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WORKING PAPER

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COMMITTEE A

Agenda Item 2: Enabling the Global Air Navigation System
2.2: Integrated CNS and spectrum strategy

CURRENT STATUS AND EVOLUTION OF THE GLONASS CONSTELLATION IN SUPPORT OF A MULTI-SYSTEM GNSS

(Presented by the Russian Federation)

EXECUTIVE SUMMARY

This paper discusses the current status of Russia's GLONASS constellation, and presents several aspects of its future development and use as part of the global navigation satellite system (GNSS) in the move towards multi-frequency, multi-constellation (MFMC) services to ensure flight safety and efficiency in international civil aviation.

In the long term, it is expected that avionics standards will be available to enable the use of all GNSS elements and signals.

Action: The Conference is invited to:

a) take note of the content of this document;
b) support Recommendation 2.2/x of Working Paper AN-Conf/13-WP/15 − *Global Navigation Satellite System (GNSS) Evolution*;
c) request ICAO to continue addressing international regulatory issues around the use of GNSS elements, and also to add development of Standards and Recommended Practices (SARPs) for new elements and new constellations to the ICAO work programme in the interests of enhancing safety and efficiency of international air navigation.

1. INTRODUCTION

1.1 During its consideration of global navigation satellite system (GNSS) evolution and, in particular, the status of the global positioning (GPS) and global navigation satellite (GLONASS) systems, the Twelfth Air Navigation Conference (Montréal, 19-30 November 2012) noted that GPS and GLONASS have been offered to the international community free of direct user fees, and recognized that

[1] Russian version provided by the Russian Federation.

GNSS is a global utility from which many useful applications can be derived and basic GNSS services should be offered without direct user fees. The use of signals from multiple constellations (MC) broadcasting in multiple frequency bands (MF) is now creating the potential for even greater improvements in navigational technical performance and for achieving significant operational benefits.

1.2 This working paper discusses the integrated utilization of several (or all) major constellations transmitting signals in multiple protected aviation frequency spectra (multi-frequency, multi-constellation (MFMC)). However, this does not preclude solutions based on initially using several constellations in two frequency bands (dual frequency multiple constellation (DFMC)) and even one constellation broadcasting in two frequency bands (dual-frequency single constellation (DFSC)) or a single frequency signal from several major constellations (single frequency multi-constellation (SFMC)).

2. CURRENT STATUS OF THE GLONASS CONSTELLATION

2.1 The Population of the System's Constellation

2.1.1 Over the past few years, the GLONASS constellation has been maintained at a nominal population of twenty-four satellites and has been significantly upgraded. As of 24 June 2018, the GLONASS system was made up of twenty-four satellites used for their intended purpose. Twenty-three are second-generation space vehicles (GLONASS-M) and one is third-generation (GLONASS-K).

2.1.2 Further GLONASS vehicles will be launched as required to replace satellites that have malfunctioned or reached the end of their service life. The reserve for future launches is made up of five upgraded GLONASS-Ms that have been manufactured and are now in storage (in addition to emitting signals with frequency division in the L1 band, the upgraded GLONASS-M satellite also broadcasts signals with code division in the L3 band). Launching upgraded GLONASS-Ms will facilitate a more rapid transition to code division of signals (CDMA) in the L3 band. Following the launch of these five satellites, any further additions to the group will be GLONASS-Ks. Starting with a certain serial number, they will transmit CDMA signals on the L1 frequency, in addition to transmitting CDMA signals on the L3 frequency. At present, two upgraded GLONASS-Ms transmitting L3 CDMA are already in orbit (the first upgraded GLONASS-M with a CDMA signal transmitter on the GLONASS L3 frequency was launched and put into operation in mid-2014, and a second one was launched on 17 June 2018 and is now being integrated into the system). There is one GLONASS-K also broadcasting L3 CDMA. The backward compatibility of new satellites is achieved, despite the introduction of CDMA, by preserving FDMA signals in L1 and L2 in addition to broadcasting CDMA signals in L1 and L3.

2.2 Current GLONASS Performance

2.2.1 Current GLONASS operational performance parameters are routinely evaluated and the results provided to ICAO to confirm compliance with the ICAO Standards and Recommended Practices (SARPs). At present, the average distance accuracy for the constellation is 1.4 m. The probability of a major service failure, for which requirements are to be included in the SARPs, is 6×10^{-5} on the basis of data available as of late 2017.

2.3 Russian Operators' Positive Experience Using Combined GLONASS/GPS Receivers

2.3.1 GLONASS is a self-contained navigation system that complies with ICAO SARPs. Nonetheless, GLONASS is frequently used by Russian civil aviation in conjunction with the GPS system, through use of combined GLONASS/GPS receivers developed by the Russian industry in compliance with national standards. Currently, more than 600 Russian aircraft are equipped with airborne GLONASS/GPS systems. Experience with using these navigation receivers has demonstrated improvements in readiness, continuity of service and integrity, particularly where there is interference hindering stable reception of GLONASS and/or GPS navigation signals.

2.3.2 Improvements in the above-mentioned parameters have enhanced the potential for vertical navigation (VNAV) both during en-route operations and in the vicinity of aerodromes, including approach procedures with vertical guidance (LNAV/VNAV) without ground-based or satellite-based augmentation. Simultaneous use of two constellations also reduces the impact of certain technical failures on their collective ability to function. For instance, during the GLONASS system failure in April 2014 and the GPS system failure in February 2016, the combined airborne GLONASS/GPS equipment remained functional and no interruptions in aircraft position location were observed.

2.3.3 In 2017, RTCA completed the development and publication of the industry standard (MOPS) DO-368 – *Minimum Operational Performance Standards for GPS/GLONASS (FDMA + antenna) L1-only Airborne Equipment*. This opens up the possibility of using the dual system navigation solution on aircraft from foreign manufacturers, as well, thus tapping into its advantages without having to wait for the standardization and implementation process to be complete for multi-constellation, dual-frequency solutions. In addition, GPS/GLONASS equipment that has been successfully operated on Russian aircraft could be used, thus reducing time and money spent on equipment.

3. EVOLUTION OF THE GLONASS SYSTEM AS PART OF A MULTI-FREQUENCY, MULTI-CONSTELLATION (MFMC) GNSS

3.1 The concept of an MFMC GNSS envisages the use of signals with code division (CDMA) as a basis for effective interoperability and compatibility of the constellations and signals that make it up. The plan is for all satellites of the GLONASS constellation to broadcast a CDMA signal on the L3 frequency by 2021 along with the FDMA signal on the L1 and L2 frequencies. Subsequently, the CDMA signals will also be broadcast on the L1 frequency, tentatively by 2028.

3.2 The interface control documents (ICDs) for GLONASS signals with code division were approved in 2016 and were also made available in English as of October 2017. The ICDs were then used as a basis for the process of preparing and subsequently validating changes to the SARPs for GLONASS CDMA signals. Under the roadmap for SARP development up to 2020, the SARPs are to be completed for all new elements of the major constellations, including CDMA GLONASS and L5 GPS signals, as well as for the Galileo and BeiDou systems.

3.3 At present, efforts have already been made to achieve the long-term objective of incorporating all GNSS elements in a receiver. That there is no substantial increase in the complexity or cost of developing equipment capable of receiving all future GNSS signals has been confirmed via a number of user navigation prototypes and antennae for aviation use.

3.4 It is expected that avionics standards will, in the long term, enable the use of all GNSS elements and signals on an MFMC basis. As the GNSS evolves, the ICAO SARPs and the industrial standards must also be updated so that they apply to all GNSS elements.

4. APPROACHES TO IMPLEMENTING THE INTRODUCTION OF ALL GNSS ELEMENTS IN THE LONG TERM

4.1 In the near future, the United States (GPS), the Russian Federation (GLONASS), Europe (Galileo) and China (BeiDou) will be commissioning GNSS constellations that broadcast a dual-frequency signal. DFMC satellite-based and ground-based augmentation systems (SBAS/GBAS) are now being deployed. In light of these facts, it is essential that ICAO continue to work actively, in close coordination with the relevant organizations, to develop standards in accordance with the principles and approaches laid out in the recently published DFMC GNSS Concept of Operations (ConOps).

4.2 In order to apply ICAO's results in practice and make efficient use of the operational capacity of the radio navigation fields being created, it is essential for the industry to continue standardizing and certifying the appropriate aeronautical equipment capable of processing the CDMA signals from all constellations and choose the most effective combinations of constellations from the point of view of performance and safety. Selecting a limited number of constellations for industry standardization could lead to unadvisable mandates to use specific GNSS elements, as well as an increase in the cost of refitting aircraft under a staged implementation of multi-system receivers with various combinations of systems.

4.3 It is essential for ICAO to scale up its efforts to raise the awareness of all States regarding the long-term goal set out in the ConOps, and particularly those aspects which relate to limitations on the use of GNSS elements and which may have negative implications for flight safety, since they make it impossible to take advantage of the flight safety benefits that come from utilizing these elements. In this respect, it would be very timely for ICAO to develop additional guidance material to assist the States with their approval and use of existing and future GNSS elements.

5. CONCLUSION

5.1 Taking into consideration the fact that the GPS and GLONASS systems are functioning in their nominal configurations and developing through implementing new signals, and also that the commissioning of the Galileo and BeiDou systems is forthcoming, international regulatory support for States' implementation of the multi-system GNSS, without prohibitions on the use of any given GNSS element or constellation, is a timely task, requiring development of the appropriate ICAO provisions. Moreover, freedom from such prohibitions should also be ensured at the industry level, avoiding the exclusion of some of the GNSS elements from the plans for industry standardization.

5.2 In general terms, the Air Navigation Conference is invited to support Recommendation 2.2/x, presented in Working Paper AN-Conf/13-WP/15 – *Global Navigation Satellite System (GNSS) Evolution.*

5.3 It is deemed advisable to develop industry standards and the appropriate aviation equipment capable of processing CDMA signals from all constellations and make the decision to select the most effective combinations of constellations based on performance and safety.

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