International Civil Aviation Organization

AN-Conf/12-WP/22
17/5/12

WORKING PAPER

TWELFTH AIR NAVIGATION CONFERENCE

Montréal, 19 to 30 November 2012

Agenda Item 6: Future Direction
6.1: Implementation plans and methodologies

RATIONALIZATION OF TERRESTRIAL NAVIGATION AIDS

(Presented by the Secretariat)

EXECUTIVE SUMMARY

The implementation of performance-based navigation (PBN) offers an opportunity for the rationalization of terrestrial navigation aids. The pace of rationalization depends on the level of PBN avionics equipage in the aircraft fleet and on the development of PBN airspace and procedures. Equipage depends to a great extent on demonstrating capacity, efficiency and environmental benefits as well as cost savings, which will be greatest at the point where aids reach the end of their life cycle and require replacement. The vulnerability of the global navigation satellite system (GNSS) signals to interference and natural phenomena dictates the retention of a minimum network of terrestrial aids to ensure that aircraft can proceed to and land safely at a suitable airport. States, air navigation service providers (ANSPs) and aircraft operators need to work together to accelerate the transition to PBN and to define a minimum network of terrestrial aids that meets safety and efficiency goals.

Action: The Conference is invited to agree to the recommendation in paragraph 7.

Strategic Objectives:	This working paper relates to the Safety and Environmental Protection and Sustainability of Air Transport Strategic Objectives.
Financial implications:	The main purpose of implementing a rationalization of terrestrial navigation aids is to obtain savings in current infrastructure costs.
References:	Annex 10 — *Aeronautical Telecommunications* Doc 9613, *Performance-based Navigation (PBN) Manual* Doc 9849, *Global Navigation Satellite System (GNSS) Manual* AN-Conf/12-WP/21

1. INTRODUCTION

1.1 Over the last two decades, the ICAO navigation systems strategy called for a transition to performance-based navigation (PBN) supported by a global navigation satellite system (GNSS). From the outset it was recognized that this transition would ultimately provide the opportunity to realize economic benefits by requiring a lower density of terrestrial navigation aids.

1.2 Since the Eleventh Air Navigation Conference, there has been significant progress within ICAO to resolve the issues that constrain the implementation of PBN operations. The most significant achievement has been the completion of the *Performance-based Navigation (PBN) Manual* (Doc 9613), which provides the necessary navigation specifications and guidance for the implementation of PBN airspace concepts in a globally harmonised manner.

2. AIRCRAFT CAPABILITIES AND RELATED OPPORTUNITIES

2.1 Today, the majority of large commercial aircraft have a PBN capability (RNAV and in some cases RNP). In some regions, it is mandatory for aircraft to meet certain PBN specifications. For example, Europe implemented a mandatory RNAV 5 (BRNAV) carriage requirement in all en-route airspace in 1998. Some aircraft achieve such basic RNAV performance without GNSS avionics, and so require the availability of an appropriate terrestrial navigation infrastructure within the region (typically based on DME). However, GNSS-based PBN equipage levels are increasing and are expected to continue to increase. This trend provides an opportunity to rationalize terrestrial infrastructure, particularly in areas with a high density of terrestrial navigation aids.

3. CURRENT TERRESTRIAL NAVIGATION INFRASTRUCTURE

3.1 The current terrestrial navigation infrastructure comprising of VHF omni-directional radio range (VOR), distance measuring equipment (DME) and non-directional radio beacon (NDB) navigation beacons was initially deployed to support conventional navigation along routes aligned between VOR and NDB facilities. As traffic levels increased, new routes were implemented which in many cases necessitated additional navigation facilities to be installed.

3.2 As a result, a non-uniform distribution of navigation aids has developed, whereby some areas (e.g. within North America and Europe) have a high density of terrestrial navigation aids while many other regions have a low density or no terrestrial navigation infrastructure.

3.3 However, with the evolution of aircraft navigation capability through PBN, and the widespread use of GNSS positioning, it is no longer true that regions of high traffic density need a high density of navigation aids. This situation presents a potential for the rationalization of the terrestrial infrastructure.

4. FUTURE TERRESTRIAL INFRASTRUCTURE REQUIREMENTS

4.1 The existing single frequency GNSS, as standardized in Annex 10 — *Aeronautical Telecommunications*, can support all levels of PBN on a global basis. With suitable augmentations as standardized within Annex 10, single frequency GNSS has the capability to support all phases of flight.

4.2 However, GNSS does not have adequate resilience to a number of vulnerabilities, most notably radio frequency interference and solar events causing ionospheric disturbances (see also AN-Conf/12-WP/21, paragraph 2.2).

4.3 Furthermore, development of a more advanced GNSS infrastructure, including dual frequency and multiple core constellation, which could mitigate such vulnerabilities, has lagged behind expectations.

4.4 It is therefore essential that a suitably dimensioned terrestrial navigation infrastructure be maintained, capable of maintaining safety and continuity of aircraft operations, taking into account the current status of aircraft equipage for PBN operations supported by GNSS and terrestrial navigation aids.

5. INFRASTRUCTURE RATIONALIZATION PLANNING

5.1 Initial plans for rationalization in several States followed the model of a 'top-down' process whereby it was hoped that the implementation of GNSS-based PBN within volumes of airspace would make terrestrial aids redundant to the point where the majority of them could be eliminated.

5.2 However, while the benefits of PBN are generally agreed in principle, it is not always easy to justify the case for full implementation of PBN within a volume of airspace unless there are capacity or safety issues to be addressed. Furthermore, even where new PBN routes have been implemented to gain operational benefits, most of the existing conventional routes have not been decommissioned. As a consequence, a 'top-down' rationalization process could take a long time to be completed.

5.3 As an alternative to the 'top-down' process, a 'bottom-up' process should therefore be considered. The justification for this approach arises from the consideration that the greatest economic benefits from rationalization come from avoiding the replacement of navigation aids at the end of their lifecycle. Therefore, rationalization efforts would be most beneficial if directed to address specifically those navigation aids that have reached the end of the lifecycle.

5.4 This should be done on the basis of an analysis aimed at identifying rationalization opportunities, evaluating the necessary route changes and ascertaining whether a limited PBN implementation on the affected routes would be more cost effective than the replacement of the aids. The analysis should also take into account other uses of the infrastructure beyond those promulgated in the AIP (e.g. to meet the needs of State operators, to support aircraft operators' contingency procedures, etc). This strategy will also provide a catalyst to start the airspace transition to a full PBN environment.

5.5 Finally, it should be mentioned that in addition to the physical rationalization of navigation aids, many airports have multiple instrument approach procedures that have been added over time and may include ILS, LNAV/VNAV, localizer, VOR and NDB non-precision approaches, VDF let-downs and surveillance radar approaches. Many of these procedures incur maintenance costs, and operator and air traffic control (ATC) training overheads. There are potential cost savings to be achieved through the withdrawal of non-essential approach procedures, which may lead to the opportunity to remove the associated navigation facilities.

6. OTHER RATIONALIZATION CONSIDERATIONS

6.1 The ultimate goal of rationalization is to evolve to a correctly dimensioned infrastructure (a "minimum network") that will make it possible to cope with a temporary loss of GNSS service, as discussed in paragraph 4 (see also AN-Conf/12-WP/21, paragraph 2.5).

6.2 The fundamental requirement to be met by the "minimum network" is to maintain safety following the loss of GNSS service. There is also a requirement to maintain a level of efficiency and continuity of operations that will meet agreed aircraft operators' expectations to the extent possible.

6.3 These requirements may be met in en route continental and terminal airspace by on board inertial systems and remaining terrestrial aids. In oceanic and remote continental airspace, where the threat of GNSS signal interference is much lower, most aircraft are equipped with inertial systems. ATC may also provide navigation assistance in areas where communications and surveillance are not dependent on GNSS. With regard to approach and landing, the minimum network would be based on the instrument landing system (ILS), with only limited potential for rationalization in areas with a high density of ILS Category I facilities.

6.4 In general, rationalization and mitigation strategies will need to be tailored to suit different traffic levels, aircraft capabilities, threat levels, and aircraft operators' expectations. For instance, major air carriers will likely require a 'near normal' service with minimum impact on capacity. General aviation and helicopter operators whose operations are primarily conducted in accordance with visual flight rules will be better able to tolerate an outage.

7. CONCLUSION

7.1 The implementation of PBN offers an opportunity for the rationalization of terrestrial navigation aids. Such rationalization should be performed taking into account the navigation aid replacement cycle and the need to retain a minimum network of terrestrial to mitigate the potential loss of GNSS service. On this basis, the Conference is invited to agree to the following recommendation:

Recommendation 6/x – Rationalization of terrestrial navigation aids

The Conference recommends that, in planning for the implementation of performance-based navigation, States should:

a) assess the opportunity for realizing economic benefits by reducing the number of navigation aids through the implementation of performance-based navigation;

b) ensure that an adequate terrestrial navigation and air traffic management infrastructure remains available to mitigate the potential loss of global navigation satellite system service; and

c) align performance-based navigation implementation plans with navigation aid replacement cycles, where feasible, to maximize cost savings by avoiding unnecessary infrastructure investment.

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