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Minimum Operational Performance Standards for GPS/GLONASS (FDMA + antenna) L1-only Airborne Equipment

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Prepared by: SC-159
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FOREWORD

This document was prepared by Special Committee 159 (SC-159) and approved by the RTCA Program Management Committee (PMC) on July 13, 2017

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- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

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EXECUTIVE SUMMARY

RTCA/DO-368 was originally prepared by RTCA Special Committee 159 (SC-159) in accordance with its Terms of Reference (TOR) that included a task to develop New MOPS for GPS/GLONASS (FDMA + antenna) L1-only airborne equipment. This MOPS was approved by the RTCA Program Management Committee on July 13, 2017

Development of RTCA Minimum Operational Performance Standards (MOPS) for a combined GPS/GLONASS receiver was initiated in 2014 by a group of Russian R & D organizations and GNSS avionics manufacturers. This MOPS is primarily based upon RTCA document DO-316 "Minimum Operational Performance Standards for Global Positioning System /Aircraft-Based Augmentation System Airborne Equipment" for a receiver also known as the “basic GPS receiver”. Similar to DO-316, this MOPS contains standards for single-frequency airborne navigation sensor equipment not augmented by ground or space-based systems. The standards define minimum performance, functions and features for GPS/GLONASS sensors that provide position information to a multi-sensor system or separate navigation system to be used for the en route, terminal, and Lateral Navigation (LNAV) phases of flight.

Since presentation of the document development plan at SC-159/91 in March 2014 the draft MOPS has been gradually upgraded and reviewed at subsequent Committee’s meetings with support from Committee members whose volunteer comments provided valuable contribution to document enhancements.

At the final development stages, this MOPS was expanded to include GPS/GLONASS antenna specifications using as a basis document RTCA DO-301 “Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band”.

RTCA Paper No. 071-17/SC159-1061 (2), which is referenced in this MOPS, provides information on integrity analysis results and rational for integrity-related assumptions stated in the MOPS.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document designated as RTCA/DO-XYZ contains Minimum Operational Performance Standards (MOPS) for airborne navigation equipment using the Global Orbiting Navigation Satellite System (GLONASS) and the Global Positioning System (GPS). The document provides standards for a combined GPS and GLONASS single-frequency airborne supplemental navigation sensor equipment not augmented by ground- or space-based systems. In this document, the terms "GPS/GLONASS equipment" or "GPS/GLONASS receiver" are used to refer to the combined GNSS airborne equipment capable of providing position information using signals from both GPS and GLONASS constellations.

Separate standards exist for GNSS using ground- or space-based augmentations. Additionally, separate documents will be created in the future to address standards for multi-constellation dual frequency (MC/DF) equipment.

The basis for this MOPS is RTCA/DO-316 (which was derived from RTCA/DO-229E class Beta 1 receiver MOPS without SBAS requirements). Therefore this MOPS makes extensive use of texts from and references to those documents, particularly to RTCA/DO-316. In doing so, the following convention is chosen:

- when a requirement stated in DO-316 relates to GLONASS only (or both GLONASS and GPS) the complete wording of the requirement from DO-316 is reproduced;
- when a requirement relates to GPS only, the reference paragraph number in DO-316 is given (without reproduction of the referenced requirement from DO-316).

The above also applies to requirements for GPS/GLONASS antenna units that are introduced in this MOPS based on RTCA/DO-301 “Minimum Operational Performance Standards for Global Navigation Satellite System (GNSS) Airborne Active Antenna Equipment for the L1 Frequency Band.”

In this document:

- the term "shall" is used to indicate requirements. An approved design has to comply with every requirement, which can be assured by inspection, test, analysis, or demonstration. In order to facilitate references to specific requirements throughout the document, all "shall" requirements are designated with [GLG X] sequential numbering (*to be inserted in the final version of the document).*
- the term "must" is used to identify items that are important but are either duplicated somewhere else in the document as a "shall", or are considered to be outside the scope of this document.
- the term "should" is used to denote a recommendation that would improve the GPS/GLONASS equipment, but does not constitute a requirement.

The standards define minimum performance, functions and features for GPS/GLONASS sensors that provide position information to a multi-sensor system or separate navigation system. They also address Area Navigation (RNAV) equipment to be used for the en route, terminal, and Lateral Navigation (LNAV) phases of flight. These standards are based upon a nominal allocation of the aircraft-level requirements in RTCA/DO-236C, *Minimum Aviation System Performance Standards: Required Navigation Performance for Area*

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Navigation, accounting for the unique issues associated with GPS/GLONASS navigation service and minimizing the need for pilot training.

Compliance with these standards by manufacturers, installers and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended functions under conditions encountered in routine aeronautical operations, and will ensure a basic compatibility with the requirements defined in RTCA/DO-236C.

The regulatory application of these standards is the responsibility of appropriate government agencies.

The words "equipment" or "receiver", as used in this document, include components or units necessary (as determined by the equipment manufacturer or installer) to properly perform its intended function. For example, the airborne "equipment" may include: sensor(s), a computer unit, an input-output unit that interfaces with existing aircraft displays/systems, a control unit, a display, shock mount(s), etc. In the case of this example, all of the foregoing components or units constitute the "equipment". It should not be inferred from this example, however, that all GPS/GLONASS navigation equipment will necessarily include all of the foregoing components or units. The particular components of the GPS/GLONASS equipment will depend upon the design used by the equipment manufacturer, subject to the constraint that the equipment must meet the applicable requirements of this MOPS.

Furthermore, distinction should be made in interpreting the term “mode” which is being used in this MOPS with different meanings:

– navigation modes (e.g. “en route mode”, “terminal mode”); or

– GPS/GLONASS receiver operation modes (e.g. “GPS/GLONASS mode”, “GPS-only” mode, “GLONASS-only” mode); or

– fault modes in integrity analysis (e.g. “satellite failure mode”, “constellation fault mode”.

Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and forms the basis for the standards stated in Section 2.

Section 2 contains the performance requirements. When measured values of equipment performance could be a function of the measurement method, this section also defines standard test conditions as well as testing methods. Section 2 contains the minimum performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. It also details the recommended test procedures necessary to demonstrate compliance; provides references to guidance material for installed equipment performance and GPS/GLONASS equipment operational characteristics.

Note 1: *The following structure of appendices include some appendices that are shown as “reserved for future use”; and, are interspersed among appendices that do contain information. This was done to maintain labeling commonality with RTCA/DO-316 to facilitate any future changes needed in both documents.*

Appendix A is reserved for future use.

Appendices B and C are normative, i.e.:

Appendix B contains GPS and GLONASS assumptions;

Appendix C describes the standard interference environment for GPS and GLONASS receivers at and around L1 frequencies.

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Appendix D describes the GPS/GLONASS L1 active antenna unit performance and testing requirements for two design versions:

- the active antenna with the combined GPS/GLONASS RF path; and
- the active antenna with the separate RF paths for GPS and GLONASS.

Appendix E includes a description of the baseline weighted least squares algorithm. It also includes an example means of implementing the navigation system error algorithm.

Appendices F and G describe additional GPS and GLONASS capabilities that are not mandated by this MOPS and are optional, i.e.:

Appendix F refers to RTCA/DO-316 which describes a suggested method for calculating velocity data if the equipment conforming to this MOPS is intended to support ADS-B that is optional under this MOPS. Equipment manufacturers must consult ADS-B performance documentation and Appendix F to RTCA/DO-316 to determine if their equipment provides acceptable positioning source performance.

Appendix G describes the requirements and test procedures for baro-aided fault detection and exclusion (FDE) capability that is optional under this MOPS.

Appendix H in RTCA/DO-316 describes a recommended output standard for implementing functions that are beyond the scope of and are not mandated by this MOPS. Therefore, the content of Appendix H is not reproduced in this MOPS, and manufacturers of GPS/GLONASS equipment planning to support on-board or external applications, such as various cockpit displays, ADS-B, TCAS etc, are referred directly to Appendix H in RTCA/DO-316.

Appendix I describes the example methods to determine most difficult to detect failed satellites.

Appendix J describes weights for use in an optional General Least-Squares position solution along with tropospheric and ionospheric error models.

Appendix K provides references to publications that manufacturers may wish to review for information on multiple simultaneous satellite faults and horizontal advanced-RAIM (A-RAIM).

Appendix L in RTCA/DO-316 describes an example method for making WGS-84 computations in GNSS equipment using WGS-84. The example method description is not reproduced in this MOPS, and manufacturers of GPS/GLONASS equipment are referred to, if necessary, directly to Appendix L in RTCA/DO-316.

Note 2: *Recommended parameters for conversion of PZ-90 coordinates to WGS-84 reference system in GLONASS equipment are provided in Appendix W to this MOPS.*

Appendices M and N are informative:

Appendix M contains background material for bench tests.

Appendix N provides guidance for determining Mean Sea Level (MSL) altitude from WGS-84 coordinates. While various models exist allowing conversion between WGS-84 height and MSL altitude, the guidance model is specific referencing to the 1996 Earth Gravitational Model (EGM 96) and the Earth Gravitational Model 2008 (EGM2008) as a acceptable MSL approximation**.**

Appendix O is a glossary.

Appendices P and Q are reserved for future use.

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Appendix R in RTCA/DO-316 describes requirements and test procedures for tightly integrated GPS/inertial systems, i.e. an equipment configuration which is not mandated by this MOPS. Therefore, the content of that appendix is not reproduced in this MOPS, and manufacturers of GPS/GLONASS equipment planning to implement such integration are referred directly to Appendix R in DO-316.

Appendix S and T are reserved for future use.

Appendix U provides guidance to potential interface with ADS-B equipment in case the equipment conforming to this MOPS is intended for such integration that is optional under this MOPS. Manufacturers must consult ADS-B performance documentation and Appendix F to RTCA/DO-316 to determine if their equipment provides acceptable positioning source performance.

Appendices V is reserved for future use.

Appendix W contains recommended parameters for conversion of PZ-90 coordinates to WGS-84 reference system.

1.2 System Overview

1.2.1 GNSS Satellite Signal Characteristics

GNSS refers to a world-wide position and time determination system that uses satellite ranging signals to determine user location. It encompasses all satellite ranging technologies and augmentation systems, including GPS, GLONASS, Satellite (Space)-Based Augmentation System (SBAS), Ground-Based Augmentation System (GBAS) and forthcoming satellite navigation systems (e.g. Galileo and Beidou). Different components of the GNSS can have different signal characteristics.

1.2.1.1 GLONASS Signal Characteristics

GLONASS is designed to determine users' location, velocity, and precise time and includes:

- Space vehicles subsystem (SVS);
- Monitoring and control subsystem (MCS);
- Users' navigation equipment subsystem (UNES).

SVS of the GLONASS consists of 24 satellites in circular orbits at 19100 km, with inclination of 64.8º and the period of 11 hours and 15 minutes 44 seconds in three orbital planes, which provides a continuous and global navigation field coverage of the Earth's surface and near-earth space.

MCS consists of the GLONASS Control Center and a network of measurement, control and monitor stations. The objectives of the MCS is to control proper functioning of the SVS, continuously rectify orbital parameters and issue time programs, control commands and navigation information to the satellites.

UNES consists of navigation receivers and processing devices for receiving GLONASS satellites navigation signals and calculation of the own coordinates, velocity and time.

The users' equipment performs pseudorange and pseudovelocity measurements to GLONASS satellites in view, and receives and processes navigation messages contained in the satellite navigation signals, which indicate the positions of the satellites in space and time.

To determine the position, signals of the standard accuracy channel with frequency spacing in the L1 frequency subband are used. Satellites at opposite spots of the orbital plane

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