Performance-based Navigation

Enhanced route spacing guidance

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Chapter 1

Introduction

One of the key supporting enablers for the UK Future Airspace Strategy (FAS) is the re-design of UK terminal airspace[1] and the wider introduction of ICAO's concept of Performance-based Navigation (PBN). An essential component supporting PBN is the definition of route spacing between proximate departure and/or arrival routes and runway transitions. The application of PBN requires a commitment from aircraft operators to enhance their fleet capability (where necessary) to reflect the navigation performance capability being asked of them within the operational requirements and strategic objectives for the airspace. This depends on the navigation specified being notified and the nature of the operation (RNAV or RNP). What is clear is that PBN can only deliver benefits including safety and capacity, if new routes are introduced which are predicated on a systemisation of the air traffic service through the strategic de-confliction of published routes so as to reduce the need for tactical ATC intervention. This is the commitment being asked of the Air Navigation Service Provider (ANSPs).

Generic ICAO and EUROCONTROL studies have indicated minimum spacing of 7 NM between routes and although UK ANSPs are able to design to less than this value, the assurance method (based on developing a Route Design Analysis Report (RDAR)) is manual and labour intensive.

The traditional method of establishing route spacing has been through Collision Risk Modelling (CRM) supplemented by hazard identification and safety assessments, ideally using representative data sets that have been 'cleaned' to remove ATC radar vectoring. There has, however, been a lack of data supporting current airspace design techniques using PBN. The last 'new' CRM analysis used 1980's and 1990's data collected in the en-route sectors of Maastricht (MUAC) and in Zurich terminal airspace. Furthermore, the studies performed to date have been limited to same and opposite direction parallel tracks. Following a review of the previous work, it was

[1] Terminal airspace comprises departure routes (Standard Instrument Departures – SIDs) and arrival routes (Standard Arrivals – STARS, and runway/approach transitions).

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concluded that the use of CRM to determine safe PBN route spacing in a complex tactically controlled airspace was inappropriate and that an alternative method was required.

The UK Civil Aviation Authority (CAA) and NATS have worked collaboratively to develop a Loss of Separation Risk Model (LSRM) which assesses the safe spacing between PBN routes in a tactically controlled airspace environment based on the predicted number of losses of separation. This method has been applied to data collected from existing RNAV 1 routes and specially designed operational trials and used to establish the predicated frequency of loss of separation associated with specific route spacing for different types of route designs and interactions.

The application of LSRM is a foundation piece for airspace change sponsors, and whilst in Chapter 8 and Annex 3 the guidance presents Minimum Acceptable Route Spacing Values for given route interactions, they cannot be applied literally. Chapter 3 details the attendant safety arguments that will have to be demonstrated in order to support a given airspace design concept.

The main difference between the LSRM and the traditional CRM approach is that the lateral track-keeping error distributions are used to estimate (for a particular traffic scenario) the number of losses of separation that would occur when aircraft are operating within their nominal navigation performance, rather than a lateral overlap probability i.e. risk of collision, for a pair of aircraft.

For any given lateral error distribution the probability of a loss of radar separation is considerably greater than the probability of lateral overlap between a pair of aircraft and less dependent on the probability of very large errors.

The probability of a lateral deviation can be used together with data on the frequency of traffic on the routes and other kinematic factors such as average aircraft speeds and length of route in proximity to estimate the frequency of losses of separation for different route interactions.

The predicated loss of separation frequency forms a part of the overall safety argument which also includes other causes of deviations that could lead to a loss of separation – see Chapter 3. The loss of separation frequency supports the

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contributing safety argument generated using the ANSP's Safety Management System (SMS), as to why the proposed route spacing is tolerably safe.

Throughout this work, DNV GL was commissioned by the CAA to support the independent review of the LSRM method and the analysis for each of the route interactions. Their report has led the CAA to conclude that subject to the conditions applied, the method is sufficiently robust and is suitable for application in future PBN route developments in UK airspace.

While the route spacing guidance within this document represents an appropriate baseline upon which to build future airspace designs, subject to appropriate safety criteria being met and agreement with the CAA, there is nothing to stop an individual ANSP or other sponsor working to other, bespoke criteria following appropriate analysis.

The CAA strongly recommends that prior to applying this guidance material the airspace design sponsor contacts the Authority to discuss their proposal.

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Chapter 2

Purpose and scope

This guidance document presents route spacing values, for which the predicated loss of separation frequency is 1 loss per 100,000 hours (10^{-5}) of operation, in support of the application of RNAV 1 Performance-based Navigation (PBN) routes in terminal airspace designs for which a minimum radar separation standard of 3NM is applied. The values are based on nominal aircraft navigation performance and do not take account of other factors as outlined in the first three bullets in Chapter 3, below.

The guidance is presented as a number of scenarios applying different straight and turning segments within typical airspace design route interactions. A summary of the respective route spacing values relative to a minimum radar separation standard of 3NM, can be found in Chapter 8. The route interactions covered in this guidance document are as described in Appendix C.

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Chapter 3

The safety argument

In setting the proximate spacing of routes in a radar monitored terminal airspace environment, there are a number of safety arguments that have to be satisfied. At the top level, the ANSP safety case has to demonstrate that PBN routes are tolerably safe – see acceptability criterion. Thereafter, a number of arguments can be made for:

- Operational or 'blunder' errors, e.g. flight crew following an instruction intended for a different aircraft or flying of the incorrect procedure;
- Generic failures leading to intentional deviations, e.g. flight crew avoiding weather without informing ATC, aircraft emergencies, loss of GNSS coverage;
- Technical errors, e.g. navigation system failure;
- Deviations for aircraft operating within their nominal navigation performance.

All of these terms can potentially lead to a Loss of Separation requiring ATC intervention in order to maintain safety. It is the nominal aircraft navigation performance for which a frequency of Loss of Separation has been established and for which the Loss of Separation Risk Model (LSRM) method is applied. The remaining safety arguments are satisfied by complementary studies to determine whether the route spacing values are acceptably safe with respect to these causes of lateral deviations.

Note: These causes already exist in conventional operations and the safety arguments needed are no different to the safety assurance applied for any new airspace design in terms of addressing the risks arising from them.

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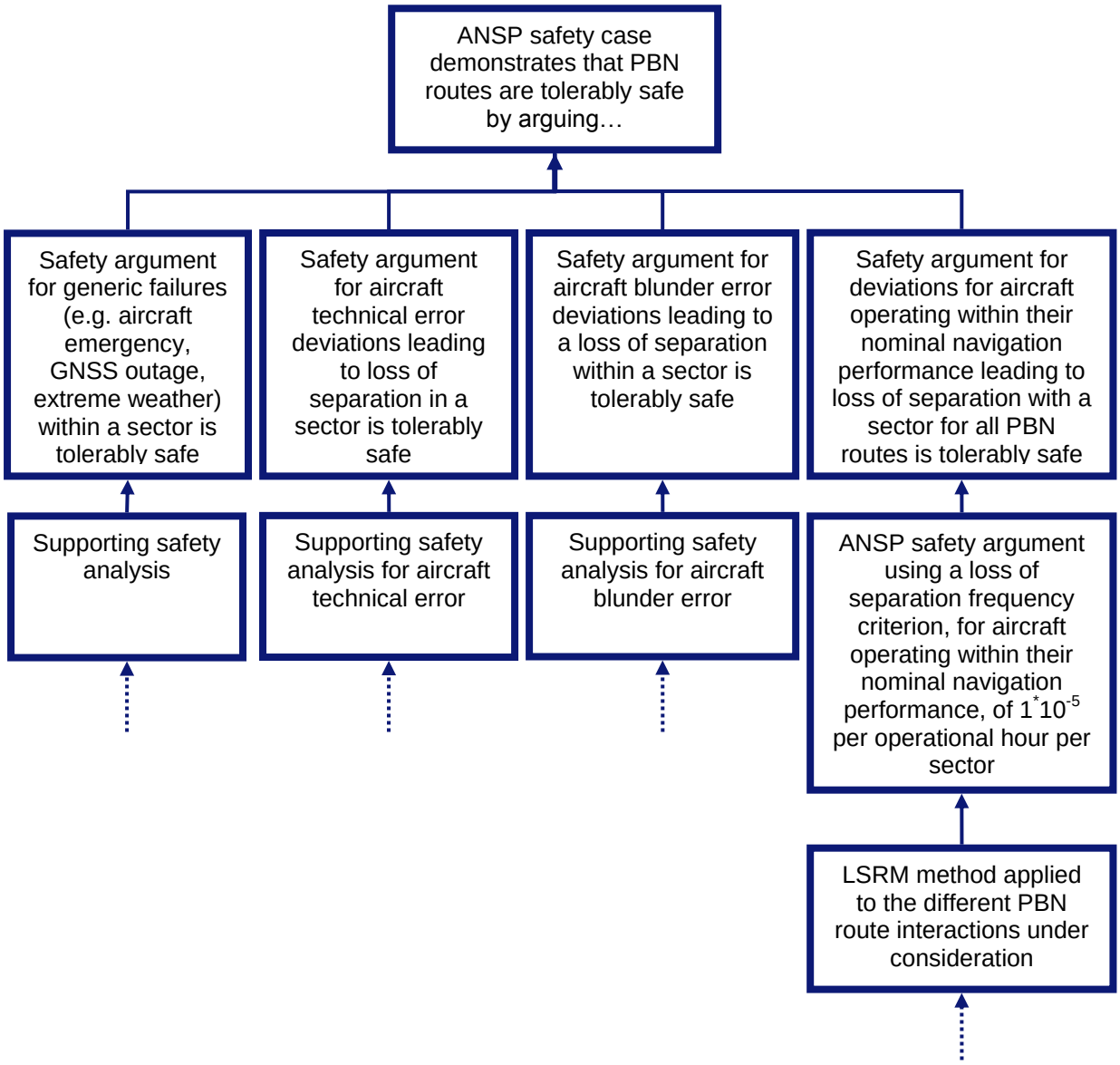
Figure 1 depicts the role of LSRM in meeting the safety argument for nominal navigation performance and the overall safety case.

Figure 1: High-level safety argument and the role of LSRM



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Chapter 4

The operating environment

The Loss of Separation Risk Model (LSRM) method has been developed from and is applicable to a specific set of service constraints as defined by the operating environment found in UK terminal airspace. These service constraints include:

- A tactical radar monitored environment;
- The controller retaining capacity to monitor all traffic within their sector and have appropriate means of tactical intervention;
- The speed of aircraft established on a PBN route is determined either by published speed constraints on the instrument flight procedure, the airspace itself e.g. airspace below FL100 or by the controller.

PBN operational approval

The PBN route can itself be considered as a constraint. Aircraft are deemed to be compliant with the published PBN specification as indicated through the airworthiness approval and it is assumed that an operator filing a flight plan for a particular PBN specification has the requisite operational approval as required by the State of the Operator or State of Registry. This implies that the flight crew are trained and operate the aircraft using Standard Operating Procedures (SOPs) in accordance with maintaining the required navigation performance. At this point the ANSP can assume that all aircraft filing for a particular PBN route are interoperable on that route in terms of navigation accuracy, integrity, continuity and the functionality required by the respective PBN specification. In order to achieve the required navigation performance, the aircraft is assumed to be operating in a Flight Guidance System mode with 'LNAV' engaged and Flight Technical Error (FTE) managed through either Autopilot and/or Flight Director being coupled[2].

[2] Less sophisticated aircraft e.g., General Aviation types, operating at slower speeds may be flown manually in LNAV against a Course Deviation Indicator (CDI).

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Infrastructure

In accordance with PBN principles, all aspects of the Instrument Flight Procedure (IFP) design shall be deployed within coverage of ground-based or space-based navigation aids e.g. DME/DME or GNSS so as to provide navigation positioning consistent with the promulgated PBN specification.

Airspace design considerations

NATS analysis of the data collected from trials and operational data has enabled the characterisation of route design elements as described within the scenarios contained in Appendix C. The scenarios may be considered as independent 'building blocks' which when assembled describe a route structure. It is important that the route design elements do not interact so as to assure fly-ability and the demonstrated navigation performance.

Within these route design elements all turns are predicated on fly-by turns, with speed restrictions applied to sharp turns and wrap-around turns. Where a scenario involves one or more turns, it is defined in terms of the earliest the turn will commence and the latest the turn will be completed (including the turn recovery), before an aircraft can be considered to be established on a straight-line segment. The route spacing values are directly linked to these characterisations allowing each design element to be used as an independent building block within an airspace design.

Whilst IFP design practices and requirements have an important bearing on this characterisation, so does aircraft behaviour and in particular, fly-ability. The published IFP shall have been validated to demonstrate the inherent fly-ability of the design under a representative range of environmental conditions i.e. adverse wind affecting groundspeed in turns. The airspace design sponsor shall therefore demonstrate to the satisfaction of the CAA that the IFP design is not susceptible to phenomena such as FMS waypoint bypass or insertion by the FMS of flight plan Discontinuities (DISCOs). Such phenomena commonly occur with large track changes and consecutive waypoints placed too close together whereby the turn stabilisation has not been achieved. Poor IFP fly-ability can invalidate the

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assumptions made within the LSRM method i.e. the controller intervention rate will increase beyond that defined for the loss of separation frequency, potentially invalidating the safety argument.

If independence between the design elements in terms of the characterisation defined in Appendix C and IFP fly-ability cannot be shown, additional assurance will have to be provided.

Note: The CAA notes that there is variance in both aircraft lateral and vertical performance and indeed, in individual FMS behaviour. This is particularly evident on Fly-by turns. However, PBN brings a minimum standard previously not available and by taking actual navigation performance data spread across representative aircraft type samples, the DEP project has accounted for these variances. Furthermore, it is assumed that the instrument flight procedure shall have been designed and approved in accordance with ICAO Document 8168 (PANS OPS) and CAA policies e.g. CAP 778 Policy and Guidance for the Design and Operation of Departure Procedures in UK Airspace and the Policy Statement for Validation of Instrument Flight Procedures.

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