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Space systems — Requirements for global navigation satellite system (GNSS) positioning augmentation centres

CD stage

Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO Technical Committee (TC) 20, *Aircraft and space vehicles*, Subcommittee (SC) 14, *Space systems and operations*.

Introduction

In the initial decades of the 21st century, several countries provide their constellations of Global Navigation Satellite System (GNSS) such as U.S. GPS, Russian GLONASS, European Galileo, Chinese BDS, Indian NavIC, Japanese QZSS and SBASs, and they have been utilized as an international public service. GNSS positioning applications have been expanding in each region across the world.

In order to maximize the capability of these GNSS constellations, the respective regions have deployed GNSS positioning augmentation centres with continuously operating reference station (CORS) network. These facilities generate different types of corrections to mitigate atmospheric propagation errors and satellite errors, as well as provide integrity information. The application of these augmentation functions helps to achieve higher performance for GNSS positioning.

Along with the development of the GNSS constellations, GNSS reference stations have been established across populous and economic areas of the world. Industrialized countries have adopted precise positioning thanks to this integrated GNSS infrastructure in global, regional and national areas. Positioning users require similar GNSS infrastructure in other areas of the world.

This document is intended to resolve this issue and aims to provide high-performance GNSS standards for users around the world.

ISO TC 20 has published ISO TC 20 Business plan 2015 (https://www.iso.org/committee/46484.html). In the business plan, Clause 2.1.2, TC 20 has set *"Space systems are defined as Space segments, Ground Segments and services (or applications)."* and namely, *Space systems* are defined to include the service or application.

During past nine years, ISO TC 20/SC 14/WG1 has discussed the standardization of *Space-based services* based on ISO TC20 Business Plan 2015, because *Space Systems* provide a huge merit for the economy and society in each country today and *Space-based Services* contribute to people's *Quality of life* across the world. *Space systems* should be utilized furthermore in the world industry also after this time.

Today, the market has required precise navigation for automated craft and vehicles. One of the most important requirements is the *safety of navigaition*. For responding this requirement, the space systems community has firm determination to take the leadership of the utilizaiton of space systems such as GNSS, for other downsteam areas of application and service. ISO TC 20/SC 14 and its WG1 promote to collaborate and cooperate with TC 20/SC 13, other ISO TCs, IEC TCs and harmonize the standards by international organizations in the GNSS relevant area shown as Figure 1.

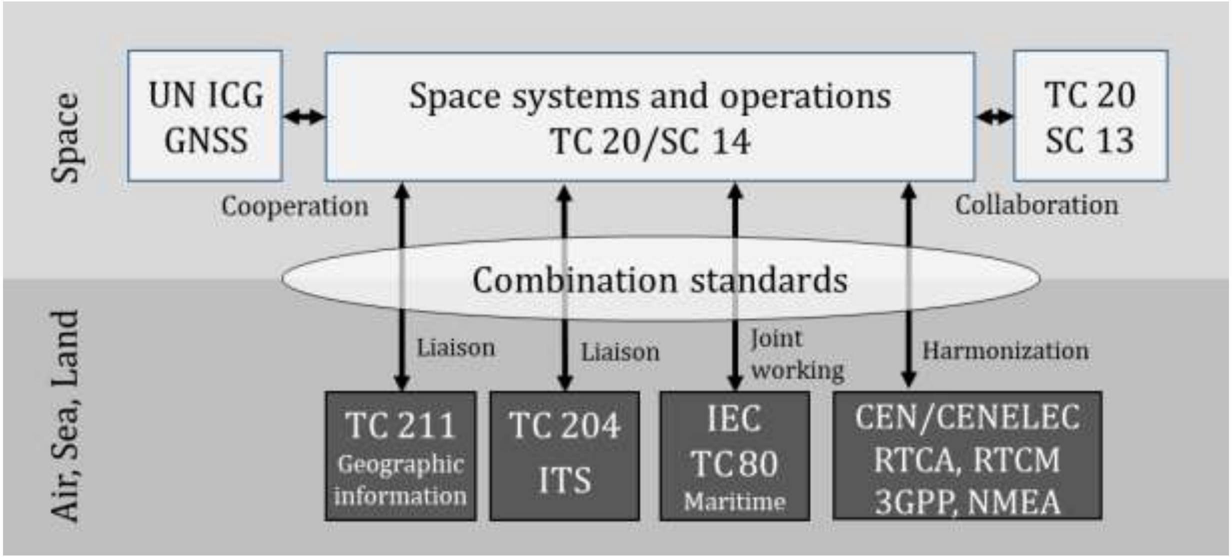

Figure 1 — Standardization of space-based services (GNSS relevant area)

The GNSS project of ISO has respected the ICG (International Committee on Global Navigation Satellite Systems) of UN (United Nations) and its achievements. The UN ICG's recomendations are reflected into this document.

This document is applicable in the civil and commercial market. Because these market emergingly requires high accuracy positioning utilizing in automated flight, driving and navigation, we need to standardize GNSS positioning augmentation centres as this document.

ISO TC 20/SC 14 already published ISO 18197:2015 Space systems – Space based services requirements for centimetre class positioning, which specified the total matters of system engineering, On the other hand, this document has dedicated GNSS positioning augmentation centres as one element of GNSS centimetre class positioning. For the realization of actual infrastructure, both documents have been needed. Please also refer ISO 18197:2015.

Space systems — Requirements for global navigation satellite system (GNSS) positioning augmentation centres

1. Scope

This document specifies requirements for GNSS positioning augmentation centres that distribute correction data to provide higher accuracy and integrity information for positioning users in the civil and commercial market.

The GNSS positioning augmentation centres cover the following types of positioning

(1) Real-time sub-metre to decimetre-level positioning,

(2) Real-time centimetre-level positioning,

(3) Post-processed geodetic positioning.

This document also specifies roles of the following stakeholders and functions of the software present at GNSS positioning augmentation centres.

(A) Role of Planner

(B) Role of Designer

(C) Role of Administrator

(D) Function of Software

2. Normative references

The following documents are referred to in this text in such a way that part or all of their content constitutes requirements of this document.

ISO 18197: 2015 Space systems - Space based services requirements for centimetre class positioning

ISO 19161-1: 2020 Geographic information—Geodetic references—Part 1: International terrestrial reference system (ITRS)

3. Terms and definitions

For the purpose of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Space-based positioning and navigation

3.1.1 radiodetermination

determination of the position, velocity and/or other characteristics of an object, of the obtaining of information relating to these characteristics, by means of radio waves

[SOURCE: IEC Space radiocommunications, IEV ref 725-12-48]

3.1.2 satellite radiodetermination
radiodetermination (3.1.1) which makes use of a satellite system

[SOURCE: IEC Space radiocommunications, IEV ref 725-12-49]

3.1.3 radionavigation
radiodetermination (3.1.1) used for the purpose of navigation, including obstruction warning

[SOURCE: IEC Space radiocommunications, IEV ref 725-12-50]

3.1.4 satellite radionavigation
satellite radiodetermination (3.1.1) used for radionavigation (3.1.3)

[SOURCE: IEC Space radiocommunications, IEV ref 725-12-51, add the word "satellite navigation"]

3.1.5 universe of discourse
view of the real or hypothetical world that includes everything of interest

[SOURCE: ISO 19101-1:2014, 4.1.38]

3.2 Positioning quality

3.2.1 accuracy
closeness of agreement between a test result or measurement result and the true value (3.2.5)

NOTE 1 to entry: In practice, the accepted reference value is substituted for the true value.

NOTE 2 to entry: The term "accuracy", when applied to a set of test or measurement result, involves a combination of random components and a common systematic error or bias component.

NOTE 3 to entry: Accuracy refers to a combination of bias (3.2.2) and precision (3.2.3).

[SOURCE: ISO 3534-2:2006, 3.3.1, Modified Note 3 to entry — replace "trueness" to "bias"]

3.2.2 bias
difference between the expectation of a test result or measurement result and a true value (3.2.5)

NOTE 1 to entry: Bias is the total systematic error as contrasted to random error. There may be one or more systematic error components contributing to the bias. A larger systematic difference from the true value is reflected by a larger bias value.

NOTE 2 to entry: The bias of a measuring instrument is normally estimated by averaging the error of indication over an appropriate number of repeated measurements. The error of indication is the: "indication of a measuring instrument minus a true value of the corresponding input quantity".

NOTE 3 to entry: In practice, the accepted true value (3.2.6) is substituted for the true value.

[SOURCE: ISO 3534-2:2006, 3.3.2]

3.2.3 precision
closeness of agreement between independent test/measurement results obtained under stipulated conditions specified

NOTE 1 to entry: Precision depends only on the distribution of random errors and does not relate to the true value or the specified value.

NOTE 2 to entry: The measure of precision is computed as a standard deviation of the test results or measurement results. Less precision is reflected by a larger standard deviation.

NOTE 3 to entry: Quantitative measures of precision depend critically on the stipulated conditions. Repeatability conditions and reproducibility conditions are particular sets of extreme stipulated conditions.

[SOURCE: ISO 3534-2:2006, 3.3.4, modified Note 2 to entry]

3.2.4 integrity

measure of the trust that can be placed in the correctness of the information supplied by a navigation system and that includes the ability of the system to provide timely warnings to users when the system should not be used for navigation

[SOURCE: United States, 2017 Federal Radionavigation Plan, DOT-VNTSC-OST-R-15-01, Appendix E]

3.2.5 true value

value which characterizes a quantity or quantitative characteristic perfectly defined in the conditions which exist when that quantity or quantitative characteristic is considered

NOTE 1 to entry: The true value of a quantity or quantitative characteristic is a theoretical concept and, in general, cannot be known exactly.

[SOURCE: ISO 3534-2:2006, 3.2.5, Deleted Note 2 to entry]

3.2.6 accepted true value

value that serves as an agreed-upon reference for comparison

NOTE 1 to entry: The accepted reference value is derived as:

a) a theoretical or established value, based on scientific principles;

b) an assigned or certified value, based on experimental work of some national or international organization;

c) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or technical group;

d) the expectation, i.e. the mean of a specified set of measurements, when a), b) and c) are not available.

[SOURCE: ISO 3534-2:2006, 3.2.7]

3.2.7 state space

space defined by the state variables as axes of a vector space, in which every vector represents a state of the system

NOTE 1 to entry: a vector space is defined in IEC IEV ref 102-03-01.

NOTE 2 to entry: “space” is this term is a methematical vector space, and if defferent from “space” of a physical unierse.

[SOURCE: IEC IEV ref 351-41-09, Control technology / Variables and signals.]

3.3 Terrestrial reference system

3.3.1 coordinate

one of a sequence of numbers designating the position of a point

NOTE 1 to entry: In a spatial coordinate reference system, the coordinate numbers are qualified by units.

[SOURCE: ISO 19111:2019, 3.1.5]

3.3.2 coordinate system

set of mathematical rules for specifying how coordinates are to be assigned to points

[SOURCE: ISO 19111:2019, 3.1.11]

3.3.3 coordinate reference system

coordinate system that is related to an object by a datum

NOTE 1 to entry: Geodetic and vertical datums are referred to as reference frames.

NOTE 2 to entry: For geodetic and vertical reference frames, the object will be the Earth. In planetary applications, geodetic and vertical reference frames may be applied to other celestial bodies.

[SOURCE: ISO 19111:2019, 3.1.9]

3.3.4 datum

parameter or set of parameters that realize the position of the origin, the scale, and the orientation of a coordinate system

NOTE 1 to entry: “Reference frame” is alias of “datum” in geodesy area (see the SOURCE below). But, in space systems area, “reference frame” means a spacecraft-fixed coordinate system. Therefore, “reference frame” is not used as alias of “datum” in this area.

[SOURCE: ISO 19111:2019, 3.1.15 and 3.1.52, NOTE 1 to entory has added.]

3.3.5 coordinate operation

process using a mathematical model, based on a one-to-one relationship, that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system, or that changes coordinates at a source coordinate epoch to coordinates at a target coordinate epoch within the same coordinate reference system

[SOURCE: ISO 19111:2019, 3.1.8]

3.3.6 coordinate transformation

coordinate operation that changes coordinates in a source coordinate reference system to coordinates in a target coordinate reference system in which the source and target coordinate reference systems are based on different datums

NOTE 1 to entry: A coordinate transformation uses parameters which are derived empirically. Any error in those coordinates will be embedded in the coordinate transformation and when the coordinate transformation is applied the embedded errors are transmitted to output coordinates.

NOTE 2 to entry: A coordinate transformation is colloquially sometimes referred to as a 'datum transformation'. This is erroneous. A coordinate transformation changes coordinate values. It does not change the definition of the datum. In this document coordinates are referenced to a coordinate reference system. A coordinate transformation operates between two coordinate reference systems, not between two datums.

[SOURCE: ISO 19111:2019, 3.1.12]

3.3.7 ellipsoid
reference ellipsoid

<geodesy> geometric reference surface embedded in 3D Euclidean space formed by an ellipse that is rotated about a main axis

NOTE 1 to entry: For the Earth the ellipsoid is bi-axial with rotation about the polar axis. This results in an oblate ellipsoid with the midpoint of the foci located at the nominal centre of the Earth.

[SOURCE: ISO 19111:2019, 3.1.22]

3.3.8 mean sea level
MSL

average level of the surface of the sea over all stages of tide and seasonal variations

NOTE 1 to entry: Mean sea level in a local context normally means mean sea level for the region calculated from observations at one or more points over a given period of time. To meet IHO standards that period should be one full lunar cycle of 19 years. Mean sea level in a global context differs from a global geoid by not more than 2 m.

[SOURCE: ISO 19111:2019, 3.1.41, the definition has deleted "<geodesy>", because it is general.]

3.3.9 geoid

equipotential surface of the Earth's gravity field which is perpendicular to the direction of gravity and which best fits mean sea level either locally, regionally or globally

[SOURCE: ISO 19111:2019, 3.1.36]

3.3.10 vertical coordinate reference system

one-dimensional coordinate reference system based on a vertical reference frame

[SOURCE: ISO 19111:2019, 3.1.70]

3.3.11 vertical datum

reference frame describing the relation of gravity-related heights or depths to the Earth

NOTE 1 to entry: In most cases, the vertical reference frame will be related to mean sea level. Vertical datums include sounding datums (used for hydrographic purposes), in which case the heights may be negative heights or depths.

NOTE 2 to entry: Ellipsoidal heights are related to a three-dimensional ellipsoidal coordinate system referenced to a geodetic reference frame.

[SOURCE: ISO 19111:2019, 3.1.72]

3.4 Positioning results

3.4.1 geodetic latitude
ellipsoidal latitude

angle from the equatorial plane to the perpendicular to the ellipsoid through a given point, northwards treated as positive

[SOURCE: ISO 19111:2019, 3.1.32, Deleted a symbol because of the conflict in navigation area]

3.4.2 geodetic longitude
ellipsoidal longitude

angle from the prime meridian plane to the meridian plane of a given point, eastward treated as positive

[SOURCE: ISO 19111:2019, 3.1.33, Deleted a symbol because of the conflict in navigation area]

3.4.3 height

distance of a point from a chosen reference surface positive upward along a line perpendicular to that surface

NOTE 1 to entry: A height below the reference surface will have a negative value.

NOTE 2 to entry: Generalization of ellipsoidal height (3.4.4) and gravity-related height (3.4.5).

[SOURCE: ISO 19111:2019, 3.1.22]

3.4.4 ellipsoidal height
geodetic height
altitude

distance of a point from the reference ellipsoid along the perpendicular from the reference ellipsoid to this point, positive if upwards or outside of the reference ellipsoid

NOTE 1 to entry: Only used as part of a three-dimensional ellipsoidal coordinate system or as part of a three-dimensional Cartesian coordinate system in a three-dimensional projected coordinate reference system, but never on its own.

[SOURCE: ISO 19111:2019, 3.1.24, modified—the term has add “altitude” as same meaning for aviation, maritime and space applications. Deleted a symbol because of the conflict in navigation area]

3.4.5 gravity-related height

height that is dependent on the Earth’s gravity field

NOTE 1 to entry: This refers to, amongst others, orthometric height and Normal height, which are both approximations of the distance of a point above the mean sea level, but also may include Normal-orthometric heights, dynamic heights or geopotential numbers.

NOTE 2 to entry: The distance from the reference surface may follow a curved line, not necessarily straight, as it is influenced by the direction of gravity.

[SOURCE: ISO 19111:2019, 3.1.37, Deleted a symbol because of the conflict in navigation area]

3.4.6 depth

distance of a point from a chosen vertical reference surface downward along a line that is perpendicular to that surface

NOTE 1 to entry: The line direction may be straight, or be dependent on the Earth's gravity field or other physical phenomena.

NOTE 2 to entry: A depth above the vertical reference surface will have a negative value.

[SOURCE: ISO 19111:2019, 3.1.17]

3.5 Cyber security

3.5.1 interference
radio-frequency interference
RFI

degradation of the reception of a wanted signal caused by a radio-frequency disturbance

NOTE 1 to entry: The English words “interference” and “disturbance” are often used indiscriminately. The expression “radio-frequency interference” is also commonly applied to a radio-frequency disturbance or an unwanted signal.

NOTE 2 to entry: Various levels of interference are defined for administrative purposes in the ITU Radio Regulations viz. permissible interference, accepted interference and harmful interference.

[SOURCE: IEC IEV ref 161-01-14, MOD, ITU-R Rec, 753 MOD, the definition has added the word “interference”.]

3.5.2 jamming
deliberate interference, caused by emissions intended to render unintelligible or falsify the whole or part of a wanted signal

[SOURCE: IEC IEV ref 713-11-23, Radiocommunications: transmitters, receivers, networks and operation / Radio-frequency noise and interference]

3.5.3 spoofing
impersonating a legitimate resource or user

[SOURCE: ISO/IEC 27033-1:2015, 3.38]

3.5.4 meaconing
interception and rebroadcast of radionavigation signal

NOTE 1 to entry: These signals are rebroadcast on the received frequency, typically, with power higher than the original signal, to confuse other’s radionavigation. Consequently, vehicle or ground stations are given inaccurate bearings.

NOTE 2 to entry: Meaconing is more of a concern to personnel in radionavigation ratings than to radio operators. However, communications transmitters are often used to transmit radionavigation signals. Since communications personnel operate the transmitters, they must know how to deal with any communications problems resulting from meaconing.

NOTE 3 to entry: Successful meaconing can cause vehicles to be lured into "hot" (ambush-ready) zones or other’s space, ships to be diverted from their intended routes, or ground stations to receive inaccurate bearings or position locations.

NOTE 4 to entry: The term 'meacon' is a portmanteau of *masking beacon*.

4. Abbreviations

For the purpose of this document, the following abbreviations apply.

4.1 Technical terms

AGNSS	Assisted GNSS
BDS	BeiDou satellite navigation System (China)
CORS	Continuously Operating Reference Station
DGNSS	Differential GNSS
DGPS	Differential Global Positioning System
GBAS	Ground Based Augmentation System
GLONASS	GLObal NAvigation Satellite System (Russian Federation)
GNSS	Global Navigation Satellite System
GPS	Global Positining System (U.S.A.)
HTTP	Hyper Text Transfer Protocol

LPP	LTE Positioning Protocol
LTE	Long Term Evolution
NavIC	Navigation with Indian Constellation (India)
NTRIP	Networked Transport of RTCM via Internet Protocol
OSR	Observation Space Representation
PPP	Precise Point Positioning
QZSS	Quasi Zenith Satellite System (Japan)
RINEX	Receiver Independent Exchange format
RMSE	Root Mean Square
RTK	Real Time Kinematic
SBAS	Satellite Based Augmentation System
SI	International System of Units
SSR	State Space Representation

4.2 Organizations

3GPP	3rd Generation Partnership Project (mobile communication)
BIH	International Time Bureau, i.e. Bureau international l'heure
CEN	European Committee for Standardization
CENTRIC	European Committee for Electronical Standardization
ICAO	International Civil Aviation Organization
NMEA	National Marine Electronics Association (U.S.A.)
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services

5. System overview

The GNSS positioning augmentation centres is a part of the system shown as Figure 2. The centres shall be supplied with data from the CORS stations and shall output the augmentation data to positioning service for many types of applications.

The centres shall also have the functions of user service and cyber security as specified in this document, and shall adopt space link or terrestrial link for delivery of augmentation data. User applications include vehicles, crafts, personages, etc.

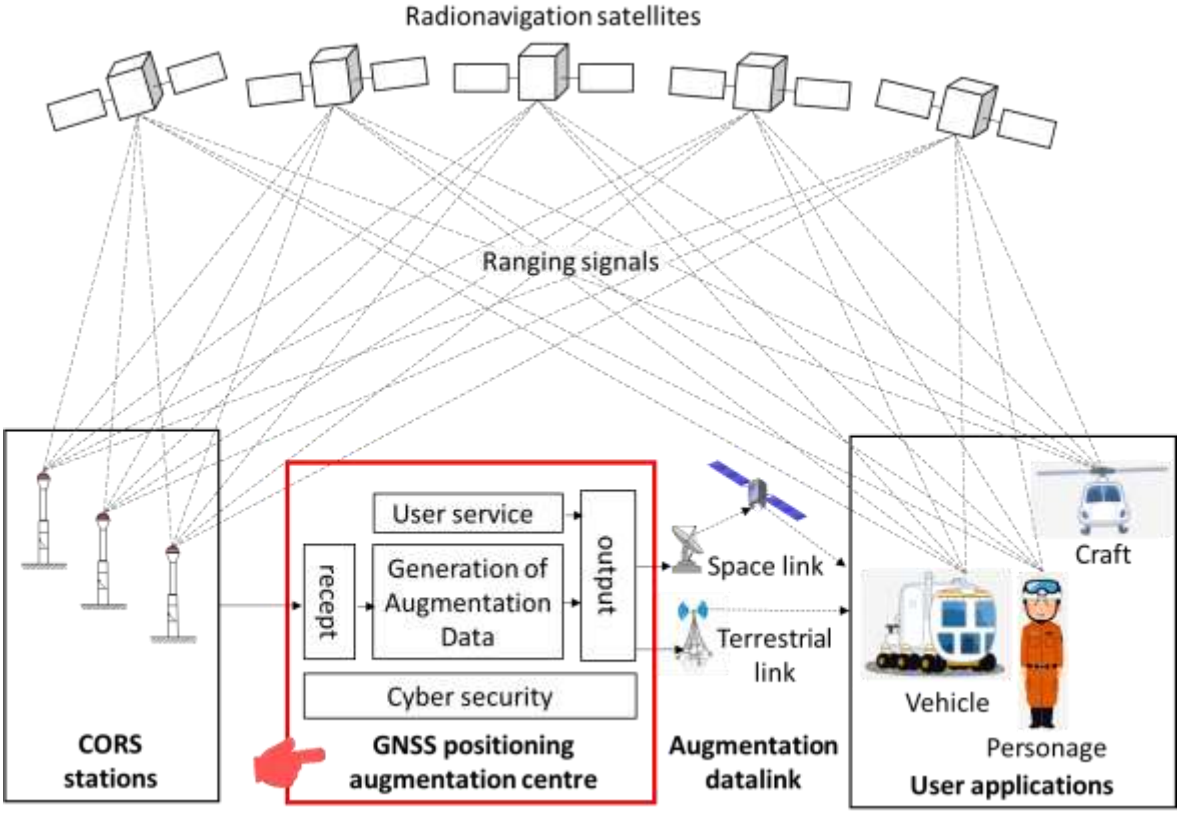

Figure 2 — GNSS positioning augmentation centre and relevant systems

6. Universe of discourse

The Planner shall define a universe of discourse for the GNSS positioning augmentation centre using satellite radionavigation technology. The Planner can define multiple universes of discourse for the centre.

The concept of "universe of discourse" and its international consensus have been fostered in geographic information and geomatics. This concept is very important for cyber-physical systems in the civil and commercial market in this age. Because this term has represented the interface between the cyber space and the physical space.

6.1 Scope of users

The Planner shall define a scope of users utilizing GNSS space systems. This scope must be defined not for the avilability of providers, but for the convenience of users.

6.2 Service type

The Planner shall define a GNSS service type from Table 1.

Table 1— Service type classification of GNSS positioning augmentation centres

No	Classification	Application	Examples
1	Type I	Applications using national coordinates (Secondary realization of ITRS)	Public surveying, Land administration, Land transport, Civil engineering, etc. (Works under national law enforcement)
2	Type II	Applications using global coordinates (agree with ITRF)	Spacecraft navigation, Earth observation, Marine transport, Fishing, Oil and gas, etc, Displacement, Positional difference etc.
3	Type III	Civil aviation	Works with the Chicago Convention of ICAO.
4	Type IV	Private applications	Private works etc.

The service type III shall refer "*ICAO Annex 10 – Aeronautical Telecommunications – Volume I – Radio Navigation Aids*." This service, however, can apply the service type II of this document as far as specified accuracy. This type has been distinguished from other types, because it specifies strict requirements for the safety of passengers.

Regarding the primary and secondary realizations of ITRS, see ISO 19161-1:2020.

The service type IV is not constrained by this document. But this service can refer this document.

6.3 Service area

The Planner shall define a GNSS service area as a geographic region.

6.4 Service time

The Planner shall define GNSS service time including date of starting, period in year and time of day.

It is recommended complete continuous service as follows.

- 356 days in a year
- 24 hours of day
- Including intercalary month, day and second

7. Positioning reference

The Planner shall define positioning reference to comply with the universe of discourse defined in Clause 6. The reference system shall be adopted ITRS that is defined in ISO 19161-1:2020.

7.1 Terrestrial reference system

This clause discribes the basis of positioning reference to choose types in Table 1 for user convinience.

The terrestrial reference system is defined by origin, orientation, scale, and time evolution as follows.

(1) Origin

The center of mass being defined for the whole earth, including oceans and atmosphere.

(2) Orientation

Initially given by the BIH orientation at 1984.0

(3) Scale

The unit of length is the metre (SI).

(4) Time evolution

The time evolution of the orientation is ensured by using a no-net-rotation condition with regard to horizontal tectonic motions over the whole earth.

The realization of the terrestrial reference system shall be a set of authorized reference points shown as Figure 3.

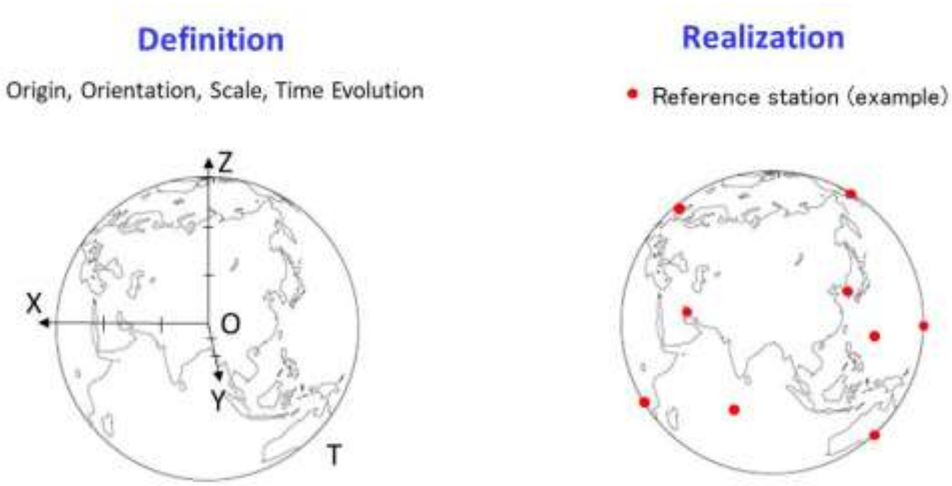

Figure 3 — Definition and realization of terrestrial reference frame

7.2 International terrestrial reference frame

This clause shall apply the service type II (6.2) to use a global coordinate system.

The global coordinate system shall adopt ITRF. It is recommended to apply the latest version.

NOTE WGS84 is widely used in space, aviation, and maritime area with international treaties and agreements. It is also used in land-consumer sectors and the measurement of displacement, relative position, and positional difference. WGS84 is often adopted as (or used in place of) ITRF in such applications.

7.3 National coordinate reference system

This clause shall apply the service type I (6.2).

It is recommended that the national coordinate reference system adopts ITRS.

In the case that national coordinate reference system does not exit, it shall apply Clause 7.5.

7.4 Transform to the national datum and crustal movement correction.

This clause shall apply the service type I (6.2).

The national coordinate reference system shall be transformed from ITRF using the following coordinate transformation.

$$\begin{pmatrix} X_N \\ Y_N \\ Z_N \end{pmatrix} = \begin{pmatrix} T_x \\ T_y \\ T_z \end{pmatrix} + \begin{pmatrix} 1+D & R_z & -R_y \\ -R_z & 1+D & R_x \\ R_y & -R_z & 1+D \end{pmatrix} \begin{pmatrix} X_G \\ Y_G \\ Y_G \end{pmatrix} + \begin{pmatrix} S_x \\ S_y \\ S_z \end{pmatrix}$$

where,

X_N, Y_N, Z_N: National coordinates

X_G, Y_G, Z_G: Global coordinates

T_x, T_y, T_z: Transition factors

R_x, R_y, R_z: Rotation factors

D, : Scaling factor

S_x, S_y, S_z: Deformation factors

7.5 Work site without national datum

The Designer shall adopt ITRS on a work site without national datum. ITRS is specified in ISO 19161-1:2020 Geographic information – *Geodetic references- Part 1: International terrestrial reference system (ITRS)*.

NOTE In an industrial work in practice, users often face with a situation without any national reference datum (e.g. undeveloped countries). But the users can apply this clause in the WTO member countries.

7.6 Reference ellipsoid

The Designer shall adopt GRS80 as the reference ellipsoid to measure a geodetic latitude and a geodetic longitude.

7.7 Height and depth

The Designer shall adopt vertical coordinate reference system to measure the ellipsoidal height.

The Designer shall prepare the data of geoid which represents the mean sea level to provide for users, that is needed for measure gravity-related height and depth.

7.8 Integrity information

The Designer shall design that the GNSS positioning augmentation centres provide integrity information to users as the following (1), or both (1) and (2).

(1) Alert flag

(2) User range error (URE) including its components or differential quanties

NOTE RTCM specifies User Range Accuracy (URA). This is alias of URE. See RTCM Standard 10403.2 or later.

8. Requirements for augmentation services

The Planner shall establish to provide for the service area defined in Clause 6.3.

(1) Standard augmentation service

This service shall be provided for real-time applications by using code-based measurements with sub-metre to decimetre- level accuracy.

(2) Precise augmentation service

This service shall be provided for real-time applications, by using carrier-phase measurements, with centimetre-level accuracy.

(3) Geodetic service

This service shall be provided for post-processing applications, by using code and carrier-phase measurements in static or kinematic mode, with decimetre up sub-centimetre accuracy.

8.1 Standard augmentation service

This service shall adopt and provide one or more services from Table 2 in the service area defined in Clause 6.3.

Table 2— Standard augmentation services and their transmitted correction data

Method	**DGNSS**	
Correction	OSR: Observation Space Representation (e.g. GBAS, DGPS, AGNSS) ・Pseudorange at a reference station	SSR: State Space Representation (e.g. SBAS) ・Satellite clock correction ・Satellite orbit correction ・Signal bias ・Ionospheric correction ・Other correction

In this document, the correction that represents an error element, is generically termed SSR. For example, the SBAS corrections may be termed SSR in this case. They must be distinguished from RTCM SSR which is an international format standard developed by RTCM for the dissemination of specific SSR information parameters. The SSR correction shall also include integrity information for users.

The satellite clock correction can be also termed as the “fast correction”, and the satellite orbit correction can be also termed as the “long-term correction”, because of Clause 8.4.1 (1) and (2).

RTCM Standard 10403.3 has supported DGNSS correction data, and RTCM is also developing a standard to support SSR information parameters. 3GPP LPP has supported standard augmentation service as AGNSS in 3GPP release 8.

8.2 Precise Augmentation Service

This service shall adopt and provide one or more services from Table 3 in the service area define in Clause 6.3.

Table 3 — Precise positioning augmentation services and its transmitted correction data

Method		Carrier-phased GNSS	
Correction		OSR: Observation State Representation	SSR: State Space Representation
	Original Technique	**RTK** ・Pseudorange ・Carrier-phase at a reference station	**PPP** ・Satellite clock correction ・Satellite orbit correction ・Signal bias
	Enhanced Technique	**Network RTK** ・Pseudorange ・Carrier-phase at not only physical but also non-physical reference stations	**PPP-RTK** ・Satellite clock correction ・Satellite orbit correction ・Signal bias (code) ・Signal bias (carrier-phase) ・Ionospheric correction ・Tropospheric correction

The SSR correction such as PPP and PPP-RTK shall also include integrity information for users.

Regarding the SSR corrections, the satellite clock correction can be also termed as the “fast correction”, and the satellite orbit correction can be also termed as the “long-term correction”, because of Clause 8.4.1 (1) and (2).

3GPP LPP also supports RTK, Network RTK, PPP in 3GPP release 15, and will support PPP-RTK in 3GPP release 16.

Table 4— Precise positioning augmentation services and their CORS Density

No.	Positioning Method	Convergence Time	CORS Density	Separation of CORS stations		
				minimum	typical	maximum
1	RTK	Short*	Very dense	10 km	20 km	30 km
2	Network RTK	Short*	Dense	20 km	50 km	150 km
3	PPP	Long*	Sparse	500 km	1000 km	3000 km
4	PPP-RTK	Short*	Dense	20 km	50 km	150 km

NOTE *: Short is categorized being from as one second to tens of seconds, Long is categorized as being one minute to tens of minutes.

ISO 18197:2015 “*Space systems — Space based services requirements for centimetre class positioning”* provides one method of PPP-RTK augmentation services.

8.3 Geodetic service

This service shall adopt and provide one or more post-processing service for geodetic level positioning in the service area defined in Clause 6.3.

8.4 Performance factors

This clause specifies performance factors on the GNSS positioning augmentation centres. The Designer shall choose the Software that is adequately considered these performance factors.

8.4.1 Communicable correction factors

The Software shall correct the following factors depending on required accuracy.

(1) Satellite clock correction

In case of using an optimal filter to induce this correction, it may be termed as 'fast correction', because its application helps to minimize the fast-changing positioning errors resulting from temporal errors in satellite clocks.

(2) Satellite orbit correction

In case of using an optimal filter to induce this correction, it may be termed 'long-term correction', because it can be applied at a lower frequency and still have considerable impact on minimized the slow-changing positioning errors associated with satellite orbits.

(3) Signal bias (code)

The Software shall additionally output the following items, when the Designer selects positioning with ambiguity resolution.

(4) Signal bias (carrier-phase)

The Software shall distribute the follows, when the Designer selects PPP-RTK positioning.

(5) Ionospheric correction

(6) Tropospheric correction

8.4.2 Receiver-dedicated correction factors

The Software shall estimate the follows, depending on required accuracy.

(1) Receiver clock error

(2) Receiver antenna phase center offset

(3) Carrier wave integer ambiguity

(4) Receiver measurement noise

(5) Multipath propagation caused by the environments at and around a receiver's antenna

8.4.3 Other correction factors

The software shall store the below parameters.

Each satellite has the following factors:

(1) Satellite antenna phase centre offset

(2) Satellite attitude and carrier-phase wind-up effect

Each constellation has the following a factor:

(3) Inter-system bias

Environment factors are

(4) Earth tide

(5) Crustal movement

(6) Relativity effect

9. Requirements for verification

This clause specifies minimum requirements for verification on the GNSS positioning augmentation centre.

9.1 Distinction of accuracy and precision

The Administrator shall use the accepted ISO definitions about accuracy and precision as Figure 3.

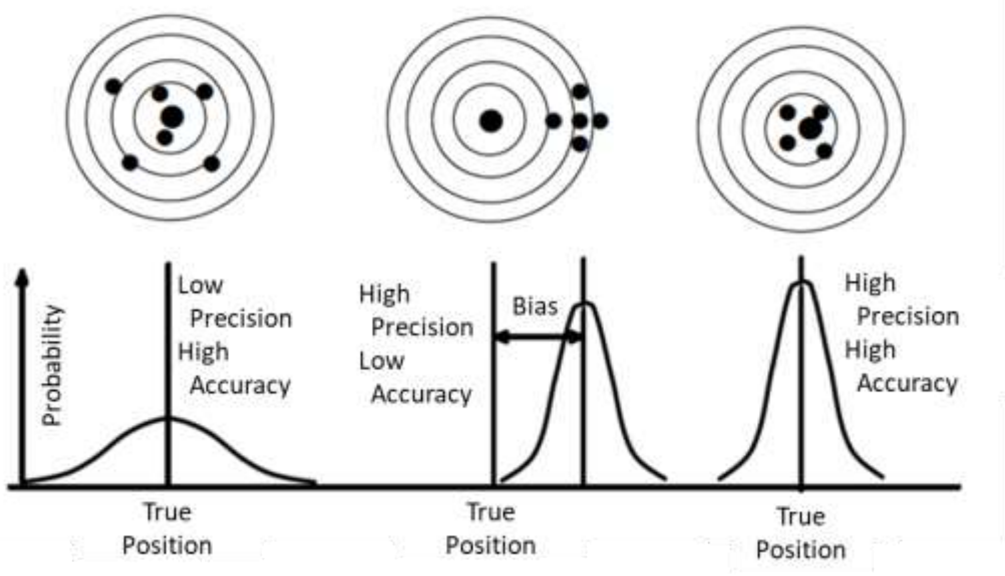

Figure 1 — Relationship of accuracy and precision

9.2 Accuracy

9.2.1 Principle

The Administrator shall evaluate and verify the following quality control statistics in three-dimensional terms.

(1) Standard deviation (precision)

(2) Bias

(3) RMSE (accuracy)

This document requires to evaluate and verify the above three values, noting that only two values are independent. The reason is to clarify and represent the following three characteristics.

(1) Repeatability of the positioning measurement system

(2) Systematic error of the positioning measurement system

(3) Overall error of the positioning measurement system

9.2.2 Horizontal

The Administrator shall evaluate and verify the following quality control statistics in two-dimensional horizontal terms.

(1) Standard deviation (precision)

(2) Bias

(3) RMSE (accuracy)

9.2.3 Vertical

The Administrator shall evaluate and verify the following quality control statistics in one-dimensional vertical or altitude terms.

(1) Standard deviation (precision)

(2) Bias

(3) RMSE (accuracy)

9.3 Calibration

The Administrator shall calibrate the positioning augmentation system to comply the below document.

ISO 19161-1:2020, Geographic information — Geodetic reference — Part1: International terrestrial reference system.

In particular, the methods of determining positioning in an ITRS realization shall refer ISO 19161-1:2020 normative Annex A.

9.4 Evaluation period

The Administrator shall evaluate the data for the following time periods.

(1) Every second in 24 hours.

(2) At least 2 days every week over 1-year period.

This specification is based on the following reasons: every sencond for GNSS epoch time, 24 hours for diurnal variation. At least 2 days for diurnal check with arbitrary start point, every week for variation depending on satellite alignment period, 1-year peried for annual and seasonal variation.

9.5 Convergence time

The Administrator shall evaluate the convergence time until obtaining the positioning result.

9.6 Quality control items

The Administrator shall describe and quantify the positioning augmentation system as follows.

(1) How the coordinates of the reference stations are computed.

(2) When the coordinates values of the reference stations are computed.

It is not mandatory that the coordinates values of the reference stations are published.

10. Requirements for maintenance

This clause specifies minimum requirements for maintenance on GNSS positioning augmentation centre.

10.1 Continuous performance monitor

The Administrator shall monitor continuously the items specified in Clause 9.2 and 9.5.

10.2 Cyber security

The Administrator should measure on cyber security including radio-frequency interference, specified the below document.

ISO/IEC 27001:2013 Information technology－Security techniques－Information security management systems－Requirements

The Administrator also should establish, implement, maintain, and improving the centre system for jamming, spoofing, and meaconing against the CORS stations within the context of the organization.

10.3 User service

The Administrator shall inform users of the GNSS positioning augmentation service with the following.

(1) Publication of the necessary information specified Clause 6, 7, 8 and 9 to users who need it.

(2) Respond the claims from users – Respond to users who require support in answering questions around system performance and operational statistics as described in 6, 7, 8 and 9.

Annex A
(Informative)

Cross-border data exchange

The services of this document are designed so that homogeneous augmented positioning performance can be realized throughout the respective countries. Relying solely on the reference stations of individual countries, the accuracy and reliability of the position services would degrade towards the country borders due to missing external geometrical information.

The cooperation of neighbouring countries is inevitable in reaching this purpose. to overcome these degradations and it is expected to see the bilateral cross-border exchange of raw GNSS measurements of reference stations in order to extend the homogeneous service coverage areas to the borders. This cross-border data exchange would help to achieve the objective of homogenous positioning performance in each country.

The purpose of this annex is to provide guidelines for the networking stations, enabling them to select appropriate exchange data contents, data formats and transport protocols.

It is recommended that the user of this document use the RTCM standards for cross-border data exchange.

Annex B
(Informative)

GNSS constellations and systems

(1) Global constellations

・GPS: Global Positioning System (U.S.A.)

・GLONASS: GLObal Navigation Satellite System (Russian Federation)

・Galileo (EU)

・BDS: BeiDou Navigation Satellite System (China)

(2) Regional constellations

・QZSS: Quasi-Zenith Satellite System (Japan)

・NavIC: Navigation with Indian Constellation (India)

(3) SBAS: Satellite Based Augmentation System

・WAAS: Wide Area Augmentation System (U.S.A.)

・MTSAT-based Augmentation System (Japan)

・EGNOS: European Geostationary Navigation Overlay Service (EU)

・GAGAN: GPS-Aided GEO Augmented Navigation (India)

・SDCM: System for Differential Corrections and Monitoring (Russian Federation)

・BDSBAS: BeiDou Satellite Based Augmentation System (China)

(4) GBAS: Ground Based Augmentation System

・LAAS: Local Area Augmentation System (U.S.A.)

・GBAS in airport (many countries)

The following GNSS augmentation systems are currently in the planning / design / implementation stages, but have not achieved initial operational capability (IOC):

・Australian SBAS (Australia)   (Note: This is already a test-bed system)

・KASS: Korea Augmentation Satellite System (Republic of Korea)

・KPS: Korean Positioning System (Republic of Korea)

Annex C
(Informative)

Transmission of Augmentation data

C.1 Standard augmentation service

This term describes the industry-known recommended specification for the transmission of augmentation data using the Internet or Satellite L-band service

- RTCM Standard 10403.x data message
- RTCM Standard 10410.1 NTRIP for the data transmission

C.2 Precise augmentation services

This term describes the industry-known recommended specification for the transmission of augmentation data in the Internet or Satellite L-band service.

- RTCM Standard 10403.x data message
- RTCM Standard 10410.1 NTRIP for the data transmission

C.3 Geodetic service

This term describes the industry-known recommended specification for the transmission of augmentation data transmission through the Internet.

- RINEX file format
- HTTPS or FTPS protocol

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