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**Techniques used for on-board PNT Data Processing**

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# Introduction

## Purpose and scope of document

Worldwide Radio Navigation Systems (WWRNS) cover services used for onboard provision of Position, Navigation, and Time (PNT) data and can basically be divided into 2 segments: services for PNT data determination and service enabling the improvement of PNT data determination by provision of correction data and integrity information. For example, Global Navigation Satellite Systems (GNSS) are space-based services providing radionavigation signals which can be used worldwide by GNSS receivers for positioning and timing. The additional use of terrestrial radionavigation services (eLoran, R-Mode) is considered as appropriate mean to reduce the impact of GNSS vulnerability on onboard PNT data provision. Augmentation services such as Differential GNSS (DGNSS) have been established to improve the process of onboard PNT data provision in relation to quality, continuity, and availability of PNT data output. For this purpose these services provide real-time corrections and/or integrity information to radionavigation signals. Representative example is the IALA Beacon DGNSS developed and deployed in the nineties by the maritime community to enable that during ship’s navigation in coastal areas the requirements on accuracy and integrity of GNSS-based positioning can be met. In the last decade the development and deployment of Satellite Based Augmentation Services (SBAS) has been driven by the aviation community to improve accuracy and integrity of GNSS based positioning and timing. But even in the maritime segment the alternatively as well as complementary use of SBAS as augmentation service is appropriate to improve the onboard provision of PNT data in relation to accuracy, integrity, continuity, and availability. Besides GNSS augmentations services and non-GNSS radionavigation services the usefulness of PNT relevant information services is also discussed. Background is that it may be sufficient in times of increasing availability of radionavigation systems to indicate only the usability and performance of PNT-relevant systems, signals and data as informational basis for ship-side equipment to control or weight their utilization.

Prerequisite for an efficient use of each PNT-relevant services is the harmonization between service provision and the onboard use of service output data. The guideline deals with the methodical description of techniques, which can be applied for onboard PNT data provision in the presence of one or more PNT-relevant services in addition to global available GNSS. In this context special attention is laid on the elaboration of meaning and supported confidence level of safety-relevant information (e.g. status, data and system integrity). The document summarizes recommendations of service providers, when and how the provided service data should be used by onboard equipment to ensure, control and improve the ship-side PNT data determination. Therefore the aim of these guidelines is the harmonisation between service provision and service utilization to enhance the safety of ships’ navigation. This enables, on the one hand, that an efficient utilization of services on board the ship can be achieved. On the other hand, this forces the clarification of responsibilities and dependencies between shore-side and ship-side parts of the maritime PNT system to achieve a reliable and resilient PNT data provision under consideration of diversity on performance requirements.

This document is related to existing and future recommendations and guidelines from IALA dealing with the development, deployment and operation of PNT-relevant service including technical specification of communication interfaces between services and users.

## Structure of document

Section 1.3 gives an overview about PNT-relevant services with relevance for the ship-side PNT data provision. Services will be classified in relation to functions, aimed data output and performance. Examples of current or foreseen service implementations are given to explain role and responsibilities within the maritime PNT system.

Chapter 2 provides technical aspects for a service user on how to access on output data of PNT-relevant services. For this purpose it is necessary to consider all supported communication means, which are applied or foreseen to realize the data exchange between service provider and service user. The applicable communication means are described in relation to communication channels and signals up to data protocols, messages, and formats.

Chapter 3 summarizes recommendations of service providers on how to use the service data during onboard PNT data processing. At beginning algorithms and methods are described, which are sufficient for the onboard generation of PNT data and the integrity monitoring. In this context special attention is laid on onboard decision processes using integrity and status information provided by the services. Furthermore the chapter provides basic principles for the integrated use of various services within onboard PNT data determination and integrity monitoring. In this context various coverage aspects are considered.

Chapter 4 deals with the coordination between shore-side and ship-side integrity monitoring. Effectively, the onboard PNT data processing acts as “user” of all PNT-relevant services. Therefore requirements on service provision should be derived from ship-side needs taking into account possibilities for a further improvement of PNT data provision in relation, to accuracy, integrity, continuity, and availability. In this context the demand on trustworthy status and integrity information in relation to available WWRNS and PNT-relevant services will be clarified.

The following annexes are included:

* Annex A: Abbreviations
* Annex B: Definitions
* Annex C: References

## Overview of PNT-relevant Services

[Short Specification of Service, Link to other IALA guidelines and recommendations dealing with service provision and operation]

## GNSS Augmentation Service

## Ground-based

## Satellite-based

## Terrestrial Radionavigation Service

## eLoran

## R-Mode

## Tbd

## Provision of PNT-relevant Safety Information

# Interfaces to ensure Service utilization

[Possibilities to access on service signals; data protocols, messages, and format; Crosscheck of interface specification in service guideline and aimed onboard utilization; unambiguous specification of data content and meaning]

## GNSS Augmentation Service

## Ground-based

## Satellite-based

## Terrestrial Radionavigation Service

## eLoran

## R-Mode

## Tbd

## Provision of PNT-relevant Safety Information

# Principles of Service utilization (ONBOARD Data processing)

[principles per services; principles for integrated use of services including consideration of integrity aspects: e.g. selection, assessment of error budget, exclusion]

## GNSS Augmentation Service

## Ground-based

## Satellite-based

## Terrestrial Radionavigation Service

## eLoran

## R-Mode

## Tbd

## Provision of PNT-relevant Safety Information

## Rules for integrated use of various services

## Service selection (alternatives, based on service integrity information)

## Service assessment (in case of redundancy)

## Service exclusion (identifiers and logic)

## Coverage aspects

[incomplete service provision; overlapping service provision; use of other communication means]

# Requirements for enhanced Integrity Monitoring and management

[Explain differences between integrity monitoring of service provision and supported integrity monitoring at user site; explain possibility of enhanced onboard integrity monitoring and management by standardized data products of services, especially regarding performance and usability of provided signals and data; evaluate provided integrity information from the perspective of onboard processing; derive requirements on enhanced integrity monitoring as prerequisite of integrity controlled PNT data processing and provision]

## GNSS Augmentation Service

## Ground-based

## Satellite-based

## Terrestrial Radionavigation Service

## eLoran

## R-Mode

## Tbd

## Provision of PNT-relevant Safety Information

## Requirements for integrated use of various services

## ANNEX A Abbreviations

|  |  |  |
| --- | --- | --- |
| BEIDOU | - | Global Navigation Satellite System (China) |
| DGALILEO | - | Differential GALILEO |
| DGLONASS | - | Differential GLONASS |
| DGNSS | - | Differential GNSS |
| DGPS | - | Differential GPS |
| DOP | - | Dilution of Precision |
| EGNOS | - | European Geostationary System |
| eLoran | - | Enhanced LORAN |
| GAGAN | - | GPS Aided Geo Augmented Navigation |
| GALILEO | - | European GNSS |
| GLONASS | - | Глоба́льная навигацио́нная спу́тниковая систе́ма,  Global Navigation Satellite System (Russia) |
| GNSS | - | Global Navigation Satellite System |
| GPS | - | Global Positioning System |
|  |  |  |
| HF | - | High Frequency (3 – 30 MHz) |
| IALA | - | International Association of Marine Aids to Navigation and Lighthouse Authorities |
| IEC | - | International Electrical Commission |
| IMO | - | International Maritime Organisation |
| IMS | - | Integrity Monitoring Station |
| INS | - | Integrated Navigation System |
| ITU | - | International Telecommunication Union |
| LORAN | - | Long Range Navigation |
| MF | - | Medium Frequency (0.3 – 3 MHz) |
| MRR | - | Multi-system Radionavigation Receiver |
| MSC | - | Maritime Safety Committee |
| MSI | - | Maritime Safety Information |
| NMEA | - | [National Marine Electronics Association](https://de.wikipedia.org/wiki/National_Marine_Electronics_Association),  Maritime Communication Standard |
| PNT | - | Position, Navigation, and Timing |
| PVT | - | Position, Velocity, and Timing |
| RAIM | - | Receiver Autonomous Integrity Monitoring |
| RS | - | Reference Station |
| RTCM | - | Radio Technical Commission for Maritime Services |
| SDMC | - | System for Differential Corrections and Monitoring |
| SHF | - | Super High Frequency (1- 2 GHz) |
| WAAS | - | Wide Area Augmentation System |
| VRS | - | Virtual Reference Station |

## ANNEX B Definitions

|  |  |
| --- | --- |
| Accuracy |  |
|  | |
| Availability |  |
|  | |
| Integrity |  |
|  | |
| Reliability |  |
|  | |
| Resilience |  |
|  | |

## ANNEX C References