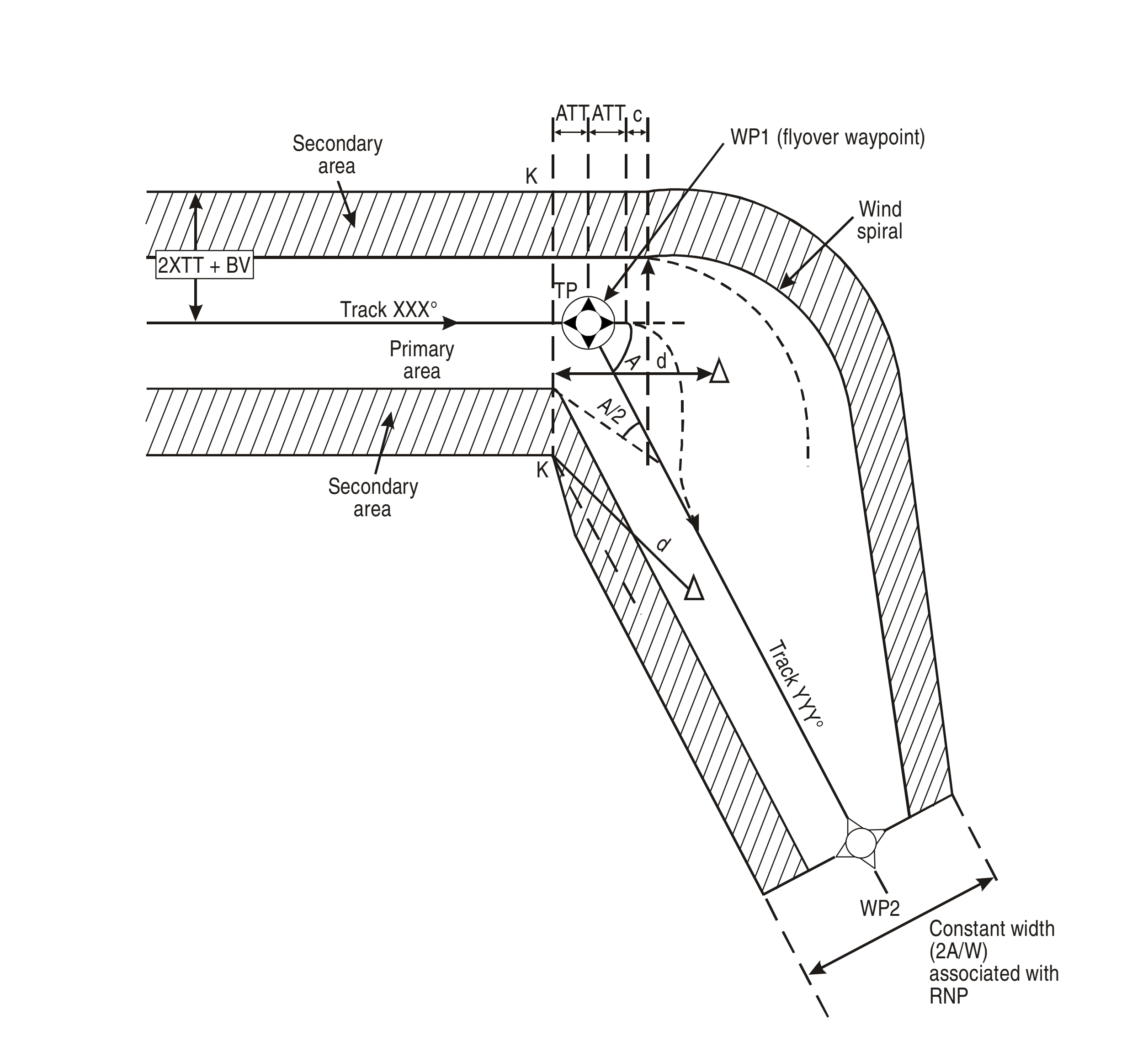


Figure III-3-2-10. Turn at a flyover waypoint

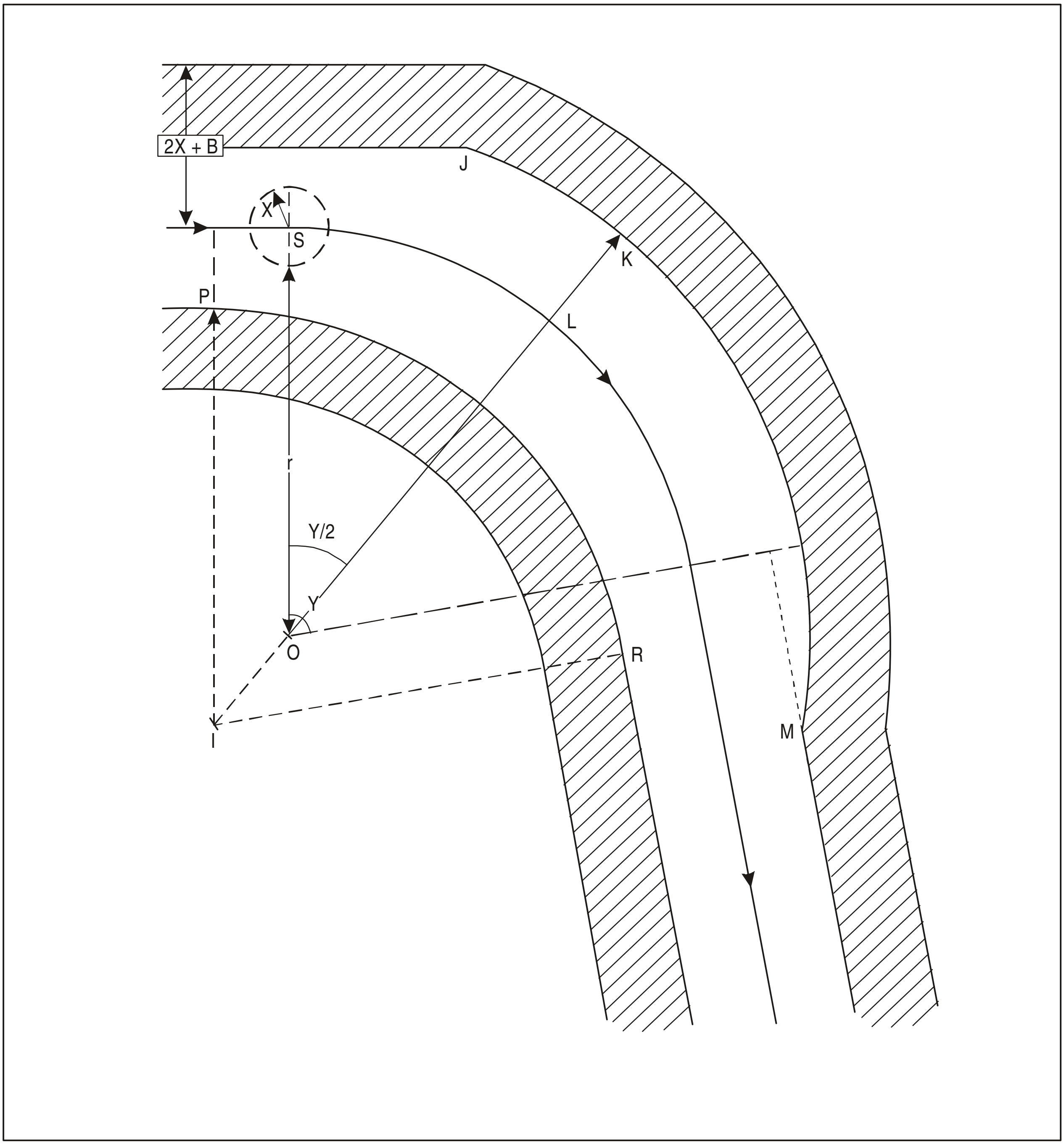


Figure III-3-2-11. Fixed radius turn

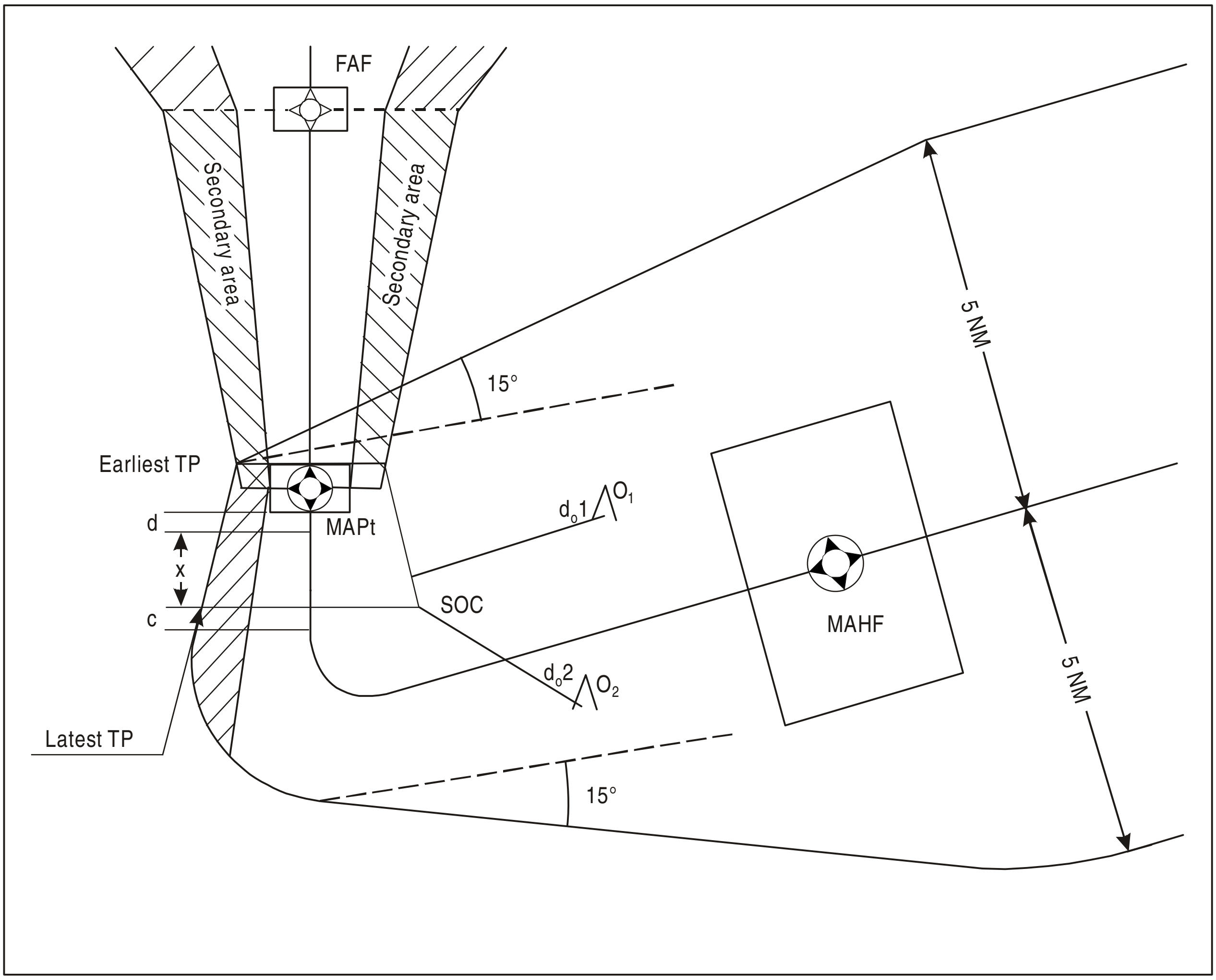


Figure III-3-2-12. Turning missed approach for basic GNSS

Chapter 3

NON-PRECISION APPROACH PROCEDURES

3.1 FINAL APPROACH SEGMENT

3.1.1 Final approach alignment

The final approach track should be aligned with the runway centre line; if this is not possible, the criteria in Part I, Section 4, Chapter 5, 5.2, "Alignment" apply.

3.1.2 Final approach length

3.1.2.1 The optimum length is 9.3 km (5.0 NM) (Cat H, 3.7 km (2 NM)), but it should normally not exceed 18.5 km (10.0 NM). For lengths greater than 11.1 km (6.0 NM) the provisions of Part I, Section 4, Chapter 5, 5.4.6.2 b) apply.

3.1.2.2 The minimum length for VOR/DME and DME/DME is determined according to Section 1, Chapter 4, Table III-1-4-2 and to the criteria in Section 1, Chapter 1, 1.2, "Satisfactory fixes".

3.1.3 Final approach area width

3.1.3.1 The principle of secondary area applies.

3.1.3.2 The final approach segment width is derived from joining the primary and secondary area boundaries at the FAF and the MAPt.

3.1.3.3 For area widths see Section 1.

3.1.4 Obstacle clearance

The minimum obstacle clearance in the primary area is 75 m (246 ft), increased as specified in Part I, Section 4, Chapter 5, 5.4.6.2 b), "Excessive length of final approach", in case of excessive length of the final segment.

3.1.5 Descent gradient

The general criteria of Part I, Section 4, Chapter 5, 5.3, "Descent gradient", apply.

3.2 INITIAL AND INTERMEDIATE MISSED APPROACH SEGMENT

General criteria apply as modified by this paragraph.

3.2.1 Missed approach point (MAPt)

The missed approach point (MAPt) shall be defined by a flyover waypoint.

3.2.2 Location of MAPt

For a runway-aligned approach, the missed approach point shall be located at or before the threshold. Where the final segment is not aligned with the runway centreline, the optimum location is the intersection of the final approach track and the extended runway centreline. (See Figure III-3-3-1.) In order to provide obstacle clearance in the missed approach area the MAPt may be positioned closer to the FAF but no further than necessary and not beyond the point where the OCH intersects an optimum 5.2 per cent/3° descent gradient to the runway.

3.2.3 Missed approach area length

Minimum segment length distances between the MAPt and the MATF or the MAHF are contained in Table III-2-1-4 or III-2-1-10.

3.2.4 Missed approach area width for VOR/DME and DME/DME

3.2.4.1 The earliest missed approach point (MAPt) is determined by the value of ATT at the MAPt. For ATT values, see Section 1, Chapter 4, 4.5.1 for VOR/DME and Section 1, Chapter 3, 3.6.1 for DME/DME.

3.2.4.2 From this point the area splays at 15° on each side of the missed approach track until it reaches the width of the area at the earliest MATF (primary area plus secondary areas). See Figure III-3-3-2.

3.2.4.3 If the MATF is close to the MAPt, the splay should be increased as required to ensure the area reaches the width of the whole area (primary area plus secondary areas) at the earliest MATF. See Figure III-3-3-2.

3.2.4.4 If the width of the whole area at the turning point is equal to or less than the area width at the earliest MAPt, the total area width is obtained as follows:

a) apply a 15° splay on each side of the missed approach track until the SOC; and

b) join the area width at the SOC to the latest MAPt and the latest MATF. See Figure III-3-3-2.

3.2.5 Missed approach area width for basic GNSS

3.2.5.1 The missed approach area shall commence at the beginning of the MAPt longitudinal tolerance at a width equal to the final approach area at that point (see Figure III-3-3-3).

3.2.5.2 After the earliest fixed tolerance area of the MAPt, the area splays at 15° on each side of the missed approach course from 1.85 km (1.00 NM), to a total width of ± 9.26 km (5.00 NM) to account for the decrease in GNSS receiver display sensitivity from 0.6 km (0.3 NM).

3.2.5.3 This last width may be reduced to ±5.56 km (3.00 NM) if the provisions of Part I, Section 4, Appendix B to Chapter 3 are employed.

3.2.5.4 *Missed approach secondary areas for basic GNSS.* Until further operational experience is obtained with basic GNSS receivers — some of which may not provide continuous track guidance after the MAPt — the full MOC applicable to the primary area should be applied to the full width of the missed approach area. That is, the principle of secondary areas does not apply. On the other hand, if a procedure is designed exclusively for use by aircraft equipped with multi-sensor systems, the missed approach criteria in 7.3.5, "Turn initiated at a designated turning point (TP)" apply, and the approach procedure shall be so annotated.

3.2.5.5 *Straight missed approach for basic GNSS.* The criteria governing straight missed approaches apply (see Part I, Section 4, Chapter 6, 6.3, "Straight missed approach"). Note that the 15° splay provided for the basic GNSS receiver is limited by the width of the area defined by the subsequent waypoint in the missed approach (MATF or MAHF). See Figure III-3-3-3.

3.2.6 Missed approach area width for RNP

See Section 1, Chapter 7, 7.5, "XTT, ATT and area semi-width".

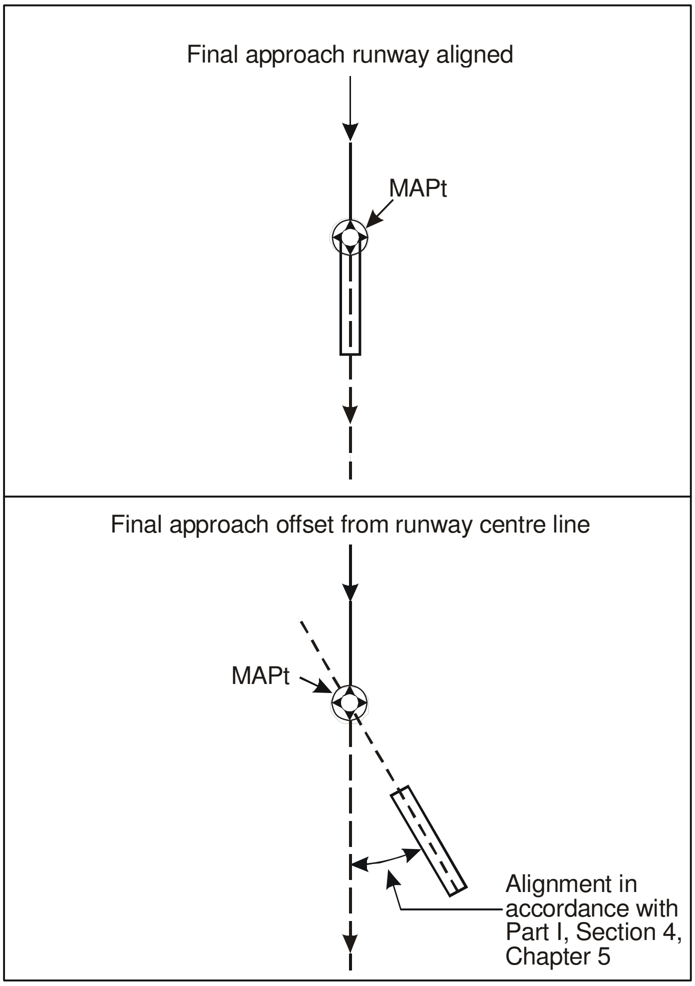


Figure III-3-3-1. Location of MAPt

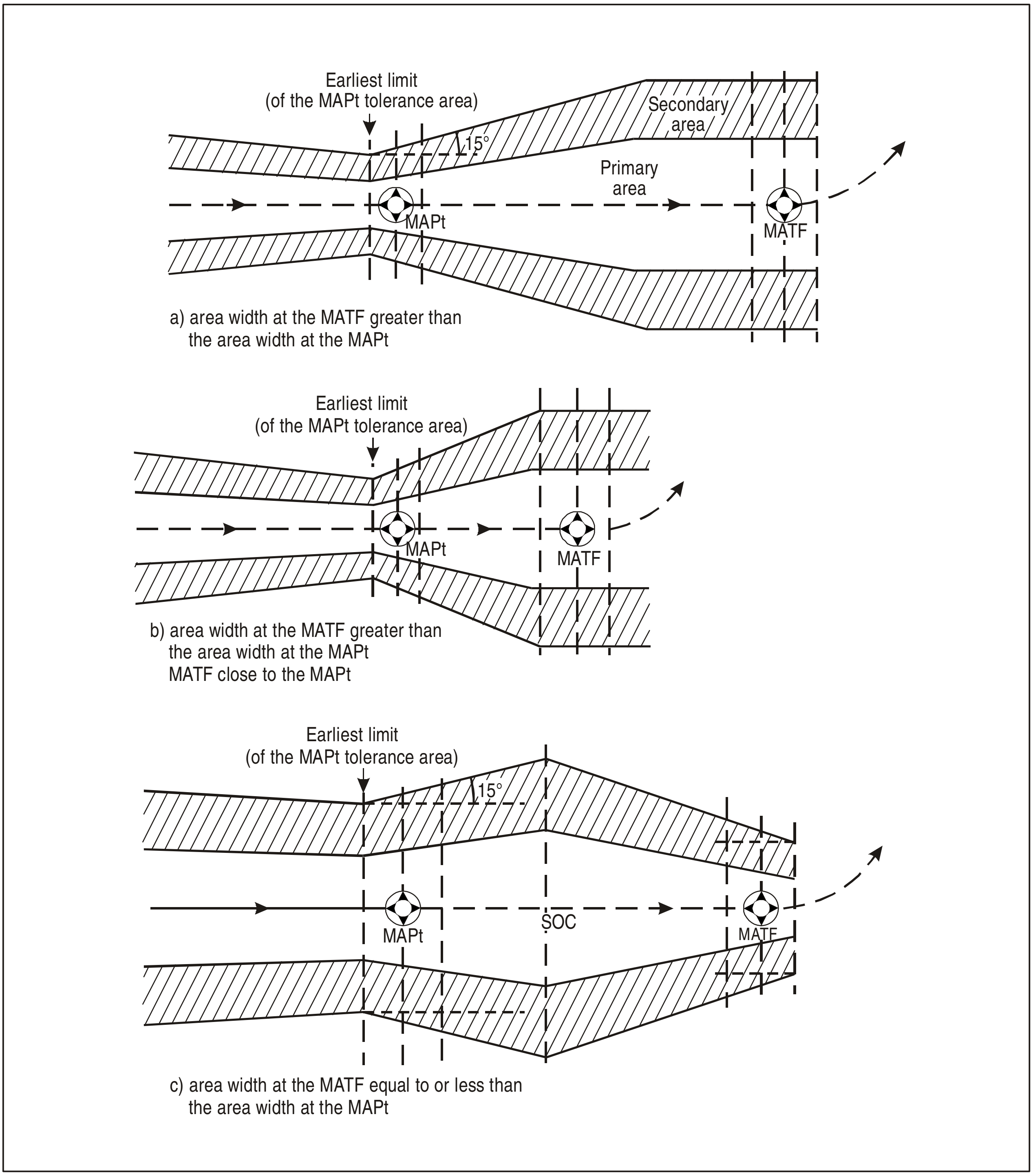


Figure III-3-3-2. Straight-in segment of a missed approach

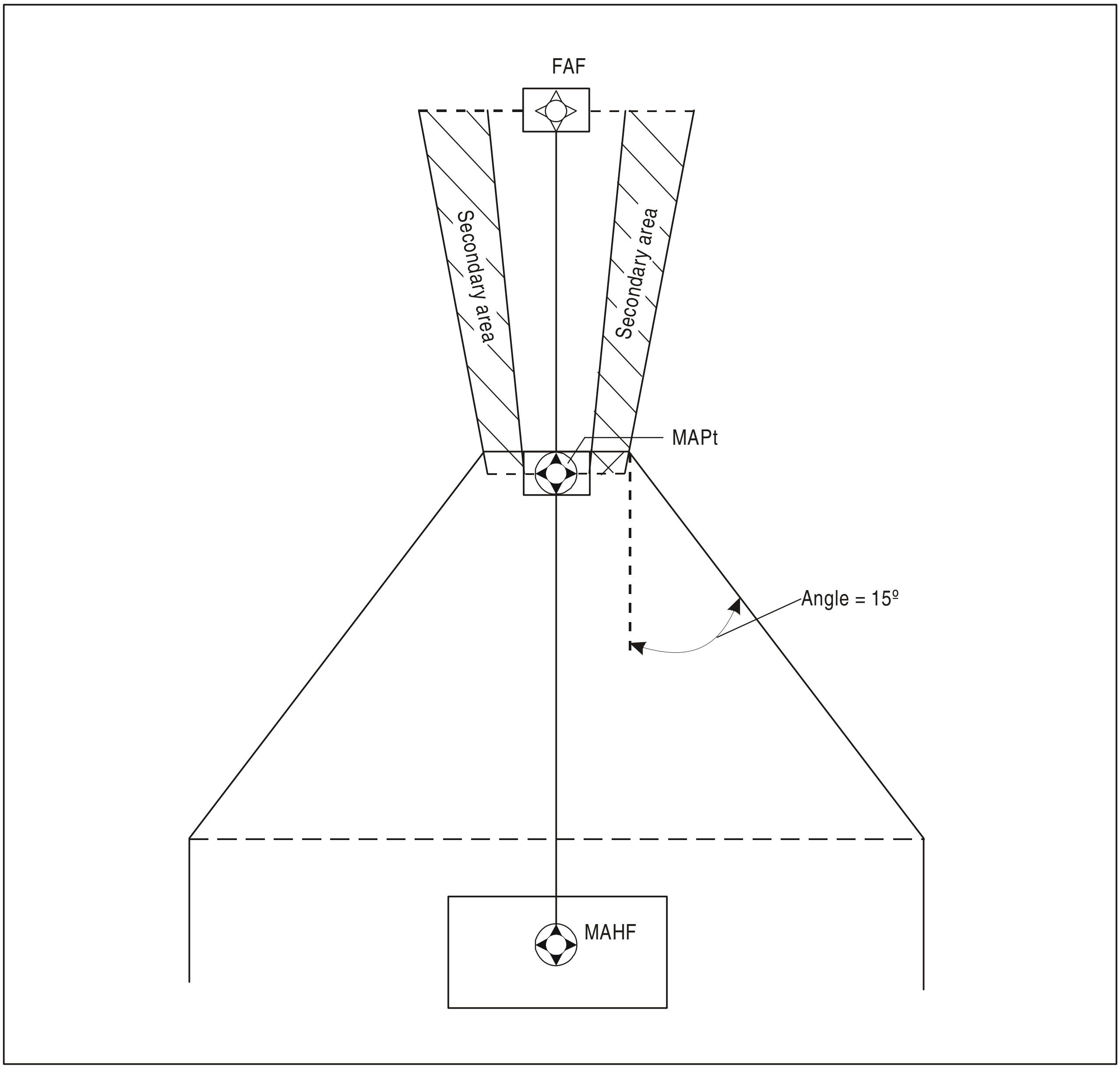


Figure III-3-3-3. Straight missed approach showing intermediate and central initial segments

Chapter 4

APV/BAROMETRIC VERTICAL NAVIGATION (BARO-VNAV)

Note 1.— Barometric vertical navigation (Baro-VNAV) is a navigation system that presents to the pilot computed vertical guidance referenced to a specified vertical path angle (VPA), nominally 3°. The computer-resolved vertical guidance is based on barometric altitude and is specified as a vertical path angle from RDH.

Note 2.— In this chapter, distances and heights related to obstacle clearance surfaces are all in SI units. Distances and heights are measured relative to threshold (positive before/above threshold, negative after/below threshold). If non-SI units are required, the appropriate conversions must be made as in the GBAS criteria (see Chapter 6).

4.1 GENERAL

4.1.1 The general criteria and Sections 1, 2 and 3, Chapter 2, as amplified or modified by criteria in this chapter, apply to area navigation (RNAV) approach procedures using barometric vertical navigation (Baro-VNAV).

4.1.2 Baro-VNAV approach procedures are classified as instrument procedures in support of approach and landing operations with vertical guidance (APV). They utilize a DA/H and not an MDA/H, and neither a FAF nor a missed approach point (MAPt) are identified. They use obstacle assessment surfaces similar to those for ILS, but based on the specific lateral guidance system.

4.1.3 Baro-VNAV procedures are used in association with LNAV-only procedures. The LNAV-only FAF and MAPt are used to define the areas but are not part of the VNAV procedure.

4.1.4 Baro-VNAV procedures shall not be authorized with a remote altimeter setting.

4.1.5 The construction of a Baro-VNAV procedure involves three steps:

a) determination of VPA and final approach surface (FAS);

b) construction of the APV-OAS; and

c) calculation of the OCA/H based on obstacles penetrating the APV-OAS.

4.2 STANDARD CONDITIONS

Note.— Acceptable means of compliance can be found in documents such as Federal Aviation Administration (FAA) AC 90-97 (Use of Barometric Vertical Navigation (VNAV) for instrument Approach Operations using Decision Altitude), which references FAA AC 20-138[1]*, AC 20-130A*[2] *and AC 20-129*[3]*. Examples of database quality*

1. *Airworthiness Approval of Global Positioning System Navigation Equipment for use as a VFR and IFR Supplemental Navigation System (FAA).*

requirements can be found in the ICAO World Geodetic System — 1984 (WGS-84) Manual *(Doc 9674) and Radio Technical Commission for Aeronautics (RTCA) Do-201A[4]/European Organization for Civil Aviation Equipment (EUROCAE) ED 77[5] and RTCA Do-200A[6]/EUROCAE ED 76[7], AC120-29A/ Criteria for Approval of Category I and Category II Weather Minima for Approach, AC25-15/Approval of Flight Management Systems in Transport Category Airplanes and RTCA Do 229C/Minimum operational performance standards for global positioning systems/wide area augmentation system airborne.*

4.2.1 Use of Baro-VNAV procedures developed in accordance with this chapter assume that the aircraft is equipped with at least the following:

a) a VNAV system certificated for approach operations including the ability to have timely changeover to positive course guidance for missed approach; and

Note.— See AC120-29A, paragraph 4.3.1.8a(2), AC 25-15, paragraph 5.e(1) (ii) (B) (1) and RTCA Do-229C.

b) an LNAV system with a certificated along- and across-track performance (TSE), equal to or less than 0.6 km (0.3 NM), 95 per cent probability (see also 4.2.2). The following systems are deemed to meet this requirement:

   1) GNSS navigation equipment certificated for approach operations; or

   2) multi-sensor systems using inertial reference units in conjunction with DME/DME or GNSS certificated for approach operations; or

   3) RNP systems approved for RNP 0.3 approach operations or less; and

c) a navigation database containing the waypoints and associated RNAV and VNAV information (RDH and VPA) for the procedure and the missed approach that is automatically loaded into the navigation system flight plan when selected by the crew.

4.2.2 Use of Baro-VNAV procedures developed in accordance with this chapter assume:

a) that no obstacles penetrate a visual protection surface. This surface is defined by:

   1) the lateral dimensions of the Annex 14 runway code No. 3/4 first and second section approach surfaces, starting 60 m before threshold and terminating at a distance before threshold equal to (OCH-RDH) /tan VPA + ATT;

   2) a slope of 3.33 per cent originating 60 m before threshold at threshold level; and

   3) that portion of the runway strip between the above surfaces and threshold;

   If such obstacles exist, no Baro-VNAV procedure may be promulgated. However, obstacles with a height less than 5 m above threshold may be disregarded when assessing the visual protection surface. See Figure III-3-4-1;

b) that a lower limit is applied to OCA/H as follows:

---

2. *Airworthiness Approval of Navigation and Flight Management Systems integrating multiple navigation sensors (FAA)*
3. *Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the United States National Airspace System (NAS) and Alaska*
4. *Industry Standards for Aeronautical Information (RTCA)*
5. *Standards for Aeronautical Information (EUROCAE)*
6. *Standards for Processing Aeronautical Information (RTCA)*
7. *Standards for Processing Aeronautical data (EUROCAE)*

1) 75 m provided that the Annex 14 inner approach, inner transitional and balked landing surfaces have been assessed and have not been penetrated; and

2) 90 m in all other cases.

4.2.3 The optimum promulgated VPA shall be 3°; it shall not be less than 3° or greater than 3.5°. See 4.3.5.2.2, "Determination of minimum promulgated temperature".

4.2.4 The reference datum height shall be 15 m (50 ft).

4.2.5 All obstacle heights are referenced to threshold elevation.

4.3 APV SEGMENT

4.3.1 *General*. The APV segment for Baro-VNAV is aligned with the extended runway centreline and contains the final descent segment for landing, and the initial, intermediate and final segments of the missed approach.

4.3.2 *APV OAS.* The APV OAS start at the final approach point (FAP) which is located at the intersection of the vertical path and the minimum height specified for the preceding segment. The FAP should not normally be located more than 19 km (10 NM) before the threshold. The APV OAS ends at the MAHF or MATF, whichever is first. The LNAV FAF and MAPt are primarily used to define the geometry of the areas and surfaces. Once the procedure has been designed, the FAF and MAPt of the associated LNAV procedure are solely used for database coding purposes.

4.3.3 *Relation of APV-OAS surface with LNAV criteria.* The upper/outer edges of the APV-OAS side surfaces are based on the outer edges of the secondary areas of the LNAV system providing the final approach guidance. The lower/inner edges of the APV-OAS side surfaces are based on the edges of the primary area of the LNAV system providing the final and missed approach guidance (see Figures III-3-4-2 to III-3-4-4). The outer edges of the side surfaces are as follows:

a) MOC_{app} value above the inner edge for side surfaces attached to the FAS;

b) 30 m above the inner edge for side surfaces attached to the intermediate missed approach surfaces; and

Note.— The height of the outer edge of the side surface joining the FAS to the intermediate missed approach surface will change from MOC_{app} value to 30 m throughout its length.

c) 50 m above the inner edges attached to the final missed approach surface.

4.3.4 *Frame of reference*. See Chapter 6, 6.4.8.2, "Frame of reference".

4.3.5 *Definition of the OAS*

4.3.5.1 The OAS are used to identify accountable obstacles and consist of the following surfaces:

a) final approach surface (FAS);

b) horizontal plane; and

c) intermediate and final missed approach surfaces (Z_i and Z_f respectively).

Each has associated side surfaces.

Note.— The initial missed approach segment is contained within the calculation of the OAS Z_i and Z_f surfaces.

4.3.5.2 *Final approach surface (FAS)*. The origin of the final approach surface is at threshold level and located at a distance before threshold equal to the point where the vertical path reaches a height of MOC_{app} above threshold, plus a longitudinal distance of 556 m (ATT). The final approach surface extends to the range of the nominal FAP + ATT with an angle as defined in 4.3.5.2.2. (See Figure III-3-4-5).

4.3.5.2.1 The final approach surface is bounded laterally by the edges of the LNAV primary area. The inner edges of the associated side surfaces are defined by the edges of the LNAV primary area at the FAS elevation and the outer edges of the LNAV secondary areas MOC_{app} value above the FAS elevation.

Note.— The calculation of VPA given a desired FAS (to eliminate a significant obstacle) is complicated by the interdependence of height at FAP, and temperature correction. Because of this, it is preferable to start the calculation with the optimum 3° VPA and calculate the associated FAS. If the FAS has to be raised to overcome significant obstacles, increase the VPA and/or reduce the height at the FAP until an optimum solution is found.

4.3.5.2.2 *Determination of minimum promulgated temperature*. Determine the minimum probable temperature (the temperature correction is obtained from Appendix A to this chapter) and round it down to the next lower 5°C increment. Then:

a) the FAS for that temperature shall be calculated (see 4.3.5.2.3) and, if less than 2.5°, the promulgated VPA shall be increased to ensure the FAS at minimum temperature is equal to or greater than 2.5°; and

b) the length of the preceding segment shall be reviewed to ensure it meets the relevant requirements for minimum distance before vertical path intercept.

Note 1.— One suitable method of obtaining the minimum temperature is to obtain the mean low temperature of the coldest month of the year for the last five years of data at the aerodrome elevation. Round this temperature down to the next lower 5°C increment for promulgation. Obtain the cold temperature correction applicable for this temperature, the aerodrome elevation, and FAP height using the criteria in the appendix to this chapter.

Note 2.— No minimum temperature restrictions apply to aircraft with flight management systems incorporating final approach temperature compensation.

Note 3.— No minimum temperature restrictions apply to aircraft with flight management systems incorporating approved final approach temperature compensation, provided the minimum temperature is not below that for which the equipment is certificated.

4.3.5.2.3 *Calculation of final approach surface angle and origin*. The angle of the final approach surface (FAS) can be determined as follows:

$$\tan^{-1}\alpha_{FAS} = \frac{(\text{height at FAP} - \text{temp. correction}) \times \tan \text{VPA}}{(\text{height at FAP})}$$

The origin of the final approach surface at threshold level can be determined as follows:

$$X_{FAS} = \frac{MOC_{app} - RDH}{\tan \text{VPA}} + ATT$$

The height of the final approach surface (h_{FAS}) at range x relative to threshold can be determined as follows:

$$h_{FAS} = (x - x_{FAS}) \times \tan \alpha_{FAS}$$

where: MOC_{app} = approach MOC
RDH = reference datum height (m)
ATT = along track tolerance (556 m)

For temperature correction see Appendix A.

4.3.5.3 *Horizontal plane*. The horizontal plane is defined by a surface at threshold level bounded by the LNAV primary area between the origin of the FAS (see 4.3.5.2.3) and the origin of the missed approach surface. The lower/inner edges of the side surfaces are defined by the edges of the LNAV primary area at threshold level. The upper/outer edges of the associated side surfaces are defined by the outer edges of the LNAV secondary areas at the value of MOC_{app} above threshold at the origin of the FAS and the outer edges of the LNAV area 30 m above threshold at the origin of the intermediate missed approach surface at a distance Z_i relative to threshold (positive before, negative after).

Note.— Appendix B to this chapter provides the equations needed to calculate the height of any x, y location in these side surfaces given the four x, y coordinates and heights of the surface vertices.

4.3.5.4 *Missed approach (Z) surfaces*

Note. — The criteria in this chapter however, assumes use of an appropriately certificated VNAV and LNAV system (including the ability to have timely change over to positive course guidance for missed approach), to allow the use of secondary areas.

4.3.5.4.1 *Intermediate missed approach surface*. The origin of the intermediate missed approach surface (Z_i) is at threshold level at a distance X_{Zi} relative to threshold. It ends at the first point at which 50 m MOC is obtained and maintained. It has a nominal gradient of 2.5 per cent. Given evidence of capability to achieve missed approach climb gradients greater than the nominal 2.5 per cent, the Z surface and associated side surfaces may be adjusted for gradients of 3, 4 and 5 per cent. It is bounded laterally by the LNAV primary area. The lower/inner edges of the associated side surfaces are defined by the edges of the LNAV missed approach primary area and the outer edges of the LNAV secondary areas 30 m above the intermediate missed approach (Z_i) surface (see Figure III-3-4-6).

4.3.5.4.1.1 *Calculation of the range of the start of the intermediate missed approach surface (X_{Zi})*

$$X_{Zi} = (MOC_{app} - RDH) / \tan VPA - ATT - d - X + (MOC_{app} - 30) / \tan Z$$

where: X_{Zi} = origin of intermediate missed approach surface
MOC_{app} = MOC for the approach
RDH = vertical path reference height
ATT = along track tolerance
tan Z = gradient of missed approach surface (2.5 per cent, optionally additional values of 3, 4 and 5 per cent)

4.3.5.4.2 *Final missed approach surface.* The final missed approach surface (Z_f) starts at the first point at which 50 m MOC can be obtained and maintained. At and after that point it is defined by a surface with origin at threshold level at a distance X_{Zf} relative to threshold. It ends at the termination of the APV segment. It has a nominal gradient of 2.5 per cent. Given evidence of capability to achieve missed approach climb gradients greater than the nominal 2.5 per cent, the Z surface and associated side surfaces may be adjusted together with the intermediate missed approach surface for gradients of 3, 4 and 5 per cent. It is bounded laterally by the LNAV primary area. The lower/inner edges of the associated side surfaces are defined by the edges of the LNAV missed approach primary area and the outer edges of the LNAV secondary areas 50 m above the final missed approach (Z_f) surface.

4.3.5.4.2.1 *Calculation of the start of the final missed approach surface (X_{Zf})*

$$X_{Zf} = (MOC_{app} - RDH) / \tan VPA - ATT - d - X + (MOC_{app} - 50) / \tan Z$$

4.3.6 *Termination of the APV segment*. The APV segment terminates at the MAPt if a turn is specified at the MAPt, at the MATF or the MAHF, whichever is earliest.

4.3.7 *Determination of minimum promulgated temperature*. Determine the minimum probable temperature and round it down to the next lower 5°C increment. Use this value to calculate the minimum VPA and the final approach surface (see 4.3.5 and 4.5.2). The resulting minimum VPA shall not be less than 2.5° at this temperature. If necessary, the published VPA shall be increased to achieve this minimum angle.

4.4 DETERMINATION OF OCH FOR APPROACH AND MISSED APPROACH OBSTACLES

4.4.1 *Minimum obstacle clearance (MOC)*

a) The MOC in the final approach (MOC_{app}) is 75 m. It shall be increased in accordance with the provisions of Part I, Section 4, Chapter 5, 5.4.6.2 a) and b), regarding increased margins for excessive length of the final approach, and for mountainous areas.

b) The MOC in the missed approach (MOC_{ma}) is 30 m for the intermediate and 50 m for the final missed approach. This margin is included in the construction of the Z_i and Z_f surfaces, which start at X_{Zi} and X_{Zf}.

4.4.2 *Approach and missed approach obstacles.* Accountable obstacles are those penetrating the APV-OAS. They are divided into approach and missed approach obstacles as follows.

4.4.2.1 The simplest method is by range: approach obstacles are those between the FAP and X_{Zi}, and missed approach obstacles are those after X_{Zi}. However in some cases this may produce an excessive penalty for certain missed approach obstacles (see Attachment to Part II, 1.9). Where desired by the appropriate Authority, missed approach obstacles may be defined as those above a plane parallel to the plane of the vertical path and with origin at X_{Zi} (See Figure III-3-4-7), i.e. obstacle height greater than [(X_{Zi} + x) tan VPA].

4.4.3 *Calculation of OCA/H within the APV segment.* OCA/H calculation involves a set of obstacle assessment surfaces (APV-OAS). If the APV-OAS are not penetrated, the OCA/H is defined by the lower limit of 75 m or 90 m (see 4.2.2 b)). However, if the APV-OAS are penetrated, the MOC_{app} (adjusted for side surface penetrations if appropriate) is added to the height of the highest approach obstacle, or the adjusted height of the largest missed approach penetration, whichever is greater. This value becomes the OCA/H.

4.4.3.1 First, determine the height of the highest approach obstacle penetrating the FAS or the horizontal plane as identified in 4.4.2. Next, reduce the heights of all missed approach obstacles to the height of equivalent approach obstacles by the formula given below:

$$h_a = \frac{h_{ma} \cot Z + (X - X_z)}{\cot z + \cot VPA}$$

where:

h_a	=	height of the equivalent approach obstacle
h_{ma}	=	height of the missed approach obstacle
cot Z	=	cotangent of the Z surface angle
cot VPA	=	cotangent of the VPA
X_Z	=	origin of the intermediate missed approach surface (Z_i) or final missed approach surface (Z_f) as appropriate relative to threshold (positive before, negative after).
X	=	Obstacle distance from threshold (positive before, negative after).

4.4.3.2 When calculating OCH in the final step above, the value of MOC_{app} can be modified to account for obstacles that penetrate the side surfaces as follows:

$$MOC_{app} = \min \{MOC_{app}; 2 \text{ x } MOC_{app} \text{ x } (1 - ABS(y))/SW\}$$

4.4.3.3 Determine OCH for the final approach, initial and intermediate missed approach segments by adding MOC_{app} to the height of the highest approach obstacle (real or equivalent). See Figure III-3-4-3.

$$OCH = h_a + MOC_{app}$$

4.4.3.4 *Final missed approach*. Recalculate h_a for obstacles penetrating the final missed approach surface (Z_f) and determine the OCH for these obstacles. If the OCH is greater than that already calculated, either adjust the turn or holding fix location, or increase the OCH to the new value.

Note.— For lower limit on OCA/H see 4.2.2.

4.5 PROMULGATION

4.5.1 The general criteria in Part I, Section 4, Chapter 9, 9.5, "Procedure naming for arrival and approach charts" apply. The instrument approach chart shall be entitled $RNAV_{(GNSS)}$ Rwy XX or $RNAV_{(DME/DME)}$. The minimum box on the chart shall include OCA/H values for LNAV and LNAV/VNAV operations and shall include the RNP value where applicable.

4.5.2 OCA/H shall be published in accordance with Part I, Section 4, Chapter 5, 5.5, "Promulgation". In no case will the OCA/H be lower than the values given in 4.2.2.

4.5.3 In addition, the following shall be promulgated:

a) RDH (waypoint coordinates, height);

b) VPA (degrees and hundredths of a degree for databases/degrees and tenths of a degree for charting);

c) the minimum temperature for which Baro-VNAV operations are authorized; and

d) for database coding purposes only, the LNAV, FAF and MAPt.

4.5.4 The optimum promulgated VPA is 3°; it shall not be less than 3° or greater than 3.5°. See 4.3.5.2.2, "Determination of minimum promulgated temperature".

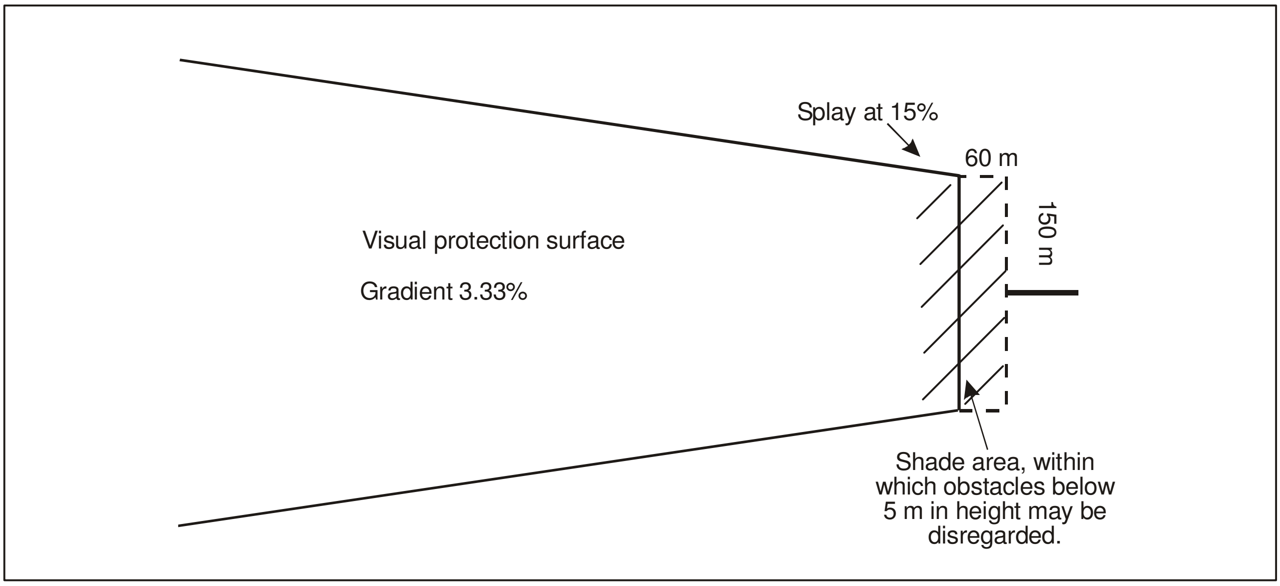


Figure III-3-4-1. Visual protection surface

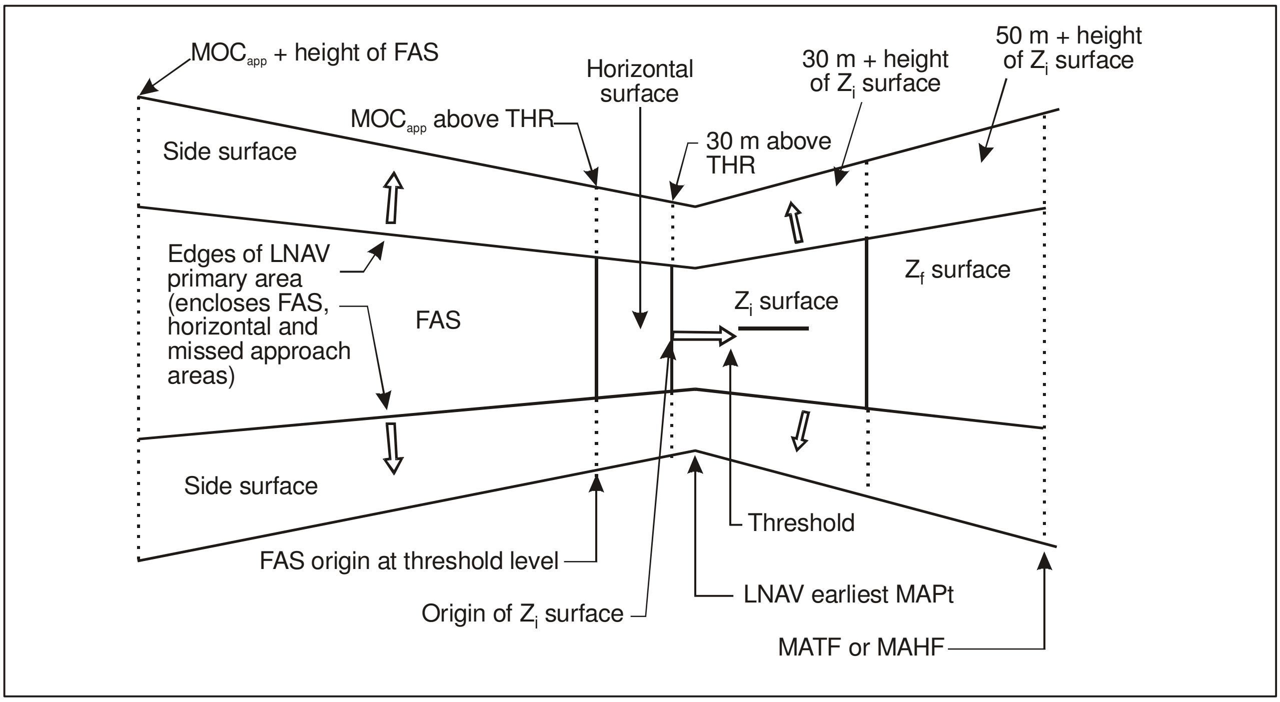


Figure III-3-4-2. Baro-VNAV area — APV OAS in plan view

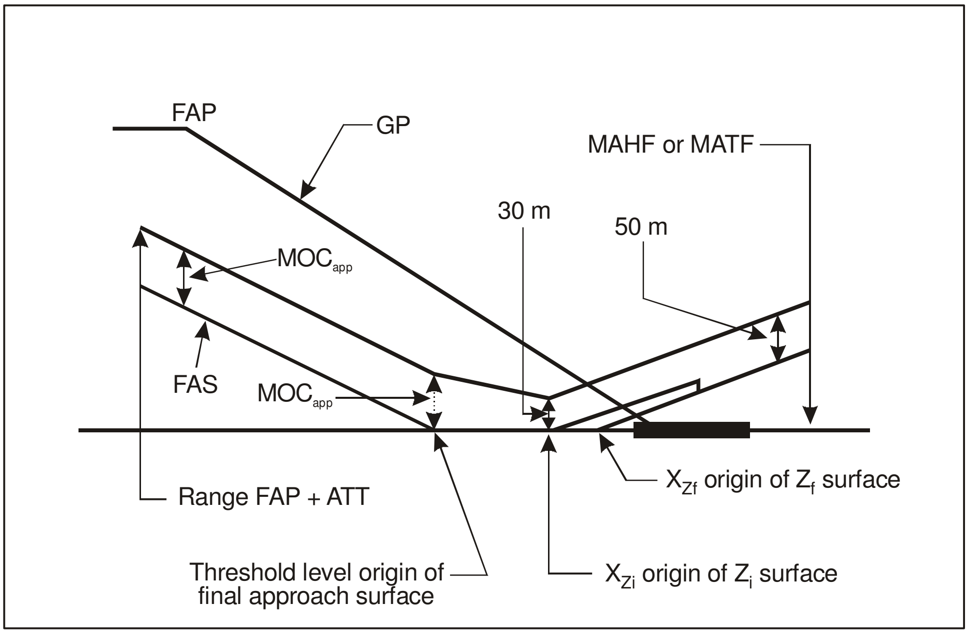


Figure III-3-4-3. Baro-VNAV — Profile view

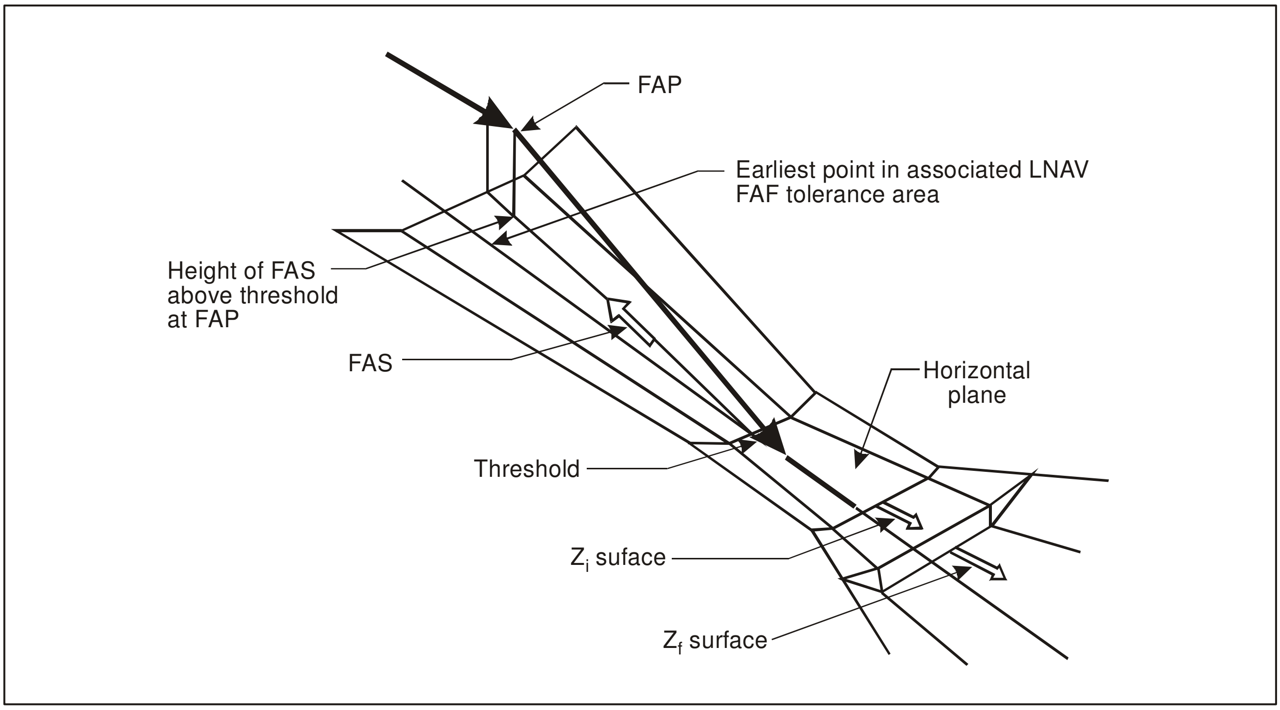
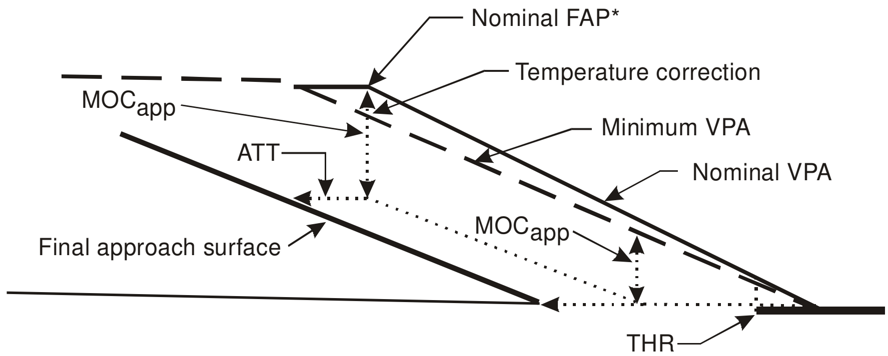


Figure III-3-4-4. Representation of APV OAS surfaces



* The range of the FAP will differ from the nominal FAP depending on the actual temperature error from ISA and the temperature compensation applied by the pilot in the intermediate segment. Systems unable to intercept a vertical angle from RDH will continue to the computed nominal FAP and smoothly intercept the VPA from above.

Figure III-3-4-5. VNAV final approach surface and minimum VPA

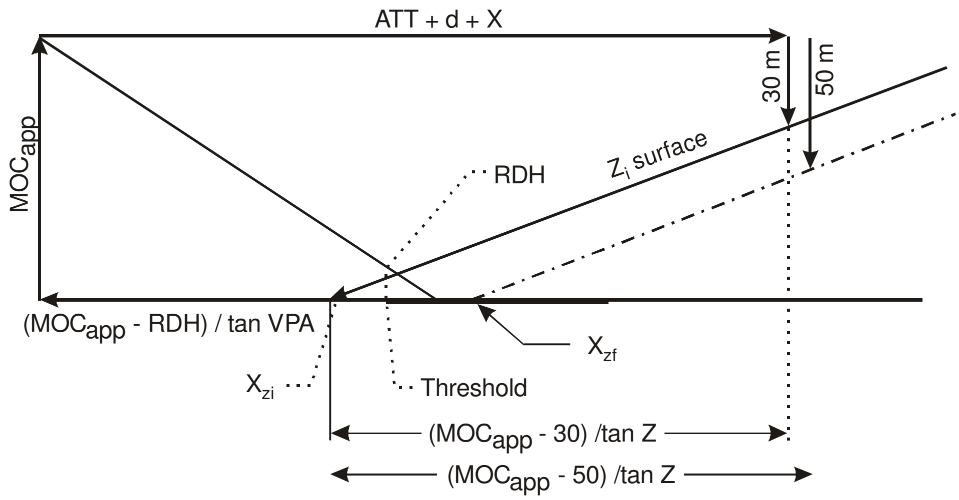


Figure III-3-4-6. Calculation of XZ

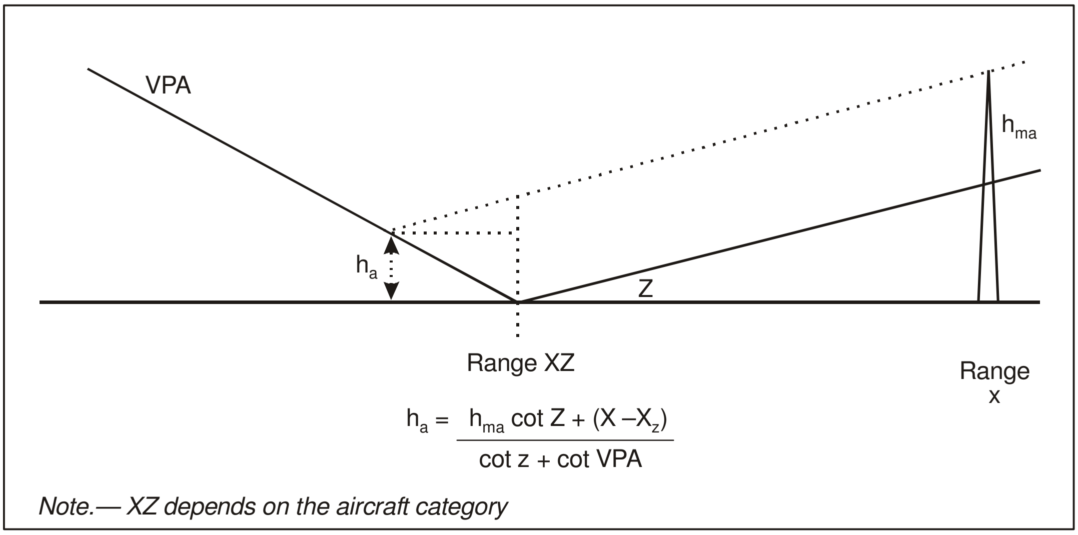


Figure III-3-4-7. Calculation of h_a from h_{ma}

— — — — — — — —

Appendix A to Chapter 4

TEMPERATURE CORRECTION

1.1 Requirement for temperature correction

The calculated minimum safe altitudes/heights must be adjusted when the ambient temperature on the surface is much lower than that predicted by the standard atmosphere.

1.2 Tabulated corrections

For FAS angle calculation the cold temperature correction should be obtained from Tables III-3-4-App A-1 and III-3-4-App A-2. These tables are calculated for a sea level aerodrome. They are therefore conservative when applied at higher aerodromes (see paragraph 3).

1.3 Calculation of corrections

1.3.1 To calculate the corrections for specific aerodrome elevations, altimeter setting sources above sea level, or for values not tabulated, use Equation 24 from Engineering Science Date Unit Publication, Performance Volume 2, Item Number 77022[1]. This assumes an off-Standard atmosphere.

$$\Delta h_{CORRECTION} = \Delta h_{PAirplane} - \Delta h_{GAirplane} = (-\Delta T_{std}/L_o) ln[1+L_o\ \Delta h_{PAirplane} / (T_o + L_o . h_{PAerodrome})]$$

where:

	$\Delta h_{PAirplane}$	=	Aircraft height above aerodrome (pressure)
	$\Delta h_{GAirplane}$	=	Aircraft height above aerodrome (geopotential)
	ΔT_{std}	=	temperature deviation from the standard day (ISA) temperature
	L_o	=	standard temperature lapse rate with pressure altitude in the first layer (sea level to tropopause) of the ISA
	T_o	=	standard temperature at sea level

Note.— Geopotential height includes a correction to account for the variation of g (average 9.8067 m sec^2) with heights. However, the effect is negligible at the minimum altitudes considered for obstacle clearance: the difference between geometric height and geopotential height increases from zero at mean sea level to –59 ft at 36 000 ft.

1.3.2 The above equation cannot be solved directly in terms of $\Delta h_{GAirplane}$, and an iterative solution is required. This can be done with a simple computer or spreadsheet programme.

---

1. Reprinted by permission of ESDU International plc., 27 Corsham Street, London, N1 6UA, UK.

1.4 Assumption regarding temperature lapse rates

The above equation assumes a constant "off-standard" temperature lapse rate. The actual lapse rate may vary considerably from the assumed standard, depending on latitude and time of year. However, the corrections derived from the calculation method are valid up to 11 000 m (36 000 ft).

Table III-3-4-App A-1. Temperature correction to be used in calculating the FAS angle (m)

Note.— T = aerodrome temperature (°C) and H = height above threshold (m).

T°C\H	*300*	*450*	*600*	*750*	*900*	*1 200*	*1 300*	*1 400*	*1 500*
0	17	25	33	42	50	67	73	78	84
–10	29	43	58	72	87	116	126	136	146
–20	42	63	84	105	126	169	183	198	212
–30	56	84	112	141	169	226	246	265	285
–40	77	107	143	179	216	289	314	339	364
–50	88	132	176	222	267	358	388	419	450

Table III-3-4-App A-2. Temperature correction to be used in calculating the FAS angle (ft)

Note.— T = aerodrome temperature (°C) and H = height above threshold (ft).

T°C\H	*1 000*	*1 500*	*2 000*	*2 500*	*3 000*	*3 500*	*4 000*	*4 500*	*5 000*
0	55	83	111	139	167	195	223	251	280
–10	96	144	192	240	289	337	387	436	485
–20	139	201	279	350	421	492	563	635	708
–30	186	280	374	469	564	659	755	852	949
–40	237	357	477	580	719	842	965	1 088	1 212
–50	293	441	590	739	890	1 041	1 193	1 347	1 500

— — — — — — — —

Appendix B to Chapter 4

ALGORITHM FOR CALCULATING THE HEIGHT OF SURFACE DEFINED BY FOUR POINTS IN SPACE

The height (Z) of a point in the OAS side surface located at (X, Y), between the origin of the FAS at threshold level (X_{FAS}) and the origin of the Z_i surface (X_{Zi}) at threshold level, could be calculated using the four vertices of the surface (X1, Y1, Z1), (X2, Y2, Z2), (X3, Y3, Z3), (X4, Y4, Z4) and the following formulae (see Figure III-3-4-App B-1):

Calculation of Z at (X,Y):

X5 = X
Y5 = Y1 + (Y2 - Y1) × ((X1 - X) / (X1 - X2))
Z5 = Z1 + (Z2 - Z1) × ((X1 - X) / (X1 - X2))

X6 = X
Y6 = Y3 + (Y4 - Y3) × ((X3 - X) / (X3 - X4))
Z6 = Z3 + (Z4 - Z3) × ((X3 - X) / (X3 - X4))

Finally, calculate the required height Z as follows:

Z = Z5 + (Z6 - Z5) × ((Y - Y5) / (Y6 - Y5))

Definitions of vertices
X1= X3 = X_{FAS}
X2 = X4 = X_{Zi}
Y1 and Y2 = distance of edge of primary area at X_{FAS} and X_{Zi} respectively
Y3 and Y4 = distance of edge of secondary area at X_{FAS} and X_{Zi} respectively
Z1 = Z2 = 0
Z3 = MOC_{app}
Z4 = 30m

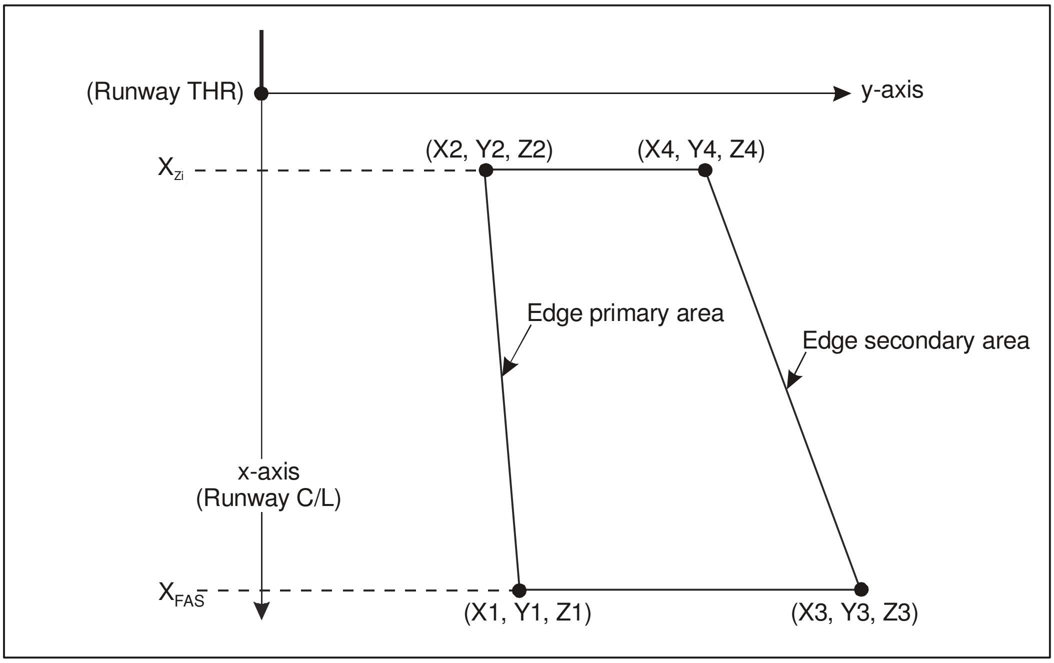


Figure III-3-4-App B-1.

Chapter 5

APV I/II PROCEDURES

(To be developed)

Chapter 6

PRECISION APPROACH PROCEDURES — GBAS

6.1 INTRODUCTION

6.1.1 Application

The GBAS criteria in this chapter are based on ILS criteria and are related to the ground and airborne equipment performance and integrity required to meet the Category I operational objectives described in Annex 10. An illustration of the specific definitions used in this chapter is given in Figure III-3-6-1.

Note.— While specific GBAS Category I criteria are in preparation, the criteria contained in this chapter are based on an ILS Category I equivalency method. Development of Annex 10 requirements for Category II and III approaches is in progress; pending their finalization, procedure design criteria will be made available.

6.1.2 Procedure construction

The procedure from en route to the GBAS final approach segment and in the final missed approach phase conforms with the general criteria. The differences are found in the physical requirements for the GBAS precision segment which contains the final approach segment as well as the initial and intermediate phases of the missed approach segment. These requirements are related to the performance of the GBAS Cat I system.

6.1.3 Standard conditions

The following list contains the standard assumptions on which procedures are developed. Provisions are made for adjustments where appropriate. Adjustments are mandatory when conditions differ adversely from standard conditions and are optional when so specified (see 6.4.8.7, "Adjustment of OAS constants").

a) Maximum aircraft dimensions are assumed to be the following:

Aircraft category	Wing span	Vertical distance between the flight paths of the wheels and the GBAS antenna (m)
H	30	3
A, B	60	6
C, D	65	7
D_L	80	8

Note 1.— OCA/H for Cat D_L aircraft is published when necessary.

Note 2.— The dimensions shown are those which encompass current aircraft types They are chosen to facilitate OCA/H calculations and promulgation of aircraft category related minima. It is assumed that these dimensions are not intended to be used for other purposes than the OCA/H calculations in other ICAO documents. The use of OAS surfaces to calculate OCA/H may result in significant differences between aircraft categories because of small differences in size. For this reason, it is always preferable to use the Collision Risk Model (6.4.9) which will allow for more realistic assessment for both height and position of obstacles.

Note 3.— Current Category E aircraft are not normally civil transport aircraft and their dimensions are not necessarily related to V_{at} *at maximum landing mass. For this reason, they should be treated separately on an individual basis.*

b) Missed approach climb gradient: 2.5 per cent.

c) GBAS course width: 210 m at threshold.

d) Glide path angle:

1) minimum/optimum: 3.0°;

2) maximum: 3.5°;

e) GBAS reference datum height: 15 m (50 ft).

f) All obstacle heights are referenced to threshold elevation. A declaration by the procedure designer shall be made for the value of undulation (N) at each runway threshold.

g) The delta length offset is zero.

6.1.3.1 *Final approach segment (FAS) data.* The final approach segment is defined by data prepared by the procedure designer. The accuracy of the path is therefore totally dependent on the accuracy and integrity of the original data on the runway and calculations carried out by the designer. The total description of the path, including the glide-path, lateral guidance sector width, alignment and all other parameters describing the path are originated by the designer and are not affected by the location of ground facilities. The path parameters are designed using geodetic and geometric calculations and the parameters are formatted into a FAS data block in electronic media as described in the appendix to this chapter. Data are then added to provide a cyclic redundancy check (CRC), and the complete block is transferred to users to insure the integrity of the data throughout the process leading to inclusion of the path data in the GBAS system for transmission to user airborne systems. A complete description of the FAS data block is included in Doc 9368, *Instrument Flight Procedures Construction Manual*, Attachment C.5, along with an example of the process and product.

6.1.4 Obstacle clearance altitude/height (OCA/H)

The GBAS criteria enable an OCA/H to be calculated for each category of aircraft. See Part I, Section 4, Chapter 1, 1.8, “Categories of aircraft”. Where statistical calculations were involved, the OCA/H values were designed against an overall safety target for risk of collision with obstacles of 1×10^{-7}, i.e. 1 in 10 million per approach. The OCA/H ensures clearance of obstacles from the start of the final approach to the end of the intermediate missed approach segment.

Note.— This OCA/H is only one *of the factors to be taken into account in determining decision height as defined in Annex 6.*

6.1.5 Methods of calculating OCA/H

6.1.5.1 *General.* Three methods of calculating OCA/H are presented, which in turn involve progressive increases in the degree of sophistication in the treatment of obstacles. Standard conditions (as specified in 6.1.3) are assumed to exist unless adjustments for non-standard conditions have been made.

6.1.5.2 *First method.* The first method involves a set of surfaces derived from the Annex 14 precision approach obstacle limitation surfaces and a missed approach surface described in 6.4.7.2, "Definition of basic ILS surfaces" and from this point forward termed "Basic ILS surfaces". Where the standard conditions exist as specified in 6.1.3 and where the basic ILS surfaces are free of penetrations (see 6.4.7.1, "General") the OCA/H for Cat I is defined by aircraft category margins. If the basic ILS surfaces are penetrated, then the OCA/H is calculated as described in 6.4.7.3, "Determination of OCA/H with basic ILS surfaces".

6.1.5.3 *Second method.* The second method involves a set of obstacle assessment surfaces (OAS) above the basic ILS surfaces (see 6.4.8.3, "Definition of OAS"). If the OAS are not penetrated, and provided the obstacle density below the OAS is operationally acceptable (see 6.4.8.9, "Effect of obstacle density on OCA/H"), the OCA/H for Cat I is still defined by the aircraft category margins. However, if the OAS are penetrated, then the aircraft category related margin is added to the height of the highest approach obstacle, or to the adjusted height of the largest missed approach penetration, whichever is greater. This value becomes the OCA/H.

6.1.5.4 *Third method.* The third method, using a collision risk model (CRM), is employed either as an alternative to the use of the OAS criteria (second method) or when the obstacle density below the OAS is considered to be excessive. The CRM accepts all objects as an input and assesses, for any specific OCA/H value, both the risk due to individual obstacles and the accumulated risk due to all the obstacles. It is intended to assist operational judgement in the choice of an OCA/H value.

Note 1.— While specific GBAS distributions for the existing CRM are being developed, use should be made of the current ILS CRM.

Note 2.— The CRM does not take into account the characteristics of helicopters. The CRM can be used but the method should be conservative.

6.1.6 References

The following relate to and amplify the material contained in this chapter:

a) background information relating to the derivation of the OAS material (Attachment to Part II, paragraph 1) and to airborne and ground equipment performance assumed in the derivation of the OAS (paragraph 2);

b) turning missed approach after precision approach (Part II, Section 1, Chapter 1, Appendix A);

c) independent parallel approaches to closely spaced parallel runways (Part II, Section 1, Chapter 1, Appendix D);

d) determining ILS glide path descents/MLS elevation heights and distances (Part II, Section 1, Chapter 1, Appendix C); and

e) PANS-OPS OAS CD-ROM.

Examples of OCA/H calculations can be found in the *Instrument Flight Procedures Construction Manual* (Doc 9368).

6.1.7 GBAS with glide path inoperative

The GBAS with glide path inoperative is a non-precision approach procedure. The principles of Chapter 3, "Non-precision approach procedures" apply.

6.2 INITIAL APPROACH SEGMENT

6.2.1 General

The initial approach segment for GBAS must ensure that the aircraft is positioned within the operational service volume of the GBAS on a track or heading that will facilitate final approach course interception. For this reason, the general criteria, which apply to the initial segment (see Chapter 2), are modified in accordance with 6.2.2, "Alignment" and 6.2.3, "Area". For RNAV initial approach segments, the criteria in the applicable RNAV chapters apply.

6.2.2 Initial approach segment alignment

The angle of interception between the initial approach track and the intermediate track should not exceed 90°. In order to permit the auto pilot to couple on to the final approach course, an interception angle not exceeding 30° is desirable. When the angle exceeds 70° a radial, bearing, radar vector, DME or RNAV information providing at least 4 km (2 NM) (Cat H, 1.9 km (1 NM)) of lead shall be identified to assist the turn onto the intermediate track. When the angle exceeds 90°, the use of a reversal, racetrack, or dead reckoning (DR) track procedure (see Part I, Section 4, Chapter 3, Appendix A, "Initial approach using dead reckoning (DR)") should be considered.

6.2.3 Initial approach segment area

The area is as described in the general criteria (see 4.3.3) The only exception to these criteria is that the intermediate approach fix (IF), must be located within the service volume of the GBAS, and normally at a distance not exceeding 37 km (20 NM) from the landing threshold point (LTP). When radar is used to provide track guidance to the IF, the area shall be in accordance with Part II, Section 2, Chapter 6, 6.2, "Initial approach segment".

6.3 INTERMEDIATE APPROACH SEGMENT

6.3.1 General

6.3.1.1 The intermediate approach segment for GBAS differs from the general criteria in that:

a) the alignment coincides with the final approach course;

b) the length may be reduced; and

c) in certain cases the secondary areas may be eliminated.

6.3.1.2 The primary and secondary areas at the FAP are defined in terms of the ILS surfaces. Consequently, the criteria in Chapter 5 are applied except as noted for alignment, area length, width and obstacle clearance in 6.3.2 through 6.3.5 below. For RNAV intermediate approach segments, the criteria in the applicable RNAV chapters apply.

6.3.2 Intermediate approach segment alignment

The intermediate approach segment of a GBAS procedure shall be aligned with the final approach course.

6.3.3 Intermediate approach segment length

6.3.3.1 The optimum length of the intermediate approach segment is 9 km (5 NM) (Cat H, 3.7 km (2 NM)). This segment shall allow interception with the final approach course and with the glide path.

6.3.3.2 The segment length should be sufficient to permit the aircraft to stabilize and establish on the final approach course prior to intercepting the glide path, taking into consideration the angle of interception with the final approach course.

6.3.3.3 Minimum values for distance between final approach and interception of the glide path are specified in Table III-3-6-1; however, these minimum values should only be used if usable airspace is restricted. The maximum length of the segment is governed by the requirement that it be located wholly within the service volume of the GBAS, and normally at a distance not exceeding 37 km (20 NM) from the landing threshold point (LTP).

6.3.4 Intermediate approach segment area width

6.3.4.1 The total width at the beginning of the intermediate approach segment is defined by the total width of the initial approach segment and tapers uniformly to match the horizontal distance between the OAS X surfaces at the FAP (see 6.4.8.3, "Definition of OAS").

6.3.4.2 For obstacle clearance purposes the intermediate approach segment is divided into a primary area bounded on each side by a secondary area. However, when a DR track is used in the initial approach segment, the primary area of the intermediate segment extends across the full width and secondary areas are not applied.

6.3.4.3 The primary area is determined by joining the primary initial approach area with the final approach surfaces (at the FAP). At the interface with the initial approach segment the width of each secondary area equals half the width of the primary area. The secondary area width decreases to zero at the interface with the final approach surfaces. See Figure III-3-6-2.

6.3.4.4 Where a racetrack or reversal manoeuvre is specified prior to intercepting the final approach course, the provisions in Part I, Section 4, Chapter 4, 4.4.4, "Turn not at the facility" apply, the facility being the GARP itself and the FAF being replaced by the FAP. (See Figure III-3-6-3).

6.3.5 Intermediate approach segment obstacle clearance

The obstacle clearance is the same as defined in Part I, Section 4, Chapter 4, except where the procedure permits a straight-in approach in which the aircraft is stabilized on the final approach course prior to crossing the IF. In this case, obstacles in the secondary areas need not be considered for the purpose of obstacle clearance.

6.4 PRECISION SEGMENT

6.4.1 General

The precision segment for GBAS is aligned with the final approach course and contains the final descent for landing, the initial and the intermediate missed approach. See Figure III-3-6-4.

6.4.2 Origin

The precision segment starts at the final approach point, that is the intersection of the nominal glide path and the minimum altitude specified for the preceding segment. The FAP should not normally be located more than 18.5 km (10.0 NM) before threshold, unless adequate glide path guidance beyond the minimum specified in Annex 10 is provided.

6.4.3 Glide path verification check

A fix at the FAP is necessary so as to permit comparison between the indicated glide path and the aircraft altimeter information.

6.4.4 Descent fix

A descent fix shall be located to start the final approach segment and it becomes the final approach point linking the MOC in the preceding segment smoothly with the precision surfaces. The descent fix should not normally be located more than 18.5 km (10.0 NM) before threshold, unless adequate glide path guidance beyond the minimum specified in Annex 10 is provided. The tolerance of the descent fix does not need to be considered due to accuracy.

Note.— Guidance material for determining the distance to the descent fix from the landing threshold is contained in Part II, Section 1, Chapter 1, Appendix C.

6.4.4.1 The provisions of Part I, Section 2, Chapter 2, 2.7.4 which allow obstacles close to the fix to be ignored, apply in the area below the 15 per cent gradient within the precision surfaces.

6.4.5 Missed approach

The missed approach shall be initiated no lower than the intersection of the nominal glide path with the decision altitude/height (DA/H). The DA/H is set at or above the OCA/H, which is determined as specified in 6.4.7 to 6.4.9 and 6.5.

6.4.6 Termination

The precision segment normally terminates at the point where the final phase of the missed approach commences (see Part I, Section 4, Chapter 6, 6.2.3, "Final phase") or where the missed approach climb surface Z starting 900 m past threshold reaches a height of 300 m (1 000 ft) above threshold, whichever is lower.

6.4.7 Obstacle clearance of the precision segment using basic ILS surfaces for GBAS operations

6.4.7.1 *General.* The area required for the precision segment is bounded overall by the basic ILS surfaces defined in 6.4.7.2. In standard conditions there is no restriction on objects beneath these surfaces (see 6.1.3, "Standard Conditions"). Objects or portions of objects that extend above these surfaces must be either:

a) minimum mass and frangible; or

b) taken into account in the calculation of the OCA/H.

6.4.7.2 *Definition of basic ILS surfaces.* The surfaces to be considered correspond to a subset of Annex 14 obstacle limitation surfaces specified for precision approach runway code numbers 3 or 4. These are (see Figure III-3-6-5):

a) the approach surface continuing to the final approach point (first section 2 per cent gradient, second section 2.5 per cent gradient as described in Annex 14);

b) the runway strip assumed to be horizontal at the elevation of the threshold;

c) the missed approach surface. This is a sloping surface which:

   1) starts at a point 900 m past the threshold (Cat H, a starting point of 700 m past the threshold can be considered if necessary) at threshold elevation;

   2) rises at a 2.5 per cent gradient; and

   3) splays so as to extend between the transitional surfaces. It extends with constant splay to the level of the inner horizontal surface, and thereafter, continues at the same gradient but with a 25 per cent splay until the termination of the precision segment; and

d) the extended transitional surfaces, which continue longitudinally along the sides of the approach and missed approach surfaces and to a height of 300 m above threshold elevation.

6.4.7.3 *Determination of OCA/H with basic ILS surfaces.*

6.4.7.3.1 Where the basic ILS surfaces specified in 6.4.7.2 are not penetrated, the OCA/H for Category I is defined by the margins specified in Table III-3-6-3. Obstacles may be excluded when they are below the transitional surface defined by Annex 14 for runways with code numbers 3 and 4, regardless of the actual runway code number (i.e., the surfaces for code numbers 3 and 4 are used for the obstacle assessment on runways with code numbers 1 and 2).

6.4.7.3.2 If the basic ILS surfaces listed above are penetrated by objects other than those tabulated in Table III-3-6-2 the OCA/H may be calculated directly by applying height loss/altimeter margins to obstacles (see 6.4.8.8). The obstacles in Table III-3-6-2 may only be exempted if the GBAS course width meets the standard condition of 210 m (see 6.1.3).

6.4.7.3.3 An object which penetrates any of the basic ILS surfaces and becomes the controlling obstacle, but which must be maintained because of its function with regard to air navigation requirements, may be ignored under certain circumstances in calculating the OCA/H, with the following provision. It must be established by the appropriate authority that the portion which penetrates the surface is of minimum mass and frangibly mounted and would not adversely affect the safety of aircraft operations.

6.4.8 Obstacle clearance of the precision segment using obstacle assessment surfaces (OAS) criteria for GBAS operations

6.4.8.1 *General*

6.4.8.1.1 This section describes the OAS surfaces, the constants which are used to define these surfaces, and the conditions under which adjustments may be made. The OAS dimensions are related to the GBAS geometry (GARP – LTP distance, glide path angle), and the category of operation. (For GBAS only Category I apply). A table of OCA/H values for each aircraft category may be promulgated for GBAS Cat I operations at the particular airfield.

6.4.8.1.2 Additional material is included to enable appropriate authorities to assess realistic benefits for claims of improved performance and associated conditions (see 6.4.8.7, "Adjustment of OAS constants").

6.4.8.1.3 Note that the OAS are not intended to replace Annex 14 surfaces as planning surfaces for unrestricted obstacle growth. The obstacle density between the basic ILS surfaces and the OAS must be accounted for (see 6.4.8.9, "Effect of obstacle density on OCA/H").

6.4.8.2 *Frame of reference*

Positions of obstacles are related to a conventional x, y, z coordinate system with its origin at threshold. See Figure III-3-6-9. The x-axis is parallel to the precision segment track, positive x coordinates measured before landing threshold and negative x coordinates measured after landing threshold. The y-axis is at right angles to the x-axis. Although shown conventionally in Figure III-3-6-9, *in all calculations associated with OAS geometry, the y-coordinate is always counted as positive.* The z-axis is vertical, heights above threshold being positive. All dimensions connected with the OAS are specified in metres only. The dimensions should include any adjustments necessary to cater for tolerances in survey data (see Part I, Section 2, Chapter 1, 1.8).

6.4.8.3 *Definition of obstacle assessment surfaces (OAS)*

6.4.8.3.1 The OAS consist of six sloping plane surfaces (denoted by letters W, X, Y, and Z) arranged symmetrically about the precision segment track, together with the horizontal plane which contains the threshold (see Figures III-3-6-7 and III-3-6-8). The geometry of the sloping surfaces is precisely defined by four simple linear equations of the form $z = Ax + By + C$. In these equations x and y are position coordinates and z is the height of the surface at that position (see Figure III-3-6-6).

6.4.8.3.2 For each surface a set of constants A, B and C are obtained from PANS-OPS OAS CD-ROM for the operational range of GARP- threshold distances and glide path angles. These constants may be modified as specified in 6.4.8.7, "Adjustment of OAS constants".

6.4.8.3.3 The Category I OAS are limited by the length of the precision segment and, except for the W and X surfaces, by a maximum height of 300 m.

6.4.8.3.4 Where the Annex 14 approach and transitional obstacle limitation surfaces for code numbers 3 and 4 precision approach runways penetrate inside the OAS, the Annex 14 surfaces become the OAS (i.e. the surfaces for code numbers 3 and 4 are used for obstacle assessment on runways with code numbers 1 and 2). The Annex 14 inner approach, inner transitional and balked landing obstacle limitation surfaces protect Category III operations provided the Category II OCA/H is at or below the top of those surfaces, which may be extended up to 60 m if necessary (see Figure III-3-6-5).

6.4.8.4 *OAS constants – specification*

For Category I operations the constants A, B and C for each sloping surface are obtained from the PANS-OPS OAS CD-ROM. The PANS-OPS OAS CD-ROM gives coefficients for glidepath angles between 2.5 and 3.5 degrees in 0.1 degree steps, and for any GARP-LTP distance between 2 000 m and 4 500 m. Extrapolation outside these limits is not permitted. if a GARP-LTP distance outside this range is entered, the PANS-OPS CD ROM gives the coefficients for 2 000 m or 4 500 m as appropriate, which must be used. For an example of the PANS-OPS OAS CD-ROM results see Figure III-3-6-11.

6.4.8.5 *Calculation of OAS heights*

To calculate the height z of any of the sloping surfaces at a location x', y', the appropriate constants should be first obtained from the PANS-OPS OAS CD-ROM. These values are then substituted in the equation z = Ax' + By' + C. If it is not clear which of the OAS surfaces is above the obstacle location, this should be repeated for the other sloping surfaces. The OAS height is the highest of the plane heights (zero if all the plane heights are negative).

Note.— The PANS-OPS OAS CD-ROM also contains an OCH calculator that will show the height of OAS surface Z above any X, Y location. It includes all the adjustments specified for ILS geometry, aircraft dimensions, missed approach climb gradient and GBAS RDH.

6.4.8.6 *OAS template construction*

Templates, or plan views of the OAS contours to map scale, are sometimes used to help identify obstacles for detail survey (see Figure III-3-6-10). The OAS data on the PANS-OPS OAS CD-ROM includes the coordinates of the points of intersection of the sloping surfaces at threshold level and at 300 m above threshold level for Cat I (see Figure III-3-6-11). The intersection coordinates at threshold level are labelled as C, D and E.

6.4.8.7 *Adjustment of OAS constants*

6.4.8.7.1 *General.* The following paragraphs describe the adjustments which may be made to the OAS constants. These adjustments are mandatory when the standard conditions are not met (See 6.1.3, "Standard Conditions"). Optional adjustments may be made when so specified. For examples of calculations see *Instrument Flight Procedures Construction Manual* (Doc 9368).

6.4.8.7.2 *Reasons for adjusting constants.* The constants may be modified by the PANS-OPS OAS CD-ROM to account for the following:

a) dimensions of specific aircraft;

b) the height of the GBAS DCP;

c) GBAS course width greater than 210 m at threshold; and

d) missed approach climb gradient.

6.4.8.7.3 *Specific aircraft dimensions.* An adjustment is mandatory where aircraft dimensions exceed those specified in 6.1.3, "Standard conditions" and is optional for aircraft with smaller dimensions. The PANS-OPS OAS CD-ROM adjusts the OAS coefficients and template coordinates for the standard dimensions of category A, B, C, D, and D_L aircraft automatically. It will do the same for specific aircraft dimensions in any category. It uses the following correction formula to adjust the coefficient C for the W, W*, X and Y surfaces:

W surface: $C_w corr = C_w - (t - 6)$

W* surface: $C_w{*}corr = C_w{*} - (t - 6)$

X surface: $C_x corr = C_x - B_x \times P$

Y surface: $C_y corr = C_y - B_y \times P$

where:

P = [t/B_x or s + (t-3)/B_x), whichever is the maximum] – [6/B_x or 30 + 3/B_x , whichever is the maximum]; and

s = semi-span

t = vertical distance between paths of the GP antenna and the lowest part of the wheels.

6.4.8.7.4 *Height of the datum crossing point (RDH).* The constants are based on a reference datum height (RDH) of 15 m. An adjustment to the OAS constants is mandatory for an RDH less than 15 m, and is optional for an RDH greater than 15 m. The PANS-OPS OAS CD-ROM adjusts the OAS coefficients and template co-ordinates by correcting the tabulated values of the coefficient C for the W, W*, X and Y surfaces as follows:

C_{corr} = C + (RDH – 15)

where: C_{corr} = corrected value of coefficient C for the appropriate surface

C = tabulated value.

6.4.8.7.5 *GBAS course width greater than 210 m at threshold.* Where the GBAS course width at threshold is greater than the nominal value of 210 m, the collision risk model (CRM) method described in 6.4.9 shall be used. Adjustments for sector widths less than 210 m shall not be made, and are inhibited on the PANS-OPS OAS CD-ROM.

6.4.8.7.6 *Missed approach gradient.* If missed approach climb gradients better than the nominal 2.5 per cent can be achieved, the Y and Z surfaces may be adjusted. This is done by selecting the desired missed approach climb gradient in the PANS-OPS OAS CD-ROM. The programme then adjusts the Y and Z surface constants.

6.4.8.8 *Determination of OCA/H with OAS*

6.4.8.8.1 *General.* The OCA/H is determined by accounting for all obstacles which penetrate the basic ILS surfaces defined in 6.4.7.2 and the OAS applicable to the GBAS Category I operation being considered. The exemptions listed in 6.4.7.3, “Determination of OCA/H with basic ILS surfaces” for obstacles penetrating the basic ILS surfaces may be applied to obstacles penetrating the OAS, providing the criteria listed in that paragraph are met. For GBAS Category I operations ILS Cat I OAS apply.

6.4.8.8.2 *Calculation of OCA/H values with OAS.* Accountable obstacles, as determined below in 6.4.8.8.2.1, “OCA/H calculation steps”, are divided into approach and missed approach obstacles. The standard method of categorization is as follows. Approach obstacles are those between the FAP and 900 m after threshold (Cat H, 700 m if necessary). Missed approach obstacles are those in the remainder of the precision segment (see Figure III-3-6-12). However, in some cases this categorization may produce an excessive penalty for certain missed approach obstacles (see Attachment to Part II, 1.9). Where desired by the appropriate authority, missed approach obstacles may be defined as those above a plane surface parallel to the plane of the glide path and with origin at -900 m (Cat H, –700 m if necessary) (see Figure III-3-6-13), i.e. obstacle height greater than (900 + x) tan θ.

6.4.8.8.2.1 *OCA/H calculation steps*

a) Determine the height of the highest approach obstacle.

b) Convert the heights of all missed approach obstacles (h_{ma}) to the heights of equivalent approach obstacles (h_a) by the formula given below, and determine the highest equivalent approach obstacle.

c) Determine which of the obstacles identified in steps a) and b) is the highest. This will give the controlling obstacle.

d) Add the appropriate aircraft category related margin (Table III-3-6-3) to the height of the highest controlling obstacle.

$$h_a = \frac{h_{ma} \cot Z + (-x_z + x)}{\cot Z + \cot \theta}$$

where: h_a = height of equivalent approach obstacle

h_{ma} = height of missed approach obstacle

θ = glide path angle

Z = angle of missed approach surface

x = range of obstacle relative to landing threshold point (negative after LTP)

x_z = distance from threshold to origin of Z surface (–900 m, –700 m for Cat H)

6.4.8.8.3 *Adjustments for high airfield elevations and steep glide path angles.*

6.4.8.8.3.1 The margins shall be adjusted as follows:

a) for airfield elevation higher than 900 m (2 953 ft), the allowances shall be increased by 2 per cent of the radio altimeter margin per 300 m (1 000 ft) airfield elevation; and

b) for glide path angles greater than 3.2° in exceptional cases, the allowances shall be increased by the 5 per cent of the radio altimeter margin per 0.1° increase in glide path angle between 3.2° and 3.5°.

6.4.8.8.3.1.1 Procedures involving glide paths greater than 3.5° or any angle when the nominal rate of descent (V_{at} for the aircraft type × the sine of the glide path angle) exceeds 5 m/sec (1 000 ft/min), are non-standard. They require the following:

a) increase of height loss margin (which may be aircraft type specific);

b) adjustment of the origin of the missed approach surface;

c) adjustment of the slope of the W surface;

d) re-survey of obstacles; and

e) the application of related operational constraints.

Such procedures are normally restricted to specifically approved operators and aircraft, and are associated with appropriate aircraft and crew restrictions. They are not to be used as a means to introduce noise abatement procedures.

6.4.8.8.3.1.2 Part II, Section 1, Chapter 1, Appendix B shows the procedure design changes required and the related operational/certification considerations.

Example: Aircraft Category C — Aerodrome elevation:

1 650 m above MSL; glide path angle 3.5°

Tabulated allowances: radio altimeter 22 m

(Table III-3-6-3) pressure altimeter 46 m

Correction for aerodrome elevation:

$22 \times 2/100 \times 1\,650/300 = 2.42$ m

Correction for glide path angle:

$22 \times 5/100 \times (3.5–3.2)/0.1 = 3.30$ m

Total correction 5.72 m rounded up to 6 m

Corrected radio altimeter margin 22 + 6 = 28 m

Corrected pressure altimeter margin 46 + 6 = 52 m

6.4.8.8.3.2 *Exceptions and adjustments to values in Table III-3-6-3.* Values in Table III-3-6-3 are calculated to account for aircraft using normal manual overshoot procedures from OCA/H on the nominal approach path. The values do not consider the lateral displacement of an obstacle nor the probability of an aircraft being so displaced. If consideration of these joint probabilities is required, then the CRM discussed in 6.4.9 shall be used. Values in Table III-3-6-3 may be adjusted for specific aircraft types where adequate flight and theoretical evidence is available, i.e. the height loss value corresponding to a probability of 1×10^{-5} (based on a missed approach rate 10^{-2}).

6.4.8.8.3.3 *Radio altimeter verification*. If the radio altimeter OCA/H are promulgated, operational checks shall have confirmed the repeatability of radio altimeter information.

6.4.8.8.3.4 *Height loss (HL)/altimeter margins for a specific speed at threshold.* If a height loss/altimeter margin is required for a specific V_{at}, the following formulae apply (see also Table III-3-6-4):

Use of radio altimeter:

Margin = $(0.096\ V_{at} - 3.2)$ metres where V_{at} in km/h

Margin = $(0.177\ V_{at} - 3.2)$ metres where V_{at} in kt

Use of pressure altimeter:

Margin = $(0.068\ V_{at} + 28.3)$ metres where V_{at} in km/h

Margin = $(0.125\ V_{at} + 28.3)$ metres where V_{at} in kt

where V_{at} is the speed at threshold based on 1.3 times stall speed in the landing configuration at maximum certificated landing mass.

Note.— The equations assume the aerodynamic and dynamic characteristics of the aircraft are directly related to the speed category. Thus, the calculated height loss/altimeter margins may not realistically represent small aircraft with V_{at} at maximum landing mass exceeding 165 kt.

6.4.8.8.3.5 *Height loss (HL)/altimeter margins for a specific speed at threshold (Helicopters).* For helicopter operations the concept of V_{at} is not applicable. Height loss margins are listed in Table III-3-6-3.

6.4.8.9 *Effect of obstacle density on OCA/H.* To assess the acceptability of obstacle density below the OAS, the CRM described in 6.4.9 may be used. This can provide assistance by comparing aerodrome environments and assessing risk levels associated with given OCA/H values. It is emphasized that it is not a substitute for operational judgement.

6.4.9 Obstacle clearance of the precision segment — application of collision risk model (CRM) for GBAS operations

Note.— A specific GBAS implementation of the CRM is in preparation.

6.4.9.1 *General.* The ILS CRM is a computer programme that establishes the numerical risk which can be compared to the target level of safety for aircraft operating to a specified OCA/H height. This ILS CRM can be used for GBAS Category I operations while the specific GBAS CRM is in preparation. A description of the ILS CRM programme and instructions on its use, including the precise format of both the data required as input and the output results, are given in the *Manual on the Use of the Collision Risk Model (CRM) for ILS Operations* (Doc 9274).

6.4.9.2 *Input.* The CRM requires the following data as input:

a) *Aerodrome details:* name, runway threshold position and runway orientation, threshold elevation above MSL, details of preceding segment;

b) *GBAS parameters:* category (Cat I only), glide path angle, GARP – LTP distance, GBAS course width and height of DCP;

c) *Missed approach parameters:* decision height/altitude (obstacle clearance height) and missed approach turn point;

d) *Aircraft parameters:* type, wheel height (antenna to bottom of wheel), and wing semi-span, aircraft category (A, B, C, D or D_L) and missed approach climb gradient; and

Note.— The CRM does not consider Category E aircraft.

e) *Obstacle data:* obstacle boundaries (either as x and y coordinates relative to the runway threshold or as map grid coordinates) and obstacle height (either above threshold elevation or above MSL). For density assessment, all obstacles penetrating the basic ILS surfaces described in 6.4.7.2 must be included.

6.4.9.3 *Output and application.* The output of the programme is the overall (total) risk of collision with obstacles to the aircraft of operating to the specified OCA/H and through the missed approach. Other information may also be produced using various output options.

6.4.9.3.1 For example, the risks associated with individual obstacles may be given, and these risks can be ordered, either in terms of obstacle range, or more usefully in terms of risk magnitude, so that the user may see at a glance which obstacles are the major contributors to the total risk.

6.4.9.3.2 The user, by rerunning the CRM with the appropriate parameters, can assess the effect on the safety of operations of any alteration in the parameters, typically varying the glide path angle, or increasing/reducing the OCA/H. The computed risk is compared with a prespecified acceptable level of risk (not worse than 1×10^{-7} per approach) which meets the overall safety target.

6.4.9.4 *Determination of OCA/H.* The determination of OCA/H is a process in which the CRM is successively rerun with changing values of OCA/H until the computed risk meets the target level of safety (i.e. better than 1 x 10^{-7} per approach).

6.5 MISSED APPROACH AFTER THE PRECISION SEGMENT (FINAL MISSED APPROACH)

6.5.1 General

The criteria for the final missed approach are based on those for the general criteria (see Chapter 7). Certain modifications have been made to allow for the different areas and surfaces associated with the GBAS precision segment and the possible variation in OCA/H for that segment with aircraft category.

6.5.1.1 The datum used for calculation of distances and gradients in obstacle clearance calculations is termed "start of climb" (SOC). It is defined by the height and range at which the plane GP' (a plane parallel with the glide path and with origin at –900 m (Cat H, –700 m) at threshold level) reaches an altitude OCA/H – HL. Area construction is according to the navigation system specified for the missed approach (where OCA/H and HL both relate to the same category of aircraft).

6.5.1.2 If obstacles identified in the final missed approach segment result in an increase in any of the OCA/H calculated for the precision segment, an additional steeper gradient may also be specified for the missed approach surface (Z) for the purpose of lowering the OCA/H (see Part I, Section 4, Chapter 6, 6.2.2.2, "Climb gradient in the intermediate phase").

6.5.2 Straight missed approach

6.5.2.1 *General.* The precision segment terminates at the range where the Z surface reaches a height 300 m above threshold LTP. The width of the Z surface at that range defines the initial width of the final missed approach area which is developed as shown in Figure III-3-6-14. There are no secondary areas.

6.5.2.2 *Straight missed approach obstacle clearance.* (See Figure III-3-6-15.) Obstacle elevation/height in this final missed approach area shall be less than

$$(OCA/H_{ps} - HL) + d_o \tan Z$$

where: OCA/H for precision segment (OCA/H_{ps}) and HL (Table III-3-6-3) both relate to the same aircraft category;

do is measured from SOC parallel to the straight missed approach track; and

Z is the angle of the missed approach surface with the horizontal plane.

If this requirement cannot be met, a turn shall be prescribed to avoid the obstacle in question. If a turn is not practical, the OCA/H shall be raised.

6.5.3 Turning missed approach

6.5.3.1 *General.* Turns may be prescribed at a designated TP, at a designated altitude/height, or "as soon as practicable". The criteria used depend on the location of the turn relative to the normal termination of the precision segment and are as follows:

a) *turn after normal termination of the precision segment.* If a turn is prescribed after the normal termination range of the precision segment, the criteria of Part I, Section 4, Chapter 6, 6.4.5, “Turn initiated at a designated altitude/height” apply with the following exceptions:

   1) OCA/H is replaced by (OCA/H – HL) as in 6.5.2.2, “Obstacle clearance”; and

   2) Because SOC is related to OCA/H, it is not possible to obtain obstacle clearance by the means used in non-precision approaches by independent adjustment of OCA/H or MAPt; and

b) *turn before normal termination of the precision segment.* If a turn is prescribed at a designated altitude/height less than 300 m above threshold or at a designated TP such that the earliest TP is within the normal termination range, the criteria specified in 6.5.3.2 and 6.5.3.3 below shall be applied.

Note.— Adjustments to designated TP location or to the designated turn altitude may involve redrawing the associated areas and recalculating the clearances. This can exclude some obstacles or introduce new ones. Thus, to obtain the minimum value of OCA/H it may be necessary to adjust the designated TP or turn altitude by trial and error. (See Part II, Section 1, Chapter 1, Appendix A.)

6.5.3.2 *Turn at a designated altitude/height less than 300 m above threshold.*

6.5.3.2.1 The general criteria apply (see Part I, Section 4, Chapter 6, 6.4.5, “Turn initiated at a designated altitude/height”) as amplified or modified by the contents of this section. Construction of the turn initiation area and the subsequent turn are illustrated in Figure III-3-6-16.

6.5.3.2.2 *Turn altitude/height.* The precision segment terminates at the TP. This allows the calculation of OCA/H_{ps} and (OCA/H_{ps} – HL). SOC is then determined, and turn altitude/height (TNA/H) is computed from the following relationship:

$$TNA/H = OCA/H_{ps} - HL + d_z \tan Z$$

where: d_z = is the horizontal distance from SOC to the TP

OCA/H_{ps} = OCA/H calculated for the precision segment

If the TP is located at the SOC, the chart shall be annotated “turn as soon as practicable to... (heading or facility)” and include sufficient information to identify the position and height of the obstacles dictating the turn requirement.

6.5.3.2.3 *Areas*

6.5.3.2.3.1 *Turn initiation area.* (See Figure III-3-6-16). The turn initiation area is bounded by the 300 m Category I Y surface contour, and it terminates at the range of the TP.

Note.— The earliest TP is considered to be at the beginning of the 300 m Category I Y surface contour (point D”) unless a fix is specified to limit early turns (see 6.5.3.2.6, “Safeguarding of early turns”).

6.5.3.2.3.2 *Turn area.* The turn area is constructed as specified in the general criteria (Part I, Section 4, Chapter 6, 6.4.3, “Turn boundary construction”).

6.5.3.2.4 *Obstacle clearance*

a) *Obstacle clearance in the turn initiation area.* Obstacle elevation/height in the turn initiation area shall be less than:

   1) turn altitude/height –50 m (164 ft) (Cat H, 40 m (132 ft)) for turns more than 15°; and

   2) turn altitude/height –30 m (98 ft) for turns 15° or less except that obstacles located under the Y surface on the outer side of the turn need not be considered when calculating turn altitude/height.

b) *Obstacle clearance in the turn area.* Obstacle elevation/height in the turn area and subsequently shall be less than:

$$\text{turn altitude/height} + d_o \tan Z - \text{MOC}$$

   where d_o is measured from the obstacle to the nearest point on the turn initiation area boundary and MOC is:

   1) 50 m (164 ft) (Cat H, 40 m (132 ft)) for turns more than 15°; and

   2) 30 m (98 ft) for turns 15° or less,

   reducing linearly to zero at the outer edge of the secondary areas, if any.

6.5.3.2.5 *Turn altitude/height adjustments.* If the criteria specified in 6.5.3.2.3 a) and/or b) above cannot be met, the turn altitude/height shall be adjusted. This can be done in two ways:

a) *adjust turn altitude/height without changing OCA/H:* this means that the TP will be moved and the areas redrawn accordingly; and

b) *raise turn altitude/height by increasing OCA/H:* this results in a higher turn altitude over the same TP. The turn areas remain unchanged.

6.5.3.2.6 *Safeguarding of early turns.* Where the published procedure does not specify a fix to limit turns for aircraft executing a missed approach from above the designated turn altitude/height, an additional check of obstacles shall be made (see Part I, Section 4, Chapter 6, 6.4.5.6, "Safeguarding of early turns").

6.5.3.3 *Turn at a designated TP with earliest TP before normal termination of precision segment*

3.5.3.3.1 Where a turn is specified at a designated TP, and the earliest TP is before the normal termination range of the precision segment, the precision segment terminates at the earliest TP. This allows the calculation of OCA/H_{ps} and (OCA/H_{ps} –HL); SOC is then determined.

6.5.3.3.2 Where the procedure requires that a turn be executed at a designated TP, the following information must be published with the procedure:

a) the TP, when it is designated by a fix; or

b) the intersecting VOR radial NDB bearing DME distance where there is no track guidance (see Part I, Section 2, Chapter 2, 2.6.4, "Missed approach fixes").

6.5.3.3.3 *Turn area.* The turn area is constructed as specified in Part I, Section 4, Chapter 6, 6.4.6.3, except that it is based on the width of the 300 m OAS Y surface contours at the earliest and latest TP (see Figure III-3-6-17).

6.5.3.3.4 *Obstacle clearance.* Obstacle elevation/height shall be less than:

$$(OCA/H_{ps} – HL) + d_o \tan Z – MOC$$

where: $d_o = d_z$ + shortest distance from obstacle to line K-K,

d_z = horizontal distance from SOC to the earliest TP,

and MOC is:

50 m (164 ft) (Cat H, 40 m (132 ft)) for turns more than 15° and
30 m (98 ft) for turns 15° or less.

If the obstacle elevation/height exceeds this value, the OCA/H must be increased, or the TP moved to obtain the required clearance (see Part II, Section 1, Chapter 1, Appendix A).

6.6 SIMULTANEOUS ILS AND/OR MLS PRECISION APPROACHES TO PARALLEL OR NEAR-PARALLEL INSTRUMENT RUNWAYS

Note.— Guidance material is contained in the Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways *(Doc 9643).*

6.6.1 General

When it is intended to use precision approach procedures to parallel runways simultaneously, the following additional criteria shall be applied in the design of both procedures:

a) the maximum intercept angle with the final approach course approach track is 30°. The point of intercepting the final approach track course should be located at least 3.7 km (2.0 NM) prior to the point of intercepting the glide path;

b) the minimum altitudes of the intermediate segments of the two procedures differ by at least 300 m (1 000 ft); and

c) the nominal tracks of the two missed approach procedures diverge by at least 30°, the associated missed approach turns being specified as "as soon as practicable" which may involve the construction of (a) missed approach procedure(s).

A single GBAS is capable of serving both runways, however, a separate safety study needs to be carried out when it is intended to use GBAS for both runways.

6.6.2 Obstacle clearance

The obstacle clearance criteria for precision approaches, as specified in the designated chapters, apply for each of the parallel precision procedures. In addition to these criteria a check of obstacles shall be made in the area on the side opposite the other parallel runway, in order to safeguard early turns required to avoid potential intruding aircraft from the adjacent runway. This check can be made using a set of separately defined parallel approach obstacle assessment surfaces (PAOAS). An example of a method to assess obstacles for these procedures is included in Part II, Section 1, Chapter 1, Appendix D.

6.7 GBAS CAT I WITH OFFSET AZIMUTH FINAL APPROACH TRACK ALIGNMENT

6.7.1 Use of GBAS Cat I with offset azimuth final approach track alignment

In certain cases it may not be physically practicable to align the final approach track with the runway centre line because of obstacle problems. An offset final approach track shall not be established as a noise abatement measure. The final approach track shall intersect the runway extended centre line:

a) at an angle not exceeding 5°; and

b) at a point where the nominal glide path reaches a height called intercept height of at least 55 m (180 ft) above threshold elevation. The procedure shall be annotated: "final approach track offset... degrees" (tenth of degrees).

The general arrangement is shown in Figure III-3-6-18.

6.7.2 Obstacle clearance criteria

The provisions contained in 6.1 to 6.6 apply except that:

a) all the obstacle clearance surfaces and calculations are based on a fictitious runway aligned with the final approach track. This fictitious runway has the same length and the same landing threshold elevation as the real one. The FTP is analogous to the LTP for aligned procedures. The GBAS course width at the FTP is the same as at the LTP. The DCP is located 15 m (50 ft) above the FTP; and

b) the OCA/H for this procedure shall be at least: intercept altitude/height + 20 m (66 ft).

6.8 PROMULGATION

6.8.1 General

The general criteria in Part I, Section 4, Chapter 9, 9.5 apply. The instrument approach chart for a GBAS approach procedure shall be identified by the title GLS Rwy XX. If more than one GBAS approach is published for the same runway, the Duplicate Procedure Title convention shall be applied, with the approach having the lowest minima being identified as GLS Z Rwy XX.

6.8.2 Promulgation of OCA/H values

Promulgation of OCA/H for GBAS Cat I approach procedures. The OCA or OCH values, as appropriate, shall be promulgated for those categories of aircraft for which the procedure is designed. The values shall be based on the following standard conditions:

a) Cat I flown with pressure altimeter;

b) standard aircraft dimensions (see 6.1.3); and

c) 2.5 per cent missed approach climb gradient.

Additional values of OCA/H may be agreed between operators and the appropriate authority and promulgated, on the basis of evidence supporting the modifications defined in 6.4.8.7.

6.8.3 Minima box

A table of OCA/H values for each aircraft category may be promulgated for Cat I operations at the particular airfield.

6.8.4 Procedures involving non-standard glide path angles

Procedures involving glide paths greater than 3.5 degrees or any angle when the nominal rate of descent exceeds 5 m/s (1 000 ft/min), are non-standard and subject to restrictions (see 6.4.8.8.3.1). They are normally restricted to specifically approved operators and aircraft, and are promulgated with appropriate aircraft and crew restrictions annotated on the approach chart.

6.8.5 Additional gradient for the final missed approach segment

If obstacles identified in the final missed approach segment result in an increase in any of the OCA/H calculated for the precision segment, an additional steeper gradient may also be specified for the gradient of the missed approach surface (Z) for the purpose of lowering the OCA/H (see Part I, Section 4, Chapter 6, 6.2.2.2, "Climb gradient in the intermediate phase").

6.8.6 Turns

6.8.6.1 *Turn at a designated altitude/height*. If the turn point is located at the SOC, the chart shall be annotated "turn as practicable to... (heading or facility)" and shall include sufficient information to identify the position and height of the obstacles dictating the turn requirement.

6.8.6.2 *Turn at a designated TP*. Where the procedure requires that a turn be executed at a designated TP, the following information must be published with the procedure:

a) the TP, when it is designated by a fix; or

b) the intersecting VOR radial, NDB bearing, or DME distance where there is no track guidance (see Part I, Section 2, Chapter 2, 2.6.4, "Missed approach fixes").

Table III-3-6-1. Minimum distance between final approach and glide path interceptions

Intercept angle with final approach (degrees)	*Cat A/B/H*	*Cat C/D/D_L/E*
0 — 15	2.8 km (1.5 NM)	2.8 km (1.5 NM)
16 — 30	3.7 km (2.0 NM)	3.7 km (2.0 NM)
31 — 60	3.7 km (2.0 NM)	4.6 km (2.5 NM)
61 — 90 or within a racetrack or reversal procedure	3.7 km (2.0 NM)	5.6 km (3.0 NM)

Table III-3-6-2. Objects which may be ignored in OCA/H calculations

	Maximum height above landing threshold	*Minimum lateral distance from runway centre line*
Landing system antenna	17 m (55 ft)	120 m
Aircraft taxiing	22 m (72 ft)	150 m
A/C in holding bay or in taxi holding position at a range between threshold and 250 m (Cat I only)	15 m (50 ft)	75 m

Table III-3-6-3. Height loss/altimeter margin

	Margin using radio altimeter		*Margin using pressure altimeter*	
Aircraft category (V_{at})	Metres	Feet	Metres	Feet
A - 169 km/h (90 kt)	13	42	40	130
B - 223 km/h (120 kt)	18	59	43	142
C - 260 km/h (140 kt)	22	71	46	150
D/D_L - 306 km/h (165 kt)	26	85	49	161
H - 167 km/h (90 kt)	8	25	35	115

Note 1 — Cat H speed is the maximum final approach speed, not V_{at}

Note 2 — For Category E aircraft refer directly to the equations given in 6.4.8.8.3.4

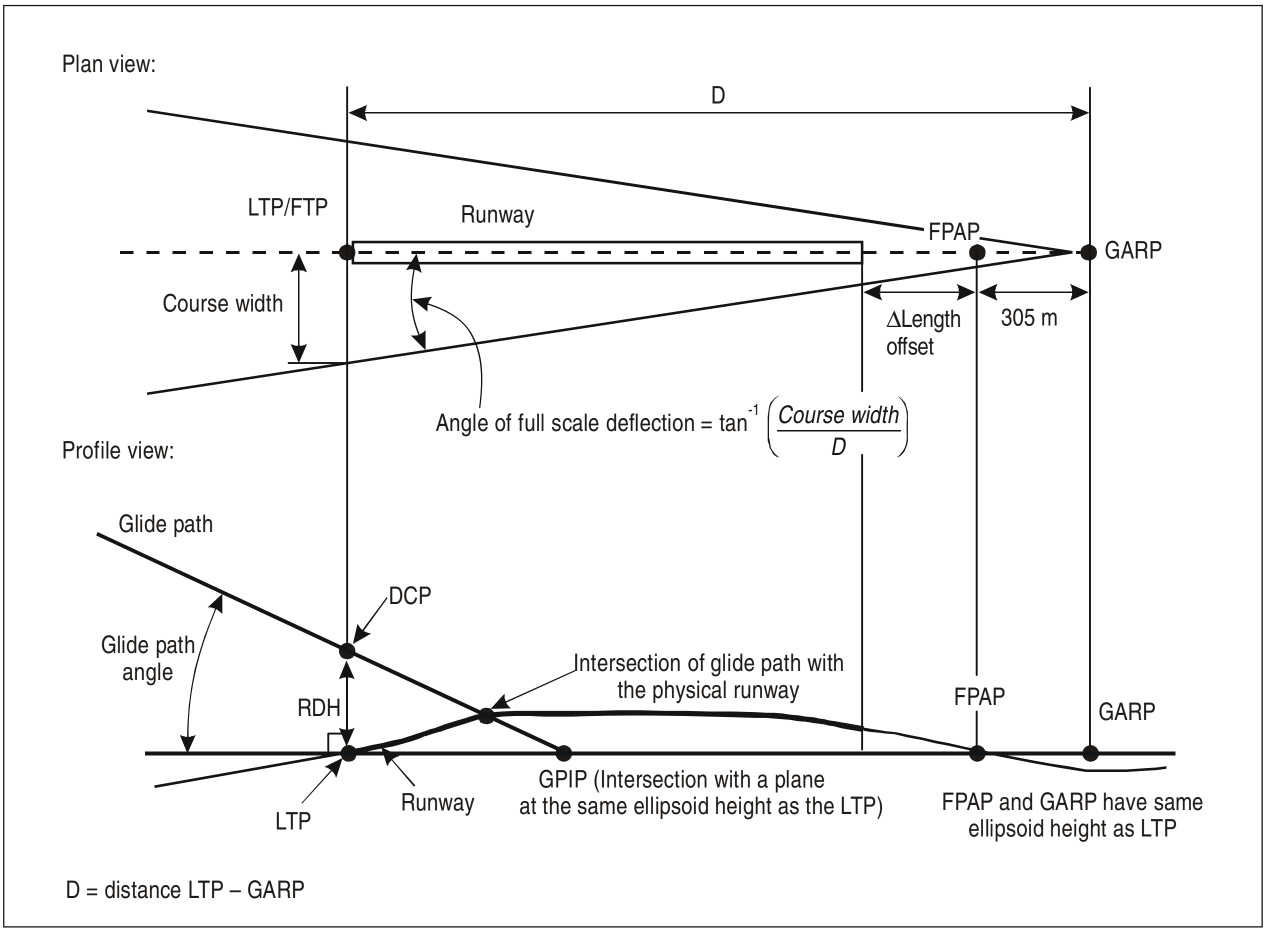


Figure III-3-6-1. Illustration of definitions

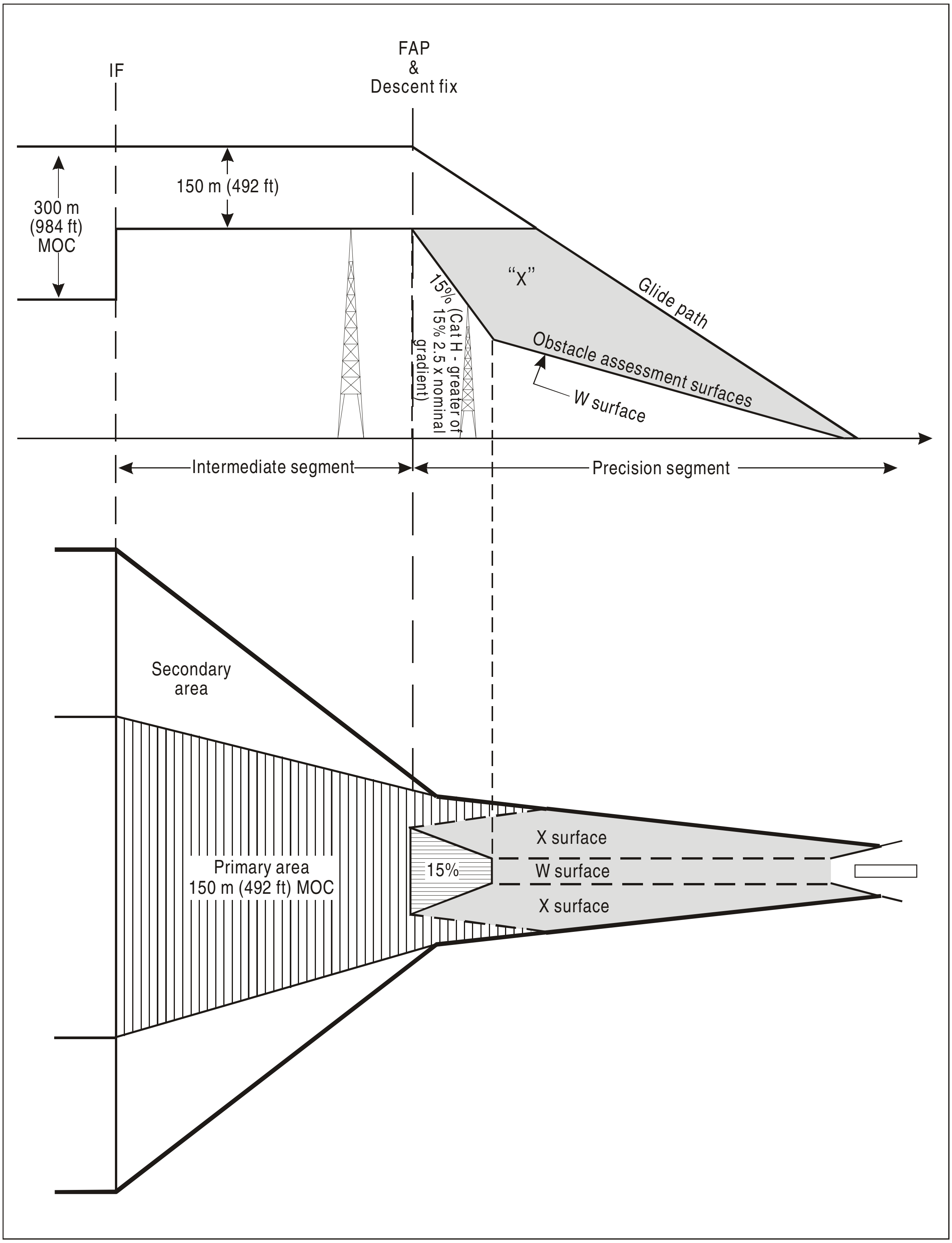


Figure III-3-6-2. Final approach point defined by descent fix

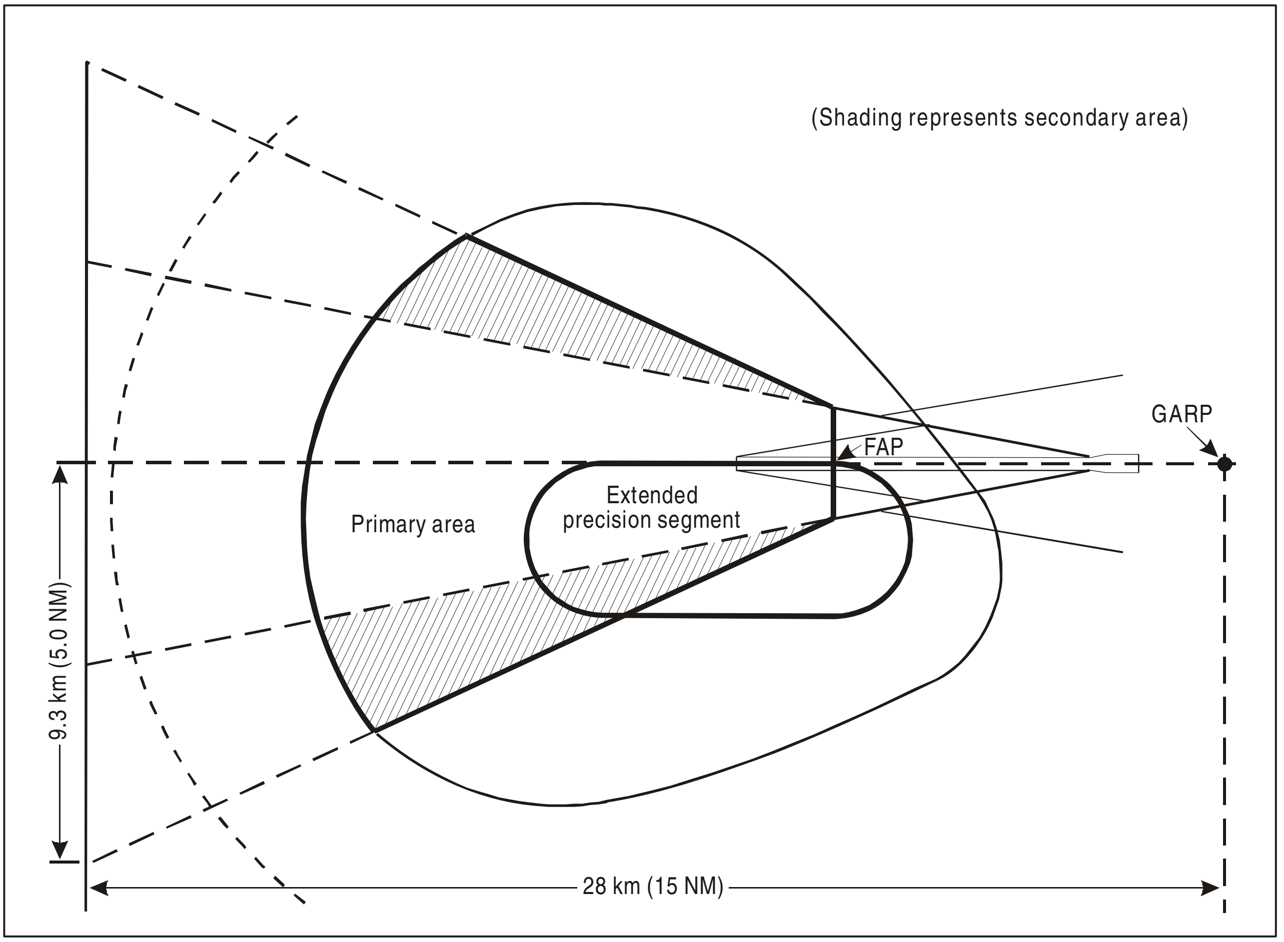


Figure III-3-6-3. Intermediate approach area. GBAS approach using reversal or racetrack procedure

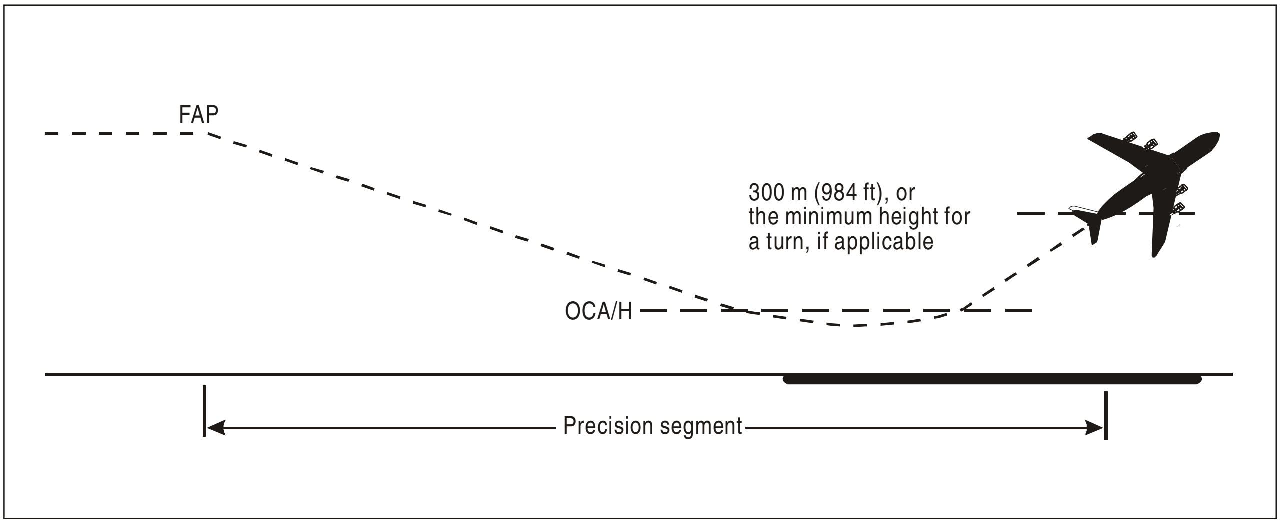


Figure III-3-6-4. Precision segment

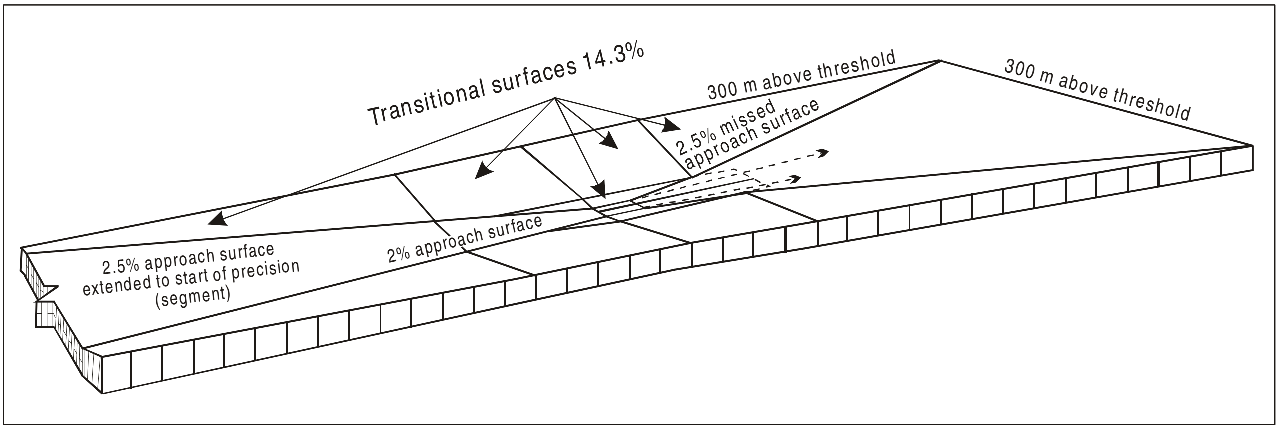
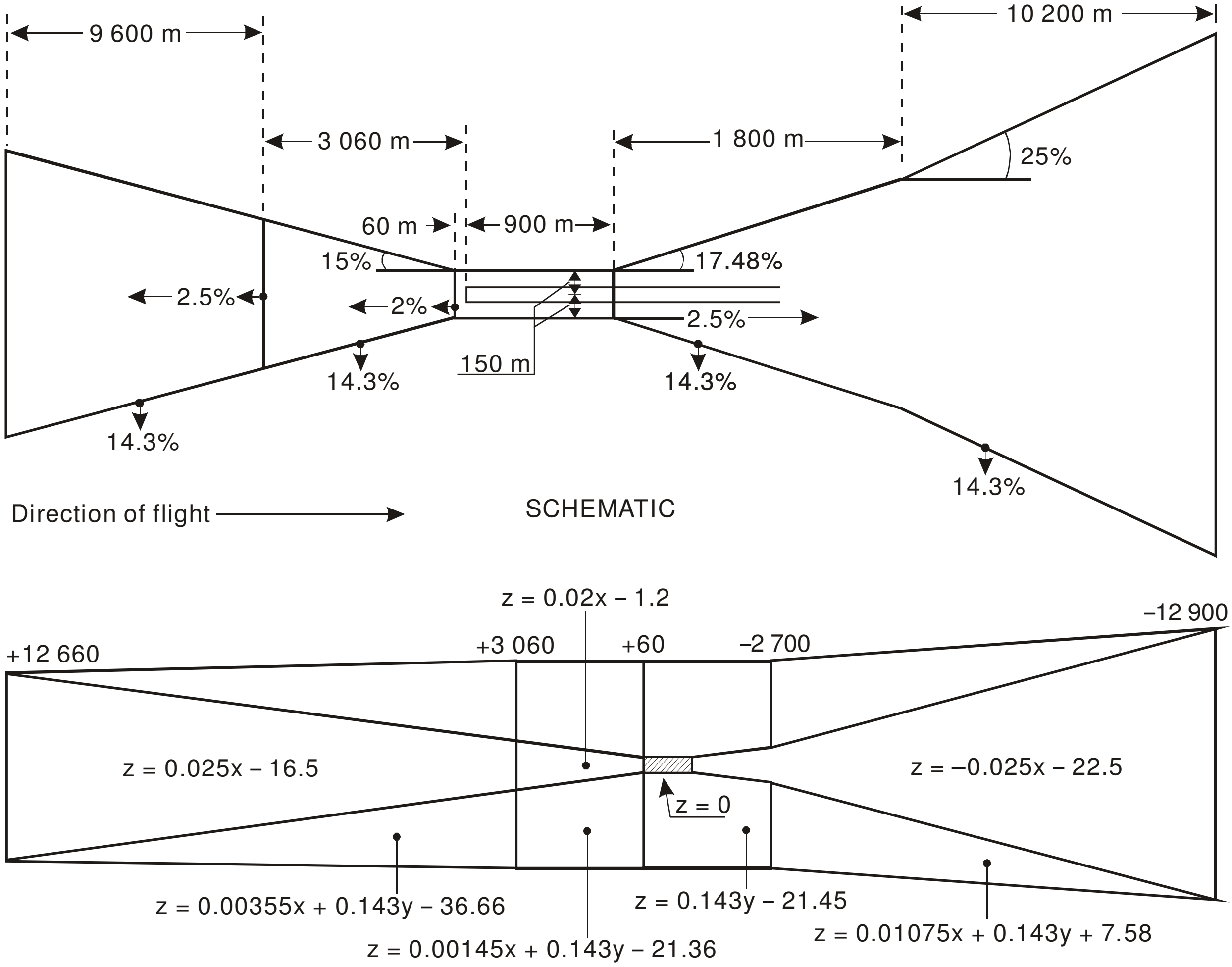


Figure III-3-6-5. Illustration of basic ILS surfaces as described in Part III, Section 3, Chapter 6, 6.4.7.2



Note.— The surface equations shown use the same frame of reference and notation as the OAS. See 6.4.8.2, 6.4.8.3 and 6.4.8.5. The equations assume the runway is horizontal. (All values are in metres.)

Figure III-3-6-6. Surface equations — basic ILS surfaces

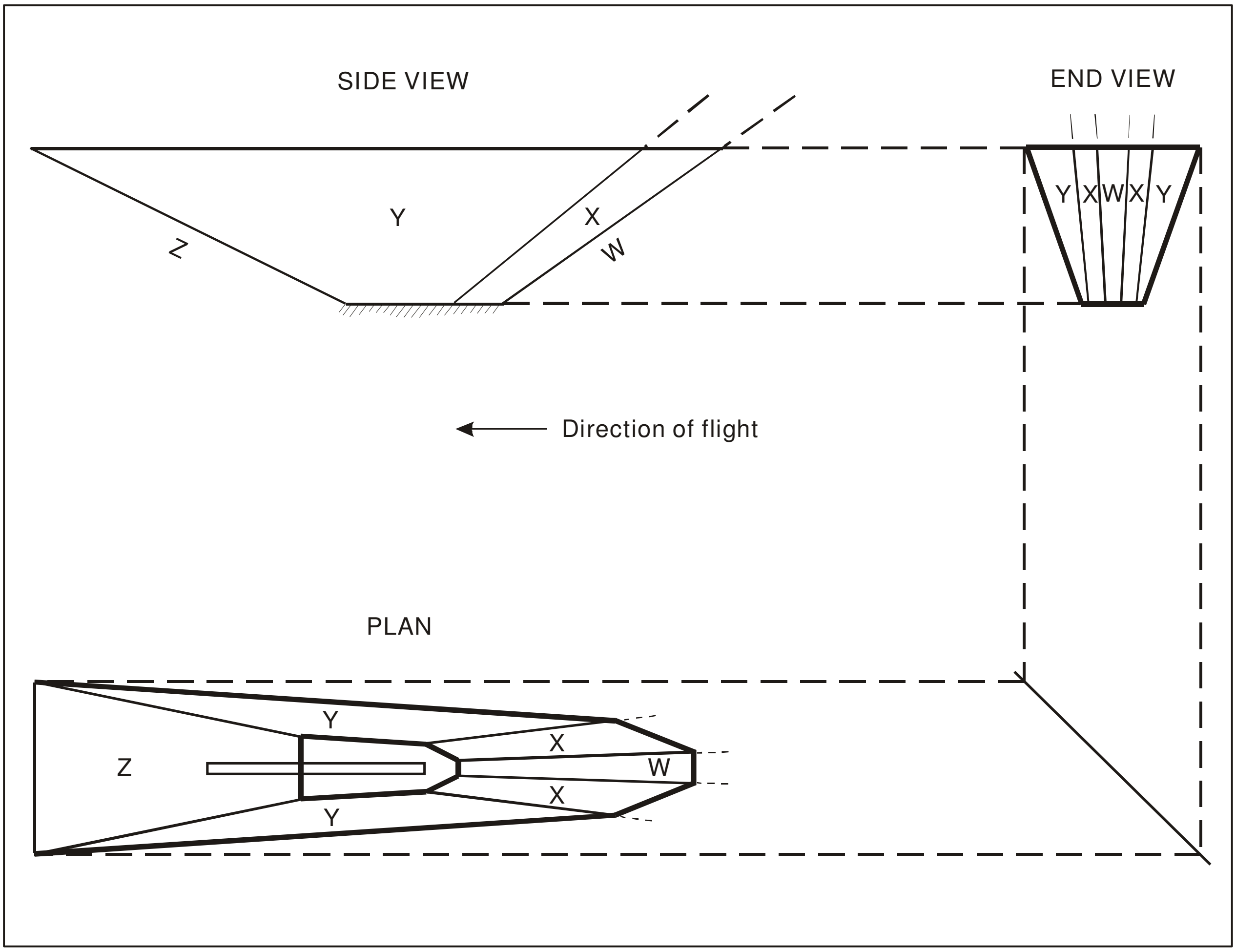


Figure III-3-6-7. Illustration of ILS obstacle assessment surfaces for GBAS operations

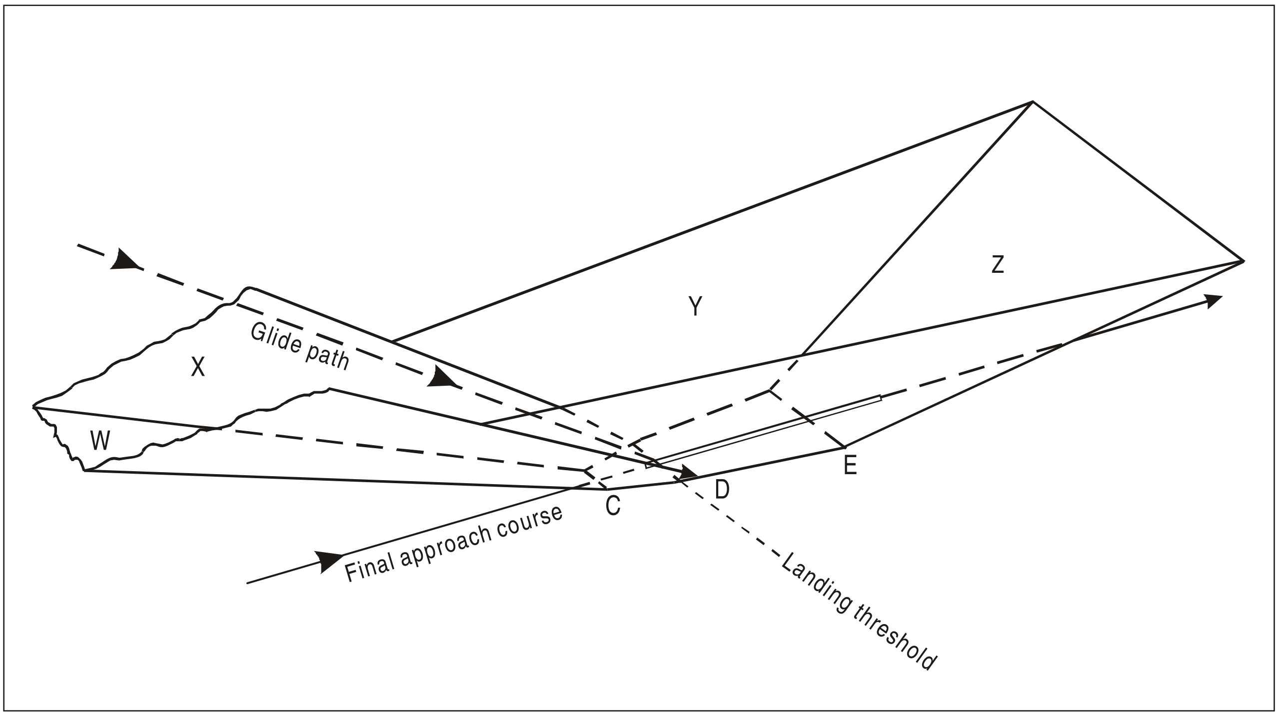


Figure III-3-6-8. Illustration of ILS obstacle assessment surfaces for GBAS operations — perspective view

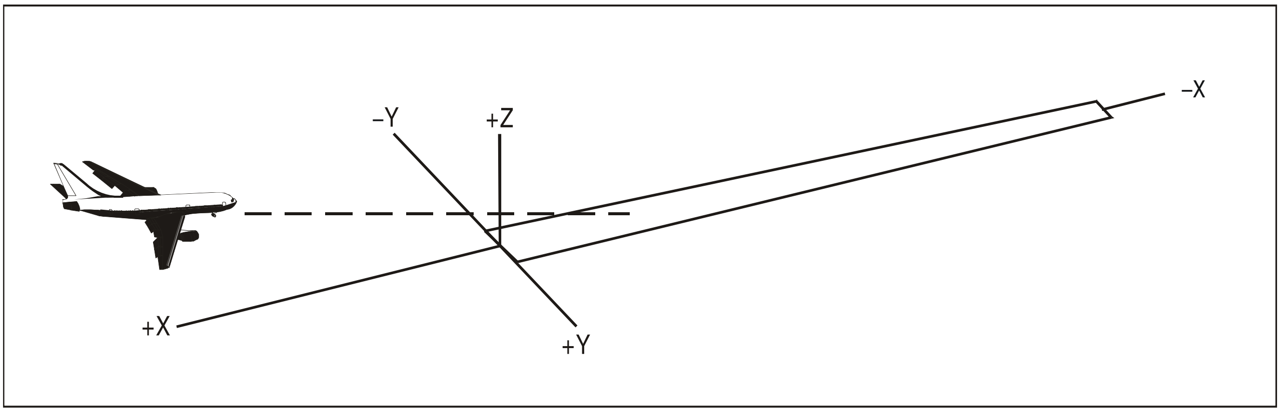
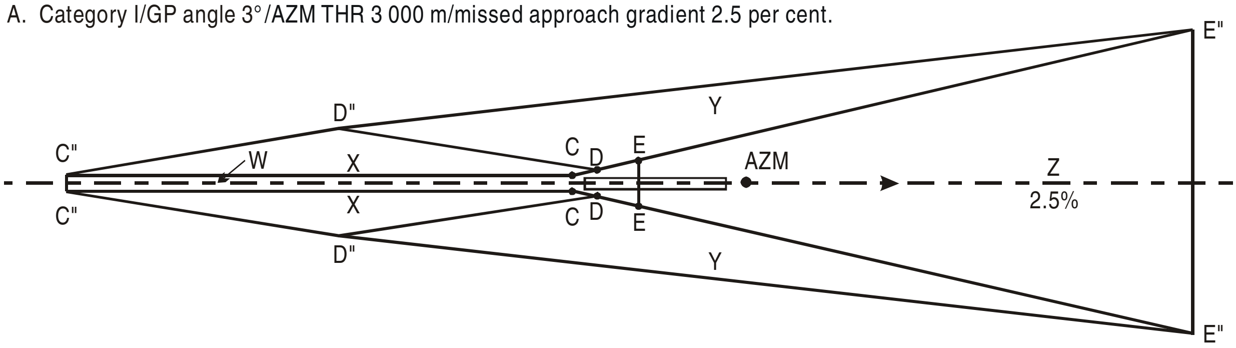


Figure III-3-6-9. System of coordinates

A. Category I/GP angle 3°/AZM THR 3 000 m/missed approach gradient 2.5 per cent.



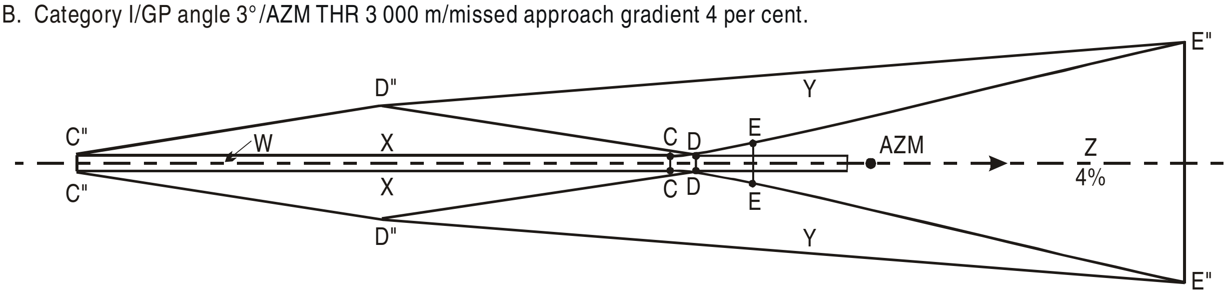
Equations of the obstacle assessment surfaces:

W l z = 0.0285x – 8.01
X l z = 0.027681x + 0.1825y – 16.72
Y l z = 0.023948x + 0.210054y – 21.51
Z l z = –0.025x – 22.50

Coordinates of points C, D, E, C", D", E" (m):

	C	D	E	C"	D"	E"
x	281	–286	–900	10 807	5 438	–12 900
y	49	135	205	96	910	3 001
z	0	0	0	300	300	300

B. Category I/GP angle 3°/AZM THR 3 000 m/missed approach gradient 4 per cent.



Equations of the obstacle assessment surfaces:

W l z = 0.0285x – 8.01
X l z = 0.027681x + 0.1825y – 16.72
Y l z = 0.020158x + 0.238021y – 26.37
Z l z = –0.04x – 36.00

Coordinates of points C, D, E, C", D", E" (m):

	C	D	E	C"	D"	E"
x	281	–286	–900	10 807	5 438	–8 400
y	49	135	187	96	910	2 082
z	0	0	0	300	300	300

Figure III-3-6-10. Typical OAS contours for standard size aircraft

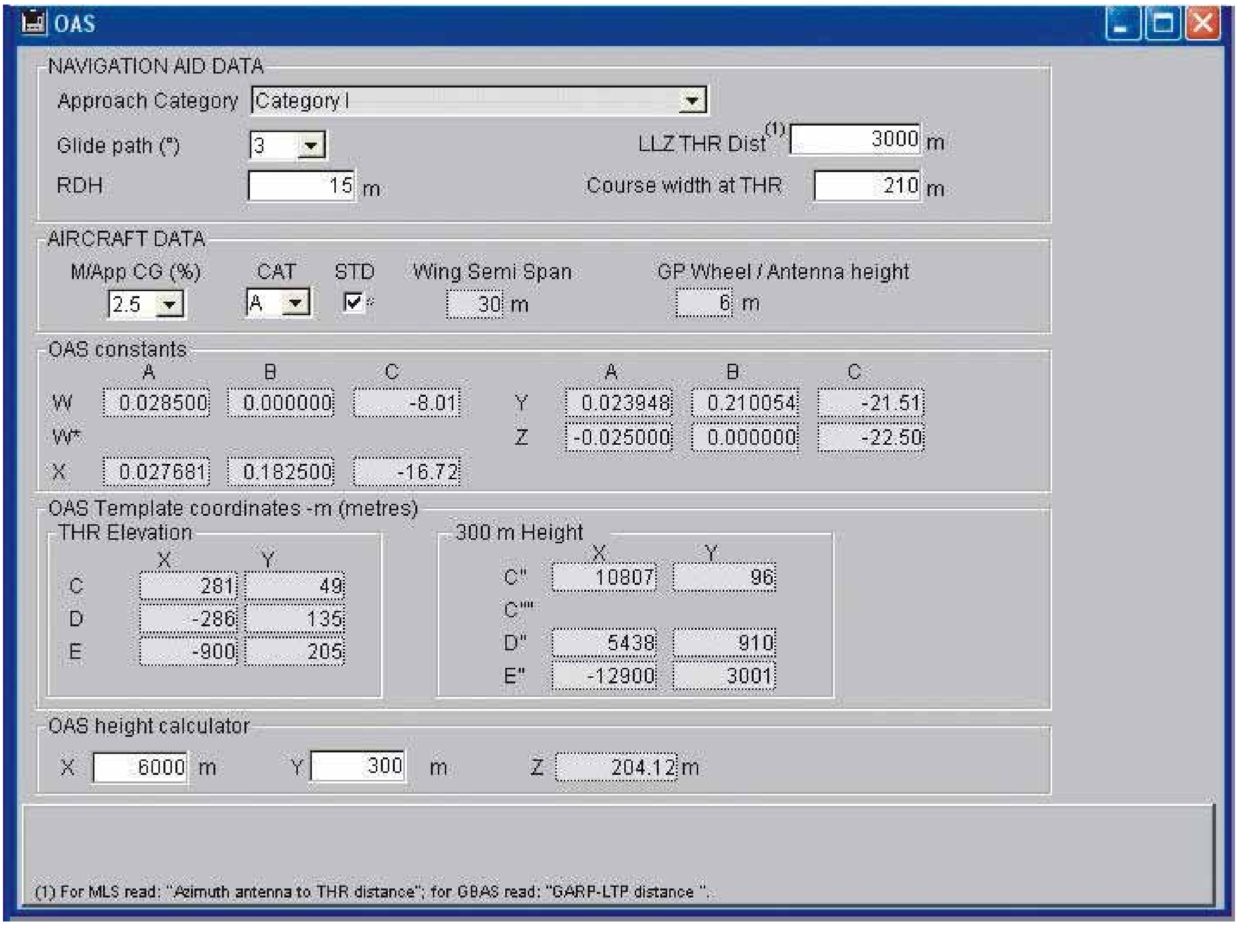


Figure III-3-6-11. OAS output data generated by the PANS-OPS OAS CD-ROM

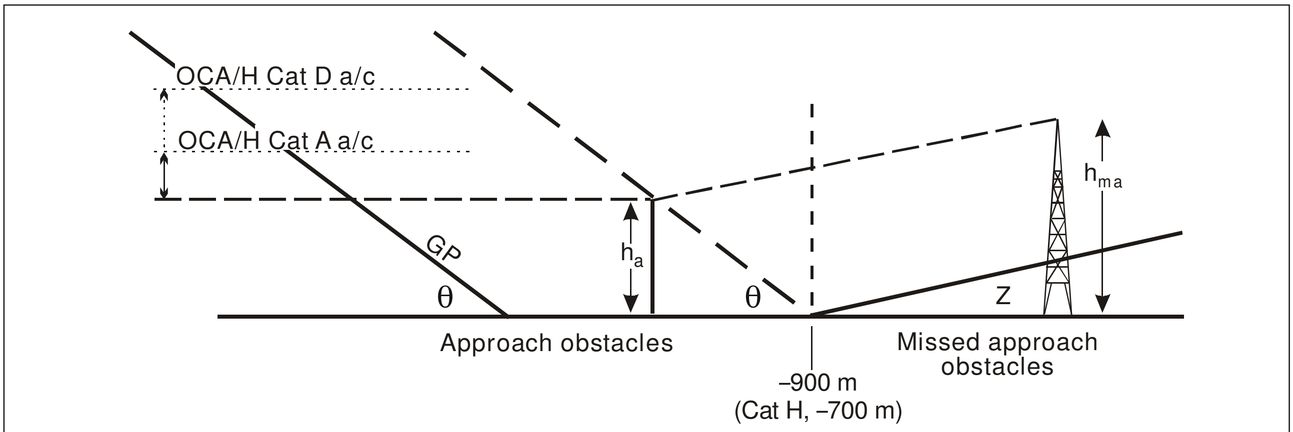


Figure III-3-6-12. Missed approach obstacle after range –900 m

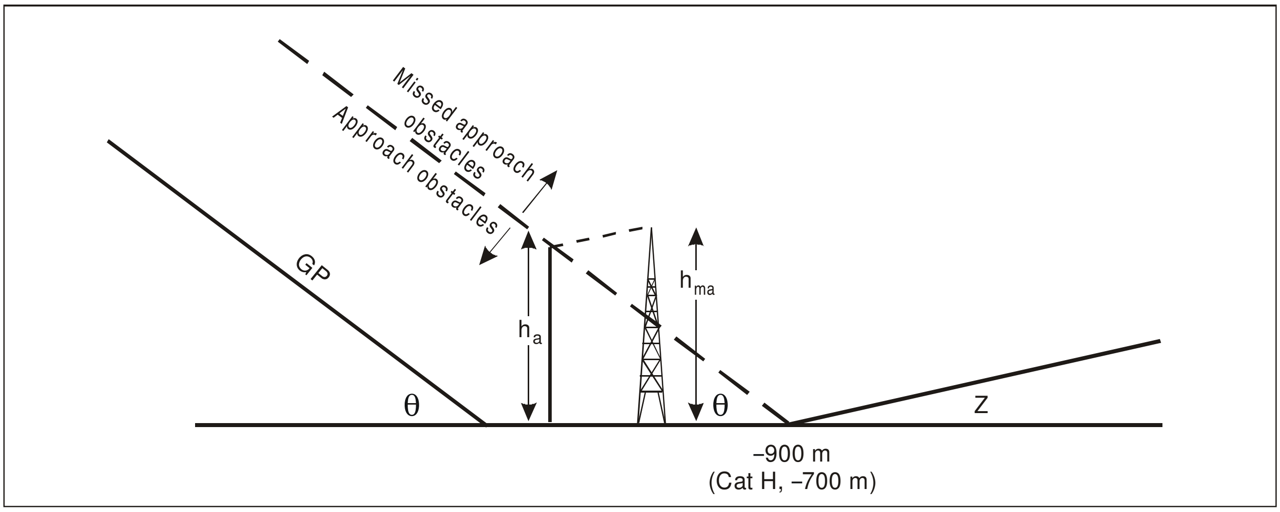


Figure III-3-6-13. Missed approach obstacle before range –900 m

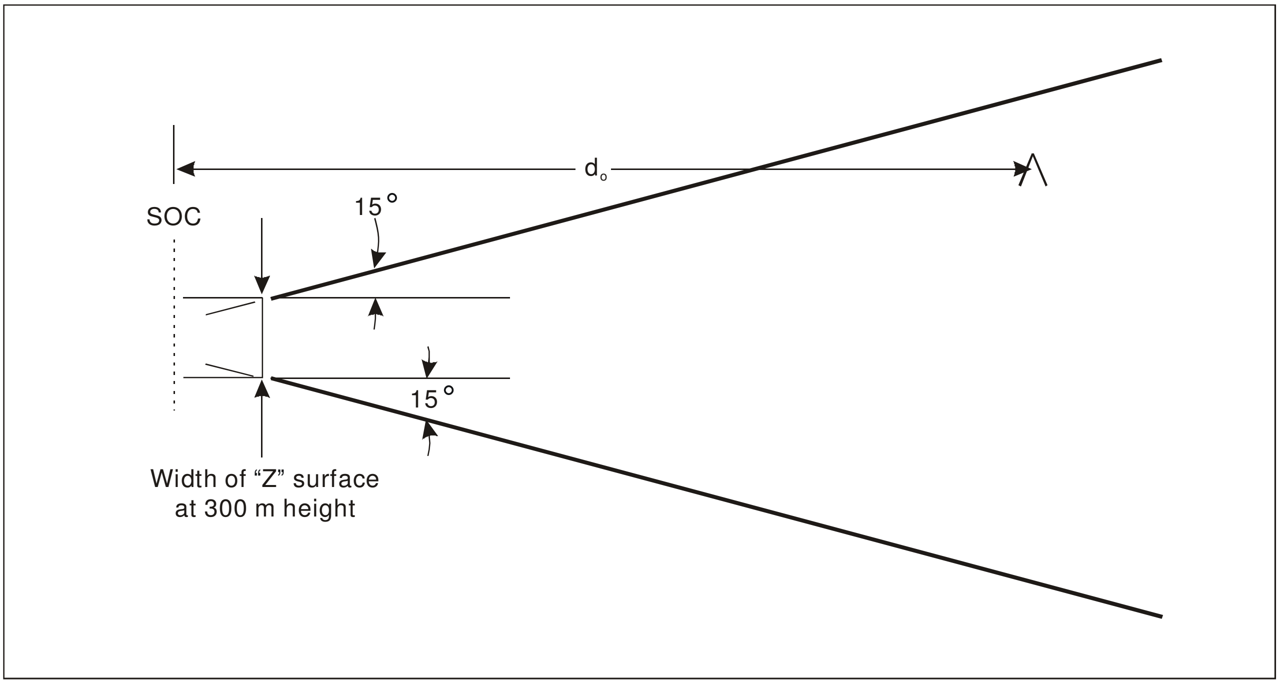


Figure III-3-6-14. Final segment of straight missed approach

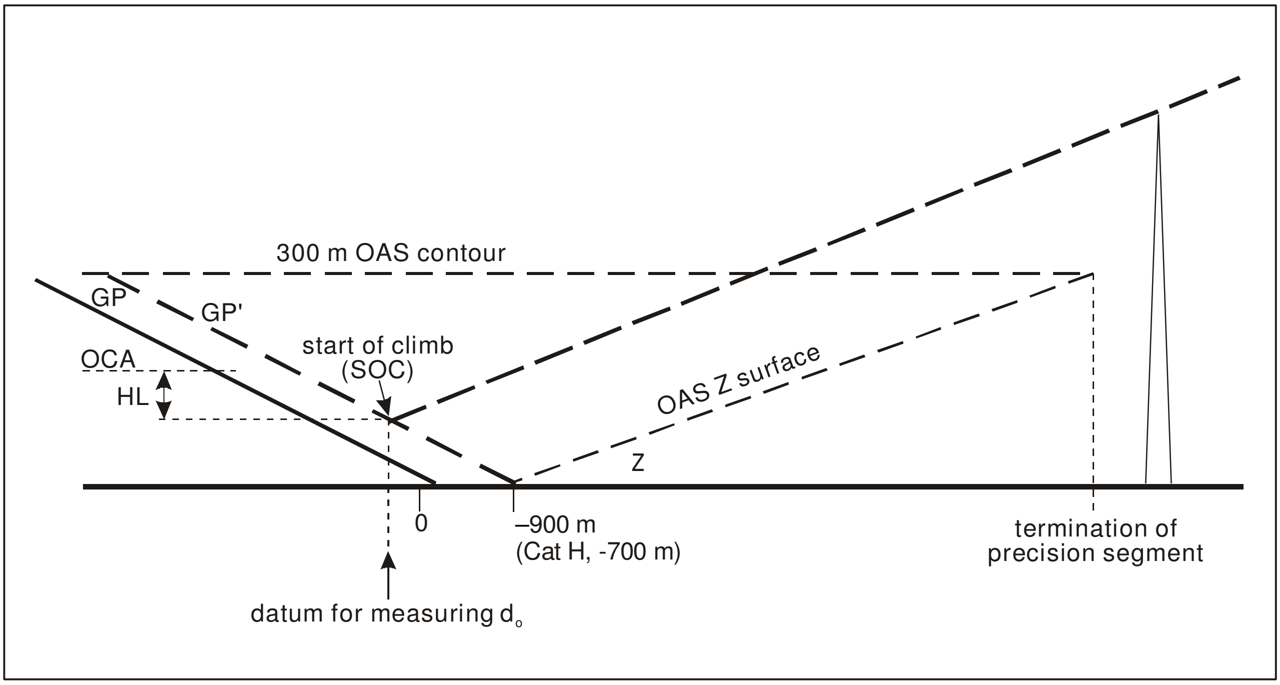


Figure III-3-6-15. Straight missed approach obstacle clearance

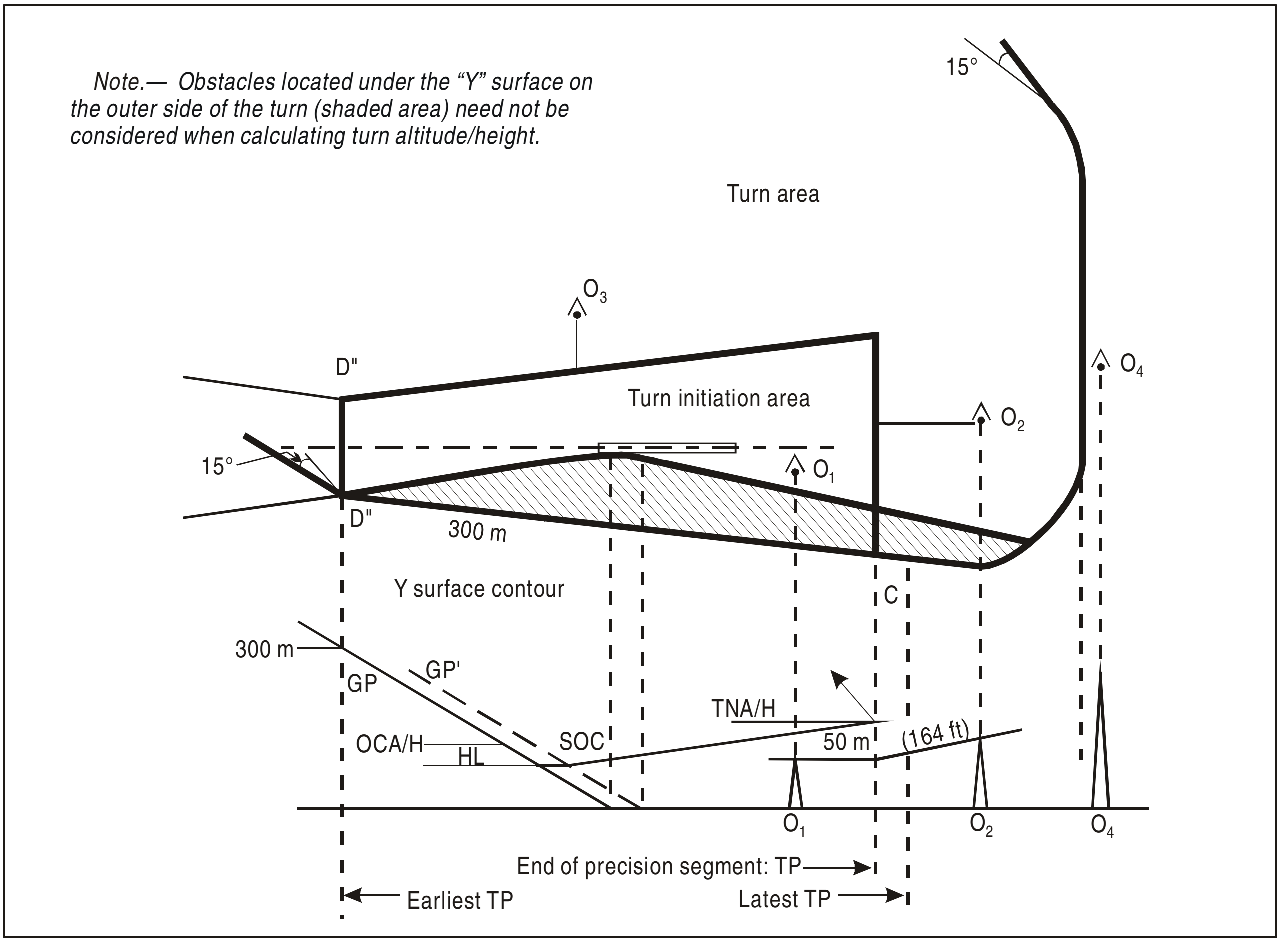
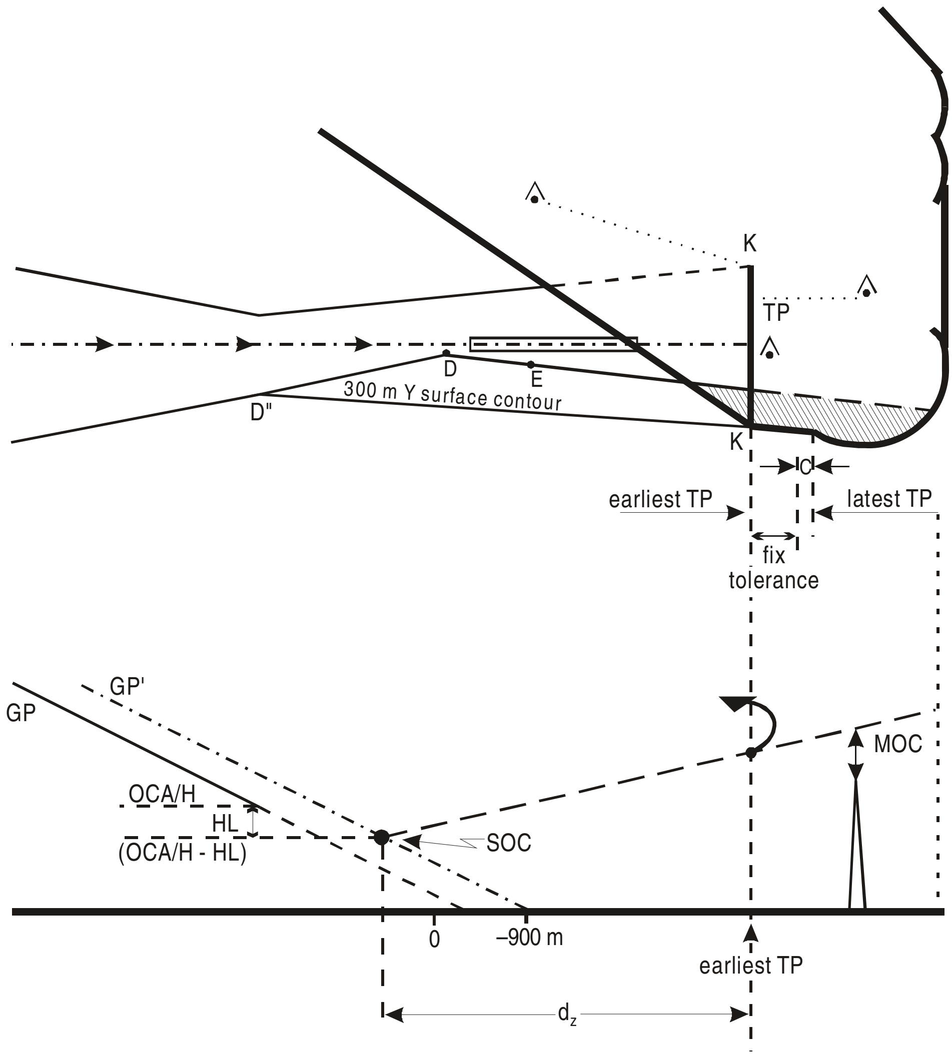


Figure III-3-6-16. Turn at a designated altitude



Note 1: $d_o = d_z$ + shortest distance from obstacle to line K-K.

Note 2: Obstacles located under the "Y" surface (shaded area) need not be considered.

Figure III-3-6-17. Turn at designated TP (with TP fix)

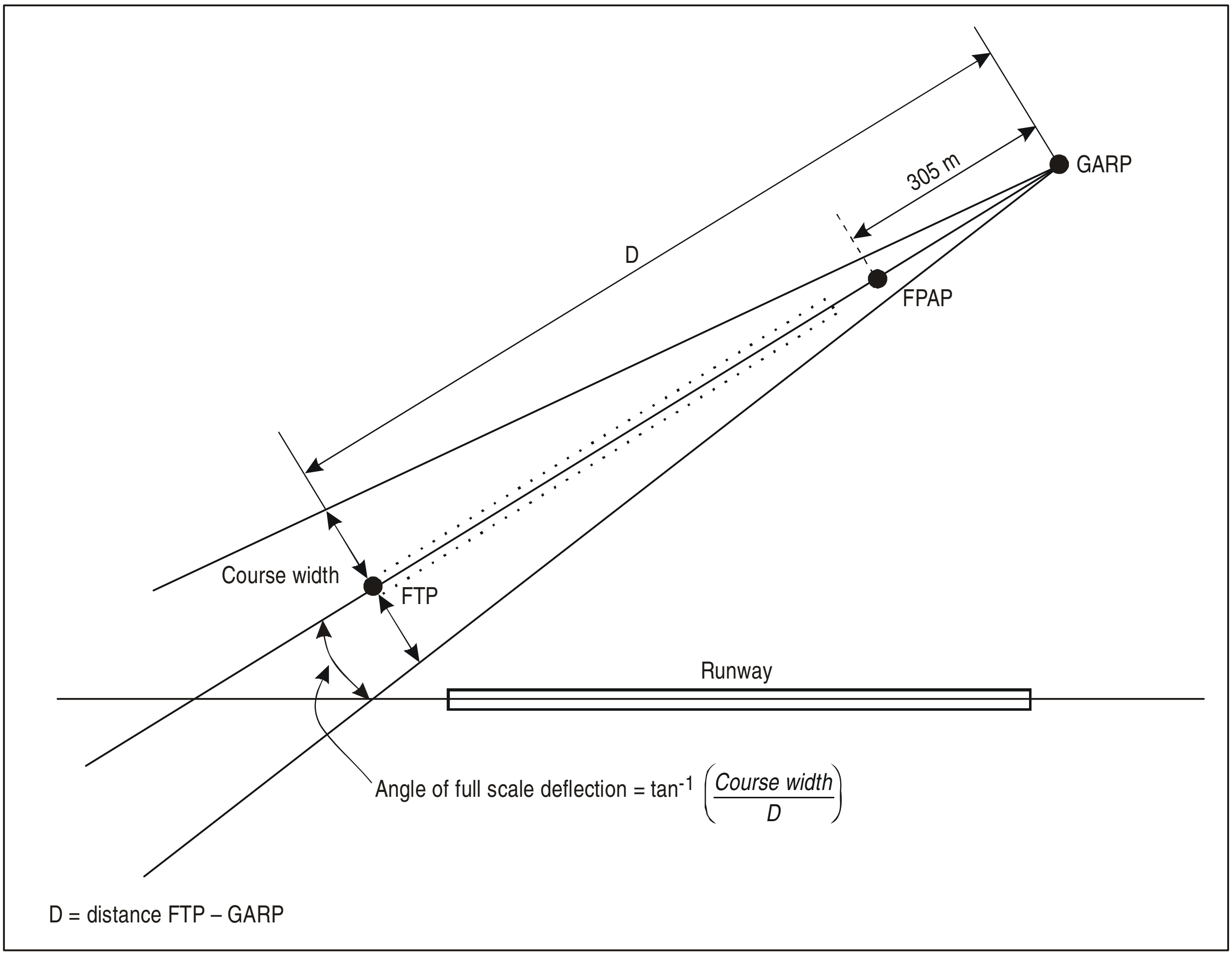


Figure III-3-6-18. GBAS Cat I with offset azimuth final approach course alignment

Chapter 7

HOLDING PROCEDURES

7.1 GENERAL

7.1.1 This chapter contains the criteria for RNAV holding procedures. Aircraft equipped with RNAV systems have the flexibility to hold on tracks which are defined by the RNAV equipment and to use procedures which are less rigid than those used in conventional holdings. The benefits of using this technique include the optimum utilization of airspace with regard to the siting and alignment of holding areas as well as, under certain circumstances, a reduction of holding area airspace.

7.1.2 Flight management systems are normally controlled through a navigation database.

7.1.3 *Location and number of holding patterns.* To avoid congestion only one holding pattern should be established for each procedure. The normal location would be at one of the IAFs. RNAV holding waypoints shall be located so that they are referenced to and verifiable from specified radio navigation facilities. The holding waypoint (MAHF) is a fly-over waypoint.

7.2 TYPES OF RNAV HOLDING FOR VOR/DME, DME/DME AND GNSS PROCEDURES

7.2.1 The following three types of RNAV holding may be established:

a) one waypoint RNAV holding;

b) two waypoint RNAV holding; and

c) area holding.

The criteria contained in Part I, Section 4, Chapter 3, Appendix C for conventional holding using an outbound leg defined by distance apply as modified by the criteria listed under each holding type.

7.2.2 *One waypoint RNAV holding*
(See Figure III-3-7-1 a))

a) It is assumed that the RNAV system is able to compensate for the effect of a wind coming from the outside of the outbound turn by a reduction of the bank angle.

b) The length of the outbound leg of the holding pattern is at least equal to one diameter of turn.

c) It is assumed that the RNAV system is able to correct the drift on straight segments.

d) No heading tolerance is taken into account on the straight segments.

7.2.3 *Two waypoint RNAV holding.* This type of holding is similar to one waypoint RNAV holding with the addition of a second waypoint to define the end of the outbound leg (see Figure III-3-7-1 b)). Inclusion of this second waypoint results in a reduction in required airspace by:

a) reducing the basic protection area; and

b) reducing the omnidirectional entry protection areas.

Note.— Flight management systems designed only for single waypoint holding procedures will normally require software modifications to cater for two waypoint holding procedures. Procedure designers are advised that not all FMS will be so modified, and provision will always be required for aircraft with unmodified systems.

7.2.4 *Area holding.* This type of holding provides a circular area, centred on a designated waypoint, large enough to contain a standard racetrack holding pattern in any orientation. (See Figure III-3-7-1 c).)

7.3 ENTRY PROCEDURES FOR VOR/DME, DME/DME AND GNSS PROCEDURES

7.3.1 One waypoint RNAV holding

Entry procedures to one waypoint RNAV holding shall be the same as those used for conventional holding.

7.3.2 Two waypoint RNAV holding

The line passing through the two waypoints divides the area into two sectors. An entry from a given sector shall be made through the corresponding waypoint. After passing the waypoint, the aircraft shall turn to follow the procedure. (See Figure III-3-7-2.)

7.3.3 Area holding

Any entry procedure which is contained within the given area is permissible.

7.4 FIX TOLERANCE

7.4.1 Fix tolerance depends on the sensors on which the holding procedure is based. DME/DME and GNSS fix tolerance are described in Section 1, Chapter 3, 3.5 and Chapter 2, 2.5 respectively. For RNP procedures the fix tolerance does not apply in the design of the procedure. For VOR/DME fix tolerance the following two paragraphs apply.

7.4.2 *Fix tolerance — one waypoint and two waypoint holding.* The waypoint tolerances for the construction of one waypoint and two waypoint fix tolerance areas (VT, DT, AVT, ADT) are calculated as shown in Section 1, Chapter 4, 4.5, “XTT and ATT”. (See also Figure III-3-7-3.)

7.4.3 *Fix tolerance — area holding.* In order to achieve a circular holding area it is necessary to construct a circular waypoint fix tolerance area centred on the holding waypoint. The radius (R^t) of this tolerance area is given by:

$$R^t = \max(DTT, D \sin \alpha)$$

where: α = VOR system use accuracy
DTT = DME system use accuracy
D = distance from holding waypoint to VOR/DME.
(See Figure III-3-7-3.)

7.5 HOLDING AREA CONSTRUCTION FOR VOR/DME, DME/DME AND GNSS PROCEDURES

7.5.1 One waypoint holding area

The holding area is constructed by applying the basic holding area, defined in Part II, Section 4, Chapter 1, "Construction of holding areas" to the waypoint tolerance area.

7.5.2 Details of protection area construction (one waypoint holding area)

7.5.2.1 *General.* The general criteria described in 3.3, "Protection area of racetrack and holding procedures" of Part I, Section 4, Chapter 3, Appendix C, "Initial approach segment" apply as modified by the criteria in this paragraph. The criteria are broken down into the following three steps:

a) construction of the RNAV template;

b) basic area construction; and

c) construction of entry area.

7.5.2.2 *Step one — Construction of the RNAV template.* Construct the RNAV template using the following guidelines (see Figure III-3-7-4 as an example):

a) choose the outbound distance: D is the length of the outbound leg; D shall be at least equal to one diameter of turn) rounded to the next higher km (NM);

b) draw the nominal trajectory; locate point "i" at the end of the outbound leg;

c) draw the protection of a turn of more than 180° as for a conventional template (see Diagram I-4-3-App C-6 in Part I, Section 4, Chapter 3, Appendix C);

d) draw a parallel to the outbound track tangent to line (2);

e) from "i", draw a perpendicular to the outbound track;

f) lines (3) and (4) intercept at i1;

g) place conventional template point "a" on "i", then on "i1", with axis parallel to the outbound leg and, in both cases, draw the protection of a turn of more than 180°; draw the tangent T to these protections;

h) draw the tangent T1 between line (6) and line (2);

i) draw the tangent T2 between line (2) and (6); and

j) locate point E on the template (see Part I, Section 4, Chapter 3, Appendix C, 3.3.2.2.4.7) and use the following formulas for XE and YE (which are different from those in Part I, Section 4, Chapter 3, Appendix C, 3.3.2.2.4.7):

(See Figures III-3-7-5 a) and III-3-7-5 b).)

$$XE = 2r + D + 11v + \left(11 + \frac{90}{R} + 11 + \frac{105}{R}\right)W'$$

$$YE = 11v.\cos 20° + r.\sin 20° + r + \left(11 + \frac{20}{R} + \frac{90}{R} + 11 + \frac{15}{R}\right)W'$$

7.5.2.3 *Step two — Construction of the basic area* (one waypoint holding case).

7.5.2.3.1 *Holding point tolerance area.* Draw around holding point A the RNAV fix tolerance associated with this point.

7.5.2.3.2 *Construction of the basic area*. (See Figure III-3-7-6). Move the RNAV template origin "a" around the RNAV tolerance area of the holding point "A".

7.5.2.4 *Step three—Construction of the entry area* (See Figure III-3-7-7). Draw the circle centred on "A" passing through A1 and A3; apply the same method as explained in Part I, Section 4, Chapter 3, Appendix C, 3.3.3.2.

7.5.3 Two waypoint holding area

The holding area is constructed by applying the techniques of Part II, Section 4, Chapter 1, "Construction of holding areas" to each waypoint as if it were a holding fix. The techniques of Part II, Section 4, Chapter 1, are used until the outbound turn from each waypoint is protected. These protection curves are then joined by their common tangents and the area thus enclosed is the holding area. The protection required for the entry manoeuvre is described by the area enclosed by wind spirals applied successively to the most penalistic points of the waypoint tolerance area and the common tangents to those spirals.

7.5.4 Area holding

The holding area shall contain the basic holding protection area rotated about the waypoint fix tolerance area described in 7.4.3. (See Figures III-3-7-1 c) and III-3-7-3.)

7.6 HOLDING AREA CONSTRUCTION FOR RNP

7.6.1 Parameters that define the maximum RNP holding pattern

The maximum RNP holding pattern is defined by:

a) a holding waypoint in WGS-84 latitude and longitude;

b) a minimum and maximum altitude;

c) a maximum holding indicated airspeed;

d) an inbound track to the holding fix;

e) length (d1) of the inbound track;

f) diameter of turn (d2);

g) the RNP value (d3); and

h) the distance (d4) used to draw the protection limit for sector 4 entries.

See Figures III-3-7-8 and III-3-7-9.

7.6.2 Diameter of turn

The diameter of turn (d2) is defined as that which can be followed throughout the turn at the defined IAS at ISA + 15°, taking into account:

a) the maximum wind speed (w) at the maximum holding altitude, assumed to be a tail wind throughout the turn; and

b) a defined bank angle ($\alpha = 23°$ for FL < 245 and 15° for FL > 245).

$$d2 = \frac{(TAS + w)^2}{34313 \tan \alpha}$$ d2 in NM; TAS and w in kt

$$d2 = \frac{(TAS + w)^2}{63547 \tan \alpha}$$ d2 in km; TAS and w in km/h

7.6.3 RNP holding plus Sector 4 entries limit

The RNP "holding plus sector 4 entries" limit results from combining the RNP holding pattern with the sector 4 protection limit (see Figure III-3-7-8).

This distance (d4) is used to draw the protection limit for sector 4 entries and is calculated using the formula:

$$d4 = \frac{d2(1 - \sin \theta)}{2 \cos \theta}$$

Where θ is equal to 20°, defined as the perpendicular to the inbound track

See the Appendix for the definition of RNAV sectors.

7.6.4 Obstacle clearance

7.7.1.1 *RNP holding area.* The holding area includes the basic RNP holding area and the additional protection for entries from Sector 4 (see above). Holding area protection (See Figure III-3-7-9) consists of two parts: primary area and buffer area. These are applied to the maximum track defined in Figure III-3-7-8 as described below.

a) *Primary area.* On the straight segments, a value (d3) equal to the RNP is applied around the maximum track. On curved segments, a value of $\sqrt{2}$ RNP is applied.

b) *Buffer area.* A buffer area is applied to the outside of the primary area. The width of the buffer area is the greater of the following values:

   XTT + 3.70 km (2.00 NM)
   9.26 km (5.00 NM)

On the curved segments, the criteria in Chapter 8, 8.1.6, "Controlled turn (for RNP 1 routes)" are applied. Obstacle clearance and buffer areas shall be provided as described in Part II, Section 4, Chapter 1, 1.3.12, "Obstacle clearance".

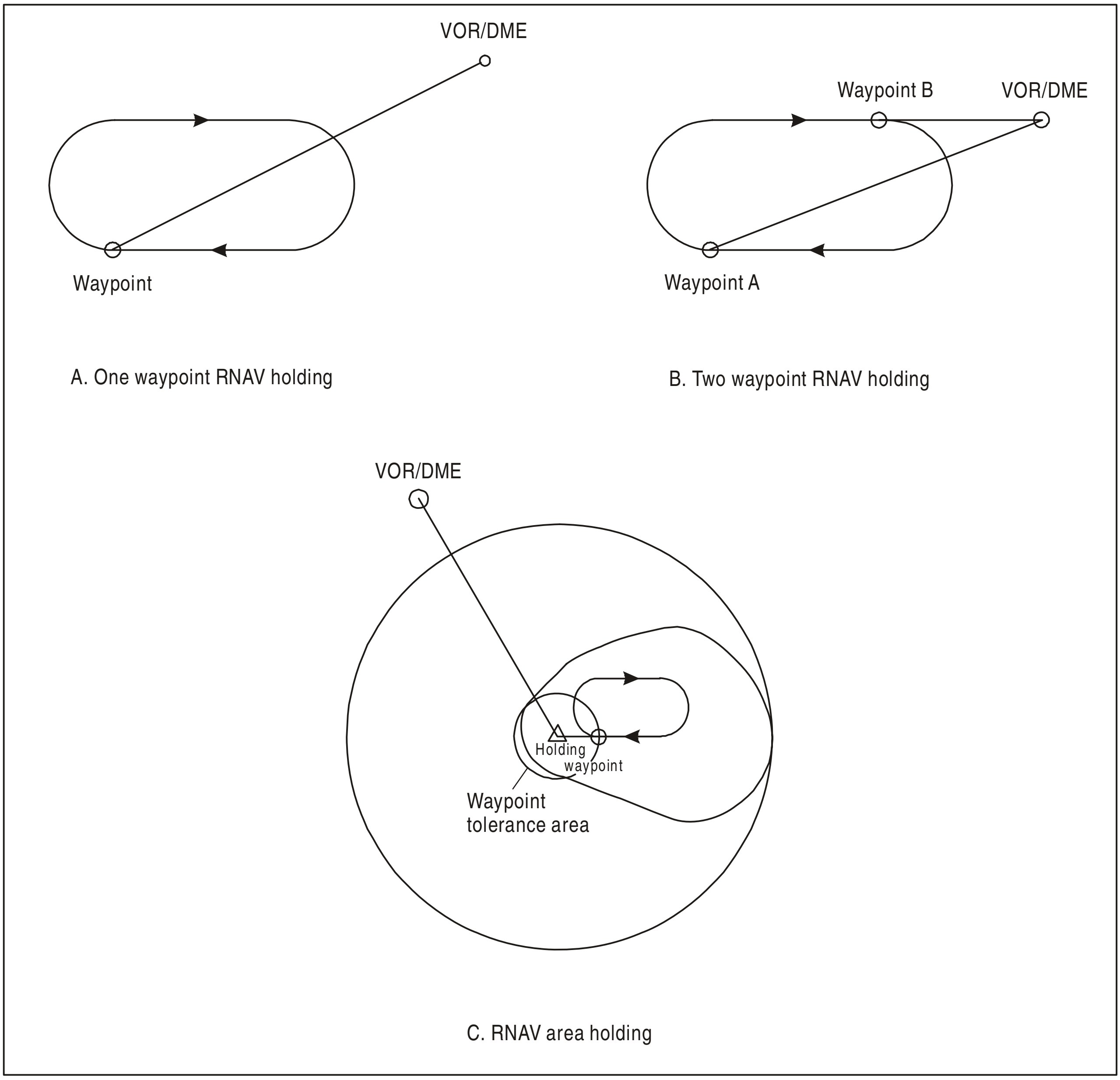


Figure III-3-7-1. Types of RNAV holding procedures

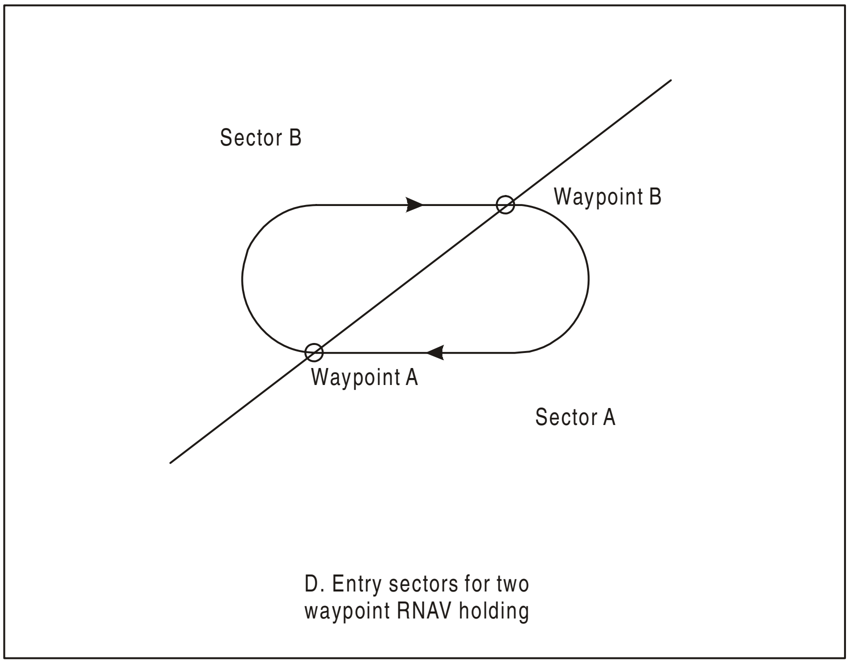


Figure III-3-7-2. Sector construction for two waypoint RNAV holding

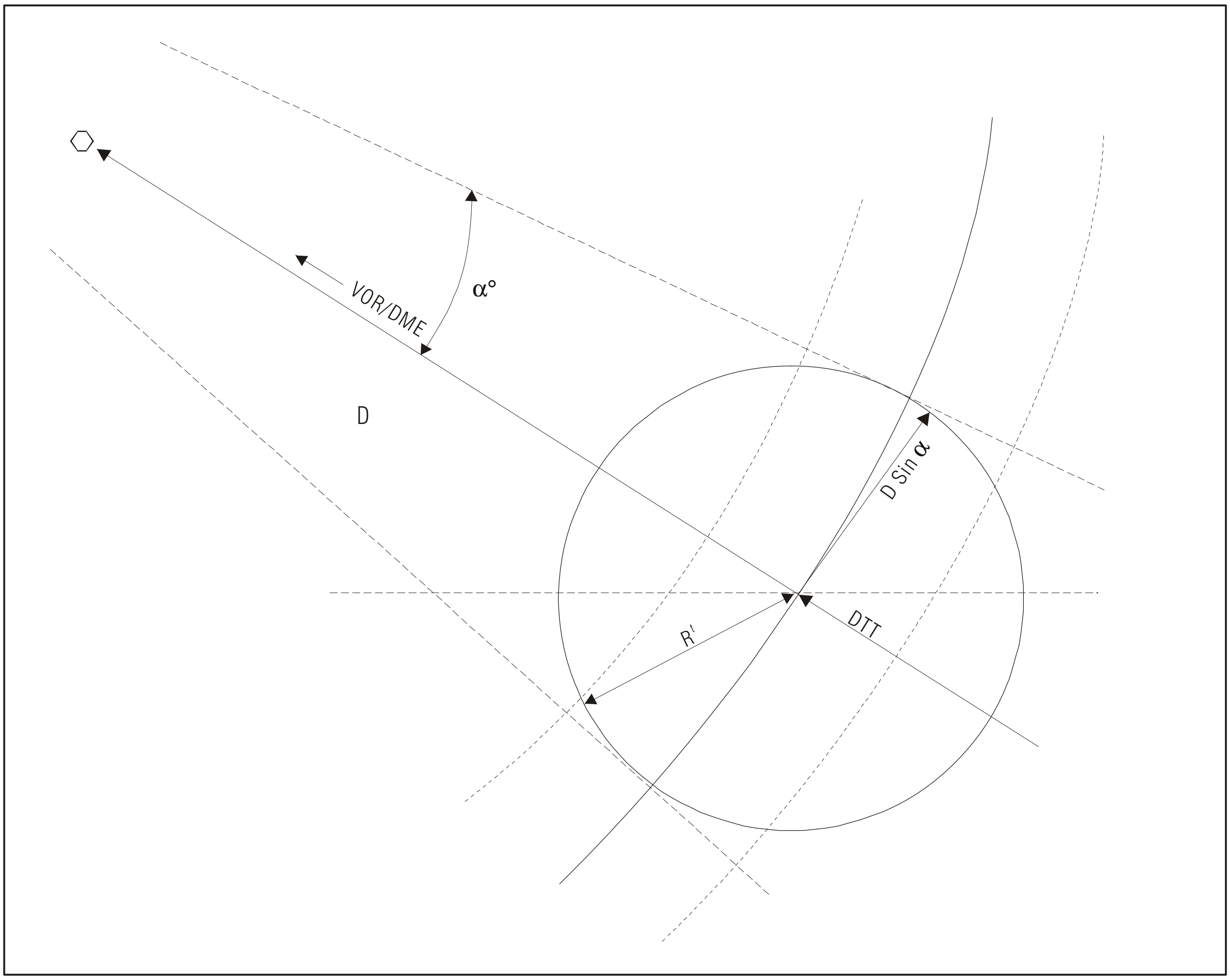


Figure III-3-7-3. Construction of waypoint tolerance areas

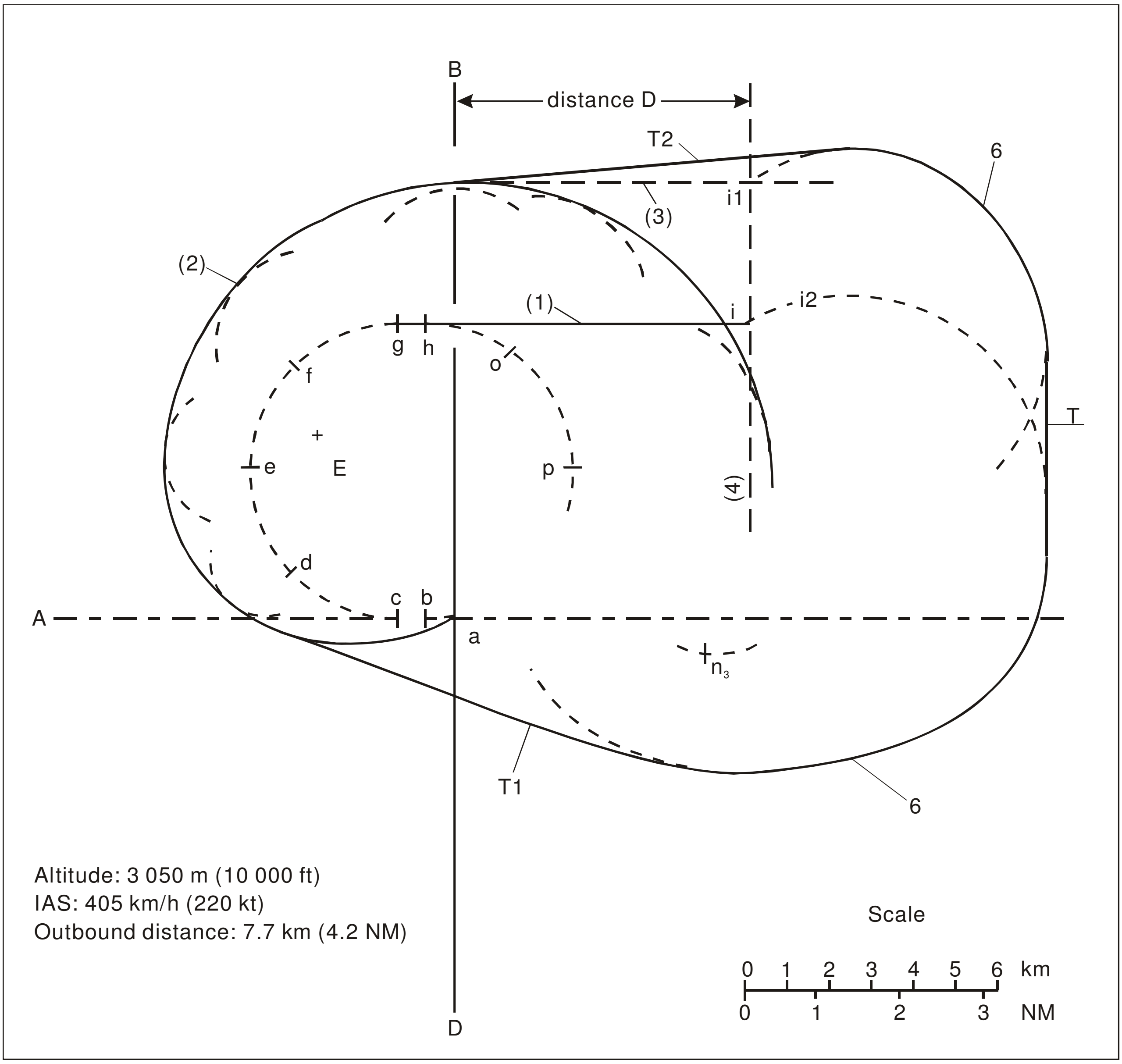


Figure III-3-7-4. RNAV template

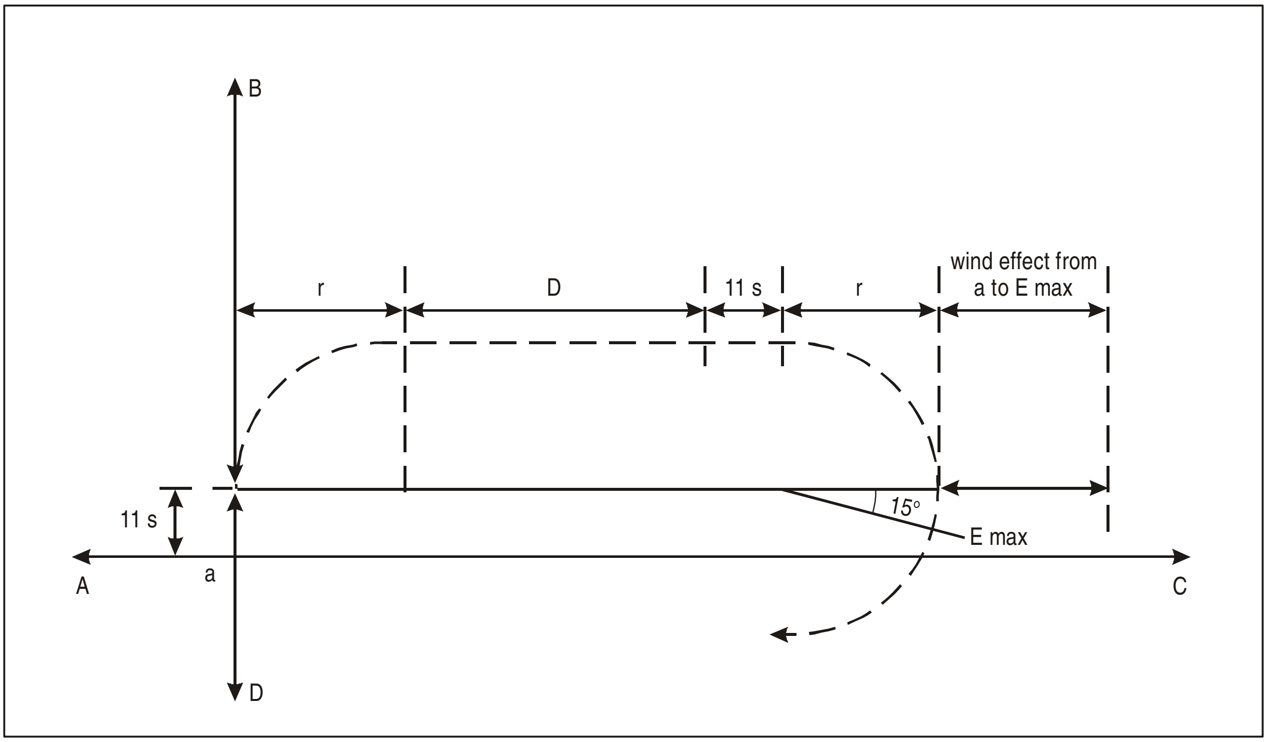


Figure III-3-7-5 a). RNAV holding: XE calculation

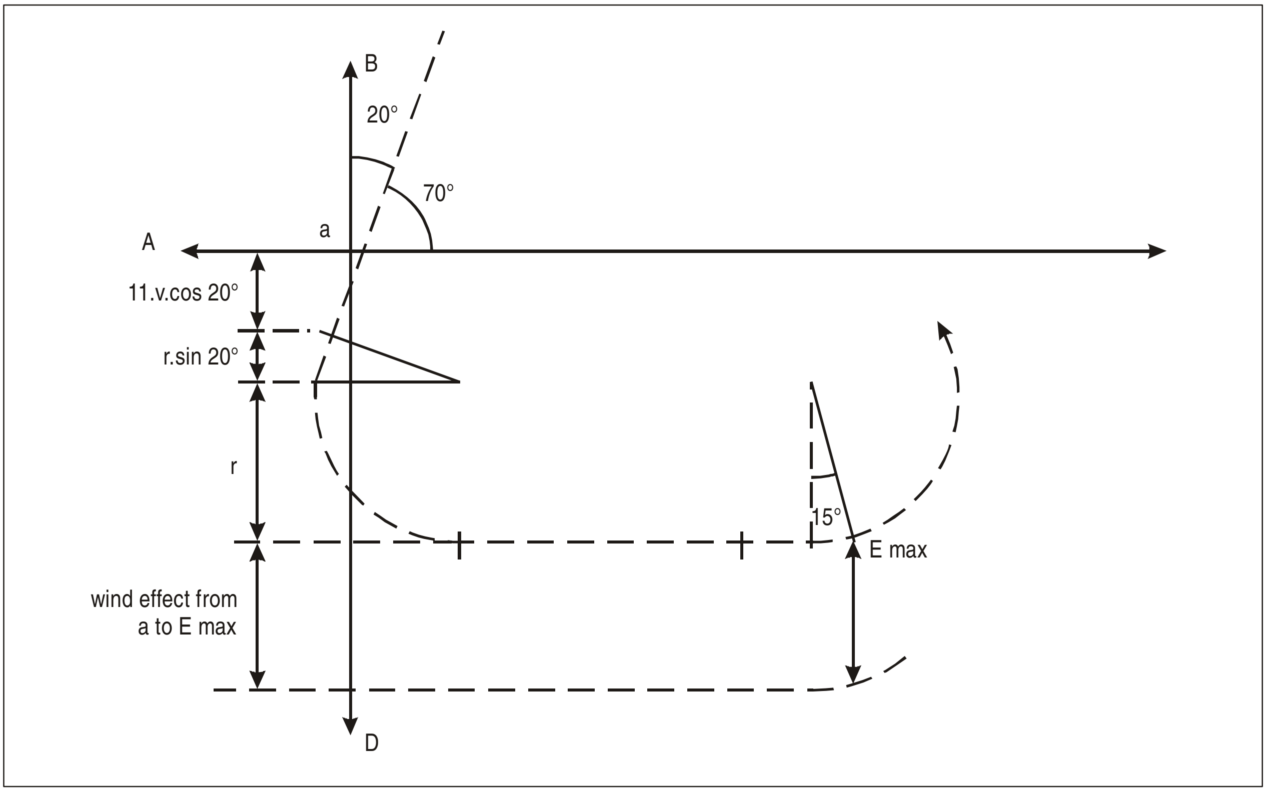


Figure III-3-7-5 b). RNAV holding: YE calculation

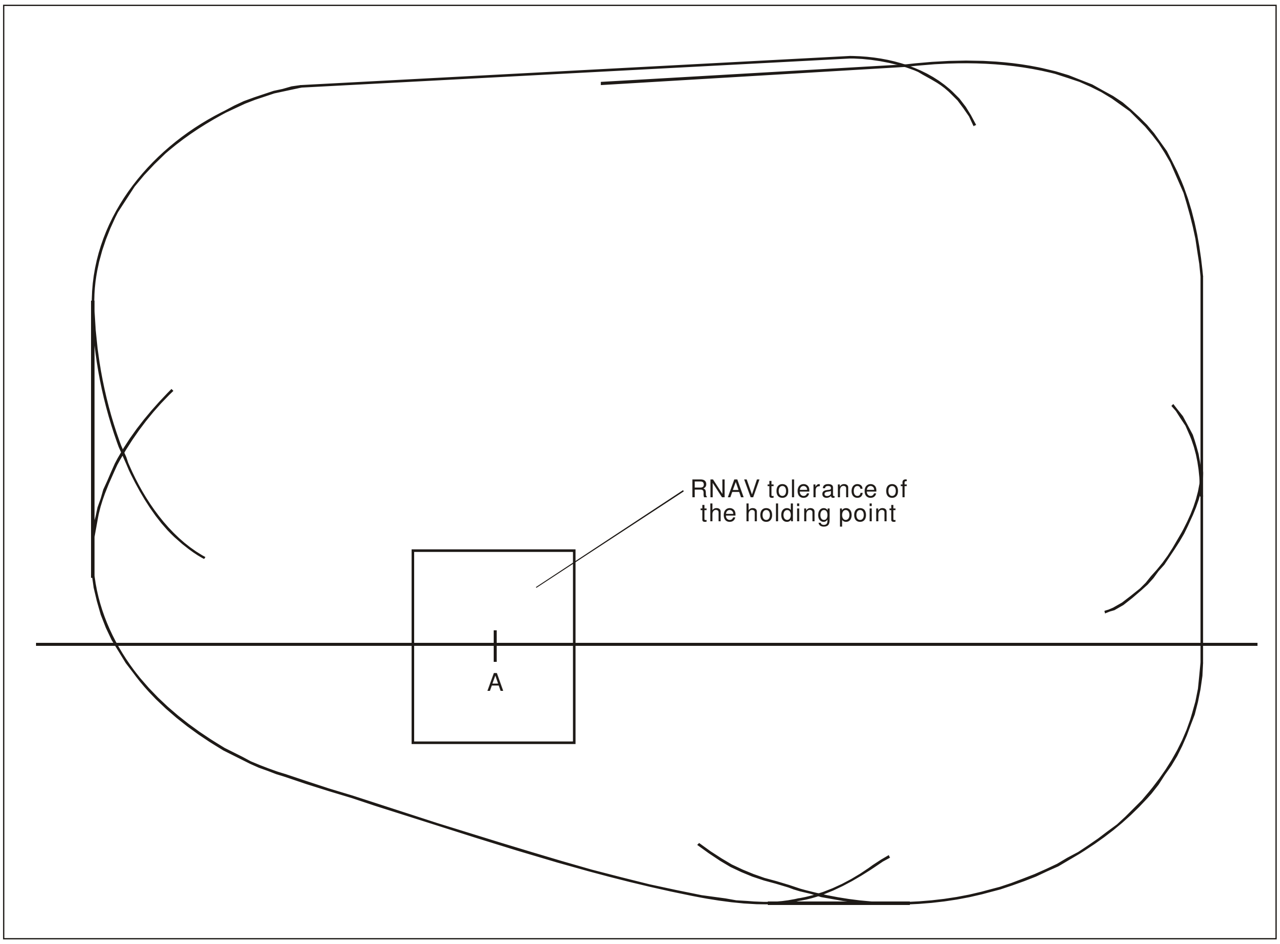


Figure III-3-7-6. RNAV basic area