**Navigation Minimal Operating Networks**

**(NAV MON) Template**

**State Name**

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TBA

Executive Summary

The shift from facility-referenced navigation to coordinate-based navigation enabled by performance-based navigation (PBN) provides significant benefits, in particular by supplying the flexibility required to design airspace and associated routes and procedures according to operational needs. The most suitable navigation infrastructure to support PBN is GNSS. Consequently, the role of conventional navigation aids is currently evolving towards that of a reversionary terrestrial infrastructure capable of maintaining safety and an adequate level of operations in case of unavailability of GNSS (for example due to outages). During this evolution, terrestrial aids may also enable PBN operations for users not yet equipped with GNSS.

Until a solution to ensure adequate GNSS resilience is available, it is essential that a terrestrial navigation infrastructure, suitably dimensioned to be capable of maintaining safety and continuity of aircraft operations, be provided.

In line with the ASBU elements NAVS-B0/4 element, this plan encompasses the definition of the Minimum Operating Network (MON) of legacy Navaids to sustain the system in case of PBN disruption or degraded operations and addresses the PBN contingency modes.

This plan, developed in partnership with the national authorities ( ANSP, Operators and Airspace users), should be revisited with the introduction of new navigation capabilities and frequently updated and considered as a living document.

1. Introduction

The implementation of Performance-Based Navigation (PBN) on a wide scale in all phases of flight is well under way and is itself a prerequisite for ground-based navigation aids (navaids) rationalization. This is because PBN procedures are enabled by GNSS as the primary navigation means. While some of the ground systems can also support PBN operations (e.g. DME), the role of the ground based navigation infrastructure will evolve towards providing a reversion capability for GNSS and supporting contingency operations in the case of GNSS becoming unusable. This offers the opportunity to rationalize some of the terrestrial infrastructure while retaining a Minimal Operational Network to maintain ATM operations using only ground-based Navaids.

This plan supports the evolution of PBN as the preferred means of navigation by sustaining and expanding the use of GNSS, providing a PBN-capable backup with the DME, and a minimum operational network of VORs to ensure aircraft can navigate safely during GNSS outages.



1. NAVS-B0/4 Navigation Minimal Operating Networks (Nav. MON):

The new element “Navigation Minimal Operating Networks” (NAVS B0/4) has been classified as priority 1 in the MID Region Air Navigation Strategy (MID Doc 002). The main purposes of the NAV MON Element (NAVS B0/4) are:

* To adjust conventional navaids networks through the increased deployment of satellite based navigation systems and procedures to ensure the necessary levels of resilience for navigation.
* To provide a minimum level of capabilities to accommodate State aircraft operations where there is a mismatch in terms of aircraft equipage.
* To make a more efficient use of the frequency spectrum

1. ICAO Strategy

The role of the ground-based Navaids will evolve towards providing a reversion for GNSS and supporting contingency operations in case of GNSS becoming unusable. This evolution offers the opportunity for the rationalization of some of the terrestrial infrastructure and retaining only a Minimum Operational Network (MON) which is designed to efficiently provide reversion service.

However, each Navaid can fulfil different operational roles irrespective of the availability of ATS Surveillance:

- During normal ATM operations, ground-based Navaids support

* PBN applications as a primary positioning source;
* PBN applications as a secondary positioning source to GNSS
* Conventional procedures (e.g. either in an environment where there are no PBN procedures; or to accommodate non-PBN capable aircraft.)

- During ATM contingency operations, ground-based Navaids support

* PBN applications as a back up positioning source due to GNSS outage;
* Conventional procedures as a means of reversion during a GNSS outage;

In order to plan the evolution of the navigation infrastructure in MID Region, it is important to have a thorough picture of the type of operations that can be supported by each type of terrestrial Navaid as per MID PBN Implementation Plan. This understanding will enable States to develop both an optimization and decommissioning plan of Navaids as well as a coordinated evolution to a reversionary terrestrial infrastructure. Table below identifies which ground-based Navaid support which PBN specification.

MID Navigation Specifications and (**R**equired or **O**ptional) Navaid Infrastructure

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | GNSS | IRU | DME/DME | DME/DME/  IRU | VOR/DME |
| RNAV 101 | O | O |  |  |  |
| RNAV 51 | O | O | O | O | O |
| RNAV 11 | O |  | O | O |  |
| RNP 1 | R |  | TBD2 | TBD2 |  |
| RNP APCH | R |  |  |  |  |
| RNP AR | R | O |  |  |  |

*Note 1: For this navigation specification without required navaid infrastructure at least one navaid is requested for the associated navigation application.*

*Note 2: the use of DME/DME for this navigation specification requires a specific State authorization.*

*Note 3: IRU may be integrated with the GNSS sensor to improve performance and continuity of the operation.*

1. **ICAO reversion strategy**

Annex 10 Attachment H defines a global “Strategy for rationalization of conventional radio navigation aids and evolution toward supporting performance based navigation”. The objective of Attachment H is to provide guidance to the States for both the rationalization and reversion of the terrestrial Navaid infrastructure. The recommendations included in this high-level strategy are based on the residual roles foreseen for each type of Navaid to support PBN operations and/or conventional procedures.

Furthermore, consideration of this strategy should be given when deciding investments into new facilities or on facility renewals. As this strategy is highly relevant to the objectives of this plan, key points of this strategy are included below, customized for the MID region.

Operational Considerations for terrestrial Navaids and reversion strategy

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Operational Roles** | **Navigation Performance** | **Specific Limitations** | **Opportunities And Solutions**  **(Residual roles – PBN/conventional)** |
| **NDB** | **PBN** | Exceptionally, can be used  for extraction on the missed  approach for RNP APCH. This  operation is not encouraged. | None | N/A | Rationalize NDB and associated conventional procedures and if NDBs are used to define PBN ATS Routes they should be replaced by RNAV waypoints. Non—Precision Approaches based on NDB should be replaced by RNP APCH. Similarly, if NDBs are used as ILS locators associated with an RNAV procedure intercept, RNAV Waypoints should replace these. |
| **CONV** | Can support en route operations and ATS Routes, SIDS/STARs and NPAs. This is not encouraged. NDB may be paired  with a DME. | Can enable homing to a beacon. When co-located with a DME, ranging information is also available. | Ref Annex 10, Chapter3 |
| **VOR** | **PBN** | Can be used in the en-route phase of flight and arrival segment of an IFP. On the missed approach it can be used for  extraction of an RNP APCH. | Can support a position estimation for RNAV 5. This enables operations in FRA and on RNAV 5 ATS Routes. | (\*) Maximum range of  conventional VOR typically 60  NM; Doppler VOR, typically 75  NM. | The opportunity arises to rationalize some VORs providing cost savings. Introduction of new VORs is not encouraged, but existing ones may be needed to support reversion operations; enhance situational; provide limited inertial updating if DME/DME not available; exceptionally to be used for NPAs if no other option is available; to support aircraft only able to navigate conventionally (this may include state aircraft) and support procedural separation.  The use of VOR(/DME) to support RNAV 5 should be considered only in exceptional cases:  • in areas where DME/DME coverage is not possible (e.g. islands environment)  • in areas where DME/DME coverage is achievable only with high investment and operational cost (e.g. near the bottom of enroute airspace in terrain rich environment) |
| **CONV** | Paired (or not) with a DME can support en route operations and SIDS/STARs and NPA and intercept to the ILS or missed approach. | Can provide bearing information and enable homing to a beacon. When co-located with a DME, range and bearing information is available. | Ref Annex 10, Chapter3 |
| **DME** | **PBN** | Can be used in all phases of flight except final approach. On the missed approach it can be used for extraction. | Can support a position estimation for RNAV 5 and RNAV 1 operations. This  enables operations in FRA, RNAV 5 ATS Routes and RNAV 1 SIDS/STARs. | Minimum range of 3NM  and maximum range of 160 NM for RNAV 1; Below 40° above the horizon as viewed from the DME facility; geometric limitations  between DME pairs of 30° to  150°; | DME/DME provides a fully redundant capability to GNSS for RNAV applications, and a suitable reversionary capability to RNAV 1 for RNP applications requiring a lateral accuracy performance of ±1  NM (95%), providing there is an adequate DME infrastructure.  Many DMEs are co-located with VORs which creates certain limitations. When VORs are decommissioned, this can be an opportunity to optimise the DME network. In such instances, to save costs or to improve DME/DME performance, DME’s can be re-located (ideally with other CNS assets) if a co-located VOR is withdrawn. To be operationally robust, efficient DME network design should fill gaps and provide DME/DME coverage as low as possible without requiring more investment unless needed for safety reasons. (Other solutions such as requiring on-board IRU, reliance on ATS surveillance and/or military TACANS may be viable alternatives). Cross-border use of DME facilities is encouraged supported by the necessary authorisations and/or  agreements. Deployment of new DME stations should avoid that part of the frequency spectrum close to the GNSS L5/E5 band (1164 – 1 215 MHz).  CONCLUSION: The application of the above principles should enable uniformity of DME deployment across the MID region;  It is recognized that in some areas, the provision of D/D navigation is not possible or practical, such as at very low altitudes, in terrain-constrained environments, or on small islands, remote areas and airspace over the water. Finally, it is possible that in some countries there could be an increase in the number of DMEs to support A-PNT.  Note: Some FMS may exclude the use of ILS-associated DMEs. Consequently, it is not possible to ensure consistent D/D service is available to all D/D-equipped users based on ILS-associated DMEs.  Therefore, those facilities should not be planned in the provision of such D/D service (regardless of whether they are published in the en-route section of the AIP), without an appropriate fleet assessment. |
| **CONV** | Paired with a VOR, ILS or NDB, it can support conventional operations.  Stand-alone it can enable the flying of DME arcs. | Can provide range when co-located with a VOR, NDB or ILS. | Ref Annex 10, Chapter3 |

*(\*) If a State wished to use a VOR in excess of the typical ranges stated, then an implementation safety assessment based on a flight inspection demonstration may enable such non-standard use, subject to approval by the competent authority.*

1. **Evolution Strategy**

There is a need to consult aircraft operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed infrastructure solutions. Based on the above, the global strategy is to:

a) Rationalize NDB and VOR and associated conventional procedures;

b) Align rationalization planning with equipment life cycles and PBN implementation planning;

c) Replace conventional approaches without vertical guidance with vertically guided approaches;

d) Where a terrestrial navigation reversion capability is required, evolve the existing DME infrastructure

towards providing a PBN infrastructure complementary to GNSS; and

e) Provide a residual capability based on VOR (or VOR/DME, if possible) to cater to airspace users not

equipped with suitable DME/DME avionics, where required.

1. **National Navigation Minimal Operating Networks**
2. **Main operations supported by VORs in the GNSS contingency concept**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VOR ID | Location | Main operations supported in the GNSS contingency concept | | | | | | | | |
| **IAP** | **TMA** | | | **EN-ROUTE** | | | | |
| IAP  - intercept  - Final  - Missed | Conventional  SIDs/STARs | cross-checking and situational awareness | Conventional  Holding | RNAV 5 and FRA | Conventional  Routes and procedural separation | Situational  Awareness &  Reach Alternate  A/D | RNAV Holding | Conventional  Holding |
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*Description to be*



1. **Evolution of the ground infrastructure towards MON configuration**

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| **Type of NAV facility** | **Location** | **ID** | **Facility life cycle** | | **Rationalization plan** | | **relocation of existing facilities or installation of new facilities** |
| **Start** | **End** | Decommissioning | Replacement |
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1. **Future components of the National Navigation Minimal Operating Networks**

*Description to be added*

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| **Type of NAV facility** | **Location** | **ID** | **Phase of flight (enroute, terminal, approach)** | **Range** | **Purpose of operation** | |
| **Normal operation** | **Contingency operation** |
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