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EUROCONTROL Handbook for Civil-Military Interoperability in Performance-Based Navigation Implementation

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TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

Performance-Based Navigation (PBN) represents a fundamental shift from a purely sensor-based to a performance-based navigation approach. The PBN concept has expanded area navigation techniques, originally centred upon lateral navigation accuracy only, to a more extensive statement of required performance related to accuracy, integrity and continuity along with how this performance is to be achieved in terms of aircraft equipage and crew requirements.

In Europe, PBN implementation is covered by the Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018. As State aircraft operating as General Air Traffic (GAT) might not be fully compliant with the mandated PBN requirements, there is a need to ensure accommodation of those State aircraft that need to perform the sovereignty roles, which includes national security and defence missions that require unrestricted access to, and freedom within, the airspace.

The introduction and regulation of PBN implementation in Europe offers transition measures that shall apply until 06 June 2030 to accommodate non-PBN aircraft. Civil-military coordination is crucial when such national transition plans are delineated. Contingency measures will remain in place when GNSS or «other methods used for PBN» are not available. This is the case before and after 2030 but only in exceptional circumstances with a network of conventional navaids retained.

The present document offers non-binding civil-military technical guidance supporting Air Traffic Management (ATM) planners and infrastructure managers when planning and implementing PBN in Europe. Such guidance is deemed necessary to ensure the continuation of State aircraft operations performed in an efficient and unconstrained way. The document also comprises detailed information on technical requirements applicable to avionics, proposing measures for compliance that minimise cost and procurement impact.

1 INTRODUCTION

1.1 Background

An International Civil Aviation Organization (ICAO) Resolution at the 36th Assembly in 2007 confirmed the launch of Performance-Based Navigation in all phases of flight as a significant step towards high-level goals and ambitions for global uptake of PBN. The provision of air traffic management/air navigation services (ATM/ANS) applying PBN can bring safety, capacity and efficiency benefits through the optimisation of air traffic service routes and instrument approach procedures. Furthermore, it can also deliver accessibility to aerodromes without conventional ground-based navigation aids.

The regulatory provisions in Europe require that Air Navigation Service Providers (ANSPs) publish PBN procedures in Member States of the European Union and in those States where European ANSPs provide a service. The approach of the European regulation on PBN is the implementation of specific navigation applications in a stepped approach.

These navigation developments drive the introduction of more demanding airspace structures in a GAT context, which raises the need for complementary civil-military interoperability actions. Those actions are particularly important to ensure that day-to-day operations as well as transitional and contingency measures take into consideration civil-military aspects in order to safeguard that State missions are carried out in the most efficient way.

1.2 Purpose

This document provides non-binding civil-military technical guidance supporting ATM planners and infrastructure managers when planning and implementing PBN in Europe. The emphasis is placed on the implementation of PBN in Europe by acting as the interconnection between existing EUROCONTROL material already published to support the implementation of PBN and civil-military elements that safeguard the continuity of State aircraft operations performed in an efficient and unconstrained way.

This document also supports military airspace users by providing a view on PBN technical requirements related to the avionics suite and identifies preliminary mitigation measures that could prompt research actions towards alternative means of compliance.

1.3 Intended readership

This document targets military and civil technical and operational staff involved in the planning and implementation of PBN, mainly at State level, as well as technical staff involved in aircraft compliance and modernisation programmes.

1.4 Abbreviations

Abbreviation	Description
ABAS	Aircraft-Based Augmentation System
AIS	Aeronautical Information Service
AMAN	Extended Arrival Management
AMC	Alternative Means of Compliance
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATS	Air Traffic Service
CDI	Course Deviation Indicator
CRM	Collision Risk Modelling
DME	Distance Measuring Equipment
FIR	Flight Information Region
FMS	Flight Management System
FRA	Free Route Airspace
FRT	Fixed Radius Transition
FTE	Flight Technical Error
GANP	Global Air Navigation Plan
GAT	General Air Traffic
ABAS	95% lateral position error within the total system error
GNSS	Global Navigation Satellite System
IAP	Instrument Approach Procedures
ICAO	International Civil Aviation Organization
IFP	Instrument Flight Procedures
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System

Abbreviation	Description
IRS	Inertial Reference System
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical Guidance
MAA	Military Aviation Authority
MON	Minimum Operational Network
NSA	National Supervisory Authority
NSE	Navigation System Error
OAT	Operational Air Traffic
OPMA	On-board Performance Monitoring and Alerting
PBN	Performance-Based Navigation
PDE	Path Definition Error
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radius to Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RSS	Root Sum Square
SARPS	Standards And Recommended Practices
SBAS	Satellite-Based Augmentation System
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
TACAN	Tactical Air Navigation System
TLS	Target Level of Safety
TMA	Terminal Maneuvering Area
TSE	Total System Error
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Radio Range
VORTAC	Collocated VOR and TACAN beacon

1.5 Reference material

[RD 1] European Commission, Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 laying down airspace usage requirements and operating procedures concerning performance-based navigation.

[RD 2] EUROCONTROL, European Airspace Concept Handbook for PBN Implementation – PBN Handbook No. 1, Edition 4.

[RD 3] EUROCONTROL, European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON) – PBN Handbook No. 4, Edition 1.

[RD 4] EUROCONTROL, European GNSS Contingency/Reversion Handbook for PBN Operations – PBN Handbook No. 6, Edition 1.1.

[RD 5] EUROCONTROL, EUROCONTROL Guideline for RNAV 1 Infrastructure Assessment, Edition 2.

[RD 6] EUROCONTROL, European PBN Implementation and Transition Planning Handbook – PBN Handbook No. 5, Edition 1.

[RD 7] EUROCONTROL, EUROCONTROL contribution to the 3-Agency framework on Performance-Based Certification - WA1 – PBC Processes, Edition 2.0.

1.6 Document structure

This document is organized as follows:

Chapter 1: Contains the present introduction.

Chapter 2: Introduces the concept of Performance-Based Navigation and provides an overview of the system's functions and specifications.

Chapter 3: Details the regulatory framework on PBN in Europe.

Chapter 4: Provides a summary of the main elements of the EUROCONTROL's handbooks that support PBN planning and infrastructure implementation intertwined with civil-military elements.

Chapter 5: Introduces the PBN requirements for aircraft equipage vis-à-vis interoperability, as well as technical mitigation measures for the sake of State aircraft compliance with PBN.

Appendix A: Presents the list of PBN requirements from the aircraft standpoint (specifications stemming from the PBN regulation).

Appendix B: Associates the aircraft requirements with the mitigation measures applicable to some of those requirements.

Appendix C: Provides a summary of the interoperability targets regarding PBN.

Annex A: Details PBN awareness material for different PBN user communities, being the ATCO flyer.

Annex B: Presents the PBN flyer for airspace designer planners.

Annex C: Covers PBN elements for procedure designers.

Annex D: Provides information related to Aeronautical Information Service (AIS) from a PBN standpoint.

Annex E: Associates PBN knowledge required by flight dispatchers.

2 PERFORMANCE-BASED NAVIGATION

2.1 Concept

The PBN concept has globally aligned area navigation applications, originally centred upon lateral navigation accuracy only, and built on these to provide a more extensive statement of required performance related to accuracy, integrity and continuity along with how this performance is to be achieved in terms of aircraft and crew requirements. ICAO's PBN concept is based on three components: the navigation infrastructure, the navigation specification, and the navigation application.

The navigation infrastructure refers to ground- and space-based navigation aids (VOR, DME, INS/IRS[1], and GNSS). In turn, the navigation specification is a technical and operational specification that identifies the required performance and functionalities of the on-board area navigation equipment and avionics. It also identifies the sensors required to meet the performance which, in turn, must match the navigation infrastructure in order to meet the operational needs of the airspace concept. The navigation application reflects the Air Traffic Service (ATS) routes (which includes Standard Instrument Departures/Standard Instrument Arrivals (SIDs/STARs)) and instrument approach procedures (IAP) based on the Navaid infrastructure and navigation specification.

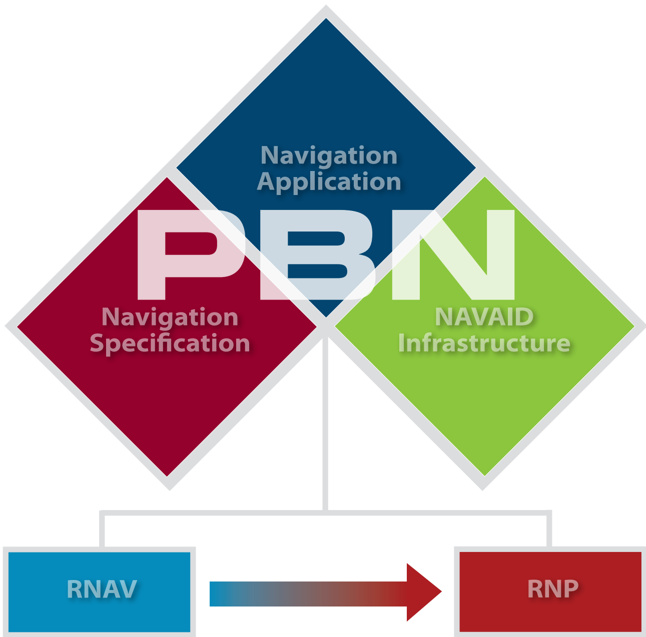

Figure 1. The PBN concept

The ICAO's PBN Manual (Document 9613, Edition 4) contains core material related to eleven navigation specifications and includes descriptions of the performance (accuracy, integrity and continuity) required from the area navigation system, the functionalities required to meet the requirements of the navigation application, the approval process, and the aircraft eligibility and operational approval. PBN defines two kinds of navigation specifications: RNAV (Area Navigation) and RNP (Required Navigation Performance). A fundamental element of RNP specifications is the requirement for an on-board performance monitoring and alerting (OPMA) capability. This system should alert the pilot if navigation performance requirements are not being met.

1 Self-contained capability which may be used either as a stand-alone or acting as part of a multi-sensor RNAV system.

The ICAO's PBN Manual also defines additional functionalities (required or optional) which can be used in association with several of the navigation specifications. Examples of these functionalities are:

- RF (Radius to Fix), which is a path terminator that provides a consistent and highly repeatable turn performance and is applicable for instrument flight procedures (SIDs, STARs and Instrument Approaches). This is a very mature functionality and is applicable to RNP specifications only;
- FRT (Fixed Radius Transition), which is an en-route turn performance providing a consistent and highly repeatable en-route leg transition. This functionality is only associated to RNP specifications and experience of its use in European airspace is extremely limited;
- RNAV Holding, which provides a more predictable holding pattern and allows a reduction in the size of the protection area around the hold permitting holds and/or ATS routes to be placed closer together or placed in more optimum locations;
- Parallel Offset related with the aircraft ability to comply with tactical parallel offset instructions as an alternative to radar vectoring.

The PBN concept does not include precision approach and landing operations predicated on the Instrument Landing System (ILS). Such enabler differ from PBN applications because it is not based on area navigation techniques.

2.2 PBN systems overview

The navigation function computes data that can include aircraft position, velocity and time, track angle, vertical flight path angle, drift angle, magnetic variation, barometric-corrected altitude, and wind direction and magnitude. It could perform automatic radio tuning as well as support manual tuning.

RNAV and RNP systems are designed to provide a given level of accuracy, with repeatable and predictable path definition in the straight segments, appropriate to the application. These systems typically integrate information from sensors, such as air data, inertial reference, radio navigation and satellite navigation, together with inputs from internal databases and data entered by the crew to perform the functions: navigation, flight plan management, guidance and control, navigation functions, and display and system control.

Within the navigation function, RNAV and RNP systems provide lateral guidance, and in many cases, vertical guidance as well (RNP system). The lateral guidance function compares the aircraft's position generated by the navigation function with the desired lateral flight path and then generates the steering commands used to fly the aircraft along the desired path. The total system error is computed by comparing the aircraft's present position and direction with the reference path.

Moreover, all RNP and select RNAV specifications require the aircraft to have a certified navigation database. The navigation database contains pre-stored information on NAVAID locations, waypoints, ATS routes and terminal procedures, and related information.

The RNAV and RNP system will use such information for flight planning and may also conduct cross-checks between sensor information and the database. A key aspect of the flight plan is the specification of flight plan waypoints using latitude and longitude, without reference to the location of any ground Navaids.

As main distinctive difference, an RNP system is an RNAV system that supports on-board performance monitoring and alerting. An RNP system uses its navigation sensors, system architecture and modes of operation to satisfy the RNP navigation specification requirements. It must perform integrity and reasonableness checks on the sensors and data. Dual system/sensor installations may also be required, depending on the intended operation or need.

The interface with the crew are the displays and system controls which provide the means for system initialization, flight planning, flight plan progress, monitoring path deviations, active guidance control and presentation of navigation data for flight crew situational awareness.

2.3 PBN specifications

The navigation specifications provide descriptions of the performance required from the area navigation system, the functionalities needed to meet the requirements of the navigation application, the approval process, aircraft eligibility and operational authorisation. It also identifies the required sensors in order to meet that performance and these must match the Navaid infrastructure to ensure the aircraft can meet the operational needs of the airspace concept.

Navigation accuracy is the main performance parameter to ensure the aircraft can meet a navigation specification and is normally identified in the title. For both RNAV X and RNP X designations, the suffix X refers to the lateral navigation accuracy in nautical miles, which is demonstrated to be achieved at least 95 percent of the flight time. If two navigation specifications share the same X value, then the functional requirements will distinguish between RNAV or RNP. Where no lateral performance is specified in the title, this indicates that there are different performance requirements in different phases of flight.

Although navigation accuracy is the designation used, it is not the only performance requirement included in a navigation specification. For each area of operations, different requirements are defined according to the performance and conditions needed which brings the allocation of a navigation specification to a specific phase of flight.

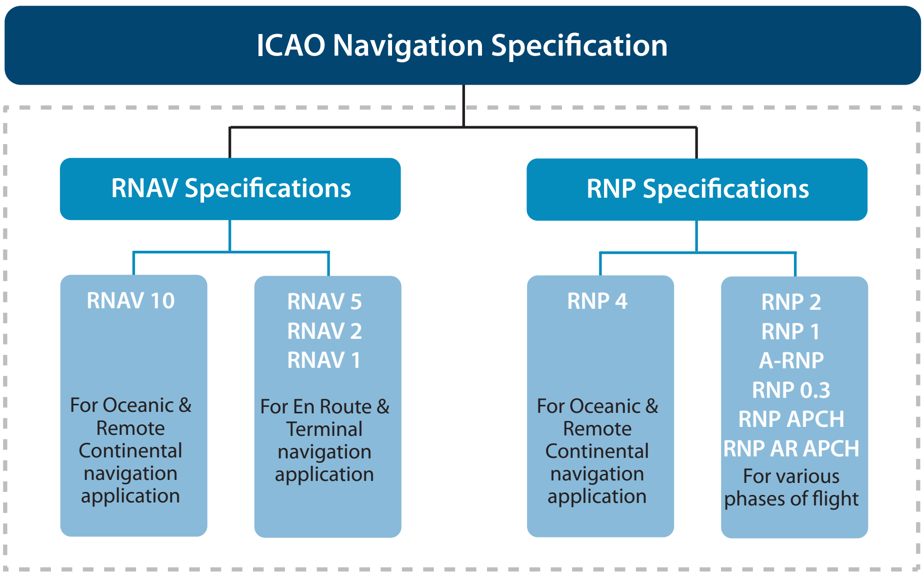

Figure 2. PBN specifications

OPMA is the main element that determines if the navigation system complies with the necessary safety level associated to an RNP application. It allows the aircrew to detect that the navigation system is not meeting, or cannot guarantee with 10-5 per flight hour integrity, the navigation performance required for the operation.

The on-board monitoring and alerting function should consist at least of a Navigation System Error (NSE) monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor and manage the Flight Technical Error (FTE). To the extent operational procedures are used to satisfy this requirement, the crew procedure, equipment characteristics, and installation are evaluated for their effectiveness and equivalence.

- PDE (Path Definition Error) occurs when the path defined in the area navigation system does not correspond to the desired path of the airspace (or procedure) designer. The start and end waypoints of this path may be loaded manually or uploaded from a navigation database. PDE is considered negligible due to the quality assurance process and crew procedures.
- NSE refers to the difference between the aircraft's estimated position and actual position.
- FTE relates to the aircrew or avionics ability to follow the defined path or track, including any display error (e.g. course deviation indicator (CDI) centring error). FTE can be monitored by the autopilot or aircrew procedures and the extent to which these procedures need to be supported by other means depends, for example, on the phase of flight and the type of operations. Such monitoring support could be provided by a map display.
- TSE is the root sum square (RSS) of the errors: PDE, NSE and FTE. TSE is what the aircraft is certified to 95% of the flight time.

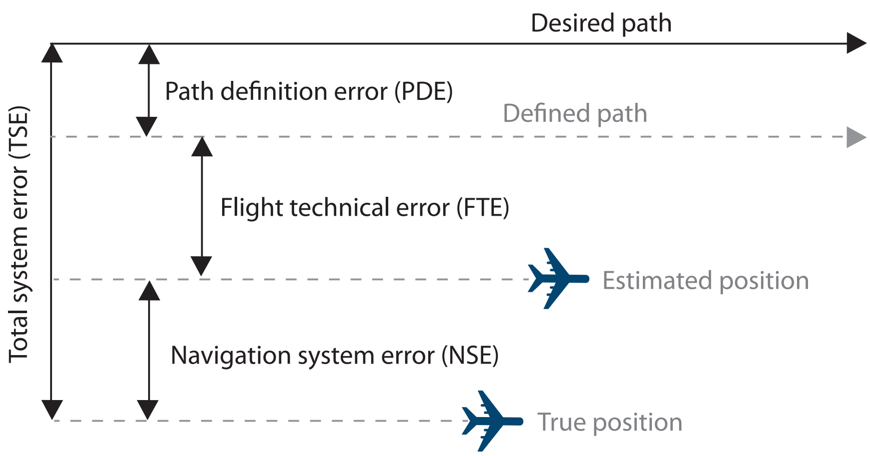

Figure 3. Lateral navigation errors

3 REGULATORY ENVIRONMENT

The Commission Regulation (EU) 2018/1048 of 18 July 2018 on PBN lays down airspace usage requirements and operating procedures concerning performance-based navigation in the Single European Sky [RD 1]. In order to implement PBN, different specifications shall be used to comply with the requirements needed to fly PBN applications.

The Regulation applies to providers of ATM/ANS and operators of aerodromes that are responsible for putting in place instrument approach procedures or ATS routes, where they provide their services in the following airspace: a) above the territory to which the Treaty applies; b) any other airspace where Member States are responsible for the provision of air navigation services in accordance with Article 1(3) of Regulation (EC) No 551/2004 of the European Parliament and of the Council.

Although the Regulation does not identify or detail airborne equipage, Commission regulations and SERA 5015 require that: «aircraft be equipped and flight crew be suitably qualified to operate on the intended route or procedure». Furthermore, Instrument Rating licences today are issued with 'PBN privileges covering the majority of the navigation specifications; RNP 0.3 and RNP AR operations are exceptions requiring special approval.

The following is an overview of the requirements set out in Regulation (EU) 2018/1048 for the implementation of performance-based navigation to be complied by providers of ATM/ANS:

- December 2020
  - RNAV 5 for ATS routes at and above FL150;
  - RNP APCH (or RNP AR APCH where justified) at all instrument runway ends (IREs) without precision approach (PA).
- 25 January 2024
  - RNAV 5 for ATS routes excluding SID/STARs established below FL150;
  - RNP 0.3, or RNP 1, or RNAV 1 for ATS routes established below FL150 for rotorcraft operations;
  - For every IRE, RNAV 1 or RNP 1 (+ RF) for at least one established SID/STAR;
  - For all IRE, RNP 0.3, or RNP 1, or RNAV 1 for at least one established SID/STAR for rotorcraft operations;
  - RNP APCH (or RNP AR APCH where justified) at all IREs with precision approach.
- 6 June 2030
  - RNAV 1 and/or RNP 1(+ RF) applicable to all SIDs/STARs;
  - RNP 0.3, or RNP 1 or RNAV 1 applicable to all SIDs/STARs for rotorcraft operations.

One of the most significant aspects of the regulation is that from 6 June 2030 "providers of ATM/ANS shall not provide their services using conventional navigation procedures". This has significant infrastructure implications.

Transitional measures are set out in the Regulation in the interests of a safe, smooth, and coordinated transition since providers of ATM/ANS should, in accordance with the requirements of the regulation and for a reasonable time period, also be allowed to provide their services through means other than PBN.

Moreover, the Implementation Regulation requires providers of ATM/ANS to develop a transition plan, which is to be kept up-to-date and take account of all relevant developments relating to the transition. Draft transition plans are evolved in consultation with interested parties, including State aircraft operators if affected, prior to being approved by the competent authority within the State. The transition measures are to apply in each step of the PBN Implementing Rule (PBN IR) and will see the migration to a full PBN environment predicated on Global Navigation Satellite System (GNSS) as the main positioning source. The affected State aircraft operations could incur when operating as GAT.

PBN IR Article 4 & 7 Applicability with AUR.2005		Applies 03/12/2020	Applies 25/01/2024	Applies 06/06/2030
Art 4	Transition Plan *(or significant updates)* approved *(living document)*[1]	X[1]	X[1]	X[1]
AUR.2005 1/2/3	RNP APCH at IREs without Precision Approach (PA)	X		
	RNP APCH at all IREs (with PA)		X	
AUR.2005 4/5	RNAV 1 or RNP 1 (+ RF if required) SID and STAR - one per IRE		X	
	RNAV 1 or RNP 1 (+RF if required) for all SID and STARs			X
AUR.2005 6	RNAV 5 ATS Routes (excl. SIDs/STARs) at and above FL150[2]	X		
	RNAV 5 ATS Routes (excl. SIDs/STARs) below FL150		X	
AUR.2005 7	Helicopter RNP 0.3 or RNAV 1 or RNP 1 (+RF if required) SID/STAR - one per IRE		X	
	Helicopter RNP 0.3 or RNAV 1 or RNP 1 (+RF if required) for all SID/STAR			X
	Helicopter RNP 0.3 or RNAV 1 or RNP 1 ATS Routes (excl. SIDs/STARs) below FL150		X	

Note 1 - The transition plan will have several iterations; Article 4 requires that the draft/significant updates to the plan must be approved by the competent authority ***early enough*** *to provide sufficient time for the ANSPs to meet the identified implementation date. (Sufficient time would include accounting for the AIRAC cycle dates, publication and regulatory approval and compliance with other national requirements - see the PBN Portal for an example of the implementation scheduling and time required: https://pbnportal.eu/epbn/main/PBN-Tools/Planning-Estimation.html). The planned implementation dates detailed in the transition plans should be commensurate with the target date obligations.*

Note 2 - CP 1 requires FRA to be implemented with two milestones: 2022 & 2025. FRA is associated with RNAV 5 through the ICAO EUR requirement for RNAV 5 published in ICAO Doc 7030. (CP 1's revised FRA requirements replace previous requirements in the PCP IR).

Figure 4. PBN implementation in Europe as in PBN IR (extracted from [RD 2]

As part of the contingency navigation environment, a minimum operational network (MON) of ground-based Navaids should be retained for providing alternative means of navigation for the PBN operations stipulated in AUR.PBN.2005. These remaining ground-based Navaids, e.g. VOR, DME could enable conventional navigation or, alternatively, support some of the mandated PBN applications. The contingency navigation performance depends on the evaluation performed by the providers of ATM/ANS.

As State aircraft operating as GAT will not all comply with the requirements mandated in the PBN regulation, there is a need for the competent authorities to assess and verify how the draft transition plans, or significant draft updates thereof, comply with the requirements of the regulation. In particular, it must be confirmed whether the evolution of the PBN plans take into account the views of airspace users where appropriate, including those operating State aircraft. This will ensure the accommodation of State aircraft required to perform their sovereign roles, including national security and defence missions that require unrestricted access to the airspace.

The certification specifications applicable to civil aircraft for the purpose of complying with the navigation (PBN) carriage requirements are set out in the EASA CS-ACNS, Subpart C [2]. Those technical requirements regarding aircraft equipage are stipulated without prejudice to alternative equipment enablers capable of offering equivalent performance levels when State aircraft compliance is sought.

2 EASA. Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-ACNS. Issue 3.

4 EUROCONTROL PBN HANDBOOKS

The implementation of PBN in Europe is supported by a set of EUROCONTROL PBN handbooks, which cover a process for implementation, route spacing considerations, infrastructure and planning to address the PBN requirements arising from the PBN regulation in Europe. A summary of the main elements of each of the published handbooks is presented below[3] in order to raise the awareness to the military community and to provide interoperability considerations.

4.1 European Airspace Concept Handbook for PBN Implementation

The European Airspace Concept Handbook for PBN Implementation (PBN Handbook No. 1) provides a methodology for an airspace change based on PBN. This methodology is made up of 17 activities, many of which are iterative, spread across four distinct phases: Planning, Design, Validation and Implementation (Figure 5).

The prime area of focus of this handbook is implementation of PBN SIDs/STARs and instrument approach procedures; whilst IAPs should be complete by 2024, the requirement for the implementation of RNAV 1 SIDs/STARs (as a minimum) to meet the PBN IR 2024 and 2030 milestones are the real driver of this document. Handbook No. 1 is primarily intended for airspace planners/designers implementing PBN in European airspace.

Effective planning is ultimately the cornerstone to a successful implementation of an airspace concept and is undertaken before starting the airspace design and validation phases. Planning must be a comprehensive process that should address the current situation and what needs to be undertaken to evolve to the new environment as well as identifying the necessary resources and the timeline to materialise it.

An Airspace Design Team needs to be organised and well managed with proper administration to ensure that, as is often necessary, it can efficiently and effectively interact with other teams within a greater managerial framework. As such, PBN Implementation Projects can be undertaken in a variety of managerial 'frameworks' or 'projects'.

The airspace design phase follows completion of the planning phase. For both en-route and terminal airspace, the conceptual design of airspace is an iterative process which involves the users of the airspace (pilots), the managers of that airspace (the controllers) together with airspace designers and technical experts. The output of this work should be an agreed, logical and efficient placement of the flows of the traffic (route configuration), the protection of those flows (defined airspace volumes) and finally the management of the flows (sectorisation).

Where the routes are placed and how they interact is a function of various factors such as the navigation specification required to operate on PBN SID/STAR or ATS route and the controller's intervention capability using ATS surveillance. In order to ensure connectivity between en-route and terminal routes, airspace planners must take into account different specifications being required on PBN ATS routes (e.g. RNAV 5) and SIDs/STARs (e.g. RNAV 1). This is because differences may affect the configuration or spacing of routes. The phases of flight need to be fully integrated, both vertically and horizontally, and an understanding of plans/strategies in the adjacent airspace is required.

By the time the airspace design is complete, the airspace concept has become a comprehensive body of work that needs to be validated and checked. Validation takes place in various phases: the airspace design is usually validated first; for nearly all major terminal airspace changes, significant reliance is placed on a

3 A thorough reading of the PBN Handbooks is recommended for extended information.

qualitative assessment of the new concept by operational controllers using real time simulation. Once this airspace design validation has been successfully completed, then the individual instrument flight procedures are designed and validated. In fact, during the design phase many of the iterations can be considered as part of an ongoing validation processes.

The implementation phase firstly involves a final confirmation that all the project objectives and performance targets can be achieved and that no 'show stoppers' have emerged. It is logical and good practice to conduct a double check at the implementation commitment point (project checkpoint) that the assumptions made during the Planning phase (Activity 6) are still valid prior to the roll out of the implementation.

When all the implementation criteria are satisfied, the airspace design team needs to plan for implementation – not only as regards their 'own' airspace and provider of ATM/ANS but also in cooperation with any affected parties which may include providers of ATM/ANS in an adjacent State. Amongst items to be covered are Air Traffic Control (ATC) system integration and pilot and controller awareness and training material.

Figure 5. Methodology for PBN Implementation

Civil-Military aspects

Military stakeholders should play an active role in the evolution of the airspace concept in order that the planned fulfilment of the State's strategic objectives (be they safety, capacity or flight efficiency, and/or environmental mitigation) do not negatively impact on their operations. Civil and military aviation are closely interlinked as they share the same airspace and might need to be supported by a common ATM/CNS infrastructure for GAT and Operational Air Traffic (OAT) operations.

Therefore, it is recommended that military stakeholders (e.g. Military Aviation Authority (MAA) and/or Air Force as decided within the State) are involved at least in the below mentioned activities of the methodology for an airspace change based on PBN, as defined in the European Airspace Concept Handbook for PBN Implementation.

Phase 1: Planning

Activity	Civil-Military elements
Activity 1 Agree Operational Requirement(s)	• Include civil and military strategic objectives; • Articulate operational requirements with military organisations when State missions are affected by the strategic objectives; • Include objectives for contingency operations taking into consideration the need to include civil-military requirements.
Activity 2 Create the Airspace Design Team	• Include military airspace users, service providers and airspace designers in the airspace design team (either in the core team, or in the ancillary team, according to the depth of the airspace change) whenever PBN is included in or affects airspace areas whose air navigation service provision is conducted by military organisations; • The military experts who are part of the team should provide the necessary support in the different technical areas.
Activity 3 Decide project objectives, scope, resources & time scales)	• Military organisations should provide the necessary resources and availability to sustain the materialisation of the project objectives.
Activity 4 Analyse the Reference Scenario	• Required data related to the reference scenario should be provided by military organisations; • Military experts should contribute to the analysis of the reference scenario.
Activity 5 Agree Operational Requirement(s)	• Include civil and military strategic objectives; • Articulate operational requirements with military organisations when State missions are affected by the strategic objectives; • Include objectives for contingency operations taking into consideration the need to include civil-military requirements.
Activity 6 Agree Enablers, Constraints and Assumptions, including fleet profile	• Military organisations should provide their medium to long-term plans to support the description of the assumptions; • Military organisations should integrate military enablers (e.g. GPS PPS; TACAN; SUR infrastructure; Performance Equivalence) to mitigate the constraints that could potentially be defined stemming from the accommodation of military operations.

Phase 2: Airspace Design

Activity	Civil-Military elements
Activity 7 Airspace Design - Routes & Holds	• Military organisations should aim for the optimal use of airspace reservations and contribute with their expertise for the new airspace design; • Civil-military inputs should be considered.
Activity 8 Initial Procedure Design	• Military organisations should be consulted and contribute with their expertise if necessary, including as an adjacent provider of ATM/ANS whenever applicable; • Civil-military elements should be considered (e.g. fleet analysis and placement of the routes).
Activity 9 Airspace Design - Structures & Sectors	• Civil-military expertise should be provided, including liaising cross-border coordination if necessary.
Activity 10 Coherency Check: Design v. Requirements	• Civil-military elements when addressed in the activities 6 to 9 should be subject of a coherency check vis-à-vis the operational requirements.

Phase 3: Validation

Activity	Civil-Military elements
Activity 11 Airspace Concept Validation	● The identified civil and military elements should be subject to the project checkpoint "Decision 1"; ● "Decision 2" should take into consideration the civil-military operational requirements identified in Activity 1; ● Military organisations should endeavour to ensure that the military enablers are in place by the implementation dates of the new airspace concept (PBN Regulation) – "Decision 3".
Activity 12 Finalisation of Procedure Design	● Civil-military expertise should be provided if necessary.
Activity 13 Instrument Flight Procedure Validation Flight Inspection of the Infrastructure	● Military enablers subject to flight inspection should follow the ICAO requirements (or national requirements when applicable).

Phase 4: Implementation

Activity	Civil-Military elements
Activity 14 ATC System & Integration Considerations	● ATC and/or ATM systems operated by the military could need to be considered for modification if part of the new airspace concept.
Activity 15 Training and Awareness	● Training could be needed to be provided to Air Traffic Controller Officers (ATCOs), flight crews, AIS staff, engineering, etc.
Activity 16 Implementation	● Military experts should be part of the monitoring of the implementation process when participating in the new airspace concept.
Activity 17 Post Implementation Review	● Military organisations should conduct or participate in system safety assessments if necessary.

4.2 European Navaid Infrastructure Planning Handbook including Minimum Operational Network

The European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON) (PBN Handbook No. 4) is intended to respond to needs arising from the EU regulations on PBN which give a clear signal that GNSS is to become the primary navigation infrastructure for PBN by 2030.

This handbook aims at providing a 'how to' package related to infrastructure evolution and creation of a minimum operational network as well as encouraging infrastructure planners to work with their airspace and procedure design colleagues to enable and achieve PBN implementation for both normal and contingency operations.

The importance of considering both normal and contingency operations is particularly addressed in two PBN Handbooks:

- The European Airspace Planning Handbook for PBN Implementation (PBN Handbook No. 1), whose activities are frequently cross-referenced in this handbook;
- The European GNSS Contingency/Reversion Handbook for PBN Operations (PBN Handbook No. 6), which provides a thinking-pack for ANSPs when developing their contingency procedures and reversion infrastructure in the event of GNSS outage.

In the context of the Handbook No. 4, minimum operational network refers to the minimum Navaid infrastructure needed to provide the required level of (ATM) service for both normal and contingency operations. In turn, the term evolution refers to all changes to the Navaid infrastructure including decommissioning, optimisation or deployment. The words decommissioning and rationalisation may be used interchangeably as regards the ground-based Navaid infrastructure. Optimisation, on the other hand, has a distinct nuance of cost-effective improvement of the infrastructure and spectrum.

The external and internal factors that impact the infrastructure management decisions are identified and described. External factors are those over which the infrastructure manager has little influence, and therefore, stem from the ATM required level of service as well as relevant strategies (e.g. spectrum), available resources (staff and budget), and regulatory rationalisation targets. On the other hand, internal factors are commonly the remit of the infrastructure manager and have technical and financial implications. Primarily, they are comprised of technical limitations, maintenance, and evolution activities, and they may constrain how the infrastructure can evolve and are largely associated with cost.

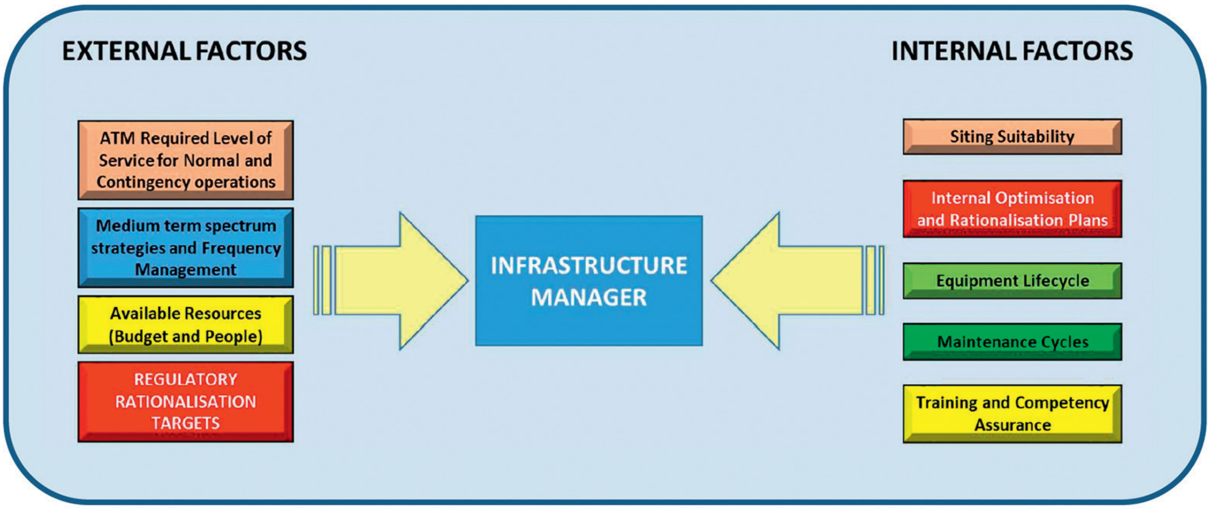

Figure 6. Factors influencing navigation infrastructure evolution [RD 3]

Infrastructure planning (which is part of the overall infrastructure management process) consists of the installation of new facilities as well as decommissioning old facilities taking account internal and external factors.

Alongside the wide scale implementation of PBN in all phases of flight, the role of the ground-based Navaids evolves towards providing a backup infrastructure to GNSS. In this context, an opportunity arises for optimising the overall infrastructure, and consequently, rationalising ground-based Navaids. Therefore, the evolution of the navigation infrastructure needs special consideration. The two approaches that can be taken for the infrastructure evolution in relation with the PBN implementation have been described in the appendix 5 of the fifth edition of the Global Air Navigation Plan (GANP).

The ICAO GANP 5th Edition identifies a top-down and bottom-up approach to infrastructure planning. The top-down approach is one where infrastructure evolution is driven almost exclusively by ATM operational requirements thus placing the infrastructure manager in a 'reactive' role. The bottom up approach has the infrastructure manager playing a pro-active role: the infrastructure manager aims to influence the airspace concept with the objective of infrastructure optimisation and achieving cost-efficiencies.

In most instances a "combined" approach should provide the best outcome i.e. the top-down and bottom-up processes are used in unison to complement each other. An example of combined approach may be that in a certain Flight Information Region (FIR) the top-down approach is followed as a general strategy, but in particular airspace areas (e.g. a certain terminal maneuvering area (TMA)) the PBN implementation is planned and implemented based on a bottom-up approach, considering the priorities of the infrastructure. Nevertheless, the connectivity between these two airspace configurations reflects that the top-down and bottom-up approaches in the relevant airspaces would need to be fully aligned and treated in a complementary manner.

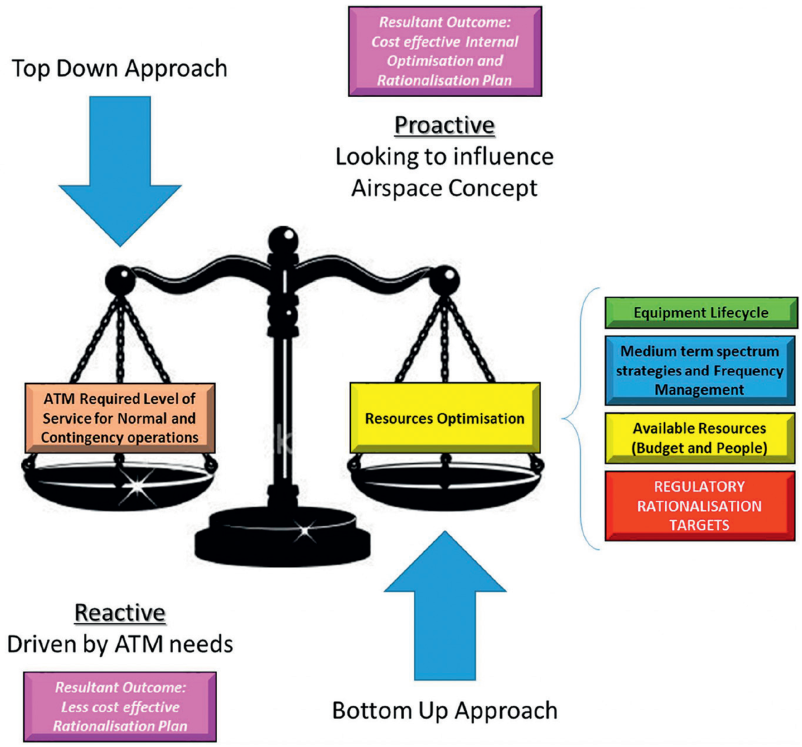

Figure 7. Complementary top-down and bottom up processes [RD 3]

The activities portrayed in the European Airspace Concept Handbook for PBN Implementation (Figure 5) make direct reference to the coordination needed between the airspace design and procedure design and the infrastructure planning. In context, the relevant activities to infrastructure planning are:

- Activity 6, PBN Assumptions & Enablers
- Activity 7, Airspace Design - Routes & Holds
- Activity 8, Initial Procedure Design

The basic principle is that in matters affecting the infrastructure, the airspace planners must work with infrastructure managers, both of whom may have their own pressures and/or priorities. In keeping with this general principal, infrastructure planners must be included in the wider airspace team and be aware of airspace changes or plans. Similarly, airspace planners need to be made aware of infrastructure evolution plans including, for example, renewal of Navaids prior to the end of life.

The infrastructure planning methodology (Figure 8) mirrors some of the activities described in the Airspace Concept handbook. The bridge between the activities and this methodology may enable the seamless integration of infrastructure planning within the development of that airspace concept.

Infrastructure planning and implementation activities can be related to more than one airspace concept activity; there is not a direct one-to-one relationship between the numbered activities. Nevertheless, in most instances, the final phase of the airspace concept development (i.e. implementation) can only occur once the relevant Navaid infrastructure has been agreed and implemented.

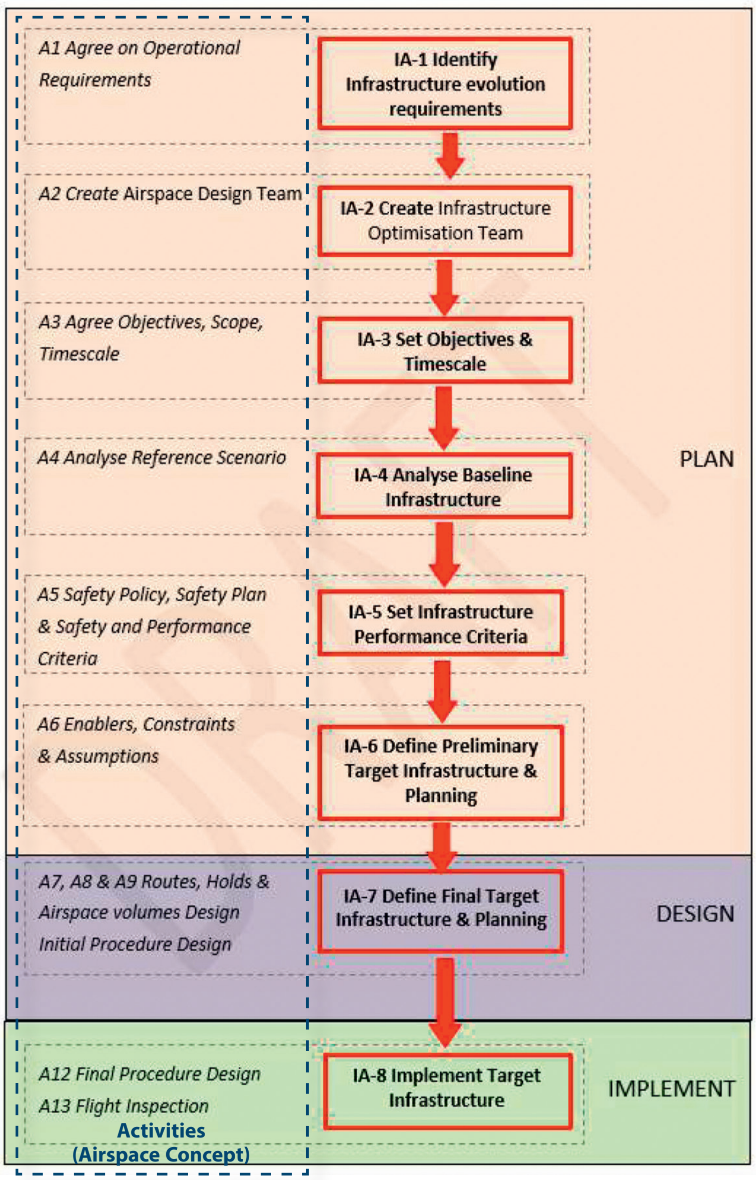

Figure 8. Infrastructure Optimisation Activities

Civil-Military aspects

The methodology set out in the infrastructure planning handbook, as depicted in Figure 8, substantiates actions that may need to integrate civil-military coordination to ensure that infrastructure activities safeguard the appropriate levels of civil-military coordination.

IA-1 Identify Infrastructure evolution requirements

The initial phase of the infrastructure project identifies all high-level objectives pertaining to the evolution of the navigation infrastructure. These objectives embrace the internal and external factors. One of the elements that should be considered as a factor is civil-military coordination as a State prerogative to ensure that State aircraft operations continue to be performed with the appropriate levels of flight efficiency on a basis of the most optimal network.

IA-2 Create Infrastructure Optimisation Team

The work on the infrastructure optimisation project might not necessarily require the integration of a military expert as a permanent member of the team. Nevertheless, military organisations should provide the necessary expertise whenever needed.

IA-3 Set Infrastructure Objectives & Timescale

IA-3 may set specific infrastructure objectives in accordance with the high-level requirements (which may be constraints) identified by IA-1. Therefore, the civil-military elements considered in the infrastructure evolution requirements should be reflected in the infrastructure objectives and timescale.

For example, uncoordinated decommissioning of Navaids can negatively affect airspace capacity and possibly impact on the safety of operations. This could then negate the anticipated short-term benefits of infrastructure rationalization. Therefore, the airspace interface to the infrastructure optimisation project must also ensure that the airspace needs are not compromised.

IA-4 Analyse Baseline Infrastructure

The baseline infrastructure may encompass navigation infrastructure that is under management of military organisations ('military' navigation systems) e.g. TACAN which is able to provide its DME component to aircraft equipped with the DME capability. Therefore, this infrastructure may also be part of the existing Navaids. Moreover, the evolution requirements may turn into benefit the consideration of 'military' navigation systems when optimising the infrastructure network. It should be noted that any optimisation must consider military (e.g. NATO) requirements.

The level of civil-military coordination required in IA-4 should be in line with the objectives established in IA-1 and make a part of it the inclusion of 'military' navigation systems for the purpose of an optimal infrastructure network in support of the airspace design whenever applicable.

IA-5 Set Infrastructure Performance Criteria

Infrastructure performance criteria must cater for the targeted level of service for both normal and contingency/reversion operations. The infrastructure experts should acquire an appreciation of the operational safety and performance criteria so as to 'translate' these into infrastructure specific safety and performance criteria to meet the required operational level of service.

Two examples of the interplay between infrastructure specific criteria and operational performance criteria are provided:

- Infrastructure specific performance criteria are accuracy with appropriate availability, continuity and integrity;
- Operational specific performance criteria, such as the continued provision of Category I precision approach may 'translate' into identifying a need for the continuation of ILS Cat I at certain airports.

This interplay raises the need to include civil-military elements in the operational specific performance criteria which will be translated into the navigation infrastructure that supports both normal and contingency/reversion operations. The design of the ground Navaid network should be predicated on the infrastructure performance criteria that can sustain the civil-military operational requirements wherever needed to be considered.

For example, the continued provision of Category I precision approach is translated into the use of ILS Cat I also to ensure the continuation of State aircraft operations at certain airports.

IA-6 Define Preliminary Target Infrastructure & Planning

IA-6 is the final activity of the planning phase and will be coherent with Infrastructure Baseline of IA-4. Once the initial design of the airspace is complete, the Infrastructure Optimisation Team together with the procedure designer can do a preliminary identification of the Navaids on which the future concept would rely. At the same time, this team could undertake a preparatory cost-benefit analysis of the desired infrastructure and identify any issues and limitations.

Civil-military inputs for defining and planning the target infrastructure from an airspace user perspective, embedded on the deployment of infrastructure in a cost-effective manner, might be provided to the following generic considerations:

- Support of multiple applications
- Redundancy
- Critical Navaids
- Military Navaids
- Spectrum

IA-7 Define Final Target Infrastructure & Planning

The final target infrastructure planning (IA-7) must confirm that the required coverage and redundancy expected from the preliminary target Navaid infrastructure (IA-6) meets the validated airspace concept. In addition, the final target infrastructure planning (IA-7) must confirm that the foreseen costs are reasonably balanced against the benefits of the validated airspace concept.

The outcome of this activity is both an infrastructure than can support the normal/contingency operations of the validated Airspace Concept and an implementation plan for the targeted infrastructure changes. Therefore, the civil-military work addressed in the previous activities is expected to be embodied in IA-7.

Moreover, the infrastructure evolution plan may be covered in the PBN Transition Plan (required by Article 4 of the PBN IR). In this case, it is also recommended that the civil-military elements considered in Part B, ANSP requirements, section 7 of the Transition Plan of the European PBN Transition and Implementation Planning Handbook, concerning the plans for infrastructure rationalisation, are included in IA-7.

IA-8 Implement Target Infrastructure

This step represents the execution of the optimisation plan which includes all planned actions and activities of the associated project. The role of military organisations takes on particular relevance if navigation infrastructure that is under management of military organisations is part of the infrastructure that supports the current and future airspace concept. In this case, the military organisations should actively engage in IA-8 by validating and monitoring the infrastructure under their responsibility and liaise with their civil counterparts in the Infrastructure Optimisation Team.

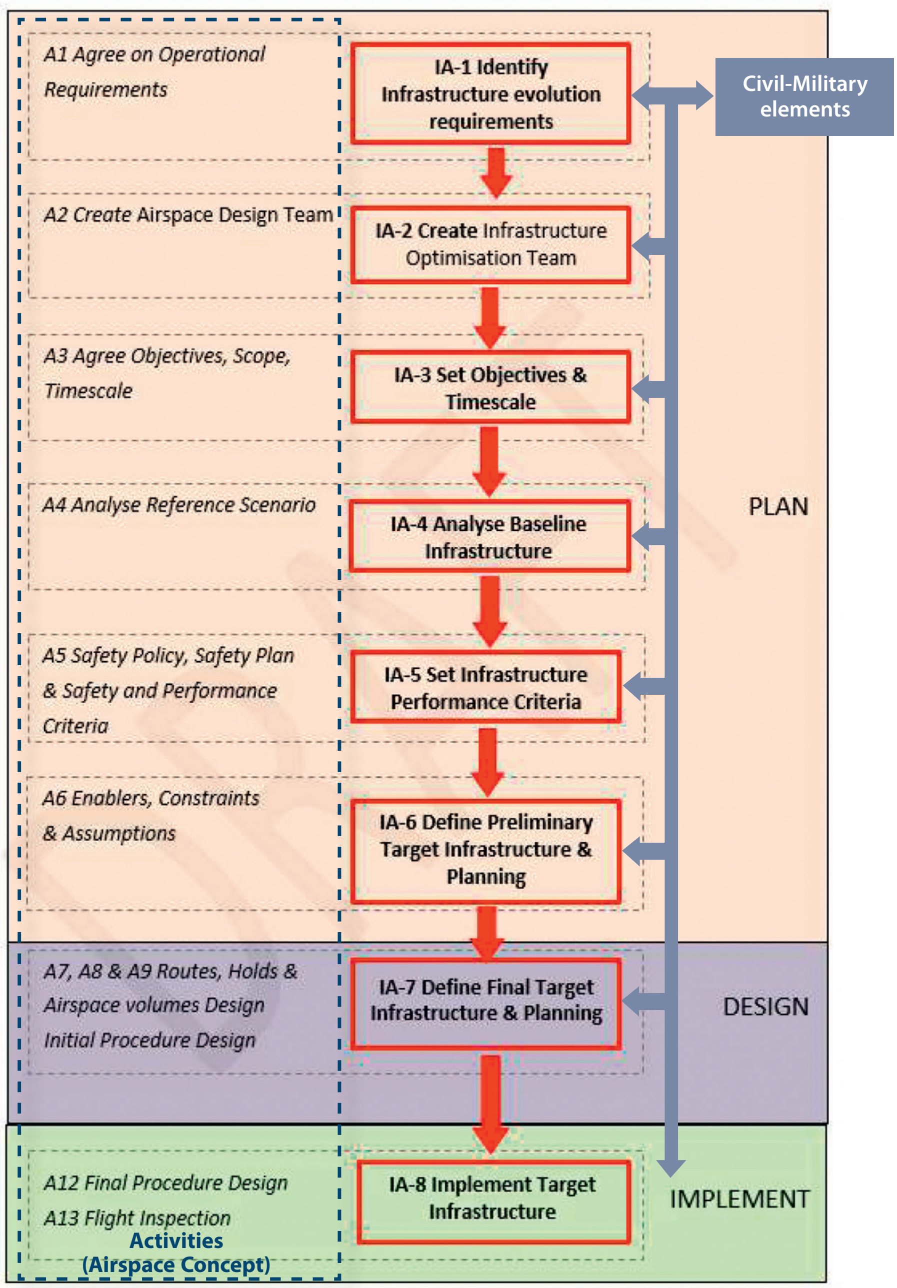

Figure 9. Infrastructure Optimisation Activities with transversal civil-military elements

4.3 European GNSS Contingency/Reversion Handbook for PBN Operations

The European GNSS Contingency/Reversion Handbook for PBN Operations (PBN Handbook No. 6) [RD 4] addresses the topic of GNSS reversion/contingency in the context of PBN operations in all flight phases, with particular emphasis placed on terminal and extended terminal operations in a surveillance environment.

This handbook is not intended to be a definitive guide to contingency operations for PBN. Rather, it provides planning considerations through explanatory text and the use of two sample contingency scenarios covering high and medium/low traffic density environments. This document is aimed as a 'starter pack' for ANSPs and regulators to assist in their deliberations when planning contingency operations for GNSS reversion.

The step-change triggered by the PBN regulation should not be underestimated in terms of GPS being placed at the centre of the positioning stage. What this 'position shift' means is that GNSS becoming unusable could have considerable impact given that it is to become central to PBN and is also used for some communication and surveillance applications (e.g. time stamping and ADS-B surveillance, respectively). This means that contingency procedures are needed in the case of GNSS being unusable which would require a reversion from GNSS.

Satellite constellations and their augmentations are vulnerable to interference, including natural and deliberate, and such vulnerability must be mitigated either by requiring systems to be more resilient and robust or by depending on contingency procedures. Contingency procedures may rely on alternative positioning sources or communication and/or surveillance in order to maintain an acceptable level of safety.

When developing the airspace concept, both normal and contingency operations need to be planned for. As such, when considering contingency operations the following considerations should be the subject of analysis by the ANSP and stakeholders:

- Probability of a GNSS outage
- How wide and/or how long is the impacted area likely to be?
- What systems can be impacted by the loss of GNSS in terms of CNS?
- List of the ATM/CNS systems which are still available following GNSS outage
- What is the likely impact to current operations?
- What level of service is to be provided during contingency operations?
- How does the ANSP maintain the desired level of operations?
- What is the contingency operations concept?
- What infrastructure exists to enable contingency operations?
- Cost Benefit Analysis considerations
- Supplementary considerations for pilots and controllers

As CNS systems evolve, there is an increasing reliance on GNSS. Operationally, and when providing for CNS-redundancy to cater for GNSS outage, it is important to remember that trade-offs between ATM and CNS are possible. This way, and in order to illustrate such trade-offs, Figure 10 below attempts to show how different decisions (trade-offs within the system) can be taken for a single scenario (an RNP 1 normal operation with two alternative contingency operations where different options have been taken but still ensuring that the required Target Level of Safety (TLS) is met).

Read rows from LEFT to RIGHT	Nav Performance	*Risk*	*Mitigation of Risk*
NORMAL OPR	RNP 1 Operations using GNSS	Acceptable level of risk included.	Radar environment; ATC tools; procedures; Airspace Design.
GNSS UNUSABLE			↓ CONTINGENCY OPTIONS ↓
High Level Scenario A *(rich DME/DME Infrastructure)*	GNSS loss impacts the entire fleet but in different ways: 20% of fleet loses NAV capability (because they only have GNSS positioning); 80% continue RNAV 1 operations using D/D/I, for which they are certified.	Increased exposure to risk as 20% of fleet need ATC assistance. (See *Budapest Simulation and Route Spacing Studies*, above)	#1 Accept all aircraft and manage by Radar vectoring those without D/D, Increased RTF and ATCO workload; training required (i.e. cost). Network Manager may be impacted. #2 Radar vector or divert ac unable to navigate. Deny further access to non-D/D ac. Manage airspace through ATFCM Measures (Demand and Capacity balancing). Increased workload for Network Management and FMPs
High Level Scenario B *(rich DME/DME Infrastructure)*	GNSS loss impacts the entire fleet but all aircraft are certified for D/D/I and so can continue to navigate using RNAV 1	Loss of on-board performance monitoring and alerting although lateral navigation performance minimally affected.	Increased Radar Monitoring, workload and training required (i.e. cost). May require Route adherence monitoring (RAM) (cost).

TLS Met

Figure 10. CNS trade-offs [RD 5

The process for the development of a contingency scenario lies in the intertwined activities described in the European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON) (PBN Handbook No. 4) that were summarised in Figure 9. To this end, the table below shows the two sets of activities in parallel, highlighting the main contingency/reversion considerations required in each of the steps. These activities, including the contingency/reversion aspects are developed at a higher granularity level in the corresponding handbooks.

Airspace Concept Handbook Activities (Left) where ATM contingency considerations needed (Right)		**Navaid Infrastructure Planning Handbook Activities (left)** and corresponding INFA contingency aspects (Right)	
Activity 1	None	**None**	None
Activity 2	None	**IA-2**	None
Activity 3	Include contingency in Objective setting	**IA-3**	Set Navaids rationalization targets; identify potential conflicts with contingency objectives
Activity 4	Include contingency in Reference Scenario Analysis	**IA-4**	Analyse the role in supporting GNSS reversion for Baseline Infrastructure
Activity 5	Include contingency in Safety Policy, Plan and Performance criteria	**IA-5**	Identify required Infrastructure performance for supporting planned operations, including GNSS reversion, as required by planned contingency operations
Activity 6	Include in ATM/CNS enablers – though iterations will be needed during activities 7-8-9-10	**IA-6**	Define preliminary target infrastructure considering required performance and rationalization targets. Iterations may be needed to find the best compromise in case of conflicting requirements (e.g. performance requirements vs rationalization targets)
Activity 7	During iterations between these activities, contingency operations will be catered for in the design (7), initial procedure design (8), adjustments made for the airspace Volume (9). This could trigger a need for more infrastructure or provide indications as to how C-N-S infrastructure could be rationalised.	**IA-7**	Plan infrastructure evolution considering foreseen nominal and contingency (GNSS reversion) operations. Iterations may be needed to find the best compromise in case of conflicting requirements (e.g. performance requirements vs rationalization targets)
Activity 8			
Activity 9			
Activity 10			
Activity 11	Include contingency in Concept Validation	**None**	None
Activity 12	Include contingency in Final Procedure Design	**IA-8**	None (the achieved infrastructure performance to be taken into account in the final procedure/ airspace design)
Activity 13	Include contingency in Instrument Flight Procedures (IFP) validation/Flight Inspection.		
Activity 14	Include contingency in ATC System Integration	**None**	None (Airspace Concept activities not directly related with the navigation infrastructure evolution)
Activity 15	Include in Awareness and Training Material		
Activity 16	Include contingency in implementation		
Activity 17	Include contingency in implementation Review		

Table 4-1. Contingency/reversion considerations in Airspace Concept and Infrastructure Planning activities [RD 4]

Civil-Military aspects

The civil-military considerations that might be taken into account in contingency/reversion planning are presented in the Scenario 2 addressed as example in the handbook. This scenario corresponds to a low/ medium density TMA and airport complying with the PBN IR.

The description of the scenario starts by showing the assumed available technology (infrastructure/avionics) followed by the supported operations. The scenario comprises 'normal operations' and a corresponding 'reversion scenario'.

The summary of the assumptions undertaken in this scenario are portrayed in Table 3[4] (civil-military insights in blue).

Normal Infrastructure	
Available Navaid Infrastructure	GPS; DME/DME; VOR/DME; NDB; SBAS
Fleet Positioning Capability for PBN	GPS + D/D > 90% + VOR/DME + NDB; SBAS 25% + ILS *State aircraft: State aircraft operators are one of the airspace users.*
Surveillance Sensors Used	MSSR and ADS-B *State aircraft: Some State aircraft are not be equipped with Mode S and/or ADS-B due to operational, technological, and procurement reasons.*
Communication Service Used	VHF Voice
Timing for On-Board Systems	Independent + GPS synchronised
Timing for Ground Systems	GPS synchronised with NTP
Normal Operations (ENR and SIDs/STARs)	
NAV Applications enabling Airspace Concept	RNAV 5 (ATS Routes & FRA); RNAV 1 (Some SID/STAR); Conventional SIDs/STARs; RNP 0.3 (All Heli)
Airspace Concept	PBN enabled Free Routes Operations above FL 310; ATS Straight parallel routes including SID/STARs and non-parallel routes; crossing
Spacing between proximate PBN SID/ STAR	5 NM on straight segments, wider spacing on turns due to fly-by transitions
Separation Minima used in Airspace	3 NM in terminal operations; 5NM en-route operations
Normal Operations (Approach)	
Available Navaid Infrastructure	RNP APCH LNAV/VNAV; LNAV; LPV; ILS;
Approach Operating Concept	RNP approaches and precision approach ILS or SBAS for CAT I
Multiple Runway Operation	Not applicable
Missed Approach guidance	RNP APCH – conventional based on VOR/DME ILS – conventional based on VOR/DME
Separation Minima	3NM longitudinal based on radar separation minima
Explanation: *DME infrastructure does not support RNAV 1 for missed approach*	

Table 4-2. Assumptions taken for the definition of Scenario

4 Explanatory note: black text is the content as written in the European GNSS Contingency/Reversion Handbook for PBN Operations; blue text reflects civil-military insights

The event of GNSS being unusable leads to the contingency operations and inherent measures that are in line with the agreed reversion plan. The first element to be observed is the infrastructure that becomes available to support the service provision. This way, the table below[5] (civil-military insights in blue) shows that the entire infrastructure is impacted, except voice communication.

Reversion Infrastructure	
Available Navaid Infrastructure	~~GPS~~; DME/DME; VOR/DME; NDB; ~~SBAS~~
Fleet Positioning Capability for PBN	~~GPS~~ + D/D > 90% + VOR/DME + NDB; ~~SBAS 25%~~ + ILS *State aircraft: State aircraft operators are one of the airspace users.*
Surveillance Sensors Used	MSSR; ~~with ADS-B~~ *State aircraft: Some State aircraft are not be equipped with Mode S and/or ADS-B due to operational, technological, and procurement reasons.*
Communication Service Used	VHF Voice
Timing for On-Board Systems	Independent ~~+ GPS synchronised~~
Timing for Ground Systems	NTP + ~~GPS synchronised~~

Table 4-3. Reversion infrastructure for Scenario 2

5 Explanatory note: Struck out red text e.g. GPS indicates that the {struck-out} technology cannot be used.

The unavailability of satellite-based services lead to the contingency operations depicted in Table 5[6].

Contingency Operations (ENR and SIDs/STARs GNSS Reversion)	
Applications which can continue in Airspace	RNAV 5 (ATS Routes + FRA); RNAV 1 using DME/DME RNAV (Some SID/STAR); Existing Conventional ATS Routes + SID/STAR; ~~RNP 0.3~~ (All Heli)
Applications Explanation: *(i) For reversions of short duration, RNAV 1 could continue though 10% of the fleet that would require vectoring or continue on conventional procedures.* *State aircraft: State aircraft can be handled by conventional navigation or radar vectoring. Nevertheless, the aircraft on-board equipage should be compatible with the ground infrastructure that supports the contingency operations.*	
Airspace Concept (revisions to mitigate impact)	PBN enabled Free Routes Operations above FL 310; ATS Straight routes incl. SID/STARs and non-parallel routes; crossing; Existing + New* Conventional Routes incl SID/STAR
Airspace Explanation: *For short-term outage, parallel routes can be maintained.* *Is the current DME/DME infrastructure robust enough to support RNAV 1 operations?* **Are additional conventional procedures required to support contingency operations?* *State aircraft: the reversion to RNAV 1 operations only predicated on DME/DME will prevent State aircraft to conduct operations in such airspace if not equipped with DME/DME capability. Civil-military coordination as a means to answer the question "*Are additional conventional procedures required to support contingency operations?" is of crucial importance. Conventional routes might need to stay in place.*	
Spacing between proximate PBN SID/STAR	5 NM on straight segments, wider spacing on turns due to fly-by transitions
Spacing Explanation: *As 90+% of fleet can continue with D/D RNAV 1, and given the potential route spacing published in the EUROCONTROL Route Spacing Handbook, continuation of this spacing likely, subject to a safety assessment. 10% of the fleet will require Radar Vectoring or clearance on to a conventional procedure.* *State aircraft: State aircraft can be handled by conventional navigation. Nevertheless, the aircraft on-board equipage should be compatible with the ground infrastructure that supports the contingency operations.*	
Separation Minima used in Airspace (revision?)	~~3 NM~~ *or possible increase due to contingency operation* 5NM en-route operations

Contingency Operations (Approach GNSS Reversion)	
Final Approach Segment Applications which can continue	~~RNP APCH LNAV/VNAV; LNAV; LPV; RNP AR APCH;~~ ILS
Approach Operating Concept (revisions to mitigate impact)	~~RNP approaches are main landing mode;~~ ILS; Conventional (VOR/DME, NDB); Visual Approach
Airspace Explanation: *Runway throughput may need to be changed. VOR/DME and NDB procedures published and Visual Approaches also possible in VMC.* *State aircraft: Conventional procedures might be needed to stay in place.*	
Missed Approach guidance (revision?)	**~~RNP APCH~~ – conventional based on VOR/DME ILS – conventional based on VOR/DME
Separation Minima	3NM longitudinal based on radar separation minima
Explanation: *** Missed approach included to accommodate aircraft on the approach when GPS becomes unusable. DME infrastructure does not support RNAV 1 for missed approach.*	

Table 4-4. Contingency operations for Scenario 2

6 Explanatory notes for the interpretation of the reversion scenario:
- Struck out red text e.g. GNSS, indicates that the {struck-out} technology cannot be used and that as a consequence, the {struck out} navigation function (e.g. RF) or navigation specification (e.g. RNP 0.3) or particular route spacing (e.g. 5 NM) cannot be used either given the remaining CNS enablers without GNSS.
- Red text written in italics, e.g. RF, means that it is considered probable that there would be significant impact in the short or medium term, thus requiring consideration when planning contingency procedures.
- Highlight text indicates what may need to be made available to accommodate contingency operations/reversion.

A safety assessment must be undertaken in both normal and contingency operations. However, a cost-benefit assessment for the contingency operation will also need to be considered, also including the additional cost required to support the agreed contingency level of service. The cost-benefit assessment may not be positive in some cases; however, it is recommended to leverage the benefits of such service via a criticality factor associated to the type of mission (e.g. search and rescue, etc.) that such service may support.

4.4 EUROCONTROL Guideline for RNAV 1 Infrastructure Assessment

The EUROCONTROL Guidelines for RNAV 1 Infrastructure Assessment (EUROCONTROL-GUID-0114) [RD 5] is intended to provide the necessary guidance for ANSPs to conduct infrastructure assessments in order to satisfy the requirements of RNAV 1. The document can be used both to determine compliance with RNAV 1 and to consider what infrastructure changes could be undertaken in order to achieve it.

Because GNSS (aircraft-based augmentation system (ABAS) using receiver autonomous integrity monitoring (RAIM) being the most commonly utilised augmentation) is available on a worldwide basis, infrastructure assessment for GNSS differs significantly from terrestrial navigation aids. Relevant aspects such as safety assessment and GNSS performance assessment are described in the GNSS Manual, ICAO DOC 9849 (2017 edition, especially chapters 7.5 and 7.8.2). In addition to considering constellation performance, the ANSP should assess that the interference environment (ionosphere and radio frequency) is satisfactory for the planned procedures and implement vulnerability mitigation measures, if appropriate (chapter 5 and appendix F of the GNSS Manual). Further guidance on assessing and measuring GNSS interference is contained in ICAO Doc 8071.

RNAV procedures should always allow the use of GNSS. However, some older RNAV avionic systems may not include GNSS. In order to provide a back up to GNSS and to accommodate DME/DME or DME/DME/Inertial - only equipped users, DME based RNAV service should also be provided where feasible and practical; this may be difficult to achieve at low altitude if there are significant ground infrastructure siting constraints (bodies of water, mountainous terrain).

The main task in the assessment is to evaluate if the DME infrastructure adequately supports the candidate RNAV procedure. Consequently, this is the focus of this guidance material. While VOR/DME can support RNAV 5 guidance, it has been found too difficult to establish harmonized criteria given fleet equipage levels and the signal in space performance does not support the accuracy required for RNAV 1. Furthermore, while VOR/DME supports RNAV 5, actual usage by aircraft is limited, both in terms of useful range (some Flight Management System (FMS) only permit the use of VOR up to a range of 25NM) and sensor priority defined in the architecture of the FMS.

Nevertheless, VOR/DME may still be a useful RNAV 5 infrastructure in cases where DME/DME coverage is difficult to achieve, as it is the case at low altitudes or near large bodies of water. Doing this would however require a consultation with airspace users to ensure that they are able to take advantage of the provided coverage. VOR/DME assessments for RNAV are simply a matter of generating cumulative coverage estimations since geometry constraints do not have to be taken into account (such as in DME/DME). Given the standardization challenges of VOR for TMA RNAV applications, States are not encouraged to rely on VOR (RNAV 5 is not to be used below minimum safe altitude or within 30NM of the aerodrome).

While a variety of cases may exist where VOR/DME provides a useful conventional navigation capability, such as in close proximity to airports, these are not addressed here (see ICAO Annex 10, attachment H). Consequently, the main residual role given to VOR is as a means of crosschecking for positional awareness.

Care must also be taken to ensure that FMSs do not provide inaccurate guidance if they revert to VOR/DME in a DME/DME coverage gap. However, for an RNAV 1 assessment it is expected that coverage gaps would normally be filled. As the implementation of RNAV matures and the number of VOR stations is reduced, the role of VOR is expected to diminish further.

Civil-Military aspects

Military organisations may decide to implement RNAV 1 procedures predicated on GNSS, and therefore, should carry out an infrastructure assessment in such cases. An assessment should also be conducted to evaluate if the DME infrastructure adequately supports the candidate RNAV 1 procedure, or that the operations are degraded to a less stringent service level.

The consideration of the DME component of ground TACAN station(s) to sustain the candidate RNAV procedures must be undertaken by initially assessing the technical compliance of the system with ICAO Annex 10 and Doc 8071. Within the context of the Guideline for RNAV 1 Infrastructure Assessment, and therefore RNAV 1 using DME/DME RNAV, the consideration of ground TACAN station(s) to support such level of service should also be subject to civil-military coordination at national level. Any TACANs fulfilling these criteria must then be published in the State's AIP. All new RNAV procedures will need to undergo instrument flight procedure validation in accordance with ICAO Doc 9906.

The use of TACAN to support candidate RNAV 1 procedures (DME/DME level of service) within civil-controlled airspace is recommended to be subject to a service level agreement between the military and the civil service providers and this should be part of the infrastructure assessment phase. The use of TACAN could not be limited to a DME/DME configuration since VORTAC stations provide VOR/DME service. Therefore, VORTAC may still be a useful RNAV 5 infrastructure in cases where DME/DME coverage is difficult to achieve or in support of conventional procedures.

4.5 European PBN Route Spacing Handbook

The European PBN Route Spacing Handbook (*PBN Handbook No. 3*) addresses the spacing of proximate flight procedures, focusing specifically on terminal and extended terminal areas in a radar surveillance environment.

The driver for this document stems from regulatory requirements to implement PBN SIDs/STARs in Europe. A particular aspect of this implementation is the route spacing between SID and STAR procedures that can be achieved in congested airspace with an independent collaborative surveillance system.

The sample spacing distances derived using Collision Risk Modelling (CRM) are based on observed data sets from three major European terminal areas, and are published in the Handbook. However, it becomes clear that with the tighter navigational performance observed from modern aircraft today navigation accuracy is no longer the prevalent factor in how close routes can be spaced today.

The limiting factors in placing routes closer together include the radar separation minima of 3 and 5 NM in terminal and en-route respectively, as well as human factors such as ATC sector size, aircraft relative speeds, and the controller's screen resolution. Furthermore, the examples given in the handbook also indicate that aspects like route configuration, procedure complexity and flyability have an important effect on achievable route spacing minima.

The European PBN Route Spacing Handbook provides a sample set of route spacings. However, it is important that these sample spacings are not just 'lifted' from the document 'as is'. The assumptions used in the EUROCONTROL modelling are very specific and must be clearly understood before utilising the spacings derived. Simply said, these sample distances are not automatically ready-made for implementation and a local implementation safety case must determine the relevance of the handbook's examples to the intended terminal area of application. Moreover, post implementation lateral navigation performance monitoring would need to confirm the achieved navigation performance.

Civil-Military aspects

PBN Handbook No. 3 is intended primarily for airspace planners and their supporting PBN specialists. Civil-military aspects related to infrastructure management should be understood and are related to the handbooks mentioned in the previous sections. The flight procedures are enabled by the space- and ground-navigation infrastructure that serves the airspace users.

4.6 European PBN Implementation and Transition Planning Handbook

The European PBN Implementation and Transition Planning Handbook (PBN Handbook No. 5) [RD 6] aims at providing a generic (or skeleton) architecture, which is intended to assist States and providers of air traffic management/air navigation services (ATM/ANS) to develop an ICAO PBN Implementation Plan and/or a PBN IR Transition Plan.

Considering the consistency of the implementation requirements and inherent timelines included in Regulation (EU) 2018/1048, and given the direct-relationship of this regulation with ICAO Resolution 37-11, it is considered logical for States to incorporate their PBN Implementation and Transition Plan into a single document.

It is expected that the State (Ministry of Transport or CAA – MAA to be involved) will develop the policy and strategic roadmap and the Service Provider will define a deployment plan to deliver the policy goals. Part A of this document would be developed by the State and will detail of the strategic vision. Part B, developed by the Service Provider(s), will lay out its plans for delivering that strategic vision – Figure 11. The PBN implementation and transition plan may, or may not, be completed in partnership; however, a collaborative approach is highly recommended.

The State's airspace requirements will be developed by the National Supervisory Authority (NSA). This section will clearly identify the State's high-level principles before setting out the 'drivers' for change (the 'why'), together with the directive to the service provider to undertake the work and the required timeframe for implementation (the 'when'). The service provider will then complete the second section which will identify the actions that must be undertaken to meet the strategic objectives (the 'what'), the location of the required changes (the 'where'), the migration from current operations to the future environment (the 'how'), and the key personnel required to successfully deliver the implementation (the 'who').

The culmination of the work progressed by the NSA and the ANSP is addressed in the Deployment Deliverables of the PBN Implementation and Transition Plan document. The Deployment Deliverables identify what is to be achieved in terms of PBN implementation and provide the answers to the questions why, what, where, who, when and how [RD 6].

	PART A	PART B
For use by....	*THE "**STATE**"* ***(also referred to, interchangeably, as the CAA or the NSA)***	***THE "ANSP"*** ***(also referred to as the Service Provider)***
Template & guidelines for building a/an	***Implementation Strategy***	***PBN Implementation Plan***
	1. High Level Principles (incl. Safety & Security Policy)	*1. Statement of Compliance intention Policy*
	2. Drivers for Change *a. Regulatory* *b. Operational* *c. Other*	*2. Compliance methodology: (outline)*
	3. Current Operations *a. Analysis* *b. Identification of additional drivers*	*3. Analysis* *a. Drivers for Change* *b. Current Operations* *c. ID of additional drivers*
	4. Strategic Implementation Objectives	*4. Implementation Objectives*
	5. Processes & Methodology *a. To include....Transition Considerations*	*5. Implementation Methodology*
	6. Transition Considerations	*6. Implementation Roadmap*
	7. Required deliverables	*7. Transition Arrangements*
		8. Deliverables

Figure 11. 'Architecture' to support in formulating a PBN implementation plan and/or transition plan [RD 6]

Civil-Military aspects

Regulation (EU) 2018/1048 requires in Article 4 that providers of ATM/ANS are to consult, among other parties, airspace users affected by the provision of their services and take into account their views. Moreover, the competent authority responsible for the approval of the transition plan shall verify whether the draft transition plan complies with the requirements of the Regulation and, in particular, whether it takes account of the views of airspace users where appropriate, including those operating State aircraft. ATM/ANS authorities should initiate the dialogue with military organisations.

Therefore, in light of the European PBN Implementation and Transition Planning Handbook, it is recommended that State aircraft operators are involved at least in the following steps of the process:

Part A – State PBN Implementation Strategy

"Analysis of Current Operations"

The State may decide to include civil-military coordination as well as State aircraft operations into the reference scenario. The consideration of civil-military coordination elements and State aircraft specifics at an early stage will facilitate the development of the implementation plan, including the transition measures, to be carried out by the service provider.

The reference scenario provides a 'baseline' to understand and analyse the current operations within the national airspace and associated aerodromes, which for the particular case of State aircraft operators could be substantiated by the following elements:

Example:

1. Airspace areas and structures within civil-controlled airspace where State aircraft operate, which are managed (or partially managed), by military personnel
2. Civil airports used by State aircraft
3. State aircraft fleet equipage assessment (and plans to modernise aircraft if existing)
4. Military navigation infrastructure assessment that could support PBN and/or conventional procedures (e.g. TACAN)

"Strategic Implementation Objectives"

State aircraft operations may be translated into a National objective, without jeopardising the implementation of the navigation requirements stated in Regulation (EU) 2018/1048, by ensuring that State aircraft are accommodated with the provision of an appropriate level of navigation service.

The contingency procedures for GNSS reversion in the event of a GNSS outage, which would need to take account of available infrastructure and the minimum operational network, might also take into consideration its best use for the accommodation of non-equipped State aircraft.

"Transition Considerations"

The transition measures are of utmost importance to ensure that State aircraft GAT operations can continue to conduct conventional procedures in the most efficient way relying on an optimal navigation infrastructure design.

Example:

The following are considerations that can be addressed in the implementation plan for the accommodation of non-PBN-compliant State aircraft:

1. Conventional procedures
   i. Optimal design of conventional procedures
   ii. Estimation of how long the provision these procedures are required
   iii. Optimal navigation infrastructure design
2. Targeted infrastructure rationalisation

Part B – ANSP PBN Deployment Plan

"National Airspace Concept"

The national airspace concept comprises the consideration of State aircraft operations, including those performed as GAT. The civil-military elements stemming from Part A – "State PBN Implementation Strategy" and the outcome of direct consultation with State aircraft operators should be embodied in the national airspace concept.

Example:

The considerations that can be addressed for the accommodation of State aircraft that are unable to comply with the PBN IR are the following:

1. National conventional operations
2. Phase-out plan for conventional procedures if foreseen
3. Civil-military coordination procedures

"Considerations for PBN Implementation"

State aircraft operators should be members of the implementation teams when airspace change is assessed to impact on their operations.

To this end, military organisations may elect to set up a team to assess the impact of a proposed airspace change and provide support to civil-military coordination in the following technical areas:

1. Airspace Management
2. Navigation Infrastructure Management
3. Aircraft Project Management

"PBN Transition Plan"

The transition plan takes into account the views of State aircraft operators when impacted by the airspace change. The measures that ensure the continuity of State aircraft operations conducted by non-PBN-compliant State aircraft should be addressed in the transition plan.

Example:

The conventional procedures for the short- to long-term arrangements can be described in the transition plan for each phase of flight.

Part A – Template for State PBN Implementation Strategy	Part B – Template for ANSP PBN Deployment Plan
Executive Summary	Executive Summary
PBN "Strategic Roadmap" or "Policy"	1. State of Strategic Compliance – Intention Policy
1. National Aviation Policy	2. Compliance Methodology
2. Drivers for PBN Implementation	3. Analysis
3. Analysis of Current Operations *(civil-military elements)*	4. National Airspace Concept *(civil-military elements)*
4. Strategic Implementation Objectives *(civil-military elements)*	5. Operational Requirements and PBN Implementation Objectives
5. Process	6. Considerations for PBN Implementation *(civil-military elements)*
6. Methodology	7. PBN Transition Plan *(civil-military elements)*
7. Transition Considerations *(civil-military elements)*	8. PBN Implementation Activities
	9. PBN Implementation

Table 4 5. Consideration of civil-military elements in the 'architecture' for the PBN implementation pla

5 AIRBORNE EQUIPAGE AND INTEROPERABILITY

The modernisation of the civil aviation infrastructure raises challenges for military aircraft operating in a civil-military environment. Global interoperability becomes a decisive factor for military operations that need seamless support from a common ATM/CNS infrastructure.

The enhanced airspace requirements mandated by the PBN regulation in Europe call for specific levels of navigation performance which affect multiple aviation stakeholders, including military operators and particularly those that need to carry out operations within TMAs and the associated aerodrome(s). The impact of the different PBN procedures on military aircraft flying as GAT is dictated by the level of PBN on-board equipage and avionics integration needed, which respond to the different PBN specification requirements.

When applied to systems, interoperability is obtained by compliance to common standards that can establish common functional and technical requirements as well as common procedures to use them. The certification-qualification basis includes the technical requirements as well as the means to be used to demonstrate the compliance.

The elaboration of the military certification basis presents differences with the civil process since the airworthiness certification programme is linked to the aircraft military qualification comprising the mission requirements. Military Aviation Authorities should be recognised as the competent authorities for military certification compliance in order to solve confidentiality issues.

Within a performance compliance context, the requirements emerging from the PBN context (accuracy, integrity, continuity) should be considered under the sense of proportionality. A proportionate requirement is a requirement which allows any interoperable system meeting the performance and the safety levels to be certified according to the current certification processes. The proportionality of a requirement is assessed by checking its 'adequate' and 'necessary' characteristics. Therefore, alternative requirements should be developed if requirements are inadequate or not necessary [RD 7].

Nevertheless, the requirements alternative to those emerging from the civil ATM/CNS context should be checked consistent with current Certification Specifications/AMC and Guidance Material (GM) where appropriate and validated with the former or a new safety case. The completeness of requirements stemming from the application of proportionality are entitled interoperability requirements [RD 7]. The coupling of military operational needs and technical interoperability requirements in the standardisation process should lead to the definition of a military standard as the standardisation element that sustains certification when applying a performance compliance approach.

The appendixes A to C detail the aircraft equipage requirements vis-à-vis the PBN specifications addressed in the regulation, as well as technical mitigation measures for State aircraft. The equipage requirements aim also to be understood as a potential baseline to the development of alternative means of compliance by the military, and therefore, further developments for performance compliance that aim at attaining interoperability.

APPENDIX A – PBN ON-BOARD REQUIREMENTS

The ability of military aircraft to fly PBN procedures is dictated by the level of PBN on-board equipage and avionics integration. The technical requirements associated to equipage and avionics integration are intrinsically associated to the PBN performance required.

Examples of equipage requirements advocated for PBN specifications that are part of the PBN IR are described, as well as technical mitigation measures for military aircraft (Appendix B). The information and data shown in this appendix are mainly extracted from ICAO Doc 9613, fourth edition, and complemented with the EASA CS-ACNS[7].

B.1 RNAV 5 (Mandated for en-route operations in the PBN IR)

B.1.1 Aircraft Systems

[REQ RNAV5_1] Equipment configurations shall be one or more of the following: VOR/DME; DME/DME; INS or IRS; GNSS.

[REQ RNAV5_2] Where approval for RNAV 5 operations requires the use of traditional navigation equipment as a back-up in the event of loss of GNSS, the required NAVAID capability, as defined in the approval (i.e. VOR, DME, and/or ADF), will need to be installed and be serviceable.

[REQ RNAV5_3] Accuracy: during operations in Free Route Airspace (FRA) or on ATS routes designated as RNAV 5, the lateral TSE and the along-track error must be within ±5 NM for at least 95 per cent of the total flight time.

[REQ RNAV5_4] Integrity: malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10-5 per hour).

[REQ RNAV5_5] Continuity: loss of the capability to provide lateral position or guidance is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. Given the case it cannot revert, it is considered a major failure condition.

[REQ RNAV5_6] SIS: if using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 10 NM exceeds 10-7 per hour.

B.1.1.1 INS/IRS

[REQ RNAV5_7] Inertial systems may be used either as a stand-alone INS or an IRS acting as part of a multi-sensor RNAV system, where inertial sensors provide augmentation to the basic position sensors, as well as a reversionary position data source when out of cover of radio navigation sources.

[REQ RNAV5_8] INS without automatic radio updating of aircraft position and when complying with the functional criteria of this specification, may be used only for a maximum of 2 hours from the last alignment/position update performed on the ground.

7 Available here: https://www.easa.europa.eu/certification-specifications/cs-acns-airborne-communications-navigation-and-surveillance

[REQ RNAV5_9] INS with automatic radio updating of aircraft position should be approved in accordance with AC 20-138, or equivalent material.

B.1.1.2 VOR

[REQ RNAV5_10] VOR equipment shall comply with EUROCAE ED-28, Chapter 4.

B.1.1.3 DME

[REQ RNAV5_11] DME equipment shall comply with EUROCAE ED-28, Chapter 4.

[REQ RNAV5_12] When the RNAV 5 system does not take account of published "Designated Operational Coverage" of the DME, the RNAV system must execute data integrity checks to confirm that the correct DME signal is being received.

B.1.1.4 GNSS

[REQ RNAV5_11] The use of GNSS to perform RNAV 5 operations is limited to equipment approved to ETSO-C129(), ETSOC145(), ETSO-C146(), FAA TSO-C145(), TSO-C146(), and TSO-C129() or equivalent, TSO-C196().

[REQ RNAV5_14] Integrity should be provided by SBAS GNSS or RAIM or an equivalent means within a multi-sensor navigation system.

[REQ RNAV5_15] Positioning data from other types of navigation sensors may be integrated with the GNSS data provided other positioning data do not cause position errors exceeding the track-keeping accuracy requirements.

B.1.2 Functional Requirements

[REQ RNAV5_16] The system must be able to store a minimum of 4 waypoints.

[REQ RNAV5_17] Appropriate failure indication of the RNAV system, including the sensors must be displayed.

[REQ RNAV5_18] Continuous indication of aircraft position relative to track must be displayed to the pilot flying the aircraft, on a navigation display situated in his/her primary field of view.

[REQ RNAV5_19] The area navigation system displays the distance and bearing to the active (to) waypoint and ground speed or time to the active (to) waypoint.

[REQ RNAV5_20] Where the minimum flight crew is two pilots, indication of the aircraft position relative to track must be displayed to the pilot not flying the aircraft, on a navigation display situated in his/her primary field of view.

B.1.3 Navigation Displays

[REQ RNAV5_21] Navigation data must be available for display either on a display forming part of the RNAV equipment or on a lateral deviation display (e.g. CDI, (EHSI, or a navigation map display).

[REQ RNAV5_22] Displays must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.

[REQ RNAV5_23] The displays must be visible to the pilot when looking forward along the flight path.

[REQ RNAV5_24] The lateral deviation display scaling should be compatible with any alerting and annunciation limits, where implemented.

[REQ RNAV5_25] The lateral deviation display must have a scaling and full-scale deflection suitable for the RNAV 5 operation.

B.2 RNAV 1 (Mandated minimum requirement for PBN SIDs/STARs in the PBN IR)

B.2.1 Aircraft Systems

[REQ RNAV1_1] The following navigation criteria are defined: GNSS, DME/DME or DME/DME/IRU.

[REQ RNAV1_2] Where DME is the only navigation service used for position updates. Integration of IRUs can permit extended gaps in DME coverage. If an IRU is not carried, then the aircraft can revert to dead reckoning.

[REQ RNAV1_3] Accuracy: The lateral track keeping accuracy of the on-board system shall be equal to or better than ±1 NM for 95 per cent of the flight time.

[REQ RNAV1_4] Integrity: Malfunction of the aircraft navigation equipment (major failure condition) shall not occur with a probability higher or equal than 10-5 per hour.

[REQ RNAV1_5] Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

[REQ RNAV1_6] SIS: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral positon error greater than 2 NM exceeds 1 × 10-7 per hour.

[REQ RNAV1_7] The navigation database suppliers should comply with RTCA DO-200A/EUROCAE document ED 76.

B.2.1.1 GNSS

[REQ RNAV1_8] The use of GPS is limited to equipment approved under FAA TSO-C145 and TSO-146, and JTSO-C129 () in the equipment classes A1, B1, C1, B3 and C3.

[REQ RNAV1_9] For routes and/or aircraft approvals requiring GNSS, if the navigation system does not automatically alert the pilot to a loss of GNSS, the operator must develop procedures to verify correct GNSS operation.

B.2.1.2 DME/DME

[REQ RNAV1_10] DME/DME RNAV equipment shall comply with the criteria listed in ICAO PBN Manual 9613 paragraph 3.3.3.2.3.

B.2.1.3 DME and IRU

[REQ RNAV1_11] Inertial system performance must satisfy the criteria of US 14 CFR Part 121, Appendix G.

[REQ RNAV1_12] Automatic position updating capability from the DME/DME solution is required.

B.2.2 Functional requirements

[REQ RNAV1_13] The system shall have the capability for automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. This does not preclude providing a means for manual navigation source selection.

B.2.3 Navigation displays

[REQ RNAV1_14] Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display.

[REQ RNAV1_15] Lateral navigation display and navigation map display must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.

[REQ RNAV1_16] The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.

[REQ RNAV1_17] The lateral deviation display scaling should agree with any alerting and annunciation limits, if implemented.

[REQ RNAV1_18] The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required total system accuracy.

[REQ RNAV1_19] The display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with en-route, terminal, or approach values.

[REQ RNAV1_20] The lateral deviation display must be automatically slaved to the RNAV computed path. The course selector of the deviation display should be automatically slewed to the RNAV computed path.

[REQ RNAV1_21] The system shall have the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path.

[REQ RNAV1_22] The system shall have the capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.

B.2.4 Navigation database

[REQ RNAV1_23] Data shall be contained in a navigation database.

[REQ RNAV1_24] The stored resolution of the data must be sufficient to achieve the required track keeping accuracy.

[REQ RNAV1_25] The database must be protected against flight crew modification of stored data.

[REQ RNAV1_26] The aircraft must have the capability to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs.

[REQ RNAV1_27] The system must have the capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR to be flown.

[REQ RNAV1_28] The system shall have the means to display the validity period of the navigation database to the flight crew.

B.2.5 System functions

[REQ RNAV1_29] The aircraft should have the possibility for the pilot to verify the route to be flown

[REQ RNAV1_30] The aircraft must have the capability to automatically execute leg transitions consistent with IF, CF, FA, DF and TF ARINC 424 path terminators.

[REQ RNAV1_31] The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARINC 424 path terminators, or must be able to manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.

[REQ RNAV1_32] The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.

[REQ RNAV1_33] The navigation system must have the capability to execute ARINC-424 "direct to" function.

[REQ RNAV1_34] The capability for automatic leg sequencing with the display of sequencing to the pilot.

[REQ RNAV1_35] The system shall have the capability to execute SIDs or STARs from the on-board database, including the capability to execute fly-over and fly-by turns.

[REQ RNAV1_36] For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided.

B.3 RNP 1 (Optional for PBN SIDs/STARs in the PBN IR – mandatory if RF required)

B.3.1 Aircraft Systems

[REQ RNAV1_1] RNP 1 is based on GNSS positioning as primary source of horizontal position. Positioning data from other types of navigation sensors may be integrated with the GNSS data if they do not cause position errors exceeding the TSE budget. Otherwise, means should be provided to deselect the other navigation sensor types.

[REQ RNP1_2] The area navigation system should be granted an ETSO authorisation against ETSO-C146c operational class 1.

[REQ RNP1_3] When the system architecture is based on a flight management system (FMS) receiving input from multiple sources of position, the FMS shall be in accordance with ETSO-C115d. Depending on the type of sources to determine position, it should be also compliant with the following standards: GNSS position source against ETSO-C196a or ETSO-C145c operational class 1; DME/DME based on DME interrogator granted an ETSO-2C66b; and/or, barometric vertical position source with ETSO-C106 A1 authorisation.

[REQ RNP1_4] The systems which meet the accuracy, integrity and continuity requirements are: aircraft with ETSO-C129a sensor (Class B or C), E/TSO-C145() and the requirements of ETSO-C115d FMS, installed for IFR use in accordance with FAA AC 20-130A; aircraft with ETSO-C129a Class A1 or ETSO-C146() equipment installed for Instrument Flight Rules (IFR) use in accordance with FAA AC 20-138 or AC 20-138A; and aircraft with RNP capability certified or approved to equivalent standards.

[REQ RNP1_5] Navigation equipment shall comply with: RTCA DO-229D (MOPS of GPS/SBAS), paragraph 2.4.

[REQ RNP1_6] Software development shall be in accordance with DO-178B, Level C.

[REQ RNP1_7] For complex firmware implementations such as application-specific integrated circuits, processes similar to those described in RTCA/DO-178B or RTCA/DO-254 provide an acceptable means of compliance with applicable airworthiness requirements.

[REQ RNP1_8] To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity for the RNP 1, including SIDs and STARs.

[REQ RNP1_9] Accuracy: To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM for autopilot or flight detector.

[REQ RNP1_10] Integrity: The area navigation system is designed to provide a level of integrity that supports the following classification of failure conditions: The presentation of erroneous lateral position or guidance is classified as a major failure condition, whilst presentation of erroneous along-track distance is classified as a minor failure under airworthiness regulations (i.e. 10-5 per hour).

[REQ RNP1_11] Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

[REQ RNP1_12] On-board performance monitoring and alerting: the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 1 NM is greater than 1 × 10-5.

[REQ RNP1_13] SIS: The aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral positon error greater than 2 NM exceeds 1 × 10-7 per hour.

[REQ RNP1_14] The area navigation system provides an annunciation if a manually entered RNP value is greater than the RNP value associated with the current routes and procedures as defined in the on-board navigation database.

B.3.2 Functional requirements

[REQ RNAV1_15] The navigation system must have the capability to execute ARINC-424 "direct to" function.

[REQ RNP1_16] The capability for automatic leg sequencing with the display of sequencing to the pilot.

[REQ RNP1_17] The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with IF, CF, DF and TF ARINC 424 path terminators, or they equivalent.

[REQ RNP1_18] The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARIAN 424 path terminators, or must be able to manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.

[REQ RNP1_19] The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.

[REQ RNP1_20] The system must have the capability to assign a magnetic variation (MAGVAR) at any location within the region where flight operations are conducted using magnetic north as a reference. For paths defined by a course, the system uses the appropriate magnetic variation value available in the navigation database.

[REQ RNP1_21] The area navigation system has the capability to initiate, maintain and discontinue holding procedures at any point and at all altitudes. It is allowed to define the holding pattern via manual or automatic definition.

[REQ RNP1_22] The area navigation system provides flight crew with the capability to create, review, modify and activate a flight plan. Activation of any new flight plan or modification of an existing flight plan requires positive action by the flight crew.

[REQ RNP1_23] The system provides a means to the flight crew to build an user-defined route by entering unique waypoints extracted from the on-board navigation database or by manually creating user-defined fixes

[REQ RNP1_24] User-defined fixes are usually defined via the entry of latitude/longitude, place/along-track, place/bearing-place and place/bearing/distance.

[REQ RNP1_25] The area navigation system is capable of acquiring and setting the RNP value for each segment of a route or procedure flown from the on-board navigation database.

B.3.3 Navigation database

[REQ RNAV1_26] The stored resolution of the data must be sufficient to achieve negligible PDE.

[REQ RNP1_27] The navigation database must be protected against pilot modification of the stored data.

[REQ RNP1_28] The system requires as a minimum a navigation database containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with AIRAC cycle and from which ATS routes can be retrieved and loaded into the system.

[REQ RNP1_29] The system shall have the means to display the validity period of the navigation data to the pilot.

[REQ RNP1_30] The system shall retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDS.

[REQ RNP1_31] The area navigation system has the capability to extract routes/procedures from the on-board navigation database, including all their characteristics, and to load them into the system's flight plan.

[REQ RNP1_32] The system shall provide the means to load and execute from the database into the RNP 1 system the entire segment of the SID or STAR to be flown, by procedure name, including the capability to execute fly-over and fly-by turns.

B.3.4 Navigation displays

[REQ RNAV1_33] The area navigation data system displays and allows manual entry of navigation data with a resolution that supports the intended operation.

[REQ RNP1_34] Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.

[REQ RNP1_35] The capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft positon relative to the path must also be provided.

[REQ RNP1_36] The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.

[REQ RNP1_37] Each display must be visible to the pilot and located in the primary field of view (±15º from the pilot's normal line of sight) when looking forward along the flight path.

[REQ RNP1_38] The lateral deviation display scaling should agree with any implemented alerting and annunciation limits.

[REQ RNP1_39] The system must display the ground speed in the flight crew's maximum field of view.

[REQ RNP1_40] The lateral deviation display must have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy.

[REQ RNP1_41] The display scaling may be set automatically by default logic automatically to a value obtained from a navigation database or manually by pilot procedures.

[REQ RNP1_42] The full-scale deflection value must be known or must be available for display to the pilot commensurate with the required track keeping accuracy.

[REQ RNP1_43] The lateral deviation display must be automatically slaved to the computed path. The course selector of the deviation display should be automatically slewed to the computed path, or the pilot must adjust the CDI or HIS selected course to the computed desired path.

[REQ RNP1_44] As an alternate means of compliance, a navigation map display can provide equivalent functionality to a lateral deviation display with appropriate map scales and giving equivalent functionality to a lateral deviation display. The map scale should be set manually to a value appropriate for the RNP 1 operation.

[REQ RNP1_45] The system shall have the capability to display an indication of the RNP 1 system failure in the pilot's primary field of view and the capability to indicate to the crew when the NSE alert limit is exceeded.

B.4 RNP APCH (Mandated minimum requirement for all IREs in the PBN IR)

B.4.1 Lateral Navigation

B.4.1.1 Aircraft System

[REQ LNAV_1] RNP APCH shall be based on GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided the other positioning data do not cause position errors exceeding the TSE budget, or if means are provided to deselect the other navigation sensor types.

[REQ LNAV_2] The systems that meet the accuracy, integrity and continuity requirements are: GNSS stand-alone systems - equipment should be approved in accordance with TSO-C129a/ ETSO-C129a Class A, E/TSO-C146() Class Gamma and operational class 1, 2 or 3, or TSO C-196(); GNSS sensors used in multi-sensor system (e.g. FMS) - equipment should be approved in accordance with TSO C129 ( )/ ETSO-C129 ( ) Class B1, C1, B3, C3 or E/TSO C145() class 1, 2 or 3, or TSO C-196(). For GNSS receiver approved in accordance with E/ TSO-C129(), capability for satellite RAIM FDE is recommended to improve continuity of function, and; multi-sensor systems using GNSS should be approved in accordance with AC20-130A or TSO-C115b, as well as having been demonstrated for RNP APCH capability.

[REQ LNAV_3] Navigation equipment shall comply with RTCA DO-229D, paragraph 2.4.

[REQ LNAV_4] To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity.

[REQ LNAV_5] Accuracy: During operations on the initial and intermediate segments and for the RNAV missed approach, of an RNP APCH, the lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time.

[REQ LNAV_6] To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial and intermediate segments, and for the RNAV missed approach, of an RNP APCH. The 95 per cent FTE should not exceed 0.25 NM on the FAS of an RNP APCH.

[REQ LNAV_7] Integrity: Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10–5 per hour).

[REQ LNAV_8] Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

[REQ LNAV_9] On-board performance monitoring and alerting. During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10–5. During operations on the FAS of an RNP APCH down to LNAV or LNAV/ VNAV minima, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 0.6 NM is greater than 10–5.

[REQ LNAV_10] SIS. During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 2 NM exceeds 10–7 per hour. During operations on the FAS of an RNP APCH down to LNAV or LNAV/VNAV minima, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 0.6 NM exceeds 10–7 per hour.

[REQ LNAV_11] Because of unplanned failure of some GNSS elements, pilots/ANSPs should realize that RAIM or GPS navigation altogether may be lost while airborne which may require reversion to an alternative means of navigation. For those GNSS systems relying on RAIM and necessitating a check of its availability for RNP APCH, the flight crew should perform a new RAIM availability check if ETA is more than 15 minutes different from the ETA used during the preflight planning.

[REQ LNAV_12] Two independent altimetry systems (sources and displays) must be operational and crew must crosscheck the displayed altitude during the approach and, in particular, when determining the Decision Altitude (DA).

B.4.1.2 Functional requirements

[REQ LNAV_13] A flight director and/or autopilot is not required for this type of operation, however, if the lateral TSE cannot be demonstrated without these systems, it becomes mandatory.

[REQ LNAV_14] The system shall provide the capability to display an indication of the RNP system failure, including the associated sensors, in the pilot's primary field of view.

[REQ LNAV_15] When Barometric VNAV is used for vertical path guidance during the FAS, deviations above and below the Barometric VNAV path must not exceed +22 m/–22 m (+75 ft/–75 ft), respectively.

B.4.1.3 Navigation displays

[REQ LNAV_16] Navigation data, including a to/from indication, and a failure indication, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display.

[REQ LNAV_17] Lateral navigation display and navigation map display must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.

[REQ LNAV_18] The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the TSE requirement. Scaling is ±1 NM for the initial and intermediate segments and ±0.3 NM for the final segment.

[REQ LNAV_19] The display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with approach values.

[REQ LNAV_20] As an alternate means, a navigation map display must give equivalent functionality to a lateral deviation display with appropriate map scales (scaling may be set manually by the pilot).

[REQ LNAV_21] It is highly recommended that the course selector of the deviation display is automatically slaved to the RNAV computed path.

[REQ LNAV_22] The displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path.

[REQ LNAV_23] The lateral deviation display scaling should agree with any alerting and annunciation limits.

[REQ LNAV_24] Enhanced navigation display (e.g. electronic map display or enhanced EHSI) to improve lateral situational awareness, navigation monitoring and approach verification (flight plan verification) could become mandatory if the RNAV installation doesn't support the display of information necessary for the accomplishment of these crew tasks.

[REQ LNAV_25] The system shall provide capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path. For aircraft where the minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided.

B.4.1.4 Navigation database

[REQ LNAV_26] A navigation database is required, containing current navigation data officially promulgated.

[REQ LNAV_27] The stored resolution of the data must be sufficient to achieve the required track-keeping accuracy.

[REQ LNAV_28] The database must be protected against pilot modification of the stored data.

[REQ LNAV_29] The system shall provide means to display the validity period of the navigation data to the pilot.

[REQ LNAV_30] Navigation database can be updated in accordance with the AIRAC cycle.

[REQ LNAV_31] The system must provide the means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs

[REQ LNAV_32] The aircraft must enable the pilot to verify the procedure to be flown.

[REQ LNAV_33] The system shall provide means to load from the database into the RNP system the whole approach to be flown. The approach must be loaded from the database, into the RNP system, by its name

[REQ LNAV_34] The system shall provide the capability to automatically load numeric values for courses and tracks from the RNP system database.

B.4.1.5 System functions

[REQ LNAV_35] The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.

[REQ LNAV_36] The system shall provide means to display, either in the pilot's primary field of view, or on a readily accessible display page, distance between flight plan waypoints, distance to go and along-track distances.

[REQ LNAV_37] The navigation system must have the capability to execute ARINC-424 "direct to" function.

[REQ LNAV_38] The system shall provide the capability for automatic leg sequencing with the display of sequencing to the pilot.

[REQ LNAV_39] The system shall provide the capability to execute procedures extracted from the on-board database, including the capability to execute fly-over and fly-by turns.

[REQ LNAV_40] The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with IF, CF, DF and TF ARINC 424 path terminators, or they equivalent. In addition, the system shall provide the capability to automatically execute leg transitions consistent with ARINC 424 FA path terminators, or the RNP system must permit the pilot to fly a course and turn at a designated altitude.

[REQ LNAV_41] The system shall provide the capability to indicate to the crew when NSE alert limit is exceeded (alert provided by the "onboard performance monitoring and alerting function").

B.4.2 Vertical Navigation

B.4.2.1 BARO/VNAV

A.4.2.1.1 Aircraft System

[REQ BARO/VNAV_1] Baro-VNAV approach operations are based upon the use of RNAV equipment that automatically determines aircraft position in the vertical plane using inputs from equipment that can include: a) FAA TSO-C106, Air Data Computer; b) air data system, ARINC 706, Mark 5 Air Data System; c) barometric altimeter system, DO-88 Altimetry, ED-26 MPS for Airborne Altitude Measurements and Coding Systems, ARP-942 Pressure Altimeter Systems, ARP-920 Design and Installation of Pitot Static Systems for Transport Aircraft; and, d) type certified integrated systems providing an air data system capability comparable to item b).

[REQ BARO/VNAV_1] The 99.7 per cent aircraft ASE for each aircraft (assuming the temperature and lapse rates of the International Standard Atmosphere) must be less than or equal to the following:

$$ASE = -8.8 \cdot 10^{-8} \cdot H^2 + 6.5 \cdot 10^{-3} \cdot H + 50 \text{ (ft)}$$

Where H is the true altitude of the aircraft

[REQ BARO/VNAV_3] For instrument approach operations, the error of the airborne baro-VNAV equipment, excluding altimetry, should have been demonstrated to be less than that shown below on a 99.7 per cent probability basis:

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	15 m (50 ft)	30 m (100 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	15 m (50 ft)	45 m (150 ft)
Above 3 000 m (10 000 ft)	15 m (50 ft)	67 m (220 ft)

[REQ BARO/VNAV_4] Flight technical (pilotage) errors. With satisfactory displays of vertical guidance information, FTEs should have been demonstrated to be less than the values shown below on a three-sigma basis.

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	45 m (150 ft)	60 m (200 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	73 m (240 ft)	91 m (300 ft)
Above 3 000 m (10 000 ft)	73 m (240 ft)	91 m (300 ft)

[REQ BARO/VNAV_5] If an installation results in larger FTEs, the total vertical error of the system (excluding altimetry) may be determined by combining equipment and FTEs using the root sum square (RSS) method. The result should be less than the values listed below.

	Level flight segments and climb/descent intercept altitude region of specified altitudes	*Climb/descent along specified vertical profile (angle)*
At or below 1 500 m (5 000 ft)	48 m (158 ft)	68 m (224 ft)
1 500 m to 3 000 m (5 000 ft to 10 000 ft)	74 m (245 ft)	102 m (335 ft)
Above 3 000 m (10 000 ft)	74 m (245 ft)	113 m (372 ft)

[REQ BARO/VNAV_6] During operations on instrument approach procedures, the probability of displaying misleading navigational or positional information to the flight crew during the approach, including the final segment, shall not occur with a probability higher or equal than 10^{-5} per hour.

[REQ BARO/VNAV_7] Loss of function with or without Barometric-VNAV guidance is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.

A.4.2.1.2 Navigation displays

[REQ BARO/VNAV_8] BARO/VNAV deviation must be displayed on a vertical deviation display (HSI, EHSI, VDI). This display must be used as primary flight instruments for the approach.

[REQ BARO/VNAV_9] The display must be visible to the pilot and located in the primary field of view (±15 degrees from pilot's normal line of sight) when looking forward along the flight path.

[REQ BARO/VNAV_10] The deviation display shall have a suitable full-scale deflection based on the required vertical track error.

[REQ BARO/VNAV_11] The system shall provide the capability to continuously display, to the pilot flying, the vertical deviation relative to the Final approach segment on the primary flight instruments for navigation of the aircraft.

[REQ BARO/VNAV_12] The navigation system shall provide an indication of loss of navigation (e.g. system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical navigation display.

[REQ BARO/VNAV_13] The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary field of view.

A.4.2.1.3 Navigation database

[REQ BARO/VNAV_14] The navigation system must have the capability to load and modify the entire procedure(s) to be flown, based upon ATC instructions, into the RNP system from the on-board navigation database.

[REQ BARO/VNAV_15] The navigation database must contain all the necessary data/information to fly the published APV BAROVNAV approach.

[REQ BARO/VNAV_16] The navigation database must contain the waypoints and associated vertical information for the procedure.

[REQ BARO/VNAV_17] Vertical Constraints associated with published procedures must be automatically extracted from the navigation database upon selecting the approach procedure.

A.4.2.1.4 System function

[REQ BARO/VNAV_18] The system shall have the capability to automatically intercept the vertical path at FAP using a vertical fly-by technique.

[REQ BARO/VNAV_19] The navigation system must be capable of defining a vertical path in accordance with the published vertical path.

[REQ BARO/VNAV_20] The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following: a) An "AT OR ABOVE" altitude constraint; b) An "AT or BELOW" altitude constraint; c) An "AT" altitude constraint; d) A "WINDOW" constraint.

[REQ BARO/VNAV_21] The system should provide the capability for entry of altimeter source temperature to compute temperature compensation for the vertical flight path angle.

B.4.2.2 Down to LPV minima

A.4.2.2.1 Aircraft System

[REQ LPV_1] Accuracy: FTE performance is considered acceptable if the lateral and vertical display full-scale deflection is compliant with the non-numeric lateral cross-track and vertical deviation requirements of RTCA DO 229 C (or subsequent version) and if the crew maintains the aircraft within one-third the full scale deflection for the lateral deviation and within one-half the full-scale deflection for the vertical deviation.

[REQ LPV_2] NSE, the accuracy itself (the error bound with 95 per cent probability) changes due to different satellite geometries. Assessment based on measurements within a sliding time window is not suitable for GNSS. Therefore, GNSS accuracy is specified as a probability for every sample. NSE requirements are fulfilled without any demonstration if the equipment computes three dimensional positions using linearized, weighted least square solution in accordance with RTCA DO 229C (or subsequent version) Appendix J.

[REQ LPV_3] Integrity: Simultaneously presenting misleading lateral and vertical guidance with misleading distance data during an RNP APCH operation down to LPV minima is considered a hazardous failure condition (extremely remote). Simultaneously presenting misleading lateral guidance with misleading distance data during an RNP APCH operation down to LP minima is considered a hazardous failure condition (extremely remote).

[REQ LPV_4] Continuity: Loss of approach capability is considered a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. For RNP APCH operations down to LP or LPV minima at least one system is required.

[REQ LPV_5] On-board performance monitoring and alerting: operations on the FAS of an RNP APCH operation down to LP and LPV minima, the on-board performance monitoring and alerting function is fulfilled by: a) NSE monitoring and alerting (see the SIS section below); b) FTE monitoring and alerting: LPV approach guidance must be displayed on a lateral and vertical deviation display (HSI, EHSI, CDI/VDI) including a failure indicator. The deviation display must have a suitable full-scale deflection based on the required track-keeping accuracy. The lateral and vertical full scale deflection are angular and associated to the lateral and vertical definitions of the FAS contained in the FAS DB; and, c) Navigation database: once the FAS DB has been decoded, the equipment shall apply the CRC to the DB to determine whether the data is valid. If the FAS DB does not pass the CRC test, the equipment shall not allow activation of the LP or LPV approach operation.

[REQ LPV_6] At a position between 2 NM from the FAP and the FAP, the aircraft navigation equipment shall provide an alert within 10 seconds if the SIS errors causing a lateral position error are greater than 0.6 NM, with a probability of 1-10-7 per hour.

[REQ LPV_7] After sequencing the FAP and during operations on the FAS, the aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a lateral position error are greater than 40 m, with a probability of 1-2.10-7 in any approach.

[REQ LPV_8] After sequencing the FAP and during operations on the FAS, the aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a vertical position error is greater than 50 m (or 35 m for LPV minima down to 200 ft), with a probability of 1-2.10-7 in any approach.

[REQ LPV_9] Navigation equipment shall comply with RTCA DO-229D, paragraph 2.4.

[REQ LPV_10] To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity for the RNP APCH LP/LPV operations.

A.4.2.2.2 Navigation displays

[REQ LPV_11] Approach guidance must be displayed on a lateral and vertical deviation display (HSI, EHSI, CDI/VDI) including a failure indicator.

[REQ LPV_12] Display must be used as primary flight instruments for the approach.

[REQ LPV_13] The displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path.

[REQ LPV_14] The lateral and vertical full-scale deflection shall be angular and associated to the lateral and vertical definitions of the FAS contained in the FAS DB.

[REQ LPV_15] The system shall provide the capability to display the GNSS approach mode (e.g. LP, LPV, LNAV/VNAV, lateral navigation) in the primary field of view.

[REQ LPV_16] The system shall provide the capability to continuously display the distance to the LTP/FTP or Missed Approach Point (MAPT) after passing the Final Approach Point in the primary field of view.

[REQ LPV_17] The system shall provide the indication of the loss of navigation (e.g. system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical and/or lateral navigation display).

A.4.2.2.3 Navigation database

[REQ LPV_18] The navigation database must contain all the necessary data/information to fly the published approach procedure (FAS). Although data may be stored or transmitted in different ways, the data has to be organized in DBs for the purpose of computing the CRC.

[REQ LPV_19] Once the FAS DB has been decoded, the equipment shall apply the CRC to the DB to determine whether the data is valid. If the FAS DB does not pass the CRC test, the equipment shall not allow activation of the approach operation.

[REQ LPV_20] The system shall provide the capability to select from the database into the installed system the whole approach procedure to be flown (SBAS channel number and/or approach name).

A.4.2.2.4 System functions

[REQ LPV_21] The system shall provide the indication of the loss of integrity function in the pilot's normal field of view (e.g. by means of an appropriately located annunciator).

[REQ LPV_22] The system shall provide capability to immediately provide track deviation indications relative to the extended FAS, in order to facilitate the interception of the extended FAS from a radar vector.

B.5 RNP AR APCH (Optional requirement for terrain challenged IREs in the PBN IR)

B.5.1 Aircraft System

[REQ LNAV_1] Lateral accuracy: All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, FTE, PDE and display error. Also, the aircraft along-track positioning error must be no greater than the applicable accuracy value for 95 per cent of the flight time.

[REQ ARAPCH_3] Vertical accuracy: The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track error, system computation error, data resolution error, and FTE. The 99.7 per cent of system error in the vertical direction must be less than the following (in feet):

$$\sqrt{((6076.115)(1.225)RNP\cdot\tan\theta)^2 + (60\tan\theta)^2 + 75^2 + ((-8.8\cdot10^{-8})(h+\Delta h)^2 + (6.5\cdot10^{-3})(h+\Delta h)+50)^2}$$

where θ is the VNAV path angle, h is the height of the local altimetry reporting station and Δh is the height of the aircraft above the reporting station.

[REQ ARAPCH_3] System monitoring: the required demonstration of RNP system performance, including lateral and vertical path steering performance (FTE), will vary accordingly to the type of AR operation being considered. It should be noted that the monitoring system might not provide warnings of FTE. The management of FTE must be addresses as a pilot procedure.

[REQ ARAPCH_4] A crew alert is required when GNSS updating is lost unless the navigation system provides an alert when the selected RNP no longer meets the requirements for continued navigation.

[REQ ARAPCH_5] Integrity: the probability of the aircraft exiting the lateral and vertical extent of the obstacle clearance volume must not exceed 10-7 per operation, including the departure, approach and missed approach.

[REQ ARAPCH_6] Continuity: the probability of loss of all navigation information is Remote. The probability of non-restorable loss of all navigation and communication functions is Extremely Improbable.

[REQ ARAPCH_7] The system should include a capability to monitor for its achieved lateral navigation performance, and to identify for the flight crew whether the operational requirement is or is not being met during an operation.

[REQ ARAPCH_8] For multi-sensor systems, automatic reversion to an alternate navigation sensor if the primary navigation sensor fails is required.

[REQ ARAPCH_9] The RNAV system must be capable of performing automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check and a manual override or deselect.

[REQ ARAPCH_10] The aircraft must provide a mean to annunciate failures of any aircraft component of the RNAV system, including navigation sensors. The annunciation must be visible to the pilot and located in the primary field of view.

B.5.1.1 ABAS and other GNSS augmentations based on GPS

[REQ ARAPCH_11] The sensor must comply with the guidelines in AC 20-138() or AC 20-130 A.

B.5.1.2 IRS

[REQ ARAPCH_12] An IRS must satisfy the criteria of US 14 CFR part 121, Appendix G, or equivalent.

B.5.1.3 DME

[REQ ARAPCH_13] Automatic tuning of DME navigation aids is needed when used for position updating together with the capability to inhibit individual navigation aids from the automatic selection process.

B.5.1.4 Temperature compensation systems

[REQ ARAPCH_14] Systems that provide temperature-based corrections to the barometric VNAV guidance must comply with EUROCAE ED-76D, Appendix H.2.

B.5.2 Navigation displays

[REQ ARAPCH_15] The navigation system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the defined lateral and vertical path (both lateral and vertical deviation) and manoeuvre anticipation.

[REQ ARAPCH_16] The display must allow the pilot to readily distinguish if the cross-track deviation exceeds the RNP or if the vertical deviation exceeds 75 feet.

[REQ ARAPCH_17] Where the minimum flight crew is two pilots, means for the pilot not flying must be provided to verify the desired path and the aircraft position relative to the path.

[REQ ARAPCH_18] The navigation system must provide a display identifying the active (To) waypoint either in the pilot's primary field of view, or on a readily accessible and visible display to the flight crew.

[REQ ARAPCH_19] The navigation system must provide a display if distance and bearing to the active (To) waypoint either in the pilot's primary field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data

[REQ ARAPCH_20] The navigation system should provide the display of groundspeed and either estimated time of arrival or time to the active (To) waypoint in the pilot's primary field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.

[REQ ARAPCH_21] The navigations system must provide a To/From display in the pilot's primary field of view.

[REQ ARAPCH_22] The navigation system must provide a course selector automatically slaved to the RNAV computed path. As an acceptable alternative is an integral navigation map display.

[REQ ARAPCH_23] The navigation system must provide the ability to display distance to go to any waypoint selected by the flight crew.

[REQ ARAPCH_24] The navigation system must provide the ability to display the distance between flight plan waypoints.

[REQ ARAPCH_25] The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary field of view. The altimeter setting input must be used simultaneously by the aircraft altimetry system and by the RNAV system.

[REQ ARAPCH_26] The aircraft must display the current navigation sensor(s) in use that are readily accessible to the flight crew.

[REQ ARAPCH_27] A display of the altitude restrictions associated with flight plan fixes must be available to the pilot. If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the equipment must display the flight path angle for that leg.

[REQ ARAPCH_28] The system should provide the means to display the validity period of the navigation database to the flight crew.

B.5.3 System functions

[REQ ARAPCH_29] The aircraft must have the capability to execute leg transitions and maintain tracks consistent with TF, CF, DF and TF ARINC 424 path terminators.

[REQ ARAPCH_30] The aircraft must have the capability to execute fly-by and fly-over fixes.

[REQ ARAPCH_31] The navigation system must have a "Direct To" function the flight crew can activate at any time. This function must be available to any fix.

[REQ ARAPCH_32] The system must be capable of defining a vertical path by a flight path angle to a fix. Also, it must be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following: a) An "AT OR ABOVE" altitude constraint; b) An "AT or BELOW" altitude constraint; c) An "AT" altitude constraint; d) A "WINDOW" constraint.

[REQ ARAPCH_33] The system must be able to construct a path to provide guidance from current position to a vertically constrained fix.

[REQ ARAPCH_34] For paths defined by a course (CF path terminator), the navigation system must use the magnetic variation value for the procedure in the navigation database.

[REQ ARAPCH_35] RNP changes to lower navigation accuracy must be complete by the fix defining the leg with the lower navigation accuracy, considering the alerting latency of the navigation system. Any operational procedures necessary to accomplish this must be identified.

[REQ ARAPCH_36] The navigation system must provide the capability to automatically sequence to the next leg and display the sequencing to the flight crew in a readily visible manner.

B.5.4 Navigation database

[REQ ARAPCH_37] The aircraft navigation system must use an on-board navigation database which can receive updates in accordance with the AIRAC cycle.

[REQ ARAPCH_38] The system must allow retrieval and loading of entire RNP AR APCH procedures to be flown into the RNP system from the on-board navigation database. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway.

[REQ ARAPCH_39] Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.

[REQ ARAPCH_40] The navigation system must provide the ability for the flight crew to verify the procedure to be flown through review of the data stored in the on-board navigation database. This includes the ability to review the data for individual waypoints and for navigation aids.

[REQ ARAPCH_41] The navigation database must provide sufficient data resolution to ensure the navigation system achieves the required accuracy. Waypoint resolution error must be less than or equal to 60 feet, including both the data storage resolution and the RNAV system computational resolution used internally for construction of flight plan waypoints.

[REQ ARAPCH_42] The database must be protected against flight crew modification of the stored data.

B.5.5 Requirements for RNP AR approaches with RF legs

[REQ ARAPCH_43] The navigation system must have the capability to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.

[REQ ARAPCH_44] The aircraft must have an electronic map display of the selected procedure.

[REQ ARAPCH_45] The navigation system, the flight director system and autopilot must be capable of commanding a bank angle up to 25 degrees at or above 400 feet AGL and up to 8 degrees below 400 feet AGL.

[REQ ARAPCH_46] Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.

[REQ ARAPCH_47] When evaluating FTE on RF legs, the effect of rolling into and out of the turn should be considered. The procedure is designed to provide 5 degrees of manoeuvrability margin, to enable the aircraft to get back on the desired track after a slight overshoot at the start of the turn.

B.5.6 Requirements for RNP AR approaches to less than RNP 0.3

[REQ ARAPCH_48] No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots and a single IRU.

[REQ ARAPCH_49] The system design must be consistent with at least a hazardous failure condition for the loss or display of misleading of lateral or vertical guidance.

[REQ ARAPCH_50] Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.

[REQ ARAPCH_51] After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy for the time necessary to fly the go-around or the missed approach.

B.5.7 Requirements for approaches with missed approach less than RNP 1

[REQ ARAPCH_52] No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots and a single IRU.

[REQ ARAPCH_53] The system design must be consistent with at least a major failure condition for the loss or display of misleading of lateral or vertical guidance.

[REQ ARAPCH_54] Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.

[REQ ARAPCH_55] After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy for the time necessary to fly the go-around or the missed approach.

B.6 Radius To Fix (RF) Path Terminator (Optional Requirement in PBN IR – only associated with RNP specifications)

RF legs are an optional capability for use with RNP 1, RNP 0.3, and RNP APCH, rather than a minimum requirement. This functionality can be used in the initial and intermediate approach segments, the final phase of the missed approach, SIDs and STARs.

RF legs are intended to be applied where accurate repeatable and predictable navigation performance is required in a constant radius turn. RF legs may be used on any segment of a terminal procedure except the FAS, the initial missed approach phase or the intermediate missed approach phase.

[REQ RF_1] The use of autopilot or flight director is required to execute RF leg transitions, except for non-type-rated CS-23 Level 1, 2 and 3 aircraft performing RNP 1 and RNP APCH operations with an RNP value of not less than 1, and at speeds of 200 knots or less, provided that the aircraft is equipped with an appropriately scaled course deviation indicator (CDI). CS ACNS.C.PBN.815

B.6.1 RNP system-specific requirements

[REQ RF_2] The navigation system should not permit the pilot to select a procedure that is not supported by the equipment, either manually or automatically.

[REQ RF_3] The navigation system should also prohibit pilot access to procedures requiring RF leg capability if the system can select the procedure, but the aircraft is not equipped.

B.6.2 On-board performance monitoring and alerting

[REQ RF_4] The lateral TSE must be within ±1 × RNP of the path defined by the published procedure for at least 95 per cent of the total flight time for each phase of flight and each autopilot and/or flight director mode requested.

[REQ RF_5] The RNP system shall provide a visible alert within the pilot's primary field of view when loss of navigation capability and/or loss of integrity are experienced.

[REQ RF_6] Any failure modes that have the potential to affect the RF leg capability should be identified.

[REQ RF_7] The ability of the aircraft to maintain the required FTE after a full of partial failure of the autopilot and/or flight director should be documented.

[REQ RF_8] If the RNP cannot be achieved during a RF leg, the flight guidance mode remains in lateral navigation.

B.6.3 Functional requirements

[REQ RF_9] An autopilot or flight director with at least "roll-steering" capability that is driven by the RNP system is required. The autopilot/flight director must operate with suitable accuracy to track the lateral and, as appropriate, vertical paths required by a specific RNP procedure.

[REQ RF_10] The navigation system must have the capability to execute leg transitions and maintain a track consistent with a RF leg between two fixes.

[REQ RF_11] The area navigation system displays the intended path on an appropriately scaled moving map display in the flight crew's maximum field of view.

[REQ RF_12] The flight management computer, the flight director system, and the autopilot must be capable of commanding and achieving a bank angle up to 30 degrees above 400 feet above ground level (AGL) and up to 8 degrees below 400 feet AGL.

[REQ RF_13] The flight guidance mode should remain in lateral navigation while on an RF leg, when a procedure is abandoned or a missed approach/go-around is initiated (through activation of TOGA or other means) to enable display of deviation and display of positive course guidance during the RF leg. As an alternative means, crew procedures may be used that ensure that the aircraft adheres to the specific flight path throughout the RF leg segment.

APPENDIX B – PBN REQUIREMENTS AND MITIGATIONS

B.1 RNAV 5

Req#	Title	Requirement	Reference	Part	Mitigation[8]
[REQ RNAV5_1]	Position source	Equipment configurations shall be one or more of the following: VOR/DME; DME/DME; INS or IRS; GNSS.	ICAO Doc 9613	Part B, Chapter 2.3.3	The main mitigations would be the eligibility of GPS PPS receiver and TACAN as sensors for PBN. Military updating/fixing means should be investigated as potential substitute of INS update in case of GNSS loss.
[REQ RNAV5_2]	Loss of GNSS	Where approval for RNAV 5 operations requires the use of traditional navigation equipment as a back-up in the event of loss of GNSS, the required NAVAID capability, as defined in the approval (i.e. VOR, DME), will need to be installed and be serviceable.			
[REQ RNAV5_3]	Position Estimation - Accuracy	Accuracy: during operations in airspace or on routes designated as RNAV 5, the lateral TSE and the along-track error must be within ±5 NM for at least 95 per cent of the total flight time.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.1 GM1 ACNS.C.PBN. 215	See RNAV5_1
[REQ RNAV5_4]	Area navigation system design - Integrity	Integrity: malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour).	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.1 AMC1 ACNS.C.PBN. 2145	To approve the use of military sensors and navigation equipment against equivalent performance criteria in civil standards (e.g. US GPS MSO).
[REQ RNAV5_5]	Area navigation system design - Continuity	Continuity: loss of the capability to provide lateral position or guidance is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. Given the case it cannot revert, it is considered a major failure condition.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.1 CS ACNS.C.PBN. 2150	This impacts the system design (redundancies of equipment might be required) and criteria for military airworthiness certification. No other mitigation of these criteria except to relax them.

8 Mitigations for all specifications are mostly extracted from FDC Study: EUROCONTROL/FDC Initial Study to Determine Feasibility of Navigation Equivalent Verification of Compliance for State Aircraft Against ATM Navigation Standards. Additional inputs are provided by NATO EF2000 and Tornado Development and Logistics Management Agency (NETMA) – text in italic.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV5_6]	Area navigation system design - SIS	SIS: if using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 10 NM exceeds 10^{-7} per hour.	ICAO Doc 9613	Part B, Chapter 2.3.3.1	To approve the usage of GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ RNAV5_7]	Equipment approval – INS/IRS	Inertial systems may be used either as a stand-alone INS or an IRS acting as part of a multi-sensor RNAV system, where inertial sensors provide augmentation to the basic position sensors, as well as a reversionary position data source when out of cover of radio navigation sources.			
[REQ RNAV5_8]	Equipment approval – INS/IRS	INS without automatic radio updating of aircraft position, but approved in accordance with AC 25-4, and when complying with the functional criteria of this specification, may be used only for a maximum of 2 hours from the last alignment/position update performed on the ground.			
[REQ RNAV5_9]	Equipment approval – INS/IRS	INS with automatic radio updating of aircraft position should be approved in accordance with AC 90-45A, AC 20-130A or equivalent material.			
[REQ RNAV5_10]	Equipment approval – VOR	VOR equipment shall comply with ED-28, Chapter 4.			
[REQ RNAV5_11]	Equipment approval – DME	DME equipment shall comply with ED-28, Chapter 4.			
[REQ RNAV5_12]	Position estimation & data integrity	When the RNAV 5 system does not take account of published “Designated Operational Coverage” of the DME, the RNAV system must execute data integrity checks to confirm that the correct DME signal is being received.			

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV5_13]	Equipment approval - GNSS	The use of GNSS to perform RNAV 5 operations is limited to equipment approved to ETSO-C129(), ETSOC145(), ETSO-C146(), FAA TSO-C145(), TSO-C146(), and TSO-C129() or equivalent.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.2 GM2 ACNS.C.PBN. 205	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ RNAV5_14]	Position source	GNSS Integrity should be provided by SBAS or RAIM or an equivalent means within a multi-sensor navigation system.			The main mitigations would be the eligibility of GPS PPS receiver with RAIM function. Military updating/ fixing means should be investigated as potential substitute of INS update in case of GNSS loss.
[REQ RNAV5_15]	GPS functions	GPS stand-alone equipment should include the following functions: pseudo-range step detection; and health word checking.			Confirm against ETSO129A that pseudo-range step detection; and health word checking are functional requirement of the receiver.
[REQ RNAV5_16]	Position source	Positioning data from other types of navigation sensors may be integrated with the GNSS data provided other positioning data do not cause position errors exceeding the track-keeping accuracy requirements.	EASA CS-ACNS	AMC1 ACNS.C.PBN. 210	It could result in a need for deselection capability (automatic or manual) to comply with these specifications. To invalidate the VOR entry in such computers.
[REQ RNAV5_17]	Waypoint storage	The system must be able to storage a minimum of 4 waypoints.			
[REQ RNAV5_18]	Navigation functions - system failure display	Appropriate failure indication of the RNAV system, including the sensors must be displayed.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 GS ACNS.C.PBN. 145	No impact.
[REQ RNAV5_19]	Navigation functions - RNAV path	Continuous indication of aircraft position relative to track must be displayed to the pilot flying the aircraft, on a navigation display situated in his/her primary field of view.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 GS ACNS.C.PBN. 280	RSM 12. No impact for aircraft equipped with a navigation computer feeding electronic primary flight instruments. For conventional HSI displaying only angular deviations, there is no mitigation.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV5_20]	Navigation functions, data display	The area navigation system displays the distance and bearing to the active (to) waypoint and ground speed or time to the active (to) waypoint.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 GM2 ACNS.C.PBN. 285	Change the format of WPT identification in the navigation computer. No impact for distance, bearing and ground speed.
[REQ RNAV5_21]	Navigation functions - RNAV path	Where the minimum flight crew is two pilots, indication of the aircraft position relative to track must be displayed to the pilot not flying the aircraft, on a navigation display situated in his/her primary field of view.	ICAO Doc 9613	Part B, Chapter 2.3.3.3	May impact two-seat combat aircraft. Some military aircraft have a navigator or weapon system with appropriate displays.
[REQ RNAV5_22]	Navigation display	Navigation data must be available for display either on a display forming part of the RNAV equipment or on a lateral deviation display (e.g. CDI, (EHSI, or a navigation map display).	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 AMC1 ACNS.C.PBN. 280	Confirm against ETSO129A that pseudo-range step detection; and health word checking are functional requirement of the receiver.
[REQ RNAV5_23]	Navigation display	Displays must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/ status/integrity indication.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV5_24]	Navigation display - visibility	The displays must be visible to the pilot when looking forward along the flight path.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3.3 CS ACNS.C.PBN. 280	On combat aircraft, in the head down displays may not comply with these requirements. Investigate equivalent possibilities offered by the HUD.
[REQ RNAV5_25]	Navigation display - scaling	The lateral deviation display scaling should be compatible with any alerting and annunciation limits, where implemented.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV5_26]	Navigation display - scaling	The lateral deviation display must have a scaling and full-scale deflection suitable for the RNAV 5 operation.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 2.3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD.

B.2 RNAV 1

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_1]	Position source	The following navigation criteria are defined: GNSS, DME/DME or DME/DME/IRU.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3 AMC1 ACNS.C.PBN.205	The main mitigations would be the eligibility of GPS PPS receiver and TACAN as sensors for PBN. Military updating/fixing means should be investigated as potential substitute of INS update in case of GNSS loss.
[REQ RNAV1_2]	Position source	Where DME is the only navigation service used for position updates. Integration of IRUs can permit extended gaps in DME coverage. If an IRU is not carried, then the aircraft can revert to dead reckoning.	EASA NPA 2018-2	AMC1 ACNS.C.PBN.205	To investigate other military updating/fixing means (Radar, MIDS, Terrain Reference Navigation).
[REQ RNAV1_3]	Position Estimation - Accuracy	Accuracy: The lateral track keeping accuracy of the on-board system shall be equal to or better than ±1 NM for 95 per cent of the flight time.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3 GM1 ACNS.C.PBN.215 Chapter 6.1	See RNAV1_1
[REQ RNAV1_4]	Area navigation system design - Integrity	Integrity: Malfunction of the aircraft navigation equipment (major failure condition) shall not occur with a probability higher or equal than 10-5 per hour.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3 AMC1 ACNS.C.PBN.2145 Chapter 6.2	To approve the MIL sensors and navigation equipment against equivalent performance criteria in civil standards (e.g. US GPS MSO).
[REQ RNAV1_5]	Area navigation system design - Continuity	Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3 CS ACNS.C.PBN.2150 Chapter 6.3	This impacts the system design (redundancies of equipment might be required) and criteria for military airworthiness certification. No other mitigation of these criteria except to relax them.
[REQ RNAV1_6]	Area navigation system design - SIS	SIS: If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral positon error greater than 2 NM exceeds 1×10^{-7} per hour.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3. AMC1 ACNS.C.PBN.2130	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_7]	Navigation database compliance	The navigation database suppliers should comply with RTCA DO-200A/EURO-CAE document ED 76.	ICAO Doc 9613 JAA TGL10	Part B, Chapter 3.3.3.3 Chapter 8.2	
[REQ RNAV1_8]	Area navigation system approval	The use of GPS is limited to equipment approved under FAA TSO-C145 and TSO-146, and JTSO-C129 (), in the equipment classes A1, B1, C1, B3 and C3.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3 GM2 ACNS.C.PBN.205 Chapter 8.3	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ RNAV1_9]	Operator verification	For routes and/or aircraft approvals requiring GNSS, if the navigation system does not automatically alert the pilot to a loss of GNSS, the operator must develop procedures to verify correct GNSS operation.			No impact on military aircraft equipped with GNSS in case crew procedural means can be accepted.
[REQ RNAV1_10]	DME/DME equipment approval	DME/DME RNAV equipment shall comply with the criteria listed in ICAO PBN Manual 9613 paragraph 3.3.3.2.3.	ICAO Doc 9613	Part B, Chapter 3.3.3	
[REQ RNAV1_11]	Inertial system performance	Inertial system performance must satisfy the criteria of US 14 CFR Part 121, Appendix G.	ICAO Doc 9613	Part B, Chapter 3.3.3	Low impact due to the performance of military inertial systems and level of equipage. To investigate other military updating/ fixing means.
[REQ RNAV1_12]	Position estimation - automatic updating	Automatic position updating capability from the DME/DME solution is required.	ICAO Doc 9613	Part B, Chapter 3.3.3	No mitigation to the auto tune requirement except to use two TACAN transceivers or 1 TACAN + 1 DME, if implemented on the aircraft, provided they are feeding the Nav Computer (or FMS) with a range/range solution for position estimation.
[REQ RNAV1_13]	Navigation functions, system failure display	The system shall have the capability for automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails. This does not preclude providing a means for manual navigation source selection.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN.202 Chapter 7.1 Item 20	Investigate if with alarms on the sensor and/or navigation performance monitoring function and a manual selection/deselection this requirement could be met.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_14]	Navigation display	Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/ or a navigation map display.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV1_15]	Navigation display	Lateral navigation display and navigation map display must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV1_16]	Navigation functions - data display	The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 285 Chapter 7.1 Item 8, 9, 10, 11	Change the format of WPT identification in the navigation computer. No impact for distance, bearing and ground speed.
[REQ RNAV1_17]	Navigation display - scaling	The lateral deviation display scaling should agree with any alerting and annunciation limits, if implemented.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV1_18]	Navigation display - scaling	The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required total system accuracy.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_19]	Navigation display - scaling	The display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with en-route, terminal, or approach values.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 AMC1 ACNS.C.PBN.280 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ RNAV1_20]	Navigation display - slaving	The lateral deviation display must be automatically slaved to the RNAV computed path. The course selector of the deviation display should be automatically slewed to the RNAV computed path.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN.2100 Chapter 7.1 Item 1	No impact.
[REQ RNAV1_21]	Navigation functions - RNAV path	The system shall have the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN.280 Chapter 7.1 Item 2	No impact for aircraft equipped with a navigation computer feeding electronic primary flight instruments. For conventional HSI displaying only angular deviations, there is no mitigation.
[REQ RNAV1_22]	Navigation functions - system failure display	The system shall have the capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN.2145 Chapter 7.1 Item 20	No impact.
[REQ RNAV1_23]	Navigation database	Data shall be contained in a navigation database.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN.2115 Chapter 7.1 Item 4	Investigate the consequences on a military mission computer to implement a NAV database (memory/management software, compliant steering with ARINC 424 path terminators etc.).

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_24]	Use of navigation database	The stored resolution of the data must be sufficient to achieve the required track keeping accuracy.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 2115 Chapter 7.1 Item 4	Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD.
[REQ RNAV1_25]	Use of navigation database	The navigation database must be protected against flight crew modification of the stored data.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 2115 Chapter 7.1 Item 4	See RNAV1_23.
[REQ RNAV1_26]	Navigation functions, data retrieve	The aircraft must have the capability to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 6	For military aircraft equipped with a navigation database, this is implemented. For non-equipped aircraft, see RNAV1_15.
[REQ RNAV1_27]	Navigation functions - data retrieve	The system must have the capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR to be flown.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 240 Chapter 7.1 Item 7	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.
[REQ RNAV1_28]	Extraction and display of navigation data	The system shall have the means to display the validity period of the navigation data to the flight crew.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 5	For military aircraft equipped with a navigation database, this is implemented. For non-equipped aircraft, see RNP1_28.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_29]	Navigation functions - data validity	The aircraft should have the possibility for the pilot to verify the route to be flown	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 2125	For military aircraft equipped with a navigation database, this is implemented. For non-equipped aircraft, see RNAV1_15.
[REQ RNAV1_30]	Navigation functions - ARINC 424 path terminators	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with IF, CF, FA, DF and TF ARINC 424 path terminators, or they equivalent.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 245 Chapter 7.1 Item 18	RSM 23, 24, 25. These routing instructions can be determined only on a case-by-case basis since depending on specific steering functions implemented in the navigation computer. Some of them might be re-usable. An extensive investigation on flight planning systems should also be carried out since such systems can often alleviate the "lack" of steering functions of the aircraft and are able to compute specific tactical paths. Some systems are able to translate ARINC 424 path terminators into a WPT sequence compliant with the navigation computer formats. Investigate the consequences on a military mission computer to implement a NAV database (memory/ management software, compliant steering with ARINC 424 path terminators etc.). Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD. Investigate the existence of specific tactical steering and assess how they could be re used. Investigate the transfer of remaining function to the flight planning system.
[REQ RNAV1_31]	Navigation functions - leg transitions	The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARIAN 424 path terminators, or must be able to manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 245	
[REQ RNAV1_32]	Navigation functions - leg transitions	The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 245	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNAV1_33]	Navigation functions "direct to" function	The navigation system must have the capability to execute ARINC-424 "direct to" function.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 250 Chapter 7.1 Item 15	Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD.
[REQ RNAV1_34]	Navigation functions - leg sequencing	The capability for automatic leg sequencing with the display of sequencing to the pilot.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 235 Chapter 7.1 Item 16	On aircraft with unsatisfactory display of the flight plan, to use the navigation computer MCDU for FPL checks if readily accessible to the pilot(s).
[REQ RNAV1_35]	Navigation functions - SIDs and STARs execution	The system must have the capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR to be flown.	ICAO Doc 9613 EASA CS-ACNS JAA TGL10	Part B, Chapter 3.3.3.3 CS ACNS.C.PBN. 240 Chapter 7.1 Item 17	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.
[REQ RNAV1_36]	Navigation functions - RNAV path	For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided.	ICAO Doc 9613 JAA TGL10	Part B, Chapter 3.3.3.3 Chapter 7.1 Item 3	May impact two-seat combat aircraft. Some military aircraft have a navigator or weapon system with appropriate displays.

B.3 RNP 1 (optional – dependent on ATM/ANS selection of application within the airspace)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_1]	Position source	RNP 1 is based on GNSS positioning as primary source of horizontal position. Positioning data from other types of navigation sensors may be integrated with the GNSS data if they do not cause position errors exceeding the TSE budget. Otherwise, means should be provided to deselect the other navigation sensor types.	EASA CS-ACNS	AMC1 ACNS.C.PBN. 210	It could result in a need for deselection capability (automatic or manual) to comply with these specifications. To invalidate the VOR entry in such computers. As alternative to the specification, RNP system may use ETSO GNSS position to cross-monitor best present position obtained by using the resident military navigation system. A cross-monitor funciton may ensure in this case that the best present position is within a certain threshold, compatible with intended operation, and it will advise if the threshold is exceeded.
[REQ RNP1_2]	Area navigation system approval	The area navigation system should be granted an ETSO authorisation against ETSO-C146c operational class 1.	EASA CS-ACNS	AMC1 ACNS.C.PBN. 205	SP1. The main mitigations would be the eligibility of GPS PPS receiver and TACAN as sensors for Performance Based Navigation. Military updating/fixing means should be investigated as potential substitute of INS update in case of GNSS loss. See also RNP1_1 for a possible alternative use of ETSO GNSS signal.
[REQ RNP1_3]	Area navigation system approval	When the system architecture is based on a flight management system (FMS) receiving input from multiple sources of position, the FMS shall be in accordance with ETSO-C115d. Depending on the type of sources to determine position, it should be also compliant with the following standards: GNSS position source against ETSO-C196a or ETSO-C145c operational class 1; DME/DME based on DME interrogator granted an ETSO-2C66b; and/or, Barometric vertical position source with ETSO-C106 A1 authorisation.	EASA CS-ACNS	AMC1 ACNS.C.PBN. 205	See RNP1_2

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_4]	Area navigation system approval	The systems which meet the accuracy, integrity and continuity requirements are: aircraft with ETSO-C129a sensor (Class B or C), E/TSO-C145() and the requirements of ETSO-C115d FMS, installed for IFR use in accordance with FAA AC 20-130A; aircraft with ETSO-C129a Class A1 or ETSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138 or AC 20-138A; and aircraft with RNP capability certified or approved to equivalent standards.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 GM2 ACNS.C.PBN. 205	SP 15-19. To approve military GPS PPS receiver against equivalent performance criteria in civil standards. This potential mitigation would have to involve the entire line of equipment involved into the generation of the area navigation function. In this context, for those elements not marked with a civil certification as per requirement RNP1_4, it may be possible to demonstrate, through qualification/test activity, that an equivalent performance can be achieved.
[REQ RNP1_5]	Equipment requirements	Navigation equipment shall comply with RTCA DO-229D, paragraph 2.4.			See RNP1_4
[REQ RNP1_6]	SW design assurance	Software development shall be in accordance with DO-178B, Level C.	EASA CS-ACNS	AMC1 ACNS.C.PBN. 205	As alternative, it may be demonstrated that the process and activities required to develop and implement the SW into a military platform are equivalent to the ones defined into RTCA DO-178B, at the appropriate DAL Levels
[REQ RNP1_7]	HW design assurance	For complex firmware implementations such as application-specific integrated circuits, processes similar to those described in RTCA/DO-178B or RTCA/DO-254 provide an acceptable means of compliance with applicable airworthiness requirements.			See RNP1_6. It may be demonstrated that the process and activities required to develop and implement complex firmware into a military platform are equivalent to the ones defined as per RNP1_7.
[REQ RNP1_8]	Navigation functions - database integrity	To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity for the RNP 1, including SIDs and STARs.			
[REQ RNP1_9]	Navigation functions - database integrity	To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity for the RNP 1, including SIDs and STARs.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3 GM1 ACNS.C.PBN. 2130	See RNP1_2. In addition, to use AP/FD and/or HUD for equipped aircraft.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_10]	Area navigation system design - Integrity	Integrity: The area navigation system is designed to provide a level of integrity that supports the following classification of failure conditions: The presentation of erroneous lateral position or guidance is classified as a major failure condition, whilst presentation of erroneous along-track distance is classified as a minor failure under airworthiness regulations (i.e. 10-5 per hour).	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 AMC1 ACNS.C.PBN. 205	To approve the military sensors and navigation equipment against equivalent performance criteria to civil standards (e.g. US GPS MSO). As alternative, it may be demonstrated that the resident safety process and activities adopted to develop and qualify the aera navigation function into a military platform provide equivalent performance in terms of level of assurance and integritiy.
[REQ RNP1_11]	Area navigation system design - Continuity	Continuity: Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 2150	This impacts the system design (redundancies of equipment might be required) and criteria for military airworthiness certification. No other mitigation of these criteria except to relax them.
[REQ RNP1_12]	On-board performance monitoring and alerting	On-board performance monitoring and alerting: The RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 1 NM is greater than 1×10^{-5}.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 2130	To accept GPS PPS with RAIM/FDE and appropriate alarms when it is the main RNAV sensor. In this context, a human factor and workload assessment will demonstrate that the alert is appropriately indicated
[REQ RNP1_13]	Signal in Space	SIS: The aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral positon error greater than 2 NM exceeds 1 × 10-7 per hour.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 2130	To approve military GPS PPS receiver against equivalent performance criteria in civil standards. See RNP1_12
[REQ RNP1_14]	Navigation accuracy alerting	The area navigation system provides an annunciation if a manually entered RNP value is greater than the RNP value associated with the current routes and procedures as defined in the on-board navigation database.	EASA CS-ACNS	CS ACNS.C.PBN. 135	
[REQ RNP1_15]	“direct to” function	The navigation system must have the capability to execute ARINC-424 “direct to” function.	ICAO Doc 9613 EASA CS-ACNS	Part B, Chapter 3.3.3. CS ACNS.C.PBN. 250	See RNP1_17, 18 and 19.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_16]	Automatic leg sequencing	The capability for automatic leg sequencing with the display of sequencing to the pilot.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 235	On aircraft with unsatisfactory display of the flight plan, to use the navigation computer MCDU for FPL checks if readily accessible to the pilot(s).
[REQ RNP1_17]	Navigation functions, ARINC 424 path terminators	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with IF, CF, DF and TF ARINC 424 path terminators, or they equivalent.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 245	These routing instructions can be determined only on a case-by-case basis since depending on specific steering functions implemented in the navigation computer. Some of them might be re-usable. An extensive investigation on flight planning systems should also be carried out since such systems can often alleviate the "lack" of steering functions of the aircraft and are able to compute specific tactical paths. Some systems are able to translate ARINC 424 path terminators into a WPT sequence compliant with the navigation computer formats. Investigate the consequences on a military mission computer to implement a NAV database (memory/ management software, compliant steering with ARINC 424 path terminators etc.). Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD. Investigate the existence of specific tactical steering and assess how they could be re used. Investigate the transfer of remaining function to the flight planning system. In case the path terminators are manually flown by the aircrew, due to lack of sufficient mechanization, a workload assessment could be considered.
[REQ RNP1_18]	Navigation functions, leg transitions	The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARIAN 424 path terminators, or must be able to manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 245	
[REQ RNP1_19]	Navigation functions - leg transitions	The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators, or the system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 245	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_20]	Magnetic aviation	The system must have the capability to assign a magnetic variation (MAGVAR) at any location within the region where flight operations are conducted using magnetic north as a reference. For paths defined by a course, the system uses the appropriate magnetic variation value available in the navigation database.	EASA CS-ACNS	CS ACNS.C.PBN. 255	No impact, however, the magnetic variation models implemented in some navigation/sensors equipment should be timely update through equipment maintenance circuits.
[REQ RNP1_21]	Holding	The area navigation system has the capability to initiate, maintain and discontinue holding procedures at any point and at all altitudes. It is allowed to define the holding pattern via manual or automatic definition.	EASA CS-ACNS	CS ACNS.C.PBN. 260	To re-use and/or adapt tactical HP function (SAR, AA Refuelling, CAP) when implemented, and to authorize manual entries to define the HP. To check if the pattern entries are compatible with the protection area implemented at HP procedure design.
[REQ RNP1_22]	Path definition	The area navigation system provides flight crew with the capability to create, review, modify and activate a flight plan. Activation of any new flight plan or modification of an existing flight plan requires positive action by the flight crew.	EASA CS-ACNS	CS ACNS.C.PBN. 245	Investigate the consequences on a military mission computer to implement a NAV data base. Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe.
[REQ RNP1_23]	User-defined routes and fixes	The system provides a means to the flight crew to build an user-defined route by entering unique waypoints extracted from the on-board navigation database or by manually creating user-defined fixes	EASA CS-ACNS	CS ACNS.C.PBN. 265	See RNP1_22
[REQ RNP1_24]	User-defined routes and fixes	User-defined fixes are usually defined via the entry of latitude/longitude, place/along-track, place/bearing-place and place/bearing/distance.	EASA CS-ACNS	CS ACNS.C.PBN. 265	See RNP1_22
[REQ RNP1_25]	Navigation accuracy	The area navigation system is capable of acquiring and setting the RNP value for each segment of a route or procedure flown from the on-board navigation database.	EASA CS-ACNS	CS ACNS.C.PBN. 270	See RNP1_22

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_26]	Use of navigation database	The stored resolution of the data must be sufficient to achieve negligible PDE.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 2115	Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD.
[REQ RNP1_27]	Use of navigation database	The navigation database must be protected against pilot modification of the stored data.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 2115	Investigate the consequences on a military mission computer to implement a NAV data base (memory/ management software, compliant steering with ARINC 424 path terminators etc.).
[REQ RNP1_28]	Use of navigation database	The system requires as a minimum a navigation database containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with AIRAC cycle and from which ATS routes can be retrieved and loaded into the system.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 2115	Investigate the consequences on a military mission computer to implement a NAV data base (memory/ management software, compliant steering with ARINC 424 path terminators etc.).
[REQ RNP1_29]	Extraction and display of navigation data	The system shall have the means to display the validity period of the navigation data to the pilot.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 2125	For military aircraft equipped with a navigation database, this is implemented. For non-equipped aircraft see RNP1_28.
[REQ RNP1_30]	Extraction and display of navigation data	The system shall retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDS.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 2125	For military aircraft equipped with a navigation database this is implemented. For non-equipped aircraft see RNP1_28.
[REQ RNP1_31]	Extraction and display of navigation data	The area navigation system has the capability to extract routes/procedures from the on-board navigation database, including all their characteristics, and to load them into the system's flight plan.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 2125	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_32]	Extraction and display of navigation data	The system shall provide the means to load and execute from the database into the RNP 1 system the entire segment of the SID or STAR to be flown, by procedure name, including the capability to execute fly-over and fly-by turns.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 CS ACNS.C.PBN. 240	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.
[REQ RNP1_33]	Display and entry of navigation data	The area navigation data system displays and allows manual entry of navigation data with a resolution that supports the intended operation.	EASA CS-ACNS	CS ACNS.C.PBN. 275	Investigate to what extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD.
[REQ RNP1_34]	Deviation display	Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 2.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equivalence/acceptable performance.
[REQ RNP1_35]	Navigation display, continuous path display	The capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the computed path and aircraft position relative to the path. For operations where the required minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft positon relative to the path must also be provided.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 280	No impact for aircraft equipped with a navigation computer feeding electronic primary flight instruments. For conventional HSI displaying only angular deviations, there is no mitigation. May impact two-seat combat aircraft. Some military aircraft have a navigator or weapon system with appropriate displays. Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equivalence/acceptable performance.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_36]	Display of active way-points	The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 285	Change the format of WPT identification in the naviga-tion computer. No impact for distance, bearing and ground speed.
[REQ RNP1_37]	Navigation display - vis-ibility	Each display must be visible to the pilot and located in the primary field of view (±15° from the pilot's normal line of sight) when looking forward along the flight path.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 280	On combat aircraft, in the head down displays may not comply with these requirements. Investigate equivalent possibilities of-fered by the HUD. In this context, a workload assessment may be carried to demonstrate equiva-lence/acceptable perfor-mance.
[REQ RNP1_38]	Navigation display - scaling	The lateral deviation display scaling should agree with any implemented alerting and annunciation limits.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equiva-lence/acceptable perfor-mance.
[REQ RNP1_39]	Navigation display - ground speed	The system must display the ground speed in the flight crew's maximum field of view.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN. 290	No impact
[REQ RNP1_40]	Navigation display - full deflection	The lateral deviation display must have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 AMC1 ACNS.C.PBN. 280	Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equiva-lence/acceptable perfor-mance.
[REQ RNP1_41]	Navigation display - automatic scaling logic	The display scaling may be set automatically by default logic automatically to a value obtained from a navi-gation database or manu-ally by pilot procedures.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 AMC1 ACNS.C.PBN. 280	To investigate the feasibil-ity of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RNP1_42]	Navigation display - full deflection	The full-scale deflection value must be known or must be available for display to the pilot commensurate with the required track keeping accuracy.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 AMC1 ACNS.C.PBN.280	Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equivalence/acceptable performance.
[REQ RNP1_43]	Navigation display - slaving	The lateral deviation display must be automatically slaved to the computed path. The course selector of the deviation display should be automatically slewed to the computed path, or the pilot must adjust the CDI or HIS selected course to the computed desired path.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN.2100	No impact.
[REQ RNP1_44]	Navigation display - map display	As an alternate means of compliance, a navigation map display can provide equivalent functionality to a lateral deviation display with appropriate map scales and giving equivalent functionality to a lateral deviation display. The map scale should be set manually to a value appropriate for the RNP 1 operation.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 AMC1 ACNS.C.PBN.2100	Investigate equivalent possibilities offered by the HUD. In this context, a workload assessment may be carried to demonstrate equivalence/acceptable performance.
[REQ RNP1_45]	Navigation functions - RNP system failure display	The system shall have the capability to display an indication of the RNP 1 system failure in the pilot's primary field of view and the capability to indicate to the crew when the NSE alert limit is exceeded.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 3.3.3 CS ACNS.C.PBN.145	No impact

B.4 RNP APCH

B.4.1 Lateral Navigation (2D approach to LNAV minima)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV_1]	Position source	RNP APCH is based on GNSS positioning.	EASA CS-ACNS EASA AMC 20-27	CS ACNS.C.PBN. 210 Chapter 6.2	The main mitigations would be the eligibility of GPS PPS receiver and TACAN as sensors for PBN.
[REQ LNAV _2]	Use of navigation database	Area navigation system approval The systems that meet the accuracy, integrity and continuity requirements are: GNSS standalone systems, equipment should be approved in accordance with TSO-C129a/ ETSO-C129a Class A, E/TSO-C146() Class Gamma and operational class 1, 2 or 3, or TSO C-196(); GNSS sensors used in multi-sensor system (e.g. FMS) equipment should be approved in accordance with TSO C129 ( )/ ETSO-C129 ( ) Class B1, C1, B3, C3 or E/TSO C145() class 1, 2 or 3, or TSO C-196(). For GNSS receiver approved in accordance with E/TSO-C129(), capability for satellite RAIM FDE is recommended to improve continuity of function, and; multi-sensor systems using GNSS should be approved in accordance with AC20-130A or TSO-C115b, as well as having been demonstrated for RNP APCH capability.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 GM2 ACNS.C.PBN. 205 Chapter 6.2	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ LNAV _3]	Equipment requirements	Navigation equipment shall comply with: RTCA DO-229D, paragraph 2.4.			
[REQ LNAV _4]	Navigation functions - database integrity	To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity.			

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _5]	Position estimation - Accuracy (Initial and intermediate segments)	Accuracy: To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial and intermediate segments, and for the RNAV missed approach.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 GM1 ACNS.C.PBN. 2140 Chapter 6.3.1a	See LNAV/VNAV_1
[REQ LNAV _6]	Position estimation- Accuracy (FAS)	Accuracy: In order to satisfy the ±0.3 NM TSE accuracy for the final approach segment, 95 per cent FTE should not exceed ±0.25 NM whatever the operating mode (manual, flight director or Autopilot).	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 GM1 ACNS.C.PBN. 140 Chapter 6.3.1b	
[REQ LNAV _7]	Area navigation system design - Integrity.	Integrity: During operations on instrument approach procedures, the probability of displaying misleading navigational or positional information to the flight crew during the approach, including the final segment, shall not occur with a probability higher or equal than 10^{-5} per hour.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 330 Chapter 6.4	To approve the military sensors and navigation equipment against equivalent performance criteria to civil standards.
[REQ LNAV _8]	Area navigation system design - Continuity	Continuity: Loss of function with or without Baro-VNAV guidance is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2150 Chapter 6.5	This impacts the system design (redundancies of equipment might be required) and criteria for military airworthiness certification. No other mitigation of these criteria except to relax them.
[REQ LNAV _9]	On-board performance monitoring and alerting. Initial and intermediate segments	OPMA: In the horizontal plane and during operations on the initial and intermediate segments and for the RNAV missed approach, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 1 NM is greater than 10^{-5}.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2130 Chapter 6.4	To accept GPS PPS with RAIM/FDE and appropriate alarms when it is the main RNAV sensor.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _10]	On-board performance monitoring and alerting - FAS	OPMA: In the horizontal plane and during operations on the FAS, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 0.3 NM is greater than 10^{-5}.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2130 Chapter 6.4	To accept GPS PPS with RAIM/FDE and appropriate alarms when it is the main RNAV sensor.
[REQ LNAV _11]	Signal in Space - Initial and intermediate segments	SIS: During operations on the initial and intermediate segments and for the RNAV missed approach, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 2 NM exceeds 10^{-7} per hour.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2130 Chapter 6.4	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ LNAV _12]	Signal in Space - FAS	SIS: During operations on the FAS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 0.6 NM exceeds 10^{-7} per hour.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2130 Chapter 6.4	To approve military GPS PPS receiver against equivalent performance criteria in civil standards.
[REQ LNAV _13]	GNSS availability- RAIM	Because of unplanned failure of some GNSS elements, pilots/ANSPs should realize that RAIM or GPS navigation altogether may be lost while airborne which may require reversion to an alternative means of navigation. For those GNSS systems relying on RAIM and necessitating a check of its availability for RNP APCH, the flight crew should perform a new RAIM availability check if ETA is more than 15 minutes different from the ETA used during the preflight planning.	ICAO Doc 9613	Part C, Chapter 5.3.4.2.1.4	
[REQ LNAV _14]	Altimetry systems	Two independent altimetry systems (sources and displays) must be operational and crew must crosscheck the displayed altitude during the approach and, in particular, when determining the Decision Altitude (DA).			

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _15]	Navigation functions - FD and AP	A flight director and/or autopilot is not required for this type of operation, however, if the lateral TSE cannot be demonstrated without these systems, it becomes mandatory.			To use AP/FD and/or HUD for equipped aircraft.
[REQ LNAV _16]	Navigation functions - system failure display	The system shall provide the capability to display an indication of the RNP system failure, including the associated sensors, in the pilot's primary field of view.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2145	No impact.
[REQ LNAV _17]	Barometric VNAV	When Barometric VNAV is used for vertical path guidance during the FAS, deviations above and below the Barometric VNAV path must not exceed +22 m/-22 m (+75 ft/-75 ft), respectively.	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 5.3.4.4.7 AMC1 ACNS.C.PBN. 555	
[REQ LNAV _18]	Deviation display	Navigation data, including a to/from indication, and a failure indication, must be displayed on a lateral deviation display (CDI, EHSI) and/or a navigation map display.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ LNAV _19]	Deviation display	Lateral navigation display and navigation map display must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ LNAV _20]	Navigation display - full deflection	The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the TSE requirement. Scaling is ±1 NM for the initial and intermediate segments and ±0.3 NM for the final segment.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 320 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _21]	Navigation display - automatic scaling logic	The display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with approach values.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ LNAV _22]	Navigation display - map display	As an alternate means, a navigation map display must give equivalent functionality to a lateral deviation display with appropriate map scales (scaling may be set manually by the pilot).	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 2100 Chapter 7 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ LNAV _23]	Navigation display - slaving	It is highly recommended that the course selector of the deviation display is automatically slaved to the RNAV computed path.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2100 Chapter 7.3 Item 2	No impact.
[REQ LNAV _24]	Navigation display - visibility	The displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 310 Chapter 7.1 Item 1	On combat aircraft, in the head down displays may not comply with these requirements. Investigate equivalent possibilities offered by the HUD.
[REQ LNAV _25]	Navigation display - scaling	The lateral deviation display scaling should agree with any alerting and annunciation limits.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN. 280 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _26]	Navigation display - enhanced navigation display	Enhanced navigation display (e.g. electronic map display or enhanced EHSI) to improve lateral situational awareness, navigation monitoring and approach verification (flight plan verification) could become mandatory if the RNAV installation doesn't support the display of information necessary for the accomplishment of these crew tasks.	ICAO Doc 9613	Part C, Chapter 5.3.3	
[REQ LNAV _27]	Navigation display - continuous path display	The system shall provide capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path. For aircraft where the minimum flight crew is two pilots, the means for the pilot not flying to verify the desired path and the aircraft position relative to the path must also be provided	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 AMC1 ACNS.C.PBN.315 Chapter 7.1 Item 2	No impact for aircraft equipped with a navigation computer feeding electronic primary flight instruments. For conventional HSI displaying only angular deviations, there is no mitigation.
[REQ LNAV _28]	Use of navigation database	A navigation database is required, containing current navigation data officially promulgated for civil aviation.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN.2115 Chapter 7.1 Item 3	Investigate the consequences on a military mission computer to implement a NAV data base.
[REQ LNAV _29]	Use of navigation database	The stored resolution of the data must be sufficient to achieve the required track-keeping accuracy.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN.2115 Chapter 7.1 Item 3	Investigate to what extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV _30]	Use of navigation database	The database must be protected against pilot modification of the stored data.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 4	Investigate to what extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe.
[REQ LNAV _31]	Extraction and display of navigation data	The system shall provide means to display the validity period of the navigation data to the pilot.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 315 Chapter 7.1 Item 2	For military aircraft equipped with a navigation database this is implemented. For non-equipped aircraft see LNAV_32.
[REQ LNAV_32]	Use of navigation database - Update	Navigation database can be updated in accordance with the AIRAC cycle.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2115 Chapter 7.1 Item 3	Investigate the consequences on a military mission computer to implement a NAV data base.
[REQ LNAV_33]	Extraction and display of navigation data	The system must provide the means to retrieve and display data stored in the navigation database relating to individual waypoints and NAVAIDs.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 5	For military aircraft equipped with a navigation database this is implemented. For non-equipped aircraft see LNAV_32.
[REQ LNAV_34]	Navigation functions - data validity	The aircraft must enable the pilot to verify the procedure to be flown.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 3	For military aircraft equipped with a navigation database this is implemented. For non-equipped aircraft see LNAV_32.
[REQ LNAV_35]	Navigation functions - data retrieve	The system shall provide means to load from the database into the RNP system the whole approach to be flown. The approach must be loaded from the database, into the RNP system, by its name.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 3.3.3.3 CS ACNS.C.PBN. 240 Chapter 7.1 Item 6	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV_36]	Navigation functions - data retrieve	The system shall provide the capability to automatically load numeric values for courses and tracks from the RNP system database.			
[REQ LNAV_37]	Display of active waypoints	The system requires the means to display the active navigation sensor type, the identification of the active (To) waypoint, the ground speed or time to the active (To) waypoint and the distance and bearing to the active (To) waypoint either in the pilot's primary field of view or on a readily accessible display page.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 285 Chapter 7.1 Item 7, 8, 11	Change the format of WPT identification in the navigation computer. No impact for distance, bearing and ground speed.
[REQ LNAV_38]	Display of distances	The system shall provide means to display, either in the pilot's primary field of view, or on a readily accessible display page, distance between flight plan waypoints, distance to go and along-track distances.	ICAO Doc 9613 EASA AMC 20-27	Part C, Chapter 5.3.3 Chapter 7.1 Item 9, 10	
[REQ LNAV_39]	"direct to" function	The navigation system must have the capability to execute ARINC-424 "direct to" function.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 250 Chapter 7.1 Item 12	See RNPAP_43
[REQ LNAV_40]	Automatic leg sequencing	The system shall provide the capability for automatic leg sequencing with the display of sequencing to the pilot.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 235 Chapter 7.1 Item 13	On aircraft with unsatisfactory display of the flight plan, to use the navigation computer MCDU for FPL checks if readily accessible to the pilot(s).
[REQ LNAV_41]	Extraction and display of navigation data	The system shall provide the capability to execute procedures extracted from the on-board database, including the capability to execute fly-over and fly-by turns.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 240 Chapter 7.1 Item 14	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LNAV_42]	Navigation functions, ARINC 424 path terminators	The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with IF, CF, DF and TF ARINC 424 path terminators, or their equivalent. In addition, the system shall provide the capability to automatically execute leg transitions consistent with ARINC 424 FA path terminators, or the RNP system must permit the pilot to fly a course and turn at a designated altitude.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 245 Chapter 7.1 Item 15, 16	These routing instructions can be determined only on a case by case basis since depending on specific steering functions implemented in the navigation computer. Some of them might be re-usable. An extensive investigation on flight planning systems should also be carried out since such systems can often alleviate the "lack" of steering functions of the aircraft and are able to compute specific tactical paths. Some systems are able to translate ARINC 424 path terminators into a WPT sequence compliant with the navigation computer formats. Investigate the consequences on a military mission computer to implement a NAV data base (memory/ management software, compliant steering with ARINC 424 path terminators etc.). Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe. In case some path terminators cannot be processed, investigate a partial reallocation of the FTE budget to PDE with obligation to use the AP/FD. Investigate the existence of specific tactical steering and assess how they could be re used. Investigate the transfer of remaining function to the flight planning system.
[REQ LNAV_43]	Navigation functions, RNP system failure display	The system shall provide the capability to indicate to the crew when NSE alert limit is exceeded (alert provided by the "onboard performance monitoring and alerting function").	ICAO Doc 9613 EASA CS-ACNS	Part C, Chapter 5.3.3 CS ACNS.C.PBN. 2145	No impact.

B.4.2 BARO/VNAV Operations (3D approach to LNAV/VNAV minima)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ BARO/ VNAV_1]	Accuracy - Total system error.	The Vertical Total System Error (using the Root Sum Square of all errors components) on a 99.7 per cent probability basis is as the table shows.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.6 Chapter 6.3.2	
[REQ BARO/ VNAV_2]	Integrity	During operations on instrument approach procedures, the probability of displaying misleading navigational or positional information to the flight crew during the approach, including the final segment, shall not occur with a probability higher or equal than 10^{-5} per hour.	ICAO Doc 9613 EASA AMC 20-27	Part C, Chapter 5.3.3 Chapter 6.4	To approve the military sensors and navigation equipment against equivalent performance criteria to civil standards.
[REQ BARO/ VNAV_3]	Continuity	Loss of function with or without Barometric-VNAV guidance is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.7 Chapter 6.5	
[REQ BARO/ VNAV_4]	Navigation display - Vertical deviation display.	BAROVNAV deviation must be displayed on a vertical deviation display (HSI, EHSI, VDI). This display must be used as primary flight instruments for the approach.	EASA AMC 20-27	Chapter 7.2 Item 1	
[REQ BARO/ VNAV_5]	Navigation display. Visibility	The display must be visible to the pilot and located in the primary field of view (±15 degrees from pilot's normal line of sight) when looking forward along the flight path.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.14 Chapter 7.2 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ BARO/ VNAV_6]	Navigation display - Full scale deflection	The deviation display shall have a suitable full scale deflection based on the required vertical track error.	EASA AMC 20-27	Chapter 7.2 Item 1	
[REQ BARO/ VNAV_7]	Navigation display - Continuous display of vertical deviation	The system shall provide the capability to continuously display, to the pilot flying, the vertical deviation relative to the Final approach segment on the primary flight instruments for navigation of the aircraft.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.14 Chapter 7.2 Item 2	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ BARO/ VNAV_8]	Navigation display - Loss of naviga-tion	The navigation system shall provide an indication of loss of navigation (e.g. system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical navigation display.	EASA AMC 20-27	Chapter 7.2 Item 6	
[REQ BARO/ VNAV_9]	Navigation display - Barometric sources	The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary field of view.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.15 Chapter 7.2 Item 7	
[REQ BARO/ VNAV_10]	Navigation database	The navigation system must have the capability to load and modify the entire procedure(s) to be flown, based upon ATC instruc-tions, into the RNP system from the on-board naviga-tion database.	ICAO Doc 9613	Attachment A, Chapter 4.10	
[REQ BARO/ VNAV_11]	Navigation database - Published data	The navigation database must contain all the neces-sary data/information to fly the published APV BAROVNAV approach.	EASA AMC 20-27	Chapter 7.2 Item 5	
[REQ BARO/ VNAV_12]	Navigation database - Procedure information	The navigation database must contain the waypoints and associated vertical information for the proce-dure.	EASA AMC 20-27	Chapter 7.2 Item 5	
[REQ BARO/ VNAV_13]	Navigation database - Automatic extraction	Vertical Constraints associ-ated with published pro-cedures must be automati-cally extracted from the navigation database upon selecting the approach procedure.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.8 Chapter 7.2 Item 5	
[REQ BARO/ VNAV_14]	Navigation functions. Automatic interception.	The system shall have the capability to automatically intercept the vertical path at FAP using a vertical fly-by technique.	EASA AMC 20-27	Chapter 7.4 Item 2	
[REQ BARO/ VNAV_15]	Navigation functions - Vertical path definition	The navigation system must be capable of defining a vertical path in accordance with the published vertical path.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.7.2.1.2 Chapter 7.2 Item 3	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ BARO/ VNAV_16]	Navigation functions - Vertical path definition	The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following: a) An "AT OR ABOVE" altitude constraint; b) An "AT or BELOW" altitude constraint; c) An "AT" altitude constraint; d) A "WINDOW" constraint.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.7 Chapter 7.1 Item 24	MIL aircraft usually do not comply with this requirement unless their navigation computer is designed to meet VNAV specifications. The impact is severe since it would require a compatible navigation data base. To investigate the performance that combat aircraft can meet in term of VNAV accuracy and to assess the operational possibilities offered by this performance. For aircraft capable of vertical guidance on tactical low level flight to investigate the possibility of re-use/adaptation of this function to VNAV requirements
[REQ BARO/ VNAV_17]	Navigation functions - Temperature compensation	The system should provide the capability for entry of altimeter source temperature to compute temperature compensation for the vertical flight path angle.	ICAO Doc 9613 EASA AMC 20-27	Attachment A, Chapter 4.20 Chapter 7.4 Item 1	

B.4.3 Down to LPV minima (3D operation - SBAS receiver required)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LPV_1]	Position estimation - Accuracy	FTE performance is considered acceptable if the lateral and vertical display full-scale deflection is compliant with the non-numeric lateral cross-track and vertical deviation requirements of RTCA DO 229 C (or subsequent version) and if the crew maintains the aircraft within one-third the full scale deflection for the lateral deviation and within one-half the full-scale deflection for the vertical deviation.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3 Chapter 6.3.2	
[REQ LPV_2]	Area navigation system design - Integrity	Simultaneously presenting misleading lateral and vertical guidance with misleading distance data during an RNP APCH operation down to LPV and LP minima is considered a hazardous failure condition (extremely remote). Threshold probability of such events shall be less than 10^{-7} per hour.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3 Chapter 6.4	To approve the MIL sensors and navigation equipment against equivalent performance criteria in civil standards.
[REQ LPV_3]	Area navigation system design - Continuity	Loss of the system that provides LPV approach capability is considered a major failure condition.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3 Chapter 6.5	
[REQ LPV_4]	Signal in space - Before FAP	At a position between 2 NM from the FAP and the FAP, the aircraft navigation equipment shall provide an alert within 10 seconds if the SIS errors causing a lateral position error are greater than 0.6 NM, with a probability of $1\text{-}10^{-7}$ per hour	ICAO Doc 9613	Part C, Chapter 5.3.3	
[REQ LPV_5]	Signal in Space - After FAP, lateral position	After sequencing the FAP and during operations on the FAS, the aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a lateral position error are greater than 40 m, with a probability of $1\text{-}2.10^{-7}$ in any approach.	ICAO Doc 9613	Part C, Chapter 5.3.3	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LPV_6]	Signal in Space - After FAP, vertical position	After sequencing the FAP and during operations on the FAS, the aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a vertical position error is greater than 50 m (or 35 m for LPV minima down to 200 ft), with a probability of $1\text{-}2.10^{-7}$ in any approach.	ICAO Doc 9613	Part C, Chapter 5.3.3	
[REQ LPV_7]	Equipment require-ments	Navigation equipment shall comply with RTCA DO-229D, paragraph 2.4.			
[REQ LPV_8]	Navigation database	To minimize PDE, the database should comply with DO-200A/ED-76, or an equivalent operational means must be in place to ensure database integrity for the RNP-APCH-LP/LPV operations.	EASA AMC 20-28	Chapter 10.4.2	
[REQ LPV_9]	Navigation display	Approach guidance must be displayed on a lat-eral and vertical deviation display (HSI, EHSI, CDI/VDI) including a failure indicator.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 1	Transport type aircraft display systems usually propose this type of entry. On combat aircraft a deep modification of the display system is often required to implement the function. On aircraft implementing verti-cal guidance for low level tactical flight, the display of the vertical path/aircraft de-viation might be adapted to comply with requirements.
[REQ LPV_10]	Navigation display	Display must be used as primary flight instruments for the approach.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 1	Investigate equivalent possibilities offered by the HUD.
[REQ LPV_11]	Navigation display - Vis-ibility	The displays must be visible to the pilot and located in the primary field of view (±15 degrees from the pilot's normal line of sight) when looking forward along the flight path.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 1	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LPV_12]	Navigation display - Angular deviations	The lateral and vertical full-scale deflection shall be angular and associated to the lateral and vertical definitions of the FAS contained in the FAS Data Block.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 1	
[REQ LPV_13]	Navigation display - GNSS approach mode	The system shall provide the capability to display the GNSS approach mode (e.g. LP, LPV, LNAV/VNAV, lateral navigation) in the primary field of view.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 2	
[REQ LPV_14]	Navigation display - Distance to the LTP/FTP	The system shall provide the capability to continuously display the distance to the LTP/FTP or Missed Approach Point (MAPT) after passing the Final Approach Point in the primary field of view.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 3	
[REQ LPV_15]	Navigation display - Loss of navigation	The system shall provide the indication of the loss of navigation (e.g. system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical and/or lateral navigation display).			
[REQ LPV_16]	Navigation database - FAS information	The navigation database must contain all the necessary data/information to fly the published approach procedure (FAS). Although data may be stored or transmitted in different ways, the data has to be organized in Data Blocks for the purpose of computing the CRC.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 4	
[REQ LPV_17]	Navigation database - FAS check	Once the FAS DB has been decoded, the equipment shall apply the CRC to the DB to determine whether the data is valid. If the FAS DB does not pass the CRC test, the equipment shall not allow activation of the approach operation.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 4	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ LPV_18]	Navigation functions - Procedure selection	The system shall provide the capability to select from the database into the installed system the whole approach procedure to be flown (SBAS channel number and/or approach name).	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 5	
[REQ LPV_19]	Navigation functions - Loss of integrity	The system shall provide the indication of the loss of integrity function in the pilot's normal field of view (e.g. by means of an appropriately located annunciator).	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 6	
[REQ LPV_20]	Navigation functions - Track deviation to extended FAS	The system shall provide capability to immediately provide track deviation indications relative to the extended FAS, in order to facilitate the interception of the extended FAS from a radar vector.	ICAO Doc 9613 EASA AMC 20-28	Part C, Chapter 5.3.3.3 Chapter 7.1 Item 8	

B.5 RNP AR APCH (3D operation – will require special authorisation)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_1]	GNSS interference	RNP AR APCH shall not be used in areas of known navigation signal (GNSS) interference.			
[REQ ARAPCH_2]	Position estimation- Lateral accuracy	Lateral accuracy: All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, FTE, PDE and display error. Also, the aircraft along-track positioning error must be no greater than the applicable accuracy value for 95 per cent of the flight time.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.2 Chapter 6.1.1	
[REQ ARAPCH_3]	Position estimation- Vertical accuracy	The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track error, system computation error, data resolution error, and FTE. The 99.7 per cent of system error in the vertical direction must be less than the computed using the given formula.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.2 AMC1 ACNS.C.PBN.670 Chapter 6.1.2	
[REQ ARAPCH_4]	Area navigation system design - Vertical System performance monitoring	The required demonstration of RNP system performance, including lateral and vertical path steering performance (FTE), will vary accordingly to the type of AR operation being considered. It should be noted that the monitoring system might not provide warnings of FTE. The management of FTE must be addresses as a pilot procedure.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.2 AMC1 ACNS.C.PBN.635 Chapter 6.1.3	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_5]	Area navigation system design. Integrity	The probability of the aircraft exiting the lateral and vertical extent of the obstacle clearance volume must not exceed 10^{-7} per operation, including the departure, approach and missed approach.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.2 CS ACNS.C.PBN. 675 Chapter 6.2	
[REQ ARAPCH_6]	Area navigation system design. Continuity	The probability of loss of all navigation information is Remote. The probability of non-restorable loss of all navigation and communication functions is Extremely Improbable.	EASA CS-ACNS EASA AMC 20-262	AMC1 ACNS.C.PBN. 280 Chapter 6.3	
[REQ ARAPCH_7]	Navigation performance	The system should include a capability to monitor for its achieved lateral navigation performance, and to identify for the flight crew whether the operational requirement is or is not being met during an operation.	EASA AMC 20-26	Chapter 7.1 Item 14	
[REQ ARAPCH_8]	GNSS updating	A crew alert is required when GNSS updating is lost unless the navigation system provides an alert when the selected RNP no longer meets the requirements for continued navigation.	ICAO Doc 9613	Part C, Chapter 6.3.3.2	
[REQ ARAPCH_9]	Multi-sensor systems	For multi-sensor systems, automatic reversion to an alternate navigation sensor if the primary navigation sensor fails is required.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.2 Chapter 7.1 Item 15	Investigate if with alarms on the sensor and/or navigation performance monitoring function and a manual selection/deselection this requirement could be met.
[REQ ARAPCH_10]	Automatic navigation sources selection	The RNAV system must be capable of performing automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check and a manual override or deselect.	EASA AMC 20-26	Chapter 7.1 Item 17	Accept manual deselection/selection of sensors in case of malfunctions or performance alert.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_11]	Failure an-nunciation	The aircraft must provide a mean to annunciate failures of any aircraft component of the RNAV system, includ-ing navigation sensors. The annunciation must be visi-ble to the pilot and located in the primary field of view.	EASA AMC 20-26	Chapter 7.1 Item 18	Basic rule implemented on military aircraft. No impact.
[REQ ARAPCH_12]	Equipment approval - GNSS aug-mentations	The sensor must comply with the guidelines in AC 20-138() or AC 20-130 A.	ICAO Doc 9613	Part C, Chapter 6.3.3.2	
[REQ ARAPCH_13]	Equipment approval - IRS	An IRS must satisfy the cri-teria of US 14 CFR part 121, Appendix G, or equivalent.	ICAO Doc 9613	Part C, Chapter 6.3.3.2	
[REQ ARAPCH_14]	DME auto-matic tuning	Automatic tuning of DME navigation aids is needed when used for position updating together with the capability to inhibit indi-vidual navigation aids from the automatic selection process.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.2 Chapter 7.1 Item 16	ensor and/or navigation perfo
[REQ ARAPCH_15]	Equipment approval - Temperature compensa-tion	Systems that provide tem-perature-based corrections to the barometric VNAV guidance must comply with EUROCAE ED-75D, Appen-dix H.2.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.2 AMC1 ACNS.C.PBN. 525	
[REQ ARAPCH_16]	Navigation display - Continuous display of deviation	The navigation system must provide the capability to continuously display to the pilot flying, on the pri-mary flight instruments for navigation of the aircraft, the aircraft position relative to the defined lateral and vertical path (both lateral and vertical deviation) and manoeuvre anticipation.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 645 Chapter 7.1 Item 1	No impact for aircraft equipped with a naviga-tion computer feeding electronic primary flight instruments. For conven-tional HSI displaying only angular deviations, there is no mitigation.
[REQ ARAPCH_17]	Navigation display - Cross-track deviation	The display must allow the pilot to readily distinguish if the cross-track deviation exceeds the RNP or if the vertical deviation exceeds 75 feet.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.24 Chapter 7.1 Item 1	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_18]	Navigation display - Minimum flight crew	Where the minimum flight crew is two pilots, means for the pilot not flying must be provided to verify the desired path and the aircraft position relative to the path.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.24 Chapter 7.1 Item 1, 9	May impact two-seat combat aircraft. Some military aircraft have a navigator or weapon system with appropriate displays.
[REQ ARAPCH_19]	Navigation display - Identification active (To) waypoint	The navigation system must provide a display identifying the active (To) waypoint either in the pilot's primary field of view, or on a readily accessible and visible display to the flight crew.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.285 Chapter 7.1 Item 2	Change the format of WPT identification in the navigation computer.
[REQ ARAPCH_20]	Navigation display - Distance and bearing	The navigation system must provide a display if distance and bearing to the active (To) waypoint either in the pilot's primary field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.285 Chapter 7.1 Item 3	No impact.
[REQ ARAPCH_21]	Navigation display - Ground speed and time	The navigation system should provide the display of groundspeed and either estimated time of arrival or time to the active (To) waypoint in the pilot's primary field of view. Where not viable, a readily accessible page on a control display unit, readily visible to the flight crew, may display the data.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.290 Chapter 7.1 Item 4	No impact.
[REQ ARAPCH_22]	Navigation display - To/From active fix	The navigations system must provide a To/From display in the pilot's primary field of view.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.4 Chapter 7.1 Item 5	Investigate equivalent possibilities offered by the HUD.
[REQ ARAPCH_23]	Navigation display - Slaved course selector	The navigation system must provide a course selector automatically slaved to the RNAV computed path. As an acceptable alternative is an integral navigation map display.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.2100 Chapter 7.1 Item 8	No impact for aircraft equipped with a navigation computer feeding electronic primary flight instruments. For conventional HSI displaying only angular deviations, there is no mitigation.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_23]	Navigation display - Slaved course selector	The navigation system must provide a course selector automatically slaved to the RNAV computed path. As an acceptable alternative is an integral navigation map display.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 230 Chapter 7.1 Item 10	
[REQ ARAPCH_24]	Navigation display - Distance to go	The navigation system must provide the ability to display distance to go to any waypoint selected by the flight crew.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 230 Chapter 7.1 Item 10	
[REQ ARAPCH_25]	Navigation display - Distance between waypoints	The navigation system must provide the ability to display the distance between flight plan waypoints.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 230 Chapter 7.1 Item 11	No impact.
[REQ ARAPCH_26]	Navigation display - Barometric altitude	The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary field of view. The altimeter setting input must be used simultaneously by the aircraft altimetry system and by the RNAV system.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 290 Chapter 7.1 Item 4	
[REQ ARAPCH_27]	Navigation display - Active sensors	The aircraft must display the current navigation sensor(s) in use that are readily accessible to the flight crew.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 545 Chapter 7.1 Item 13	Investigate the consequences on a military mission computer to implement a NAV data base.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_28]	Navigation display - Altitude restrictions	A display of the altitude restrictions associated with flight plan fixes must be available to the pilot. If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the equipment must display the flight path angle for that leg.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.4 Chapter 7.1 Item 32	
[REQ ARAPCH_29]	Navigation display - Navigation database status	The system should provide the means to display the validity period of the navigation database to the flight crew.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 19	For MIL aircraft equipped with a navigation database this is implemented. For non-equipped aircraft see ARAPCH_40.
[REQ ARAPCH_30]	Navigation functions - ARINC 424 path terminators	The aircraft must have the capability to execute leg transitions and maintain tracks consistent with TF, CF, DF and TF ARINC 424 path terminators.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 245 Chapter 7.1 Item 20	These routing instructions can be determined only on a case by case basis since depending on specific steering functions implemented in the navigation computer. Some of them might be re-usable. An extensive investigation on flight planning systems should also be carried out since such systems can often alleviate the "lack" of steering functions of the aircraft and are able to compute specific tactical paths. Some systems are able to translate ARINC 424 path terminators into a WPT sequence compliant with the navigation computer formats.
[REQ ARAPCH_31]	Navigation functions - ARINC 424 path terminators	The aircraft must have the capability to execute leg transitions and maintain tracks consistent with TF, CF, DF and TF ARINC 424 path terminators.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 245 Chapter 7.1 Item 21	Investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_32]	Navigation functions - "Direct To"	The navigation system must have a "DirectTo" function the flight crew can activate at any time. This function must be available to any fix.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.250 Chapter 7.1 Item 23	Investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.
[REQ ARAPCH_33]	Navigation functions - Vertical path definition	The system must be capable of defining a vertical path by a flight path angle to a fix. Also, it must be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan. Fix altitude constraints must be defined as one of the following: a) An "AT OR ABOVE" altitude constraint; b) An "AT or BELOW" altitude constraint; c) An "AT" altitude constraint; d) A "WINDOW" constraint.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN.510 Chapter 7.1 Item 24	Military aircraft usually do not comply with this requirement unless their navigation computer is designed to meet VNAV specifications.
[REQ ARAPCH_34]	Navigation functions - Vertical path construction	The system must be able to construct a path to provide guidance from current position to a vertically constrained fix.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.510 Chapter 7.1 Item 26	
[REQ ARAPCH_35]	Navigation functions - Magnetic variation	For paths defined by a course (CF path terminator), the navigation system must use the magnetic variation value for the procedure in the navigation database.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN.255 Chapter 7.1 Item 29	No impact, however the magnetic variation models implemented in some navigation/sensors equipment should be timely update through equipment maintenance circuits.
[REQ ARAPCH_36]	Navigation functions - Changes in navigation accuracy	RNP changes to lower navigation accuracy must be complete by the fix defining the leg with the lower navigation accuracy, considering the alerting latency of the navigation system. Any operational procedures necessary to accomplish this must be identified.	ICAO Doc 9613 EASA AMC 20-26	Part C, Chapter 6.3.3.4 Chapter 7.1 Item 30	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_37]	Navigation functions - Automatic leg sequencing	The navigation system must provide the capability to automatically sequence to the next leg and display the sequencing to the flight crew in a readily visible manner.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 235 Chapter 7.1 Item 31	On aircraft with unsatisfactory display of the flight plan, to use the navigation computer MCDU for FPL checks if readily accessible to the pilot(s).
[REQ ARAPCH_38]	Navigation database. AIRAC cycle	The aircraft navigation system must use an on-board navigation database which can receive updates in accordance with the AIRAC cycle.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 115 Chapter 7.1 Item 33	Investigate the consequences on a military mission computer to implement a NAV data base.
[REQ ARAPCH_39]	Navigation database - Procedures retrieval and loading	The system must allow retrieval and loading of entire RNP AR APCH procedures to be flown into the RNP system from the on-board navigation database. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 240 Chapter 7.1 Item 27	To investigate the feasibility of a transfer to the flight planning system to create end-to-end flight plans with appropriate path.
[REQ ARAPCH_40]	Navigation database - Modification protection	The database must be protected against flight crew modification of the stored data.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 2115 Chapter 7.1 Item 33	Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe.
[REQ ARAPCH_41]	Navigation database - Extraction altitudes and speeds	Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 215 Chapter 7.1 Item 25	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_42]	Navigation database - Data stored verification and review	The navigation system must provide the ability for the flight crew to verify the procedure to be flown through review of the data stored in the on-board navigation database. This includes the ability to review the data for individual waypoints and for navigation aids.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 2125 Chapter 7.1 Item 28	For MIL aircraft equipped with a navigation database, this is implemented. For non-equipped aircraft, see ARAPCH_40.
[REQ ARAPCH_43]	Navigation database - Waypoint resolution error	The navigation database must provide sufficient data resolution to ensure the navigation system achieves the required accuracy. Waypoint resolution error must be less than or equal to 60 feet, including both the data storage resolution and the RNAV system computational resolution used internally for construction of flight plan waypoints.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 655 Chapter 7.1 Item 22	Investigate to which extent a transfer of the capabilities and functions to the flight planning system would be operationally acceptable and safe.
[REQ ARAPCH_44]	Additional functions: RF legs. Leg transitions	The navigation system must have the capability to execute leg transitions and maintain tracks consistent with an RF leg between two fixes.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 630 Chapter 7.2 Item 1.1	
[REQ ARAPCH_45]	Additional functions: RF legs. Electronic map display	The aircraft must have an electronic map display of the selected procedure.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 820 Chapter 7.2 Item 1.2	
[REQ ARAPCH_46]	Additional functions: RF legs. Bank angle	The navigation system, the flight director system and autopilot must be capable of commanding a bank angle up to 25 degrees at or above 400 feet AGL and up to 8 degrees below 400 feet AGL.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 805 Chapter 7.2 Item 1.3	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_47]	Additional functions: RF legs. Go-around guidance	Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 625 Chapter 7.2 Item 1.4	
[REQ ARAPCH_48]	Additional functions: RF legs. Turn rolling	When evaluating FTE on RF legs, the effect of rolling into and out of the turn should be considered. The procedure is designed to provide 5 degrees of manoeuvrability margin, to enable the aircraft to get back on the desired track after a slight overshoot at the start of the turn.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 805 Chapter 7.2 Item 1.5	
[REQ ARAPCH_49]	Additional functions: less than RNP 0.3: Single point of failure	No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots and a single IRU.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 GM1 ACNS.C.PBN. 610 Chapter 7.2 Item 2.1	
[REQ ARAPCH_50]	Additional functions: less than RNP 0.3: Hazardous failure	The system design must be consistent with at least a hazardous failure condition for the loss or display of misleading of lateral or vertical guidance.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 AMC1 ACNS.C.PBN. 675 Chapter 7.2 Item 2.2	
[REQ ARAPCH_51]	Additional functions: less than RNP 0.3: Go-around guidance	Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 625 Chapter 7.2 Item 2.3	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ ARAPCH_52]	Additional functions: less than RNP 0.3: Loss of GNSS	After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy for the time necessary to fly the go-around or the missed approach.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 625 Chapter 7.2 Item 2.4	
[REQ ARAPCH_53]	Additional functions: less than RNP 1: Single point of failure	No single point of failure can cause the loss of guidance compliant with the navigation accuracy associated with the approach. Typically, the aircraft must have at least the following equipment: dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots and a single IRU.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 GM1 ACNS.C.PBN. 610 Chapter 7.2 Item 3.1	
[REQ ARAPCH_54]	Additional functions: less than RNP 1: Major failure	The system design must be consistent with at least a major failure condition for the loss or display of misleading of lateral or vertical guidance.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 GM1 ACNS.C.PBN. 610 Chapter 7.2 Item 2.1	
[REQ ARAPCH_55]	Additional functions: less than RNP 1: Go-around guidance	Upon initiating a go-around or missed approach (through activation of TOGA or other means), the flight guidance mode should remain in LNAV to enable continuous track guidance during an RF leg.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 625 Chapter 7.2 Item 3.3	
[REQ ARAPCH_56]	Additional functions: less than RNP 1: Loss of GNSS	After initiating a go-around or missed approach following loss of GNSS, the aircraft must automatically revert to another means of navigation that complies with the navigation accuracy for the time necessary to fly the go-around or the missed approach.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-26	Part C, Chapter 6.3.3.4 CS ACNS.C.PBN. 625 Chapter 7.2 Item 3.4	

B.6 RF (Optional and only applied to RNP applications)

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RF_1]	Use of autopilot	The use of autopilot or flight director is required to execute RF leg transitions, except for non-type-rated CS-23 Level 1, 2 and 3 aircraft performing RNP 1 and RNP APCH operations with an RNP value of not less than 1, and at speeds of 200 knots or less, provided that the aircraft is equipped with an appropriately scaled course deviation indicator (CDI).	EASA CS-ACNS	CS ACNS.C.PBN.815	
[REQ RF_2]	Supported procedure selection	The navigation system should not permit the pilot to select a procedure that is not supported by the equipment, either manually or automatically.	ICAO Doc 9613	Part C, Appendix 1 Chapter 4.1	
[REQ RF_3]	Procedure selection	The navigation system should also prohibit pilot access to procedures requiring RF leg capability if the system can select the procedure, but the aircraft is not equipped.	ICAO Doc 9613	Part C, Appendix 1 Chapter 4.1	
[REQ RF_4]	Accuracy	The lateral TSE must be within ±1 × RNP of the path defined by the published procedure for at least 95 per cent of the total flight time for each phase of flight and each autopilot and/or flight director mode requested.	ICAO Doc 9613	Part C Appendix 1 Chapter 4.2	
[REQ RF_5]	Loss of navigation/Loss of integrity	The RNP system shall provide a visible alert within the pilot's primary field of view when loss of navigation capability and/or loss of integrity are experienced.	ICAO Doc 9613	Part C Appendix 1 Chapter 4.3	
[REQ RF_6]	Failure modes identification	Any failure modes that have the potential to affect the RF leg capability should be identified.	ICAO Doc 9613	Part C Appendix 1 Chapter 4.3	
[REQ RF_7]	Failure mitigation	The ability of the aircraft to maintain the required FTE after a full of partial failure of the autopilot and/or flight director should be documented.	ICAO Doc 9613 EASA CS-ACNS	Part C Appendix 1 Chapter 4.3 AMC1 ACNS.C.PBN.805	

Req#	Title	Requirement	Reference	Part	Mitigation
[REQ RF_8]	RNP unavail-able	If the RNP cannot be achieved during a RF leg, the flight guidance mode remains in lateral navigation.	EASA CS-ACNS	CS ACNS.C.PBN. 810	
[REQ RF_9]	"roll-steering"	An autopilot or flight director with at least "roll-steering" capability that is driven by the RNP system is required. The autopilot/flight director must operate with suitable accuracy to track the lateral and, as appropriate, vertical paths required by a specific RNP procedure.	ICAO Doc 9613	Part C, Appendix 1 Chapter 4.4	
[REQ RF_10]	Leg transi-tions	The navigation system must have the capability to execute leg transitions and maintain a track consistent with a RF leg between two fixes.	EASA CS-ACNS	CS ACNS.C.PBN. 805	
[REQ RF_11]	Path display	The area navigation system displays the intended path on an appropriately scaled moving map display in the flight crew's maximum field of view.	ICAO Doc 9613 EASA CS-ACNS	Part C Appendix 1 Chapter 4.4 CS ACNS.C.PBN. 820	
[REQ RF_12]	Bank angle	The flight management com-puter, the flight director sys-tem, and the autopilot must be capable of commanding and achieving a bank angle up to 30 degrees above 400 feet above ground level (AGL) and up to 8 degrees below 400 feet AGL.	ICAO Doc 9613 EASA CS-ACNS	Part C Appendix 1 Chapter 4.4 CS ACNS.C.PBN. 805	
[REQ RF_13]	Navigation mode	The flight guidance mode should remain in lateral navigation while on an RF leg, when a procedure is abandoned or a missed approach/go-around is initi-ated (through activation of TOGA or other means) to en-able display of deviation and display of positive course guidance during the RF leg. As an alternative means, crew procedures may be used that ensure that the air-craft adheres to the specific flight path throughout the RF leg segment.	ICAO Doc 9613	Part C Appendix 1 Chapter 4.4	

Note: *This appendix depicts the navigation performance and functional criteria for aircrafts to qualify for the different PBN specifications. Nevertheless, the presented requirements should not be liable for Research & Development or system development purposes without full reading of SARPs to complement them.*

APPENDIX C – SUMMARY OF INTEROPERABILITY TARGETS REGARDING PBN

Requirement	Description	Detailed Description	References	Support to Certification
RNAV 5	The lateral TSE must be within 5 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±5 NM for at least 95 per cent of the total flight time. **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition **Continuity:** Loss of function is classified as a minor failure condition More details are available regarding INS/IRS, VHF VOR, DME, GNSS.	**Accuracy:** During operations in airspace or on routes designated as RNAV 5, the lateral TSE must be within 5 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±5 NM for at least 95 per cent of the total flight time. **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10–5per hour). **Continuity:** Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. **SIS:** If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 10 NM exceeds 10–7per hour. ***Note:*** *The minimum level of integrity and continuity required for RNAV 5 systems for use in airspace designated for RNAV 5 would normally be met by a single installed system comprising one or more sensors, an RNAV computer, a control display unit and navigation display(s) (e.g. ND, HSI or CDI), provided that the system is monitored by the pilot and that in the event of a system failure the aircraft retains the capability to navigate relative to ground-based NAVAIDs (e.g. VOR/DME or NDB).* Although not prescribing performance targets to be met, their use and approvals are described with more detailed information.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20–4 FAA 90-96	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613. RNAV 5 operations are based on the use of RNAV equipment which automatically determines the aircraft position using input from one or a combination of the following types of position sensors, together with the means to establish and follow a desired path: a) VOR/DME; b) DME/DME; c) INS or IRS; and d) GNSS

Requirement	Description	Detailed Description	References	Support to Certification
RNAV 1	The lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition. **Continuity:** Loss of function is classified as a minor failure condition.	**Accuracy:** During operations in airspace or on routes designated as RNAV 1, the lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10–5per hour). **Continuity:** Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. **SIS:** During operations in airspace or on routes designated as RNAV 1 if using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 2 NM exceeds 10–7per hour.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20–5 FAA 90-96 and JAA TGL10 -Revision 1 OPS approval required to fly P-RNAV	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613. RNAV 1 and RNAV 2 operations are based upon the use of RNAV equipment that automatically determines the aircraft position in the horizontal plane using input from the following types of position sensors (no specific priority): a) GNSS in accordance with FAA TSO-C145(), TSO-C146(), or TSO-C129(). Positioning data from other types of navigation sensors may be integrated with the GNSS data provided other position data do not cause position errors exceeding the total system accuracy requirements. The use of GNSS equipment approved to TSO-C129 () is limited to those systems which include the minimum functions specified in the ICAO PBN Manual; b) DME/DME RNAV equipment complying with the criteria listed in the ICAO PBN Manual; c) DME/DME/IRU RNAV equipment complying with the criteria listed in the ICAO PBN Manual.
	Additional requirements have been described as criteria for specific navigation services, in particular for GNSS, DME/DME RNAV and DME/IRU equipped aircraft.	In paragraph 3.3.3.2 of ICAO doc 9613 (Part B Implementing RNAV 1 and RNAV 2), figures are provided related to update rates, accuracy, position estimation error, etc. Please take into account the guidance provided in the described document for more detailed information.		

Requirement	Description	Detailed Description	References	Support to Certification
RNP 1 (optional)	The lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM.	**Accuracy:** During operations in airspace or on routes designated as RNP 1, the lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM. ***Note:*** *The use of a deviation indicator with 1 NM full-scale deflection has been found to be an acceptable means of compliance. The use of an autopilot or flight director has been found to be an acceptable means of compliance (roll stabilization systems do not qualify).* **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 1 × 10–5per hour). **Continuity:** Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. **On-board performance monitoring and alerting:** The RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 1 NM is greater than 1 × 10–5. **SIS:** If using GNSS, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 2 NM exceeds 1 × 10–7per hour.	ICAO Doc 9613 EASA CS-ACNS See Note on certification references for Advanced RNP	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613. The following systems meet the accuracy, integrity and continuity requirements of these criteria: a) aircraft with E/TSO-C129a sensor (Class B or C), E/TSO-C145() and the requirements of E/TSOC115b FMS, installed for IFR use in accordance with FAA AC 20-130A; b) aircraft with E/TSO-C129a Class A1 or E/TSO-C146() equipment installed for IFR use in accordance with FAA AC 20-138 or AC 20-138A; and c) aircraft with RNP capability certified or approved to equivalent standards. Compliance with the on-board performance monitoring and alerting requirements does not imply automatic monitoring of FTEs. The on-board monitoring and alerting function should at least consist of an NSE monitoring and alerting algorithm and a lateral deviation display enabling the crew to monitor the FTE. To the extent operational procedures are used to monitor FTE, the crew procedure, equipment characteristics, and installation are evaluated for their effectiveness and equivalence, as described in the functional requirements and operating procedures. PDE is considered negligible due to the quality assurance process and crew procedure.
	Related to GNSS positioning, some special criteria have been identified and are described further in paragraph 3.3.3.3 of ICAO doc 9613 (Part C Implementing RNP 1).	RNP 1 is based on GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided the other positioning data do not cause position errors exceeding the TSE budget. Otherwise, means should be provided to deselect the other navigation sensor types. ***Note:*** *For RNP procedures, the RNP system may only use DME updating when authorized by the State.*		

Requirement	Description	Detailed Description	References	Support to Certification
RNP APCH OPERATIONS DOWN TO LNAV AND LNAV/VNAV MINIMA	The lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. Malfunction of the aircraft navigation equipment is classified as a major failure condition. Loss of function is classified as a minor failure condition. The RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met.	**Accuracy:** During operations on the initial and intermediate segments and for the RNAV missed approach, of an RNP APCH, the lateral TSE must be within ±1 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±1 NM for at least 95 per cent of the total flight time. During operations on the FAS of an RNP APCH down to LNAV or LNAV/VNAV minima, the lateral TSE must be within ±0.3 NM for at least 95 per cent of the total flight time. The along-track error must also be within ±0.3 NM for at least 95 per cent of the total flight time. To satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial and intermediate segments, and for the RNAV missed approach, of an RNP APCH. The 95 per cent FTE should not exceed 0.25 NM on the FAS of an RNP APCH. ***Note:*** *The use of a deviation indicator with 1 NM full-scale deflection on the initial and intermediate segments, and for the RNAV missed approach and 0.3 NM full-scale deflection on the FAS, has been found to be an acceptable means of compliance. The use of an autopilot or flight director has been found to be an acceptable means of compliance (roll stabilization systems do not qualify).* **Integrity:** Malfunction of the aircraft navigation equipment is classified as a major failure condition under airworthiness regulations (i.e. 10^{-5} per hour). **Continuity:** Loss of function is classified as a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. **On-board performance monitoring and alerting:** During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10^{-5}. During operations on the FAS of an RNP APCH down to LNAV or LNAV/VNAV minima, the RNP system, or the RNP system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 0.6 NM is greater than 10^{-5}. **SIS:** During operations on the initial and intermediate segments and for the RNAV missed approach of an RNP APCH, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 2 NM exceeds 10^{-7}per hour. During operations on the FAS of an RNP APCH down to LNAV or LNAV/VNAV minima, the aircraft navigation equipment shall provide an alert if the probability of SIS errors causing a lateral position error greater than 0.6 NM exceeds 10^{-7} per hour.	ICAO Doc 9613 EASA CS-ACNS EASA AMC 20-27 FAA documents AC20-138, AC20-130A and AC20-129.	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613. There are no RNP APCH requirements for the missed approach if it is based on conventional means (VOR, DME, NDB) or on dead reckoning. The following systems meet the accuracy, integrity and continuity requirements of these criteria: a) GNSS stand-alone systems, equipment should be approved in accordance with TSO-C129a/ ETSO-C129a Class A, E/TSO-C146() Class Gamma and operational class 1, 2 or 3, or TSO C-196(); b) GNSS sensors used in multi-sensor system (e.g. FMS) equipment should be approved in accordance with TSO C129 ( )/ ETSO-C129 ( ) Class B1, C1, B3, C3 or E/TSO C145() class 1, 2 or 3, or TSO C-196(). For GNSS receiver approved in accordance with E/TSO-C129(), capability for satellite FDE is recommended to improve continuity of function; and c) multi-sensor systems using GNSS should be approved in accordance with AC20-130A or TSO-C115b, as well as having been demonstrated for RNP APCH capability.
	Additional requirements have been described as criteria for specific navigation services, in particular for GNSS.	RNP APCH is based on GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided the other positioning data do not cause position errors exceeding the TSE (TSE) budget, or if means are provided to deselect the other navigation sensor types.	ICAO Doc 9613 (Part C, Chapter 5, 5.3.3.2- Section A)	

Requirement	Description	Detailed Description	References	Support to Certification
RNP APCH OPERATIONS DOWN TO LPV MINIMA		**Accuracy:** Along the FAS and the straight continuation of the final approach in the missed approach, the lateral and vertical TSE is dependent on the NSE, PDE and FTE: a) NSE: the accuracy itself (the error bound with 95 per cent probability) changes due to different satellite geometries. Assessment based on measurements within a sliding time window is not suitable for GNSS. Therefore, GNSS accuracy is specified as a probability for each and every sample. NSE requirements are fulfilled without any demonstration if the equipment computes three dimensional positions using linearized, weighted least square solution in accordance with RTCA DO 229C (or subsequent version) Appendix J. b) FTE: FTE performance is considered acceptable if the lateral and vertical display full-scale deflection is compliant with the non-numeric lateral cross-track and vertical deviation requirements of RTCA DO 229 C (or subsequent version) and if the crew maintains the aircraft within one-third the full scale deflection for the lateral deviation and within one-half the full scale deflection for the vertical deviation. c) PDE: PDE is considered negligible based upon the process of path specification to data specification and associated quality assurance that is included in the FAS data-block generation process which is a standardized process. The responsibilities for FAS DB generation lies with the ANSP. ***Note:*** *FTE performance is considered acceptable if the approach mode of the FGS is used during such approach.* **Integrity:** Simultaneously presenting misleading lateral and vertical guidance with misleading distance data during an RNP APCH operation down to LPV minima is considered a hazardous failure condition (extremely remote). Simultaneously presenting misleading lateral guidance with misleading distance data during an RNP APCH operation down to LP minima is considered a hazardous failure condition (extremely remote). **Continuity:** Loss of approach capability is considered a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. For RNP APCH operations down to LP or LPV minima at least one system is required. **SIS:** At a position between 2 NM from the FAP and the FAP, the aircraft navigation equipment shall provide an alert within 10 seconds if the SIS errors causing a lateral position error are greater than 0.6 NM, with a probability of $1\text{-}10^{-7}$ per hour. *Note on additional performance issues*[9]	ICAO Doc 9613 EASA CS-ACNS Requirements for SBAS receivers is contained in ICAO annex 10 Volume 1 Also see specification RTCA DO 229C and FAA TSO C145/146A. EASA AMC 20-28	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613. **On-board performance monitoring and alerting:** Operations on the FAS of an RNP APCH operation down to LP and LPV minima, the on-board performance monitoring and alerting function is fulfilled by: a) NSE monitoring and alerting (see the SIS section below); b) FTE monitoring and alerting: LPV approach guidance must be displayed on a lateral and vertical deviation display (HSI, EHSI, CDI/VDI) including a failure indicator. The deviation display must have a suitable full-scale deflection based on the required track-keeping accuracy. The lateral and vertical full scale deflection are angular and associated to the lateral and vertical definitions of the FAS contained in the FAS DB; and c) Navigation database: once the FAS DB has been decoded, the equipment shall apply the CRC to the DB to determine whether the data is valid. If the FAS DB does not pass the CRC test, the equipment shall not allow activation of the LP or LPV approach operation.

9 After sequencing the FAP and during operations on the FAS of an RNP APCH operation down to LP or LPV minima:

a) the aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a lateral position error are greater than 40 m, with a probability of 1-2.10–7 in any approach (Annex 10, Volume I, Table 3.7.2.4-1); and

b) The aircraft navigation equipment shall provide an alert within 6 seconds if the SIS errors causing a vertical position error is greater than 50 m (or 35 m for LPV minima down to 200 ft), with a probability of 1-2.10–7 in any approach (Annex 10, Volume I, Table 3.7.2.4-1).

Requirement	Description	Detailed Description	References	Support to Certification
RNP APCH OPERATIONS DOWN TO LPV MINIMA		The following systems meet the accuracy, integrity and continuity requirements of these criteria: a) GNSS SBAS stand-alone equipment approved in accordance with E/TSO C146a (or subsequent version). Application of this standard guarantees that the equipment is at least compliant with RTCA DO 229C. The equipment should be a class gamma, operational class 3; b) for an integrated navigation system (e.g. FMS) incorporating a GNSS SBAS sensor, E/TSO C115b and AC 20- 130A provide an acceptable means of compliance for the approval of this navigation system when augmented by the following guidelines: i) the performance requirements of E/TSO-C146a (or subsequent version) that apply to the functional class gamma, operational class 3 or delta 4 is demonstrated; and ii) The GNSS SBAS sensor is approved in accordance with E/TSO C145a class beta, operational class 3; c) approach system incorporating a class delta GNSS SBAS equipment approved in accordance with E/TSO C146a (or subsequent version). This standard guarantees that the equipment is at least compliant with RTCA DO 229C. The equipment should be a class delta 4; and d) future augmented GNSS systems are also expected to meet these requirements.		Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613.
	Additional requirements have been described as criteria for specific navigation services, in particular for GNSS.	RNP APCH operations down to LP or LPV minima are based on augmented GNSS positioning. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors exceeding the TSE budget, or if means are provided to deselect the other navigation sensor types.	ICAO Doc 9613 (Part C, Chapter 5, 5.3.3.2-Section B)	

Requirement	Description	Detailed Description	References	Support to Certification
RNP AR APCH (Special approval required)	All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. A critical component of RNP is the ability of the aircraft navigation system to monitor its achieved navigation performance, and to identify, for the pilot, whether the operational requirement is or is not being met during an operation.	Lateral accuracy. All aircraft operating on RNP AR APCH procedures must have a cross-track navigation error no greater than the applicable accuracy value (0.1 NM to 0.3 NM) for 95 per cent of the flight time. This includes positioning error, FTE, PDE and display error. Also, the aircraft along-track positioning error must be no greater than the applicable accuracy value for 95 per cent of the flight time. Vertical accuracy. The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track error, system computation error, data resolution error, and FTE. The 99.7 per cent of system error in the vertical direction must be less than the following (in feet): $\sqrt{((6076.115)(1.225)RNP \cdot \tan\theta)^2 + (60 \tan\theta)^2 + 75^2 + ((-8.8 \cdot 10^{-8})(h+\Delta h)^2 + (6.5 \cdot 10^{-3})(h+\Delta h) + 50)^2}$ where θ is the VNAV path angle, h is the height of the local altimetry reporting station and Δh is the height of the aircraft above the reporting station. ***Note:*** *VNAV systems compliant with the performance specification for RNP APCH operations down to LPV minima (see Chapter 5, Section B) meet or exceed this vertical accuracy performance criteria.* System monitoring. A critical component of RNP is the ability of the aircraft navigation system to monitor its achieved navigation performance, and to identify, for the pilot, whether the operational requirement is or is not being met during an operation (e.g. "Unable RNP", "Nav Accur Downgrade"). It should be noted that the monitoring system may not provide warnings of FTE. The management of FTE must be addressed as a pilot procedure. GNSS updating. A crew alert is required when GNSS updating is lost unless the navigation system provides an alert when the selected RNP no longer meets the requirements for continued navigation.	ICAO Doc 9613 EASA CS-ACNS The aircraft must comply with FAA AC 20-129 and either FAA AC 20-130 or AC 20-138, or equivalent. EASA AMC 20-26	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613.
	Additional requirements have been described as criteria for specific navigation services, in particular for augmentation based on GPS, IRS, DME, VHF and multi-sensor systems.	Related to usage of GPS equipment, there is additional guidance related to compliance, system accuracy, position estimation error, etc. Related to IRS, DME and VOR; there is additional guidance related to drift rates, update rates, etc. For multi-sensor systems, there must be automatic reversion to an alternate area navigation sensor if the primary area navigation sensor fails. Automatic reversion from one multi-sensor system to another multi-sensor system is not required. Furthermore details are provided for Altimetry System Error and Temperature Compensations systems.	ICAO doc 9613, Part C, Chapter 6, 6.3.3.3)	

Requirement	Description	Detailed Description	References	Support to Certification
Radius to Fix (RF) Path Terminator	The lateral TSE must be within +/- 1 × RNP of the path defined by the published procedure for at least 95 per cent of the total flight time for each phase of flight and each autopilot and/or flight director mode requested.	The navigation system must have the capability to execute leg transitions and maintain a track consistent with an RF leg between two fixes. The lateral TSE must be within +/- 1 × RNP of the path defined by the published procedure for at least 95 per cent of the total flight time for each phase of flight and each autopilot and/or flight director mode requested. ***Note:*** *1. Industry standards for RF defined paths can be found in RTCA DO-236B/EUROCAE ED-75B (section 3.2.5.4.1 and 3.2.5.4.2).* *2. Default values for FTE can be found in RTCA DO-283A. FAA AC 120-29A, 5.19.2.2 and 5.19.3.1, also provides guidance on establishing FTE values.*	ICAO Doc 9613 (Part C, Ap-pendix 1, 4).	Requirement suitable for direct application of performance based approach within the limits of system requirements defined in ICAO document 9613.
	The autopilot, flight director and flight management computer to have at least "roll-steering" capability and be able to achieve a bank angle up to 25 degrees above 400ft AGL.	An autopilot or flight director with at least "roll-steering" capability that is driven by the RNP system is required. The autopilot/flight director must operate with suitable accuracy to track the lateral and, as appropriate, vertical paths required by a specific RNP procedure. The flight management computer, the flight director system, and the autopilot must be capable of commanding and achie-ving a bank angle up to 25 degrees above 400 ft AGL.		
	The ability of the aircraft to maintain the required FTE after a full or partial failure.	The ability of the aircraft to maintain the required FTE after a full or partial failure of the autopilot and/or flight director should be documented.		

ANNEX A – ATCO FLYER

*(**Note:** Additional information can be found on the EUROCONTROL PBN Portal)*

What’s new with PBN

Knowledge Check

Tower Controllers

SID/DEP
RTF: Issues SIDs no change to RTF
RTF: Unable RNP/RNAV – meaning/possible reasons > action

ARR
RTF: no change > give landing clearance
RVR: can be required for some RNP approaches (chart)
MA: no change – could be due unable RNP (above) – meaning/possible reasons > action

Approach Controllers (SIDs/STARs/RV/Clear aircraft for APCH)

1. SEPARATION/spacing MINIMA – e.g. ADS-B only env and NML:/CONT

2. ATC contingency
   a. RF capability when GNSS fails and RNP not possible.
   b. unable RNP meaning (possible reasons)
      i. that it might be single or multiple aircraft affected
      ii. impact > action + awareness (depends on whether aircraft on SID/STAR/cleared for APP)

Problem		Potential contingency solution	
Possible Cause	**Sample RTF report**	**Impact**	**Action**
Airborne receiver failure or	Single A/C CLEARED FOR APP says ‘unable RNP	RNP APCH procedure not usable by single aircraft	Clear this aircraft for alternative procedure e.g. ILS
Total GNSS signal loss (over an area) – duration unknown	Several aircraft aligned for APP say ‘unable RNP’	RNP APCH procedure not usable by all aircraft	Clear all aircraft for alternative procedure e.g. ILS
Aircraft has FMS failure Total GNSS signal loss (over an area)	One or more A/C ON PBN STAR says ‘UNABLE RNAV’ (Radar Environment)	Flight(s) continue(s) if conventional NAV available throughout Flight(s) turn(s) back if above n/a	Controller to issue Radar Vectors (unless flight crew states that conventional procedures possible). Potentially, traffic flow management regulation
Aircraft with single FMS has FMS failure	A/C ON PBN STAR says ‘UNABLE RNP’	Aircraft cannot fly STAR	Controller Radar Vectors
Total GNSS signal loss (over an area)	(Radar Environment)	Some aircraft cannot fly STAR others can continue normally	Controller Radar Vectors who cannot fly STAR; no action for those aircraft able to fly RNAV STAR
Aircraft has FMS failure	One or more A/C ON PBN STAR says ‘UNABLE RNAV’ (Radar Environment)	Flight(s) continue(s) if conventional NAV available throughout	Controller to issue Radar Vectors (unless flight crew states that conventional procedures possible). Potentially, traffic flow management regulation
Total GNSS signal loss (over an area)		Flight(s) turn(s) back if above n/a	

Problem		Potential contingency solution	
Possible Cause	**Sample RTF report**	**Impact**	**Action**
Aircraft with single FMS has FMS failure	A/C ON PBN STAR says 'UNABLE RNP' (ADS-B only Environment)	Aircraft cannot fly STAR	Vectoring provided using ADS-B
Total GNSS signal loss (over an area)		Some aircraft cannot fly STAR others can continue normally.	Procedural Control (local implementation) and potentially, traffic flow management regulation
Aircraft has FMS failure	One or more A/C ON PBN STAR says 'UNABLE RNAV' (ADS-B only Environment)	Flight(s) continue(s) if conventional NAV available throughout	Vectoring provided using ADS-B
Total GNSS signal loss (over an area)		Flight(s) turn(s) back if above n/a	Procedural Control (local implementation) and potentially, traffic flow management regulation
Aircraft has FMS failure	On or more aircraft on Free Route says 'Unable RNAV' or 'Unable RNP'	Single aircraft cannot continue cleared flight path.	Controller to issue Radar Vectors and continue to maintain separation assurance
Total GNSS signal loss		No aircraft can continue on cleared trajectory	Conventional navigation if available or Radar Vectoring and Traffic Flow Management regulation
Note: *there may be several causes for UNABLE RNP above those included in this table. E.g. jamming or spoofing of the GNSS signal(s); signal interference (e.g. locally, unintentional), space weather.*			

3. Mixed equipage environment/mixed mode (RV+PBN).

4. Path management:
   a. Understand the notion of strategic de-deconfliction in specific (local) airspace concept.
   b. Turn Performance

- RF (RadiuMax intercept angle to final approach path (vertical/lateral) 30°

- Direct To instructions to WPT on STAR or WPT off STAR > then RV.

- Different between RF and Fly By.

- Impact of GPS Outage on RF performance:
   c. c.Impact of alternative controller instructions (speed/alt/track & RF) on published procedure
   d. Terrain clearance responsibility
   e. ACAS in parallel runway operations

5. RTF: Unable RNP/RNAV – meaning/possible reasons > action: established on what?

6. Which PBN Approach options are available at my airports (associated RTF).

7. Management of Helicopters in a PBN environment (if locally applied) – difference PINS.

8. Be able to find PBN Information per flight provided by the ATC System.

9. Be able to correctly interpret the change to the aircraft label in the event of a GNSS outage, if functionality provided by ATC System.

Area controllers (ATS and FRA) – additions to above list

1. Turn anticipation on fly by turns.

2. Impact of GNSS Outage on free routes – function of aircraft ability to fly RNAV 1 without GPS.

3. Be able to find PBN Information per flight provided by the ATC System.

4. Be able to correctly interpret the change to the aircraft label in the event of a GNSS outage, if functionality provided by ATC System.

Nice to know: (AC Handbook for PBN Implementation):

1. Track confidence and level of accuracy of PBN? (link to positioning source used)

2. Chart titling change

3. ACAS in parallel runway operation;

4. Additional Approach Options introduced by PBN

5. AC capability, NAV Infrastructure, ATCO requirements

6. Time limits on GPS outage - impact per flight phase

7. PBN Codes used in the ATC FPL and ATM System Integration

8. mixed mode of operations

9. required elements for different RNAV/RNP specs

10. Operations capability (chicken and the Egg)

11. interaction between different nav specs (what you get including Path Terminators)

12. PBN Box of IAP Chart

13. Common terminology 'phraseology' definitions

14. PBN benefits: environmental mitigation – public consultation needed in support of environmental mitigation (ATCO awareness); CCO and CDO (impact - fuel/emissions) > global/common approach to PBN implementation; environmental mitigation; Noise respite routes;

15. FMS knowledge (see PBN Manual Vol I)

ANNEX B – AIRSPACE DESIGNER PLANNER FLYER

Knowledge Check

All Routes – Fixed or Free

AC Handbook for PBN Implementation, Edition 4 (w.i.p)

- Understand the role played by the navigation infrastructure as regards route placement, when designing an airspace concept.
- Understand the relationship between Communication, Navigation and Surveillance infrastructures when designing an airspace concept.
- Understand the role (including limitations) of the target implementation environment 's ATC system including the FDP/SDP when designating PBN ATS Routes including SIDs/STARs;
- Know and provide airspace design to cater for contingency operations, particularly for a GNSS outage which may compromise a greater/lesser percentage of the fleet's availability to navigate.
- Know how to conduct a fleet survey and analyse PBN fleet equipage data for aircraft operating within the airspace to be design by the airspace designer.
- Know which reliable sources may be used for fleet equipage analysis.

Free Route Operations For Operation In RNAV 5 FRA

Airspace Concept to include available ATS routes for GNSS only aircraft that may not be able to navigate in the event of GNSS outage.

PBN ATS Routes (excl. SID/STARs) Based on RNAV 5

- Understand and apply the principles of strategic de-confliction of fixed PBN ATS routes.
- Understand and apply appropriate crossing between ATS Routes used for climbing/descending traffic to avoid minimum restriction and thus enable CDO/CCO. (This requires understanding of the relationship between vertical vs lateral, and understand how a change in one affects the other).
- Understand the minimum capabilities and limitations of the RNAV 5 specification e.g. that RNAV 5 may not be used within 30 NM of an ARP and it only applies to ATS routes excluding SIDs/STARs according to the PBN IR.
- Understand how to determine usable spacing between RNAV 5 ATS routes and or between RNAV 5 routes and a TRA.
- Understand Fly By Waypoints.
- Understand, calculate and apply turn initiation distance especially for proximate ATS routes.
- Spacing between straight/turning PBN Routes to have taken into account both normal/contingency operations as well as fleet equipage (especially those that are GNSS only equipped) into account. Additionally, when parallel routes turn in parallel, the spacing between the routes must be adapted.

- Know which Navaid infrastructure is able to support RNAV 5 ATS Routes;
- Know how to design contingency procedures in an Airspace Concept to cater for GNSS only aircraft that may not be able to navigate in the event of a GNSS outage.
- Publication of PBN ATS Routes – in place.

PBN SID/STARs using RNAV 1 or RNP 1 WITH RF

- Understand and apply the principles of strategic de-confliction of PBN SIDs/STARs.
- Understand and apply appropriate crossing between PBN SIDs/STARs to avoid minimum restriction and thus enable CDO/CCO. (This requires understanding of the relationship between a SID and/or STARs vertical vs lateral, and understand how a change in one affects the other).
- Understand the difference between RNP 1 and RNAV 1
- Understand that RNAV 1 (or RNP 1 with RF or other advanced functionalities) is to be used for PBN SIDs/STARs according to the PBN IR.
- Understand the difference between a fixed radius turn (RF) and a fly-by turn on SIDs/STARs;
- Understand vertical aircraft performance and usable PBN functionalities to accommodate vertical windows usable with RNP 1.
- Understanding RF functionality, its usability only with RNP 1 specification and its judicious use is required.
- Understand how to determine usable spacing between RNAV 1 SID/STARs and/or between RNP 1 SIDs/STARs (with/out RF) or a combination of these.
- Understand how to determine between an RNAV 1 or RNP 1 SID/STAR and RNAV 5 ATS Route.
- Know that when RNAV 1 SID/STARs turn in parallel, the spacing between the routes must be adapted. Know that when RNP 1+RF SID/STARs turn in parallel, the spacing between the routes need not be adapted.
- Know which Navaid infrastructure is able to support RNAV 1 or RNP 1 (+RF) SIDs/STARs;
- Know how to design contingency procedures in an Airspace Concept to cater for GNSS only aircraft that may not be able to navigate in the event of a GNSS outage.
- Know that spacing between PBN Routes to have taken into account both normal/contingency operations as well as fleet equipage (especially those that are GNSS only equipped) into account. Additionally, the effect of GNSS outage on RF execution and account for this in designing contingency routes.
- Know how to design the Airspace Concept so that it includes contingency procedures for GNSS only aircraft that may not be able to revert to or continue with RNAV 1 in the event of a GNSS outage thus make available radar vectoring areas for approach controllers.

- Understand and be able to weigh up the benefits/disadvantages of different traffic sequencing design concepts in order to select the best option e.g. Point Merge, T-Bar, Trombones;
- Understand and be able to appropriately design open vs. closed procedures;
- Understand the impact on traffic sequencing design concept of high descent slopes;
- Know how to use the available RNAV and RNP functionality in order to maximise CDO/CCO techniques through de-conflicted SID/STARs
- Understand and interpret the publication of PBN SID/STARs published in PANS-OPS including PBN Box.

Nice to know:

16. Track confidence and level of accuracy of PBN?

17. ACAS in parallel runway operation;

18. AC capability, NAV Infrastructure, ATCO requirements

19. Time limits on GPS outage - impact per flight phase

20. PBN Codes used in the ATC FPL and ATM System Integration

21. Required elements for different RNAV/RNP specs

22. Interaction between different nav specs (what you get including Path Terminators)

23. Common terminology 'phraseology' definitions

24. PBN benefits: environmental mitigation – public consultation needed in support of environmental mitigation (ATCO awareness); CCO and CDO (impact - fuel/emissions) > global/common approach to PBN implementation; environmental mitigation; Noise respite routes;

25. FMS knowledge (see PBN Manual Vol I)

ANNEX C – PROCEDURE DESIGN FLYER

What's new due to PBN

Free Route Operations for Operation in RNAV 5 FRA

- Altitude at which procedures will start and end at.
- How does a procedure link directly to FRA? What is the connectivity.
- RNAV 5 is the mandated en route Nav Spec.
- If IFPs connect to Free Route airspace the this will be RNAV 1 as a minimum.

PBN Arrival Routes Based on RNAV 5

- Understand that RNAV 5 may not be used within 30 NM of an ARP and not below the MSA. It only applies to ATS routes excluding SIDs/STARs according to the PBN IR.
- Understand that en route design criteria is to be used.

PBN SID/STARs using RNAV 1 or RNP 1 with RF

- Understand the approach to RNAV and or PNP operations as overlays/underlays of existing conventional procedures.
- Understand that RNAV 1 (or RNP 1 with RF or other advanced functionalities) is to be used for PBN SIDs/STARs according to the PBN IR.
- Understand how to determine usable spacing between RNAV 1 (RNP 1 + RF) SID/STARs.
- Understand the track accuracy; the precision, tolerance of performance, the acceptable deviation (how many aircraft) and mitigation.
- Understand the different Nav Specs (RNAV 5/ RNAV 1/ RNP 1/ RNP 0.3/ RNP APCH and RNP AR APCH), the available path terminators (PT) and specifically for the RF functionality, its use only with RNP specifications and where RF can be employed and where RNP AR APCH is required.
- Understand the importance of judicious use of RF and pressure on the Nav DB.
- Understand the use of speed constraints to manage turn performance; awareness of explicit instructions overriding published constraints.
- Awareness of FMS performance and possible PT execution differences
- Understanding vertical guidance, VNAV (with temp compensation issues), Geometric (but lack of airframes and EGNOS service area) and use of advisory VNAV (in airspace design).
- Understand the benefits of good vertical spacing between crossing tracks to facilitate CCOs and CDOs; highlight the vertical interaction tool (available on the ePBN Portal)
- Understand the impact of ACAS on operations.

- Different design criteria for APV I and LPV 200
- Awareness of terrain and obstacle separation responsibility between ATC and the flight deck; with clear provision of terrain data.
- Awareness of TAWS/EGPWS databases; and any procedure validation requirements of these.
- Understand the design options of Point Merge v Holds, Open and Closed STARs (impact on CDO management), the Trombone and approach design (T or Y).

PBN Approach Procedures

- Understand the philosophy of RNP to xLS
- Understand where aircraft will initiate the approach, and how they will intercept the Final Approach (radar vectoring to intercept a published RNP APCH procedure).
- Understand the different type of minima and the requirements of the PBN IR. Explain OCH, DA/DA and DDH and their relationship to LNAV, LNAV/VNAV and LPV and relate to Type A/B operations.
- Be aware of parallel approach design and opportunities with PBN – 'Established on RNP AR APCH'.
- Understand the approach charting changes – Title change and PBN box. Circular 353 – what, when and how. Does PBN Box follow ICAO or EASA rules?
- GNSS – Awareness of RAIM and provision of information for AUs and ATCOs. The impact of interference (what can cause and outage) and the contingency operations. Be aware of availability of SBAS and where the service volumes are defined.
- If applicable – Understand RNP0.3 for rotorcraft and the design of PINS procedures. Awareness of what can and cannot be done.

Contingency Operations

- Understand reversion strategy – awareness of how ac will be managed, impact on capacity, required infrastructure to support fallback operations. Awareness of costs and expected changes in provision of infra.
- Awareness of FPL data and provision of CNS dashboard information.

Validation and Certification

- Understand FMS coding – airways record requirements (designator & published in AIP), transitions/runway and transitions/en route.
- Understand LOAs and ADQ2.
- PANS OPS OAS versus Annex 14 OCS
- PBN IR implementation dates
- How to manage with a limited design team and/or limited regulatory support.

ANNEX D – AIS FLYER

What's new due to PBN

En Route Airspace

- Understand designation of ATS Routes – what to publish. How does Free Route airspace connect to fixed routes?
- Understand how to publish Free Routes. Use of RAD as well as AIP – be aware of what is lost if no Airways record is created.
- Understand the importance of making Nav Spec clear for airspace and aircraft connectivity
- Understand the information available in Flight Plan
- Understand the importance of provision of GPS status for AUs.
- Understand what RAIM is and why monitoring is important, be aware of where information on RAIM availability is located. RNAV 5 is the mandated en route Nav Spec.
- If IFPs connect to Free Route airspace this will be RNAV 1 as a minimum.
- PBN (RNAV and RNP) position sensor information in AIP.

PBN Arrival Routes Based On RNAV 5

- Understand that RNAV 5 may not be used within 30 NM of an ARP and not below the MSA.

IFP Chart Publication

- Understand the requirements of PBN IR. What is the impact on AIS and when are the target dates
- Understand the ICAO IAP chart title changes and inclusion of PBN box. What, when and how will it be achieved. What are the AIS responsibilities in these changes.
- Understand what information will be published in the PBN box and relate that to phase of flight
- Understand what an APV SBAS requires in terms of the provision of the SBAS and GPS signals. Be aware of EWA agreements and the issuance of SBAS/EGNOS NOTAMS.
- Be aware of the minima lines and what do they indicate to the pilots; OCH, DA/DA and DDH and their relationship to LNAV, LNAV/VNAV and LPV and how they relate to Type A/B operations.
- Be aware of the LP minima and where it is possible it would be used.

Flight Plan

- Understand the reversion strategy – timely issuance of NOTAMS. GPS monitoring and lack of RAIM impact.
- Understand impact of loss of EGNOS signal and which operations will be impacted.

Validation and Certification

- Understand the data flow and best practices in maintaining data integrity.
- Understand ADQ1, LOAs and ADQ2.
- PBN IR implementation dates.
- Understand the importance of rolling out implementations on AIRAC cycle turnover dates

ANNEX E – FLIGHT DISPATCH FLYER

What's new due to PBN

Area		What is new to PBN?
Operations	General knowledge PBN	Understanding PBN Navigation Specifications
Operations	General knowledge PBN	Which aircraft can operate? Having the qualified equipment for the Flight
Operations	General knowledge PBN	Availability of the NAVAID infrastructure, required for the intended routes, including those for use in a non-GNSS contingency, for the period of intended operations using all available information.
	MEL considerations	Understanding of MEL requirements for PBN – Dispatchers/ Operators must adjust the MEL, or equivalent, and specify the required dispatch conditions. Contingency procedures needed.
ICAO flight plan	Item 10 and 18	RNAV/RNP specification approved on aircraft & crew
ICAO flight plan	Item 10 and 18	What do acronyms and symbols mean exactly?
ICAO flight plan	RAIM	AUs with only GNSS - GNSS status information? Operators should use the appropriate ICAO flight plan designation specified for the RNP route flown.
ICAO flight plan	RAIM	Applicability in general of RAIM (AUGUR)

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