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1. 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]).

Traditionally, maritime users have relied on the marine radiobeacon DGPS (Differential GPS) augmentation service, provided by maritime administrations, to improve accuracy and provide integrity for GPS. For those administrations evaluating the possibility to rationalize their DGPS services, Satellite Based Augmentation Systems (SBAS) can be considered as a backup solution for DGNSS or as a complementary means to provide augmentation to mariners. Recent navigation receivers installed on ships also generally utilize SBAS. However, at the time of writing this Guideline, there is no formal approval process in place for SBAS marine navigation receivers.

Administrations can take advantage of the use of SBAS, which provide enhanced performance over the capabilities of GNSS and Regional Navigation Satellite System (RNSS) constellations. SBAS improves the accuracy and reliability of GNSS by correcting signal measurement errors and by providing information about the accuracy, integrity and availability of GNSS signals.

Thus, clear guidance of how and when to use SBAS in maritime is required, so as to make the most of the SBAS services for the benefit of marine safety for harbour approaches and coastal navigation.

1.1. SCOPE OF THE DOCUMENT

The scope of this Guideline is to identify aspects that maritime or coastal administrations may take into account when considering the use of SBAS by ships in their waters. The Guideline provides the description of all the elements of SBAS relevant to the maritime administrations (direct reception of SBAS Signal in Space (SiS) onboard the vessels¹). This includes the reference requirements, the user equipment, and also the description of the service and the operational scheme.

1.2. STRUCTURE OF THE DOCUMENT

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

Section 2 references the IMO Resolution *A.1046(27)*[2] operational requirements as the reference for the implementation of SBAS Maritime Service.

Section 3 describes the main elements of a basic SBAS architecture and the existing SBAS.

Section 4 proposes a list of service parameters to characterize SBAS for maritime use, including their definition.

Section 5 describes the SBAS Service compatible equipment and type approval considerations.

Section 6 describes an example of the SBAS Maritime Service provision scheme.

2. IMO RESOLUTION A.1046 (27) REFERENCE REQUIREMENTS

The International Maritime Organization (IMO) Resolution *A.1046(27)* on Worldwide Radionavigation Systems [2] provides operational requirements, which are considered to be the appropriate reference requirements for the implementation of SBAS Service for maritime navigation.

The IMO Resolution *A.1046(27)* establishes the requirements that a radionavigation system needs to fulfil to be recognized by IMO as a component of the World-Wide Radionavigation System (WWRNS). This means that the

¹ Note that IALA Guideline *G1129* covers the retransmission of SBAS corrections using MF-radiobeacon and AIS.

system is recognized to be able to provide adequate position information within its coverage area and that the carriage of receiving equipment for use with the system satisfies the relevant requirements of the 1974 SOLAS Convention. IMO recognize GNSS as part of WWRNS only for ocean areas where required performance levels can be achieved without using augmentation systems [e.g., IMO Circular *SN.1/Circ.329*]. In order to achieve the levels of performance required in IMO Resolution *A.1046(27)* for coastal areas and harbour approaches, augmentation of GNSS is needed. However, IMO (at the Maritime Safety Committee (MSC) 98 - June 2017) does not require augmentation systems to be recognized as part of the WWRNS.

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

Table 1 IMO Resolution A.1046(27)[2] 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)

- For ocean waters, the system should provide positional information with an error not greater than 100 m with a probability of 95%. Signal availability should exceed 99.8%. An integrity warning of system malfunction, non-availability or discontinuity should be provided to users as soon as practicable by Maritime Safety Information (MSI) systems.
- For harbour entrances, harbour approaches and coastal waters, positional information with an error not greater than 10 m with a probability of 95%. Signal availability should exceed 99.8%. When the system is available, the service continuity should be $\geq 99.97\%$ over a period of 15 minutes. An integrity warning of system malfunction, non-availability or discontinuity should be provided to users within 10s.

It should be noted that, according to existing documentation [3] the signal availability and continuity requirements could be relaxed to 99.5% and 99.95% respectively for the augmentation system, when it is used in combination with other back-up system (for areas of overlapping coverage).

Note that IMO Resolution *A.1046(27)* considers the integrity at “system level”, this means that in case a failure is detected in the system the user is warned.

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 receiving equipment.

The administration may consider if the above requirements should be fulfilled and documented by the SBAS provider. IALA is developing an approach that will allow augmentation service providers to recognise a maritime user.

3. SBAS ARCHITECTURE

The main elements of a basic SBAS architecture are usually as following:

3.1. SPACE SEGMENT

Includes the satellites with payloads aimed to transmit the corrections to the GNSS core constellations and integrity information.

3.2. GROUND SEGMENT

Includes all the ground elements which provide the SBAS navigation message:

- Monitoring Station Network
- Processing Facility Centre
- Satellite Control Centre
- Communication Layer

3.3. USER SEGMENT

Includes the user equipment needed to receive and use the SBAS information.

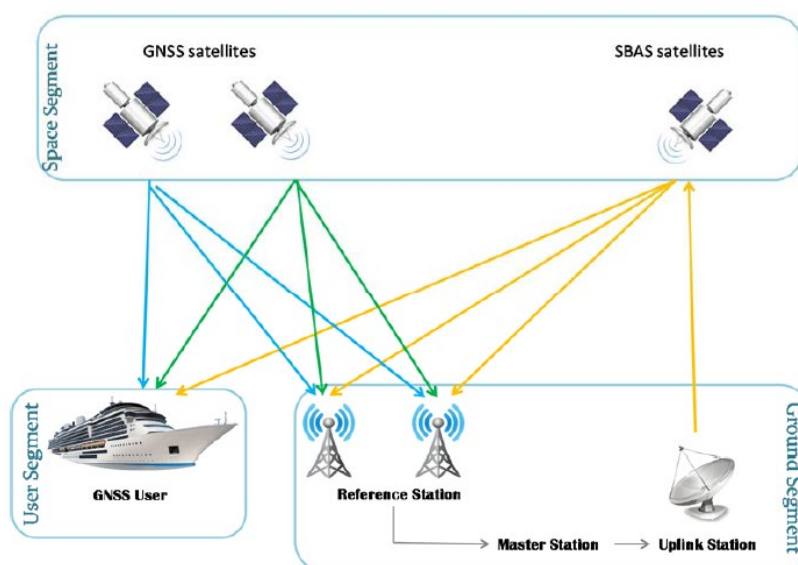


Figure 1 Basic SBAS architecture



3.4. EXISTING AND PLANNED SBAS

Several organizations have already implemented SBAS. Others are currently developing new SBAS. At the time of writing this Guideline the existing and planned SBAS and their status are shown in table 2 below:

Table 2 Existing and planned SBAS

Country/Region	SBAS	Status	GNSS Augmented
Europe	European Geostationary Navigation Overlay Service (EGNOS)	Operational	GPS (Galileo) ²
USA	Wide Area Augmentation System (WAAS)	Operational	GPS
Japan	Multi-functional Satellite Augmentation System (MSAS)	Operational	GPS
India	GPS and GEO Augmented Navigation (GAGAN)	Operational	GPS
China	Beidou Satellite-Based Augmentation System (BDSBAS)	In development	GPS BDS
Republic of Korea	Korea Augmentation Satellite System (KASS)	In development	GPS
Russia	System for Differential Corrections and Monitoring (SDCM)	In development	GPS GLONASS
Australia region	<i>Still to be named</i>	In development	GPS

SBAS was originally designed for aviation users, however several SBAS service providers have stated that their services can support other users such as the maritime.

All these systems comply with or will be designed to comply with a common global standard [4] and are therefore:

- *Compatible*, in the sense that they do not interfere with each other;
- *Interoperable*, in the sense that a user with a standard receiver can benefit from the same level of service and performance, regardless of their location.

² At the time of writing this Guideline the augmentation of Galileo is not operational.

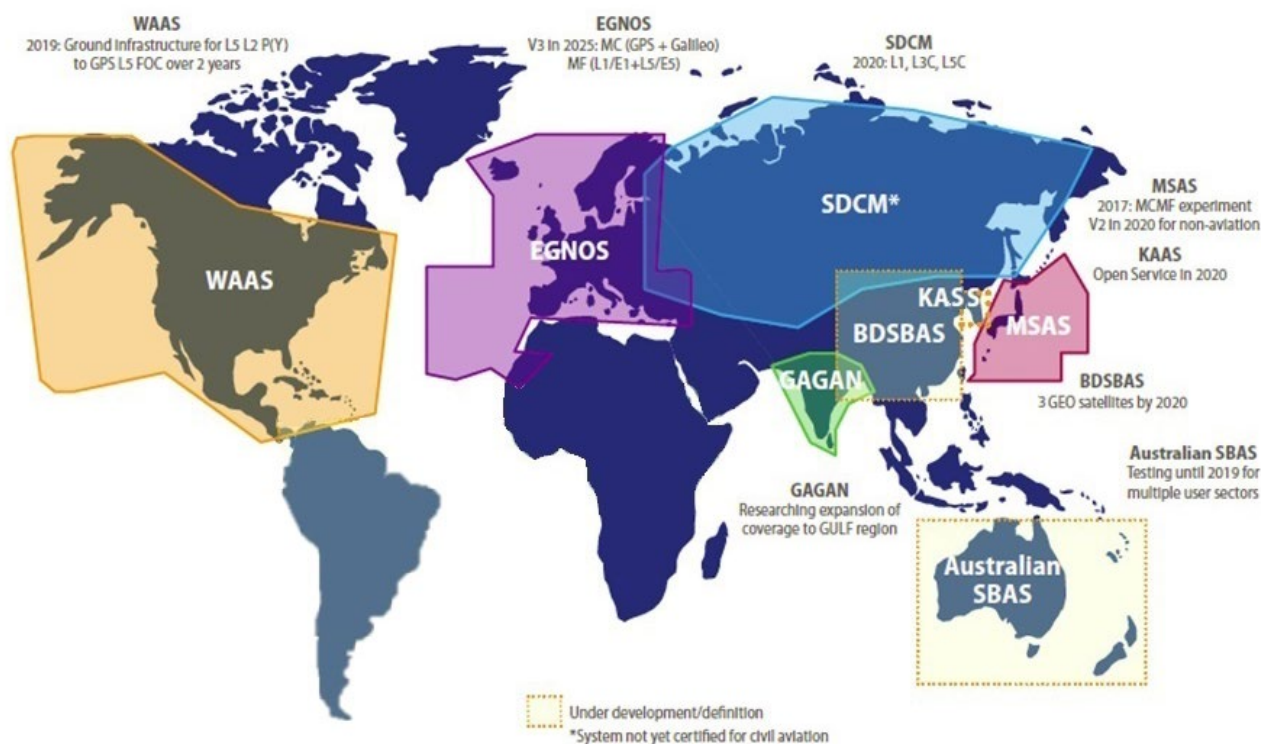


Figure 2 Existing SBAS (in operation and under development)³

4. SBAS SERVICE PERFORMANCE PARAMETERS

This section proposes a list of service parameters to characterize SBAS for maritime use which are different for “ocean waters” and for “harbour entrances, harbour approaches and coastal waters”.

The list of service parameters required for a complete characterization of an SBAS Maritime Service are derived from the list in IMO Resolution A.1046(27), together with the parameters defined in IALA Guideline G1112 *Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 –325 kHz*, as shown in table 3.

Table 3 SBAS Performance parameters

Ocean Waters	Harbour entrances, harbour approaches and coastal waters
Signal Availability Service Availability Horizontal Accuracy 95% Position update rate Service Coverage	Signal Availability Service Availability Service Continuity Horizontal Accuracy 95% Position update rate Time To Alarm Service Coverage

³ The figure 2 shows the service areas for aviation users



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

4.1. SIGNAL AVAILABILITY

The signal is considered available when provided according to its specification. For maritime, SBAS Signal Availability is the percentage of time the SBAS SiS is provided by the Geostationary Satellites (GEOs) throughout the specified service coverage area. Therefore, the signal availability is calculated as the combined signal availability of the operational SBAS GEOs. SBAS receivers are expected to be capable of instantaneous GEO switching without impacting the user.

4.2. SERVICE AVAILABILITY

Service Availability is the probability of the system providing the necessary information that would enable the user to determine their position, with the specified accuracy and integrity within the service coverage area.

4.3. SERVICE CONTINUITY

The probability that, assuming a fault-free receiver, a user will be able to determine position with specified accuracy and is able to monitor the integrity of the determined position over the (short) time interval applicable for a particular operation within a limited part of the coverage area.

An expression on how to calculate continuity is provided in IALA Guideline *G1112*.

4.4. HORIZONTAL ACCURACY

The degree of conformance between the estimated or measured parameter of a craft at a given time and its true parameter at that time. Accuracy is specified as the position error at 95% confidence level.

4.5. TIME TO ALARM

The Time to Alarm (TTA) is defined as the maximum acceptable time starting when a (system integrity) alarm condition occurs to the time that the alarm is displayed at the user interface. The time to detect the alarm condition is included as a component of this requirement.

4.6. POSITION UPDATE RATE

SBAS receivers must be designed to meet the 2s update rate required by IMO Resolution *A.1046(27)*.

4.7. SERVICE COVERAGE AREA

The maritime service coverage area is a designated geographical area where, taking into account the radio frequency environment, SBAS is adequate to provide required service performance throughout a phase of navigation.

5. USER SEGMENT APPROACH

This section describes the SBAS Service compatible user equipment, including requirements for standardization of user equipment and required upgrades.

5.1. SBAS TYPE APPROVED RECEIVERS

To reliably benefit from the SBAS maritime service, including integrity at system level, the vessels should use receivers where the reception and processing of SBAS signals is ensured to meet appropriate requirements. Such assurance is normally acquired through type approval test procedures against standards where reception and processing of SBAS signals is included. Standards for such tests do not exist yet, but are expected to be available in the future.

The administration should take into consideration the regulatory status of SBAS receivers regarding the recognition of SBAS for maritime use.

In the future such type approval standards may be created and type approved shipborne SBAS receivers may be offered and installed on ships. This process should also be taken into consideration.

Administrations should also consider the backwards compatibility offered by future SBAS systems versions, ensuring that previously approved receivers will maintain performance with future SBAS versions.

6. SBAS MARITIME SERVICE PROVISION SCHEME

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

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

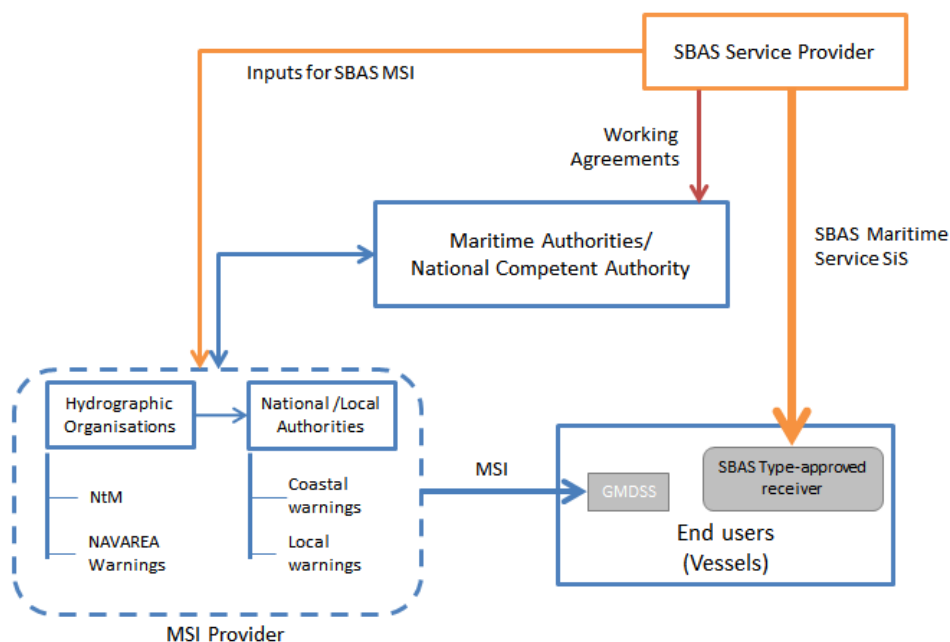


Figure 3 SBAS Maritime Service Provision Scheme



This example considers the reception of the SBAS SiS directly on-board the vessels equipped with type approved receivers.

The stakeholders involved in this high-level service provision model, including their expected roles and responsibilities, are described below:

6.1. THE SBAS SERVICE PROVIDER

The SBAS Service Provider will be the entity which provides the SBAS Maritime Service. The SBAS Service Provider will also be responsible for establishing and supporting all the required operational interfaces with the other stakeholders (end users, Marine Aids to Navigation competent authorities and MSI Providers)⁴, including the generation of any SBAS MSI proposals to be distributed by the MSI providers to the end users of the service.

6.1.1. SBAS SERVICE PROVIDER RESPONSIBILITIES

The SBAS Service Provider responsibilities may be structured in four main blocks, as follows:

6.1.1.1. Operation and Maintenance:

The SBAS Service Provider should continuously monitor the service to detect and manage service disruptions and performance degradations and inform the users. The information regarding planned and unintended SBAS service degradations and unavailability is delivered to the MSI provider.

6.1.1.2. Performance Verification:

The SBAS service provider should verify that the service is performing according to its specifications.

6.1.1.3. Publication of information:

The SBAS service provider should make publicly available the description of the service and also report scheduled maintenance activities and planned unavailability. The SBAS service provider could also provide service performance reporting and support to all the users.

6.1.1.4. Working agreements:

The formalization of SBAS Service Provider commitment to provide the service and the engagement with administrations could be done by establishing working agreements, including:

- Roles, responsibilities and liability⁵ scheme
- Assurance of the long-term operation of the SBAS service and backwards compatibility
- Service offered and its characteristics
- Service performance in compliance to the IMO Resolution *A.1046(27)* and maritime service coverage area
- SBAS MSI provision (generation and distribution procedure)
- Costs of the service (e.g., free of charge)
- Legal data recording needs

⁴ Orange and red arrows in figure 3

⁵ Including technical, operational and legal aspects



6.1.2. MARINE AIDS TO NAVIGATION AUTHORITIES

Marine Aids to Navigation authorities are encouraged to work with the SBAS maritime service provider through mutual cooperation and consider any additional responsibility for the authorities for the delivery of the service or the maritime safety information, beyond their existing roles. Authorities are encouraged to monitor the service and ensure that appropriate MSI is being conveyed to the user.

For MSI existing internationally agreed procedures should be followed.

6.2. END USERS

The end users are the mariners/vessels using the SBAS Maritime Service SiS. End users that wish to use this service need to use a type approved receiver, once the appropriate standards are in place. The end users are also the recipient of the MSI related to SBAS.

6.3. MSI PROVIDER

The MSI provider is encouraged to promulgate to the users, using approved procedures, the MSI related to SBAS Maritime Service status and degradations.

The SBAS Service Provider should send details of the SBAS MSI (e.g., service performance degradations) to the MSI provider, in a format agreed between these parties. The MSI provider will use the procedures and channels already in place for the transmission of MSI to the vessels. Depending on the specific characteristics of the SBAS MSI, the MSI provider will distribute the information as Navigational warnings (NAVAREA, coastal or local warnings)^{6 7} or Notices to Mariners (NtM)⁸.

7. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) at <http://www.iala-aism.org/wiki/dictionary> and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

8. ABBREVIATIONS

DGPS/DGNSS	Differential GPS/GNSS
GEO	Geostationary satellite
GNSS	Global Navigation Satellite Systems
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
MSC	(IMO) Maritime Safety Committee

⁶ NAVAREA warning is the MSI of temporary nature applicable to one of the 21 navigational areas in the world.

⁷ Coastal or local warnings are the MSI of temporary nature applicable to a coastal or local area.

⁸ Notices to Mariners (NtM) is the MSI permanent information published by the National Hydrographic Office.



MSI	Maritime Safety Information
RNSS	Regional Navigation Satellite System
SBAS	Satellite Based Augmentation Systems
SiS	Signal in Space

9. REFERENCES

- [1] IMO. International Convention for the Safety of Life at Sea (SOLAS), Chapter V (Safety of navigation), 1974 (as amended).
- [2] IMO. Resolution A.1046 (27) on the World Wide Radio Navigation System (WWRNS), November 2011.
- [3] IALA. Guideline G1112 Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 –325 kHz, Edition 1, May 2015
- [4] ICAO. Standards and Recommended Practices (SARPS) Standard for SBAS systems – Volume 1 Annex 10.