2024

Report on Fisheries and Aquaculture

User Needs and Requirements

#EUSpace

EUSPA European Union Agency for the Space Programme

Executive Summary

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

The fisheries industry is increasingly adopting monitoring systems combining multiple data sources to enhance efficient management and sustainability of fish stocks, to minimise bycatch and allow efficient movement across the sea with a higher level of automation. A growing frequency in security events, jamming, and spoofing are directly impacting the GNSS and SATCOM requirements and make that both monitoring, VMS, and onboard navigational systems must be very robust.

Vessel Monitoring Systems (VMS) play a crucial role in tracking fishing activities, ensuring compliance with regulations. The 2024 UCP event underscored the importance of integrating VMS with multi-constellation GNSS and authentication to provide both authorities and fisheries with a legitimate tool to prove they operate in dedicated areas and not on protected fish stocks. Therefore, the fisheries sector is looking at the new Copernicus Sentinel-1 enabled AIS and Galileo OSNMA as a potential technology to provide the desired feature of authentication and robustness.

Copernicus together with other data can also support the control of sustainable fisheries, to reduce fuel consumption, to estimate the areas where pelagic fish is and will be with high probability, measuring and estimating by correlation different physical and biological parameters.

Aquaculture is a rapidly growing sector, with increasing ambitions to move operations deeper into the ocean. This shift is driven by the need to reduce environmental impacts on coastal areas and to access new resources. Seaweed farming is seen as a potential alternative in the race to meet a growing need in food production. The main challenge remains to produce at scale, for which EO can be a key enabler.

The 2024 UCP analysis highlighted the potential of new EO technology to support this transition. High-resolution optical satellite imagery and SAR data are increasingly tested and used to monitor marine ecosystems, detect pollution, and assess the impact of climate change. EO data supports various applications, including the detection of fish stocks, and prediction of environmental conditions. Especially, for aquaculture, it can contribute to site selection, time to seed, time to harvest and infrastructure monitoring. EO can enhance decision-making in aquaculture management by offering data on environmental conditions and risks, water quality, algal blooms and farm site characteristics. Especially the ability to reach remote areas during all types of environmental conditions is a deciding factor for new users.

Users are expecting integrated services which are easy to use and accessible to non-technical users as many farmers are not aware or do not know about the services. The Copernicus datasets remain extensive and are not seen as very accessible. An active go-to-market of Copernicus Services with use cases proving positive cost-benefit, user-friendliness and compatibility with existing reporting schemes through pilot projects is expected to support user uptake.

In conclusion, the more traditional fisheries market is experiencing a technological transformation in which key user requirements will serve as a driver for scalable monitoring. The aquaculture segment is welcoming further pilot activities as an enabler for the development of specialised services.

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1 INTRODUCTION AND SCOPE OF THE REPORT

1.1 Scope

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

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

UCP process contains a regular event, where users from different market segments meet to discuss their needs and application-level requirements relevant for PNT, EO and SATCOM and the conclusions are presented in this document. This report is a living and evolving document that is regularly updated by EUSPA. It served as a key input to the UCP, that is continuous process to reflect the evolution of the user needs, market and technology captured during the event. This report does not represent any commitment of the EU Space Programme to address or satisfy the listed needs and requirements in the current or future versions of the services and/or data delivered by its different components.

The report is organised as follows:

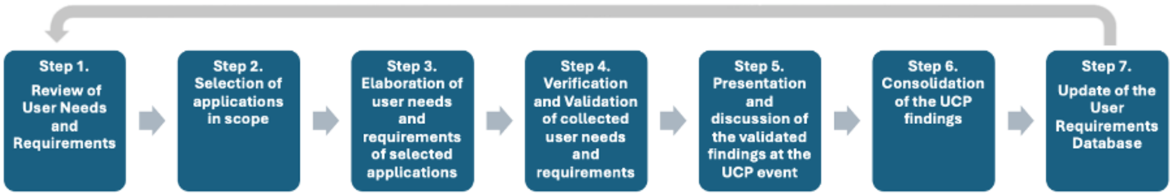
- Section 2.1 provides in an overview of the role of the European Union Space Program services in the Fisheries and Aquaculture segment and its interaction with user needs
- Section 2.2 presents market evolution and key trends, together with definition of main user groups and actors in the value chain.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

This report distinct itself from its previous version in the sense that it brings together the requirements for GNSS, EO and SATCOM; and that it provides in a focused assessment of Fisheries and Aquaculture segments. Several new applications have been analysed in this edition of the report, with the primary focus on EO and SATCOM requirements.

1.2 Methodology

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

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



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

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

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

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

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

2 FISHERIES AND AQUACULTURE

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

The role of EUSPA

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

1. User-Centric Approach

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

2. Service Provisioning

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

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

3. Enhancing the European Space Ecosystem

EUSPA works to foster a robust European space ecosystem by:

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

4. Ensuring Security

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

5. Stakeholder Engagement

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

EUSPA conducts various essential activities which include:

- User Consultation Processes: These are designed to gather insights and perceptions from users to improve service delivery.
- Market and Technology Monitoring: EUSPA analyses trends and forecasts in the space industry to inform strategic decisions.

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

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

The role of COPERNICUS

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

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

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

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

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

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

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

Copernicus together with other EO data can contribute to an enhanced monitoring capacity to ensure sustainable fisheries, to reduce fuel consumption, to estimate the areas where pelagic fish is and will be with high probability, measuring and estimating by correlation different physical and biological parameters.

Table 1: Takeaways for EO from the 2024 UCP

A multitude of users have a positive outlook on the diverse possible applications and support services related to the integration of remote sensing and Copernicus. During UCP 2024 event there was a **positive perspective expressed on the scalability of oceanographic services and the modelling** of species other than tuna. The current services allow service providers to integrate Copernicus data with commercial higher spatial and temporal resolution data to make sophisticated models.

Users in the Fisheries and Aquaculture segment are expecting integrated services which are easy to use and accessible to non-technical users as many farmers are not aware or do not know how to use the EO services and rely on in site data in majority for now. During the UCP 2024 event, users argued that the Copernicus datasets remain extensive but are not seen as very accessible. An active go to market of Copernicus Services in combination with proven cost-benefit use cases through pilot projects would be able to support user uptake and impact the sector through further optimised operations and monitoring. Further actions in terms of studies, pilot projects and coordination between authorities are expected to benefit the wider sector, and different stakeholders have clearly indicated their interest and willingness to participate.

The main challenge for aquaculture farms remains to produce at scale. **Copernicus and EO can be a significant enabler** that can contribute to site selection, time to deploy, time to harvest and infrastructure monitoring. EO can **enhance decision-making** in aquaculture management by offering data on environmental conditions and risks, water quality, algal blooms and farm site characteristics. Especially the **ability to reach remote areas during all types of environmental conditions** is a deciding factor for new users. In general, solid technical performance of supporting services in addition to improved procedures or skills to use EO data and services are expected to be the breakthrough EO services in Fisheries and Aquaculture. Also, the importance of user-friendliness, compatibility with existing reporting schemes, confidentiality and cost when trying to get the sector stakeholders on board was re-emphasised as of key importance during the discussion at the 2024 UCP event.

The role of European Global Navigation Satellite System (EGNSS)

EGNSS is the European satellite navigation program designed to provide highly accurate and reliable positioning, navigation, and timing services on a global scale and ensuring Europe's technological autonomy. EGNSS offers high-precision and multi-constellation capability. There is a free positioning service available

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

to the public, as well as encrypted services for government and commercial use, like the Public Regulated Service (PRS) for government-authorized users. EGNSS includes two main systems:

- **Galileo** is the European satellite navigation system that provides highly accurate global positioning and timing information. It offers several unique features, including higher accuracy (especially in urban areas), improved availability, and an authentication service to prevent signal spoofing. Numerous EU economic sectors rely on Galileo, from transport and agriculture to border management and search and rescue. Its 20cm accuracy makes Galileo a game changer for autonomous driving and commercial drones. Already more than 3.5 billion smartphones are Galileo-enabled.

- **EGNOS** (European Geostationary Navigation Overlay Service) is a satellite-based augmentation system (SBAS) that improves the accuracy, integrity, and reliability of the navigation services to aviation, maritime and land-based users in over 30+ countries.

Table 2: Takeaways for GNSS from the 2024 UCP

Especially in VMS, users in the Fisheries and Aquaculture segment are exploring the use of different technologies and integrations. During the UCP 2024, users expressed the **need for multi-constellation receivers and integrity authentication** to be able to perform meaningful and robust monitoring. A new Galileo OSNMA prototype is being tested in enhanced VMS equipment, VMS is compulsory for fishing vessels as it is used to monitor fishing vessel presence and activity. Galileo OSNMA will provide an additional layer of trust to the information provided to the authorities, which uses this information for fisheries monitoring and control. It will provide an additional layer of trust to authenticate SATCOM and improve the reliability of the information provided to the authorities and relevant EU bodies.

European Secure SATCOM

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

2.2 Market Overview & Trends

2.2.1 Market Evolution and Key Trends

Introduction to Fisheries and Aquaculture

The fisheries and aquaculture segment is a vital component of the global food supply chain, providing a **significant source of protein and livelihoods for millions of people worldwide**. This segment is characterised by its diverse range of activities, including wild capture fisheries and aquaculture farming such as fish, shellfish, algae, plants and seaweed farming. The industry is heavily influenced by environmental, economic, and regulatory factors, and is currently undergoing several macro trends that are shaping its future. The main objective is to balance economic efficiency with environmental sustainability.

One of the most prominent macro trends is the decarbonisation of the marine industry, which includes also fisheries and aquaculture. This involves adopting more energy-efficient practices, utilising renewable energy sources, and implementing sustainable fishing methods. The **need for sustainability and conservation** is driving efforts to combat overfishing, protect marine habitats, and promote responsible aquaculture practices. Technological advancements are also playing a crucial role in transforming the way fisheries and aquaculture operations are conducted, enabling more efficient and effective management. Innovations in remote sensing, AI, and machine learning are particularly noteworthy in this regard.

Regulatory compliance is another significant trend, with increasingly stringent regulations aimed at protecting marine ecosystems and ensuring food safety influencing operational practices within the segment. The effects of climate change, including marine heatwaves and changing ocean conditions, are posing significant challenges to fisheries and aquaculture, necessitating adaptive strategies to mitigate these impacts. Overall, these macro trends are driving the evolution of the fisheries and aquaculture segment towards more sustainable, efficient, and resilient practices.

Services development

The development of services within the fisheries and aquaculture segment is evolving rapidly, driven by the need for more precise, efficient, and sustainable operations. Satellite services are playing a crucial role in this evolution. The fisheries and aquaculture segment has been an early adopter of satellite technologies, leveraging GNSS, EO, and SATCOM to **enhance operational efficiency and sustainability**.

The market is witnessing the entry of new players offering innovative satellite-based solutions tailored to the specific needs of fisheries and aquaculture. These solutions include **high-resolution imagery, real-time monitoring, and advanced analytics.** Together with the big satellite constellations, the revisit times for areas that are not regularly monitored is increasing, ensuring more timely and accurate data collection. Satellites equipped with AIS receivers[2] are capturing imagery and AIS data simultaneously, providing comprehensive insights into vessel movements and activities.

Increased resolution of satellite imagery, particularly in coastal areas, is enabling more detailed monitoring and analysis of marine environments and aquaculture sites. The use of AI and machine learning is becoming more prevalent, allowing for the fine-tuning of models for tasks such as detecting thermal fronts and vessel detection. These technologies are reducing the time required to train models and improving the accuracy of predictions. Combining in situ data with satellite observations is enhancing the accuracy and reliability of monitoring and management efforts. Additionally, aquaculture operations are increasingly moving to open ocean environments, utilising remote sensing and evaluation to quantify growth and perform site selection, with the aim of scaling up production.

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[2] On the 5th of December 2024, the Sentinel 1C was launched with an AIS payload which will allow more robust fisheries monitoring

2.2.1.1 GNSS Key Market Trends

Advances in GNSS technology are providing more accurate and reliable positioning data, which is critical for tracking vessels and managing aquaculture operations. The integration of GNSS with other systems, such as AIS, VMS and EO, is becoming increasingly common, providing comprehensive situational awareness and improving decision-making. Efforts to enhance the resilience and security of GNSS against interference and spoofing are gaining importance, ensuring uninterrupted service for critical operations.

- **Enhanced Accuracy and Reliability**: The development of multi-constellation GNSS systems, such as Galileo, GPS, GLONASS, and BeiDou, has significantly improved the accuracy and reliability of positioning data. This is particularly important for precise navigation and tracking in fisheries and aquaculture, where accurate location information is essential for monitoring vessel movements and managing farm operations.
- **Integration with Other Systems**: GNSS is increasingly being integrated with other systems, such as VMS through AIS (i.e., in Sentinel 1-C) and EO, to provide a more comprehensive view of the activities. This integration allows for better situational awareness, enabling operators to make more informed decisions. For example, combining GNSS data with AIS and VMS can help track vessel movements more accurately, while integrating GNSS with EO can enhance the monitoring of environmental conditions.
- **Resilience and Security**: As reliance on GNSS for operations grows, so does the need for resilience and security against potential threats such as interference, jamming, and spoofing. Efforts are being made to develop more robust GNSS systems that can withstand these threats[3], ensuring continuous and reliable service. This includes the implementation of advanced signal processing techniques and the development of backup systems to maintain service continuity in the event of disruptions.
- **Cost-Effective Solutions**: The increasing availability of cost-effective GNSS solutions is making advanced positioning technologies accessible to a wider range of users, including small-scale fisheries and aquaculture operations. This democratisation of technology is enabling more operators to benefit from the advantages of precise positioning and navigation.

2.2.1.2 EO Key Market Trends

The deployment of satellite constellations is improving the resolution and frequency of EO data, enabling more accurate and timely monitoring of marine environments. The use of AI and machine learning is enhancing the analysis of EO data, allowing for more accurate detection of environmental changes and operational anomalies. Combining EO data with in-situ observations is providing a more comprehensive understanding of marine conditions and supporting more effective management strategies.

- **Increased Resolution and Frequency**: The launch of new satellite constellations, especially by commercial providers, is significantly enhancing the resolution and frequency of EO data. This allows for more detailed and frequent monitoring of coastal areas, aquaculture sites, and marine environments. High-resolution imagery is crucial for tasks such as sustainable and efficient fishing and fisheries control, monitoring fish stocks, and assessing the health of marine ecosystems.
- **AI and Machine Learning**: The integration of AI and machine learning with EO data is revolutionising the way environmental changes and operational anomalies are detected and analysed. These technologies enable the development of advanced models that can identify patterns and trends in EO data, leading to more accurate predictions and timely interventions. For example, AI can be used to detect thermal fronts, identify vessel movements, and monitor the growth of aquaculture farms.

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[3] Galileo OSNMA (expected operational launch in 2025) will provide GNSS receivers with the assurance that the received Galileo navigation message is coming from the system itself and has not been modified

- **Integration with In-Situ Data**: Combining EO data with in-situ observations, such as data collected from buoys, sensors, and other monitoring equipment, is providing a more comprehensive understanding of marine conditions. This integration enhances the accuracy and reliability of monitoring efforts, supporting more effective management and decision-making. For instance, merging satellite imagery with in-situ water quality measurements can help identify areas of concern and guide targeted interventions.
- **Environmental Monitoring and Conservation**: EO is playing a critical role in environmental monitoring and conservation efforts. High-resolution satellite imagery is being used to monitor protected marine areas, assess habitat health, and detect environmental changes such as marine heatwaves and pollution. This information is essential for developing and implementing conservation strategies to protect marine biodiversity and ecosystems.

2.2.1.3 SATCOM Key Market Trends

Advances in SATCOM technology are enabling real-time communication between vessels and shore-based operations, improving coordination and response times, and more robust VMS / fishing monitoring through AIS and future VDES. The development of more cost-effective SATCOM solutions is making it accessible to a wider range of users, including small-scale fisheries and aquaculture operations. Expanding satellite coverage is ensuring reliable communication in remote and open ocean areas, supporting the expansion of aquaculture and other activities.

- **Real-Time Communication**: The ability to communicate in real-time is crucial for the efficient and safe operation of the activities. Advances in SATCOM technology are enabling seamless communication between vessels and shore-based operations, allowing for better coordination and faster response times. This is particularly important for monitoring and managing aquaculture farms, where timely information can help address issues such as disease outbreaks and equipment failures.
- **Cost-Effective Solutions**: The development of more affordable SATCOM solutions is making advanced communication technologies accessible to a broader range of users. This includes small-scale fisheries and aquaculture operations that may have previously been unable to afford such technologies. Cost-effective SATCOM solutions are enabling these operators to benefit from real-time communication, enhancing their operational efficiency and safety.
- **Enhanced Coverage**: Expanding satellite coverage is ensuring reliable communication in remote and open ocean areas, which are often beyond the reach of traditional communication networks. This is supporting the expansion of aquaculture and other activities into these areas, enabling operators to maintain connectivity and monitor their operations effectively. Enhanced coverage is also crucial for ensuring the safety of vessels operating in remote regions.
- **Integration with Other Technologies:** SATCOM is increasingly being integrated with other technologies, such as GNSS and AIS for VMS and fisheries monitoring. This integration allows both fisheries and authorities from more reliable positioning and monitoring tools, and allows for the seamless exchange of data and information, enhancing situational awareness and decision-making.

2.2.2 Main User Communities

The fisheries and aquaculture sectors are increasingly leveraging GNSS, EO, and SATCOM technologies to enhance **operational efficiency, safety, and sustainability**. This section focuses on the key user communities within these sectors, detailing their specific needs and the primary market players involved. The integration of these technologies is critical for addressing challenges such as **fishing monitoring, environmental monitoring, and optimising aquaculture operations**.

For Fisheries and Aquaculture, there are users' communities along the value chain that express very different needs. The UCP analysis is focusing on the needs and requirements of the end users and intermediate users. These user communities can be divided into the following groups:

- Fishermen and aquaculture managers
- National fisheries monitoring centres (FMC), port authorities, fisheries control and maritime safety agencies
- Research institutions and government agencies
- Environmental monitoring agencies

This entire value chain of the Fisheries and Aquaculture segment can be found in the EUSPA Market Report [RD1].

2.2.2.1 GNSS Key Users

In the fisheries and aquaculture sectors, GNSS technology is indispensable for precise navigation, positioning, and operational management. End users such as **fishermen and aquaculture managers** rely on GNSS and VMS for tracking vessels, selecting optimal sites for aquaculture farms, and managing daily operations. For instance, authenticated GNSS enables fishermen to accurately locate and navigate to fishing grounds, ensuring efficient and sustainable harvesting of marine resources. It also allows fishermen to ensure and prove that they operate in designated areas, avoiding regulatory and legal issues. Similarly, aquaculture managers use GNSS to monitor the positioning of cages and equipment, optimising farm layout and reducing the risk of losses due to drifting or misplacement.

Intermediate users, including **national fisheries monitoring centres, port authorities, fisheries control and maritime safety agencies**, also benefit from GNSS technology. Port authorities utilise GNSS for vessel traffic management, ensuring safe and efficient navigation within port areas. Fisheries control agencies and Fisheries Monitoring Centres depend on **GNSS** data provided by **VMS and AIS** to monitor fishing vessels and ensure sustainable fishing practice. They will rely on the authentication services of Galileo OSNMA to mitigate spoofing and jamming cases. Maritime safety agencies depend on GNSS for search and rescue operations, as well as monitoring compliance with regulations. The enhanced accuracy and reliability of GNSS systems, driven by advancements in multi-constellation GNSS, are crucial for these applications, providing precise location data that supports effective decision-making and operational efficiency.

2.2.2.2 EO Key Users

EO technology plays a vital role in environmental monitoring, resource management, and operational optimisation within the fisheries and aquaculture sectors. **Environmental monitoring agencies** are key end users of EO data, using high-resolution satellite imagery to monitor marine ecosystems, detect pollution, and assess the impact of climate change. This information is essential for developing and implementing conservation strategies to protect marine biodiversity and ecosystems.

Fisheries and aquaculture managers also rely heavily on EO technology. For example, EO data is used to monitor fish stocks, assess water quality, and select suitable sites for aquaculture farms. High-resolution imagery allows for detailed analysis of coastal areas and marine environments, enabling managers to make informed decisions that enhance productivity and sustainability. The integration of AI and machine learning with EO data further enhances these capabilities, allowing for the development of advanced models that can identify patterns and trends, leading to more accurate predictions and timely interventions.

Intermediate users, such as **fisheries control agencies**, **government agencies and research institutions**, utilise EO data for various purposes, like fisheries control and research activities with the objective to develop sustainable models, and support policymaking. These organisations play a critical role in advancing the understanding of marine environments and informing regulatory frameworks that promote sustainable practices in fisheries and aquaculture.

2.2.2.3 SATCOM Key Users

SATCOM technology is essential for real-time communication and data exchange in the fisheries and aquaculture sectors. End users, including **fishermen and aquaculture managers**, depend on SATCOM for remote monitoring and management of operations. For instance, SATCOM enables real-time communication between vessels and shore-based operations, allowing for better coordination and faster response times. This is particularly important for addressing issues such as disease outbreaks and equipment failures in aquaculture farms.

The development of more cost-effective SATCOM solutions is making advanced communication technologies accessible to a broader range of users, including small-scale fisheries and aquaculture operations. This democratisation of technology enhances operational efficiency and safety, enabling these operators to benefit from real-time communication and data exchange. Expanding satellite coverage ensures reliable communication in remote and open ocean areas, supporting the expansion of aquaculture and other activities into these regions.

Intermediate users, including **national fisheries monitoring centres, port authorities, fisheries control and maritime safety agencies**, also rely on SATCOM and VMS for efficient communication and coordination of activities. As stated under the section on Key GNSS users, Fisheries control agencies and Fisheries Monitoring Centres depend on **GNSS** data provided by **VMS and AIS, also provided by the satellite components**. They use VMS for sustainable fisheries monitoring and require authentication services such as Galileo OSNMA. Maritime safety agencies use SATCOM for emergency communication and coordination during search and rescue operations, while port authorities depend on SATCOM for managing port activities and ensuring smooth operations.

2.3 Key market drivers – Policies, Regulations, Standards

The Fisheries and Aquaculture is a regulated segment, where local and regional public policies/regulations/standards are driving not only the need for the improved and new services but also many innovations on the market. The driving regulations and standards linked to satellite services focus on the performance requirements of navigational aids and safety related applications and are largely aligned with the requirements set out for the segment.

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

2.3.1 Relevant organisations

International regulators

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

Food and Agriculture Organisation's (FAO): A specialized agency of the United Nations that leads international efforts to defeat hunger and improve nutrition and food security. The FAO plays a significant role in developing guidelines and policies for sustainable fishing and aquaculture practices.

European Regulators and Agencies

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

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

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

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

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

European Maritime, Fisheries and Aquaculture Fund (EMFAF): helps fishers transitioning to sustainable fishing, supports coastal communities in diversifying their economies, finances projects that create new jobs and improve quality of life along European coasts, supports sustainable aquaculture developments, and supports the implementation of the European maritime policy.

European Fisheries Control Agency (EFCA): EFCA is an EU agency that promotes uniform and effective enforcement of the rules of the Common Fisheries Policy.

European associations

Federation of European Aquaculture Producers (FEAP): FEAP aims to promote the sustainable development of aquaculture and ensure the industry's economic viability.

European Association of Fish Producers Organizations (EAPO): EAPO advocates for the interests of fish producers, promotes sustainable fisheries management, and engages with policymakers on regulatory issues.

European Aquaculture Society (EAS): EAS promotes the exchange of information and knowledge among aquaculture professionals in Europe. It supports research, education, and sustainable aquaculture practices.

European Aquaculture Technology and Innovation Platform (EATiP): EATiP is an industry-led platform that promotes sustainable aquaculture practices through research, innovation, and technology transfer.

Aquaculture Advisory Council (AAC): provides advice to the EC and Member States on legislative, regulatory and legal measures at European or National level, affecting aquaculture

Europeche: the association of national organisation of fishing enterprises in the EU, promoting responsible and sustainable fishing practices and an economically and socially sustainable fishing sector

International Conference on Fisheries and Aquaculture (ICFA): global platform aimed at the urgent need for sustainable and equitable fisheries and aquaculture

2.3.2 Selection of applicable regulations

International regulation

- *SOLAS Convention [RD6]:* ensures that ships flagged by signatory states comply with minimum safety standards in construction, equipment and operation
- *SOLAS Regulation 13 [RD7]*: establishment and operation of aids to navigation
- *SOLAS Regulation 15 [RD7]:* Principles relating to bridge design and navigational systems)
- *SOLAS Regulation 25 [RD7]:* Operation of steering gear)
- *SOLAS Resolution A.893(21) [RD7]:* Guidelines for Voyage Planning

IMO regulations

- *IMO Resolution A.915 (22) [RD8]:* recognises the need for a future civil and internationally controlled Global Navigation Satellite System. It also seeks to address the needs of the sector, which are not only restricted to general navigation but include also positioning activities
- *IMO Resolution A.1046 (27) [RD11]:* 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)

- *IMO RESOLUTIONS MSC 112(73) [RD12], 113(73) [RD13], 114(73) [RD14], 115(73 [RD15]), 233(82) [RD16], 379(93) [RD17] & 401(95) [RD18]:* establish performance standards for shipborne GNSS or DGNSS equipment
- *Resolution A.1106 (29) [RD9]:* concern the revised Guidelines for the Onboard Operational Use of Shipborne Automatic Identification System

FAO Code of Conduct for Responsible Fisheries

- *2009 FAO Agreement on Port State Measures:* instrument to target IUU fishing
- The International Declaration on Transnational Organized Crime in the Global Fishing Industry ('Copenhagen Declaration')

European Strategies and Initiatives

- *EU Green Deal:* The European Green Deal is a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral by 2050.
- *EMFAF:* The European Maritime, Fisheries and Aquaculture Fund (EMFAF) supports the European Union's maritime and fisheries policies for sustainable blue economy and coastal communities.
- *Common Fisheries Policy:* The CFP is a set of rules for managing European fishing fleets and conserving fish stocks.
- *Farm to Fork Strategy:* The Farm to Fork Strategy aims to make food systems fair, healthy, and environmentally friendly.
- *Circular Economy Action Plan:* The Circular Economy Action Plan is a set of initiatives to make Europe's economy sustainable by turning waste into resources and promoting sustainable consumption.
- *Bioeconomy Strategy:* The Bioeconomy Strategy aims to develop a sustainable and circular bioeconomy that serves society, the environment, and the economy.
- *Blue Growth:* Blue Growth is the long-term strategy to support sustainable growth in the marine sector as a whole.
- *Food from the Oceans:* the Food from the Oceans initiative aims to sustainably increase the amount of food obtained from the oceans.

Relevant Standards for EO

EO techniques require significant consistency between sensors and their calibration, in data formats and structures, in accuracies and terminology, and structures. Integrating data into the Marine data store requires a rigourous procedure for the data provider qualification. Specifically for in-situ data, this is managed through the 'in-situ Thematic Assembly Centre' , which aggregates local sensor data an supplies it to Copernicus Marine Service. Copernicus Marine Service has established a process for the calibration and integration o f in-situ components from several sources.

Uptake of some EO techniques has been slow and there have been challenges in ensuring interpretability. International standards would help address these issues, and these guidelines aim to go some way towards improving the accessibility of EO data products and technologies.

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

- The International Organization for Standardization (ISO)
    - ISO/TR19121:2000 concerning Geographic information, imagery, and gridded data

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

2.3.3 Potential regulation evolution

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

In 2023, EUSPA introduced new guidelines for GNSS resilience, focusing on enhanced cybersecurity measures and anti-jamming technologies. These guidelines aim to protect GNSS applications from emerging threats and ensure continuous and reliable service.

The IMO continues to play a significant role in GNSS standardisation through its six main bodies: the Assembly, Council, and four Committees, with the Maritime Safety Committee being the most relevant. The procedure for changing conventions involves "tacit acceptance" of amendments by States, meaning an amendment enters into force unless objections are received from a specified number of Parties within a set period. Most amendments enter into force within 18 to 24 months under this procedure.

The evolution of performance requirements is driven by higher dependencies on electronic positioning onboard ships, explorative applications of remote sensing, the development of larger and faster ships, autonomous ships and fishing installations, remote controlling, increased shipping and aquaculture installations in certain regions leading to the need for alternative communication channels, and the demand for alternative energy sources.

In addition to the macro-economic developments, the EC launched a consultation to assess the effectiveness and efficiency of the Common Fisheries Policy. The results of the consultations, alongside other analyses and studies will be used to assess the CFP's performance in achieving its objectives, its economic implications, and its relevance in the context of emerging needs. The Commission will publish a summary report of the consultations, including the evidence gathered, at the beginning of 2025. This evaluation and its recommendations could pose additional requirements for VMS in terms of authentication, which are expected to impact the performance requirements for supporting technologies within the applications described within this report[4].

In 2019 in Oslo, the Blue Justice Initiative was launched during the Our Ocean Conference in Oslo, in support of implementation of the Copenhagen Declaration. The Blue Justice Initiative responds to the need to cooperate and build capacity to address transnational organized crime in the global fishing industry and is supported today by 61 countries. This initiative aims to support fishing monitoring, protect marine resources, and ensure food security and economic stability for coastal communities. The space-based monitoring technologies is also expected to increasingly support these efforts.

[4] VMS location reports are expected to benefit from Galileo OSNMA

2.4 User Needs and Requirements

In the current analysis of the Fisheries and Aquaculture segment, 9 applications and use cases of GNSS, EO and SATCOM were introduced and/or described. The following subchapters provide a description of the relevant sub-segments/applications, and the related user needs and/or requirements.

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

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

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

Table 3: Overview of covered applications - Fisheries and Aquaculture

Sub-segments	Application	Type of application (GNSS, EO, SATCOM)	In-depth coverage within this report
Fisheries	Catch Optimisation	EO	Yes, added in 2024 edition
	Fish stock detection and modelling	EO	Yes
	Fish provenance and ecolabelling	GNSS	No
	Fishing aggregating devices	GNSS	Yes
	Fishing vessels navigation	GNSS	Yes
	Fisheries monitoring	GNSS	Yes, added in the 2024 edition
Aquaculture	Aquaculture operations optimisation	GNSS + EO	Yes, added in 2024 edition
	Aquaculture site selection	EO	Yes
	Marine pollution monitoring	EO	Yes, added in 2024 edition

2.4.1.1 Catch Optimisation

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

Catch optimisation in fisheries is a sub-segment dedicated to maximising the efficiency and sustainability of fish harvesting practices. This application relies on a wide array of data and predictive models, from satellite-based EO data to vessel tracking systems and historical catch records. By combining these data sources, fisheries can enhance their operations, reduce costs, and contribute to long-term ecological health and fish stock sustainability.

- Identification of areas of potential fish aggregation based on ocean front detection and chlorophyll data.
- By using EO data and predictive models, fisheries can establish dynamic fishing zones that change based on environmental conditions and fish movement.
- Reduction of fishing search time, fuel consumption, and bycatch (reducing the unintentional capture of non-target species) ultimately enhancing **Yield Per Effort** and sustainability of fishing operations.
- Fisheries managers can use these data sources to set sustainable catch limits, track compliance with fishing regulations, and adjust fishing quotas based on real-time environmental conditions and stock health.

EO data can provide fishers with critical information about fish populations, their locations, and movements. By analysing satellite data and identifying ocean fronts, EO systems can identify potential fishing zones, predict fish aggregation patterns, and monitor oceanographic conditions that influence fish behaviour, such as sea surface temperature, chlorophyll concentrations, and ocean currents. Thanks to that, EO data supports reduction of fishing search time, fuel consumption, and bycatch (reducing the unintentional capture of non-target species) ultimately enhancing Yield Per Effort and sustainability of fishing operations.

The operational scenario for catch optimisation involves the strategic planning of where to fish first and where to move to afterwards. Catch optimisation considers the fuel reduction as well for the fishing vessels on top of locating and improving the catch. EO technology supports the fishing industry by enhancing the precision of fishing efforts, leading to more targeted and productive operations while contributing to the conservation of marine ecosystems. Advanced satellite data and environmental information can be combined to enable commercial fishing companies, fisheries management organisations, and consultants to optimise fishing efforts while promoting sustainability. More precisely, EO data for catch optimisation provide data about Monitoring oceanographic conditions such as:

- Sea surface temperature (SST) - sea surface temperature anomalies can be linked to fish migration, helping predict the movement of species like tuna.
- Chlorophyll concentration (an indicator of phytoplankton abundance, which forms the base of the marine food web), can indicate primary production, which attracts fish species. At the same time, it is an indicator for harmful algal blooms (HABs) that can affect both fish and the health of ecosystems.
- Ocean currents, sea surface height and salinity, weather conditions (wind speed, storms, etc.) These parameters are critical in determining the distribution and migration patterns of fish. Fish species often congregate in areas with optimal temperature, nutrient availability, and upwelling zones.

At the same time, EO data supports Sustainable Fisheries. EO data helps ensure that catch optimisation does not lead to overfishing or habitat destruction by enabling, ensuring that fishing practices are sustainable and compliant with regulations. Finally, EO data will help sustainable and efficient fishing and fisheries control within marine protected areas (MPAs).

Overview of user needs for the application

The Fisheries sector is expecting to combinate multiple data sources and uptake of new technologies and services, ultimately improving the fishing abilities and operations with integrated sensors to minimise bycatch and allow efficient movement across the sea with a higher level of automation.

Fishers and fisheries managers require EO technology to provide accurate, real-time data that can guide supporting decision-making for catch optimisation. They need high-resolution imagery and analytics that can pinpoint the most promising fishing areas, reducing time and fuel spent searching for fish. Copernicus together with other EO data can contribute to support the control of sustainable fisheries, to reduce fuel consumption, to estimate the areas where pelagic fish is and will be with high probability, measuring and estimating by correlation different physical and biological parameters. For the latter, users demand reliability and consistency in EO data to plan fishing activities that align with seasonal and migratory patterns.

In a more operational level, the ability to integrate EO data with onboard navigation and fish-finding equipment is crucial for operational efficiency. In this reasoning, users also seek EO systems that are user-friendly and easily interpretable, allowing fishers of varying levels of technical expertise to utilise the information effectively.

Lastly, the fishing industry needs EO solutions that are scalable and adaptable to different types of fisheries and species, from small-scale artisanal operations to large commercial fleets, ensuring that catch optimisation can be achieved across the entire sector. Looking ahead, fisheries automation of fishing operations and modelling of different species (other than tuna) were identified as potential future application where space data and services could prove valuable.

During the UCP 2024 event, technical performance and improvement of the procedures and skills to use EO data and services were brought forward as the main challenges for uptake of (EO) based solutions.

User story: Zunibal Tuna Maps

The Tuna Maps are designed to support skippers and fleet managers by combining environmental data (temperature, salinity, altimetry, plankton, etc.) with buoy information to identify high-probability fishing zones. Beyond identifying fishing locations, the system predicts buoy drift trajectories, assists in route planning, and adapts to changing oceanographic conditions, ensuring efficient and sustainable fishing operations.

The Zunibal Tuna Maps are an advanced solution tailored for tuna fishing fleets, offering precise and real-time insights to optimize fishing operations. This system integrates state-of-the-art **oceanographic mapping and artificial intelligence (AI)** technologies, providing users with a comprehensive toolset for efficient decision-making and operational planning.

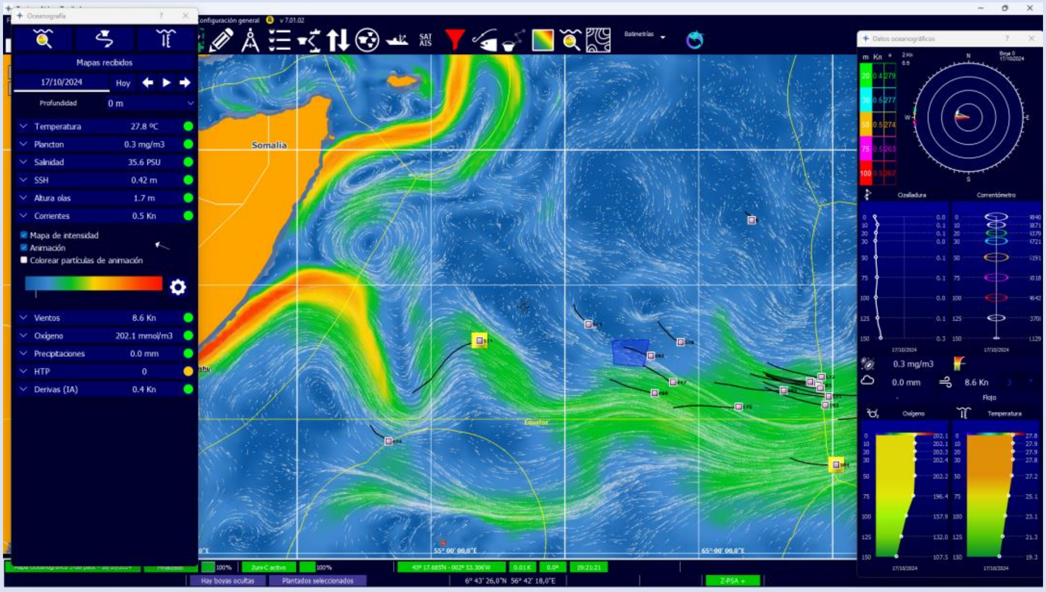
As primary users, **tuna fishing skippers** and **fleet managers** utilize the system for on-sea operational decisions. On the other hand, **vessel owners** and office-based personnel utilize the system for monitoring fleet performance and optimizing operations remotely.

The features of the system allow having information regarding:

- Optimal fishing zone
- Route planning
- Buoy management
- Environmental adaptability

The **Zunibal Tuna Maps** allow fishers **increase efficiency** saving time and resources by enabling **data-driven decisions**, cost savings by optimizing routes and **reducing fuel consumption** and operational expenses, **enhanced safety** by real-time updates avoiding unsafe conditions and areas and supports responsible fishing practices, targeting optimal zones while preserving marine habitats and allowing **a more sustainable tuna fishing**. Finally, this user-friendly solution, with nearly 30 years of proven reliability, empowers tuna fleets to enhance operational performance, reduce environmental impact, and achieve long-term sustainability in fishing practices.

Figure 2: Zunibal current maps



Preliminary User Needs and Requirements relevant to EO

Table 4: Synthesis of Requirements Relevant to EO – Catch optimisation

ID	EUSPA-EO-UR-FISH-001
Application	Catch optimisation
Users	• Fisheries • Fishery managers • Marine industry
End Users Application Needs	
Operational scenario	Identification of areas of potential tuna aggregation based on ocean front detection to reduce fuel consumption and search time, reduce bycatch and support fisheries management
Size of area of interest	Ocean-wide coverage, locally a few km range
Frequency of information needed	Regular updates for accurate localisation of fishing stock, and plotting of routes
Type of service	Forecasting
Other	N/A
Satellite EO Data Requirements	
Spatial resolution	Typically, high resolution, 10m
Temporal resolution	Daily
Spectral resolution	N/A

Type of EO data needed	Optical data (water quality parameters: Chlorophyll-a, turbidity, salinity, oxygen) SAR data for winds, currents, wave height.
Other requirements	Data archive needed (source from 2007-present) Copernicus services used: • Copernicus Marine Service European Ocean Sea Surface Temperature • Copernicus Marine Service for ocean colour data (chlorophyll) from the Sentinel 3 OLCI sensor Shapefiles of ocean fronts and potential fishing areas for tuna for the current date, plus forecasts for the next 4 days Fishing catch data to validate the service

2.4.1.2 Fish stock detection and modelling

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

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.

Overview of user needs for the application

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.

Fish stock detection and modelling services provide 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

User Needs and Requirements relevant to EO

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

Table 5: Synthesis of Requirements Relevant to EO – Fish stock detection and modelling

ID	EUSPA-EO-UR-FISH-002
Application	Fish stock detection and modelling
Users	• Fisheries • Fishery managers • Authorities (national and local, e.g. coast guards) • Fish markets • Monitoring and control entities • Marine industry • Scientific community • Retail organisations • (Fishing) tourism organisations • Fish welfare organisations (e.g. FAO, EFSA) • NGOs
End Users Application 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 area of interest	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.
Frequency of information needed	Weekly, monthly, seasonal, annual
Type of service	Forecasting
Other	According to size the scale can range from 1:250.000 to 1:5000 WebGis to visualise the thematic data and/or integration with other instruments on board
Satellite EO Data 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).
Spectral resolution	N/A
Type of EO data needed	Optical data (for water quality parameters: Chlorophyll-a, turbidity, salinity, oxygen): Sentinel 2 (e.g. CMEMS, ocean colour, suspended matter) and 3 (e.g. OLCI, SLSTR, altimetry), VHR.

	SAR data (for winds, currents, wave height): Sentinel 1 (e.g. wind, waves), CosmoSkymed
Other requirements	Historical data Aerial, drones (RGB), buoys, echo-sounders and sonars (detection of fish, biomass estimation), fish finders on-board of fishing vessels, on-board cameras.

2.4.1.3 Fish provenance and ecolabelling

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

Fish provenance and ecolabelling are critical components of the sustainable fisheries and aquaculture sub-segment, focusing on the traceability and certification of fish products. EO contributes to this area by providing data that can verify the geographic origin of fish catches and the environmental conditions under which they were harvested.

The operational scenario involves the use of satellite data to monitor fishing activities, habitat health, and compliance with sustainable fishing practices, which are all factors that influence ecolabelling certifications. EO technology assists in ensuring that fish products labelled as sustainable or eco-friendly meet the required standards, providing consumers with transparent information about the environmental impact of their seafood choices. This application supports the entire supply chain, from fishers and processors to retailers and consumers, promoting responsible consumption and conservation of marine resources.

Overview of user needs for the application

Stakeholders in the fish provenance and ecolabelling sector have distinct needs that EO technology can address. They require precise and verifiable data on the location and methods of fish harvests to ensure that products meet sustainability criteria.

Users need EO systems to provide consistent and reliable monitoring of fishing vessels and areas, supporting fisheries monitoring. The ability to integrate EO data with other traceability systems, such as catch documentation schemes and blockchain technology, is essential for creating a transparent supply chain. Users also seek EO technology that can support the certification process by providing evidence of compliance with environmental standards and conservation measures. Furthermore, users expect EO solutions to be adaptable to various ecolabelling programs and to be able to respond to evolving sustainability criteria and consumer demands.

Lastly, stakeholders need EO data to be accessible and easily communicated to consumers, contributing to informed decision-making and the promotion of eco-conscious seafood consumption.

2.4.1.4 Fishing aggregating devices

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

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[5] 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

[5] 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.

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 CO_2 emissions.

Overview of user needs for the application

Users require accurate and reliable GNSS data to track the deployment locations of FADs and to navigate fishing vessels to these sites efficiently. Real-time GNSS information is essential for monitoring the movement of floating FADs, which can drift with ocean currents, and for planning the retrieval or repositioning of the devices. Users need GNSS systems that can integrate with other onboard equipment, such as fish finders and chart plotters, to optimise fishing efforts around FADs. The durability and longevity of GNSS equipment are important, as FADs are often deployed in harsh marine environments. Users also prioritise the ability to track multiple FADs simultaneously, ensuring effective management of the devices and the associated fishing activities. Additionally, users expect GNSS solutions to support sustainable fishing practices by helping to prevent overconcentration of FADs and reducing bycatch. Lastly, users demand technical support and maintenance services that can address any GNSS-related issues promptly, minimising downtime and maintaining the productivity of fishing operations involving FADs.

User Needs and Requirements relevant to GNSS

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

Table 6: 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 synchronisation)	The timing features provided by GNSS are mainly used for synchronisation applications, using the clock of the signal provided by the satellites to synchronise multiple buoys in this case. However, in the fishing area no requirements in terms of synchronisation 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

Criterion	Characterisation
	the IMO A.1046 (27) [RD11] 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 OSNMA in this sense. In addition, the increment of cost due to the introduction of a timing source to support the OSNMA 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) [RD11] requirements (at least 99,97%) are applicable and fulfilled by most GNSS systems.

2.4.1.5 Fishing vessels navigation

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

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.

Overview of user needs for the application

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 ground*: 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 fishing*: 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 monitoring*: 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.

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) [RD11]).

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

Table 7: 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) [RD8]
ID: EUSPA-GN-UR-MAR-0020	The PNT solution shall provide 10 m horizontal positioning accuracy (95%) (up to 100 m for Ocean waters)	Performance (Accuracy Horizontal)	Resolution IMO A.915(22) –-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0030	Continuity is not relevant to ocean and coastal navigation Type: Performance (Continuity % over 3 hours)	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) –-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity–- Alert Limit)	Resolution IMO A.915(22) –-29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046 [RD11])
ID: EUSPA-GN-UR-MAR-0050	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity–- Time to Alert)	Resolution IMO A.915(22) –-29/11/2001 [RD8]
ID: EUSPA-GN-UR-MAR-0060	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity Risk – per 3 hours)	Resolution IMO A.915(22) –-29/11/2001 [RD8] (not mandatory for the applications in IMO resolution A.1046[RD11])
ID: EUSPA-GN-UR-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) –-29/11/2001 [RD8]

ID	Description	Type	Source
ID: EUSPA-GN-UR-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval-seconds)	Resolution IMO A.1046(27) 20/12/2011 [RD11]

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

Table 8: 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 Integrity Risk – per 3 hours Susceptible to interference Susceptibility to spoofing	25 m horizontal alert limit Time to alarm smaller than 10 s. 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) [RD11])
Continuity		For port approaches and entrances: the addition of a continuity requirement, of 99,97 % over 15 minutes, regional

2.4.1.6 Fisheries Monitoring

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

Satellite data has surveillance capabilities for the fisheries monitoring activities and can contribute to protect sustainable fisheries. GNSS provides the 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.

From a monitoring perspective, the reliable tracking and need for the possibility of authentication was expressed by users during UCP24 as a key new requirement. Spoofing and VMS signal problems complicate tracking of fishing vessels, leading to complications for both authorities and fishing companies. Due to the integration of GNSS in all VMS equipment, reliability has become a key parameter. Authentication of GNSS is foreseen in the Galileo OSNMA services, which are highly anticipated by both fisheries as authorities.

During the UCP 2024 event the users discussed the possibility for authentication that could enhance the confidence for fisheries to comply with regulations and avoid risk penalties by monitoring authorities to prove the fishing vessel is true and reliable.

Overview of user needs for the application

Users involved in fisheries monitoring, such as fisheries authorities and enforcement agencies, have specific needs that GNSS technology helps to meet. They require accurate and reliable GNSS data for the precise tracking of fishing vessels, enabling the effective monitoring of fishing activities within national and international waters.

Users need GNSS systems to be fully integrated with other MCS tools, such as AIS and VMS, to provide a comprehensive picture of marine activities and facilitate cross-checking of reported data. The resilience of GNSS technology is important, as it must function consistently in various marine environments and weather conditions. Users also prioritise the interoperability of GNSS with international databases and information-sharing platforms to support fisheries monitoring. Additionally, users expect GNSS solutions to support the enforcement of fisheries regulations and contribute to the sustainability of fish stocks. Lastly, robust technical support and maintenance services are essential to ensure the continuous and effective operation of GNSS systems in fisheries monitoring.

User Needs and Requirements Relevant to GNSS

Table 9: Synthesis of Requirements Relevant to GNSS – VMS

Criterion	Characterisation
Accuracy (positioning)	10m
Accuracy (timing and synchronisation)	Positioning updates every 5min Time to first fix/authenticated fix: 5min
Coverage	Oceanwide
Availability	The PNT solution shall provide independent position fixes at least once every five minutes
Integrity	25m
Authentication	Need for authentication of the signal
Continuity	N/A

2.4.1.7 Aquaculture operations optimisation

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

Aquaculture, the farming of fish, shellfish, and aquatic plants, is a growing sector in global food production. Aquaculture operations optimisation, inclusive of seaweed farming, is a sub-segment dedicated to advancing the productivity and ecological sustainability of marine cultivation.

Optimising aquaculture operations is essential for increasing production efficiency, improving environmental sustainability, and ensuring the health and quality of farmed species. The goal is to enhance the yield of farmed species while minimizing costs, resource use, and environmental impact.

This application harnesses both technology and data analytics to refine processes such as site selection, growth monitoring, and environmental management. In the specific context of seaweed farming, operational scenarios encompass deploying sensor networks for monitoring water quality, utilising satellite-based EO to assess oceanographic conditions, and implementing automated systems for the seeding and harvesting of seaweed. Different data types are collected incl. water quality and oceanographic data (current, depth, light penetration, nutrients, nitrates, phosphorus, salinity...).

Earth Observation can enhance decision-making in aquaculture management by offering data on environmental conditions and risks, water quality, algal blooms, and farm site characteristics. GNSS technology is crucial for providing precise geolocation data, ensuring accurate placement of seaweed farms and efficient navigation of vessels and equipment within the cultivation area.

Overview of user needs for the application

Users involved in seaweed farming and broader aquaculture operations have distinct needs that are addressed by the integration of GNSS and EO technologies.

Real-time GNSS information facilitates the effective management of daily farm operations and the coordination of harvesting activities. The integration of GNSS and EO data with aquaculture management systems is crucial for automating tasks and enhancing decision-making through spatial analysis. Users require EO technology to provide insights into larger environmental factors, such as chlorophyll levels, water temperatures, and current patterns, which are vital for predicting seaweed growth and health.

Through more accurate predictions of growth and health, aquaculture operation managers can define optimal harvest times and optimise their revenues. They can identify upwelling zones (nutrient rich zones which occur seasonally related to oceanographic conditions) which offer optimal aquaculture farming zones and find the optimal positioning for their farms in function of adequate nitrate levels, chlorophyll, sea surface temperature, salinity, and bathymetric data, ocean currents, winds and waves. In aquaculture operations, the water quality parameters are central in the farming operations as no external fertilizers can be added. Thus, through a combination of satellite-derived water quality, bathymetry (in shallow waters), aquatic habitat mapping, digital elevation models, and web application/IT development; aquaculture operation managers are able map, project, and understand the performance of their rigs.

In addition to harvest monitoring and the definition of the optimal harvest time, remote sensing and GNSS allows for aquaculture operations to be organised further away from the shoreline. For these installations, users prioritise the resilience and durability of these technologies, as seaweed farms often face challenging marine conditions. Additionally, users expect these systems to support sustainable farming practices, contributing to the traceability of seaweed products and compliance with environmental regulations.

Another consideration is the use of EO and remote sensing as an early warning system for marine pollution or algae blooms, which can lead to reduced or entirely destroyed harvests. This is further elaborated under the section dedicated to marine pollution monitoring, but holds a major point of interest for the monitoring and optimisation of aquaculture operations.

During the 2024 UCP event it became apparent that the availability, ease of access and data coverage in combination with the availability of data are the key factors in the uptake of EO and GNSS data and services. In addition, robust technical support and maintenance services are essential to address any issues with GNSS and EO systems promptly, ensuring uninterrupted operation and the long-term success of aquaculture optimisation efforts. These considerations imply that this specific application was rightly assessed as a growth area for Copernicus Marine services.

User story: EOMAP

The European seaweed marketplace is on the rise: Seaweed serves as a sustainable and versatile resource for various sectors such as food, pharmaceuticals, personal care, animal feed, and fertilizers. Moreover, the European Union is promoting sustainable seaweed farming to safeguard food security. At present, farming practices are exempt from fertilisers and pest control. Thus, robust information on the marine environment matters both in terms of production efficiency and health care.

EOMAP's new seaweed online tool addresses this demand. Seaweed farmers can access near real-time information on the marine environment, including nitrate, temperature or chlorophyll. For these parameters, EOMAP integrates relevant satellite-derived information from their product portfolio, the

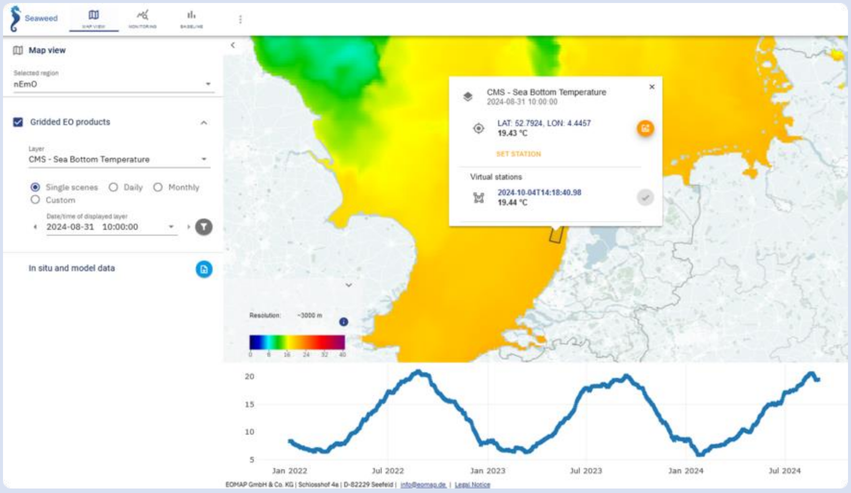
Copernicus Marine Services and the EMODnet program. Data can be ordered for specific farm locations or a wider radius, worldwide.

The service covers two key applications for seaweed farmers:

- By operational monitoring they can regularly observe key environmental parameters and derive production parameters. An alert system warns them if a threshold of environmental conditions is at risk.
- Secondly, the tool is deployed for advanced time series to detect trends in environmental variables from retrospective data. "This provides valuable insights into the suitability of a region for seaweed planting and thus supports site assessments and expanding operations", says Stefan Mühlbauer.

The environmental data provided by EOMAP's seaweed tool can benefit the entire aquaculture sector, including mussel, shrimp, shellfish, and finfish farming. Satellite-based insights into spatial and temporal nutrient levels, ocean conditions, and water quality can guide operational choices, streamline workflows, and enhance profitability.

Figure 3: EOMAP Sea bottom temperature



User Needs and Requirements Relevant to EO

Table 10: Synthesis of Requirements Relevant to EO – Aquaculture operations optimisation

ID	EUSPA-EO-UR-FISH-003 EUSPA-EO-UR-FISH-004
Application	Aquaculture operations optimisation
Users	Seaweed farmers
End Users Application Needs	
Operational scenario	Collection of oceanographic data (wind, wave, current, depth, light penetration, nutrients, temperature, chlorophyll, nitrates, phosphorus, salinity…) for the monitoring of seaweed farming lines that are placed into the ocean.
Size of area of interest	The current setting of seaweed farming remains local, but the farms are expecting to grow deeper into the ocean, which will require coverage of larger areas. Units are currently 700m x 200m, with an expected growth of licences to 1km by 2km and open ocean lines of 500m x 1km
Frequency of information needed	Every 12h to daily updates are required for the monitoring of the rigs
Type of service	Monitoring and forecasting
Other	MetOcean and early warning systems for pollution- and algal blooming
Satellite EO Data Requirements	
Spatial resolution	High resolution (10m)
Temporal resolution	12h
Spectral resolution	N/A
Type of EO data needed	SAR, optical
Other requirements	Sentinel-1, Sentinel-2

2.4.1.8 Aquaculture site selection

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

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 sones, or location near critical habitats for endangered species, as well as ocean currents linking these aquatic ecosystems.

Overview of user needs for the application

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 sones 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[6] 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;

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

- And other data used are lidar, vessels, in-situ sensors.

Aquaculture site selection services provide a set of thematic maps, which should be combined to identify potential sites. They It also provide 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.

User Needs and Requirements relevant to EO

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

Table 11: Synthesis of Requirements Relevant to EO – Aquaculture Site Selection

ID	EUSPA-EO-UR-FISH-005
Application	Aquaculture site selection
Users	Aquafarmers, public administration (national and local) Monitoring and control entities Marine industry Scientific community Recreational and tourism organisation Investors NGOs
End Users Application Needs	
Operational scenario	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 following activities are required: • Preliminary analysis • Territory analysis • Consultation • Eligibility • Environmental analysis • Zoning • Identification of sites
Size of area of interest	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).
Frequency of information needed	One-off
Type of service	One-off
Other	WebGis to visualise the thematic data

Satellite EO Data 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)
Spectral resolution	N/A
Type of EO data needed	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 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 requirements	Integration with other sensors: Aerial, drones (RGB), buoys, in situ data (bathymetry, tide, current) 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)

2.4.1.9 Marine pollution monitoring

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

Marine pollution monitoring is a crucial sub-segment within the marine industry, focused on the detection and tracking of pollutants such as sargassum, oil, and plastics in the marine environment. EO is at the forefront of this application, employing satellite imagery and remote sensing to identify and quantify pollution over vast oceanic areas. The operational scenario for EO in marine pollution monitoring involves the systematic scanning of water bodies to provide timely alerts on pollution events, facilitating rapid response and mitigation efforts. This is particularly important for managing the impact of sargassum blooms, oil spills, and the accumulation of plastics, which can have devastating effects on marine ecosystems, coastal communities, and economic activities such as tourism and fishing. EO technology enables environmental agencies, authorities, and cleanup operations to assess the scale of pollution, plan intervention strategies, and monitor the effectiveness of remediation efforts.

Overview of user needs for the application

Users engaged in marine pollution monitoring have a set of defined needs that EO technology can fulfil. High spatial and temporal resolution is essential for detecting and tracking various pollutants, especially in dynamic marine environments where conditions change rapidly. Users require EO data to be precise and dependable, as it forms the basis for critical decision-making in pollution response strategies. The ability to differentiate between types of pollutants, such as distinguishing oil from sargassum or identifying concentrations of plastics, is also a key need. Users need EO systems that can integrate with other monitoring tools and data sources to provide a comprehensive understanding of pollution patterns and trends. Accessibility to EO data and analytics is important for users across different sectors, including government agencies, research institutions, and non-governmental organisations. Additionally, users expect EO technology to be adaptable and scalable, capable of monitoring pollution at both local and global scales. Lastly, users seek EO solutions that comply with environmental regulations and contribute to international efforts to combat marine pollution and protect ocean health.

User story: Sea Alarm

The threat of oil spills remains real to marine and coastal wildlife as they are to fisheries and aquaculture. Oiled wildlife incidents do not happen very frequently, but when they do, scenarios of impacted marine birds, turtles or mammals on the shore. Also, they disrupt fisheries and aquaculture operations and installations.

Marine risk profiles are also changing with the drive to decarbonise and the growth in alternative fuels such as low-sulphur oil, LNG and products such as ammonia or methanol. These new and alternative fuel types are more challenging to deal with, as they can involve serious safety and toxicity risks and they also behave differently on the water than oil, so traditional equipment and cleanup techniques may not work as well.

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

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

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

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

User Needs and Requirements Relevant to EO

Table 12: Synthesis of Requirements Relevant to EO –Marine pollution monitoring

ID	EUSPA-EO-UR-MAR-008 EUSPA-EO-UR-MAR-009 EUSPA-EO-UR-MAR-010
Application	Marine pollution monitoring
Users	Authorities NGOs Emergency and disaster management organisations
End Users Application Needs	
Operational scenario	Prevention, preparedness and response to marine environmental emergencies Localisation of animal groupings and their position in relation to oil and plastics Monitoring and prediction of algal blooms
Size of area of interest	Very large areas of the ocean as oil tends to dilute and spread, new types of oils (low sulphur oils) and other chemicals float sub-surface Shoreline for the localisations of large groups of animals Large areas for the monitoring and prediction of algal blooms
Frequency of information needed	An update every 12 hours is needed to accurately assess the movement of oil and animal flocks and predict the movement between the two A similar timeframe is needed for the monitoring of algal blooms, as they pose a threat to birds and other species
Type of service	Continuous monitoring and forecasting (for algal blooms)
Other	Weather data and current predictions help in assessing the potential location and spread of oils and chemicals in the ocean.
Satellite EO Data Requirements	
Spatial resolution	10m x10m for oil spills, which are identified through the reflection on the water 20cm x 20cm for the identification of animals, although less resolution is needed for the verification of large groups and flocks 10m x 10m for algal blooms
Temporal resolution	12h
Spectral resolution	N/A

Type of EO data needed	Optical
Other requirements	Availability for all responders

2.5 User Requirements Specification

2.5.1 Synthesis of Requirements Relevant to GNSS

The following tables show the specific requirements relevant to GNSS:

Table 13: Synthesis of Requirements Relevant to GNSS – Fishing aggregating devices (2.4.1.4)

Criterion	Characterisation
Accuracy (positioning)	5-10 m horizontal accuracy
Accuracy (timing and synchronisation)	N/A
Coverage	Global
Availability	99,8%
Initialisation time (TTFF)	Fishing applications also showcase an interest in reducing the TTFF, mainly to achieve a battery consumption reduction.
Integrity	None foreseen
Authentication	N/A
Continuity	Fishing applications do not require a strict value of continuity due to the nature of their activities and IMO A.1046 (27) requirements (at least 99,97%) are applicable and fulfilled by most GNSS systems.

Table 14: Synthesis of Requirements Relevant to GNSS – Fishing vessels' navigation – Category 1. (2.4.1.5)

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

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

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

Table 15: Additional GNSS Requirements–- Fishing vessel navigation (2.4.1.5)

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 Integrity Risk – per 3 hours Susceptible to interference Susceptibility to spoofing	25 m horizontal alert limit Time to alarm smaller than 10 s. The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours (not

Criterion	Performance	Characterisation
		mandatory for the applications in IMO resolution A.1046 (27) [RD11])
Continuity		For port approaches and entrances: the addition of a continuity requirement, of 99,97 % over 15 minutes, regional

Table 16: Synthesis of Requirements Relevant to GNSS – VMS (2.4.1.6)

Criterion	Characterisation
Accuracy (positioning)	10m
Accuracy (timing and synchronisation)	Positioning updates every 5min Time to first fix/authenticated fix: 5min
Coverage	Oceanwide
Availability	The PNT solution shall provide independent position fixes at least once every five minutes
Integrity	25m
Authentication	Need for authentication I support of VMS
Continuity	N/A

2.5.2 Synthesis of Requirements Relevant to EO

ID	Application	Operational Scenario	Abstract of the Need & Requirement	Size of the area of interest	Smallest size of object to be observed	Spatial resolution	Temporal resolution	Type of EO data	Source
EUSPA-EO-UR-FISH-001	*Catch optimisation*	*Identification ideal sequence for fishing areas*	*Need for identification of areas of potential tuna aggregations*	*Ocean-wide coverage, locally a few km range*	*N/A*	*High resolution, 10m*	*Daily*	*Optical, SAR*	*EUSPA UCP 2024 Interviews Analysis, 2024*
EUSPA-EO-UR-FISH-002	*Fish stock detection*	*Ecosystem productivity, based on environmental factors of productivity hotspots*	*Identification on environmental characteristics.*	*Variable*	*Fish shoal*	*10 m –- 1 km*	*Weekly, monthly, seasonal, annual*	*Optical, SAR*	*EUSPA UCP 2022 Report, 2022*
EUSPA-EO-UR-FISH-003	*Aquaculture operations optimisation*	*Monitoring of water quality, environmental impact and determinants*	*Need for current modelling and water depth mapping*	*Single unit 700mx200m General license 1x2km Open Ocean 500m x 1km*	*10m*	*10m*	*Daily*	*Optical*	*EUSPA UCP 2024 Interviews Analysis, 2024*

ID	Application	Operational Scenario	Abstract of the Need & Requirement	Size of the area of interest	Smallest size of object to be observed	Spatial resolution	Temporal resolution	Type of EO data	Source
EUSPA-EO-UR-FISH-004	*Aquaculture operations optimisation*	*Observation of biomass for the definition of composition of biomass*	*Need to optimise harvesting times*	*Single unit 700mx200m General license 1x2km Open Ocean 500m x 1km*	*N/A*	*10m*	*12h*	*Optical, SAR*	*EUSPA UCP 2024 Interviews Analysis, 2024*
EUSPA-EO-UR-FISH-005	*Aquaculture site selection*	*EO data and forecasting helps select the aquaculture site location*	*Indication of preferred spots for aquaculture sites*	*1-2 km2 to 800 km2*	*N/A*	*10m*	*Annual,*	*Optical, SAR*	*EUSPA UCP 2022 Report, 2022*
EUSPA-EO-UR-MAR-008	Marine pollution monitoring	Prevention, preparedness and response to marine environmental emergencies	Need for monitoring of animal groupings	Shoreline for groupings of animals	Bird	20cm	12h	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-009	Marine pollution monitoring	Monitoring and prediction of algal blooms	Need for accurate visuals on ocean surface to monitor algal blooms	Extended areas	Reflection	10m	12h	Optical	EUSPA UCP 2024 Interviews Analysis, 2024
EUSPA-EO-UR-MAR-010	Marine pollution monitoring	Monitoring of sargassum, oil and plastics	Need to identify and forecast the movement of oil spills	Extended areas	Reflection	10m	Daily	Optical	EUSPA UCP 2024 Interviews Analysis, 2024

3 ANNEXES

A.1 Definition of key EO performance parameters

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

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

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

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

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

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

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

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

A.2 Additional EO definitions

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

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

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

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

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

A.3 Definition of key GNSS performance parameters

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A.4 Definition of key SATCOM performance parameters

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

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

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

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

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

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

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

A.5 Other performance parameters

EO

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

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

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

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

GNSS

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

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

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

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

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

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

A.6 List of Acronyms

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

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

A.7 Reference Documents

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

Id.	Reference	Title	Date
[RD24]	IALA R-129	GNSS Vulnerabilities and mitigation measures	3 Dec. 2012
[RD25]	IALA R-115	Provision of maritime radionavigation services in the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in Region 2 and 3 115	1 Dec. 2005
[RD26]	IALA R-121	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	29 May 2015
[RD27]	IALA Guideline No. 1112	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	May 2015
[RD28]	IALA Guideline No. 1082	An Overview of AIS	1 June 2011
[RD29]	IALA Guideline No. 1028	The Automatic Identification System (AIS), Vol. 1 Part 1 Operational Issues	3 Dec. 2004
[RD30]	IALA Guideline No. 1029	The Automatic Identification System (AIS), Vol. 1 Part 2 Technical Issues	1 Dec. 2002
[RD31]	IALA Standard S1030	Standard S1030 Radionavigation Services	1 May 2018
[RD32]	IALA Guideline G1129	The retransmission of SBAS corrections using MF-Radio beacon and AIS	Rev. 3 June 2022
[RD33]	IALA Guideline G1152	SBAS Maritime Service	13 December 2019
[RD34]	IALA Guideline G1154	Use of Mobile Aids to Navigation	December 2020 Ed. Corrections July 2022
[RD35]	IALA Standard S1030	Radionavigation Services	3 June 2023
[RD36]	IALA Guideline G1117	VDES Overview	16 December 2016 Corrections 16 December 2022
EC			
[RD37]	Directive 2005/44/EC	Directive on harmonised river information services (RIS) on inland waterways in the Community	7 Sept. 2005
[RD38]	Regulation (EC) No 414/2007	Regulation concerning the technical guidelines for the planning, implementation and operational use of river information services (RIS)	13 March 2007
[RD39]	Regulation (EC) No 415/2007	Regulation concerning the technical specifications for vessel tracking and tracing systems	13 March 2007
[RD40]	ERNP	European Radionavigation Plan - draft Link to presentation at UCP	29 Nov. 2017
ITU			
[RD41]	Recommendation M.823-3	Technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in Region 1 and 285-325 kHz in Regions 2 and 3	March 2006

Id.	Reference	Title	Date
[RD42]	Recommendation M.1371-5	Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band	Feb. 2014
US DoT			
[RD43]	DOT-VNTSC- OST-R-15-01	2017 Federal Radio Navigation Plan	2017
IEC			
[RD44]	IEC 60945	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results	Ed. 4.0 2002-2008
[RD45]	IEC 61108-1	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) -Receiver equipment - Performance standards, methods of testing and required test results	Ed. 2.0 2003
[RD46]	IEC 61108-2	Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) – Receiver equipment - Performance standards, methods of testing and required test results	Ed. 1. 1998
[RD47]	IEC 61108-3	Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 2010
[RD48]	IEC 61108-4	Global navigation satellite systems (GNSS) - Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 2004
[RD49]	IEC 61162 - Parts 1 to 4	Maritime navigation and radiocommunication equipment and systems – Digital interfaces	2010-1998-2014-2015
[RD50]	IEC 61993 Part 2	Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results.	Ed. 2 19 Oct. 2012
[RD51]	IEC 61108-5	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 5: BeiDou navigation satellite system (BDS) - Receiver equipment - Performance requirements, methods of testing and required test results	Ed. 1.0 11 March 2020
[RD52]	IEC 61108-6	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 6: Navigation with Indian constellation (NavIC)/Indian regional navigation satellite system (IRNSS) - Receiver equipment - Performance requirements, methods of testing and required test results (under development)	Ed 1.0 23 February 2023

Id.	Reference	Title	Date
[RD53]	IEC 61108-7	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 7: Satellite Based Augmentation Systems - Receiver Equipment - Performance requirements and method of testing (under development)	Under developme nt
[RD54]	IEC-61108-8	Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 8: Quasi-Zenith Satellite System (QZSS) receiver equipment - Performance requirements, methods of testing and required test results	Under developme nt
[RD55]	IEC 61097-9	Global maritime distress and safety system (GMDSS) - Part 9: Shipborne transmitters and receivers for use in the MF and HF bands suitable for telephony, digital selective calling (DSC) and reception of Maritime Safety Information and Search and Rescue related information - Operational and performance requirements, methods of testing and required test results	Under developme nt
Other			
[RD56]	MOM 2020 UCP	User Consultation Platform 2020– Minutes of Meeting of the Maritime and Ocean monitoring Panel	2020
[RD57]	MOM 2022 UCP	User Consultation platform 2022 – Minutes of Meeting	2022
[RD58]	MOM 2024 UCP	User Consultation platform 2024 – Maritime and Inland Waterways Session – Minutes of Meeting	2024
[RD59]	MOM 2024 UCP	User Consultation platform 2024 – Fisheries and Aquaculture Session – Minutes of Meeting	2024

A.8 Annex on regulations, standards, policies

A.8.1 IMO regulations related to GNSS user requirements

SOLAS CONVENTION

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

RESOLUTION A.915 (22)

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

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

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

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

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

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

RESOLUTION A.1046 (27)

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

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

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

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

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

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

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

Table 17: 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[7]	N/A
Harbour entrances, Harbour approaches and Coastal Waters	10m	Once/2s	99.80%	10s	99.97% over 15min

Port approach and restricted waters

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

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

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

[7] MSI: Maritime Safety Information

Table 18: Resolutions on Performance Standards for shipborne GNSS or DGNSS Equipment.

Resolution N° Title	Title	Date
MSC 112(73)	Performance standards for shipborne GPS receiver equipment	1 Dec. 2000
MSC 113(73)	Performance standards for shipborne GLONASS receiver equipment	1 Dec. 2000
MSC 114(73)	Performance standards for shipborne DGPS and DGLONASS	1 Dec. 2000
MSC 115(73)	Performance standards for shipborne combined GPS-GLONASS	1 Dec. 2000
MSC 233(82)	Performance standards for shipborne Galileo receiver equipment	5 Dec. 2006
MSC 379(93)	Performance standards for shipborne BDS receiver equipment	16 May 2014
MSC 401(95)	Performance standards for multi-system shipborne navigation	8 June 2015
MSC.432 (98)	Amendments to performance standards for multi-system shipborne radionavigation receivers	16 June 2017
MSC.449(99)	Performance standards for shipborne Indian regional navigation satellite system (IRNSS) receiver equipment	24 May 2018

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

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

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

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

- The reported ship's position (with RAIM flag and accuracy flag), position time stamp, course over ground, speed over ground is all automatically updated from the ship's main position sensor connected to AIS

- The accuracy flag is for better or worse than 10 m
- The AIS internal GNSS receiver is used for data link synchronisation and as a secondary (back-up) source of positioning information

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

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

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

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

Description of AIS

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

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

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

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

A.8.2 IALA recommendations, guidelines and standards

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

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

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

IALA Guideline G1129

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

Although IALA recommendations used to lack the regulatory force of IMO resolutions and there was an implicit expectation that individual national members will observe and implement IALA Recommendations, following its transformation to an intergovernmental organisation, it will now be able to issue standards.

IALA Guideline G1152

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

IALA Guideline G1154

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

IALA Standard S1030

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

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

Normative:

- Satellite positioning and timing: IALA Standard S1030.1
    - Recommendation R1017 on Resilient Position, Navigation and Timing (PNT)
- Terrestrial positioning and timing: IALA Standard S1030.2
    - Recommendation R1011: The Performance and Monitoring of eLORAN Services in the Frequency Band 90-110 kHs
- Augmentation services: IALA Standard S1030.3
    - Recommendation R0115: The Provision of Maritime Radionavigation Services in the Frequency Band 283.5-315 kHs in Region 1 and 285-325 kHs in Regions 2 and 3

    - Recommendation R0121: The Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 - 325 kHs
- Racon and radar positioning: IALA Standard S10.30.4
    - Recommandation R0101: Marine Radar Beacons (Racons)
    - Recommandation R0146: Strategy for Maintaining Racon Service Capability

Informative:

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

IALA World-Wide Radio Navigation Plan

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

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

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

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

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

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

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

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

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

IALA Aids to navigation guide (Navguide)

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

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

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

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

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

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

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

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

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

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

This is the founding act of the IALA DGNSS service.

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

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

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

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

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

They recommend those providing or intending to provide DGNSS to:

- Provide the service in accordance with ITU-R Recommendation M.823-3, which verses about message formats types and contents for DGNSS;
- Provide integrity information for GNSS;
- Provide the service with a level of redundancy to achieve performance requirements IMO A.1046 (27);
- Provide means of verifying the performance of the service;
- Provide mariners with information about the service, for example:

    - description of the service,
    - achieved service performance,
    - service disruptions,
    - geographical service area;
- Adopt the design and implementation principles set out in the relevant IALA Guideline(s).

Recommendation R-135 on the future of DGNSS

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

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

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

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

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

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

Recommendation R-129 on GNSS vulnerabilities and mitigation measures

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

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

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

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

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

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

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

Guideline No. 1082 on an overview of AIS

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

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

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

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

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

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

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

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

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

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

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

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

The operating principles of a shipborne mobile AIS device can be described as follows.

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

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

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

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

The position accuracy flag is defined as follows:

Table 19: 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 20: RAIM Flag

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

Specific case of DGNSS

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

IALA Guideline G1117: VDES Overview

This Guideline provides insights into the Very High Frequency Data Exchange System (VDES). It gives information about the development of the VDES, the concepts of VDES, the role within the e-Navigation concept of IMO and the potential of VDES in the maritime environment and the use cases supported by VDES. The document is intended to assist in the understanding, integration, further development and promotion of VDES in the maritime domain.

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

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

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

A.8.3 ITU recommendations

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

- The use of a vast range of wireless services, including popular new mobile communication technologies;
- The management of the radio-frequency spectrum and satellite orbits;
- The efficient use of the radio-frequency spectrum by all radiocommunication services;
- Terrestrial and satellite radiocommunication broadcasting;
- Radio wave propagation;
- Systems and networks for the fixed-satellite service, for the fixed service and the mobile service;
- Space operation, Earth exploration-satellite, meteorological-satellite and radio astronomy services.[8]

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

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

voluntarily carry AIS, the so-called Class B AIS. Technical requirements are globally set by the International Telecommunications Union (ITU)[9].

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

The latest edition available stems from 2024.

Recommendation M.823-3

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

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

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

Recommendation M.1371-5

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

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

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

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

Recommendation M.2092-1

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

It introduces expanded applications for VDES, emphasising its role in improving maritime communication, navigation, and safety through integration with other maritime systems. Updated technical specifications

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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 reflect the latest advancements in VDES technology, including enhancements in data transmission rates, frequency management, and interoperability with existing maritime communication systems.

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

A.8.4 Interpretation of requirements for bridge operations

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

SOLAS Chapter V:

- Regulation 13 (Establishment and operation of aids to navigation): GNSS can be considered an aid to navigation, providing accurate positioning information that is essential for safe and efficient inland waterway navigation, including bridge passing.
- Regulation 15 (Principles relating to bridge design and navigational systems):
    - .1: GNSS equipment should facilitate the tasks of the bridge team and pilot by providing accurate and reliable positioning data.
    - .5: GNSS should allow for continuous and effective information processing, aiding decision-making.
    - .6: GNSS should be user-friendly to prevent fatigue and maintain vigilance.
    - .7: GNSS should include monitoring and alarm systems to minimize human error and provide alerts for timely corrective action.
- Regulation 25 (Operation of steering gear): In critical navigation areas, such as near bridges, GNSS can provide the precise positioning needed to operate steering gear effectively, especially when multiple power units are required.
- Resolution A.893(21) (Guidelines for Voyage Planning): GNSS is integral to the appraisal and detailed planning of voyages, including the execution and monitoring of the plan, ensuring the vessel's progress is in line with the intended route, which is particularly important in confined waterways and when passing under bridges.

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

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

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

A.8.5 IEC standards

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

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

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

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

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

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

Table 21: IEC Standards and corresponding IMO Resolutions

IEC Reference	IMO Reference	Subject
IEC 60945 Ed. 4.0	A.694(17)	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
IEC 61108-1 Ed. 2.0	MSC.112(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) -Receiver equipment - Performance standards, methods of testing and required test results
EC 61108-2 Ed. 1.0	MSC.113(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) - Receiver equipment - Performance standards, methods of testing and required test results

IEC Reference	IMO Reference	Subject
IEC 61108-3 Ed. 1.0	MSC.233(82)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 3: Galileo receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-4 Ed. 1.0	MSC.114(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-5		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 5: BeiDou navigation satellite system (BDS) - Receiver equipment - Performance requirements, methods of testing and required test results
IEC 61108-6		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 6: Navigation with Indian constellation (NavIC)/Indian regional navigation satellite system (IRNSS) - Receiver equipment - Performance requirements, methods of testing and required test results (under development)
IEC 61108-7		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 7: Satellite Based Augmentation Systems - Receiver Equipment - Performance requirements and method of testing
IEC 61162 - Parts 1 to 4		Maritime navigation and radiocommunication equipment and systems – Digital interfaces
IEC 61993-2 Ed. 2.0	MSC.74(69) Annex 3	Maritime navigation and radiocommunication equipment and systems - Automatic identification systems (AIS) - Part 2: Class A shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results
IEC 61108-8 ED1		Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 8: Quasi-Senith Satellite System (QSSS) receiver equipment - Performance requirements, methods of testing and required test results (under development)
IEC 61108-9 ED1		Global maritime distress and safety system (GMDSS) - Part 9: Shipborne transmitters and receivers for use in the MF and HF bands suitable for telephony, digital selective calling (DSC) and

IEC Reference	IMO Reference	Subject
		reception of Maritime Safety Information and Search and Rescue related information

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

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

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

A.8.6 EC – River Information Service (RIS)

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

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

DIRECTIVE 2005/44/EC AND AMENDMENT 219/2009

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

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

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

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

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

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

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

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

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

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

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

REGULATION (EC) NO 414/2007 [RD38]

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

REGULATION (EC) NO 415/2007 [RD39]

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

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

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

Table 22: 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	—	—

Operation	Position	Speed over ground	Course over ground	Heading
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".

A.8.7 European Radionavigation Plan (ERNP)

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

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

A.8.8 US Federal Radionavigation Plan (FRP)

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

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

INLAND WATERWAYS

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

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

Table 23: FRP Maritime User Requirements - Inland Waterway Phase.

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

	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
Requirements	Accuracy (Metres, 2 drms)	Availability	Continuity	Integrity	Time to Alert	Coverage
Vessels						Waterwa y Systems

* Dependent upon mission time.

** Vertical dimension.

Harbour entrance and approach

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

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

Table 24: FRP Maritime User Requirements/Benefits - Harbour Entrance and Approach Phase.

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

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

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

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

COASTAL

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

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

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

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

Table 25: 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	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal /

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

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

OCEAN NAVIGATION

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

Table 26: 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 27: FRP Maritime User Requirements – Sub-surface marine applications.

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

Other applications

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

Table 28: FRP Maritime User Requirements –Hydrographic survey.

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

Future Marine PNT requirements

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

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

A.8.9 IHO Requirements

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

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

Table 29: IHO survey accuracy requirements

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

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

Table 30: Zone Of Confidence (SOC) values for hydrographic charts.

SOC	Position Accuracy	Depth Accuracy		Seafloor coverage	Typical survey characteristics
A1	±5 m + 5%	=0.50	+ 1%d	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
		Depth (m)	Accuracy (m)		
		10	± 0.6		
		30	± 0.8		
		100	± 1.5		
		1,000	± 10.5		
A2	± 20 m	= 1.00	+ 2%d	Full area search not achieved; uncharted features, hasardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving position and depth accuracy less than SOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		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 SOC 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		

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

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

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

A.8.10 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)[10]. 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:

   (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

   (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 localisación de buques*

[10] 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.

pesqueros vía satélite y por la que se establecen las bases reguladoras de las ayudas para la adquisición e instalación de los sistemas de localisación de buques pesqueros.[11]

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 OSNMA[12], that authenticates that the origin of the navigation message obtained from signal-in-space (SiS) are provided by the Galileo System.

A.8.11 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[13]. 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[14].

A.8.12 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.

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[11] 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.*

[12] 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.

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

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

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 by the European Commission.

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
4) Strengthening international ocean governance and enabling safe, secure, clean, and sustainably managed seas and oceans.[15]

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[16]" 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.

A.8.13 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 sones 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[17].

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.

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

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

[17] 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

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.

The EC launched a consultation to assess the effectiveness and efficiency of the CFP. The results of the consultations, alongside other analyses and studies will be used to assess the CFP's performance in achieving its objectives, its economic implications, and its relevance in the context of emerging needs.

The Commission will publish a summary report of the consultations, including the evidence gathered, at the beginning of 2025.

A.8.14 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:

- 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.[18]

A.8.15 EU Aquaculture policy

The European Commission aims to develop the EU aquaculture sector to ensure the supply of nutritious, healthy, and tasty food with a low environmental and climate footprint. It has four strategic objectives:

- Building resilience and competitiveness: The strategy aims to enhance the sector's ability to withstand economic and environmental challenges, ensuring long-term viability and growth.
- Ensuring participation in the green transition: The strategy promotes the integration of sustainable practices and technologies to reduce the environmental impact of aquaculture activities.
- Ensuring social acceptance and consumer information: The strategy emphasizes the importance of transparency and consumer awareness regarding EU aquaculture activities and products, fostering trust and acceptance.

[18] The Blue Economy Report 2022

- Increasing knowledge and innovation: The strategy supports research and development to drive innovation and improve practices within the aquaculture sector.

A.8.16 Relevant Standards for EO

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

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

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

A.9 Critical Analysis on GNSS User Requirements

A.9.1 Analysis of IMO requirements

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

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

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

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

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

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

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

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

A 1106 (29) - REVISED GUIDELINES FOR AIS [RD9]
IMO requirements vs. GNSS capabilities

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

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

Analysis of IALA recommendations and guidelines

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

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

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

Comparison between IMO and US regulation

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

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

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

Table 31: Comparison between FRP and IMO user requirements for safety of navigation.

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

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

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

The most likely explanations are:

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

requirements for a future GNSS, although it is widely accepted as the IMO reference for user requirements).

A.9.2 Comparison between IHO requirements with IMO

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

Table 32: 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	Consistent	Consistent	Except for isolated hazards to navigation, the IMO en-route accuracy

IHO Description of areas	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
	IHO most stringent ones			requirements are more stringent than the IHO ones.

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

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

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

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

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

Nautical charts are produced or updated using state of the art equipment, which is indeed more accurate than the minimum IHO requirement or than the position available to mariners via “standard” EPFS / GNSS. However, the rate of production and / or of updates of the nautical charts does not allow to have a complete portfolio of “modern” charts covering the whole surface of the oceans. To cope with this difficulty and to inform users of the real quality of their nautical documents, cartographers use the concept of “Sones of Confidence”, ranging from Category A1 (best) to U (unassessed quality).

A.9.3 GNSS and augmentation systems limitation

No existing GNSS can meet all operational requirements, especially integrity, without the use of augmentation systems including SBAS.

Despite its theoretical capacity to fulfil IMO resolution A.1046 (27) [RD11], there are no existing maritime standards for SBAS receivers yet. This does not prevent the maritime community from using SBAS (but not its integrity concept), but to spread its use as permanent and consolidated it would be necessary to have specific regulation concerning the maritime users’ needs. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers to minimise implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and the fact that SBAS have limited signal availability in northern latitudes (i.e. above 70°).

As discussed before, the particularities of maritime navigation culture result in more independence among the several navigation instruments, and consequently, in more freedom for ship and equipment manufacturers. However, this situation will probably evolve thanks to the development of e-Navigation, which is a strategy to increase safety of navigation in commercial shipping through better organisation of data on ships and on shore, and better data exchange between ships and with the shore. This topic will be more thoroughly discussed later.

A.9.4 Inland waterways – Special analysis on user requirements with IMO, FRP, EC, MARUSE

Previous chapters show the different requirements for inland waterways safety of navigation proposed by IMO, FRP, EC and Maruse project. In this chapter an analysis of these requirements for merchant vessels is presented using the values specified in IMO resolution A.915 [RD8] and A.1046 (27) [RD11] as the reference. IMO resolution A.915 [RD8] sets the value of 10m accuracy (95%) and 25m for the Horizontal Alert limit. These values for accuracy are applicable in Europe by REGULATION (EC) No 415/2007. These are the values to be considered for the mission. In case of specific operations under bridges or in locks, the regulation sets 1m accuracy (95%). On the other hand, the MARUSE project proposed a more stringent requirement for inland waterways navigation with 3m accuracy (95%) and 7.5m as Horizontal Alert limit while keeping the rest of the values as in IMO resolutions. The MARUSE project also proposed to measure the continuity over 15 minutes in line with IMO resolution A.1046, proposing this change with respect IMO resolution A.915 [RD8]. In the Federal Navigation Plan, the requirement for inland waterways for merchant vessels and tows an accuracy in the range of 2-5m (95%) is proposed depending on if it is a merchant vessel or a tow performing complex manoeuvres. Finally, IHO is proposing for the hydrographic surveys that are used to update the navigation charts an accuracy of 2m (95%) in those areas where under-keel clearance is critical.

Considering that the IMO does not have jurisdiction over IWW, and that a consensus exists (MARUSE, UCP, but also the US FRP and the IHO all give figures in the 2-5 m range), the horizontal accuracy requirement is set to 3m.

EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the EU. In the execution of its mission, EUSPA counts on strong partnerships with the European Commission, European Parliament, Member States, European Space Agency, and private actors across the EU.

The EU Agency for the Space Programme:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for GOVSATCOM and soon IRIS², and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness;
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, GOVSATCOM and soon IRIS² across a broad range of domains;
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms;
- Implements and monitors the security of the EU Space Programme components in space and on the ground with the aim to enhance the security of the Union and its Member States. To do so, EUSPA operates the Galileo Security Monitoring Centre (GSMC).

The EU Space Programme Security Accreditation Board is established within the Agency, representing the security accreditation authority for all of the EU Space Programme's components.

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