Evidence in Support of UK CAS Containment Policy Change for RNAV1 Routes

Introduction

It is assumed that the risks associated with an aircraft flying within controlled airspace (CAS) on an RNAV1 route in the vicinity of the CAS boundary can be broken down into three types:

a) Infringement of CAS by aircraft supposed to be outside CAS;
b) Penetration of the CAS boundary by controlled aircraft due to blunder or technical error;
c) Penetration of the CAS boundary by controlled aircraft due to the technical navigation performance of the aircraft on an RNAV1 route under own navigation.

Risks a) and b) are the same as the risks experienced by an aircraft being vectored in the vicinity of a CAS boundary, therefore the CAS containment required for vectoring can be considered sufficient to manage these risks [redacted]. Typically it is recommended that controllers aim to keep the aircraft under their control at least 2NM within the boundary while vectoring, although this is sometimes reduced depending on additional risk mitigations and airspace context.

Existing UK policy [Controlled Airspace Containment Policy, CAA SARG, Jan 2014] specifies that risk c) can be safely managed by designing RNAV1 routes (SIDs, STARs and ATS Routes) 3NM from the CAS boundary. This is based on the principle that RNAV1 route navigation performance standard is based on a Total System Error (TSE) for navigational tolerances being + or – 1NM either side of the nominal track for 95% of the total flight time, with an acknowledgment of the normal radar vectoring limitation of 2NM. However, it is commonly known that modern aircraft navigation capability is substantially better than implied by the 95% ±1NM criterion, which suggests that PBN route design requirements founded on this principle may be excessively conservative.

UK PBN Research

In order to better characterise navigation performance and inform UK airspace design guidance, NATS and the CAA have jointly undertaken a PBN research project including a programme of RNAV1 trials and data collection activities. The data from these trials has confirmed that actual navigation performance is better than the 95% ±1NM criterion by a substantial margin.

The work has resulted in a set of probability distributions describing expected lateral deviations from the nominal track of RNAV1 turns and straight legs which are much closer to actual navigation performance than the 95% ±1NM criterion, while still being conservative. These distributions have been validated by third-party audit (DNV-GL) and have formed the basis of the CAA publication CAP1385 [Performance-based Navigation (PBN): Enhanced Route Spacing Guidance, Apr2016]. The goodness-of-fit of the distribution for straight leg navigation performance is shown in Figure 1.

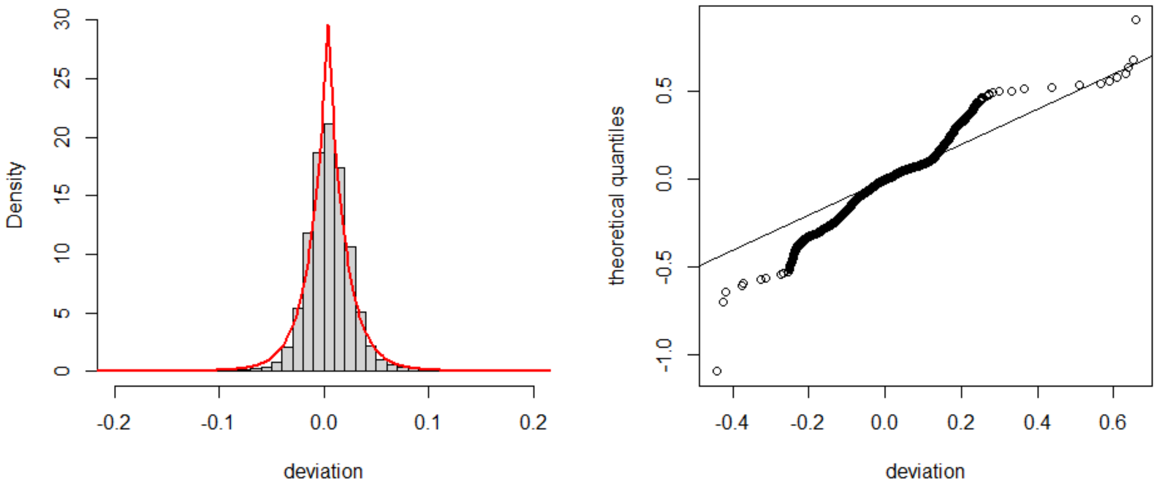

Figure 1: RNAV1 straight leg deviation data (histogram) with fitted distribution (red line); quantile-quantile plot showing conservatism of fitted distribution in the tails.

RNAV1 CAS Containment Requirements

New separation or spacing minima are typically found either by performing a quantitative risk assessment of the proposal and comparing to an absolute target level of safety (e.g. 1.55×10^{-8} [redacted]), or by doing a relative risk assessment compared to an existing acceptably safe procedure. In the case of CAS containment there is no obvious absolute target level of safety since:

- The recommendation to keep vectored aircraft 2NM within the CAS is not equivalent to a separation minimum, so the acceptability criterion of 10^{-5} losses of separation per sector hour used in CAP1385 is not applicable;
- There is no known existing acceptability criterion for penetrations of the CAS boundary;
- The use of the standard target level of safety of 1.55×10^{-8} [redacted] would require knowledge of the traffic density and behaviour outside controlled airspace, which is inherently unpredictable.

Instead, a relative risk assessment compared to the existing CAS containment policy can be used. The policy is founded on the assumption of 95% containment within ±1NM of the nominal route centreline. RNAV navigation inaccuracy is typically assumed to have a zero-mean Gaussian distribution [ICAO Doc 9613 PBN Manual, 2.2.1.1], with a standard deviation of approximately 0.5NM.

[redacted].

The actual known distribution for RNAV1 straight leg navigation performance is a double-exponential mixture distribution as shown in Figure 1. The comparison between this and the assumed Gaussian distribution is shown in Figure 2 and demonstrates that the true probability of a CAS boundary penetration is many orders of magnitude lower than the current policy is designed to protect against.

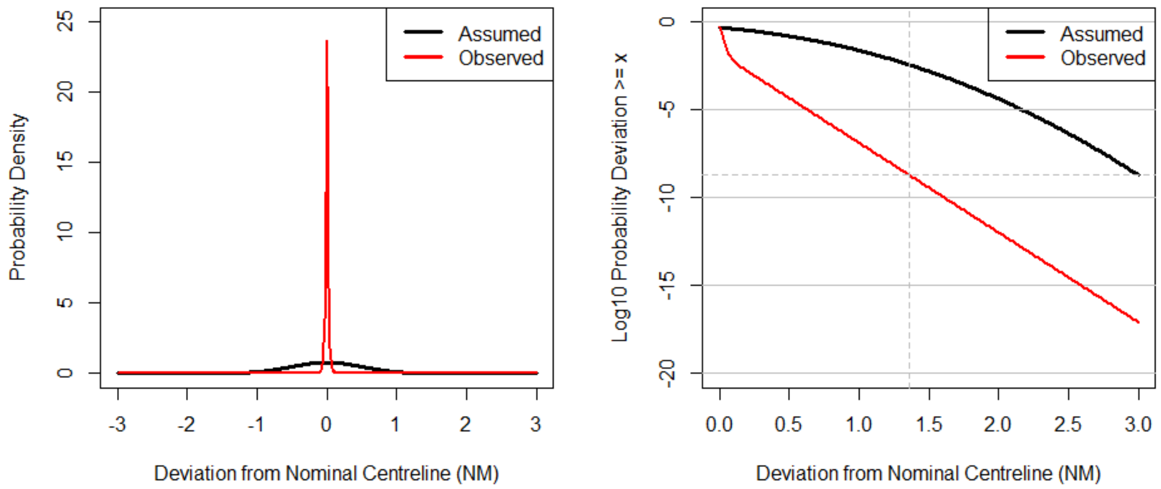

Figure 2: Comparison of assumed Gaussian distribution versus observed double-exponential distribution.

Instead, the nearest equivalent CAS containment is 1.4NM, which gives a probability of boundary penetration of 1.19×10^{-9}, and would therefore provide a similar or better protection against boundary penetration due to the technical navigation performance of the aircraft than the current policy is designed for. [redacted].

It is therefore recommended that the CAS Containment policy should be amended to permit the straight leg portion of RNAV1 routes to be placed at the greater of 1.4NM or the distance required for vectoring. Typically this would be 2NM.