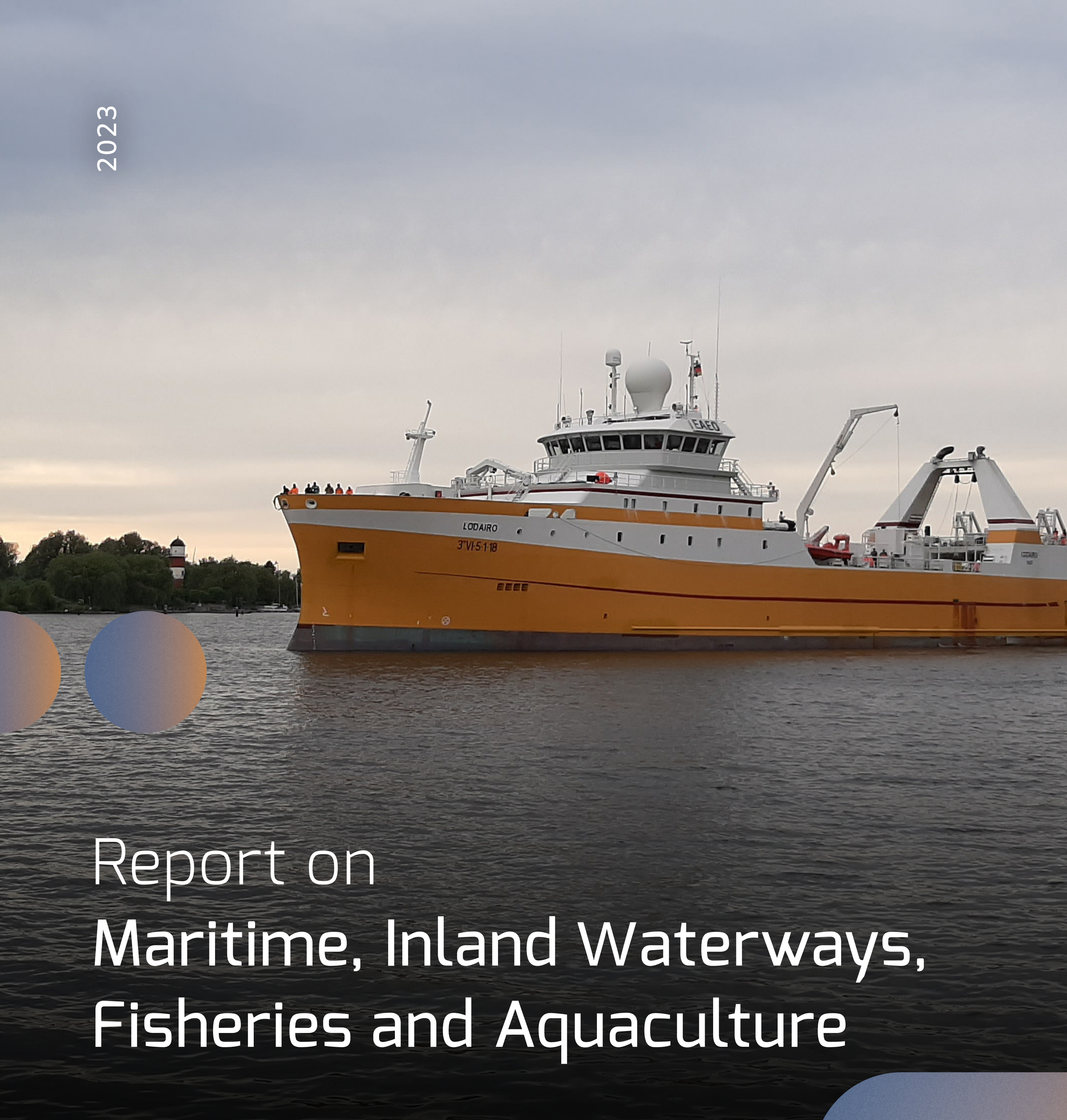

2023

Report on
Maritime, Inland Waterways, Fisheries and Aquaculture

User Needs and Requirements

#EUSpace

EUSPA European Union Agency for the Space Programme

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1 INTRODUCTION AND CONTEXT OF THE REPORT

EUSPA is the operational European Union Agency for the Space Programme, established in its current form on 21 May 2021, tasked, among other things, with promoting the commercialization of Galileo, Copernicus data and services and EGNOS. In the field of Maritime, Inland Waterways, Fisheries and Aquaculture, Earth Observation (EO) and the Global Navigation Satellite System (GNSS) are used for both navigation and positioning. They have become the primary means of navigation in many Maritime, Inland Waterways, Fisheries and Aquaculture applications. This year's User Needs and Requirements Report will feature Earth Observation for the first time after EUSPA's mandate was extended to also support the promotion and commercialisation of the downstream Copernicus services.

Maritime, Inland Waterways, Fisheries and Aquaculture Sector is a truly international industry, and it can only operate effectively if the regulations and standards are themselves agreed, adopted and implemented on an international basis. It is already highly regulated, and regulations have been reinforced over the last decades. The International Maritime Organization (IMO) is setting the regulatory framework for the shipping industry, including performance requirements for GNSS. Some of the most important parameters of operational requirements for GNSS are integrity, continuity, accuracy, availability and coverage. These requirements are developed based on risk analysis, considering risk exposure time and critical risk exposure time. However, user requirements relevant to GNSS in Maritime are very complex and oftentimes not aligned. Also, the maritime sector is dynamic with the ongoing development of e-Navigation, maritime service portfolios and the debate how to provide resilient positioning, navigation and timing (R-PNT).

Some of the expected future requirements are indeed related with the e-Navigation initiative, which can drive the uptake of multi-constellation GNSS, and with the need to develop new performance standards for navigation receivers. The International Maritime Organization (IMO) is setting the regulatory framework for the shipping industry, including performance requirements for EO. The marine component of Copernicus, Copernicus Marine Environment Monitoring Service, provides data on the physical state and dynamics of oceans and marine ecosystems, and is evolving to becoming the EU reference for ocean forecasting, relevant for safe and optimised ship routes and many other applications.

The User Consultation Platform (UCP) is a periodic forum organised by the European Commission (EC) and the European Union Agency for the Space Programme (EUSPA), where users from different market segments meet to discuss their needs for applications relying on Position, Navigation and time (PNT), Earth observation and secure governmental communications. The event is involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers and application developers. It also gathers organisations and institutions dealing, directly and indirectly, with the two European satellite navigation systems, Galileo and EGNOS and newly since 2020, also with the EU Earth Observation system, Copernicus, and with GOVSATCOM, the upcoming system for secure governmental communications. The UCP event is a part of the process developed at 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.

In this context, the objective of this document is to provide a reference for the EU Space Programme and for the Maritime, Inland Waterways, Fisheries and Aquaculture communities, reporting periodically the most up-to-date user needs and requirements in the Maritime, Inland Waterways, Fisheries and Aquaculture market segment. This report a living and evolving document that will periodically be updated by EUSPA. It serves as a key input to the UCP, where it will be reviewed and subsequently updated and expanded in order to reflect the evolutions in the user needs, market and technology captured during the event.

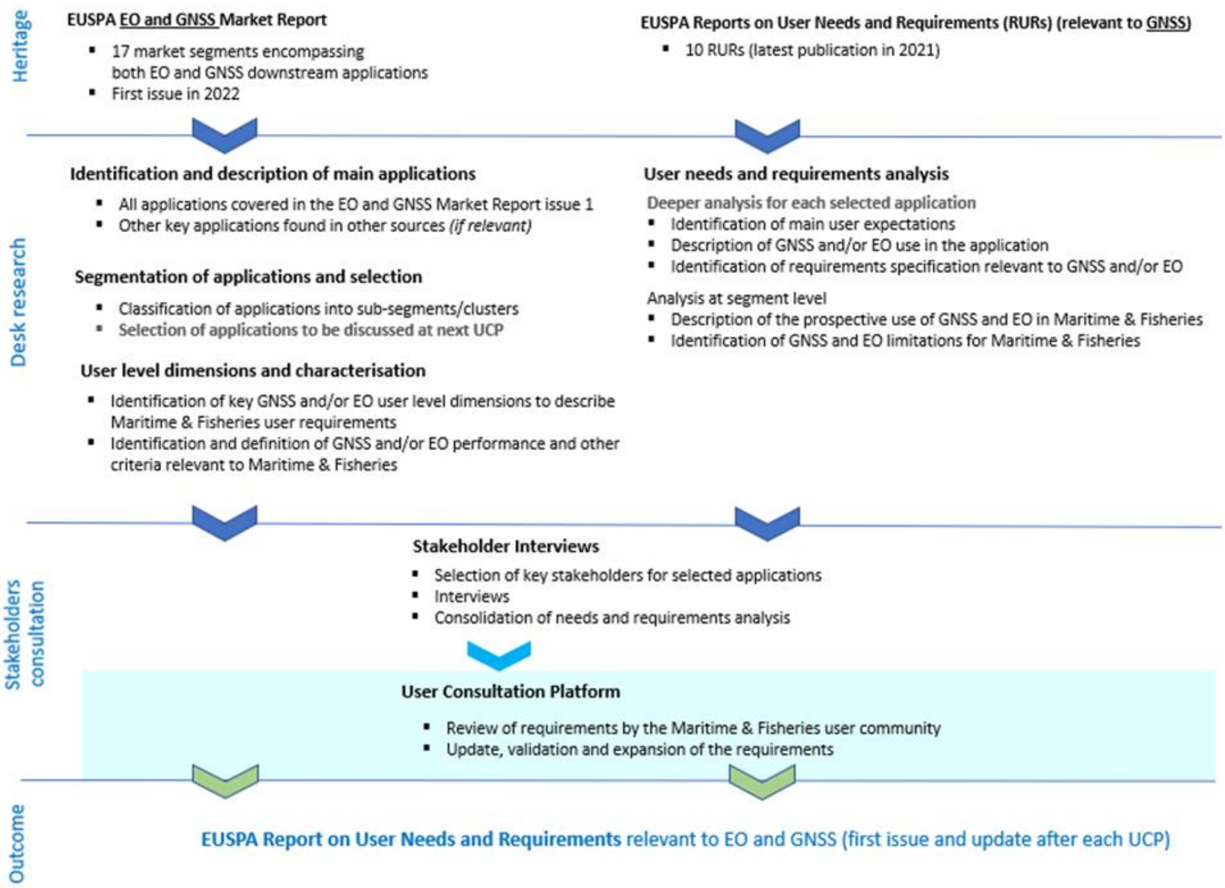
The report aims to provide EUSPA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the services provided by the EU Space Programme components. In line with the extended mandate of EUSPA, the Report on User needs and Requirements (RURs) previously focused on GNSS, have been revamped in order to also encompass the needs of commercial users with respect to Earth Observation (EO) and is now organised according to the market segmentation of the EUSPA EO and GNSS Market Report.

Finally, as the report is publicly available, it also serves as a reference for users and industry, supporting planning and decision-making activities for those concerned with the use of PNT and of EO technologies. This report represents the commitment of the EUSPA to mapping, understanding and to address or satisfy the listed user needs and requirements in the current or future versions of the services and/or data delivered by its different components in order to ensure a seamless fit between service offering and users that meets evolving market demands.

1.1 Methodology

The figure below details the methodology adopted for the analysis of the Maritime, Inland Waterways (IWW), Fisheries and Aquaculture user requirements:

Figure 1: Maritime, IWW, Fisheries and Aquaculture user requirements analysis methodology.



As presented in the figure above, the work leverages on the latest EUSPA EO and GNSS Market Report, adopting as starting point the market segmentation for EO and GNSS downstream applications and takes on board the baseline of user needs and requirements relevant to GNSS compiled in the previous RURs published by the agency.

The analysis is split into two main steps, including a "desk research", aiming at refining and extending the heritage inputs and at gathering main insights, and a "stakeholders' consultation" to validate main outcomes.

Desk research was carried out to consolidate the list of applications and their classification, to identify the key parameters driving their performances or other relevant requirements together with the main requirements specification, etc. A deeper analysis was conducted for a set of applications prioritised for discussion at the last UCP event. The outcomes of this preliminary analysis were shared and consolidated prior to the UCP with a small group of key stakeholders, operating in the field of the selected applications.

The results of the analysis of user requirements were then presented and debated at the UCP with the Maritime, Inland Waterways, Fisheries and Aquaculture user community. The outcomes of the Maritime, Inland Waterways, Fisheries and Aquaculture forum discussions were finally examined in order to validate and fine-tune the study findings.

The steps described above have resulted in the outcomes that are presented in detail hereafter.

1.2 Scope

This document is part of the User Requirements documents issued by the European Union Agency for the Space Programme for the Market Segments where Position Navigation and Time (PNT) and Earth Observation (EO) data play a key role. Its scope is to cover requirements on PNT and Earth Observation-based solutions strictly from a user perspective, taking into account the market conditions, regulations, and standards that drive such requirements.

The document starts with a market overview for Maritime, Inland Waterways, Fisheries and Aquaculture (section 3), focusing on the market evolution and key trends applicable to the whole segment or more specific ones relevant to a group of applications or to the use of GNSS or EO. This section also presents the main market players and user communities. The report then provides an overview of the applicable policies, regulations and standards (section 4). It then moves on to presenting a detailed analysis of user requirements (section 5). This section first presents an overview of the market segments of downstream applications and indicates for each application the depth of information that will be made available in the current version of the report: i) broad specification of needs and requirements relevant to GNSS and EO; ii) partial specification that is limited at this stage to needs and requirements relevant to GNSS; iii) Or limited to an introduction to the application and its main use cases at operational level.

The content of this section will be expanded and completed in the next releases of the RUR.

Following its introduction, section 5 is organised as follows:

- Section 5.1 aims to present current GNSS and/or EO use and requirements per application, starting with a description of the application, presenting main user expectations and describing the current use of GNSS and/or EO space services and data for the application and providing a detailed overview of the related requirements at application level.
- Section 5.2 describes the main limitations of GNSS and EO to fulfil user needs in the market segment.
- Section 5.3 presents prospective use cases of GNSS and EO in *Maritime, Inland Waterways, Fisheries and Aquaculture*
- Section 5.4 concludes the section with a synthesis of the main drivers for the user requirements in *Maritime, Inland Waterways, Fisheries and Aquaculture.*

Section 6 summarises the main GNSS and EO User Requirements for *Maritime, Inland Waterways, Fisheries and Aquaculture* in the application domains analysed in this report.

The final section 7 contains pertinent annexes.

The current version of the report will be expanded and completed through its future releases.

The RUR is 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.

2 EXECUTIVE SUMMARY

This report aims to improve the understanding of market evolution, strengths, limitations, technology trends, and key drivers related to the adoption of GNSS and EO solutions in the different applications of the *Maritime, Inland Waterways, Fisheries and Aquaculture* sectors. These analyses are essential to frame the technological developments required in the near future and how the supply can be adapted with respect to the demands of the corresponding users.

This document presents a thorough analysis of a number of applications in the *Maritime, Inland Waterways, Fisheries and Aquaculture* domains. The report provides a broad overview of GNSS and EO in the sectors based upon information available in the latest issue of the EUSPA EO and GNSS market report[1] [RD42] recalls the most important market and technology trends, the main market players and the main user groups.

The report addresses the core question of application-level requirements relevant to EO and Requirements Relevant to GNSS in the *Maritime, Inland Waterways, Fisheries and Aquaculture* domains. The International Maritime Regulatory Framework is presented. The most relevant international organisations are presented, such as IMO, IALA/ AISM, IEC, EC (with regard to River Information System), US DoT (with regard to their Federal Navigation Plan), FAO and other fisheries policies are introduced and their relevant Regulations, Resolutions, Directives, Recommendations and Plans are compiled and presented. Information regarding the expression of GNSS Maritime and IWW Requirements is extracted from these documents. A critical analysis of the various sources listed above is provided in Chapter 3.4, evidencing some discrepancies in the user requirements parameter values that can be found in the studied documents.

The discussions during the **UCP2022,** which focussed mostly on EO user requirements, but also covered some GNSS requirements in specific instances, reinforced the message that certain user requirements linked the applications identified and covered in this report, would ideally be more precision, with higher revisit rates or more frequently than is the case today. However, already with the technology as it is made available users can derive insights and better plan operations than without space-derived insights. The identified user requirements were largely validated and but a few newly added, such as wavelength for instance for MetOcean used by offshore floating wind parks to ensure the integrity of the infrastructure and safety of operations (including installation and maintenance).

Specifically, the operational scenarios for MetOcean, ship route optimisation, inland waterways navigation, aquaculture site selection and fish stock detection were discussed, as each application has a different operational scenario that leads to identifying very concrete requirements in terms of the size of interest, the frequency of information, or the spatial/temporal resolution, along many other variables. At the **UCP2022** it was also suggested that EO user requirements and future standards should reference ongoing work at international bodies and industry initiatives.

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[1] EUSPA (2022), EUSPA EO and GNSS Market Report, Issue 1, retrieved from: https://www.euspa.europa.eu/sites/default/files/uplo ads/euspa_market_report_2022.pdf

3 MARKET OVERVIEW & TRENDS

3.1 Market Evolution and Key Trends

Introduction to Maritime & Inland Waterways

GNSS underpins all marine navigation and other geospatial data such as EO is increasingly being used and numerous other applications. GNSS is vital for the safety and commercial success of the maritime and inland waterways sector. Reliance on GNSS and EO is only likely to increase, as initiatives such as e-Navigation and MASS evolve and as confirmed by the evidence outlined by **the latest EUSPA EO & GNSS Market Report** [RD42], summarised below.

During 2020 the global commercial shipping fleet grew by 3 per cent, much reduced from the peak growth in 2011 that reached 11%.[2] Also in 2020, European inland shipping transported around 143.46 billion tonne-kilometres, with most goods transported on waterways on the Rhine with around 55 billion ton-kilometres.[3] According to **the latest EUSPA EO & GNSS Market Report**, due to the large number of recreational vessels in the world, their growth and their users that are enthusiastic adopters of new GNSS applications, recreational navigation still is the dominant driver for GNSS, whereby Inland waterways vessel make up the second largest group of GNSS devices. Search & Rescue applications represent a very relevant market for GNSS, as GNSS is the preferred positioning technology for maritime Search & Rescue solutions. The market for EO related services is mainly driven by public entities active in the fields of safety of navigation and pollution monitoring.

Introduction to Fisheries & Aquaculture

Satellite data and capabilities support multiple crucial applications for users in the fisheries and aquaculture or marine living resources subsegment. In the domain of fisheries, EO is used to **assess the location of fish stocks** and to potentially **optimise fishing efforts**. Optical and radar data is also used to trace and track fishing vessels and assess the legality of their actions, thus also helping to prevent and combat **illegal, unreported and unregulated (IUU) fishing**. GNSS also contributes to IUU detection with its traditional use in the field, namely tracking the location of vessels through Automatic Identification System (AIS) and Vessel Monitoring System (VMS). Another no less important application of GNSS data for fisheries relates to improving safety at sea for fishing vessels and their crews by using GNSS-enabled navigation devices as well as AIS for position reporting and to support collision avoidance.

In the field of **aquaculture**, EO-based applications mostly support **site selection** for future fish farms (with input of environmental conditions, forecasts and predictions, often in the form of maritime spatial planning products). Both EO and GNSS applications contribute to the **optimisation and planning of aquaculture operations** by providing a host of information to authorities and aquafarmers, including early warning and supply forecasting, which can be used both by farmers and other stakeholders (e.g. retailers, insurers, investors).

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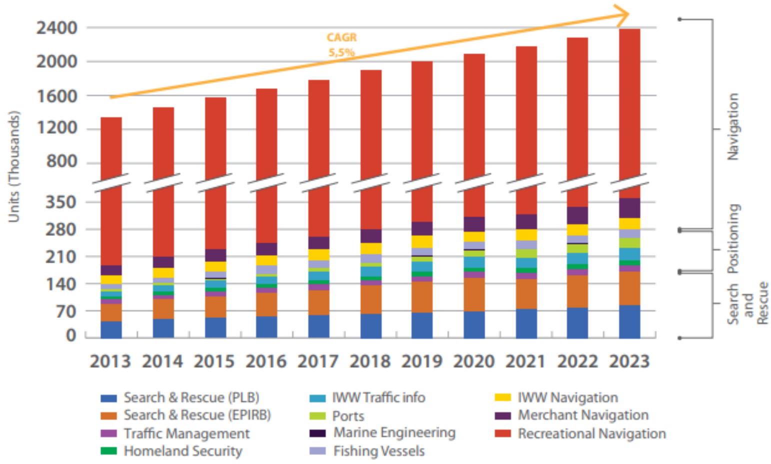
[2] UNCTAD (2021), Review of Maritime Transport 2021, PDF page 57/177, https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

[3] S. Kelller (2022), Statista, Amount of transported goods in European inland navigation by selected waterways in 2020 [German original: Menge der beförderten Güter in der europäischen Binnenschifffahrt nach ausgewählten Wasserstraßen im Jahr 2020], retrieved from: https://de.statista.com/statistik/daten/studie/1079803/umfrage/gueterbefoerderung-in-der-europaeischen-binnenschifffahrt-nach-wasserstrassen/#:~:text=Die%20europ%C3%A4ische%20Binnenschifffahrt%20bef%C3%B6rderte%20im,auf%20Wasserstra%C3%9Fen%20in%20Europa%20bef%C3%B6rdert

Figure 2: GNSS unit shipments by application.



Key Market Trends

Some key trends as identified in the EUSPA EO and GNSS Market Report [RD42] are explained below.

EARTH OBSERVATION IN MARITIME AND INLAND WATERWAYS

Earth Observation is enhancing existing navigation systems such as Vessel Traffic Service (VTS) and Automatic Identification System (AIS) and can further help to improve traffic monitoring and guidance of vessels along shipping routes. EO in synergy with GNSS enables ship route optimisation that contributes to a more efficient means of maritime transport. This optimisation also leads to reduced emissions as well as safer means of navigation, leading to net benefits for the industry and society. EO can support accident investigation, for instance the 2021 Suez Canal obstruction[4] that lasted for six days and caused delays ling after, showing EO added value for the global shipping industry to adapt to unforeseen circumstances. Synthetic Aperture Radar (SAR) has proven particularly useful for several critical applications given its advantage of all-weather operations. SAR systems are also able to detect offshore vessels and have most notably detection of 'dark vessels' by customs authorities and marine NGOs. SAR is also being used to detect oil spills that can be traced back to the polluter by cross-matching tracking data using AIS, VMS and EO imagery.

AUTONOMOUS VESSELS

While autonomous vessels are still in a very initial stage, the trends towards unmanned vehicles are evident and the question is not if there will be a market for autonomous vessels, but rather when. The Maritime Safety Committee (MSC) in its 98th session, held in June 2017, included the issue of marine autonomous surface ships on its agenda. It was agreed to initiate a Scoping Paper on autonomous vessels at the next MSC session, planned for 2018. This was in the form of a scoping exercise to determine how safe, secure and environmentally sound operations may be introduced in IMO instruments. It was anticipated that the work would take place over four MSC sessions (until mid-2020). The International Maritime Organisation (IMO) has established the Maritime Autonomous Surface Ships (MASS) Correspondence Group on autonomous vessels that is to assess existing IMO instruments to see how they might apply to ships with varying degrees of automation. The IMO in it its 103rd session in May 2021, completed a regulatory scoping exercise to analyse relevant ship safety treaties, in order to assess how Maritime Autonomous Surface Ships (MASS) could be regulated. In 2022 work started on the development of a goal-based instrument regulating the operation of maritime autonomous surface ships (MASS), with a mandatory MASS Code expected to enter into force on 1 January 2028.

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[4] The traffic jam as with Copernicus Sentinel-1 mission imager can be seen here: https://www.esa.int/ESA_Multimedia/Images/2021/03/Suez_Canal_traffic_jam_seen_from_space

E-NAVIGATION

Another important key trend is e-Navigation, which is an IMO initiative to integrate all navigational tools within the bridge system in order to enhance safety and ease of navigation, which is to be implemented from 2020 onwards. Since 2008, e-Navigation has been considered the future. However, its implementation is far from simple, as the Secretary General of the IMO recognized in 2016.[5] e-Navigation can be understood as an effort to bring standardization and interoperability to maritime information systems with the intention of improving safety of navigation and traffic management, reducing human errors and costs, protecting the environment, and enhancing efficiency. This is a key opportunity to spread the use of multi-constellation GNSS.

The IMO is the only international organization identified to define the technical, operational and legalities necessary to outline and enforce the general framework for the implementation of electronic navigation. The development of e-Navigation is a collective task among stakeholders in the maritime sector, but the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the International Hydrographic Organization (IHO) are essential.[6]

The IMO issues the e-navigation Strategy Implementation Plan (SIP), which was approved by MSC 94 in November 2014, containing a list of tasks required to be conducted in order to address 5 prioritized e-navigation solutions, namely:

- Improved, harmonized and user-friendly bridge design;
- Means for standardized and automated reporting;
- Improved reliability, resilience and integrity of bridge equipment and navigation information;
- Integration and presentation of available information in graphical displays received via communication equipment; and
- Improved Communication of VTS Service Portfolio (not limited to VTS stations).

These tasks were to be completed during the period 2015–2019 in order to provide the industry with harmonized information in order to start designing products and services to meet the e-navigation solutions. From August 2021, bridge systems integrated into newbuilds and retrofit projects for European Union vessels need additional certification to prove conformance with IMO's performance standards for Bridge Alert Management (BAM). In the longer term, the IHO is implementing the S-100 standard and related changes as part of IMO's e-navigation Strategy Implementation Plan. This would result in changes to standards for ECDIS and other electronic navigational charts (ENCs) in this decade.[7] As of 2022, the digital technology is still maturing.

RECREATIONAL VESSELS

As there are more than 8 recreational vessels for every other type of craft, according to the International Council of Marine Industry Associations (ICOMIA), the interest of improving GNSS penetration for recreational navigation can be easily understood. GNSS solutions spread quickly in this sector due to end users' strong inclination towards technological aids to navigation tools and robust spending power. Users use non-professional handheld or portable navigation devices. Some operations like geofencing, boat inspections, ship docking, deliveries on ship, in areas with high number of vessels will benefit from positioning accuracy well below 10m.

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[5] Keynote address by Kitack Lim, Secretary-General of IMO at e-Navigation Underway conference on February 2, 2016

[6] À. Uyà Juncadella (2022) Vessel Traffic Services, towards e-Navigation The role of Oceanic VTS in Global Maritime Surveillance, https://upcommons.upc.edu/bitstream/handle/2117/370239/TAUJ1de1.pdf?sequence=1, page 147.

[7] M. Wingrove (2021), New standards for bridge systems and e-navigation, in Riviera Maritime Media Ltd, retrieved from: https://www.rivieramm.com/news-content-hub/news-content-hub/new-standards-for-bridge-systems-and-e-navigation-66462

SEARCH AND RESCUE SOLUTIONS

Search and Rescue (SAR) solutions will have a significant impact on improving the effectiveness of SAR operations, especially in light of the increasing migrant flows through the Mediterranean. SAR is the second most relevant market for GNSS, due to its stabilized demand of 80 000 units of GNSS-enabled emergency beacons per year. The penetration of GNSS in EPIRBs is expected to grow from 70% to 100%, whose main regional market is the Asia-Pacific and EU28. One of the technological improvements for this domain is that, along with the Forward Link to transmit distress calls, Galileo will also be able to provide a Return Link Service to inform the casualty of the reception of its message, becoming the only system to provide a two-ways communication.

MONITORING AND CONTROL OF FISHING VESSELS OPERATIONS

Another key trend is the monitoring and control of fishing vessels operations, thanks to national authorities' need to track and monitor their fleets' activities. This service consists basically in Europe in the development of 2 systems: The Vessel Monitoring System (VMS), a satellite-based system providing authorities on the location, course and speed of EU fishing vessels; and the Automatic Identification System (AIS), an identification and communication system used for maritime safety, security and control which allows vessels to exchange information such as their identification, position, course and speed.

ACCIDENT INVESTIGATION (CASUALTY ANALYSIS)

During accident investigation it is important to use accurate and reliable position information. Monitoring shall prove that in the time of the accident the service was reliable. Integrity shall be monitored. In this frame, it is a crucial to provide high quality position information because court and insurance procedures are relying on the historical movement of the vessels.

FISHERIES AND AQUACULTURE

Fisheries and aquaculture are an essential part of the economy and a major contributor to food production – fishermen, fishing companies and societies, and aquafarmers are dependent on having sufficient and sustainable catch or production. The main market drivers for this subsegment for the years and decades to come are the **growing global food demand** and **economic, social, and environmental sustainability**. According to the latest report by the Food and Agriculture Organisation (FAO)[8], in 2020 yet another record was broken when it comes to global fisheries and aquaculture production, which reached 214 million tonnes worth around USD 424 billion. Accounting for about 3.3% of global fisheries and aquaculture production, the EU is the fifth largest producer and the largest importer of fisheries products worldwide. It is estimated that 80% of EU fish production comes from fisheries with the EU fleet landing €6.3 billion worth of seafood in 2019[9] with yield increasing in regions where fish stocks have recovered. The other 20% comes from aquaculture where the EU production has stagnated in volume while its value has increased. Overall, 30% of EU fish production is covered by local catch and production with 70% being imported.

Mirroring the Green Transition, fisheries and aquaculture sectors are going through **a Blue Transformation.** In Europe, the flagship initiative BlueInvest, supported by the **European Maritime, Fisheries and Aquaculture Fund** (EMFAF, previously EMFF), aims to boost innovation and investment in sustainable technologies for the **blue economy** by supporting readiness and access to finance for early-stage businesses, SMEs and scale-ups. Globally the transformation unfortunately saw a setback during the COVID-19 pandemic, and therefore international players, governments, the private sector, and civil society need to show an even stronger commitment to speed it up and make significant progress in relation to the SDGs at the international level and fulfil the ambitions of the Green Deal at the European level.

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[8] https://www.fao.org/3/cc0461en/online/cc0461en.html

[9] The EU blue economy report 2022: https://op.europa.eu/en/publication-detail/-/publication/156eecbd-d7eb-11ec-a95f-01aa75ed71a1

FISHERIES: Concerns of traceability and sustainability of catch

As the seafood market is growing due to an increased demand worldwide, so do the concerns related to the long-term sustainability of fishing activities. Complementing the global efforts in combatting IUU fishing carried out by local authorities and international actors such as the European Fisheries Control Agency (EFCA), various public, private and non-governmental initiatives have been created with the objective of **supporting sustainable fishing by improving "catch to plate" traceability.** Organisations such as the Marine Stewardship Council (MSC) are establishing standards to address key social and environmental impacts and stress the importance of traceability. Similarly, retailers and supermarkets are looking to gain competitive advantage in the eyes of increasingly demanding consumers on the origin and traceability of the products sold. **EO and GNSS technologies are key enablers of traceability features.** For instance, AIS can be used in combination with EO to seamlessly track certified fishing fleets, informing sustainable production all the way to the final product. Furthermore, satellite data has been esteemed to be vital to fill in gaps in existing fisheries datasets as showcased, for instance, in a recent study assessing the level of IUU fishing in the Pacific region[10].

AQUACULTURE: The fastest growing food industry in the world enters deeper waters

With global aquaculture production projected to reach 109 million tonnes in 2030, an increase of 32 percent (26 million tonnes) over 2018, aquaculture is the fastest growing food industry in the world. By 2030 aquaculture could ensure around two thirds of global seafood requirements[11]. At the same time concerns of sustainability and competitiveness drive aquaculture more and more offshore. This means that more complex, time and investment consuming efforts are needed for selecting an appropriate location, constructing and ensuring smooth daily operations of such offshore aquaculture sites. The data provided by EO instruments gathers an important series of information points to make the aquaculture site selection faster, cheaper and more accurate. EO and GNSS with support of in situ observations and operational modelling can support informed decisions for authorities and timely interventions for aquafarmers. While GNSS is crucial for efficiently operating offshore farms with fully automated vessels. At the moment aquaculture is still lagging behind fisheries and agriculture in terms of use of EO in value-added services, however, the rapid growth of the industry goes hand in hand with efforts of more advanced digitalisation of "aquatech", where EO and GNSS have an important and increasing role to play[12].

OTHER KEY TRENDS

Finally, we can also list the development of a multi-system receiver performance standard and of harbour services with high precision and robust positioning systems as two last interesting tendencies of the market. Since IMO has set operational performance requirements for GNSS, the adoption of multi-constellation equipment is spreading. This allows receivers to have a higher probability of acquiring a greater number of satellites at any single point in time. Consequently, navigation performances will be greatly improved. This tendency of simultaneously receiving GNSS and augmentation signals from multiple satellites belonging to different constellations is also one more step towards the adoption of Galileo in SOLAS regulated vessels

GNSS Market Evolution: Maritime and Inland Waterways

The market for GNSS applications in the maritime and Inland waterways domain, has evolved moderately positively in the last decade. The European industry is the market leader, making up for more than 80%

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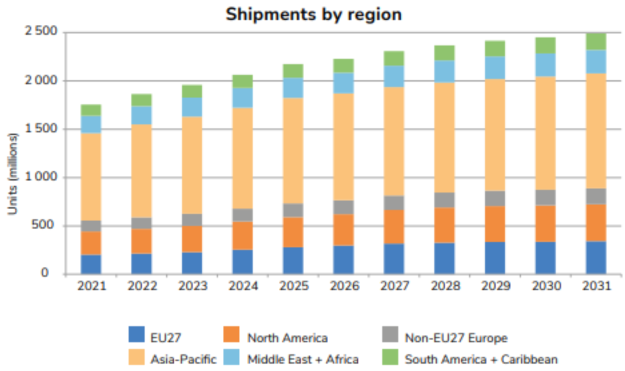
[10] The Quantification of Illegal, Unreported and Unregulated (IUU) Fishing in the Pacific Islands Region – a 2020 Update: https://sustainpacfish.ffa.int/wp-content/uploads/2021/12/ZN2869-FFA-IUU-2020-Update-final.pdf

[11] EIT Food "Can Sustainable sustainable Aquaculture aquaculture Help help tTo Achieve achieve the UN SDGs": https://www.eitfood.eu/blog/can-sustainable-aquaculture-help-to-achieve-the-un-sdgs

[12] Aqua Insights: The Transformative Power of Digital Aquatech: https://aqua-spark.nl/report-on-the-transformative-power-of-digital-aquatech-online-reader/?subscribed=1&reading=&id=4#page=4

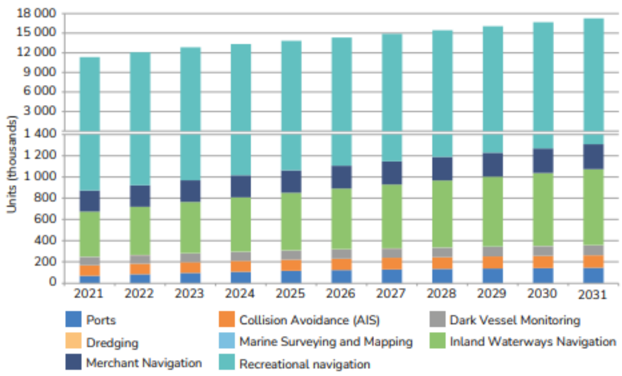
of the global market in the segments Maritime and Inland Waterways, and Fisheries and Aquaculture. The Maritime segment of GNSS is the second largest market in 2021, which corresponds to some 11 million units. By the year 2031 this number is expected to increase in absolute terms to 17 million units, even though the relative market share is expected to remain similar, going from 16.8% in 2021 to 16.0 % in 2031). Throughout the coming decade, the EU27 and non-EU27 Europe combined make up for the second most important market globally in terms of device shipments, after Asia-Pacific and closely matched by North America.

Figure 3: GNSS unit shipments by application.



Even though the growth rate in Europe is slow it is steady. GNSS penetration in maritime vessels is expected to double over the next decade, mostly driven by recreational and inland waterways navigation; Merchant vessels are already fitted with more than one GNSS receiver to cover navigation and positioning applications.

Figure 4: Installed base of GNSS devices by application.

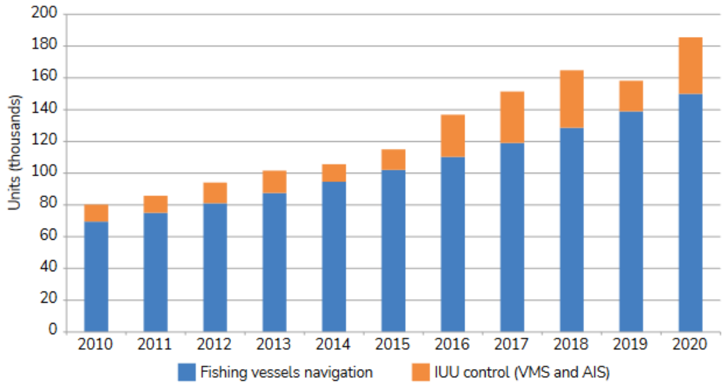


GNSS Market Evolution: Fisheries and Aquaculture

For fisheries, the past decade saw a doubling of **annual sales of units for navigation applications** from roughly 75,000 units in 2010 to slightly over 150,000 sales in 2020. As forecasted in the EUSPA EO & GNSS Market Report , the total installed base of GNSS devices is expected to further increase to close to 2 million in 2031, with sales revenues reaching €350 million. The underlying reasons for this growth are twofold. Firstly, safety of navigation is improved by relying on a dedicated navigation device, especially in combination with an **Automatic Identification System (AIS)** that supports collision avoidance. Secondly, innovative applications such as GNSS-tracked fishing buoys or EO products supporting fish stock detection rely on trustworthy GNSS navigation to direct the fishing vessel to fishing grounds.

While the GNSS receivers are similar to those used in the Maritime sector, the market differs regionally as in the fisheries and aquaculture sector, a clear **regional leader is Asia-Pacific**. It represented close to three quarters of the market in 2021, and its share is expected to reach 80% by 2031. By contrast, the revenues for GNSS device sales in other regions with a sizeable share (around 10% each), notably, EU27 and North America, are expected to stagnate and therefore lose their share of the overall increasing market. Currently fishing vessels navigation represents around €150 million, close to 70% of the share of these revenues, while IUU control (VMS and AIS) represents the other 30%. As sales in both of these markets are expected to grow similarly, in the next decade this proportion is going to remain unchanged.

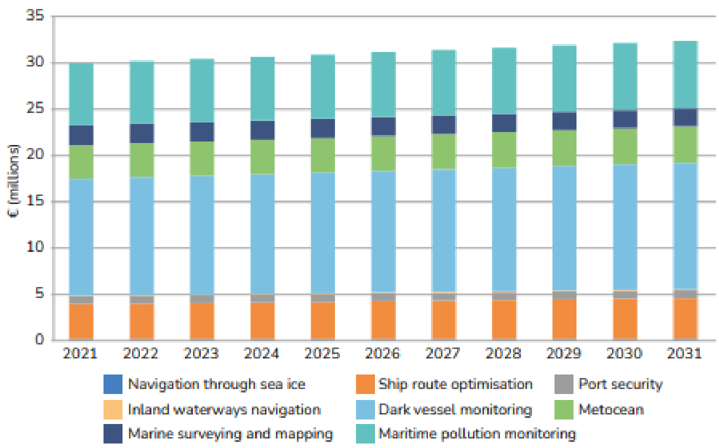
Figure 5: Shipments of GNSS devices by application type in the fisheries subsegment.



EO Market Evolution: Maritime and Inland Waterways

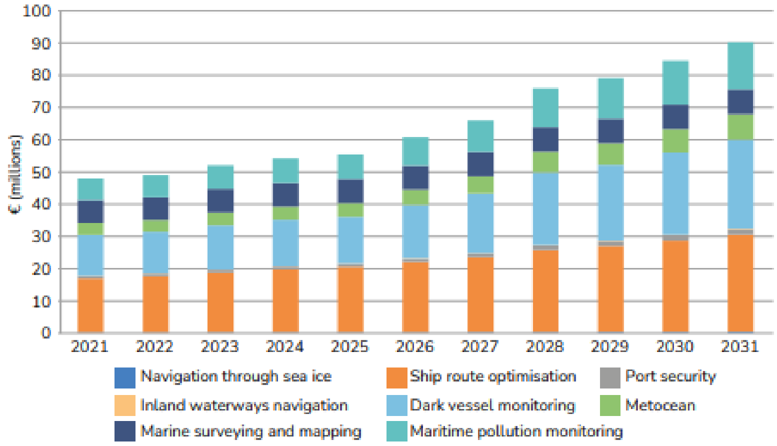
The market for EO-value added and geospatial products/services is growing, and the market is rapidly evolving. Over the next decade, the market for Earth Observation applications is set to double in terms of revenues, from roughly €2.8 billion to more than €5.5 billion. In the global ranking, the EU27 comes in third by market size after North America and Asia-Pacific. A closer look at the segments of this report reveals that *Maritime, Inland Waterways, Fisheries and Aquaculture* combined account for €132 million of revenues in 2021, or just under 5% of the total market for EO data and value-added services. Maritime and Inland Waterways account for €79 million revenues, Fisheries and Aquaculture for €54 million.

Figure 6: Revenue from EO data sales by application in the maritime and inland waterways subsegment. [13]



[13] EUSPA (2022), EUSPA EO and GNSS Market Report, Page 147. Available here: https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf

Figure 7: Revenue from EO services sales by application in the maritime and inland waterways subsegment.[14]



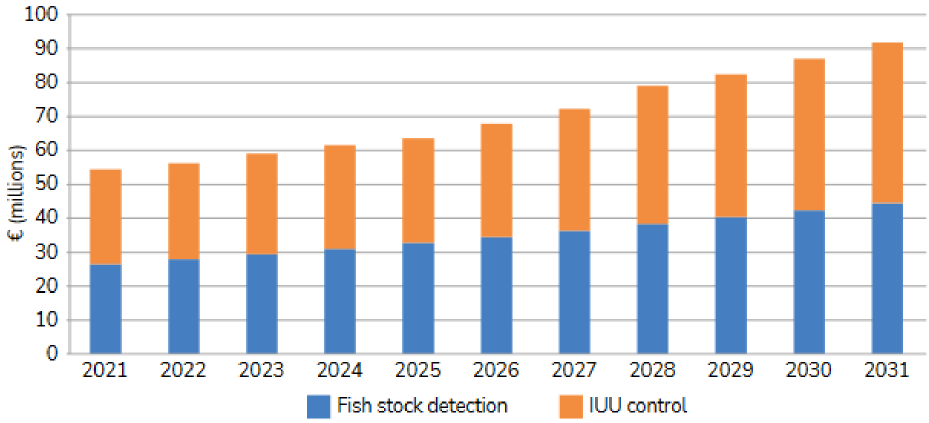
EO Market Evolution: Fisheries and Aquaculture

The annual revenue from the sale of both EO data and services to the fisheries sector is estimated to grow from €54 m in 2021 to €92 m in 2031. Fish stock detection and Illegal, unreported, and unregulated (IUU) fishing control hold almost equal shares throughout the projected timeframe. The structure of the total revenue for each of the two applications is, however, very different.

For Fish stock detection revenues from services make up to 97% of the total by 2031. On the other hand, IUU fishing control revenues will comprise in 2031 of 67% in services and 33% in data sales.

The revenues from applications using EO data for aquaculture activities are not plotted, as this market is currently in its infancy. Nonetheless, given the importance aquaculture has gained in recent key policies as well as the overall growth of the market, one can expect that in the very near future such revenues will become substantial.

Figure 8: Revenue from EO data & services sales by application in the fisheries subsegment.



[14] EUSPA (2022), EUSPA EO and GNSS Market Report, Page 147. Available here: https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf

3.2 Main User Communities

Both the user requirements relevant to GNSS and application-level requirements relevant to EO depend heavily on the applications, which have been designed to satisfy needs of improved safety and productivity. The main user categories include **ship masters, recreational boaters, pilots and port authorities**. Furthermore, this year's report will extend the main user categories to also include fishing and aquaculture. The two additional user categories will be **fishing and aquafarming companies, and fishing authorities**. The beneficiaries are a much wider category, including passengers, companies served by the maritime supply chain and through logistic applications, and consumers of sea products.

User Communities in Maritime & Inland Waterways

Although the pandemic has caused a major disruption to global supply chains and maritime logistics operations, more than 80% of the volume of international trade in goods is carried by sea.[15] To better understand what the real needs of the main user communities are, six surveys have been organised to understand GNSS user requirements from the maritime community perspective. Similar surveys could be undertaken in future iterations of the UCP on application-level requirements relevant to EO. A summary of 6 surveys on GNSS can be found in Annex 1.5 of this report.

The surveys targeted a wide range stakeholder, such as end users, user associations and representatives of the maritime value chain such as receiver and chipset manufacturers, application developers, port authorities, harbour masters, pilots and shipmasters, receiver manufacturers, as well as organizations and institutions. Past round of the UCP gathered participants from the industry, research institutes, national authorities and European institutions with interest in maritime and inland waterways.

The main user groups of EO and GNSS applications in Maritime & Inland Waterways include national, regional and international maritime authorities who are tasked with charged with the promotion of maritime safety and setting regulatory measures to improve security and safety, and avoiding or acting upon irregular activities at sea, in ports and inland waterways. Also, global **logistics companies, actors/operators active in the blue ocean economy[16],** and the manufacturers of vessels, equipment and devices.

Additional users are NGOs that are increasingly active and responding to society's rising environmental concerns and renowned organisations such as the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) that is out to ensure safe, economic and efficient movement of vessels by improving and harmonizing aids to navigation worldwide. IALA is best known for its sea mark systems (Europe falls under Region A) that are used in the pilotage of vessels at sea.[17]

User Communities in Fisheries & Aquaculture

In 2019 the EU fisheries and aquaculture industries together counted more than 200 000 jobs representing 4% of the total workforce of the Blue Economy. The EU fishing fleet is very diverse (vessels ranging from 6 to 75 m)[18] and included 57 236 active vessels directly employing 129,540 fishers in 2019[19]. **Small-scale coastal fishing** plays an important socio-economic role for the local communities as

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[15] https://unctad.org/webflyer/review-maritime-transport-2021

[16] The European Commission defines the blue economy as "all economic activities related to oceans, seas and coasts, distinguishing between activities in the marine environment (shipping, seafood, energy generation) or on land (ports, shipyards, coastal infrastructure). See: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2341.

[17] https://www.marineinsight.com/marine-navigation/iala-buoyage-system-for-mariners-types-of-marks/

[18] CFP facts and figures.

[19] The Blue Economy Report 2022

it employs close to half of the employees of the sector and represents close to 75% of all fishing vessels registered in the EU.[20] While decreasing in size, tonnage, and engine power, the EU fishing fleet gained in profitability from barely profitable in 2009 to gaining net profits of €1.3 billion in 2019. High fuel prices and post-Brexit trade deals have already and will further affect the EU fishing fleet with fishing rights in UK waters gradually reduced by 25 %. Around 75 000 people are employed in the European aquaculture sector.

Both industries are organised around key actors which are producer organisations. They help to improve the profitability of these businesses by developing marketing and production plans. In 2019 the aquaculture sector counted 34 and fisheries 181 producer organisations across 19 Member States.

Furthermore, the EU supports 11 advisory councils gathering industry and other interest group representatives to provide recommendations on issues related to fisheries and aquaculture to the Commission and the Member States. Most of the councils have a geographical focus (Baltic Sea, Mediterranean Sea, North Sea, North-Western Waters, South-Western Waters, Black Sea, Outermost Regions), however distinct bodies have been established also for Long Distance Fleet, Pelagic Stocks and more recently also for Aquaculture and Market.

The Market Advisory Council, for instance, is made up of 59 European and national organisations from 12 Member States across the value chain of both industries. Amongst its main aims and objectives are the support for sustainable production practices and better governance which are implemented through recommendations, but also actions such as a thematic webinar on blockchain and technologies for traceability.

Promotion of R&D efforts in the aquaculture sector is organised through entities like **Aquaculture Technology and Innovation Platform (ATIP).** By engaging 16 mirror platforms throughout Europe, ATIP represents around 850 aquaculture entities in Europe. To some extent fisheries and aquaculture are included within the scope of some of the EIT FOOD activities. Innovative R&D projects have been supported through EIT FOOD and even specific call for sustainable aquaculture was launched at the end of 2020.

Core users of EO and GNSS applications include also national, regional and international fishing authorities such as EFCA who are tasked to efficiently and sustainably manage fish stock, defining restrictions on the catch amount and indicating legal fishing areas, permanently or temporarily limiting fishing activities if needed. Authorities need to efficiently monitor and control IUU to avoid economic and environmental loss created by such uncontrolled practices.

Other non-core user groups include NGOs contributing to the IUU control at global level (e.g. Global fishing watch) as a response to the rising environmental concerns and awareness of practices and consequences of IUU. Similarly, certification agencies (e.g. Marine Stewardship Council - MSC), labels, sea food processors and retailers face an increased scrutiny related to traceability («catch to plate») and transparency of sustainability claims.

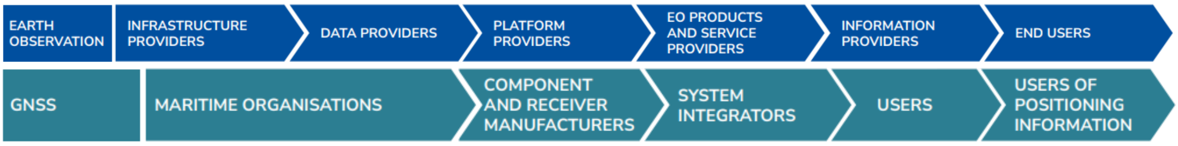
3.3 Main Market Players

The main players involved in Earth Observation and GNSS are depicted the value chains[21] below. The role of the key players is as follows:

[20] EMFAF FAQ: https://oceans-and-fisheries.ec.europa.eu/system/files/2021-07/emfaf-faq_en.pdf

[21] Please consult the EUSPA EO and GNSS Market Report (issue 1, 2022) for a more detailed value chain.

Figure 9: Value chains for Maritime, Inland Waterways, Fisheries and Aquaculture for EO (above in blue) and GNSS (below in green).



EO Value chain

Infrastructure providers offer various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated, such as cloud infrastructure, servers, databases, and storage systems. The increasing volumes of EO and geospatial data needs the capabilities and possibilities offered by cloud environments to store, process and exchange data. The infrastructure providers make up the backbone by providing data centres and computing resources. Besides the global leading IT companies, there are a few European infrastructure providers across Europe (mostly cloud infrastructure): Thales Services, UpCloud, OVHcloud, 1&1 Ionos, Fuga Cloud, Cloudsigma, KSAT/Kongsberg Satellite Services but also the GAIA-X initiative.

Data providers offer un- or pre-processed EO data. Earth Observation data services can be provided by public agencies, or commercial actors. In the field of public providers, the Sentinels are one of several data providers, alongside ESA, Eumetsat, Landsat and others. Some of the leading European private data providers are Airbus, Deimos Imaging, European Space Imagining, Iceye, Open Cosmos, Telespazio and many more.

Platform providers offer online platforms and/or digital services on which users can benefit from tools and capabilities to analyse EO data, develop algorithms and build applications. Platform providers generally offer everything needed to develop new software in a virtual environment. Besides the main global leading companies, there are a few leading European providers of platform services, such as SAP (has collaborations with ESA), Scalingo and Clever Cloud.

EO products and Service Providers are providers of products or services (e.g. land cover classifications or ground motion monitoring) that make full use of EO data and processing capabilities offered by data and platform providers. In Europe, the market is mostly made up of micro-sized companies, followed by smaller companies and much less large and medium companies.[22] There is a growing number of European EO service providers, such as Aerospacelab, EOAnalytics, EOMAP, GeoVille, Iceye, and Open Cosmo, Planetek Hellas.

Information Providers offer sector-specific information that incorporates EO data along with non-EO data, such as aerial imagery, IoT, buoys or other sensors, tailored to sector specific clients. For coastal and maritime preservation for instance, EOMAP is a leading provider, with headquarters in Seefeld (Germany). A leading French company (based in Versailles) is SAT-OCEAN that provides MetOcean services to marine industries, offshore and for shipping and maritime transport.

End users are the final users of the applications and services offered by the providers. These users, mostly public but also private users, cover a range of economic activities, from research institutes and numerous authorities to surveillance actors and global logistics companies but also data-analytics companies.

GNSS Value chain

Maritime and Inland Waterways organizations include IMO, IALA, RTCM, IHO, IEC, ITU and other associations responsible for regulation, standardization and certification within the Maritime community. Within this category, individual states are responsible for the provision of aids to navigation in their area

[22] https://www.innovationnewsnetwork.com/analysing-european-earth-observation-market/21775/

of responsibility (SOLAS convention) through a designated national competent authority. In the case of inland waterways, the competent authorities are mainly River Information Services (RIS) Authorities; RIS Providers provide Differential GNSS (DGNSS) services as well as other river related information services.

Component Manufacturers include manufacturers of GNSS-specific components (chipsets or antennae), handheld GNSS receivers and integration-ready GNSS receivers (i.e. supplied to system integrators). This is a highly consolidated industry, which represents most of the core value of the GNSS industry. The most important manufacturers are Furuno, Orolia, Japan Radio Co, Hexagon, Novatel, Trimble, Rakon, Samyung Enc and Laird. Orolia focuses on Search and Rescue and vessel monitoring solutions, while Furuno, the largest receiver manufacturer, is active in most Maritime applications, including recreational and merchant navigation and vessel monitoring.

System Integrators are responsible for integrating GNSS capability into larger systems and, for this reason GNSS represents only a small part of the total product offering. Among the most representative in the market are Garmin ltd, Kongsberg, Navico, Johnson Outdoors, Mitsubishi, Safran, Furuno, Raymarine. Garmin focuses on recreational navigation; Kongsberg provides high-tech professional solutions for merchant fleets and oil and gas applications. Within this category, SAR Beacon Manufacturers such as Orolia, ACR Electronics and Jotron integrate GNSS solutions into a range of different beacons.

Ship owners and *operators* are the main GNSS Users, which includes Maersk Line, MSC, CMA CGM Group, Evergreen, APL and Ports. Ports can be further split into Container Ports, Cruise or Ferry Terminals and Marinas.

End users of positioning information generated by GNSS receivers are numerous, and include Search and Rescue (SAR) response teams, maritime surveillance and port authorities, ship operators that track their vessels.

4 POLICY, REGULATION AND STANDARDS

4.1 Maritime and Inland Waterways

Shipping is a truly international industry, and it can only operate effectively if the regulations and standards are themselves agreed, adopted and implemented on an international basis. For this reason, the maritime domain is highly regulated, and regulations have been reinforced over the last decades. The main principles constituting the basis of shipping regulations are harmonized national rules based on international conventions and resolutions enacted by the International Maritime Organization (IMO). Additionally, to IMO, other organizations are involved in the regulatory and normative environment of the maritime domain: IALA (International Association of the Marine Aids to Navigation and Lighthouse Authorities), CIRM (Comité International Radio Maritime), EMRF (European Maritime Radionavigation Forum), IMPA (International Maritime Pilots' Association) and RTCM (Radio Technical Commission for Maritime Services). A brief description is provided here after for the main relevant international organizations ([RD16]):

INTERNATIONAL ORGANISATIONS

IMO: International Maritime Organisation. A specialized agency of the United Nations established in Geneva in 1948 and came into force ten years later meeting for the first time in 1959 is the global regulatory authority for the safety, security and environmental performance of international shipping. IMO's main task is to develop and maintain a regulatory framework for shipping industry that is fair and effective, universally adopted and universally implemented. Its remit includes navigational safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. Requirements for radio-navigation systems and performance standards for shipborne equipment are formulated by the IMO Sub-Committee on Safety of Navigation and ratified as resolutions of the IMO Maritime Safety Committee or Assembly.

Full membership of the IMO is reserved for Member States with maritime interests. The European Union holds observer status at the IMO.[23]

IALA: The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is an international association whose aim is to foster the safe, economic and efficient movement of vessels, through improvement and harmonization of aids to navigation worldwide and other appropriate means, for the benefit of the maritime community and the protection of the environment. IALA was formed in 1957 as a non-government, non-profit making, technical association that provides a framework for aids to navigation authorities, manufacturers and consultants from all parts of the world to work with a common effort to:

- Harmonise standards for aids to navigation systems worldwide;
- Facilitate the safe and efficient movement of shipping, and;
- Enhance the protection of the marine environment.

The functions of IALA include, among other things:

- Developing international cooperation by promoting close working relationships and assistance between members;

[23] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733517/EPRS_BRI(2022)733517_EN.pdf

- Collecting and circulating information on recent developments and matters of common interest;
- Liaison with relevant inter-governmental, international and other organisations. For example, the International Maritime Organization (IMO), the International Hydrographic Organisation (IHO), the Commission on Illumination (CIE), and the International Telecommunication Union (ITU);
- Liaison with organisations representing the aids to navigation users;
- Addressing emerging navigational technologies, hydrographic matters and vessel traffic management." (Whole above citation from [RD14]).

IALA publishes recommendations, guidelines, manuals and other material to fulfil its missions.

IALA recommendations can be viewed as the equivalent to a "resolution" in an intergovernmental organization and provide direction on uniform procedures and processes. They contain information on how members should plan, operate and manage Aids to Navigation. They however do not carry the authority of e.g. an IMO resolution and are not binding. Nevertheless, "there is an implicit expectation that individual national members will observe and implement IALA Recommendations" [RD15].

IALA guidelines complement the recommendations with detailed operational and technical specifications. They can be viewed as high level functional or operational "standards".

In 2020, following the diplomatic conference hosted in Kuala Lumpur, a new convention has been adopted transforming IALA from an NGO to an IGO. Rather than hampering momentum, in its new status maritime authorities expect IALA to become a key international organisation paving the way for digital navigation.

For Europe, IALA is a partner of choice for several reasons:

- IALA is headquartered in Saint Germain en l'Haye (France);
- IALA most active contributors are very often European maritime safety agencies and aids to navigation service providers;
- IALA works are generally ahead of IMO, and its navigation committee is very proactive both within the IALA process and externally in other organisations, such as IEC and RTCM (see below).

ITU: International Telecommunication Union. The UN specialised agency responsible for telecommunications, in particular for spectrum management and technical characteristics of systems. Recommendations on radio-navigation systems are prepared by ITU-R Study Group 8 for approval by a Radiocommunication Assembly.

IEC: International Electro-technical Commission. The IEC prepares and publishes international standards for all electrical, electronic and related technologies. These serve as a basis for national standardization and as references when drafting international tenders and contracts. IEC Technical Committee 80 deals with maritime navigation and communications equipment.

IEC Technical Committee 80 deals with maritime navigation and communications equipment.

RTCM: Radio Technical Commission for Maritime Services. A US-based organisation that develops standards and recommendations for marine systems and equipment. In particular RTCM Special Committee 104 has produced the recommendations for the data formats used in differential GNSS.

4.1.1 IMO regulations related to GNSS user requirements

SOLAS CONVENTION

The International Convention for the Safety of Life at Sea (SOLAS) [RD1] 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 May 2011. 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. In particular 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) "Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)" from the International Maritime Organization (IMO), adopted on 29 November 2001 [RD3].

This resolution recognizes 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 harmonized 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 organization, 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 recognize 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 recognized 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;
- Coastal;
- Port approach and restricted waters;
- Port;
- Inland Waterways.

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.

IMO A. 915(22) defines 5 phases of general navigation:

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.

GNSS must be suitable to both conventional and high-speed crafts, which demand more stringent requirements, in all phases of navigation.

RESOLUTION A.1046 (27)

IMO Resolution A.1046 (27) "Worldwide Radionavigation System" [RD6], 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) [RD5];
- The continuity risk has been modified to 15 min (as compared to A.915 (22) [RD3] and A. 953 (23) [RD5]).

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) [RD6] 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 1: 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[24]	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 Port Operations, 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 [RD7] to [RD13]) are performance standards for shipborne GNSS or DGNSS equipment. Their specific purposes and dates of adoption are summarised in Table 19 below.

Table 2: Resolutions on Performance Standards for shipborne GNSS or DGNSS Equipment.

Resolution N° Title	Title	Date
MSC 112(73) [RD7]	Performance standards for shipborne GPS receiver equipment	1 Dec. 2000
MSC 113(73) [RD8]	Performance standards for shipborne GLONASS receiver equipment	1 Dec. 2000
MSC 114(73) [RD9]	Performance standards for shipborne DGPS and DGLONASS	1 Dec. 2000
MSC 115(73) [RD10]	Performance standards for shipborne combined GPS-GLONASS	1 Dec. 2000
MSC 233(82) [RD11]	Performance standards for shipborne Galileo receiver equipment	5 Dec. 2006
MSC 379(93) [RD12]	Performance standards for shipborne BDS receiver equipment	16 May 2014
MSC 401(95) [RD13]	Performance standards for multi-system shipborne navigation	8 June 2015
MSC.432 (98) [RD 57]	Amendments to performance standards for multi-system shipborne radionavigation receivers	16 June 2017

[24] MSI: Maritime Safety Information

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) [RD3] and A.1046(27) [RD6] 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) – Revised Guidelines for AIS

Resolution A.1106 (29) concerns the revised Guidelines for the Onboard Operational Use of Shipborne Automatic Identification System [RD4]. Automatic Identification Systems or AIS means a maritime navigation safety communications system standardized by the International Telecommunication Union (ITU) [RD33], adopted by the International Maritime Organization (IMO) [RD2] that:

- Provides vessel information, including the vessel's identity, type, position, course, speed, navigational status and other safety-related information automatically to appropriately equipped shore stations, other ships, and aircraft;
- Receives automatically such information from similarly fitted ships, monitors and tracks ships; and
- Exchanges data with shore-based facilities.

Regulation 19 of SOLAS chapter V "Carriage requirements for shipborne navigational systems and equipment" [RD2] 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.

Ships fitted with AIS shall maintain AIS in operations at all times 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.

AIS 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'.

Indeed, the AIS network is continuously self-organizing 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" [RD22].

Resolution A.1106(29)

This resolution gives "Revised Guidelines for the Onboard Operational Use of Shipborne Automatic Identification System (AIS)" [RD4] which are dated 02 December 2015 and have been developed to promote the safe and effective use of shipborne AIS, in particular to inform the mariner about the operational use, limits and potential uses of AIS.

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 are 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 synchronization 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) [RD31];
- IEC Standard 61993 Part 2: Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results [RD41].

4.1.2 IALA recommendations, guidelines and standards

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is an intergovernmental organisation that collects and provides nautical expertise. IALA is a technical association seeks to harmonise Marine Aids to Navigation worldwide and to ensure that the movements of vessels are safe, expeditious and cost-effective while protecting the environment. IALA committees develop common best practices through the publication of Standards, Recommendations, Guidelines and Model courses. 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" [RD14].

Actually, 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.

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) [RD26] 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 [RD14], 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 [RD27] 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, includes the Goal to ensure that "Marine Aids to Navigation are developed and harmonised through international cooperation and the provision of standards."

IALA Standards are suitable for direct citation by States in the interest of an efficient and harmonised global network of Marine Aids to Navigation and services. In terms of application this Standard is suitable for implementation by all marine aids to navigation authorities. [RD25].

In terms of scope, IALA Standards may contain normative and informative provisions. Normative provisions are those with which it is necessary to conform in order to claim compliance to the Standard. Informative provisions are those which specify additional desirable practices but with which it is not necessary to conform in order to claim compliance to the Standard. This Standard references normative and informative provisions, detailed in the listed IALA Recommendations, covering the following scope:

- Satellite positioning and timing IALA Standard S1030 [RD25];
- Terrestrial positioning and timing;
- Racon and radar positioning; and
- Augmentation services.

IALA World Wide Radio Navigation Plan

The IALA World Wide Radio Navigation Plan [RD16] 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 Organization (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 realized:

- 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) [RD6] and A 915 (22) [RD3].

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 [RD14 and 15] is a very complete guide, reviewing all aspects of the provision and use of all maritime aids to navigation, including institutional, legal, political, operational, functional and technical aspects.

It reviews existing as well as planned policies, systems, standards, definitions, etc.

In short, this is "the" reference document for Maritime aids to Navigation.

Regarding more specifically PNT users requirements, this Navguide does not introduce anything new as compared to IMO A.1046 (27) [RD6] and A 915 (22) [RD3].

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 kHz in region 1 and 285-325 kHz in region 2 and 3

This recommendation [RD19] 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 kHz

This Recommendation ([RD20]) and associated Guideline ([RD21]) last updated in May 2015 concern the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz (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 recognize 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 [RD32], 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) [RD6];
- 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 [RD17] 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) [RD3].

This strategy should be viewed in the context of the development by IALA of proposals for a World-Wide Radio Navigation Plan (WWRNP) [RD16] 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 modernization, 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) [RD3].

Recommendation R-129 on GNSS vulnerabilities and mitigation measures

This recommendation [RD18] 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 [RD22] published in June 2011 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 [RD23]) 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 [RD24]) here discussed below.

IALA guidelines No. 1029 [RD24] 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 ([RD33]):

- 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 3: 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 4: 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.

4.1.3 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.[25]

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).[26] Relevant ITU documentation is discussed in section xx for reference.

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 organization and operation of the Global Maritime Distress and Safety System (GMDSS) and other maritime operational procedures. It also provides all the rules and procedures of the Global Maritime Distress and Safety System (GMDSS) a collection of radio communications procedures and their supporting radio systems that support maritime safety and the rescue of ships or crew during distress situations worldwide.

Volume 2 contains the extracts of the regulatory texts associated with maritime operations.

The 2020 edition of the Maritime Manual is valid through 2024.

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" ([RD32]) 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 Hz;

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

[26] 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

- Frequency tolerance of the carrier is ± 2 Hz;
- 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" [RD33] 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.

4.1.4 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 Organization'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 Organization'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 (for this study) IEC publications together with their IMO counterpart when available.

Table 5: IEC Standards and corresponding IMO Resolutions.

IEC Reference	IMO Reference	Subject
IEC 60945 Ed. 4.0 [RD35]	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 [RD36]	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 [RD37]	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 [RD38]	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 [RD39]	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 [RD54]		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 [RD55]		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 [RD56]		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		Maritime navigation and radiocommunication equipment and systems – Digital interfaces

4 [RD40]		
IEC 61993-2 Ed. 2.0 [RD41]	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

The TC 80 has a subcommittee (PT 61108-07) that is preparing a standard for a Satellite Based Augmentation Systems (SBAS)Receiver Equipment

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.

4.1.5 EC – River Information Service (RIS)

River Information Services (RIS) are information technology related services designed to optimize 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 harmonize 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 [RD28] 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".

COMMISSION REGULATIONS (EC) NO 414/2007 AND 415/2007

These regulations, both dated 13 March 2007 are the consequence of the Directive 2005/44 [RD28], Article 5, calling for the establishment of technical RIS guidelines.

REGULATION (EC) NO 414/2007

This regulation [RD29] 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

This regulation [RD30]deals with the technical specifications for vessel tracking and tracing systems used in RIS, as referred to in Directive 2005/44/EC [RD28]. Contrary to the more general regulation 414/2007 [RD29], 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 summarizes 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 6: 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	—	—	—
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."

4.1.6 European RadioNavigation Plan (ERNP)

The European Radio Navigation Plan, ERNP [RD31], will provide a radio navigation knowledge base with inventory of existing and emerging radio navigation systems , modernisation plans, user needs, key stakeholders and the relevant EU legislative procedures and other regulatory measures. The focus on satellite aids to radio navigation is a major emphasis of the ERNP. Its first release is planned for 2018.

The ERNP will include a section on user needs per application domain, consistent with the EUSPA analysis of user requirements (i.e. this document for the maritime user requirements).

Since the EUSPA User requirements documents and the ERNP may have different publication dates and update cycles, minor discrepancies may appear. In such case the source documents (the EUSPA User Requirements) should be used.

4.1.7 US Federal Radionavigation Plan (FRP)

INTRODUCTION

This section covers the Maritime User Requirements in the U.S.A. present in the 2017 Federal Radio Navigation Plan [RD34].

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) [RD3] 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 WATERWAY

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 7: FRP Maritime User Requirements - Inland Waterway Phase.

Requirements	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	Accuracy (Metres, 2 drms)	Availa-bility	Conti-nuity	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 zone and the intended mooring.

Table 8: 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 Zone, the U.S. Customs Zone, and the territorial waters of the U.S.

Table 9: 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. commercial sport fishing)	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal / 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 hazards of shallow water and of collision are comparatively small. These requirements must provide a ships' Master with a capability to avoid hazards 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 10: 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 11: FRP Maritime User Requirements – Sub-surface marine applications.

Requirements	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET 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 12: FRP Maritime User Requirements –Hydrographic survey.

Requirements	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS						
	Accuracy (Metres, 2 drms)		Availa-bility	Continuity	Inte-grity	Time to Alert	Cover-age
	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

4.1.8 IHO Requirements

The International Hydrographic Organization (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 [RD48]:

Table 13: 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 Zone of confidence" values (CATZOC) 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 ZOC value:

Table 14: Zone Of Confidence (ZOC) values for hydrographic charts.

ZOC	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)	Full area search not achieved; uncharted features, hazardous to surface navigation are	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.

				not expected but may exist.	
		10	± 1.2		
		30	± 1.6		
		100	± 3.0		
		1,000	± 21.0		
B	± 50 m	= 1.00	+ 2%d	Full area search not achieved; depth anomalies may be expected.	Controlled, systematic survey achieving similar depth but less position accuracy than ZOC A2, using a modern survey echosounder but no sonar nor mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10	± 1.2		
		30	± 1.6		
		100	± 3.0		
		1,000	± 21.0		
C	± 500 m	= 2.00	+ 5%d	Full area search not achieved; depth anomalies may be expected.	20m
		Depth (m)	Accuracy (m)		
		10	± 2.5		
		30	± 3.5		
		100	± 7.0		
		1,000	± 52.0		
D	Worse than ZOC C	Worse than ZOC 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.

4.1.9 Other organisations

Other organisations are in close contact with maritime user communities, such as the International Marine Contractors Association (IMCA). However, they do not issue user requirements in a form suitable to input to this document. IMCA specifically concerns marine engineering and oil and gas specific operations, providing mainly guidelines and recommendations rather than navigation or positioning requirements. In particular, the document [RD46] presents the GNSS techniques (including DGNSS, RTK, PPP, WADGNSS) and performances; and provides guidelines for the use of GNSS to position vessels, vehicles and other fixed and mobile installations during oil exploration and production related surveying and positioning activities. IMCA M 235, IMCA S 023 [RD47] Presents Guidelines on the Shared Use of Sensors for Survey and Positioning Purposes.

The **International Seabed Authority** [27](ISA) is mandated under the UN Convention on the Law of the Sea, and to which 167 countries and the EU are party, to organize and control all mineral-resources-related activities and ensure the protection of the marine environment from harmful effects that may arise from deep-seabed related activities. Increasing pressure on supply chains and raw materials is pushing many nations to explore deep sea mining of polymetallic nodules, minerals and precious metals that can be used in the production of products like smartphones, computers and batteries for electric vehicles. The Canadian company The Metals Company[28] could be setting up a pioneering industrial-scale maritime mining operation in international waters, as it was granted approval by the ISA to begin testing a mining collection system in in the Clarion-Clipperton Zone of the Pacific Ocean.

Figure 10: Location of the Clarion-Clipperton Zone (CCZ).

4.1.10 EO-related developments

The Group on Earth observation (GEO) is a partnership of more than 100 national governments, in excess of 100 Participating Organizations and the European Commission. GEO provides a framework within which new projects can be developed, and strategies and investments coordinated, leading to the creation of synergies and maximising the benefits of investments in Earth observation. The GEO community is creating a Global Earth Observation System of Systems (GEOSS) that will link Earth observation resources worldwide across the following multiple Societal Benefit Areas (i.e. water resources management, public health surveillance and infrastructure and transportation management).

The GEOSS data sharing principles post-2015 reflect the trend towards full, free and open access to EO data, while acknowledging specific restrictions on the dissemination and use of certain data, metadata and products based on international instruments and national policies and legislation. In the GEO Strategic Plan for 2016-2025 it defines the Biodiversity and Ecosystem Sustainability of the of the Ocean and Transportation Management via sea and ports as one of many priority areas. Geo will advocate the value of Earth observations, engage communities and deliver data and information in support of planning, monitoring and management of infrastructure (i.e. ports and pipelines) and transportation (air, land and sea), and in support of marine planning and ocean use at local, regional, national and global level in order to minimize environmental impacts while moving towards a low carbon footprint; GEO also wants to

[27] https://www.isa.org.jm/

[28] NORI-D Project – Nauru Ocean Resources Inc., see: https://metals.co/nori/

strengthen conservation, restoration and sustainable use of ecosystems and biodiversity, including marine planning and ocean use with the help of EO.

There are other industry-led developments that might impact EO data, especially from a technical/IT point of view:

- Spatio Temporal Asset Catalog (STAC) provides a common structure for describing and cataloguing spatiotemporal data. It is a data standard proposed and developed by a community of collaborations with the aim to making geospatial data more accessible and interoperable. It is an open specification that evolved from different organizations coming together to increase the interoperability of searching for satellite imagery, to enable a global index of all imagery (satellite, aerial, drone, etc), derived data products and alternative geospatial captures (LiDAR, SAR, Full Motion Video, Hyperspectral and more).
- The SpaceTech startup Open Cosmos launched DataCosmos in 2022 as a platform that provides a full-service alternative, adopting the newest geospatial standards, such as STAC (described earlier) and COG (Cloud Optimised GeoTIFF), The platform DataCosmos integrates with a wide range of GIS tools and Python Jupyter Notebooks.29
- A Geographic Information System (GIS) is a mapping tools for geographic information. IT used for geospatial creation, management, analysis and mapping of all types of data by integrating location data to a map with all types of descriptive information. This is often divided into four categories: desktop, web, server and specialized. Some tools—such as Esri ArcGIS Pro, Esri Story Maps, and QGIS—are the most commonly used.

4.1.11 Potential regulation evolution

Considering the requirements used to standardize GNSS, some of the most important are operational requirements such as integrity, continuity, accuracy, availability and others. These requirements should be developed based on risk analysis, considering risk exposure time and critical risk exposure time. Due to the ever-increasing and almost total reliance of many maritime applications on GNSS, for positioning, navigation and timing, resilience is increasingly becoming a major concern. Resilience, resistance to unintentional and intentional interference, or even spoofing is more and more required and could need to be translated into standards and regulations.

The need for minimum performance requirements, further standards with test plans regarding the Galileo SAR service equipment has also been expressed during interviews.

More generally, requirements are evolving due to higher dependencies onboard a ship from the electronic position, development of greater and faster ship, autonomous ship, remote control, increase of shipping in some regions and the demand for alternative energy sources.

IMO has six main bodies concerned with the adoption or implementation of conventions: the Assembly, Council and four Committees, among which the most related to GNSS standardization is the Maritime Safety Committee. The need for a new convention or an amendment to an existing one can be raised in any of them.

The current procedure for changing conventions involves “tacit acceptance” of amendments by States. This means that an amendment shall enter into force at a particular time unless before that date, objections to the amendment are received from a specified number of Parties. The period for submitting objections varies from a minimum limit of 1 year to two, in general; and the number of Parties who must object can vary from one third of Contracting Governments to those owning not less than 50% of the world's gross merchant tonnage. The majority of amendments enter into force within 18 to 24 months, with the “tacit acceptance” procedure.

[29] https://www.open-cosmos.com/datacosmos

4.2 Fisheries and Aquaculture

Given the increasing importance of fisheries and aquaculture in supporting sustainable food production, policy initiatives at global, European, and national/local level are the main drivers for user requirements. These various initiatives address sustainability in all its interlinked dimensions, aiming to improve the economic, environmental, and social sustainability of fisheries and aquaculture.

4.2.1 FAO Code of Conduct for Responsible Fisheries

The 1995 Food and Agriculture Organisation's (FAO) Code of Conduct for Responsible Fisheries is an international reference framework for various national and international instruments – policies, agreements, strategies, guidelines, legal frameworks. While voluntary, parts of it are based on the international law (United Nations Convention on the Law of the Sea (UNCLOS)) and legally binding (flag States' responsibilities) and it has been unanimously adopted by over 170 member Governments of the FAO Conference in 1995. In addition, building from Article 8.3 of the Code, in 2016 entered into force the first international and legally binding instrument to target IUU fishing – the 2009 FAO Agreement on Port State Measures[30]. As part of the implementation of the Code of Conduct, a set of further documents has been developed between 2000 and 2020:

- 9 international guidelines, which include such non-binding documents as guidelines for ecolabelling of fish and fishery products from marine capture fisheries (rev.1 2009) and inland capture fisheries (2011), as well as voluntary guidelines for catch documentation (2017), small-scale fisheries (2017) and others.
- 2 strategies to improve the information on status and trends in fisheries (2003) and aquaculture (2008)
- international plans of action
- 33 technical guidelines developed between 2000 and 2020[31].

4.2.2 EU: Green Deal and EMFAF

At the European level fisheries and aquaculture form a key component of the Green Deal with a dedicated European Maritime, Fisheries and Aquaculture Fund (EMFAF, previously EMFF) boosting innovation and investment in sustainable technologies for the blue economy. The EU's commitment to become the first climate-neutral continent by 2050 requires decisive steps towards restoring the health of our oceans, securing food production through fisheries and aquaculture, and fostering a sustainable blue economy.

The Green Deal calls for 30% of the EMFAF to contribute to climate action and 7.5% (for annual spending in 2024) for biodiversity conservation. For the period 2021-2027, the overall EMFAF budget of EUR 6.108 billion in current prices is by 87% allocated to shared management with Member States (90% in the previous period 2014-2020) with 13% spent for direct management.

With sustainability as the overarching goal, EMFAF supports the implementation of Common fisheries policy (CFP) (see the following section below) and maritime policy along the following four priorities:

1) Fostering sustainable fisheries and the conservation of marine biological resources
2) Contributing to food security in the Union through competitive and sustainable aquaculture and markets
3) Enabling the growth of a sustainable blue economy and fostering prosperous coastal communities

[30] Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated (IUU) Fishing

[31] Implementation of the Code of Conduct for Responsible Fisheries: https://www.fao.org/3/cb2990en/CB2990EN.pdf

4) Strengthening international ocean governance and enabling safe, secure, clean, and sustainably managed seas and oceans.[32]

Aquaculture is gaining strong political momentum as exemplified through the EMFAF priorities as well as the recent strategic guidelines for a more sustainable and competitive EU aquaculture, also in the light of Sustainable Development Goal (SDG) 14 – Life below water.

Furthermore, "Restore our Ocean and Waters by 2030[33]" is one of the 5 EU missions for Horizon Europe 2021-2027, meaning that the focus of research and innovation investments of this key funding programme is also set on achieving the marine and freshwater targets of the European Green Deal. For example, protecting 30% of EU's marine area and restoring the ecosystem. This mission will help to further mobilise efforts across different levels of authorities involved in achieving this target – EU, national and local levels.

4.2.3 EU: Common Fisheries Policy

The **Common fisheries policy (CFP)** originated as a part of the Common Agricultural Policy (CAP), but multiple reforms, specific legislation, introduction of exclusive economic zones and structural policies as well as the latest reform in 2013 has turned it into the first comprehensive legal framework with environmental, economic, and social sustainability as its core aim.
A set of rules apply for fishing in the European waters:

- Respecting the Maximum Sustainable Yield (MSY) by 2020 to harvest fish to allow regeneration of stocks;
- Reducing environmental impact by limiting what, where and when can be harvested, using appropriate boat capacity and gear;
- Landing obligation as of 2019[34].

In addition, multiple tools are used to improve the management and understanding of fisheries through **regionalisation**, **multiannual plans** targeting the various se basins and ceilings for EU fleet capacity per country. Furthermore, as of 2018 and as part of the EU REFIT programme, there is an ongoing **revision of EU fisheries control system** launched to ensure sustainability and increase the level playing field in the sector.

CFP also aims to contribute to sustainable fishing worldwide through **EU's involvement in regional fisheries management organisations (RFMOs)**. EU is a member of 17 RFMOs (12 regional and 5 tuna RFMOs for tuna and other highly migratory fish stocks), making it the most prominent actor worldwide.

4.2.4 EU: Farm to Fork and Biodiversity strategies

The EU Biodiversity and Farm to Fork (F2F) strategies mutually reinforce each other to shape a more sustainable and competitive future for all stakeholders – nature, farmers, businesses, and consumers. New guidelines of the EC include aquaculture as part of the F2F, while a multitude of fisheries aspects are also treated by this strategy.

Compared to other parts of the world, the EU has amongst the most stringent regulatory standards for quality, health, and the environment in aquaculture, which is essential to be respected for it to actually position as a source of low-impact food. Various recent initiatives of F2F target both sectors:

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[32] EMFAF: https://cinea.ec.europa.eu/programmes/european-maritime-fisheries-and-aquaculture-fund/about-emfaf_en

[33] Further about the mission: https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en

[34] Facts and Figures on the CFP 2020 and Common fisheries policy (CFP) https://oceans-and-fisheries.ec.europa.eu/policy/common-fisheries-policy-cfp_en

- European Food Security Crisis preparedness and response Mechanism (EFSCM) is the result of a contingency plan for **ensuring food supply and security** (as a response to COVID-19 pandemic);
- Common Market Organisation (CMO) Regulation with an objective to improve transparency on sustainability of seafood products by **standardisation of product information** on well-defined sustainability criteria and indicators is another crucial initiative of F2F with a direct impact on fisheries and aquaculture;
- The **Code of Conduct for responsible business and marketing practices** launched in July 2021 which initially targets the middle of the supply chain, but has an aim to cover the whole chain which has been signed by some fisheries and aquaculture associations;
- The **Action plan to accelerate the development of the organic sector** (March 2021) targets also the aquafarms and provides 23 actions to achieve three objectives in 1) consumption boost while maintaining consumer trust, 2) increasing production and 3) improving the sustainability of the organic sector.[35]

4.3 Critical Analysis on GNSS User Requirements

4.3.1 Analysis of IMO requirements

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

The IMO Resolutions A. 915 (22) and A.1046 (27) [RD6] form the main structure of IMO's requirements for Maritime Radio Navigation Systems. Resolution A.1046 (27) give the formal requirements and procedures for accepting new systems as components of the World-Wide Radio navigation System (WWRNS), while A.915 (22) [RD3] 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).

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), 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

IMO resolution A 1106 (29) 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

[35] The Blue Economy Report 2022

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) [RD3], according to the study "A critical look at the IMO requirements for GNSS" [RD44] undertaken within the scope of MarNIS FP6 project (Maritime Navigation and Information Services, see E.2). However, IMO Resolution A.1046 (27) [RD6] 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.

4.3.2 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" [RD14]. Actually, 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.

4.3.3 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 [RD14] 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 15: 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) and A1046 (27)) 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).

4.3.4 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 16: 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 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 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 well 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.

Actually, 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 “Zones of Confidence”, ranging from Category A1 (best) to U (unassessed quality). Refer to section 5.3.9 for full details.

4.3.5 GNSS and augmentation systems limitation

No existing GNSS is capable of meeting all operational requirements, especially integrity, without the use of augmentation systems including SBAS.

Despite its theoretical capacity to fulfil IMO resolution A.1046 (27) [RD6], 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 in order 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 in order to minimize implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and also 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 organization of data on ships and on shore, and also better data exchange between ships and with the shore. This topic will be more thoroughly discussed later.

4.3.6 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 and A.1046 (27) [RD6] as the reference. IMO resolution A.915 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 [RD30]. These are the values to be taken into account 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. 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 if it is a merchant vessel or a tow performing complex manoeuvres. Finally, IHO is proposing for the hydrographic surveys [RD48] 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 3 m.

4.3.7 Fishing vessel monitoring systems

Commission Implementing Regulation (EU) No 404/2011 of 8 April 2011 sets detailed rules for the implementation of Council Regulation (EC) No 1224/2009 establishing a community control system for ensuring compliance with the rules of the Common Fisheries Policy (in force)[36]. Article 19 sets the minimum requirements for satellite-tracking devices.

Article 19

Characteristics of satellite-tracking devices:

1. The satellite-tracking device installed on board EU fishing vessels shall ensure the automatic transmission to the FMC of the flag Member State, at regular intervals, of data relating to:

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[36] European Commission (EC) Implementing Regulation No 404/2011 of 8 April 2011 laying down detailed rules for the implementation of Council Regulation (EC) No 1224/2009 establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy, see here: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32011R0404.

(a) the fishing vessel identification;

(b) the most recent geographical position of the fishing vessel, with a position error which shall be less than 500 metres, with a confidence interval of 99 %;

(c) the date and time (expressed in Coordinated Universal Time (UTC)) of the fixing of the said position of the fishing vessel; and

(d) the instant speed and course of the fishing vessel.

2. Member States shall ensure that satellite-tracking devices are protected against input or output of false positions and cannot be manually over-ridden.

Paragraph 1 establishes a minimum requirement for accuracy which is in some cases complemented by the national regulations with more stringent requirements. This is the case, for example, of the Spanish regulation:

- ***Orden APA/899/2018***, *de 23 de agosto, por la que se modifica la Orden APA/3660/2003, de 22 de diciembre, por la que se regula en España el sistema de localización de buques pesqueros vía satélite y por la que se establecen las bases reguladoras de las ayudas para la adquisición e instalación de los sistemas de localización de buques pesqueros.*[37]

In this regulation, the position error requirement is complemented and shall be as well less than 25m RMS.

Paragraph 2 can be also supported with the use of new authentication techniques, which is the case of the Galileo OS-NMA[38], that authenticates that the origin of the navigation message obtained from signal-in-space (SiS) are provided by the Galileo System.

4.3.8 Conclusions

Since its introduction, GNSS represented a disruptive technology in Maritime, as it allowed for the worldwide adoption of a new approach for positioning and navigation. This report has provided an overview of GNSS-enabled Maritime and Inland Waterways applications, shed light on the current market and technology trends and outlined the key user requirements for GNSS. GNSS is used in many applications within the Maritime market segment:

- Considering the use of GNSS for navigation, recreational and leisure navigation is overall the largest application. SOLAS vessels navigation is smaller in terms of market size, but of key importance in terms of safety and efficiency of Sea transport. The same holds for Inland Waterways navigation;
- Focusing on positioning applications, GNSS is used for very diverse purposes, including Search & Rescue, maritime and Inland Waterways traffic management and surveillance, fishing vessels control, as well as engineering activities and port operations;
- Through provision of precise timing, GNSS underpins many other maritime applications and systems and is vital to safe and commercially viable maritime operations.

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[37] Order APA/899/2018, of *August 23, which modifies Order APA/3660/2003, of December 22, which regulates the satellite fishing vessel location system in Spain and by which the regulatory bases of aid for the acquisition and installation of fishing vessel location systems are established], Official Newsletter of the State (BOE) [Boletín Oficial del Estado (BOE)], BOE No. 211, 31 August 2018, pp. 85876 – 85896, BOE-A-2018-11979.*

[38] European Union for the Space Programme (EUSPA) (2021), Galileo Open Service Navigation Message Authentication (OSNMA) Info Note, see here: https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_OSNMA_Info_Note.pdf.

Aside the notable exception of recreational navigation, regulation has a strong role in defining user requirements and represents a key driver for the adoption of new solutions for navigation and positioning, including satellite-based systems and services.

In this multi-faceted framework, trends such as the e-navigation initiatives by IMO, the activities of a multi-system receiver performance standard, as well as the ongoing work on harbour services, represent interesting opportunities for Galileo in a multi-constellation context, for Galileo Commercial Service High Accuracy (HA) and Authentication (AUTH) in dual frequency receivers (or even multi-frequency in the wake of PPP), as well for increasing the uptake of EGNOS.

The heterogeneity of the applications (along with the difference in terms of user requirements within the same application, based on different operational scenarios, such as the various phases of navigation) implies that performance parameters and the stringency of associated requirements have a different importance and stringency from case to case.

In general, the main positioning and navigation performance parameters in the Maritime and Inland Waterways sector are horizontal and vertical accuracy, availability, continuity, integrity and time to alarm. Based on an extensive review of regulation and on validation with stakeholders, the report maps the requirements based first on categories showing similar requirements in terms of horizontal accuracy (i.e. 3 categories corresponding approximately to 10m, 1m, and 0.1 m of horizontal accuracy) and, within each category, based on clusters showing different requirements under other key performance parameters (e.g. vertical accuracy, continuity, integrity, etc.). Applications are grouped in clusters with similar requirements to facilitate the practical use of the analysis performed.

Considering the international aspect of the Maritime sector, it is clear that an agreement and mutual understanding is needed in terms of regulation and standards in order to fully benefit from the GNSS potential. In this context, improving maritime E-GNSS based positioning and navigation will require appropriate system evolution, based on the identification of clear user requirements, which was the objective of the critical analysis done in the report.

4.4 Considerations on Earth Observation (EO) value proposition

EO is expected to become more important in the future for maritime spatial planning, detect and link pollution to ships at sea, and to ensure the sustainability of fisheries and aquaculture, although EO is feeding more into evidence-based policy making than it is to regulations or standards.

Although regulations do not address really EO for the moment, the evolution of technologies such as Maritime Autonomous Surface Ships and the applications and the corresponding user needs that are closely related, will be key to drive innovation in the blue economy, while reducing the environmental footprint of anthropogenic activities. Especially the coexistence of technologies, the complexity and possible interference of terrestrial and space-based systems seem to be crucial in the future. An increasing number of terrestrial, air-borne and space-based systems are being used to monitor the climate, gather data for MetOcean and general weather forecasting, and establish early warning systems. As such, the protection and allocation of the radio spectrum for maritime communications and the development of standards for maritime radio systems by specialised bodies will be decisive in years to come.

5 USER REQUIREMENTS ANALYSIS

This chapter aims at providing a detailed analysis of user needs and requirements pertaining to applications in *Maritime, Inland Waterways, Fisheries and Aquaculture* fields. In addition, this chapter aims to describe the different roles and needs covered by GNSS and EO and identify the corresponding requirements from a user perspective.

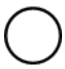
Table 17 depicts the main applications making use of GNSS and/or EO technologies in Maritime, inland waterways, fisheries and aquaculture. The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it. The current report being the first version of the *Maritime, Inland Waterways, Fisheries and Aquaculture* report on User Needs and Requirements addressing EO in addition to GNSS, it is a living and evolving document that will periodically be updated and expanded by EUSPA in future releases.

While the applications addressed in this document can benefit from GNSS and/or EO, the current issue of the RUR does not completely cover the needs and requirements of all applications. A categorisation was performed that has led to prioritising some applications over others based on their maturity level and relevance to the market trends and drivers. Other applications are foreseen to be covered in more detail in future versions of this report.

The following categorisation reflects the depth of information that can be found for the applications covered in section 5:

- **Application Type A:** these applications correspond to those for which an in-depth investigation is presented, and for which needs and requirements relevant to GNSS and EO have been identified and validated with the *Maritime, Inland Waterways, Fisheries and Aquaculture* user community at the UCP.

- **Application Type B:** these applications correspond to those not selected for in-depth investigation in the current version of the RUR, and for which a partial specification of needs and requirements is provided. At this stage, this is mostly limited to GNSS.



- **Application Type C:** these applications correspond to those not selected for in-depth investigation in the current version of the document. A high-level description of the application is included, considering that they will be further analysed and developed in next versions of the RUR.

The table below maps the **25 Maritime, Inland Waterways, Fisheries and Aquaculture related applications** to the three above-mentioned types. The following list of applications and their categorisation are **expected to evolve in the next versions of the document**

Legend

- EO only application
- GNSS only application
- Hybrid/synergetic application (combined use of EO and GNSS)

Table 17: Applications, typology and depth of analysis.

Subsegment	Application	Type of application	Depth of analysis
Merchant vessels	Ship route optimisation	A	●
	Navigation through sea ice	B	◐
	Collision avoidance (AIS)	B	◐
	GNSS vessel engine management systems	C	○
	Merchant navigation	B	◐
Inland waterways	Inland waterways navigation	A	●
Ocean Services	*MetOcean*	A	●
Environmental monitoring	*Marine pollution monitoring*	C	○
Maritime engineering	*Marine surveying and mapping*	B	◐
	Dredging	A	●
Ports	*GNSS automated port operations*	B	◐
	Piloting assist at ports	B	◐
	Port safety	B	◐
	Port security	C	○
	Port-based Port navigation devices, PPUs and Vessel docking	B	◐
Recreational craft	*Recreational navigation*	B	◐
Vessel tracking	*Dark vessel monitoring*	C	○
Fisheries	*Illegal, unreported and unregulated (IUU) fishing control*	C	○
	Fish stock detection	A	●
	Catch Optimisation	C	○
	Fishing aggregating devices	B	◐
	Fishing vessels navigation	C	○
Aquaculture	*Aquaculture site selection*	A	●
	Aquaculture operations optimisation	C	○
Search and Rescue	*Beacons for maritime (e.g. EPIRB, PLB)*	B	◐

EO-related Requirements:

For each of the applications under section 5.1 the following table format contains the application-level **requirements relevant to EO**:

Table 18: Description of needs and requirements relevant to EO.

ID	Identifier
Application	Name of the application
Users	Main users of the product/service
User Needs	
Operational scenario	Describes the operational scenario faced by the user
Size of area of interest (AOI)	Describes the AOI
Scale	Describes the scale of interest

Frequency of information	Describes how often the user requires the information to be updated
Other (if applicable)	Other user needs, i.e. contextual information (weather data), file formatting requirements
Service Provider Offer	
What the service does	Description of the service that satisfies the users' needs
How does the service work	(Technical) description of how the service works
Service Provider Satellite EO Requirements	
Spatial resolution	The satellite image ground sampling distance (GSD) required by the service provider to provide the service
Temporal resolution	Frequency of satellite data (revisit time) over the AOI
Data type / Spectral range	Type of data (e.g. RGB, SAR) and spectral range (if relevant)
Other (if applicable)	Other data requirements
Service Inputs	
Satellite data sources	Type of required data and examples of operational satellites
Other data sources	Other sources of data

Disclaimer: The EO-related requirements presented in the next section should be considered as "work-in-progress". They must be seen as a first attempt to specify requirements relevant to EO and are likely to evolve throughout the UCP process.

GNSS-related Requirements:

Regarding the GNSS needs and requirements, the previous Maritime Report (RD43] presented a table on the consolidated user requirements in the Maritime and Inland Waterways domain. The table below presents the grouping of applications with similar requirements. It is the result of a mapping exercise of the requirements listed in the internationally agreed reference document IMO resolution A.915 against 3 main categories that correspond grossly to 10, 1, and 0.1 m horizontal accuracy. The applications listed by the resolution IMO A.915 have been retained as it is the internationally agreed reference document summarising the needs of the Maritime users.

The parameters for the user requirements synthesis contained below are based on IMO requirements, except for Accuracy Horizontal (95%) in IWW. According to IMO resolution A.915(22) [RD3] both Accuracy and Integrity are system level parameters, whereas Availability, continuity and Coverage are service level parameters.

- Availability (% over 30 days);
- Accuracy Horizontal (95%);
- Accuracy Vertical (95%);
- Continuity (over 15 minutes);
- Continuity (over 20 hours);
- Error max.;
- Probability;
- Update rate integrity;
- Warning integrity;
- Alert limit integrity;
- Time to Alert;
- Integrity risk (per 3 hours);
- Coverage; and
- Fix intervals (seconds).

Resolution A.915(22) [RD3] provides a list most maritime applications, regulated or not, requiring the knowledge of the craft position or velocity for general navigation or other concrete manoeuvres.

Table 19: Consolidated Maritime, Inland Waterways, Fisheries and Aquaculture user needs and requirements relevant to GNSS.

Category	Application	Main User Requirements
Category 1 (10m horizontal accuracy)	General navigation (SOLAS), ocean General navigation (recreation and leisure), ocean and coastal Casualty analysis, ocean and coastal Search and Rescue: initial rescue approach Fisheries: location of fishing grounds, positioning during fishing, yield analysis and fisheries monitoring	10m horizontal accuracy 95% (Up to 100 m for Ocean navigation) 99.8% availability over any 30 day (over 2 years for ocean and coastal waters) 25m horizontal alert limit (not mandatory for the applications in IMO resolution A.1046 (27) [RD6]) Time to alarm smaller than 10 s. Integrity risk smaller than 10-5 per 3 hours (not mandatory for the applications in IMO resolution A.1046) Global coverage Position fixes at least once per 2 second.
Category 1+ (Same as 1 + regional continuity requirement)	General navigation (SOLAS); Coastal, Port approaches and entrances General navigation (recreation and leisure); Port approaches 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	Identical to category 1, with the addition of a continuity requirement, of 99,97 % over 15 minutes, regional
Category 1++ **(Same as 1 + enhanced horizontal accuracy requirement)**	General navigation (SOLAS); Inland waterways	Identical to category 1+, with the addition of a more stringent horizontal accuracy requirement: 3m at 95%.
Category 1+++ **(Same as 1 + vertical requirement)**	Oceanography	Identical to category 1, with the addition of a vertical positioning accuracy requirement of 10 m (95%)
Category 2 (1m horizontal accuracy requirement)	Marine Engineering, construction, maintenance and management: cable and pipe laying Aids to Navigation management Port Operations: Local VTS Casualty Analysis: Port approach, restricted waters and inland waterways Search and Rescue: final rescue approach	1m horizontal accuracy 95% 99.8% availability over any 30 day, 2.5m horizontal alert limit, Time to alarm smaller than 10 s. Integrity risk smaller than 10-5 per 3 hours Regional coverage (local for VTS)

	Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance) Offshore exploration and exploitation: Exploration, Appraisal drilling, Field development, Support to production, post-production.	Position fixes at least once per second
Category 2+ **(Same as 2 + local continuity requirement)**	General Navigation (SOLAS): Ports and restricted waters. General navigation (recreation and leisure): Ports and restricted waters Operations of Locks, Tugs, Pushers and Icebreakers	Identical to category 2, with the addition of a local coverage and a continuity of 99,97 % over 15 minutes
Category 2++ **(Same as 2 + local 1m vertical accuracy requirement)**	Ports operations: Container / Cargo management & Law enforcement	Identical to category 2, with the addition of a local coverage and a positioning accuracy requirement of 1 m vertical (95%)
Category 2+++ **(2 with relaxed horizontal accuracy + 0.1m vertical accuracy requirement)**	Hydrography Bridges operation (IWW)	Identical to category 2, with the addition of a local coverage, a positioning accuracy requirement of 1 to 2m horizontal accuracy (95%), 0.1 m vertical positioning accuracy (95%) and a 2.5 to 5 m horizontal alert limit. For bridge warning, the PNT solution shall have an integrity risk smaller than 10^{-5} per 2 minutes
Category 3 **(0.1m horizontal accuracy requirement)**	Marine Engineering: Dredging and construction works Inland Waterways: bridge collision warning systems, automatic guidance, mooring assistance, conning display	0.1m horizontal and vertical accuracy 95% 99.8% availability over any 30 day 0.25m horizontal alert limit Time to alarm smaller than 10 s. Integrity risk smaller than 10^{-5} per 3 hours For conning display, the PNT solution shall have an integrity risk smaller than 10^{-5} per 1 hour For mooring assistance, the PNT solution shall have an integrity risk smaller than 10^{-5} per 10 minutes Local coverage Position fixes at least once per second
Category 3+ **(Same as 3 + continuity requirements - no vertical accuracy)**	Operations: Docking	Requirements differs from category 3 with vertical accuracy, which is not applicable and a continuity requirement of 99,97 % over 15 minutes. 0.1m/s accuracy of Speed over Ground (SOG).

Category 3++ **(Same as 3 + stringent Time to Alarm (TTA) requirement)**	Port Operations: Cargo handling	Requirements are identical to category 3, except a stringent integrity requirement with a time to alarm smaller than 1 s.

Please refer to Annexes A1.3 and A1.4 for a brief exposition of the most commonly used GNSS and EO performance parameters, respectively.

5.1 Current GNSS/EO use and requirements per application

The Maritime, Inland Waterways, Aquaculture and Fisheries applications that are considered in this analysis are consistent with the EUSPA EO & GNSS Market Report [RD42], and might be further expanded or experience modifications in the future.

5.1.1 Ship route optimisation

EO technology can be used for ship route optimisation thanks to the continuous update of maps and electronic map display. The technology can also support digital ship route planning based on geographic/meteorological conditions and optimise ship routes according to the most efficient route (fuel consumption or speed/time) and can feature information about the surrounding marine environment such as vessel traffic, weather conditions, blocked straits, hazards and defined waterways.

Taking the example of container shipping, a route analyst of the shipping company can construct a preliminary route in a route planning system (from StormGeo, Jeppesen, Tranzas, Sofar, etc.) taking into account vessel type, cargo type, loading conditions using EO data. It then shows the optimum route, optimum speed and fuel consumption. The vessel is tracked via AIS and any deviations from the plan are reported. The route planning system allows the integration/use of weather data and ocean conditions (wave, currents) on the route. Models will help the managers of the shipping company to plan ahead and the captain to decide on the spot which route will eventually help the ship achieve its primary goal - arrive safely and in time at the port of destination.

The ideal route for a container ship would be one that allows the ship to avoid changing speed too much, allowing it to maintain constant power for optimal efficiency. Other factors may also affect which route is most economical, e.g. rent prices, bunker prices, speed inside and outside emission control areas. The captain on the bridge needs to react at each time to rapidly changing weather and ocean conditions and to decide whether it makes sense to adjust course, speed or RTA. At the destination port the harbour mast can plan ahead the logistics processes to unload the cargo. The follow-on logistics enterprises (e.g. trucks) can plan their logistics processes to further distribute the cargo.

User Needs and Requirements relevant to EO

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

Table 20: Ship route optimisation – Application-level requirements relevant to EO.

ID	EUSPA-EO-UR-MAR-0001
Application	Ship route optimisation
Users	• Ship owners • Shipping companies (e.g. route analyst/route planner) • Vessel operators

	• Destination ports (ETA) • Follow-on logistics enterprises
User 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 (section 5.1.7 contains more detailed information) 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.
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.
Scale	Route optimisation models are usually included into ECDIS chart solutions on board. 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.
Frequency of information	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.
Other if applicable (e.g. non-functional, data format, contextual information, etc.)	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 (ECDIS). The information provided from satellites (weather, ocean conditions) has to be reliable (no false positives, no false negatives) in order to avoid misrouting the vessels (resulting in additional fuel cost, delayed arrival, etc.
Service Provider Offering	
What the Service does	Provides optimisation of ship routes along the most efficient route (fuel consumption or speed/time), and using data on currents, waves, atmospheric and other weather conditions to calculate the most economical and safest route for the ship to port navigation.

	The service allows to predict and avoid 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. Obstacles that can be identified in NRT are for instance whales or floating containers (which are usually submerged, e.g. 1 m below surface), although more frequently vessels usually carry radar systems on board that detect close objects and provide alerts. 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.
How the Service works	Ship route optimisation dashboards use maps and real time data using optimisation software and tool planning features that rely on big data, Machine Learning processes and AI algorithms.

Service Provider Satellite EO Requirements	
Spatial Resolution	Wave height: 1 m Ocean conditions: 100 m
Temporal resolution	For forecasts up to 10 days this is 6 h, depending on the underlying model requirements
Data type / Spectral range	E.g. DHI MetOcean Data Portal (section 5.1.7 contains more detailed information) offers the possibility for users to save data in different formats, e.g. .MAT, .CVS, .NC, .DFS0.
Other if applicable (e.g. non-functional, latency, availability of historical data, reanalysis, pre-processing, etc.)	No user requirements were gathered.

Service inputs	
Satellite data sources	• VH Resolution satellite data • 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)
Other data sources	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 See https://resources.marine.copernicus.eu/products

5.1.1.1 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 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) [RD6]).

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)). 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

Table 21: Synthesis of Requirements Relevant to GNSS – Ship Route Optimisation – 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 [RD3]
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
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
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 (27) [RD6])
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
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)
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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+

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.

Requirements are identical to Category 1, except the following:

Table 22: Synthesis of Requirements Relevant to GNSS – Ship Route Optimisation – 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)	[RD44]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] 20/12/2011

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 23: Synthesis of Requirements Relevant to GNSS – Ship Route Optimisation – 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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
ID: EUSPA-GN-UR-MAR-0150	The service continuity (% over 3	Performance	Resolution IMO A.915(22) - 29/11/2001

ID	Description	Type	Source
	Hours) is not applicable to Category 2 applications.	(Continuity - % over 3 hours)	
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
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 (not mandatory for the applications in IMO resolution A.1046 (27) [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

*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.

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. Requirements are identical to Category 2, except the following:

Table 24: Synthesis of Requirements Relevant to GNSS – Ship Route Optimisation – 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 [RD3] Regulation (EC) No

ID	Description	Type	Source
			415/2007 [RD30]
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) [RD6] 20/12/2011 Regulation (EC) No 415/2007

* 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.

5.1.2 Navigation through sea ice

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.

5.1.2.1 User Needs and Requirements relevant to GNSS

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

Category 2+

Operations of Locks, Tugs, Pushers and Icebreakers 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 25: 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 [RD3] Regulation (EC) No 415/2007 [RD30]

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) [RD6] 20/12/2011 Regulation (EC) No 415/2007

* 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.

5.1.3 Collision avoidance

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.

5.1.3.1 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 26: 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)	[RD44]
ID: EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] 20/12/2011

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

5.1.4 GNSS vessels' engine management systems

Withal 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.

5.1.5 Merchant navigation

GNSS is the primary source of positioning information in sea navigation. In the case of Safety of Life at Sea (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.

5.1.5.1 User Needs and Requirements relevant to GNSS

The user requirements relevant to GNSS for General navigation (SOLAS) in ocean is 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) [RD6]).

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)). 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

Table 27: 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 [RD3]
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
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
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 [RD6])

ID	Description	Type	Source
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
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)
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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 28: 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 (iECDIS navigation mode req)	Performance (Accuracy Horizontal)	[RD44]
ID: EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] 20/12/2011

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 29: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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
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
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
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 (not mandatory for the applications in IMO resolution A.1046 (27)[RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

*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 30: 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 [RD3] Regulation (EC) No 415/2007 [RD30]
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) [RD6] 20/12/2011 Regulation (EC) No 415/2007

* 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 3

Bridge collision warning systems, automatic guidance, mooring assistance, and conning display in inland waterways navigation falls under Category 3. This category is characterised by having 0.1m horizontal accuracy requirement.

Table 31: Synthesis of Requirements Relevant to GNSS – Merchant navigation – Category 3.

ID	Description	Type	Source
ID: 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
ID: 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

ID	Description	Type	Source
ID: 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
ID: 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
ID: 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
ID: 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
ID: 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)	[RD44]
ID: 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
ID: 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)	[RD44]
ID: 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)	[RD44]
ID: EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
ID: 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

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.

5.1.5.1.1 User Needs and Requirements relevant to MASS

Maritime Autonomous Surface Ships are gradually becoming a reality as the technologies that enable automated operations are becoming more autonomous and independent from human intervention.

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) [RD3] 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). Both MASS and IMO Resolution A.915(22) 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).

Requirements for MASS need to impose at least the same level of safety as the ones imposed to conventional vessels.

For the different phases of navigation, the following GNSS requirements are proposed:

Table 32: Proposed Requirements Relevant to GNSS – MASS Ocean Navigation.

Performance parameter		IMO Resolution A.915 (2001)	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}	7.2×10^{-5}	10^{-5}
	>15 min	8.33×10^{-7}	6×10^{-6}	8.33×10^{-7}
	Per sample	1.39×10^{-7}	1×10^{-9}	1.39×10^{-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 33: Proposed Requirements Relevant to GNSS – MASS Coastal Navigation & Port Approach.

Performance parameter	IMO Resolution A.915 / H2H (2001)	EGUS-SC4* (2016)	Proposed GNSS requirements (2022)
Horizontal Accuracy (95%)	<10 m	<0.3 m	<1 m
Continuity Risk (over 15 min)	N/A	3×10^{-4}	3×10^{-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 34: Proposed Requirements Relevant to GNSS – MASS Port Navigation.

Performance parameter		IMO Resolution A.915 (2001)	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.

The requirements here proposed apply exclusively to the GNSS antenna PVT computation. For vessel positioning additional parameters shall be considered as proposed in IMO MSC. Circ. 1575.

It is generally 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.

5.1.6 Inland waterways navigation

EO data can support 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. GNSS is also 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.

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.

E.g. commercial shipping is interested to receive information on obstacles on their route such as ice building in winter (low temperature), sand banks in summer (high temperature, low water level), blocking obstacles (e.g. stranded ship), the available navigation channel in relation to the water level.

On the other hand, for recreational tourism more general information is relevant such as weather, map of the waterway, water levels, water quality, wildlife protection areas, harbours and their occupation, camping grounds (incl. information on flooding risk, fire risk zones, etc.), obstacles like embankments, barrages, locks.

Then there are the interests 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 zones 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). Last but not least the monitoring of the water quality is of interest.

User Needs and Requirements relevant to EO

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

Table 35: Inland waterways navigation – Application-level requirements relevant to EO.

ID	EUSPA-EO-UR-MAR-0002
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
User needs	
Operational scenario	Determining fairways Mapping embankments, barrages, locks. Provide overview for VTS Centre of complete traffic situation (professional and leisure boats). 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. However, the WSV is also responsible for leisure boat navigation, which is not subject to this AIS equipment obligation. 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,
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.
Scale	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 these obstacles can range from A few meters (e.g. single obstacles, sandbank) to larger areas (e.g. ice building). Accordingly, the spatial resolution has to 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.
Frequency of information	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).
Other if applicable (e.g. non-functional, data format, contextual information, etc.)	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).

Service Provider Offering	
What the Service does	Enables safe navigation through inland waterways using most accurate and timely information available. Sediments and natural erosion are continuously changing, e.g. Wadden islands in the Netherlands and Germany (ferries operate regular services, coastguard interventions). Supports the preservation and maintenance of the waterways and related surroundings for commercial shipping, recreational use, environmental and wildlife protection.
How the Service works	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 zones, maintenance work)
Service Provider Satellite EO Requirements	
Spatial Resolution	1 meter/ The size of leisure boats
Temporal resolution	6 hours
Data type / Spectral range	No user requirements were gathered.
Other if applicable (e.g. non-functional, latency, availability of historical data, reanalysis, pre-processing, etc.)	For safe routing on fairways it is absolutely necessary to include immediate warnings on obstructions, i.e. accident detection in real-time by other means other than satellite imagery.
Service inputs	
Satellite data sources	• Aerial/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.
Other data sources	• 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)

5.1.6.1 User Needs and Requirements relevant to GNSS

The **GNSS requirements** are contained in the section below.

Category 1++

General navigation (SOLAS); Inland waterways falls 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 36: Synthesis of Requirements Relevant to GNSS – Inland Waterways Navigation – 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

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 37: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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
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
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

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 (not mandatory for the applications in IMO resolution A.1046 [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

**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+++

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 38: 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)	[RD44]
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 [RD3]
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
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 Regulation (EC) No 415/2007 [RD30]

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.

Table 39: 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
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
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
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
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
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)	[RD44]
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
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)	[RD44]
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)	[RD44]

EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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.

5.1.7 MetOcean

EO provides data for meteorology over oceans (offshore weather and sea state monitoring) complemented with frequent data collection of variables such as wave height and frequency, wind speed and direction and ocean current velocity on global and regional scales. EO can support to detect and map a most up-to-date meteorological, oceanographic and geobiophysical conditions and a more accurate MetOcean forecasts to optimise sea-borne operations/activities.

MetOcean refers to the combination of meteorology and (physical) oceanography. Meteorology covers aspects like wind speed, direction, gustiness, wind rose and wind spectrum, air temperature, humidity, occurrence and strength of typhoons, hurricanes and (other) cyclones. Physical oceanography includes information on water level fluctuations (i.e. sea level changes, storm surges, tides, tsunamis, wind waves), bathymetry, salinity, temperature and other constituents, stratification, currents, ice building. As such, any organisation operating offshore in oceans is interested in such information to support safe operations, safety of infrastructure, safety of lives.

The life cycle of offshore platforms (oil, gas, wind power, tidal energy) starts with the site detection and selection requiring information on the energy source (primary objective) as well as on the surrounding environmental conditions (MetOcean) determining the operational scenario. Following the potential approval by authorities also requiring all information for their decision making, the construction cost of platforms is highly dependent on the MetOcean conditions, as equipment and field teams are allowed to operate only under safe conditions. As usually a mix of different work and specialised companies /know how is required, the planning process is quite complex. Therefore, prediction of MetOcean conditions days/weeks ahead allows a cost-efficient planning and utilisation of the required resources (avoiding idle cost for non-utilisation). Once the construction is finished, the operative utilisation starts. Especially critical for any type of platforms is the knowledge ahead of extreme weather events (e.g. cyclones, extreme waves) to secure these platforms (e.g. stop operations, secure equipment and personnel), as these events can exceed the capabilities of the platforms. With the advent of climate change, i.e. increasing temperatures, the number and power of such extreme weather events is increasing accordingly and the knowledge ahead in time becomes even more important.

For regenerative energy production platforms (e.g. wind power, tidal energy) the environmental conditions (wind, waves, currents, tides) also determine the operative result, and allow the calculation and prediction of the energy outputs to be fed into the energy grids. This is important knowledge for the energy providers participating in the planning of the energy mix and determining their financial results (aiming for profits), as well as for the energy coordinators to plan the energy mix (planning is usually done for time intervals 24 hours and 72 hours ahead) in order to safeguard the availability of energy for their region/country.

Any vessel shipping on the oceans or people using the ocean for business or leisure (container/transport ships, passenger ships, fishermen, leisure sailor, divers, coast guard, rescue operations (incl. helicopters), etc.) is interested in a subset of the MetOcean information depending on their objectives in order to guarantee safety of life of their crew or passengers, with weather information as the most important aspect.

Finally, some extreme natural phenomena originate over or in the oceans (e.g. hurricanes/cyclones, tsunamis) and effect regions/countries along the shoreline and further into the land. Accordingly, any authority, rescue organisation, industry, individual is interested to receive relevant warnings ahead of time to safeguard/rescue lives and goods.

GNSS spotter buoys serve as in-situ measurements, such as those launched by Sofar Ocean Technologies. Spotter is a MetOcean buoy that collects and transmits data in real-time on variables such as wave, wind, sea surface temperature, and barometric pressure. The spotters are providing data continuously and serving a host of applications, such as ship route optimisation, aquaculture, offshore energy and port operation to name just a few. The spotter buoys are connected via satellite 25/7 and data is accessible via a dashboard and API. Consult Map on Ocean.com. Also, in line with buoys for route optimisation is bathymetry as the ocean topography has an effect on waves and defines ocean surfaces, e.g. waves breaking in water lines.

User Needs and Requirements relevant to EO

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

Table 40 - MetOcean - Application-level requirements relevant to EO.

ID	EUSPA-EO-UR-MAR-0003
Application	MetOcean
Users	Exploration companies, licencing/national authorities, construction companies (e.g. platforms, pipelines), organisations operating offshore platforms (e.g. oil, gas, wind power), energy providers, vessels/ships/boats in general (shipping companies, passenger ships, fishermen, sailing boats, diving, coast guards, rescue operations, etc.), authorities / rescue organisations in countries affected by extreme weather events (e.g. hurricanes, tropical storms, tsunamis).
User needs	
Operational scenario	Meteorological conditions monitoring to ensure safety of operations/activities Forecasting of energy production Monitoring of geobiophysical conditions of seas, oceans and coastal regions for environmental/economic purposes.
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.
Scale	MetOcean data are usually included into ECDIS chart solutions. The scales available on ECDIS maps are classified according to navigation purposes, e.g.: • Harbour 1:4,000 - 1:21,999 • Approach 1:20,000 - 1:89,999 • Coastal 1:90,000 - 1:349,000 • General shipping 1:350,000 - 1, 1499,999 • Overview 1:<1,499,999 (see: https://knowledgeofsea.com/ecdis-compilation-scale-and-scale-minimum/) The applicable scale depends on the type of utilisation (see ECDIS scale.

	Regarding the oceanographic aspects, local phenomena can have significant influence depending on the specific type of operation (e.g. underwater geology can have significant effect on the generation of waves, currents can be influenced by underwater geology, islands, land tongues, peninsulas) a higher resolution at respective geolocations would be required, e.g. in the range of 100 m.
Frequency of information	The most critical information for users in this environment 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. The majority of the oceanographic aspects are stable in time. The only exception may be underwater events causing extreme consequences (e.g. earthquake/seaquake causing a tsunami). Also, here the important aspect is to detect such events as soon as possible in order to issue warnings for the affected operations (including the concerned regions/countries).
Other if applicable (e.g. non-functional, data format, contextual information, etc.)	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)). **Other if applicable** As MetOcean is mostly used for predictions / forecasts, the underlying models play a significant role. Due to climate change, models need to be enhanced/developed which allow to predict the related changes that can be expected in the coming years.
Service Provider Offering	
What the Service does	Meteorological/ocean conditions include wide-ranging parameters, i.e. ocean currents, waves, temperature, salinity, algae blooms and nutrients, sea level, and all-weather conditions such as winds, rains, storms and more. Most accurate MetOcean forecasts serve to optimise sea-borne operations/activities and reduce risk (human and economic)
How the Service works	MetOcean services incorporates up-to-date meteorological, oceanographic and geobiophysical conditions. MetOcean services are offered by a variety of organisations on different levels: • The World Meteorological Organisation (WMO) is the specialised UN agency development whose mandate is meteorology, climatology, operational hydrology and related environmental services as well as to reap the benefits from their application. WMO provides the framework for such international cooperation. WMO offers a Worldwide Met-Ocean Information and Warning Service (WWMIWS). The National Oceanic and Atmospheric Administration (NOAA) NOAA • In Europe there is the European Centre for Medium-Range Weather Forecast (ECMWF) that produces global numerical weather predictions. The ECMWF is considered to be the most accurate global model, although this may vary.

	• On the national level there are meteorological offices, such as Meteo France (F), DWD (DE), UK Met Office (UK) and Italy, that run their own numerical weather prediction models using local augmentations, and issuing national alerts. • Commercial organisations provide customised met services (e.g. StormGeo, MetGis). The growth of sustainable commercial weather services started around 2010 when more data became available for free. [39]
Service Provider Satellite EO Requirements	
Spatial Resolution	Wave height: 1 m Ocean conditions: 100 m
Temporal resolution	For forecasts up to 10 days this is 6 hours, depending on the underlying model requirements
Data type / Spectral range	These are some commonly used data formats: • General Regularly distributed Information in Binary form (GRIB) is a file format for storing historical and forecast meteorological data. • Unified Model (UM): numerical model for atmosphere system modelling software provides medium-range weather forecasts. • NetCDF (network Common Data Form) is a file format that stores multidimensional variables (temperature, humidity, pressure, wind speed, etc.).
Other if applicable (e.g. non-functional, latency, availability of historical data, reanalysis, pre-processing, etc.)	No user requirements were gathered.
Service inputs	
Satellite data sources	Meteorological satellites in Europe are operated by EUMETSAT[40]. It comprises: • GEO satellites METEOSAT 2nd (and upcoming 3rd) • LEO satellites METOP 1st (and upcoming 2nd) generation.41 • Jason-3 satellites (cooperation between EUMETSAT, CNES, NOAA, NASA). • Sentinels 3, S-6, upcoming S-4 and S-5 More information under https://www.eumetsat.int/our-satellites. Follow this link for ECMWF overview of satellite data.
Other data sources	Sentinel-1, -2 and -3

[39]R.E.W. Pettifer (2014), The development of the commercial weather services market in Europe: 1970-2012.

[40] EUMETSAT is an intergovernmental organisation with 30 member states. The representatives of the member states are the national met offices, funded by the national transport or research ministries. As the European operational satellite agency for monitoring weather, climate and the environment from space, its members are all the MS of the EU as well as Iceland, Switzerland, Türkiye and United Kingdom., see: https://www.eumetsat.int/who-we-are/eumetsat-member-states

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

5.1.8 Marine pollution monitoring

SAR-based and optical satellite data can be used for detecting and monitoring of the marine environment. The world's oceans are increasingly saturated with Anthropogenic contaminants (ACs), substances found in the environment that are due to human activities and affect living organisms, ecosystems and economic activities directly or indirectly. Common ACs are SO_2, NO_x, CO_2 (uptake of CO_2 causes the acidification of the oceans), (micro)plastics, debris, contaminants coming from ships, eutrophication and numerous chemical substances. EO data and models can provide forecasts of sea currents and sea-surface heights (altimetry), sea-surface salinity, sea-surface temperature, ocean colour and sea-ice data - useful for monitoring and forecasting the course of the pollution. Moreover, remote sensing data can also contribute to identifying the polluters.

5.1.9 Marine surveying and mapping

This applications covers a wide range of GNSS-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.

5.1.9.1 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 Organization for Standardization, 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 German 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.

5.1.9.2 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 4.1.8 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 41: 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 [RD3]

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 42: 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)	[RD44]
EUSPA-GN-UR- MAR-0250	The PNT solution shall provide 1 to 2 m	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) – 29/11/2001 [RD3]

	horizontal positioning accuracy		
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
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 Regulation (EC) No 415/2007 [RD30]

5.1.10 Dredging

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 is a method of surveying shallow waters and can be used to monitor and support dredging activities through multispectral images (MSI). MSI allows experts to measure both the depth (i.e. In clear waters optical imagery acquired from Sentinel 2 can reach up to 25m of depth) of the water and to map the sub-sea surface to place reefs, vegetation and other natural/man-made structures nature of the seabed.

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.

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.). in order to comply with contractual requirements.

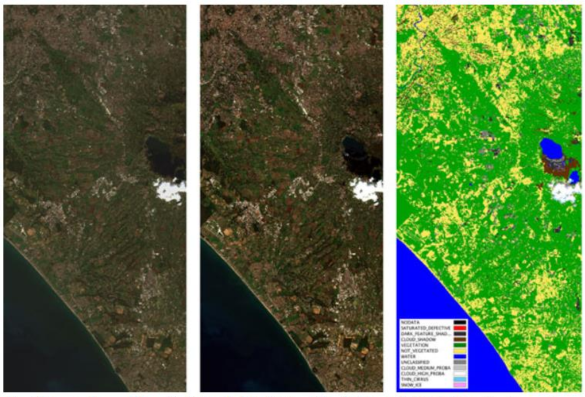
5.1.10.1 User Needs and Requirements relevant to EO

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

Table 43: Application-level requirements relevant to EO – Dredging.

ID	EUSPA-EO-UR-MAR-0004
Application	Dredging
Users	• Dredging companies • National Authorities (Maritime, Environmental)
User 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
Scale	No user requirements gathered.
Frequency of information	For SDB only typically 1 a day up to several times a day. For water quality up to hundreds a day.
Other if applicable (e.g. non-functional, data format, contextual information, etc.)	No user requirements gathered.
Service Provider Offering	
What the Service does	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
How the Service works	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.
Service Provider Satellite EO 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
Data type / Spectral range	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[42]:

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

	 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.
Other if applicable (e.g. non-functional, latency, availability of historical data, reanalysis, pre-processing, etc.)	No user requirements gathered.
Service inputs	
Satellite data sources	MODIS, Partly DIAS, Sentinel-2 and -3 VHR Commercial: Planet, Maxar, Ipp partner. Airbus, Planet, Maxar
Other data sources	Altimeter, SAR data, Lidar ICESAT, AWS **Occasionally in-situ data measurements (provided by client)**

5.1.10.2 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 44: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]

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
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
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
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 (not mandatory for the applications in IMO resolution A.1046 (27) [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22)–- 29/11/2001
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

*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 45: 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

ID	Description	Type	Source
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
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
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
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
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)	[RD44]
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
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)	[RD44]
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)	[RD44]
EUSPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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.

5.1.11 GNSS automated port operations

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 46: 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. [RD3]

5.1.12 Piloting assist at ports

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.

The user requirements relevant to GNSS are contained in the table 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.

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 47: 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)	[RD44]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] - 20/12/2011

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 48: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]

ID	Description	Type	Source
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
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
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
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 (not mandatory for the applications in IMO resolution A.1046 (27) [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22)–-29/11/2001
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

*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 49: 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 [RD3] Regulation (EC) No 415/2007 [RD30]
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) [RD6] 20/12/2011 Regulation (EC) No 415/2007 [RD30]

* 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++

Ports operations: Container / Cargo management & Law enforcement fall under Category 2++.This Category presents the same main requirements as Category 2, except that the vertical accuracy requirement is 1m local.

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 50: 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 [RD3] Regulation (EC) No 415/2007 [RD30]

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) [RD6] 20/12/2011 Regulation (EC) No 415/2007

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

5.1.13 Port safety

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.

5.1.13.1 User Needs and Requirements relevant to GNSS

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

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 51: 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 [RD3] Regulation (EC) No 415/2007 [RD30]
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) [RD6] 20/12/2011 Regulation (EC) No 415/2007 [RD30]

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 52: 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 [RD3]

5.1.14 Port security

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.

5.1.15 Port-based port navigation devices

Port navigation devices for transit progress, docking and loading-unloading operations are monitored through GNSS-based technologies.

Portable pilot units (PPUs) are professional, portable devices used by maritime pilots to navigate vessels through narrow passages such as locks and ports. Used together with the vessel's bridge and interfaced with high-accuracy GNSS, PPUs make docking of large marine vessels by pilots safer and more time and fuel efficient.

Docking assist systems provide efficient and safe manoeuvring within the entire port area by providing the necessary centimetre positioning/speed accuracy (covering the complete port/ harbour zone). This enhances vessel trajectory and facilitates the constant monitoring for moored/docked vessels.

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 53: Synthesis of Requirements Relevant to GNSS – Port-based Port navigation devices, PPUs and Vessel docking – 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)	[RD44]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] 20/12/2011

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 54: Synthesis of Requirements Relevant to GNSS – Port-based Port navigation devices, PPUs and Vessel docking – 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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

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
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
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 (not mandatory for the applications in IMO resolution A.1046 (27) [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22)–-29/11/2001
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

*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 55: Synthesis of Requirements Relevant to GNSS – Port-based Port navigation devices, PPUs and Vessel docking – 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 [RD3]

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

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) [RD6].

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 56: Synthesis of Requirements Relevant to GNSS – Port-based Port navigation devices, PPUs and Vessel docking – 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 [RD3]
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) [RD6] 20/12/2011
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 57: Synthesis of Requirements Relevant to GNSS – Port-based Port navigation devices, PPUs and Vessel docking – 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 [RD3]

5.1.16 Recreational navigation

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) [RD6]).

Table 58: 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 [RD3]
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
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
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)
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s	Performance	Resolution IMO A.915(22) - 29/11/2001

ID	Description	Type	Source
		(Integrity, Time to Alert)	
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)
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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 59: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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
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
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
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 (not mandatory for the

ID	Description	Type	Source
			applications in IMO resolution A.1046 (27) [RD6])
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
ID: EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

*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 60: 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 [RD3] Regulation (EC) No 415/2007 [RD30]
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) [RD6] 20/12/2011 Regulation (EC) No 415/2007

* 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.

5.1.17 Dark vessel monitoring

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.

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.

5.1.18 Illegal, unreported and unregulated (IUU) fishing control

Satellite data has surveillance capabilities for the IUU fishing activities and can contribute to the identification of perpetrators. The data concerned is both EO (optical and radar) and GNSS (providing identification of the vessels, including through positioning systems such as AIS and VMS). With AIS and VMS being mandatory depending on the vessel size (i.e. 15m for AIS, 12m for VMS), the GNSS receiver of these applications is a different to the receiver used for general navigation.

5.1.19 Fish stock detection

EO enables services which allow better protection and management of the limited fishing resources available. EO services can provide information which is crucial to both the **fishing industry** as well as **local authorities** who ensure conformity with existing regulations and protecting fish stocks. **Authorities** are tasked to protect and manage existing resources and use regulations, quotas, and fines to fight against excessive fishing due to global issues such as large fish fleets, poor management, by-catches. While in the past remote sensing was used predominantly to assist in the efficient harvesting of natural resources, today it is increasingly being used for resource management, conservation and exploitation.

EO services and products can be used to monitor and/or model the location of fish stocks or shoals and to optimise fishing efforts. Applications use physical, bio-geochemical analyses and forecasts to understand the vulnerability or resilience of the stocks. While no satellite measurements are directly sensitive to fish stocks, EO can provide information on the habitat, observing various parameters which forecast the presence of fish. Global and regional sea temperature, salinity, topography, ocean colour, and ocean currents are key inputs for **fish stock numerical modelling**. Professional fishing vessels detect the actual fish stock in-situ directly by echo-sounders and sonars.

User Needs and Requirements relevant to EO

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

Table 61: Application-level requirements relevant to EO – Fish stock detection.

ID	EUSPA-EO-UR-MAR-0005
Application	Fish stock detection
Users	• Fisheries • Fishery managers • Authorities (national and local, e.g. coast guards) • Fish markets • Monitoring and control entities • Maritime industry • Scientific community • Retail organisations • (Fishing) tourism organisations • Fish welfare organisations (e.g. FAO, EFSA) • NGOs
User Needs	
Operational scenario	Ecosystem productivity, based on Chlorophyll-a and associated with fields of temperature, salinity, oxygen, wind intensity, wave height, depth, for the identification of oceanographic discontinuities and productivity hotspots.
Size of AOI	Size of area depends on the end-user and their AOI: • Large territorial water areas for public administrations with mandate on own waters; • Smaller areas for use by e.g. fish tourism operator covering their area of operation.
Scale	According to size the scale can range from 1:250.000 to 1:5000
Frequency of information	Weekly, monthly, seasonal, annual
Other (if applicable)	WebGis to visualize the thematic data and/or integration with other instruments on board
Service Provider Offer	
What the service does	The service provides indirect indicators of possible presence of fish: Chlorophyll-a, surface temperature, salinity, oxygen, ocean colour (surface optical or bio-optical properties: diffuse attenuation coefficient, total suspended matter, yellow substance, chlorophyll pigments and macrophytes); vertical and horizontal circulation features (e.g. wind, wave); oil pollution; sea state.
How does the service work	The parameters are acquired daily by satellite data and displayed on a dashboard in aggregated data to provide information with the required frequency (weekly, monthly, seasonal, annual). The dashboard displays anomalous data and send alerts for parameters out of the thresholds
Service Provider Satellite EO Requirements	
Spatial resolution	10 m–- 1 km, depending on the size of fish shoal. Based on **UCP2022** feedback, any resolution below 12m (or 10m) would be fine since fishing vessels typically measure about 12m. In certain ports it would be useful to identify activities with 0.5m resolutions.

Temporal resolution	Range depending on the user: from near-real-time (for use onboard of fishing vessels) to every few hours/daily (authorities, daily fishing trips with smaller boats), to long term (for fish stock expansion).
Data type / Spectral range	Optical data (water quality parameters: Chlorophyll-a, turbidity, salinity, oxygen) SAR data for winds, currents, wave height
Other (if applicable)	Historical data
Service Inputs	
Satellite data sources	• Optical data: Sentinel 2 (e.g. CMEMS, ocean colour, suspended matter) and 3 (e.g. OLCI, SLSTR, altimetry), VHR. • SAR data: Sentinel 1 (e.g. wind, waves), CosmoSkymed
Other data sources	Aerial, drones (RGB), buoys, echo-sounders and sonars (detection of fish, biomass estimation), fish finders on-board of fishing vessels, on-board cameras

5.1.20 Catch optimisation

EO data contributes to habitat mapping for fish species. Combined with weather data and data on other relevant parameters (e.g. bio-geochemical analyses and forecasts for global and regional seas, topography, bathymetry, ocean colour, sea-surface temperature and ocean currents), the catch optimisation application provides relevant information which allows for the selection of the optimal timing, location, and means for fishing activities.

5.1.21 Fishing aggregating devices

Fishing aggregating devices are GNSS-enabled buoys that assist fishermen both in locating their fishing nets and equipment as well as the identification and location of fish stock.

Smart fishing buoys[43] are used to detect fish banks, such as Tuna. End users need smart fishing buoys to ensure more efficient and sustainable fishing practices in their daily operations. Thanks to built-in echosounders beneath the surface, the information is periodically transmitted via satellite to the vessel, communicating the exact position of the buoy, helping fishery industries save tons of fuel and consequently reduce their CO2 emissions.

User Needs and Requirements relevant to GNSS

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

[43] This type of buoys is equipped with a GNSS receiver that transmits positioning information through an external antenna to the vessel so that information about time and distance to the buoys can be used to optimise the route planning. Often, these buoys are also equipped with LEDs for a quick and visual monitoring when near the buoys. The latest receivers rely on spread-spectrum communication technology which make it difficult to detect by third parties. Examples of such receivers are the MSR-2 receiver that relies on the Iridium network.

Table 62: Synthesis of Requirements Relevant to GNSS – Fishing aggregating devices.

Criterion	Characterisation
Accuracy (positioning)	As buoys are essentially used to easily locate fishing lines and fish banks, only a rough estimation of its location is required in order to visually locate the buoys when close enough. Therefore, standalone GNSS and single-constellation solutions (e.g.: GPS only) are enough to provide the required 5-10 m horizontal accuracy, which is below nominal Galileo performance (around 2 metres). Vertical accuracy is not relevant for this use.
Accuracy (timing and synchronization)	The timing features provided by GNSS are mainly used for synchronization applications, using the clock of the signal provided by the satellites to synchronize multiple buoys in this case. However, in the fishing area no requirements in terms of synchronization are extracted from the performed interviews.
Coverage	The coverage provided by Galileo is improved in some areas with high values of latitude like the poles, due to the inclination of the satellite orbits. Therefore, those fishing activities performed at these latitudes may be benefited by the use of Galileo. Many interviewed companies see the increase of the coverage as an interesting feature, above all in terms of battery use since the visibility of more satellites may reduce the TTFF and thus the battery consumption.
Availability	Fishing applications range from buoys used to identify the location of bank of fishes thanks to the implemented sonars, to buoys which set the position of fishing nets. Thereby, fishing boats are able to leave these devices over the sea and return once a bank has been detected or after a period of time that allows fishes to get caught in the launched nets. Again, in this use-case, fishers only need a rough location of the buoys and as extracted from the interviews, a continuous value of the position is not necessary since only periodic position stamps are reported. Therefore, the conclusion established in this case again is that a high-level availability is not required, and that the availability already provided by systems such as Galileo and GPS (compliant with the IMO A.1046 (27) [RD6] requirement of at least 99,8%) would be enough for the purposes of this application.
Initialisation time (TTFF)	As specified before in the previous section the TTFF defines the elapsed time between the time a receiver was switched-on and the moment the first position estimation was acquired. In this sense, the fishing applications also showcase an interest in reducing the TTFF, mainly to achieve a battery consumption reduction.
Integrity	In the GNSS fishing applications previously explained no integrity requirements are foreseen and the performed interviews neither show an interest in the introduction of this feature.
Authentication	As specified for the scientific buoys, the lack of remarkable spoofing attacks specifically in the fishing area, makes not required the implementation for authentication methods like OS-NMA in this sense. In addition, the increment of cost due to the introduction of a timing source to support the OS-NMA functionality, as well as the installation of greater batteries in order to support the augment in energy requirement is not desired by the clients of this products as showcased in the interviews.
Continuity	As it happens with the availability performance, it may be concluded that fishing applications do not require a strict value of continuity due to the nature of their activities and that IMO A.1046 (27) [RD6] requirements (at least 99,97%) are applicable and fulfilled by most GNSS systems.

5.1.22 Fishing vessels' navigation

Using GNSS-enabled navigation devices, fishing vessels can accurately and safely navigate their fishing waters as well as navigate towards their equipment such as fishing cages, buoys or fish lines. In navigation, fishing vessels should respect the minimum requirements for satellite-tracking devices to comply with the rules related to the Common Fisheries Policy[44].

Navigation and positioning in the fisheries context may be separated in:

- *General navigation*: this includes the phases of ocean and coastal navigation, ports, port approaches and restricted waters navigation, inland waterways and transition from sea to river navigation.
- *Location of fishing groun*d: in which the GNSS must be able to enable fishing vessels to relocate and return to rich fishing grounds, requiring a high repeatable accuracy.
- *Positioning during fishin*g: which requires control of the position of the vessel and nets during fishing. It becomes more important if the activity is taking place near to underwater constructions. Recording of fishing tracks and yield analysis.
- *Fisheries monitorin*g: in order to certify that European Community's quotas are not exceeded, fishing vessels are required to monitor their activities by reporting their position back to a national fisheries control and monitoring centre. Assurance of the integrity of the information is required for the position reports to be of use in case of legal actions.

5.1.22.1 User Needs and Requirements relevant to GNSS

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

Category 1

Fisheries: location of fishing grounds, positioning during fishing, yield analysis and fisheries monitoring all fall 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) [RD6]).

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)). 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

Table 63: Synthesis of Requirements Relevant to GNSS – Fishing vessels' 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 [RD3]
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

[44] See details in Chapter 4.3.7. on Fishing vessel monitoring systems.

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
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)
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
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)
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22)–- 29/11/2001
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

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.

Table 64: Additional GNSS Requirements–- Fishing vessel'' navigation.

Criterion	Performance	Characterisation
Accuracy	*Horizontal*	10m horizontal positioning accuracy 95% For inland waterways: more stringent horizontal accuracy requirement: 3m at 95%.
Service area	*Geographical coverage*	Global coverage
Availability/timeliness	*Availability* *Fix Interval-seconds*	99.8% availability over any 30-day period (over 2 years for ocean and coastal waters) The PNT solution shall provide independent position fixes at least two per second
Resilience (Robustness / Trust)	*Integrity – Alert Limit* *Integrity – Time to Alert*	25 m horizontal alert limit Time to alarm smaller than 10 s.

	Integrity Risk – per 3 hours *Susceptible to interference* *Susceptibility to spoofing*	The PNT solution shall have an integrity risk smaller than 10^{-5} per 3 hours (not mandatory for the applications in IMO resolution A.1046 (27) [RD6])
Continuity		For port approaches and entrances: the addition of a continuity requirement, of 99,97 % over 15 minutes, regional

5.1.23 Aquaculture site selection

For **aquaculture site selection**, applications use inputs on environmental conditions (weather conditions, wave heights, water depth, seafloor conditions, currents), forecasts and predictions. EO data and forecasting helps select the aquaculture site location and type in both the inshore and offshore environment.

Aquaculture is carried out in various **breeding environments** all over the world – seas, rivers, ponds, lakes, lagoons, or artificial basins, to name the most common. At the moment, due to the coarse resolution (of around 1km) of satellite images, EO services are mainly used in marine waters. More recent developments and accessibility of higher-resolution data open the way for aquaculture site selection to operate closer to the coast and even in inland waters. Moreover, with countries working to establish farms in open waters, potential for EO use increases as such farms can be easily monitored with medium-resolution data.

Authorities identify specific areas assigned to aquaculture as part of a strategic coastal spatial planning process, which can be carried out at local, regional, or national level. Here the environmental data is combined with administrative and socio-economic criteria to define the suitability of an area for development of aquaculture. For **aquafarmers** multiple additional criteria is added in the aquaculture site selection process, considering that there is a large variety of species cultivated and specific aspects of each cultivated aquatic organism can vary. Indeed, nowadays more than 500 aquatic species are farmed all over the world.

For both user groups the assessment of **environmental, land use** and **marine spatial planning** aspects of farm site are crucial. Users need to consider existing protected **ecosystems**, environmentally sensitive zones, or location near critical habitats for endangered species, as well as ocean currents linking these aquatic ecosystems.

Aquafarm structure requires important investments; therefore, a series of additional aspects are considered by the users:

- **Farm features** such as coastal barriers, riparian buffers and corridors for enhanced disease and predator control;
- The surrounding **infrastructure** (energy availability, for example, for pumps and aerators in controlled intensification shrimp farms);
- **Coastal access;**
- Any potential conflicts with **local communities** and sea or land **tourism;**
- Assessment of **risks** and their mitigation: **extreme events** (storms, floods) or **slow changing phenomena** (coastal erosion, salt-water intrusion only for in land based freshwater fish farms) and more in general **climate change** risk that increases the number and the frequency of the extreme events and affects the water quality parameters with a direct impact on the underwater life;
- Assessment of **water quality** (assessment of chemical (e.g. oil spill, pollution from chemical industry) and physical conditions (e.g. water temperature, water transparency and colour,

phytoplankton, etc.), water pollution from neighbouring land use or industries (e.g. discharge of effluents);

- Identification of eutrophication zones and areas prone to harmful **algal blooms** (e.g. Chlorophyll-a) producing toxic or harmful effects (fish mortality, food poisoning, ecological degradation, etc.);
- Other species-specific aspects (e.g. jellyfish blooming).

During the **UCP2022** Mercator Ocean International[45] held a presentation on the Copernicus Marine Environment Monitoring Service (CMEMS) that currently has about 170 ocean products used to support Blue, Green and White Ocean Activities. Mercator supports Aquaculture and Fisheries in the selection of optimal mussels' growth sites use case, within 10km of the coastline, as this leads to the optimal location to reduce costs. Some relevant technical features of the indicators were shared:

- The **temporary resolution** ranges from hourly, daily and covers **historical records** of 45 years, with multiyear products starting from 1993;
- **Forecasts** cover 2-10 days;
- The **Geographical coverage** is global, with specific subregions for all European Oceans;
- Concerning **Sources of data**: L3 daily composite multisensory; L4 daily interpolated;
- Regarding **spatial resolution** this ranges from 200 metres up to 25 kilometres;
- And **other data** used are lidar, vessels, in-situ sensors.

User Needs and Requirements relevant to EO

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

Table 65: Application-level requirements relevant to EO – Aquaculture site selection.

ID	EUSPA-EO-UR-MAR-0006
Application	Aquaculture site selection
Users	• Aquafarmers, public administration (national and local) • Monitoring and control entities • Maritime industry • Scientific community • Recreational and tourism organisation • Investors • NGOs
User Needs	
Operational scenario	The following activities are required: 1. Preliminary analysis 2. Territory analysis 3. Consultation 4. Eligibility 5. Environmental analysis 6. Zoning 8. Identification of sites
Size of AOI	Coverage: coastal and off-shore areas.

[45] Mercator Ocean International is the entrusted entity by the European Commission to implement and operate the Copernicus Marine environment Monitoring Service (CMEMS).

	In-shore and off-shore areas (marine waters); the size ranges from 1-2 km2 (for small areas) to 800 km2 (for large); variations are due to fish and seafood farmed from e.g. mussels (very small) to pelagic fish (very large).
Scale	According to size the scale can range from 1:250.000 to 1:5000
Frequency of information	One-off
Other (if applicable)	WebGis to visualize the thematic data
Service Provider Offer	
What the service does	The service provides maps indicating preferred spots for aquaculture sites. It prepares information on land cover, land use (including any restrictions), water quality, and supports risk and environmental assessments with historical meteorological and climate data. It provides zoning of the area to identify the most appropriate sites for aquafarming.
How does the service work	The service provides a set of thematic maps, which should be combined to identify potential sites. It also provides the historical trend of meteorological (weather conditions) and climatic data for environmental and risk assessment. Finally, according to the rules set by the Administration it provides zoning of the area. Various parameters (general or specific to a species) are relevant: weather conditions, water quality (temperature, Chlorophyll-a, nutrients/eutrophication, algae blooms), currents, man-made pollution (e.g. oil spill, eutrophication, chemicals), transportation aspects, energy production.
Service Provider Satellite EO Requirements	
Spatial resolution	**1m - 1km**, range of 10m considered sufficient for most species
Temporal resolution	Annual, but also combining data for a number of complete years for forecasts and control (climate change, HAB, pollution)
Data type / Spectral range	Optical data for the territory analysis (landcover/land use maps; marine vegetation maps (sea floor covers such as Posidonia), water quality parameters (Chlorophyll-a, turbidity, salinity, oxygen) SAR data for winds, currents, wave height
Other (if applicable)	Information on vessel traffic and routes in the area; information about pipelines; restricted areas; available transportation modes (handling of sludge and sediments); other information on utilisation of the sea or neighbouring land (agriculture usage, industry, sea and land tourism, energy production)
Service Inputs	
Satellite data sources	Optical data: - Sentinel 2 (e.g. Bathymetry, land use) and 3 (e.g. OLCI, SLSTR, altimetry) - VHR (e.g. bathymetry, landcover and land use) SAR data: - Sentinel 1 (e.g. Wind, waves, currents) - CosmoSkymed (e.g. winds, waves, currents)
Other data sources	Aerial, drones (RGB), buoys, in situ data (bathymetry, tide, current)

5.1.24 Aquaculture operations optimisation

Throughout the operational phase of the aquaculture plants, EO can provide water quality monitoring notably on harmful algae blooms (HABs), as well as assessment of fish farming environmental impacts and data for modelling of species invasion. When combining in models, such data can provide periodical estimation to aquafarmers about estimated growth and health of the stock. GNSS plays a role when the operation of offshore farms is carried out by fully automated vessels that rely on accurate positioning and navigation, or in the upcoming use of GNSS for the localisation of networks of buoys.

The issue of Algal blooms was one of many topics discussed during the **UCP2022** in Prague. The Spanish National Research Council (CSIS) shared insights on how it is using Sentinels and Copernicus to detect harmful algal blooms (HAB). The red-edge bands on Sentinel 2 (704 nm) and Sentinel 3 (708 nm) are used for the calculation of normalized difference chlorophyll index (NDCI) and the subsequent comprehensive mapping of the algal bloom at unprecedented spatial scales in highly productive near-shore coastal waters. The extent and duration of the HAB is further deduced/extrapolated by using other remote sensing technologies, as well as field observations. The value added of Copernicus products was in terms of its frequency and that observations are synoptic, by providing a combined view/summary of the current situation, which is paramount importance for water quality monitoring plans and for ecological and management purposes at regional and national scales.

Furthermore, during the **UCP2022** it was also brought up that the temporal resolution for algal blooms and water quality in general would ideally be 6h; the spatial resolution of 1 metre was considered to be optimal.

5.1.25 Search and Rescue beacons

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 situation, 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.

During the **UCP2022** the GAMBAS project[46] presented the definition of a new potential Galileo service based on return link: the SAR/Galileo Distress Position Sharing.

The operational concept for this potential new service is built on the existing procedures and does not require additional workload for SAR operators. The SAR/Galileo Distress Position Sharing (DPS) is a function that could be provided by the Return Link Service. The operational concept enables Authorised Rescue Coordination Centres (RCCs) to share the position of a distress beacon with other nearby Galileo receivers that could potentially assist in the search and rescue operations.

The activated distress beacon sends out a distress alert message, that is detected and located by Galileo. Galileo acknowledges the distress message and enables authorised users to share beacon positions to nearby beacons or other devices with Galileo receivers via the User Management Function.

The proposed DPS Service concept is thought so that to allow an RCC to reach vessels in the distress zone and communicate with nearby vessels faster. **DPS information can be received seamlessly by compatible GNSS receiver** and does not require additional equipment for vessels. The DPS information can be received by compatible GNSS receivers and will not require additional equipment for vessels. Furthermore, the mobile satellite communication systems are recognised by the IMO resolution A.1001 (25). DPS complementary service is expected to enlarge the vessels that can come to the rescue of people in distress.

[46] See more here: https://gambasgsaproject.com.

A wide consultation was performed with numerous maritime stakeholders (i.e. Institutional, SAR forces and Ship Owners organizations) and will be subject to further definition and evolution, especially to determine the formal procedures involved in sending and receiving a distress position in a certain zone. The zone is still to be defined as a dynamic and/or static circle around the distress position and will require each RCC involvement in setting their course of action to initiate the rescue operation.

User Needs and Requirements relevant to GNSS

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

Category 1

The initial rescue approach of Search and Rescue 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) [RD6]).

Table 66: 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 [RD3]
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
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
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)
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
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)
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001

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

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.

This category is characterised by having 1 m horizontal accuracy requirement. Category 2 includes the following applications:

- Marine Engineering, construction, maintenance and management: cable and pipe laying;
- Aids to Navigation management;
- Port Operations: Local VTS;
- Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance);
- Casualty Analysis: Port approach, restricted waters and inland waterways;
- Search and Rescue: final rescue approach; and

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) [RD6]).

Table 67: 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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
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
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

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
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
EUSPA-GN-UR- MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

5.2 Limitations of GNSS and EO

GNSS limitations

As described in earlier versions of this report, the main **GNSS limitations** in the Maritime and Inland waterways domains are that today no GNSS alone is capable of meeting all operational requirements for the determination of the position without the use of augmentation systems, including a satellite-based augmentation system (SBAS) and Receiver autonomous integrity monitoring (RAIM) techniques.

GNSS integrity is key for safety-related applications. It is the measure of trust in the correctness of the information supplied by the navigation system, and monitoring it is essential to safety-critical applications that relies on accurate and reliable GNSS measurements. This cannot be provided without augmentation, since augmentation allows to improve the GNSS signal's features (i.e. precision, reliability, availability) by integrating external information. The European Geostationary Navigation Overlay Service (EGNOS)[47] is an SBAS that reports on the reliability and accuracy of their GNSS positioning data and sends out corrections. EGNOS has been deployed to provide safety of life navigation services to maritime, aviation and other land-based users over most of Europe.

The particularities of maritime navigation systems result in more independence among the different 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, a strategy that is set out to increase safety of navigation in commercial shipping by means of better organising data exchanges between ships and on shore, and also better data exchange between ships and with the shore. As part of the e-Navigation strategy, the Maritime community is strongly involved in the development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "multi-system shipborne navigation receiver" for which performance standards have been published in June 2015 (see [RD51] "Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land-based radionavigation.

The Technical Committee 80 (TC-80) at the International Electrotechnical Commission (IEC), which prepare standards for maritime navigation and radiocommunication equipment and systems making use of electrotechnical, electronic, electroacoustic, electro-optical and data processing techniques, is preparing a standard for a Satellite Based Augmentation Systems Receiver Equipment that is expected

[47] Find out more about EGNOS: https://www.euspa.europa.eu/european-space/egnos/what-egnos.

to be finalised by end of 2023. This standard will define an integrity concept for SBAS L1 and RAIM. An update of this standard is also expected to be developed by 2027, so that to consider an integrity concept with multi-constellation and multifrequency solutions together with A-RAIM.

Resiliency of PNT, relies as well in the authentication of the GNSS data received that will serve to rely in the position computed with this data as well. Galileo OS-NMA is expected to start providing an authentication service by end of 2023.

EO limitations

With respect to **EO,** there are no **limitations** that generically apply to all types of satellite imagery and will, for the most part, vary depending on the payload used to acquire the images (for instance optical or radar). The particular usage in the maritime domain will determine its prevalence and possible corrective measures. A few limitations that could apply to EO in some instances are explained below with a short example of its effect and possible countermeasures:

Latency of signal

In the EO domain there has been a trend in recent years towards near real time (NRT) data, together with increased resolution and revisit rates. NRT refers to low latency and fast processing of workflows to deliver EO data and analysis rapidly. This serves the needs of certain users in need of fast responses in fields like emergency response, environmental monitoring for agricultural purposes meteorology. Latency will always exist between satellites and ground sensors, as an inherent quality of space communications, but it is in fast processing capabilities and pre-tasked orders, that the industry is becoming more agile in delivering products and services.

Spatial resolution and coverage

The spatial resolution of EO imagery refers to the size of the smallest feature that can be detected by a satellite sensor or displayed in a satellite image, usually expressed in kilometres, metres or centimetres for the highest resolution. The value indicates the size or length of each pixel in a given image. This varies greatly across satellites and has significantly improved in recent years. The spatial coverage is the swath or band that a circling satellite captures at any given moment in time, that is defined by its orbit, orbital plane and technical capabilities.

Cloud coverage

One of the most common interferences that especially optical imagery faces when capturing images of the earth's surface is the abundance of clouds at different altitudes; This is also true for some of the sentinels that operate in the multispectral ranges. To mitigate the information loss caused by cloud-coverage, complementary technologies such as Synthetic Aperture Radar (SAR), and a series of processing approaches can be used, increasingly ML and AI that extrapolate information and build on historical data.

Archive with historical data

The Sentinel Hub services supports various data collections, such as Envisat, ESA, Landsat and commercial collections, from the moment that this data became available. The availability of data is not homogeneous trough time and space and researchers might face data gaps in their investigations.

Angles

The absolute accuracy of imagery is not normally given, and off-nadir imagery requires some adaptations and processing to convert it into truly accurate 2D maps. Images can be assembled from multiple angles to complete the gaps created by shadows of buildings in the case of urban settings. Although off-nadir imagery can lead to less resolution it leads to more ground coverage, which might be more important in emergency situations that require NRT information, where any information is better than none.

5.3 Prospective use of GNSS and EO

5.3.1 Prospective use of GNSS

GNSS derived services has become widely adopted in numerous maritime operations and situations, from everything ranging from cargo monitoring to port operations and comprehensive fleet management. For instance, GNSS has become the main source of position and timing information for the integrated Electronic Chart Display and Information Systems (ECDIS) used on merchant ships. Galileo joined the ranks of other satellite positioning constellations of the Worldwide Radio Navigation System (WWRNS) in 2016 following the IMO vote to recognise Galileo Open and Search and Rescue Services. Integrity of accuracy will be provided by RAIM solutions together with SBAS and their evolutions (A-RAIM, DFMC SBAS). The demand for increased security and anti-spoof function is increasing and the Galileo OS-NMA service could provide significant benefits. Certain applications will benefit from the increased accuracy provided by Galileo HAS[48], like pilotage and offshore operations.

As it comes to the added value of the future GNSS, Galileo system will improve the GNSS applications in Maritime, e.g.: Search and Rescue will allow near real time alert localisation and message detection, higher beacon localization accuracy, high availability and global multi-satellite coverage. It will reduce the false alert rate thanks to return link service. In Fisheries, the Galileo authentication service will help to introduce an additional protection for position reporting.

Galileo will bring benefits to river navigation and port operations thanks to the higher number of visible satellites in urban and mountainous environments. In autonomous vessels, precise requirements still need to be defined, but it is expected that Galileo could help achieve accuracy and availability requirements, while EGNOS together with RAIM (and their evolutions) will support the fulfilment of integrity requirements.

5.3.2 Prospective use of EO

The principal trends that will characterize the EO technology can be summarized as the following. The list does not focus on the technical trends that are going to be developed, but many of the following considerations are useful in understanding the market changes and user needs examined in the previous chapters.

- **Exponential growth in number of satellites**, which will be mainly driven by the increase in number of satellites. Among all, the smaller satellites, which are cheaper and easier to launch, will increase exponentially and will make a direct impact in the EO data available for *Maritime, Inland Waterways, Fisheries and Aquaculture* activities as a result.
- **Cost optimisation**: satellites and the materials to manufacture them will become progressively cheaper. It is a virtuous circle in which, decreasing costs promote an increase in satellite launches which increases the sources of data available. In turn, more data, the greater the spread, the greater the demand and the greater the possibility of lowering production and maintenance costs.
- **Reduction in revisit time**: the demand for data at an ever-decreasing latency and availability has also become a key trend for EO technology. As we have seen in many applications, the need for data updated at short intervals, or even in real time, is critical to function and service delivery.
- **Rise of artificial intelligence**: ML/AI algorithms have proven to be a powerful tool to analyse satellite imagery of any resolution and demonstrate better, more nuanced information.

[48] European Union Programme for the Space Programme (EUSPA) (2021), Galileo High Accuracy Service (HAS) Info Note, see here: https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_Info_Note.pdf

- **Changes in business model**: traditionally EO service providers relied on government-supported business models with large lucrative contracts and supplied mostly very high-resolution data. In recent years, the business model is more industry-focused, providing low-resolution data but with a high level of review and analysis, leveraging the added value that can be provided to services.
- **Move up the service chain**: demand is changing toward the demand for usable information and solution-based products instead of just image.
- **Multisource solutions**: now the unidimensional approach based on data from a single source is losing relevance. When end users require contextual solutions, a single data source is not enough and it is necessary to integrate information with other sources, heterogeneous and able to contextualize the data, creating a multidimensional solution of information that is integrated with each other proficiently [RD40].

5.4 Summary of drivers for user requirements

The main GNSS drivers for *Maritime, Inland Waterways, Fisheries and Aquaculture* applications are:

- Resiliency and trustworthiness provided by the **integrity of position**, especially important for safety-critical applications. Integrity is understood as the trust that can be placed in the correctness of the information supplied by Global Navigation Satellite Systems that leads to a very low probability that the position error is higher than a certain value (alert limit).
- The **authentication** of the data used to compute the position. GNSS authentication is the capability of a GNSS receiver to verify the authenticity of the GNSS information and of the entity transmitting it being a **trusted source**. In this regard, **Galileo OS-NMA** (Open Service – Navigation Message Authentication) is an authentication function, that is freely accessible by users worldwide, enabling GNSS receivers to verify the authenticity of the GNSS information.
- The availability of **high accuracy solutions** is helping users to provide safety-critical solutions, contributing to a safe and efficient maritime navigation. The **High Accuracy Service** (HAS) of Galileo is fully operational since January of 2023, making it the first GNSS to provide free-of-charge, high accuracy Precise Point Positioning (PPP) corrections worldwide through the Galileo signal in space (E6-B) and via the internet. With a positioning accuracy of roughly 20 cm Galileo is currently the world's most precise satellite navigation system.

The main EO drivers for *Maritime, Inland Waterways, Fisheries and Aquaculture* applications are:

- **Spatial resolution**: several applications require Very High Resolution imagery, with metre-level or submetre-level resolution;
- The availability of **historical data** to enable change detection or to identify trends such as fish stock or dredging;
- For MetOcean and ship route navigation the ability to cover **large-scale areas**, e.g. several hundreds of square kilometres;
- Users need are driven by faster data provision, as well as more user-friendly Human-Machine Interfaces (HMI) or dashboards.

In the following table we present a summary of drivers common to the entire segment and sub-segments/groups of applications. Many drivers and needs for the future have been analyzed in previous chapters, within the specific applications.

Table 68: Future main drivers in the Maritime, Inland Waterways, Fisheries and Aquaculture segment.

Maritime and Inland Waterways	Fisheries and Aquaculture
• Resilience and reliability • Data/Sensor fusion • High availability • Improved robustness to interference • Data processing and integration • High resolution and availability • GNSS Continuity of service • Multisource solutions	• Legislation and sustainability efforts • Increase in demand for marine life products • Climate change and adaptation • Technological advances • Resilience and reliability • GNSS Continuity of service • Data and Sensor fusion • High availability • Data processing and integration • Multisource solutions

In addition to the above-mentioned performance-related drivers the legislative/regulatory aspect of EO in the *Maritime, Inland Waterways, Fisheries and Aquaculture* domain is a main driver for the uptake of EO-based applications, such as all aspects related to the monitoring of the impact that maritime operations have on their environment (i.e. in general, dredging operations and aquaculture benefit from satellite derived services, while they can also be monitored to assess the environmental impacts).

6 USER REQUIREMENTS SPECIFICATION

The chapter provides a synthesis of the user requirements described in section 5.1 for GNSS (section 6.1) and EO (section 6.2). 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.

6.1 Synthesis of Requirements Relevant to GNSS

The GNSS-related requirements presented in this chapter are the same ones as those presented in the Report on Maritime and Inland Waterways User Needs and Requirements (and its annexes) [RD43], and constitutes a compendium of GNSS requirements across all categories 1 to 3++.

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) [RD6]). Category 1 can be subdivided into smaller groups of applications, namely) applications that 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 includes the following use cases:

- General navigation (SOLAS), ocean;
- General navigation (recreation and leisure), ocean and coastal;
- Casualty analysis, ocean and coastal;
- Search and Rescue: initial rescue approach;
- Fisheries: location of fishing grounds, positioning during fishing, yield analysis and fisheries monitoring;
- Fishing aggregating devices[49].
- MASS ocean navigation.

[49] For this type of applications, stakeholders did not express a need for a horizontal alert limit, a Time to Alarm, nor the need for integrity.

Table 69: Synthesis of Requirements Relevant to GNSS – Category 1.

ID	Description	Type	Source
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 [RD3]
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
EUSPA-GN-UR- MAR-0030	Continuity is not relevant to ocean and coastal navigation.	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001
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 (27) [RD6])
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
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 (27))
EUSPA-GN-UR- MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

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+

This category differs from Category 1 only regarding continuity, which in this cade is regional in this and of 99.97%. This category includes the following use cases:

- General navigation (SOLAS); Coastal, Port approach and entrances;
- General navigation (recreation and leisure); 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.

Requirements are identical to Category 1, except the following:

Table 70: Synthesis of Requirements Relevant to GNSS – 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)	[RD44]
EUSPA-GN-UR- MAR-0090	The PNT solution shall have regional coverage.	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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) [RD6] 20/12/2011

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

CATEGORY 1++

This category presents the same requirements of Category 1+, except the horizontal accuracy, which must be of 3m for this application. This category includes the following use case:

- General navigation (SOLAS); Inland waterways.

Table 71: Synthesis of Requirements Relevant to GNSS – Category 1++.

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

CATEGORY 1+++

This category presents the same requirements of Category 1, except the vertical accuracy, which must be of 10m for this application. This category includes the following use case:

- Oceanography.

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.

Table 72: Synthesis of Requirements Relevant to GNSS – Category 1+++.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0110	The PNT solution shall provide 10 m horizontal positioning accuracy (95%)	Performance (Accuracy vertical)	Resolution IMO A.915(22) - 29/11/2001 [RD3]

CATEGORY 2

This category is characterised by having 1 m horizontal accuracy requirement. Category 2 includes the following applications:

- Marine Engineering, construction, maintenance and management: cable and pipe laying;
- Aids to Navigation management;
- Port Operations: Local VTS;
- Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance);
- Casualty Analysis: Port approach, restricted waters and inland waterways;
- Search and Rescue: final rescue approach; and
- Offshore exploration and exploitation: Exploration, Appraisal drilling, Field development, Support to pro- duction, Post-production.

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

Out of all the applications that belong to Category 2, only Casualty Analysis had its environment clearly stated by IMO (Port Approach and Restricted Waters). The others applications are placed in two different environment classes as follows: i) applications that take place in Port Approach and Restricted Waters (Casualty Analysis, as defined by IMO and Port Operations, evidently); ii) applications such as Marine Engineering, Aids to Navigation Management and Offshore exploration and exploitation were considered to fit best in Ocean environment.

It is worth noticing that, in this group of applications, Local VTS is the only instance that requires local coverage, instead of regional.

Table 73: Synthesis of Requirements Relevant to GNSS – 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 [RD3]
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 Regulation (EC) No 415/2007 [RD30]
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

ID	Description	Type	Source
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
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
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
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
EUSPA-GN-UR- MAR-0190	The PNT solution shall have regional coverage*	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
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

CATEGORY 2+

This category presents the same main requirements Category 2, except that continuity is required to be of 99.97% over 15 min for a local coverage.

Category 2+ includes the following applications:

- General navigation (SOLAS): Ports and Restricted Waters;
- General navigation (recreation and leisure): Ports and restricted waters; and
- Operations of Locks, Tugs, Pushers and Icebreakers;
- MASS coastal navigation & port approach;
- MASS port operations.

Operations of tugs, pushers and ice breakers 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. Requirements are identical to Category 2, except the following:

Table 74: Synthesis of Requirements Relevant to GNSS – Category 2+.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3] Regulation (EC) No 415/2017
EUSPA-GN-UR- MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) [RD6] 20/12/2011 Regulation (EC) No 415/2017

* 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++

The Category is the same as Category 2 + with the local 1m vertical accuracy requirement but differs from Category 2 in the need of 1m vertical accuracy requirement.

Category 2++ includes only the following applications according to IMO:

- Ports operations: Container / Cargo management & Law enforcement.

However, Port and Lock approach, Track control, Calamity Abatement and Fairway information system are 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.

Therefore, the requirements are identical to Category 2, except the following:

Table 75: Synthesis of Requirements Relevant to GNSS – Category 2++.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0230	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
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

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, which must be of 0.1m; and the alert limit, which needs to be between 2.5 and 5m in the horizontal axis. This category includes:

- Hydrography
- Bridges operation in inland waterways.

Hydrography Environment was not clearly stated in IMO Resolutions; therefore, this application was considered to be in the most general environment category as possible. Although this application might take place in Inland Waterways, no specific requirements for dynamic data were found.

Table 76: Synthesis of Requirements Relevant to GNSS – Category 2+++.

ID	Description	Type	Source
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)	[RD44]
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 [RD3]
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
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 Regulation (EC) No 415/2007 [RD30]

CATEGORY 3

This category is characterised by having 0.1m horizontal accuracy requirement and it includes the following applications:

- Marine Engineering;
- Inland Waterways: bridge collision warning systems;
- Automatic guidance;
- Mooring assistance;
- Conning display.

IMO Resolutions do not state clearly the environment for Marine Engineering. As such, it was placed in the most general category as possible. Although this application might take place in Inland Waterways, no specific requirements for dynamic data were found.

Table 77: 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
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

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
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
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
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
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)	[RD44]
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
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)	[RD44]
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)	[RD44]
EUSPA-GN-UR- MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) -- 29/11/2001
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

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+

This category differs from Category 3 in the vertical accuracy, which is not applicable, and concerning continuity, which is described as 99.97% at least over 15min, by IMO Resolution A.1046 (27) [RD6].

This category includes one application:

- Operations: Docking

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

Therefore, the requirements are identical to Category 3, except the following:

Table 78: Synthesis of Requirements Relevant to GNSS – Category 3+.

ID	Description	Type	Source
EUSPA-GN-UR- MAR-0370	The vertical positioning accuracy is not applicable for Category 3+ applications	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR- MAR-0380	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) [RD6] 20/12/2011
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++

The main difference between Category 3++ and Category 3 is regarding integrity. The time to alarm must be smaller than 1s.

This category includes one application:

- Cargo handling

The requirements are identical to Category 3, except the following:

Table 79: Synthesis of Requirements Relevant to GNSS – Category 3++.

Id	Description	Type	Source
EUSPA-GN-UR- MAR-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

6.2 Synthesis of Requirements Relevant to EO

This section presents a synthesis of the User Requirements relevant to EO for Type A applications only: i) Ship route optimisation (see section 5.1.1) ii) Inland Waterways Navigation (see section 5.1.6); iii) MetOcean (see section 5.1.7); Dredging (see section 5.1.10); iv) Fish stock detection (see section 5.1.19); v) Aquaculture site selection (see section 5.1.23).

Table 80: EO Requirements Synthesis – Ship route optimisation.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0001	Ship route optimisation	• Ship owners •Shipping companies (e.g. route analyst/planner) • Vessel operator • Destination Ports (ETA) • Follow-on logistics enterprise	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.	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.	Route optimisation models are usually included into ECDIS chart solutions on board. 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.	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.	Incoming data on weather and ocean conditions have to seamlessly integrate with the operating route planning tools and models on board of the ship (ECDIS). Information coming from satellites (weather, ocean conditions) has to be reliable (no false positives, no false negatives) in order to avoid misrouting the vessels (resulting in additional fuel cost, delayed arrival, etc.	Provides optimisation of ship routes along the most efficient route (fuel consumption or speed/time), and using data on currents, waves, atmospheric and other weather conditions to calculate the most economical and safest route for the ship to port navigation. The service allows to predict and avoid 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. Obstacles that can be identified in NRT are for instance whales or floating containers (which are usually submerged, e.g. 1 m below surface), although more frequently vessels usually carry radar systems on board that detect close objects and provide alerts. 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.	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.	Wave height: 1 m Ocean conditions: 100 m	For forecasts up to 10 days: 6 h (depending on the underlying model requirements)	E.g. DHI MetOcean Data Portal (section 5.1.7 contains more detailed information) offers the possibility for users to save data in different formats, e.g. .MAT, .CVS, .NC, .DFS0.	No user requirements were gathered.	• VHR satellite data • ECDIS • Marine Digital route planner based on 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)	• 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 See: https://resources.marine.copernicus.eu/products

Table 81: EO Requirements Synthesis - Inland Waterways navigation.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0002	Inland waterways navigation	•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	Determining fairways Mapping embankments, barrages, locks. Provide overview for VTS Centre of complete traffic situation (professional and leisure boats). 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. However, the WSV is also responsible for leisure boat navigation, which is not subject to this AIS equipment obligation. 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.	The size of AOI depends on the application scenario (commercial, recreational) and covers the waterway AOI (e.g. shipping parts of a large river, sailing the lake or water area, canoeing parts of a small to very small river, fishing specific spots of a water area, etc.) Commercial shipping routes are usually well explored and mapped. 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 these obstacles can range from: •A few metres (e.g. single obstacles, sandbank) • To larger areas (e.g. ice building). Accordingly, the spatial resolution has to start in the metre range (VHR). For recreational users, the spatial resolution depends on the size/width of the waterway and can also start in the metre 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 metre range.	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 these obstacles can range from • A few metres (e.g. single obstacles, sandbank) • To larger areas (e.g. ice building). Accordingly, the spatial resolution has to start in the metre range (VHR). For recreational users, the spatial resolution depends on the size/width of the waterway and can also start in the metre 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 metre range.	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).	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).	• Enables safe navigation through inland waterways using most accurate and timely information available. • Sediments and natural erosion are continuously changing, e.g. Wadden islands in the Netherlands and Germany (ferries operate regular services, coastguard interventions). • Supports the preservation and maintenance of the waterways and related surroundings for commercial shipping, recreational use, environmental and wildlife protection.	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 zones, maintenance work)	1 meter / The size of leisure boats	6 hours	No user requirements were gathered.	For safe routing on fairways, it is absolutely necessary to include immediate warnings on obstructions, i.e. accident detection in real-time by other means other than satellite imagery.	• Aerial/VHR satellite data • Other satellites beyond Sentinels may be required, depending on the spatial resolution (metre 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

Table 82: EO Requirements Synthesis – MetOcean.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0003	MetOcean	Exploration companies National authorities (e.g. licensing) Construction companies (e.g. platforms, pipelines), Organisations operating offshore platforms (e.g. oil, gas, wind power), Energy providers. Shipping companies, passenger ships, fishermen, sailing boats, divers) Coast guards, rescue operations, etc.), Rescue organisations in countries affected by extreme weather events (e.g. hurricanes, tropical storms, tsunamis).	- Meteorological conditions monitoring to ensure safety of operations/activities - Forecasting of energy production - Monitoring of geobiophysical conditions of seas, oceans and coastal regions for environmental/economic purposes.	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.	MetOcean data are usually included into ECDIS chart solutions. The scales available on ECDIS maps are classified according to navigation purposes e.g. Harbour 1:4,000 - 1:21,999 Approach 1:20,000 - 1:89,999 Coastal 1:90,000 - 1:349,000 General shipping 1:350,000 - 1, 1499,999) overview 1:<1,499,999). (see: https://knowledgeofsea.com/ecdis-compilation-scale-and-scale-minimum/) The applicable scale depends on the type of utilisation (see ECDIS scale. Regarding the oceanographic aspects, local phenomena can have significant influence depending on the specific type of operation (e.g. underwater geology can have significant effect on the generation of waves, currents can be influenced by underwater geology, islands, land tongues, peninsulas) a higher resolution at respective geolocations would be required, e.g. in the range of 100 m.	The most critical information for users in this environment 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. The majority of the oceanographic aspects are stable in time. The only exception may be underwater events causing extreme consequences (e.g. earthquake/seaquake causing a tsunami). Also, here the important aspect is to detect such events as soon as possible in order to issue warnings for the affected operations (including the concerned regions/countries).	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)). Other if applicable As MetOcean is mostly used for predictions / forecasts, the underlying models play a significant role. Due to climate change, models need to be enhanced/developed which allow to predict the related changes that can be expected in the coming years.	Meteorological/ ocean conditions include wide-ranging parameters, i.e. ocean currents, waves, temperature, salinity, algae blooms and nutrients, sea level, and all-weather conditions such as winds, rains, storms and more. Most accurate MetOcean forecasts serve to optimise sea-borne operations/activities and reduce risk (human and economic).	MetOcean services incorporates up-to-date meteorological, oceanographic and geobiophysical conditions. MetOcean services are offered by a variety of organisations on different levels: The World Meteorological Organisation (WMO) is the specialised UN agency development whose mandate is meteorology, climatology, operational hydrology and related environmental services as well as to reap the benefits from their application. WMO provides the framework for such international cooperation. WMO offers a Worldwide Met-Ocean Information and Warning Service (WWMIWS). The National Oceanic and Atmospheric Administration (NOAA) NOAA In Europe there is the European Centre for Medium-Range Weather Forecast (ECMWF) that produces global numerical weather predictions. The ECMWF is considered to be the most accurate global model, although this may vary. On the national level there are meteorological offices, such as Meteo France (F), DWD (DE), UK Met Office (UK) and Italy, that run their own numerical weather prediction models using local augmentations, and issuing national alerts. Commercial organisations provide customised met services (e.g. StormGeo, MetGis). The growth of sustainable commercial weather services started around 2010 when more data became available for free.	Wave height: 1 m Ocean conditions: 100 m	For forecasts up to 10 days this is 6 hours, depending on the underlying model requirements	These are some commonly used data formats: General Regularly distributed Information in Binary form (GRIB) is a file format for storing historical and forecast meteorological data. Unified Model (UM): numerical model for atmosphere system modelling software provides medium-range weather forecasts. NetCDF (network Common Data Form) is a file format that stores multidimensional variables (temperature, humidity, pressure, wind speed, etc.).	No user requirements were gathered.	Meteorological satellites in Europe are operated by EUMETSAT . It comprises: • GEO satellites METEOSAT 2nd (and upcoming 3rd) • LEO satellites METOP 1st (and upcoming 2nd) generation. • Jason-3 satellites (cooperation between EUMETSAT, CNES, NOAA, NASA). • Sentinels 3, S-6, upcoming S-4 and S-5 More information under https://www.eumetsat.int/our-satellites. Follow this link for ECMWF overview of satellite data.	Sentinel-1, -2 and -3

Table 83: EO Requirements Synthesis - Dredging.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0004	Dredging	• Dredging companies • National Authorities (Maritime, Environmental)	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.	Extremely variable, for instance: • Fluvial courses of Inland Waterways • Delta • Canals • Coastal regions	No user requirements gathered.	For SDB only typically 1 a day up to several times a day. For water quality up to hundreds a day.	No user requirements gathered.	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.	The spatial resolution achieved can reach up to 2 metres, depending on the underlying EO data used. Between 50 cm and 10 m typically.	Multiple sensors are used in parallel with harmonised products to comply with temporal resolution requirements	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.	No user requirements gathered.	MODIS, Partly DIAS, Sentinel-2 and -3 VHR Commercial: Planet, Maxar, Ipp partner. Airbus, Planet, Maxar	Altimeter, SAR data, Lidar ICESAT, AWS Occasionally in-situ data measurements (provided by client)

Table 84: EO Requirements Synthesis - Fish stock detection.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0005	Fish stock detection	•Fisheries •Fishery managers •Authorities (national and local, e.g. coast guards) •Fish markets •Monitoring and control entities •Maritime industry •Scientific community •Retail organisations •(Fishing) tourism organisations •Fish welfare organisations (e.g. FAO, EFSA) •NGOs	Ecosystem productivity, based on Chlorophyll-a and associated with fields of temperature, salinity, oxygen, wind intensity, wave height, depth, for the identification of oceanographic discontinuities and productivity hotspots.	Size of area depends on the end-user and their AOI: • Large territorial water areas for public administrations with mandate on own waters; • Smaller areas for use by e.g. fish tourism operator covering their area of operation.	According to size the scale can range from 1:250.000 to 1:5000	Weekly, monthly, seasonal, annual	WebGis to visualize the thematic data and/or integration with other instruments on board	The service provides indirect indicators of possible presence of fish: Chlorophyll-a, surface temperature, salinity, oxygen, ocean colour (surface optical or bio-optical properties: diffuse attenuation coefficient, total suspended matter, yellow substance, chlorophyll pigments and macrophytes); vertical and horizontal circulation features (e.g. wind, wave); oil pollution; sea state.	The parameters are acquired daily by satellite data and displayed on a dashboard in aggregated data to provide information with the required frequency (weekly, monthly, seasonal, annual). The dashboard displays anomalous data and send alerts for parameters out of the thresholds	10 m - 1 km, depending on the size of fish shoal Based on **UCP2022** feedback, any resolution below 12m (or 10m) would be fine since fishing vessels typically measure about 12m. In certain ports it would be useful to identify activities with 0.5m resolutions.	Range depending on the user: from near-real-time (for use onboard of fishing vessels) to every few hours/daily (authorities, daily fishing trips with smaller boats), to long term (for fish stock expansion).	Optical data (water quality parameters: Chlorophyll-a, turbidity, salinity, oxygen) SAR data for winds, currents, wave height	Historical data	•Optical data: Sentinel 2 (e.g. CMEMS, ocean colour, suspended matter) and 3 (e.g. OLCI, SLSTR, altimetry), VHR •SAR data: Sentinel 1 (e.g. wind, waves), CosmoSkymed	Aerial, drones (RGB), buoys, echo-sounders and sonars (detection of fish, biomass estimation), fish finders on-board of fishing vessels, on-board cameras

Table 85: EO Requirements Synthesis – Aquaculture site selection.

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	Size of AOI	Scale	Frequency of Information	Other (if applicable)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite data sources	Other Data Sources
EUSPA-EO-UR-MAR-0006	Aquaculture site selection	• Aquafarmers, public administration (national and local) • Monitoring and control entities • Maritime industry • Scientific community • Recreational and tourism organisation • Investors NGOs	The following activities are required: 1. Preliminary analysis 2. Territory analysis 3. Consultation 4. Eligibility 5. Environmental analysis 6. Zoning 8. Identification of sites	Coverage: coastal and offshore areas. In-shore and off-shore areas (marine waters); the size ranges from 1-2 km2 (for small areas) to 800 km2 (for large); variations are due to fish and seafood farmed from e.g. mussels (very small) to pelagic fish (very large).	According to size the scale can range from 1:250.000 to 1:5000	One-off	WebGis to visualize the thematic data	The service provides maps indicating preferred spots for aquaculture sites. It prepares information on land cover, land use (including any restrictions), water quality, and supports risk and environmental assessments with historical meteorological and climate data. It provides zoning of the area to identify the most appropriate sites for aquafarming.	The service provides a set of thematic maps, which should be combined to identify potential sites. It also provides the historical trend of meteorological (weather conditions) and climatic data for environmental and risk assessment. Finally, according to the rules set by the Administration it provides zoning of the area. Various parameters (general or specific to a species) are relevant: weather conditions, water quality (temperature, Chlorophyll-a, nutrients/eutrophication, algae blooms), currents, man-made pollution (e.g. oil spill, eutrophication, chemicals), transportation aspects, energy production.	**1m - 1km**, range of 10m considered sufficient for most species	Annual, but also combining data for a number of complete years for forecasts and control (climate change, HAB, pollution)	Optical data for the territory analysis (landcover/land use maps; marine vegetation maps (sea floor covers such as Posidonia), water quality parameters (Chlorophyll-a, turbidity, salinity, oxygen) SAR data for winds, currents, wave height	Information on vessel traffic and routes in the area; information about pipelines; restricted areas; available transportation modes (handling of sludge and sediments); other information on utilisation of the sea or neighbouring land (agriculture usage, industry, sea and land tourism, energy production)	Optical data: - Sentinel 2 (e.g. Bathymetry, land use) and 3 (e.g. OLCI, SLSTR, altimetry) - VHR (e.g. bathymetry, landcover and land use) SAR data: - Sentinel 1 (e.g. Wind, waves, currents) - CosmoSkymed (e.g. winds, waves, currents)	Aerial, drones (RGB), buoys, in situ data (bathymetry, tide, current)

7 ANNEXES

A1.1 List of Acronyms

Table 86: List of Acronyms.

Acronym	Definition
AC	Anthropogenic contaminant
AI	Artificial Intelligence
AIS	Automatic Identification System
AISM	L'Association internationale de signalisation maritime (Commonly referred to as IALA)
API	Advanced Programming Interface
AtoN	Aids to Navigation
AUTH	Authentication
BAM	Bridge Alert Management
BDS	BeiDou Navigation Satellite
BGC	Biogeochemical
BOA	Bottom-of-Atmosphere (Reflectance)
CATZOC	Category Zone of confidence" values
CCIR	Radiocommunication Sector of ITU
CCZ	Clarion-Clipperton Zone
CFP	Common Fisheries Policy
CIE	International Hydrographic Organisation
CIRM	Comité International Radio Maritime
CMEMS	Copernicus Marine Environment Monitoring Service
CMO	Common Market Organisation
CNES	Centre national d'études spatiales / National Centre for Space Studies
COG	Cloud Optimised GeoTIFFs
DGLONASS	Differential GNSS (see GLONASS)
DGNSS	Differential GNSS (see GNSS)
DIAS	Data and Information Access Services
DPS	Distress Position Sharing
EATIP	Aquaculture Technology and Innovation Platform
EC	European Commission
ECDIS	Electronic chart display and information system

Acronym	Definition
EFCA	European Fisheries Control Agency of the European Union
EFSCM	European Food Security Crisis preparedness and response Mechanism
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EIT FOOD	European Institute of Innovation and Technology
EMC	Electromagnetic Compatibility
EMFAF	European Maritime Fisheries and Aquaculture Fund
EMRF	European Maritime Radionavigation Forum
ENC	Electronic navigational charts
ENC	Electronic Navigation Chart
EO	Earth Observation
EPFD	External position fixing device
EPIRB	Emergency Position-Indicating Radio Beacon
ERNP	European RadioNavigation Plan
E/RTA	Required Time of Arrival
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUSPA	European Agency for the Space Programme
F2F	Farm to Fork
FAO	Food and Agriculture Organization of the United Nations
FRP	(US) Federal Radionavigation Plan
GEO	Group on Earth observation
GIS	Geographic Information System
GLONASS	ГЛОбальная НАвигационная Спутниковая Система / Global Navigation Satellite System
GMDSS	Global Maritime Distress Safety System
GNSS	Global Navigation Satellite System
GOVSATCOM	The European Union Governmental Satellite Communications Programme
GPS	Global Positioning System
GPS-GLONASS	See GPSS and GLONASS
GRIB	General Regularly-distributed Information in Binary form
GSD	Ground Sample Distance
GT	GIGA TONS

Acronym	Definition
HAB	Harmful algae blooms
HAL	Horizontal Alert Limit
HAS	High Accuracy Service
HMI	Human-Machine Interface
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAS	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICD	Interface Control Document
ICESAT	Ice, Cloud and land Elevation Satellite
ICOMIA	International Council of Marine Industry Associations
IEC	International Electrotechnical Commission
IECEE	International committee for electrical and electrotechnical equipment
IECEx	International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres
IECQ	IEC Quality Assessment System for Electronic Components
IHO	International Hydrographic Organisation
IMO	International Maritime Organization
IMPA	International Maritime Pilots' Association
ISA	International Seabed Authority
ITU	International Telecommunication Union
IUU	Illegal, Unreported and Unregulated(fishing)
IWW	Inland Waterways
LAESSI	Control and Assistance Systems to Enhance the Safety of Navigation in Inland Waterways
LEO	Low earth orbit
LiDAR	Light Detection And Ranging; Alternatively, Laser imaging, Detection, and Ranging
LOP	Line(s) of position
LRIT	Long-Range Identification and Tracking
MASS	Maritime autonomous Surface Ships
MAtoN	Mobile Marine Aids to Navigation
METEOSAT	Geostationary meteorological satellites operated by EUMETSAT under the Meteosat Transition Programme
MetOcean	Ocean Meteorology
MF	Multi-frequency MODIS

Acronym	Definition
ML	Machine Learning
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPS	Minimum Operational Performance Standards
MPC	Minimum Performance Criteria
MR	Market Report
MSC	Maritime Safety Committee
MSC	Marine Stewardship Council
MSI	Maritime Safety Information
MSI	multispectral images
MSY	Maximum Sustainable Yield
NASA	National Aeronautics and Space Administration of the United States
Navguide	Navigation guide
NOAA	US National Oceanic and Atmospheric Administration
NRT	Near Real Time
OLCI	Ocean and Land Colour Instrument (Sentinel-3)
OOW	Officers of the Watch
OS-NMA	Open Service Navigation Message Authentication
PLB	Passenger Locator Beacon
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
PPU	Portable pilot unit
PVT	Position, Velocity and Time
R&D	Research and development
R&I	Research and Innovation
RAIM	Receiver autonomous integrity monitoring
RCC	Rescue Coordination Centre
RD	Reference Document
RFMO	Regional fisheries management organisations
RGB	Red, Green and Blue colour model
RIS	River Information Service
RNAV	RNAV
R-PNT	Resilient positioning, navigation and timing
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-time kinematic positioning

Acronym	Definition
RUR	Report on User needs and Requirements
SAR	Synthetic Aperture Radar
SATCOM	Satellite communications
SBAS	Satellite Based Augmentation System
SC	Standard Contract
SDB	Satellite Derived Bathymetry
SDG	Sustainable Development Goals
SIP	Strategy Implementation Plan
SLAM	Simultaneous localization and mapping
SLSTR	Sea and Land Surface Temperature Radiometer
SME	Small and Medium-sized Enterprise
SOG	Speed Over Ground
SOLAS	(International Convention for the) Safety Of Life At Sea
SRS	Ship Reporting Systems
SSAS	Ship security alert system
STAC	Spatio Temporal Asset Catalogue
TC	Technical Committee
TDMA	Time-division multiple access
THU	Total Horizontal Uncertainty
TTA	Time to Alarm
TTFF	Time To First Fix
UCP	User Consultation Platform
UCP	User Consultation Platform
UDRE	User Differential Range Error
UM	Unified Model
UNCLOS	United Nations Convention on the Law of the Sea
UR	User Requirement
USCG	United States Coast Guard
USDoT	United States Department of Transportation
VDL	VHF Data link
VHF	Very High Frequency
VHR	VERY HIGH RESOLUTION
VMS	Vessel Monitoring System
VTS	Vessel Traffic Service

Acronym	Definition
WADGNSS	Wide Area Differential Global Navigation Satellite System
WFID	Workforce Identification
WGS84	World Geodetic System 1984
WiFi	Wireless network protocols
WMO	World Meteorological Organisation
WWMIWS	Worldwide Met-Ocean Information and Warning Service
WWRNS	World Wide Radio Navigation System
ZOC	Zone Of Confidence

A1.2 Reference Documents

Table 87: Reference documents.

ID	Reference	Title	Date
		IMO	
[RD1]	SOLAS	SOLAS International Convention for the Safety of Life at Sea	1 Nov. 1974
[RD2]	SOLAS Chapter V – Safety of Navigation[50]	Regulation 19.2 of SOLAS Chapter V	2007 Revision
[RD3]	Resolution A.915 (22)	Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)	29 Nov. 2001
[RD4]	Resolution A.1106 (29)	Revised Guidelines for the onboard operational use of shipborne automatic identification systems	2 Dec. 2015
[RD5]	Resolution A.953 (23)	World-Wide Radionavigation System	5 Dec. 2003
[RD6]	Resolution A.1046 (27)	Worldwide Radionavigation System	30 Nov. 2011
[RD7]	Resolution MSC 112 (73)	Performance standards for shipborne GPS receiver equipment	1 Dec. 2000
[RD8]	Resolution MSC 113 (73)	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 Dec.2000
[RD9]	Resolution MSC 114 (73)	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 Dec.2000
[RD10]	Resolution MSC 115 (73)	Performance standards for shipborne combined GPS-GLONASS receiver equipment	1 Dec.2000
[RD11]	Resolution MSC 233 (82)	Performance Standards for Shipborne Galileo Receiver Equipment	5 Dec.2006
[RD12]	Resolution MSC 379(93)	Performance standards for shipborne BDS receiver equipment	16 May 2014
[RD13]	Resolution MSC 401(95)	Performance standards for multi-system shipborne navigation receivers	8 June 2015
[RD57]	Resolution MSC.432 (98)	Amendments to performance standards for multi-system shipborne radionavigation receivers	16 June 2017
		IALA	
[RD14]	IALA Navguide	IALA Aids to Navigation Manual, Issue 4	Dec. 2001
[RD15]	IALA Navguide	IALA Aids to Navigation Manual, 7th edition	2014
[RD16]	IALA WWRNP	World Wide Radio Navigation Plan	Dec. 2009 Revised Dec. 2012
[RD17]	IALA R-135	Future of DGNSS	4 Dec. 2008
[RD18]	IALA R-129	GNSS Vulnerabilities and mitigation measures	3 Dec. 2012
[RD19]	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
[RD20]	IALA R-121	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	29 May 2015
[RD21]	IALA Guideline No. 1112	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	May 2015
[RD22]	IALA Guideline No. 1082	An Overview of AIS	1 June 2011
[RD23]	IALA Guideline No. 1028	The Automatic Identification System (AIS), Vol. 1 Part 1 Operational Issues	3 Dec. 2004
[RD24]	IALA Guideline No. 1029	The Automatic Identification System (AIS), Vol. 1 Part 2 Technical Issues	1 Dec. 2002
[RD25]	IALA Standard S1030	Standard S1030 Radionavigation Services	1 May 2018

[50] http://solasv.mcga.gov.uk/

ID	Reference	Title	Date
[RD26]	IALA Guideline G1129	The retransmission of SBAS corrections using MF-Radio beacon and AIS	Rev. 3 June 2022
[RD27]	IALA Guideline G1154	Use of Mobile Aids to Navigation	December 2020 Ed. Corrections July 2022
EC			
[RD28]	Directive 2005/44/EC	Directive on harmonised river information services (RIS) on inland waterways in the Community	7 Sept. 2005
[RD29]	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
[RD30]	Regulation (EC) No 415/2007	Regulation concerning the technical specifications for vessel tracking and tracing systems	13 March 2007
[RD31]	ERNP	European Radionavigation Plan - draft Link to presentation at UCP	29 Nov. 2017
ITU			
[RD32]	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
[RD33]	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			
[RD34]	DOT-VNTSC- OST-R-15-01	2017 Federal Radio Navigation Plan	2017
IEC			
[RD35]	IEC 60945	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results	Ed. 4.0 2002-2008
[RD36]	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
[RD37]	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
[RD38]	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
[RD39]	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
[RD40]	IEC 61162 - Parts 1 to 4	Maritime navigation and radiocommunication equipment and systems – Digital interfaces	2010-1998-2014-2015
[RD41]	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

ID	Reference	Title	Date
[RD54]	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
[RD55]	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
[RD56]	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)	In development
EUSPA			
[RD42]	Market Report 7	EUSPA EO & GNSS Market Report issue 1	Jan. 2022
[RD43]	GSA-MKD-MAR-UREQ-229399	Report on Maritime and Inland Waterways User Needs and Requirements	1 Aug. 2021
[RD44]	GSA-MKD-UM-MOM-A10416-UCP2020	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel	1 December 2020
OTHER			
[RD45]	ION GNSS 20th technical meeting of the satellite division paper	A critical look at the IMO requirements for GNSS, J. O. Klepsvik et al.	25-28 Sept. 2007
[RD46]	IMCA S 015 Report No. 373-19	Guidelines for GNSS positioning in the oil & gas industry	June 2011
[RD47]	IMCA S 023	Guidelines on the Shared Use of Sensors for Survey and Positioning Purposes	Oct. 2015
[RD48]	IHO Special Publication 44 5th Edition	IHO Standards for Hydrographic Surveys	Feb. 2008
[RD49]	SC8 – WP6	Maritime interviews	March 2016
[RD50]	ALG - SC7 D1.3-02	Survey for accuracy for positioning applications in ports done with Harbour Masters	Jan. 2016
[RD51]	ALG - SC9 D1.1-02	Survey and Interviews with receivers' manufacturers about the technology trends and gaps	June 2015
[RD52]	GSA MKD	Survey for accuracy, integrity, availability and continuity for navigation in ports done with Pilots and Shipmasters	2016
[RD53]	EGUS - SC4	Survey and interview with users on requirements for EGNSS in autonomous vessels	2016

A1.3 Definition of key GNSS performance parameters

This annex provides a definition of the most commonly used GNSS performance parameters, and includes additional details which are relevant for the *Maritime, Inland Waterways, Fisheries and Aquaculture*.

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: takes into account 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).

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).

A1.4 Definition of key EO performance parameters

This annex provides a definition of the most commonly used EO performance parameters and includes additional details which are relevant for *Maritime, Inland Waterways, Fisheries and Aquaculture*.

Spatial resolution relates to the level of detail that can be retrieved from a scene. In the case of a satellite image, which consists of an array of pixels, it corresponds to the smallest feature that can be detected on the image. A common way of characterising the spatial resolution is to use the Ground Sample Distance (GSD) which corresponds to the distance measured on the ground between the centres of two adjacent pixels. As such, a spatial resolution of 1 metre means that each pixel represents a 1 by 1 metre area on the ground.

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).

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).

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, a resolution of 8 bit meaning that the "brightness" of the image is measured with a scale of 28=256 nuances.

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 map on fishing grounds or aquafarming).

Other performance parameters

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction in order 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)

A1.5 User Communities

To better understand what the real needs of the main user communities are, **six surveys** have been organised in 2015 and 2016. The outcome of these surveys helped to realise the actual need of GNSS user requirements from the maritime community perspective. A summary of each survey and of its outcome is given in the next paragraphs, and some takeaways from earlier User Consultation Platforms.

Finally, following the success of the 2017's User Consultation Platform (UCP), the second UCP took place on 3rd of December in Marseille, France. It was organized as a forum for interaction between end users, user associations and representatives of the value chain such as receiver and chipset manufacturers, application developers, and the organizations and institutions dealing, directly and indirectly, with Galileo and EGNOS. In 2018, the Maritime and Inland Waterways panel gathered 32 participants, representing industry, research institutes, national authorities and European institutions with interest in maritime and inland waterways.

The third edition took place in 2020. The Maritime and Ocean Monitoring panel gathered 132 participants. It served to update user requirements and help identify trends. synergies between EGNSS and Copernicus

The minutes of the 2017, 2018 and 2020 editions of the Maritime and Inland Waterways UCP panels are enclosed the previous report [RD43].

The EO segmentation of the main user groups identified above will be as follows:

- *(Classic EO) Service Providers*
- *Information Providers*
- *End-Users*

SURVEY No. 1 FOR ACCURACY FOR POSITIONING APPLICATIONS IN PORTS DONE WITH PORT AUTHORITIES, 2015 [RD50]

In an effort to provide the most suitable satellite navigation service to the maritime users, a consultation has been performed among European port authorities to have their view on the need of intermediate performance levels for navigation and positioning operations in ports. The performance levels required for a global navigation satellite system (GNSS) are described in IMO Resolution A.915(22) [RD3]. This mandate specifies user requirements for both general navigation and positioning applications. Among them, different operations and applications are considered, and their required performances are specified in terms of accuracy, integrity, availability, continuity, and coverage.

This resolution was adopted in 2001 but it is not fulfilled today by any GNSS system. It seems to be accepted at the maritime community that some of its requirements should be reconsidered in the light of experience, while they should be also based on more rigorous assessment of the current user needs. Some of the requirements set out in A.915 are even impossible to meet, with existing or any envisaged GNSS, enforcing the need for a future revision. The review is expected to cover the continuity and integrity requirements, but also the accuracy ones. Mainly three different levels of accuracy are required according to IMO A. 915(22):

- Operations such as general navigation, except in ports, and many of maritime applications that require horizontal accuracies of 10m;
- More demanding applications such as navigation in ports or tugs and pushers operations require horizontal accuracies of 1m;
- The most demanding requirements are related to specific positioning applications such as automatic docking, cargo handling and specific marine engineering, construction, maintenance and management applications. All these require accuracies of 0.1m.

The consultation attempts to identify both:

- Operations requiring 10m of accuracy for which more stringent performances might result on a significant benefit for the users; and
- Operations requiring 1m of accuracy for which accuracy might be relaxed without any relevant impact in operations.

The consultation has been addressed by means of an on-line questionnaire distributed by e-mail to around five hundred European port authorities. Despite the difficulties in reaching the port authorities and catching the interest of their representatives, the questionnaire has been finally completed by 24 representatives of 22 port authorities, and 1 coastal administration, who represent a total of 41 ports: 32 maritime and 9 river ports spread around 12 countries.

The feedback provided by the representatives completing the survey confirms that there is interest in intermediate level performances for port navigation or operations in ports. The applications arousing more interest are summarised in Table 4.

Vertical positioning has raised very low interest from the port authorities. The most relevant applications where respondents have identified an interest in vertical position are river services, support to pier approaches with difficult access, and bathymetric surveys.

Anyway, the number of samples resulting from this consultation process does not allow yet obtaining definitive conclusions. This interest in intermediate performances needs to be consolidated and further endorsed by a majority of port authorities and a larger representation of other stakeholders. The ultimate goal is to obtain the material for the preparation of a proposal to the IMO for the revision of the A.915 resolution, including an intermediate performance level that could become candidate to be supported by EGNOS.

In particular, it is recommended to involve and consolidate this interest with ship's master and coast pilot's community, technical port services, additional port authorities, national administrations, and the International Maritime Organization.

In order to involve these partners, it is important to enforce awareness and participation activities. In particular, suitable forum for discussion can be promoted by different means such as the creation of a dedicated working group. One possibility that may be worth to consider is the constitution of a specific working group dependant on the EMRF-EGNOS Service Provision working group formed by representatives of the different stakeholders.

Once consolidated and agreed, intermediate accuracy levels could be considered in the definition of the EGNOS early maritime service and revision of IMO Resolution A. 1046. Instead, revision of IMO Resolution A. 915 additionally needs consolidation of the continuity requirement and the integrity concept at user level as currently being pursued by on-going European initiatives.

The feedback provided by the representatives completing the survey confirmed that there is interest in intermediate level performances for port navigation or operations in ports. The applications arousing more interest are summarised below:

Table 88: Port authorities' interest in intermediate accuracy level.

Application	Horizontal accuracy in A 22/Res.915	Higher Accuracy needed ↑ Lower Accuracy enough ↓
Navigation in ports	1 metre	↑
Tugs and pushers operations	1 metre	↑
General port approaches	10 metres	↓
Aids to navigation management	1 metre	↑

SURVEY No. 2 FOR ACCURACY FOR NAVIGATION IN PORTS DONE WITH HARBOUR MASTERS, 2015 [RD49]

The IMO Resolution A.915 on the "Revised maritime policy and requirements for a future Global Navigation Satellite System (GNSS)" lays down the performance requirements for future GNSS devices to be used in the maritime domain.

These requirements were established more than 10 years ago, and GNSS have evolved considerably since the adoption of this IMO Resolution. Thus, the question of whether these requirements are still applicable arises: different maritime experts believe that some of the requirements in IMO Resolution A.915 should be reconsidered and could be based on more rigorous assessment of user needs and current trends in the maritime sector. This assessment is addressed by action EMA15-MA-07 and the results of this activity have been gathered and analysed in this document. The objective of this activity was to contact different European Port Authorities so as to identify actual users' needs for navigation in ports, in order to find out in which cases EGNOS achieves the desired accuracy and is suitable for maritime use and, if possible (based on the answers obtained from the Authorities contacted) to try to define a criteria that may allow an unofficial classification of ports with different ranges of accuracy requirements.

The main outcomes of the answers received from Port Authorities regarding the actual users' requirements for navigation in ports are presented in this document (§6). The preliminary results of this research activity present a good starting point for the characterization of ports and give a clue on what are the actual user needs for navigation in ports. In particular, some answers identify different operations and port areas which are less demanding in terms of accuracy, and have been used, as presented in this document, to generate a preliminary classification of ports with different accuracy needs.

However, the amount of answers received from Port Authorities sustaining these points is not enough to form a strong argument to support the revision of the IMO Resolution A.915. Consequently, there is still work to be done. In this regard, this document also includes several suggestions on the next steps to be followed in order to consolidate a strong argument to rationalise the revision of the accuracy requirement for navigation in ports in IMO Resolution A.915.

SURVEY No. 3 AND INTERVIEWS WITH RECEIVERS' MANUFACTURERS ABOUT THE TECHNOLOGY TRENDS AND GAPS, 2015-2016 [RD51]

This report analyses the technology gaps existing for the introduction of multi-frequency and multi-constellation SBAS receivers for maritime navigation (Solas and Non-Solas) and positioning applications. The analysis is built on top of the current state-of-art of SBAS maritime receivers and is complemented by a consultation process carried out with a relevant sample of representative maritime receiver's manufacturers. This consultation has been aimed to confirm the preliminary outcomes of the state-of-art analysis in D01-01 and to obtain a more precise knowledge of some of the issues from which little information has been found. The questionnaire includes questions about:

- Identification of trends and new developments;
- Maritime regulation and standardization framework;
- Navigation and positioning performances, in particular, to harmonise the performances published by the manufacturers and to know the usage of system or user integrity techniques;
- PVT computation using different sources, to know the management of multiple positioning sources (e.g. re-configuration of the DGNSS and SBAS receivers).

The target audience has been defined based on the preliminary outcomes from the state-of-the-art analysis. The audience includes 16 integrators and manufacturers of SOLAS and non-SOLAS receivers, ensuring a good representation of the maritime market. The consultation process has been carried out from November 2015 to January 2016
The main outcomes from the consultation process are summarized hereafter: and reached a final participation higher than 50%.

- The **horizontal accuracy** requirement of 10 m (with a percentile of 95%) specified in the resolution A.915 for most of the applications is already covered by the specifications of the current maritime receivers. SOLAS receiver manufacturers do not see the need of more demanding accuracies for operations where satellite navigation systems are involved. Applications requiring those demanding accuracies usually take profit of the integration with other sensors or local augmentation techniques. As a consequence, the improvements of the accuracy performances are not seen as a short-term priority by the manufacturers.
    - A future definition of intermediate performance levels, in the frame of the A.915 review, for some applications (e.g. port and inland waters navigation, tugs and pushers, aids to navigation management) could pave the way for increasing that interest. EGNOS could appear at that point as an alternative to the position solutions currently used (e.g. DGNSS, RTK, etc.) if operational and economic benefits are demonstrated;
- The provision of **system integrity** is declared by more than the half of the respondents, however only few of them state compliance with resolution A.1046 (27) [RD6]. System integrity is usually provided by means IALA DGNSS corrections, PPP services and/or MMS. None of the manufacturers participating in the consultation has mentioned the usage of the integrity information inside SBAS SIS to provide any type of alarms or warnings to the users.
    - No references of recommendations or guidelines for the interpretation of RTCA DO-229D SBAS MOPS for maritime applications have been found. Manufacturers do not make use of integrity information disseminated by EGNOS inside the SiS;
- **User integrity** is widely implemented by means of RAIM techniques, even no manufacturer has responded about its current implementation and their intention to adapt these technologies to the particularities of the maritime environment. There is concern within the maritime community about the validity of RAIM algorithms and considerable effort is being expended to develop maritime suitable RAIM solutions. In few cases a user integrity check is done by comparing data from independent systems. This contrasts with the recommendations of relevant maritime authorities, such as US and Canadian Coast Guards, who require the user equipment to use the User Differential Range Error (UDRE) values to compute integrity confidence levels about the user's displayed position.
    - The consolidation of the user integrity concept for the maritime constitutes a very important gap to be addressed in the future. Manufacturers state their commitment to adapt their product roadmaps to the proposed standardisation process provided that EGNOS is recognised by IMO and also IEC test specification standards and sterling guidance are published;
- **Higher resilience** to jamming and interferences seems to be the most relevant characteristic for both Navigation and Positioning;
- **Provision of system integrity information** to the users is the second characteristic most relevant for Navigation;
- **Higher integration** with other positioning technologies is the second characteristic most relevant for Positioning;
- **Multi-constellation capabilities** are considered a must, in particular for SOLAS, whilst Multi-frequency is not perceived as a need;
- **Interoperability** between DGNSS and SBAS is already provided by the commercial receivers. The selection of the navigation source is performed in some cases automatically but in this case the criterion is identified as commercially sensitive by the manufacturers.

The full analysis is to be found in the Chapter D.3 of the previous report [RD43].

SURVEY No. 4 FOR ACCURACY, INTEGRITY, AVAILABILITY AND CONTINUITY FOR NAVIGATION IN PORTS DONE WITH PILOTS AND SHIPMASTERS, 2016 [RD52]

The scope of this consultation is to have a practical view on the need of intermediate performance levels for navigation and positioning operations in ports to be able to provide the most suitable satellite navigation service to the maritime users.

To carry out this survey, the selected tool was LinkedIn, a popular professional social media. The invitation to compile the survey was sent to 151 people qualified as “pilot” and “ship master” that currently working in Europe. Out of these, 28 people replied. At the very beginning of the questionnaire a question enquired about the qualification of the users to better target the type of questions.

Based on the survey it can be said that the participants represent the following Countries:

Table 89: User Communities – Survey list of participating countries.

Countries	No. of Participants
Netherlands	5
United Kingdom	5
Italy	4
Ireland	3
Spain	2
France	2
Portugal	2
Belgium	1
Bulgaria	1
Germany	1
Denmark	1
Croatia	1

Unfortunately, no harbour master has replied to the survey, so the consultation process was among pilots and shipmasters only.

The conclusions that can be extracted from the result analysis are quite interesting.

What stands out at the very beginning is that ship masters can also be qualified as pilots. Unfortunately, harbour masters are not represented in the results of the survey.

In carrying out high accuracy operations, the use of SBAS is still limited while the use other means such as visual operations, radar and AIS are commonly preferred.

Furthermore, the use of the Portable Pilot Unit is quite popular for large ships, mostly for the ones above 60000 GT in the case of dangerous goods tankers, cargo ships and passenger ships. What is to be highlighted is that here is a demand for high accuracy when navigating in ports and also more stringent values related to the time to alarm and the maximum allowable error.

In the positioning operations in ports (medium accuracy applications), the general feedback is that there is a need for a better accuracy level.

With regards to low accuracy applications, the answers comply with the IMO 1046(27) standards without any implicit request of higher accuracy levels.

Overall, the feedback received is quite positive and above initial expectation due to the fact of the unconventional tool used for this type of consultation.

SURVEY No. 5 AND INTERVIEW WITH USERS FOR THE USE OF EGNSS IN AUTONOMOUS VESSELS, 2016 [RD53]

The autonomous vessel requirements have been collected through surveys and interviews launched to the key players on autonomous vessel navigation.

The content of the surveys is detailed in the Appendix D, section D.5.3, of the previous report document [RD43].

The identified key players are included in Appendix D, section D.5.2, of the previous document [RD43].

The conclusion of the responses of the key players are summarised in Table 5.

Autonomous vessels requirements need to be in coherence with IMO1046, and therefore any value that is not in line with this IMO requirements have been discarded for the derivation of the following requirements (remove of outliers). The following table summarizes the E-GNSS receiver performance requirements identified during the survey based on the received responses (the values of the table are the mean of all received responses removing outliers).

Table 90: e-GNSS performance requirements for autonomous vessels according to survey results.

Performance parameter	Oceanic deep-sea navigation	Coastal navigation
Horizontal accuracy 95%	<15m	<5m
Continuity (over 15 minutes)	$1{\cdot}1\text{x}10^{-5}$	$1{\cdot}1\text{x}10^{-6}$
AL	<28m	<12,5m
TTA	<8s	<6s
Integrity risk	$1{\cdot}1\text{x}10^{-6}$	1·1x10-7
Availability	99.8%	99.8%

No. 6 INTERVIEWS WITH MARITIME STAKEHOLDERS, 2016

A limited number of interviews have been organised in early 2016 to validate the maritime user requirements set out in this document. The full questions and answers sessions were recorded and are attached in Appendix D, section D.6 of the previous report [RD43]. They are of limited interest for deriving information useful for the purpose of this document.

UCP 2017

A consultation has been organised in November 2017 to validate the maritime user requirements set out in this document. The full questions and answers sessions were recorded and are attached in Appendix D, section D.7 of the previous report [RD43].

One of the key messages was that the institutional statutory requirements (e.g. IMO) are the bare minimum and they generally do not reflect the real more stringent operational requirements for the inland waterways and maritime sectors. Participants approved the approach to categorise the maritime applications and their required performances per type of operation and per order of magnitude (i.e. 0.1m, 1m and 10m).

The overall objective of the segment continues to be resilient PNT but non-performance requirements such as authentication, resilience are also very important. To meet the requirements of critical applications, fusion from different sensors to provide redundancy to the system is needed. Timing is also becoming increasingly important with requirements ranging from 1 second (low performance) to 1 micro second (high performance).

UCP 2018

The UCP 2018, organised in December in Marseille gathered participants representing a comprehensive market coverage in terms of applications and value chain. Overall, the group confirmed the following main trends in the maritime sector:

- Autonomous vessels (manned and unmanned);
- Resilient PNT;
- Sensor fusion;
- Portable Search and Rescue beacons (PLB) with return link capabilities and AIS-enabled;
- Drones to support surveillance;
- Confirmed need for robustness against spoofing and jamming.

Feedback on the refinement of the user requirements was received from the maritime and inland waterway community and new applications related to SAR, IWW and port navigation and berthing have been added to as part of the user requirements.

A consensus was reached on the high interest of the Galileo RLS for the SAR user community and the interest in exploring additional uses for the RLS as the remote activation of EPIRBs following a similar approach to the ELT-DT under discussion in EUROCAE WG98-RLS. Galileo Open Service Navigation Message Authentication (OS-NMA) can play an important role as differentiator in the maritime sector by enhancing the GNSS robustness and security and EGNOS v3 and Galileo HA will enable new maritime applications. \

It was also highlighted that there is a high dependency on GNSS in maritime but the impact of a potential GNSS outages (e.g. positioning, timing and synchronisation) needs to be further analysed. With respect to back-ups for positioning, IALA already published a recommendation on the requirements for these systems [RD 18].

UCP2020

The third UCP was held virtually in December 2020, covering twelve different market segments. The participants represented a comprehensive market coverage in terms of applications and value chain.

Among many topics, this UCP forum discussed the main technological or market trends in the maritime sector, such as EGNSS and Copernicus services, and Maritime and Ocean Monitoring and their impact on user requirements evolution.

Overall, the group confirmed the following main trends in the maritime sector:

- development of new assistance functions and first steps towards automated vessels (valid for maritime and inland waterways but also for Maritime surveillance and fisheries control);
- GNSS is the central sensor to provide position velocity and time; and
- new applications require high accuracy position, high integrity and resilience to jamming and spoofing (security) – not only related to GNSS but also to consider redundancy in navigation systems.

Concerning the main technological or market trends in the maritime sector on EGNSS and Copernicus services, there was high expectations for the Galileo High Accuracy Service (HAS) for autonomous vessels. Also, the EGNOS Maritime Service for integrity, and moving forward, the Galileo authentication (OS-NMA) was something that was seen to increase the level of security.

With regard to technological and market trends in the Maritime and Ocean Monitoring sector the trend towards the development of new assistance functionalities and services and first steps towards automated vessels was put forward as affecting several subsectors in the marine environment: maritime and inland waterways, maritime surveillance and fisheries control.

When integrated to Copernicus Marine Monitoring services, Galileo and EGNOS services could benefit from the optimisation of routing. New applications for inland shipping were also discussed, such as bridge collision warning, automatic guidance and mooring assistance. For fisheries control, a precise verified location was seen as essential to monitor vessels and resolve legal disputes. Galileo - at metre level - and OS-NMA authentication could be used to ensure undisputable positions.

The only update that is of any substance is the addition of the requirement of resilience of PNT solutions. This comes from new guidance from both IMO and IALA. Other updates are either confirmation of old requirements or editorials or clarification nature. The most important update is on IALA sources, this comes with the fact that IALA now is and international recognised organisation and can now issue standards. IALA as a consequence have issued standards, one that is of importance to the PNT solutions (Standard S1030 [RD25]).

A1.6 Additional annexes

Please refer to the previous report [RD43] for additional (and historical) annexes (see here).

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 European Union.

Its goal is to:

- Provide long-term, state-of-the-art safe and secure Galileo and EGNOS positioning, navigation and timing services and cost-effective satellite communications services for GOVSATCOM, whilst ensuring service continuity and robustness;
- Communicate, promote, and develop the market for data, information and services offered by Galileo, EGNOS, Copernicus and GOVSATCOM;
- Provide space-based tools and services to enhance the safety of the Union and its Member States. In particular, to support PRS usage across the EU;
- Implement and monitor the security of the EU Space Programme and to assist in and be the reference for the use of the secured services, enhancing the security of the Union and its Member States;
- Contribute to fostering a competitive European industry for Galileo, EGNOS, and GOVSATCOM, reinforcing the autonomy, including technological autonomy, of the Union and its Member States;
- Contribute to maximising the socio-economic benefits of the EU Space Programme by fostering the development of a competitive and innovative downstream industry for Galileo, EGNOS, and Copernicus, leveraging also Horizon Europe, other EU funding mechanisms and innovative procurement mechanisms;
- Contribute to fostering the development of a wider European space ecosystem, with a particular focus on innovation, entrepreneurship and start-ups, and reinforcing know-how in Member States and Union regions.
- As of July 2023, EUSPA will take the responsibility for the Programme's Space Surveillance Tracking Front Desk operations service.

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