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Towards an IALA Guideline for Maritime Ground-based GNSS Precise Positioning Services: Lessons from the Republic of Korea’s POINT Service

# introduction

Maritime autonomous applications, encompassing the operation of unmanned vessels or remotely controlled boats, are rapidly transforming the global maritime industry. These advanced systems, controlled by sophisticated computer systems and sensors, are being deployed for a diverse range of purposes, including surveying, shipping, logistics, environmental monitoring, and security. A key area of innovation is cargo handling automation, where robotic systems are employed for the loading and unloading of ships, significantly enhancing efficiency and safety while reducing operational costs. However, the successful and safe operation of these systems is fundamentally contingent upon high-precision positioning and navigation capabilities.

Accurate and reliable positioning and navigation are not merely supplementary features but rather essential prerequisites for maritime autonomy. They enable vessels to operate effectively in a variety of environments, from open seas to congested port and restricted waters. Navigational safety is paramount for autonomous vessels, as they must continuously identify and avoid hazards to prevent collisions and groundings. Furthermore, precise navigation is critical for mission-specific tasks, such as following predetermined survey lines or executing complex maneuvers for automated cargo handling. Without continuous and reliable positioning data, autonomous systems cannot function with the necessary degree of safety and precision.

While GNSS (Global Navigation Satellite System)-based systems, particularly GPS, provide the foundational data for positioning, they often fall short of the high-accuracy requirements for modern maritime autonomous applications. The required positioning accuracy for these applications is typically in the centimeter to decimeter range, which is far beyond the capabilities of standalone GPS. To address this limitation, various GNSS-based augmentation technologies, such as RTK (Real Time Kinematic), PPP (Precise Point Positioning), and PPP-RTK, have been developed. These technologies utilize correction information from ground-based reference stations to significantly improve positioning accuracy, reliability, and integrity. This enhanced data is crucial for applications like hydrographic surveying, where minor positioning errors can render data unusable, and automated cargo handling, where centimeter-level precision is vital for safety and efficiency.

The Republic of Korea has been at the forefront of developing a national infrastructure to support these emerging maritime needs. The POINT project (Precise Positioning and INTegrity monitoring) was conducted from 2020 to 2024, with its research and development results transferred to the Korean government in December 2024. The system has since been in a pilot operational phase, which began in December 2024 and is ongoing. This paper will focus on sharing the operational status of the POINT service, which is currently being run by the Korean government based on the project’s research outcomes. We will present specific results from the pilot operation, conducted from January to August 2025, to demonstrate that the service is stable and ready for practical use. Based on this successful pilot operation, we have identified a critical need for international collaboration and the establishment of a standardized guideline for these services, a topic this paper will address in its final section.

# Operational Status and Performance Analysis

## Operational Status of the POINT Service

The successful completion of the POINT project marked a significant milestone for maritime safety and autonomy in the Republic of Korea. Following the transfer of its research and development outcomes to the government in December 2024, the operational responsibility for the newly established POINT service was officially entrusted to the Korean National Maritime PNT Office (NMPO, a government agency under the Ministry of Oceans and Fisheries). This transition ensured that the system, developed through years of dedicated research, would be managed and maintained by a dedicated public authority with the primary mission of enhancing maritime positioning, navigation, and timing (PNT) capabilities. This section provides a comprehensive overview of the current operational status of the POINT service, detailing its core infrastructure, service delivery mechanisms, and the successful outcomes of its initial pilot phase.

The operational backbone of the POINT service is a sophisticated and robust ground-based network designed to provide high-precision GNSS augmentation and integrity monitoring. At its core, the system consists of three main components: a nationwide network of GNSS reference stations, a centralized Data Processing and Control Center, and a resilient communication infrastructure. The network of reference stations is strategically deployed across the Korean peninsula and its surrounding islands, with a particular focus on key coastal areas and major ports. Each station is equipped with high-grade, geodetic-quality GNSS receivers that continuously track signals from all available satellite constellations, including GPS, GLONASS, Galileo, and BeiDou. The design of this network prioritizes redundancy and geographical diversity, ensuring that even if a few stations were to go offline, service continuity would be maintained throughout the coverage area. This architecture guarantees a stable and consistent flow of raw GNSS data, which is the foundational input for the entire service.

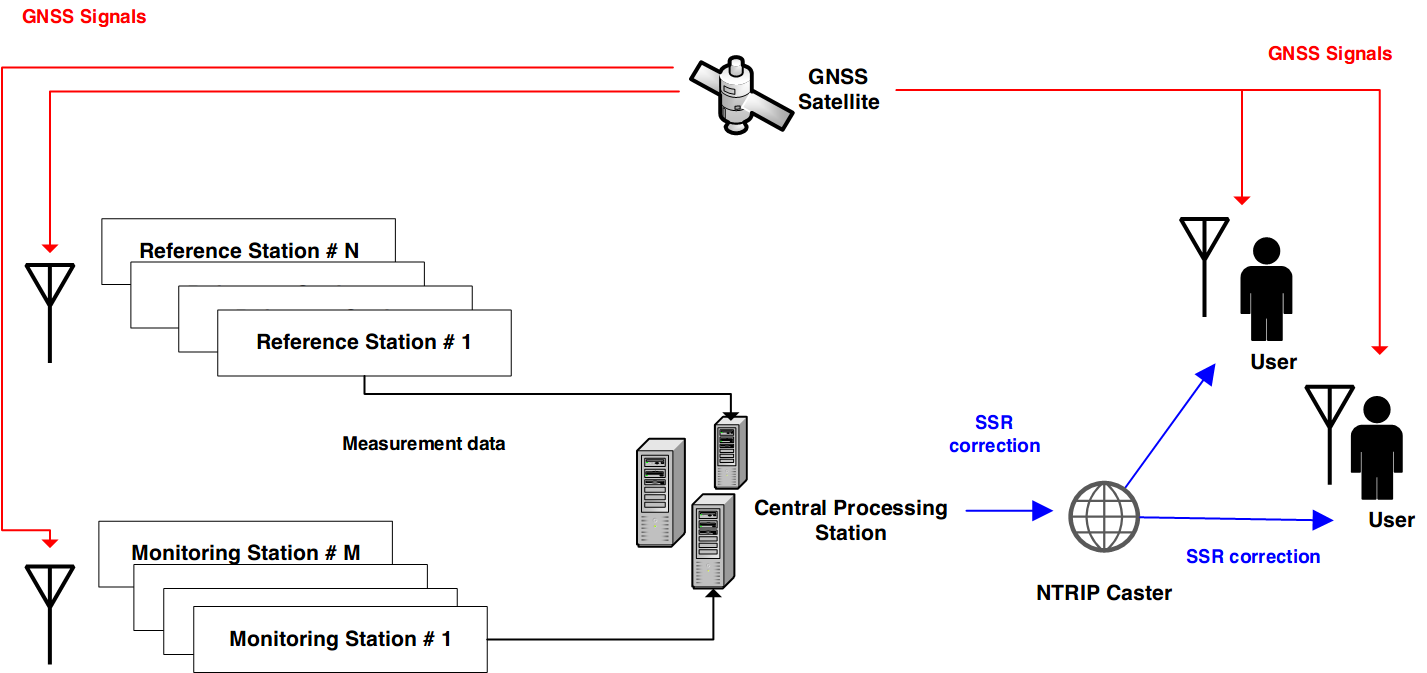
At the heart of the system is the Data Processing and Control Center, housed within the Korean NMPO's headquarters. This center serves as the brain of the POINT service, where vast amounts of raw data from the reference station network are collected, processed, and validated. The center's server infrastructure operates with a high degree of redundancy and fail-safe mechanisms to ensure uninterrupted operation. Here, specialized software performs a series of complex calculations using a PPP-RTK engine to generate highly accurate correction messages. This single technique provides centimeter-level corrections for both short-range coastal applications and long-range open-sea navigation. Furthermore, the center continuously monitors the integrity of all GNSS signals and the overall system, calculating integrity metrics like Protection Levels (PLs) and providing timely alerts in case of any system degradation or satellite malfunction. This real-time integrity monitoring is a crucial feature that provides users with a critical layer of safety and confidence in their positioning data.

The service's seamless operation is heavily dependent on a robust communication infrastructure. Data from each reference station is transmitted to the central processing center via a dedicated fiber-optic network, ensuring high-speed, low-latency data transfer that is essential for real-time applications. From the central center to the end-users on vessels, the processed correction and integrity data are disseminated through a variety of broadcast channels to maximize reach and reliability. The primary dissemination method for real-time services utilizes broadcasting signals such as DMB or UHD to deliver RTCM (Radio Technical Commission for Maritime Services) messages to vessels. Additionally, the service is provided through LTE data communication via the Internet-based NTRIP (Networked Transport of RTCM via Internet Protocol) service, allowing users to receive data streams over cellular networks. This multi-channel approach guarantees that users can access the service in diverse operational environments, from nearshore to the open ocean.

The operational workflow of the POINT service is built on a 24/7 monitoring and maintenance protocol. A dedicated team of engineers and operators at the Korean NMPO's control center maintains constant surveillance over every aspect of the system. This includes monitoring the health and status of all reference stations, the performance of the central processing servers, and the integrity of the data being broadcast. Any anomaly, no matter how small, triggers an immediate investigation and resolution process. Automated quality control checks are implemented throughout the data pipeline to detect outliers or potential errors, ensuring that only the most reliable data is transmitted to maritime users. Regular system diagnostics and preventive maintenance are also conducted to preemptively address potential issues and maintain the system's exceptional availability. This rigorous operational framework is a testament to the Korean government's commitment to providing a top-tier, reliable PNT service for the maritime community.

In order to validate the system's performance under real-world conditions, a comprehensive pilot operational phase was initiated in December 2024 and is ongoing. This paper shares the results from the initial eight-month trial, conducted from January to August 2025. The pilot operation will continue to be conducted until December of this year, with the full-scale service scheduled to begin in January 2026. The results from the initial trial were overwhelmingly positive. The system consistently maintained an uptime of over 99.8% while the communication network was operating normally, demonstrating exceptional reliability. Most importantly, the pilot operation confirmed centimeter-level accuracy for both short and long-range applications. Data latency was minimal, ensuring that real-time applications could function without delay. Furthermore, the integrity monitoring system successfully provided accurate and timely warnings, proving its capability to enhance navigational safety.

In conclusion, the operational status of the POINT service is robust, well-managed, and a direct result of the successful POINT project. The transfer of the project's outcomes to the Korean NMPO has led to the establishment of a professionally managed, nationwide PNT infrastructure. The pilot operation has confirmed that this service is not only theoretically sound but also stable, reliable, and ready for practical use in diverse maritime applications. This successful operational phase provides compelling evidence for the necessity of international collaboration and the establishment of a standardized guideline for these services, a topic we will discuss in later sections of this paper.



1. Overall architecture of the POINT ground-based GNSS augmentation system



1. The Korean NMPO's control center for POINT service

## Performance Analysis of the POINT Service

This section shares the results of the POINT service's pilot operation, drawing from the extensive data collected during the eight-month trial from January to August 2025. The primary objective of this analysis was to validate that the service meets the stringent accuracy and integrity requirements for modern maritime autonomous applications. The results presented here were derived from the analysis of verification data collected by the monitoring stations installed by the Korean National Maritime PNT Office across the Republic of Korea to monitor the performance of the POINT service. The findings demonstrate that the POINT service consistently delivers on its performance promises, confirming its readiness for practical, real-world deployment.

A core component of the analysis focused on evaluating the positioning accuracy provided by the service. The data was meticulously collected from multiple fixed test platforms across various maritime environments, including congested port areas and open coastal waters. The performance metrics were then calculated by comparing the real-time corrected positions with precise reference coordinates. The results unequivocally show that the POINT service consistently achieved exceptional accuracy. Specifically, the analysis confirmed that the horizontal positioning accuracy (rms) remained well within the 5 cm target, while the vertical positioning accuracy (rms) was consistently maintained within the 10 cm threshold. These performance levels are crucial for high-stakes applications such as automated docking and hydrographic surveying, where even minor errors can have significant consequences.

Table 1 presents the average monthly horizontal and vertical positioning accuracy (rms) and availability observed during the pilot operation. As shown, the performance remained stable and consistently met the specified targets throughout the eight-month period, demonstrating the service’s robust and reliable nature despite seasonal and environmental variations. In addition to accuracy, the integrity monitoring of the service was a top priority for performance validation. Integrity is a critical safety component, providing users with a measure of confidence in the provided positioning data and alerting them to any potential errors or system failures. The integrity monitoring results were continuously observed and logged at the central control station throughout the pilot period. The analysis revealed a flawless performance record: over the eight-month duration, the system maintained 100% integrity without any instances of false alarms or missed detections. This perfect record signifies that the service can be relied upon to provide consistent and trustworthy positioning information, which is a non-negotiable requirement for the safe operation of autonomous vessels.

1. Positioning accuracy and availability during the pilot operation

|  |  |  |  |
| --- | --- | --- | --- |
|  | Horizontal Accuracy  (rms, cm) | Vertical Accuracy  (rms, cm) | Availability  (%) |
| January 2025 | 3.042 | 3.709 | 100% |
| February 2025 | 3.038 | 3.702 | 100% |
| March 2025 | 3.071 | 3.716 | 100% |
| April 2025 | - | - | - |
| May 2025 | 3.002 | 3.626 | 96.8% |
| June 2025 | 2.941 | 3.546 | 90.0% |
| July 2025 | 3.033 | 3.649 | 96.8% |
| August 2025 | 3.096 | 3.728 | 100% |

\* Note that a communication network replacement took place from April to July. This resulted in no normal pilot operation in April, and the availability was reduced from May to July due to testing of the new communication network.

The combined results of the positioning accuracy and integrity monitoring analysis provide compelling evidence of the POINT service’s high-quality performance. The pilot operation successfully validated that the system is fully capable of providing the centimeter-level accuracy and robust integrity required for a wide range of maritime autonomous and safety-critical applications. This exceptional performance record confirms that the service is not only a conceptual success but a practical and reliable solution ready to meet the evolving demands of the maritime industry. The data from this pilot phase will serve as a foundational reference for the full-scale service launch scheduled for January 2026.

# the Need for IALA Guideline

The successful implementation and proven performance of the POINT service in the Republic of Korea highlight an important gap in current international standards: the absence of a dedicated IALA guideline for ground-based GNSS precise positioning services. While the IALA ENG committee is currently developing a "Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Service," a parallel effort to create a guideline for ground-based services is equally, if not more, urgent. The POINT service's operational data demonstrates that ground-based systems are not only viable but also highly practical for real-world maritime applications, necessitating the swift development of a corresponding international standard.

Just as with satellite-based services, ground-based GNSS precise positioning offers a transformative solution for maritime navigation. However, ground-based systems present a higher degree of operational feasibility for many nations. They are often more cost-effective to deploy and manage, leveraging existing national geodetic networks and telecommunications infrastructure. For countries with extensive coastlines, busy ports, and diverse maritime activities, a ground-based network provides a robust and reliable solution for high-precision PNT. The POINT service, with its nationwide network of reference stations, central processing center, and multi-channel data dissemination, serves as a powerful example of how such a system can be successfully implemented on a national scale. Its demonstrated stability and centimeter-level accuracy confirm that this technology is mature and ready for global consideration.

The development of a guideline for ground-based services can and should be expedited by leveraging the work already completed for the satellite-based PPP guideline. Many of the fundamental principles, technical specifications, and performance metrics—such as accuracy, integrity, and availability—are directly applicable to both service types. By using the existing draft as a reference, the IALA committee can adapt and expand upon established frameworks rather than starting from scratch. This approach would allow for a more efficient process, enabling the quick integration of best practices and lessons learned from successful national deployments like the POINT service. The Republic of Korea stands ready to share operational expertise, data, and lessons learned from the POINT service with IALA and its members to support this effort.

Ultimately, the need for a guideline on Maritime Ground-based GNSS Precise Positioning Services is driven by its immediate and tangible utility for the maritime community. For applications like autonomous navigation, automated docking, and hydrographic surveying, the high-accuracy and integrity provided by ground-based systems are indispensable. The operational viability of these systems, confirmed by our pilot study, underscores their immediate relevance to enhancing maritime safety and efficiency. To facilitate the broader adoption of this technology, a standardized framework is essential. An IALA guideline would provide the necessary technical specifications, operational procedures, and performance requirements, giving countries the confidence to deploy their own services and ensuring seamless interoperability for international users. Without a guideline, the full potential of ground-based GNSS augmentation for maritime applications may be hampered by a lack of standardization and clear operational best practices. Therefore, it is imperative for IALA to prioritize the development of this crucial guideline to support the ongoing digital transformation of the maritime industry.

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