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EUROCONTROL'S CIVIL-MILITARY VIEWS ON A EUROPEAN AIR NAVIGATION STRATEGY

An Overarching Perspective
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OBJECTIVE

This Information Paper presents ATM planners and military stakeholders with key civil-military recommendations for their consideration when developing a European Air Navigation Strategy. It must be seen as non-binding expert-level advisory material prepared by the EUROCONTROL Agency (DATM/CMC/CNS) and consolidated in the civil-military CNS Focus Group.

INTRODUCTION

A European air navigation strategy derives from an airspace concept to meet strategic objectives such as safety, capacity, flight efficiency and airport accessibility, as well as the reduction of environmental impact. A transition to a more modern navigation infrastructure must reflect those objectives.

In this context, Performance-Based Navigation (PBN) is one of the enablers of that airspace concept, as it responds to more stringent airspace requirements than conventional procedures do.

Therefore, any navigation roadmap should be based on predefined airspace design which, on a system level, is supported by the navigation infrastructure that meets the performance requirements identified. Nevertheless, the aircraft NAV avionics suite must comply with the overarching navigation infrastructure (ground- and space-based) and this determines the definition of an integrated architecture that adheres to operational concepts and requirements.

The navigation strategy should synchronise operational concepts with aviation stakeholders' needs, including the military's. In this sense, European navigation arrangements should take State aircraft operational needs into consideration, in particular when they operate as General Air Traffic (GAT). Military-related (ground- and space-based) navigation infrastructure, the enabler of navigation applications, should also feature.

This document sets out EUROCONTROL's civil-military expert-level advisory views and elements to contribute to a technical discussion on some aspects of a European air navigation strategy; it identifies navigation infrastructure solutions and describes airborne equipage challenges facing State aircraft.

DISCUSSION

Navigation Trends

The ICAO Global Air Navigation Plan (GANP) gives strategic guidance for regional and national air navigation planning for civil aviation. In line with the International Civil Aviation Organization's (ICAO) strategic objectives, PBN implementation is the GANP's highest priority.

A navigation baseline was developed under the auspices of the Single European Sky ATM Research (SESAR) framework in SESAR 1 project 15.03.01. It defined the optimum combination of navigation systems (ground- and space-based infrastructure) to support navigation applications.

The main trends associated with the evolution of aeronautical navigation are:

- Migration towards satellite-based navigation (and associated multi-frequency, multi-constellation augmentation systems) as a primary means of navigation, including PBN applications;
- Airspace structures and approach procedures based on PBN applications;
- Evolution of the navigation infrastructure towards a terrestrial PBN support network where Global Navigation Satellite System (GNSS) is not available/used;
- Advent of Trajectory Based Operations (relying on COM enablers but potentially using the Required Time of Arrival (RTA) functionality in the future).

GNSS technology will continue to display some vulnerabilities that justify the transitional retention of ground-based terrestrial navigation aids for reversionary modes of operation. For the longer-term, technology alternatives might have to be considered in accordance with rationalisation plans and the emergence of Alternative-Position, Navigation and Timing (A-PNT).

In ICAO, the migration from the Global Positioning System (GPS) L1 to concurrent use of GPS L5 and other constellations, plus augmentation, is under discussion. It is likely that a multi-constellation/multi-frequency concept will be deployed. Of particular interest for the military will be the possibility of using restricted signals (e.g. GPS Precise Positioning Service (PPS), GALILEO Public Regulated Service (PRS)).

GNSS enables a wide variety of functions like PBN, Automatic Dependent Surveillance-Broadcast (ADS-B), Automatic Dependent Surveillance-Contract (ADS-C), Timing, Synchronisation, Terrain Avoidance Warning System (TAWS), Autonomous Distress Tracking (ADT), etc.

En route and TMA phases of flight

GNSS multi-frequency and multi-constellation technologies as a primary means of navigation

The vast majority of in-service State aircraft already use GPS PPS and, alongside this capability, GALILEO PRS may be introduced in the future. The military could take advantage of the restricted signals available in support of aviation GNSS concepts; they provide significant advantages in terms of avionics rationalisation, security and performance (e.g. robustness)[1].

Nevertheless, it should be highlighted that the use of GNSS restricted signals may only be considered if technological solutions are deemed capable of offering, at least, an equivalent level of performance when compared to original civil requirements and if their use gives operational added value to the military. The process for Performance Equivalence is currently being defined by NATO, EUROCONTROL, the EDA and National Military Organisations. It is expected that they will define the framework process for pursuing this approach for certification.

In summary, a European navigation strategy should not constrain the potential use of stand-alone or combined restricted signals (GALILEO PRS and/or GPS PPS) for State aircraft, if Military Authorities decide accordingly, in a medium/longer-term perspective.

That would respond both to the technological developments (including the potential reutilisation of current military capabilities to meet General Air Traffic-related requirements) and certification/compliance processes to respond to the regulatory framework. In this sense, a European navigation strategy must recognise CNS Performance Equivalence as an alternative process for State aircraft's compliance so that they can navigate as General Air Traffic in controlled airspace (without excluding compliance through other approaches, e.g. straight application of "civil" solutions, where these are more favourable).

Recommendation 1: A European navigation strategy should not constrain the potential use of stand-alone or combined restricted signals (GALILEO PRS and/or GPS PPS) for State aircraft, if Military Authorities decide accordingly, in a medium/longer-term perspective.

[1] EUROCONTROL. Roadmap on Enhanced Civil-Military CNS Interoperability and Technology Convergence. Edition 2.0.

Reversionary mode based on a combination of DME/DME and a gradually reduced network of VORs

A European navigation strategy should also consider reversionary modes based on non-GNSS technologies in order to: 1) enable the co-existence of civil and military flights in the same airspace volumes by accommodating non-equipped aircraft as a transitional step and/or 2) be used as secondary capabilities/gap fillers to ensure the availability of navigation services during GNSS outages/interference.

Currently, GPS is the main enabling infrastructure for PBN applications, namely Area Navigation (RNAV) and Required Navigation Performance (RNP), the latter including On-Board Performance Monitoring and Alerting (OPMA). The focus on DME/DME is justified by the high level of DME infrastructure in Europe as well as by the availability of DME on-board equipage giving navigation information to the cockpit.

In terms of performance, DME/DME can currently support RNAV1 thus ensuring not only safe reversion but also business continuity in the case of GNSS outage. This feature is an essential asset in reducing current GPS L1 vulnerabilities, mainly with regard to interference, and to sustain General Air Traffic operations of some transport-type State aircraft that rely on DME/DME as the primary means of navigation to support PBN-based procedures.

The vast majority of State aircraft are equipped with Tactical Air Navigation aids (TACAN). For the military, these remain the primary means of navigation, providing azimuth/bearing and distance/ranging information for Operational Air Traffic (OAT) operations relying on the TACAN route structure.

Considering that airborne TACAN transponders can interrogate ground DMEs and because of TACAN's relevance to the military and the high equipage rates, this navigation system should be recognised in the navigation strategy as one of the particular aircraft enablers for State aircraft when operating as GAT[2].

Recommendation 2: TACAN should be recognised in the navigation strategy as one of the particular aircraft enablers for State aircraft when operating as GAT.

A significant percentage of State aircraft are not equipped with DME/DME or VOR/DME[3], deemed to support PBN specifications such as RNAV 5 or RNAV 1 (in this case relying on DME/DME capability). As a result, the recognition of the TACAN infrastructure (where available) as an alternative to/complement of DME might provide higher levels of flexibility for State aircraft operations in a PBN-based environment - without prejudicing airborne TACAN interoperability with ground DME provision.

Nevertheless, if a minimum network of VOR/DME (VOR/DME MON – Minimum Operational Network), which might include VORTAC[4] facilities, is maintained, such infrastructure must be acknowledged as a reversionary capability for State aircraft not equipped with DME/DME-capable avionics as well as a contingency network when GNSS signal-in-space (continuity and/or integrity) cannot be used. A VOR/DME network will also allow pilots to maintain situational awareness during radar vectoring or procedural control as well as when proceeding to the closest airport when diverting.

Recommendation 3: VOR/DME (or VORTAC) MON infrastructure must be acknowledged as a reversionary capability for State aircraft not equipped with DME/DME-capable avionics.

Reversionary mode based on Alternative-Position, Navigation and Timing[5]

The reversion to A-PNT navigation should be provided on the basis of the same performance level required by the nominal navigation mode and by allowing normal operations to continue.

Should an A-PNT solution based on DME/DME/IRS be envisaged (assuming that the implementation of a solution based on new technologies would require a longer time period), ground TACAN must be considered as an equivalent means of navigation to DME, provided that ICAO Annex 10 requirements are met by such TACANs. Nevertheless, it is important that the navigation strategy recognises that A-PNT is not yet fully defined and that research activities are still ongoing in the SESAR 2020 context.

2 EUROCONTROL. Roadmap on Enhanced Civil-Military CNS Interoperability and Technology Convergence. Edition 2.0.
3 Information derived from General Air Traffic flight plan information.
4 Very High Omnidirectional Radio Range/Tactical Air Navigation (VORTAC) is a navigational facility consisting of two components, VOR and TACAN, which provide three services: VOR azimuth, TACAN azimuth, and TACAN slang range. The DME portion of the TACAN is available for civil use.
5 A-PNT is currently subject of research in SESAR 2020.

The initial A-PNT findings emerging from the SESAR framework predict that the short-term mitigations for GNSS outages will mainly rely on the use of DME/DME navigation. This means that a short-term solution will focus on the DME technical system while longer-term options may include new technologies, such as Mode N or the use of data link, to support A-PNT. DME/DME is commonly considered to support RNAV applications only, which leads to the perception that in case of loss of RNP capabilities based on GPS, reversion to a lesser navigation capability and associated mitigation measures become necessary[6].

However, under the SESAR programme (SESAR 1, project 15.03.02), a concept of an equivalent ground-based concept to OPMA, aimed at providing a fully equivalent capability for at least RNP1 navigation applications based on DME/DME, has also been formulated. Subsequent activities have been proposed in EUROCAE, supported by the continued effort in SESAR to provide a formally documented, standardised concept and means of compliance to allow DME/DME positioning capabilities to support RNP1 navigation applications[7].

Recommendation 4: For A-PNT, ground TACAN must be considered as an equivalent means of navigation to DME.

Air Traffic Control (ATC) vectoring as an ultimate (conventional) reversionary navigation solution

ATC vectoring might be recognised as an optional procedure to handle non-equipped traffic, including State aircraft flying as GAT in PBN airspace. ATC may also provide navigation assistance during GNSS outage in areas where communications and surveillance remain available.

However, for safety and capacity reasons, in general it is not recommended to rely on ATC vectoring as the sole reversion mode, which means that an alternative navigation service is needed in order to allow the pilot to maintain situational awareness and reduce cockpit workload. In this case, contingency operations might be supported by a minimum VOR/DME (or VORTAC) network.

Recommendation 5: ATC vectoring might be an optional procedure to handle non-equipped traffic, including State aircraft, but shall not be the sole reversion.

Approach phase of flight

Means of navigation to support ICAO type A approaches – non-precision approaches

State aircraft are mainly equipped with conventional means of navigation that support non-precision approach procedures (ICAO type A approaches). The possible new challenge for State aircraft operations, possibly conducted at secondary airports, could result from the implementation of approach procedures with vertical guidance (APVs) (PBN RNP APCH specification) and associated PBN functionalities, in instrument runway ends (in particular where no vertical guidance is available).

APVs at European secondary airports, which might not retain conventional means of navigation, will probably have more impact on State aircraft operations due to the lower level of State aircraft on-board equipage to fly either APV Baro (LNAV/VNAV) or APV SBAS (LPV) procedures.

Therefore, conventional means of navigation might need to be retained, not only to sustain the reversion to a contingency backup, but also to be an option for handling non-equipped State aircraft. Moreover, reversion to ATC vectoring supported by a minimum operational network of VOR/DME (or VORTAC) might also be considered in areas where radar service is available for supporting aircraft not equipped with a DME/DME capability.

Recommendation 6: Where RNP APCH is introduced, conventional means of navigation might need to be retained as an option for handling non-equipped State aircraft.

Means of navigation to support ICAO type B approaches - Category I precision approaches

An Instrument Landing System (ILS) is the preferred option for State aircraft operations as the majority of State aircraft are equipped with Multi Mode Receivers (MMR) that comprise this capability (those which, at equipage level, are able to carry out precision approaches), despite the fact that the Precision Approach Radar (PAR) is still a military (NATO) standard.

The new ICAO approach classification introduces SBAS as one of the GNSS augmentation capabilities that currently meet CAT I operations (SBAS Cat I), in addition to Ground-Based Augmentation System (GBAS)

6 SESAR JU (PJ15.03.01). (2016). SESAR Navigation Baseline and Roadmap. D9. Edition 00.01.01.
7 EUROCAE (Technical Advisory Committee). (2017). Alternate Positioning, Navigation and Timing. DP-114.

and ILS/MLS. The introduction of type B approaches relying on SBAS Cat I raises new challenges for State aircraft, since the vast majority of those aircraft are not equipped with SBAS receivers (EGNOS or WAAS). Given that SBAS is considered to be one of the most cost-effective ways of maintaining approach procedures, the widespread implementation of SBAS-related procedures down to CAT I minima will probably be regulated and implemented in Europe for a significant number of IREs in the medium- and/or long-term.

Nevertheless, where SBAS Cat I is implemented, the criticality of the phase of flight raises the need for adequate reversionary capability either by advocating ILS as a complementary means of navigation or by providing conventional procedures with degradation of the mode of operation.

With regard to GBAS, it is recognised that this system might become the main future technical solution for precision approaches down to CAT III performance. Therefore, the introduction of GBAS could be expected at the busiest airports in Europe, either as a primary means of navigation for precision approaches or as a replacement for ILS.

The retention of ILS capability ensures redundancy and provides flexibility for handling State aircraft not equipped with either SBAS or GBAS in a medium- and long-term perspective. Besides, it provides backup services in satellite outages or GNSS SIS interference. Where ILSs are used to support State aircraft operations, they should not be replaced by other means of navigation without prior civil-military coordination.

Recommendation 7: ILSs should not be replaced by other means of navigation without prior civil-military coordination where they are used to support State aircraft operations.

'Self-contained' navigation solutions

A navigation system option which provides positioning information to the pilot without relying on the availability of ground- or space-based navigation systems is considered to be a 'self-contained' system. In this area, inertial navigation systems have been identified as enablers.

The ICAO PBN Manual recognises inertial systems as one of the capabilities that can meet RNAV 5 performance, which is the envisaged requirement for the en route phase of flight. These systems can be used either as a stand-alone capability or as part of a multi-sensor RNAV system. In this sense, considering that the majority of State aircraft are equipped with inertial systems, such systems could be used to meet RNAV 5 requirements, for a specific time or for the duration of a flight.

For more stringent performance, inertial systems might be considered to complement DME (TACAN for the military) coverage as well as a reversionary capability/gap filler within the safety limits. The specific nature and performance of military INS/IRS might increase the "status" of such enablers for wider usage, and therefore, for other navigation functions and not only as a gap filler option. But that still depends on further investigation and research. The use of military inertial systems may also be considered in relation to Performance Equivalence processes.

Despite being a GNSS system, Advanced Receiver Autonomous Integrity Monitoring (ARAIM) is also considered as a "self-contained" system based on the fact that augmentation in reaching GNSS capability is mainly carried out on board. However, it should not be overlooked that this particular enabler does depend on the space-based segment.

The performance of ARAIM must also be taken into consideration as a means of navigation for en route, terminal and approach procedures down to Category I in a long-term perspective for some State aircraft operations. ARAIM is currently expected to be implemented incrementally. The concept of ARAIM will be fielded to support horizontal guidance (H-ARAIM) services only as a first step. It is envisaged that it will become available as of 2023 and, at a later stage, it will also support vertical guidance (V-ARAIM) for precision approaches down to 200ft decision height, with potential full service in the 2035+ timeframe[8]. However the number of RAIM-equipped State aircraft remains low.

[8] EU-US Cooperation on Satellite Navigation (Working Group C – ARAIM Technical Subgroup). (2016). Milestone 3 Report. Final Version.

Recommendation 8: Inertial systems might be considered to complement DME (TACAN for the military) service coverage as well as providing a reversionary capability/gap filler within the safety limits. The specific nature and performance of military specific INS/IRS might increase the "status" of such enablers for more stringent navigation functions.

Recommendation 9: The performance of ARAIM must also be taken into consideration as a means of navigation for en route, terminal and approach procedures down to Category I in the long-term perspective for some State aircraft operations, depending on the progress of aircraft equipage.

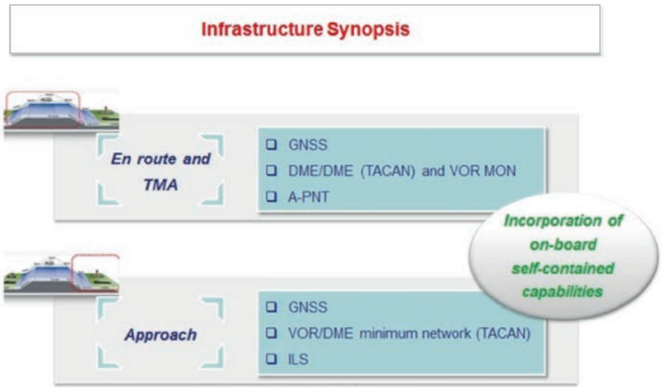

Figure 1. Infrastructure synopsis for all phases of flight.

NAV Infrastructure rationalisation

Infrastructure rationalisation strategies should ensure that a minimum navigation infrastructure guarantees the continuity of operations, endeavouring to ensure the same levels of performance or appropriate degraded modes of operations in accordance with local performance requirements.

State aircraft, in any kind of operation, must be able to operate in all-weather conditions, day or night. This requirement must be also valid when flying in controlled airspace, at civil airfields, and when conducting military training in a mixed environment with civil traffic. Therefore, taking into account the specifics of State aircraft operations, civil-military coordination and cooperation must be considered on both European and State levels.

Infrastructure rationalisation decisions should also cater for State aircraft specifics/equipage levels and needs. A minimum ground-based legacy navigation infrastructure should remain in place in order to enable State aircraft-related operations.

A minimum VOR network - including the retention of a residual number of VORs to support State aircraft local operations, mainly in the vicinity of military airports - should be subject to civil-military coordination on local levels in order to cope with limited/mismatched airborne equipage.

DME/DME-based positioning has been identified as an essential near-term capability to support PBN operations, in both en route and terminal areas. With the high coverage of installed DME infrastructure in Europe as well as DME on-board equipage, this system option should be retained in an optimised way (with due care taken of spectrum constraints). A terrestrial DME/DME capability to support PBN can safeguard both safety and business continuity for the large majority of air operations in Europe, while mitigating concerns about GNSS outages/availability.

TACAN structures for en route and terminal operations should remain in place until an alternative military consolidated navigational system has been implemented. This will increase airspace flexibility as well as overcoming the coverage limitations inherent in the European DME network through the use of the DME component of TACAN, without jeopardising military navigation infrastructure plans/decisions.

The emergence of GNSS-based approach and landing systems as primary means of navigation (e.g. GBAS or SBAS based on EGNOS) underlines the need to retain ILS capability until complete convergence is met in the long-term or until a military standard precision approach and landing system has been adopted. Considering that the majority of State aircraft equipped with precision approach capability rely on ILS, this navigation system must be the main system option for State aircraft operations down to 200ft in the short- and medium-term, at least.

As the levels of PBN on-board equipage gradually increase, incentive mechanisms are crucial in order to promote the equipage of those State aircraft on-board capabilities needed for GAT operations that are based on regulated PBN applications. This will be particularly relevant for transport-type State aircraft flying as GAT.

Recommendation 10: Infrastructure rationalisation decisions should also cater for State aircraft specifics/equipage levels and needs. A minimum ground-based legacy navigation infrastructure should remain in place in order to enable State aircraft-related operations.

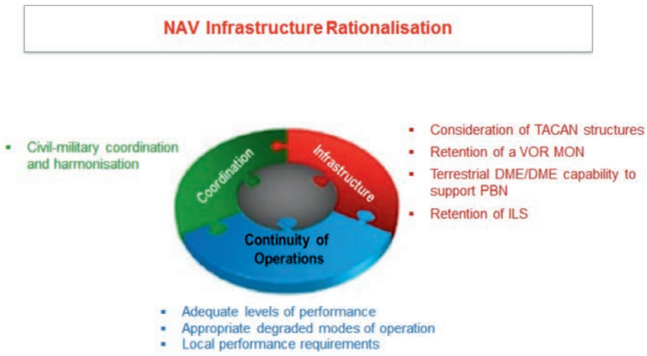

Figure 2. The three key areas for NAV infrastructure rationalisation decision making.

CONCLUSION

The introduction of PBN will lead to a network-like navigation infrastructure instead of a modular one. Therefore, ground- and space-based system options must offer defined levels of performance that support airspace requirements and aircraft operations - including those carried out by State aircraft - efficiently.

The multitude of NAV system options should be assessed in the context of an airspace concept that satisfies strategic objectives - such as safety, capacity, flight efficiency, airport access - and which mitigates environmental impact. Nevertheless, an integrated architecture composed of the navigation infrastructure and aircraft NAV avionics suite is crucial for the harmonised implementation of new airspace requirements.

Satellite-based navigation systems are expected to become the primary means of navigation for all phases of flight. This raises the need for aircraft performance that meets the airspace procedures and related NAV applications in place. Nevertheless, the robustness of the satellite-based services depends on the availability of reversionary ground-based capabilities.

Therefore, a navigation strategy should be based on the combination of ground- and space-based infrastructure that meets both the airspace requirements and airspace users' needs, including those of the military. The assessment of the system options that will fit with a proposed strategy should rely on appropriate levels of civil-military coordination and harmonisation in order to ensure the continuity of State aircraft operations.

The retention of ground-based navigation infrastructure, in accordance with State's needs, is crucial for sustaining State aircraft operations in controlled airspace and at civil airports, since a significant percentage of State aircraft are not equipped with on-board capabilities that meet the most stringent PBN applications.

The future European air navigation strategy must take due account of and offer opportunities for the re-utilisation of available military capabilities like GPS/PPS, TACAN (used in a DME environment), ILS in military multi-mode receiver configurations as well as inertial systems on military aircraft.

ABBREVIATIONS

ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
ADT	Autonomous Distress Tracking
APCH	Approach
A-PNT	Alternative-Position, Navigation and Timing
APV	Approach procedure with vertical guidance
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
ATC	Air Traffic Control
CNS	Communications, Navigation and Surveillance
DME	Distance Measuring Equipment
EDA	European Defence Agency
EGNOS	European Geostationary Navigation Overlay Service
EUROCAE	European Organisation for Civil Aviation Equipment
GANP	Global Air Navigation Plan
GAT	General Air Traffic
GBAS	Ground-Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INS	Inertial Navigation System
IRE	Instrument Runway End
IRS	Inertial Reference System
LNAV/VNAV	Lateral Navigation/Vertical Navigation
LPV	Localizer Performance with Vertical Guidance
MLS	Microwave Landing System
MMR	Multimode Receiver
NATO	North Atlantic Treaty Organization
OAT	Operational Air Traffic
OPMA	On-Board Performance Monitoring and Alerting
PBN	Performance-based Navigation
PPS	Precise Positioning Service
PRS	Public Regulated Service
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SBAS	Satellite-based Augmentation System
SESAR	Single European Sky ATM Research
SIS	Signal-In-Space
TACAN	Tactical Air Navigation Aid
TAWS	Terrain Avoidance Warning System
VOR	VHF Omnidirectional Radio Range
VORTAC	Omnidirectional Radio Range/Tactical Air Navigation System
WAAS	Wide Area Augmentation System

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