Federal Aviation Administration

Memorandum

Date: SEP - 7 2011

To: Chas. Frederic Anderson, Acting Director, Aeronautical Products, AJV-3

From: Leslie H. Smith, Manager, Flight Technologies and Procedures Division, AFS-400

Subject: Heading to an Altitude (VA) Followed by a Direct-to Fix (DF) Segment Design Analysis

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The purpose of this memorandum is to provide guidance for analyzing a VA climb segment followed by a DF segment to a fly-over (FO) or fly-by (FB) fix design. It supersedes the VA→DF guidance contained in the Flight Technologies and Procedures Division (AFS-400) memorandum titled "*Performance Based Navigation Instrument Procedure Minimum Segment Length Standard*" dated October 2, 2009, Step 3c.

Analysis Method

For a departure/missed approach VA-DF segment, an earliest and latest turn point (TP) treated as FO is determined in this analysis method:

Earliest TP (departure only): Measure from the departure reference point (DRP) at airport elevation with 1,100 feet per nautical mile climb gradient, which reaches the earliest climb-to altitude or the departure end of runway (DER), whichever occurs first. If the climb-to altitude is not reached by the DER, continue the climb determination using the climb gradients shown in the note below starting at the DER.

Earliest TP (missed approach): Determined using the climb gradients in the note below and at the end of section 1 of the missed approach segment as defined in Order 8260.54A, The United States Standard for Area Navigation (RNAV).

Note: To determine the altitude at a point along the departure or missed approach route, use a climb gradient of 500 feet/nautical mile (NM) until reaching 10,000 feet, then 350 feet/NM to 18,000 feet, then 200 feet/NM.

Latest TP: Aircraft reaches the climb-to altitude climbing at the minimum required climb gradient of 200 feet/NM (*or minimum required by obstacles*) , commencing at the departure end of the runway, at DER elevation, unless a higher gradient is specified.

Calculations: Given a fix (Fx) location for the end of the DF segment and the track outbound from Fx, analyze a FO and FB turn at Fx from the earliest TP then every 0.10 NM to the latest TP to verify: a) if Fx is on or outside the path scribed by the aircraft turn radius; b) if the turn to the subsequent segment is 90 degrees or less; and c) if Fx is designated FB, required distance of turn anticipation (DTA) is available. If the resulting verification of a, b, and c is positively met, then the design analysis "PASSES" and is acceptable. The algorithms and illustrations for this analysis are shown in the attachment. Note to use existing Obstacle Evaluation Area construction and airspeed criteria as outlined in Order 8260.44A, Civil Utilization of Area Navigation (RNAV) Departure Procedures or Order 8260.54A as appropriate. AFS-400 memorandum "Harmonized Flight Instrument Procedure Design Calculations" dated October 19, 2010 applies. There is no limit on the number of degrees of the initial DF turn.

A calculator (VA2DF) that performs the evaluation is in the "Terminal Instrument Procedures (TERPS) Tools" section of the Flight Procedures Standards Branch web site or use the September 2011 (or newer) release in TARGETS.

http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/afs420/terps_tools/

This memorandum will be incorporated into Order 8260.PBN. If you have any questions, please contact Mr. Rick Dunham, Manager, Flight Procedure Standards Branch, AFS-420, at (405) 954-4164.

VA followed by DF feasibility algorithm

[algorithm VA-DF Feasibility Test] start

(1) input $TC_{\rightarrow TP}$ is the true departure course (from AER) to turn point (TP) in degrees

AER (lat, lon)

Fx is Fix (lat, lon)

track is track from Fx in degrees

$Elev_{Airport}$ is the Airport Elevation MSL

Alt is the climb-to-altitude MSL

$Runway_{Length}$

MinCG is the Minimum Climb Gradient

Constants

$$r = 20890537 \times \frac{0.3048}{1852}$$

Use 1,100 feet per nautical mile climb gradient until reaching the climb-to altitude or the departure end of runway (whichever comes first), then the max(500, MinCG) until reaching 10,000 feet, then max(350, MinCG) to 18,000 feet then max(200, MinCG)

Use 250 V_{KIAS} until 10,000 feet and 300 knots after

(2) To calculate DRP, move AER $2000 \times \frac{0.3048}{1852}$ nm on course $TC_{\rightarrow TP}$

To calculate DER, move AER $Runway_{Length} \times \frac{0.3048}{1852}$ nm on course $TC_{\rightarrow TP}$

minDist = minimum distance to achieve altitude from DRP + $2000 \times \frac{0.3048}{1852}$

maxDist = maximum distance to achieve altitude using MinCG from DER + $Runway_{Length} \times \frac{0.3048}{1852}$

(3) Calculate the Turn Radius R using Alt as input altitude

```
dist = minDist
Configuration = PASSES  (default setting)
while (dist < maxDist)
  call VA->DF for specified turn point Algorithm
     where TP is AER moved dist nm along TC→TP with the direct algorithm
  if (VA->DF for specified turn point Algorithm fails) then Configuration=FAILS
  end if
  dist = dist + 0.1
end while
```

(4) call VA->DF for specified turn point Algorithm

```
   where TP is AER moved maxDist nm along TC→TP with the direct algorithm
   if (VA->DF for specified turn point Algorithm fails) then Configuration=FAILS
   end if
```

[algorithm VA-DF Feasibility Test] end

VA->DF Specified Turn Point Algorithm

[algorithm VA->DF for specified turn point] start

(1) Use the inverse algorithm to determine course from TP to FX, $TC_{TP \to Fx}$. Use the direct algorithm to solve for the center point of turn, R_C (Lat,Lon), using R for the distance from TP and course $TC_{TP \to Fx}$ ± 90° as appropriate

(2) Use the inverse algorithm to compute the distance from R_C to Fx ($D_{R_C \to Fx}$) and the true course from Fx to R_C ($TC_{Fx \to R_C}$)

if ($D_{R_C \to Fx} < R$) then Configuration=FAILS
end if

(3) $$\alpha = \sin^{-1}\left(\frac{\sin\left(\frac{R}{r}\right)}{\sin\left(\frac{D_{R_C \to Fx}}{r}\right)}\right) \times \frac{180^\circ}{\pi}$$

(4) $$D_{Fx \to RO_{TP}} = r \times \cos^{-1}\left(\frac{\cos\left(\frac{D_{R_C \to Fx}}{r}\right)}{\cos\left(\frac{R}{r}\right)}\right)$$

Use the direct algorithm to place RO_{TP} (Roll Out Tangent Point) $D_{Fx \to RO_{TP}}$ from Fx on a course of $TC_{Fx \to R_C} \pm \alpha$ as appropriate

(5) Use the inverse algorithm to solve for the true course from RO_{TP} to Fx ($TC_{RO_{TP} \to Fx}$ in degrees)

(6) $course_{change}$ is the positive course change from $TC_{RO_{TP} \to Fx}$ to following leg

(7) if $\left(course_{change} > 90^\circ\right)$ then Configuration=FAILS
end if

(8) if (fly-by turn) then
Compute the Turn Radius R2
Call turn radius algorithm where the distance from TP to Fx ($D_{TP \to FX}$) is calculated using inverse algorithm. Use the specified climb gradients in the VA-DF Feasiblity Algorithm [step (1) Constants] to determine indicated airspeed and turn altitude.

$$DTA_{RO_{TP} \to Fx} = \text{round}\left(R2 \times \tan\left(\frac{course_{change}}{2} \times \frac{\pi}{180}\right), 2\right)$$

if $\left(D_{Fx \to RO_{TP}}\right) < DTA_{RO_{TP} \to Fx}$ then Configuration=FAILS
end if
end if

[algorithm VA->DF for specified turn point] end

True Airspeed

```
start
Remark:  Calculate true airspeed (V_KTAS) in knots
(1)  input   V_KIAS
             alt
```

$$(2)\quad V_{KTAS} = round\left(\frac{V_{KIAS} \times 171233 \times \sqrt{303 - 0.00198 \times alt}}{(288 - 0.00198 \times alt)^{2.628}}, 0\right)$$

```
Remark:  303 is the value for ISA at MSL (15°C) on the Kelvin scale
         (288K=15°C,+15°C=303K)
end
```

Tailwind Component

```
start
Remark:  Calculate tailwind component (V_KTW) in knots
(1)  input   apt_elev in feet
             alt
(2)  if  (alt-apt_elev) ≤ 2000   then
        V_KTW = 30
     else
        V_KTW = round(0.00198 × alt + 47, 0)
     end if
end
```

Turn Radius

```
start
Remark:  Calculate turn radius (R) in nautical miles
(1)  input  V_ground
```

$$(2)\quad R = round\left(\frac{V_{ground}^{2}}{\tan\left(25^\circ \times \frac{\pi}{180^\circ}\right) \times 68625.4}, 2\right)$$

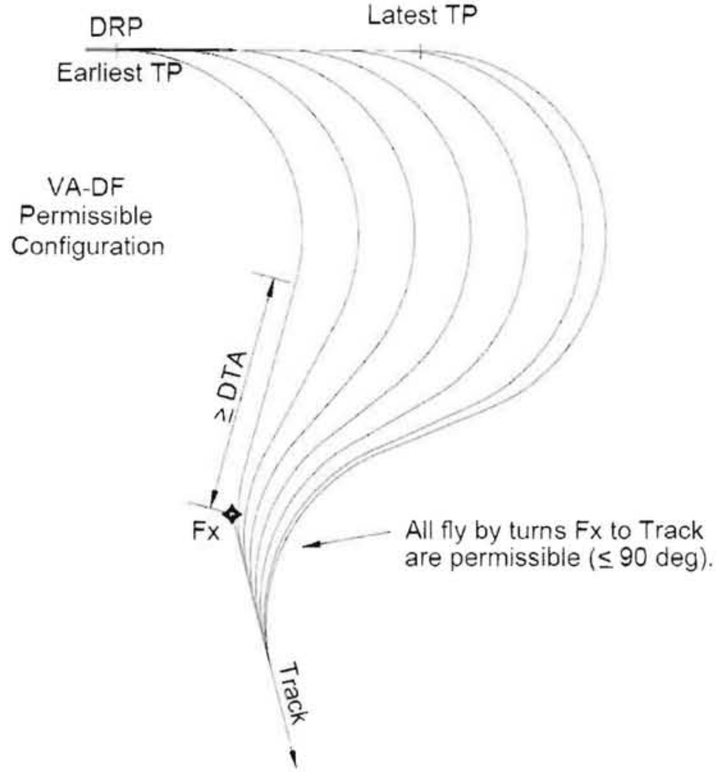
```
end
```

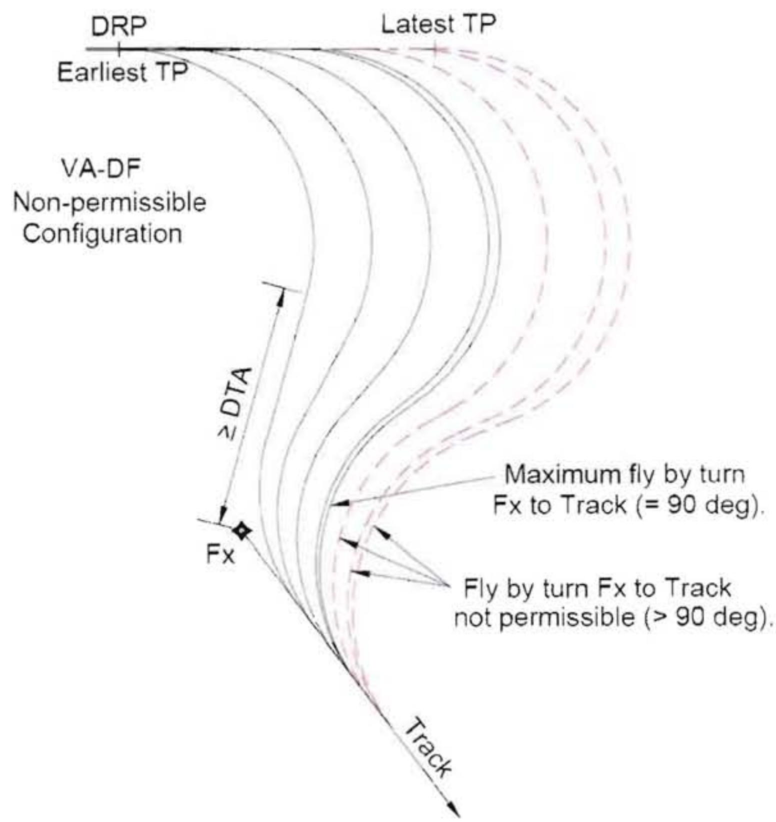
Ground Speed

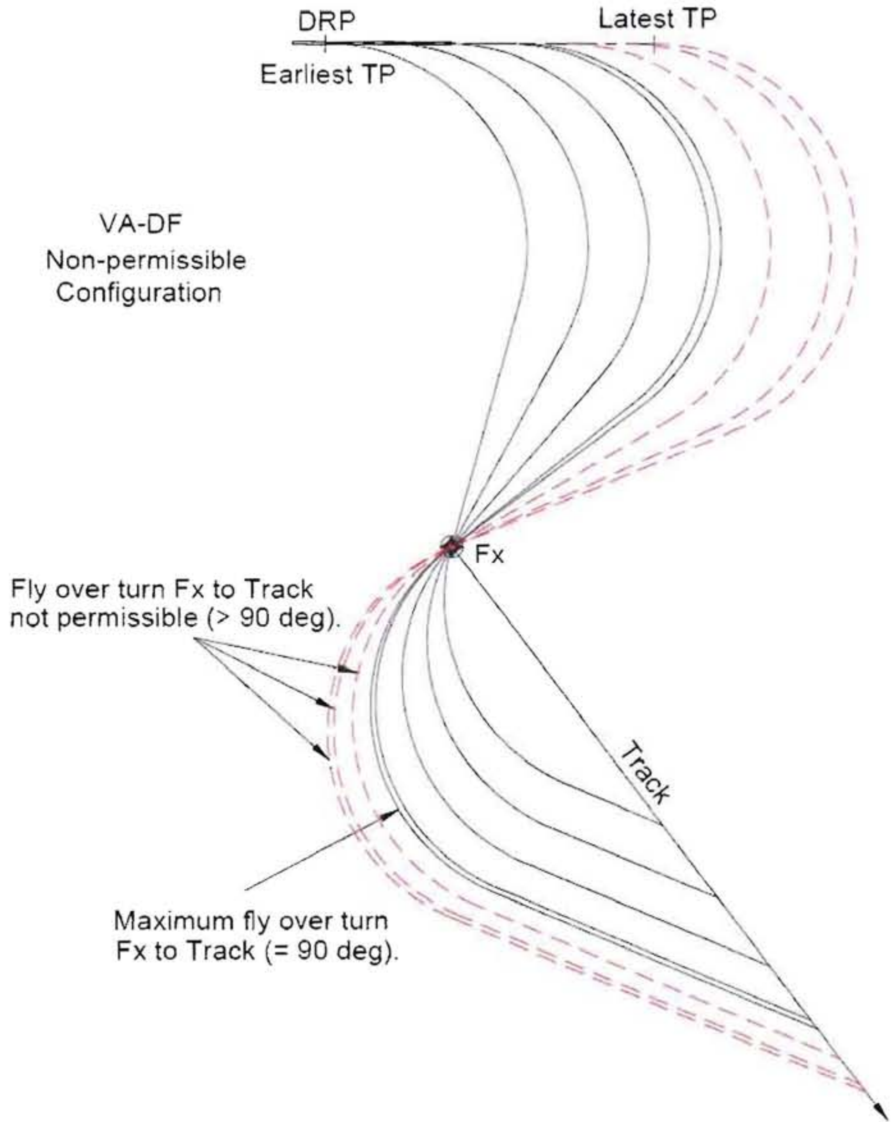
```
start
Remark:  Determine ground speed in knots (V_ground)
(1)   input  V_KTAS
             V_KTW
             alt
(2)  if alt > 19500 then
```

$$V_{ground} = round\left(\min\left(570, 0.9941 \times \frac{alt}{100} + 287\right), 0\right)$$

```
     else if alt ≥ 10000 then
              V_ground = min(500, V_KTAS + V_KTW)
     else V_ground = V_KTAS + V_KTW
     end if
end
```


DRP
Latest TP
Earliest TP
VA-DF
Permissible
Configuration
≥ DTA
Fx
All fly by turns Fx to Track
are permissible (≤ 90 deg).
Track


DRP
Latest TP
Earliest TP
VA-DF
Non-permissible
Configuration
≥ DTA
Fx
Maximum fly by turn
Fx to Track (= 90 deg).
Fly by turn Fx to Track
not permissible (> 90 deg).
Track


DRP
Latest TP
Earliest TP
VA-DF
Non-permissible
Configuration
Fx
Fly over turn Fx to Track
not permissible (> 90 deg).
Track
Maximum fly over turn
Fx to Track (= 90 deg).