2024

Report on Maritime and Inland Waterways

User Needs and Requirements

#EUSpace

EUSPA
European Union Agency for the Space Programme

Executive Summary

This report provides a comprehensive analysis of the Maritime and Inland Waterways (IWW) segment, focusing on the operational scenarios, key user needs and requirements, challenges, gaps, and opportunities of downstream space components. It specifically explores the current and prospective use of Global Navigation Satellite System (GNSS), Earth Observation (EO), and Satellite Communication (SATCOM) in this segment, and how these services should evolve to meet the needs of the users.

The Maritime and Inland Waterways market segment is highly regulated in terms of performance requirements. The new regulations are keeping up with the technological advancements, like development of autonomous vessels, as well as the push for more sustainable operations. As it comes to new regulations, IALA published performance specifications and guidelines to authorities to facilitate adoption of SBAS for maritime. In this process, specific Maritime and IWW needs were considered by the EU Space programme with the declaration of a first EGNOS service for maritime users in 2024.

In parallel, the maritime community is further developing means of communication at sea, like VDES and worldwide available SATCOM. VDES specifically offers the secure features and robustness which Maritime and IWW applications require. Thus, IALA is contributing to define user requirements and specifications in (DTEC WG3) to further allow standardization to ensure manufacturers, service providers for the long-term business case for integration these technologies in their offering.

The maritime community is also waiting for the International Maritime Organization (IMO) regulatory standards via the goal-based maritime autonomous surface ship (MASS) Code, which is expected to be adopted as a mandatory code under the Safety of Life at Sea (SOLAS) Convention in 2028 and will be essential for the future of non-human dependant maritime operations.

In addition to GNSS and SATCOM as the key enablers of the applications in Maritime and Inland Waterways for reliable and secure navigation and communication, EO is having an important supporting role by providing key weather and marine ecosystems data. Together, these satellite technologies support needs for more precise, efficient, secure and sustainable operations.

Challenges remain however in adopting PNT services for inland waterway navigation and future automated and autonomous navigation, where resilient and robust PNT is essential. Efforts to improve the resilience and security of GNSS against interference and spoofing are gaining importance. This includes developing robust GNSS systems and backup solutions to ensure continuous and reliable service, even in challenging environments.

In conclusion, the user needs and requirements in the Maritime and Inland Waterway segment are becoming more sophisticated with technological advancements. The focus on automated navigation, autonomous vessels, PNT authentication, and VDES implementation highlights the industry's need to enhance safety, efficiency, and sustainability. These developments are expected to play a crucial role in shaping the future of maritime operations.

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1 INTRODUCTION AND SCOPE OF THE REPORT

1.1 Scope

The User Consultation Platform (UCP) is a process developed at the European Union Agency for the Space Programme (EUSPA) to collect user needs and requirements and take them as inputs for the provision of user driven space data-based services by the EU Space Programme.

The objective of the presented report is to provide a reference for the EU Space Programme and for the Maritime and Inland Waterways communities, reporting the most up-to-date user needs and requirements in the respective market segments for the use of Position, Navigation and Timing (PNT), Earth Observation (EO) and secure telecommunications (SATCOM) technologies. Its scope is to cover needs and requirements from the user perspective, considering the market conditions, regulations, and standards that influence them. The report serves as a reference for end users, service providers and the whole EO community in planning and decision-making activities for those concerned. The report is also intended to serve as an input to more technical discussions on systems engineering and to shape the evolution of the European Union's satellite navigation systems, Galileo and EGNOS and the Earth Observation system, Copernicus, and in the future Space Situational Awareness, GOVSATCOM and IRIS2.

UCP process contains a regular event, where users from different market segments meet to discuss their needs and application-level requirements relevant for PNT, EO and SATCOM and the conclusions are presented in this document. This report is a living and evolving document that is regularly updated by EUSPA. It served as a key input to the UCP, that is continuous process to reflect the evolution of the user needs, market and technology captured during the event.

This report does not represent any commitment of the EU Space Programme to address or satisfy the listed needs and requirements in the current or future versions of the services and/or data delivered by its different components.

The report is organised as follows:

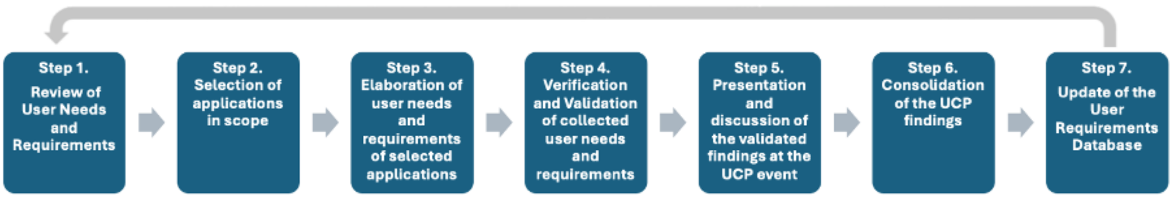
- Section 2.1 provides in an overview of the role of the European Union Space Program services in the Maritime and Inland Waterways segment and its interaction with user needs
- Section 2.2 presents market evolution and key trends in the Maritime and Inland Waterways, together with definition of main user groups and actors in the value chain, followed by Section 2.3, that describes the market drivers (regulations, standards etc.)
- Section 2.4 presents the current segment applications and operational scenarios relevant for EO/GNSS/SATCOM in Maritime and Inland Waterways, presenting main user needs and expectations towards services and data to serve operational scenarios, together with limitations and gaps identified by end users.
- Section 2.5 provides a synthesis of requirements relevant to the different EO/GNSS/SATCOM services

This report distinct itself from its previous version in the sense that it brings together the requirements for GNSS, EO and now also SATCOM. Several new applications have been analysed in this edition of the report, with the primary focus on EO and SATCOM requirements.

1.2 Methodology

The UCP process is composed by systematic steps that are implemented in a continuous, repetitive manner, with logical order. The repeated steps allow transparency and continuous updates of the results, considering the new market developments and evolving user needs and requirements. For each step, depending on the peculiarities of the market segments and technological components of the analysis, additional steps, involving specific expertise might be added.

Figure 1: User Consultation Process high level methodology with continuous steps



In each market segment there is a constant evolution due to the changes in legislation, standards, technological trends and so forth, therefore the update of the Report on User Need and Requirements occurs at least every two years.

UCP user needs and requirements collection and analysis is based on the one hand side on desk research and on the other hand, on stakeholders' consultations and experts' knowledge.

The UCP process starts (Step 1) with review and analysis of the most up-to-date sources related to the user needs and requirements in selected market segments. This step leverages on the previous UCP Reports on User Requirements, latest EUSPA EO and GNSS Market Report, Technology Reports and other expert publications and knowledge. The selection of relevant applications (Step 2) in each market segment is made based on the market analysis, the gap analysis from the earlier editions of the UCP and EUSPA Market Report, as well as external experts' know-how.

After the initial desk research, the stakeholders' consultations are carried out, both representing end users and intermediate users (service providers), to validate the findings and collect missing information (Step 3). Validation of user needs (Step 4) requires additional feedback from relevant users' representatives that review the draft version of the Report on User Needs and Requirements, prepared in advance of the UCP event.

The UCP event (Step 5) is organized by EUSPA on an annual basis and offers a forum to present and discuss the findings, being an additional layer of updates, gap filling and validation in the process. All the information and data gathered during the previous steps are consolidated in the segment-specific Report on User Needs and Requirements (RUR) (Step 6, this Report) and later in the EUSPA User Requirements Database (Step 7).

2 MARITIME AND INLAND WATERWAYS

2.1 The role of the European Union Space Programme to meet the evolving user needs

The role of EUSPA

EUSPA (European Union Agency for the Space Programme) plays a pivotal role in the context of the EU Space Programme, acting as a key operational agency that is user-oriented and focused on promoting and maximizing the uptake of satellite-based services across various sectors, through the following activities:

1. User-Centric Approach

- EUSPA adopts strategies that prioritize the needs and requirements of users. It aims to enhance the accessibility and integration of satellite services, ensuring that a broad spectrum of users, including governmental bodies, businesses, and citizens, can benefit from services related to Earth Observation, Satellite Navigation, and Connectivity.

2. Service Provisioning

EUSPA is responsible for providing state-of-the-art services in areas such as:

- Positioning, Navigation, and Timing: Through the Galileo and EGNOS systems.
- Satellite Communications: It facilitates communication services for governmental applications through GOVSATCOM and is working on the new IRIS2 initiative.
- Space Surveillance: EUSPA manages Front Desk services for the EU Space Surveillance and Tracking program, ensuring safety and security in space operations.

3. Enhancing the European Space Ecosystem

EUSPA works to foster a robust European space ecosystem by:

- Providing market intelligence and technical expertise to innovators, SMEs, and academia.
- Leveraging EU funding programs such as Horizon Europe to stimulate innovation and research in space-related technologies.
- Supporting startups and developing partnerships that enhance technological advancements.

4. Ensuring Security

- EUSPA plays a critical role in the security of the EU Space Programme. By operating the Galileo Security Monitoring Centre (GSMC), it implements and monitors the security of satellite services, thereby bolstering the overall security framework for EU Member States.

5. Stakeholder Engagement

- EUSPA actively engages stakeholders from the entire space value chain, including industry leaders, academic institutions, and end-users. It facilitates feedback mechanisms where users can express their needs and satisfaction levels regarding EU satellite services. This engagement is crucial for the continuous evolution of the EU Space Programme.

EUSPA conducts various essential activities which include:

- User Consultation Processes: These are designed to gather insights and perceptions from users to improve service delivery.

- Market and Technology Monitoring: EUSPA analyses trends and forecasts in the space industry to inform strategic decisions.
- Research and Development Funding: The agency identifies funding needs for R&D initiatives and ensures their implementation.
- Pilot Programs: EUSPA supports the testing and piloting of innovative applications to explore new possibilities in space services.
- Commercial Acceleration Programs: Through the CASSINI Programme, EUSPA promotes innovative commercial ideas and facilitates their growth in the marketplace.

In summary, EUSPA serves as a cornerstone of the EU Space Programme, bridging the gap between technological advancements and user needs. By providing innovative satellite services, fostering a collaborative space ecosystem, ensuring security, and engaging with a wide array of stakeholders, EUSPA is crucial in advancing the EU's strategic interests in space and enhancing the overall benefit of space technologies for society.

The role of COPERNICUS

Copernicus is the Earth Observation component of the European Union's space programme, looking at our planet to support the management of the environment, mitigate the effects of climate change and ensure safety and civil security across Europe. Copernicus delivers its data and services with a free and open policy. It consists of three main components:

Space Component, which delivers data from a fleet of dedicated observation satellites (the 'Sentinels') and other Copernicus Contribution Missions (CCM). Six Sentinel satellites families are designed to serve a wide range of users and are provided with a free and open access globally. They ensure an independent and autonomous Earth Observation capacity for Europe with global coverage. The satellites provide observations which serve a wide range of users for a multitude of applications in the areas of climate, land and ocean services, emergency management, atmosphere and air quality, among others.

- Sentinel-1A provides all-weather, day and night radar imagery for land and ocean services. Sentinel 1-B was retired in December 2021. The Sentinel-1C satellite was launched on 5 December 2024 and Sentinel-1D launch is planned in 2025.
- Sentinel-2A & -2B provide optical imagery for land and emergency services.
- Sentinel-3A & -3B provide optical, radar and altimetry data for marine and land services.
- Sentinel-5P provides atmospheric data, bridging the gap between ENVISAT and future Sentinel-5 data.
- Sentinel-4 & Sentinel-5 will fly aboard EUMETSAT MTG-S and Metop-SG satellites. They will monitor air quality, trace gases and aerosols over Europe at high spatial resolution and very high frequency.
- Sentinel-6 provides radar data to measure global sea surface height observations for climate monitoring and ocean and seasonal forecasts. It continues a time series of mean sea level rise measurements dating back to 1992.

CCMs complement the data portfolio in the Sentinel satellites missions with another layer of value to meet user needs, providing data from commercial data providers. There are around 30 existing or planned to contribute missions, encompassing various technologies like SAR, optical sensors, spectrometers and altimetry systems.

In-Situ Component collects data acquired by a multitude of sensors at air-, sea- and ground-level, and includes geospatial reference data.

Service Component of Copernicus programme transforms the various data into timely and actionable information products. The Copernicus Services deliver value-added information products in six thematic areas:

Atmosphere	Climate	Emergency	Land	Marine	Security
Atmosphere Monitoring Service (CAMS)	Climate Change Service (C3S)	Emergency Management Service (CEMS)	Land Monitoring Service (CLMS)	Marine Environment Monitoring Service (CMEMS)	Security Service (CSS)[1]

Copernicus Marine Service, ran by Mercator, provides a single access point to over 300 scientifically proven products, that are provided for free. Copernicus Marine Service provides multi-year datasets, as well as almost NRT datasets. The datasets are subdivided in three categories, Blue Ocean, White Ocean and Green Ocean. Their models are developed on satellite observation data, in-situ data and numerical models. The Mercator **product offering supports trade and marine navigation** for various stakeholders through information on ocean currents, sea level, waves, temperature, among others. The data assists in route optimisation and ocean condition modelling.

Copernicus is **increasingly important for maritime spatial planning**, detecting and linking pollution to ships at sea, and ensuring the sustainability of fisheries and aquaculture. While it primarily feeds into evidence-based policymaking rather than regulations or standards, its role is expected to grow.

First, in terms of **environmental and marine pollution monitoring**, high-resolution satellite imagery can be used to monitor marine ecosystems, detect pollution, and assess the impact of climate change. Copernicus .is currently already being used in combination with commercial EO data to enable advanced modelling of species and polluted surfaces and is seen as a key tool.

For **marine disaster management**, EO data, including public data from Copernicus and NASA, are being used for monitoring oil spills and chemical spills. Advanced EO techniques are necessary to detect and monitor new types of oils, such as low sulphur oils, which behave differently on water. In 2023, the Copernicus Marine Environment Monitoring Service (CMEMS) expanded its capabilities by incorporating new high-resolution satellite data and advanced machine learning algorithms. This enhancement allows for more accurate and timely monitoring of marine environments, supporting better decision-making for maritime spatial planning and environmental protection. Copernicus services are seen as a more cost-effective solution than physical monitoring, planes, and drones; as well as a more robust and flexible tool to cover large and remote areas.

Secondly, in route optimisation and merchant navigation, EUMETSAT data is becoming central to solutions aimed at optimising fuel efficiency and reducing emissions. Accurate weather forecasting and ocean condition monitoring enable ship operators to plan optimal routes, minimising fuel consumption and emissions. Weather and Spotter Buoys complement satellite data by providing in-situ measurements of weather conditions and sea state.

EUMETSAT operates a fleet of Geostationary (GEO) and Low Earth Orbit (LEO) satellites that provide continuous weather monitoring and forecasting capabilities.

- METEOSAT 2nd and Upcoming 3rd Generation: Provide continuous weather monitoring and forecasting capabilities.
- METOP 1st and Upcoming 2nd Generation: Deliver high-resolution atmospheric data for weather prediction and climate monitoring.

[1] Copernicus Security Service is provided to registered public users only.

- Jason-3 Satellites: Provide precise measurements of sea surface height, essential for oceanography.
- Sentinels 3, S-6, Upcoming S-4 and S-5: Enhance the capabilities of the Copernicus programme by providing additional data for environmental monitoring and climate change studies.

Table 1: Takeaways for EO from the 2024 UCP

The inland navigation sector is however still in an **early stage of integration of Copernicus services**. The use cases for infrastructure monitoring and for Copernicus as an **early warning system** for extreme weather events / exceptional river discharge are still to be proven with cost-benefit analysis. Similarly, for MASS and ASV's, Copernicus is assessed as a **supporting service** which allows for route planning and as an early warning system. The support of Copernicus to more regular and frequent ENC updating was identified as a possible future application.

A common challenge across Maritime and IWW applications remains **data sharing, standardisation, and data integration**. The coexistence of technologies and the complexity and potential interference of terrestrial and space-based sensors and systems are crucial considerations for the future. An increasing number of terrestrial, air-borne, and space-based systems are being used simultaneously to monitor the climate, gather data for MetOcean and general weather forecasting, and establish early warning systems. Protecting and allocating the radio spectrum for maritime communications and developing standards for maritime radio systems by specialised bodies will be decisive in the coming years.

The role of European Global Navigation Satellite System (EGNSS)

EGNSS is the European satellite navigation program designed to provide highly accurate and reliable positioning, navigation, and timing services on a global scale and ensuring Europe's technological autonomy. EGNSS offers high-precision and multi-constellation capability. There is a free positioning service available to the public, as well as encrypted services for government and commercial use, like the Public Regulated Service (PRS) for government-authorized users. EGNSS includes two main systems:

- **Galileo** is the European satellite navigation system that provides highly accurate global positioning and timing information. It offers several unique features, including higher accuracy (especially in urban areas), improved availability, and an authentication service to prevent signal spoofing. Numerous EU economic sectors rely on Galileo, from transport and agriculture to border management and search and rescue. Its 20cm accuracy makes Galileo a game changer for autonomous driving and commercial drones. Already more than 3.5 billion smartphones are Galileo-enabled.
- **EGNOS** (European Geostationary Navigation Overlay Service) is a satellite-based augmentation system (SBAS) that improves the accuracy, integrity, and reliability of the navigation services to aviation, maritime and land-based users in over 30+ countries.

For the Maritime and IWW segment, Galileo provides highly accurate PNT information, essential for safe and efficient Maritime operations, including navigation, collision avoidance, and search and rescue missions. Galileo's unique features, such as higher accuracy and improved availability, making it a valuable tool and asset.

Table 2: Takeaways for GNSS from the 2024 UCP

Continued need for high accuracy and reliability have been reiterated during the 2024 UCP consultations. Advances in **multi-constellation GNSS** systems, are providing more precise positioning data. This is essential for accurate navigation and route optimization, which helps in **complying with stringent emission regulations** and ultimately **reducing fuel consumption**. Especially for inland waterway navigation and automated and autonomous navigation, **resilient and robust PNT** is essential. Efforts to enhance the **resilience and security of GNSS** against interference and spoofing are gaining importance. This includes the development of robust GNSS systems and backup solutions to ensure continuous and reliable service, even in challenging environments

Given growing international uncertainties and incidents, **authentication of PNT** information has become a key user requirement for both navigation and monitoring purposes. Galileo OSNMA is expected to be a key component to fill in this market demand and provide both authorities and shipping companies with a reliable tool to plan and assess their operations.

Also, similar to Copernicus services, **integration with other technologies** provides comprehensive situational awareness and improved decision-making. In-situ sensors allow for more real-time information which allows for higher levels of accuracy. Also, combining GNSS data with EO weather data allows for better route planning and fuel efficiency, and additional sensors (cameras, lidar) allows for remote navigation.

European Secure SATCOM

The EU Secure Satellite Communication System, known as **GOVSATCOM** is an investment made by the EU, which aims to provide secure and cost-efficient communication capabilities to security and safety-critical missions and operations. **IRIS²,** the new multi-orbital constellation of 290 satellites will provide secure connectivity services to the EU and its Member States as well as broadband connectivity for governmental authorities, private companies and European citizens, while ensuring high-speed internet broadband to cope with connectivity dead zones**.** The program is part of the EU's broader strategy to strengthen its autonomy, security, and defence capabilities, especially in response to increasing geopolitical challenges and cybersecurity threats.

Table 3: Takeaways for SATCOM from the 2024 UCP

The discussion during the UCP 2024 event showed that there is a need in both general navigation, inland waterway navigation, ASV, MASS and automated vessels on IWW for **real-time secure and robust communication channels**. Growing data-exchanges between onboard and shore-based operations will require for communication tools that are future ready and reliable and available in remote locations. While VTS interaction with ships has traditionally almost exclusively been via VHF voice communications it is expected that **digital communications will largely replace VHF voice in the future**, for between shore and ship and ship control centres.

In line with the growing need for seamless exchange of data and information, the ITU has initiated a new working group focused on the allocation and protection of radio spectrum for maritime communications. This group aims to address the growing demand for spectrum and ensure the coexistence of terrestrial and space-based systems, which is critical for the future of maritime applications.

The UCP 2024 Event indicated that the development of legislation, standards and codes of conduct to ensure safety of operations identified as the key enabler, in combination with the affordability of services

2.2 Market Overview & Trends

2.2.1 Market Evolution and Key Trends

Introduction to the Maritime and Inland Waterways

The maritime industry is undergoing significant transformations driven by regulations, technological advancements, and the urgent need to address environmental concerns. Safety and security of operations play a central role for the expectations towards services' requirements and their acceptance to use.

The International Maritime Organisation (IMO) and other regulatory bodies impose strict requirements on ship owners concerning safety aspects, but also particularly concerning fuel emissions. These **regulations are pushing the industry towards decarbonisation**, with ship owners and operators increasingly eager to adopt sustainable practices and technologies to reduce their carbon footprint. Ship manufacturers are also anticipating these regulatory developments, as the average lifespan of a ship is around 30 years. To stay ahead, they are **investing in innovative technologies and designs that comply with future regulations**.

Services development

The development of services within the maritime industry is evolving rapidly, driven by the **need for more precise, efficient, and sustainable operations.** Satellite services, such as navigation, earth observation and communication are playing a crucial role in this evolution, offering a range of applications that enhance operational efficiency, safety, and environmental sustainability. One of the most significant trends in services development is the **focus on decarbonisation and emission reduction**.

2.2.1.1 GNSS Key Market Trends

GNSS is indispensable for navigation, positioning, and operational management in the maritime industry. The development of GNSS services is characterised by several key trends that are enhancing the accuracy, reliability, and resilience of these systems.

Advances in multi-constellation GNSS systems, such as Galileo, GPS, GLONASS, and BeiDou, are providing **more precise positioning data**, which is essential for accurate navigation and route optimisation. Additionally**, efforts to enhance the resilience and security of GNSS and AIS against interference and spoofing** are gaining importance. These efforts include the development of robust GNSS systems and backup solutions to ensure continuous and reliable service, even in challenging environments. Specifically, **VDES** is highly anticipated as a more robust version of AIS, and as a meaningful solution for the requirement set out under IMO A.1046 (27) as per the 2092 recommendation.

AIS is becoming congested and is not secure. Its evolution, **VDES, will provide more capacity and global coverage** and IMO is finalizing a new performance standard for 2025. VDES supports authentication of marine services with the Maritime Connectivity Platform and has the future potential to support safety of navigation, GMDSS and additional features. VDES will benefit both the operators as well as the authorities relying on the positioning information provided now through AIS, exchange of secure search patterns in the Arctic and more.

2.2.1.2 EO Key Market Trends

EO data is becoming central to solutions aimed at optimising fuel efficiency and reducing emissions. **Accurate weather forecasting and ocean condition monitoring** enable ship operators to plan optimal routes, minimising fuel consumption and emissions.

High-resolution satellite imagery is used to monitor marine ecosystems, detect pollution, and assess the impact of climate change. EO data, including public data from Copernicus, are being used for disaster management, such as monitoring oil spills and chemical spills. New types of oils, such as low sulphur oils, behave differently on water, necessitating advanced EO techniques to detect and monitor these spills. SAR (radar) satellite data are especially useful for maritime and fisheries operations, as they are not limited by clouds and lack of sunlight.

Additionally, **EO is used for predicting the movement of oil to protect wildlife and for chemical testing to detect gas clouds and concentrations of chemicals in the water column**. Drones equipped with remote sensing and Lidar technology are increasingly used for waterway maintenance, surveying, and monitoring of infrastructure. These technologies provide high-resolution orthophotos and multi-beam riverbed management, enhancing the accuracy and efficiency of inland waterway operations. They also support environmental monitoring by providing detailed information on underwater topography and sediment movement. In conclusion, the development of services within the maritime industry is being driven by the need for **more precise, efficient, and sustainable operations**, and indicates the dedicated role of satellite services in supporting sustainable and efficient operations.

2.2.1.3 SATCOM Key Market Trends

Advances in SATCOM technology are enabling **seamless real-time communication and data exchange** between vessels and shore-based operations. This is crucial for coordinating operations, responding to emergencies, and ensuring compliance with IMO circulars related to the GMDSS. **Expanding satellite coverage** ensures reliable communication in remote and open ocean areas, supporting the maritime activities outside of the 70°N and -S or A3 region.

The development of **more affordable and secure SATCOM solutions** is making advanced communication technologies accessible to a broader range of users, including small-scale maritime operators. SATCOM is also being **integrated with other technologies**, allowing for the seamless exchange of data and information, enhancing situational awareness and decision-making. For example, combining SATCOM with GNSS can provide real-time tracking of vessels, while integrating SATCOM with EO can enable the real-time transmission of EO data for monitoring purposes.

2.2.2 Main User Communities

For the Maritime and Inland Waterways segment, there are users' communities along the value chain that express different needs. The UCP analysis is focusing on the needs and requirements of the end users and intermediate users (service providers). These user communities can be divided into the following groups:

- **Ship operators, Inland Waterways Transport companies;**
- **Ship owners;**
- **Service providers;**
- **Port Authorities, Maritime Safety Agencies and Regulatory Bodies, Environmental Monitoring Agencies**

This entire value chain of the Maritime and Inland Waterways segment can be found in the EUSPA Market Report [RD1].

2.2.2.1 GNSS Key Users

In the maritime and inland waterways sectors, key end users include **ship operators, port authorities, and inland waterway transport companies.** Ship operators rely on GNSS for accurate navigation and route optimisation, which are essential for complying with stringent emission regulations and reducing fuel consumption. **Port authorities** use GNSS for vessel traffic management, ensuring safe and efficient navigation within port areas. Inland waterway transport companies depend on GNSS for precise positioning and navigation along rivers and canals, enhancing the efficiency and safety of their operations.

Intermediate users, such as **maritime safety agencies and regulatory bodies**, also benefit from GNSS technology. Maritime safety agencies use GNSS for search and rescue operations, monitoring vessel movements, and ensuring compliance with maritime regulations. Regulatory bodies rely on GNSS data to enforce navigation and safety standards, contributing to the overall safety and efficiency of maritime and inland waterway operations. The enhanced accuracy and reliability of GNSS systems, driven by advancements in multi-constellation GNSS, are crucial for these applications, providing precise location data that supports effective decision-making and operational efficiency.

2.2.2.2 EO Key Users

EO technology plays a vital role in environmental monitoring, resource management, and operational optimisation within the maritime and inland waterways sectors. Key end users include **environmental monitoring agencies, port authorities, and inland waterway management organisations**. Environmental monitoring agencies use high-resolution satellite imagery to monitor and protect marine and freshwater ecosystems, detect pollution, and assess the impact of climate change.

Port authorities and inland waterway management organisations rely on EO data for monitoring water quality, assessing sediment movement, and managing dredging operations. High-resolution imagery allows for detailed analysis of coastal and inland waterway areas, enabling these organisations to make informed decisions that enhance operational efficiency and environmental sustainability. The integration of AI and machine learning with EO data further enhances these capabilities, allowing for the development of advanced models that can identify patterns and trends, leading to more accurate predictions and timely interventions.

Intermediate users, such as **research institutions and government agencies**, utilise EO data for various purposes, including conducting studies, developing models, and supporting policymaking. These organisations play a critical role in advancing the understanding of marine and freshwater environments and informing regulatory frameworks that promote sustainable practices in maritime and inland waterway operations.

2.2.2.3 SATCOM Key Users

SATCOM technology is essential for real-time communication and data exchange in the maritime and inland waterways sectors. Key end users include ship operators, inland waterway transport companies, and port authorities. **Ship operators** depend on SATCOM for real-time communication between vessels and shore-based operations, allowing for better coordination and faster response times. This is particularly important for ensuring compliance with regulations, responding to emergencies, and optimising route planning.

Inland waterway transport companies use SATCOM for remote monitoring and management of their operations, enhancing the efficiency and safety of their transport activities**. Port authorities** rely on SATCOM for efficient communication and coordination of port activities, ensuring smooth operations and timely responses to any issues that may arise. The development of more cost-effective SATCOM solutions is making advanced communication technologies accessible to a broader range of users, including small-scale maritime and inland waterway operators. Expanding satellite coverage ensures reliable communication in remote and open water areas, supporting the expansion of maritime and inland waterway activities into these regions.

Intermediate users, such as **maritime safety agencies and regulatory bodies**, also rely on SATCOM for efficient communication and coordination of activities. Maritime safety agencies use SATCOM for emergency communication and coordination during search and rescue operations, while regulatory bodies depend on SATCOM for monitoring compliance with safety and navigation standards.

2.3 Key market drivers – Policies, Regulations, and Standards

The Maritime segment is a highly regulated market. Public policies, regulations and standards are driving not only the need for improved and new services but also many innovations on the market. The driving regulations and standards are linked to the performance requirements of navigational aids and safety related applications.

The following chapter gathers a non-exhaustive list of relevant organisations, regulations, standards and other guidelines that influence implementation of satellite-based services and define their requirements. The analysis of the regulations and their impact on GNSS, EO and SATCOM requirements is further elaborated in annex A.8.

2.3.1 Relevant organisations

International regulators

International Maritime Organisation (IMO): A specialised agency of the United Nations acting as the global regulatory authority for the safety, security and environmental performance of international shipping.

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA): An international association whose aim is to foster the safe, economic and efficient movement of vessels, through improvement and harmonisation of aids to navigation worldwide and other appropriate means, for the benefit of the maritime community and the protection of the environment.

International Telecommunication Union (ITU): The UN specialised agency responsible for telecommunications, in particular for spectrum management and technical characteristics of systems.

International Electro-technical Commission (IEC): The IEC prepares and publishes international standards for all electrical, electronic and related technologies.

Radio Technical Commission for Maritime Services (RTCM): A US-based organisation that develops standards and recommendations for marine systems and equipment.

European Regulators and Agencies

DG for Mobility and Transport (MOVE): Focuses on transport policies, including maritime transport and the integration of satellite technologies.

DG for Maritime Affairs and Fisheries (MARE): Manages maritime policies and the sustainable use of oceans and seas.

DG for Defence Industry and Space (DEFIS): Manages the EU's space policy, including GNSS, EO and GOVSATCOM.

DG for Communications Networks, Content and Technology (CNECT): Oversees digital policies, including satellite communications.

European Global Navigation Satellite Systems Agency (EUSPA): Implements the EU GNSS, EO and SATCOM programs and promotes their use in various sectors, including Maritime and Inland Waterways.

European Maritime Safety Agency (EMSA): Provides technical support and services to improve maritime safety, including the use of satellite technologies.

European Space Agency (ESA): ESA conducts various programs and projects related to GNSS, EO, and SATCOM, including the Galileo and Copernicus programs.

European Committee for drawing up Standards in the field of Inland Navigation (CESNI/TI): develops technical standards for inland navigation vessels to ensure safety, environmental protection, and interoperability across European waterways.

European associations

European Association of Remote Sensing Companies (EARSC): Represents the EO services industry in Europe.

2.3.2 Selection of applicable regulations

International regulation

- *SOLAS Convention [RD6]:* ensures that ships flagged by signatory states comply with minimum safety standards in construction, equipment and operation
- *SOLAS Regulation 13 [RD7]*: establishment and operation of aids to navigation
- *SOLAS Regulation 15 [RD7]:* Principles relating to bridge design and navigational systems)
- *SOLAS Regulation 25 [RD7]:* Operation of steering gear)
- *SOLAS Resolution A.893(21) [RD7]:* Guidelines for Voyage Planning
- *IMO Resolution A.915 (22) [RD8]:* defines the GNSS requirements for maritime operations and navigation
- *IMO Resolution A.1046 (27) [RD11]:* describes procedures concerning recognition of World-Wide Radio Navigation System (WWRNS) and requirements regarding shipborne receiving equipment and operational requirements for a World-Wide Radio Navigation System
- *IMO RESOLUTIONS MSC 112(73) [RD12], 113(73) [RD13], 114(73) [RD14], 115(73 [RD15]), 233(82) [RD16], 379(93) [RD17] & 401(95) [RD18]:* establish performance standards for shipborne GNSS or DGNSS equipment
- *Resolution A.1106 (29) [RD9]:* concern the revised Guidelines for the Onboard Operational Use of Shipborne Automatic Identification System

IALA guidelines and recommendations

- *IALA Guideline G1129 [RD29]:* sets out guidance for Marine Aids to Navigation (AtoN) service providers wishing to understand where SBAS information could be used to support the mariner and then how to employ such data, by describing the SBAS use within augmentation services via marine radio beacon and AIS transmissions

- *IALA Guideline G1152 [RD33]:* identifies several aspects (reference requirements, user equipment, and a description of the service and the operational scheme) that maritime or coastal administrations may take into account when considering the use of SBAS by ships in their waters
- *IALA Guideline G1154 [RD34]:* assists IALA members and other competent authorities when they consider the use of Mobile Marine Aids to Navigation (MAtoN) to mark a moving or drifting hazard to navigation.
- *IALA Standard S1030 [RD35]:* ensures that Marine Aids to Navigation are developed and harmonised through international cooperation and the provision of standards
- *IALA World-Wide Radio Navigation Plan [RD22]:* aims to build on individual National and Regional plans and identify the Radio Navigation components which will be key to the successful implementation of e-Navigation
- *IALA Aids to navigation guide (Navguide) [RD20] [RD21]:* serves as a guide, reviewing all aspects of the provision and use of all maritime aids to navigation, including institutional, legal, political, operational, functional and technical aspects
- *Recommendation IALA R-115 [RD25]:* specifies the requirements for provision of maritime radionavigation services in the frequency band 283.5-315 kHs in region 1 and 285-325 kHs in region 2 and 3
- *Recommendation IALA R-121 [RD26] and Guideline 1112 [RD27]:* specifies the requirements for performance and monitoring of DGNSS services in the frequency band 283.5 – 325 kHs
- *Recommendation IALA R-135 [RD23]:* argues for the discontinuation of HF and replacement by DGNSS
- *Recommendation IALA R-129 [RD24]:* addresses the problem of GNSS vulnerabilities and increased user reliance on GNSS
- *IALA Guideline No. 1082 [RD28]:* on an overview of AIS
- *IALA Guideline No. 1028 [RD29]:* on the automatic identification system, operational issues
- *IALA guidelines No. 1029 [RD30]:* on the automatic identification system, technical issues
- *IALA Guideline G1117 [R36]:* VDES Overview

ITU Recommendations

- *Recommendation M.823-3 [RD41]:* elicits technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHs in Region 1 and 285-325 kHs in Regions 2 and 3
- *Recommendation M.1371-5 [RD42]:* elicits technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band

IEC Standards

- IEC 60945 Ed. 4.0 *[RD44]*: Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results

- IEC 61108-1 Ed. 2.0 *[RD45]*: Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) -Receiver equipment - Performance standards, methods of testing and required test results

- EC 61108-2 Ed. 1.0 *[RD46]*: Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) - Receiver equipment - Performance standards, methods of testing and required test results

- IEC 61108-3 Ed. 1.0 *[RD47]*: Maritime navigation and radiocommunication equipment and systems Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results

- IEC 61108-4 Ed. 1.0 *[RD48]*: Maritime navigation and radiocommunication equipment and systems Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results

- IEC 61108-5 *[RD51]*: Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 5: BeiDou navigation satellite system (BDS) - Receiver equipment - Performance requirements, methods of testing and required test results

- IEC 61108-6 *[RD52]*: Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 6: Navigation with Indian constellation (NavIC)/Indian regional navigation satellite system (IRNSS) - Receiver equipment - Performance requirements, methods of testing and required test results (under development)

- IEC 61108-7 *[RD53]*: Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 7: Satellite Based Augmentation Systems - Receiver Equipment - Performance requirements and method of testing (under development)

- IEC 61162 -Parts 1 to 4 *[RD49]*: Maritime navigation and radiocommunication equipment and systems – Digital interfaces

- IEC 61993-2 Ed. 2.0 *[RD50]*: Maritime navigation and radiocommunication equipment and systems - Automatic identification systems (AIS) - Part 2: Class A shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results

River information service (RIS)

- *DIRECTIVE 2005/44/EC AND AMENDMENT 219/2009 [RD37]:* framework for the deployment and use of river information services (RIS) in the Community along with the further development of technical requirements, specifications and conditions to ensure its harmony and interoperability, in order to support inland waterway transport enhancing safety, efficiency and environmental friendliness and facilitating interfaces with other transport modes

- *REGULATION (EC) NO 414/2007 [RD38]:* defines guidelines for the planning, implementation and operational use of RIS

- *REGULATION (EC) NO 415/2007 [RD39]:* contains the technical specifications for vessel tracking and tracing systems used in RIS, as referred to in Directive 2005/44/EC [RD37]

IHO requirements

- IHO requirements concern the accuracy of nautical charts and are not directly related with IMO expressed requirements concerning positioning of ships. There is however an inherent relation, since a vessel position as reported by its “Electronic Position Fixing Device” is feeding its ECDIS and is plotted on the displayed electronic chart

Relevant Standards for EO

There are currently few standards or regulatory documents guiding data quality, processing, and products for EO. A limited set of internationally adopted standards in data formats and metadata associated with digital spatial data were provided by ISO, IEEE, OGC, GRSS and SEOAH:

- The International Organization for Standardization (ISO)
  - ISO/TR19121:2000 concerning Geographic information, imagery, and gridded data
  - ISO 19115:2014 Geographic Information - Metadata
- The Open Geospatial Consortium (OGC) provides Standards and Schemas (XSD, JSON Schema, etc) for the geospatial information interoperability and implementation used by international organizations
  - EO product metadata: OGC's GML Application Schema for EO Products
  - Collection and service discovery: OGC's Cataloguing of ISO Metadata using the ebRIM profile of CS-W
  - Catalogue Service: OGC's Catalogue Services Specification 2.0 Extension Package for ebRIM Application Profile: EO Products
  - Order: OGC's Ordering Services for EO Products
  - Feasibility Analysis: OGC's Sensor Planning Service Application Profile for EO Sensors
  - Online Data Access: OGC's WMS EO Extension
  - Identity (User) Management: OGC's User Management Interfaces for EO Services
- Geoscience and Remote Sensing Society (GRSS) created the Standards in Earth Observations (GSEO) Technical Committee to support the development and promotion of technical standards related to the generation, distribution, and utilisation of interoperable data products from remote sensing systems
- The Standards in Earth Observations Ad Hoc Committee (SEOAH) is the managing organizational unit within GRSS to handle standards development within the IEEE

2.3.3 Potential regulation evolution

The increasing reliance on GNSS for positioning, navigation, and timing in maritime applications has heightened concerns about resilience. Ensuring resistance to unintentional and intentional interference, including spoofing, is becoming more critical and may need to be translated into standards and regulations. For this reason, the continued standardisation of GNSS requirements remains crucial, focusing on operational aspects such as integrity, continuity, accuracy, availability, and security / authentication.

In 2024, EUSPA introduced new guidelines for OSNMA Receivers and GNSS resilience, focusing on enhanced cybersecurity measures and anti-spoofing technologies[2]. These guidelines aim to protect maritime GNSS applications from emerging threats and ensure continuous and reliable service.

[2] Via: Galileo OSNMA Receiver Guidelines

The IMO continues to play a significant role in GNSS standardisation through its six main bodies: the Assembly, Council, and four Committees, with the Maritime Safety Committee being the most relevant. The procedure for changing conventions involves "tacit acceptance" of amendments by States, meaning an amendment enters into force unless objections are received from a specified number of Parties within a set period. Most amendments enter into force within 18 to 24 months under this procedure. The evolution of requirements is driven by higher dependencies on electronic positioning onboard ships, the development of larger and faster ships, autonomous ships, remote control, increased shipping in certain regions, and the demand for alternative energy sources.

The review of the RIS directive and the currently still under development regulatory framework for MASS are expected to impact the requirements for GNSS, EO and SATCOM altogether. As argued in the previous chapter, increasing demand for accurate and resilient has a continued growing demand. The following chapter outlines the current and projected user needs and requirements within these specific applications.

2.4 User Needs and Requirements

This chapter provides a summary of user needs and requirements pertaining to Maritime and Inland Waterways applications introduced before, describing the different roles and needs covered by EO, GNSS and SATCOM and, ultimately, identifying the corresponding requirements from a user perspective.

The table below depicts the main applications making use of EO/GNSS/SATCOM technologies in Maritime and Inland Waterways, with indication whether this report covers it in the scope of the analysis or not. The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it. While each one of the applications addressed in this document can benefit or potentially benefit from satellite technologies, the current issue of the RUR does not cover in detail the needs and requirements of all applications. Some applications are more mature than the others when it comes to uptake of EO/GNSS/SATCOM, therefore there is no equal level of details provided to all of them. The table below presents the scope of the analysis covered in the current version of user needs and requirements report.

Table 4: Overview of covered applications - Maritime and Inland Waterways

Sub-segments	Application	Type of application (GNSS, EO, SATCOM)	In-depth coverage within this report
Merchant Vessels	Merchant navigation	GNSS	Yes
	Ship route optimisation	GNSS + EO	Yes, updated in 2024 edition
	Navigation through sea ice	GNSS + EO	Yes
	Maritime Autonomous Surface Ships	GNSS + EO + SATCOM	Yes, updated in 2024 edition
	Connectivity at sea	SATCOM	Yes, added in 2024 edition
Merchant and inland waterway vessels	Collision avoidance (through AIS + VDES)	GNSS	Yes
	GNSS vessel engine management systems	GNSS	No
Inland waterway vessels	Inland waterways navigation	GNSS + EO	Yes
	Autonomous surface vessels	GNSS + EO + SATCOM	Yes, updated in 2024 edition
	Water level estimation	EO	Yes, added in 2024
Ocean and Environmental monitoring	Marine pollution monitoring	EO	Yes, added in 2024 edition
	Dredging	GNSS + EO	Yes

Sub-segments	Application	Type of application (GNSS, EO, SATCOM)	In-depth coverage within this report
Maritime engineering	Marine surveying and mapping	GNSS + EO	Yes
Ports	Automated port operations	GNSS	Yes
	Piloting assist at ports	GNSS + EO	Yes
	Port operations	GNSS	Yes
	Port safety	GNSS + EO	Yes
	Port security	EO	Yes
Recreational navigation	Recreational navigation	GNSS	Yes
Vessel tracking	Dark vessel monitoring	GNSS + EO	No
Search and rescue operations	Maritime Search and Rescue operations	GNSS	Yes

2.4.1 Segment applications and current EO/GNSS/SATCOM needs and requirements

In this analysis of the Maritime and Inland Waterways segment, 21 applications and use cases of GNSS, EO and SATCOM were introduced and/or described. The following subchapters provide a description of the relevant sub-segments/applications, and the related user needs and/or requirements.

2.4.1.1 Merchant navigation

Description of the sub-segment and application/operational scenario:

The sub-segment of merchant navigation encompasses the use of advanced navigational tools and systems to ensure the safe and efficient transit of commercial vessels across the world's oceans and waterways. This includes all type of SOLAS vessels such as passenger vessels, container ships, bulk carriers, tankers, and other vessels involved in the global trade of goods and passengers.

Overview of user needs for the application

In this operational scenario, GNSS technology is indispensable, providing accurate and reliable PNT information that is critical for plotting courses, avoiding collisions, and maintaining schedules. Merchant navigation relies heavily on GNSS to determine precise locations, monitor vessel movements, and make real-time navigational decisions, especially in congested sea lanes and ports. The integration of GNSS with other navigational aids, such as AIS and ECDIS, forms the backbone of modern merchant vessel navigation.

GNSS is the primary source of positioning information in sea navigation. In the case of SOLAS vessels: all passenger ships, cargo ships larger than 500 gross tonnage or larger than 300 tons if engaged on international voyages are regulated and rely heavily on GNSS to support navigation activities. At least 3 devices are typically fitted on vessels for redundancy reasons.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS for General navigation (SOLAS) in ocean are contained in the tables below:

Category 1

This category is characterised by requiring 10 m of horizontal accuracy (up to 100 m for the specific case of Ocean waters in Resolution IMO A.1046(27) [RD11]).

Table 5: Synthesis of Requirements Relevant to GNSS – Merchant Navigation – Category 1

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0010	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0020	The PNT solution shall provide 10 m horizontal positioning accuracy (95%) (up to 100 m for Ocean waters)	Performance (Accuracy Horizontal)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0030	Continuity is not relevant to ocean and coastal navigation Type: Performance (Continuity % over 3 hours)	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity - Alert Limit)	Resolution IMO A.915(22) - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046) [RD8]
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity - Time to Alert)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0060	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity Risk – per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046) [RD11]
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval in seconds)	Resolution IMO A.1046(27) 20/12/2011 [RD11]

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 1+

General navigation (SOLAS); Coastal, Port Approaches and Entrances falls under Category 1+. It is the same as Category 1, + regional continuity requirement. Requirements are identical to Category 1, except the following:

Table 6: Synthesis of Requirements Relevant to GNSS – Merchant Navigation – Category 1+.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (in ECDIS navigation mode)	Performance (Accuracy Horizontal)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
ID: EUSPA-GN-UR-MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) 20/12/2011 [RD11]

Category 2

Aids to navigation management and casualty analysis in port approach, restricted waters and inland waterways fall under Category 2, which is characterised by having 1 m horizontal accuracy requirement.

Table 7: Synthesis of Requirements Relevant to GNSS – Merchant Navigation – Category 2.

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal - 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27) [RD11]
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk per 3 hours	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Of the applications belonging to this category, only Casualty Analysis had its environment clearly stated by IMO (Port Approach and Restricted Waters). The others were placed in two different environment classes as follows: those taking place in Port Approach and Restricted Waters (Casualty Analysis, as defined by IMO and Port Operations, evidently); Marine Engineering, Aids to Navigation Management and Offshore exploration and exploitation were considered to fit best in Ocean environment.

IMO Resolutions consider that for ships operating above 30 knots, applications may need more stringent requirements.

Category 2+

General navigation (SOLAS): Ports and Restricted Waters falls under Category 2+. This category presents the same main requirements as Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage. Requirements are identical to Category 2, except the following:

Table 8: Synthesis of Requirements Relevant to GNSS – Merchant Navigation – Category 2+.

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11] Regulation (EC) No 415/2007 [RD39]

* Resolution IMO A.1046(27) 20/12/2011 states exactly: "When the system is available, the service continuity should be ≥99.97% over a period of 15 minutes."

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

2.4.1.2 Ship route optimisation

Description of the sub-segment and application/operational scenario:

The development of ship route optimisation services is driven by several factors, including regulatory compliance and the desire to minimise maintenance and operational costs as well as to maximise environmental ambitions and objectives striving towards decarbonisation. Legislation and environmental standards often necessitate precise navigation to avoid ecologically sensitive areas and to adhere to emission control regulations.

Ship route optimisation utilises the continuous, real-time updating of maps and electronic display systems to provide dynamic and most efficient planning in terms of fuel consumption or travel time, incorporating real-time information about the marine environment, including vessel traffic, weather conditions, and potential hazards. The service allows to predict and avoid hazards such as storms, strong undercurrents, high waves, safety in terms of team health and cargo integrity, prediction of E/RTA (Estimated/Required Time of Arrival) to support follow-on logistic processes. Decisions made through this service are multifaceted. Route analysts from shipping companies can devise preliminary paths considering various factors such as vessel and cargo types, loading conditions, fuel efficiency and cost savings. minimizing travel time and avoiding delays. weather conditions and general safety and security. Captains can make informed decisions on-the-fly, adjusting course and speed in response to changing conditions to ensure timely and safe arrival at the destination port.

Components of the service encompassing route planning systems are complemented by Automatic Identification System (AIS), MetOcean, and ocean condition analytics to support decision-making at both the managerial and operational levels.

Overview of user needs for the application

For the optimal ship route optimisation services, users prioritise accuracy, efficiency, and timely responses. They require up-to-date information, access to historical data for trend analysis and change detection, and the capability to manage large-scale areas. While these are critical, the importance of less tangible factors, such as user-friendliness of the systems, may be secondary yet still relevant.

Currently, the application is served by a combination of EO technology, AIS for traffic management, and advanced route planning software that integrates meteorological and oceanographic data. GNSS and EO are integral to ship route optimisation, providing the foundational data and information that enable comprehensive route planning and real-time decision-making.

These technologies are increasingly recognised as essential tools for modern maritime operations and are growing in maturity, contributing significantly to the safety, efficiency, and environmental sustainability of shipping practices.

User story: D-ICE-Engineering

The shipping industry is undergoing a shift towards innovative technologies to reduce greenhouse gas emissions and enhance energy efficiency, driven by evolving environmental regulations. Among other solutions, Wind-Assisted Ship Propulsion (WASP) technologies are being developed, but they still need to be evaluated on commercial routes, integrating operational constraints.

Testing the long-term viability and commercial return of investment of a WASP device directly on a vessel can be done through statistical routing studies, meaning launching large amounts of voyage optimizations in the past years to get reliable statistics on weather conditions and ship performances. Those studies are difficult and time-consuming and are therefore often conducted at the end of a project, as a validation, even though the results can be also important during the design process.

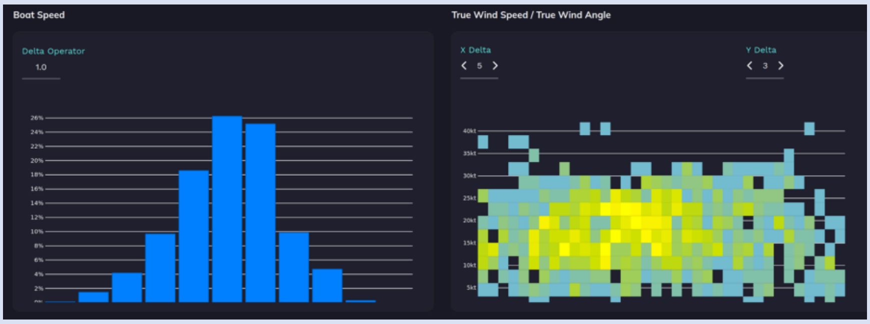
SATORI offers a cost-efficient and easy solution for shipowners, naval architects, and technology developers to conduct statistical weather routing studies on any type of vessel via an online platform.

Users upload a digital twin of their vessel and initiate fully customizable statistical studies. They can define their routes, with advanced specificities (navigational restrictions, weather constraints etc) and the granularity of the statistical study (e.g. 1 departure each week during 5 years). Leveraging data from Copernicus Marine Services, SATORI enables routing simulations for any period from 2010 to 2024.

The results are then available through a dynamic dashboard that users can both customize and share with partners or clients offering valuable insights for optimizing ship operations.

The service is commercially available since 2020 and has provided more than 300,000 calculations to help clients in defining their optimal assets.

Figure 2: D-ICE use case - SATORI



Ship route optimisation dashboards use maps, real time data using optimisation software and tool planning features that rely on big data, Machine Learning (ML) processes and Artificial Intelligence (AI) algorithms. Its main components are NTSI, autopilot, navigational charts and weather analysis tools. These tools allow captain to use different weather analytics to optimise the route of the vessel.

From the environment evaluation (wind, waves and current), models can calculate the ship velocity and engine power between two points at a specific time. Allowing global objectives such as travel time or consumption to be further optimised. The incoming data on weather and ocean conditions have to seamlessly integrate with the operating route planning tools and models on board of the ship.

In summary, ship route optimisation relies on EO for establishing a full picture on the weather conditions, sea surface temperatures and currents, ice coverage and pollution. Users require the services to be delivered in real-time. **EO data frequency and latency was identified as a key user requirement** for improvement during the 2024 UCP event. Moreover, the data fusion and integration with the data from in-situ sensors was identified as sometimes challenging but improving dynamically with the use of AI and ML. At the same time, EO can also be leveraged for environmental considerations. In the field of biofouling, EO provides the capability to monitor large areas and plot optimal shipping routes to avoid unnecessary pollution.

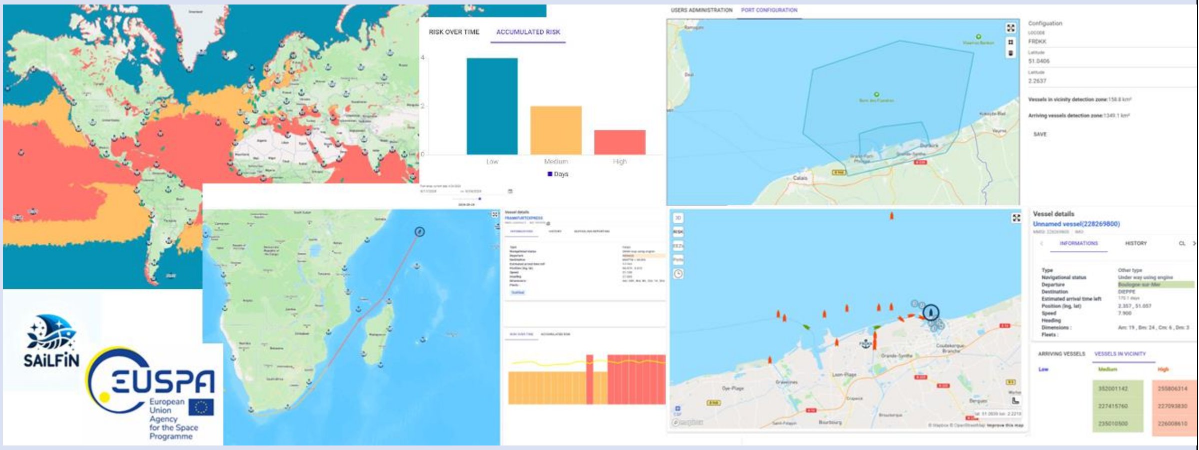
User story: LuxSpace

The impact of biofouling (organic growth on ship hulls, propellers, and other surfaces exposed to water), is estimated to cost the shipping industry as much as $8 billion per year in extra fuel and 70M tones CO2 emissions, in addition to local ecosystem damage due to alien invasive species. The Sailfin platform provides a global, region, and per-vessel biofouling risk assessment calculation to help minimalize these impacts.

This biofouling risk assessment is calculated by combining the rich data set provided daily by the Copernicus Maritime Service with per-vessel Automated Identification System (AIS) data—both live and historical—as well as in-situ data optionally provided by each vessel owner/operator such as date of last hull cleaning, anti-biofouling measures, etc.

Vessel owners/operators, port authorities, and other interested stakeholders are then able to take this risk assessment into consideration to optimize vessel routing, hull cleaning scheduling, and in the case of port authorities, to monitor and inspect incoming vessels, and manage anchorage waiting zones with greater efficiency days in advance of arrival at port.

Figure 3: LuxSpace use case



User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS for **General navigation** (SOLAS) in ocean and coastal; and **Casualty analysis**, ocean and coastal, are contained in the **tables set out under merchant navigation under 3.3.1.1**.

Category 1

This category is characterised by requiring 10 m of horizontal accuracy (up to 100 m for the specific case of Ocean waters in Resolution IMO A.1046(27) [RD11]). Internally it can be separated in smaller groups of applications: those who take place in an ocean environment and those represented by both ocean and coastal environment. The difference of environment results in different constraints

Category 1+

Traffic management. Ship to ship coordination, Ship to shore coordination and Shore to ship traffic management; falls under Category 1+. Category 1+ differs from 1 in that there is a regional continuity requirement.

Category 2

Aids to navigation management and casualty analysis in port approach, restricted waters and inland waterways fall under Category 2, which is characterised by having 1 m horizontal accuracy requirement.

IMO Resolutions consider that for ships operating above 30 knots, applications may need more stringent requirements. Of the applications belonging to this category, only Casualty Analysis had its environment clearly stated by IMO (Port Approach and Restricted Waters). The others were placed in two different environment classes as follows: those taking place in Port Approach and Restricted Waters (Casualty Analysis, as defined by IMO and Port Operations, evidently); Marine Engineering, Aids to Navigation Management and Offshore exploration and exploitation were considered to fit best in Ocean environment.

Category 2+

General navigation (SOLAS): Ports and Restricted Waters falls under Category2+.This category presents the same main requirements as Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage.

User Needs and Requirements relevant to EO

The **EO requirements** are contained in the table below:

Table 9: Ship route optimisation – Application-level requirements relevant to EO.

ID	EUSPA-EO-UR-MAR-001
Application	Ship route optimisation
Users	• Ship owners • Shipping companies (e.g. route analyst/route planner) • Vessel operators • Destination ports (ETA) • Follow-on logistics enterprises
End Users Application Needs	
Operational scenario	Route planning and optimisation for container ships using the Electronic Chart Display and Information. ECDIS can be connected to GNSS, radar and gyro systems. MetOcean data is essential to establish safe navigation condition along shipping routes, with the highest possible granularity of meteorological conditions that can be very local, unstable and difficult to predict. Weather routing allows to efficiently plan the voyage of all kinds of vessels (conventional, sailing, hybrid) and allows to reduce fuel consumption and emissions. Biofouling Risk Management Platforms and monitoring of biofouling on ship performance, finances and the environment.
Size of area of interest	The AOI is the shipping route from port of departure to port of destination. Accordingly, this can vary significantly; for large shipping vessels this usually covers 1000s of nautical miles (e.g. from Singapore to Rotterdam). Weather data is usually collected with a resolution in the km range (e.g. MSG Seviri - at 1 km or 3 km). Waves and currents can be also influenced by local phenomena, e.g. in the Mediterranean islands, land tongues, peninsulas and underwater geology and in this case a higher resolution at respective geolocations would be required, in the range of 100 m.
Frequency of information needed	As ship routes cannot be changed fast, usually updates of the weather situation every 6 hours is sufficient. As Ocean conditions (wave, currents, etc.) also build up and disappear slowly, this time interval can be considered sufficient as well. The most critical information for MetOcean users is the availability of weather information, especially warning of adverse weather conditions for the respective operational use. The earlier and the more reliable such information is the better it is. This means that collected data will be fed into weather models which then produce information for the weeks/days to come.
Type of service	Forecasting and monitoring
Other	Route optimisation models are usually included into ECDIS chart solutions on board. Incoming data on weather and ocean conditions must seamlessly integrate with the operating route planning tools and models on board of the ship (ECDIS).

	The scales available on ECDIS maps are classified according to navigation purposes (e.g. harbour 1:4,000 - 1:21,999, coastal 1:90,000 - 1:349,000, general shipping 1:350,000 - 1, 1499,999) overview 1:<1,499,999). Ship route optimisation will usually not affect the final harbour approach but may be relevant for coastal shipping. It is certainly relevant for general shipping and overview charts. Weather data are usually collected with a resolution in the km range (e.g. MSG Seviri - at 1 km or 3 km). As waves and currents can be also influenced by local phenomena (e.g. in the Mediterranean influenced by islands, land tongues, peninsulas, underwater geology) a higher resolution at respective geolocations would be required, e.g. in the range of 100 m. It is known that weather forecasting includes uncertainty, and this is widely accepted. However, any type of warning has to be reliable (no false positives, no false negatives), as related reactions or missed reactions (shut down of operations, evacuation of people, etc.) have a significant effect (in positive cases rescue of people and goods, in negative cases loss of lives and goods (no warning), or unnecessary cost (wrong warning)).
Satellite EO Data Requirements	
Spatial resolution	Wave height: 1m Ocean conditions: 100m
Temporal resolution	Multiple times a day, daily
Spectral resolution	n/a
Type of EO data needed	Optical (VHR and HR), Radar and Meteorological
Other requirements	Need for historical data to calculate ship interactions with environment. Electronic Chart Display Information System Marine Digital route planner based on geo, storm and weather conditions Bathymetry data along shorelines Wave height and wind speed from altimetry data, surface wind speed from scatterometer, sea surface temperature (e.g. Sentinel 3). Copernicus data used: • Sentinel-1 (e.g. ice monitoring, ship monitoring, marine winds and waves) • Sentinel-2 (e.g. CMEMS) • Sentinel-3 (e.g. altimetry) • Weather and spotter buoys EUMETSAT: • GEO satellites METEOSAT 2nd (and upcoming 3rd) • LEO satellites METOP 1st (and upcoming 2nd) generation.[3]

[3] Regarding the LEO satellites METOP are operated in close cooperation with the NOAA/NASA satellites POES.

	• Jason-3 satellites (cooperation between EUMETSAT, CNES, NOAA, NASA). • Sentinels 3, S-6, upcoming S-4 and S-5

2.4.1.3 Navigation through sea ice

Description of the sub-segment and application/operational scenario:

Ice maps generated using EO data in combination with GNSS positioning information enable navigation applications that automatically avoid waters with high iceberg concentrations. This allows ships to sail faster and more safely through open waters. Reflections of satellite navigation signals collected in space can be used to accurately map the extent of the sea ice in the Arctic and Antarctic oceans.

Operations of Locks, Tugs, Pushers and Icebreakers did not have their environment stated by IMO and were considered to fit best in the widest Environment category: Ocean, Coastal, Port and Port approach, Restricted Waters and Inland Waterways. IMO resolutions indicate the need of relative accuracy for tugs, pushers and icebreakers and a possible requirement of vertical accuracy depending on the port and restricted water operation. Overview of user needs for the application. Users involved in navigation through sea ice require accurate and up-to-date information on ice conditions, including ice concentration, thickness, and movement. They need reliable ice forecasting and ice management services to plan safe routes and avoid potential hazards. The ability to integrate EO data, such as satellite imagery and radar scans, with onboard navigation systems is a key user need for real-time decision-making. Users also prioritise the availability of icebreaker assistance for convoy operations and emergency support. The need for vessels to be equipped with ice-strengthened features and to have crews trained in ice navigation techniques is essential for operational safety. Additionally, users seek technologies that can enhance the situational awareness of the crew, such as thermal imaging and sonar systems. Users expect navigation solutions to comply with international regulations, such as the Polar Code, to ensure the protection of polar environments and the safety of maritime operations. Finally, users demand cost-effective and efficient navigation strategies that can reduce transit times and fuel consumption, even in the presence of sea ice.

User Needs and Requirements Relevant to GNSS

The user requirements to GNSS for icebreakers fall under the **Category 2+**, as set out under GNSS requirement section for merchant navigation.

User Needs and Requirements Relevant to EO

The EO requirements for navigation through sea ice are integrated into the requirements table set out under the ship route optimisation application.

2.4.1.4 Maritime Autonomous Surface Ships (MASS)

Description of the sub-segment and application/operational scenario:

MASS represent a transformative and developing sub-segment in the maritime industry, focusing on the development and deployment of self-navigating vessels that operate with varying levels of human oversight. These vessels range from semi-autonomous, where some human oversight is required, to fully autonomous, where the ship operates independently. There are currently 4 degrees of MASS set out by the IMO:

- Degree 1: Some operations are automated, but operational crew is on board.
- Degree 2: Remotely controlled and operated ship but seafarers are on board.

- Degree 3: Remotely controlled ship without seafarers on board.
- Degree 4: Fully autonomous ship, which operating system makes decisions and determines actions.

Autonomous ships are equipped with advanced sensors, control algorithms, and communication systems that enable them to perform tasks such as transportation, surveillance, and environmental monitoring autonomously. Operational scenarios for MASS range from short coastal voyages to long-distance transoceanic journeys, with applications in commercial shipping, defence, and scientific research. The integration of GNSS, radar, lidar, and computer vision allows these vessels to navigate complex marine environments safely and efficiently. The optimisation of MASS operations is crucial for enhancing maritime safety, reducing operational costs, and minimising the environmental impact of shipping.

Overview of user needs for the application

The user needs and requirements towards MASS first and foremost express the need of international regulatory standards. The International Maritime Organization (IMO) has been working on the regulatory standards via the goal-based maritime autonomous surface ship (MASS) Code, that is expected to be adopted as a mandatory code under e Safety of Life at Sea (SOLAS) Convention in 2028. Satellite systems will be essential for providing navigation, communication, and environmental monitoring, all of which are critical for the safe and efficient operations of autonomous vessels. As these technologies evolve, they will play a key role in enabling the future of maritime automation.

As MASS systems become more connected, they will be vulnerable to cyberattacks. Robust cybersecurity systems will be necessary to ensure the safety of these vessels from potential threats such as hacking. Ports will need to adapt to MASS by incorporating automated systems for docking, loading/unloading, and traffic management, and the services will need to integrate these changes in infrastructure.

During the 2024 UCP event, an elaborate discussion concluded that for the most important action to further development and implement secure and safe MASS, the policy and regulatory development with common standards has to be developed. It was added that regulatory evolutions are driven by bi-national, digitalisation, VTS (from the shore) and traditional aids to navigation. Traditional navigational aids will be used to accommodate with MASS, in terms of readability of buoys and others. This entails that the existing requirements for navigation will be the minimum requirement for MASS and that several regulatory frameworks should be integrated into one comprehensive guideline. It was specifically added that additional resilience of PNT will be the key differentiator in terms of use requirements between MASS and general navigation. Given the vulnerability of GNSS to spoofing, the interlinkage of positioning with decision-making components and potential consequences of errors, this robustness will prove as a deciding factor for future uptake of autonomous shipping[4].

User Needs and Requirements Relevant to GNSS

To elaborate more what was expressed before, during the UCP2022 the outcomes of a project (GSA/OP/09/16/Lot 3/SC10) related to the implementation of the EGNSS adoption roadmap for transport applications were presented, specifically consolidated GNSS User Requirements for autonomous vessels for ocean, coastal approach phase and port navigation. The requirements were set up based on IMO Resolution A.915(22) [RD8] as the main reference containing user requirements, as well as the classical GNSS SIS Performance Parameters and outputs from projects such as EGUS-SC4 (currently collected in UCP reports) and Hull to Hull (H2H). The requirements for MASS aim to be part of a potential IMO regulation covering GNSS requirements at user application level, for instance. as an amendment to IMO Resolution A.915(22) [RD8]. Both MASS and IMO Resolution A.915(22) [RD8] requirements shall converge in terms of parameters. These GNSS requirements apply only to the GNSS antenna Position, Velocity and Time (PVT) computation (for vessel positioning additional parameters shall be considered as proposed in IMO MSC. Circ. 1575).

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[4] As demonstrated through the presentation of the RBAT model by EMSA at the 2024 UCP event

As explained, requirements for MASS need to impose at least the same level of safety as the ones imposed on conventional vessels. Especially given the current global context, the integrity and resilience of PNT has to be ensured to allow for automated navigation. For the different phases of navigation, the following GNSS requirements were already proposed during the 2022 UCP:

Table 10: Proposed Requirements Relevant to GNSS – MASS Ocean Navigation.

Performance parameter		IMO Resolution A.915 (2001) [RD8]	EGUS-SC4* (2016)	Proposed GNSS requirements (2022)
Horizontal Accuracy (95%)		<10 m	<15 m	<10 m
Continuity Risk (over 15 min)		N/A	N/A	N/A
HAL		<25 m	<37.5 m	<25 m
Time to Alarm		<10 s	<8 s	<8 s
Integrity Risk	>3 h	10-5	7.2x10-5	10-5
	>15 min	8.33x10-7	6x10-6	8.33x10-7
	Per sample	1.39x10-7	1x10-9	1.39x10-7
Availability		99.8%	99.8%	99.8%

* Original EGUS MASS requirements do not specify the time window linked to this integrity risk. For this reason, it has been assumed that this integrity risk applies per independent sample. Values in this table are already converted to different time windows.

Table 11: Proposed Requirements Relevant to GNSS – MASS Coastal Navigation & Port Approach.

Performance parameter		IMO Resolution A.915 / H2H (2001) [RD8]	EGUS-SC4* (2016)	Proposed GNSS requirements (2022)
Horizontal Accuracy (95%)		<10 m	<0.3 m	<1 m
Continuity Risk (over 15 min)		N/A	3x10-4	3x10-4
HAL		<25 m	<12.5 m	<7.5 – 12.5 m
Time to Alarm		<10 s	<6 s	<6 s
Integrity Risk	>3 h	10-5	7.2x10-6	7.2x10-6
	>15 min	8.33x10-7	6x10-7	6x10-7
	Per sample	1.39x10-7	1x10-7	1x10-7
Availability		99.8%	99.8%	99.8%

* Original EGUS MASS requirements do not specify the time window linked to this integrity risk. For this reason, it has been assumed that this integrity risk applies per independent sample. Values in this table are already converted to different time windows.

Table 12: Proposed Requirements Relevant to GNSS – MASS Port Navigation.

Performance parameter		IMO Resolution A.915 (2001) [RD8]	H2H for autodocking* (2020)	Proposed GNSS requirements (2022)
Horizontal Accuracy (95%)		<1 m	<0.3 m	<1 m
Continuity Risk (over 15 min)		$3x10^{-4}$	$9x10^{-4}$	$3x10^{-4}$
HAL		<2.5 m	<50 m	<2.5 m
Time to Alarm		<10 s	<10 s	<6 s
Integrity Risk	>3 h	10^{-5}	$3.6x10^{-7}$	$7.2x10^{-6}$
	>15 min	$8.33x10^{-7}$	$3x10^{-8}$	$6x10^{-7}$
	Per sample	$1.39x10^{-7}$	$5x10^{-9}$	$1x10^{-7}$
Availability		99.8%	99.8%	99.8%

* Original EGUS MASS requirements do not specify the time window linked to this integrity risk. For this reason, it has been assumed that this integrity risk applies per independent sample. Values in this table are already converted to different time windows.

It is found that the Horizontal Accuracy and HAL values are generally acceptable for merchant vessels, but that these values need to be confirmed for all vessel types/sizes and levels of autonomy. Further work is needed to understand the future evolution of MASS and the specific needs and requirements that result from MASS typology (dimensions, level of automation, etc.). the Continuity and Integrity Risk values will need to be further confirmed through more extensive safely analyses per each level of autonomy, and the Availability requirement may require additional sensors.

During the UCP 2024 event it further was discussed that test trials for the remote operational centres and synchronisation showed the need for synchronisation onboard of the ships. This demonstrated that hybridisation of sensors on board is needed to autonomously compute navigation. To allow this, additional dedicated channels will be needed to ensure reliable timing and synchronization. A clear harmonised concept is yet to be defined, and market players are looking in the direction of the IMO to stipulate the specific requirements.

User Needs and Requirements Relevant to EO

EO data for MASS is foreseen to have a supporting role, especially for the uptake of automated navigation. EO contributes by ocean condition monitoring in route planning, weather monitoring for safety and efficiency of voyages, surveillance of illegal activities, as well as environmental monitoring. During the UCP 2024 event, it was also indicated that EO is seen as a fundamental supporting service to GNSS based navigation and could serve as an early warning system if sufficient performance levels can be achieved in terms of temporal resolution.

The EO requirements for MASS are integrated into the requirements table set out under the ship route optimisation application, as these are closely intertwined and interdependent.

The following user story provides a first glimpse into the current and future of autonomous navigation:

User story: Kongsberg Autonomous Vessel

Yara Birkeland developed by Kongsberg is the world's first electric and autonomous vessel with zero emissions. The vessel will transport mineral fertilizer from the Yara production plant in Porsgrunn to the regional export port in Brevik. It shows the operational capacity and real benefits of the transition towards autonomous sailing.

Figure 4: Yara Birkeland

User Needs and Requirements Relevant to SATCOM[5][6]

SATCOM is essential for the operation of autonomous maritime surface ships, as it enables the constant transmission of critical data from multiple on-board sources to the shipping company's Control Centre for remote operation. Broadband-capable SATCOM equipment is required to handle the high volumes of data, including engine management and control, rudder control, radar scanning and avoidance, speed log, gyro heading, echo sounder depth scanning, GPS, and dynamic positioning. The advent of MASS at varying different levels means an increase in decision support tools. This requires connectivity that is resilient.

Additionally, there may be a need for bandwidth-intensive live feeds from high-definition cameras offering 360-degree visibility, which are transmitted back to the Control Centre. The SATCOM equipment must support high data throughput and, for safety reasons, multiple identical systems with independent backup power generators may be necessary to ensure fail-safe communication.

Currently, VSAT technology, particularly in Ku-Band or C-Band, provides the most suitable means of delivering the high levels of data required to operate these advanced autonomous and drone vessels, with maritime broadband services via satellite offering a fixed monthly cost for easy budgeting.

The table below shows a preliminary mapping of user requirements for SATCOM in MASS:

[5] Desk research, via: https://magazines.marinelink.com/Magazines/MaritimeReporter/201512/content/satcoms-autonomous-shipping-502647

[6] Desk research, via: https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2986204/Petersen_2020_IOP_Conf._Ser.__Mater._Sci._Eng._929_012009.pdf?sequence=1&isAllowed=y

Table 13: Proposed Requirements Relevant to SATCOM – MASS Port Navigation.

SATCOM User Requirements for MASS*[7]	
ID: EUSPA-SAT-UR-MAR-0001	
Link Type: the type of communication for voice or data	Bi-directional data
Availability: a qualitative indication of the availability required of the communications system when the application is in use exceeding a certain quality of service.	High
Latency: The delay between action and reaction.	Low: immediate (e. g. <300ms)
Bandwidth (bit rate): a qualitative indication of the anticipated rate of data transfer when using the application.	Medium (order of MB)
Coverage: an indication of geographical area which can be reached by the service.	Worldwide
Symmetry Up/Down: The ratio between the uplink traffic and the downlink traffic.	50/50
Distribution:	Multi-User: between a group of users, where a user can be a human or a system
Setup: a qualitative indication of the time to establish a voice or data communication session with the application that would be acceptable to a user and is sufficient to perform the railway operation.	Immediate
Speed: the speed that a user is travelling in, maximum value:	Low ≤40 Km/h
Security protection	Need for a secure connection

2.4.1.5 Connectivity at sea

Description of the sub-segment and application/operational scenario:

Connectivity at sea is a vital sub-segment in maritime operations. This area addresses the need for reliable and continuous communication links between vessels at sea and entities on land, including shipping companies, maritime authorities, and sailors' families. The operational scenario encompasses the use of SATCOM to facilitate various forms of communication, such as voice calls, emails, internet access, and real-time data exchange, which are essential for operational coordination, emergency response, and personal correspondence. The wellbeing of sailors is closely tied to their ability to stay connected with the outside world, combatting the isolation and mental challenges associated with extended periods at sea. SATCOM

[7] The table presented is based on desk research and still has to be validated during the2024 UCP event

enables access to online resources, social media, and entertainment, which are important for maintaining the morale and mental health of crew members.

Overview of user needs for the application

Users in the maritime industry have specific needs related to communication at sea that SATCOM technology addresses. The primary need is for consistent and high-quality communication channels that are available across all oceanic regions, regardless of weather conditions or the vessel's location. Users require systems that can handle high data throughput to support a variety of communication needs, from operational data exchange to personal use by sailors. The ability to provide bandwidth management and prioritise critical communications is also essential. Users seek SATCOM solutions that offer flexibility in service plans and scalability to accommodate different vessel sizes and communication demands. The integration of SATCOM with onboard communication systems should be seamless and user-friendly. For the wellbeing of sailors, users need communication services that allow for private and secure contact with family and friends, as well as access to online content that can reduce the sense of isolation. Additionally, users expect SATCOM services to be cost-effective, with transparent pricing structures that enable shipping companies to budget for communication expenses. Lastly, users demand reliable customer support and technical assistance to ensure uninterrupted communication services at sea.

User Needs and Requirements Relevant to SATCOM

Table 14: Proposed Requirements Relevant to SATCOM – Connectivity at Sea

Preliminary SATCOM User Requirements for Connectivity at Sea	
ID: EUSPA-SAT-UR-MAR-0003	
Link Type: the type of communication for voice or data	Bi-directional Data
Availability: a qualitative indication of the availability required of the communications system when the application is in use exceeding a certain quality of service	Aiming for High
Latency: The delay between action and reaction	/
Bandwidth (bit rate): a qualitative indication of the anticipated rate of data transfer when using the application	Depending on the vessels, for which the average split is: 20% high (greater than 10MB) 30% medium (order of MB) 50% low (order of KB)
Coverage: an indication of geographical area which can be reached by the service	Global, but limited around the poles (76 north, 76 south)
Symmetry Up/Down: The ratio between the uplink traffic and the downlink traffic	50/50 for ship 80/20 for crew
Distribution	Most technology is application based and multiuser by design
Setup: a qualitative indication of the time to establish a voice or data communication session with the application that would be acceptable to	Only safety services have time requirements

Preliminary SATCOM User Requirements for Connectivity at Sea	
ID: EUSPA-SAT-UR-MAR-0003	
a user and is sufficient to perform the railway operation	
Speed: the speed that a user is travelling in, maximum value	N/A
Security protection	Applicable frameworks: • CIA framework • IMO guidelines • Class societies: • ICS 26 & 28 Need for a firewall per ship, as well as other threat management systems

2.4.1.6 Collision avoidance (through AIS + VDES)

Merchant vessels above 300GT are required through the IMO SOLAS regulation to be equipped with a RADAR and an Automatic Identification System (AIS), alongside the receivers for navigation. Nearby vessels communicate their position and heading through the AIS with each other and with shore-based infrastructures (e.g., near ports) to improve the traffic management and safety of navigation.

Automatic collision avoidance uses auto-tracking combining the navigation information of the vessel with that of other vessels. Its objective is to provide alerts when the system predicts a pre-defined minimum range of closest approach will be breached, but it can also be used to monitor the traffic situation and set targets for navigation.

The VHF Data Exchange System (VDES) represents a significant advancement in maritime communication technology, addressing the limitations of the Automatic Identification System (AIS). VDES offers increased capacity and global coverage, which are crucial for enhancing collision avoidance measures. Unlike AIS, which is becoming congested and lacks security, VDES supports the authentication of marine services through the Maritime Connectivity Platform. This system not only improves the safety of navigation but also supports the Global Maritime Distress and Safety System (GMDSS) and other essential features. The IMO is finalising a new performance standard for VDES, expected to be implemented by 2025.

User Needs and Requirements Relevant to GNSS

The user requirements relevant to GNSS are contained in the table below:

Category 1+

Operations: automatic collision avoidance and track control are categorised as Category 1+. It requires 10 m of horizontal accuracy, with Category 1 + additionally incorporating a regional continuity requirement. Requirements are identical to Category 1, Category 1, except the following:

Table 15: Synthesis of Requirements Relevant to GNSS –Collision Avoidance – Category 1+.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (iECDIS navigation mode req.)	Performance (Accuracy Horizontal)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel
ID: EUSPA-GN-UR-MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) 20/12/2011

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

2.4.1.7 GNSS vessel engine management systems

Description of the sub-segment and application/operational scenario:

GNSS supports remote monitoring of ships' conditions (e.g., engine diagnostics). This provides the vessel operators with the necessary information to perform routine check on the engine and improves the overall maintenance of vital elements of the vessel.

Overview of user needs for the application

The analysis of the user needs and requirement for vessel engine management systems is still at an explorative stage and therefore not further elicited in this report.

2.4.1.8 Inland waterways navigation

Description of the sub-segment and application/operational scenario:

GNSS is used to ensure safe navigation in inland waterways (rivers, canals, lakes and estuaries). Beside large rivers and channels used for commercial shipping (large ships with limited manoeuvrability), there is a plethora of waterways which are used mainly for recreational purposes such as fishing, sailing, canoeing (small boats). Whereas commercial shipping vessels are equipped with professional GNSS navigation tools containing lots of information, recreational tourism is usually relying on mobile phone as GNSS tool with very limited information on general aspects of a waterway.

In parallel to GNSS enabled navigation, EO data can support route planning and chart updating, more efficient water management and can be used to detect periods of flood or low flow that may cause disruptions to waterway traffic, allowing the bodies responsible for inland waterways to make informed decisions about traffic flows, as well as sedimentation.

Overview of user needs for the application

Accordingly, there are **two basic utilisation profiles for users navigating on inland waterways.** Depending on the interest of the users, services can range from general maps including various layers of information to very specific aspects. **Commercial shipping** is interested to receive information on weather, map of the waterway, obstacles on their route such as ice building in winter (low temperature), sand banks in summer (high temperature, low water level), obstacles (e.g. embankments, barrages, locks, stranded ships,..), harbours and their occupation, and the available navigation channel in relation to the water level. On the other hand, for **recreational tourism** more specific information is relevant such as water quality, wildlife protection areas, and camping grounds (incl. information on flooding risk, fire risk zones, etc).

Then there are the int**erests of the organisations and authorities in charge of preservation and maintenance of waterways and related habitats**. This can range from identification, preservation, and protection of protected sones like bird habitats up to maintenance work along the waterways, e.g. drenching of the shipping channel, monitoring of natural erosion of riverbanks, impact of severe weather events on the waterway (blockages like trees, flooding and related pollution). As sediments and natural erosion are continuously changing, e.g. Wadden islands in the Netherlands and Germany (ferries operate regular services, coastguard interventions), EO imagery can be used to monitor riverbank erosion and to detect/perform maintenance activities by authorities. EO imagery (radar, optical) can be used for singular object detection as well as for continuous monitoring of various aspects throughout the seasons (e.g. sandbank detection in summer, ice building in winter, sedimentation and erosion, protected sones, maintenance work). At UCP2024, the AVIS project team presented their assessment of the role of Space Data and EO in Automated Navigation, in which they foresee a role for EO in river edge and bedding monitoring, and the assessment of river throughput. Finally, the monitoring of the water quality is seen as a possible application.

On inland waterways, there is a mandatory carriage requirement using AIS transponders on professional vessels. In principle, this enables the provision of a traffic situation image in the corresponding VTS centres. Recreational navigation is currently not subject to AIS equipment obligation, but it can be assumed that in the future, requirements will be set for the monitoring of recreational shipping. Since these will not have a corresponding transponder at present and presumably not in the future, the question arises how they could be monitored. The equipment along the waterways with optical sensors seems to be very costly and difficult due to different weather conditions. Thus, detection via an EO system would be of great advantage here. However, it can be assumed that due to the small targets, reliable detection with a sufficient update rate will be difficult to realise.

With regards to communication systems for shore-to-ship and navigational aids, the AVIS project led by DG MOVE argued that VDES capabilities will provide an improved toolbox for communicating navigational information to masters (more data capacity) and enhance safer navigation. In addition, the authentication features in VDES will benefit the authorities relying on AIS signalling for traffic management. Overall, automation require a combination with in-situ sensors to be able to support accurate, reliable and safe navigation.

During the 2024 UCP event, VDES was presented as a key enabler to achieve necessary integrity levels for future applications in both maritime and inland navigation. For Maritime the enhanced robustness is seen as the key factor, whereas in Inland Waterway navigation, the possibility of VDES as a more suitable communication channel is playing a major factor for future RIS and navigation capabilities.

User Needs and Requirements relevant to GNSS

The **GNSS requirements** are contained in the section below. These requirements were already published in the previous version of this report. During the 2024 UCP event, the importance of authentication was identified as an additional requirement to be integrated in future assessments. It was stressed that lessons learned from Maritime scalable architecture (multi-system-radionavigation receivers) could be integrated into Inland Waterways.

Category 1++

General navigation (SOLAS); Inland waterways fall under Category 1++. Category 1++ differs from 1+ in that the horizontal accuracy is 3m.

Requirements are identical to Category 1, except the following:

Table 16: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – Category

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0101	The PNT solution shall provide 3 m horizontal positioning accuracy (95%)	Performance (Accuracy Horizontal)	MARUSE + UCP 2017

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

Category 2

Casualty analysis in Port approach, restricted waters and inland waterways falls under Category 2, which is characterised by having 1 m horizontal accuracy requirement.

Table 17: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – Category 2.

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39] User Consultation platform 2022 – Minutes of Meeting [RD57]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8] User Consultation platform 2022 – Minutes of Meeting [RD57]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8] User Consultation platform 2022 – Minutes of Meeting [RD57]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 [RD11])
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

**Except Local VTS which requires only a local coverage.*

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2+

General navigation (SOLAS): Ports and Restricted Waters falls under Category 2+. This category presents the same main requirements as Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage. Requirements are identical to Category 2, except the following:

Table 18: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – Category 2+.

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11] Regulation (EC) No 415/2007 [RD39]

* Resolution IMO A.1046(27) 20/12/2011 states exactly: "When the system is available, the service continuity should be ≥99.97% over a period of 15 minutes."

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

Category 2+++

Bridges operations in inland waterways falls under Category 2+++. This category presents the same requirements as of those in category 2, except for the horizontal accuracy, which varies from 1 to 2m, the vertical accuracy must be of 0.1m, and the alert limit, which needs to be between 2.5 and 5m in the horizontal axis.

Requirements are identical to Category 2, except the following:

Table 19: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – Category 2+++.

ID	Description	Type	Source
ID: EUSPA-GN-UR - MAR-0184	The PNT solution shall have an integrity risk smaller than 10-5 per 2 minutes (LAESSI bridge warning)	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting [RD56]
ID: EUSPA-GN-UR-MAR-0250	The PNT solution shall provide 1 to 2 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0260	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8] User Consultation platform 2022 – Minutes of Meeting [RD57]
ID: EUSPA-GN-UR-MAR-0270	The PNT solution shall provide a 2.5 to 6m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No415/2007 [RD39]

Category 3

Bridge collision warning systems, automatic guidance, mooring assistance and conning systems in Inland Waterways falls under Category 3. This category is characterised by having 0.1m horizontal accuracy requirement. A deeper legal analysis regarding the backbone to bridge operations requirements can be found under Annex 8.

Table 20: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – Cat. 3.

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0280	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability, % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0290	The PNT solution shall provide 0.1 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0300	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0310	The service continuity (% over 3 hours) is not applicable to Category 3 applications.	Performance (Continuity -% over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0320	The PNT solution shall provide a 0.25 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0330	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0332	The PNT solution shall have a time to alarm smaller than 6 s (LAESSI IWW applications	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0340	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk, per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0343	The PNT solution shall have an integrity risk smaller than 10-5 per 10 minutes (LAESSI mooring assistance)	Performance (Integrity – Integrity risk, per 10 minutes)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0344	The PNT solution shall have an integrity risk smaller than 10-5 per 1 hour (LAESSI conning display)	Performance (Integrity – Integrity risk, per 1 hour)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0360	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

User Needs and Requirements Relevant to EO

The **EO requirements** are contained in the table below:

Table 21 Synthesis of Requirements Relevant to EO – Inland Waterways Navigation

ID	EUSPA-EO-UR-MAR-002 EUSPA-EO-UR-MAR-003 EUSPA-EO-UR-MAR-004
Application	• Inland Waterways Navigation
Users	• Waterways and Shipping Administration • Commercial shipping companies (freight and passenger) • Harbour master • Non-commercial, recreational tourism e.g. fishing, sailing, canoeing • Local authorities • Wildlife protection organisations
End Users Application Needs	
Operational scenario	Determining fairways and mapping of embankments, barrages, locks as well as providing overview for VTS Centre of complete traffic situation (professional and leisure boats). Monitoring of IWW and port infrastructure in function of dynamic water levels related to (extreme) weather events, ice melting and prolonged dry seasons. Earth observation data should help identify potential hazards (e.g., submerged obstacles, floating debris) and environmental changes affecting navigation. ENC updating and additional layer for the assessment of river bedding and monitoring of shorelines and infrastructure. Access to high-resolution satellite imagery for detailed mapping of waterways, identifying potential changes in the environment, and ensuring compliance with navigational charts. Monitoring of surrounding vessels and weather-related alarms for maritime and inland waterway navigation Users require real-time and historical data on waterway conditions, including water levels, currents, tides, and ice presence to plan safe navigation routes.
Size of area of interest	Size of AOI depends on the application scenario: for rescue operations it will be the route towards the operational arena as well as the operational arena, for platforms the surrounding sea area and the route connection to land, for shipping the route between port of departure and port of destination, etc. Weather data are usually collected with a resolution in the km range (e.g. MSG Seviri - at 1 km or 3 km). This is sufficient to allow predictions in the AOI.
Frequency of information needed	The temporal resolution for the commercial shipping and the obstacle detection starts with NRT monitoring of obstacles (e.g. another ship stranded in front of the ship) and can go up to daily/weekly observations (e.g. ice building). For recreational users, most information is not time critical except e.g. the availability of weather information (extreme weather events) and harbour place availability.

	For local authorities the temporal resolution varies as well, from NRT observation of blockages effecting immediately any traffic and the safety of the waterway users up to observations over time (e.g. erosion). As for the monitoring of infrastructure in the case of extreme weather events, more regular updates in the hours are needed.
Type of service	Forecasting and monitoring
Other	Commercial shipping in the range of ECDIS scale: • Harbour conditions 1:4,000 - 1: 21,999 • Berthing conditions 1:>4,000 • Recreational tourism in the range of 1:4,000 - 1:21,999 Commercial shipping routes are usually well explored and mapped. Therefore, for commercial shipping especially elements usually not captured in those maps and occurring as short-term or seasonal obstacles are of interest. The dimension of obstacles can range from a few meters (e.g. single obstacles, sandbank) to larger areas (e.g. ice building). Accordingly, the spatial resolution must start in the meter range (VHR). For recreational users, the spatial resolution depends on the size/width of the waterway and can also start in the meter range. For applications related to the conditions of the waterway (e.g. erosion, impact of weather events, maintenance work) spatial resolution starts also in the meter range. Specific requirements are related to the aspects effecting the safety of goods and lives. Therefore, reporting on related aspects like obstacles has to be available and reliable (avoiding false positives and false negatives). For recreational utilisation, all services related to safety of life have to be reliable as well (especially weather, flooding, fire risk).
Satellite EO Data Requirements	
Spatial resolution	VHR (<1 meter) to detect objects in size of leisure boats and kayaks.
Temporal resolution	Near Real Time (NRT), multiple times a day (every 6 hours)
Spectral resolution	N/A
Type of EO data needed	Optical, Radar, Meteorological
Other requirements	• For safe routing on fairways, it is necessary to include immediate warnings on obstructions, i.e. accident detection in real-time by other means other than satellite imagery. • Aerial data might be needed to complement VHR satellite data • Other satellites beyond Sentinels may be required, depending on the spatial resolution (meter range) as well as the temporal resolution (especially NRT detection of objects), to allow NRT detection of obstacles (e.g. Cosmo-SkyMed). • Data received from aerial, or satellite monitoring will have to be complemented by in-situ/ground measurements, e.g. water gauges regarding

	water levels, local observations from authorities, water samples to determine the water quality, specific harbour information (invasive species), etc. • AIS Data • Sentinel-1 (object detection, ice monitoring, deformation mapping, flood monitoring) • Sentinel 2 (Maritime Monitoring CMEMS) • Sentinel 3 (altimetry for narrow rivers and small lakes)

2.4.1.9 Autonomous surface vessels

Description of the sub-segment and application/operational scenario:

Autonomous surface vessels (ASV) represent a forward-looking sub-segment in the maritime and inland waterways industry, focusing on the development and operation of unmanned vessels. These vessels are equipped with sophisticated automation systems that enable them to operate independently, with minimal or no human intervention. The application of GNSS is crucial in this scenario, as it provides the high-precision positioning and timing information necessary for autonomous navigation and control.

Overview of user needs for the application

For users of autonomous surface vessels, the integration of GNSS and Secure SATCOM addresses several critical needs. Both technologies are considered as the key enablers for ASV. First and foremost is the need for high-precision navigation that GNSS provides, which is vital for accurate and safe navigation. The reliability and authentication of PNT is paramount, as any disruption could compromise safe navigation. Secure SATCOM is equally important, as it ensures that communication links are always available, resistant to interference, and secure from cyber threats, which is crucial for maintaining operational control and data integrity.

EO is expected to have a supporting role in ASVs, in combination with other sensors, provided it is validated and complies with existing regulations and performance standards. For the full situational awareness for ASVs operations, local on-board sensors were indicated as of the highest importance during the 2024 UCP event consultation. Users also require a high level of integration between GNSS, onboard sensors, and control systems to enable sophisticated autonomous capabilities. Furthermore, the scalability of these technologies is essential, allowing for their application across a diverse fleet of vessels with varying operational profiles.

Finally, users expect these systems to be compliant with maritime regulations and standards, ensuring that autonomous service vessels can safely coexist with traditional shipping traffic and contribute to the overall efficiency and safety of maritime operations. They do however stress that a combination of technologies will be needed to achieve sufficient performance levels in specific operations (such as locks and bridge passings).

User Needs and Requirements Relevant to GNSS

The GNSS requirements for Autonomous surface vessels are in line with the minimum requirements set out for Inland waterways navigation.

User Needs and Requirements Relevant to EO

The EO requirements for Autonomous surface vessels are in line with the minimum requirements set out for Inland waterways navigation.

User Needs and Requirements Relevant to SATCOM

The requirements below were discussed and validated and validated during the 2024 UCP event. The results showed that in terms of temporal resolution, multiple updates per day are needed for meaningful support to navigation.

Table 22: Preliminary SATCOM User Requirements for Autonomous Surface Vessels

Preliminary SATCOM User Requirements for Autonomous Surface Vessels	
ID: EUSPA-SAT-UR-MAR-0002	
Link Type: the type of communication for voice or data	Bi-directional data
Availability: a qualitative indication of the availability required of the communications system when the application is in use exceeding a certain quality of service.	High
Latency: The delay between action and reaction.	Low: immediate (e. g. <300ms)
Bandwidth (bit rate): a qualitative indication of the anticipated rate of data transfer when using the application.	Medium (order of MB)
Coverage: an indication of geographical area which can be reached by the service.	Local
Symmetry Up/Down: The ratio between the uplink traffic and the downlink traffic.	50/50
Distribution:	Multi-User: between a group of users, where a user can be a human or a system
Setup: a qualitative indication of the time to establish a voice or data communication session with the application that would be acceptable to a user and is sufficient to perform the railway operation.	Immediate
Speed: the speed that a user is travelling in, maximum value:	Low ≤40 Km/h
Security protection	The framework is currently still under development

2.4.1.10 Water level estimation

Description of the sub-segment and application/operational scenario:

The sub-segment of water level estimation in inland waterways is a critical area of focus for maintaining navigability and ensuring the safety of inland maritime traffic. EO plays a pivotal role in this application by providing accurate and timely data on water levels across extensive networks of rivers, canals, and lakes.

The operational scenario involves the use of satellite imagery and remote sensing techniques to monitor water levels, which can fluctuate due to natural phenomena such as precipitation, snowmelt, and droughts. Accurate water level estimation is essential for route planning, cargo management, and the prevention of accidents due to grounding or bridge strikes. EO technology enables authorities and vessel operators to make informed decisions about vessel drafts, loading capacities, and the timing of transits through inland waterways.

During the 2024 UCP event, the possibility of measuring river throughput was identified as a possible future tool in the monitoring of river discharge and prevention or mitigation toolbox of floods and extreme weather events. Also, the updating of ENC charts was further discussed as a potential elaboration on the current functionalities of EO in IWW management.

Overview of user needs for the application

Users involved in the management and operation of inland waterways have specific needs that EO technology addresses. High-resolution and up-to-date information on water levels is crucial for the safe and efficient movement of goods and passengers. Users require EO data to be accurate and reliable, as it directly impacts operational decisions and safety measures. The ability to predict water level changes is also essential, necessitating EO systems that can provide not only current data but also trend analysis and forecasting. Users need EO technology to be easily accessible and interpretable, allowing for quick integration into their existing waterway management systems. Furthermore, the capacity to monitor large areas and provide comprehensive coverage of all critical points along the waterways is a key user requirement. Finally, EO data must be consistent and compatible with international standards, ensuring that the information can be shared and utilised across different regions and by various stakeholders involved in inland waterway transportation.

User Needs and Requirements Relevant to EO

Table 23: Synthesis of Requirements Relevant to EO –Water level estimation

ID	EUSPA-EO-UR-MAR-005 EUSPA-EO-UR-MAR-006 EUSPA-EO-UR-MAR-007
Application	Water level estimation for inland waterways
Users	Waterways and Shipping Administration Commercial shipping companies (freight and passenger) Harbour master Local authorities
End Users Application Needs	
Operational scenario	Monitoring of IWW and port infrastructure in function of dynamic water levels related to (extreme) weather events, ice melting and prolonged dry seasons ENC updating and additional layer for the assessment of river bedding and monitoring of shorelines and infrastructure
Size of area of interest	A meter range for verification of buoys • A few meters for e.g. barges, bridges, erosion • 50m x10m for vessels • Larger areas (e.g. ice building).
Frequency of information needed	Event based for extreme weather events Daily for general monitoring Yearly for additional layer of ENC updating
Type of service	Continuous Monitoring, forecasting

Other	N/A
Satellite EO Data Requirements	
Spatial resolution	VHR, <1m
Temporal resolution	Multiple times a day in case of extreme events monitoring Monthly or quarterly for planning and preparedness purposes
Spectral resolution	N/A
Type of EO data needed	Optical, radar
Other requirements	N/A

2.4.1.11 Marine pollution monitoring

Description of the sub-segment and application/operational scenario:

Marine pollution monitoring is a crucial sub-segment within the maritime industry, focused on the detection and tracking of pollutants such as sargassum, oil, and plastics in the marine environment. EO is at the forefront of this application, employing satellite imagery and remote sensing to identify and quantify pollution over vast oceanic areas.

The operational scenario for EO in marine pollution monitoring involves the systematic scanning of water bodies to provide timely alerts on pollution events, facilitating rapid response and mitigation efforts. This is particularly important for managing the impact of sargassum blooms, oil spills, and the accumulation of plastics, which can have devastating effects on marine ecosystems, coastal communities, and economic activities such as tourism and fishing. EO technology enables environmental agencies, maritime authorities, and cleanup operations to assess the scale of pollution, plan intervention strategies, and monitor the effectiveness of remediation efforts.

In addition, EO also allows the tracking and modelling of species populations and their movements in relation to marine pollution (see the user story of Sea Alarm below).

Overview of user needs for the application

Users engaged in marine pollution monitoring have a set of defined needs that EO technology can fulfil. High spatial and temporal resolution is essential for detecting and tracking various pollutants, especially in dynamic marine environments where conditions change rapidly. Users require EO data to be precise and dependable, as it forms the basis for critical decision-making in pollution response strategies. The ability to differentiate between types of pollutants, such as distinguishing oil from sargassum or identifying concentrations of plastics, is also a key need.

Users need EO systems that can integrate with other monitoring tools and data sources to provide a comprehensive understanding of pollution patterns and trends. Accessibility to EO data and analytics is important for users across different sectors, including government agencies, research institutions, and non-governmental organisations. Additionally, users expect EO technology to be adaptable and scalable, capable of monitoring pollution at both local and global scales. Lastly, users seek EO solutions that comply with environmental regulations and contribute to international efforts to combat marine pollution and protect ocean health.

User story: Sea Alarm

The threat of oil spills remains real to marine and coastal wildlife. Oiled wildlife incidents do not happen very frequently, but when they do, scenarios of impacted marine birds, turtles or mammals on the shore. Maritime risk profiles are also changing with the drive to decarbonise and the growth in alternative fuels such as low-sulphur oil, LNG and products such as ammonia or methanol. These new and alternative fuel types are more challenging to deal with, as they can involve serious safety and toxicity risks and they also behave differently on the water than oil, so traditional equipment and cleanup techniques may not work as well.

It is important for authorities and oil/shipping industry who may have to deal with marine pollution incidents to be able to predict where the oil or other pollutant is going, in order to protect coastal communities, marine wildlife & ecosystems and other socio-economic assets. Drones or aircraft overflights can also be used to identify and track pollutants, but these resources are not always available quickly and may be limited in their availability.

In case of an oil spill or spill of other product from a marine vessel, satellite imagery can assist to determine:

- Whereabouts of oil/pollutant in relation to position of observed marine/coastal wildlife or their known aggregation area
- Number estimations of groups of animals in relation to oil/pollutant location or expected location
- Monitoring of sea containers that have fallen off vessels.

Satellite data should be easily available to the authorities managing an emergency response, so the data can become part of the Common Operating Picture and be shared with all entities involved.

User Needs and Requirements Relevant to EO

Table 24: Synthesis of Requirements Relevant to EO –Marine pollution monitoring

ID	EUSPA-EO-UR-MAR-008 EUSPA-EO-UR-MAR-009 EUSPA-EO-UR-MAR-010
Application	Marine pollution monitoring
Users	Authorities NGOs Emergency and disaster management organisations
End Users Application Needs	
Operational scenario	Prevention, preparedness and response to marine environmental emergencies Localisation of animal groupings and their position in relation to oil and plastics Monitoring and prediction of algal blooms
Size of area of interest	Very large areas of the ocean as oil tends to dilute and spread, new types of oils (low sulphur oils) and other chemicals float sub-surface Shoreline for the localisations of large groups of animals Large areas for the monitoring and prediction of algal blooms
Frequency of information needed	An update every 12 hours is needed to accurately assess the movement of oil and animal flocks and predict the movement between the two A similar timeframe is needed for the monitoring of algal blooms, as they pose a threat to birds and other species

Type of service	Continuous monitoring and forecasting (for algal blooms)
Other	Weather data and current predictions help in assessing the potential location and spread of oils and chemicals in the ocean.
Satellite EO Data Requirements	
Spatial resolution	10m x10m for oil spills, which are identified through the reflection on the water 20cm x 20cm for the identification of animals, although less resolution is needed for the verification of large groups and flocks 10m x 10m for algal blooms
Temporal resolution	12h
Spectral resolution	N/A
Type of EO data needed	Optical
Other requirements	Availability for all responders

2.4.1.12 Dredging

Description of the sub-segment and application/operational scenario:

Dredging is the extraction of sediments from the bottom of waterbodies (e.g. rivers, harbours, coastline, etc.) to ensure that waterways and ports remain navigable. This application ensures that channels or shallow coastal areas can be safely navigated by ship traffic. The hydrographic maps of these waters are often out of date and not suitable to rely on by dredgers. A satellite-derived technique called **Satellite Derived Bathymetry (SDB)** can produce on-demand and up to date hydrographic maps that can be used by dredge companies to plan and manage their operations. SDB can produce on-demand and up to date hydrographic maps that can be used by dredge companies to plan and manage their operations. SDB is a method of surveying shallow waters and can be used to monitor and support dredging activities.

Multispectral images allow experts to measure both the depth of the water and to map the sub-sea surface to place reefs, vegetation and the nature of the seabed. In clear waters–- as is the case in tropical regions–- optical imagery acquired from satellites such as Sentinel 2 can "see" down to the sea bottom up to 25m of depth. Vice versa, areas with lack of clear waters (e.g. rivers do not represent an appealing use case for SDB. In contrast to other survey methods, SDB requires no mobilisation of persons or equipment. On top of allowing to survey extended and/or difficult to reach locations, it provides rapid access to bathymetric data and saves costs.

Satellite-derived turbidity data (stirred-up sediment from anthropogenic activities such as dredging) provide a reliable and cost-effective overview of turbidity plumes generated during dredging operations without the need for on-site field deployment. MSI can cover the area of operations pre, during and post dredging and measure the suspension of sediment, also by using historical data. GNSS in combination with PPP/RTK Positioning Techniques supplies high accuracy real-time positioning needed for dredging operations.

Overview of user needs for the application

In the framework of another contract (GSA/OP/09/16/Lot 3/SC10) that investigated Gaps and user needs in selected applications for EO data, one of which being dredging, an interview was held with the CEO of a leading optical remote sensing company. One of the main takeaways was that was found that Copernicus data is mostly being used to determine water quality by suspended materials and turbidity, as well as currents monitoring. The use of Copernicus raw data (combined with other data sources) is beneficial as it has global coverage, if free of charge and the imagery provided allows to monitor the improvement of the construction site.

The dredging Industry has different regulatory requirements, with different countries and applications. The regulatory aspect depends on the country, the location and the nature of the project. Here, the service provider must closely monitor the actual dredging operation (depth, plumes, etc.). to comply with contractual requirements.

User Needs and Requirements relevant to GNSS

IMO Resolutions do not state clearly the environment for Marine Engineering, so it was placed in the most general category as possible:

The user requirements relevant to GNSS for dredging operations are contained in the tables below.

Category 2

Category 2 is characterised by having 1 m horizontal accuracy requirement. It concerns Marine Engineering, construction, maintenance and management: cable and pipe laying; also, Offshore exploration and exploitation: Exploration, Appraisal drilling, Field development, Support to pro- duction, post-production.

Table 25: Synthesis of Requirements Relevant to GNSS – Dredging – Category 2.

ID	Description	Type	Source
EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) –– 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) –– 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) –– 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity, % over 3 hours)	Resolution IMO A.915(22) –– 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity, Alert limit)	Resolution IMO A.915(22) –– 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) –– 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27) [RD11])

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) –- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) –- 29/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 3

Marine Engineering falls under Category 3, which is characterised by having 0.1m horizontal accuracy requirement, although IMO Resolutions do not state clearly the environment for Marine Engineering. It was placed in the most general category as possible.

Table 26: Synthesis of Requirements Relevant to GNSS – Dredging – Category 3.

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0280	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability, % per 30 days)	Resolution IMO A.915(22) - 29/11/2001[RD8]
EUSPA-GN-UR-MAR-0290	The PNT solution shall provide 0.1 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0300	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0310	The service continuity (% over 3 hours) is not applicable to Category 3 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0320	The PNT solution shall provide a 0.25 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0330	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0332	The PNT solution shall have a time to alarm smaller than 6 s (LAESSI IWW applications	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0340	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk, per 3 hours)	Resolution IMO A.915(22)- 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0343	The PNT solution shall have an integrity risk smaller than 10-5 per 10 minutes (LAESSI mooring assistance)	Performance (Integrity – Integrity risk, per 10 minutes)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0344	The PNT solution shall have an integrity risk smaller than 10-5 per 1 hour (LAESSI conning display)	Performance (Integrity – Integrity risk, per 1 hour)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22)- 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0360	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22)- 29/11/2001 [RD8]

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

User Needs and Requirements relevant to EO

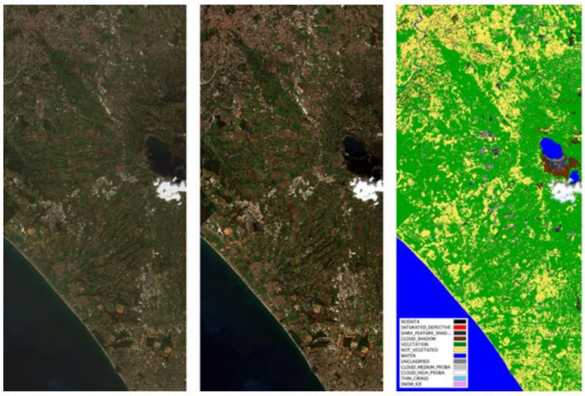
The application-level requirements relevant to EO are contained in the table below:

Table 27: Synthesis of Requirements Relevant to EO – Dredging

ID	EUSPA-EO-UR-MAR-011
Application	Dredging
Users	Dredging companies National Authorities (Maritime, Environmental)
End Users Application Needs	
Operational scenario	Dredging is an activity that ensures that channels or shallow coastal areas are navigable for recreational and/or large vessels. The hydrographic maps of these waters are often out of date and not suitable to rely on by dredgers. Satellite Derived Bathymetry (SDB) is the most recently developed method of surveying shallow waters, providing fast, reliable and cost-efficient access to bathymetric data.
Size of area of interest	Extremely variable, for instance: • Fluvial courses of Inland Waterways • Delta • Canals • Coastal regions
Frequency of information needed	For SDB only typically 1 a day up to several times a day. For water quality up to hundreds a day.
Type of service	Monitoring
Other	N/A
Satellite EO Data Requirements	
Spatial resolution	The spatial resolution achieved can reach up to 2 metres, depending on the underlying EO data used. Between 50 cm and 10 m typically.
Temporal resolution	Multiple sensors are used in parallel with harmonised products to comply with temporal resolution requirements.
Spectral resolution	N/A
Type of EO data needed	Altimeter, SAR data, Optical, Sentinel-2 and -3. DIAS satellite data Terra/MODIS SST,NSST, Lidar ICESAT, AWS VHR Commercial: Planet, Maxar, Airbus
Other requirements	Occasionally in-situ data measurements For each new sensor EO companies might have to develop an interface. Processing levels and the format of Sentinel-2 data represent the processing of data. Level-1C (Top-of-Atmospheric reflectance) and Level-2A (Bottom-of-Atmospheric reflectance) are the most commonly used products in land cover/use mapping. At level 2A data is accessible and utilised by all the users. BOA harmonisation with other data sources

requires Level 2 products. See example below with Sentinel Levels 1-C and 2A products[8]:

Figure 5: Comparison of Sentinel images for Dredging



The figure shows from left to right: (1) Sentinel-2 Level-1C TOA reflectance input image, (2) the atmospherically corrected Level-2A BOA reflectance image, (3) the output scene classification of the Level-1C product.

2.4.1.13 Marine surveying and mapping

Description of the sub-segment and application/operational scenario:

This application covers a wide range of GNSS and EO-enabled activities (seabed exploration, tide and current estimation, offshore surveying, etc.); the outcomes of these surveys are very important for maritime navigation. Satellite technology uses radar and multi-spectral analysis to survey and map data on ocean heights and, as a result, helps to interpret gravity and bathymetry for the Earth's oceans. Satellite-derived bathymetry (SDB) in particular, is the most recently developed method of surveying shallow waters. In contrast to other survey methods, SDB requires no mobilisation of persons or equipment. SDB provides rapid access to bathymetric data and saves costs.

- *Hydrography* provides data for charting seas and inland waterways and adjacent topography. The provision of hydrographic information adequate to support the safety of navigation is a national obligation under the SOLAS convention. The determination of position and depth sounding information must be undertaken with sufficient accuracy to ensure safety of navigation.
- *Oceanography* is a scientific application concerned with identifying and understanding the behaviour of the ocean, mapping their boundaries (extent and depth), their geology, the physics and chemistry of their waters, their biology and both the conservation and the exploitation of their resources. Both horizontal and vertical accuracy are required, together with global coverage.

Overview of user needs for the application

Users involved in marine surveying and mapping, such as hydrographers, geophysicists, and marine biologists, have specific needs that EO and GNSS technologies address. They require high-resolution and accurate GNSS positioning to ensure that survey data are precisely georeferenced, enabling the creation of reliable marine charts and maps. Real-time GNSS information is crucial for guiding survey vessels and remotely operated vehicles during data collection operations. Users need EO technology to provide a macro view of the marine environment, including surface conditions and large-scale phenomena that may impact surveying activities. The integration of GNSS and EO data with survey instruments, such as multibeam echosounders and side-scan sonars, is essential for the comprehensive analysis and visualisation of marine

[8] https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-2

data. Users prioritise the ability of these technologies to operate effectively in a range of marine settings, from shallow coastal areas to deep ocean basins. Additionally, users expect GNSS and EO solutions to support the adherence to international standards for hydrographic surveying and marine mapping. Lastly, users demand robust technical support and maintenance services to ensure the continuous and effective operation of GNSS and EO systems, which are vital for the accuracy and success of marine surveying and mapping endeavours.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS for hydrography and oceanography are contained in the tables below. Hydrography Environment was not clearly stated in IMO Resolutions, so this application was considered to be in the most general environment category as possible.

Please also refer to section A.8.9 IHO requirements for GNSS requirements for nautical charts. IHO Standard 44 specifies the minimum standards to be achieved depending on the intended use, but national hydrographic offices and organisations may still establish more stringent or specific requirements.

Category 1+++

Oceanography falls under Category 1+++, which differs from the general Category 1 in that the vertical accuracy must be of 10m. Even though Oceanography application did not have its environment clearly defined in IMO Resolutions, it is placed in Ocean environment because it describes the application more accurately than placing it in a more general environment category.

Requirements are identical to Category 1, except the following:

Table 28: Synthesis of Requirements Relevant to GNSS – Marine Surveying and Mapping – Category 1+++.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0110	The PNT solution shall provide 10 m vertical positioning accuracy (95%)	Performance (Accuracy Vertical)	Resolution IMO A.915(22) – 29/11/2001 [RD8]

Category 2+++

Hydrography falls under Category 2+++. This category presents the same requirements as of those in category 2, except for the horizontal accuracy, which varies from 1 to 2m, the vertical accuracy must be of 0.1m, and the alert limit, which needs to be between 2.5 and 5m in the horizontal axis.

Requirements are identical to Category 2, except the following:

Table 29: Synthesis of Requirements Relevant to GNSS – Marine Surveying and Mapping – Category 2+++.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR -0184	The PNT solution shall have an integrity risk smaller than 10-5 per 2 minutes (LAESSI bridge warning)	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR- MAR-0250	The PNT solution shall provide 1 to 2 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) – 29/11/2001 [RD8]

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0260	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) – 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0270	The PNT solution shall provide a 2.5 to 5 m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) – 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]

User Needs and Requirements relevant to EO

During the UCP2022, hydrographic surveys were discussed in detail. The IHO S-100 standard, the Universal Hydrographic Data model, and IHO S-44 standard that defines the standard applicable to hydrographic surveys, were identified as the two main sources relevant for bathymetry.

Bathymetric maps contain information on the depths and shape of the seabed, which is relevant to support the conservation of the oceans, support a sustainable use of marine resources, and to determine safe fairways along coastlines. Consequently, SDB is increasingly being used for synoptic mapping of coastal regions.

The S-100 Standard is a framework document for the development of digital products/services for hydrographic, maritime and geographic information systems (GIS). S-100 comprises multiple parts that are based on the geospatial standards developed by the International Organisation for Standardisation, Technical Committee 211 (ISO/TC211). The IHO matrix S44 tries to map errors for each depth, so that evaluation can be made based on this S44 matrix. The matrix of parameters and data types to define realisations of survey standards and specifications is not intended to be understood as a standard as such; It can, however, serve as a reference to specifying dedicated surveys and provide a tool for a broader classification.

More concretely, and returning to the discussions at the UCP2022, the EO user requirements identified for SDB in particular are:

- The spatial resolution of 10 metres is enough for SDB, as it would allow measurements to go from 0 to 30 m depth.
- A spatial resolution of 2.5 metres would be desirable for bathymetry applied to IWW.

The requirements as discussed above are reflected in the EO requirements table presented under dredging.

2.4.1.14 Automated port operations

Description of the sub-segment and application/operational scenario:

Automated port operations represent a rapidly advancing sub-segment in the maritime industry, focusing on the use of technology to streamline and enhance the efficiency of port activities. This application encompasses the deployment of automated systems and machinery, such as cranes, guided vehicles, and drones, all integrated through advanced software platforms to manage cargo handling, vessel loading and unloading, and yard operations with minimal human intervention. The operational scenario for automated port operations includes the precise coordination of various tasks to optimise the flow of goods, reduce turnaround times, and increase overall port throughput. GNSS technology is integral to these operations, providing accurate positioning data that is essential for the synchronisation and navigation of automated equipment within the complex port environment.

Overview of user needs for the application

GNSS positioning supports automation of operations at ports and intermodal hubs. Port operation applications are restricted to activities associated directly to the vessels themselves, including for example:

- Local Traffic Management
- Container and cargo tracking and asset management
- Law enforcement activities
- Cargo handling

The requirements such as accuracy and coverage need to be adjusted to meet the specific port environment, and a vertical dimension may be required.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS are contained in the table below:

Category 3++

Cargo handling operations fall under Category 3++. This Category is the same as 3 + stringent Time to Alarm requirement. The main difference between this category and Category 3 regards integrity, since the time to alarm must be smaller than 1s.

Requirements are identical to Category 3, except the following:

Table 30: Synthesis of Requirements Relevant to GNSS – GNSS Automated Port Operations – Category 3++.

ID	Description	Type	Source
EUSPA-GN-URMAR-0400	The PNT solution shall have a time to alarm smaller than 1 s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

2.4.1.15 Piloting assist at ports

Description of the sub-segment and application/operational scenario:

EO data on port traffic and MetOcean conditions is used to complement in situ data to support Vessel Traffic Management, enabling safer and more efficient piloting of vessels in busy port environments. Real-time navigation information (based on GNSS) provides pilots with greater control, safety and accuracy during port approach and manoeuvres.

Feedback gathered at the UCP2022 found that the main contribution of EO data to port operations was found in both MetOcean and bathymetry. Both aspects were very important and expected to become part of day-to-day port operations.

Overview of user needs for the application

Users involved in automated port operations have specific needs that GNSS technology addresses. They require highly accurate and reliable positioning information to ensure the precise movement and operation of automated machinery. Real-time GNSS data is essential for the seamless coordination of equipment, allowing for synchronised operations and the prevention of collisions or mishaps. Users need GNSS systems that can integrate with port operation software to facilitate the efficient management of cargo and resources. The scalability of GNSS solutions is crucial to support the expansion and upgrading of automated systems as port demands grow. Users also prioritise the resilience and robustness of GNSS technology, as it must perform consistently in a range of environmental conditions and amidst potential signal obstructions found in ports.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS are contained in the tables below. It can be noted however that Port and Lock approach, Track control, Calamity Abatement and Fairway information system were applications cited in MARUSE and RIS Regulation referring to Vessel Track & Trace in Inland Navigation, which could possibly be added in this category because of the 1m horizontal accuracy requirement and the environment which includes inland waterways and ports and their approaches.

Category 1+

General navigation (SOLAS); Coastal, Port approach and entrances fall under Category 1+. Category 1+ differs from 1 in that there is a regional continuity requirement. Requirements are identical to Category 1, except the following:

Table 31: Synthesis of Requirements Relevant to GNSS – Piloting Assist at Ports– Category 1+.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (iECDIS navigation mode req.)	Performance (Accuracy Horizontal)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) - 20/12/2011 [RD11]

Category 2

Category 2 is characterised by having 1 m horizontal accuracy requirement. Port Operations: Local VTS and Casualty Analysis: Port approach fall under this category.

Table 32: Synthesis of Requirements Relevant to GNSS – Piloting Assist at Ports– Category 2.

ID	Description	Type	Source
EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22)–-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22)–-29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %	Resolution IMO A.915(22) –29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22)–-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity, Alert limit)	Resolution IMO A.915(22)–-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22)–-29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27) [RD11])
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity, Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22)–-29/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2+

Operations of Locks, Tugs, Pushers and Icebreakers and General navigation (SOLAS): Ports and Restricted Waters fall under Category 2+. This category presents the same main requirements as Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage. Requirements are identical to Category 2, except the following:

Table 33: Synthesis of Requirements Relevant to GNSS – Piloting Assist at Ports– Category 2+.

ID	Description	Type	Source
EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11] Regulation (EC) No 415/2007 [RD39]

* Resolution IMO A.1046(27) 20/12/2011 states exactly: "When the system is available, the service continuity should be ≥99.97% over a period of 15 minutes.

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

User Needs and Requirements relevant to EO

The main contribution of EO data to port operations and piloting assists are found in both MetOcean and bathymetry. The latter is described in the EO requirements set out under dredging and not repeated under this section.

2.4.1.16 Port operations (port-based navigation)

Description of the sub-segment and application/operational scenario:

This application involves the use of GNSS for precise positioning and timing information, which is critical for various aspects of port management, including vessel berthing, cargo handling, and logistics coordination. Operational scenarios where GNSS plays a key role include the navigation of ships into and out of port, the synchronisation of loading and unloading schedules, and the tracking of cargo and equipment within the port area. The integration of GNSS with other port operation systems, such as terminal operating systems (TOS) and vessel traffic services (VTS), streamlines processes and improves the throughput of goods, ultimately boosting port competitiveness.

PPUs are sophisticated, portable navigation aids used by maritime pilots to assist in the manoeuvring of vessels during berthing and unberthing processes. These devices utilise GNSS technology to provide precise positioning, speed, and heading data, which are critical for making informed decisions in the confined and often congested spaces of a port. Operational scenarios for PPUs and port navigation devices include piloting large vessels into docks, coordinating the movement of multiple ships within a port, and managing the logistics of cargo operations. The integration of GNSS with these devices ensures high levels of accuracy and reliability, which are paramount for the smooth functioning of port activities and the prevention of accidents.

Overview of user needs for the application

Accurate and reliable positioning data is essential for the precise manoeuvring of vessels during docking and undocking procedures, ensuring safety and preventing collisions or infrastructure damage. Users require real-time GNSS data for the efficient scheduling and execution of cargo handling operations, which can minimise turnaround times and reduce operational costs. The ability to integrate GNSS data with port operation software and equipment is a key user need for seamless workflow management. Users also prioritise the scalability of GNSS solutions to accommodate future growth and technological advancements within the port. Furthermore, users seek GNSS technology that is compatible with international standards and regulations, ensuring consistent operations across global supply chains. Lastly, users demand robust GNSS systems that can operate effectively in the complex and often congested environment of a port, providing uninterrupted service for continuous port activities.

User Needs and Requirements relevant to GNSS

It can be noted however that Port and Lock approach, Track control, Calamity Abatement and Fairway information system were applications cited in MARUSE and RIS Regulation referring to Vessel Track & Trace in Inland Navigation, which could possibly be added in this category because of the 1m horizontal accuracy requirement and the environment which includes inland waterways and ports and their approaches.

This category includes Port approach and entrances; Traffic management; Ship to ship coordination, Ship to shore coordination and Shore to ship traffic management; Operations: automatic collision avoidance and track control; Port Operations: Local VTS; Casualty Analysis: Port approach.

The user requirements relevant to GNSS for Port-based port navigation devices are contained in the tables below:

Category 1+

Category 1 requires 10 m of horizontal accuracy, with Category 1 + incorporating a regional continuity requirement. Requirements are identical to Category 1, except the following:

Table 34: Synthesis of Requirements Relevant to GNSS – Port operations – Category 1+.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (iECDIS navigation mode req)	Performance (Accuracy Horizontal)	A critical look at the IMO requirements for GNSS
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) 20/12/2011 [RD8]

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

Category 2

Category 2 is characterised by having 1 m horizontal accuracy requirement. Local VTS is the only one to require local coverage, instead of regional.

Table 35: Synthesis of Requirements Relevant to GNSS – Port operations – Category 2.

ID	Description	Type	Source
EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22)–- 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % overn3 hours)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity, Alert limit)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27)[RD11])
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity, Integrity risk per 3 hours)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters

Category 2++

Category 2++ is characterised by having local 1m vertical accuracy requirement). Ports operations: Container / Cargo management & Law enforcement is classified under this Category by IMO.

It can be noted however that Port and Lock approach, Track control, Calamity Abatement and Fairway information system were applications cited in MARUSE and RIS Regulation referring to Vessel Track & Trace in Inland Navigation, which could possibly be added in this cate- gory because of the 1m horizontal accuracy requirement and the environment which includes inland waterways and ports and their approaches.

Requirements are identical to Category 2, except the following:

Table 36: Synthesis of Requirements Relevant to GNSS – Port operations – Category 2++.

ID	Description	Type	Source
EUSPA-GN-URMAR-0230	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0240	The PNT solution shall provide 1 m vertical positioning accuracy	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

Please note that according to the resolution IMO A.915 Coverage is a service level parameter.

Category 3+

Docking operations fall under Category 3+. This Category is the same as 3 + continuity requirement, – (without) vertical accuracy. Vertical accuracy is not applicable and concerning continuity, this is described as 99.97% at least over 15min, by IMO Resolution A.1046 (27).

IMO Resolutions consider a possible need for a vertical accuracy requirement for some port and restricted waters operations.

Requirements are identical to Category 3, except the following:

Table 37: Synthesis of Requirements Relevant to GNSS – Port operations – Category 3+.

ID	Description	Type	Source
EUSPA-GN-URMAR-0370	The vertical positioning accuracy is not applicable for Category 3+ applications	Performance (Accuracy Vertical 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0380	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11]
ID: EUSPA-GN-UR-MAR-0390	The Accuracy of SOG is 0.1m/s	Performance (Accuracy of SOG)	IEC-61108-3 – 26/05/2010

* Resolution IMO A.1046(27) 20/12/2011 states exactly: "When the system is available, the service continuity should be ≥99.97% over a period of 15 minutes." Please note that according to the resolution IMO A.915 Continuity is a service level parameter.

Category 3++

Cargo handling operations fall under Category 3++. This Category is the same as 3 + stringent Time to Alarm requirement. The main difference between this category and Category 3 regards integrity, since the time to alarm must be smaller than 1s.

Requirements are identical to Category 3, except the following:

Table 38: Synthesis of Requirements Relevant to GNSS – Port operations – Category 3++.

ID	Description	Type	Source
EUSPA-GN-URMAR-0400	The PNT solution shall have a time to alarm smaller than 1 s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

2.4.1.17 Port safety

Description of the sub-segment and application/operational scenario:

Port safety is a critical sub-segment within the maritime industry, focusing on the protection of people, vessels, infrastructure, and the environment within the port area. This application involves the implementation of safety protocols, surveillance systems, and emergency response strategies to prevent accidents and security breaches. Operational scenarios for port safety include vessel traffic management, hazardous cargo handling, fire prevention and control, and pollution response. The use GNSS, along with other navigational aids such as radar and AIS, is essential for monitoring vessel movements and ensuring they maintain safe distances from each other and port structures.

Overview of user needs for the application

EO data provides an overview of port traffic and berth estimations, allowing for risk models to be created. These assess the risk of damage at the port cause by adverse events such as extreme weather, congestion or oil spills. This enables port officials to take risk mitigation measures and to plan for safety when developing port infrastructures. The safety of port terminal operations is ensured by GNSS positioning information.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS are contained in the tables below.

Category 1+

General navigation (SOLAS); Coastal, Port approach and entrances fall under Category 1+. Category 1+ differs from 1 in that there is a regional continuity requirement. Requirements are identical to Category 1, except the following:

Table 39: Synthesis of Requirements Relevant to GNSS – Piloting Assist at Ports– Category 1+.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (iECDIS navigation mode req.)	Performance (Accuracy Horizontal)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) - 20/12/2011 [RD11]

Category 2

Category 2 is characterised by having 1 m horizontal accuracy requirement. Port Operations: Local VTS and Casualty Analysis: Port approach fall under this category.

Table 40: Synthesis of Requirements Relevant to GNSS – Piloting Assist at Ports– Category 2.

ID	Description	Type	Source
EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22)–- 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %	Resolution IMO A.915(22) –29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity, Alert limit)	Resolution IMO A.915(22)–- 29/11/2001 [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22)–-29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27) [RD11])
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity, Integrity risk per 3 hours)	Resolution IMO A.915(22)–-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22)–-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22)–-29/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2++

Law enforcement falls under Category 2++. This Category presents the same main requirements as Category 2, except that the vertical accuracy requirement is 1m local.

Requirements are identical to Category 2, except the following:

Table 41: Synthesis of Requirements Relevant to GNSS – Port Safety Category 2++.

ID	Description	Type	Source
EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22)–-29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11] Regulation (EC) No 415/2007 [RD39]

Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

Category 3++

Cargo handling operations fall under Category 3++. This Category is the same as 3 + stringent Time to Alarm requirement. The main difference between this category and Category 3 regards integrity, since the time to alarm must be smaller than 1s. Requirements are identical to Category 3, except the following:

Table 42: Synthesis of Requirements Relevant to GNSS – Port Safety – Category 3++.

ID	Description	Type	Source
EUSPA-GN-URMAR-0400	The PNT solution shall have a time to alarm smaller than 1 s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22)–-29/11/2001 [RD8]

2.4.1.18 Port security

Description of the sub-segment and application/operational scenario:

EO data contributes to enhanced situational awareness with the goal to prevent crime or any illicit good entering or exiting the country. High resolution SAR data for instance enables port authorities to access most recent information on changes in cargo and passenger ports, tracking vessels, estimating amount of stored goods. EO imager and other remote sensing technologies can play a significant role in ocean surveillance by being able to track vessels and detection changes at key ports, and trigger response actions when unusual activities, security breaches or other threats are affecting ports' perimeters. Port authorities and maritime agencies and use EO imagery and derived services for round the clock observation and can also use it to support the investigation of irregular activities, such as smuggling of (illegal) goods, of persons and similar criminal activities.

Overview of user needs for the application

Users involved in port security operations have a set of defined needs that GNSS technology can address. They require accurate and reliable positioning data to track the movement of assets and personnel within the port, ensuring that security resources are deployed effectively. Real-time GNSS information is essential for maintaining situational awareness and responding swiftly to potential security incidents. Users need GNSS systems to be integrated with other security technologies, such as CCTV, radar, and access control systems, to create a layered security approach. The resilience of GNSS technology is crucial, as it must function consistently in various environmental conditions and resist potential jamming or spoofing attempts. Users also prioritise the interoperability of GNSS with communication networks to facilitate the exchange of security-related information between different agencies and stakeholders. Additionally, users expect GNSS solutions to adhere to international security standards and regulations, reinforcing the port's defence against threats. Lastly, users demand reliable technical support and robust maintenance services to ensure the uninterrupted operation of GNSS systems in supporting port security measures.

The analysis of the user needs and requirement for port security is still at an explorative stage and therefore not further elicited in this report.

2.4.1.19 Recreational navigation

Description of the sub-segment and application/operational scenario:

Recreational navigation is a sub-segment within the maritime industry that caters to leisure activities such as yachting, sailing, powerboating, and personal watercraft use. This application involves the use of navigational aids and technologies to ensure the safety and enjoyment of individuals engaging in marine recreation. Operational scenarios for recreational navigation include coastal cruising, offshore voyages, regattas, and fishing trips. GNSS technology is central to recreational navigation, providing boaters with accurate positioning, waypoint marking, and route planning capabilities. GNSS data assists in avoiding hazards, adhering to maritime regulations, and exploring new areas with confidence. The integration of GNSS with other systems like chart plotters, fish finders, and autopilot systems enhances the overall navigation experience for recreational mariners.

Overview of user needs for the application

GNSS-based systems for maritime navigation are widespread not only across commercial, but also recreational vessels. They are used both for overseas and high traffic areas.

Recreational navigation's demands for GNSS are comparable to those of commercial traffic for general navigation. The level of penetration of these devices in recreational vessels depends mainly on the cost of equipment and the availability of an accurate and easy to use navigation system.

User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS for general navigation (recreation and leisure), ocean and coastal; are contained in the tables below:

Category 1

This category is characterised by requiring 10 m of horizontal accuracy (up to 100 m for the specific case of Ocean waters in Resolution IMO A.1046(27)).

Table 43: Synthesis of Requirements Relevant to GNSS – Recreational navigation – Category 1.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0010	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0020	The PNT solution shall provide 10 m horizontal positioning accuracy (95%) (up to 100 m for Ocean waters)	Performance (Accuracy Horizontal)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0030	Continuity is not relevant to ocean and coastal navigation Type: Performance (Continuity % over 3 hours)	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity, Alert Limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 [RD11])
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity, Time to Alert)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0060	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity Risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 [RD11])

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval-seconds)	Resolution IMO A.1046(27) 20/12/2011 [RD11]

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2

Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance) fall under Category 2, which is characterised by having 1 m horizontal accuracy requirement.

Table 44: Synthesis of Requirements Relevant to GNSS – Recreational navigation – Category 2.

ID	Description	Type	Source
EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity, Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 (27) [RD11])

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity, Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) - 9/11/2001 [RD8]

*Except Local VTS which requires only a local coverage.
Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2+

General navigation (recreation and leisure): Ports and restricted waters falls under Category2+.This category presents the same main requirements as Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage. Requirements are identical to Category 2, except the following:

Table 45: Synthesis of Requirements Relevant to GNSS – Recreational navigation – Category 2+.

ID	Description	Type	Source
EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22)–-29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]
ID: EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11] Regulation (EC) No 415/2007 [RD39]

* Resolution IMO A.1046(27) 20/12/2011 states exactly: "When the system is available, the service continuity should be ≥99.97% over a period of 15 minutes.
Please note that according to the resolution IMO A.915 Continuity and Coverage are service level parameters.

2.4.1.20 Dark vessel monitoring

Description of the sub-segment and application/operational scenario:

GNSS-enabled Long-Range Identification and Tracking (LRIT) as well as the Automated Identification System (AIS) or Vessel Monitoring Systems (VMS) provide the means to identify and track suspicious vessels. When those vessels intentionally turn off disable their AIS or VMS, EO data is still able to provide enhanced situational awareness that can be used by maritime authorities to monitor and track so-called dark vessels by the enhanced use EO imagery and SAR data.

Overview of user needs for the application

Listing GNSS requirements for this application would be an oxymoron. The IMO Convention for the Safety Of Life At Sea (SOLAS) Regulation V/19.2. 4 requires all vessels of 300 GT and above engaged on international voyages and all passenger ships, irrespective of size, to carry AIS onboard. The AIS is a critical collision avoidance tool. However, if the master believes that the continual operation of AIS might compromise the safety/security of the ship or security incidents are imminent, such as piracy, the AIS may be switched off.

The analysis of the user needs and requirement for dark vessel monitoring is still at an explorative stage and therefore not further elicited in this report.

2.4.1.21 Maritime Search and Rescue operations

Description of the sub-segment and application/operational scenario:

Maritime search and rescue (SAR) operations form a critical sub-segment within the maritime industry, dedicated to saving lives and providing aid to those in distress at sea. This application involves coordinated efforts by SAR organisations, coast guards, and naval forces to locate and assist vessels, aircraft, or individuals facing emergency situations in marine environments. Operational scenarios for maritime SAR include responding to distress signals, coordinating rescue efforts during severe weather events, and executing medical evacuations. GNSS is a cornerstone of SAR operations, offering precise and reliable positioning data that is crucial for the rapid and accurate deployment of rescue assets. GNSS facilitates the efficient search of vast ocean areas, enhances the tracking of rescue units, and assists in the navigation to and from the rescue site.

Overview of user needs for the application

During SAR operations, individuals in distress ideally activate a SAR beacon, which emits a signal that is detected by the COSPAS-SARSAT international satellite system for search and rescue. While the user needs for SAR beacons themselves are specifically addressed by COSPAS-SARSAT protocols and requirements, the focus here is on the user needs related to the approach and assistance provided by vessels bringing aid, such as Coast Guard ships or nearby vessels equipped with GNSS technology.

Distress or emergency beacons are lightweight device that are use GNSS to alert and connect to the Rescue Coordination Centre in the event of an emergency. It is a potentially lifesaving piece of equipment that skippers carry onboard of their vessel. Upon activation in an emergency, beacons broadcast a signal via satellite that includes the GNSS coordinates to facilitate the intervention of SAR (Search and Rescue) responders.

There are several types of beacons, most notably:

- An emergency position-indicating radio beacon (**EPIRB**) is a portable emergency locator beacon for commercial and recreational boats to alert search and rescue services (SAR).
- A Personal locator beacon (**PLB**) is a portable device sends an SOS satellite signal to rescue agencies, along with positioning coordinates.
- Ship security alert systems (**SSAS**) consist of a discreet switch/button on the ship that can be used by seagoing vessels to discreetly inform authorities of an attack.

COSPAS-SARSAT is an international satellite system that assists in locating distress signals from GNSS-enabled emergency beacons used by aircraft, ships, and individuals in distress. These beacons transmit their location, derived from GNSS systems to COSPAS-SARSAT satellites, which then relay the information to search and rescue authorities. Technical notes T001[9] and T018[10] contain specific requirements for the beacons and their interaction with the COSPAS-SARSAT system, detailing design, operation, and testing procedures. These documents are available through the COSPAS-SARSAT Programme for those needing detailed technical information.

Users involved in the aid-providing aspect of SAR operations require GNSS technology to deliver highly accurate and reliable positioning information to navigate swiftly and directly to the location indicated by the SAR beacon signal. They need real-time GNSS data to effectively coordinate with other rescue assets and to adjust their search patterns and rescue strategies based on the dynamic conditions at sea. The GNSS systems must be interoperable with SAR communication networks and equipment to ensure a seamless and integrated response. Resilience is crucial, as GNSS technology must provide consistent performance in adverse weather conditions and challenging maritime environments where SAR operations often take place. Users also prioritise GNSS compatibility with international SAR protocols to ensure compliance with established rescue procedures. Additionally, users expect GNSS solutions to facilitate the rapid relay of distress information and the efficient mobilisation of SAR resources. Lastly, robust technical support and maintenance services are essential to maintain the operational readiness of GNSS systems, which play a vital role in the life-saving efforts of maritime search and rescue operations.

User Needs and Requirements relevant to GNSS

As explained above, the user requirements in the following tables are not for the SAR beacons, but the actual approach of a vessel to a location known to be in distress (e.g. Vessel, man overboard, platforms, etc.):

Category 1

The initial rescue approach of Search and Rescue (the positioning of vessel, not the positioning of the beacon) falls under Category 1, which is characterised by requiring 10 m of horizontal accuracy (up to 100 m for the specific case of Ocean waters in Resolution IMO A.1046(27)).

Table 46: Synthesis of Requirements Relevant to GNSS – Search and Rescue, initial approach – Category 1.

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0010	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0020	The PNT solution shall provide 10 m horizontal positioning accuracy (95%) (up to 100 m for Ocean waters)	Performance (Accuracy Horizontal)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0030	Continuity is not relevant to ocean and coastal navigation Type: Performance (Continuity % over 3 hours)	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

[9] Via: https://www.scribd.com/document/282821649/Cospas-Sarsat-T-001-Oct2014

[10] Via: https://sar.mot.go.th/document/THMCC/T018-MAR-26-2021%20SPECIFICATION%20FOR%20SECOND-GENERATION%20COSPAS-SARSAT%20406-MHz%20DISTRESS%20BEACONS.pdf

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity - Alert Limit)	Resolution IMO A.915(22) [RD8] - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046 [RD11])
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s.	Performance (Integrity - Time to Alert)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0060	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity Risk – per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 [RD11])
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval-seconds))	Resolution IMO A.1046(27) 20/12/2011 [RD11]

Please note that according to the resolution IMO A.915 Accuracy and Integrity are system level parameters, whereas Availability, Continuity and Coverage are service level parameters.

Category 2

The final rescue approach of Search and Rescue falls under Category 2, which is characterised by requiring 1 m of horizontal accuracy (up to 100 m for the specific case of Ocean waters in Resolution IMO A.1046(27)).

Table 47: Synthesis of Requirements Relevant to GNSS – Search and Rescue, initial approach – Category 2.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007 [RD39]

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 Hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0170	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR- MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

2.5 User Requirements Specification

The chapter provides a synthesis of the requirements described in section 2.4. The content of this section will be updated, completed, and expanded by EUSPA in the next releases of the RUR based on the results of further investigations discussed and validated in the frame of the UCP.

As this document is mostly based on interviews, the requirements come from the feedback from experts and various UCP participants.

2.5.1 Synthesis of Requirements Relevant to GNSS

GNSS performance requirements are organised per the following categories:

Category 1

Table 48: Synthesis of Requirements Relevant to GNSS – Category 1

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0010	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0020	The PNT solution shall provide 10 m horizontal positioning accuracy (95%) (up to 100 m for Ocean waters)	Performance (Accuracy Horizontal)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0030	Continuity is not relevant to ocean and coastal navigation Type: Performance (Continuity % over 3 hours)	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity - Alert Limit)	Resolution IMO A.915(22) - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046) [RD8]
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity - Time to Alert)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0060	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity Risk –per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046) [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval in seconds)	Resolution IMO A.1046(27) 20/12/2011 [RD8]

Category 1+

Table 49: Synthesis of Requirements Relevant to GNSS – Category 1+

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0022	The PNT solution shall provide less than 5 m horizontal positioning accuracy with detection on errors > 3 σ within 30 seconds integrity (in ECDIS navigation mode	Performance (Accuracy Horizontal)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
ID: EUSPA-GN-UR-MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0100	The PNT solution shall have a continuity of 99.97 % over 15 minutes	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) 20/12/2011 [RD11]

Category 1++

Table 50: Synthesis of Requirements Relevant to GNSS – Category 1++

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0101	The PNT solution shall provide 3 m horizontal positioning accuracy (95%)	Performance (Accuracy Horizontal)	MARUSE + UCP 2017

Category 1+++

Table 51: Synthesis of Requirements Relevant to GNSS – Category 1+++

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0110	The PNT solution shall provide 10 m vertical positioning accuracy (95%)	Performance (Accuracy Vertical)	Resolution IMO A.915(22) – 29/11/2001 [RD8]

Category 2

Table 52: Synthesis of Requirements Relevant to GNSS – Category 2

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1 m horizontal positioning accuracy	Performance (Accuracy Horizontal - 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007
ID: EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5 m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) [RD8] - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046 (27)
ID: EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk per 3 hours	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

Category 2+

Table 53: Synthesis of Requirements Relevant to GNSS – Category 2+

ID	Description	Type	Source
ID: EUSPA-GN-URMAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007
ID: EUSPA-GN-UR-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 Regulation (EC) No 415/2007

Category 2++

Table 54: Synthesis of Requirements Relevant to GNSS – Category 2++

ID	Description	Type	Source
EUSPA-GN-URMAR-0230	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0240	The PNT solution shall provide 1 m vertical positioning accuracy	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001- [RD8]

Category 2+++

Table 55: Synthesis of Requirements Relevant to GNSS – Category 2+++

ID	Description	Type	Source
ID: EUSPA-GN-UR - MAR-0184	The PNT solution shall have an integrity risk smaller than 10-5 per 2 minutes (LAESSI bridge warning)	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting [RD56]
ID: EUSPA-GN-UR-MAR-0250	The PNT solution shall provide 1 to 2 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0260	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
			User Consultation platform 2022 – Minutes of Meeting [RD57]
ID: EUSPA-GN-UR-MAR-0270	The PNT solution shall provide a 2.5 to 6m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8] Regulation (EC) No 415/2007

Category 3

Table 56: Synthesis of Requirements Relevant to GNSS – Category 3

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0280	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability, % per 30 days)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0290	The PNT solution shall provide 0.1 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0300	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0310	The service continuity (% over 3 hours) is not applicable to Category 3 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0320	The PNT solution shall provide a 0.25 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0330	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0332	The PNT solution shall have a time to alarm smaller than 6 s (LAESSI IWW applications	Performance (Integrity – Time to Alarm)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0340	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity – Integrity risk, per 3 hours)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0343	The PNT solution shall have an integrity risk smaller than 10-5 per 10 minutes (LAESSI mooring assistance)	Performance (Integrity – Integrity risk, per 10 minutes)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0344	The PNT solution shall have an integrity risk smaller than 10-5 per 1 hour (LAESSI conning display)	Performance (Integrity – Integrity risk, per 1 hour)	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel [RD56]
EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
EUSPA-GN-UR-MAR-0360	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22) - 29/11/2001 [RD8]

Category 3+

Table 57: Synthesis of Requirements Relevant to GNSS – Category 3+

ID	Description	Type	Source
EUSPA-GN-URMAR-0370	The vertical positioning accuracy is not applicable for Category 3+ applications	Performance (Accuracy Vertical 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0380	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity % over 15 min)	Resolution IMO A.1046(27) 20/12/2011 [RD11]
ID: EUSPA-GN-UR-MAR-0390	The Accuracy of SOG is 0.1m/s	Performance (Accuracy of SOG)	IEC-61108-3 – 26/05/2010

Category 3++

Table 58: Synthesis of Requirements Relevant to GNSS – Category 3++

ID	Description	Type	Source
EUSPA-GN-URMAR-0400	The PNT solution shall have a time to alarm smaller than 1 s	Performance (Integrity, Time to Alarm)	Resolution IMO A.915(22) –- 29/11/2001 [RD8]

2.5.2 Synthesis of Requirements Relevant to EO

ID	Application	Operational Scenario	Abstract of the Need & Requirement	Size of the area of interest	Smallest size of object to be observed	Challenges, gaps and opportunities	Spatial resolution	Temporal resolution	Type of EO data	Source
EUSPA-EO-UR-MAR-001	Ship route optimisation; Navigation through sea ice; MASS	Route planning and optimisation for container ships using the ECDIS	Need for reducing fuel consumption and emissions.	+1000 Nm	N/A	Need for harmonised data standards General lack of knowledge on EU development/innovation funds	1m to 100m	6h	Optical, radar, meteorological	EUSPA UCP 2024 Interviews Analysis, 2024 EUSPA UCP 2022 Report
EUSPA-EO-UR-MAR-002	Inland waterway navigation	Intelligent buoy management	Need for verification of buoy PNT	Fairway	1,5m x 1,5m	N/A	1,5m			EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-003	Inland waterway navigation	ENC updating	Need for assessment of river bedding and monitoring of shorelines and infrastructure	Fairway	1m	N/A	1m	N/A	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-004	Inland waterway navigation	Collision detection and ideal fairway determination	Need for monitoring of surrounding vessels and weather-related alarms	Urban areas: 250mx25m Non-urban areas: 2kmx25m	Buoy, kayak, waterski 2mx2m	N/A	2m	2,5sec	Optical	EUSPA UCP 2024 Interviews Analysis, 2024 EUSPA UCP 2022 Report
EUSPA-EO-UR-MAR-005	Water level estimation	Waterway infrastructure monitoring in function of water levels	Need for monitoring IWW and port infrastructure in function of dynamic water levels	Fairway	Barges: 12m	N/A	1m	1h	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-006	Water level estimation	Water level estimation in inland waterways.	Need for real-time references of water level, submersion levels, and actual vertical clearance of bridges	2kmx25m	Vessels >50m	Need for landside infrastructure to translate data (possibly via AIS)	50m	30min	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-007	Water level estimation	Monitoring of river discharge and throughput	Need for periodic reference and projections of river discharge	Fairway	N/A	N/A	N/A	N/A	N/A	EUSPA UCP 2024 Event, 2024

ID	Application	Operational Scenario	Abstract of the Need & Requirement	Size of the area of interest	Smallest size of object to be observed	Challenges, gaps and opportunities	Spatial resolution	Temporal resolution	Type of EO data	Source
EUSPA-EO-UR-MAR-008	Marine pollution monitoring	Prevention, preparedness and response to marine environmental emergencies	Need for monitoring of animal groupings	Shoreline for groupings of animals	Bird	N/A	20cm	12h	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-009	Marine pollution monitoring	Monitoring and prediction of algal blooms	Need for accurate visuals on ocean surface to monitor algal blooms	Extended areas	Reflection	N/A	10m	12h	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-010	Marine pollution monitoring	Monitoring of sargassum, oil and plastics	Need to identify and forecast the movement of oil spills	Extended areas	Reflection	New oils tend to dilute and sink lower in the water	10m	Daily	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-011	Dredging	Satellite Derived Bathymetry (SDB)	Users need regular updates of hydrographic maps and bathymetric data for the exploration and dredging operations in shallow coastal areas	Extremely variable, for instance: Fluvial courses of Inland Waterways Delta Canals Coastal regions	N/A	N/A	Up to 2 m, depending on the underlying EO data used.	For SDB typically 1x a day, up to several times a day. For water quality up to hundreds a day.	Optical, SAR, MODIS	EUSPA UCP 2022 Report

2.5.3 Synthesis of Requirements Relevant to SATCOM

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Challenges and gaps	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution	Source
EUSPA-SAT-UR-MAR-0001	Maritime Autonomous Surface Ships (MASS)	Communication for MASS operations	Bi-directional data	High	Worldwide	Immediate	Yes	Low ≤40 Km/h	Standards still under preparation by IMO, High cybersecurity threats	Low: immediate (e. g. <300ms)	Medium (order of MB)	50/50	Multi-User: between a group of users, where a user can be a human or a system	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-SAT-UR-MAR-0002	Autonomous Surface Vessels (ASVs)	Communication for ASVs operations	Bi-directional data	High	Worldwide	Immediate	Yes	Low ≤40 Km/h	Standards still under preparation by IMO, High cybersecurity threats	Low: immediate (e. g. <300ms)	Medium (order of MB)	50/50	Multi-User: between a group of users, where a user can be a human or a system	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-SAT-UR-MAR-0003	Connectivity at sea	Ensuring consistent high-quality communication channels	Bi-directional data	Aiming for high	Global	Only safety services have specific time requirements	Yes	N/A	N/A	N/A	All	50/50 for ship 80/20 for crew	Multi-User: between a group of users, where a user can be a human or a system	EUSPA UCP 2024 Interviews Analysis, 2024

3 ANNEXES

A.1 Definition of key EO performance parameters

This annex provides a definition of the most used EO performance parameters and includes additional details which are relevant for Road and Automotive community.

Spatial resolution refers to the level of detail and clarity in the images, specifically the size of the smallest discernible ground features. It is determined by the pixel size, which is the smallest unit in the image that represents a spatial area on the Earth's surface. Spatial resolution is usually measured in terms of meters per pixel. Thus, a spatial resolution of 1 meter means that each pixel represents a 1 by 1 meter area on the ground.

Spectral resolution refers to the ability of a sensor to differentiate electromagnetic radiation of different wavelengths. In other words, it refers to the number and “size” of wavelength intervals that the sensor is able to measure. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. In remote sensing, features (e.g. water, vegetation) can be characterised by comparing their “response” in different spectral bands.

Radiometric resolution expresses the sensitivity of the sensor, that is to say its ability to differentiate between different magnitudes of the electromagnetic energy. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object. The radiometric resolution is generally expressed in bit, e.g. an 8-bit image has a scale of 2^8=256 nuances.

Temporal resolution relates to the time elapsed between two consecutive observations of the same area on the ground. The higher the temporal resolution, the shorter the time between the acquisitions of two consecutive observations of the same area. In absolute terms, the temporal resolution of a remote sensing system corresponds to the time elapsed between two consecutive passes of the satellite over the exact same point on the ground (generally referred to as “revisit time” or “orbit cycle”). However, several parameters like the overlap between the swaths of adjacent passes, the agility of the satellites and in case of a constellation, the number of satellites mean that some areas of the Earth can be reimaged more frequently. For a given system, the temporal resolution can therefore be better than the revisit time of the satellite(s).

Geolocation accuracy refers to the ability of an EO remote sensing platform to assign an accurate geographic position on the ground to the features captured in a scene. An accurate geolocation makes easier the combination of several images (e.g. combination of a Synthetic Aperture Radar image with a cadastral map and a vegetation map).

Spectral range refers to the wavelength range of a particular channel or band over in which remote sensing data must be collected.

Latency is the difference between the reference time of the satellite measurement and the time the final product is made available to the user (here the service provider).

A.2 Additional EO definitions

Ground deformation monitoring is the process which consists in tracking the vertical and horizontal movements of the land surface and their dynamics, whatever these movements are caused by natural phenomena (e.g. volcanic activity) or by human activities (e.g. aquifer exploitation).

Change detection is the process which aims at identifying difference in the state of "objects" (e.g. bridges, constructions, urban areas) or of a phenomenon (e.g. deforestation, soil sealing) by comparing snapshots of the situation at different times. In Earth Observation, change detection is extensively based on satellite imagery obtained through a wide variety of sensors (e.g. optical, radar, infrared, microwave, etc.

Geodesy (see [RD3]) is the earth science of accurately measuring and understanding three of Earth's fundamental properties: its geometric shape, orientation in space, and gravitational field. The field also studies of how these properties change over time. Today, geodesy goes beyond that, being the geoscience that deals among other with the monitoring the solid Earth (which includes the monitoring of displacement, subsidence or deformation of the ground and structures due to tectonic, volcanic, and other natural phenomena as well as human activity.

Interferometric Synthetic Aperture Radar (InSAR) is a technique enabling to generate surface deformation maps based on the processing of SAR images captured at different moments in time. The processing uses the fact that if the ground has moved between the times of two SAR images of the same area, a slightly different portion of the wavelength is reflected to the satellite resulting in a measurable phase shift that is proportional to displacement. The processing therefore consists in obtaining information about the vertical movements of the ground surface by calculating the phase difference between the emitted radar signal and the signal backscattered by the surface for successive images. InSAR can potentially measure deformations of millimetre-scale during periods ranging from days to years.

Near-Real-Time (NRT) refers, when used in the context of EO applications, to applications/services/products for which the time delay between the occurrence of a given event and the availability of the outcomes of the processing of the Earth observation data corresponding to that event is considered as being not significant from a user perspective. The notion of "near real-time" is therefore depending on user requirements. For Earth observation, the corresponding time delays may range from a few hours to a few days depending on the application/service/product.

A.3 Definition of key GNSS performance parameters

This annex provides a definition of the most commonly used GNSS performance parameters, taken from [RD2] and includes additional details which are relevant for Road and Automotive community.

Availability: the percentage of time the position, navigation or timing solution can be computed by the user. Values vary greatly according to the specific application and services used, but typically range from 95-99.9%. There are two classes of availability:

- System availability: the percentage of time the system allows the user to compute a position - this is what GNSS Interface Control Documents (ICDs) refer to.
- Overall availability: considers the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

Accuracy is the difference between true and computed solution (position or time). This is expressed as the value within which a specified proportion – usually 95% – of samples would fall if measured. This report refers to positioning accuracy using the following convention: centimetre-level: 0-10cm; decimetre level: 10-100cm; metre-level: 1-10 metres.

Continuity is the ability of a system to perform its function (deliver PNT services with the required performance levels) without interruption once the operation has started. It is usually expressed as the risk of discontinuity and depends entirely on the timeframe of the application. A typical value is around 1*10-4 over the course of the procedure where the system is in use.

Indoor penetration is the ability of a signal to penetrate inside buildings (e.g. through windows). Indoor penetration does not have an agreed or typical means for expression. In GNSS this parameter is dictated by the sensitivity of the receiver, whereas for other positioning technologies there are vastly different factors that determine performance (for example, availability of Wi-Fi base stations for Wi-Fi-based positioning).

Integrity is a term used to express the ability of the system to provide warnings to users when it should not be used. It is the probability of a user being exposed to an error larger than the alert limits without timely warning. The way integrity is ensured and assessed, and the means of delivering integrity-related information to users are highly application dependent. Throughout this report, the "integrity concept" is to be understood at large, i.e. not restricted to safety-critical or civil aviation definitions but also encompassing concepts of quality assurance/quality control as used in other applications and sectors.

Latency is the difference between the reference time of the solution and the time this solution is made available to the end user or application (i.e. including all delays). Latency is typically accounted for in a receiver but presents a potential problem for integration (fusion) of multiple positioning solutions, or for high dynamics mobile devices.

Robustness relates to spoofing and jamming and how the system can cope with these issues. It is a more qualitative than quantitative parameter and depends on the type of attack or interference the receiver is capable of mitigating. Robustness can be improved by authentication information and services.

Authentication gives a level of assurance that the data provided by a positioning system has been derived from real signals. Radio frequency spoofing may affect the positioning system, resulting in false data as output of the system itself.

Power consumption is the amount of power a device uses to provide a position. It will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of milliwatts (for smartphone chipsets).

Probability of false alarm refers to the likelihood of the receiver to indicate the presence of a signal when no signal is present.

Probability of detection refers to the likelihood of a receiver to detect the presence of a GNSS signal when a signal is indeed present.

Time To First Fix (TTFF) is a measure of time between activation of a receiver and the availability of a solution, including any power on self-test, acquisition of satellite signals and navigation data and computation of the solution. It mainly depends on data that the receiver has access to before activation: cold start (the receiver has no knowledge of the current situation and must thus systematically search for and identify signals before processing them – a process that can take up to several minutes.); warm start (the receiver has estimates of the current situation – typically taking tens of seconds) or hot start (the receiver understands the current situation – typically taking a few seconds).

Time To First accurate Fix (TTFaF) is a measure of a receiver's/solution's performance covering the time between activation and output of a position within the required accuracy bounds.

A.4 Definition of key SATCOM performance parameters

Availability concerns the percentage of time the SATCOM service is operational and accessible to users. It is a critical parameter that ensures continuous communication, especially in remote and challenging environments.

Latency indicates the time delay between the transmission and reception of data. Low latency is essential for real-time applications such as voice communication and video conferencing.

Throughput expresses the amount of data that can be transmitted over the SATCOM link in a given period. High throughput is necessary for applications requiring large data transfers, such as video streaming and file sharing.

Coverage indicates the geographical area where the SATCOM service is available. Wide coverage ensures that users can access the service in various locations, including remote and maritime regions.

Reliability indicates the ability of the SATCOM system to perform consistently without failures. High reliability is crucial for mission-critical applications where communication disruptions can have significant consequences.

Bandwidth concerns the range of frequencies available for data transmission. Sufficient bandwidth is required to support multiple users and high-data-rate applications simultaneously.

Security concerns the measures in place to protect the SATCOM system from unauthorized access and cyber threats. Robust security protocols are essential to safeguard sensitive data and ensure the integrity of communications.

A.5 Other performance parameters

EO

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction to observe areas of interest outside its ground trace. High agility can improve the temporal resolution compared with the revisit time of the satellite.

Swath corresponds to width of the portion of the ground that the satellite "sees" at each pass. The larger the swath, the bigger the observed area at each pass.

Off-nadir angle corresponds to the angle at which images are acquired compared with the "nadir", i.e. looking straight down at the target. In practice, objects located directly below the sensor only have their tops visible, thus making it impossible to represent the three-dimensional surface of the Earth. High resolution images are therefore generally not collected at nadir but at an angle. A large off-nadir angle enables a wider ground coverage at each pass and the identification of features not visible at nadir, but it reduces the spatial resolution. For optical imagery, typical off-nadir angles are in the range of 25-30 degrees.

Sun-elevation angle corresponds to the angle of the sun above the horizon at the time an image is collected. High elevation angles can lead to bright spots on the imagery while low elevation angles lead to darker images and longer shadows. The most appropriate angle depends on the type of application: a high sun elevation is appropriate for spectral analysis since the objects to be observed are well illuminated while a lower elevation angle is better suited to interpretation of surface morphology (e.g. the projected shadows can enable a better image interpretation).

GNSS

Size, weight, autonomy, and power consumption. Power consumption and size are not strictly GNSS performance parameters, however they are also considered in this analysis, especially for GIS and Mapping-related applications.

- **Autonomy**. Power consumption is the amount of power a device uses to provide a position. The power consumption of the positioning technology will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of mW (for smartphone chipsets). GNSS is considered one of the heaviest drains on smartphones batteries
- **Size, weight**. Most GIS devices used by NGOs are handheld or rugged tablets/phones, which implies that they must remain small and lightweight.

Resiliency is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; including the ability to recover from deliberate attacks, accidents, or naturally occurring threats or incidents. A resilient system will change its way of operations while continuing to function under stress, while a robust (but non-resilient) system will reach a failure state at the end, without being able to recover.

Connectivity refers to the need for a communication and/or connectivity link of an application to be able to receive and communicate data to third parties. Connectivity relies on the integration with both satellite and terrestrial networks, such as 5G, LEO satellites, or LPWANs.

Interoperability refers to the characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, in either implementation or access, without any restrictions (e.g. ability of GNSS devices to be combined with other technologies and the possibility to merge the GNSS output with the output coming from different sources).

Traceability is the ability to relate a measurement to national or international standards using an unbroken chain of measurements, each of which has a stated uncertainty. For Finance applications, knowledge of the traceability of the time signal to UTC is essential to ensure regulatory compliance of the timestamp.

A.6 List of Acronyms

Acronym	Definition
AIS	Automatic Identification System
CNECT	DG for Communications Networks, Content and Technology
DEFIS	DG for Defence Industry and Space
DG	Directorate General
EARSC	European Association of Remote Sensing Companies
EO	Earth Observation
ESA	European Space Agency
EUSPA	European Union Agency for the Space Programme
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GOVSATCOM	Governmental Satellite Communications
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IEC	International Electro-technical Commission
IMO	International Maritime Organisation
IRIS2	Infrastructure for Resilience, Interoperability, and Security by Satellites
ITU	International Telecommunication Union
IWW	Inland Waterways
MARE	DG for Maritime Affairs and Fisheries
MDI	Maritime Domain Integration
MOVE	DG for Mobility and Transport
PNT	Position, Navigation, and Timing
RD	Reference Document
RTCM	Radio Technical Commission for Maritime Services

Acronym	Definition
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication
SOLAS	Safety of Life at Sea
SSA	Space Situational Awareness
UCP	User Consultation Platform
VDES	VHF Data Exchange System

A.7 Reference Documents

Id.	Reference	Title	Date
[RD1]	EUSPA Market Report	EUSPA EO and GNSS Market Report (Issue 2)	2024
[RD2]	GNSS Technology Report	GSA GNSS Technology Report (Issue 3)	Sept. 2020
[RD3]	SAR and Optical Satellite Images for Advanced Asset Monitoring	https://spottitt.com/industry-news/sar-and-optical-satellite-images-for-advanced-asset-monitoring/	
[RD4]	EUSPA Secure SATCOM Report	EUSPA Secure SATCOM Market and User Technology Report, Issue 1	2023
[RD5]	Expression of User Needs for the Copernicus Programme	Commission Staff Working Document Expression of User Needs for the Copernicus Programme	Nov 2019
SOLAS			
[RD6]	SOLAS	SOLAS International Convention for the Safety of Life at Sea	1 Nov. 1974
[RD7]	SOLAS Chapter V – Safety of Navigation	Regulation 19.2 of SOLAS Chapter V	2007 Revision
[RD8]	Resolution A.915 (22)	Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)	29 Nov. 2001
[RD9]	Resolution A.1106 (29)	Revised Guidelines for the onboard operational use of shipborne automatic identification systems	2 Dec. 2015
[RD10]	Resolution A.953 (23)	World-Wide Radionavigation System	5 Dec. 2003
[RD11]	Resolution A.1046 (27)	Worldwide Radionavigation System	30 Nov. 2011
[RD12]	Resolution MSC 112 (73)	Performance standards for shipborne GPS receiver equipment	1 Dec. 2000
[RD13]	Resolution MSC 113 (73)	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 Dec.2000
[RD14]	Resolution MSC 114 (73)	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 Dec.2000
[RD15]	Resolution MSC 115 (73)	Performance standards for shipborne combined GPS-GLONASS receiver equipment	1 Dec.2000
[RD16]	Resolution MSC 233 (82)	Performance Standards for Shipborne Galileo Receiver Equipment	5 Dec.2006
[RD17]	Resolution MSC 379(93)	Performance standards for shipborne BDS receiver equipment	16 May 2014
[RD18]	Resolution MSC 401(95)	Performance standards for multi-system shipborne navigation receivers	8 June 2015
[RD19]	Resolution MSC.432 (98)	Amendments to performance standards for multi-system shipborne radionavigation receivers	16 June 2017
IALA			
[RD20]	IALA Navguide	IALA Aids to Navigation Manual, Issue 4	Dec. 2001
[RD21]	IALA Navguide	IALA Aids to Navigation Manual, 7th edition	2014
[RD22]	IALA WWRNP	World Wide Radio Navigation Plan	Dec. 2009 Revised Dec. 2012
[RD23]	IALA R-135	Future of DGNSS	4 Dec. 2008

Id.	Reference	Title	Date
[RD24]	IALA R-129	GNSS Vulnerabilities and mitigation measures	3 Dec. 2012
[RD25]	IALA R-115	Provision of maritime radionavigation services in the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in Region 2 and 3 115	1 Dec. 2005
[RD26]	IALA R-121	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	29 May 2015
[RD27]	IALA Guideline No. 1112	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	May 2015
[RD28]	IALA Guideline No. 1082	An Overview of AIS	1 June 2011
[RD29]	IALA Guideline No. 1028	The Automatic Identification System (AIS), Vol. 1 Part 1 Operational Issues	3 Dec. 2004
[RD30]	IALA Guideline No. 1029	The Automatic Identification System (AIS), Vol. 1 Part 2 Technical Issues	1 Dec. 2002
[RD31]	IALA Standard S1030	Standard S1030 Radionavigation Services	1 May 2018
[RD32]	IALA Guideline G1129	The retransmission of SBAS corrections using MF-Radio beacon and AIS	Rev. 3 June 2022
[RD33]	IALA Guideline G1152	SBAS Maritime Service	13 December 2019
[RD34]	IALA Guideline G1154	Use of Mobile Aids to Navigation	December 2020 Ed. Corrections July 2022
[RD35]	IALA Standard S1030	Radionavigation Services	3 June 2023
[RD36]	IALA Guideline G1117	VDES Overview	16 December 2016 Corrections 16 December 2022
EC			
[RD37]	Directive 2005/44/EC	Directive on harmonised river information services (RIS) on inland waterways in the Community	7 Sept. 2005
[RD38]	Regulation (EC) No 414/2007	Regulation concerning the technical guidelines for the planning, implementation and operational use of river information services (RIS)	13 March 2007
[RD39]	Regulation (EC) No 415/2007	Regulation concerning the technical specifications for vessel tracking and tracing systems	13 March 2007
[RD40]	ERNP	European Radionavigation Plan - draft Link to presentation at UCP	29 Nov. 2017
ITU			

Id.	Reference	Title	Date
[RD41]	Recommendation M.823-3	Technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in Region 1 and 285-325 kHz in Regions 2 and 3	March 2006
[RD42]	Recommendation M.1371-5	Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band	Feb. 2014
US DoT			
[RD43]	DOT-VNTSC- OST-R-15-01	2017 Federal Radio Navigation Plan	2017
IEC			
[RD44]	IEC 60945	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results	Ed. 4.0 2002-2008
[RD45]	IEC 61108-1	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) -Receiver equipment - Performance standards, methods of testing and required test results	Ed. 2.0 2003
[RD46]	IEC 61108-2	Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) – Receiver equipment - Performance standards, methods of testing and required test results	Ed. 1. 1998
[RD47]	IEC 61108-3	Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 2010
[RD48]	IEC 61108-4	Global navigation satellite systems (GNSS) - Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 2004
[RD49]	IEC 61162 - Parts 1 to 4	Maritime navigation and radiocommunication equipment and systems – Digital interfaces	2010- 1998- 2014- 2015
[RD50]	IEC 61993 Part 2	Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results.	Ed. 2 19 Oct. 2012
[RD51]	IEC 61108-5	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 5: BeiDou navigation satellite system (BDS) - Receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 11 March 2020

Id.	Reference	Title	Date
[RD52]	IEC 61108-6	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 6: Navigation with Indian constellation (NavIC)/Indian regional navigation satellite system (IRNSS) - Receiver equipment - Performance requirements, methods of testing and required test results (under development)	Ed 1.0 23 February 2023
[RD53]	IEC 61108-7	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 7: Satellite Based Augmentation Systems - Receiver Equipment - Performance requirements and method of testing (under development)	Under developme nt
[RD54]	IEC-61108-8	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 8: Quasi-Zenith Satellite System (QZSS) receiver equipment - Performance requirements, methods of testing and required test results	Under developme nt
[RD55]	IEC 61097-9	Global maritime distress and safety system (GMDSS) - Part 9: Shipborne transmitters and receivers for use in the MF and HF bands suitable for telephony, digital selective calling (DSC) and reception of Maritime Safety Information and Search and Rescue related information - Operational and performance requirements, methods of testing and required test results	Under developme nt
Other			
[RD56]	MOM 2020 UCP	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel	2020
[RD57]	MOM 2022 UCP	User Consultation platform 2022 – Minutes of Meeting	2022
[RD58]	MOM 2024 UCP	User Consultation platform 2024 – Maritime and Inland Waterways Session – Minutes of Meeting	2024

A.8 Annex on regulations, standards, policies

A.8.1 IMO regulations related to GNSS user requirements

SOLAS CONVENTION

SOLAS is an international maritime safety treaty. It ensures that ships flagged by signatory States comply with minimum safety standards in construction, equipment and operation. The Convention was adopted in November 1974 and entered into force in May 1980; the latest amendments are dated July 2024 (requirements related to safety for offshore personnel). The SOLAS Convention in its successive forms is generally regarded as the most important of all international treaties concerning the safety of ships. The SOLAS convention sets the frame for all the IMO resolutions listed here after. Unless specifically mentioned most resolutions are relevant only for SOLAS vessels.

RESOLUTION A.915 (22)

One of the most important regulations on the use of GNSS applied to maritime applications is the resolution A.915(22) [RD8] “Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)” from the IMO, adopted on 29 November 2001.

This resolution recognises the need for a future civil and internationally controlled Global Navigation Satellite System. It also seeks to address the needs of the maritime sector, which are not only restricted to general navigation but include also positioning activities. For this reason, the resolution highlights the need to identify, at an early stage, the maritime user requirements for a future GNSS in order to ensure these requirements will be taken into account into the development of such system.

Proposals of a specific future GNSS should be presented to IMO for recognition, which will then assess such proposals on the basis of any revised requirements. Maritime requirements can be subdivided into general, operational, institutional and transitional requirements: **General requirements** include the requirements to serve the operational user, primarily for general navigation, including in restricted waters and harbour entrances and approaches, as well as for operational navigation and positioning. They also include the requirements to use local augmentation in order to meet additional area-specific requirements. These augmentation provisions must be harmonised worldwide so that a ship will not need to carry more than one shipborne receiver. The GNSS must be able to be used by an unlimited number of multimodal users, being also reliable and of low user cost. **Operational requirements** include integrity, continuity, accuracy, availability and others, which refer to both general navigation and positioning applications. It also states that service providers are not responsible for the performance of shipborne equipment and recommends the integration of GNSS and terrestrial systems, using compatible geodetic and time reference systems, in order to provide the users with information on position, time, course and speed over the ground. Finally, they insist on the need that the system informs users of degradations in performance through the provision of integrity messages. The **institutional requirements** intend to ensure that GNSS is controlled by an international civil organisation, existent or to be created, who should have the means of supervising provision, operation, monitoring and control of the system at minimum cost. Although IMO is not in the position to provide and operate a GNSS, it must be able to assess and recognise its provision and operation regarding maritime users, and application of internationally established principles. Lastly, the **transitional requirements** concern the development of future GNSS in parallel to present satellite navigation systems. It states that an already fully operational system may be recognised as a component of the WWRNS and that shipborne receivers should be compatible with the equipment required for current satellite navigation systems. This resolution separates general navigation into **five environments**, in order to address their specific needs in terms of accuracy, integrity, availability, continuity, coverage and fix interval:

- Ocean: The main use of navigation systems is to ensure the execution of safe and efficient routes, accounting for weather conditions, therefore this application is both safety and mission critical. The main radionavigation system used is GPS, due to its global availability, associated with traditional methods as celestial navigation for example.

- Coastal: As the distance from the coast decreases, bigger are the chances of encountering with other vessels or grounding. The navigation systems in this phase are mostly used to maintain safety. GPS is the principal radionavigation system, associated with augmentation systems and traditional aids to navigation such as lights, buoys and markers.
- Ports approach and restricted waters phase; and port phase: In this case, manoeuvring has its freedom limited yet it is more frequent. Due to the close proximity to other vessels and grounding, navigation requirements are more stringent and reaction time to the manoeuvres can become critical, since collision risks are more important. Onboard systems, such as depth sounders may also be used in association to those listed in coastal navigation.
- Inland Waterways: This phase is safety critical. Augmented GPS signals and radar are used along with visual aids. Requirements and services for this application are generally governed by local or regional authorities, which may or not adopt IMO recommendations. The same requirements of navigation in restricted waters, ports and approaches are considered in this phase.

Beyond navigation, this resolution also gives minimum user positioning requirements for a list of several applications. These applications will be more deeply explained later in this document, according to their importance.

RESOLUTION A.1046 (27)

IMO Resolution A.1046 (27) "Worldwide Radionavigation System", adopted on 30 November 2011, describes procedures concerning recognition of World-Wide Radio Navigation System and requirements regarding shipborne receiving equipment and operational requirements for a World-Wide Radio Navigation System (WWRNS). Among the updated requirements introduced by A.1046 (27), the following should be highlighted:

- There is no more mention to high vs. low traffic/risk (as compared with A.953 (23);
- The continuity risk has been modified to 15 min (as compared to A.915 (22) and A. 953 (23)).

Requirements may be met by individual systems or by a combination of different systems, and they have been separated for navigation in two different environments:

- Ocean waters;
- Harbour entrances, harbour approaches and coastal waters;

For **ocean navigation**, the resolution states a limit of 100m for positional information error, with a probability of 95%, an update rate of the computed position data not less than once in 2 seconds, with signal availability over 99.8%, and the system must assure the provision of integrity warnings in case of system malfunction.

For **navigation in harbour entrances, harbour approaches and coastal waters**, the error cannot exceed 10m, with a probability of 95%, there must be updates of the position data once every 2s and signal availability over 99.8%. It also defines the need of the service continuity to be equal or greater than 99.97% over a period of 15 minutes, with the provision of integrity warnings within 10 seconds.

It is important to highlight that the operational requirements in IMO resolution A.1046 (27) have to be mandatory fulfilled by GNSS alone or with the support of augmentation systems (i.e. IALA beacons, EGNOS). In this resolution, there are no mandatory requirements for alert limit and integrity risk.

Table 59: IMO Resolution A.1046 (27) performance requirements

IMO Resolution A.1046	Horizontal Error (95%)	Update Rate	Availability (signal)	Integrity Warning (system)	Continuity (service)
Ocean Waters	100m	Once/2s	99.80%	ASAP by MSI[11]	N/A
Harbour entrances, Harbour approaches and Coastal Waters	10m	Once/2s	99.80%	10s	99.97% over 15min

Port approach and restricted waters

IMO Resolutions consider that for ships operating above 30 knots applications may need more stringent requirements. Of the applications belonging to this category, only Casualty Analysis had its environment clearly stated by IMO (Port Approach and Restricted Waters). The others were placed in two different environment classes as follows: those taking place in Port Approach and Restricted Waters (Casualty Analysis, as defined by IMO and reiterations, evidently); Marine Engineering, Aids to Navigation Management and Offshore exploration and exploitation were considered to fit best in Ocean environment.

RESOLUTIONS MSC 112(73), 113(73), 114(73), 115(73), 233(82), 379(93) & 401(95

These resolutions are performance standards for shipborne GNSS or DGNSS equipment. Their specific purposes and dates of adoption are summarised in the table below.

Table 60: Resolutions on Performance Standards for shipborne GNSS or DGNSS Equipment.

Resolution N° Title	Title	Date
MSC 112(73)	Performance standards for shipborne GPS receiver equipment	1 Dec. 2000
MSC 113(73)	Performance standards for shipborne GLONASS receiver equipment	1 Dec. 2000
MSC 114(73)	Performance standards for shipborne DGPS and DGLONASS	1 Dec. 2000
MSC 115(73)	Performance standards for shipborne combined GPS-GLONASS	1 Dec. 2000
MSC 233(82)	Performance standards for shipborne Galileo receiver equipment	5 Dec. 2006
MSC 379(93)	Performance standards for shipborne BDS receiver equipment	16 May 2014

[11] MSI: Maritime Safety Information

Resolution N° Title	Title	Date
MSC 401(95)	Performance standards for multi-system shipborne navigation	8 June 2015
MSC.432 (98)	Amendments to performance standards for multi-system shipborne radionavigation receivers	16 June 2017
MSC.449(99)	Performance standards for shipborne Indian regional navigation satellite system (IRNSS) receiver equipment	24 May 2018

These resolutions do not set specific requirements in terms of accuracy, integrity or other qualities of the PNT solution. They refer to resolutions A.915(22) and A.1046(27) for this purpose. The most recently adopted of these resolutions does not target one specific GNSS, but rather addresses the question of the "multi-system" receiver potentially capable of using multiple GNSS, correction sources (including SBAS mentioned for the first time in an IMO resolution) and terrestrial system(s).

Resolution A.1106 (29) [RD9] – Revised Guidelines for AIS

Resolution A.1106 (29) [RD9] concerns the revised Guidelines for the Onboard Operational Use of Shipborne Automatic Identification System. Automatic Identification Systems or AIS means a maritime navigation safety communications system standardised by the International Telecommunication Union (ITU), adopted by the International Maritime Organisation (IMO) that:

It gives a high -level description of the information reported by the ship's AIS, the reporting interval as a function of the ship's dynamics, and a block diagram of a shipborne AIS. It does not provide quantified requirements regarding PNT, but specifies that:

- The reported ship's position (with RAIM flag and accuracy flag), position time stamp, course over ground, speed over ground is all automatically updated from the ship's main position sensor connected to AIS
- The accuracy flag is for better or worse than 10 m
- The AIS internal GNSS receiver is used for data link synchronisation and as a secondary (back-up) source of positioning information

It also gives reference to important AIS related documentation, most notably:

- ITU Recommendation on the Technical Characteristics for a Universal Shipborne Automatic Identification System (AIS) Using Time Division Multiple Access in the Maritime Mobile Band (ITU-R M.1371)
- IEC Standard 61993 Part 2: Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results

Regulation 19 of SOLAS chapter V "Carriage requirements for shipborne navigational systems and equipment" sets out navigational equipment to be carried on board ships, according to ship type. In 2000, IMO adopted a new requirement (as part of a revised new chapter V) for all ships to carry automatic identification systems (AISs) capable of providing information about the ship to other ships and to coastal authorities automatically.

The regulation requires AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004.oShips fitted with AIS shall always maintain AIS in operations except where international agreements, rules or standards or standards provide for the protection of navigational information. Finally, it can be noted that AIS can be used to support SAR operations and navigation.

Description of AIS

The AIS can be considered a maritime safety-related information service, the purpose of which is to allow its clients to interface with the different AIS stations that can be used by mariners or maritime administrations on the VHF Data Link (VDL).

It provides both the mariners and the maritime administrations for increased situational awareness which enables improved safety of navigation (collision avoidance, VTS) and effective responses to emergencies such as search and rescue (SAR) or environmental pollution rely upon what is known as a time-division multiple access (TDMA) communications protocol, which means the frequency (data link) used is divided into time defined slots which can only hold a set amount (packets) of data. What makes AIS unique and very different from other TDMA systems (e.g. mobile telephone networks) is the ability to dynamically 'self-organise'. The AIS network is continuously self-organising around the user, thus reducing the likelihood of 'dropped call' (undelivered AIS messages). As regards PNT requirements for shipborne AIS, they are twofold:

- The shipborne AIS must periodically report position in WGS84, position accuracy flag, and Receiver autonomous integrity monitoring (RAIM) flag. The periodicity varies from 3 minutes to 2 seconds depending on the ship's dynamic conditions;
- The underlying VHF data link (VDL) TDMA is synchronised to UTC by mean of the AIS device internal (D) GNSS receiver.

For an overall description of AIS, complete with an overview of applicable documents and standards, please refer to IALA's "Overview of AIS".

A.8.2 IALA recommendations, guidelines and standards

Although IALA recommendations lack the regulatory force of IMO resolutions, "there is an implicit expectation that individual national members will observe and implement IALA Recommendations".

The SOLAS Convention recalls IALA's Guidelines on specific topics. Furthermore, such recommendations are referring to relevant international standards and regulations, very often including parts of them, together with clarifications, explanations and complementary information (e.g. contextual). In short, they are almost self-sufficient, except for equipment manufacturers which may have to refer to IEC complementary standards. Additionally, IALA documents are often (if not always) published and updated faster than their IMO counterparts, and IALA can even be at the origin of some IMO regulations (as it was the case for AIS).

For the purpose of deriving user requirements, **IALA documents are never in contradiction with IMO ones**, but they may be ahead of them. Besides, they can be useful to justify some of the requirements found in IMO, and / or to place them in their operational context.

IALA Guideline G1129

IALA Guideline G1129 on the retransmission of SBAS corrections using MF-radio beacon and AIS (issued in December 2017 and revised in June 2022) sets out guidance for Marine Aids to Navigation (AtoN) service providers wishing to understand where SBAS information could be used to support the mariner and then how to employ such data, by describing the SBAS use within augmentation services via marine radio beacon and AIS transmissions.

Although IALA recommendations used to lack the regulatory force of IMO resolutions and there was an implicit expectation that individual national members will observe and implement IALA

Recommendations, following its transformation to an intergovernmental organisation, it will now be able to issue standards.

IALA Guideline G1152

IALA Guideline G1152 on SBAS Maritime Service (issued in December 2019 and updated in July 2022) identifies several aspects (reference requirements, user equipment, and a description of the service and the operational scheme) that maritime or coastal administrations may take into account when considering the use of SBAS by ships in their waters.

IALA Guideline G1154

IALA Guideline G1154 on the use of Mobile Aids to Navigation, approved on 10 December 2020, is meant to assist IALA members and other competent authorities when they consider the use of Mobile Marine Aids to Navigation (MAtoN) to mark a moving or drifting hazard to navigation. The guideline includes information on instances where MAtoN can be used, detailing responsibilities for their use, how moving or drifting hazards can be marked, and other pertinent guidance. The Guideline should serve as an aid (more than an exhaustive document) to assist national members and competent authorities in managing the marking of moving or drifting hazards.

IALA Standard S1030

The IALA Strategic Vision for the period 2018-2026, approved by the General Assembly in 2018 and updated in 2023, includes the Goal to ensure that "Marine Aids to Navigation are developed and harmonised through international cooperation and the provision of standards."

This Standard references normative and informative provisions, detailed in the listed IALA Recommendations, covering the following scope:

Normative:

- Satellite positioning and timing: IALA Standard S1030.1
  - Recommendation R1017 on Resilient Position, Navigation and Timing (PNT)
- Terrestrial positioning and timing: IALA Standard S1030.2
  - Recommendation R1011: The Performance and Monitoring of eLORAN Services in the Frequency Band 90-110 kHs
- Augmentation services: IALA Standard S1030.3
  - Recommendation R0115: The Provision of Maritime Radionavigation Services in the Frequency Band 283.5-315 kHs in Region 1 and 285-325 kHs in Regions 2 and 3
  - Recommendation R0121: The Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 - 325 kHs
- Racon and radar positioning: IALA Standard S10.30.4
  - Recommandation R0101: Marine Radar Beacons (Racons)
  - Recommendation R0146: Strategy for Maintaining Racon Service Capability

Informative:

- Satellite positioning and timing: IALA Standard S1030.1
  - Recommendation R1020 Terrestrial Radionavigation Systems
  - Recommendation R0129 GNSS Vulnerability and Mitigation Measures
- Augmentation services: IALA Standard S1030.3
  - Recommendation R0135 The Future of DGNSS
  - Recommendation R0150 DGNSS Service Provision, Upgrades and Future Uses
  - Recommendation R1022 Provision of GN

IALA World-Wide Radio Navigation Plan

The IALA World Wide Radio Navigation Plan aims to build on individual National and Regional plans and identify the Radio Navigation components which will be key to the successful implementation of e-Navigation. One of the cornerstones of e-Navigation is the universal availability of robust position-fixing, navigation and timing services.

e-Navigation is an International Maritime Organisation (IMO) led concept based on the harmonisation of marine navigation systems and supporting shore services driven by user needs.

The working definition of e-Navigation as adopted by IMO is:

“e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.”

There are 3 key elements or strands that must first be in place before e-Navigation can be realised:

- Electronic Navigation Chart (ENC) coverage of navigational areas;
- A robust electronic position, navigation and timing system (with redundancy); and
- An agreed infrastructure of communications to link ship and shore.

This WWRNP focuses solely on the need to provide robust electronic position, navigation and timing (PNT) information, primarily via radio navigation systems. It presents the IALA position on current, developing and future PNT solutions within the maritime environment.

This plan does not introduce new user requirements, but rather refers to IMO A 1046 (27) and A 915 (22).

It places GNSS in the context of a worldwide plan and introduces or re-enforces the concepts of “robust PNT” (also called “resilient PNT” in some publications) and of “e-Navigation”, which are currently the two major trends in maritime navigation.

IALA Aids to navigation guide (Navguide)

The IALA Navguide is a very complete guide, last updated in 2023, reviewing all aspects of the provision and use of all maritime aids to navigation, including institutional, legal, political, operational, functional and technical aspects.

The structure of NAVGUIDE Ed 9.0 conforms to the standards and incorporates the latest advancements in AtoN technology, including enhancements in digital systems and the integration of new devices such as Mobile AtoN and MASS. The last update covers aspects such as training components, AtoN services in extreme weather conditions, and an increased focus on sustainability, cybersecurity, and the adoption of autonomous systems within the maritime industry.

Regarding more specifically PNT users’ requirements, this Navguide does not introduce anything new as compared to IMO A.1046 (27) and A 915 (22).

It does however recall Accuracy Standards for Navigation, definition of Phases of Navigation, definitions of Measurement Errors and Accuracy, definitions of Availability and Continuity for a radio navigation system, etc. In particular, the Navguide gives an “environmental” (physical) description of the ship’s environment in each phase of navigation and discusses / justifies some requirements that are simply “stated” in other documents (such as the IMO A.1046 (27) and A.915 (22).

Unfortunately, it does not go as far as describing the radio electrical / interference / multipath environment that would complete the description.

To conclude on the Navguide, this is a very important input to user requirements, in terms of:

- Clarification of the definitions used
- Justification / traceability of the requirements
- Definition of the environmental constraints

Recommendation IALA R-115 on provision of maritime radionavigation services in the frequency band 283.5-315 kHs in region 1 and 285-325 kHs in region 2 and 3

This recommendation issued in December 1999 and last updated in December 2005 recommends:

- The discontinuation of radio beacon services in the maritime MF frequency bands;
- Their replacement by DGNSS services "to improve the safety of navigation in confined coastal waterways and harbour approaches".

This is the founding act of the IALA DGNSS service.

This recommendation does not describe the (then) planned DGNSS but sets the frame for its deployment, re-allocating the frequency bands previously dedicated to the radio beacon services to DGNSS.

Recommendation IALA R-121 and Guideline 1112 on performance and monitoring of DGNSS services in the frequency band 283.5 – 325 kHs

This Recommendation and associated Guideline last updated in May 2015 concern the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHs (Maritime Radio beacons); commonly known as "IALA DGPS".

The Guideline 1112 presents as positioning performance requirements a table compiled using as a reference IMO resolutions A.915 and A.1046 to take into account the latest value agreed at IMO for continuity.

They recognise that the minimum standards should include the signal format, reference datum, availability, continuity, integrity, accuracy, signal monitoring, range and coverage, status reporting, validation, and the publication of information about the system.

They recommend those providing or intending to provide DGNSS to:

- Provide the service in accordance with ITU-R Recommendation M.823-3, which verses about message formats types and contents for DGNSS;
- Provide integrity information for GNSS;
- Provide the service with a level of redundancy to achieve performance requirements IMO A.1046 (27);
- Provide means of verifying the performance of the service;
- Provide mariners with information about the service, for example:
    - description of the service,
    - achieved service performance,
    - service disruptions,
    - geographical service area;
- Adopt the design and implementation principles set out in the relevant IALA Guideline(s).

Recommendation R-135 on the future of DGNSS

This document outlines an updated (as of December 2008) strategy for the recapitalisation of DGNSS, setting out the requirements and options and identifying areas still needing further study.

IALA assessed the current and potential use of the DGNSS system and concluded in 2006 that there would be a requirement to recapitalise (i.e. replace) older systems. There is also potential to develop the system for the benefit of existing users and to enhance GNSS capabilities to take account of technical innovations, in accordance with IMO Resolution A.915 (22) [RD8].

This strategy should be viewed in the context of the development by IALA of proposals for a World-Wide Radio Navigation Plan (WWRNP) in support of e-Navigation.

One key concept in this Plan is the possibility of separating the generation of correction data from the means of transmission, to facilitate broadcasting by a variety of methods. This could lead to the integration of terrestrial systems (DGNSS beacons, eLoran, AIS) to provide shared data channels and common correction sources. Additional ranging signals could also be provided, contributing to a redundant position-fixing solution, complementary to, but independent of GNSS.

This plan accounts for developments in GNSS (GPS L2C, L5, GLONASS M, Compass and Galileo) which will require the introduction of new message types and new equipment. It considers several possibilities for the re-engineering of the DGNSS system, including SBAS integration. It does not conclude on a firm path to modernisation, but rather sets principles and recommendations for continuing work in this area.

Regarding end user PNT requirements, this recommendation does not deal with the subject other than referring to IMO A 915 (22).

Recommendation R-129 on GNSS vulnerabilities and mitigation measures

This recommendation last updated in December 2012 addresses the problem of GNSS vulnerabilities and increased user reliance on GNSS.

It must be viewed in the context of the IMO Strategy for e-Navigation which contains a high-level user need for data and system integrity:

"e-Navigation systems should be resilient and take into account issues of data validity, plausibility and integrity for the system to be robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems, should be considered."

In addressing the issue of Position Fixing, it can be defined as accurate and reliable electronic position, navigation and timing signals, with 'fail-safe' performance (probably provided through multiple redundancy, e.g. GNSS, differential transmitters, eLoran and defaulting receivers or on-board inertial navigation devices.

This recommendation reviews, in a maritime context, known GNSS vulnerability as well as known or potential mitigation measures. It then devises an action plan comprising:

- Risk Assessment;
- Requirements for a Backup Navigation System;
- GNSS Integrity Warning System;
- User Receiver Architecture.

In terms of user requirements, this recommendation does not go beyond the high-level user need for data and system integrity, as per IMO Strategy for e-Navigation. This is another example of the importance for the maritime community of the "Resilient PNT" and "e-Navigation" concepts.

Guideline No. 1082 on an overview of AIS

This guideline published in June 2011 and revised in 2016 gives a complete overview of AIS, its purposes, its functional and operational description, its institutional regulatory framework, a high-level technical description, its development timeline, applicable documentation, etc.

It is more a presentation document than a regulatory or standardisation one, quite useful to describe the full context for AIS but falling short of addressing specific details related to the PNT requirements.

IALA Guideline No. 1028 on the automatic identification system (AIS) operational issues

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) has been the primary organisation sponsoring and co-ordinating the development of the Automatic Identification System (AIS). In 1996, the Vessel Traffic Services (VTS) and Radionavigation Committees (RNAV) of IALA prepared a draft recommendation that, with further refinement within IMO NAV, became the basis for the IMO Performance Standard on AIS.

The IALA AIS Guidelines provide a 'one-stop' information source for both operational and technical aspects of AIS and cover an increasingly wide range of ship and shore-based applications. Such guidance also aims to serve as inspiration and motivation to make full use of AIS, achieving efficiency and effectiveness, supporting maritime productivity, safety and environmental protection. This guidance keeps ship- to-ship safety as its primary objective.

Volume 1 Part 1 of Guidelines G1028) takes an operational approach, as it was compiled from a users' point of view. The range of users extends from competent authorities to Officers of the Watch (OOW), pilots, VTS Operators, managers and students.

The current version (Ed. 1.3) was released in December 2004. Since AIS "core" functionality is a communication one, PNT related aspects are not treated in any detail in this document. They are however dealt with in the next document (Volume 1 Part 2 of the guidelines here discussed below.

IALA guidelines No. 1029 on the automatic identification system AIS, technical issues

The purpose of Volume 1 Part 2 of the IALA guidelines is technical guidance and description, including shipborne and shore-based devices e.g., Vessel Traffic Services (VTS), Ship Reporting Systems (SRS) and Aids to Navigation (AtoN). Its current version is Ed. 1.1 released in December 2002.

It does include a number of considerations and details related to PNT that are summarised below.

Two types of shipborne AIS mobile stations for vessels have been defined in ITU-R M.1371:

- Class A Shipborne Mobile Stations (Class A) will comply with IMO carriage requirements. They must be 100% compliant with the IMO performance standard and the IEC 61993-2 standard.
- Class B Shipborne mobile stations (Class B) will provide facilities not necessarily in full accordance with IMO AIS carriage requirements. This type is mainly intended for pleasure craft. These stations have a different functionality on VDL message level: the position and static information reports are transmitted with their own VDL messages and with different reporting rate. There may be other varieties of mobile stations that have not yet been defined. This group of mobile AIS stations concerns professional users, not required to use Class A mobile stations but needing the Class A functionality. This AIS mobile equipment is called 'Class A Derivatives'. The most important issue is that all categories of mobile AIS stations must be fully compliant on the VDL level. They must recognise all different types of messages, only the processing of the messages can be different. The interfaces to external display systems and sensor system may vary between different types of AIS stations.

The operating principles of a shipborne mobile AIS device can be described as follows.
A ship determines its geographical position with an Electronic Position Fixing Device (EPFD). The AIS station transmits this position, combined with ship identity and other ship data via the VDL (VHF radio link) to other AIS equipped ships and AIS base stations that are within radio range. In a similar fashion, the ship, when not transmitting, receives corresponding information from all ships and base stations that are within radio range.

For Class A AIS, the external position fixing device (EPFD) is the ship's main position fixing device, external to the AIS device. The AIS device may have an internal GNSS receiver for UTC synchronisation of the VDL, but this is not compulsory (alternate synchronisation mechanisms exist). When such an internal GNSS receiver exists, it can be used as a secondary (back-up) source of position information. Note that almost all Class A devices are fitted with an internal GNSS, despite this being optional.

For Class B devices, the internal GNSS receiver is compulsory and is the source of the reported position data.

There is no accuracy requirement for the reported positions. However, the position should be expressed in WGS84, and be transmitted with an “accuracy flag” and a “RAIM flag” (applicable to either class). See Table below.

The position accuracy flag is defined as follows:

Table 61: Position Accuracy Flag

Flag	Description
1	High accuracy (< 10 m; Differential Mode of e.g. DGNSS receiver)
0	Low accuracy (> 10 m; Autonomous Mode of e.g. GNSS receiver or of other Electronic Position Fixing Device) Default = 0

The RAIM flag is defined as follows:

Table 62: RAIM Flag

Flag	Description
1	RAIM in use
0	RAIM not in use Default = 0

Specific case of DGNSS

AIS being a communication system with ship to ship, ship to shore, and shore to ship capabilities, it can be used to broadcast DGNSS corrections from an AIS shore station to mobile stations in the area of coverage. A specific message (message n° 17) has been devised for that purpose. This capability is useful in areas where no IALA DGNSS coverage is available. Furthermore, the received corrections can be output from the Class A mobile station to feed external position fixing devices (in this case DGNSS receivers), although this function is almost never used. These different possibilities (GNSS or not, corrections available from 0, 1 or 2 sources…) may create ambiguous situations and have led to the definition of priority rules: By default, and in accordance with IMO requirements, the Class A shipborne mobile AIS station will use the ship’s own position sensor for position reporting by AIS, which is also used for navigation of the ship. If an internal GNSS receiver, which conforms to the applicable requirements of IMO and IEC for position sensors, is integrated in the design of the shipborne mobile AIS station, this internal GNSS receiver will be used for position reporting by AIS, when there is no external differentially corrected position source presented to the shipborne mobile AIS station and DGNSS corrections are available to the shipborne mobile AIS station from either IALA DGNSS MF beacons or via the AIS VDL. (When both of these sources of DGNSS correction data are available to the shipborne mobile AIS station under these circumstances, the DGNSS corrections via the AIS VDL take precedence over MF beacon DGNSS corrections.) In other words, the internal DGNSS position will supersede the external position fixing device (EPFD) (for position reporting) when this EPFD is not itself providing a DGNSS solution (and is assumed to be of a lesser accuracy). This creates a situation where the ship’s master or officer on watch has a less accurate knowledge of the ship’s position (the EPFD one) than other ships or VTS authorities.

IALA Guideline G1117: VDES Overview

This Guideline provides insights into the Very High Frequency Data Exchange System (VDES). It gives information about the development of the VDES, the concepts of VDES, the role within the e-Navigation concept of IMO and the potential of VDES in the maritime environment and the use cases supported by

VDES. The document is intended to assist in the understanding, integration, further development and promotion of VDES in the maritime domain.

The 2023 update, features expanded applications for VDES, highlighting its potential for improving maritime communication, navigation, and safety through integration with other maritime systems.

Comprehensive operational guidelines have been introduced for the deployment and use of VDES, covering best practices for installation, maintenance, and operation. New cybersecurity measures have been incorporated to protect VDES communications from potential threats, with recommendations for encryption, authentication, and other security protocols.

The update also emphasises the environmental benefits of VDES, such as reducing the carbon footprint of maritime operations through more efficient communication and navigation and includes guidelines for minimising the environmental impact of VDES infrastructure. Additionally, the guideline now features case studies and practical examples demonstrating the successful implementation of VDES in various maritime scenarios, providing valuable insights and lessons learned for other users.

A.8.3 ITU recommendations

The ITU-R Recommendations constitute a set of international technical standards developed by the Radiocommunication Sector (formerly CCIR) of the ITU. They are the result of studies undertaken by Radiocommunication Study Groups on:

- The use of a vast range of wireless services, including popular new mobile communication technologies;
- The management of the radio-frequency spectrum and satellite orbits;
- The efficient use of the radio-frequency spectrum by all radiocommunication services;
- Terrestrial and satellite radiocommunication broadcasting;
- Radio wave propagation;
- Systems and networks for the fixed-satellite service, for the fixed service and the mobile service;
- Space operation, Earth exploration-satellite, meteorological-satellite and radio astronomy services.[12]

For what concerns maritime users, ITU recommendations are fundamental to allow, regulate, standardise and protect radio transmissions supporting the IALA DGNSS service and the AIS. Smaller ships may voluntarily carry AIS, the so-called Class B AIS. Technical requirements are globally set by the International Telecommunications Union (ITU)[13].

The Maritime Manual for Use by the Maritime Mobile and Maritime Mobile-Satellite Services, published in accordance with Article 20 (No. 20.14) of the Radio Regulations, is the result of studies carried out in the ITU-R since 2008. Volume 1 provides descriptive text of the organisation and operation of the GMDSS and other maritime operational procedures, while Volume 2 contains the extracts of the regulatory texts associated with maritime operations.

The latest edition available stems from 2024.

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[12] ITU web site contains Individual recommendations for the Radiocommunication Sector that are not mandatory: www.itu.int/pub/R-REC)

[13]

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC121206/jrc_technicalreport_print_arctic_final_1.pdf

https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1371-1-200108-S!!PDF-E.pdf

Recommendation M.823-3

"Technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHs in Region 1 and 285-325 kHs in Regions 2 and 3" is fundamental to the IALA DGNSS service. It gives a detailed technical description of such service, but more importantly it implicitly re-allocated the frequencies in the two designated frequency bands to DGNSS without having recourse to the whole frequency allocation process (long and difficult) that such a new service would usually require.

As for the DGNSS transmissions, its most important determinations are:

- The carrier frequency of the differential correction signal of a radio-beacon station is an integer multiple of 500 Hs;
- Frequency tolerance of the carrier is ± 2 Hs;
- Format and content of messages for reference station parameters, differential corrections and constellation health of GPS, GLONASS and other types of messages.

Recommendation M.1371-5

The "Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band" were last updated in February 2014.

This recommendation gives an in-depth operational and technical characterisation of the automatic identification system (AIS) using Time Division Multiple Access in the VHF maritime mobile band.

As for recommendation M.823 on DGNSS discussed above, it is fundamental to the maritime AIS, since it allocates the frequencies for that service worldwide.

Besides being the most detailed document describing AIS, it appears to be the most current as well, with frequent revisions (1998-2001-2006-2007-2010-2014), while IALA guidelines were last updated in 2002. For instance, it includes Galileo as one type of possible EPFD (external position fixing device), when IALA corresponding documents fail to do so.

Recommendation M.2092-1

Incorporating changes to add VDES Satellite functionality and updates consequential to feasibility tests, the recommendation outlines the technical characteristics for the VDES in the maritime mobile service, includes several significant enhancements and additions.

It introduces expanded applications for VDES, emphasising its role in improving maritime communication, navigation, and safety through integration with other maritime systems. Updated technical specifications reflect the latest advancements in VDES technology, including enhancements in data transmission rates, frequency management, and interoperability with existing maritime communication systems.

Comprehensive operational guidelines have been provided for the deployment and use of VDES, covering best practices for installation, maintenance, and operation. New cybersecurity measures have been incorporated to protect VDES communications from potential threats, with recommendations for encryption, authentication, and other security protocols.

A.8.4 Interpretation of requirements for bridge operations

Bridges operations as an operational scenario are not mentioned in the IMO resolution and minimum requirements, but are influenced by the following frameworks:

SOLAS Chapter V:

- Regulation 13 (Establishment and operation of aids to navigation): GNSS can be considered an aid to navigation, providing accurate positioning information that is essential for safe and efficient inland waterway navigation, including bridge passing.

- Regulation 15 (Principles relating to bridge design and navigational systems):
    - .1: GNSS equipment should facilitate the tasks of the bridge team and pilot by providing accurate and reliable positioning data.
    - .5: GNSS should allow for continuous and effective information processing, aiding decision-making.
    - .6: GNSS should be user-friendly to prevent fatigue and maintain vigilance.
    - .7: GNSS should include monitoring and alarm systems to minimize human error and provide alerts for timely corrective action.
- Regulation 25 (Operation of steering gear): In critical navigation areas, such as near bridges, GNSS can provide the precise positioning needed to operate steering gear effectively, especially when multiple power units are required.
- Resolution A.893(21) (Guidelines for Voyage Planning): GNSS is integral to the appraisal and detailed planning of voyages, including the execution and monitoring of the plan, ensuring the vessel's progress is in line with the intended route, which is particularly important in confined waterways and when passing under bridges.

ISM Code (International Safety Management Code): requires that shipboard operations, including navigation, are planned and executed safely. GNSS data is essential for developing these plans, particularly for pollution prevention and safety during bridge transits.

MSC.1-Circ.1638 (Maritime Autonomous Surface Ships - MASS): discusses the implications of autonomous ships on current regulations. For MASS, GNSS would be even more critical as it would provide the necessary positioning and timing information for remote control centres and autonomous decision-making systems.

COLREG 1972 (International Regulations for Preventing Collisions at Sea): While not directly related to GNSS, COLREGs are essential for navigation safety, and GNSS data helps in complying with these regulations, especially when visibility is poor or when navigating close to bridges.

A.8.5 IEC standards

The International Electrotechnical Commission (IEC) is an international standards organisation that prepares and publishes international standards for all electrical, electronic and related technologies. The IEC administers three global Conformity Assessment Systems (IECEE, IECEx and IECQ) for testing, certification and approval of equipment, systems and components to its International Standards. The IEC collaborates with IMO and has taken on the role of developing international standards for the Global Maritime Distress and Safety Systems (GMDSS), which is an internationally agreed set of safety procedures and communication protocols used to increase safety and make it easier to rescue ships in distress.

The IEC Technical Committees provide the industry with standards that are also accepted by governments as suitable for type approval where this is required by the International Maritime Organisation’s SOLAS Convention. Such standards deal with all electrical, electronic and related technologies; and by extension issues with other issues concerning the design of the equipment, its power supplies, Electromagnetic Compatibility (EMC) and safety. These standards do not deal with user requirements in any way; they allow test certification agencies to declare equipment “fit for use” through type approval procedures.

IEC develops numerous standards which help to prepare an increasingly sustainable future for maritime transport, from electric-propelled ships to renewable energy systems which can be adapted to shipping. Two IEC Technical Committees are directly dedicated to the maritime industry. The “IEC Technical Committee 80” (IEC TC 80) on maritime navigation and radiocommunications equipment and systems produces operational and performance requirements together with test methods.

The IEC TC 80 produces operational and performance requirements together with test methods for maritime navigation and radiocommunication equipment and systems. It provides industry with standards that are accepted by governments as suitable for type approval where this is required by the International Maritime Organisation's SOLAS Convention. Such standards deal with all electrical, electronic and related technologies; and by extension issues with other issues concerning the design of the equipment, its power supplies, Electromagnetic Compatibility (EMC) and safety. These standards do not deal with user requirements in any way; they allow test certification agencies to declare equipment "fit for use" through type approval procedures.

IEC TC 80 has produced standards for all the equipment which is required by the Safety of Life at Sea (SOLAS) Convention to be carried on the bridge of a ship. This includes the Automatic Identification System (AIS), the Electronic Chart Display and Information System (ECDIS), the Voyage Data Recorder, the radio installation, GNSS receivers and the radar.

Where appropriate, such as in the case of the Automatic Identification System, TC 80 has also produced standards for equipment intended for use on small vessels which has to interwork with the SOLAS equipment and also for supporting shore-based equipment. The table below lists some of the most relevant IEC publications together with their IMO counterpart when available.

Table 63: IEC Standards and corresponding IMO Resolutions

IEC Reference	IMO Reference	Subject
IEC 60945 Ed. 4.0	A.694(17)	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
IEC 61108-1 Ed. 2.0	MSC.112(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) -Receiver equipment - Performance standards, methods of testing and required test results
EC 61108-2 Ed. 1.0	MSC.113(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) - Receiver equipment - Performance standards, methods of testing and required test results
IEC 61108-3 Ed. 1.0	MSC.233(82)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-4 Ed. 1.0	MSC.114(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-5		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 5:

IEC Reference	IMO Reference	Subject
		BeiDou navigation satellite system (BDS) - Receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-6		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 6: Navigation with Indian constellation (NavIC)/Indian regional navigation satellite system (IRNSS) - Receiver equipment - Performance requirements, methods of testing and required test results (under development)
IEC 61108-7		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 7: Satellite Based Augmentation Systems - Receiver Equipment - Performance requirements and method of testing
IEC 61162 - Parts 1 to 4		Maritime navigation and radiocommunication equipment and systems – Digital interfaces
IEC 61993-2 Ed. 2.0	MSC.74(69) Annex 3	Maritime navigation and radiocommunication equipment and systems - Automatic identification systems (AIS) - Part 2: Class A shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results
IEC 61108-8 ED1		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 8: Quasi-Senith Satellite System (QSSS) receiver equipment - Performance requirements, methods of testing and required test results (under development)
IEC 61108-9 ED1		Global maritime distress and safety system (GMDSS) - Part 9: Shipborne transmitters and receivers for use in the MF and HF bands suitable for telephony, digital selective calling (DSC) and reception of Maritime Safety Information and Search and Rescue related information

The PT 61108-8 is currently working on performance requirements for Quasi-Senith Satellite System (QSSS) receivers, expecting to publish in 2028.

The PTT 61108-09 is currently working on operational requirements for GMDSS and the use of MF and HF for DSC, expecting to publish in 2025.

The IEC TC 18 deals with the electrical installations of ships and of mobile and fixed offshore units. Also IEC TC 23 is relevant to maritime transport, as it develops standards for electrical accessories which publish standards on ship couplers for high-voltage shore connection systems.

A.8.6 EC – River Information Service (RIS)

River Information Services (RIS) are information technology related services designed to optimise traffic and transport processes in inland navigation, enhancing a swift electronic data transfer between water and shore through in advance and real-time exchange of information. RIS aims to streamline the exchange of information between waterway operators and users.

EU framework directives and guidelines providing minimum requirements to enable cross-border compatibility of national systems are continuously developed to harmonise the existing standards for particular river information systems and services within a common framework. In particular the roles of Danube Commission and Central Rhine Commission are to be highlighted.

DIRECTIVE 2005/44/EC AND AMENDMENT 219/2009

This Directive dated 7 September 2005 and its Amending Regulation EU 219/2009 establishes a framework for the deployment and use of river information services (RIS) in the Community along with the further development of technical requirements, specifications and conditions to ensure its harmony and interoperability, in order to support inland waterway transport enhancing safety, efficiency and environmental friendliness and facilitating interfaces with other transport modes.

The Directive in its Article 5 requests the Commission to define technical specifications in particular in the following areas:

- Electronic chart display and information system for inland navigation (inland ECDIS);
- Electronic ship reporting;
- Notices to skippers;
- Vessel tracking and tracing systems;
- Compatibility of the equipment necessary for the use of RIS.

It also states sets out technical principles as a basis for said specifications, among which:

Compatibility with maritime ECDIS (point a above)
Compatibility with maritime AIS (point d above)

Guidelines and specifications shall take account of the work carried out in this field by relevant international organisations.

Lastly, it encourages the use of GNSS in its Article 6 which reads:

“For the purpose of RIS, for which exact positioning is required, the use of satellite positioning technologies is recommended”.

The directive is currently under review, and a EC proposal has been launched in January 2024.

COMMISSION REGULATIONS (EC) NO 414/2007 [RD38] AND 415/2007 [RD39]

These regulations, both dated 13 March 2007 are the consequence of the Directive 2005/44, Article 5, calling for the establishment of technical RIS guidelines.

REGULATION (EC) NO 414/2007 [RD38]

This regulation defines guidelines for the planning, implementation and operational use of RIS. As such, it focuses on services rather than on systems or functions. Consequently, it does not give detailed operational or technical requirements but rather gives an overall operational description of the River Information Services and of each “individual” service part of the RIS.

REGULATION (EC) NO 415/2007 [RD39]

This regulation deals with the technical specifications for vessel tracking and tracing systems used in RIS, as referred to in Directive 2005/44/EC [RD37]. Contrary to the more general regulation 414/2007 [RD38], it addresses in details the functional and technical requirements of the vessel tracking and tracing system, which is based upon "Inland AIS".

Among the most important functional requirements (for PNT), this directive introduces inland specific (or RIS specific) operations and phases of navigation, and specifies accuracy requirements for each of those. Table 7 summarises these requirements.

As can be noted, we have here not only requirements concerning the position, but also other navigational data that can be derived from the positioning sensor (speed over ground, course over ground) or other sub-system (heading).

Table 64: Overview of accuracy requirements for RIS dynamic data.

Operation	Position	Speed over ground	Course over ground	Heading
Navigation medium-term ahead	15 — 100 m	1- 5 km/h	—	—
Navigation short-term ahead	10 m (1)	1 km/h	5°	5°
VTS information service	100 m — 1 km	—	—	—
VTS navigational assistance service	10 m (1)	1 km/h	5°	5°
VTS traffic organisation service	10 m (1)	1 km/h	5°	5°
Lock planning long-term	100 m — 1 km	1 km/h	—	—
Lock planning medium-term	100 m	0,5 km/h	—	—
Lock operation	1 m	0,5 km/h	3°	—
Bridge planning medium-term	100 m — 1 km	1 km/h	—	—
Bridge planning short term	100 m	0,5 km/h	—	—
Bridge operation	1 m	0,5 km/h	3°	—
Voyage planning	15 — 100 m	—	—	—
Transport logistics	100 m — 1 km	—	—	—
Port and terminal management	100 m — 1 km	—	—	—
Cargo and fleet management	100 m — 1 km	—	—	—

Operation	Position	Speed over ground	Course over ground	Heading
Calamity abatement	100 m	—	—	—
Enforcement	100 m — 1 km	—	—	—
Waterway and port infrastructure charges	100 m — 1 km	—	—	—

Beyond these requirements, this directive gives technical specifications for the "Inland AIS", which are all subject to the overarching one: compatibility with IMO standards. Indeed, it states:

"To serve the specific requirements of inland navigation, AIS has to be further developed to the so-called Inland AIS technical specification while preserving full compatibility with IMO's maritime AIS and already existing standards and technical specifications in inland navigation."

And further:

"The technical solution of Inland AIS is based on the same technical standards as IMO SOLAS AIS (Rec. ITU-R M.1371-1, IEC 61993-2)." Consequently, Inland AIS can be treated as an extension of maritime AIS, and only "inland specific" additions must be checked for possible additional constraints or requirements. No such additional requirement can be found in the current version of the directive".

A.8.7 European Radionavigation Plan (ERNP)

The European Radionavigation Plan (ERNP) is a strategic document developed to guide the development, implementation, and coordination of radionavigation systems across Europe. It aims to ensure the availability, reliability, and integrity of radionavigation services for various sectors, including maritime, aviation, and land transportation. The ERNP is designed to support the European Union's goals of enhancing safety, security, and efficiency in transportation and other critical infrastructures.

In 2023, the European Radionavigation Plan was updated to include new satellite navigation systems and enhanced coordination among European countries. The updated plan emphasises the integration of emerging technologies, such as multi-constellation GNSS and advanced augmentation systems, to improve the resilience and reliability of radionavigation services. Additionally, the plan incorporates new measures to address cybersecurity threats and ensure the protection of radionavigation infrastructure.

A.8.8 US Federal Radionavigation Plan (FRP)

This section covers the Maritime User Requirements in the U.S.A. present in the 2017 Federal Radio Navigation Plan.

The FRP separates requirements into phases of navigation and relates them to nautical conditions (distance to the closest danger, but also type of craft). Four major phases are identified, namely inland waterways, harbour entrance and approach, coastal and ocean navigation. In comparison, IMO A.915(22) identifies a 5th phase: "port" which is not discussed in the FRP. It is to be noticed though that IMO requirements for "port navigation" are currently subject to discussion and are indeed lacking justification or traceability. Another important aspect of the FRP is that it distinguishes requirements for "safety of navigation" and requirements for "benefits" (most often economic benefits). These requirements are summarised hereafter, together with their context. Finally, the FRP introduces requirements for underwater navigation that cannot be found anywhere else.

INLAND WATERWAYS

Inland waterway navigation is conducted in restricted areas, being the focus on non-seagoing ships and their requirements on long voyages in restricted waterways. Although seagoing craft in the harbour phase of navigation and inland craft in the inland waterway phase may share the use of the same restricted waterway in some areas, the distinction between the two phases depends primarily on the type of craft, due to the differences between them and their needs in terms of requirements for aids to navigation.

As recreational and small craft are found in both seagoing and inland commercial traffic and generally have less stringent requirements for either case, the requirements are separated according to the type of craft. Visual and audio aids to navigation, radar, and inter-ship communications are used to enable safe navigation in those areas.

Table 65: FRP Maritime User Requirements - Inland Waterway Phase.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	Accuracy (Metres, 2 drms)	Availability	Continuity	Integrity	Time to Alert	Coverage
Safety of Navigation (All Ships and Tows)	2-5	99.9%	*	N/A	N/A	U.S. Inland Waterway Systems
Safety of Navigation (Recreational Boats and Smaller Vessels)	5-10	99.9%	*	N/A	N/A	U.S. Inland Waterway Systems
River Engineering and Construction Vessels	0.1**-5	99.9%	*	N/A	N/A	U.S. Inland Waterway Systems

* Dependent upon mission time.

** Vertical dimension.

Harbour entrance and approach

Harbour entrance and approach navigation is conducted in waters inland from those of the coastal phase. Usually, harbour entrance requires navigation of a well-defined channel.

From the viewpoint of establishing standards or requirements for safety of navigation and promotion of economic efficiency, there is some generic commonality in harbour entrance and approach. In each case, the nature of the waterway, the physical characteristics of the vessel, the need for frequent manoeuvring of the vessel to avoid collision, and the closer proximity to grounding danger, impose more stringent requirements for accuracy and for real-time guidance information than for the coastal phase. The phase of harbour entrance and approach is built around the problems of precise navigation of large ships in narrow channels between the transition sone and the intended mooring.

Table 66: FRP Maritime User Requirements/Benefits - Harbour Entrance and Approach Phase.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	**Accuracy (Metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
Safety of navigation (large ships & tows)	8 – 20***	99.7%	**	N/A	N/A	U.S. harbour entrance and approach
Safety of navigation (smaller ships)	8 – 20	99.9%	**	N/A	N/A	U.S. harbour entrance and approach
Resource exploration	1 – 5*	99%	**	N/A	N/A	U.S. harbour entrance and approach
Engineering and construction vessels - Harbour phase	0.1**** – 5	99%	**	N/A	N/A	Entrance channel & jetties, etc.
	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					
Benefits	**Accuracy (metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
Fishing, Recreational and other small vessels	8-20	99.7%	**	N/A	N/A	U.S. harbour entrance and approach

* Based on stated user need.
** Dependent upon mission time.
*** Varies from one harbour to another. Specific requirements are being reviewed by the USCG.
**** Vertical dimension.

The pilot of a vessel in restricted waters needs highly accurate verification of position almost continuously in order to navigate safely, once the ship is unable to turn around, and severely limited in the ability to stop to resolve a navigation problem.

The requirements stated above are Minimum Performance Criteria (MPC), while the PNT solution accuracy required varies with the harbour and with the size of the ship. A need exists to more accurately determine these PNT requirements for various-sized vessels while operating in such restricted confines, because for many mariners, the PNT solution becomes a secondary tool to other aids to navigation during this phase.

COASTAL

Coastal navigation is that phase in which a ship is in waters contiguous to major land masses or island groups where transoceanic traffic patterns tend to converge in approaching destination areas; where inter-port traffic exists in patterns that are essentially parallel to coastlines; and within which ships of lesser range usually confine their operations. Traffic-routing systems and scientific or industrial activity on the continental shelf are encountered frequently in this phase of navigation.

There is a need for continuous, all-weather PNT service in the coastal area to provide, at the least, the position fixing accuracy to satisfy minimum safety requirements for general navigation.

Requirements on the accuracy of position fixing for safety purposes in the coastal phase are established by:

- The need for larger vessels to navigate within the designated one-way traffic and at safe distances from shallow water.
- The need to define accurately the boundaries of the Fishery Conservation Sone, the U.S. Customs Sone, and the territorial waters of the U.S.

Table 67: FRP Maritime User Requirements/Benefits - Coastal Phase.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	**Accuracy (Metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
Safety of navigation (all ships)	0.25 nmi (460 m)	99.7%	**	N/A	N/A	U.S. harbour entrance and approach
Safety of navigation (recreation boats and other small vessels)	0.25 – 2 nmi (460 – 3,700 m)	99%	**	N/A	N/A	U.S. coastal waters
Resource exploration	1 – 5*	99%	**	N/A	N/A	U.S. coastal waters
	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					
Benefits	**Accuracy (Metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
Commercial fishing (incl.	0.25 nmi	99%	**	N/A	N/A	U.S. coastal /

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	**Accuracy (Metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
commercial sport fishing)	(460 m)					fisheries areas
Resource exploration	1.0 – 100 m*	99%	**	N/A	N/A	U.S. coastal areas
Search operations **Law enforcement**	0.25 nmi (460 m)	99.7%	**	N/A	N/A	U.S. coastal / fisheries areas
Recreational sports fishing	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal areas

* Based on stated user need.
** Dependent upon mission time.

OCEAN NAVIGATION

Ocean navigation is that phase in which a ship is beyond the continental shelf, in waters where position fixing by visual reference to land or to fixed or floating aids to navigation is not practical. Ocean navigation is sufficiently far from land masses so that the hasards of shallow water and of collision are comparatively small. These requirements must provide a ships' Master with a capability to avoid hasards in the ocean (e.g., small islands, reefs) and to plan correctly the approach to land or restricted waters. For many operational purposes, repeatability is necessary.

Table 68: FRP Maritime User Requirements/Benefits - Ocean Phase.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	**Accuracy (Metres, 2 drms)**	**Availability**	**Continuity**	**Integrity**	**Time to Alert**	**Coverage**
Safety of navigation (all craft)	2-4 nmi (3.7 – 7.4 km) minimum 1-2 nmi (1.8 – 3.7 km) desirable	99% fix at least every 12 hours	**	N/A	N/A	Global
	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					

Benefits	Accuracy (Metres, 2 drms)	Availability	Continuity	Integrity	Time to Alert	Coverage
Large ships Maximum efficiency	0.1-0.25 nmi* (185 – 460 m)	99%	**	N/A	N/A	Global except polar regions
Resource exploration	10–100 m*	99%	**	N/A	N/A	Global
Search operations	0.1–0.25 nmi 185 – 460 m)	99%	**	N/A	N/A	National maritime SAR regions
Recreational sports fishing	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal areas

* Based on stated user need.
** Dependent upon mission time.

Sub-surface PNT user requirements

Sub-surface marine PNT users consist of naval submariners, offshore oil exploration, deep sea salvage, trans-oceanic cabling, deep sea fishing, and even recreational scuba divers. The positioning and timing requirements vary drastically depending on the application. Sub-surface marine users typically rely on systems more adept to this milieu, such as sound navigation and ranging (SONAR), compasses, and water pressure sensors. The requirements for these applications are stated as follows:

Table 69: FRP Maritime User Requirements – Sub-surface marine applications.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	Accuracy (Metres, 2 drms)	Availability	Continuity	Integrity	Time to Alert	Coverage
Sub-surface marine applications	0.1-5m	90-99%	N/A	0.2-10m	1-15s	Global

Other applications

Some applications identified e.g. in IMO resolution A915 (22) are listed in the FRP, albeit in different sections than "maritime". Among them hydrographic survey:

Table 70: FRP Maritime User Requirements –Hydrographic survey.

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS						
Requirements	Accuracy (Metres, 2 drms)		Availability	Continuity	Inte-grity	Time to Alert	Coverage
	H	V					
Hydrographic survey	3	0.15	99%	-8x10-6/15s	1s	1s	Global

Future Marine PNT requirements

The FRP also addresses the evolution of Marine PNT Requirements. The main factors that will impact future requirements are:

- Safety
- Increased Risk from Collision and Grounding
- Increased Size and Decreased Manoeuvrability of Marine Vessels
- Greater Need for Traffic Management/Navigation Surveillance Integration
- Economics
- Greater Congestion in Inland Waterways and Harbour Entrances and Approaches
- All Weather Operations; y Environment; y Energy Conservation.
- Environment
- Energy Conservation

A.8.9 IHO Requirements

The International Hydrographic Organisation (IHO) role is to ensure that world's seas, oceans and navigable waters are surveyed and charted. IHO requirements concern the accuracy of nautical charts and are not directly related with IMO expressed requirements concerning positioning of ships. There is however an inherent relation, since a vessel position as reported by its “Electronic Position Fixing Device” is feeding its ECDIS and is plotted on the displayed electronic chart.

As for nautical charts, the following requirements can be found in:

Table 71: IHO survey accuracy requirements

Description of areas	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Maximum allowable total horizontal uncertainty (THU) (95% confidence level)	2m	5m +5% of depth	5m +5% of depth	20m +10% of depth
Positioning of fixed aids to navigation and topography significant to navigation (95% confidence level)	2m	2m	2m	5m
Positioning of the coastline and topography less significant to navigation (95% confidence level)	10m	20m	20m	20m
Mean position of floating aids to navigation (95% confidence level)	10m	10m	10m	20m

However, not all available nautical charts conform to these requirements. Indeed, many have been produced with equipment obsolete by today's standards, and some areas are poorly charted. Newly produced charts, on the other hand, often use state of the art methods and equipment and exceed these requirements. To depict this situation, cartographers use "Category Sone of confidence" values (CATSOC) to highlight the accuracy of data presented on charts (which may differ from the above table). The following table outlines the position accuracy, depth accuracy and seafloor coverage for each SOC value:

Table 72: Zone Of Confidence (SOC) values for hydrographic charts.

SOC	Position Accuracy	Depth Accuracy	Seafloor coverage	Typical survey characteristics
A1	±5 m + 5%	=0.50 + 1%d Depth (m) – Accuracy (m) 10 – ± 0.6 30 – ± 0.8 100 – ± 1.5 1,000 – ± 10.5	Full area search undertaken, significant seafloor features detected, and depths measured.	Controlled, systematic survey high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system
A2	± 20 m	= 1.00 + 2%d Depth (m) – Accuracy (m) 10 – ± 1.2 30 – ± 1.6 100 – ± 3.0 1,000 – ± 21.0	Full area search not achieved; uncharted features, hasardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving position and depth accuracy less than SOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.
B	± 50 m	= 1.00 + 2%d Depth (m) – Accuracy (m) 10 – ± 1.2 30 – ± 1.6 100 – ± 3.0 1,000 – ± 21.0	Full area search not achieved; depth anomalies may be expected.	Controlled, systematic survey achieving similar depth but less position accuracy than SOC A2, using a modern survey echosounder but no sonar nor mechanical sweep system.
C	± 500 m	= 2.00 + 5%d Depth (m) – Accuracy (m) 10 – ± 2.5 30 – ± 3.5 100 – ± 7.0 1,000 – ± 52.0	Full area search not achieved; depth anomalies may be expected.	20m

SOC	Position Accuracy	Depth Accuracy	Seafloor coverage	Typical survey characteristics
D	Worse than SOC C	Worse than SOC C	Full search not achieved, large depth anomalies expected.	Poor quality data or data that cannot be quality assessed due to lack of information
U	Unassessed - The quality of the bathymetric data has yet to be assessed			

The Joint IMO/IHO/WMO Manual on Maritime Safety Information (MSI) is a practical guide for anyone who is concerned with drafting navigational warnings or with the issuance of meteorological forecasts and warnings under the Global Maritime Distress and Safety System (GMDSS).

Maritime Safety Information (MSI) is promulgated in accordance with the requirements of IMO resolution A.705(17), as amended.

A.8.10 Relevant Standards for EO

EO techniques present a lack of consistency between sensors and their calibration, in data formats and structures, in accuracies and terminology, and structures. Uptake of some EO techniques has been slow and there have been challenges in ensuring interpretability. International standards would help address these issues, and these guidelines aimto go some way towards improving the accessibility of EO data products and technologies.

There are currently very few standards or regulatory documents in EO, either in data quality or in processing or products. The internationally adopted standards in data formats and metadata associated with digital spatial data were provided by ISO, IEEE, OGC, GRSS and SEOAH:

- The International Organization for Standardization (ISO);
- ISO/TR19121:2000 concerning Geographic information, imagery, and gridded data
- ISO 19115:2014 Geographic Information - Metadata.
- The Open Geospatial Consortium (OGC) provides Standards and Schemas (XSD, JSON Schema, etc) for the geospatial information interoperability and implementation used by international organizations.
- EO product metadata: OGC's GML Application Schema for EO Products
- Collection and service discovery: OGC's Cataloguing of ISO Metadata using the ebRIM profile of CS-W.
- Catalogue Service: OGC's Catalogue Services Specification 2.0 Extension Package for ebRIM Application Profile: EO Products.
- Order: OGC's Ordering Services for EO Products
- Feasibility Analysis: OGC's Sensor Planning Service Application Profile for EO Sensors
- Online Data Access: OGC's WMS EO Extension
- Identity (User) Management: OGC's User Management Interfaces for EO Services.
- Geoscience and Remote Sensing Society (GRSS) created the Standards in Earth Observations (GSEO) Technical Committee to support the development and promotion of technical standards related to the generation, distribution, and utilization of interoperable data products from remote sensing systems.

- The Standards in Earth Observations Ad Hoc Committee (SEOAH) is the managing organizational unit within GRSS to handle standards development within the IEEE.

A.8.11 Critical Analysis on GNSS User Requirements

A.8.1.1.1 Analysis of IMO requirements

A. 915 (22) AND A.1046 (27)

The IMO Resolutions A. 915 (22) [RD8] and A.1046 (27) [RD11] form the main structure of IMO's requirements for Maritime Radio Navigation Systems. Resolution A.1046 (27) [RD11] give the formal requirements and procedures for accepting new systems as components of the World-Wide Radio navigation System (WWRNS), while A.915 (22) [RD8] must be viewed as a "navigation and positioning" document related to requirements for future developments of GNSS to be considered within the framework of A.1046(27) [RD11].

It is quite difficult to assess the requirements found in these two resolutions, due to their lack of traceability and of explanation or justification for the allocated integrity and continuity risks in operational terms.

Furthermore, even when detailed requirements are available (e.g. A.915 (22) [RD8], they are at best related to a phase of navigation or a particular positioning application, but they generally lack a description of the "conditions", be it in terms of vessel dynamics or physical or radio electrical environments. Such necessary complementary information is to be found in ITU or IALA or IEC publications, when available at all.

Although these Resolutions entered into force respectively in 2002 and 2011, and should be updated in some parts (e.g. with regards to continuity requirements), the assessment performed in this work through primary research suggests that the order of magnitude of the requirements is appropriate.

A 1106 (29) - REVISED GUIDELINES FOR AIS [RD9]

IMO resolution A 1106 (29) [RD9] was updated in the end of 2015. The resolution is of little interest to extract PNT related user requirements (except for the reporting intervals, that go from 2 seconds to 3 minutes). The more detailed ITU or IALA or IEC relevant publications must be used instead.

An additional analysis of technical performance offered against the different uses would be of interest in a future version.

A 1106 (29) - REVISED GUIDELINES FOR AIS [RD9]

IMO requirements vs. GNSS capabilities

Even though GNSS have gained wide acceptance as the preferred positioning systems for a majority of maritime applications, none of the existing or planned GNSS seem to be able to comply with the requirements for integrity and continuity of Resolution A.915 (22) [RD8], according to the study "A critical look at the IMO requirements for GNSS" undertaken within the scope of MarNIS FP6 project (Maritime Navigation and Information Services, see E.2). However, IMO Resolution A.1046 (27) [RD11] was released after the conclusion of this study and one of the important changes it brought was reducing continuity from 3h to 15min in harbour entrances and approaches and coastal waters.

The MarNIS conclusion should therefore be revised / updated to account for this relaxed continuity specification.

Analysis of IALA recommendations and guidelines

Although IALA recommendations lack the regulatory force of IMO resolutions; "there is an implicit expectation that individual national members will observe and implement IALA Recommendations". The SOLAS Convention recalls IALA's Guidelines on specific topics. Furthermore, such recommendations are referring to relevant international standards and regulations, very often including parts of them, together with clarifications, explanations and complementary information (e.g. contextual). In short, they are almost self-sufficient, with the possible exception of equipment manufacturers which may have to refer to IEC complementary standards.

Additionally, IALA documents are often (if not always) published and updated faster than their IMO counterparts, and IALA can even be at the origin of some IMO regulations (as it was the case for AIS).

For the purpose of deriving user requirements, IALA documents are never in contradiction with IMO ones, but they may be ahead of them. Besides, they can be useful to justify some of the requirements found in IMO, and / or to place them in their operational context.

Comparison between IMO and US regulation

There are significant differences in the way the US FRP on one hand, and current IMO resolutions on the other hand, list and justify user requirements. In many ways, the FRP is closer to the IALA Navguide than to IMO resolutions:

- It describes the phases of navigation (nautical context);
- It justifies requirements with safety of navigation concepts (distance from danger and vessel speed).

A direct comparison with IMO resolutions is not straightforward, so that we shall focus on the "Safety of navigation" requirements only, assuming they are reflected in IMO documents under the "SOLAS vessels navigation" category.

Table 73: Comparison between FRP and IMO user requirements for safety of navigation.

	Accuracy (m)		Availability (%/period)		Continuity (over 15min)		Integrity (alert limit / risk per 3h)		Time to alert (s)	
Phase of navigation	IMO	FRP	IMO	FRP	IMO	FRP	IMO	FRP	IMO	FRP
Ocean	10-100	1800-3700	99.8 30 days	99 12 h	N/A	*	25 10^{-5}	TBD	10	TBD
Coastal	10	460	99.8 30 days	99.7	N/A	*	25 10^{-5}	TBD	10	TBD
Port approach & restricted waters	10	8-20**	99.8 30 days	99.7	99.97	*	25 10^{-5}	TBD	10	TBD
Port	1	-	99.8 30 days	-	99.97	-	25 10^{-5}	-	10	TBD
Inland waterways	10	10	99.8 30 days	99.9	99.97	*	25 10^{-5}	TBD	10	TBD

* Dependent upon mission time
** Varies from one harbour to another

The large discrepancies apparent in this comparison cannot be attributed to different conditions or types of vessels, which are identical for the USA and the rest of the world at least for the oceanic and coastal phases of navigation. Furthermore, the two major IMO resolutions (A915 (22)[RD8] and A1046 (27)[RD11]) do not include justification for their operational requirements, making it almost impossible to make a sensible analysis of these differences.

The most likely explanations are:

- The FRP makes a strict interpretation of "Safety of life requirements" and derives its figures in the traditional way, accounting for distance to closest hazard to navigation and vessel speed / manoeuvrability.
- The IMO resolutions make a looser interpretation, and probably include economic efficiency as a parameter. Furthermore, they may also be influenced by actual radionavigation systems observed or predicted performance (it is to be kept in mind that A915 (22) deals with requirements for a future GNSS, although it is widely accepted as the IMO reference for user requirements).

A.8.1.1.2 Comparison between IHO requirements with IMO

The IHO and IMO horizontal accuracy requirements are compared in Table 15 below. It should be kept in mind that IHO deals with the accuracy of nautical charts, which should be better than that of the vessels and which is an input rather than a user requirement.

Table 74: Comparison of IHO and IMO accuracy requirements.

IHO Description of areas	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Interpretation	Shallow waters such as those in Ports, Inland Waterways and possibly Ports Approaches,	Continental shelf, such as encountered for Coastal navigation and Port approaches	Continental shelf, such as encountered for Coastal navigation and Port approaches (low SOLAS traffic area)	Beyond continental shelf, i.e. mostly abyssal plain (depth averaged at 4000 metres); such as encountered in Oceanic navigation
IMO Phase of navigation	Ports Inland Waterways (Ports Approaches)	Coastal navigation Port approaches	Coastal navigation Port approaches	Ocean
IMO accuracy requirement	1 metre 10 metres	10 metres	10 metres	10-100 metres

IHO Description of areas	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
IHO accuracy requirement (most stringent	2 metres	2 metres	2 metres	5 metres
IHO Maximum allowable THU*	2 metres	5 metres + 5% of depth; i.e. 5 to 10 metres	5 metres + 5% of depth; i.e. 5 to 10 metres	20 metres + 10% of depth; i.e. 30 to 420 metres
Comments	IMO accuracy requirements for port navigation are more stringent than IHO most stringent ones	Consistent	Consistent	Except for isolated hazards to navigation, the IMO en-route accuracy requirements are more stringent than the IHO ones.

The IHO most stringent requirements apply to "Positioning of fixed aids to navigation and topography significant to navigation", i.e. potential hazards to navigation.

In most cases, they are consistent with the IMO A1046 [RD11] requirements, which means than the dangers positions are known to the navigator with a better accuracy than the ship's current position (the actual "safety of life" relevant information is indeed the distance to nearest danger).

In the case of port navigation, the IMO requirement of 1 metre is not justified unless the actual accuracy of the nautical chart in use is better than the IHO requirement, which is indeed possible but cannot be assumed.

In the case of oceanic navigation, an "isolated danger to navigation" will be chartered with 5 metre accuracy, consistent with IMO's 10 to 100 metres. However, it should be kept in mind that such dangers are either considered by mariners as landmarks / waypoints, or the planned route is designed well clear of them. For the rest of enroute navigation, the seafloor is mapped with a required accuracy of typically 500 metres (for 5000 m depth); when mapped at all. Here again, the IMO accuracy requirement is largely better than the nautical charts required accuracy (the US FRP is more consistent on this aspect). Such requirement cannot generate harmful situations but cannot either be justified by safety of navigation reasons only.

Hydrographers are aware of these discrepancies between the position accuracy obtained by mariners using modern electronic position fixing equipment (typically GNSS) and the required (per IHO) horizontal accuracy of charts; the actual accuracy of the available charts and the required (per IHO standards) accuracy.

Nautical charts are produced or updated using state of the art equipment, which is indeed more accurate than the minimum IHO requirement or than the position available to mariners via "standard" EPFS / GNSS. However, the rate of production and / or of updates of the nautical charts does not allow to have a complete portfolio of "modern" charts covering the whole surface of the oceans. To cope with this difficulty and to inform users of the real quality of their nautical documents, cartographers use the concept of "Sones of Confidence", ranging from Category A1 (best) to U (unassessed quality).

A.8.1.1.3 GNSS and augmentation systems limitation

No existing GNSS can meet all operational requirements, especially integrity, without the use of augmentation systems including SBAS.

Despite its theoretical capacity to fulfil IMO resolution A.1046 (27) [RD11], there are no existing maritime standards for SBAS receivers yet. This does not prevent the maritime community from using SBAS (but not its integrity concept), but to spread its use as permanent and consolidated it would be necessary to have specific regulation concerning the maritime users' needs. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers to minimise implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and the fact that SBAS have limited signal availability in northern latitudes (i.e. above 70°).

As discussed before, the particularities of maritime navigation culture result in more independence among the several navigation instruments, and consequently, in more freedom for ship and equipment manufacturers. However, this situation will probably evolve thanks to the development of e-Navigation, which is a strategy to increase safety of navigation in commercial shipping through better organisation of data on ships and on shore, and better data exchange between ships and with the shore. This topic will be more thoroughly discussed later.

A.8.1.1.4 Inland waterways – Special analysis on user requirements with IMO, FRP, EC, MARUSE

Previous chapters show the different requirements for inland waterways safety of navigation proposed by IMO, FRP, EC and Maruse project. In this chapter an analysis of these requirements for merchant vessels is presented using the values specified in IMO resolution A.915 [RD8] and A.1046 (27) [RD11] as the reference. IMO resolution A.915 [RD8] sets the value of 10m accuracy (95%) and 25m for the Horizontal Alert limit. These values for accuracy are applicable in Europe by REGULATION (EC) No 415/2007. These are the values to be considered for the mission. In case of specific operations under bridges or in locks, the regulation sets 1m accuracy (95%). On the other hand, the MARUSE project proposed a more stringent requirement for inland waterways navigation with 3m accuracy (95%) and 7.5m as Horizontal Alert limit while keeping the rest of the values as in IMO resolutions. The MARUSE project also proposed to measure the continuity over 15 minutes in line with IMO resolution A.1046, proposing this change with respect IMO resolution A.915 [RD8]. In the Federal Navigation Plan, the requirement for inland waterways for merchant vessels and tows an accuracy in the range of 2-5m (95%) is proposed depending on if it is a merchant vessel or a tow performing complex manoeuvres. Finally, IHO is proposing for the hydrographic surveys that are used to update the navigation charts an accuracy of 2m (95%) in those areas where under-keel clearance is critical.

Considering that the IMO does not have jurisdiction over IWW, and that a consensus exists (MARUSE, UCP, but also the US FRP and the IHO all give figures in the 2-5 m range), the horizontal accuracy requirement is set to 3m.

EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the EU. In the execution of its mission, EUSPA counts on strong partnerships with the European Commission, European Parliament, Member States, European Space Agency, and private actors across the EU.

The EU Agency for the Space Programme:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for GOVSATCOM and soon IRIS², and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness;
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, GOVSATCOM and soon IRIS² across a broad range of domains;
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms;
- Implements and monitors the security of the EU Space Programme components in space and on the ground with the aim to enhance the security of the Union and its Member States. To do so, EUSPA operates the Galileo Security Monitoring Centre (GSMC).

The EU Space Programme Security Accreditation Board is established within the Agency, representing the security accreditation authority for all of the EU Space Programme's components.

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