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WORKING PAPER

THIRTEENTH AIR NAVIGATION CONFERENCE

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COMMITTEE A

Agenda Item 2: Enabling the global air navigation system
2.2: Integrated CNS and spectrum strategy

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) EVOLUTION

(Presented by the Secretariat)

EXECUTIVE SUMMARY

This paper discusses the evolution of the global navigation satellite system (GNSS) towards the introduction of dual-frequency, multi-constellation (DFMC) services. It outlines the standardization process currently underway, the expected benefits, the long-term goal of seamless global acceptance of DFMC GNSS, the challenges in achieving the goal, and presents a way forward for ICAO and States to meet those challenges.

Action: The Conference is invited to agree to Recommendation 2.2/x — Global navigation satellite system (GNSS) evolution in paragraph 3.2.

Strategic Objectives:	This working paper relates to the Safety and Air Navigation Capacity and Efficiency Strategic Objectives.
Financial implications:	*Impact for the aviation community:* The increased performance and robustness provided by DFMC GNSS will enable the achievement of operational benefits and the optimization of the navigation infrastructure. The financial implications would be mainly associated with the need for new avionics, and with the costs to States implementing DFMC GNSS elements and revising aeronautical publications. *Impact for ICAO (relative to the current Regular Programme Budget resource levels)*: Since ICAO's current Standards and Recommended Practices (SARPs) development and implementation roll-out will continue over the next triennia, additional resources are required to support ICAO's work on GNSS evolution.
References:	Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids* Doc 9750, *Global Air Navigation Plan*

1. INTRODUCTION

1.1 The global navigation satellite system (GNSS), as standardized by ICAO, is an essential enabler of the performance-based navigation (PBN) concept, and supports safer and more efficient flight operations on a global basis.

1.2 The current emergence of dual-frequency, multi-constellation (DFMC)[1] GNSS offers an opportunity to further enhance GNSS navigation performance and operational benefits. This paper discusses the evolution towards gradual introduction of DFMC GNSS as a key element of the Navigation Roadmap defined in the ICAO Global Air Navigation Plan[2].

2. DISCUSSION

2.1 *Current use of GNSS.* Current civil aviation use of GNSS is predominantly based on a single frequency of a single GNSS satellite constellation, namely the L1 frequency of the US Global Positioning System (GPS) constellation, which provides the foundation for the global implementation of PBN and automatic dependent surveillance (ADS). Within the Russian Federation, similar applications based on a single frequency of the Global Navigation Satellite System (GLONASS) constellation are in operation. In addition to PBN and ADS, GNSS is also used in many other aircraft applications that require position or time information. They include aircraft systems (such as the ground proximity warning system) that have led to significant improvements in safety. Since the introduction of GNSS in aviation, there has been increased dependency on GNSS position and time, and it is expected that this trend will continue as new applications are introduced and the conventional navigation infrastructure is rationalized.

2.2 *Evolution towards DFMC GNSS.* The evolution of the various GNSS elements[3] towards DFMC will take place gradually. GNSS constellations offering dual-frequency signals will be introduced into service during the 2020s by the United States (GPS), the Russian Federation (GLONASS), Europe (Galileo) and China (BeiDou). A number of States and regions also plan to deploy DFMC satellite-based augmentation systems (SBAS). Ground-based augmentation systems (GBAS) already support single-frequency dual-constellation GNSS and it is expected that they will evolve to support DFMC. Even after the introduction of DFMC, current GNSS services and equipment will remain a solution for many aircraft and will be supported by the DFMC infrastructure to allow backwards compatibility.

2.3 *Standardization.* Draft ICAO SARPs for DFMC GNSS core constellations and augmentation systems are currently being developed by the NSP. In parallel, industry standardization activities for DFMC GNSS avionics have started. Avionics standards will be consistent with SARPs requirements. Initial implementation and certification on commercial aircraft is expected to follow, at a pace that will depend on the costs and benefits for the initial capabilities. The timeline of ICAO and industry developments suggests that the initial operational introduction of DFMC GNSS would occur in the 2025 - 2028 timeframe. In the long term, it is expected that avionics standards will be available to enable the use of all DFMC GNSS elements and signals.

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[1] The term DFMC GNSS refers to any dual-frequency implementation of up to four GNSS constellations with associated aircraft-, ground- and satellite-based augmentations systems (ABAS, GBAS and SBAS respectively).

[2] The considerations presented in this paper are based on a Concept of Operations (CONOPS) for DFMC GNSS developed by the Navigation Systems Panel (NSP), taking into account inputs from other ICAO expert groups, Regional Offices and external entities, including recognized standards-making organizations. The CONOPS is an informal document, intended to build consensus on how new GNSS technology will be introduced in ATM in a safe and cost-efficient manner bringing operational benefits while addressing identified technical and institutional challenges.

[3] GNSS elements are defined in Annex 10, Volume I, Chapter 3, 3.7.2.2. They include GNSS core constellations, augmentation systems and aircraft receivers.

2.4 *Benefits.* DFMC GNSS can improve robustness and navigation performance. The use of dual frequencies will help mitigate vulnerabilities in respect of ionospheric disturbance and of radio frequency interference affecting a single frequency. The availability of multiple constellations will contribute to mitigate ionospheric scintillation and the risk of having insufficient satellites within a single constellation. These technical improvements will enable operational benefits in terms of safety and efficiency, such as improved operational reliability for communications, navigation and surveillance (CNS) applications, increased deployment of 3D instrument approach operations worldwide in line with ICAO PBN global goals, introduction of innovative operational concepts and applications and continued rationalization of conventional navigation aids. The value of these operational benefits will vary among different stakeholders. The actual achievement of the benefits will depend on GNSS service performance capabilities, the percentage of aircraft equipped with DFMC avionics, the number of GNSS elements in use, the ability of DFMC to support existing operational procedures and to be integrated into the air traffic management (ATM) system in a way that is as transparent as possible to the flight crew and ATC.

2.5 *Long-term goal.* GNSS is a seamless, global system that broadcasts signals that can be received independent of airspace boundaries. To fully achieve the benefits associated with the seamless nature of GNSS, a desirable long-term goal is that all States be able to accept, for lateral navigation use[4] in their airspace, all GNSS elements standardized by ICAO. Aircraft could then independently select suitable combinations of GNSS elements, subject only to compliance with the applicable SARPs and PBN navigation specifications, rather than dependent on airspace boundaries. This would increase availability and continuity of operations while limiting avionics complexity, and thus best meet aircraft operators' needs.

2.6 *Medium-term challenges* In practice, the process of acceptance of GNSS elements by States can be complex and run into hurdles that may affect the achievement of the long-term goal. In general, before acceptance for use in a State, several steps may need to be considered. They include approval of the GNSS element for aviation use by the entity managing it, airworthiness approval (avionics certification), operational approval issued to the operator, and acceptance of the use of the element for specific operations in an airspace. While the current processes addressing the first three steps provide a basis that can be directly applied to DFMC, experience has shown that institutional concerns and/or regulatory requirements may delay the acceptance of the use of GNSS elements in a given airspace, and/or lead to restrictions on their use.

2.7 *Way forward: ICAO actions.* To facilitate the progress towards the long-term goal against the challenges outlined above, there is a need for ICAO to develop guidance material to assist States in minimizing regulatory and institutional hurdles to acceptance and use of current and future GNSS elements. This material would primarily be aimed at supporting the decision-making process of States considering the use of GNSS elements over which they do not have direct control. Additionally, there is a complementary need for ICAO to develop provisions intended for States and organizations that provide GNSS elements (e.g. core constellation providers). Such provisions would address the publication of service performance standards, regular performance assessments, and notification of events that may affect the service. They would further facilitate the acceptance of GNSS elements by other States by making available information that would assist their decision-making process. These ICAO developments will have to be coordinated with recognized standards-making organizations and other aviation stakeholders to ensure that all the dimensions of the challenges are fully addressed.

2.8 *Way forward: States' actions.* States should be aware of the long-term goal outlined in 2.5 and should aim to achieve it to the extent possible. In particular, States should note that restrictions on the use of GNSS elements may in some cases have a negative impact on safety by denying the associated safety benefits. Accordingly, States should avoid prohibiting the use of GNSS elements that are compliant

[4] GNSS is used for lateral navigation in PBN applications for oceanic, en-route, terminal area navigation, and for RNP AR, LNAV and BaroVNAV approaches. GNSS elements used for approaches with vertical guidance based on GNSS and defined by a final approach segment data block will continue to be specified by States through the information contained in the data block.

with the applicable SARPs. States should also note that the introduction of mandates for equipage or use of specific GNSS elements in different States or regions could significantly impact users in terms of additional cockpit controls and procedures, crew training and maintenance support, and possibly raise human factors concerns. Accordingly, they should carefully consider and assess if mandates for equipage or use of any GNSS element are necessary or appropriate. More generally, States should recognize that lack of global uniformity in the acceptance of GNSS will increase equipment complexity and associated costs and will delay achievement of the potential benefits. States should also ensure full implementation of ICAO provisions for publication of information related to the use of GNSS elements in the aeronautical information publications (AIP).

3. CONCLUSION

3.1 DFMC GNSS can improve performance and robustness for all CNS applications that are currently based on single-frequency, single-constellation GNSS. Operational benefits will accrue progressively as aircraft become equipped with DFMC avionics and able to use multiple GNSS elements on a global basis. The desirable long-term goal is that all States accept for lateral navigation all GNSS elements that have been standardized by ICAO. The challenge facing ICAO, States and aviation stakeholders in the medium-term is to address individual States' requirements for the use of specific GNSS elements while limiting the complexity of DFMC equipment and ensuring backwards compatibility for existing equipment.

3.2 On this basis, the Conference is invited to agree to the following recommendation:

Recommendation 2.2/x — Global navigation satellite system (GNSS) evolution

That the Conference:

a) request ICAO to continue the development of Standards and Recommended Practices (SARPs) and guidance material for existing and future global navigation satellite systems (GNSS) elements in coordination with recognized standards-making organizations;

b) request ICAO to further develop provisions intended for States and organizations that provide GNSS services, regarding publication of service performance standards, regular performance assessment and notification of events that may affect the service;

c) request ICAO to develop additional guidance to assist States in their acceptance and use of existing and future GNSS elements;

d) urge States, when defining their air navigation strategic plans, to take advantage of the improved robustness and performance offered by dual-frequency, multi-constellation (DFMC) GNSS and to encourage related industry developments;

e) urge States to avoid prohibiting the use of GNSS elements that are compliant with applicable ICAO SARPS and to carefully consider and assess if mandates for equipage or use of any particular GNSS element are necessary or appropriate; and

f) urge States to ensure full implementation of ICAO provisions for publication of information related to the use of GNSS elements in the aeronautical information publications (AIP).

— END —