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Agenda item [[2]](#footnote-2)

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Author(s) / Submitter(s) China MSA

Working Draft of Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service

1. **ABSTRACT**

Based on the discussion at ENG 18 meeting and the feedback from the offline communication group, China MSA has revised the working draft of Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service for further consideration under ENG 19.

* 1. **PURPOSE**

The purpose of this document is to propose a working draft of guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service. It provides an introduction of the GNSS Satellite-based PPP service, and describes the service parameters to characterize GNSS satellite-based PPP service for maritime use, and gives suggestions on the GNSS satellite-based maritime application scheme.

1. **BACKGROUND**

At ENG 17, China MSA proposed a new work item of development of guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service and the IALA Council in mid-December 2023 approved to add this new work item for work programme 2023-2027. At ENG 18, the input ENG 18-3.2.2.1 on the development of Guidelines on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service During ENG 18, the whole structure and chapter 1,2 were discussed. Further details were added to chapter 3. The work on the draft guideline is planned to continue during ENG19 as a task group.

1. **DISCUSSION**

Revisions of the working draft guideline:

* Revise and improve Chapter 3;
* Modify chapters 1 to 6 based on the suggestion at ENG 18.

1. **PROPOSAL**

It is proposed that the ENG Committee continue to revise the guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service based on the working draft guideline submitted by China MSA.

1. **Reference**
2. IALA Guidelines 1127, SYSTEMS AND SERVICES FOR HIGH ACCURACY POSITIONING AND RANGING
3. **Action requested of the Committee**

The Committee is requested to consider the Working Draft of Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service and jointly supplement the contents of the guideline.

|  |
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| IALA Guideline |

GXXXX

GNSS satellite-based Precise Point Positioning(PPP) MARITIME SERVICE

Edition x.x

Document date

Revisions to this IALA document are to be noted in the table prior to the issue of a revised document.

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| Date | Page / Section Revised | Requirement for Revision |
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# Introduction

Global Navigation Satellite Systems (GNSS) have become the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. Most ships are equipped with GNSS receivers (SOLAS carriage requirement [1]).

Precise Point Positioning (PPP) is a method for global absolute positioning that typically combines multi-frequency GNSS phase measurements with provided precise satellite orbits and clock corrections. PPP data products are generated based on the measurements of a global or regional network of GNSS monitoring stations. Local effects have to be compensated at the user side when the PPP service provider does not offer data for regional or local corrections. If single frequency phase measurements are used, additional precise ionosphere models have to be considered. Once the PPP corrections are calculated, they are delivered to the end users via satellite, Internet or any other dissemination means. These corrections are used by the receivers, resulting in decimetre-level or centimetre-level positioning without the need for communication with close range GNSS reference stations.

PPP can achieve high accurate positioning, but it strongly depends on accurate and uninterrupted satellite orbit and clock error estimations, the number of tracked satellites and the time of continuous phase measurements. The main error sources for PPP are mitigated by Dual-Frequency Operation, External Error Correction Data, Modelling or PPP Filter Algorithms. A typical PPP solution requires a period of time to converge to dm or cm accuracy in order to resolve any local biases such as the atmospheric conditions, multipath environment and satellite geometry. The actual accuracy achieved and the convergence time required is dependent on the quality of the corrections and how they are applied in the receiver.

Currently, there are two types of consolidated PPP implementations. One is to obtain post-processed solutions and the other is to have real-time solutions. Post-processed PPP solutions have been in use for many years and generally achieve better results than real-time solutions. The main difference between the two implementations is that, post-processed solutions apply correction after measuring using the corrections provided by the service provider, while real-time solutions require precise orbit information and clock corrections to be sent in real-time to the GNSS receiver location.

A communication channel is continuously needed to broadcast correction parameters. Satellite-based Precision Point Positioning (PPP) services broadcast PPP navigation messages on the public service signals of GNSS satellites It is an important technology for satellite navigation systems to achieve wide-area high-precision positioning through satellite navigation signals due to its wide signal coverage, uniform accuracy distribution, and small number of ground reference monitoring stations. Especially in the use cases of PPP fields, such as autonomous unmanned ship automatic berthing, channel mapping, dredging, cargo loading and unloading, etc., decametre or centimetre level positioning accuracy is very necessary.

## Scope of the document

The guideline provides the description of all the elements of GNSS satellite-based PPP service relevant to the maritime administrations (direct reception of GNSS satellite-based PPP service Signal in Space (SiS) onboard the vessels). This includes some scenarios about maritime application and the scheme for maritime use.

## Structure of the document

Section 1 is the introduction to this Guideline, including the scope of the document.

Section 2 establishes the IMO Resolution A.1046(27) and A.915(22) operational requirements as the reference for the implementation of GNSS satellite-based PPP Maritime Service.

Section 3 describes the main elements of a basic GNSS satellite-based PPP service architecture and the existing systems.

Section 4 proposes a list of service parameters to characterize GNSS satellite-based PPP service for maritime use, including their definition.

Section 5 describes the GNSS satellite-based PPP service compatible equipment and maritime application scheme.

And Section 6 describes scenarios of the GNSS satellite-based PPP service in Maritime Service.

# IMO Resolution A 1046(27) and a.915(22) Reference Requirements

The IMO Resolution A.1046(27) establishedd the requirements that a radionavigation system needs to fulfil to be recognized by IMO as a component of the Worldwide RadionNavigation System (WWRNS), and the IMO Resolution A.915(22) operational requirements published in 2001 are considered to be the appropriate reference requirements for the implementation of GNSS after GPS and GLONASS.

Till 2024, IMO has recognized six GNSS systems (GPS, GLONASS, BDS, Galileo, IRNSS, QZSS) as the WWRNS elements in ocean waters. As one potential capability of the recognized GNSS elements by IMO WWRNS such as BDS, Galileo, QZSS and so on, GNSS satellite-based PPP service should be in compliance with the responsibilities of Governments or organizations and the operational requirements. Meanwhile, with the capability of better than decimeter precise positioning of GNSS satellite-based PPP service, the recognized WWRNS can achieve the levels of performance required in IMO Resolution A.1046(27) for coastal areas and harbour approaches.

The IMO Resolution A.1046(27) establishes the operational requirements that a radionavigation system shall fulfil, which are summarized in the table below:

Table 2 1: IMO Resolution A.1046(27) operational Requirements

|  |  |  |
| --- | --- | --- |
|  | Ocean waters | Harbour entrance, harbour approach and coastal waters |
| Accuracy  (95%) | 100 m | 10 m |
| System Integrity  (Time to alarm) | As soon as practicable by Maritime Safety Information | Within 10s |
| Signal Availability | 99.8% | 99.8% |
| Continuity | N/A | 99.97%(over 15 min) |

Moreover, IMO Resolution A.1046(27) requires that governments or organizations owning and operating the recognized radionavigation systems should comply with the following points:

• The government or organization providing and operating the system has stated formally that the system is operational and available for use by merchant shipping.

• The continued provision of the service is assured.

• The system is able to provide position information within the declared coverage area with a performance not less than that established in the present resolution.

• Adequate arrangements have been made for publication of the characteristics and parameters of the system and of its status.

• Adequate arrangements have been made to protect the safety of navigation should it be necessary to

introduce changes in the characteristics or parameters of the system that could adversely affect the

performance of shipborne receiver equipment.

Secondly, the IMO Resolution A.915(22) established general requirements, operational requirements, institutional requirements and transitional requirements for the WWRNS GNSS elements after 2001, the requirements can be summarized below:

• A future GNSS should primarily serve the operational user requirements for general navigation. This includes navigation in harbor entrances and approaches, and other waters in which navigation is restricted.

• A future GNSS should have the operational and institutional capability to meet additional area-specific requirements through local augmentation, if this capability is not otherwise provided. Augmentation provisions should be harmonized worldwide to avoid the necessity of carrying more than one shipborne receiver or other devices.

• A regional satellite navigation system that is fully operational may be recognized as a component of the WWRNS.

Therefore, the administration may consider if the above requirements should be fulfilled and documented by the GNSS satellite-based PPP service provider. This may possibly be achieved by using the appropriate IALA recommended methods.

# GNSS satellite-based PPP service

The main elements of a basic GNSS satellite-based PPP service architecture is usually as following:

* **Space segment**: Includes the satellites with payloads aimed to transmit the corrections to the GNSS core constellations.
* **Ground segment**: Includes all the ground elements which provide the PPP navigation messages.
* master control station (MCS)
* uplink stations (ULS)
* monitoring stations (MS)
* **User segment**: Includes the user equipment needed to receive and use the GNSS high accuracy PPP service information.

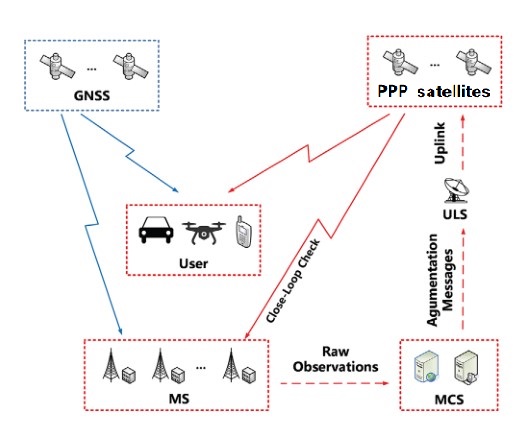


Figure 3‑1: Basic GNSS satellite-based PPP service architecture

## Existing and planned GNSS satellite-based PPP systems

At the time of writing this document the existing GNSS satellite-based PPP service and their status are shown in Table 3‑1 below:

Table 3‑1: The existing and planned GNSS satellite-based PPP systems

| Country/Region | GNSS satellite-based PPP system | Organisation in charge | Coverage area | Status | GNSS Augmented | CHARGE/FREE |
| --- | --- | --- | --- | --- | --- | --- |
| China | BDS PPP B2b | China Satellite Navigation Office | Asian-Pacific Area | Operational  WWRNS | GPS  BDS  GALILEO  GLONASS | free |
| Europe | Galileo HAS | EUSPA | SL1：GLOBAL  SL2：EUROPEAN AREA | Operational  WWRNS | GPS  Galileo | free |
| Japan | QZSS MADOCA-PPP | cabinet Office of Japanese Government |  | Operational  WWRNS | QZSS  BDS  GPS  GALILEO  GLONASS |  |
| Australia and New Zealand | SouthPAN | Australian and New Zealand governments |  | In development | GPS |  |

## Correction parameters

Correction parameters messages for Satellite-Based PPP are broadcast through GNSS satellites, mainly include satellite orbit correction, clock correction, biases(code and phase) and user range accuracy. shown in Table 3‑1 below.

Table 3‑2: Correction parameters for Satellite-Based PPP

|  |  |  |  |
| --- | --- | --- | --- |
| Correction parameters | BDS PPP | Galileo HAS | QZSS MADOCA-PPP |
| Time | BDT | GST | QZSST |
| Reference frame | BeiDou Coordinate System (BDCS) | Galileo Terrestrial Reference Frame (GTRF) | ITRF |
| Satellite mask | Y | Y | Y |
| Satellite orbit correction | Y | Y | Y |
| Clock correction | Y | Y | Y |
| Code Biases | Y | Y | Y |
| Phase Biases | - | Y | Y |
| User Range Accuracy | Y | Y | Y |
| Atmospheric corrections | n/a | Service Leve 2 | n/a |
| Broadcasting Frequencies | B2b | E6 | L6 |

## Augmented navigation message

The BDS PPP-B2b signal is designed to provide PPP service for GNSS and their combinations. For each satellite navigation system, the reference broadcast navigation messages corresponding to various corrections are:

1) BDS: PPP-B2b information is used to correct the CNAV1 navigation messagesofB1C signal.

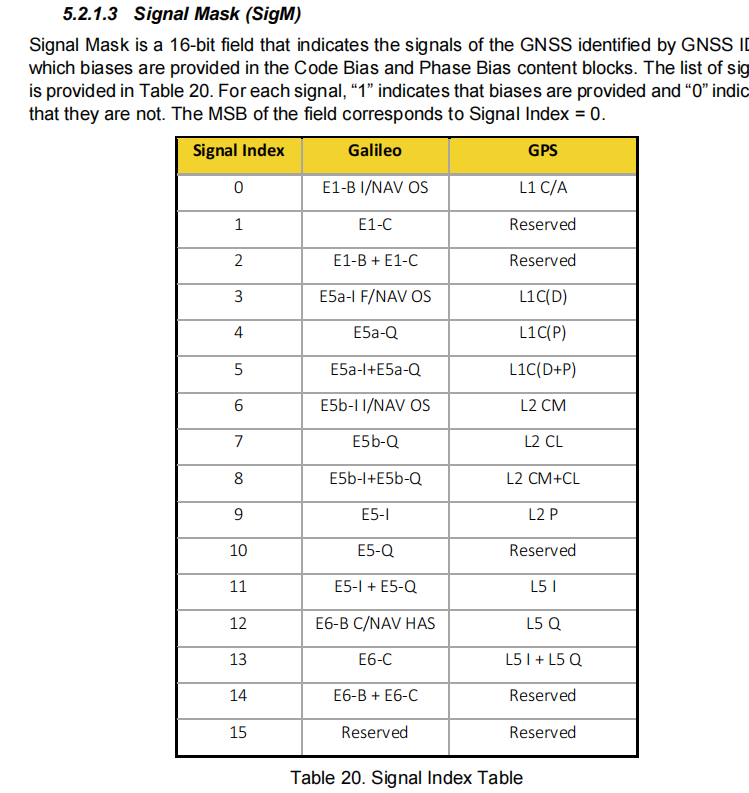
2) GPS: PPP-B2b information is used to correct the LNAV navigation messages.

3) Galileo: PPP-B2b information is used to correct the I/NAV navigation messages.

4) GLONASS: PPP-B2b information is used to correct the L1OCd navigation messages

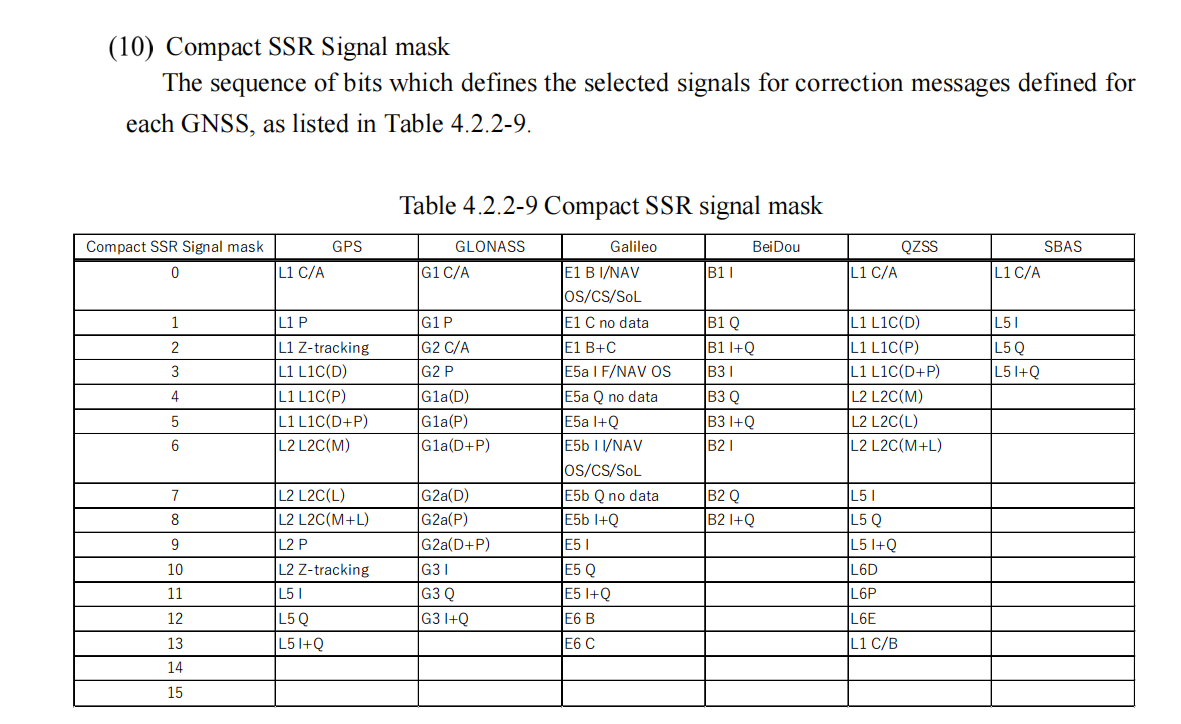
Galileo augmented navigation message

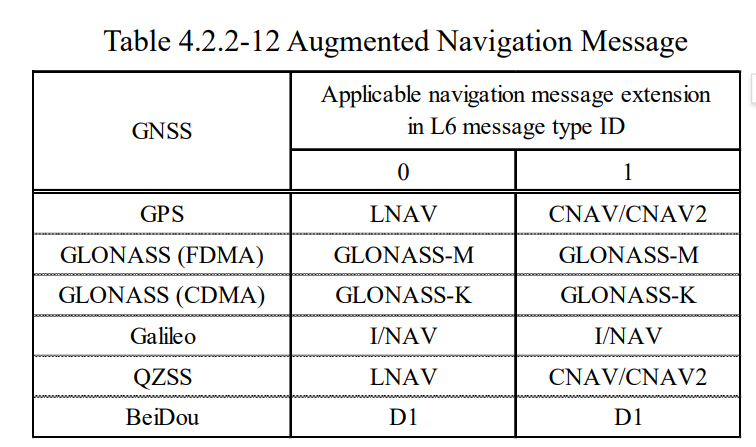
Reference: Galileo HAS SIS ICD, Issue 1.0, May 2022



QZSS: augmented navigation message

Reference: Quasi-Zenith Satellite System Interface Specification Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning (IS-QZSS-MDC-002)- (November 2023) Cabinet office





# GNSS satellite-based PPP service Performance Parameters

This section proposes a list of service parameters to characterize GNSS satellite-based PPP service for maritime use.

The list of service parameters required for a complete characterization of a GNSS satellite-based PPP service are derived from the list in IMO Resolution A.915(22) and IALA Guideline 1127.

Table 4‑1: IMO Resolution A.915(22) service requirements

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | System level parameters | | | | | Service level parameters | | | |
|  | Accuracy | | Integrity | | | Availability  % per 30 days | Continuity  % over 3hours | Coverage | Fix interval2  (seconds) |
|  | Horizontal  (metres) | Vertical  (metres) | Alert limit (metres) | Time to alarm2(seconds) | Integrity risk (per 3 hours) |
| **Operations** | Relative accuracy | |  |  |  |  |  |  |  |
| tugs and pushers | 1 |  | 2.5 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
| icebreakers | 1 |  | 2.5 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
|  | Absolute accuracy | |  |  |  |  |  |  |  |
| automatic docking | 0.1 |  | 0.25 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
| Hydrography | 1-2 | 0.1 | 2.5-5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| **Marine engineering, construction, maintenance and management** |  |  |  |  |  |  |  |  |  |
| dredging | 0.1 | 0.1 | 0.25 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| cable and pipeline laying | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| construction works | 0.1 | 0.1 | 0.25 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| Aids to navigation management | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| Port operations | Absolute accuracy | |  |  |  |  |  |  |  |
| local VTS | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| container/cargo management | 1 | 1 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| law enforcement | 1 | 1 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| cargo handling | 0.1 | 0.1 | 0.25 | 1 | 10^-5 | 99.8 | N/A | Local | 1 |
| Casualty analysis | Predictable accuracy | |  |  |  |  |  |  |  |
| port approach and  restricted waters | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| Offshore exploration and  exploitation | Absolute accuracy | |  |  |  |  |  |  |  |
| exploration | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| appraisal drilling | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| field development | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| support to production | 1 | N/A^2 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| post-production | 1 | N/A^2 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |

The paragraphs below detail how these parameters can be understood and measured.

* Signal Availability
* Service Availability
* Service Continuity
* Horizontal Accuracy 95%
* Time to Alarm
* Position Update Rate
* Service Coverage Area

# GNSS satellite-based PPP MARITIME Service Provision Scheme

Kind of correction what we are discussed

A scheme for providing the users with the appropriate GNSS Satellite-based PPP Maritime Service should be established, including the provision of maritime safety related information to the end users.

This section describes an example of this scheme, with relevant stakeholders involved, including the interfaces between them and the provision of GNSS satellite-based PPP service related Maritime Safety Information (MSI) to the end users. The picture below presents schematically this High level Service provision model:



Figure 5‑1: GNSS Satellite-based PPP Maritime Service Provision Scheme

# User Segment Approach

[Including specific scenarios for maritime usage]

Considering the method under free or charging

## MASS

## Dredging

Dredging is the removal of sediments and debris from the bottom of lakes, rivers, harbors, and other water bodies. It is a routine necessity in waterways around the world because sedimentation—the natural process of sand and silt washing downstream—gradually fills channels and harbors. Dredging often is focused on maintaining or increasing the depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of boats and ships. Vessels require a certain amount of water in order to float and not touch bottom. A Dredge Positioning System is often used combined with GNSS Real-time kinematic (RTK) positioning devices to show a superimposed view of the dredge location in real-time over the survey. GNSS satellite-based PPP service can provide real-time high accuracy location without extra augmentation GNSS devices. It precisely identifies the location of the attachment at the end of the excavator boom/stick assembly. And together with the dredge positioning system, displays a survey or map of an as-built color bathometric surface of the area to be dredged. It decreases the potential for damage by increasing situational awareness, and keeping the operator alerted when the digging attachment is positioned too close to environmental borders, infrastructure, or any other areas where the digging attachment can cause undesired damage.

## automatic docking

Among maritime operations, the docking of a vessel is considered to be one of the most critical. This is because the vessel operates in a constrained area where highly accurate positioning measurements are required. Real-time kinematic (RTK) GNSS can be used to determine position in centimeters. However, RTK GNSS is an expensive solution and has a large number of dropouts since it needs extro augmentation stations. GNSS satellite-based PPP service can provide centimeter accuracy during autonomous docking by a single receiver. Autonomous vessels have the potential to operate reliably under safety-critical docking operations

## .cargo handling

## construction works

## Hydrography

# Acronyms

BEIDOU Chinese Global Navigation Satellite System

CHAYKA Russian long range navigation system

CLAS Centimetre Level Augmentation Service

DGNSS Differential GNSS

EGNOS European Geostationary Navigation Overlay Service

Galileo European GNSS

GLONASS Russian Global Navigation Satellite System

GMDSS Global Maritime Distress and Safety System

GNSS Global Navigation Satellite System such as Galileo, GPS, GLONASS or BEIDOU.

GPS U.S. Global Positioning System

IALA International Association of Marine Aids to Navigation and Lighthouse Authorities

IEC International Electrotechnical Commission

IGS International GNSS Service

IMO International Maritime Organization

IRNSS Indian Regional Navigation Satellite System

MADOCA-PPP Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning

PNT Position, Navigation, and Time

PPP Precise Point Positioning

QZSS Quasi-Zenith Satellite System

RTK Real Time Kinematic

SBAS Satellite-based Augmentation System

SDCM System of Differential Correction and Monitoring

WWRNS World Wide Radio Navigation Systems

# References

1. IMO Resolution A.1046(27), Adopted on 30 November 2011, WORLDWIDE RADIONAVIGATION SYSTEM.
2. IMO Resolution A.915(22), Adopted on 29 November 2001 , REVISED MARITIME POLICY AND REQUIREMENTS FOR A FUTURE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS).
3. IALA Guidelines 1180,RESILIENT PNT
4. IALA Guidelines 1152, SBAS MARITIME SERVICE
5. IALA Guideline G1112 Performance and Monitoring Of DGNSS Services in the Frequency Band 283.5 – 325
6. IALA Guidelines 1127, SYSTEMS AND SERVICES FOR HIGH ACCURACY POSITIONING AND RANGING
7. IALA Guidelines 1129, THE RETRANSMISSION OF SBAS CORRECTIONS USING MF-RADIO BEACON AND AIS
8. IALA Recommendation 1022 PROVISION OF GNSS AUGMENTATION SERVICE FOR MARITIME APPLICATION
9. IALA NAVGUIDE 2023.
10. IMO Guideline MSC.1/Circ.1575, GUIDELINES FOR SHIPBORNE POSITION, NAVIGATION AND TIMING (PNT) DATA PROCESSING.
11. IALA World Wide Radio Navigation Plan, Edition 2, December 2012.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)