Application of the Terminal PBN Separation Standard

PANS ATM RNP Amendment

Amendment 3, 18 November 2010

Presentation Objective

To promote:

- a background understanding of the PBN terminal separation standards;
- critical thinking about the basis of PBN-based separation standards; and
- a clear understanding of the available implementation options.

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5.4.1.2.1.3 *By use of different navigation aids or methods.* Lateral separation between aircraft using different navigation aids, or when one aircraft is using RNAV equipment, shall be established by ensuring that the derived protected airspaces for the navigation aid(s) or RNP do not overlap.

5.4.1.2.1.4 *Lateral separation of aircraft on published adjacent instrument flight procedures for arrivals and departures*

5.4.1.2.1.4.1 Lateral separation of departing and/or arriving aircraft, using instrument flight procedures, will exist:

a) where the distance between RNAV 1, Basic RNP 1, RNP APCH and/or RNP AR APCH tracks is not less than 13 km (7 NM); or…

Note 1.— The 13 km (7 NM) value was determined by collision risk analysis using multiple navigation specifications. Information on this analysis is contained in Circular 324, Guidelines for Lateral Separation of Arriving and Departing Aircraft on Published Adjacent Instrument Flight Procedures.

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5.4.1.2.1.4.1 Lateral separation of departing and/or arriving aircraft, using instrument flight procedures, will exist:

b) where the protected areas of tracks designed using obstacle clearance criteria do not overlap and provided operational error is considered.

Note 2.— Circular 324 also contains information on separation of arrival and departure tracks using non-overlapping protected areas based on obstacle clearance criteria, as provided for in the Procedures for Air Navigation Services — Aircraft Operations, Volume II — Construction of Visual and Instrument Flight Procedures (PANS-OPS, Doc 8168).

Note 3.— Provisions concerning reductions in separation minima are contained in Chapter 2, ATS Safety Management, and Chapter 5, Separation Methods and Minima, Section 5.11.

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Conservative Modeling Assumptions

The risk modeling assumed:

- a terminal environment of 400 IFR air traffic movements per day (200 arriving and 200 departing flights per day = 146,000 movements per year);
- no ATC surveillance, visual or electronic (thus no ATC intervention); and
- no pilot cross-checking of navigational position.

In essence, a completely procedural, moderately busy controlled aerodrome with no ATC!

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Conservative Modeling Assumptions

- Target Level of Safety: conservative TLS of 5 x 10^{-10} collisions per arrival-departure pair.
- Maximum risk: every departure always passes exactly abeam the arrival at the same altitude with a 2.5% (150ft/NM) climb gradient– increased conflict exposure.
- Lateral containment : RNAV protected airspace typically10-15 times larger than data indicates the real 99.99% (4σ, 2 RNP) containment requires and 2.0 NM area semi-width for the entire final segment (RNP APCH = 0.6 NM).
- Monitoring: no ATC monitoring or pilot cross-monitoring, or ATC intervention capability.
- Not one but two protected airspaces used.

~~The cumulative effect result in an extremely conservative 7NM standard!~~

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Conservative Modeling Assumptions

- RNAV v RNP Turn Performance: Gaussian distribution was used for RNP aircraft, but for RNAV aircraft, Double Exponential distribution was used, resulting in a performance for RNAV 1 to 4 orders of magnitude worse than RNP.

  RNP aircraft accident risk rate assumed to be once every 136, 986, 301 years (1 x 10^{-11} fatal accidents per day); RNAV risk rate of once every 1,575 years = risk 87,000 times more likely for RNAV.

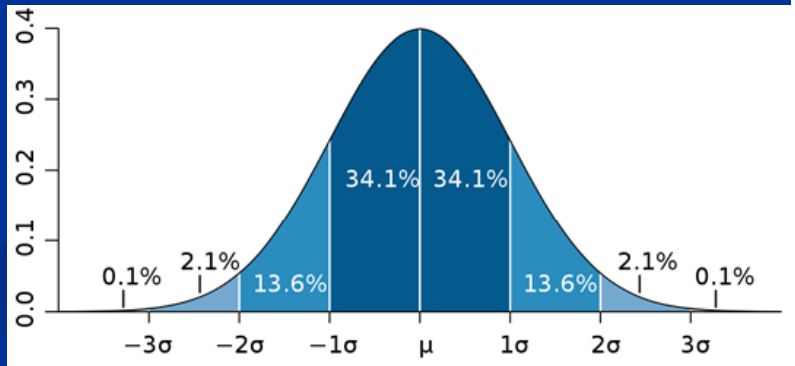

Figure 3.2: A plot of a Gaussian or Normal distribution curve.

- The modeled 90° turn inaccuracy was assumed to increase risk by 29 to 31 times compared to a 15° turn

The cumulative effect of these assumptions resulted in an extremely conservative 7NM standard!

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Basis of PBN 'Protected Airspace'

- 40 years ago, the ILS protection surfaces were created by analysis of empirical data from thousands of tracked flights.
- Today, we use RNAV or RNP protected airspace based to a large degree on an allowance of pilot/aircraft track-keeping performance in given situations (TSE), and the navigation specifications take into account the lowest common denominator such as VOR/DME sensing.
- Thus it is no surprise that the actual navigation capability of PBN aircraft is consistently much better than assumed.
- In order to reap the full benefits of PBN States must understand the ultra conservative nature of the assumptions behind PBN.

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Option 1

States may consider modifying the 7NM standard by using the Circular 324 tables, or by using improved assumptions based on empirical data in CRA.

RNAV 1 pairs		
Turn Angle (degrees)	**Distance between tracks** D **(NM)**	**Collision Risk with Double Exponential position errors** $\lambda = 0.333333$
15	7	9.0E-12
15	6	1.5E-10
15	5	2.7E-09
15	4	4.6E-08
45	7	2.6E-11
45	6	5.0E-10
45	5	1.0E-08
45	4	2.0E-08
90	7	2.7E-10
90	6	4.4E-09
90	5	7.0E-08
90	4	1.0E-06

Using RNAV assumed performance...

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…the best track spacing that could be achieved was 7 NM.

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Basic-RNP 1 pairs			
Turn Angle (degrees)	**Distance between tracks D (NM)**	**Collision Risk with Gaussian position errors $\sigma = 0.44843$**	**Collision Risk with Double Exponential position errors $\lambda = 0.162602$**
15	6	2.3E-21	9.0E-18
15	5	6.0E-16	3.9E-15
15	4	1.5E-11	1.5E-12
15	3	3.2E-08	6.0E-10
45	6	1.1E-16	3.7E-16
45	5	3.0E-12	1.8E-13
45	4	7.5E-09	8.0E-11
45	3	1.9E-06	3.7E-08
90	6	5.0E-14	3.7E-14
90	5	3.4E-10	1.3E-11

However if a State determines through data evaluation that Basic RNP 1 performance is not significantly statistically dissimilar to RNAV in a terminal environment…

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15	3	3.2E-08	6.0E-10
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[redacted]			
90	6	5.0E-14	3.7E-14
[redacted]			

…and if a State determines that using ATC surveillance, the 90 and 45º blunder scenarios on the modeled turn might be able to be disregarded…

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Basic-RNP 1 pairs			
Turn Angle (degrees)	Distance between tracks D (NM)	Collision Risk with Gaussian position errors $\sigma = 0.44841$	Collision Risk with Double Exponential position errors $\lambda = 0.162602$
15	6	2.3E-21	9.0E-18
15	5	6.0E-16	3.9E-15
15	4	1.5E-11	1.5E-12
15	3	3.2E-08	6.0E-10
45	6	1.1E-16	3.7E-16
45	5	3.0E-12	1.8E-13
45	4	7.5E-09	8.0E-11
45	3	1.9E-06	3.7E-08
90	6	5.0E-14	3.7E-14
90	5	2.4E-10	1.3E-11

…this could result in a 4 NM spacing meeting the conservative TLS.

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RNAV 1 pairs		
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45	5	1.0E-08
45	4	2.0E-08
90	7	2.7E-10
90	6	4.4E-09
90	5	7.0E-08
90	4	1.0E-06

This is only a theoretical example!

Safety assessment of such modifications must be conducted in accordance with Annex 11, paragraph 2.27.5; and

Doc 4444 Chapter 2, ATS Safety Management, and Chapter 5, Separation Methods and Minima, Section 5.11.

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Option 2

States can use the PANS-OPS based standard using two non-overlapping Doc 8168 protected airspaces, which can result in a horizontal separation of much less than 7NM.

Using this method, a safety assessment must also determine if a buffer needs to be applied between the surfaces to account for local operating conditions.

Note – there is no specific limitation on the PANS OPS types that could be used, although this is not intended to include precision procedures such as ILS.

Note – using decades-old standards, aircraft can be separated by as little as 4.1 NM NM (VOR 15º,15 NM DME).

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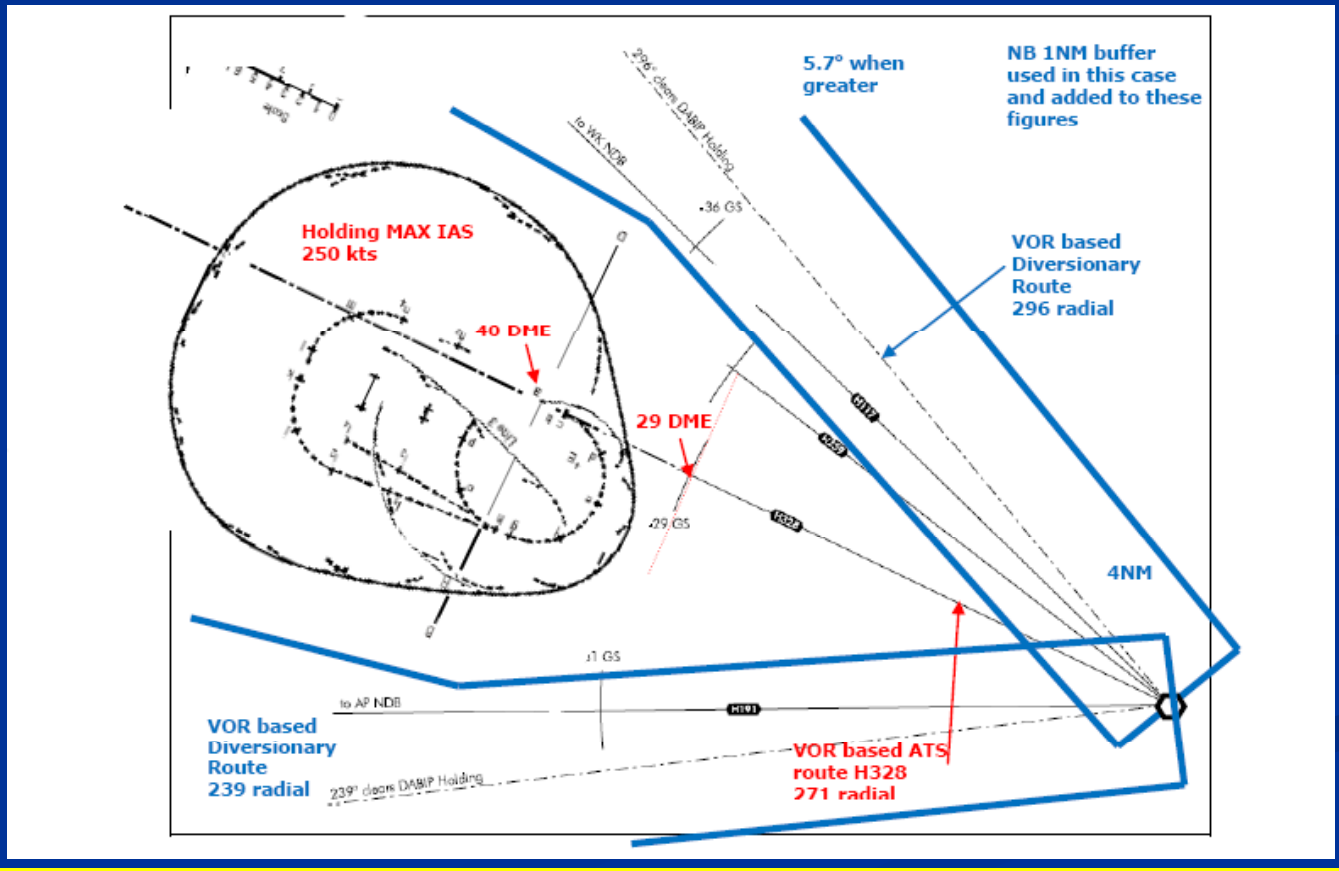
Option 2



Thank You

Q and A