EUROPEAN GNSS (GALILEO) INITIAL SERVICES

OPEN SERVICE SERVICE DEFINITION DOCUMENT

NAVIGATION SOLUTIONS POWERED BY EUROPE

TERMS AND CONDITIONS OF USE OF THE GALILEO INITIAL OPEN SERVICE

The Galileo OS, unless augmented by certified or otherwise legally approved dedicated systems designed to this effect, has been designed and can only be used for non-safety critical purposes, i.e. purposes that have no impact on the safety of human life and where an underperformance in availability, continuity, accuracy and/or integrity of the Galileo SIS could not cause any kind of direct or indirect personal damage, including bodily injuries or death.

Scope of Galileo OS Commitment

Although care has been taken in designing, implementing and operating the system, as well as in providing the OS, the OS is not meant to offer any service guarantee to the users.

The minimum level of performance against which the system has been validated and is operated, as well as data of actual performance of the OS are expressed in this document in statistical values that are valid under assumptions described in the Galileo OS SDD. The Commission reserves the right to revise the Galileo Initial OS SDD should these assumptions change or to reflect changes in performance during the deployment of the Galileo infrastructure. This commitment regarding the minimum level of performance shall be without prejudice to the disclaimer of liability below, measures potentially affecting service availability that may be taken either by the Security Accreditation Board, or according to the Council decision 2014/496/CSFP, or in the interests of Member States' national security.

The European Union plans to take all necessary measures for the foreseeable future to maintain or exceed the minimum levels of the OS performance described herein.

The minimum level of performance of the Galileo OS, as specified in the Galileo OS SDD, is obtained under the condition that the user equipment processes the health and status flags as described in section 2.3.1.3 and only uses signals declared "HEALTHY". The users are also reminded that important service notices (Notice Advisory to Galileo Users – NAGUs) are published through the Galileo service centre which shall be taken into account when planning to use the Galileo OS for any purpose.

User responsibilities

The user retains his responsibility to exercise a level of care appropriate with respect to the uses he intends to make of the Galileo OS, taking into account the considerations outlined above.

The users are reminded that the timing and positioning performance they will experience is also driven by other parameters outside the control of the Galileo OS provider (e.g. signal propagation errors or user receiver induced errors) which have to be taken into account when deciding to use the Galileo OS for a given purpose.

Before any use of the Galileo OS, users should study this document in order to understand how they can use the service, as well as to familiarise themselves with the performance level and other aspects of the service they can rely on, in particular the Annex C.4 for a more comprehensive discussion of the relationships between the Galileo Initial OS performance and the end user PVT performance expectations.

In case of doubt, the users and other parties should contact the Galileo helpdesk (see section 1.6.4 for contact details) and their user equipment manufacturer.

Disclaimer of liability

As the owner of the Galileo system, the European Union - including any of its institutions, offices or agencies, such as the European Commission, the European GNSS Agency (GSA), and other entities acting on the basis of a contract or agreement with the European Union involved in the Galileo OS service provision - does not offer any warranties of any kind (whether expressed or implied) with respect to the Open Service, including, but not limited to, the warranties regarding availability, continuity, accuracy, integrity, reliability and fitness for a particular purpose or meeting the users´ requirements. No advice or information, whether oral or written, obtained from the European Union - including any of its institutions, offices or agencies, such as the European Commission, the European GNSS Agency (GSA), and other entities acting on the basis of a contract or agreement with the European Union involved in the Galileo OS service provision - shall create any such warranty.

By using the Galileo Open Service, the user accepts and agrees that the European Union - including any of its institutions, offices or agencies, such as the European Commission, the European GNSS Agency (GSA), and other entities acting on the basis of a contract or agreement with the European Union involved in the Galileo OS service provision - shall not be held responsible or liable for any damages resulting from the use of, misuse of, or the inability to use the Galileo Open Service, including, but not limited to, direct, indirect, special or consequential damages, including, but not limited to, damages for interruption of business, loss of profits, goodwill or other intangible losses, other than in accordance with Article 340 of the Treaty on the Functioning of the European Union.

DOCUMENT CHANGE RECORD

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FOREWORD

This "Galileo Initial Services – Open Service – Service Definition Document" (Galileo Initial OS SDD) defines the Minimum Performance Levels (MPLs) of the Galileo Open Service (OS) to be provided during the Galileo Initial Services provision phase.

The document will be updated in the future to reflect further changes and improvements of the Galileo Open Service, in particular during the deployment of the Galileo system infrastructure, until the Full Operational Capability (FOC) is achieved.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1: THE GALILEO OPEN SERVICE

Galileo[1] is the European Global Navigation Satellite System (EGNSS), under civil control, that provides satellite positioning services to European citizens and worldwide.

Galileo provides ranging signals in three different frequency bands, enabling single- and dual- frequency positioning for users equipped with suitable receivers.

As one of the services offered by Galileo, the Galileo Open Service (OS) enables free of charge, global ranging, positioning and timing, by means of the Galileo OS Signal-In-Space (SIS).

In order for users to be able to benefit as early as possible from the Galileo services, the Galileo Initial Services provision phase will start before the Galileo core infrastructure is fully deployed. Galileo Initial Services will evolve in accordance with the infrastructure deployment until the Full Operational Capability (FOC) is achieved. As a consequence, specific releases of this document will be issued to properly take into account such evolution in future service declaration milestones.

1.1 PURPOSE OF THE DOCUMENT

The purpose of this Galileo Initial Services – Open Service Definition Document (Initial OS SDD) is to describe the characteristics and performance of the Galileo OS provided through the Galileo OS SIS during this initial phase. The Initial OS SDD presents the Minimum Performance Levels (MPLs) targeted for such service and defines the conditions under which such MPLs can be reached. This document addresses all users of Galileo Initial OS. The Galileo Initial OS is provided free of charge to all users.

This Initial OS SDD consists of a main body and five annexes. It provides an overview of the EGNSS program as well as an overview of the OS SIS. It then presents the Minimum Performance Levels for the Initial OS. It concludes with the relevant reference documents. The annexes provide additional information on Initial OS and about the target performance at FOC.

The main document comprises the following sections:

1) The Galileo Open Service

   The main purpose of this section is to introduce the document, define the Galileo Open Service and to provide a general description of the Galileo system.

2) Galileo Open Service SIS Characteristics and Minimum Usage Assumptions

   This section includes a description of the Galileo SIS and the definition of the parameters used to identify the MPLs.

3) Galileo OS Minimum Performance Levels

   This section provides the Galileo Initial Services – Open Service Minimum Performance Levels and describes additional OS SIS functionality.

The following Annexes close the document:

- Annex A: Reference Documents.
- Annex B: Abbreviations and Acronyms.
- Annex C: OS SIS Background Information and PVT Accuracy Performance Drivers.
- Annex D: Galileo Open Service – Performance Evolution.
- Annex E: Description of Notice Advisory to Galileo Users.

1.2 SCOPE OF THE DOCUMENT

This Galileo Initial OS SDD only applies to the Galileo Initial OS as defined in the Service Declaration currently in force. This document does not address Galileo restricted access signals such as the E1A signal nor the signals broadcast in E6 band.

The Initial OS SDD belongs to the series of Galileo Programme Reference Documents published for the benefits of Galileo users, to present and explain various aspects of the EGNSS concerning Galileo OS. The other Programme Reference Documents are:

- The European GNSS (Galileo) – Open Service - Signal In Space Interface Control Document (Annex A [1] (OS SIS ICD))

  By describing exhaustively the SIS, it specifies the interface between the Galileo Space Segment

1 The name "Galileo" means the system established under the Galileo programme of the European Union.

and the Galileo User Segment. It is addressed to the whole Galileo OS user community.

- The European GNSS (Galileo) – Open Service - Ionospheric Correction Algorithm for Galileo Single-Frequency Users (Annex A [2]).

  It describes in detail the reference algorithm to be implemented by user receivers to compute the Galileo ionospheric corrections. It is addressed mainly to Galileo OS receiver manufacturers.

The document "European GNSS (Galileo) – Open Service – Signal In Space Operational Status Definition" (OS SIS OSD), which describes the encoding and use of the Galileo SIS Status and provides information on the usage of navigation parameters, has been integrated into this OS SDD, which therefore supersedes the OS SIS OSD.

All public Galileo Programme Reference Documents are made available to users through the web portal of the European GNSS Service Centre (http://www.gsc-europa.eu).

1.3 TERMS AND CONDITIONS OF USE

The terms and conditions of use of the Galileo Initial Open Service are described on page (i), at the beginning of this document.

1.4 ABBREVIATIONS AND ACRONYMS

Abbreviations and acronyms used in this document are provided in Annex B.

1.5 GALILEO OPEN SERVICE DEFINITION

The Galileo Open Service is a free of charge global ranging, positioning and timing service. Each Galileo satellite transmits navigation signals (Signal-In-Space, SIS) in three frequency bands. The OS SIS, broadcast on two out of these three bands, provide access to the Galileo OS ranging, positioning and timing services for users equipped with a Galileo OS compatible receiver. The following services are supported by Galileo OS SIS:

- Single-Frequency and Dual-Frequency Ranging,
- Single-Frequency and Dual-Frequency Positioning,
- UTC Time Determination.

During the Galileo Initial Services phase, the Galileo OS comprises the Ranging Service and the UTC Time Determination Service, together referred to as Initial OS. New issues of this document will be published to include new services as they become available.

Concerning the Positioning Service, at the current stage of deployment of the Galileo infrastructure, the percentage of time during which four Galileo satellites are simultaneously in view, therefore allowing the calculation of user's PVT solution with Galileo only, is limited due to the number of satellites in orbit. However, Galileo will improve the positioning performance of multi-GNSS solutions and the availability of Galileo only positioning will steadily increase as new satellites are added to the operational constellation. As additional information, considering the performance achieved by the Ranging Services and the characteristics of the constellation already deployed at Initial Service Declaration, an indication is provided in Annex C for the expected availability of Horizontal Positioning [2].

OS are generally provided in either single-frequency (SF) or dual-frequency (DF) mode. In the case of SF usage mode the user equipment tracks and processes the information provided by only one of the three OS frequencies. The different OS single-frequency usage modes are E5a (only), E5b (only) and E1 (only). In any

2....... *Horizontal Positioning (or 2D-Positioning) is limited to the determination of receiver latitude and longitude and is applied by receivers at known or fixed altitude (altitude-hold mode). It only requires availability of at least three satellites in view.*

SF usage mode, specific compensations need to be applied: Broadcast Group Delay (BGD), to compensate for specific satellite systematic delays between the different frequencies, and ionospheric compensation, to compensate for atmospheric delays of the signals. The respective algorithms are specified in the Galileo OS SIS ICD (Annex A [1]) and in the Ionospheric Correction Algorithm for Galileo Single-Frequency Users (Annex A [2]).

In the case of DF usage mode, the user equipment tracks and processes the information provided by two of the three OS frequencies. The different OS dual-frequency usage modes are E5a/E1 and E5b/E1. In dual-frequency usage modes, BGD compensation is not required, and ionospheric delays are measured directly by Galileo OS receivers, making use of the dispersive property of the ionosphere.

1.5.1 GALILEO OS RANGING SERVICE

Ranging allows users to continuously estimate their distance to the satellite. This measure is the core of positioning-based services since the user's position and time can be estimated using ranging measurements from (at least) four different satellites. GNSS ranging services comprise a set of electromagnetic signals transmitted by satellites and properly modulated to carry the information, generated by an appropriate ground infrastructure, needed by receivers to estimate the user-to-satellite range. The minimum level of expected performance in accuracy and availability of range estimation will constantly improve during the deployment of Galileo system until its final configuration is reached.

The Galileo OS Ranging Service is provided in both SF usage mode and DF usage mode (see also section 2.2.1).

DF usage mode is characterised by higher accuracy of the range measurement. The use of two frequencies permits better compensation of the disturbing effect of the ionosphere on the SIS, thus providing better performance to the end user.

The Galileo OS Ranging Service is interoperable with GPS ranging services (see section 3.6.1 for more details) and therefore it provides a direct benefit to users who are able to exploit both Galileo and GPS constellations, by increasing the number of available signals-in-space.

1.5.2 GALILEO OS UTC TIME DETERMINATION SERVICE

GNSS satellites broadcast additional data which allow GNSS receivers to relate the GNSS time scale to international reference timescales. The precise atomic clocks in the Galileo system allow delivery to users of very accurate timing data. The OS UTC Time Determination Service provides Galileo users worldwide with direct and accurate access to the Universal Time Coordinated (UTC) reference. It provides both the integer offset between the Galileo System Time (GST) and UTC (see also section 1.6.5.2) and the fractional GST-UTC difference at nanosecond level. This allows users to time-stamp their data in UTC or local time and to precisely synchronise to UTC their clocks, which can be situated at very different locations in the world.

Since this service only requires visibility of one Galileo OS SIS, availability is already very high globally during the Initial OS phase.

1.6 GALILEO SYSTEM OVERVIEW

The Galileo system is composed of a Core Infrastructure and a number of Service Facilities. The Core Infrastructure, in turn, comprises a Space Segment and a Ground Segment.

The Galileo Space Segment consists of a constellation of satellites transmitting navigation signals providing user access to the Galileo services. The Galileo Ground Segment consists of a ground infrastructure providing the functionality to monitor and control the satellite constellation and the generation and further dissemination of the mission data that are included in the navigation signals (i.e. the Galileo navigation message) and broadcast to the users.

The Galileo system, once fully deployed, will offer four high-performance services worldwide:

- **Open Service (OS):** Galileo open and free of user charge service set up for positioning and timing services. The OS provided during the Galileo Initial Services phase are the only services addressed in this document.

- **Public Regulated Service (PRS):** Service restricted to government-authorised users, for sensitive applications that require a high level of service continuity.
- **Commercial Service (CS):** A service complementing the OS by providing an additional navigation signal and added-value services in a different frequency band. The CS signal can be encrypted in order to control the access to the Galileo CS services.
- **Search and Rescue Service (SAR):** Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system.

Further information on services not covered by this Galileo Initial OS SDD are provided in specific dedicated documents.

1.6.1 GALILEO SPACE SEGMENT

The Galileo Space Segment generates and transmits the Galileo navigation signals as specified in the Galileo OS SIS ICD (Annex A [1]) .

The baseline Galileo constellation configuration is defined as a 24/3/1 Walker constellation: 24 nominal Medium Earth Orbit satellites are arranged in 3 orbital planes, with their ascending nodes uniformly distributed at intervals of 120 degrees, inclined at 56 degrees with respect to the Equator. Each orbital plane includes 8 satellites uniformly distributed within the plane, at intervals of 45 degrees of argument of latitude. The angular shift between satellites in two adjacent planes is 15 degrees. The constellation is complemented by spare satellites that can be repositioned to any given nominal slot depending on maintenance or service evolution needs.

The constellation geometry repetition period corresponding to the nominal orbital parameters is approximately 10 sidereal days (corresponding to 17 orbital revolutions). This means that for any fixed Galileo user, the local satellite geometry at a given instant will repeat every 10 sidereal days, approximately.

The main reference orbit parameters of the Galileo constellation are specified in Table 1. The fully deployed constellation is further described in Annex C, while the constellation that is operational at the beginning of Initial Services is described in Section 3.2.

REFERENCE ORBIT PARAMETER	NOMINAL VALUE
Constellation Type	Walker 24/3/1
Orbit semi-major axis, m	29599801
Orbit eccentricity	0
Orbit inclination, deg	56.0
Argument of Perigee, deg	0.0

Table 1. Reference Orbit Parameters

1.6.2 GALILEO GROUND SEGMENT

The Galileo Ground Segment includes both the Ground Control Segment and the Ground Mission Segment and it encompasses the following infrastructure:

- Two Galileo Control Centres (GCC), implementing ground control and ground mission capabilities at each site.
- A worldwide network of Galileo Sensor Stations (GSS), which collects and forwards Galileo SIS measurements and data to the GCCs in real time.
- A worldwide network of Galileo Uplink Stations (ULS), which distributes and uplinks the mission data to the Galileo constellation.
- A worldwide network of Telemetry, Tracking & Control stations (TTC stations), which collects and forwards telemetry data generated by the Galileo satellites, and distributes and uplinks the control commands required to maintain the Galileo satellites and constellation in nominal operational conditions.

An overview of the Galileo Ground Segment is provided in Figure 1, where only the Galileo Ground Segment functionality related to the Open Service is included.

The Galileo Ground Segment implements all functions required to:

- Generate the Galileo mission support data (e.g. satellite orbit and time synchronisation data, ionospheric correction model data and other information transmitted in the navigation signals).
- Perform the monitoring and control of all Galileo system assets (both ground and space segment).
- Interface with the Service Facilities, entities that are not part of the Galileo Core Infrastructure ground segment but nevertheless have a role involved in the provision of the Galileo services and considered part of the Galileo System (e.g.

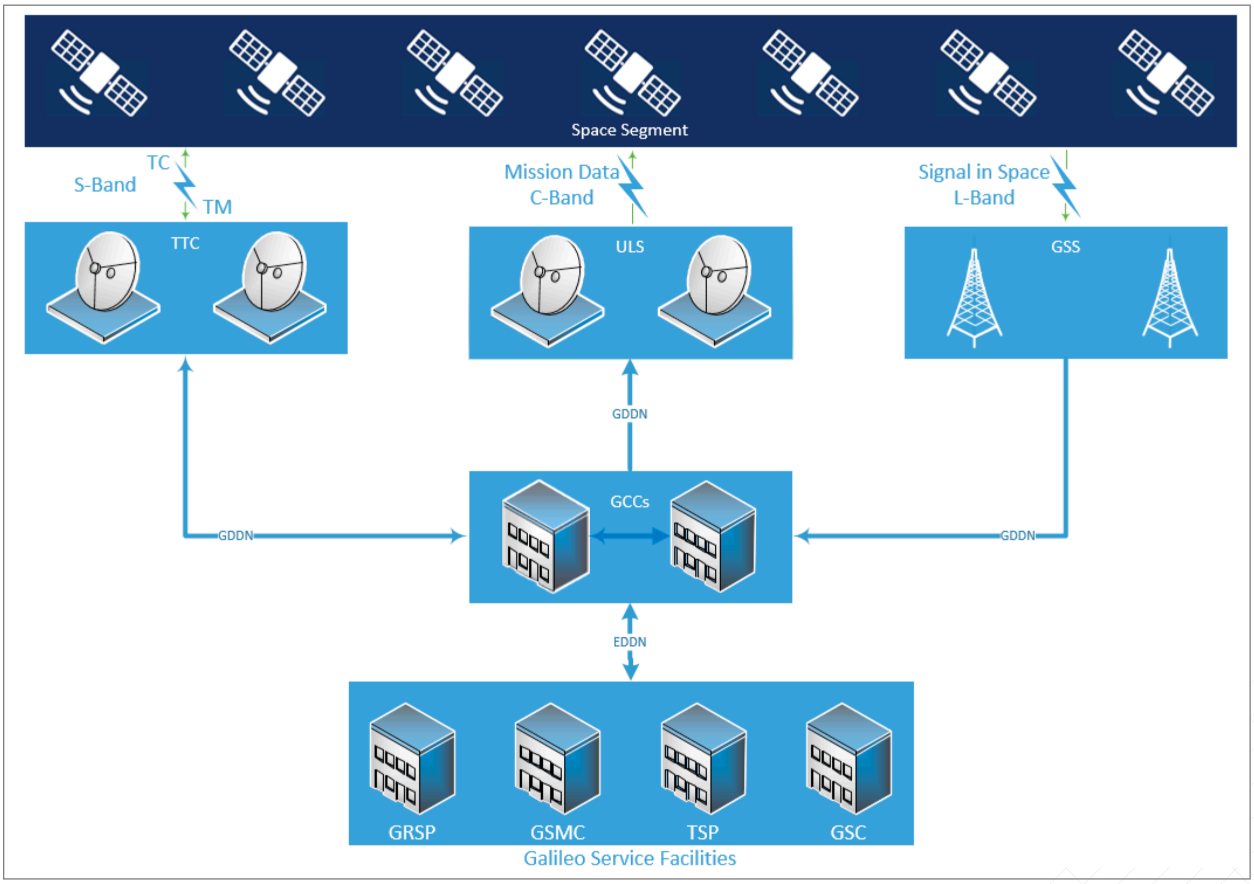


Figure 1. High level scheme of the Galileo Ground Segment Architecture.

Time Service Provider, Geodetic Service Provider, COSPAS – SARSAT mission segment, European GNSS Service Centre).

1.6.2.1. GROUND CONTROL SEGMENT

The Galileo Ground Control Segment (GCS) provides a large range of functions to support the management and control of the satellite constellation. The scope of this functionality includes control and monitoring of the satellites and payload, planning and automation functions that allow safe and correct operations to take place, and the support of payload related operations by means of TT&C links.

1.6.2.2. GROUND MISSION SEGMENT

The Galileo Ground Mission Segment (GMS) determines the navigation and timing data part of the navigation messages and transmits it to the satellite via its C-Band ground stations.

The GMS architecture consists of facilities deployed in the 2 Galileo Control Centres (GCCs) plus ULS and GSS Stations deployed at remote sites located around the world.

The Ground Mission Segment includes the Processing Chain, which is in charge of computing the data to be broadcast in the Galileo navigation messages.

1.6.3 GALILEO SERVICE FACILITIES

The Galileo Service Facilities are elements located outside the perimeter of the Galileo Core Infrastructure that support the provision of Galileo services.

The service facilities contributing to the provision of the Galileo OS are [3]:

- The European GNSS Service Centre (GSC): GSC is the interface between the Galileo Initial OS and CS user communities and the Galileo system (see section 1.6.4 for further information).
- The Geodetic Reference Service Provider (GRSP): This entity supports the GCC in realising the Galileo Terrestrial Reference Frame (GTRF), consistently with the International Terrestrial Reference Frame (ITRF).

3 *During the provision of the Galileo Initial Services, some of these facilities or part of their functionality may be undertaken by other parts of the Galileo system infrastructure.*

- The Time Service Provider (TSP): This entity supports the GCC in the realisation of the Galileo System Time (GST) and its alignment to the Coordinated Universal Time (UTC).
- The Galileo Security Monitoring Centre (GSMC): This facility is in charge of monitoring the system security.

An additional service facility, the Galileo Reference Centre (GRC), is responsible for monitoring and assessment of the performance of the Galileo services, completely independently from the Galileo core infrastructure and its operations.

1.6.4 THE EUROPEAN GNSS SERVICE CENTRE (GSC): GALILEO INTERFACE WITH USERS

The European GNSS Service Centre (GSC), part of the European GNSS infrastructure, provides the single centralised ground interface between the Galileo OS (and CS) user communities and the Galileo system infrastructure and operator, for the provision of specific services beyond the SIS transmitted by the Galileo satellites.

The GSC is conceived as a centre of expertise, knowledge sharing, custom performance assessment, information dissemination and support to the provision of value-added services enabled by the Galileo OS and CS core services. To implement these objectives, the GSC interfaces with the key elements of the Galileo ground segment, as well as with external entities. Figure 2 depicts the overall context of the GSC.

1.6.4.1. GSC FUNCTIONALITY

The GSC has the task of interfacing with the user communities across the entire value chain, including users of the commercial service.

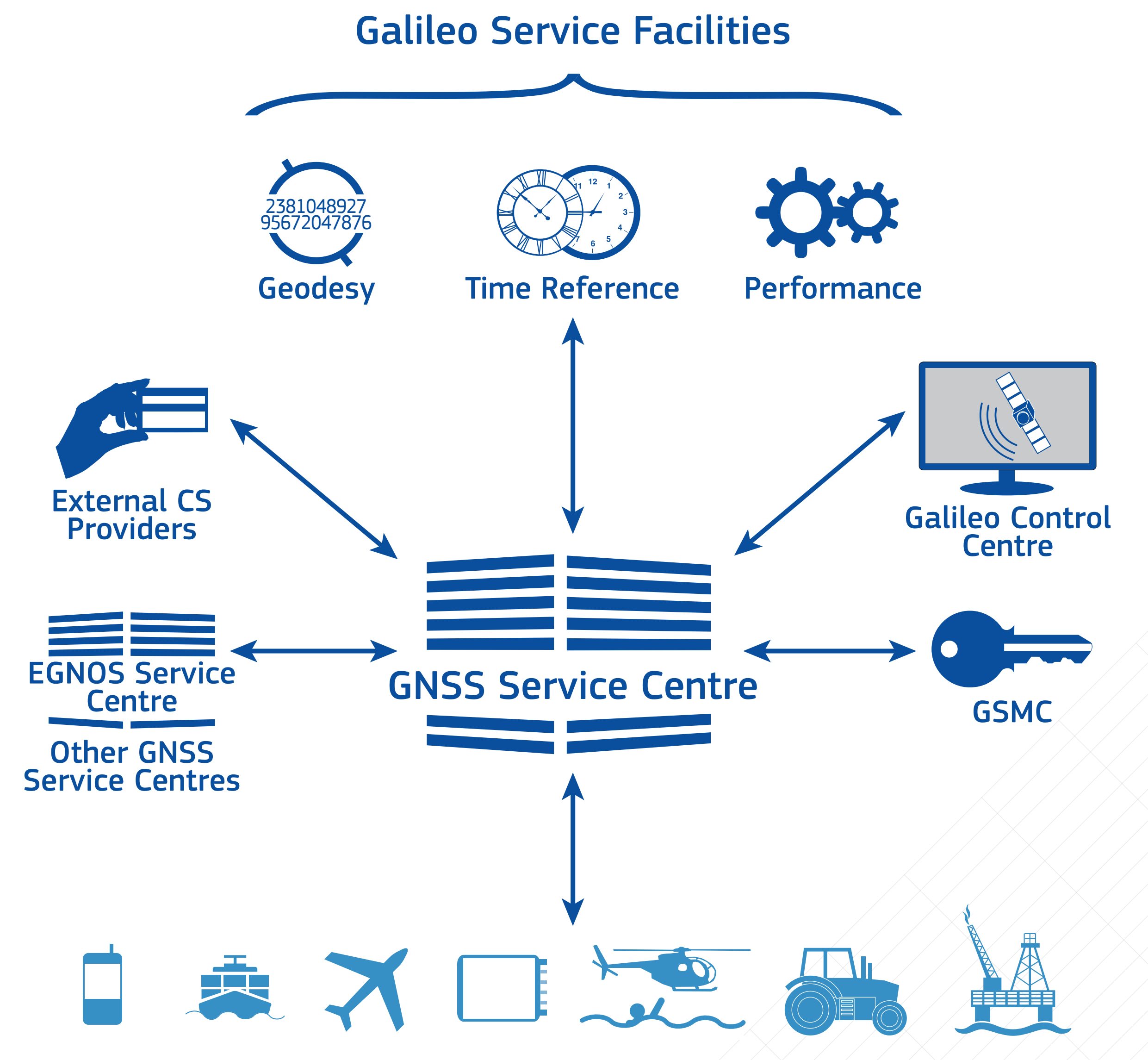
The GSC web portal (www.gsc-europa.eu) is conceived as the one-stop-shop for Galileo OS users, CS providers and end users, and Safety of Life (SoL) user communities (as the Galileo OS could be used, in combination with other systems or augmentations, for SoL purposes), providing ready access to key information.

The functionality and services covered by the GSC when fully developed are:

- Helpdesk support:
  - It is intended to answer general queries from OS Users on Galileo OS SIS, GSC OS Support Services and specific queries from OS receiver and application developers on the official Galileo OS User Documentation. In addition, registered users can subscribe to be informed in real time about events affecting the Galileo services.
- Information on Galileo system status:
  - Publication of Galileo Almanacs and ephemeris, of constellation status and Provision of Galileo Service Notices.
- Publication of notifications to users:
  - General information on the constellation and current status of the different space vehicles are published by means of Notice Advisory to Galileo Users messages (NAGUs, see section 1.6.4.1.1) informing regularly about the system status. Users have the possibility of subscribing to the automatic notification of NAGUs via e- mail.
  - Reports on the Galileo Open Service navigation key performance indicators and on the GSC performance itself are also published for the users´ information.
- Electronic Library, including Programme Reference documentation and general information.
- Support to GNSS developers, including the GNSS Simulation and Testing Infrastructure (GSTI).
- Interface with other GNSS Service Providers.
- Galileo user satisfaction monitoring, including customised performance assessment, reporting and forecasts for specific communities, and support to the Galileo services development for each community or domain.

1.6.4.1.1. NOTIFICATIONS TO USERS (NAGUS)

TThe GSC is responsible for the publication of Notice Advisory to Galileo Users (NAGU) messages. NAGUs are used to notify Galileo users about the SIS status of all satellites in the Galileo constellation. Different kinds of NAGUs are issued depending on the specific event to be communicated, related to either changes in the constellation (commissioned and decommissioned



* GNSS stands for 'Global Navigation Satellite System'.

Figure 2. Overall context of the GSC

satellites, for example) or to occurrence and recovery of (planned and unplanned) outages of SIS.

Examples of planned events which are anticipated through the publication of a specific NAGU are satellite manoeuvres and maintenance activities, declaration of a satellite entering into service, recovery from outages. Examples of unplanned events which are notified through the publication of a specific NAGU are satellite failure, information about short outages already recovered, unscheduled outages of SIS of an undefined duration.

The description of the structure and content of the NAGUs is provided in Annex E. This information, together with the list of active and archived NAGUs can be also found in the GSC web page, www.gsc-europa.eu, under "System Status".

Specific MPLs apply for the timely publication of NAGUs (see section 3.7.1).

1.6.5 GALILEO TIME AND GEODETIC REFERENCE FRAMES

The Galileo system establishes its independent terrestrial reference frame and system time scale. The satellite positions and satellite clock offsets encoded in the navigation data are referenced to these Galileo time and terrestrial internal references. Without additional processing, the navigation solution computed by a Galileo OS receiver (using the mathematical algorithms described in the SIS-ICD) provides the receiver's position and time offset referenced to these internal references. The Galileo system terrestrial and time references are:

- Galileo Terrestrial Reference Frame (GTRF): the Galileo spatial reference frame

  The instantaneous satellite positions derived from the data provided in the OS SIS and using the algorithm defined in the OS SIS ICD (Annex A [1]) are referenced to the GTRF. The GTRF is specified to always be in line with the international terrestrial reference frame, as defined by the International Earth Rotation and Reference Systems Service (IERS). The GTRF specification is provided in section 1.6.5.1.

- Galileo System Time (GST): the Galileo time and frequency reference

  The instantaneous satellite clock parameters derived from the data provided in the OS SIS and using the algorithm defined in the OS SIS ICD (Annex A [1]) are referenced to the Galileo System Time. The GST is aligned with the International Atomic Time (TAI) and the required parameters to transform it to UTC are transmitted in the navigation message, as explained in 1.6.5.2

1.6.5.1. GALILEO TERRESTRIAL REFERENCE FRAME

The Galileo Terrestrial Reference Frame is the independent realisation of the International Terrestrial Reference System based on the estimated coordinates of each one of the Galileo Sensor Station (GSS) sites.

The determination of the GSS positions is based on global free network adjustment and the precise network solution thus obtained is aligned to the International Terrestrial Reference Frame. For this purpose, a significant number of ITRF stations co-located or non-co-located with GSSs are part of the network of stations operated by the GRSP.

The GTRF is a highly accurate realisation of the ITRS. At any time, the alignment between the GTRF and the latest physical realisation of the ITRF is such that the difference between the ITRF and the GTRF coordinates of the ITRF stations/markers used in the realisation of the GTRF is less than 3 cm (2σ).

The Galileo system uses the geodetic input information to produce navigation data (e.g. satellite ephemeris) referenced to the GTRF. Accordingly, the user position coordinates derived from Galileo position solutions are referenced to GTRF. Due to the good alignment of GTRF to ITRF both reference frames are understood to be equivalent in the frame of this document. The GTRF is regularly aligned if new ITRF realisations are published.

To obtain the position in any reference frame different from ITRF, Galileo OS user equipment needs to apply the appropriate valid transformation parameters between the latest ITRF and the desired reference frame. This transformation is under full control and responsibility of the Galileo OS user.

Concerning the interoperability between GPS and Galileo, the GPS terrestrial reference frame and the GTRF are both realisations of the ITRF. Therefore, for most OS applications, a high level of interoperability is provided between the spatial positions obtained with GPS and those obtained with Galileo, without further activity by the user equipment.

1.6.5.2. GALILEO SYSTEM TIME

The Galileo System Time is a continuous timescale based on the definition of the second (according to the International System of Units, SI) whose origin/reference epoch GST(T0) is defined as 13 seconds before 1999-08-22 00:00:00 UTC. UTC is the time scale endorsed by the 15th General Conference of Weights and Measures for worldwide time coordination and dissemination. It is the international time metrological standard and it is maintained, coordinated and disseminated by the BIPM.

UTC is defined as an atomic timescale (time interval is consistent with the SI definition of the second), but unlike GST, it is steered (through leap seconds [4]) towards UT timescale (which is not based on atomic standards but on the Earth rotation period).

The time synchronisation information disseminated in the Galileo SIS (e.g. satellite clock offsets) is referenced to GST. This information allows the Galileo OS users to estimate their local time referenced to the GST realisation computed by the OS receiver.

In order to better support timing applications based on UTC, the Galileo OS data message includes additional parameters which enable the Galileo OS users to obtain a realisation of the UTC time by applying a correction to the GST (further details are provided in Annex C.4.7).

4....... 17 leap seconds as of 1st July 2016.

SECTION 2: GALILEO OPEN SERVICE SIS CHARACTERISTICS AND MINIMUM USAGE ASSUMPTIONS

This section starts by providing an overview of the Galileo OS SIS interface characteristics. This short description is given for information purposes. The user should always refer to the OS SIS ICD (Annex A [1]) when looking for details of the Galileo OS SIS Interface characteristics.

A description is then provided of the different MPLs, along with the minimum usage assumptions for the users of the Galileo OS.

2.1 OS SIS INTERFACE CONTROL DOCUMENT REQUIREMENTS

The OS SIS shall comply with the technical requirements related to the interface between the Space Segment and the OS receivers as established by the OS SIS Interface Control Document (ICD) (Annex A [1]). In the event of conflict between the OS SIS interface characteristics described in this document and the ICD, the latter shall prevail.

2.2 OVERVIEW OF OS SIS INTERFACE CHARACTERISTICS

2.2.1 GALILEO OS SIS RF CHARACTERISTICS

Galileo transmits several signals and codes on four different carrier frequencies within the 1.1 to 1.6 GHz band, namely:

- E1, centred at 1575.42 MHz;
- E5a and E5b, at 1176.45 and 1207.14 MHz respectively, multiplexed together through an AltBOC scheme and transmitted at the E5 carrier frequency centred at 1191.795 MHz;
- E6, centred at 1278.75 MHz.

A complete representation of the Galileo signal baseline is provided in Figure 3.

The Galileo SF OS is provided by each of the three signals: E1 E5a and E5b, whereas the Galileo DF OS is provided by each of the following signal combinations broadcast by the same satellite:

- E1 and E5a.
- E1 and E5b.

The E1 OS signal comprises a pair of components modulated with the CBOC(6,1,1/11) scheme:

- a data component (E1-B), carrying the I/NAV navigation message (see section 2.2.2) with a data rate of 125 bps and a symbol rate (after FEC) of 250 sps, modulated with CBOC(6,1,1/11,+);

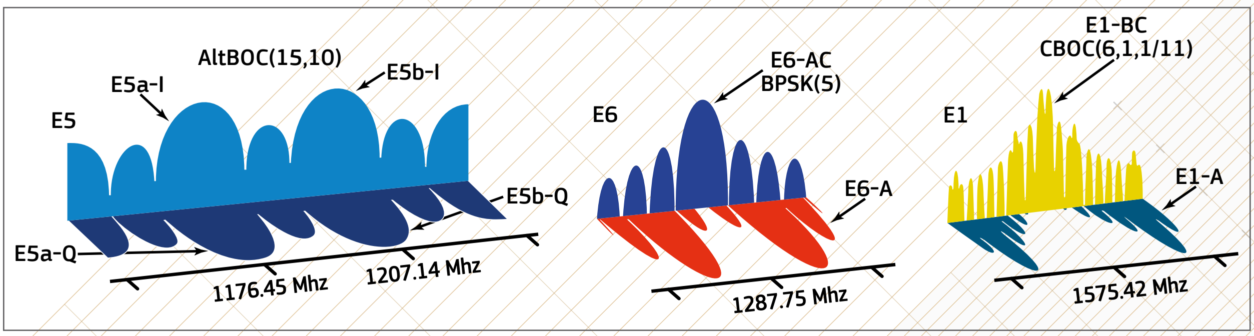


Figure 3. Signals transmitted by Galileo satellites

- a data-less component (E1-C), modulated with a CBOC(6,1,1/11,-).

The E5 signal is made of four components multiplexed together through an AltBOC(15,10) scheme:

- A pair of components on the E5a carrier:
  - a data component (E5a-I), carrying the F/NAV navigation with a data rate of 25 bps and a symbol rate of 50 sps.
  - a data-less component (E5a-Q).
- A pair of components on the E5b carrier:
  - a data component (E5b-I), carrying the I/NAV navigation message with a data rate of 125 bps and a symbol rate of 250 sps;
  - a data-less component (E5b-Q).

All components of E5a and E5b are generated coherently, which allows them to be processed together for increased accuracy and redundancy, when required.

2.2.2 GALILEO OS SIS NAV MESSAGE CHARACTERISTICS

The Galileo OS is provided through two different message types (see Table 2): the F/NAV and the I/NAV navigation messages.

MESSAGE TYPE	COMPONENT
F/NAV	E5a-I
I/NAV	E5b-I and E1-B

Table 2. Mapping of Message types to Signal Components

The complete navigation message data are transmitted on each data component as a sequence of frames. A frame is composed of several sub-frames, and a sub-frame in turn is composed of several pages. The page is the basic structure for building the navigation messages.

Each navigation message contains all the necessary parameters and information that enable the OS Users to access the services. This includes:

- the time parameters and clock corrections, needed to compute satellite clock offsets and time conversions;
- the ephemeris parameters, needed to compute the satellite coordinates;
- the service parameters, with satellite health information;
- the ionospheric parameters model, needed for single-frequency receivers;
- the almanacs, allowing less precise computation of the position of all satellites in the constellation to facilitate the initial acquisition of the signals by the receiver.

The purpose, structure and content with full details concerning the Galileo OS SIS Navigation Message can be found in the Galileo OS SIS ICD (Annex A [1]).

In the context of this document, by "navigation message" a sub-frame is meant (50 seconds for F/NAV and 30 seconds for I/NAV) that contains ephemeris and clock and ionospheric corrections or SIS status information, that is, Page Type 1 to 4 for the F/NAV and Word Type 1 to 6 for the I/NAV, unless otherwise specified.

2.2.2.1. *THE CYCLIC REDUNDANCY CHECK IN GALILEO NAVIGATION MESSAGE*

To detect corruption of the received data, a checksum is used by the Galileo navigation message, employing a CRC technique. The detailed description of this checksum is provided in the OS SIS ICD (Annex A [1]).

The CRC is not used to indicate any problem at satellite level, on the transmitter side. The CRC checksum is related exclusively to the errorless reception of the transmitted bits, i.e. to the transmission channel, not to the correctness of the structure or the contents of the message as transmitted by the Galileo system. The CRC within the navigation message of Galileo is therefore not involved in the definition of the SIS Status.

If the CRC checksum is not passed successfully the respective data must be rejected and no determination of the SIS Status is possible. Once a navigation message is finally received with a successful CRC the user can then proceed to the SIS Status determination, as described in the previous section, and eventually to the utilisation of such SIS.

2.3 OVERVIEW OF GALILEO INITIAL OS PERFORMANCE CHARACTERISTICS

The Galileo Initial OS performance characteristics are Status, Accuracy and Availability.

2.3.1 GALILEO OS SIS STATUS

Users of the Galileo Initial OS can obtain information about the OS SIS Status, i.e. about the operational status of the OS SIS broadcast by each one of the Galileo satellites, through the signals themselves, when transmitted.

The Galileo OS SIS Status can take one of the following three values:

- Healthy,
- Unhealthy,
- Marginal.

The meaning of the three possible values of the SIS Status is the following:

- SIS "Healthy": The SIS is expected to meet the Minimum Performance Level[5].
- SIS "Unhealthy": The SIS is out of service or under test.
- SIS "Marginal": The SIS is in neither of the two previous states.

The Galileo OS Minimum Performance Levels reported in the Galileo OS SDD refer exclusively to Healthy SIS. No MPL is defined for Unhealthy or Marginal SIS.

2.3.1.1. SIS STATUS DISSEMINATION

The status of each Galileo signal involved in the provision of OS is determined by the SIS Status information embedded in the navigation message and by a specific type of message that may replace the standard one: the so called dummy message (see section 2.3.1.2).

Users are also notified off-line about the SIS status of the satellites in the Galileo constellation through the publication of the Notice Advisory to Galileo Users, by the GSC (see section 1.6.4.1.1).

2.3.1.2. DUMMY NAVIGATION MESSAGE

Dummy pages are defined in the Galileo OS SIS ICD (Annex A [1]) (Page/Word Types 63 for F/NAV and I/NAV, respectively). Such dummy pages, if transmitted, replace all the sub-frames with ephemeris and clock corrections of the navigation message, which is then defined as dummy navigation message. A dummy navigation message indicates an Unhealthy SIS. Therefore, as soon as a dummy page, i.e. Page/Word Types 63, is decoded by a receiver, the respective SIS must be considered Unhealthy.

Once the transmission of the dummy message terminates and normal transmission is recovered, users must follow the appropriate procedure to check the SIS Status, as described in the next sections, before starting to reuse the SIS.

Note that in the case of Dual-Frequency (DF) users, a dummy navigation message on either one of the frequencies implies that the DF SIS is not Healthy (see also section 2.3.1.4 [6]).

2.3.1.3. SIS STATUS FLAGS

The status of the Signal-In-Space is encoded within the navigation message through three SIS Status Flags:

- The Signal Health Status (SHS) flag.
- The Data Validity Status (DVS) flag.
- The Signal-In-Space Accuracy (SISA) value.

Full details concerning the position of the Galileo SIS Status flag within the Galileo SIS Navigation Message can be found in the Galileo OS SIS ICD (Annex A [1])

5 *This assertion does not apply to the Minimum Performance Level for the provision of the Galileo-GPS System Time Offset (GGTO, see section 3.6.1.1). Healthy SIS can broadcast parameters that indicate a non-valid GGTO (see (Annex A [1]) for more details about the dummy value of the GGTO parameters).*

6 *The navigation message, specifically the I/NAV, transmitted on E1 and E5b, has been designed to include another type of page: the Alert Pages (see OS SIS ICD, Annex A [1] for a detailed definition). The transmission of Alert Pages is a capability that the Galileo system is currently not exploiting.*

Signal Health Status (SHS)

The SHS flag is contained in the navigation data and the almanac messages of each Galileo OS signal (E1, E5a or E5b). For E1 and E5b, the SHS flags are included in the I/NAV navigation data stream. For E5a, the SHS flag is included in the F/NAV navigation data stream.

The SHS flag to be used is the one broadcast in the navigation data transmitted by the satellite whose SIS is being used.

The SHS flags broadcast as part of the almanac data are provided for convenience in support of satellite acquisition but should not be used operationally to determine the SIS Status.

The SHS flag can be raised by the system at any moment [7]. The SHS flags can take the values defined in the OS SIS ICD (Annex A [1]), which are recalled for convenience in Table 3

SIGNAL HEALTH STATUS (SHS)	DEFINITION
0	Signal OK
1	Signal out of service
2	Signal will be out of service
3	Signal component currently in Test

Table 3. Signal Health Status Bit Values

Data Validity Status (DVS)

For each Galileo OS signal (E1, E5a or E5b), the DVS flag is contained in the navigation data. For E1 and E5b, the DVS flags are included in the I/NAV navigation data stream. For E5a, the DVS flag is included in the F/NAV navigation data stream. The flag can assume the values defined in the OS SIS ICD (Annex A [1]), which are recalled for convenience in Table 4.

The DVS can be triggered independent of navigation message refresh and users shall expect that its value can change at any time.

DATA VALIDITY STATUS (DVS)	DEFINITION
0	Navigation data valid
1	Working without guarantee (WWG)

Table 4. Data Validity Status Bit Values

7....... *The Time To Alert between the occurrence of an event and the setting of the SHS is under definition.*

Signal-In-Space Accuracy (SISA)

For E1 and E5b, the SISA Index is contained in the I/NAV navigation data stream. For E5a, the SISA Index is contained in the F/NAV navigation data stream.

The SISA Index values relevant to the assessment of the SIS Status, as defined in the OS SIS ICD (Annex A [1]), are recalled for convenience in Table 5.

As described in the OS SIS ICD, the SISA parameter can assume 255 values. Nevertheless, when the SISA is used as one of the means for determining the SIS Status, it must be considered as a binary indicator, with its only meaningful values being “No Accuracy Prediction Available” (that is NAPA, when SISA=255) or “not NAPA” (when SISA≠255). Note that those SISA values described in the OS SIS ICD (Annex A [1]) as Spare (from 126 to 254) are to be considered as not NAPA.

SISA INDEX	SISA VALUE
255	No Accuracy Prediction Available (NAPA)
0......254	Not NAPA

Table 5. SISA Index values relevant to the assessment of the SIS Status

2.3.1.4. *MAPPING BETWEEN SIS STATUS FLAGS AND SIS STATUS*

The mapping between the values of the SIS Status Flags, presented in section 2.3.1.3, and the three values of the SIS Status is provided in Table 6. In order to determine the Status for a specific SIS broadcast by a Galileo satellite, the user must ensure that the navigation message has been properly received, i.e. it has successfully passed the CRC check (see section 2.2.2.1).

The first condition to be fulfilled by the navigation message in order for the user to proceed with the determination of the SIS Status is that it must not be a dummy message. As explained in section 2.3.1.2, in case of dummy message the respective SIS must be considered Unhealthy.

If the message is not dummy, the user can proceed with checking the other conditions to determine the SIS Status as specified in Table 6. The order in which the flags are checked by a receiver on receipt of a non-dummy navigation message is arbitrary and up to the manufacturer. The value of each flag can be read (and taken into account) independently from the value of the other flags. An example of a possible decision tree for the determination of the SIS Status is provided in Figure 4.

SIS STATUS	DUMMY MESSAGE	SIS FLAGS		
		SHS	DVS	SISA
Healthy	No	OK	NDV	not NAPA
Unhealthy	No	Out of Service	Any Value	Any Value
	No	In Test	Any Value	Any Value
	Yes	N/A	N/A	N/A
Marginal	No	Ok	WWG	Any Value
	No	Ok	Any Value	NAPA
	No	Will be out of Service	Any Value	Any Value

Table 6. Galileo Initial Open Service SIS Status vs SIS Status Flags

As an example of receiver operations, in section 2.3.1.3 it is explained that DVS flag equal to WWG implies that the respective SIS cannot be considered Healthy but, depending on the value of the other flags, only Marginal. This means that the SIS might not meet the MPLs defined in this document. As soon as receivers detect that the DVS value has been set back to 0 and that, taking into account the other relevant flags, the SIS Status is back to Healthy, they will have to retrieve the most recently broadcast navigation data in order to use such SIS.

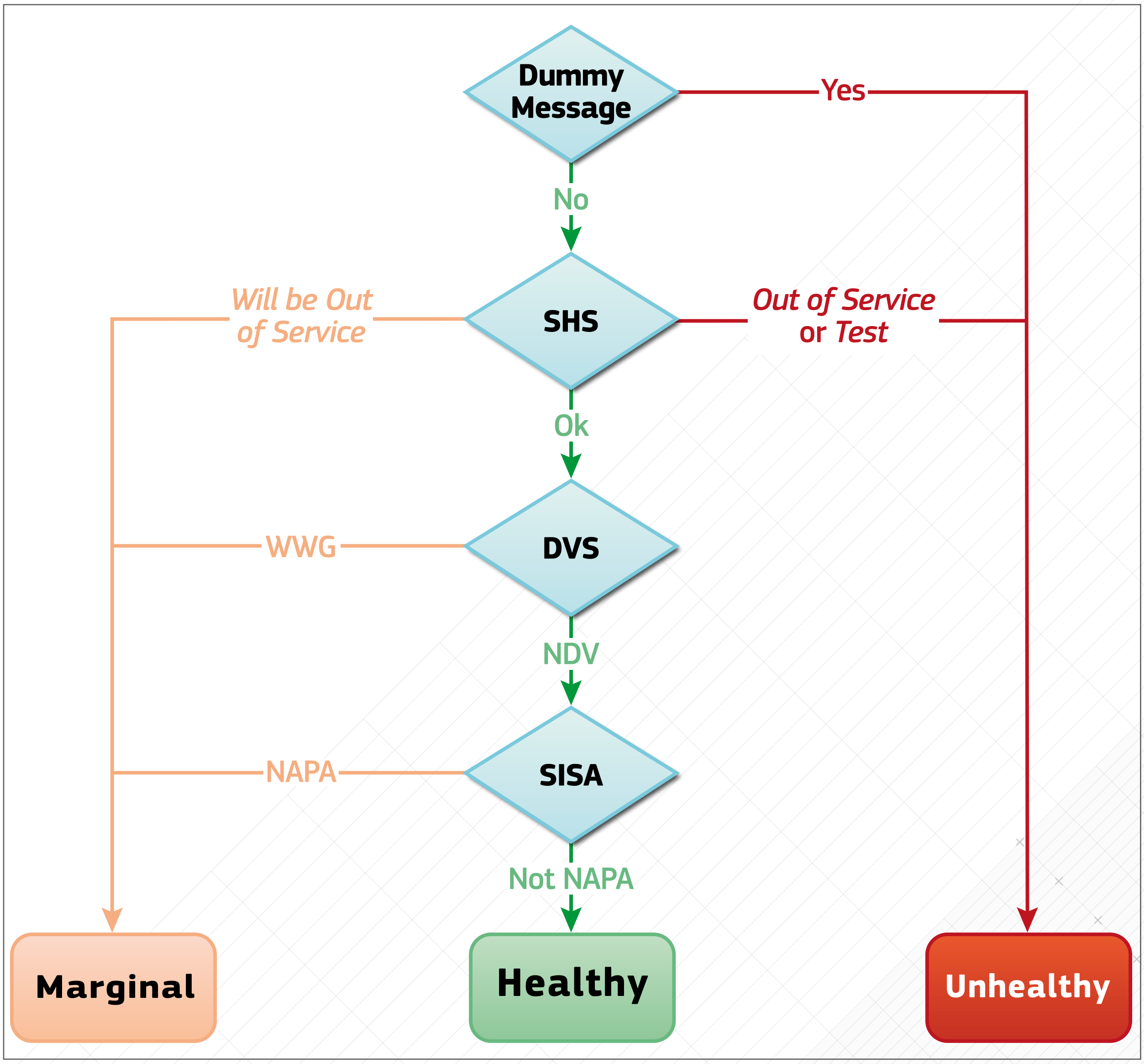


Figure 4. Example of a Decision Tree for the Determination of the Status of broadcast SIS.

This means that all parameters requested by a receiver have to be retrieved after the SIS is (back to) Healthy in order to ensure that the MPLs are expected to be met.

Note also that the value of SIS Status flags applies to the whole sub-frame they belong to. As an example, the DVS flag in the I/NAV message is located in Word Type 5 but its value is applicable also to the content of the Word Type 1, 2, 3 and 4.

Depending on the service to be used, Single-Frequency (SF) or Dual-Frequency (DF), Users will have to check the value of the various flags on different SIS. Table 7 shows the summary of the SIS Status Flags to be checked by the different Galileo OS users for both SF and DF services.

USERS		F/NAV			I/NAV				
		$E5a_{HS}$	$E5a_{DVS}$	SISA(E1,E5a)	$E1B_{HS}$	$E1B_{DVS}$	$E5b_{HS}$	$E5b_{DVS}$	SISA(E1,E5b)
SINGLE FREQUENCY	E1				X	X			X
	E5a	X	X	X					
	E5b						X	X	X
DOUBLE FREQUENCY	E1/E5a	X	X	X	X	X			
	E1/E5b				X	X	X	X	X

Table 7. Summary of SIS flags to be checked by the different Galileo OS Initial users to compute the Status of Signals-In-Space

2.3.2 GALILEO OS RANGING SERVICE ACCURACY

The Galileo OS Ranging Service Accuracy performance is based on the following two parameters:

- Galileo OS Ranging Accuracy
- Galileo OS Ranging Rate Accuracy.

2.3.2.1. GALILEO OS RANGING ACCURACY

The Galileo OS Ranging Accuracy is defined as a statistical measure of the Galileo SIS Ranging Error (SISE). The SISE is defined as the instantaneous difference between the position and time of a Galileo satellite as broadcast by the Galileo OS navigation message and the true satellite position and time, projected to the user-satellite direction. The SISE is the system contribution to the GNSS error budgets to the user equivalent range error (UERE), and contains all effects originating from and/or controlled by the Galileo system, while user local effects as well as atmospheric effects and SIS propagation effects (ionospheric/tropospheric) are not considered.

Since the SISE depends on the user-satellite direction i.e. on the user position, a "global average" of the instantaneous SISE is defined as the root-mean-square of the instantaneous SISE across the coverage area of the Galileo satellite considered.

The Galileo OS Ranging Accuracy is defined as the 95th percentile of the time series of the global average SISE. It is only measured for time periods during which the transmitted SIS was healthy. Galileo OS Ranging Accuracy is evaluated over all age of data (AOD [8]) values, i.e. the SISE time series will consider the navigation message at the age of data when it was observed.

2.3.2.2. GALILEO OS RANGING RATE ACCURACY

(To be developed in future issues of the document.)

2.3.3 GALILEO OS UTC TIME DETERMINATION SERVICE ACCURACY

The Galileo OS provides means for users to determine UTC by estimation of the GST-UTC difference using the parameters transmitted in the Galileo OS SIS. This is done by first estimating the local offset from GST, and secondly estimating the offset of GST with respect to UTC applying the GST-UTC conversion provided in the Galileo OS navigation data (see Annex A [1]).

The Galileo OS UTC Time Determination Accuracy performance is characterised by:

- Galileo SIS UTC Time Dissemination Accuracy
- Galileo SIS UTC Frequency Dissemination Accuracy.

8....... The Age of Data is the elapsed time since the generation of the navigation message data.

2.3.3.1. GALILEO SIS UTC TIME DISSEMINATION ACCURACY

The accuracy in the UTC solution experienced by the user, i.e. the Galileo UTC Time Determination Accuracy, depends on the instantaneous GST determination error and on the error in the broadcast GST-UTC conversion parameters. This second component is defined as the Galileo SIS UTC Time Dissemination Accuracy. In other words, the Galileo SIS UTC Time Dissemination Accuracy is the SIS component of the overall user UTC Time Determination (see Annex C.4.7), which is driven by the accuracy of the broadcast GST-UTC parameters and does not contain effects that are not under the control of the Galileo operator, such as user local contributions depending on the receivers or due to atmospheric effects. Figure 5 shows the various components of the UTC Time Determination Accuracy.

Galileo SIS UTC Time Dissemination Accuracy is defined as the 95th percentile of the broadcast GST-UTC conversion parameters error.

2.3.3.2. GALILEO SIS UTC FREQUENCY DISSEMINATION ACCURACY

The Galileo SIS UTC Frequency Dissemination Accuracy, defined on the basis of the derivative of the Galileo SIS UTC Time Dissemination Accuracy, is the major contribution to the UTC frequency transfer accuracy.

Galileo SIS UTC Frequency Dissemination Accuracy is defined as the 95th percentile of the first derivative of the broadcast GST-UTC conversion parameters error, i.e. the normalised frequency offset relative to UTC.

2.3.4 GALILEO OS AVAILABILITY

The availability performance of the Galileo Initial OS comprises:

Per-Slot Availability of Initial OS SIS:

Per-Slot Availability of Initial OS SIS is defined as the average availability of Healthy SIS at any slot of the Galileo satellite constellation[9]. The Per-Slot Availability of Initial OS SIS is provided as normalised annual value.

Availability of the Galileo Initial OS SF Ranging Service:

Availability of Galileo Initial OS SF Ranging Service for each frequency is computed at any user location as the percentage of time when the user location is provided with at least one such healthy Galileo OS SIS allowing SF ranging. Minimum Performance Levels for the Availability of Galileo Initial OS SF Ranging Service is specified for the worst user location within the service coverage area (See section 3.3 for the definition of service coverage area).

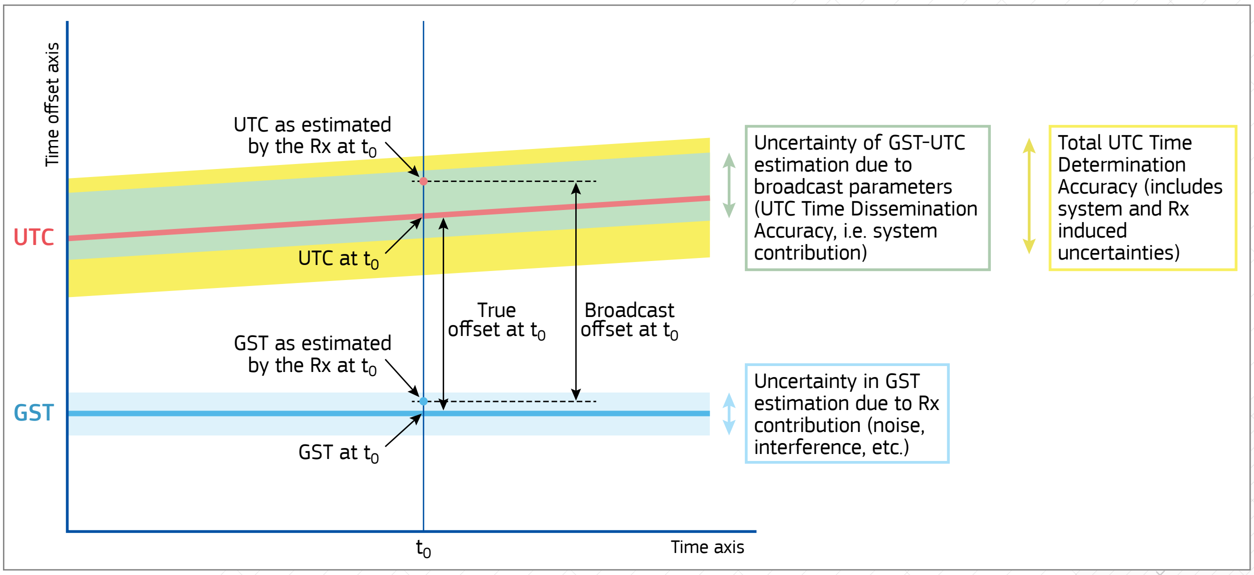


Figure 5. Graphical representation of the various components of the UTC Time Determination Accuracy.

9 The Galileo Space Segment is currently under deployment. At any moment, the Galileo constellation to be taken as reference is the one published by the GSC (http://www.gsc-europa.eu/system-status/Constellation-Information).

Availability of the Galileo Initial OS DF Ranging Service:

Availability of Galileo Initial OS DF Ranging Service for each dual-frequency combination is computed at any user location as the percentage of time when the user location is provided with at least one such healthy Galileo OS SIS combination allowing dual-frequency ranging. Minimum Performance Level for the Availability of Galileo Initial OS DF Ranging Service is specified for the worst user location within the service coverage area (see section 3.3 for the definition of service coverage area).

Availability of the Galileo Initial OS UTC Time Determination Service:

Availability of Galileo Initial OS UTC Time Dissemination Service is computed at any user location as the percentage of time when a user is provided with a healthy SIS, either single-frequency (E1, E5a, E5b) or dual-frequency (E1-E5a, E1-E5b), allowing UTC time determination. Minimum Performance Level for the Availability of Galileo Initial OS UTC Time Determination Service is specified for the worst user location within the service coverage area (see section 3.3 for the definition of service coverage area).

In the computation of all the Galileo OS availability Minimum Performance Levels, both planned and unplanned outages are included. Outages comprise the time intervals when SIS is not broadcast.

2.4 USAGE ASSUMPTIONS FOR INITIAL SERVICE PERFORMANCE

The MLPs contained in this Initial OS SDD are conditioned upon certain assumptions regarding the use of the OS SIS. Those assumptions are as follows.

2.4.1 OS USERS' RECEIVERS

This Initial OS SDD assumes that the Galileo OS user receiver complies with the technical requirements related to the interface between the Space Segment and Galileo OS receivers as established by the Galileo OS SIS ICD (Annex A [1]).

For each frequency or pair of frequencies used, it is assumed that the user receiver is capable of tracking the respective OS SIS (compliant to the SIS ICD (Annex A [1])) from all Galileo satellites in view above a masking angle of 5 degrees over the local horizon. The user has unobstructed visibility of the sky above this mask angle. As detailed in section 2.4.3, any error source related to the user receiver is not accounted for in the definition of the MPL.

It is also assumed that the user receiver uses up-to-date ephemeris and clock data for all satellites. More specifically, receivers must retrieve the values of navigation parameters relevant to the type of navigation solution to be computed from the most recent navigation data set broadcast on a Healthy SIS by the Galileo system after the start of the current receiver operation.

The navigation solution is expected to meet the Minimum Performance Levels only if receivers do not use navigation parameters beyond their broadcast period. The maximum nominal broadcast period of a healthy navigation message data set is currently 4 hours [10].

It is underlined that Galileo receivers, like most GNSS receivers, can increase navigation performance by implementing fault detection and isolation algorithms, for example by using algorithms based on the consistency of redundant pseudorange data sets (such as Receiver Autonomous Integrity Monitoring (RAIM) algorithms).

2.4.1.1. USAGE OF PARAMETERS IDENTIFIED BY AN ISSUE OF DATA

As defined in the OS SIS ICD, (Annex A [1]), the navigation parameters are disseminated in data batches, each identified by an Issue of Data (IOD) value. The identification of each batch by an IOD value enables:

- the users to distinguish the data in different batches received from each satellite;
- the user receiver to compute the full batch of data even if it misses some pages or starts receiving the data somewhere during the transmission.

10.... This time interval might be modified in the future. A procedure is described in Annex C to estimate the age of ephemeris as prediction time from reference Time of Ephemeris (t-t0e). Applying this algorithm, users are able to compare the age of the navigation parameters they have available with the maximum nominal broadcast period of a healthy navigation message data set.

- Two independent IODs are defined for:
- the ephemeris, satellite clock correction parameters and SISA;
- the almanacs.

To compute position and clock corrections, receivers must use, for each satellite, IOD-tagged parameters corresponding to the same IOD Value. Moreover, these parameters must be retrieved from the most recent navigation data set broadcast on a Healthy SIS by the Galileo satellite after the start of the current receiver operation. These are the two conditions regarding the IOD-tagged parameters under which the navigation solution is expected to meet the Minimum Performance Level. The utilisation of parameters identified by different IOD Values from a single satellite is not recommended and the resulting performance is not expected to meet the Minimum Performance Level.

Galileo satellites are not expected to all transmit the same IOD. For positioning, users can combine SIS from different satellites with different IOD Values provided that the navigation parameters derived from each satellite are tagged by a unique IOD Value.

It is relevant to note that IOD Values are not necessarily incremented in steps of one and that an IOD with higher value does not necessarily mean that it tags more recent data. The only valid comparison between IOD Values is whether they are equal or not.

Concerning the parameters not tagged by an IOD, i.e. the BGD, the ionospheric corrections, the GST-UTC and GST-GPS conversion parameters, the DVS and the SHS flags, as stated in section 2.4.1, receivers must retrieve their values (for those parameters relevant to the type of navigation solution to be computed [11]) from the most recent navigation data set broadcast on a Healthy SIS by the Galileo system after the start of the current receiver operation. This is the condition regarding the parameters not tagged by an IOD under which the navigation solution is expected to meet the Minimum Performance Level.

The satellite specific parameters (BGD, DVS, SHS) have to be obtained separately from each satellite and for each frequency while system parameters (ionospheric corrections, GST-UTC and GST-GPS conversion parameters) can be obtained from any Healthy SIS.

11.... As an example, DF users do not need to retrieve ionospheric parameters.

2.4.2 LIMITATIONS ON OS SIS STATUS

This OS SDD assumes that a Galileo receiver will only use OS SISs whose Status is indicated as Healthy. This Initial OS SDD explicitly assumes that a Galileo receiver will not make use of an OS SIS whose health status is indicated as either Marginal or Unhealthy.

2.4.2.1. PRIORITY OF BROADCAST OS SIS STATUS INFORMATION

As described in section 2.3.1, for each Galileo OS signal (E1, E5a, E5b), the SHS flag is contained in the navigation data. As detailed in Annex A [1], for E1 and E5b, the SHS flag is included in the Type 5 words of the I/NAV navigation data stream while for E5a, the SHS flag is included in the Type 1 words of the F/NAV navigation data stream. These are the flags that should normally be used for determining the SIS Status.

Additionally, these flags are also included in the corresponding almanac messages for indicative purposes. This allows focusing the search of satellites during initial acquisition on satellites with a healthy signal. In cases of conflict, the value in the Type 5 words of the I/Nav and the Type 1 words of the F/Nav message streams must be used, in line with section 2.3.1.3.

2.4.3 EXCLUDED ERRORS

The Minimum Performance Levels reported in section 3 of this Initial OS SDD do not take into account any error source that is not under direct control of the Galileo system. Specifically excluded errors comprise those due to the effects of:

- Signal distortion caused by ionospheric and/or tropospheric propagation effects,
- Residual receiver ionospheric delay compensation errors,
- Residual receiver tropospheric delay compensation errors,
- Receiver noise (including received signal power and interference power) and resolution,
- Receiver hardware/software faults,
- Multipath and receiver multipath mitigation,
- User antenna effects,
- Receiver operator error.

2.5 OPERATIONAL CAPABILITY EVOLUTION

The entry into the service provision phase of the Galileo Initial OS is taking place before the Galileo core infrastructure is fully deployed. As a consequence, an evolution of the performance is expected as the system, and in particular its space segment, reaches its full operational capability (FOC).

The minimum performance levels included in the current version of the document has been derived taking into account the current Galileo system deployment status. Future updates of the minimum performance level are foreseen, as the Galileo system reaches its final maturity.

Information about the current Galileo system status is available to users through the European GNSS Service Centre (GSC) webpage (see section 1.6.4).

SECTION 3: GALILEO INITIAL OS MINIMUM PERFORMANCE LEVELS

3.1 OVERVIEW

This section specifies the Galileo Initial OS performance in terms of Minimum Performance Levels (MPLs) defined for the set of performance parameters described in section 2. In addition, it provides further specifications about the constellation applicable at Initial Services declaration and the service coverage area, and lists the potential conditions or constraints that are applicable for service provision.

For all MPLs, all Ages of Data (AOD) observed during the measurement time interval are considered.

The navigation solution is expected to meet the OS MPLs only if the usage assumptions for Initial Service Performance as provided in section 2.4 and specifically those related to the OS user receiver in section 2.4.1. are fulfilled.

The Galileo OS MPLs do not include any contributions that are not under the control of the Galileo system. In particular, tropospheric, ionospheric, and receiver noise contributions or interference are not included in the specifications (see also section 2.4.3).

3.2 GALILEO INITIAL OS CONSTELLATION DEFINITION

The baseline Galileo constellation configuration is described in section 1.6.1 and in Annex C. The Galileo constellation status at the declaration of the Initial Services is reported in Table 8.

The Galileo constellation is currently under deployment. The up-to-date status of the Galileo constellation is available through the European GNSS Service Centre (GSC) webpage at http://www.gsc-europa.eu/system-status/Constellation-Information. All events related to the Galileo Space Segment are communicated to users through the Notice Advisories to Galileo Users (NAGUs) provided by the GSC (see Section 1.6.4.1.1).

The correspondence between satellite plane and slot and Space Vehicle Identifier (SVID) is reported in http://www.gsc-europa.eu/system-status/orbital-and-technical-parameters.

3.3 GALILEO INITIAL OS COVERAGE

The Galileo Initial Open Service is a global service. The Galileo system has been designed to ensure the provision

POSITION		SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	RAAN	ARG. PERIGEE	MEAN ANOMALY
Plane	Slot	km		deg	deg	deg	deg
A	2	29599.801	0	56.0	317.632	0	225.153
A	5	29599.801	0	56.0	317.632	0	0.153
A	6	29599.801	0	56.0	317.632	0	45.153
A	8	29599.801	0	56.0	317.632	0	135.153
B	3	29599.801	0	56.0	77.632	0	285.153
B	5	29599.801	0	56.0	77.632	0	15.153
B	6	29599.801	0	56.0	77.632	0	60.153
B	8	29599.801	0	56.0	77.632	0	150.153
C	2	29599.801	0	56.0	197.632	0	255.153
C	4	29599.801	0	56.0	197.632	0	345.153
C	7	29599.801	0	56.0	197.632	0	120.153

Table 8. Galileo FOC2 (Walker 24/3/1) Constellation Parameters (Ref. Epoch: 2016/11/21 00:00:00) – slots filled at the time of the declaration of the Initial OS provision.

of global coverage to users located within the nominal Galileo Service Volume, which is the region defined by the Earth's surface up to a maximum altitude of 30.48 kilometres[12]. A Space Service Volume, addressing altitudes beyond the current service volume, is under definition.

3.4 GALILEO INITIAL OS ACCURACY

This section provides the Minimum Performance Levels of the accuracy of the Galileo Initial OS. The MPLs provided in this section correspond to the Galileo deployment configuration status at declaration of Initial Services.

The following MPLs define Initial OS performance in accuracy:

For ranging services:

- Galileo SIS Ranging Accuracy for any satellite,
- Galileo SIS Ranging Accuracy over all satellites.

For timing services:

- Galileo SIS UTC Time Dissemination Accuracy
- Galileo SIS UTC Frequency Dissemination Accuracy.

The associated MPLs for the availability of services are defined in section 3.5. Note that the Galileo SIS Ranging Rate Accuracy MPL will be defined in a future issue of the OS SDD.

3.4.1 GALILEO SIS RANGING ACCURACY MPL

The Galileo SIS Ranging Accuracy MPL for any satellite for Initial OS, as defined in 2.3.2.1, is specified in Table 9.

The Galileo SIS Ranging Accuracy MPL over all satellites is the average over the Galileo constellation of the SIS Ranging Accuracy (95%) of each satellite calculated over a period of 30 days. The Initial OS is specified in Table 10.

GALILEO SIS RANGING ACCURACY MPL FOR ANY SATELLITE	CONDITIONS AND CONSTRAINTS
For each SF: • ≤ 7m (95%) global average, over all AODs	• Calculated over a period of 30 days • For any healthy OS SIS above a minimum elevation angle of 5 degrees • Including Broadcast Group Delay errors • Propagation and user contributions excluded • Neglecting single frequency ionospheric delay model errors[13]
For each DF combination: • ≤ 7m (95%) global average, over all AODs	• Calculated over a period of 30 days • For any healthy OS SIS above a minimum elevation angle of 5 degrees • Propagation and user contributions excluded

Table 9. Galileo SIS Ranging Accuracy MPL for any satellite.

GALILEO SIS RANGING ACCURACY MPL OVER ALL SATELLITES	CONDITIONS AND CONSTRAINTS
For each SF: • ≤ 2m	• Calculated over a period of 30 days • Average, over the constellation, of the Galileo SIS Ranging Accuracy (95%) of each Healthy SIS
For each DF combination: • ≤ 2m	• Calculated over a period of 30 days • Average, over the constellation, of the Galileo SIS Ranging Accuracy (95%) of each Healthy SIS

Table 10. Galileo SIS Ranging Accuracy MPL over all satellites.

3.4.2 GALILEO SIS RANGING RATE ACCURACY MPL

The Galileo SIS Ranging Rate Accuracy MPL will be defined in a future issue of the OS SDD.

Table 11. Reserved

12.... *This height corresponds to 100.000 feet. Users of E5a and E5b SIS should be aware that the OS performance might decrease at heights above 1000 metres due to possible interference with Aeronautics Radio Navigation Systems (ARNS) services.*

13.... *Note that although parameters for the correction of the ionospheric effect for SF users are broadcast by the Galileo OS SIS, the single-frequency ionospheric delay model errors are not accounted for in the MPL, just like any contribution to the MPL due to propagation that is not under control of the Galileo operator. This is valid throughout the document.*

3.4.3 GALILEO SIS UTC TIME DISSEMINATION ACCURACY MPL

The Galileo SIS UTC Time Dissemination Accuracy MPL for Initial OS is specified in Table 12.

GALILEO SIS UTC TIME DISSEMINATION ACCURACY MPL	CONDITIONS AND CONSTRAINTS
For each SF and DF combination: • < 30ns (95%) over all AODs	• For any healthy OS SIS • At any user location • Normalised annually • Propagation and user contributions excluded.

Table 12. Galileo SIS UTC Time Dissemination Accuracy MPL.

3.4.4 GALILEO SIS UTC FREQUENCY DISSEMINATION ACCURACY MPL

The Galileo SIS UTC Frequency Dissemination Accuracy MPL for Initial OS is specified in Table 13.

GALILEO SIS UTC FREQUENCY DISSEMINATION ACCURACY MPL	CONDITIONS AND CONSTRAINTS
For each SF and DF combination: • < $3E^{-13}$(95%) over all AODs	• For any healthy OS SIS • At any user location • Normalised annually • Propagation and user contributions excluded

Table 13. Galileo SIS UTC Frequency Dissemination Accuracy MPL.

3.5 GALILEO INITIAL OS AVAILABILITY

This section provides the MPLs associated with the Initial OS availability. The availability MPLs provided in this section correspond to the current Galileo deployment configuration status.

The following availability MPLs currently define Initial OS availability performance (see section 2):

- Per-Slot Availability
- Availability of the Galileo SF Ranging Service
- Availability of the Galileo DF Ranging Service
- Availability of the Galileo DF UTC Time Determination Service

3.5.1 PER-SLOT AVAILABILITY

The MPL for the Per-Slot Availability for Initial OS is specified in Table 14.

MPL OF THE PER-SLOT AVAILABILITY	CONDITIONS AND CONSTRAINTS
For each SF: • ≥ 87% probability that an orbital slot in the Galileo constellation [14] is occupied by a Galileo satellite transmitting the healthy SF SIS	• Calculated as an average of the availability of the SF SIS over all orbital slots in the Galileo satellite constellation [14], normalised annually • Including planned and unplanned outages
For each DF combination: • ≥ 87% probability that an orbital slot in the Galileo constellation [14] is occupied by a Galileo satellite transmitting the healthy DF SIS combination	• Calculated as an average of the availability of the DF SIS combination over all orbital slots in the Galileo satellite constellation [14], normalised annually • Including planned and unplanned outages

Table 14. MPL of the Per-Slot Availability.

14.... *The Galileo Space Segment is currently under deployment. At any time, the Galileo constellation to be taken as reference is the one published by the GSC (http://www.gsc-europa.eu/system-status/Constellation-Information). Because the deployment of the Galileo constellation has not been completed at the time of the IS Declaration, constellation maintenance and replenishment during this phase will be covered by continuation of the satellite deployment plan.*

3.5.2 AVAILABILITY OF THE GALILEO SF RANGING SERVICE

The MPL for the Availability of the Galileo SF Ranging Service for Initial OS is specified in Table 15.

MPL OF THE AVAILABILITY OF THE GALILEO SF RANGING SERVICE	CONDITIONS AND CONSTRAINTS
Single frequency E1: • ≥ 87% of time a user is provided with at least one healthy SIS on E1 frequency	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages
Single frequency E5a: • ≥ 87% of time a user is provided with at least one healthy SIS on E5a frequency	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages
Single frequency E5b: • ≥ 87% of time a user is provided with at least one healthy SIS on E5b frequency	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages

Table 15. MPL of the Availability of the Galileo SF Ranging Service.

3.5.3 AVAILABILITY OF THE GALILEO DF RANGING SERVICE

The MPL for the Availability of the Galileo DF Ranging Service Availability of the Galileo DF Ranging Service for Initial OS is specified in Table 16.

3.5.4 AVAILABILITY OF THE GALILEO UTC TIME DETERMINATION SERVICE

The MPL for the Availability of the Galileo UTC Time Determination Service for Initial OS is specified in Table 17.

MPL OF THE AVAILABILITY OF THE GALILEO DF RANGING SERVICE	CONDITIONS AND CONSTRAINTS
Dual frequency E1/E5a: • ≥ 87% of time a user is provided at least one pair of E1 and E5a healthy SIS	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages
Dual frequency E5b/E1: • ≥ 87% of time a user is provided at least one pair of E1 and E5b healthy SIS	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages

Table 16. MPL of the Availability of the Galileo DF Ranging Service.

MPL OF THE AVAILABILITY OF THE GALILEO INITIAL OS UTC TIME DETERMINATION SERVICE	CONDITIONS AND CONSTRAINTS
For each SF: • ≥ 87% of time a user is provided at least one healthy SF SIS	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages
For each DF combination: • ≥ 87% of time a user is provided at least one healthy DF SIS combination	• Calculated over a period of 30 days • Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Including planned and unplanned outages

Table 17. MPL of the Availability of the Galileo Initial OS UTC Time Determination Service.

3.6 ADDITIONAL FUNCTIONALITY

3.6.1 GALILEO OS COMPATIBILITY AND INTEROPERABILITY WITH OTHER GNSS

The Galileo OS is compatible, i.e. operates on non-harmful interference basis, with the other GNSS services, such as GPS, GLONASS and Beidou services. One of the main drivers of the Galileo system design has been its interoperability with other GNSS. In the GNSS context, interoperability should be understood as the capability for user equipment to exploit available navigation signals of different GNSS and to produce a combined solution which generally exhibits performance benefits (e.g. better accuracy, higher availability) with respect to the standalone system solution.

The design of the Galileo system has addressed interoperability from different perspectives:

- The Galileo frequency bands have been allocated in the Radio Navigation Satellite Services (RNSS) part of the spectrum. The OS carrier frequencies (in particular E1, and E5a) and their modulation characteristics simplify the combined use of Galileo with other constellations (GPS, GLONASS, and Beidou).
- The Galileo terrestrial and time reference systems have been defined and are continuously aligned to the corresponding international terrestrial and time reference systems, ITRF and UTC, respectively (see sections 1.6.5.1 and 1.6.5.2).

Furthermore, Galileo implements additional features in order to support an enhanced level of interoperability with GPS, as explained in the next section.

3.6.1.1. GALILEO SYSTEM TIME TO GPS TIME OFFSET

In order to take advantage of the combined Galileo/GPS constellation, a precise knowledge is required of the differences between Galileo and GPS systems in terms of system time.

Galileo System Time (GST) (see section 1.6.5.2) and GPS time are two independent continuous timescales steered respectively to UTC(k) and UTC(USNO). Although the coherence of all UTC realisations inherently provides a high degree of interoperability between Galileo and GPS, the actual physical realisations are independent, hence Galileo and GPS system times are different and this difference is variable with time.

This inconsistency between Galileo and GPS time references can be solved either by autonomous calculation in the user equipment or by provision of system time offsets by any of the participating GNSS.

For autonomous calculation in the user equipment, an additional unknown parameter is introduced into the positioning system of equations for the a priori unknown time difference between the systems. In solving the set of equations, the time difference is also inherently resolved. The disadvantage of this approach is that at least one additional line-of-sight measurement is required for solving the set of equations. Effectively, at least one available satellite of the combined visible constellation is dedicated to solving for the time difference.

The Galileo system provides the "Galileo to GPS Time Offset" (GGTO) as part of its navigation message. The MPLs for the GGTO parameter are presented in section 3.6.1.2.

3.6.1.2. GALILEO GPS-GST TIME OFFSET DETERMINATION PERFORMANCE

The accuracy in determination of the GST-GPS time offset is defined as the 95th percentile of the difference between the GST versus GPS time as computed using the Galileo navigation message and the true GGTO, averaged over one day. True GGTO is the GST-GPS Time offset as observed through the SIS of the two systems.

The availability of determination of the GST-GPS time offset is defined as the global average percentage of time that the GGTO is broadcast on one or more healthy SIS receivable above a minimum elevation angle of 5 degrees from any point in the service coverage area (including both planned and unplanned outages).

The GGTO determination accuracy for Initial OS is specified in Table 18. The GGTO determination availability for Initial OS is specified in Table 19.

MPL OF GALILEO GST-GPS TIME OFFSET DETERMINATION ACCURACY	CONDITIONS AND CONSTRAINTS
Any OS SIS: • < 20ns (95%) difference between the broadcast GGTO and the true GGTO, averaged daily	• For any healthy OS SIS • Normalised annually • Propagation and user contributions excluded

Table 18. MPL of Galileo GST-GPS Time Offset Determination Accuracy.

MPL OF GALILEO GST-GPS TIME OFFSET DETERMINATION AVAILABILITY	CONDITIONS AND CONSTRAINTS
Any SIS OS: • ≥ 80% of time that GGTO is broadcast on at least one healthy SIS	• Above a minimum elevation angle of 5 degrees • From any point in the service coverage area • Normalised annually • Including planned and unplanned outages

Table 19. MPL of Galileo GST-GPS Time Offset Determination Availability.

3.7 PERFORMANCE LEVEL FOR THE GNSS SERVICE CENTRE

As described in section 1.6.4, the GSC is the single centralised ground interface between the Galileo OS (and CS) user community and the Galileo system infrastructure and operator. It is responsible, among other tasks, for reporting on the status of the service through the dissemination of NAGUs and for providing helpdesk service to the users.

These two services by the GSC are part of the overall service provided by Galileo to its users and are subject to MPLs.

During the provision of Galileo Initial Services, the GSC performance is characterised by the Timely publication of NAGUs.

3.7.1 TIMELY PUBLICATION OF NAGUS

The Timely publication of NAGUs refers to the time intervals within which Galileo NAGUs will be published, before any planned event or after any unplanned event.

The MPL for the Timely publication of NAGUs for Initial OS is specified in Table 20.

MPL OF THE TIMELY PUBLICATION OF NAGUS	CONDITIONS AND CONSTRAINTS
For scheduled events affecting the service • ≥ 24 hours before the service is affected	• Including both Planned and General NAGUs
For unscheduled outages or events affecting the service • ≤ 72 hours after the event affecting the service is detected	• Only for Unplanned NAGUs

Table 20. MPL of the Timely publication of NAGUs.

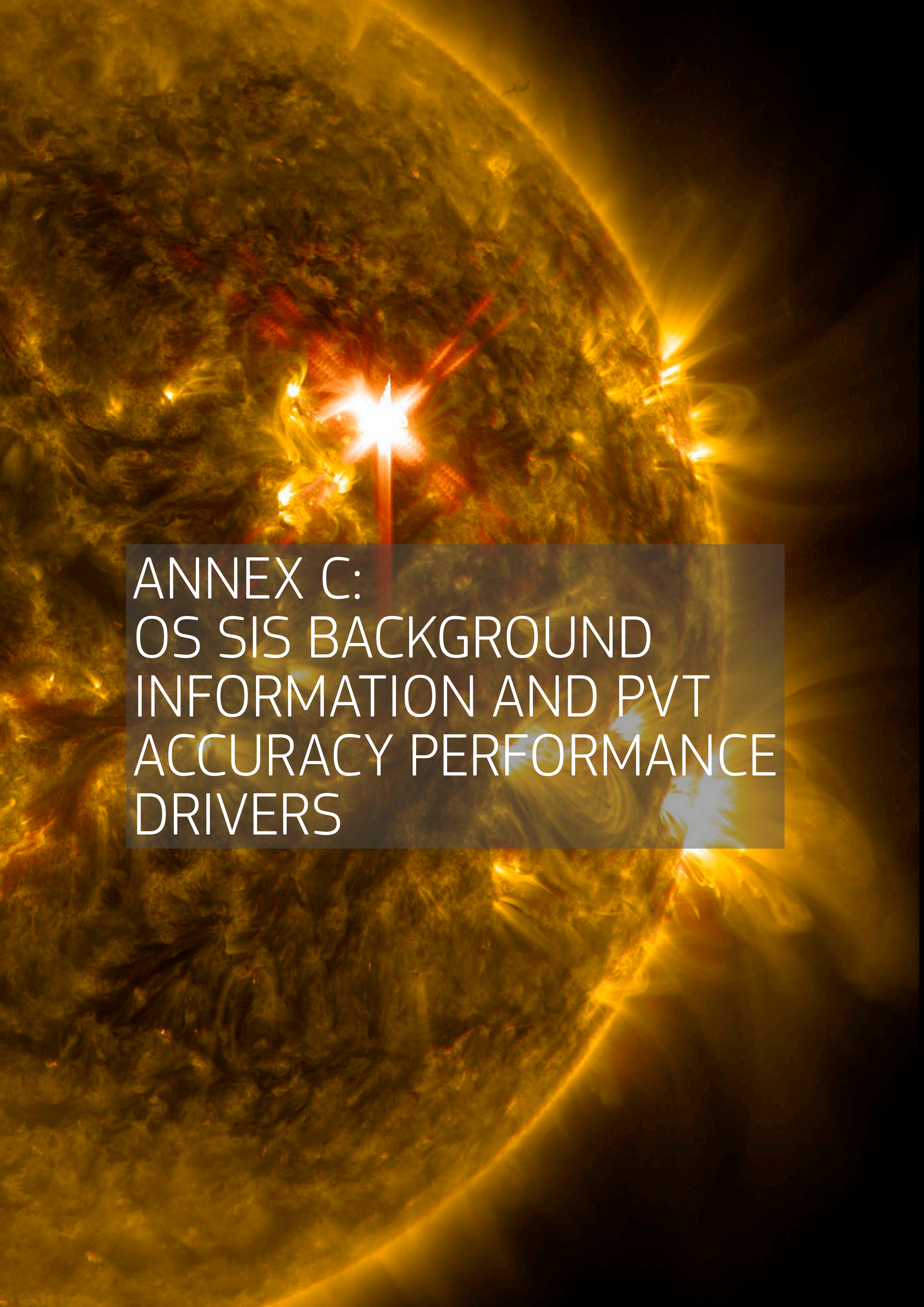
ANNEX A: REFERENCE DOCUMENTS

This section identifies the documents explicitly referenced in this Initial Open Service Requirement Document.

REFERENCE	TITLE	ISSUE
[1]	European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (OS SIS ICD).	Issue 1.3, European Union, December 2016.
[2]	Ionospheric Correction Algorithm for Galileo Single Frequency Users.	Issue 1.2, European Union, September 2016.

ANNEX B: ABBREVIATIONS AND ACRONYMS

AltBOC	Alternative BOC modulation
AOD	Age of Data
BGD	Broadcast Group Delay
BIPM	International Bureau of Weights and Measures
BOC	Binary Offset Carrier modulation
CBOC	Composite BOC modulation
CIRS	Celestial Intermediate Reference System
CRC	Cyclic Redundancy Check
CS	Commercial Service
DF	Dual-Frequency
DOP	Dilution Of Precision
DVS	Data Validity Status
EDDN	External Data Distribution Network
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European GNSS
EM	Electromagnetic
EU	European Union
F/NAV	Navigation Message broadcast on Galileo E5a signal
FE	Frequency Error
FEC	Forward Error Correction
FOC	Full Operation Capability
FP7	Seventh Framework Programme
GCC	Galileo Control Centre
GCS	Ground Control Segment
GDDN	Galileo Data Distribution Network
GDOP	Geometric DOP
GGTO	Galileo-GPS Time Offset
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema
GMS	Ground Mission Segment
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRSP	Geodetic Reference Service Provider
GSA	European GNSS Agency
GSC	European GNSS Service Centre
GSMC	Galileo Security Monitoring Centre
GSS	Galileo Sensor Station
GST	Galileo System Time
GTRF	Galileo Terrestrial Reference Frame
HDOP	Horizontal DOP
HPE	Horizontal Position Error
HPOS	Horizontal Positioning
I/NAV	Navigation Message broadcast on Galileo E5ab and E1 signal
ICD	Interface Control Document
IERS	International Earth Rotation and Reference Systems Service
IOD	Issue of Data
ITRF	International Terrestrial Reference Frame
MPL	Minimum Performance Level
NAGU	Notice Advisory to Galileo Users
NavCen	Navigation Center
NAPA	No Accuracy Prediction Available
NDV	Navigation Data Validity
OS	Open Service
PDOP	Position DOP
PE	Position Error
PRS	Public Regulated Service
PVT	Position, Time, and Velocity
R&D	Research and Development
RAAN	Right Ascension of the Ascending Node
RF	Radio Frequency
RNSS	Radio Navigation Satellite Services
SAR	Search And Rescue
SDD	Service Definition Document
SF	Single-Frequency
SHS	Signal Health Status
SIS	Signal In Space
SISA	SIS Accuracy
SISE	SIS Ranging Error
SISRRE	SIS Ranging Rate Error
SV	Space Vehicle
SVID	Space Vehicle Identifier
TAI	International Atomic Time
TDOP	Time DOP
TOC	Time of Clock
TOE	Time of Ephemeris
TE	Time Error
TSP	Time Service Provider
TTC	Telemetry, Tracking, and Commanding
UEE	User Equipment Error
UERE	User Equivalent Range Error
UERRE	User Equivalent Rage Rate Error
ULS	Galileo Uplink Station
USNO	United States Naval Observatory
UTC	Coordinated Universal Time
VDOP	Vertical DOP
VE	Velocity Error
VPE	Vertical Position Error
WGS84	World Geodetic System 1984
WWG	Working Without Guarantee



ANNEX C: OS SIS BACKGROUND INFORMATION AND PVT ACCURACY PERFORMANCE DRIVERS

C.1. INTRODUCTION

C.1.1 SCOPE

This Annex comprises additional background information and details regarding the Galileo OS SIS performance parameters.

C.1.2 LIMITATIONS

The information in this Annex is provided exclusively for reference and does not in any way affect the MPLs presented in section 3 of this Initial OS SDD.

C.2. CONSTELLATION

C.2.1 RELATIONSHIP WITH SECTION 3.2

Section 3.2 of this document provides the Galileo constellation operational configuration at the time of declaration of the Initial Services. In the next section, information is provided on the Galileo constellation expected at FOC.

C.2.2 BASELINE 24-SLOT CONSTELLATION CONFIGURATION

The baseline Galileo constellation configuration is defined as a 24/3/1 Walker constellation: 24 nominal Medium Earth Orbit satellites are arranged in 3 orbital planes, with their ascending nodes uniformly distributed at intervals of 120 degrees, inclined at 56 degrees with respect to the Equator.

Each orbital plane includes 8 satellites uniformly distributed within the plane, at intervals of 45 degrees of argument of latitude. The angular shift between satellites in two adjacent planes is 15 degrees. This constellation is complemented by spare satellites that can be repositioned to any given nominal slot depending on maintenance or service evolution needs. The location in each plane is not yet frozen and will be decided at the time of deployment of the spare capability.

The reference constellation geometry of the 24-slot Galileo constellation is defined in Table 22. The Keplerian parameters are given in Celestial Intermediate Reference System (CIRS) frame [15].

Table 22 shows a snapshot of the reference orbit at the reference epoch 2016/11/21 00:00:00 UTC. The reference RAAN, argument of perigee and Mean Anomaly are dynamic parameters, while the others are static. To calculate values for other epochs, users are advised to use a linear extrapolation for the RAAN, argument of perigee and the Mean Anomaly with the temporal rates shown in Table 21.

REFERENCE PARAMETER RATES	SLOTS
d(RAAN)/dt	-0.02764398 deg/day
d(Arg. peri)/dt	0.00000000 deg/day
d(Mean Anomaly)/dt	613.72253566 deg/day

Table 21. Galileo Constellation Reference Technical Parameters.

15. The CIRS is a geocentric coordinate system based on the current position of the Celestial Intermediate Pole. In this system, the right ascension is calculated along the Celestial Intermediate Equator from the Celestial Intermediate Origin, a point close to the vernal equinox. The exact definition can be found in the Nomenclature for Fundamental Astronomy Glossary edited by the International Astronomical Union.

POSITION		SEMI-MAJOR AXIS	ECCENTRICITY	INCLINATION	RAAN	ARG. PERIGEE	MEAN ANOMALY
Plane	Slot	Km		deg	deg	deg	deg
A	1	29599.801	0	56	317.632	0	180.153
A	2	29599.801	0	56	317.632	0	225.153
A	3	29599.801	0	56	317.632	0	270.153
A	4	29599.801	0	56	317.632	0	315.153
A	5	29599.801	0	56	317.632	0	0.153
A	6	29599.801	0	56	317.632	0	45.153
A	7	29599.801	0	56	317.632	0	90.153
A	8	29599.801	0	56	317.632	0	135.153
B	1	29599.801	0	56	77.632	0	195.153
B	2	29599.801	0	56	77.632	0	240.153
B	3	29599.801	0	56	77.632	0	285.153
B	4	29599.801	0	56	77.632	0	330.153
B	5	29599.801	0	56	77.632	0	15.153
B	6	29599.801	0	56	77.632	0	60.153
B	7	29599.801	0	56	77.632	0	105.153
B	8	29599.801	0	56	77.632	0	150.153
C	1	29599.801	0	56	197.632	0	210.153
C	2	29599.801	0	56	197.632	0	255.153
C	3	29599.801	0	56	197.632	0	300.153
C	4	29599.801	0	56	197.632	0	345.153
C	5	29599.801	0	56	197.632	0	30.153
C	6	29599.801	0	56	197.632	0	75.153
C	7	29599.801	0	56	197.632	0	120.153
C	8	29599.801	0	56	197.632	0	165.153

Table 22. Galileo Constellation Reference Geometry at 2016/11/21 00:00:00 UTC.

C.3. COVERAGE

C.3.1 RELATIONSHIP WITH SECTION 3.3

This section of the Annex provides further information with respect to section 3.3 of this document regarding the service coverage, particularly with respect to the coverage from each Galileo satellite.

C.3.2 PER-SATELLITE COVERAGE

C.3.2.1. MASKING ANGLES

The Galileo OS SIS ICD (Annex A [1]) defines the minimum power levels of Galileo signals above a 5 degree elevation angle. However, this definition does not recommend or impose any specific minimum user masking angle.

The Galileo user masking angle is a function of various factors: the SIS ICD defined minimum user-received power levels, the specific signals tracked, the Galileo user receiver antenna gain patterns for each frequency, the receiver front-end sensitivity at each frequency, and the particular usage objective, as well as other signal environment and user receiver related factors.

For the scope of the assessments in this SDD a typical minimum user elevation angle of 5 degrees has been used. Other user needs might mandate different minimum elevation angles.

C.3.2.2. SATELLITE FOOTPRINT

The footprint of a satellite is defined as the fraction of the surface of the Earth that is illuminated by signals from that particular satellite. The footprint of each satellite occupying a slot in the baseline 24-slot constellation covers under purely geometrical aspects approximately 39% of the Earth's surface at 0 degrees minimum user elevation angle. However, the footprint area is reduced by the consideration of user elevation masking angle. With a 5-degree user masking angle, the satellite's footprint is reduced to roughly one-third of the Earth's surface (35%).

C.3.3 CONSTELLATION COVERAGE

The terrestrial service volume defines the region on and around Earth in which the Galileo services are provided. The terrestrial service volume is defined as the region extending from the surface of the Earth up to an altitude of 30.48 km above the surface of the Earth.

C.4. ACCURACY

C.4.1 RELATIONSHIP WITH SECTION 3.4

To complement the information provided in section 3.4 of the document, this part of Annex C provide further details about several aspects concerning the definition of the SISE accuracy and its behaviour in time. In addition, insight is provided about how to estimate the error in position and time experienced by Galileo users, through the definition of the User Equivalent Range Error and of the Position Dilution Of Precision.

C.4.2 DEFINITION OF SIGNAL-IN-SPACE RANGING ERROR

The Signal In Space Ranging Error (SISE) is defined as the difference of the satellite position and time as broadcast by the navigation message and the true satellite position and time, projected on the user-satellite direction. The SISE is the system contribution to the Galileo User Equivalent Range Error (UERE). The following section illustrates the SISE performance metrics used for the Galileo system performance verification.

C.4.3 INSTANTANEOUS SISE PERFORMANCE METRICS

The SISE can be computed by comparing the predicted satellite position and time, based on the broadcast navigation message, with a posteriori precise clock and orbit estimations. Derivation of the instantaneous SISE can be performed in two different ways, numerically and analytically.

C.4.3.1. NUMERICAL DERIVATION

The SISE can be evaluated through a numerical iteration over each grid point defined in the satellite service area, projecting orbit and clock errors onto the line of sight between the satellite and user locations. The maximum error, SISE Worst User Location, typically occurs at the edge of the visibility cone, as shown in Figure 6.

The global average can be computed as the RMS of the errors over all grid points in the visibility footprint of the satellite at each time iteration.

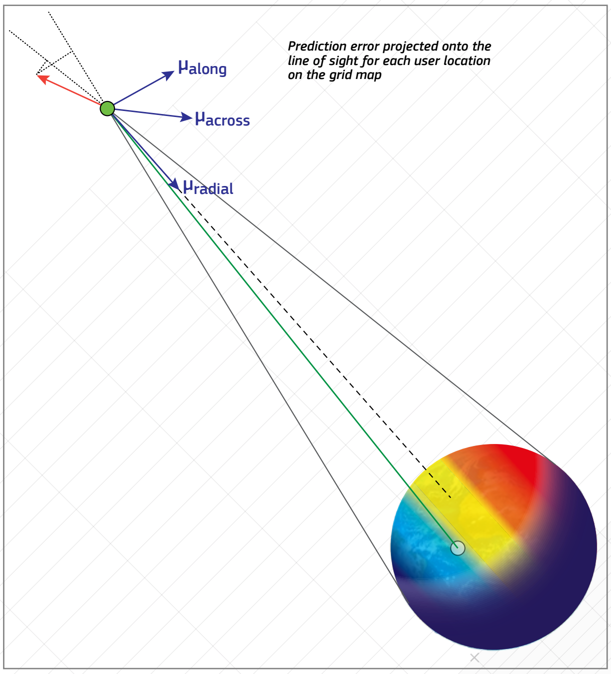


Figure 6. SISE projection onto the line of sight for each user location

C.4.3.2. ANALYTICAL DERIVATION

The global average SISE value can be derived analytically from the Galileo satellite's along-track (A), cross-track (C) and radial (R) orbit error components and its total SIS clock prediction error (CLK) by means of the following formula.

$$SISE_{GlobalAverage} = \sqrt{0.9673 \cdot R^2 + CLK^2 + 0.01632 \cdot (A^2 + C^2) + 1.967 \cdot CLK \cdot R} \quad \text{Eq. 1}$$

The following convention has been considered for clock and orbit components:

- Clock prediction error is computed as the satellite predicted clock minus the estimated one.
- Radial direction: from the satellite towards the Earth centre.
- Cross direction: direction perpendicular to the orbital plane aligned with the cross product of the radius and velocity.
- Along direction: perpendicular to the radius in the orbital plane, positive in the same semi-plane of the velocity.

The instantaneous SISE is typically estimated either as Global Average or at Worst User Location (WUL).

C.4.4 TIME DEPENDENCY

C.4.4.1. SISE EVOLUTION WITH UPLOADS AS A FUNCTION OF TIME

The Galileo system generates and uploads 8 batches of navigation data (see the Galileo OS SIS ICD (Annex A [1]) for more details). In nominal operations each navigation message can potentially be broadcast for up to 3 hours.

The Age of Navigation Data (AOD) is the elapsed time between reception of a navigation message at user level and its generation by the Ground Segment. Aging of the data (characterised by AOD) impacts the accuracy of the orbit and clock models. The accuracy of their prediction inevitably degrades with higher ages.

Dissemination of the navigation message is a compromise between upload frequency and navigation data accuracy. A high upload frequency ensures a low age of data (better orbit and clock prediction accuracy) but also requires more frequent decoding of the message by users.

The age of Time of Ephemeris (ToE), i.e. the prediction time from the reference ToE (set at the beginning of the prediction interval of each batch), can be checked by the users. Figure 7 illustrates the SISE evolution as a function of the Age of ToE and typical and maximum age of data service envelops.

The nominal service envelope is given by the lower bound illustrated in Figure 7. For extended operations the message error could grow within the area defined as maximum. The system will target operations in the nominal service envelope.

The navigation dataset refresh rate is a parameter defined by the system. The typical refresh rate of the navigation data broadcast by the satellites ranges from 10 minutes to 3 hours.

The maximum nominal broadcast period of a healthy navigation message data set is currently 4 hours [16]. A navigation message data set may be superseded before its expiration at 4 hours by the broadcast of a new navigation message data set.

16.... The following procedure can be used to estimate the age of ephemeris as prediction time from the reference Time of Ephemeris (t-toe). Applying this algorithm, users are able to compare the age of the navigation parameters they have available with the maximum nominal broadcast period of a healthy navigation message data set. The Age of Ephemeris t_k is defined as follows (see also Annex A [1]):

$$t_k = t - t_{oe}$$

where

t........is the Time of Reception of the message in GST time [s] based on the broadcast Time Of Week (TOW), defined as the number of seconds that have occurred since the transition from the previous week, ranging from 0 to 604799 seconds and reset to zero at the end of each week (00:00 Sunday).

t_{oe}.....is the Time of Ephemeris in GST time [s] (as for t ranging from 0 to 604799 seconds), as broadcast by the navigation message.

If a receiver wishes to check whether the age of ephemeris of a certain set of navigation data is within a certain time interval VT it will have to evaluate the following inequality:

$$0 \leq t_k \leq VT$$

*Note that, as explained in Annex A [1], note to Table 58, t_k is the actual total time difference between the broadcast GST and the Time of Ephemeris **accounting for the possible beginning or end of week crossover**. To take this into account, if t_k is greater than 302400 second, 604800 seconds must be subtracted from t_k. If t_k is less than -302400 seconds, 604800 seconds must be added to t_k.*

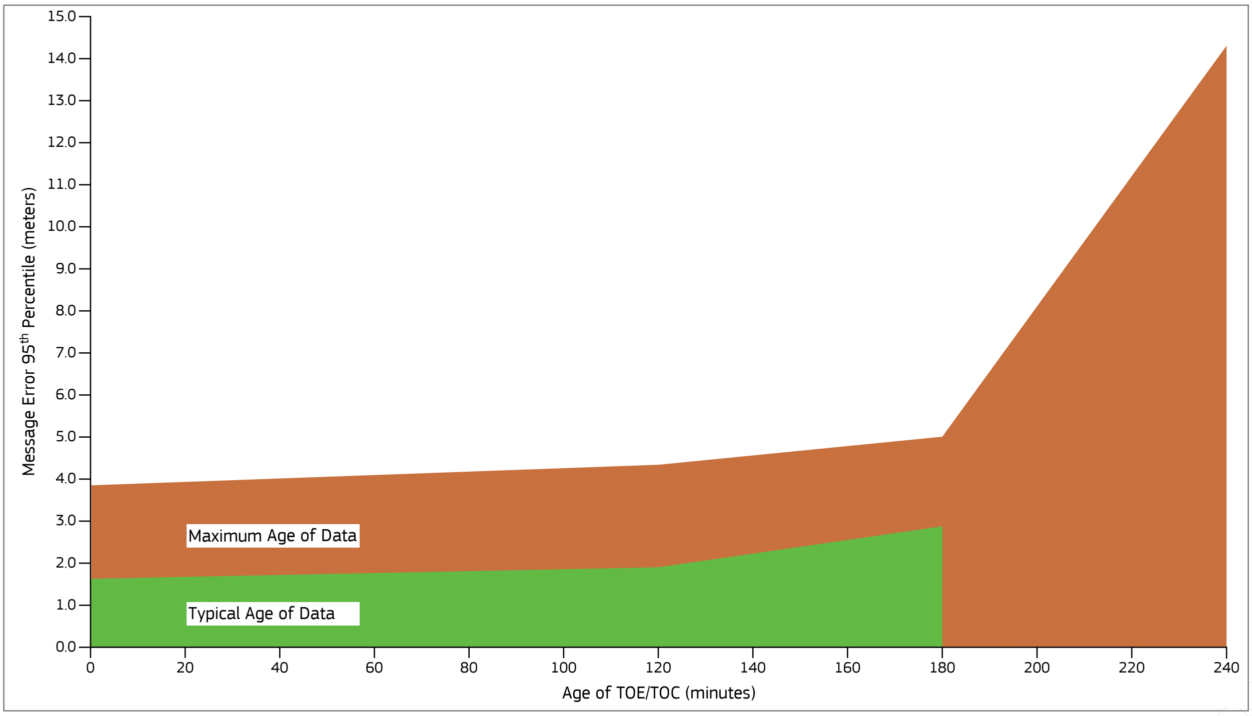


Figure 7. Typical SISE vs. Prediction Time from ToE (All Batches)[17]

As specified in section 2.4.1 the Galileo OS Minimum Performance Levels are expected to be met only if the navigation solution is computed by a receiver employing Healthy SIS and using the navigation parameters retrieved from the most recent navigation data set broadcast by the Galileo system after the start of the current receiver operation. The utilisation by a receiver of navigation parameters stored during previous receiver operations implies that the navigation performance that can be achieved is not expected to meet the Minimum Performance Level. Furthermore, given the way the DVS and SHS flags can be triggered, a navigation data set within the maximum nominal broadcast period of a healthy navigation message data set but not retrieved from the currently broadcast SIS might lead to the use of non-Healthy signals: the use of an old navigation data set stored in the memory of the receiver instead of the most recent data set transmitted by Galileo is at the user's own risk.

Concerning the GST-UTC conversion parameters, in the current system configuration they are updated daily (although this may change in future configurations). With respect to the almanacs, their refresh rate is the same as for the navigation data.

17.... *FOR ILLUSTRATION ONLY – Please note performance will gradually improve 1 over time toward the full system deployment.*

C.4.5 UERE BUDGET

TThe User Equivalent Ranging Error (UERE) quantifies the distribution that describes the pseudorange errors of a specific set of user receiver measurements. The UERE includes the following contributions:

- Signal-In-Space Range Error (SISE). The Signal-In-Space Range Error is the satellite-to-user range error due to satellite signal generation and navigation message clock and ephemeris errors, which is a function of time and user location within the satellite coverage area.
- User Equipment Error (UEE). The User Equipment Error is the satellite-to-user range error due to all residual error contributions in the range domain that are not under the direct control of the GNSS system.

The UERE breakdown into SISE and UEE distributions is important in order to differentiate between the contributions under control of the system and those arising from factors not controlled by the Galileo system, and to compare their relative effect on the overall pseudorange error.

The true characteristics of SISE and UEE distributions are not necessarily Gaussian. However, both SISE and UEE can be considered sufficiently close to unbiased, uncorrelated Gaussian distributions, and hence SISE and UEE are expressed by means of their standard deviations.

Under this assumption, the resulting UERE is the standard deviation of the pseudorange error distribution:

$$UERE = \sqrt{SISE^2 + UEE^2} \qquad \text{Eq. 2}$$

C.4.5.1. DEFINITION OF DILUTION OF PRECISION

The relative user-tracked transmitter geometry at a given point in time defines the mapping function which relates the UERE to a PVT error distribution. The parameter that provides the relation between the error contributions in the range domain and in the position and time domains is called the "Dilution Of Precision" (DOP).

Because the DOP depends exclusively on the relative geometry between user equipment and the tracked satellites, it is completely deterministic and predictable under certain assumptions, namely:

- Knowledge of the approximate user and transmitter locations at the desired time in the future
- The user's sky visibility conditions or horizon mask

Several variants of DOP can be differentiated for the components of the PVT solution, according to their respective mathematical formulation:

- The Horizontal DOP (HDOP) is the scale factor to be applied to the UERE to obtain the corresponding position error in the local horizontal plane
- The Vertical DOP (VDOP) is the scale factor to be applied to the UERE to obtain the corresponding position error in the local vertical plane
- The Position DOP (PDOP) is the scale factor to be applied to the UERE to obtain the corresponding three-dimensional position error. It is calculated from the horizontal and vertical DOP according to

$$PDOP = \sqrt{HDOP^2 + VDOP^2} \qquad \text{Eq. 3}$$

- The Time DOP (TDOP) is the scale factor to be applied to the ranging measurement error to obtain the corresponding time offset determination error (with respect to the particular system's reference timescale) for mobile users
- Geometric DOP (GDOP), which by definition includes the position and time DOP, according to

$$GDOP = \sqrt{PDOP^2 + TDOP^2} \qquad \text{Eq. 4}$$

C.4.5.2. STATISTICAL MODELLING OF THE PVT ACCURACY

This section provides the derivation of the position and timing accuracy performance based on the definitions of UERE and DOP in the previous sections.

The basic equations for position errors (Horizontal Error, Vertical Error and Time Error) based on UERE definition and DOP factors are:

$$\begin{aligned} \text{HE}\ (rms) &= UERE \cdot HDOP \\ \text{VE}(rms) &= UERE \cdot VDOP \\ \text{TE}\ (rms) &= \frac{UERE}{c} \cdot TDOP \end{aligned} \qquad \text{Eq. 5}$$

This approximation for the position errors can be used under the assumption of zero mean and normally distributed pseudorange errors characterised by the same UERE.

C.4.5.3. TYPICAL UERE BUDGETS

Typical UERE budgets in nominal operations are presented for the single frequency rural pedestrian and dual frequency rural vehicle users, shown respectively in Table 23 and Table 24.

These UERE budgets are shown for illustration purposed only, in particular for those contributors related to the receiver.

ERROR SOURCE	[METERS]
Signal In Space Ranging Error (SISE)	0.67
Residual Ionosphere error	6 (5°) -3 (90°)
Residual Troposphere error	1.35 (5°) – 0.14 (90°)
Thermal noise, Interfer, Multipath	0.35 (5°) – 0.23 (90°)
Multipath bias error	0.59
Satellite BGD error	0.30
Code-Carrier Ionospheric divergence error	0.30
Total (1-sigma error [cm])	6.26 (5°) – 3.10 (90°)

Table 23. Single Frequency E1 – Rural Pedestrian (RP) User Environment (*)

ERROR SOURCE	[METERS]
Signal In Space Ranging Error (SISE)	0.67
Residual Ionosphere error	0.08 (5°) - 0.03 (90°)
Residual Troposphere error	1.35 (5°) – 0.14 (90°)
Thermal noise, Interfer, Multipath	0.46 (5°) – 0.13 (90°)
Multipath bias error	0.19
Satellite BGD error	0.0
Code-Carrier Ionospheric divergence error	0.0
Total (1-sigma error [cm])	1.59 (5°) – 0.72 (90°)

Table 24. Dual Frequency E1-E5a – Rural Vehicle (RP) User Environment (*)

(*) Typical range of elevation-dependent error sources are provided. Note that the two typical error budgets are based on different environmental assumptions and dynamics that explain the different values in the tables.

C.4.6 SISE TIME DERIVATIVE ACCURACIES

(to be developed in future issues of the document)

C.4.7 USER UTC TIME DETERMINATION ACCURACY

As shown in Table 12, during normal operations, the Galileo SIS UTC dissemination accuracy is within 30 ns 95%.

As introduced in section 2.3.3.1, non-system contributions should also be considered in the estimation of the overall user UTC time transfer accuracy. This can be estimated with the following equation

$$UUTCE = \sqrt{\left(\frac{UERE \cdot TDOP}{c}\right)^2 + UTCDE^2} \qquad \text{Eq. 6}$$

where

- $UUTCE$ = User UTC(SIS) Error (rms)
- $TDOP$ = Time Dilution of Precision
- $UTCDE$ = UTC(SIS) dissemination error (system only contribution).

C.4.8 IONOSPHERIC DELAY MODEL FOR GALILEO SINGLE-FREQUENCY USERS

The ionospheric delay model for Galileo single-frequency users is the *NeQuick* model described in (Annex A [2]). The Galileo navigation message includes several parameters that are used by receivers implementing the *NeQuick* model to compute the ionospheric effect in order to be able to apply the corresponding corrections.

C.4.9 SINGLE-FREQUENCY GROUP DELAY TIME CORRECTION ERRORS

A single-frequency user receiver must apply the Broadcast Group Delay (BGD) corrections to the SV clock following the equations described in the Galileo OS SIS ICD (Annex A [1]). Errors in the BGD values affect the SISE experienced by the single-frequency users.

As an example, the UERE budget illustrated for the single-frequency E1 – Rural Pedestrian (RP) in Table 23 also includes a typical BGD error contribution.

C.5. INTEGRITY

(to be developed in future issues of the document).

C.6. CONTINUITY

(to be developed in future issues of the document).

C.7. AVAILABILITY

As mentioned in section 1.5, at the current stage of deployment of the Galileo infrastructure, the percentage of time during which four Galileo satellites are simultaneously in view, therefore allowing the calculation of user's PVT solution, is limited due to the number of satellites in orbit.

Nevertheless, considering the performance achieved by the Ranging Services and the characteristics of the constellation already deployed at Initial Service Declaration, an indication is herewith provided for the expected availability of HDOP and of Horizontal Positioning.

C.7.1 AVAILABILITY OF GLOBAL HDOP

The availability of HDOP is computed at any user location as the percentage of time at least 3 Galileo satellites are visible, transmitting healthy SIS and with an HDOP <= 5. The expected availability of global HDOP is specified for the average user location within the service coverage area, i.e. computed as the global average over all user locations (see section 3.3 for the definition of service coverage area).

The expected availability of global HDOP for Initial OS is specified in Table 25.

MPL OF THE AVAILABILITY OF GLOBAL HDOP	CONDITIONS AND CONSTRAINTS
For each SF and DF combination: • ≥ 50% at average location	• With a Horizontal Dilution of Precision less than or equal to 5 • Minimum 3 satellites broadcasting healthy SIS, in view above a minimum elevation of 5 degrees • Normalised annually [18] • Including planned and unplanned outages

Table 25. MPL of the Availability of global HDOP.

C.7.2 AVAILABILITY OF SF AND DF HORIZONTAL POSITIONING

The availability of DF and SF Horizontal Positioning for Initial OS is computed at any user location as the percentage of time that the DF and respectively SF horizontal positioning error is less than or equal to a specific threshold at 95%, considering only SIS error contributions and only healthy Galileo SIS and assuming a receiver operating in altitude hold mode (i.e. using previous altitude estimation or approximation available). The expected availability of such global HPOS accuracy is specified for the average user location within the service coverage area, i.e. computed as the average over all user locations (see section 3.3 for the definition of service coverage area).

18.... *This value is provided normalised annually due to the current deployment stage of the Galileo constellation.*

The expected HPOS availability is derived from the expected HDOP values (Table 25) and the MPL defined for the OS SIS range accuracies (section 3.4.1). The resulting expected SF and DF HPOS availability for Initial OS is specified in Table 26.

MPL OF THE AVAILABILITY OF HORIZONTAL POSITIONING SF AND DF	CONDITIONS AND CONSTRAINTS
For each SF: • ≥ 50% at average location	• With a horizontal positioning accuracy better than 10m (95%) [19] • At least 3 satellites in view above a minimum elevation of 5 degrees • Normalised annually [18] • Including planned and unplanned outages • Assuming a receiver operating in altitude hold mode • Including Broadcast Group Delay errors • Propagation and user contributions excluded • Neglecting single frequency ionospheric delay model errors[20]
For each DF combination: • ≥ 50% at average location	• With a horizontal positioning accuracy better than 10m (95%) [19] • At least 3 satellites in view above a minimum elevation of 5 degrees • Normalised annually [18] • Including planned and unplanned outages • Assuming a receiver operating in altitude hold mode • Propagation and user contributions excluded

Table 26. MPL of the Availability of Horizontal Positioning SF and DF.

19.... *The accuracy thresholds for the expected Availability of Horizontal Positioning Service is calculated combining the constellation average of the monthly ranging accuracy (see Table 10) with the worst case tolerable HDOP, i.e. 5.*

20.... *Note that although parameters for the correction of the ionospheric effect for SF users are broadcast by the Galileo OS SIS, the single-frequency ionospheric delay model errors are not accounted for.*

ANNEX D: GALILEO OPEN SERVICE – PERFORMANCE EVOLUTION

D.1. INTRODUCTION

D.1.1 SCOPE

The main body of this Galileo Initial OS SDD focuses on the performance provided during the Galileo Initial Service phase. This annex provides complementary forward looking information about the expected performance evolution during deployment of the system and until its completion at FOC. The expected values of each performance parameter are provided in this Annex as a function of the number of operational satellites [21] in orbit. The values of performance parameters reported for the constellation of 9 satellites are typical values.

D.1.2 LIMITATIONS

The information in this Annex is provided exclusively for reference and does not in any way affect the MPLs presented in section 3 of this Initial OS SDD.

D.1.3 GALILEO CONSTELLATION EXPECTED EVOLUTION

In Table 8, the status of the Galileo constellation at the time of the declaration of the Initial OS is provided. The evolution of the expected values of the performance parameters presented in the following sections assumes three deployment stages with respectively 9, 15 and 24 operational satellites. Details of the final constellation of 24 satellites can be found in section C.2.

D.2. GALILEO OS ACCURACY AT FOC

D.2.1 GALILEO SIS RANGING ACCURACY: EVOLUTION OF SISE

As explained in section 2.3.2.1, , the Galileo OS Ranging Accuracy is defined as a statistic of the Galileo SIS Ranging Error (SISE), which is the SIS portion of the GNSS error budgets to the user equivalent range error (UERE) and comprises all effects originating from and/or controlled by the Galileo system while user local effects and atmospheric effects (ionospheric/tropospheric) are not included. The Galileo SISE is driven by the error of the broadcast ephemeris and clock correction parameters. The accuracy in the estimation of these values depends mainly on the number of observables, i.e. ranging measures, available to the algorithms implemented in the GS that computes such values. For this reason, the increase of the number of operational satellites in the Galileo constellation implies an improvement of the determination of the broadcast ephemeris and clock correction parameters and therefore of the SIS ranging accuracy.

The expected evolution of the Galileo SISE is indicated in Table 27, from the Initial OS to FOC phases. Given that the SISE depends on the user-satellite direction i.e. on the user position, values in Table 27 are provided at Worst User Location (WUL), as worst case. The values of Galileo SISE reported for the constellation of 9 satellites are typical values.

SERVICE	NUMBER OF SATELLITES		
	9	15	24
SF	1.8	1.5	1.4
DF	1.7	1.4	1.3

Table 27. Evolution of typical Galileo SIS Ranging Accuracy (in metres, 95%).

21. *Operational Galileo Satellites are those satellites that have been commissioned and are declared usable for Initial Open Service, independently of their actual SIS Status.*

D.3. GALILEO OS AVAILABILITY AT FOC

D.3.1 EVOLUTION OF THE EXPECTED AVAILABILITY OF GLOBAL PDOP

Although the Initial OS SDD does not include any MPL concerning the availability of the Position Dilution of Precision (PDOP), due to the limited number of operational satellites, in this Annex values are provided for the Evolution of the Expected Availability of Global PDOP, as a function of the number of operational healthy satellites (Table 28). The Availability of PDOP is computed at any user location as the percentage of time at least 4 Galileo satellites, transmitting healthy SIS, are in view above a minimum elevation angle of 5 degrees, and with a threshold of PDOP ≤ 6 to identify sufficiently good local geometries. The Availability of Global PDOP is specified for the average user location within the service coverage area, i.e. computed as the global average over all user locations (See section 3.3 for the definition of service coverage area). Figure 8, demonstrates the limited availability of PDOP≤6 for the constellation of 9 satellites. As shown in Table 28 this availability significantly improves with the deployment of the additional satellites.

	NUMBER OF SATELLITES		
	9	15	24
PDOP ≤ 6	21.9%	88.1%	100%

Table 28. Evolution of the Expected Availability of Global PDOP

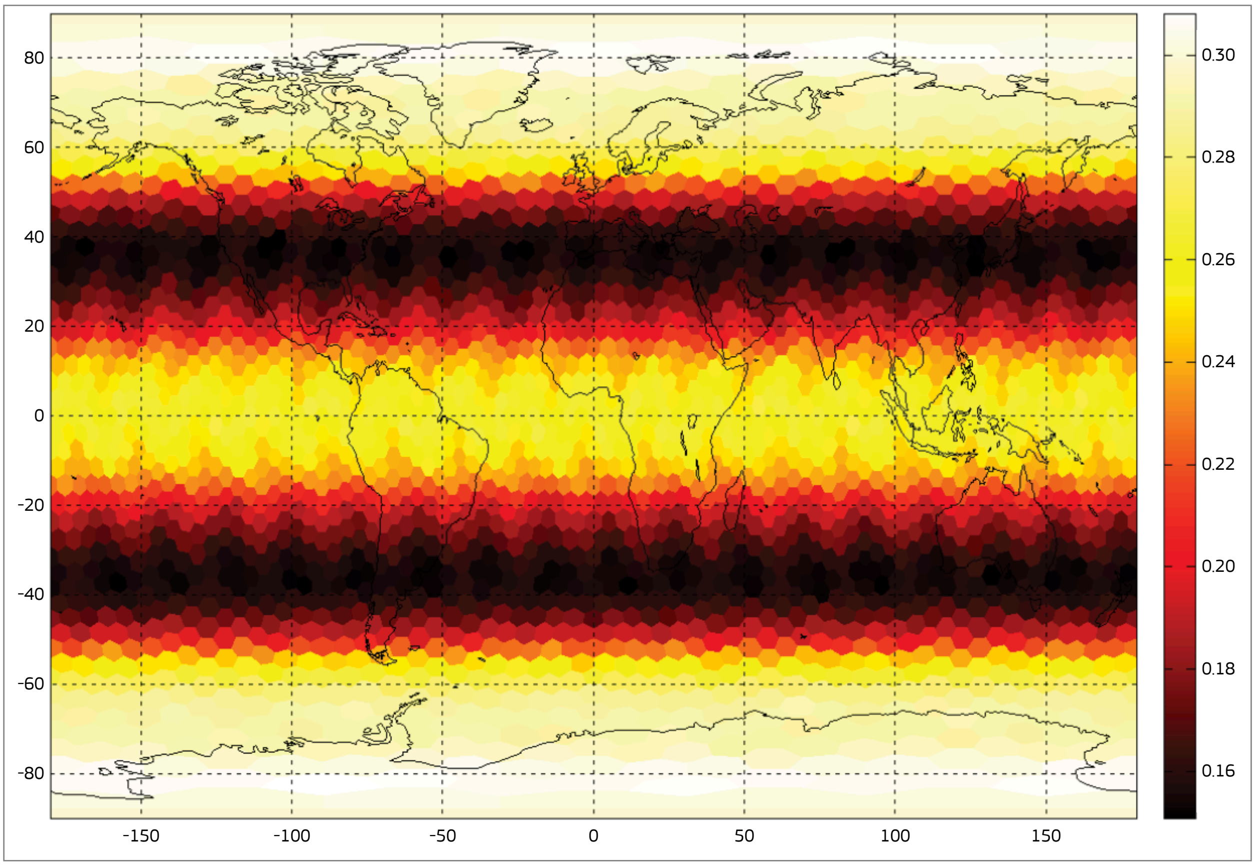


Figure 8. Availability of PDOP (colour coded) for the constellation of 9 satellites, considering PDOP ≤ 6.

D.3.2 EVOLUTION OF THE EXPECTED AVAILABILITY OF THE GALILEO OS RANGING SERVICE

In Table 29, , the evolution of the Expected Availability of Galileo OS Ranging Service as a function of the number of operational healthy satellites is provided, for any healthy OS SIS.

SERVICE SIS	NUMBER OF SATELLITES		
	9	15	24
DF E5a/E1	>87%	>96%	>99.5%
DF E5b/E1	>87%	>96%	>99.5%
SF E1	>87%	>96%	>99.5%
SF E5a	>87%	>96%	>99.5%
SF E5b	>87%	>96%	>99.5%

Table 29. Evolution of the expected Availability of Galileo OS Ranging Services at FOC.

D.4. EVOLUTION OF THE EXPECTED GALILEO OS POSITIONING PERFORMANCE

This section of Annex D presents how the expected positioning performance of the Galileo OS will evolve with the deployment of the system until FOC is reached.

D.4.1 EVOLUTION OF THE GALILEO OS POSITIONING SERVICE EXPECTED ACCURACY

As explained in Annex C, the Galileo system, the signal propagation channel and the user equipment all contribute to the positioning accuracy experienced by the Galileo users. Although in the main part of this document all contributions to the performance of Galileo that are not under control of the system are not considered, in this Annex such contributions are considered so that it is possible to indicate the global average positioning performance that a Galileo only user can expect to experience. Specifically, Table 30 presents the evolution of the horizontal and vertical expected position accuracy for the Galileo OS Positioning versus the number of operational healthy satellites, using the UERE values shown in Table 24. The values provided are global values, taking into account the constraint of PDOP≤6.

SERVICE		NUMBER OF SATELLITES		
		9	15	24
DF	H	5.0	3.3	1.8
	V	6.7	4.6	2.9
SF	H	19.3	14.1	7.7
	V	25.5	19.7	12.6

Table 30. Evolution of the Expected Galileo OS Positioning Performance in nominal configuration (global mean, in metres, 95% values).

D.4.2 EVOLUTION OF THE GALILEO OS POSITIONING SERVICE EXPECTED AVAILABILITY

Full deployment of the Galileo system will also imply an increase of the OS Positioning Service Availability.

The Availability of DF and SF Positioning for OS is computed at any user location as the percentage of time with a DF and respectively SF positioning error less than or equal to a specific value, considering only healthy Galileo SIS from satellites above a minimum elevation angle of 5 degrees, for the average user location within the service coverage area (i.e. computed as the average over all user locations, see section 3.3 for the definition of service coverage area). The Availability of DF and SF Positioning are provided as normalised annual values. Table 31 presents the evolution of the Availability of DF and SF Positioning for OS versus the number of operational healthy satellites. The values provided are global values, taking into account the constraint of PDOP≤6 for the intermediate constellations. For the full constellation the value represents the expected availability of Open Service over the full lifetime of the Service, including degraded constellation configurations.

SERVICE			NUMBER OF SATELLITES		
	Horizontal Accuracy (95%)	Vertical Accuracy (95%)	9	15	24
DF	≤ 4m	≤ 8m	6.6%	66.3%	99.5%
SF	≤ 15m	≤ 35m	7.3%	58.9%	99.5%

Table 31. Evolution of the Galileo OS Positioning Service Expected Availability (global mean).

ANNEX E: DESCRIPTION OF ADVISORY NOTICE TO GALILEO USERS

E.1. NAGU FORMAT

This section of the Annex describes the format of the NAGUs issued to Galileo users through the European GNSS Service Centre web portal.

Two types of NAGU can be issued:

- Specific NAGUs
- General NAGUs.

E.1.1 SPECIFIC NAGU

Specific NAGUs follow the format defined below:

NOTICE ADVISORY TO GALILEO USERS (NAGU)	YYYYNNN
DATE GENERATED (UTC):	YYYY-MM-DD hh:mm
NAGU TYPE:	AS PER NAGU DEFINITION
NAGU NUMBER:	YYYYNNN
NAGU SUBJECT:	AS PER NAGU TEMPLATE
NAGU REFERENCED TO:	YYYYRRR OR N/A
START DATE EVENT (UTC):	YYYY-MM-DD hh:mm
END DATE EVENT (UTC):	YYYY-MM-DD hh:mm OR N/A
SATELLITE AFFECTED:	SATELLITE_NAME
SPACE VEHICLE ID:	SVID
SIGNAL(S) AFFECTED:	E1, E5a, E5b, E6, E6-B, E6-C OR ALL
EVENT DESCRIPTION:	AS PER NAGU TEMPLATE

E.1.2 GENERAL NAGU

General NAGUs follow a simplified version of the format used for specific NAGUs, providing additional flexibility on the definition of the subject (e.g. launch, validation campaigns, status flags, etc.):

NOTICE ADVISORY TO GALILEO USERS (NAGU)	YYYYNNN
DATE GENERATED (UTC):	YYYY-MM-DD hh:mm
NAGU TYPE:	GENERAL
NAGU NUMBER:	YYYYNNN
NAGU SUBJECT:	FREE TEXT
NAGU REFERENCED TO:	YYYYRRR OR N/A
START DATE EVENT (UTC):	YYYY-MM-DD hh:mm
END DATE EVENT (UTC):	YYYY-MM-DD hh:mm OR N/A
SATELLITE AFFECTED:	SATELLITE_NAME OR ALL
EVENT DESCRIPTION:	FREE TEXT

E.1.3 DESCRIPTION OF NAGU'S CONTENT

The fields used within the specific and general NAGUs are defined as follows:

1) HEADER: The first line of the text field refers to the title "NOTICE ADVISORY TO GALILEO USERS (NAGU), followed by the NAGU number in the format **YYYYNNN**, where:
    - **YYYY:** Gregorian year.
    - **NNN:** sequential number of the NAGU, starting with 001 on the 1st of January every year and incrementing by 1 for each subsequent NAGU.
2) DATE GENERATED (UTC): The date when the NAGU is generated on the GSC web portal, in UTC time scale with format **YYYY-MM-DD hh:mm**, where:
    - **YYYY:** Gregorian year.
    - **MM:** number of the month from 1-12 in sequence starting with 1 being January, and finishing with 12 being December.
    - **DD:** day within the Gregorian year
    - **hh:** hour in the 24 hour format
    - **mm:** minute
3) NAGU TYPE: The different NAGU types as defined in Annex E.2.
4) NAGU NUMBER: Reference to the NAGU number in the format **YYYYNNN** (as defined in the Header field).
5) NAGU SUBJECT: The subject of the NAGU summarizing the information provided in the "Event Description". The text to be used in the subject is defined by the template of each NAGU. For GENERAL NAGU, this is a free text description.
6) NAGU REFERENCED TO: If the current NAGU refers to a previous NAGU, this field contains the referenced NAGU number in the format **YYYYRRR**, where:
    - **YYYY:** Gregorian year when the NAGU was issued.
    - **RRR:** issue number of the NAGU for that year.

    Otherwise, the field contains N/A (not applicable) when there is no reference to a previous NAGU.

7) START DATE EVENT (UTC): The start date of the event notified by the NAGU, in UTC time scale with format **YYYY-MM-DD HH:mm**.

8) END DATE EVENT (UTC): The end date of the event notified by the NAGU, in UTC time scale with format **YYYY-MM-DD HH:mm**.

9) SATELLITE AFFECTED: The name of the satellite affected (GSAT, Galileo SATellite). For GENERAL NAGU, this field contains ALL to indicate that all satellites are affected.

10) SPACE VEHICLE ID: The Space Vehicle ID (SVID) of the satellite affected. This field is not present in the GENERAL NAGU.

11) SIGNAL(S) AFFECTED: The signal(s) affected by the satellite indicated in the NAGU. The signals affected can be one or a combination of the following: E1, E5a, E5b, E6, E6-B, E6-C or ALL. Partial outage/availability of the signals is indicated in the NAGU subject if ALL signals are not affected. This field is not present in the GENERAL NAGU.

12) EVENT DESCRIPTION: The event description following the templates defined for each NAGU.

E.2. LIST OF DEFINED NAGUS

This section of the Annex describes the different NAGUs that are defined and that can be issued to the Galileo users through the GSC web portal.

NAGU TYPE (ABBREVIATION)	NAGU TYPE	NAGU DESCRIPTION
PLN_MANV	Planned manoeuvre	Planned activity affecting the attitude and/or orbit. The planned outage start and end times due to manoeuvre operation are indicated.
PLN_OUTAGE	Planned outage	Planned activity (space or ground segment) that causes an outage of the satellite SIS broadcasted. The planned outage start and end times are indicated.
AVAILINIT	Satellite first time available	The satellite is for first time providing healthy SIS following completion of satellite in-orbit commissioning activities. The type of clock being used to drive the navigation payload is also indicated. Satellite is not yet contributing to service provision.
USABINIT	Satellite first time usable	The satellite is for the first time providing signals and navigation messages according to the service performance commitment. The type of clock being used to drive the navigation payload is also indicated. Satellite enters into service and contributing to service provision.
AVAILABLE	Available for testing	The satellite starts transmitting healthy SIS following the end of a planned outage or recovery of an unplanned outage. The exact outage start and end times are indicated. The type of clock being used to drive the navigation payload is also indicated. This NAGU type is used prior to Service Declaration.
USABLE	Usable for service provision	The satellite starts transmitting healthy SIS following the end of a planned outage or recovery of an unplanned outage. The exact outage start and end times are indicated. The type of clock being used to drive the navigation payload is also indicated. This NAGU type is used following Service Declaration.
PLN_CANCEL	Cancellation	Cancellation of published NAGUs.
PLN_RESCH	Reschedule	Provision of new start/end times for published planned NAGU.
PLN_EXTNS	Extension	Provision of new end time for published planned NAGU or notification of the planned outage end time for published unplanned NAGU (UNP_UNUFN).
DECOMMSNG	Satellite decommissioned	Commencement of satellite decommissioning phase.
UNP_UNUFN	Unavailable until further notice	Unscheduled outage of the satellite SIS broadcasted of undefined duration.

NAGU TYPE (ABBREVIATION)	NAGU TYPE	NAGU DESCRIPTION
UNP_SHTRCVR	Short term outage recovered	Events (short term) that have been recovered before a NAGU could be published.
GENERAL (NOTICE)	General notice	General notifications such as announcing the IOV campaign, Initial Service validation, announcement of Initial Service declaration, introduction of services, IOC, FOC, etc.
GENERAL (LAUNCH)	Launch	Notification of the satellite launch.
GENERAL (LEAP SECOND)	Leap second	Notification of leap second adjustment.
GENERAL (TIMING PLN_OUTAGE)	Planned outage timing services	Notification of a planned operation entailing an outage of timing services.
GENERAL (TIMING AVAILABLE)	Availability of timing services	Notification of availability of timing services following the end of a planned operations/ recovery of an unplanned outage with impact related only to timing services.
GENERAL (TIMING PLN_CANCEL)	Cancellation of planned outage timing services	Cancellation of published general NAGU notification for a planned operation entailing an outage of timing services.
GENERAL (TIMING PLN_RESCH)	Reschedule of planned outage timing services	Provision of new start/end times for published general NAGU notification for a planned operation entailing an outage of timing services.
GENERAL (TIMING PLN_EXTNS)	Extension of planned outage timing services	Provision of new end time for published planned NAGU.
GENERAL (TIMING UNP_UNUFN)	Unplanned outage timing services	This general NAGU provides notification of an unplanned outage related with timing services.
GENERAL (TIMING UNP_SHTRCVR)	Short term outage timing services	This general NAGU provides notification of short term timing services outage that have been recovered before a NAGU could be published.