Federal Aviation Administration

Memorandum

Date: FEB 0 6 2012

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

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

Subject: Performance Based Navigation (PBN) Instrument Procedure Minimum Segment Length Standard

The purpose of this memorandum is to establish the minimum segment length (fix-to-fix distance) for PBN procedure design.

The minimum segment length between waypoints for straight segments is **1** NM (*turns of ten degrees or less are considered straight*). For any leg incorporating a turn greater than ten degrees, minimum segment length is 1 NM or the leg's Distance of Turn Anticipation (DTA) requirement, whichever is greater. Specifically, with regard to Required Navigation Performance (RNP) Authorization Required (AR) only, the minimum is 2 times RNP value or 1 NM, whichever is less.

The attachment defines the design construction formulas for minimum segment length. Please note that design construction permutations may require a larger segment length than the attached formulas and should be used in lieu of the minimum segment length formulas.

This memorandum cancels Flight Technologies and Procedures Division, AFS-400, Oct 2, 2009 memorandum, subject "Performance Based Navigation Instrument Procedure Minimum Segment Length Standard" and supersedes the minimum segment leg length standards contained in the following FAA Orders:

- 8260.44A, *Civil Utilization of Area Navigation (RNAV) Departure Procedures*, dated March 23, 2000,
- 8260.52, *United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR)*, dated June 3, 2005
- 8260.54A, *The United States Standard for Area Navigation (RNAV)*, dated December 7, 2007.

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

Cc: Joe McCarthy, Manager, AJV-14
Jeff Bruce, Airspace Design and Simulation, Jeppesen Sanderson, Inc.
Giovanni Spitale, General Manager, Naverus-GE Aviation, PBN Services

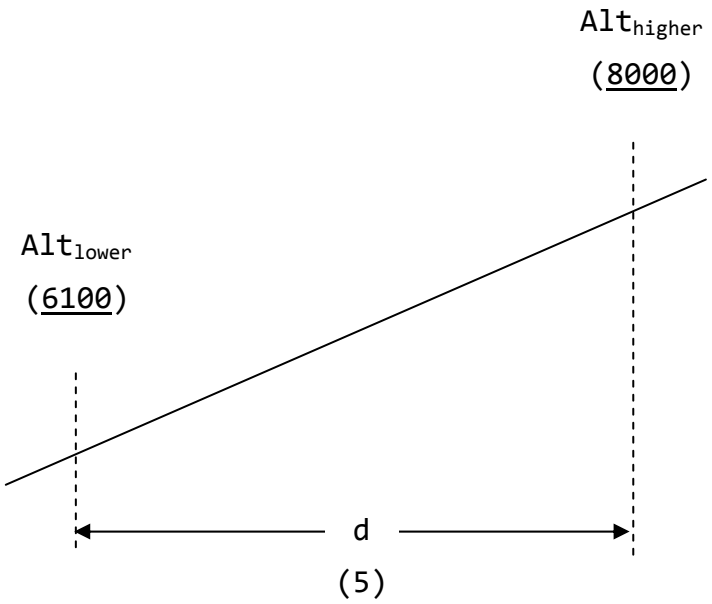
* *Red asterisked formulas were updated (in red) on March 6, 2012*

Minimum PBN Leg Length Policy for Altitudes

(Does not apply to RF segments)

Apply the following guidance to determine the minimum segment length (fix-to-fix). Fixes added between the segment initial and termination fixes for air traffic control purposes that do not create a turn and not used for obstacle clearance or OEA construction are not considered in segment length determination. For segment length purposes, turns of 10 degrees or less are considered straight. Steps 1 and 2 yield turn radius values (*if there is a turn >10 degrees at the segment initial and/or termination fix*) used in the appropriate minimum length calculation in Step 3.

The calculation of assumed effective ground speed requires a value for turn altitude expressed in thousands of feet. For approach procedures and STARs, determine the higher projected fix altitude by multiplying the fix distance (*"d" measured fix to fix in nautical mile (NM) increments)* from the lower fix by 250 and add the product to the lower fix altitude (Alt_{lower}). Compare this value to the published minimum fix altitude (Alt_{higher}). Use the higher value as the turn altitude. This is the starting altitude for the next segment up. Exception: If this altitude is higher than the highest altitude expected at the fix (*can be specified by ATC*), use the highest expected altitude.



Example: d=5 alt_{Lower}=6100 alt_{higher}=8000

$Alt_{Lower}+d\times 250$

$6100+5\times 250=7350$ *

Select 8000

For Q and T routes, use the highest altitude expected by ATC.

For departures, SIDs, and missed approach routes, measure the fix distance (*along designed track fix to fix in NM)* from the start-of-climb point. Assume a climb gradient of 500 ft/NM until reaching 10,000 ft, then 350 ft/NM.

Note: If the following formulas are used on a hand-held calculator, it must be in the "radian" mode, not the "degree" mode.

Function **round(x,f)** rounds **x** toward the nearest integer, **f** is the number of decimals (0-9) of the resulting value.

STEP 1: Determine Ground Speed (V_{ground})

a = turn altitude in feet
f=MSL field elevation
V_{KIAS} *= appropriate value from 8260.54A, table 2-3*

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

(2) *case* $(a\text{-}f \le 2000)$: $V_{KTW} = 30$

case $(a\text{-}f > 2000)$: $V_{KTW} = round[a \times 0.00198 + 47, 0]$ *

Note : Lower V_{KTW} values may be used if the last 5 year weather history at the turn fix location and turn altitude indicates the lower value maximum value is typical. Record the value used and justification in procedure documentation.

(3) *case* $(a \le 19500)$: $V_g = V_{KTAS} + V_{KTW}$

case $(a > 19500)$: $V_g = \mathbf{round}\left[0.9941 \times \frac{a}{100} + 287, 0\right]$

$V_{ground} = \mathbf{min}[V_g, 570]$

STEP 2: Determine Turn radius (R)

V_{ground}=ground speed from Step 1

β*=bank angle

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

*The OPTIMUM design bank angle is 18°, maximum is 25°. Above 19500 the bank angle is 5°.

STEP 3. Set value for shortest minimum length (λ)

if RNP SAAAR/AR then

$\lambda = \min(1, 2 \times RNP)$

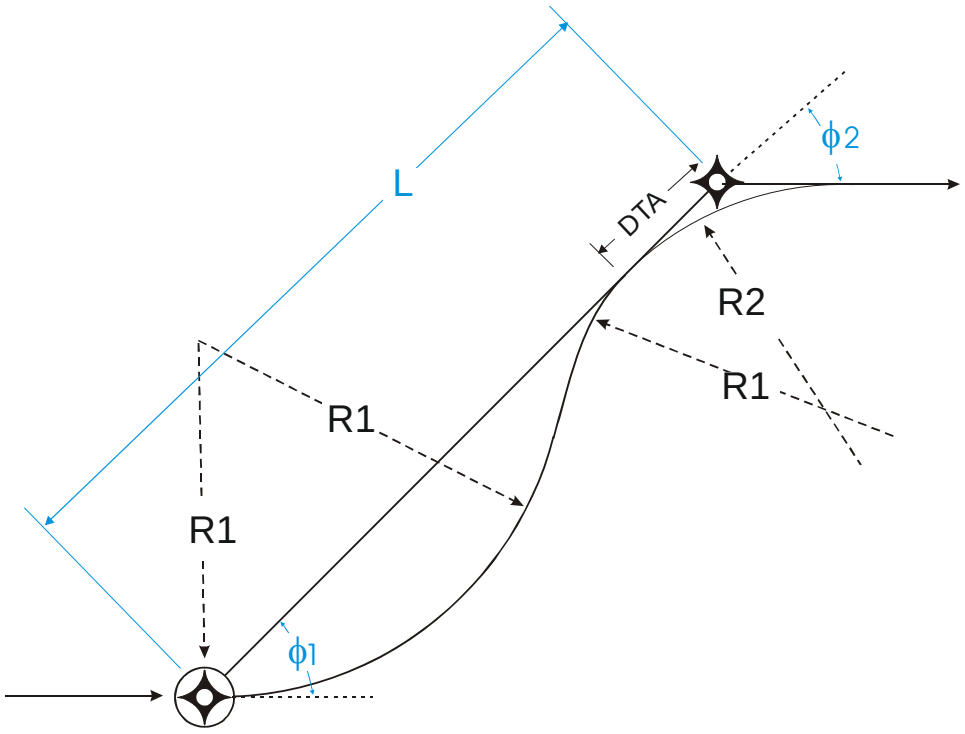
else

$\lambda = 1$

end if

STEP 4. Determine Minimum Segment Length

A. Track-to-fix (TF) leg following a fly-over turn.



R1 = turn radius at the segment initial fix
R2 = turn radius (0 if no turn) of the segment termination fix
ϕ1 = turn magnitude at segment initial fix
ϕ2 = turn magnitude at segment termination fix (0 if no turn)

if $\phi 1 < \frac{180}{\pi} \times \mathbf{acos}\left(\sqrt{3}-1\right)$ *then*

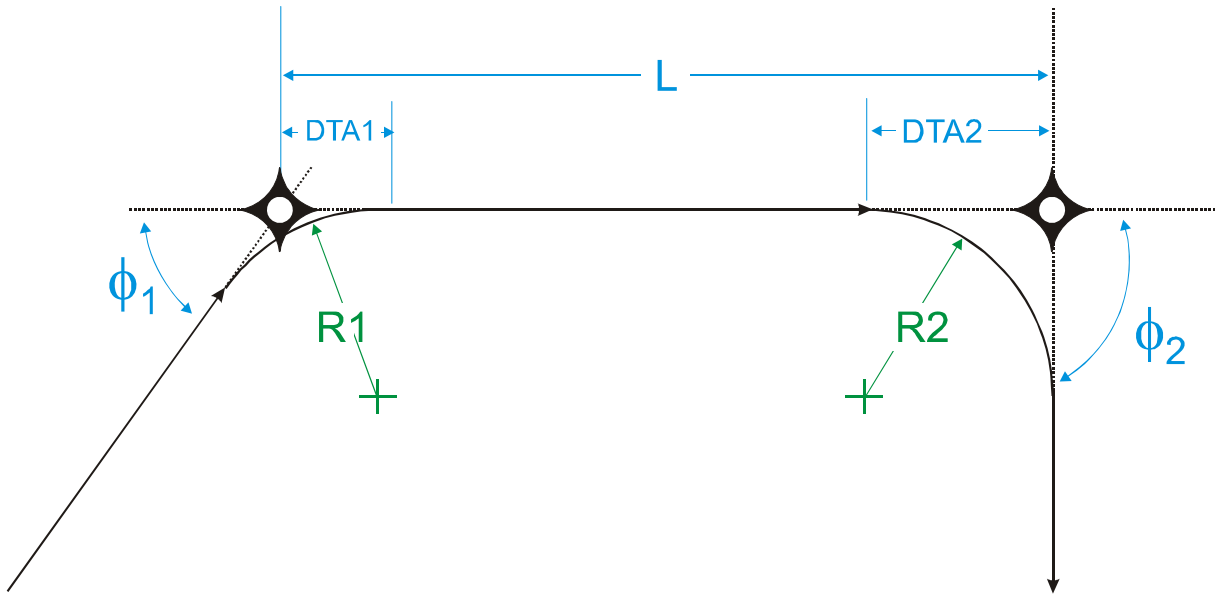
$$\textit{Minimum Length} = \mathbf{max}\left[\lambda, \mathbf{round}\left(R1 \times \left(\sin\left(\phi 1° \times \frac{\pi}{180°}\right) + 2 \times \sin\left(\mathbf{acos}\left(\frac{1+\cos\left(\phi 1° \times \frac{\pi}{180°}\right)}{2}\right)\right)\right) + R2 \times \tan\left(\frac{\phi 2°}{2} \times \frac{\pi}{180°}\right), 2\right)\right] *$$

else

$$\textit{Minimum Length} = \mathbf{max}\left[\lambda, \mathbf{round}\left(R1 \times \left(\sin\left(\phi 1 \times \frac{\pi}{180}\right) + 4 - \sqrt{3} - \sqrt{3} \times \cos\left(\phi 1 \times \frac{\pi}{180}\right)\right) + R2 \times \tan\left(\frac{\phi 2}{2} \times \frac{\pi}{180}\right), 2\right)\right] *$$

end if

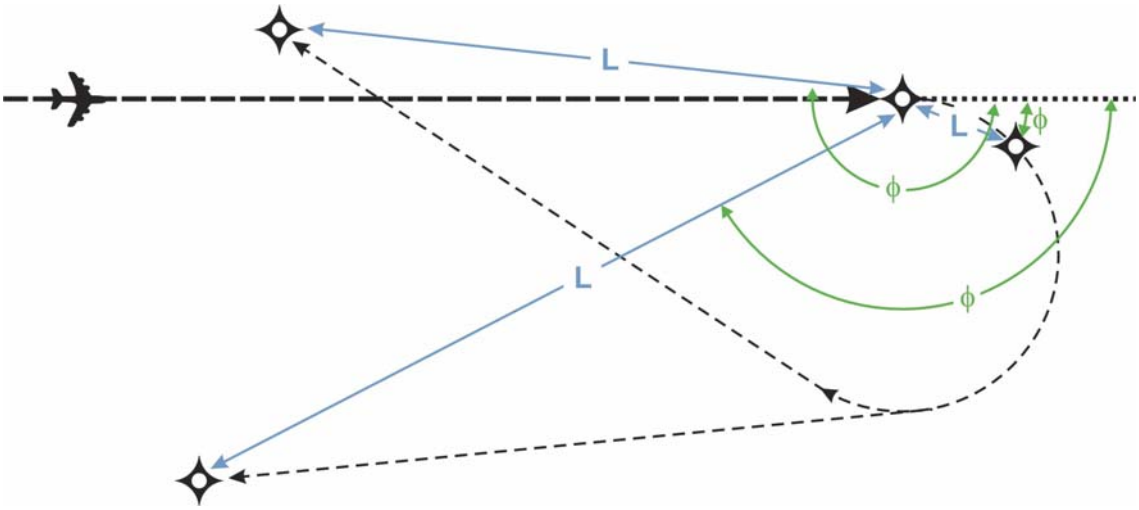
B. TF leg to a Fly-by turn following a Fly-by turn



R1 = turn radius at the segment initial fix
R2 = turn radius (0 if no turn) of the segment termination fix
ϕ1 = turn magnitude at segment initial fix
ϕ2 = turn magnitude at segment termination fix (0 if no turn)

$$\textit{Minimum Length} = \mathbf{max}\left[\lambda, \textit{round}\left(R1 \times \tan\left(\frac{\phi 1}{2} \times \frac{\pi}{180}\right) + R2 \times \tan\left(\frac{\phi 2}{2} \times \frac{\pi}{180}\right), 2\right)\right]$$

C. Defined path (RF/TF/CF) to a fix followed by a DF leg



R=turn radius

ϕ=turn magnitude at segment initial fix

$$\textit{case } (\phi > 30)\textit{: minimum length} = \mathbf{max}\left[\lambda, \mathbf{round}\left[4 \times R \times \left(\mathbf{sin}\left(\frac{\phi+30}{2} \times \frac{\pi}{180}\right)\right)^2, 2\right]\right]$$

$$\textit{case } (\phi \leq 30)\textit{: minimum length} = \mathbf{max}\left[\lambda, \mathbf{round}\left[2 \times R \times \mathbf{sin}\left(\phi \times \frac{\pi}{180}\right), 2\right]\right]$$