REPORT ON MARITIME AND INLAND WATERWAYS USER NEEDS AND REQUIREMENTS

OUTCOME OF THE EUSPA USER CONSULTATION PLATFORM

GALILEO EGNOS Copernicus

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01 INTRODUCTION AND CONTEXT OF THE REPORT

In Maritime and Inland Waterways (IWW) domains, the Global Navigation Satellite System (GNSS) is used for both navigation and positioning and it has become the primary means of navigation in many Maritime and IWW applications. Maritime and IWW is a truly international industry, and it can only operate effectively if the regulations and standards are themselves agreed, adopted and implemented on an international basis. It is already highly regulated, and regulations have been reinforced over the last decades. The International Maritime Organization (IMO) is setting the regulatory framework for the shipping industry, including performance requirements for GNSS. Some of the most important parameters of operational requirements for GNSS are integrity, continuity, accuracy, availability and coverage. These requirements are developed based on risk analysis, considering risk exposure time and critical risk exposure time. However, the GNSS user requirements in Maritime are very complex and often even contradictive. Also, the maritime sector is dynamic with the ongoing development of e-Navigation, maritime service portfolios and the debate how to provide resilient positioning, navigation and timing (R-PNT). Some of the expected future requirements are indeed related with the e-Navigation initiative, which can drive the uptake of multi-constellation GNSS, and with the need to develop new performance standards for navigation receivers.

The User Consultation Platform (UCP) is a periodic forum organised by the European Commission and the EUSPA involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers, application developers and the organisations and institutions dealing, directly and indirectly, with Galileo and EGNOS. The event is a part of the process developed at the EUSPA to collect user needs and requirements and take them as inputs for provision of user driven Galileo and EGNOS services. In this context, the objective of this document is to provide a reference for the European GNSS Programmes and for the Maritime and IWW community reporting periodically the most up-to-date GNSS user needs and requirements in the Maritime and IWW market segment. This report is considered a "living document" in the sense that it will serve as a key input to the next UCP event where it will be reviewed and subsequently updated. The UCP will be held periodically (e.g. once per year) and this report will be also periodically updated, to reflect the evolution in the user needs, market and technology captured during the UCP.

The report aims to provide the EUSPA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the services provided by the European GNSS systems and their evolutions.

GNSS HAS BECOME THE PRIMARY MEANS FOR NAVIGATION IN MANY MARITIME AND IWW APPLICATIONS.

Finally, as the report is publicly available, it serves also as a reference for users and industry, supporting planning and decision-making activities for those concerned with the use of location technologies.

It must be noted that the listed user needs and requirements cannot usually be addressed by a single technological solution but rather by combination of several signals and sensors. Therefore the report does not represent any commitment of the European GNSS Programmes to address or satisfy the listed user needs and requirements in the current or future versions of the EGNSS services.

1.1 METHODOLOGY

The following figure details the methodology adopted for the analysis of the Maritime and IWW user requirements.

The analysis is split into two main steps including a "*desk research*", to gather main insights, and a *"stakeholders consultation"*, to validate main outcomes.

More in details, "*desk research*" was based on a secondary research and aimed at providing a preliminary structured analysis:

- leveraging on the Maritime and IWW applications' segmentation as included in the EUSPA GNSS Market Report, additional relevant applications have been identified

Figure 1: Maritime and IWW User Requirements Analysis methodology

OVERALL METHODOLOGY

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Desk Research

Identification of all existing Maritime and IWW applications along with the function that they perform

- All Maritime and IWW applications covered in MR5
- Maritime and IWW applications found in other sources

User level dimension and characterisation

- Identification of the key GNSS user level dimensions to describe Maritime user requirements
- Identification and definition of GNSS performance criteria relevant to Maritime and IWW

Segmentation of Maritime and IWW applications

- Definition and classification of applications
- Focused on GNSS usage (non device-based)

Definition of the functions and level of performance required for each application

- Maritime and IWW user requirements analysis based on open Secondary research information
- GNSS limitations, market/techno trends and drivers
- Table matching the main applications with the performance criteria

User requirement analysis – *draft 1*

SECONDARY RESEARCH INFORMATION

GNSS magazines- Coordinates, GPS World, Inside GNSS; ESA website; Articles on Google Scholar; Thesis and dissertations on specific database; European regulation or standard; Google

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Stakeholders Consultation

Validation interviews

- Interview guide
- Selection of the consulted stakeholders
- Primary research: Interviews and reporting

User requirement analysis – *final version*

User Consultation Platform

- User requirements submitted to the first UCP forum for review and finalisation
- Update, validation and expansion of the User Requirements analysis at each UCP

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and included; and

- for each application identified, the function and level of performance required has been determined.

As a result of this activity, a first draft of the *Maritime and Inland Waterways User Requirements* document has been produced.

In the second step, the "stakeholder consultation" has been performed, and main outcomes included in the document have been validated and updated. In this regards, preliminary validation interviews with selected stakeholders produced version 1.2 of this document which was used as a input for the UPC review and finalisation, leading to the release of this version 1.3. The report also includes the answers from independent surveys to different fora composed of Harbour masters, ship captains and pilots covering all the coast of Europe. In particular, 41 harbour masters and 28 pilots from 12 countries provided feedback to the surveys.

1.2 SCOPE

This document is part of the User Requirements documents issued by the European GNSS Agency for the Market Segments where Position Navigation and Time (PNT) play a key role. Its scope is to cover user requirements on PNT solutions from the strict user perspective and the market conditions, regulations, and standards that drive them. Therefore, the document includes an analysis of the market trends on this particular segment, then performs a detailed analysis including the prospective uses of GNSS in this market finalising with a specification of user requirements in a format that can be used for System Engineering activities.

More specifically, this report is laid out as follows. It starts with a summarised market overview for Maritime and IWW domains **(Chapter 4)**, where market evolution and key trends, the main market players and user groups are presented.

Then the report moves on to the analysis of GNSS User Requirements (UR) for Maritime and IWW **(Chapter 5)**, which is organised as follows:

- Chapter 5.1 identifies and defines the GNSS use in Maritime and IWW;
- Chapter 5.2 presents an prospective use of GNSS in Maritime and IWW;
- Chapter 5.3 is dedicated to Policy and Regulatory frameworks;
- Critical analysis is made under Chapter 5.4;
- Chapter 5.5 presents the main conclusions.

The **Chapter 6** displays the User Requirements specification:

- Chapter 6.1 is a synthesis of the UR analysis;
- Chapter 6.2 exposes the mission and system requirements for EGNSS.

Chapter 7 presents all the Annexes.

The document is intended to serve as an input to more technical discussions on Systems Engineering and evolution of the European GNSS systems so that space infrastructures are effectively linked to user needs.

02 EXECUTIVE SUMMARY

This document makes a status and an analysis of the GNSS Maritime and Inland Waterways User Requirements. It first (Chapter 4) gives a rapid overview of GNSS use in the maritime sector, based upon information available in the latest issue of the GSA GNSS Market Report. It recalls the most important market and technology trends of the sector, the main market players and the main user groups. The importance of the maritime sector can be summarised with one figure: the EU28 region counts with an installed base of 1.5 million GNSS devices, and this number reaches 2 million units when the Non-EU28 Europe is included.

GNSS USER REQUIREMENTS IN MARITIME ARE VERY COMPLEX AND OFTEN CONTRADICTIVE.

The report then (Chapter 5) addresses the core question of GNSS users requirements in the maritime and IWW domains. The International Maritime Regulatory Framework is presented. The most relevant International organisations in terms of expression of GNSS Maritime Requirements, i.e. IMO, IALA/AISM, IEC, EC (with regard to River Information System), US DoT (with regard to their Federal Navigation Plan) are introduced and their relevant Regulations, Resolutions, Directives, Recommendations and Plans are compiled and presented. Information regarding the expression of GNSS Maritime and IWW Requirements is extracted from these documents. Upcoming regulatory elements, such as the European Radionavigation Plan, will be considered in the analysis as soon as publicly available. In addition, an analysis of past and on-going European projects has been done in particular to identify trends and any assumption on requirement which can complement the user requirements expressed through formal channels and found in the official documents. The formal references are listed in Chapter 3 and the analysis of past projects is provided in Annexes (Chapter 7).

A critical analysis of the various sources listed above is provided in Chapter 5.4, evidencing the some discrepancies in the user requirements parameter values that can be found in the studied documents. Such analysis is not straightforward, since:

- Documents originating from various sources cannot be compared directly;
- None of the studied documents can be considered "self-sufficient";
- There are discrepancies between stated performance values;
- The justification or traceability of the quoted requirements is generally missing;
- The two major IMO resolutions on this subject are not fully consistent in some parameters;
- Some key documents may need a revision (e.g. IMO resolution A.915(22) was issued in 2001);
- The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are generally not specified.

The main findings (for SOLAS navigation) are recapitulated below, with the figures in red corresponding to accuracy values validated by the User Consultation Platform (UCP) in 2017. Indeed, they correspond to the IMO regulations, with one exception for the accuracy in Inland Waterways (IWW) where the UCP agreed on a more stringent requirement, as given by the MARUSE analysis. 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), these user requirements adopt the 3 m horizontal accuracy requirement.

Besides this specific IWW case, the UCP consultation confirmed that institutional statutory requirements (IMO) should remain the basis for user requirements. However, it was pointed out that such requirements being broad and globally applicable, they represent "the bare minimum". Real requirements may be more challenging and are likely to vary from place-to-place.

More stringent local requirements could be reflected as guidelines to define what the service should deliver. Guidelines are preferred to formal statutory requirements as they offer more flexibility and are easier to change.

The discussions during the UCP 2018 reinforced the message that the user requirements are linked to specific applications and can be considerably more stringent than institutional statutory requirements. For instance, the IMO requirement for harbour transit and manoeuvring is 1m, which does not correspond to the real needs for performing such operations. One of the most critical factors in harbour transit and manoeuvring are the angle and speed of approach

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Table 1: Comparison of IMO, FRP and IHO main performance parameters

Phase of Navigation	ACCURACY (meters, 2 drms)				AVAILABILITY % / period		CONTINUITY (over 15 min)		INTEGRITY (Alert Limit / risk per 3 hours)			TIME TO ALARM (s)	
	IMO	MAR	FRP	IHO	IMO	FRP	IMO	FRP	IMO	MAR	FRP	IMO	FRP
Ocean	10 - 100	10	1800 – 3700	30 - 420	99.8 30 days	99 12 h	N/A	*	25 / 10^{-5}	25 / 10^{-5}	TBD	10	TBD
Coastal	10	10	460	5 - 10	99.8 30 days	99.7	N/A	*	25 / 10^{-5}	25 / 10^{-5}	TBD	10	TBD
Port Approach & Restricted waters	10	10	8 - 20**	5 - 10	99.8 30 days	99.7	99.97	*	25 / 10^{-5}	25 / 10^{-5}	TBD	10	TBD
Port	1	1	-	2	99.8 30 days	-	99.97	-	2.5 / 10^{-5}	2.5 / 10^{-5}	-	10	-
Inland waterways	10	3	2 – 5	2	99.8 30 days	99.9	99.97	*	25 / 10^{-5}	7.5 / 10^{-5}	TBD	10	TBD

* Dependent upon mission time
** Varies from one harbour to another
IHO quoted accuracy is "Maximum allowable Total Horizontal Uncertainty" at 95%

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to berth and a high impact speed of the vessel can cause serious damage to the fendering and to the infrastructure. The impact speed should be below 0.2 knots (i.e. 0.1 m/s) which is the level of precision required for this operation.

Finally, a synthesis of the retained (consolidated) GNSS Maritime and IWW User Requirements is provided in Chapter 6.1.

Some documents have been deliberately eliminated from this consolidation to keep only the most widely accepted ones in the maritime community (i.e. IMO resolutions A.915(22) and A.1046(27)), even though they are not beyond criticism as discussed above). The analysis of the inland waterways needs have taken into account the IMO requirements, the European RIS REGULATION (EC) No 415/2007, the MARUSE project (MAR).To a lesser extent the US FRP would allow derivation of a more detailed list of specifications. In fact, the MARUSE project recommends an intermediate value of accuracy and alert limit of 3m and 7.5m respectively, while the European RIS regulation keeps the values from IMO for general navigation (10m 95% accuracy) and propose 1m 95% accuracy for operations in locks and under bridges. The UCP concludes on IWW that 10 m is not enough, and that 3 m should be considered instead, in line with MARUSE recommendations.

The main conclusion of the study, supported by the answers received in the different surveys with users and by the UCP outcome, is that the requirements captured in IMO resolution A.915 represent an order of magnitude which in most of the cases is quite conservative, and take into account the most stringent requirements for the majority of the applications. In the case of navigation in narrow inland waterways and other positioning applications in inland waterways, the accuracy requirement goes down to 1m. IMO resolution A.1046, published in 2011, included for the continuity requirement a smaller time window (over 15 minutes) than the one included in the older IMO resolution A.915 (over 3 hours). In this report, the requirements from A.915 are updated taken into account this fact and also in line with the user requirements presented in IALA Guidelines 1112 on performance and monitoring of DGNSS Services. It is important to highlight that the operational requirements in IMO resolution A.1046 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.

The IMO resolution A.915(22) [RD3] provides a **list most maritime applications**, regulated or not, requiring the knowledge of the craft position or velocity for general navigation or any other purpose. This list shall be kept "as is" because the IMO resolution A.915 or its future updated version is indeed the internationally agreed reference document summarising the needs of the maritime users. We have however mapped the requirements listed in this resolution to a smaller number of categories (3 main categories corresponding grossly to 10, 1, and 0.1 m horizontal accuracy), grouping applications with similar requirements in order to facilitate the exploitation of this information as summarised in the table 2.

In addition, the report includes annexes that contain reference information:

- Appendix A provides Acronyms and Abbreviations table;
- Appendix B details the list of acronyms;
- Appendix C presents the policy and Regulatory framework;
- Appendix D includes the results of validation surveys conducted with user communities;
- Appendix E contains an analysis of relevant past EU projects and a presentation of their outcomes.

Table 2: Consolidated maritime and IWW users requirements

Category	Applications	Main User requirements
Category 1 *(10m horizontal accuracy requirement)*	General navigation (SOLAS), ~~ocean~~ General navigation (recreation and leisure), ocean and coastal Casualty analysis, ocean and coastal Search and Rescue: initial rescue approach Fisheries: location of fishing grounds, positioning during fishing, yield analysis and fisheries monitoring	10m horizontal accuracy 95% (up to 100 m for Ocean navigation) 99.8% availability over any 30 day (over 2 years for ocean and coastal waters) 25m horizontal alert limit (not mandatory for the applications in IMO resolution A.1046) Time to alarm smaller than 10 s Integrity risk smaller than 10^{-5} per 3 hours (not mandatory for the applications in IMO resolution A.1046) Global coverage Position fixes at least once per 2 second. See Section 6.1 for more detail
Category 1+ *(same as 1 + regional continuity requirement)*	General navigation (SOLAS); Coastal, Port approaches and entrances General navigation (recreation and leisure); Port approaches and entrances Traffic management; Ship to ship coordination, Ship to shore coordination and Shore to ship traffic management Operations: automatic collision avoidance and track control	Identical to category 1, with the addition of a continuity requirement, of 99,97 % over 15 minutes, regional (c.f. Section 6.1 for more detail).
Category 1++ *(same as 1 +, enhanced horizontal accuracy requirement)*	General navigation (SOLAS); Inland waterways	Identical to category 1+, with the addition of a more stringent horizontal accuracy requirement: 3m at 95%. (c.f. Section 6.1 for more detail).
Category 1+++ *(same as 1 + vertical requirement)*	Oceanography	Identical to category 1, with the addition of a vertical positioning accuracy requirement of 10 m (95%) (c.f. Section 6.1 for more detail).

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Category 2 *(1m horizontal accuracy requirement)*	Marine Engineering, construction, maintenance and management: cable and pipe laying Aids to Navigation management Port Operations: Local VTS Casualty Analysis: Port approach, restricted waters and inland waterways Search and Rescue: final rescue approach Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance) Offshore exploration and exploitation: Exploration, Appraisal drilling, Field development, Support to production, Post-production	1m horizontal accuracy 95% 99.8% availability over any 30 day, 2.5m horizontal alert limit, Time to alarm smaller than 10 s, Integrity risk smaller than 10^{-5} per 3 hours, Regional coverage (local for VTS) Position fixes at least once per second See Section 6.1 for more detail
Category 2+ *(same as 2 + local continuity requirement)*	General Navigation (SOLAS): Ports and restricted waters. General navigation (recreation and leisure): Ports and restricted waters Operations of Locks, Tugs, Pushers and Icebreakers	Identical to category 2, with the addition of a local coverage and a continuity of 99,97 % over 15 minutes (c.f. Section 6.1 for more detail).
Category 2++ *(same as 2 + local 1m vertical accuracy requirement)*	Ports operations: Container / Cargo management & Law enforcement	Identical to category 2, with the addition of a local coverage and a positioning accuracy requirement of 1 m vertical (95%) (c.f. Section 6.1 for more detail).
Category 2+++ *(2 with relaxed horizontal accuracy + 0.1m vertical accuracy requirement)*	Hydrography Bridges operation (IWW)	Identical to category 2, with the addition of a local coverage, a positioning accuracy requirement of 1 to 2m horizontal accuracy (95%), 0.1 m vertical positioning accuracy (95%) and a 2.5 to 5 m horizontal alert limit (c.f. Section 6.1 for more detail).
Category 3 *(0.1m horizontal accuracy requirement)*	Marine Engineering : Dredging and construction works Inland Waterways: bridge collision warning systems	0.1m horizontal and vertical accuracy 95% 99.8% availability over any 30 day, 0.25m horizontal alert limit, Time to alarm smaller than 10 s, Integrity risk smaller than 10^{-5} per 3 hours, Local coverage Position fixes at least once per second (c.f. Section 6.1 for more detail).
Category 3+ *(same as 3 – no vertical accuracy + continuity requirements)*	Operations: Docking	Requirements differs from category 3 with vertical accuracy, which is not applicable and a continuity requirement of 99,97 % over 15 minutes (c.f. Section 6.1 for more detail). 0.1m/s accuracy of Speed over Ground (SOG)
Category 3++ *(same as 3 + stringent TTA requirement)*	Port Operations: Cargo handling	Requirements are identical to category 3, except a stringent integrity requirement with a time to alarm smaller than 1 s (c.f. Section 6.1 for more detail).

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03 REFERENCE DOCUMENTS

Id.	Reference	Title	Date
		IMO	
[RD1]	SOLAS	International Convention for the Safety of Life at Sea	1st November 1974
[RD2]	SOLAS Chapter V – Safety of Navigation[1]	Regulation 19.2 of SOLAS Chapter V	2007 Revision
[RD3]	Resolution A.915 (22)	Revised Maritime Policy And Requirements For A Future Global Navigation Satellite System (GNSS)	29 November 2001
[RD4]	Resolution A.1106 (29)	Revised Guidelines for the onboard operational use of shipborne automatic identification systems	2 December 2015
[RD5]	Resolution A.953 (23)	World-Wide Radionavigation System	5 December 2003
[RD6]	Resolution A.1046 (27)	Worldwide Radionavigation System	30 November 2011
[RD7]	Resolution MSC 112 (73)	Performance standards for shipborne GPS receiver equipment	1 December 2000
[RD8]	Resolution MSC 113(73)	Performance standards for shipborne GLONASS receiver equipment	1 December 2000
[RD9]	Resolution MSC 114(73)	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 December 2000
[RD10]	Resolution MSC 115(73)	Performance standards for shipborne combined GPS-GLONASS receiver equipment	1 December 2000
[RD11]	Resolution MSC 233 (82)	Performance Standards For Shipborne Galileo Receiver Equipment	5 December 2006
[RD12]	Resolution MSC 379(93)	Performance standards for shipborne BDS receiver equipment	16 May 2014
[RD13]	Resolution MSC 401(95)	Performance standards for multi-system shipborne navigation receivers	08 June 2015
		IALA	
[RD14]	IALA Navguide	IALA Aids to Navigation Manual, Issue 4	December 2001
[RD15]	IALA Navguide	IALA Aids To Navigation Manual, 7th edition	2014
[RD16]	IALA WWRNP	World Wide Radio Navigation Plan	December 2009 revised December 2012
[RD17]	IALA R-135	Future of DGNSS	04 December 2008
[RD18]	IALA Guideline 1160	Recapitalisation of DGNSS	Ed. 2 June 2011

1 http://solasv.mcga.gov.uk/

Id.	Reference	Title	Date
[RD19]	IALA R-129	GNSS Vulnerabilities and mitigation measures	Ed. 3 December 2012
[RD20]	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	Ed. 1.1 December 2005
[RD21]	IALA R-121	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	29 May 2015
[RD22]	IALA Guideline No. 1112	Performance and Monitoring of DGNSS Services in the Frequency Band 283.5-325kHz	May 2015
[RD23]	IALA Guideline No. 1082	An Overview of AIS	Ed. 1 June 2011
[RD24]	IALA Guideline No. 1028	The Automatic Identification System (AIS), Vol. 1 Part 1 Operational Issues	Ed. 1.3 December 2004
[RD25]	IALA Guideline No. 1029	The Automatic Identification System (AIS), Vol. 1 Part 2 Technical Issues	Ed. 1.1 December 2002
EC			
[RD26]	Directive 2005/44/EC	Directive on harmonised river information services (RIS) on inland waterways in the Community	7 September 2005
[RD27]	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
[RD28]	Regulation (EC) No 415/2007	Regulation concerning the technical specifications for vessel tracking and tracing systems	13 March 2007
[RD29]	ERNP	European Radionavigation Plan - *draft* Link to presentation at UCP	29 November 2017
ITU			
[RD30]	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
[RD31]	Recommendation M.1371-5	Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band	February 2014
US DoT			
[RD32]	DOT-VNTSC-OST-R-15-01	2017 Federal Radio Navigation Plan	2017
[RD33]	US Coast Guard COMDTINST M16577.1	Broadcast Standard for the USCG DGPS Navigation Service	April 1993
IEC			
[RD34]	IEC 60945	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results	Ed. 4.0 2002-2008

Id.	Reference	Title	Date
[RD35]	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
[RD36]	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. 1.0 1998
[RD37]	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
[RD38]	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
[RD39]	IEC 61162- Parts 1 to 4	Maritime navigation and radiocommunication equipment and systems – Digital interfaces	2010-1998-2014-2015
[RD40]	IEC 61993 Part 2:	Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results.	Ed. 2 19 October 2012
		EUSPA	
[RD41]	Market Report 4	GSA GNSS Market Report Issue 4	March 2015
[RD42]	Market Report 5	GSA GNSS Market Report Issue 5	May 2017
[RD43]	EGNOS Multimodal Adoption Plan 2016	EGNOS Adoption activities in aviation, maritime, rail, agriculture and surveying market segments	2017
[RD44]	EGNOS Multimodal Adoption Plan 2017	EGNOS Adoption activities in aviation, maritime, rail, agriculture and surveying market segments	27th-28th September 2016
[RD45]	GSA-MKD-MAR-MOM-236052	1st Galileo Assembly - User Consultation Platform – Transport- Maritime – Minutes of Meeting	28 November 2017
[RD62]	GSA-MKD-MAR-MOM-241692-UCP2018	User Consultation Platform 2018– Minutes of Meeting of the Maritime and Inland Waterways Panel	03 December 2018
		OTHERS	
[RD46]	Geomark 2000 conference paper	Navigation & Positioning Practices in the Offshore Industry, Jean-Pierre Barboux	10-12 April 2000
[RD47]	ION GNSS 20th technical meeting of the satellite division paper	A critical look at the IMO requirements for GNSS, J. O. Klepsvik et al.	25-28 September 2007
[RD48]	IMCA S 015 Report No. 373-19	Guidelines for GNSS positioning in the oil & gas industry	June 2011
[RD49]	IMCA S 023	Guidelines on the Shared Use of Sensors for Survey and Positioning Purposes	October 2015
[RD50]	IHO Special Publication 44 5th Edition	IHO Standards for Hydrographic Surveys	February 2008
[RD51]	SC8 – WP6	Maritime interviews	March 2016

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Id.	Reference	Title	Date
[RD52]	ALG - SC7 D1.3-02	Survey for accuracy for positioning applications in ports done with Harbour Masters	January 2016
[RD53]	ALG - SC9 D1.1-02	Survey and Interviews with receivers' manufacturers about the technology trends and gaps	June 2015
[RD54]	GSA MKD	Survey for accuracy, integrity, availability and continuity for navigation in ports done with Pilots and Shipmasters.	2016
[RD55]	EGUS - SC4	Survey and interview with users on requirements for EGNSS in autonomous vessels.	2016
[RD56]	ESSP-TN-14412 Issue 02-01	Survey for accuracy for navigation in ports done with Harbour Masters.	September 2015
[RD57]		http://www.port-authorities.com/	
[RD58]	EMRF-GSA	Third Workshop on the Maritime Use of EGNOS, Minutes of meeting,	October 2015
[RD59]	PROSBAS	Report on multipath error model preliminary validation	January 2015
[RD60]	Canadian Coast Guard	Canadian Marine Differential Global Positioning System (DGPS) Broadcast Standard	version 2.3 October 11, 2007
[RD61]		http://www.cirm.org	

04 GNSS MARKET OVERVIEW AND TRENDS FOR MARITIME AND INLAND WATERWAYS

4.1 MARKET EVOLUTION AND KEY TRENDS

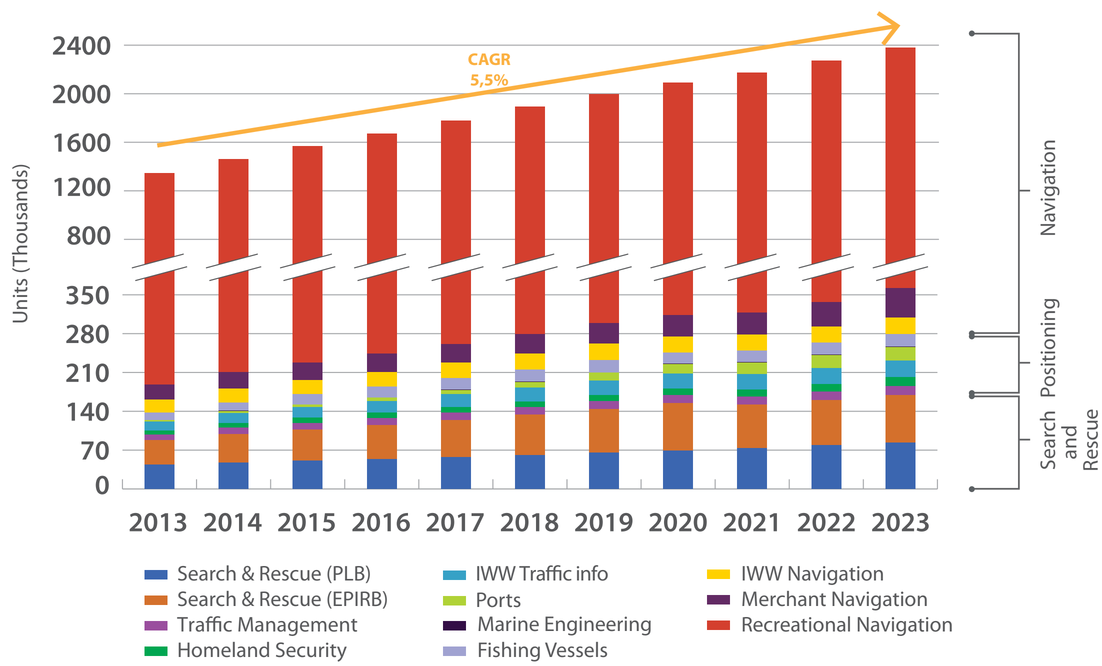
GNSS underpins all marine navigation and many other applications. GNSS is vital for the safety and commercial success of the maritime and inland waterways sector. Reliance on GNSS is only likely to increase, as initiatives such as e-Navigation evolve and as confirmed by the evidence outlined by the GNSS market report, summarised below.

According to the GNSS Market Report issue 4, due to the large number of recreational vessels in the world, their growth and their users that are enthusiastic adopters of new GNSS applications, recreational navigation is and still will have dominant importance for GNSS. Besides that, Search & Rescue applications represent a very relevant market for GNSS, as GNSS is the preferred positioning technology for maritime Search & Rescue solutions.

As it comes to geographic distribution of GNSS devices and revenues, North America is the most important region in installed GNSS devices for maritime applications, although Asia-Pacific is growing at a faster pace. The installed base of GNSS devices in Europe (EU28 and non-EU28) has an established base of 2 000 000 installed GNSS devices. The growth in Europe is slow but steady. Overall, the GNSS penetration in maritime vessels is expected to double over the next decade, from 20% to 40%, as recreational vessels will increasingly making use of GNSS – whereas merchant vessels are already fitted with more than one GNSS receiver to cover navigation and positioning applications.

Some additional important key trends for specific applications are reported below:

Figure 2: GNSS unit shipments by application. Source: GNSS Market Report issue 4



RECREATIONAL VESSELS

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

SEARCH AND RESCUE SOLUTIONS

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

E-NAVIGATION

Another important key trend is e-Navigation, which is an IMO initiative to integrate all navigational tools within the bridge system in order to enhance safety and ease of navigation, which is to be implemented from 2020 onwards. e-Navigation can be understood as an effort to bring standardization and interoperability to maritime information systems with the intention of improving safety of navigation and traffic management, reducing human errors and costs, protecting the environment, and enhancing efficiency. This is a key opportunity to spread the use of multi-constellation GNSS since e-Navigation is likely to be introduced from 2015 to 2019.

MONITORING AND CONTROL OF FISHING VESSELS OPERATIONS

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

ACCIDENT INVESTIGATION (CASUALTY ANALYSIS)

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

AUTONOMOUS VESSELS

While autonomous vessels are still in a very initial stage, the trends towards unmanned vehicles are evident and the question is not if there will be a market for autonomous vessels, but rather when. The International Maritime Organisation (IMO) is starting to work on autonomous vessels. The Maritime Safety Committee (MSC) in its 98th session, held in June 2017, included the issue of marine autonomous surface ships on its agenda. It was agreed to initiate a Scoping Paper on autonomous vessels at the next MSC session, planned for 2018. This will be in the form of a scoping exercise to determine how safe, secure and environmentally sound operations may be introduced in IMO instruments. It is anticipated that the work will take place over four MSC sessions, meaning that it will be developed until mid-2020.

GNSS USE IN MARITIME VESSELS IS EXPECTED TO DOUBLE OVER THE NEXT DECADE, INCREASING FROM 20% TO 40%.

OTHER KEY TRENDS

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

4.2 MAIN MARKET PLAYERS

The main players involved in GNSS context are depicted in the value chain below.

The role of the key players is as follows:

Maritime and Inland Waterways organizations include IMO, IALA, RTCM, IEC, ITU and other associations responsible for regulation, standardization and certification within the Maritime community. Within this category, *States* are responsible for the provision of aids to navigation in their area of responsibility *(SOLAS convention)* through a designated *National competent authority*. In inland waterways mainly River Information Services (RIS) Authorities and RIS Providers provide DGNSS service beside other river related information services.

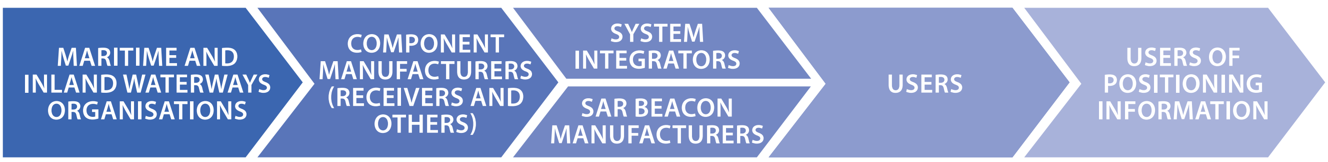
Component Manufacturers include manufacturers of GNSS-specific components (chipsets or antennae), handheld GNSS receivers and integration-ready GNSS receivers (i.e. supplied to system integrators). This is a highly consolidated industry, which represents most of the core value of the GNSS industry. The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

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

GNSS *Users* include *ship owners and operators* such as Maersk Line, MSC, CMA CGM Group, Evergreen, APL and *Ports, which* can be split into Container Ports, Cruise or Ferry Terminals and Marinas.

Users of positioning information generated by GNSS receivers include SAR response teams as well as surveillance and port authorities.

Value Chain



4.3 MAIN USER GROUPS INVOLVED IN THE VALIDATION OF USER REQUIREMENTS

The GNSS user requirements depend heavily on the applications, designed to satisfy needs of improved safety and productivity. The main user categories include: *ship masters, pilots and port authorities*. The *beneficiaries* are a much wider category, including passengers, companies served by the maritime supply chain and through logistic applications, and consumers of sea products.

To better understand what the real needs of the main user communities are, six surveys have been organised. The outcome of these surveys helped to realise the actual need of GNSS user requirements from the maritime community perspective. A summary of each survey and of its outcome is given in the next paragraphs. Detailed information about the contents of the surveys is enclosed in Appendix D.

2019 update

Finally, following the success of the 2017's User Consultation Platform (UCP), the second UCP took place on 3rd of December in Marseille, France. It was organized as a forum for interaction between end users, user associations and representatives of the value chain such as receiver and chipset manufacturers, application developers, and the organizations and institutions dealing, directly and indirectly, with Galileo and EGNOS.

In 2018, the Maritime and Inland Waterways panel gathered 32 participants, representing industry, research institutes, national authorities and European institutions with interest in maritime and inland waterways. The minutes of the 2017 and 2018 editions of the Maritime and Inland Waterways UCP panels are enclosed in Appendix 4.

4.3.1 SURVEY FOR ACCURACY FOR POSITIONING APPLICATIONS IN PORTS DONE WITH PORT AUTHORITIES, 2015.

In an effort to provide the most suitable satellite navigation service to the maritime users, a consultation has been performed among European port authorities to have their view on the need of *intermediate performance levels for navigation and positioning operations in ports*.

The performance levels required for a global navigation satellite system (GNSS) are described in IMO Resolution A.915(22)

[RD3]. This mandate specifies user requirements for both general navigation and positioning applications. Among them, different operations and applications are considered and their required performances are specified in terms of accuracy, integrity, availability, continuity, and coverage.

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

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

The consultation attempts to identify both

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

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

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

Figure 3: Potential intermediate performance level

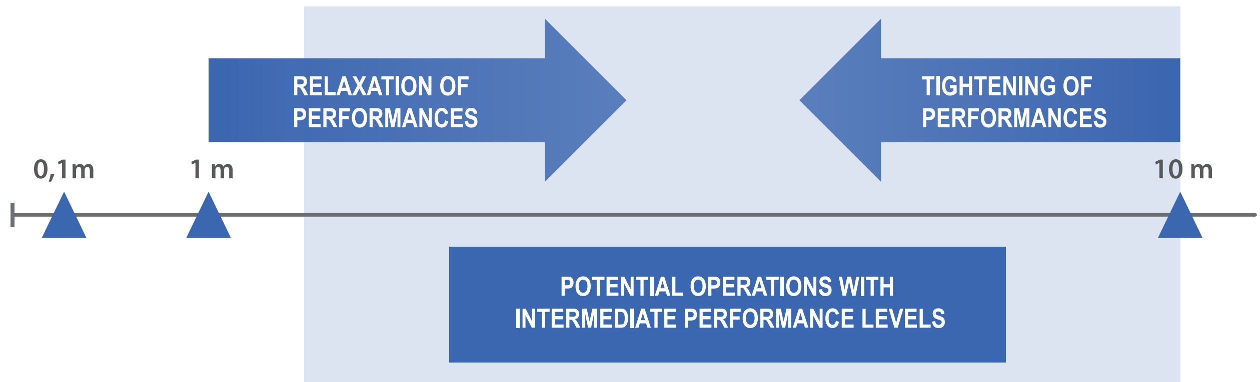
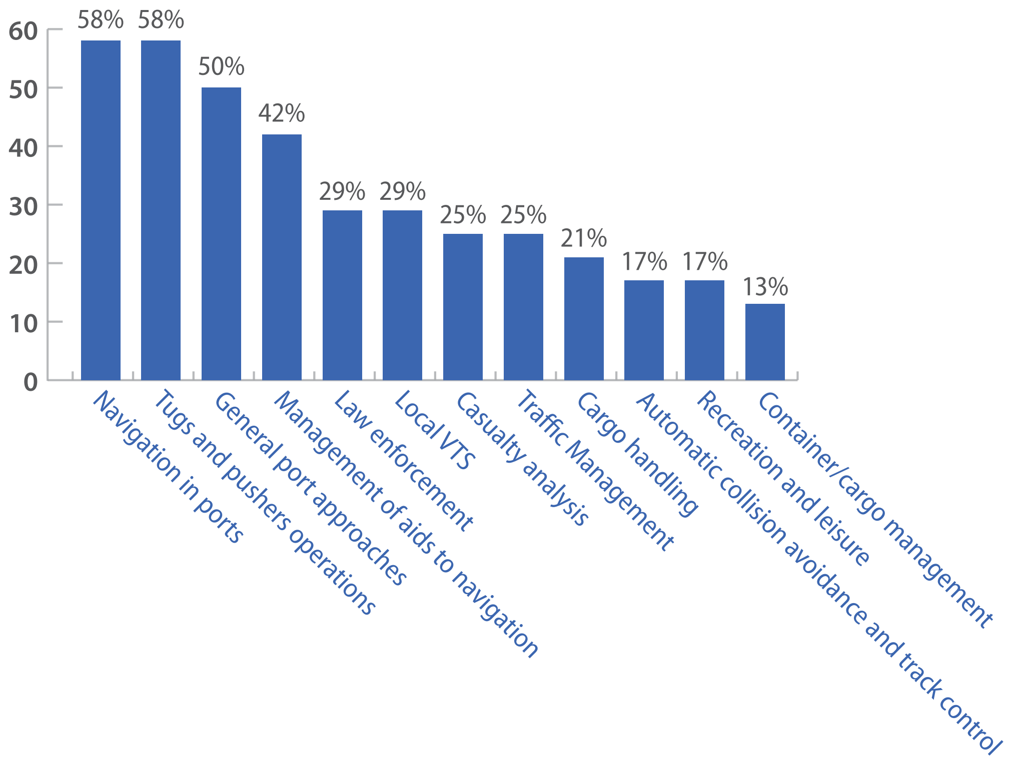


Table 4: Port Authorities interest in intermediate accuracy level

Application	Horizontal accuracy in A 22/Res.915	Higher Accuracy needed ⇩ / Lower Accuracy enough ⇧
Navigation in ports	1 meter	⇧
Tugs and pushers operations	1 meter	⇧
General port approaches	10 meters	⬇
Aids to navigation management	1 meter	⇧

Interest from Port Authorities

Figure 4: Port applications potentially candidates for an intermediate accuracy level



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

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

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

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

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

4.3.2 SURVEY FOR ACCURACY FOR NAVIGATION IN PORTS DONE WITH HARBOUR MASTERS, 2015.

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

These requirements were established more than 10 years ago, and GNSS have evolved considerably since the adoption of this IMO Resolution. Thus, the question of whether these requirements are still applicable arises: different maritime experts believe that some of the requirements in IMO Resolution A.915 should be reconsidered and could be based on more rigorous assessment of user needs and current trends in the maritime sector. This assessment is addressed

by action EMA15-MA-07 and the results of this activity have been gathered and analysed in this document. The objective of this activity was to contact different European Port Authorities so as to identify actual users' needs for navigation in ports, in order to find out in which cases EGNOS achieves the desired accuracy and is suitable for maritime use and, if possible (based on the answers obtained from the Authorities contacted) to try to define a criteria that may allow an unofficial classification of ports with different ranges of accuracy requirements.

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

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

4.3.3 SURVEY AND INTERVIEWS WITH RECEIVERS' MANUFACTURERS ABOUT THE TECHNOLOGY TRENDS AND GAPS, 2016.

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

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

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

The main outcomes from the consultation process are summarized hereafter:

- The **horizontal accuracy** requirement of 10 m (with a percentile of 95%) specified in the resolution A.915 for most of the applications is already covered by the specifications of the current maritime receivers. SOLAS receiver manufacturers do not see the need of more demanding accuracies for operations where satellite navigation systems are involved. Applications requiring those demanding accuracies usually take profit of the integration with other sensors or local augmentation techniques. As a consequence, the improvements of the accuracy performances are not seen as a short-term priority by the manufacturers.
  - A future definition of intermediate performance levels, in the frame of the A.915 review, for some applications (e.g. port and inland waters navigation, tugs and pushers, aids to navigation management) could pave the way for increasing that interest. EGNOS could appear at that point as an alternative to the position solutions currently used (e.g. DGNSS, RTK, etc.) if operational and economic benefits are demonstrated;

HIGHER RESILIENCE TO JAMMING AND INTERFERENCE IS THE KEY CHARACTERISTIC FOR NAVIGATION AND POSITIONING.

- The provision of **system integrity** is declared by more than the half of the respondents, however only few of them state compliance with resolution A.1046. System integrity is usually provided by means IALA DGNSS corrections, PPP services and/or MMS. None of the manufacturers participating in the consultation has mentioned the usage of the integrity information inside SBAS SIS to provide any type of alarms or warnings to the users.
  - No references of recommendations or guidelines for the interpretation of RTCA DO-229D SBAS MOPS for maritime applications have been found. Manufacturers do not make use of integrity information disseminated by EGNOS inside the SiS;
- **User integrity** is widely implemented by means of RAIM techniques, even no manufacturer has responded about its current implementation and their intention to adapt these technologies to the particularities of the maritime environment. There is concern within the maritime community about the validity of RAIM algorithms and considerable effort is being expended to develop maritime suitable RAIM solutions. In few cases a user integrity check is done by comparing data from independent systems. This contrasts with the recommendations of relevant maritime authorities, such as US and Canadian Coast Guards, who require the user equipment to use the UDRE values to compute integrity confidence levels about the user's displayed position.
  - The consolidation of the user integrity concept for the maritime constitutes a very important gap to be addressed in the future. Manufacturers state their commitment to adapt their product roadmaps to the proposed standardisation process provided that EGNOS is recognised by IMO and also IEC test specification standards and sterling guidance are published;
- **Higher resilience to jamming and interferences** seems to be the most relevant characteristic for both Navigation and Positioning;
- **Provision of system integrity information to the users** is the second characteristic most relevant for Navigation;
- **Higher integration with other positioning** technologies is the second characteristic most relevant for Positioning;
- **Multi-constellation capabilities** are considered a must, in particular for SOLAS, whilst **Multi-frequency** is not perceived as a need;
- **Interoperability between DGNSS and SBAS** is already provided by the commercial receivers. The selection of the navigation source is performed in some cases automatically but in this case the criterion is identified as commercially sensitive by the manufacturers.

The full analysis is to be found in the Appendix D, Chapter D.3.

4.3.4 SURVEY FOR ACCURACY, INTEGRITY, AVAILABILITY AND CONTINUITY FOR NAVIGATION IN PORTS DONE WITH PILOTS AND SHIPMASTERS, 2016.

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

To carry out this survey, the selected tool was LinkedIn, a popular professional social media. The invitation to compile the survey was sent to 151 people qualified as "pilot" and "ship master" that currently work in Europe. Out of these, 28 people replied.

At the very beginning of the questionnaire it was asked the qualification of the users to target better the type of questions.

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

Countries	N. Participants
Netherlands	5
United Kingdom	5
Italy	4
Ireland	3
Spain	2
France	2
Portugal	2
Belgium	1
Bulgaria	1
Germany	1
Denmark	1
Croatia	1

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

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

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

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

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

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

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

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

4.3.5 SURVEY AND INTERVIEW WITH USERS FOR THE USE OF EGNSS IN AUTONOMOUS VESSELS, 2016.

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

The content of the surveys is detailed in the Appendix D, section D.5.3, of the present document.

The identified key players are included in the Appendix D, section D.5.2, of the present document.

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

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

Table 5: E-GNSS performance requirements for autonomous vessels according to survey results

Performance Parameter	Oceanic deep Sea Navigation	Coastal Navigation
Horizontal accuracy (95%)	<15m	<5m
Continuity (over 15 minutes)	$1{\cdot}1\times10^{-5}$	$1{\cdot}1\times10^{-6}$
HAL	<28m	<12,5m
TTA	<8s	<6s
Integrity Risk	$1{\cdot}1\times10^{-6}$	$1{\cdot}1\times10^{-7}$
Availability	99,8%	99,8%

4.3.6 INTERVIEWS WITH MARITIME STAKEHOLDERS, 2016.

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

4.3.7 UCP 2017

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

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

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

2019 update

4.3.8 UCP 2018

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

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

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

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

It was also highlighted that there is a high dependency on GNSS in maritime but the impact of a potential GNSS outrages (e.g. positioning, timing and synchronisation) needs to be further analysed. With respect to back-ups for positioning, IALA already published a recommendation on the requirements for these systems (c.f. [RD 19]).

2019 update

05 GNSS USER REQUIREMENTS ANALYSIS

5.1 GNSS USE IN MARITIME AND INLAND WATERWAYS

5.1.1 GNSS AND AUGMENTATION SYSTEMS APPLICATIONS IN THE MARITIME SEGMENT

In maritime, GNSS is mainly used for both positioning and navigation. It can also provide timing for slot synchronisation of AIS.

POSITIONING

Positioning is merely what its name states, i.e. determining the craft's position to perform an operation or manoeuvre which is not navigation. In summary, it concerns everything but navigation.

NAVIGATION

IMO Resolution A.915(22) defines navigation as "the process of planning, recording and controlling the movement of a craft from one place to another."

The principal methods of marine navigation are briefly described as follows: (IALA Navguide)

Terrestrial Navigation: navigation using visual, radar and, (if appropriate) depth sounding observations of identifiable, conspicuous features, objects and marks to determine position.

Celestial or Astronomical Navigation: navigation using observation of celestial bodies (i.e. sun, moon, planets and stars) to determine position.

Dead Reckoning: navigation based on speed, elapsed time and direction from a known position. The term was originally based on the course steered and the speed through the water, however, the expression may also refer to positions determined by the use of the course and speed expected to be made good over the ground, thus making an estimated allowance for disturbing elements such as current and wind. A position that is determined by this method is generally called an estimated position.

Radionavigation: navigation using radio signals to determine a position or a line of position (e.g. GNSS, DGNSS etc.).

Wherever possible it is recommended that reliance on a single method of determining position is avoided.

Navigation is an application regulated by the IMO; at least for what concerns the so-called SOLAS vessels to which IMO resolutions apply. However, it is obvious that navigation is performed by all vessels, at sea as well as in inland waterways.

The majority of general navigation applications are supported by GNSS augmented by DGNSS using the IALA medium frequency DGNSS system. The penetration rate of GNSS in shipborne receivers is higher in merchant vessels than in recreational and fishing vessels (87% in merchant against 22% in recreational vessels and 8% in fishing vessels across all applications and globally). The adoption of SBAS in shipborne receivers is also very high (for both SOLAS and non-SOLAS vessels). 2016 EGNOS receiver survey [RD43] showed that around 75% of shipborne receivers models in the market are SBAS enabled and that 90% of manufacturers offer at least 1 SBAS-enabled receiver model among their products. 2017 EGNOS receiver survey [RD44] showed that 80% of new receivers introduced in the market are SBAS-enabled.

80% OF ALL NEW SHIPBORNE RECEIVER MODELS THAT CAME TO MARKET IN 2017 WERE SBAS-ENABLED.

As for positioning applications, some of the most important ones according to GSA's GNSS Market Report Issue 4 include *traffic management and surveillance*, *search and rescue activities*, *fishing vessel control*, *port operations* and *marine engineering*, which will be further developed in the topic "Market evolution and key trends".

Such applications also make an extensive use of (D)GNSS, stand alone or in association with complementary techniques (acoustics, Inertial navigation systems, etc.)

SBAS could offer added value in the form three main benefits, as identified in PROSBAS:

- Accuracy backing DGPS;
- Resistance to unintentional interference;
- Provision of integrity information.

However, SBAS has been initially designed for aeronautical navigation and is currently not adapted to the maritime domain, due to the several differences concerning mostly the environment, behaviour and navigation culture.

Concerning the environment, the shape of ships is much more variable than the one of aircraft in aviation, causing different reflection conditions and a more significant multipath error condition.

GNSS MUST BE SUITABLE TO BOTH CONVENTIONAL AND HIGH-SPEED CRAFTS AND FOR ALL PHASES OF NAVIGATION.

The differences in behaviour can be explained by ships' different needs in terms of speed, capacity to speed up or slow down and change course rapidly.

Regarding the navigation culture, it is important to notice that ship bridges are less integrated than aviation Flight Management Systems. In the maritime domain several instruments are providing data (of which GNSS is only a part), directly to the ship's master, who will analyse them and make a decision based on his experience, never trusting only one system.

5.1.2 APPLICATIONS LISTED BY IMO

Below there are listed applications by IMO resolution A.915 (22) with a brief description of each one of them along with the navigation environments.

GENERAL NAVIGATION

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

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

Coastal: As the distance from the coast decreases, bigger are the chances of encountering with other vessels or grounding. The navigation systems in this phase are mostly used to maintain safety. GPS is the principal radionavigation system, associated with augmentation systems and traditional aids to navigation such as lights, buoys and markers.

Ports approach and restricted waters phase; and *port phase*: In this case, manoeuvring has its freedom limited yet it is more frequent. Due to the close proximity to other vessels and grounding, navigation requirements are more stringent and reaction time to the manoeuvres can become critical, since collision risks are more important. Onboard systems, such as depth sounders may also be used in association to those listed in coastal navigation.

Inland waterways: This phase is safety critical. Augmented GPS signals and radar are used along with visual aids. Requirements and services for this application are generally governed by local or regional authorities, which may or not adopt IMO recommendations. The same requirements of navigation in restricted waters, ports and approaches are considered in this phase

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

OPERATIONS

This group of applications had not been officially specified prior to the adoption of IMO Resolution A.915 (22). It includes:

Tugs and pushers: which require a relative positioning between the tug and the other vessel. They are currently performed visually, but there is a high potential for contribution by radionavigation systems.

Icebreakers: they also require a relative positioning, but between the icebreaker and the ice floe. Although it is usually performed visually, the path of the icebreaker and the cleared channel can be controlled using GNSS.

Track control: this application consists of automatically keeping the ship on a pre-planned track using position, heading and speed information. Absolute accuracy is required.

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

Automatic docking: this is a potential future application which will require position-fixing to be performed in both horizontal and vertical planes, always keeping control of residual speed, which must be always very slow in order to avoid damages to both vessel and dock. It will possibly require that propulsion and rudder controls be integrated to the ship's controls, which makes it rather unlikely that satellite-based navigation positioning systems offer the best solution to meet this application's requirements.

TRAFFIC MANAGEMENT AND SURVEILLANCE

The information required for traffic management typically comprises *static information* (name and call-sign), *variable information* (load and destination) and *dynamic information* (position and course).

Three different basic regimes can be identified:

- Ship-to-Ship coordination;
- Ship-to-Shore reporting and shore-to-ship monitoring;
- Shore-to-Ship management.

All these regimes require an automatic identification system (AIS) capable of supporting ship-to-ship and ship-to-shore identification in order to assist vessel traffic services (VTS).

SEARCH AND RESCUE ACTIVITIES

Search and Rescue SAR activities combine two different tasks: *alerting*, which is a positioning function, and *tracking and search*, which is a navigation function. The alert procedure covers two different scales, and for this reason the vessel must be able not only to send a *local emergency* response but also to coordinate with the worldwide Global Maritime Distress and Safety System (GMDSS). GMDSS alerting systems include emergency position indication radiobeacons (EPIRBs), personal locator beacons (PLB) and emergency locating transmitters (ELT). SAR effectiveness depends on knowledge of accurate positions of incidents and also of supporting SAR assets.

HYDROGRAPHY

Hydrography provides data for charting seas and inland waterways and adjacent topography. The provision of hydrographic information adequate to support the safety of navigation is a national obligation under the SOLAS convention. The determination of position and depth sounding information must be undertaken with sufficient accuracy to ensure safety of navigation.

OCEANOGRAPHY

This is a scientific application concerned with identifying and understanding the behaviour of the ocean, mapping their boundaries (extent and depth), their geology, the physics and chemistry of their waters, their biology and both the conservation and the exploitation of their resources. Both horizontal and vertical accuracy are required, together with global coverage.

MARINE ENGINEERING, CONSTRUCTION, MAINTENANCE AND MANAGEMENT

This set of applications requires very accurate positioning, with absolute accuracy requirements in the range of 0.1 to 1m both in the horizontal and in the vertical, depending on application and geographical circumstances. Some of the applications included are:

Dredging for the maintenance of fairways, channels and port areas with coverage confined to the area of interest. Real-time solutions are needed.

Cable and pipe-laying, where coverage may be required over large areas. It also needs real-time positioning.

Construction works, which requires limited coverage volumes. This application is identical to other land-based construction applications and uses similar solutions.

AIDS TO NAVIGATION MANAGEMENT

The position of a floating aid to navigation requires a higher degree of accuracy than general navigations. The need for an accurate position for a floating aid depends on its purpose, its location and specific circumstances as depth of water, for example. GNSS can be used as a survey-tool to initially position floating aids to navigation and subsequently monitor their position providing alerts when the drift off-station is beyond and acceptable limit.

PORT OPERATIONS

These applications are restricted to activities associated directly to the vessels themselves, including for example:

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

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

CASUALTY ANALYSIS

IMO requires some ships engaged on international voyages to carry voyage data recorders (VDR) to aid in the analysis and reconstruction of accidents and incidents. The ship's navigation systems will provide the position-fixing input to the VDR, along with the input of its other navigation sensors.

OFFSHORE EXPLORATION AND EXPLOITATION

These applications are of major economic importance, but they are also hazardous and have Safety of Life implications. They can be classified in:

Exploration: Mainly performed using seismic survey. Post-processing techniques can be used.

Appraisal drilling: Examination of the extent of a potential site is performed by drilling subsidiary wells, accounting for previous drilling and extractions.

Field development: Involves the location of drilling wells, delineation of boundaries, identification of hazards, laying of pipelines and field control.

Support to production: Involves provision of access to all parts of the fields for maintenance and repair, supply and delivery in all weathers, and includes the operation of support vessels and helicopters.

Post production: Involves the removal of all structures, pipelines and debris and needs to provide efficient location of all material.

Each of these phases may include a variety of tasks to perform and precise positioning is generally a must. A detailed, although somewhat outdated description of these tasks can be found in [RD41].

FISHERIES

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.

RECREATION AND LEISURE

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

5.2 PROSPECTIVE USE OF GNSS IN MARITIME

As it comes to the added value of the future GNSS, Galileo system will improve the GNSS applications in Maritime, e.g.:

Search and Rescue will allow near real time alert localisation and message detection, higher beacon localization accuracy, high availability and global multi-satellite coverage. It will reduce the false alert rate thanks to return link service.

In Fisheries, the Galileo authentication service has high potential.

Galileo will bring benefits to river navigation and port operations thanks to the higher number of visible satellites in urban and mountainous environments.

In autonomous vessels, precise requirements still need to be defined, but it is expected that Galileo could help achieve accuracy and availability requirements, while EGNOS could support the fulfilment of integrity requirements.

Interviews also underline the trend towards the adoption of multi-GNSS, but expecting the ability to select the constellation and/or the satellites based on the comparison of the observed performances. Detailed information about the contents of the interviews is enclosed in Appendix D.

5.3 POLICY AND REGULATORY FRAMEWORK

5.3.1 POLICY AND REGULATORY STAKEHOLDERS

Shipping is a truly international industry, and it can only operate effectively if the regulations and standards are themselves agreed, adopted and implemented on an international basis. For this reason, the maritime domain is highly regulated, and regulations have been reinforced over the last decades. The main principles constituting the basis of shipping regulations are harmonized national rules based on international conventions and resolutions enacted by the International Maritime Organization (IMO).

Additionally to IMO, other organizations are involved in the regulatory and normative environment of the maritime domain: IALA (International Association of the Marine Aids to Navigation and Lighthouse Authorities), CIRM (Comité International Radio Maritime), EMRF (European Maritime Radionavigation Forum), IMPA (International Maritime Pilots' Association) and RTCM (Radio Technical Commission for Maritime Services). A brief description is provided here after for the main relevant international organizations ([RD16]):

INTERNATIONAL ORGANISATIONS

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

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

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

AS AN INTERNATIONAL INDUSTRY, SHIPPING CAN ONLY OPERATE EFFECTIVELY WHEN GOVERNED BY GLOBALLY ACCEPTED REGULATIONS.

The functions of IALA include, among other things:

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

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

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

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

IALA being an *association* rather than an international / intergovernmental body, it is not subject to the same procedures as the IMO, and can therefore publish or update reference documents in a much faster way. Note however that there are never any conflicts between IMO and IALA, IALA documents always making reference to the relevant IMO ones. IALA and IALA members also contribute actively to IMO, which makes the two bodies even more complementary.

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

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

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

IEC: International Electro-technical Commission. The IEC prepares and publishes international standards for all electrical, electronic and related technologies. These serve as a basis for national standardization and as references when drafting international tenders and contracts.

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

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

5.3.2 IMO REGULATIONS RELATED TO GNSS USER REQUIREMENTS

SOLAS CONVENTION

The International Convention for the Safety of Life at Sea (SOLAS) [RD1] is an international maritime safety treaty. It ensures that ships flagged by signatory States comply with minimum safety standards in construction, equipment and operation. Adopted in November 1974 and entered into force in May 1980, the latest amendments are dated May 2011. The SOLAS Convention in its successive forms is generally regarded as the most important of all international treaties concerning the safety of ships.

The SOLAS convention sets the frame for all the IMO resolutions listed here after. In particular unless specifically mentioned most resolutions are relevant only for SOLAS vessels.

RESOLUTION A.915 (22)

One of the most important regulations on the use of GNSS applied to maritime applications is the resolution A.915(22) "*Revised Maritime Policy And Requirements For A Future Global Navigation Satellite System (GNSS)*" from the International Maritime Organization (IMO), adopted on 29 November 2001 [RD3].

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

Proposals of a specific future GNSS should be presented to IMO for recognition, which will then assess such proposals on the basis of any revised requirements.

Maritime requirements can be subdivided into general, operational, institutional and transitional requirements:

General requirements include the requirements to serve the operational user, primarily for general navigation, including in restricted waters and harbour entrances and approaches, as well as for operational navigation and positioning. They also include the requirements to use local augmentation in order to meet additional area-specific requirements. These augmentation provisions must be harmonized worldwide so that a ship will not need to carry more than one shipborne receiver. The GNSS must be able to be used by an unlimited number of multimodal users, being also reliable and of low user cost.

Operational requirements include integrity, continuity, accuracy, availability and others, which refer to both general navigation and positioning applications. It also states that service providers are not responsible for the performance of shipborne equipment and recommends the integration of GNSS and terrestrial systems, using compatible geodetic and time reference systems, in order to provide the users with information on position, time, course and speed over the ground. Finally, they insist on the need that the system informs users of degradations in performance through the provision of integrity messages.

The **institutional requirements** intend to ensure that GNSS is controlled by an international civil organization, existent or to be created, who should have the means of supervising provision, operation, monitoring and control of the system at minimum cost. Although IMO is not in the position to provide and operate a GNSS, it must be able to assess and recognize its provision and operation regarding maritime users, and application of internationally established principles.

Lastly, the **transitional requirements** concern the development of future GNSS in parallel to present satellite navigation systems. It states that an already fully operational system may be recognized as a component of the WWRNS and that shipborne receivers should be compatible with the equipment required for current satellite navigation systems.

This resolution separates general navigation into five **environments**, in order to address their specific needs in terms of accuracy, integrity, availability, continuity, coverage and fix interval:

- Ocean;
- Coastal;
- Port approach and restricted waters;
- Port;
- Inland Waterways.

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

RESOLUTION A.1046 (27)

IMO Resolution A.1046 (27) "Worldwide Radionavigation System" [RD6], adopted on 30 November 2011, describes procedures concerning recognition of World Wide Radio Navigation System and requirements regarding shipborne receiving equipment and operational requirements for a World Wide RadioNavigation System (WWRNS). Among the updated requirements introduced by A.1046 (27), the following should be highlighted:

- There is no more mention to high vs. low traffic/risk (as compared with A.953 (23) [RD5];
- The continuity risk has been modified to 15 min (as compared to A.915 (22) [RD3] and A. 953 (23) [RD5]).

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

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

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

It is important to highlight that the operational requirements in IMO resolution A.1046 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 6: IMO Resolution A.1046 (27) performance requirements

IMO Resolution A.1046 (27)	Horizontal Error (95%)	Update Rate	Availability (signal)	Integrity Warning (system)	Continuity (service)
Ocean Waters	100m	once/2s	99,80%	ASAP by MSI	N/A
Harbour Entrances, Harbour Approaches and Coastal Waters	10m	once/2s	99,80%	10s	99,97% over 15min

5.3.3 IALA RECOMMENDATIONS AND GUIDELINES

Although IALA recommendations lack the regulatory force of IMO resolutions, "*there is an implicit expectation that individual national members will observe and implement IALA Recommendations*" [RD14].

Actually the SOLAS Convention recalls IALA's Guidelines on specific topics. Furthermore, such recommendations are referring to relevant international standards and regulations, very often including parts of them, together with clarifications, explanations and complementary information (e.g. contextual). In short, they are almost self-sufficient, with the possible exception of equipment manufacturers which may have to refer to IEC complementary standards.

IALA DOCUMENTS CAN BE USEFUL IN UNDERSTANDING IMO REQUIREMENTS WITHIN AN OPERATIONAL CONTEXT.

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.

Relevant IALA documentation is discussed in 7 for reference.

5.3.4 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;
- radiowave 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.

(Source: ITU web site www.itu.int/pub/R-REC)

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*.

Relevant ITU documentation is discussed in 7 for reference.

5.3.5 IEC STANDARDS

The "IEC Technical Committee 80" produces operational and performance requirements together with test methods for maritime navigation and radiocommunication equipment and systems.

The committee provides industry with standards that are also accepted by governments as suitable for *type approval* where this is required by the International Maritime Organization's SOLAS Convention. Such standards deal with all electrical, electronic and related technologies; and by extension issues with other issues concerning the design of the equipment, its power supplies, Electromagnetic Compatibility (EMC) and safety. *These standards do no deal with user requirements* in any way; they allow test certification agencies to declare equipment "fit for use" through type approval procedures.

Relevant IEC documentation is discussed in 7 for reference.

5.3.6 EC - RIVER INFORMATION SERVICE (RIS)

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

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

DIRECTIVE 2005/44/EC AND AMENDMENT 219/2009

This Directive dated 7 September 2005 and its Amending Act Reg. 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.

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

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

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

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

REGULATION (EC) NO 414/2007

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

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

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

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

Table 7: Overview of accuracy requirements for RIS dynamic data

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

1 In addition, the requirements of the IMO Resolution A.915 (22) regarding the integrity, the availability and the continuity for position accuracy on inland waterways shall be fulfilled.

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.

5.3.7 EUROPEAN RADIONAVIGATION PLAN (ERNP)

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

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

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

5.3.8 US FEDERAL RADIONAVIGATION PLAN (FRP)

INTRODUCTION

In this chapter , the Maritime User Requirements in the U.S.A. present in the 2017 Federal Radio Navigation Plan [RD32] are discussed.

The FRP separates requirements into phases of navigation and relates them to nautical conditions (distance to the closest danger, but also type of craft). Four major phases are identified, namely *inland waterways, harbour entrance and approach, coastal* and *ocean navigation*. In comparison, IMO A.915(22) [RD3] identifies a 5th phase: "*port*" which is not discussed in the FRP. It is to be noticed though that IMO requirements for "*port navigation*" are currently subject to discussion and are indeed lacking justification or traceability.

Another important aspect of the FRP is that it distinguishes requirements for "safety of navigation" and requirements for "benefits" (most often economic benefits). These requirements are summarised hereafter, together with their context.

Finally, the FRP introduces requirements for underwater navigation that cannot be found anywhere else.

INLAND WATERWAY

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

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

HARBOUR ENTRANCE AND APPROACH

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

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

Table 8: FRP Maritime User Requirements - Inland Waterway Phase

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	ACCURACY (meters, 2 drms)	AVAILABILITY	CONTINUITY	INTEGRITY	TIME TO ALERT	COVERAGE
Safety of Navigation (All Ships and Tows)	2-5	99.9%	*	N/A	N/A	U.S. Inland Waterway Systems
Safety of Navigation (Recreational Boats and Smaller Vessels)	5-10	99.9%	*	N/A	N/A	U.S. Inland Waterway Systems
River Engineering and Construction Vessels	0.1**-5	99%	*	N/A	N/A	U.S. Inland Waterway Systems

* Dependent upon mission time.

** Vertical dimension.

Table 9: FRP Maritime User Requirements/Benefits - Harbour Entrance and Approach Phase

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	ACCURACY (meters, 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.

BENEFITS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					
	ACCURACY (meters, 2drms)	AVAILABILITY	CONTINUITY	INTEGRITY	TIME TO ALERT	COVERAGE
Fishing, Recreational and Other Small Vessels	8 – 20	99.7%	**	N/A	N/A	U.S. harbour entrance and approach

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

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

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

COASTAL

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

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

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

The need for larger vessels to navigate within the designated one-way traffic and at safe distances from shallow water

The need to define accurately the boundaries of the Fishery Conservation Zone, the U.S. Customs Zone, and the territorial waters of the U.S.

Table 10: FRP Maritime User Requirements/Benefits - Coastal Phase

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	ACCURACY (meters, 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. coastal waters
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

BENEFITS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					
	ACCURACY (meters, 2drms)	AVAILABILITY	CONTINUITY	INTEGRITY	TIME TO ALERT	COVERAGE
Commercial Fishing (Include Commercial Sport Fishing)	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal / Fisheries areas
Resource Exploration	1.0 – 100 m*	99%	**	N/A	N/A	U.S. coastal areas
Search Operations, Law Enforcement	0.25 nmi (460 m)	99.7%	**	N/A	N/A	U.S. coastal/ Fisheries areas
Recreational Sports Fishing	0.25 nmi (460 m)	99%	**	N/A	N/A	U.S. coastal areas

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

OCEAN NAVIGATION

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

Table 11: FRP Maritime User Requirements/Benefits - Ocean Phase

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	ACCURACY (meters, 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 hr	**	N/A	N/A	Worldwide

BENEFITS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET BENEFITS					
	ACCURACY (meters, 2drms)	AVAILABILITY	CONTINUITY	INTEGRITY	TIME TO ALERT	COVERAGE
Large Ships Maximum Efficiency	0.1 – 0.25 nmi* (185 – 460 m)	99%	**	N/A	N/A	Worldwide, except polar regions
Resource Exploration	10 – 100 m*	99%	**	N/A	N/A	Worldwide
Search Operations	0.1 – 0.25 nmi (185 – 460 m)	99%	**	N/A	N/A	National Maritime SAR regions

* 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:

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS					
	ACCURACY (meters, 2 drms)	AVAILABILITY	CONTINUITY	INTEGRITY (Alert Limit)	RECORDING RATE	COVERAGE
Sub-Surface Marine Applications	0.1 – 5 m	90-99%	N/A	0.2 – 10 m	1 – 15 s	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:

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS						
	ACCURACY (meters, 2 drms)		AVAILABILITY	CONTINUITY	INTEGRITY (session duration)	RECORDING RATE	COVERAGE
	H	V					
Hydrographic Survey	3	0.15	99%	1-8x10-6/15 s	1 s	1 s	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;
- Environment;
- Energy Conservation.

5.3.9 IHO REQUIREMENTS

The International Hydrographic Organization (IHO) role is to ensure that world's seas, oceans and navigable waters are surveyed and charted. IHO requirements concern the accuracy of nautical charts and are not *directly* related with IMO expressed requirements concerning positioning of ships. There is however an inherent relation, since a vessel position as reported by its "Electronic Position Fixing Device" is feeding its ECDIS and is plotted on the displayed electronic chart. The consistency between the nautical charts accuracy and the positioning equipment is discussed in paragraph 5.4.4 of this report.

As for nautical charts, the following requirements can be found in [RD50]:

Table 12: 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 THU* (95% *Confidence level*)	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)	2 metres	2 metres	2 metres	5 metres
Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)	10 metres	20 metres	20 metres	20 metres
Mean position of floating aids to navigation (95% *Confidence level*)	10 metres	10 metres	10 metres	20 metres

*Total Horizontal Uncertainty

However, not all available nautical charts are conform to these requirements. Indeed, many have been produced with equipment obsolete by today's standards, and some areas are poorly chartered. Newly produced chart on the other hand often use state of the art methods and equipment, and exceed these requirements. To depict this situation, cartographers use "Category Zone of confidence" values (CATZOC) to highlight the accuracy of data presented on charts (which may differ from the above table). The following table outlines the position accuracy, depth accuracy and seafloor coverage for each ZOC value (source: UK Admiralty https://www.admiralty.co.uk/AdmiraltyDownloadMedia/Blog/CATZOC%20Table.pdf):

5.3.10 OTHER ORGANISATIONS

Other organisations are in close contact with maritime user communities, such as the International Marine Contractors Association (IMCA). However, they do not issue user requirements in a form suitable to input to this document. IMCA specifically concerns marine engineering and oil and gas specific operations, providing mainly guidelines and recommendations rather than navigation or positioning requirements. In particular, the document [RD48] presents the GNSS techniques (including DGNSS, RTK, PPP, WADGNSS) and performances; and provides guidelines for the use of GNSS to position

Table 13: ZOC (Zone Of Confidence) values for hydrographic charts

ZOC	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics
A1	± 5 m + 5% depth	=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 30 100 1000	± 0.6 ± 0.8 ± 1.5 ± 10.5		
A2	± 20 m	= 1.00 + 2%d		Full area search undertaken. Significant seafloor features detected and depths measured.	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
B	± 50 m	= 1.00 + 2%d		Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echosounder, but no sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
C	± 500 m	= 2.00 + 5%d		Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 2.5 ± 3.5 ± 7.0 ± 52.0		
D	*Worse than ZOC C*	Worse than ZOC C		Full search not achieved, large depth anomalies expected.	Poor quality data or data that cannot be quality assessed due to lack of information.
U	Unassessed - The quality of the bathymetric data has yet to be assessed				

vessels, vehicles and other fixed and mobile installations during oil exploration and production related surveying and positioning activities.

5.3.11 POTENTIAL REGULATION EVOLUTION

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

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

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

Interviews also stressed the need to address multi-constellation equipment, and in particular the capability to choose which constellation and/or satellite to use in a certain moment based on the comparison of their performance. Performance in difficult environments is also not addressed, e.g. in the middle of the storm with limited sky visibility. In those cases, the receiver might be looking to a part of the sky, then due to a wave looking to another part losing previous satellites. Cold start has also been highlighted as a critical criterion for all those applications requiring to turn on the GNSS receiver only in particular circumstances (e.g. beacons).

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

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

Roles and activities of IALA, ITU, IEC, IHO, IMCA, EC and US (FRP) in the potential regulation evolution should be considered in a future version of the document.

5.4 CRITICAL ANALYSIS

5.4.1 ANALYSIS OF IMO REQUIREMENTS

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

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

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

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

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

A 1106 (29) - REVISED GUIDELINES FOR AIS

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

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

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), according to the study "A critical look at the IMO requirements for GNSS" [RD47] undertaken within the scope of MarNIS FP6 project (Maritime Navigation and Information Services, see E.2). However, IMO Resolution A.1046 (27) 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.

Similarly, resolution A.915 (22) should be revised to be consistent with A1046 (27). Such a revision however cannot be realized before 2018, according to EMRF.

5.4.2 ANALYSIS OF IALA RECOMMENDATIONS AND GUIDELINES

Although IALA recommendations lack the regulatory force of IMO resolutions; "*there is an implicit expectation that individual national members will observe and implement IALA Recommendations*" [RD14]. Actually the SOLAS Convention recalls IALA's Guidelines on specific topics. Furthermore, such recommendations are referring to relevant international standards and regulations, very often including parts of them, together with clarifications, explanations and complementary information (e.g. contextual). In short, they are almost self-sufficient, with the possible exception of equipment manufacturers which may have to refer to IEC complementary standards.

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

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

5.4.3 COMPARISON BETWEEN IMO AND US REGULATION

There are significant differences in the way the US FRP on one hand, and current IMO resolutions on the other hand, list and justify user requirements. In many ways, the FRP is closer to the IALA Navguide [RD14] than to IMO resolutions:

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

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

Table 14 : Comparison between FRP and IMO user requirements for safety of navigation

Phase of Navigation	ACCURACY (meters, 2 drms)		AVAILABILITY % / period		CONTINUITY (over 15 min)		INTEGRITY (Alert Limit / risk per 3 hours)		TIME TO ALERT (s)	
	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	-	2.5 10^{-5}	-	10	-
Inland waterways	10	2 - 5	99.8 30 days	99.9	99.97	*	25 10^{-5}	TBD	10	TBD

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

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

The most likely explanations are:

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

5.4.4 COMPARISON 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 15: 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 encountered in Ports, Inland Waterways and possibly Ports Approaches,	Continental shelf, such as encountered for Coastal navigation and Port approaches	Continental shelf, such as encountered for Coastal navigation and Port approaches (low SOLAS traffic area)	Beyond continental shelf, i.e. mostly abyssal plain (depth averaged at 4000 metres); such as encountered in Oceanic navigation
IMO phase of navigation	Ports Inland Waterways (Ports Approaches)	Coastal navigation Port approaches	Coastal navigation Port approaches	Ocean
IMO accuracy requirement	**1 metre** **10 metres**	**10 metres**	**10 metres**	**10-100 metres**
IHO accuracy requirement (most stringent)	2 metres	2 metres	2 metres	5 metres
IHO Maximum allowable THU*	2 metres	5 metres + 5% of depth; i.e. 5 to 10 metres	5 metres + 5% of depth; i.e. 5 to 10 metres	20 metres + 10% of depth; i.e. 30 to 420 metres
Comments	IMO accuracy requirements for port navigation are more stringent than IHO most stringent ones	Consistent	Consistent	Except for isolated hazards to navigation, the IMO "en-route" accuracy requirements are more stringent than the IHO ones.

*Total Horizontal Uncertainty

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

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

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

GNSS CANNOT MEET ALL OPERATIONAL REQUIREMENTS, ESPECIALLY INTEGRITY, WITHOUT THE USE OF AUGMENTATION SYSTEMS.

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 en-route navigation, the seafloor is mapped with a required accuracy of typically 500 metres (for 5000 m depth); when mapped at all. Here again, *the IMO accuracy requirement is largely better than the nautical charts required accuracy* (the US FRP is more consistent on this aspect). *Such requirement cannot generate harmful situations, but cannot either be justified by safety of navigation reasons only*.

Hydrographers are well aware of these discrepancies between:

- The position accuracy obtained by mariners using modern electronic position fixing equipment (typically GNSS) and the required (per IHO) horizontal accuracy of charts;
- The actual accuracy of the available charts and the required (per IHO standards) accuracy.

Actually, nautical charts are produced or updated using state of the art equipment, which is indeed more accurate than the minimum IHO requirement or than the position available to mariners via "standard" EPFS / GNSS. However, the rate of production and / or of updates of the nautical charts does not allow to have a complete portfolio of "modern" charts covering the whole surface of the oceans. To cope with this difficulty and to inform users of the real quality of their nautical documents, cartographers use the concept of "Zones of Confidence", ranging from Category A1 (best) to U (unassessed quality). Refer to section 5.3.9 for full details.

5.4.5 GNSS AND AUGMENTATION SYSTEMS LIMITATIONS

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

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

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

As part of the e-Navigation strategy, the Maritime community is strongly involved in the development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "*multi-system shipborne navigation receiver*" for which performance standards have been published in June 2015 (see [RD53] "Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land based radionavigation.

5.4.6 INLAND WATERWAYS - SPECIAL ANALYSIS ON USER REQUIREMENTS WITH IMO, FRP, EC, MARUSE

Previous chapters show the different requirements for inland waterways safety of navigation proposed by IMO, FRP, EC and Maruse project. In this chapter an analysis of these requirements for merchant vessels is presented using the values specified in IMO resolution A.915 and A.1046 as the reference. IMO resolution A.915 sets the value of 10m accuracy (95%) and 25m for the Horizontal Alert limit. These values for accuracy are applicable in Europe by REGULATION (EC) No 415/2007. These are the values to be taken into

account for the mission. In case of specific operations under bridges or in locks, the regulation sets 1m accuracy (95%). On the other hand, the MARUSE project proposed a more stringent requirement for inland waterways navigation with 3m accuracy (95%) and 7.5m as Horizontal Alert limit while keeping the rest of the values as in IMO resolutions. The MARUSE project also proposed to measure the continuity over 15 minutes in line with IMO resolution A.1046, proposing this change with respect IMO resolution A.915. In the Federal Navigation Plan, the requirement for inland waterways for merchant vessels and tows an accuracy in the range of 2-5m (95%) is proposed depending if it is a merchant vessel or a tow performing complex manoeuvres. Finally IHO is proposing for the hydrographic surveys that are used to update the navigation charts an accuracy of 2m (95%) in those areas where under-keel clearance is critical.

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

5.5 CONCLUSIONS

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

Table 16: Parameters for the user requirements synthesis

Phase of Navigation	ACCURACY (m 95%)				AVAILABILITY % over period		CONTINUITY (% over 15 min)	INTEGRITY (Horizontal Alert Limit (m) / risk per 3 hours)		TIME TO ALERT (s)
	IMO/ EC	MARUSE	FRP	IHO	IMO/ MARUSE	FRP	IMO/MARUSE	IMO	MARUSE	IMO/ MARUSE
Navigation in Inland waterways	10	3	2 – 5	2	99.8% over 30 days	99.9%	99.97%	25 / 10^{-5}	7.5/ 10^{-5}	10

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

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

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

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

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

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

These user requirements have been validated (and updated when necessary) by a 1st User Consultation Platform, held in Madrid in November 2017. Considering the evolutions of the available technologies, the applications and the corresponding user needs, this document will be regularly updated and submitted to experts review and validation through future UCP meetings.

06 USER REQUIREMENTS SPECIFICATION

6.1 SYNTHESIS OF THE UR ANALYSIS

This chapter presents the synthesis of the maritime user requirements, as extracted from the many sources reviewed in this document. The references are presented in 7 0 and an analysis of past projects potentially of interest is provided in 0 (in particular PROSBAS in E.8).

As discussed in Chapter 5.4 above, such a synthesis is almost impossible, since:

- Documents originating from various sources cannot be directly compared;
- None of the studied documents can be considered "self-sufficient";
- There are huge discrepancies between stated performance values, e.g. for oceanic navigation where IMO A.915 quotes an accuracy of 10 m versus 1800 m for the US FRP;
- The justification or traceability of the quoted requirements is missing, especially in IMO resolutions (IALA guidelines & Navguide, as well as the US FRP, make some attempts at putting the requirements in context);
- The two major IMO resolutions on this subject are not fully consistent, and the only way to reconcile them is to consider that one applies for current requirements (A.1046) while the other deals with future requirements (A.915);
- Some requirements are almost impossible to comprehend, and there is often no way to trace the origin of these requirements to get a justification e.g. accuracy for oceanic navigation which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the manoeuvre;
- The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are not present.

We have consequently elected to deliberately eliminate some documents and to keep only the most widely accepted ones in the maritime community (i.e. IMO resolutions A.915(22) and A.1046(27), even though they are not beyond criticism as discussed above).

The reader should be aware that the selection of documents to be retained or eliminated from this consolidation has a very significant influence on the results. In this respect, our choice of IMO will likely meet the widest institutional, regulatory or political acceptance. There is no guarantee however that it is the most accurate representation of actual user needs.

FOR EUROPEAN USERS, THE ARCTIC SEA HAS SIGNIFICANT POTENTIAL THANKS TO THE SAFETY BENEFITS THAT EGNOS MAY BRING.

We have also limited the analysis of the inland waterways needs to the general IMO approach, although the European RIS regulation, the MARUSE project, and to a lesser extent the US FRP would allow to derive a very detailed list of specifications. However, the horizontal accuracy parameter for IWW stated by IMO being widely accepted as not stringent enough, we had retained the MARUSE value.

We have retained all applications listed by the resolution IMO A.915 because it is indeed the internationally agreed reference document summarising the needs of the Maritime users.

To facilitate the analysis, applications were grouped into sets defined through similar Recommended Navigation Performance (RNP) parameters (3 categories corresponding grossly to 10, 1, and 0.1 m horizontal accuracy).

Table 17: Parameters for the user requirements synthesis

	Origin of the specification
Availability (% over 30 days)	**IMO** requirements Except Accuracy horizontal (95%) in IWW
Accuracy Horizontal (95%)	
Accuracy Vertical (95%)	
Continuity (over 15 min)	
Continuity (over 3 hours)	
Error max	
Probability	
Update Rate	
Integrity Warning	
Integrity - Alert Limit	
Integrity - Time to Alert	
Integrity Risk (per 3 hours)	
Coverage	
Fix Interval (seconds)	

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.

6.1.1 CATEGORY 1

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

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

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-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
GSA-MKD-USR-REQ-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
GSA-MKD-USR-REQ-MAR-0030	Continuity is not relevant to ocean and coastal navigation.	Performance (Continuity % over 3 hours)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0040	The PNT solution shall provide a 25 m horizontal alert limit	Performance (Integrity - Alert Limit)	Resolution IMO A.915(22) -29/11/2001 (not mandatory for the applications in IMO resolution A.1046)
GSA-MKD-USR-REQ-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
GSA-MKD-USR-REQ-MAR-0060	The PNT solution shall have an integrity risk smaller than 10^{-5} per 3 hours	Performance (Integrity Risk –per 3 hours)	Resolution IMO A.915(22) -29/11/2001 (not mandatory for the applications in IMO resolution A.1046)
GSA-MKD-USR-REQ-MAR-0070	The PNT solution shall have global coverage	Performance (Coverage)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0080	The PNT solution shall provide independent position fixes at least two per second	Performance (Fix Interval-seconds)	Resolution IMO A.1046(27) 20/12/2011

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

6.1.2 CATEGORY 1+

(same as 1 + regional continuity requirement)

This category differs from the previous one only regarding continuity, which is needed to be regional in this case and of 99.97%.

This category includes the following applications:

2019 update

- General navigation (SOLAS); Coastal, Port approach and entrances;
- General navigation (recreation and leisure); port approach and entrances;
- Traffic management; Ship to ship coordination, Ship to shore coordination and Shore to ship traffic management;
- Operations: automatic collision avoidance and track control.

2019 update

Requirements are identical to Category 1, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0090	The PNT solution shall have regional coverage	Performance (Coverage)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0100	The PNT solution shall have a continuity of 99,97 % over 15 minutes.	Performance (Continuity, **% over 15 minutes**)	**Resolution IMO A.1046(27) 20/12/2011**

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

6.1.3 CATEGORY 1++

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

This category includes the following application:

- General navigation (SOLAS); Inland waterways

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0101	The PNT solution shall provide 3 m horizontal positioning accuracy (95%)	Performance (Accuracy Horizontal)	MARUSE + UCP 2017

6.1.4 CATEGORY 1+++

This category presents the same requirements of Category 1, except the vertical accuracy, which must be of 10m for this application.
Even though Oceanography application did not have its environment clearly defined in IMO Resolutions, it is placed in Ocean environment because it describes the application more accurately than placing it in a more general environment category.

Requirements are identical to Category 1, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0110	The PNT solution shall provide 10 m vertical positioning accuracy (95%)	Performance (Accuracy Vertical)	Resolution IMO A.915(22) -29/11/2001

6.1.5 CATEGORY 2

This category is characterized by having **1 m horizontal accuracy** requirement.

This category includes the following applications:

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

2019 update

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

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

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

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

*Except Local VTS which requires only a local coverage.

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

6.1.6 CATEGORY 2+

(same as 2 + local continuity requirement)

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

This category includes the following applications:

2019 update

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

Operations of Tugs, Pushers and Icebreakers did not have their environment stated by IMO and were considered to fit best in the widest Environment category: Ocean, Coastal, Port and Port approach, Restricted Waters and Inland Waterways.

IMO resolutions indicate the need of relative accuracy for tugs, pushers and icebreakers and a possible requirement of vertical accuracy depending on the port and restricted water operation.

Requirements are identical to Category 2, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0210	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) -29/11/2001 Regulation (EC) No 415/2007
GSA-MKD-USR-REQ-MAR-0220	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity, % **over 15 minutes**)	**Resolution IMO A.1046(27) 20/12/2011** Regulation (EC) No 415/2007

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

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

6.1.7 CATEGORY 2++

(same as 2 + local 1m vertical accuracy requirement)

This category differs from Category 2 in the need of 1m vertical accuracy requirement.

This category includes only the following applications according to IMO:

- Ports operations: Container / Cargo management & Law enforcement

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

Requirements are identical to Category 2, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0230	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0240	The PNT solution shall provide 1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95 %)	Resolution IMO A.915(22) -29/11/2001

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

6.1.8 CATEGORY 2+++

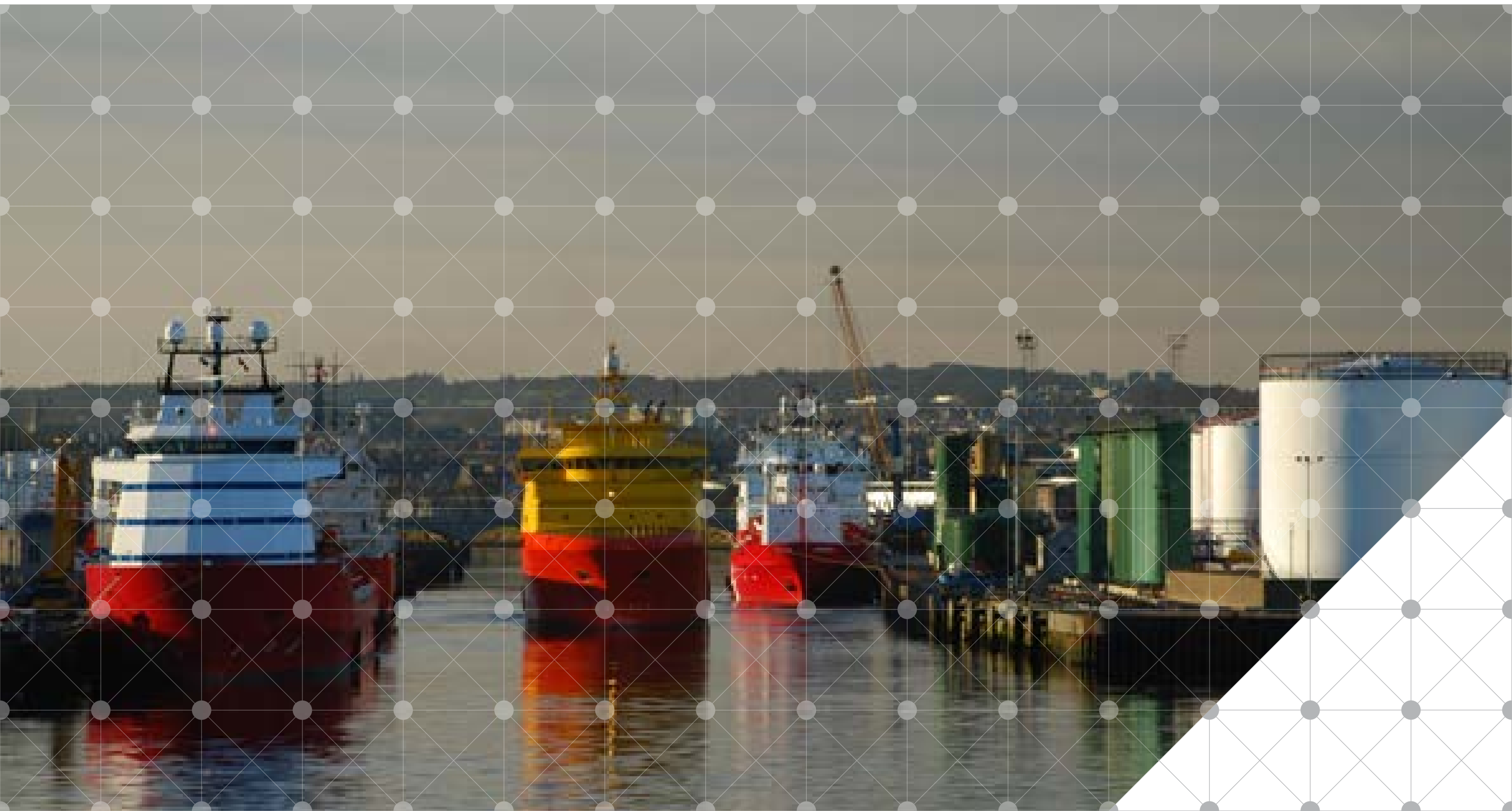
(2 with relaxed horizontal accuracy + 0.1m vertical accuracy requirement)

This category presents the same requirements as of those in category 2, except for the horizontal accuracy, which varies from 1 to 2m, the vertical accuracy, which must be of 0.1m, and the alert limit, which needs to be between 2.5 and 5m in the horizontal axis. It comprises hydrography and bridges operation in inland waterways.

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

Requirements are identical to Category 2, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0250	The PNT solution shall provide 1 to 2 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) -29/11/2001 Regulation (EC) No 415/2007
GSA-MKD-USR-REQ-MAR-00260	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-00270	The PNT solution shall provide a 2.5 to 5 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) -29/11/2001 Regulation (EC) No 415/2007



2019 update

6.1.9 CATEGORY 3

(0.1m horizontal accuracy requirement)

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

- Marine Engineering
- Inland Waterways: bridge collision warning systems

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

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0280	The PNT solution shall have a 99.8% availability over any 30 day period	Performance (Availability, % per 30 days)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0290	The PNT solution shall provide 0.1 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0300	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0310	The service continuity (% over 3 hours) is not applicable to Category 3 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0320	The PNT solution shall provide a 0.25 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0330	The PNT solution shall have a time to alarm smaller than 10 s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0340	The PNT solution shall have an integrity risk smaller than 10^{-5} per 3 hours	Performance (Integrity – Integrity risk, per 3 hours)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0360	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22) -29/11/2001

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

6.1.10 CATEGORY 3+

(same as 3 – no vertical accuracy + continuity requirements)

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

2019 update

This category includes the following applications:

- Operations: Docking

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

Requirements are identical to Category 3, except the following:

Id	Description	Type	Source
GSA-MKD-USR-REQ-MAR-0370	The vertical positioning accuracy is not applicable for Category 3+ applications	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) -29/11/2001
GSA-MKD-USR-REQ-MAR-0380	The PNT solution shall have a continuity of 99,97 % over 15 minutes*	Performance (Continuity, % over 15 minutes)	Resolution IMO A.1046(27) 20/12/2011
2019 update GSA-MKD-USR_REQ-MAR-0390	The Accuracy of SOG is 0.1m/s	Performance (Accuracy of SOG)	IEC-61108-3 – 26/05/2010

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

6.1.11 CATEGORY 3++

(same as 3 + stringent TTA requirement)

The main difference between this category and Category 3 regards integrity: here the time to alarm must be smaller than 1s.

It only concerns cargo handling.

Requirements are identical to Category 3, except the following:

Id	Description	Type	Source
2019 update GSA-MKD-USR-REQ-MAR-400	The PNT solution shall have a time to alarm smaller than 1 s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) -29/11/2001

6.2 COVERAGE NEEDS FOR MARITIME USERS IN EUROPE

This chapter is focused on the coverage needs for maritime users in Europe.

It reports results obtained by a dedicated study carried in 2016, supported by a complete traffic analysis elaborated from AIS data in the period 2013-2014. The density maps generated help better understanding the nature of the maritime activities around Europe, and identifying the service levels to be guaranteed in the future.

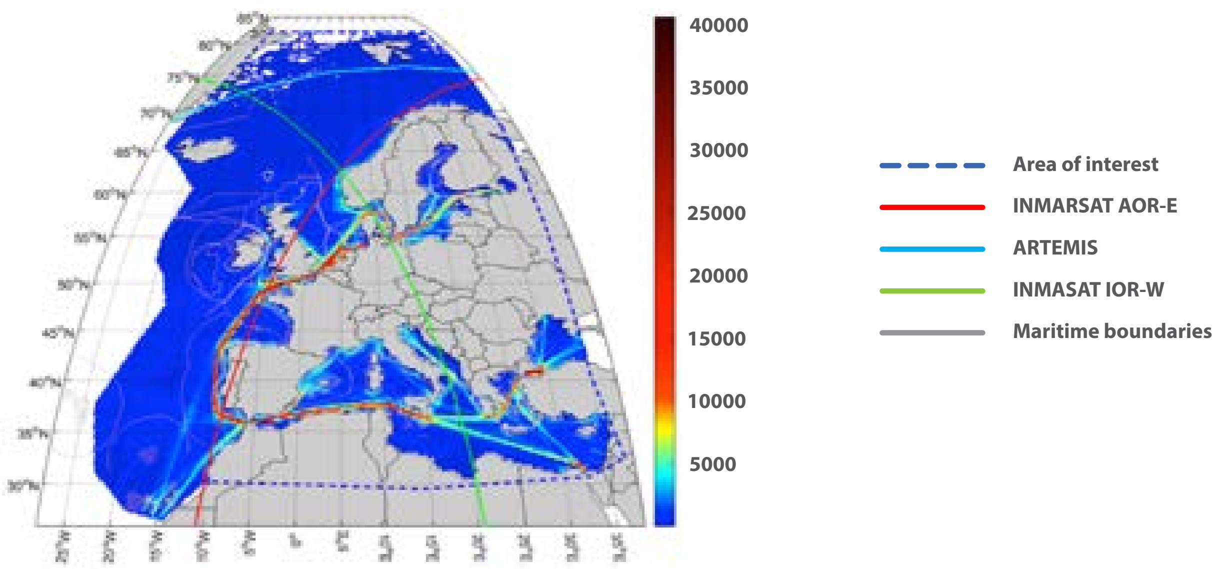
The activity of the SOLAS vessels has been dimensioned and the prevailing shipping routes and areas where the main operations take place have been identified. The operations that take place in every geographical region have been also identified. The outcomes by sub-region are as follows:

- In the **Arctic zone**, cargos and fishing are the AIS categories concentrating the vast majority of traffic. A very high percentage of the SOLAS routes (including the Northeast Passage) and areas of operations are less than 140 nautical miles from the coast, well within the nominal coverage for IALA beacons stations. The number of ships going over 82° N is very low, in the order of tens.

  The Arctic sea has significant potential thanks to the benefits that EGNOS may bring in the safety of the operations in those cold and harsh climatic conditions. The current provision of the EGNOS services is anyway limited to 75°N as it is conditioned by the footprints of the geostationary satellites broadcasting the signal. Waiting for long-term solutions likely involving broadcasting EGNOS signals from polar satellites, the broadcast of EGNOS messages from AIS and IALA stations could be act as a short-term enabler for a maritime usage of EGNOS in this region;

- In the area including the **Mediterranean Sea, the Atlantic East and the Turkish Straits**:
  - The Suez Route concentrates a very high SOLAS traffic (mainly cargo and tanker) due to its important role as a connection between the Atlantic, the Mediterranean, the Arabian Sea and the Indian Ocean. Most of the areas traversed by the Suez Route are out of the volume where more demanding performances are currently offered by EGNOS. The same applies for a possible use of EGNOS to support the coastal, port approach, and port operations in the south Mediterranean coast,
  - The Turkish Straits present a significant growth in traffic of all SOLAS vessels, particularly noticeable in the ports and the routes over the Marmara Sea and the Turkish Straits,
  - Routes between the Canary Islands and the European continent are also well-established and show relevant traffic intensities.

Figure 5: Map of maritime traffic – 2014



07 ANNEXES

APPENDIX 1
PERFORMANCE PARAMETERS

HORIZONTAL POSITION ACCURACY

Statistical measure of the horizontal position (or velocity) error (e.g. 95th percentiles of the cumulative error distribution), being this error the difference between the true horizontal position and the position (or velocity) estimated by a positioning system at a given time. The requirements for this feature can range from relaxed constraints for personal navigation applications, to more stringent ones for LCA such as road user charging and tracking of dangerous goods.

VERTICAL POSITION ACCURACY

Statistical measure of the vertical position error (e.g. 95th percentiles of the cumulative error distribution), being this error the difference between the true vertical position and the position estimated by a positioning system at a given time. This feature applies when vertical guidance is required, for instance to allow proper positioning in case of parkade (multi-levels parking) or overlapping road segments, especially in urban environments.

GNSS TIME ACCURACY

Statistical measure of the GNSS time error (e.g. 95th percentiles of the cumulative error distribution), being this error the difference between the true GNSS time (as implemented in the GNSS system timing facility) and the time returned by the positioning system based on the PVT solution. Generally, this feature is of interest for applications requiring synchronisation of assets distributed across wide geographical areas, where GNSS time is used as a reference. Focusing on the road segment, GNSS time accuracy applies for example in case on VANET applications (involving a very large number of distributed nodes) that in future might require the use of synchronous Medium Access Control (MAC) in order to overcome the known scalability issue of the decentralized and asynchronous Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) method.

TIME TO FIRST FIX

Time taken by the positioning system to report a PVT solution (fix) starting either from the reception of a specific “start” request, or from another triggering event that switches the positioning system on. This feature is of particular interest for the navigation support (route guidance) of emergency vehicles, provided that the positioning system in the emergency vehicle has to be prompt to accurately estimate its position.

POSITION AUTHENTICITY

Authenticity 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 position data as output of the system itself.

ROBUSTNESS TO INTERFERENCE

Ability of the positioning system to operate under interference conditions and to maintain the applicable positioning service level requirements. Location Systems might be required to operate in constrained RF environments, in particular in the GNSS frequency bands. Note that interference can be either unintentional or deliberate (e.g. jamming)

POSITION INTEGRITY

General performance feature referring to the trust a user can have in the value of a given PVT provided by a positioning system. It is relevant to SCA and LCA (e.g. critical navigation, billing) where integrity is important. It is expressed through the computation of a protection level associated to a predetermined integrity risk, as a function of the type end-user application

GNSS SENSITIVITY

Minimum GNSS signal strength at the antenna, detectable by the receiver (dBW or dBm). The GNSS sensitivity is a relevant feature in all the applications involving possible urban and light indoor scenarios (especially eCall and emergency services).

AVAILABILITY

The availability of a navigation system is the percentage of time that the services of the system are usable by the users for navigation purposes. Availability is an indication of the ability of the system to provide usable service within the specified coverage area. The availability is one of the most important performance features in supporting any safety-critical application, e.g. emergency services.

CONTINUITY

Continuity is defined as the operation given that the service level requirements are provided at the start of the capability of a system to provide a positioning service fulfilling a set of applicable service level requirements, throughout the intended operation.

POSITION FIX RATE

It is the rate at which the positioning terminal outputs the PVT data. This is not independent from the PVT update rate of the GNSS receiver, for which the typical rate is 1 Hz. Consequently, the distance between two positions if the vehicle drives at 90Km/h, would be 25 meters. Nonetheless some positioning architectures (e.g.: GNSS receiver coupled with inertial sensors) might require higher output rates from the GNSS receiver. For certain automotive application like collision avoidance or red light violation warning the fix rate should be 10 Hz or more.

LATENCY

It represents the time elapsed between the nominal instant at which a set of location data should be produced by the positioning terminal and the instant at which such data are available at the application interface. Generally, for most of existing applications which use GNSS receivers for real-time PVT estimates, this parameter is not critical. Nonetheless, in the context addressed in this document, the PVT latency may matter in two families of cases:

- **GNSS latency**: the first case is the integration of GNSS measurements with other higher-rate sensors, in which a latency in the provision of the PVT-related measurements by the GNSS sensor may encompasses several adjacent measurements of the higher-rate sensor, imposing the need for a non-trivial re- synchronization. This case might be significant for autonomous driving applications, in which high-rate sensors readings may be a safety factor.
- **PVT latency** (from the positioning terminal): the second case represents the situation in which the PVT solution provided by positioning terminal to the application interface is delayed by a certain amount of time with respect to the nominal instant of the measurements, due to the amount of processing performed by the PVT determination function. PVT latency may become non-negligible in case of complex integration processing, or latencies in data retrieval from the sensors or from other external sources (e.g., PPP corrections from the internet).

APPENDIX 2
LIST OF ACRONYMS

Table 18 - Abbreviations

AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
AtoN	Aids to Navigation
CCB	Configuration Control Board
CIRM	Comité International Radio-Maritime
CS	Commercial Service
DFMC	Dual-Frequency Multi-Constellation
DGNSS	Differential Global Navigation Satellite System
DGON	German Institute of Navigation
DGPS	Differential GPS
DSC	Digital Selective Calling
EC	European Commission
ECAC	European Civil Aviation Conference
ECDIS	Electronic Chart Display Information System
EDAS	EGNOS Data Application Service
EGNOS	European Geostationary Navigation Overlay System
E-GNSS	European GNSS
EMRF	European Maritime Radionavigation Forum
ESA	European Space Agency
EU	European Union
FRP	Federal Radionavigation Plan
FTA	Fault Tree Analysis
FTP	File Transfer Protocol
F2F	Face to Face
GBAS	Ground-Based Augmentation System
GMDSS	Global Maritime Distress & Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
HAL	Horizontal Alarm Limit
HLAP	High Level Action Plan
HNSE	Horizontal Navigation System Error
HPE	Horizontal Protection Error
HPL	Horizontal Protection Level
IALA	International Association of Lighthouse Authorities
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IMO	International Maritime Organization
IMU	Inertial Measurement Units
INS	Inertial Navigation System
ITU	International Telecommunication Union
LA	Local Area
LRIT	Long Range Identification & Tracking
MC	Multi-Constellation
MF	Multi-Frequency
MMS	Magnetospheric Multiscale satellite
MRD	Mission Requirements Document
MSC	Maritime Safety Committee
NA	Not Available / Not Applicable
NCSR	Navigation, Communications and Search and Rescue
NMSA	National Maritime Safety Authority
NTRIP	Networked Transport of RTCM via Internet Protocol
OS	Open Service
PL	Protection Level
PPP	Precise Point Positioning
PRS	Public Regulated Service
PVT	Position Velocity time
RAIM	Receiver Autonomous Integrity Monitoring
RBB	Results-Based Budget
RD	Reference Document
RIMS	Ranging and Integrity Monitoring Stations
RIS	River Information Services
RTCM	Radio Technical Commission For Maritime Services
SA	Selective Availability
SAR	Search and Rescue
SAT-AIS	Space-based AIS
SBAS	Satellite-based Augmentation Systems
SDD	Service Definition Document
SoL	EGNOS Safety of Life Service

SOLAS	International Convention for Safety Of Life At Sea
SP	Strategic Plan
TRL	Technology Readiness Level
UCP	User Consultation Platform
UMS	Unmanned Maritime Systems
VDE	VHF Data Exchange
VDES	VHF Data Exchange System
VDR	Voyage Data Recorder
VHF	Very High Frequency
VSRMS	Vessel Shore reporting Management System
VTMIS	Vessel Traffic Monitoring and Information System
WA	Wide Area
WAAS	Wide Area Augmentation System
WWRNS	World Wide Radionavigation System

APPENDIX 3
POLICY AND REGULATORY FRAMEWORK

3.1 IMO

3.1.1 RESOLUTION A.953 (23)[RD5]

Revoked by IMO Resolution A.1046 (27) [RD6].

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

These resolutions [RD7] to[RD13]) are performance standards for shipborne GNSS or DGNSS equipment. Their specific purposes and dates of adoption are summarised in Table 19 below.

These resolutions do not set specific requirements in terms of accuracy, integrity or other qualities of the PNT solution. They refer to resolutions A.915(22) [RD3] and A.1046(27) [RD6] for this purpose.

The most recently adopted of these resolutions does not target one specific GNSS, but rather addresses the question of the "multi-system" receiver potentially capable of using multiple GNSS, correction sources (including SBAS mentioned for the first time in an IMO resolution) and terrestrial system(s).

3.1.3 RESOLUTION A.1106 (29) – REVISED GUIDELINES FOR AIS

Automatic Identification Systems or *AIS* means a maritime navigation safety communications system standardized by the International Telecommunication Union (ITU) [RD31], adopted by the International Maritime Organization (IMO) [RD2] that:

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

Regulation 19 of SOLAS chapter V "*Carriage requirements for shipborne navigational systems and equipment*" [RD2] sets out navigational equipment to be carried on board ships, according to ship type. In 2000, IMO adopted a new requirement (as part of a revised new chapter V) for all ships to carry automatic identification systems (AISs) capable of providing information about the ship to other ships and to coastal authorities automatically.

The regulation requires AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004.

Table 19: IMO resolutions concerning shipborne receiver standards

Resolution N°	Title	Date
MSC 112(73) [RD7]	Performance standards for shipborne GPS receiver equipment	1 December 2000
MSC 113(73) [RD8]	Performance standards for shipborne GLONASS receiver equipment	1 December 2000
MSC 114(73) [RD9]	Performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment	1 December 2000
MSC 115(73) [RD10]	Performance standards for shipborne combined GPS-GLONASS receiver equipment	1 December 2000
MSC 233(82) [RD11]	Performance standards for shipborne Galileo receiver equipment	5 December 2006
MSC 379(93) [RD12]	Performance standards for shipborne BDS receiver equipment	16 May 2014
MSC 401(95) [RD13]	Performance standards for multi-system shipborne navigation receivers	8 June 2015

Further, ships fitted with AIS shall maintain AIS in operation at all times except where international agreements, rules or standards provide for the protection of navigational information. Finally, it can be noted that AIS can be used to support SAR operations and navigation.

DESCRIPTION OF AIS

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

It provides both the mariners and the maritime administrations for increased situational awareness which enables improved safety of navigation (collision avoidance, VTS) and effective responses to emergencies such as search and rescue (SAR) or environmental pollution.

AIS rely upon what is known as a time-division multiple access (TDMA) communications protocol, which means the frequency (data link) used is divided into time defined slots which can only hold a set amount (packets) of data. What makes AIS unique and very different from other TDMA systems (e.g. mobile telephone networks) is the ability to dynamically 'self-organise'.

Indeed, the AIS network is continuously self-organizing around the user, thus reducing the likelihood of 'dropped call' (undelivered AIS messages).

As regards PNT requirements for shipborne AIS, they are twofold:

- The shipborne AIS must periodically report position in WGS84, position accuracy flag, and 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*" [RD23].

RESOLUTION A.1106 (29)

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

It gives a high level description of the information reported by the ship's AIS, the reporting interval as a function of the ship's dynamics, and a block diagram of a shipborne AIS device.

It does not provide quantified requirements regarding PNT, but specifies that:

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

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

- ITU Recommendation on the Technical Characteristics for a Universal Shipborne Automatic Identification System (AIS) Using Time Division Multiple Access in the Maritime Mobile Band (ITU-R M.1371) [RD31];
- IEC Standard 61993 Part 2: Universal Shipborne Automatic Identification System (AIS) Operational and Performance Requirements, Methods of Testing and required Test Results [RD40].

3.2 IALA / AISM

3.2.1 IALA - WORLD WIDE RADIO NAVIGATION PLAN

This 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 Organization (IMO) led concept based on the harmonisation of marine navigation systems and supporting shore services driven by user needs.

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

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

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

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

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

This plan does not introduce new user requirements, but rather refers to IMO A 1046 (27) [RD6] and A 915 (22)[RD3].

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

3.2.2 IALA AIDS TO NAVIGATION GUIDE (NAVGUIDE)

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

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

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

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

It does however recall *Accuracy Standards for Navigation*, definition of *Phases of Navigation*, definitions of *Measurement Errors and Accuracy*, definitions of *Availability and Continuity* for a radio navigation system, etc. In particular, *the Navguide gives an "environmental" (physical) description of the ship's environment in each phase of navigation, and discusses / justifies some requirements that are simply "stated" in other documents* (such as the IMO A.1046 (27) [RD6] and A.915 (22) [RD3].

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.

3.2.3 RECOMMENDATION IALA R-115 ON PROVISION OF MARITIME RADIONAVIGATION SERVICES IN THE FREQUENCY BAND 283.5-315 KHZ IN REGION 1 AND 285-325 KHZ IN REGION 2 AND 3

This recommendation ([RD20]) 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 (see paragraph C.2.4 below for this), but sets the frame for its deployment, re-allocating the frequency bands previously dedicated to the radio beacon services to DGNSS.

3.2.4 RECOMMENDATION IALA R-121 AND GUIDELINE 1112 ON PERFORMANCE AND MONITORING OF DGNSS SERVICES IN THE FREQUENCY BAND 283.5 – 325 KHZ

This Recommendation ([RD21]) and associated Guideline ([RD22]) last updated in May 2015 concern the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz (Maritime Radiobeacons); commonly known as "IALA DGPS".

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

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

They recommend those providing or intending to provide DGNSS to:

- Provide the service in accordance with *ITU-R Recommendation M.823-3* [RD30](which verses about message formats types and contents for DGNSS);

Maritime requirements based on IMO Recommendations [IMO A.915(22) & A.1046 (27)]

	System Level				Service Level	
	Absolute Horizontal Accuracy (95%)	Integrity			Availability (2 years)	Continuity (over 15 minutes)
		Alarm Limit	Time to Alarm (1)	Integrity Risk		
Area	m	m	s	%	%	%
Ocean	≤ 100	N/A	N/A	N/A	≥ 99.8	N/A
Harbour entrances, harbour approaches and coastal waters	≤ 10	25	10	10^{-5}	≥ 99.8	99.7

(1) Generation of integrity warnings in cases of system malfunctions, non-availability or discontinuities.

- Provide integrity information for GNSS;
- Provide the service with a level of redundancy to achieve performance requirements IMO A.1046 (27) [RD6];
- Provide means of verifying the performance of the service;
- Provide mariners with information about the service, for example
  - description of the service,
  - achieved service performance,
  - service disruptions,
  - geographical service area;
- Adopt the design and implementation principles set out in the relevant IALA Guideline(s).

3.2.5 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)[RD3].

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

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

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

Regarding end user PNT requirements, this recommendation does not deal with the subject other than referring to IMO A 915 (22) [RD3].

3.2.6 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.

3.2.7 GUIDELINE NO. 1082 ON AN OVERVIEW OF AIS

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

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

3.2.8 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.

The purpose of Volume 1 Part 1 of these guidelines (N° 1028 [RD24]) is operational guidance, written from the 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 Part2 of the guidelines [RD25]) discussed below.

3.2.9 IALA GUIDELINE NO. 1029 ON THE AUTOMATIC IDENTIFICATION SYSTEM (AIS), TECHNICAL ISSUES

The purpose of Volume 1 Part 2 of the IALA guidelines [RD25] 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 ([RD31]):

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 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.

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 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.

3.3 ITU

3.3.1 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" ([RD30]) 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.

The position accuracy flag is defined as follows:

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:

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

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

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

3.3.2 RECOMMENDATION M.1371-5

The "Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band" [RD31] 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.

3.4 IEC STANDARDS AND REQUIREMENTS

The "IEC Technical Committee 80" produces operational and performance requirements together with test methods for maritime navigation and radiocommunication equipment and systems.

The committee provides industry with standards that are also accepted by governments as suitable for *type approval* where this is required by the International Maritime Organization's SOLAS Convention. Such standards deal with all electrical, electronic and related technologies; and by extension issues with other issues concerning the design of the equipment, its power supplies, ElectroMagnetic Compatibility (EMC) and safety. *These standards do no 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.

Table 20 lists some of the most relevant (for this study) IEC publications together with their IMO counterpart when available.

3.5 EUROPEAN COMMISSION FRAMEWORK ON RIVER INFORMATION SERVICES

3.5.1 DIRECTIVE 2005/44/EC

This Directive dated 7 September 2005 and its Amending Act Reg. 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: a) Electronic chart display and information system for inland navigation (inland ECDIS); b) Electronic ship reporting; c) Notices to skippers; d) Vessel tracking and tracing systems; e) 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: a) *Compatibility with maritime ECDIS (point a above); b) Compatibility with maritime AIS (point d above); c) Guidelines and specifications shall take account of the work carried out in this field by relevant international organisations*

Last, 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".

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

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.

Table 20: IEC standards and corresponding IMO resolutions

IEC Reference	IMO Reference	Subject
IEC 60945 Ed. 4.0 [RD34]	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 [RD35]	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
IEC 61108-2 Ed. 1.0 [RD36]	MSC.113(73)	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS) - Receiver equipment - Performance standards, methods of testing and required test results
IEC 61108-3 Ed. 1.0 [RD37]	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 [RD38]	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 61162-Parts 1 to 4 [RD39]		Maritime navigation and radiocommunication equipment and systems – Digital interfaces
IEC 61993-2 Ed. 2.0 [RD40]	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

REGULATION (EC) NO 414/2007

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

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

APPENDIX 4 VALIDATION WITH MAIN USER COMMUNITIES

4.1 SURVEY FOR ACCURACY FOR POSITIONING APPLICATIONS IN PORTS DONE WITH HARBOUR MASTERS, 2015.

4.1.1 INTRODUCTION

This chapter presents the results of a consultation process performed in 2015 to identify the port navigation and positioning operations arousing higher interest among the port authorities, and the required performance levels.

It is structured in different sections:

- Section D.1.2 presents the objectives and audience of the consultation process, together with the used methodology;
- Section D.1.3 presents the conclusions of the analysis, including the assessment of the user needs, the drafting of the intermediate performance levels and the derived recommendations;
- Annex A: **Questionnaire and statistics** presents the content of the questionnaire and the statistics for each one of the answers;
- Annex B: **List of port authorities** lists the port authorities invited to participate in the survey.

4.1.2 THE CONSULTATION PROCESS

CONTEXT

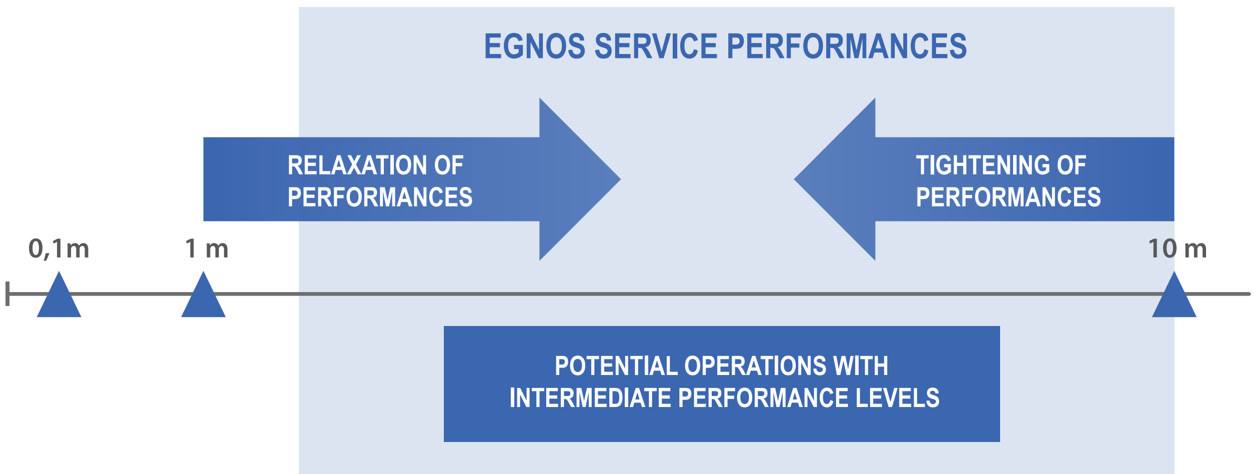
In an effort to provide the most suitable satellite navigation service to maritime users, a consultation has been performed among European port authorities to have their view on the need of intermediate performance levels for navigation and positioning operations in ports.

The performance levels required for a global navigation satellite system (GNSS) are described in IMO Resolution A.915(22) [RD3]. This mandate specifies user requirements for both general navigation and positioning applications. Among them, different type of operations and applications are considered and their required performances are specified in terms of accuracy, integrity, availability, continuity, and coverage.

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

- Operations such as general navigation, except in ports, and many of maritime applications that require **horizontal accuracies of 10m;**

Figure 6: Intermediate performances



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

OBJECTIVE

The consultation is an step forward in the assessment of the **user needs**, by identifying both:

- Operations with 10m accuracy requirements for which higher performances might result on significant operational benefits; and
- Operations requiring 1m of accuracy for which accuracy might be relaxed without penalties.

The aim is to better specify the performances required by maritime community for those applications and to assess if accuracy performances, as offered by EGNOS, could provide an added value in the frame of those applications.

METHODOLOGY

The consultation process has followed an iterative approach. First, the consultation has been performed among a limited number of port authorities, being later extended to a higher number using the feedback and lessons learned from the first iteration. Both iterations have involved the phases and activities presented in the table below.

THE QUESTIONNAIRE

The consultation process has been addressed by means of an on-line questionnaire. The questionnaire has been distributed by e-mail to European port authorities. The questionnaire is organized as follows:

- Welcome, by presenting the purpose and contents of the survey and few indications for filling the questionnaire;
- User needs for navigation applications in ports;
- User needs for positioning applications in ports requiring demanding accuracy performances;
- User needs for positioning applications in ports requiring lower accuracy performances;
- Farewell and awareness, by presenting EGNOS and the benefits it may bring to the maritime users.

A sample of the questionnaire is presented in Annex A: Questionnaire and statistics.

THE AUDIENCE

The list of port authorities contacted has been mainly retrieved from [RD57], a ports' website managed by Compass Publications LTD featuring the major ports of the world. Around five hundred European port authorities have been contacted by e-mail. In addition to the port authorities, the consultation was extended to the Norwegian Coastal Administration after attendance to the EMRF-GSA third workshop on EGNOS use. The complete list of contacted authorities can be found in Annex B: List of port authorities.

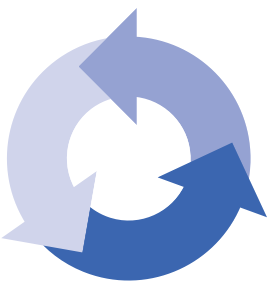
THE OUTCOMES

The participation

This chapter presents the results obtained from the survey. It is worth to highlight here that different difficulties in reaching the target authority have been found. After distribution of the mail invitations it has been noticed that ~20% of the mail addresses in [RD57] were obsolete and never reached the target authority. For the successfully delivered e-mail invitations, it is presumed that also a high percentage of invitations did not reach a relevant representative to complete this survey and the invitations were simply disregarded.

The following 22 port authorities, and 1 coastal administration, had submitted their answers.

Consultation Process



Phase	Main tasks
I - Definition and planning	Desktop research Definition and preparation of the questionnaires and guidelines for the meetings. Consolidation of the list of stakeholders to be interviewed Preparation of the interactions with the stakeholders
II – Survey	Interactions based on on-line questionnaires distributed by e-mail and phone calls
III - Analysis	Gathering and assessment of the user needs Drafting of the intermediate performance levels Drafting of the recommendations

Table 21: List of port authorities that have completed the survey

Country	Port authority
Croatia	Lucka Uprava Split
Croatia	Port Authority of Dubrovnik
France	Grand Port Maritime de Bordeaux
France	Grand Port Maritime de Marseille
Germany	Niedersachsen Ports GmbH & Co. KG
Germany	Rheinhafen Karlsruhe
Ireland	Galway Harbour Company
Italy	Autorita Portuale di Messina
Monaco	Societe d'Exploitation des Ports de Monaco (SEPM)
Norway	Karmsund Havnevesund
Norway	Norwegian Coastal Administration
Poland	Szczecin-Swinoujscie Seaports Authority
Poland	Ustka Port Authority
Portugal	Administracao do Porto de Sines S.A.
Spain	Autoridad Portuaria de Aviles
Spain	Autoridad Portuaria de Vigo
Spain	Autoridad Portuaria de Gijón
Sweden	Solvesborgs Stuveri & Hamn AB
UK	Aggregate Industries UK Ltd. T/A Yeoman Glensanda[2]
UK	Falmouth Harbour Commissioners
UK	Milford Haven Port Authority
UK	Padstow Harbour Commissioners
UK	Stena Line Ports Ltd

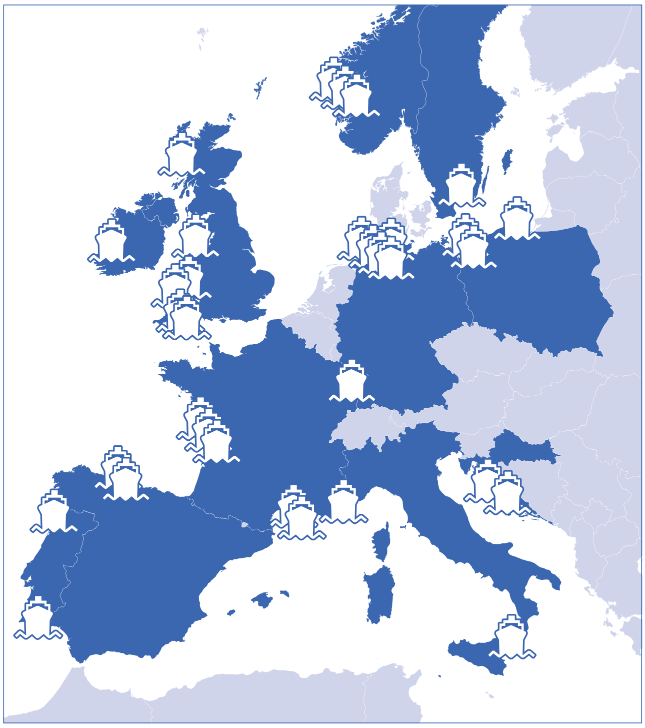
2 The survey has been completed twice by two different representatives of this port authority.

The 22 port authorities represent a total of 41 ports: 32 maritime and 9 river ports spread around 12 countries. Table 22 and Figure 7 indicate the number of port authorities participating on the survey together with the ports represented by them and organized by country.

Table 22: Survey representation per country

	Croatia	France	Germany	Ireland	Italy	Monaco	Norway	Poland	Portugal	Spain	Sweden	United Kingdom
# Authorities participating in the survey	2	2	2	1	1	1	1	2	1	3	1	5
# Ports represented by the survey	2	10	7	1	1	1	6	3	1	3	1	5

Figure 7: Ports and States represented by the survey



THE FEEDBACK

This section summarises the outcomes of the analysis performed on top of the individual feedback provided by the Port Authorities. Note that the content of the questionnaire and the statistics for each one of the answers are provided Annex A: Questionnaire and statistics.

The 24 representatives completing the questionnaire have identified more than one type of operation in their ports that could take benefit of horizontal accuracy levels between 1 and 10 m at 95%.

Navigation in ports, port approaches but also some of the positioning operations (e.g. Tugs and pushes operations) seems to be ones arousing more interest. This interest has been summarized in Table 23 per maritime operation type.

Once the respondents identified potential applications that could be performed with performances in the range between 1 and 10m, they were requested to identify which specific accuracy might be of interest for that application. However, the limited number of completed surveys and the variety of answers provided has not enabled to derive specific recommendations for intermediate performance levels per operation. Please refer to Annex A: Questionnaire and statistics to consult the entire provided answers.

It is to be highlighted that the questionnaire was intended to capture the real needs in ports. In order to prevent to lead answers, respondents were offered to provide additional comments right after each question, in particular, ever after providing the specific accuracy per operation.

As it can be observed from the entire set of answers, most respondents proposed accuracy levels between 3 and 7m for the applications raising more interest, and few proposed 1.5m as a necessary accuracy level.

Vertical positioning has raised very low interest from the port authorities. Only 4 out of 24 representatives completing the survey have shown interest in vertical positioning. The applications indicated by the respondents where vertical position may have an interest are as follows:

- **River services**;
- support to **pier approaches** with difficult access;
- **bathymetric surveys**;
- and support to future overhead clearance requirement (10 cm).

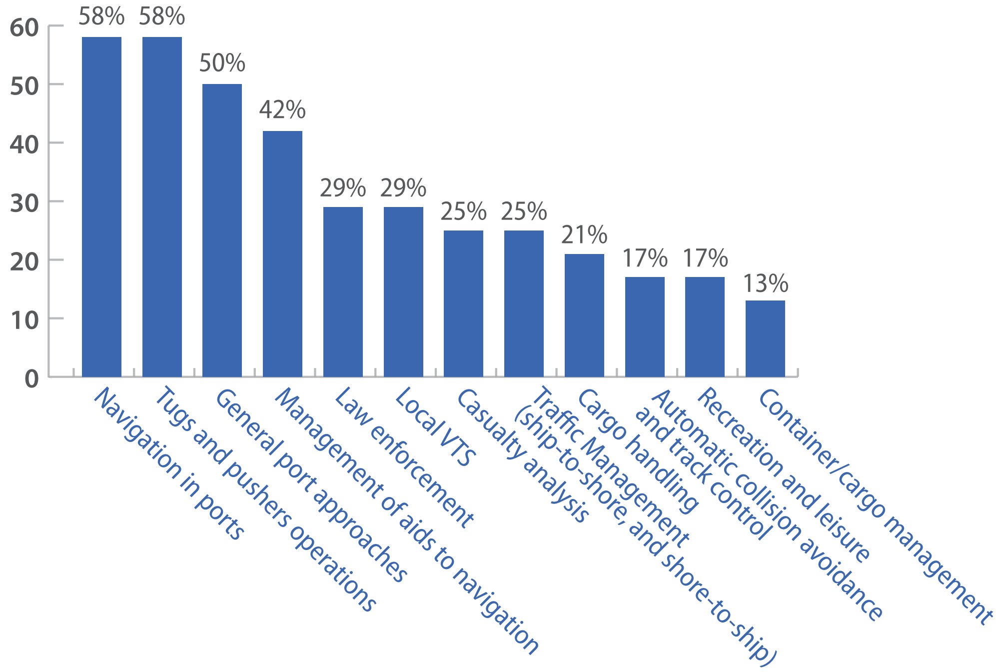
Among these applications, the first three applications may be compatible with current EGNOS performances and take benefit of a dedicated maritime service.

Few additional applications have been identified by respondents: mapping of vessels during loading operations, some towing operations, and potential upgrade of PPU if navigational tolerance reduces in the future.

Table 23: Summary of port authorities interest in intermediate performance levels

		Feedback	PA identifying interest in intermediate performance levels	
Maritime operation	**Horizontal accuracy in Res.915 (meters)**	**Higher Accuracy needed ⇩** **Lower Accuracy enough ⇧**	**Absolute number**	**Percentage**
Navigation in ports	1	⇧	14	58%
Tugs and pushers operations	1	⇧	14	58%
General port approaches	10	⇩	12	50%
Aids to navigation management	1	⇧	10	42%
Law enforcement	1	⇧	7	29%
Local VTS	1	⇧	7	29%
Casualty analysis during port approach	1	⇧	6	25%
Traffic Management (ship-to-shore, and shore-to-ship)	10	⇩	6	25%
Cargo handling	0.1	⇧ ⇧	5	21%
Automatic collision avoidance and track control	10	⇩	4	17%
Recreation and leisure during port approach	10	⇩	4	17%
Container/cargo management	1	⇧	3	13%

Figure 8: Interest from Port Authorities



4.1.3 CONCLUSIONS

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

Instead, respondents have shown low interest in vertical positioning. The most relevant applications where respondents have identified an interest in vertical position are river services, support to pier approaches with difficult access, and bathymetric surveys.

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

In order to consolidate the proposal for the intermediate performance levels and to have the endorsement from the maritime community, it is recommended to involve and extend the consultation to the following stakeholders

- **Ship's master and Coast pilot's community**. These communities are considered one of the most relevant stakeholders to refine on positioning needs during navigation in ports and port approaches, as it has been highlighted during EMRF meetings [RD58]**;**
- **Technical port services**. Cargo handling and the service provided by tugs and pushers are usually externalized to private companies. A representation of these external technical port services would provide more accurate insight of the specific positioning needs required by these services;
- **Port authorities**. Larger participation of port authorities is also necessary to agree on general performances of positioning operations performed under their responsibility (e.g. traffic management and management of navigation aids);
- **National administrations**. Feedback from national coastal and maritime administrations might also support consolidation of navigation requirements in the proximity of ports and during port approaches.

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

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

Applications identified with intermediate performance level

Application	Horizontal accuracy in A 22/Res.915	Higher Accuracy needed ⇩ Lower Accuracy enough ⇧
Navigation in ports	1 meter	⇧
Tugs and pushers operations	1 meter	⇧
General port approaches	10 meters	⬇
Aids to navigation management	1 meter	⇧

ANNEX A: QUESTIONNAIRE AND STATISTICS

NAVIGATION IN PORTS - NECESSARY ACCURACY

Which horizontal accuracy (in meters) do you consider necessary to support vessel navigation within the ports under your responsibility?

24 out of 24 people answered this question

		Answers / Ratio
1	5m (at 95%)	8 / 33%
2	less than 1m (at 95%)	6 / 25%
3	1.5m (at 95%)	3/ 13%
4	10m (at 95%) or higher	2 / 8%
5	1m (at 95%)	2 / 8%
6	3m (at 95%)	2 / 8%
7	2m (at 95%)	1 / 4%

POSITIONING OPERATIONS IN PORTS - HIGH ACCURACY APPLICATIONS

The following port applications usually require high horizontal accuracy. Based on the activity and characteristics in the ports under your responsibility, which of the following applications can be performed with accuracy levels of ~1.5m (at 95%), or even under more relaxed accuracy conditions?

24 out of 24 people answered this question

		Answers / Ratio
1	Management of aids to navigation	15 / 63%
2	Tugs and pushers operations	15 / 63%
3	Local VTS	13 / 54%
4	Law enforcement	9 / 38%
5	Casualty Analysis	8 / 33%
6	Cargo handling	5 / 21%
7	Container/cargo management	3 / 13%
8	None	2 / 8%

TUGS AND PUSHERS OPERATIONS

Which accuracy level enables operations of tugs and pushers within your ports?

15 out of 24 people answered this question

		Answers / Ratio
1	1.5m at 95%	5 / 33%
2	5m at 95%	5 / 33%
3	3m at 95%	4 / 27%
4	> 10m at 95%	1 / 7%
5	10 m at 95%	0 / 0%
6	7m at 95%	0 / 0%

LOCAL VTS

Which accuracy level enables local Vessel Traffic Services (VTS) offered in your ports?

13 out of 24 people answered this question

		Answers / Ratio
1	1.5m at 95%	5 / 38%
2	10m at 95%	3 / 23%
3	> 10m at 95%	3 / 23%
4	3m at 95%	1 / 8%
5	5m at 96%	1 / 8%
6	7m at 95%	0 / 0%

LAW ENFORCEMENT

Which accuracy level enables law enforcement within your ports?

9 out of 24 people answered this question

		Answers / Ratio
1	5m at 96%	4 / 44%
2	3m at 95%	2 / 22%
3	1.5m at 95%	1 / 11%
4	10m at 95%	1 / 11%
5	> 10m at 95%	1 / 11%
6	7m at 95%	0 / 0%

MANAGEMENT OF ATON

Which accuracy level enables management of the Aids to Navigation (ATON) within your ports?

15 out of 24 people answered this question

		Answers / Ratio
1	1.5m at 95%	5 / 33%
2	5m at 96%	4 / 27%
3	10m at 95%	2 / 13%
4	3m at 95%	2 / 13%
5	> 10m at 95%	2 / 13%
6	7m at 95%	0 / 0%

If different accuracy levels are required for some of the aids, you can specify them in the comments field further below.

One of the respondents indicating 1.5m accuracy further indicates in the comments section that management of must be surveyed to better than 1m accuracy. Therefore, this answer has been removed from the statistics presented in Table 23: Summary of port authorities interest in intermediate performance levels

CONTAINER/CARGO MANAGEMENT

Which accuracy level enables container and cargo management within your ports?

3 out of 24 people answered this question

		Answers / Ratio
1	5m at 96% 67%	2 / 67%
2	7m at 95%	1 / 33%
3	1.5m at 95%	0 / 0%
4	10m at 95%	0 / 0%
5	3m at 95%	0 / 0%
6	> 10m at 95%	0 / 0%

CARGO HANDLING

Which accuracy level enables cargo handling within your ports?

5 out of 24 people answered this question

		Answers / Ratio
1	3m at 95%	2 / 40%
2	1.5m at 95%	1 / 20%
3	5m at 96%	1 / 20%
4	7m at 95%	1 / 20%
5	10m at 95%	0 / 0%
6	> 10m at 95%	0 / 0%

CASUALTY ANALYSIS

Which accuracy level enables casualty analysis within your ports?

8 out of 24 people answered this question — Answers / Ratio

1	5m at 96%	3 / 38%
2	1.5m at 95%	1 /13%
3	10 m at 95%	1 /13%
4	3m at 95%	1 /13%
5	7m at 95%	1 /13%
6	> 10m at 95%	1 /13%

Comments from port authorities

Answer	Comments
5m at 95%	Recording is undertaken using AIS and standard accuracy GPS

POSITIONING OPERATIONS IN PORTS - LOW ACCURACY APPLICATIONS

The following port applications do not traditionally require high horizontal accuracy. However, current traffic trends and modern maritime applications might lead to higher accuracy needs (e.g. increased port capacity or operability).

For which of the following maritime applications do you consider worth improving the accuracy?

24 out of 24 people answered this question — Answers / Ratio

1	General port approaches	14 / 58%
2	Traffic Management (ship-to-shore, and shore-to-ship)	10 / 42%
3	Automatic collision avoidance and track control	6 / 25%
4	None	5 / 21%
5	Recreation and leisure	5 / 21%

GENERAL PORT APPROACHES

Which accuracy level would you consider worth having for general port approaches?

14 out of 24 people answered this question — Answers / Ratio

1	5m at 95%	4 / 29%
2	7m at 95%	4 / 29%
3	3m at 95%	3 / 21%
4	1.5m at 95%	1 / 7%
5	1m at 95%	1 / 7%
6	< 1m at 95%	1 / 7%

Comments from port authorities

Answer	Comments
7m at 95%	Approach channel is only appx 30 metres wide at some states of tide - many recreational users come in on chart plotters and follow these blindly - this is where increased accuracy would benefit

AUTOMATIC COLLISION AVOIDANCE AND TRACK CONTROL

Which accuracy level do you consider worth for automatic collision avoidance and for track control?

6 out of 24 people answered this question

		Answers / Ratio
1	1.5m at 95%	2 / 33%
2	3m at 95%	2 / 33%
3	< 1m at 95%	2 / 33%
4	1m at 95%	0 / 0%
5	5m at 95%	0 / 0%
6	7m at 95%	0 / 0%

TRAFFIC MANAGEMENT

Which accuracy level do you consider worth for ship-to-shore coordination and shore-to-ship management?

10 out of 24 people answered this question

		Answers / Ratio
1	< 1m at 95%	3 / 30%
2	1.5m at 95%	2 / 20%
3	5m at 95%	2 / 20%
4	1m at 95%	1 / 10%
5	3m at 95%	1 / 10%
6	7m at 95%	1 / 10%

If you consider different accuracy levels for coordination versus management, you can specify that in the comments field further below.

Answer	Comments
7m at 95%	VTS radar errors make normal VTS useless at shore based traffic management, therefore accurate positioning would improve this.

RECREATION AND LEISURE

Which accuracy level do you consider worth for recreation and leisure?

5 out of 24 people answered this question

		Answers / Ratio
1	7m at 95%	4 / 80%
2	1m at 95%	4 / 20%
3	1.5m at 95%	0 / 0%
4	3m at 95%	0 / 0%
5	5m at 95%	0 / 0%
6	< 1m at 95%	0 / 0%

OTHER PORT APPLICATIONS

Can you identify additional current or future port applications that may require a horizontal positioning accuracy level between 1.5m and 10m?

In case you know, please specify the accuracy level required for each application.

Comments
To allow small ports to accurately complete hydrographic surveys without expensive equipment
Portable Pilot Units if navigational tolerance reduces in the future.
Some towing operations (3m)
Mapping of vessel holds for loading operations

VERTICAL POSITIONING IN PORTS

Is **vertical positioning** currently relevant, or will it be relevant in the future, for the applications used in your ports?

24 out of 24 people answered this question

		Answers / Ratio
1	No	20 / 83%
2	Yes	4 / 17%

In case you know, please specify the approximate accuracy level required for each application.

Comments
Vertical positioning might support approaches to a specific pier that require crossing of a road bridge
Interesting for bathymetric survey
Possibly in the future overhead clearance (10cm) since Equipment for relative measurement of overhead clearance is not common today
Allied river service

ANNEX B: LIST OF PORT AUTHORITIES

Following table includes the list of port authorities invited to participate in the survey.

Table 24: Complete list of port authorities invited to participate in the survey

Country	Port authority
Albania	Seaport of Vlore
Belgium	Afdeling Kust
Belgium	Haven Genk
Belgium	Port Authority Bruges-Zeebrugge (MBZ) N.V.
Belgium	Port de Bruxelles-Haven van Brussel
Belgium	Vopak Terminal Hemiksem
Belgium	Waterwegen en Zeekanaal N.V.
Croatia	Lucka Uprava Pula
Croatia	Lucka Uprava Rovinj
Croatia	Lucka Uprava Sibenik
Croatia	Lucka Uprava Split
Croatia	Lucka Uprava Zadar
Croatia	Port Authority of Dubrovnik
Croatia	Port of Ploce Authority
Croatia	Port of Rijeka Authority
Croatia	TE Plomin
Cyprus	Electricity Authority of Cyprus
Denmark	Aabenraa Port
Denmark	Assens Havn
Denmark	Associated Danish Ports A/S
Denmark	DONG Energy A/S
Denmark	DONG Energy A/S
Denmark	DONG Energy A/S
Denmark	DONGEnergy A/S
Denmark	DONGEnergy A/S
Denmark	Elsinore Statshavn
Denmark	Faaborg Havn
Denmark	Frederiksvaerk Havn
Denmark	Grenaa Havn A/S
Denmark	Guldborgsund Havne
Denmark	Hanstholm Havn
Denmark	Hasle Havn

Country	Port authority
Denmark	Havnekontoret Scandlines A/S
Denmark	Hobro Havn
Denmark	Holstebro-Struer Havn
Denmark	Horsens Havn A/S
Denmark	Kalundborg Havn
Denmark	Kerteminde Havn
Denmark	Koge Havn
Denmark	Kolding Havn
Denmark	Lemvig Havn
Denmark	Naestved Havn
Denmark	Nakskov Havn
Denmark	Nexo Havn A/S
Denmark	Nykobing Mors Havnevesen
Denmark	Omya A/S
Denmark	Port of Aarhus
Denmark	Port of Esbjerg
Denmark	Port of Frederikshavn Ltd
Denmark	Port of Hirtshals
Denmark	Port of Korsoer
Denmark	Randers Havn
Denmark	Ronne Havn A/S
Denmark	Skagen Havn
Denmark	Stubbekobing Havn
Denmark	Svendborg Port Authority
Denmark	Thisted Havn
Denmark	Vejle Havn
Estonia	Miiduranna Sadam
Estonia	RasmusSon Ltd
Estonia	Roomassaare Harbour
Estonia	Vene-Balti Sadam OU
Finland	Celsa Steel Service Oy
Finland	City of Lappeenranta Port Authority
Finland	Finnish Maritime Administration
Finland	Finnsementti OY
Finland	Finnsteve OY AB
Finland	Inkoo Shipping OY AB
Finland	Kemphos OY

Country	Port authority
Finland	Neste Oil Oyj
Finland	O/Y Saimaa Terminals A/B
Finland	Ovako Wire Oy Ab
Finland	Port of Hanko
Finland	Port of Joensuu
Finland	Port of Kalajoki
Finland	Port of Kaskinen
Finland	Port of Kemi Authority
Finland	Port of Kokkola
Finland	Port of Kristiinankaupunki
Finland	Port of Loviisa
Finland	Port of Mariehamn
Finland	Port of Naantali
Finland	Port of Pietarsaari Authority
Finland	Port of Pori Authority
Finland	Port of Raahe
Finland	Port of Savonlinna
Finland	Port of Tornio
Finland	Port of Vaasa
France	Capitainerie du Port de Bayonne
France	Capitainerie du Port de Commerce de Bastia
France	Chambre de Commerce et d'Industrie
France	Chambre de Commerce et d'Industrie de Ajaccio et South Corsica (CCIACS)
France	Chambre de Commerce et d'Industrie de Calais
France	Chambre de Commerce et d'Industrie de Cherbourg Cotentin
France	Chambre de Commerce et d'Industrie du Var
France	Chambre de Commerce et d'Industrie Nice Cote d'Azur
France	Conseil General des Cotes d'Armor
France	Conseil General du Morbihan
France	Direction Departementale de l'Equipement
France	Direction Departementale des Infrastructures Generales
France	Grand Port Maritime de Bordeaux
France	Grand Port Maritime de Bordeaux
France	Grand Port Maritime de Dunkerque
France	Grand Port Maritime de La Rochelle
France	Grand Port Maritime de Marseille
France	Grand Port Maritime de Nantes-St.Nazaire

Country	Port authority
France	Morlaix Chambre de Commerce et d'Industrie
France	Port Autonome de Paris
France	Port de Commerce de Caen-Ouistreham
France	Port de Commerce de Rochefort Tonnay-Charente
France	Port de Sete
France	Port of Lorient
France	Service Maritime de Boulogne
Georgia	Batumi Sea Trading Port Ltd
Georgia	Poti Sea Port Ltd
Germany	Butzfleth Port Authority
Germany	Duisburger Hafen AG
Germany	Fahrhafen Sassnitz GmbH
Germany	Flensburger Hafen GmbH
Germany	Hafen Frankfurt Managementgesellschaft mbH
Germany	Hafen und Bahnbetriebe der Stadt Krefeld
Germany	Hafen und Guterverkehr Koln AG (HGK)
Germany	Hafenbetriebe Ludwigshafen am Rhein GmbH
Germany	Hafengesellschaft Brunsbuttel mbH
Germany	Hafengesellschaft Gluckstadt mbH &amp, Co. KG
Germany	Hafen-und Seemannsamt Rostock
Germany	Hafenverwaltung Kehl
Germany	Hansestadt Bremisches Hafenamt
Germany	Kreishafenamt Rendsburg
Germany	Laboe Harbour
Germany	Lubecker Hafen-Gesellschaft mbH
Germany	Neuss Duesseldorfer Haefen GmbH &amp, Co. KG.
Germany	Niedersachsen Ports GmbH & Co. KG
Germany	Niedersachsen Ports GmbH & Co. KG
Germany	Niedersachsen Ports GmbH &amp, Co. KG
Germany	Niedersachsen Ports GmbH &amp, Co. KG
Germany	Niedersachsen Ports GmbH &amp, Co. KG
Germany	Niedersachsen PortsGmbH&amp, Co. KG
Germany	Port of Regensburg
Germany	Rheinhafen Karlsruhe
Germany	Rhenus Midgard GmbH
Germany	Seehafen Kiel GmbH &amp, Co. KG
Germany	Seehafen Stralsund GmbH

Country	Port authority
Germany	Seehafen Wismar GmbH
Germany	Shipbroker Artur Koch
Germany	Staatliche Rhein-Neckar-Hafengesellschaft Mannheim mbH
Germany	Stadtwerke Eckernforde GmbH
Germany	Stadtwerke Itzehoe GmbH
Germany	Stadtwerke Leer GmbH
Germany	Wasser-und Schiffahrtsamt Kiel-Holtenau
Germany	Wolgaster Hafengesellschaft mbH
Greece	AKARPORT S.A.
Greece	Grecian Magnesite S.A.
Greece	Hellenic Petroleum S.A.
Greece	Heraklion Port Authority S.A.
Greece	Igoumenitsa Port Authority S.A.
Greece	Kavala Port Authority S.A.
Greece	Lava Mining &amp, Quarrying Co.
Greece	Lavrion Port Authority S.A.
Greece	Motor Oil (Hellas) Refineries S.A.
Greece	Patras Port Authority S.A.
Greece	Public Gas Corp. of Greece (DEPA) S.A.
Greece	Seka S.A.
Greece	Thessaloniki Port Authority S.A.
Greece	Volos Port Authority S.A.
Iceland	Associated Icelandic Ports
Iceland	Bolungarvikurhofn
Iceland	Dalvikurbyggd-Hafnasjodur
Iceland	Fjardabyggd Port Authority
Iceland	Fjardabyggd Port Authority
Iceland	Grindavikurhofn AB
Iceland	Hafnarfjordur Port Authority
Iceland	Hafnarstjorn Vestmannaeyja
Iceland	Hvammstangahreppur
Iceland	Langaneshafnir
Iceland	Port Authority of Akureyri
Iceland	Port of Djupivogur
Iceland	Port of Grundarfjordur
Iceland	Port of Isafjordur
Iceland	Port of Keflavik

Country	Port authority
Iceland	Port of Seydisfjordur
Iceland	Thorlakshofn Port Authority
Iceland	Vopnafjardarhofn
Ireland	Bantry Bay Harbour Commissioners
Ireland	Castletownbere Fishery Harbour
Ireland	Drogheda Port Company
Ireland	Galway Harbour Company
Ireland	Iarnród Eireann
Ireland	Kerry County Council
Ireland	Killybegs Harbour Centre
Ireland	Kinsale Harbour Commissioners
Ireland	Shannon Foynes Port Company
Ireland	Wicklow Port Company
Italy	Autorita Portuale di Ancona
Italy	Autorita Portuale di Bari
Italy	Autorita Portuale di Brindisi
Italy	Autorita Portuale di Civitavecchia
Italy	Autorita Portuale di Fiumicino
Italy	Autorita Portuale di Gaeta
Italy	Autorita Portuale di Marina di Carrara
Italy	Autorita Portuale di Messina
Italy	Autorita Portuale di Napoli
Italy	Autorita Portuale di Olbia e Golfo Aranci
Italy	Autorita Portuale di Piombino
Italy	Autorita Portuale di Ravenna
Italy	Autorita Portuale di Salerno
Italy	Autorita Portuale di Taranto
Italy	Autorita Portuale Gioia Tauro
Italy	Azienda Speciale per il Porto di Monfalcone
Italy	Capitaneria di Porto di Chioggia
Italy	Capitaneria di Porto di Lipari
Italy	Capitaneria di Porto di Manfredonia
Italy	Capitaneria di Porto di Mazara del Vallo
Italy	Capitaneria di Porto di Milazzo
Italy	Capitaneria di Porto di Ortona
Italy	Capitaneria di Porto di Otranto
Italy	Capitaneria di Porto di Pesaro

Country	Port authority
Italy	Capitaneria di Porto di Pescara
Italy	Capitaneria di Porto di Portoferraio
Italy	Capitaneria di Porto di Pozzuoli
Italy	Capitaneria di Porto di Reggio di Calabria
Italy	Capitaneria di Porto di Sant' Antioco
Italy	Capitaneria di Porto di Siracusa
Italy	Capitanerie di Porto di Oristano
Italy	Compamare Augusta
Italy	Consorzio dei Porto di Trapani
Italy	Della Zona Dell'Aussa Corno
Italy	La Spezia Port Authority
Italy	Ufficio Circondariale Marittimo di Alghero
Italy	Ufficio Circondariale Marittimo di Arbatax
Italy	Ufficio Circondariale Marittimo di Marsala
Italy	Ufficio Circondariale Marittimo di Monopoli
Italy	Ufficio Circondariale Marittimo di Porto Santo Stefano
Italy	Ufficio Circondariale Marittimo di San Remo
Italy	Ufficio Circondariale Marittimo di Torre Annunziata
Italy	Ufficio Locale Marittimo di Lampedusa
Latvia	Port of Mersrags
Latvia	Skulte Port Authority
Monaco	Societe d'Exploitation des Ports de Monaco (SEPM)
Montenegro	Luka Bar-Preduzece
Montenegro	Port of Kotor JSC
Netherlands	Gemeente Harlingen Afd. Havenbeheer
Netherlands	Gemeente Middlesburg dienst Stadesbeheer
Netherlands	Gemeente Schouwen-Duiveland
Netherlands	Gemeentelijk Havenwezen Groningen
Netherlands	Groningen Seaports
Netherlands	Havenbedrijf Dordrecht
Netherlands	Havendienst Nijmegen
Netherlands	Havendienst Vlaardingen
Netherlands	Havendienst Zaandam
Netherlands	Havenschap Moerdijk
Netherlands	Municipal Port Authority (Gemeentelijke Havendienst)
Netherlands	Port Management of Amsterdam
Netherlands	Zeeland Seaports

Country	Port authority
Norway	Aalesundregionens Havnevesen
Norway	Alta Havn KF
Norway	Arendal Havnevesen KF
Norway	Aurland Harbour District
Norway	Bodo Havn KF
Norway	Borg Havn IKS
Norway	Bremanger Hamnevesen KF
Norway	Bronnoy Havn KF
Norway	Egersund Havnevesen KF
Norway	Esso Norge A/S
Norway	Flekkefjord Kommune
Norway	Grenland Havn IKS
Norway	Halden Havnevesen
Norway	Harstad Havn KF
Norway	Holmestrand Havnevesen
Norway	Horten Havnevesen KF
Norway	Husnes Havn AS
Norway	Indre Trondheimsfjord Havnevesen IKS
Norway	Karmsund Havnevesund
Norway	KS Coast Center Base
Norway	Larvik Havn KF
Norway	Lillesand Havn KF
Norway	Lodingen Havnevesen
Norway	Mandal Port of Agder
Norway	Mo i Rana Havn KF
Norway	Molde og Romsdal Havn IKS
Norway	Moss Havn KF
Norway	Namsos Havnevesen
Norway	Narvik Havn KF
Norway	Norsk Hydro A/S
Norway	Norwegian Coastal Administration
Norway	Odda Havnevesen
Norway	Oslo Havn KF
Norway	Port of Drammen Authority
Norway	Port of Kirkenes
Norway	Port of Kristiansand
Norway	Risor Havnekontor

Country	Port authority
Norway	Sandefjord Havnevesen
Norway	Sandnes Havn KF
Norway	Sola Havn A/S
Norway	StatoilHydro ASA
Norway	Stavangerregionen Havn IKS
Norway	Stord Harbour Authority
Norway	Tonsberg Havnevesen
Norway	Tromso Havn KF
Norway	Trondheim Havn
Norway	Vadso Havn KF
Norway	Vagan Havnevesen KF
Norway	Vardo Havn KF
Norway	Yara International ASA
Poland	Kolobrzeg Sea Port Authority
Poland	Port of Gdansk Authority S.A.
Poland	Port of Gdynia Authority S.A.
Poland	PPiUR 'Szkuner'
Poland	Szczecin-Swinoujscie Seaports Authority
Poland	Ustka Port Authority
Poland	Zarzad Morskiego Portu Police Ltd.
Poland	Zarzad Portu Morskiego Darlowo Spolka z o.o.
Poland	Zarzad Portu Morskiego Elblag Sp zoo
Portugal	Adminiistracao dos Portos da Terceira e Graciosa S.A.
Portugal	Administracao do Porto de Sines S.A.
Portugal	Administracao dos Portos da Regiao Autonoma da Madeira S.A.
Portugal	Administracao dos Portos de Setubal e Sesimbra S.A.
Portugal	Administracao dos Portos do Douro e Leixoes S.A. (APDL)
Portugal	Administracao dos Portos do Triangulo e do Grupo Ocidental S.A.
Portugal	dminiistracao dos Portos da Terceira e Graciosa S.A.
Portugal	Instituto Portuario do Centro
Portugal	Instituto Portuario do Sul
Portugal	Instituto Portuario do Sul
Portugal	Instituto Portuario e dos Transportes Maritimos
Romania	Administratia Porturilor Dunarii Maritime (APDM)
Romania	Sulina Free Zone Administration
Serbia	Luka Beograd a.d.
Serbia	Luka Dunav Pancevo

Country	Port authority
Spain	Autoridad Portuaria de Almeria
Spain	Autoridad Portuaria de Aviles
Spain	Autoridad Portuaria de Baleares
Spain	Autoridad Portuaria de Cartagena
Spain	Autoridad Portuaria de Castellon
Spain	Autoridad Portuaria de Ferrol-San Ciprian
Spain	Autoridad Portuaria de Gijón
Spain	Autoridad Portuaria de la Bahia de Cadiz
Spain	Autoridad Portuaria de Las Palmas
Spain	Autoridad Portuaria de Las Palmas
Spain	Autoridad Portuaria de Las Palmas
Spain	Autoridad Portuaria de Malaga
Spain	Autoridad Portuaria de Marin-Pontevedra
Spain	Autoridad Portuaria de Melilla
Spain	Autoridad Portuaria de Motril
Spain	Autoridad Portuaria de Pasajes
Spain	Autoridad Portuaria de Santa Cruz de Tenerife
Spain	Autoridad Portuaria de Santa Cruz de Tenerife
Spain	Autoridad Portuaria de Santander
Spain	Autoridad Portuaria de Sevilla
Spain	Autoridad Portuaria de Tarragona
Spain	Autoridad Portuaria de Valencia
Spain	Autoridad Portuaria de Valencia
Spain	Autoridad Portuaria de Vigo
Spain	Autoridad Portuaria de Villagarcia de Arosa
Spain	Empresa Publica de Puertos de Andalucia
Spain	Ports de la Generalitat
Sweden	A/B Gota Kanalbolag
Sweden	Ahus Hamn &amp, Stuveri AB
Sweden	Bergkvara Hamn &amp, Stuveri AB
Sweden	Bottenvikens Stuveri AB
Sweden	Bottenvikens Stuveri AB
Sweden	Bottenvikens Stuveri AB
Sweden	Cementa AB
Sweden	Cementa AB
Sweden	Copenhagen Malmo Port AB
Sweden	Delta Terminal AB

Country	Port authority
Sweden	Falkenbergs Terminal AB
Sweden	Gavle Hamn
Sweden	Gotland Ports
Sweden	Halmstads Hamn Och Stuveri AB
Sweden	Hargs Hamn AB
Sweden	Harnosands Hamn
Sweden	Hudiksvalls Hamn
Sweden	Karlshamn Hamnforvaltning och Stuveri AB
Sweden	Karlskrona Hamn
Sweden	Landskrona Hamn AB
Sweden	Lysekils Hamnforvaltning
Sweden	Malarhamnar AB
Sweden	Nordkalk A/B
Sweden	Norrkoping Hamn &amp, Stuveri AB
Sweden	Nynashamns Hamn AB
Sweden	Ornskoldsvik Hamn
Sweden	Oxelosunds Hamn A/B
Sweden	Port of Hallstavik
Sweden	Port of Kapellskar
Sweden	Preemraff Lysekil
Sweden	Skarnas Terminal AB
Sweden	Soderhamns Stuveri och Hamn AB
Sweden	Sodertalje Hamn AB
Sweden	Solvesborgs Stuveri & Hamn AB
Sweden	Stenungsunds Hamntjanst AB
Sweden	Sundsvalls Hamn AB
Sweden	Trelleborgs Hamn AB
Sweden	Uddevalla Hamn-Terminal A/B
Sweden	Umea Hamn
Sweden	Vanerhamn AB
Sweden	Vanerhamn AB
Sweden	Vanerhamn AB
Sweden	Varbergs Hamn
Sweden	Vasterviks Logistik och Industri AB
Sweden	Wallhamn AB
Sweden	Ystad Hamn Logistik AB
Switzerland	Rheinschifffahrtsdirektion Basel

Country	Port authority
Ukraine	Belgorod-Dnestrovskiy Sea Port
Ukraine	Berdyansk Commercial Sea Port
Ukraine	Commercial Sea Port of Kerch
Ukraine	Commercial Sea Port of Reni
Ukraine	Izmail Sea Commercial Port
Ukraine	Kherson Commercial Sea Port
Ukraine	Mariupol Sea Commercial Port
Ukraine	Odessa Commercial Sea Port
Ukraine	Sea Commercial Port of Ilyichevsk
Ukraine	Sea Commercial Port of Nikolayev
Ukraine	Sea Commercial Port of Yuzhnyy
Ukraine	Sevastopol Sea Trade Port
Ukraine	Yalta Sea Trade Port
United Kingdom	Able UK Ltd
United Kingdom	Aggregate Industries UK Ltd. T/A Yeoman Glensanda
United Kingdom	ARC Northern
United Kingdom	Argyll & Bute Council
United Kingdom	Argyll & Bute Council
United Kingdom	Argyll & Bute Council
United Kingdom	Arisaig Marine Ltd
United Kingdom	Berwick Harbour Commission
United Kingdom	Blyth Harbour Commission
United Kingdom	Brightlingsea Harbour Commissioners Operator: Sita Suez
United Kingdom	Bristol City Council
United Kingdom	Caledonian MacBrayne Ltd
United Kingdom	Caledonian Maritime Assets Ltd (CMAL) Operator CalMac Ferries Ltd (CFL)
United Kingdom	Carrick District Council
United Kingdom	Chichester Harbour Conservancy
United Kingdom	Clydeport Operations Ltd Operator Clydeport Operations Ltd
United Kingdom	Clydeport Operations Ltd Operator: Clydeport Operations Ltd
United Kingdom	Clydeport Port Operations Ltd Operator Clydeport Operations Ltd
United Kingdom	Comhairle Nan Eilean Siar
United Kingdom	Cornwall Council
United Kingdom	Cornwall Council
United Kingdom	Cromarty Firth Port Authority
United Kingdom	Dart Harbour & Navigation Authority
United Kingdom	Department for Regional Development

Country	Port authority
United Kingdom	Dunbar Harbour Trust
United Kingdom	Environment Agency
United Kingdom	Falmouth Harbour Commissioners
United Kingdom	Felixstowe Dock &amp, Railway Company
United Kingdom	Fife Council
United Kingdom	Fife Council
United Kingdom	Fife Council
United Kingdom	Forth Ports Limited
United Kingdom	Forth Ports Limited
United Kingdom	Forth Ports Limited
United Kingdom	Gloucester Harbour Trustees
United Kingdom	Guernsey Harbours
United Kingdom	Hampshire County Council
United Kingdom	Harbour Authority Building
United Kingdom	Harwich Haven Authority
United Kingdom	Hayle Harbour Authority Ltd (HHAL)
United Kingdom	Highland Council
United Kingdom	Highland Council
United Kingdom	Highland Council
United Kingdom	Highland Council
United Kingdom	Inverness Harbour Trust
United Kingdom	Isle of Anglesey County Council
United Kingdom	Jersey Harbours
United Kingdom	Larne Harbour Limited
United Kingdom	Lerwick Port Authority
United Kingdom	Littlehampton Harbour Board
United Kingdom	Londonderry Port &amp, Harbour Commissioners
United Kingdom	Lymington Harbour Commissioners Operator Wighlink Ferries
United Kingdom	Medway Ports Flagstaff House
United Kingdom	Mersey Docks &amp, Harbour Company Limited Operator Several
United Kingdom	Mevagissey Harbour Trustees
United Kingdom	Milford Haven Port Authority
United Kingdom	Mistley Quay &amp, Forwarding Co.
United Kingdom	Montrose Port Authority
United Kingdom	Nene Ports Authority
United Kingdom	New Holland Bulk Services Ltd
United Kingdom	Newlyn Pier &amp, Harbour Commissioners

Country	Port authority
United Kingdom	Padstow Harbour Commissioners
United Kingdom	Perth and Kinross Council
United Kingdom	Poole Harbour Commissioners
United Kingdom	Port of Boston Ltd
United Kingdom	Port of Dundee Ltd
United Kingdom	Port of Dundee Ltd
United Kingdom	Port of London Authority Operator: Port of Tilbury London Ltd
United Kingdom	Port of Mostyn Ltd
United Kingdom	Port of Sunderland
United Kingdom	Port of Tyne Authority
United Kingdom	Port Penrhyn Plant Ltd
United Kingdom	Portland Port Limited
United Kingdom	Salcombe Harbour Also operates Kingsbridge
United Kingdom	Scarborough Borough Council
United Kingdom	Scrabster Harbour Trust
United Kingdom	Sennen Cove Harbour Commissioners
United Kingdom	Sharpness Port Authority
United Kingdom	Shoreham Port Authority
United Kingdom	Stena Line
United Kingdom	Stena Line Ports Ltd
United Kingdom	Sutton Bridge Wharfage Co Ltd
United Kingdom	Sutton Harbour Group
United Kingdom	Tarbert Harbour Authority
United Kingdom	Tees &amp, Hartlepool Port Authority Ltd
United Kingdom	Torbay Council Also operates Brixham &amp, Paignton
United Kingdom	Ullapool Harbour Trustees
United Kingdom	Wells Harbour Commissioners
United Kingdom	West Somerset District Council
United Kingdom	Whitehaven Harbour Commissioners
United Kingdom	Whitstable Harbour
United Kingdom	Wick Harbour Trust
United Kingdom	Yarmouth (IOW) Harbour Commissioners

4.2 SURVEY FOR ACCURACY FOR NAVIGATION IN PORTS DONE WITH HARBOUR MASTERS, 2015

Refer to study EMA15-MA-07 [RD51].

4.3 SURVEY AND INTERVIEWS WITH RECEIVERS' MANUFACTURERS ABOUT THE TECHNOLOGY TRENDS AND GAPS, 2016

4.3.1 INTRODUCTION

This chapter presents the results of a consultation process performed in 2016 to identify the technology gaps existing for the introduction of multi-frequency and multi-constellation SBAS receivers for maritime navigation (Solas and Non-Solas) and positioning applications. The analysis is built on top the outcomes of a study on the state-of-the-art of SBAS maritime receivers and the outcomes of a consultation process carried out with maritime receiver's manufacturers.

It is structured in different sections:

- Section D.3.2 summarises the assessment of the state of the art, trends and technology gaps of the maritime receivers;
- Section D.3.3 describes the consultation process performed among the maritime receiver manufacturers;
- Section D.3.4 presents the outcomes derived from the consultation process and the associated recommendations;
- Finally section D.3.5 presents the conclusions of this work.

The questionnaire used during the consultation process is available online at : https://gsa-sc7-surveys.typeform.com/to/WcmI4g?mail=email@company.com%20&pa=SBAS%20Manufacturer

4.3.2 STATE-OF-THE-ART OF SBAS MARITIME RECEIVERS

The survey on the state-of-the-art of SBAS maritime receivers, performed among 45 different models from twelve different manufacturers, revealed the following conclusions regarding the availability and quality of the information published by the manufacturers:

- There is a lack of standardization among the manufacturers about how to present the receiver performances (e.g. accuracy) in their catalogues. This lack of homogeneity hinders the comparison and assessment of different models with respect to the performances to be fulfilled, and may make difficult to the users the selection of receivers to be purchased;
- As expected, integrity is not currently a key performance highlighted in the commercial information. It is assumed that in most cases this lack of information may be due to the fact that this concept is not implemented, but it was expected to be confirmed with the manufacturers during the consultation process;
- On the contrary, technologies to compute the PVT are considered very relevant by the receiver manufacturers and therefore are clearly specified in the datasheets or product specifications. Anyway, there is no published information at all about interoperability between DGNSS and SBAS sources.

As for the state of the art itself, the main conclusions were the following:

- **There are already some multi-frequency multi-constellation non-SOLAS receivers in the market** (Kongsberg, Hemisphere GNSS, Septentrio, Trimble) supporting SBAS, DGNSS and RTK technologies;
- **SBAS SOLAS receivers do not support multi-frequency and present very limited multi-constellation support**, with only about 30% supporting global navigation systems different from GPS (being GLONASS in all of the cases). The entire SBAS SOLAS receivers offer DGNSS support, and most also include RAIM technology;
- A great diversity of accuracies can be found, mainly determined by the technologies included in the receivers, but there is also a noticeable variation in the accuracy specifications between different manufacturers with the same technologies. Enhanced accuracies go from less than a meter in some cases with DGNSS or SBAS, up to a centimetre when using RTK technologies;
- As far as integrity alarm processing technologies is concerned, some manufacturers mention the usage of RAIM technologies or having them as optional in some receivers, but details about the RAIM techniques applied are almost never provided;
- There are a few receivers equipped with IMU systems, and no receiver including eLoran was identified in this survey.

4.3.3 MANUFACTURERS TRENDS CONSULTATION

OBJECTIVES

The understanding of the above mentioned state of the art and trends is complemented by a consultation process with representative manufacturers. This consultation has been aimed to confirm the preliminary outcomes of the survey and to obtain a more precise knowledge of some of the issues from which little information has been found.

THE QUESTIONNAIRE

The consultation has been planned by means of an on-line questionnaire[3] and phone conferences. A sample of the questionnaire is presented as an annex to this chapter and includes specific questions related to:

- Identification of trends and new developments;
- Maritime regulation and standardization framework;
- Navigation and positioning performances, in particular:
  - to harmonise the performances published by the manufacturers,
  - to know the usage of system or user integrity techniques.

THE AUDIENCE

The target audience has been defined based on the outcomes from a desktop survey, the GNSS Market Report [RD41] and the CIRM webpage [RD61]. The audience includes manufacturers participating in maritime navigation working groups (e.g. EMRF, RTCM, IALA, etc.), ensuring that the selected manufacturers or integrators provide a good representation of the maritime market.

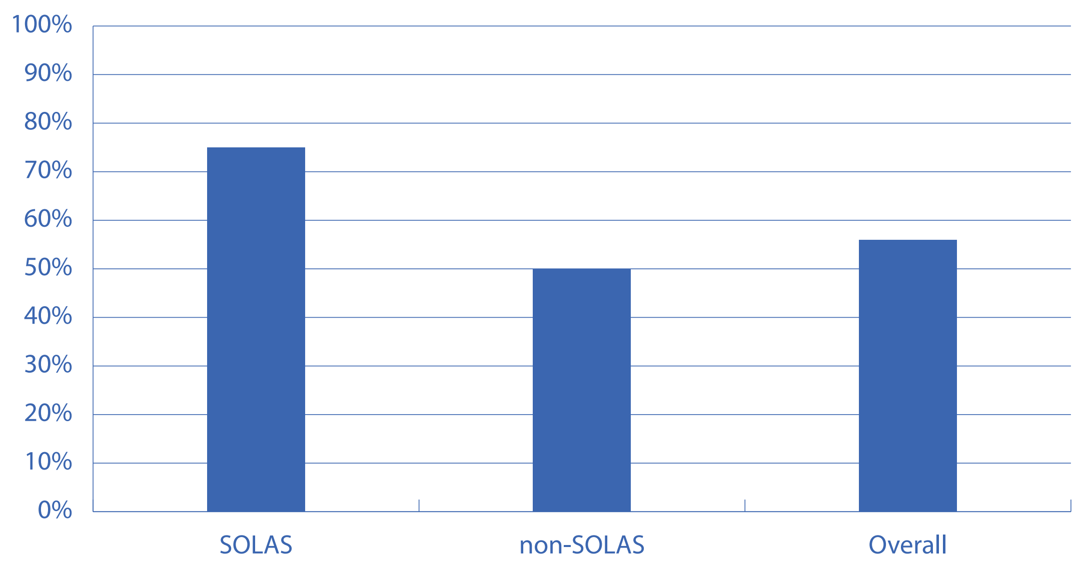
4.3.4 THE OUTCOMES

The consultation process has been carried out from November 2015 to January 2016. Sixteen manufacturers were contacted by e-mail and invited to participate by means of an on-line questionnaire. Those of them who initially did not participate on-line were contacted again by phone and/or by dedicated e-mail. The participation has finally exceeded 50%.

Table 25: Audience of the consultation process

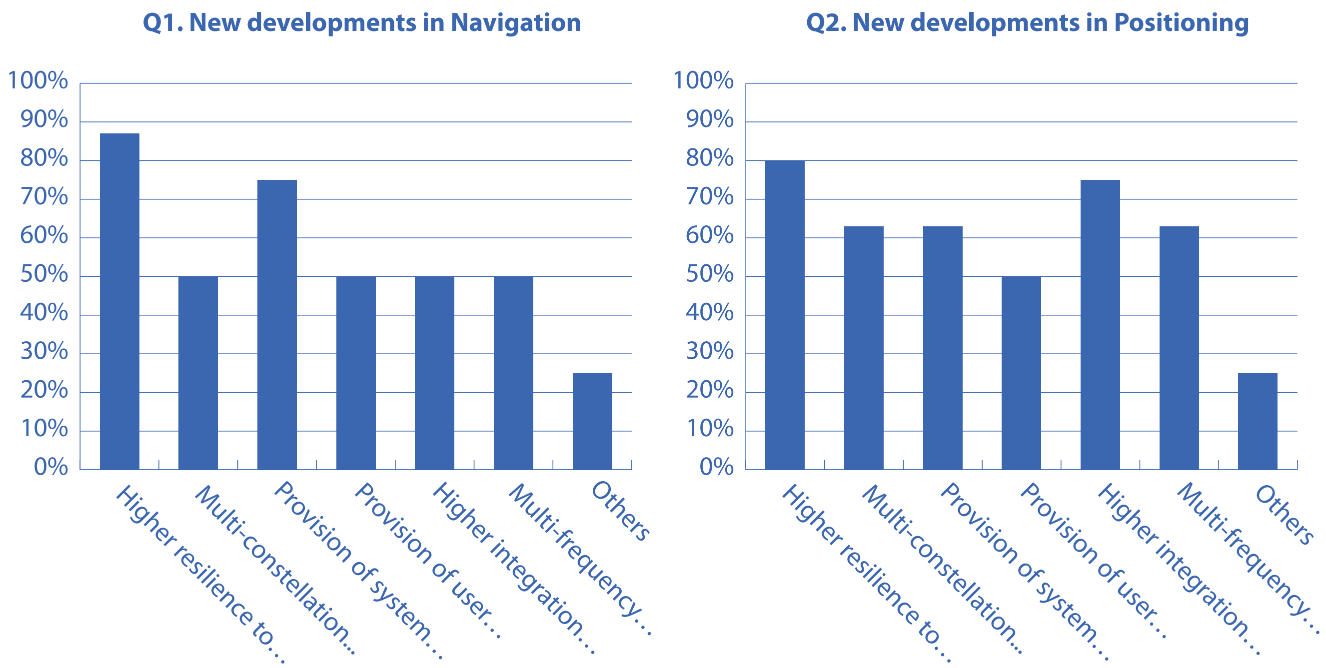
SOLAS	Non-SOLAS	
Furuno	Eagle	Novatel
JRC	Fugro	Raymarine
Koden	Garmin	Saab
Simrad	Hemisphere	Samyung Enc
	Kongsberg	Septentrio
	Lowrance	Trimble

Table 26: Percentage of participation to the consultation process (Solas and Non-Solas)



3 https://gsa-sc7-surveys.typeform.com/to/Wcml4g?mail=email@company.com &pa=SBAS Manufacturer

Figure 9: Consultation results for Q1) new developments in Navigation and Q2) new developments in Positioning



NEW DEVELOPMENTS AND TRENDS

Figure 9 depicts the the features that the manufacturers are interested to incorporate in their products to improve navigation and positioning capabilities.

Higher resilience to jamming and interferences seems to be the most relevant functionality considered for both Navigation and Positioning applications.

Provision of system integrity information to the users and **Higher integration with other positioning technologies** would be the second priority for Navigation and Positioning respectively.

Some manufacturers highlight that **multi-constellation** is a must since it is becoming a need to meet the performances demanded for current and future navigation and positioning applications. However, it is pointed out for some manufacturers that Galileo is still not recognised, therefore the use of combined GPS and GLONASS is the multi-constellation option more extended among them.

Multi-frequency capabilities does not seem to present so much interest, in particular for Navigation applications and neither in the Positioning applications, where is highlighted by the manufacturers that accuracies of 10 m are mostly enough and when more precision is required, they are tending to integrate other positioning technologies to support such operations.

The main drivers in the adoption of the Multi-Frequency and Multi-Constellation capabilities from receiver manufacturer's point of view go through:

Table 27: Main drivers for adoption of MC and MF in the receivers (Q4)

Market demand (i.e. end-user needs)
Approving of the corresponding IEC (TC80) test specification standard before adoption in wheel marked products
Generation of a "sterling" Receiver Guidance
Moderate receiver price

The respondents have not identified any technical problem for the development and deployment of these new capabilities into their products. There still exist anyway some challenges to be faced by the manufacturers in front of future maritime receivers. The most relevant challenges derived from the consultation process can be seen in Table 28.

Finally, the consultancy results shows that there is no a perception of a competitive advantage for the EU receiver manufacturers industry regarding the MF and MC capabilities, although a few respondents were pointing out Galileo as a strength of the EU.

REGULATORY FRAMEWORK COMMITMENT

The definition of the new maritime safety services based on EGNOS is running along with a process of EGNOS recognition by IMO as part of the WWRNS.

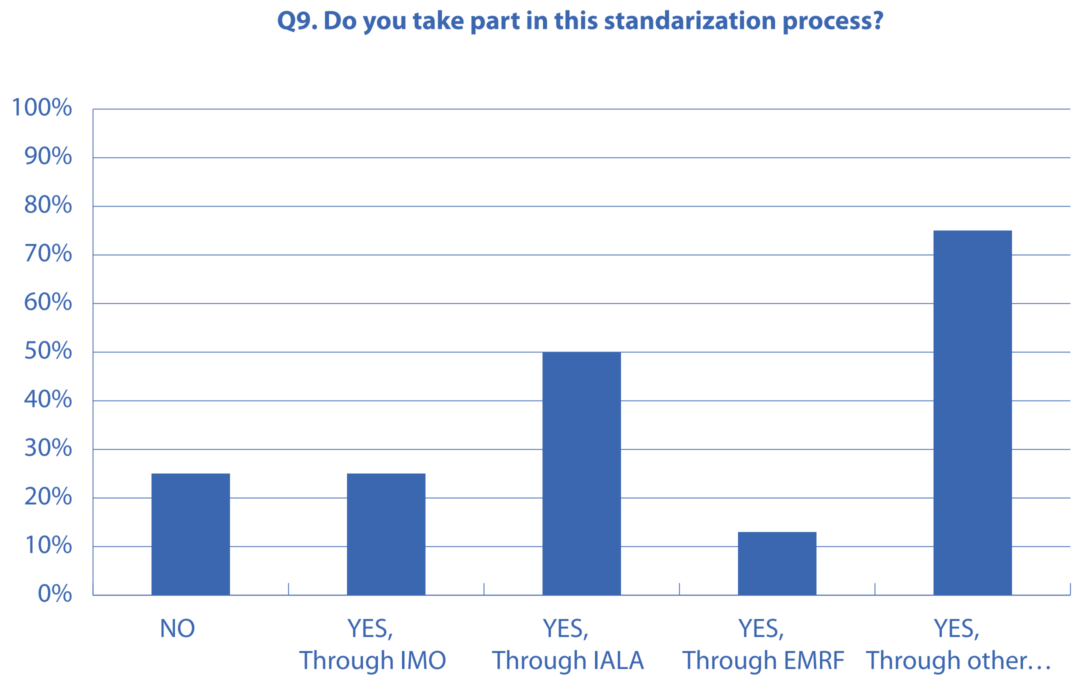
Most of the manufacturers are aware of the process to have Galileo recognized by IMO as part of the WWRNS, and also of the discussions aiming to have SBAS recognised too. There is anyway a certain lack of awareness about the new maritime safety services that could be supported by EGNOS and in general about the activities of the EMRF working group. When the EMRF objectives have been recalled to the manufacturers, some of them have shown a high willingness to participate in that forum.

Figure 10 summarises the results regarding the awareness of the standardisation process.

Table 28: Technology and non-technology challenges for adoption of MC and MF in the receivers.

Technology challenges (Q5)	Non-technology challenges (Q6)
Non-intentional Interference	Recognition of Galileo and EGNOS by IMO as part of the WWRNS and Getting IEC performance standard publication
Management due to the integration of multiple radio systems on vessels	Avoiding special marine receiver requirements in EU that will harm international cost-competitiveness
Detection and Mitigation of intentional (hostile) jamming of GNSS signals	Safety certification 'paperwork'

Figure 10: Awareness of the standardisation roadmap by manufacturers



The results show that the majority of the participants are aware and participated in the standardization processes currently on-going through different means: IALA ENAV, IEC TC80 WG15, RTCM, CIRM and DGON.

The consulted manufacturers do not provide any comments regarding the standardization process but all of them remark it is taken into account when defining their product roadmaps.

NAVIGATION AND POSITIONING PERFORMANCES

Accuracy

Most of the manufacturers consulted are presenting the **accuracy** in their commercial information using a 95% percentile (as requested in IMO resolutions A.915 and A.1046). The remaining manufacturers declare they could provide those figures without major inconvenience. The decision to us a percentile or another is driven by the usual type of services to be supported by the receiver.

The improvement of the accuracy performances is not seen as a short-term priority by the manufacturers.

Integrity

System level integrity is specified in resolution A.1046. This integrity concept provides information about the integrity of the system, but it does not cover error sources that are particular for each user. This integrity concept is mandatory for recognition as part of WWRNS.

The calculation of some type of system integrity is declared by more than the half of the respondents, however only around a 25% state compliance with resolution A.1046. Manufacturers still not compliant with the resolution are willing to do it in the future.

Those manufacturers which are providing system integrity are implementing technology based on IALA DGNSS corrections, PPP services and/or MMS.

User level integrity is specified in resolution A.915 (22). In this case, the integrity requirement needs a revision based on a proper analysis of the maritime concept of operations and local specificities: it is not appropriate to simply translate known values derived from the aviation context into maritime requirements because of the significant local differences, including sources of errors such as multipath.

User integrity is widely implemented by means of RAIM techniques, even no manufacturer has responded about its current implementation and their intention to adapt these technologies to the particularities of the maritime environment (e.g. multipath over-bounding models). One of the respondents (i.e. SOLAS manufacturer) mentions that they are performing a user integrity check by mean of comparison of data from independent systems. This contrasts with the recommendations of relevant maritime authorities, such as US and Canadian Coast Guards, who require the user equipment to use the UDRE values to compute integrity confidence levels about the user's displayed position ([RD33],[RD60]).

Figure 11: System level integrity usage

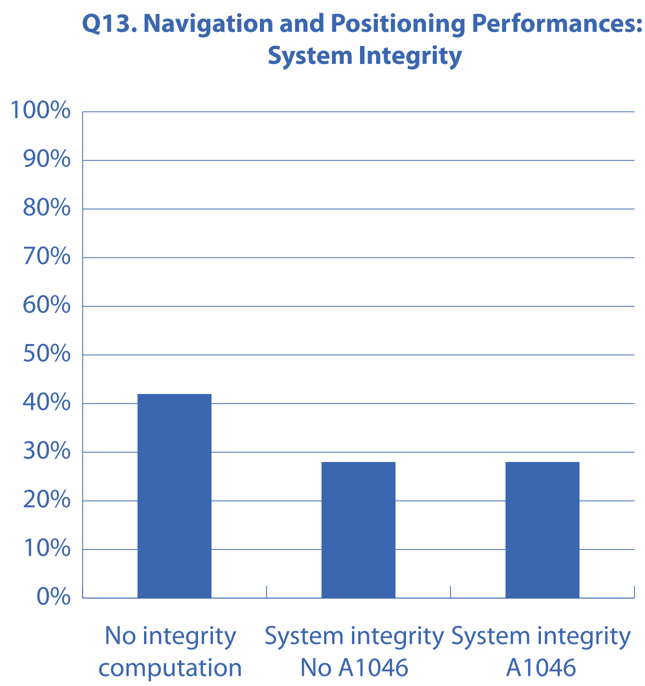
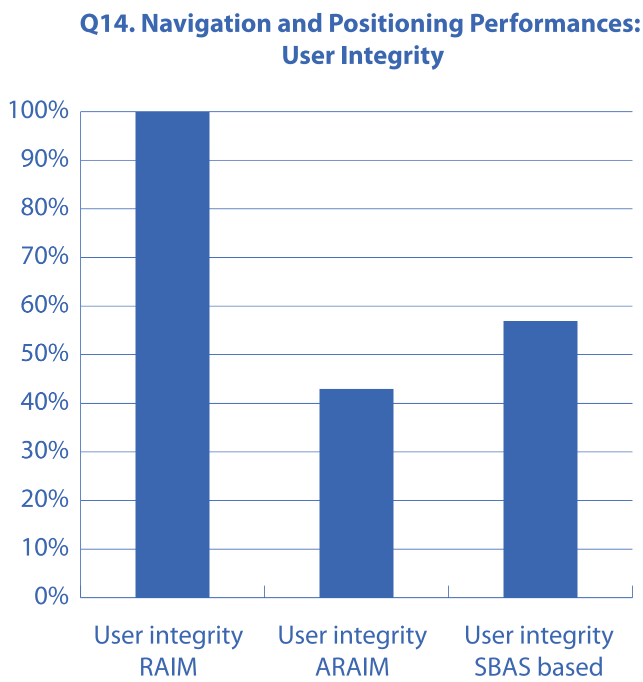


Figure 12: System level integrity usage



PVT COMPUTATION USING DIFFERENT SOURCES

38% of the respondents confirm that their receivers can use simultaneously DGNSS and SBAS sources for PVT computation whilst the rest are only using one source.

One third of the respondents are making the selection of the navigation source **manually** whilst the others two-thirds are making it **automatically** by means of the receiver (Figure 14:). However, the respondents are not providing information about how they manage this process since this information is identified as commercially sensitive.

The respondents confirm that their products always provide visibility to the user about the navigation source used for navigation or positioning.

4.3.5 CONCLUSIONS

The summary conclusions of this survey are provided in the main User Requirements document, in section 4.3.3.

4.3.6 GUIDELINES AND RECOMMENDATIONS

The following guidelines and recommendations are derived from the conclusions of the consultation process and gap analysis.

The **promotion of EGNOS and Galileo shall be enforced** among the manufacturers of maritime equipment, with particular emphasis in the manufacturers of SOLAS receivers. In the case of EGNOS, this promotion would take advantage from the incoming grant for the development of an EGNOS maritime receiver, but also from the planned definition of the guidelines for receiver manufacturers. In the advent of Galileo IMO recognition, this awareness would help also increasing Galileo penetration in particular in terms of SOLAS vessels, where multi constellation capabilities are up to now based on GPS and GLONASS.

The **organization of a dedicated workshop with manufacturers of maritime receivers** is highly recommended, preferably collocated with a relevant maritime event in order to ensure high attendance.

Invitation to participate in the EMRF should be renewed to the manufacturers, in particular, the SOLAS ones, taking profit of the new contact points that have been identified during the consultation.

The information about the relevant points of contact in the manufacturers should be centralized in a database and keep up-to-date, preferably together with the data associated to other relevant stakeholders in the maritime domain (as resulting from WP1 in the SC7 contract).

EGNOS recognition by IMO as part of the WWRNS is encouraged as the feedback received from the manufacturers indicates it would foster their penetration in the maritime community. The roadmap for the definition and provision of an EGNOS maritime service should be secured, giving priority to the resolution of main uncertainties and risks behind, as for example the level of compliance of the service to the maritime and port operations and the associated cost benefit analysis that manufacturers highlight as of the utmost relevance.

Galileo recognition by IMO as part of the WWRNS should be also secured by supporting the IMO process. SOLAS manufacturers highlights the importance of this recognition in order to include Galileo in their products, increasing in this way their multi-constellation capabilities.

Figure 13: Simultaneity of sources for PVT computation (Q16)

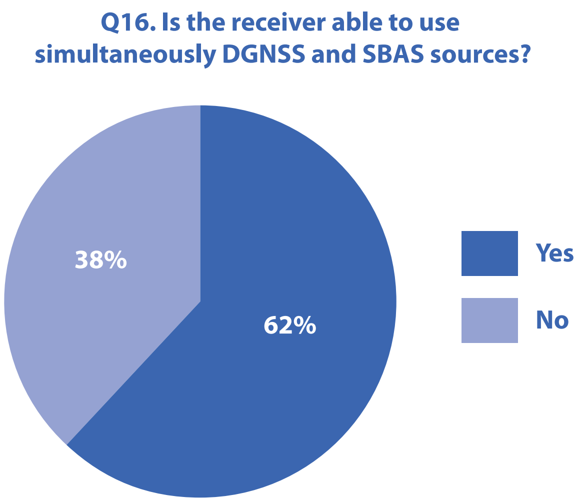
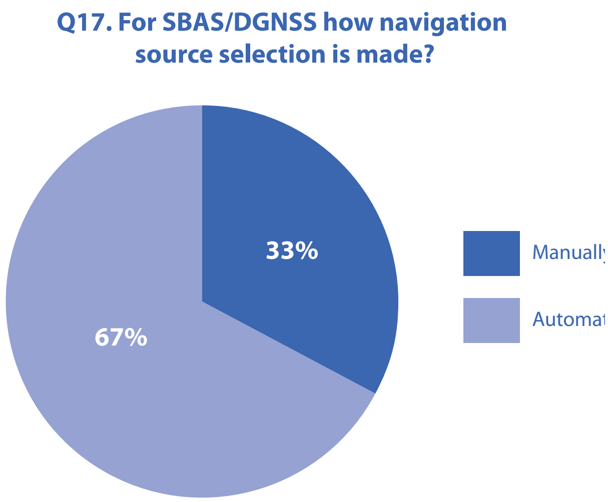


Figure 14: Navigation sources selection method (Q17)



4.4 SURVEY FOR ACCURACY, INTEGRITY, AVAILABILITY AND CONTINUITY FOR NAVIGATION IN PORTS DONE WITH PILOTS AND SHIPMASTERS, 2016.

4.4.1 INTRODUCTION

The aim of this survey is to provide additional support to the EUSPA in the identification of maritime user needs in ports that could take special benefit of an EGNOS maritime service. The consultation is a step forward in the assessment of the user needs, by identifying both:

- Operations with 10m accuracy requirements for which higher performances might result on significant operational benefits; and
- Operations requiring 1m of accuracy for which accuracy might be relaxed without penalties.

The aim is to better specify the performances and to assess if accuracy performances, as offered by EGNOS, could provide an added value in the frame of those applications.

With this aim, a new consultation has been performed targeting the pilots and harbour masters taking the as a basis the ESSP and ALG consultation for port authorities (sections D.1 and D.2 of this annex), and the GMV consultation for autonomous vessels for specific aspects (section D.5).

This report presents the results of the consultation and identifies the port navigation and positioning operations arousing higher interest among the pilots and harbour masters and the performance levels that are required.

The document is structured in different sections:

- Section D.4.2 presents the objectives and audience of the consultation process, together with the used methodology;
- Section D.4.3 presents the conclusions of the analysis, including the assessment of the user needs, the drafting of the intermediate performance levels and the derived recommendations;
- Annex A: Questionnaire and Statistics presents the content of the questionnaire and the statistics for each one of the answers.

4.4.2 THE CONSULTATION PROCESS

METHODOLOGY

Three phases have been identified to accomplish this survey.

1. **Definition and planning**
Definition and preparation of the questions for the survey.
Consolidation of the list of maritime users to be contacted.
Preparation of the interactions with the target users.

2. **Survey**
Interactions based on on-line questionnaires distributed by a LinkedIn private message.

3. **Analysis**
Gathering the received information.
Assessment of the user needs.

THE SURVEY

The consultation process has been addressed by means of an on-line questionnaire. The survey has been distributed by LinkedIn message to pilots, ship masters and harbour masters actively working in European ports.

The survey is organized as follows:

- Welcome, by presenting the purpose and contents of the survey and few indications for filling the questionnaire;
- User needs for navigation applications in ports;
- User needs for positioning applications in ports requiring demanding medium accuracy performances;
- User needs for positioning applications in ports requiring lower accuracy performances;
- User needs for other positioning applications;
- User needs for vertical positioning in port operations;
- The country of origin of the user.

A sample of the survey is presented in Annex A: Questionnaire and Statistics.

THE OUTCOMES

The participation

This chapter presents the results obtained from the survey. It is worth to say that there was an initial uncertainty of the used tool, not knowing how the targeted audience would react or be active on such professional social network. In fact, out of 151 contacted users, across all over Europe, only 28 replied to the questionnaire.

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

Countries	N. Participants
Netherlands	5
United Kingdom	5
Italy	4
Ireland	3
Spain	2
France	2
Portugal	2
Belgium	1
Bulgaria	1
Germany	1
Denmark	1
Croatia	1

The feedback

This section summarises the outcomes of the survey with the feedback provided by the pilots, ship masters and harbour masters.

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

4.4.3 CONCLUSIONS

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

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

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

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

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

The answers related to low accuracy applications, instead, comply with the IMO 1046(27) standards without any specific request of higher accuracy levels.

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

ANNEX A: QUESTIONNAIRE AND STATISTICS

Before presenting the results with the related statistic, it must be highlighted that the participants had multiple choice option, starting from question 4.1.1.

GETTING STARTED...

Which is your qualification?

28 out of 28 replied to this question

		Answers / Ratio
1	Pilot	26 / 92.86%
2	Ship Master	7 / 25%
3	Harbour Master	0 / 0%
4	No Answer	0 / 0%

Which are the main technological or non-technological means used to support navigation in ports?

28 out of 28 replied to this question

		Answers / Ratio
1	Visual Operation	28 / 100%
2	RADAR	26 / 92.86%
3	AIS	16 / 57.14%
4	DGPS	13 / 46.43%
5	SBAS	2 / 7.14%
6	RTK	8 / 28.57%
7	Other*	2 / 7.14%
8	No Answer	0 / 0%

* Other Specified: Shore radar sent to ppu

Are you using the Portable Pilot Unit (PPU)?

27 out of 28 replied to this question

		Answers / Ratio
1	Yes	17 / 60.71%
2	No	10 / 35.71%
3	No Answer	1 / 3.57%

If yes, which technology is it using?

17 out of 28 replied to this question

		Answers / Ratio
1	AIS	11 / 39.29%
2	SBAS	3 / 10.71%
3	DGPS	8 / 28.57%
4	RTK	10 / 35.71%
5	No Answer	11 / 39.29%

For which ship tonnage are you using the PPU?

17 out of 28 replied to this question

		Answers / Ratio
1	300GT-499GT	0 / 0%
2	500GT-4999GT	0 / 0%
3	5000GT-24999GT	6 / 21.43%
4	25000GT-59999GT	10 / 35.71%
5	>60000GT	16 / 57.14%
6	No Answer	11 / 39.29%

For which type of vessels are you using the PPU?

17 out of 28 replied to this question

		Answers / Ratio
1	Dangerous Goods Tankers	15 / 53.57%
2	Passenger Ships	8 / 28.57%
3	Cargo Ships	11 / 39.29%
4	Other*	7 / 25%
5	No Answer	11 / 39.29%

* Other Specified: Sensitive vessels- where size of vessel & dock area creates limitations; Dead ships; Other vessels on a case by case basis; Car Carriers, Container v/ls; LCS > 350m; tug-and-tow, Oil-rigs, trips in/out dry dock; All above loa 300m and special transports like barges loadouts and MOU's; LNG

What other systems different from the above mentioned are/can be used to increase safety when navigating in ports?

14 out of 28 replied to this question

Answers
ECDIS
Second Pilot
Transas
VTS
ELoran
Terrestrial Radio Based Systems
Alternative for GNSS like edLoran; maximize amount of GNSS, switch on Galileo; use of L1 and L2 freqs; technique that recognizes/resolves multi-path of sat signals
WiMax based system
Laser Guidil Lines
Virtual Aids to Navigation
ED Loran
Simple PPU, working on AIS and VTS radar fusing traffic image
Buoyage, and fixed terrestrial aids such as leading lights and markers

Which horizontal accuracy (at 95% of probability, in meters) do you consider necessary to support vessel navigation in ports?

28 out of 28 replied to this question

		Answers / Ratio
1	10m	4 / 14.29%
2	5m	3 / 10.71%
3	3m	3 / 10.71%
4	2m	5 / 17.86%
5	1,5m	3 / 10.71%
6	1m	2 / 7.14%
7	Less than 1m	13 / 46.43%
8	No Answer	0 / 0%

Which are the reasons for the applicable accuracy?

23 out of 28 replied to this question

Answers
Although it us useful to have as a guide personally don't rely on DGPS or ECDIS to conduct a vessel into port. I rely more on radar ranges, bearings, transits & visual aids. For this reason I don't feel it necessary for the positioning system to be overly accurate.
Restricted twisting room becoming more "narrow" due to the increased dimensions of ships.
avoid collisions with other vessels and berths.
General use= 2m is ok. Lock approach <1.0m is desirable but only available with RTK.
It's less than 1 meter for docking operations to navigate in the fairway 5m is enough. Main concern is not accuracy but delay and dynamics coherence with visual operation.
In foggy weather.
Good enough for river transit.
Safety.
Safety margins in piloting can be very tight hence 3 metres.
1-2 metres is acceptable for general Channel Navigation, however less than 1m is necessary for certain operations, such as berthing, lock-work and special projects.
10m is sufficient for most ship sizes and conditions, application of tidal and wind allowances especially on large ships render high accuracy specifications overkill on passage. Berthing accuracy is a different matter though. In those circumstances, the highest possible accuracy is desired.
Require (and use) 1 cm accuracy at 95 %. Besides position it is the derived data: independent heading, rate of turn, side speed on bow and stern and prediction of the vessel (RTK for cm accuracy) - due to various reasons on board installation nice to cross ocean, not good enough for precise navigation in port; often errors in settings of ship equipment. Max amount of satellites because port area's usually suffers much disturbance/interference.
Open port.
Error must be lower than 2 percent of the narrowest place in the pilotage region.
PPU docking mode.
Precision navigation on encounters, accurate speed on final approach to berth.

Answers
Because when we are talking about manoeuvring a big Tanker in port, for example an LNG tanker loaded, the accuracy for the positioning at berthing moment must to be exact, I mean for example when we are putting the vessel in the right position against the terminal loading arms, this ones have a poor level of movement.
I am using the equipment for swinging large vessels when I am unable to see some of the obstructions due to poor visibility from the bridge.
Possibility to use as support in fog.
Narrow ports with ships becoming larger.
Berthing is precise operation.
shallow water, narrow passages, locks without fenders.
our port is very narrow to manoeuvre a new generation vessel.

What should be, in your opinion, the maximum allowable error in the measured position (Alert limit) for navigation in ports?

28 out of 28 replied to this question — Answers / Ratio

1	25m	2 / 7.14%
2	12.5m	3 / 10.71%
3	7.5m	0 / 0%
4	5m	6 / 21.43%
5	3.75m	0 / 0%
6	2.5m	1 / 3.57%
7	Less than 2.5m	16 / 57.14%
8	No Answer	0 / 0%

What should be, in your opinion, the time elapsed between the occurrence of a failure in the system and its presentation on the bridge (Time to alarm)? Within...

28 out of 28 replied to this question — Answers / Ratio

1	15s	2 / 7.14%
2	10s	8 / 28.57%
3	6s	18 / 64.29%
4	No Answer	0 / 0%

Let assume that the system leads to an error above the maximum allowable error specified and that the user is not warned on time. What would be the maximum probability allowed for such an event during the time of the operation?

27 out of 28 replied to this question — Answers / Ratio

1	High 10^{-6} (one chance over 1 million)	11 / 39.29%
2	Medium 10^{-5} (one chance over 100,000)	8 / 28.57%
3	Low 10^{-4} (one chance over 10,000)	8 / 28.57%
4	No Answer	1 / 3.57%

What would be the typical/average duration of the operation?

17 out of 28 replied to this question

		Answers / Ratio
1	1-10h	1 / 3%
2	2h	6 / 35%
3	2,5	1 / 3%
4	from 2 to 4 h	1 / 3%
5	from 2 to 8h	1 / 3%
6	3h	3 / 10%
7	3,5 h	1 / 3%
8	from 3 to 5h	1 / 3%
8	from 3 to 56h	1 / 3%
10	4h (2 Hours for entering and 2 hours when leaving the port, depending if there are river/channel navigation or not)	1 / 3%
11	No Answer	11 / 39%

Assuming that valid GNSS information is provided at the beginning of a critical phase of an operation. What would be the maximum tolerable probability of having service interruption during this phase (Continuity risk)?

26 out of 28 replied to this question

		Answers / Ratio
1	0.01%	11 / 39.29%
2	0.03%	5 / 17.86%
3	0.05%	10 / 35.71%
4	No Answer	2 / 7.14%

Which would be, in your opinion, the percentage of time that an aid, or system of aids, is performing a required function under stated conditions (Availability)?

28 out of 28 replied to this question

		Answers / Ratio
1	99.9%	14 / 50%
2	99.8%	4 / 14.29%
3	99.5%	2 / 7.14%
4	95%	8 / 28.57%
5	No Answer	0 / 0%

POSITIONING OPERATIONS IN PORTS - MEDIUM ACCURACY APPLICATIONS

The following port applications usually require high horizontal accuracy. Based on the activity and characteristics in the port under your responsibility, which of the following applications can be performed with accuracy levels of ~1,5m (at 95%) or even under more relaxed accuracy conditions?

27 out of 28 replied to this question

		Answers / Ratio
1	Management of aids to navigation	16 / 57.14%
2	Tugs and pusher operations	14 / 50%
3	Local VTS	16 / 57.14%
4	Law enforcement	13 / 46.43%
5	Casualty analysis	7 / 25%
6	Cargo handling	6 / 21.43%
7	Container/cargo management	8 / 28.57%
8	None	2 / 7.14%
9	No Answer	1 / 3.57%

Tugs and Pusher Operations: Which accuracy level would be sufficient for operations of tugs and pushers within your port?

26 out of 28 replied to this question

		Answers / Ratio
1	10m at 95%	3 / 10.71%
2	7m at 95%	1 / 3.57%
3	5m at 95%	5 / 17.86%
4	3m at 95%	2 / 7.14%
5	1,5 m at 95%	9 / 32.14%
6	1m at 95%	8 / 28.57%
7	No Answer	2 / 7.14%

POSITIONING OPERATIONS IN PORTS - LOW ACCURACY APPLICATIONS

The following port applications do not traditionally require high horizontal accuracy. However, current traffic trends and modern maritime applications might lead to higher accuracy needs (e.g. increased port capacity and operability). For which of the following applications do you consider worth improving the accuracy?

28 out of 28 replied to this question

		Answers / Ratio
1	General port approaches	13 / 46.43%
2	Traffic management (ship-to-shore and shore-to-ship)	20 / 71.43%
3	Automatic collision avoidance and track control	12 / 42.86%
4	Recreation and leisure	5 / 17.86%
5	None	2 / 7.14%
6	No Answer	1 / 3.57%

General Port approaches: Which accuracy level would you consider worth having for general port approaches?

28 out of 28 replied to this question

		Answers / Ratio
1	10m at 95%	10 / 35.71%
2	7m at 95%	0 / 0%
3	5m at 95%	9 / 32.14%
4	3m at 95%	5 / 17.86%
5	1,5m at 95%	2 / 7.14%
6	1m at 95%	5 / 17.86%
7	No Answer	0 / 0%

Comments
The specific Port Approach requires a high degree of accuracy when Piloting large vessels through the harbour entrance to prevent grounding.
Port approach does not require high accuracy positioning.
Shore systems tend to use ships AIS data (instead of shore based radar). Ships AIS outcome suffers from erroneous installing, setup and smoothing filters: speed change too late noticed.
The moment that vessels pass the Non Return Line.
For pilots to use the equipment it needs to be highly accurate and highly reliable. So both they and the ships master can have confidence in the system.

Automatic collision avoidance and track control: Which accuracy level do you consider worth for automatic collision avoidance and for track control?

23 out of 28 replied to this question

		Answers / Ratio
1	10m at 95%	5 / 17.86%
2	7m at 95%	0 / 0%
3	5m at 95%	4 / 14.29%
4	3m at 95%	4 / 14.29%
5	1,5m at 95%	5 / 17.86%
6	1m at 95%	6 / 21.43%
7	No Answer	5 / 17.86%

Comments
Absolute accuracy is not the point but relative accuracy, Time lapse. Avoiding collision only with Gps is No sense. Colreg must be change to achieve that.
Accuracy can be relaxed somewhat, however a high degree is still required.
Automatic collision avoidance is an inevitable development BUT it is not about positional accuracy only and must be viewed more holistically than at present.
Shore systems tend to use ships AIS data (instead of shore based radar). Ships AIS outcome suffers from erroneous installing, setup and smoothing filters: speed change too late noticed.
We need the accuracy, overall, when the risks are close to the vessel mainly.
Automatic collision avoidance does not work in confined waters.
In port condition we can't use.

Traffic management: Which accuracy level do you consider worth for ship-to-shore coordination and shore-to-ship management?

27 out of 28 replied to this question

		Answers / Ratio
1	10m at 95%	10 / 35.71%
2	7m at 95%	0 / 0%
3	5m at 95%	4 / 14.29%
4	3m at 95%	7 / 25%
5	1,5m at 95%	3 / 10.71%
6	1m at 95%	5 / 17.86%
7	No Answer	1 / 3.57%

Recreation and leisure: Which accuracy level do you consider worth for recreation and leisure?

26 out of 28 replied to this question

		Answers / Ratio
1	10m at 95%	11 / 39.29%
2	7m at 95%	2 / 7.14%
3	5m at 95%	7 / 25%
4	3m at 95%	4 / 14.29%
5	1,5m at 95%	0 / 0%
6	1m at 95%	2 / 7.14%
7	No Answer	3 / 10.71%

OTHER PORT APPLICATIONS

Can you identify current or future applications that may require a horizontal positioning accuracy level between 1,5m and 10m? In case you know please specify the accuracy level required for each application.

7 out of 28 replied to this question — Answers / Ratio

1	Lock approach.	1 / 3%
2	Passage under bridges, Container Cranes, Bridges. All within 1m preferably.	1 / 3%
3	No	1 / 3%
4	Exact manfolding ship to shore 1m at 95 per	1 / 3%
5	VTM, port throuput, fairway utilisation, port/fairway accessibility	1 / 3%
6	Autonomous barging	1 / 3%
7	Lock approach, swinging vlcc in shallow/confined waters	1 / 3%
8	No Answer	21 / 75%

VERTICAL POSITIONING IN PORTS

Is vertical positioning currently relevant or will it be relevant in the future for the applications used in your ports?

27 out of 28 replied to this question — Answers / Ratio

1	Yes	15 / 53.57%
2	No	12 / 42.86%
3	No Answer	1 / 3.57%

Comments
Change in vertical position seems to create horizontal accuracy issues- (Lock level etc.).
Squat 1cm.
1.5 m for bridge transits.
Operating at minimal UKC and minimal Air Draft clearances are essential elements. There is no simple answer to the question regarding UKC but in general depending on tidal and weather conditions in my port a simple 0.9 - 1.4 m allowance for UKC is made. For airdraft clearances - it will depend on the nature of the vessel and prevailing conditions.
For Dynamic UKC 0,1 m at 95 %.
bridge / cable clearances must be observed at accuracy 2 ft.
Less than 10cm 99.7%.
Maybe can be useful when navigating in channels or rivers with bridges crossing. For Airdraft matters.
Crane jib positions.
No Answer.

BEFORE YOU LEAVE...

From which Country you are from?

28 out of 28 replied to this question

		Answers / Ratio
1	Austria	0 / 0%
2	Belgium	1 / 3.57%
3	Bulgaria	1 / 3.57%
4	Cyprus	0 / 0%
5	Czech Republic	0 / 0%
6	Germany	1 / 3.57%
7	Denmark	1 / 3.57%
8	Estonia	0 / 0%
9	Greece	0 / 0%
10	Spain	2 / 7.14%
11	Finland	0 / 0%
12	France	2 / 7.14%
13	Hungary	0 / 0%
14	Croatia	1 / 3.57%
15	Ireland	3 / 10.71%
16	Italy	4 / 14.29%
17	Lithuania	0 / 0%
18	Luxembourg	0 / 0%
19	Latvia	0 / 0%
20	Malta	0 / 0%
21	Netherlands	5 / 17.86%
22	Poland	0 / 0%
23	Portugal	2 / 7.14%
24	Romania	0 / 0%
25	Sweden	0 / 0%
26	Slovenia	0 / 0%
27	Slovak Republic	0 / 0%
28	United Kingdom	5 / 17.86%
29	No Answer	0 / 0%

4.5 SURVEY AND INTERVIEW WITH USERS FOR THE USE OF EGNSS IN AUTONOMOUS VESSELS, 2016.

4.5.1 INTRODUCTION

This chapter presents the results of a consultation process performed in 2016 to identify the users' positioning and navigation needs for the autonomous vessels; as well as the potential use of EGNSS for this application.

It is structured in different sections:

- Section D.5.2 presents the stakeholders interviewed during this study, and the structure of the questionnaire;
- Section D.5.3 presents the full questionnaire used during the consultation process.

The results of the consultation, for what concerns required navigation performance, are summarised in section 4.3.5 of the Maritime User Requirements report.

4.5.2 INFORMATION ON KEY SURVEYS AND INTERVIEWS

The following set of representative stakeholders has participated in this research:

- Fraunhofer CML (3/14/2016 13:12:56);
- MARINTEK (3/14/2016 16:46:22);
- Técnicas y Servicios de Ingeniería, S.L (3/15/2016 11:46:31);
- Puertos del Estado (3/15/2016 12:13:23);
- ELMAN S.r.l. (3/18/2016 18:44:00);
- Furuno Electric Co., Ltd. (3/22/2016 10:38:46);
- Norwegian University of Science and Technology/Dep. of Product Design (3/23/2016 11:16:47);
- SPANISH INSTITUTE OF NAVIGATION (3/28/2016 17:40:56);
- Fundacion Valenciaport (3/29/2016 11:55:09).

Each of them has answered to a thorough questionnaire, divided in the following sections:

1. CONTEXT OF AUTONOMOUS VESSELS;
2. RESPONDENT INFORMATION;
3. AUTONOMOUS VESSEL - USER NEEDS;
4. AUTONOMOUS VESSEL E-GNSS TECHNOLOGIES - SWOT ANALYSIS;
5. AUTONOMOUS VESSEL - MARKET ANALYSIS;
6. AUTONOMOUS VESSEL - USER REQUIREMENTS;
7. AUTONOMOUS VESSEL OCEANIC/DEEP SEA NAVIGATION - PERFORMANCE REQUIREMENTS;
8. AUTONOMOUS VESSEL COASTAL WATERS NAVIGATION - PERFORMANCE REQUIREMENTS.

Sections 7 and 8 are the basis for the aggregated results presented in section 4.3.5 of the Maritime User Requirements report.

4.5.3 SURVEY

This section presents the full questionnaire as distributed to the interviewees.

Support for E-GNSS market development in a maritime domain

Promote the use of E-GNSS in vessel aiming at autonomous navigation

European Global Navigation Satellite Systems Agency

1 Context of Autonomous Vessels

Recent technological developments have encouraged the development and implementation of autonomous systems in areas ranging from military surveillance (i.e. Unmanned Aerial Vehicles, UAVs) to civilian transport. There are several examples of land-based applications using autonomous control concepts to meet current and envisaged future competitiveness, safety and sustainability challenges.

WATERBORNE TP is an initiative that came forth from the Maritime Industries Forum (MIF) and its R&D committee in 2005 and is making strident efforts to regularly update R&D requirements for European competitiveness, innovation and the meeting of regulations like safety and environmen (http://www.waterborne-tp.org/).

Waterborne states that in the case of maritime transport, next generation modular control systems and communications technology that will enable wireless monitoring and control functions both on and off board. These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control.

Ship Intelligence will be the next major transition for the shipping industry as ships are set to become more complex and will require high levels of data analysis to operate on-board systems to manage propulsion, navigation and potentially lead to autonomous vessels.

The project MUNIN – Maritime Unmanned Navigation through Intelligence in Networks – is a collaborative research project, co-funded by the European Commissions under its Seventh Framework Programme. MUNIN aims to develop and verify a concept for an autonomous ship, which is defined as a vessel primarily guided by automated on-board decision systems but controlled by a remote operator in a shore side control station. (http://www.unmanned-ship.org/munin/)

The Munin project states that no persons are expected on board for whole or part of the voyage. The ship, with partial help from remote control centre, must be able to manage the voyage on its own.

1.1 Assumptions

In the Work Programme 2015 the GSA aims at accelerating the adoption of E-GNSS and at analyzing market segments with promising prospects for its utilization. The present Specific Contract (Specific Contract GSA/OP/08/12/LOT3/SC4) "Support for E-GNSS market development in maritime domain" focuses on the adoption of EGNOS and Galileo in the maritime segment.

Hence, a further analysis of user needs and market potential is necessary to assess the potential for EGNOS and Galileo for further applications than those mentioned in IMO resolution A.915. Particularly this Specific Contract focuses on a market study on the use of EGNSS in Offshore Operations and in vessels aiming at an autonomous navigation.

A preliminary division of vessel navigation is made:

- Oceanic/Deep Sea Navigation
- Coastal Waters Navigation
- Berth/Inside Port Navigation

The scope of this survey is gathering information from key players to support to GSA in the Market Development of Autonomous Vessels. The information needed from the key players, will be focused only on the first and second category considered above, the Oceanic/deep sea and Coastal navigation. The other identified vessel navigation phase identified will be out of scope of the survey.

Due to the lack of maturity of this application, the iterations with stakeholder will be focused and restricted to a short list of key players.

2. Respondent information

This question list aims to collect information regarding the autonomous vessel context (Market, industrial players, Shipping Lines, On board equipment manufacturers and research universities) user needs and technologies,

2.1.I respond on behalf of:

- ☐ Ports Authorities
- ☐ On board equipment manufacturers
- ☐ Shipyard
- ☐ Shipping Line
- ☐ Research University / Institute
- ☐ Other:

2.2. Company / Organism

2.3. Country

2.4. Your name and surname

2.5. Your Position and job title

2.6. Email address

2.7. Telephone

3. Autonomous vessel - User Needs

Oceanic/Deep Sea Navigation & Coastal Waters Navigation

3.1. Could you please describe the projects on autonomous navigation in which you are involved?

3.2. Could you please indicate which area of Shore Control Center for autonomous navigation are you involved?

The Shore Control Centre will be in charge of Human supervision, the main task will be: Monitor drone ship's voyage and Resolve problems

- ☐ Decision Support Systems
- ☐ Data integrity & security
- ☐ Communications to Ships
- ☐ Remote operations, shore coordination, including VTS/Pilot/SAR
- ☐ Other:

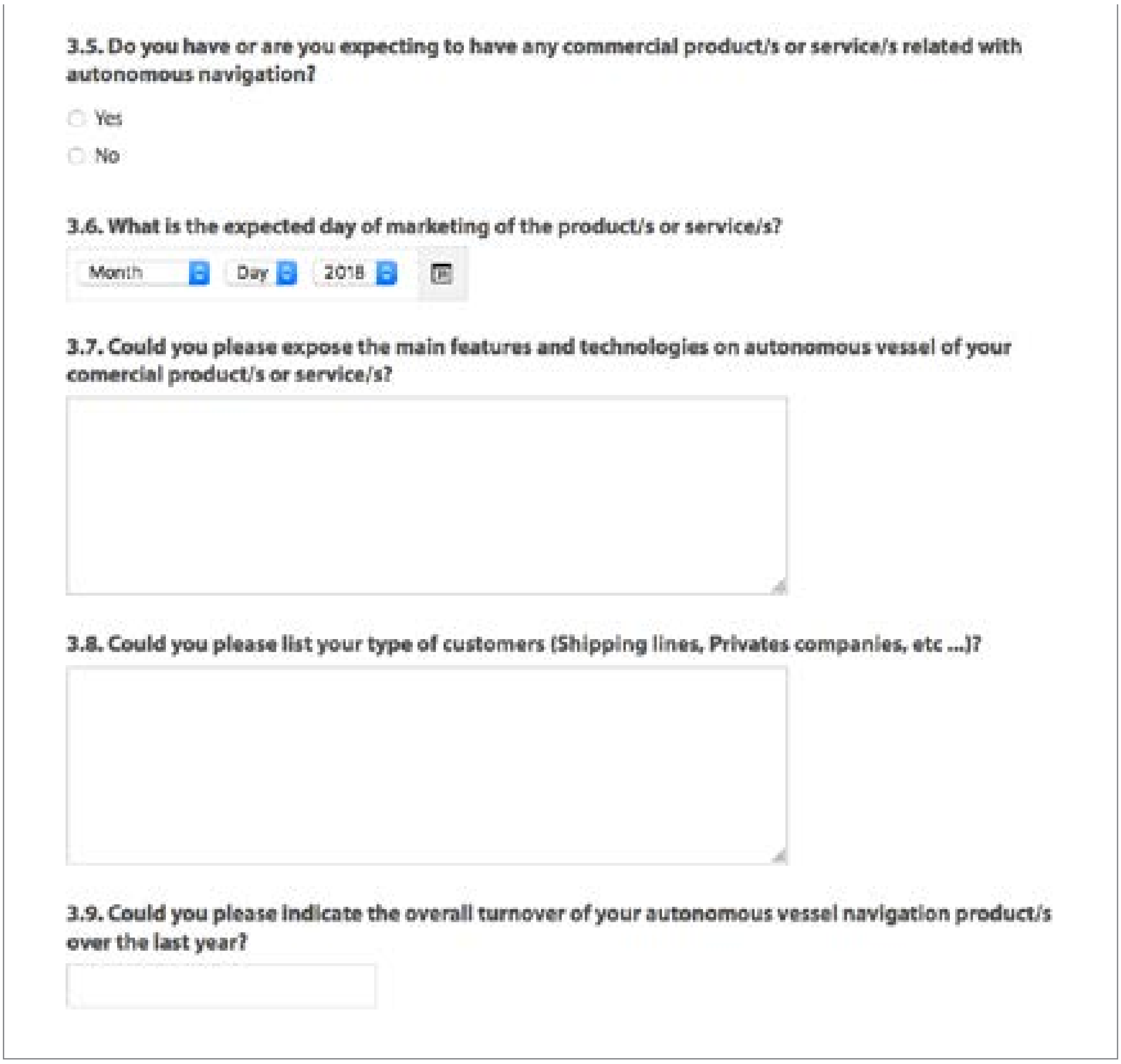
3.3. Could you please indicate which area of Autonomous Engine & Monitoring are you involved?

The target of the Autonomous Engine is that an engine can reliably operate for an intercontinental voyage without physical interference from a person in the engine room

- ☐ Environmental: Environmental performance and emissions to air and sea
- ☐ Economy: Fuel use and potential for late arrival/off hire
- ☐ Hull equipment: Hull and equipment status, anchor, towing, ladders
- ☐ Propulsion: Autonomus Engine & Monitoring(Propeller and steering systems
- ☐ Machinery: Engine, auxiliaries, piping, fuel
- ☐ Electric: Electric power systems, switchboards, emergency power
- ☐ Safety: Fire, evacuation, extinguishing, escape
- ☐ Cargo: Cargo status: Temperature, humidity, levels, etc...
- ☐ Other:

3.4. Could you please indicate which area of Autonomous Bridge are you involved?

- ☐ Sensor Module
- ☐ Shore Control Centres(VTMIS/Pilot; Fleet Operation)
- ☐ Location: Position, heading, speed, distance from planned position, etc...
- ☐ Weather: Wind speed/direction, wave and swell height/length/direction, etc ...
- ☐ Visibility: Visibility IR/Normal, radar range and clutter, etc ...
- ☐ Collision: Vectors to targets, status/heading/speed of targets, etc..
- ☐ Grounding: Depth, distance to shore, complexity, etc..
- ☐ Communications: Critical communication directly to ship, e.g., on VHF, GMDSS, NAVTEX, DSC, AIS
- ☐ Stability: Trim, heel, draft, watertight integrity, void space, water ingress



3.5. Do you have or are you expecting to have any commercial product/s or service/s related with autonomous navigation?

- Yes
- No

3.6. What is the expected day of marketing of the product/s or service/s?

Month | Day | 2018

3.7. Could you please expose the main features and technologies on autonomous vessel of your comercial product/s or service/s?

3.8. Could you please list your type of customers (Shipping lines, Privates companies, etc ...)?

3.9. Could you please indicate the overall turnover of your autonomous vessel navigation product/s over the last year?

4. Autonomous vessel E-GNSS technologies - SWOT Analysis

Oceanic/Deep Sea Navigation & Coastal Waters Navigation

4.1. Could you list strengths of using E-GNSS technologies in autonomous navigation applications?

4.2. Could you list the opportunities of using E-GNSS technologies in autonomous navigation applications?

4.3. Could you list the weaknesses of using E-GNSS technologies in autonomous navigation?

4.4. Could you list the threats of using E-GNSS technologies in autonomous navigation?

4.5. What are the main open Points you identify in E-GNSS technologies for autonomous navigation applications?

4.6. You could provide the CAPEX and OPEX of the E-GNSS products / services you offer?

4.7. What benefits (economic, human social terms, environment, ...) that are identified for E-GNSS products / services you offer?

5. Autonomous Vessel - Market analysis

Oceanic & Coastal Waters Navigation

5.1. What are the potential end user of the autonomous navigation?

- ☐ Port authority proving navigation infrastructure
- ☐ Navigation and Lighthouse Authority/ Vessel Traffic Management
- ☐ Association of Maritime aids
- ☐ Offshore Oil and Gas company
- ☐ Fishing vessel operator
- ☐ Passenger vessel operator
- ☐ Cargo vessel operator
- ☐ Recreational boats and marinas
- ☐ GNSS receiver manufacturer
- ☐ shipbuilding company
- ☐ Other:

5.2. Could you list the potential technologies and services on improved sensor and detection systems of the autonomous vessel navigation?

5.3. Could you list the potential technologies and services on improved technical maintenance strategies of the autonomous vessel navigation?

5.4. Could you list the potential technologies and services on improved ship-shore cooperation of the autonomous vessel navigation?

5.5. Could you provide an approximate cost of on-board GNSS recievers required for the autonomous vessel navigation?

5.6. Which degree of autonomy levels on autonomous vessel navigation are available nowadays?

- ☐ Remote control
- ☐ Fail to safe
- ☐ Automatic
- ☐ Autonomous
- ☐ Intelligent
- ☐ Other:

5.7. Which degree of autonomy levels on autonomous vessel navigation are available within four years?

- ☐ Remote control
- ☐ Fail to safe
- ☐ Automatic
- ☐ Autonomous
- ☐ Intelligent
- ☐ Other:

5.8. What phases of autonomous navigation implementation is feasible including the E-GNSS technologies?

- ☐ Oceanic/Deep Sea Navigation
- ☐ Coastal Waters Navigation
- ☐ Port approach and restricted waters Navigation
- ☐ Port
- ☐ Inland waterways
- ☐ Other:

6. Autonomous Vessel - User Requirements

6.1. How would you describe your interest on a GNSS based solution for the autonomous vessel navigation?

- High
- Medium
- Low

6.2. If a valid GNSS based solution for the autonomous vessel navigation was achieved, who would you expect to pay for it?

- Private users
- The service should be free (publicly granted).
- Other:

6.3. Would you expect the cost of the GNSS receiver to be an important driver regarding market penetration of a valid GNSS based solution for the autonomous vessel navigation?

- Yes
- No

6.4. In what kind(s) of environment would you expect a valid GNSS solution for the autonomous vessel navigation to work?

- Full visibility to satellites (no skyline masking)
- Environments with few and/or low masking situations (few skyline masking)
- High masking environments (skyline significantly masked in some or all directions)
- Other:

6.5. Would you expect high access control features (authentication) from a valid GNSS solution for the autonomous vessel navigation?

- Yes
- No

7. Autonomous vessel Oceanic/Deep Sea Navigation - Performance Requirements

Positioning is a key indicator in Shore Control Center the autonomous bridge. This section seeks to identify the user requirements necessary for proper operation of autonomous navigation service.

7.1. What level of horizontal accuracy (95% of the time, in meters) would you expect from a valid GNSS solution for autonomous vessel Oceanic/Deep Sea Navigation? (If unknown, please indicate an estimation)

- Very High (<1m)
- High (<5m)
- Medium (<10m)
- Low (<100m)
- Other:

7.2. Do you expect an occasional error in the system performance to cause safety issues of legal or economical trouble to the user for autonomous vessel Oceanic/Deep Sea Navigation?

- Yes
- No (Skip next two questions)

7.3. What would be the maximum tolerable error (meters) in the horizontal direction for autonomous vessel Oceanic/Deep Sea Navigation? (If unknown, please indicate an estimation)

- Very High (<5m)
- High (<20m)
- Medium (<40m)
- Low (<100m)
- Other:

7.4. Let assume that there is a failure in the system, and the user is warned. How much time after the failure would be the warning useless (the failure has already had major undesired consequences) for autonomous vessel Oceanic/Deep Sea Navigation?

- <2s
- <6s
- <10s
- <15s
- <60s
- >60s

7.5. Let assume that the system leads to an error above the maximum tolerable error specified and that the user is not warned on time. What would be the maximum probability allowed for such an event during the time of the operation (see 7.4. Risk exposure time) for autonomous vessel Oceanic/Deep Sea Navigation?

- Very High :<10-8 (one chance over 100 millions)
- High <10-7 (one chance over 10 millions)
- Medium <10-6 (one chance over 1 millions)
- Low <10-5 (one chance over 100 000)
- Other:

7.6. What would be the typical/average duration of the autonomous vessel Oceanic/Deep Sea Navigation operation?

7.7. During the time of the operation of the autonomous vessel Oceanic/Deep Sea Navigation, what would be the maximum duration of the most critical phases of the operation (regarding the provision of valid GNSS information)? Could you describe briefly these phases?

7.8. Assuming that valid GNSS information is provided at the beginning of a critical phase of an autonomous vessel Oceanic/Deep Sea Navigation operation. What would be the maximum tolerable probability of having service interruption (i.e. alert meaning the system is unreliable for the specified requirement levels) during this phase?

- High <10-7 (one chance over 10 millions)
- Medium <10-6 (one chance over 1 millions)
- Low <10-5 (one chance over 100 thousands)
- Other:

7.9. In question 7.5, the maximum failure rate has been set for autonomous vessel Oceanic/Deep Sea Navigation. Is it critical to ensure a minimum time separation between failures? If yes,(please indicate the time separation in seconds)

7.10. What would be the maximum probability that the time separation between failures is not met in autonomous vessel Oceanic/Deep Sea Navigation?

- < 10-2 (one chance over 100)
- <10-5 (one chance over 100 000)
- <10-7 (one chance over 10 millions)
- Other:

7.11. In question 7.5., the maximum failure rate has been set for autonomous vessel Oceanic/Deep Sea Navigation. Is it critical to ensure a minimum time before recovering a full quality of service ? If yes,(please indicate the time separation in seconds)

7.12. What would be the maximum probability that recovering a full quality of service is not met within the specified time for autonomous vessel Oceanic/Deep Sea Navigation?

- <10-2 (one chance over 100)
- <10-5 (one chance over 100 000)
- <10-7 (one chance over 10 millions)
- Other:

7.13. In order to consider a GNSS solution as valid, what is the minimum percentage of successful operations for autonomous vessel Oceanic/Deep Sea Navigation that you would expect the system to ensure?

- 90%
- 95%
- 99.5%
- 99.9
- Other:

7.14. Do you think EGNOS can contribute to a clear competitive advantage and to your own business growth for oceanic navigation? Why?

7.14. Could you please specify the reason why EGNOS could not be implented in autonomous Coastal Waters Navigation?

- High cost
- Lack of support in developing an EGNOS based solution
- Lack of support in certifying an EGNOS based solution
- Other:

8. Autonomous vessel Coastal Waters Navigation - Performance Requirements

8.1. What level of horizontal accuracy (95% of the time, in meters) would you expect from a valid GNSS solution for autonomous vessel Coastal Waters Navigation? (If unknown, please indicate an estimation)

- Very High (<1m)
- High (<5m)
- Medium (<10m)
- Low (<100m)
- Other:

8.2. Do you expect an occasional error in the system performance to cause safety issues of legal or economical trouble to the user for autonomous vessel Coastal Waters Navigation?

- Yes
- No (Skip next two questions)

8.3. What would be the maximum tolerable error (meters) in the horizontal direction for autonomous vessel Coastal Waters Navigation? (If unknown, please indicate an estimation)

- Very High (<5m)
- High (<20m)
- Medium (<40m)
- Low (<100m)
- Other:

8.4. Let assume that there is a failure in the system, and the user is warned. How much time after the failure would be the warning useless (the failure has already had major undesired consequences) for autonomous vessel Coastal Waters Navigation?

- <2s
- <6s
- <10s
- <15s
- <60s
- >60s

8.5. Let assume that the system leads to an error above the maximum tolerable error specified and that the user is not warned on time. What would be the maximum probability allowed for such an event during the time of the operation (see 8.4. Risk exposure time) for autonomous vessel Coastal Waters Navigation?

- Very High :<10-8 (one chance over 100 millions)
- High <10-7 (one chance over 10 millions)
- Medium <10-6 (one chance over 1 millions)
- Low <10-5 (one chance over 100 000)
- Other:

8.6. What would be the typical/average duration of the autonomous vessel Coastal Waters Navigation operation?

8.7. During the time of the operation of the autonomous vessel Coastal Waters Navigation, what would be the maximum duration of the most critical phases of the operation (regarding the provision of valid GNSS information)? Could you describe briefly these phases?

8.8. Assuming that valid GNSS information is provided at the beginning of a critical phase of an autonomous vessel Coastal Waters Navigation operation. What would be the maximum tolerable probability of having service interruption (i.e. alert meaning the system is unreliable for the specified requirement levels) during this phase?

- High <10-7 (one chance over 10 millions)
- Medium <10-6 (one chance over 1 millions)
- Low <10-5 (one chance over 100 thousands)
- Other:

8.9. In question 8.5, the maximum failure rate has been set for autonomous vessel Coastal Waters Navigation. Is it critical to ensure a minimum time separation between failures? If yes,(please indicate the time separation in seconds)

8.10. What would be the maximum probability that the time separation between failures is not met in autonomous vessel Coastal Waters Navigation?

- <10-2 (one chance over 100on 1)
- <10-5 (one chance over 100 000)
- <10-7 (one chance over 10 millions)
- Other:

8.11. In question 8.5., the maximum failure rate has been set for autonomous vessel Coastal Waters Navigation. Is it critical to ensure a minimum time before recovering a full quality of service ? If yes,(please indicate the time separation in seconds)

8.12. What would be the maximum probability that recovering a full quality of service is not met within the specified time for autonomous vessel Coastal Waters Navigation?

- <10-2 (one chance over 100)
- <10-5 (one chance over 100 000)
- <10-7 (one chance over 10 millions)
- Other:

8.13. In order to consider a GNSS solution as valid, what is the minimum percentage of successful operations for autonomous vessel Coastal Waters Navigation that you would expect the system to ensure?

- 90%
- 95%
- 99.5%
- 99.9
- Other:

8.14. Could you please specify the reason why EGNOS could not be implented in autonomous Coastal Waters Navigation?

- High cost
- Lack of support in developing an EGNOS based solution
- Lack of support in certifying an EGNOS based solution
- Other:

4.6 INTERVIEW WITH MARITIME STAKEHOLDERS, 2016

4.6.1 INTRODUCTION AND OVERVIEW OF CONTACTS

In the validation phase [of draft Maritime Users Requirements document], 4 interviews have been performed. The table below provides an overview of the contacts. Mr Christophe Reux, Secrétaire Général of FFPM was suggested by the EUSPA but declared himself unable to answer the questions, and did not manage to provide a suggested contact by the time of writing.

Table 29 – Interviewees

Company Maritime	Name of contact	Title
Danske Lodser	Bjarne Jensen	Chairman
McMurdo Group	Robin George	Product manager
Kongsberg	Carl Rustand	Product manager
ACR Electronics	Christopher Hoffman	Director of technology strategy

4.6.2 INTERVIEW NOTES

DANSKE LODSER

Interviewee: Bjarne Jensen,
Role: Chairman, Danske Lodser

Based on results of the report "ANALYSIS OF THE GNSS MARITIME USER REQUIREMENTS" for European GNSS Agency

1. From the user perspective, do you currently find some challenges regarding GNSS user requirements in Maritime applications?

In light of:

- **Stated performance values:** There are huge discrepancies between stated performance values in various sources, e.g. for oceanic navigation where IMO A.915 quotes an accuracy of 10 m versus 1800 m for the US FRP...
- **Traceability:** The justification or traceability of the quoted requirements is missing, especially in IMO resolutions (IALA guidelines & Navguide, as well as the US FRP, make some attempts at putting the requirements in context).
- **Justification of requirements:** Some requirements are almost impossible to justify, e.g. accuracy for oceanic navigation, which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the manoeuvre. What is the average duration of a typical manoeuvre when entering a port (is it rather 15 minutes or 3 hours)?
- **Contradictions in regulations even by the same stakeholders:** The two major IMO resolutions on this subject contradict each other, and the only way to reconcile them is to consider that one applies for current requirements (A.1046) while the other deals with future requirements (A.915).
- **Missing requirements:** The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are not present.

  What is the importance of velocity requirements wrt position requirements? Are there any other important requirements?
  What is the accuracy requirements for port operation and how does it differ from ports?

With all this kind of regulations it is hard to find the wording, sometimes you have the academic English which is hard to understand from the user perspective.

It is very hard to deal with the different requirements. In general, at the moment accuracy is the main requirement, and we need the maximum accuracy possible, all over the globe. This because there are waters that are not so frequently used and accuracy is needed there.

Newer systems are really good and offer high accuracy and precision. GPS might become obsolete. 10m is not even good enough anymore. We need to install extra equipment to give achieve better accuracy in certain environments (e.g. docking with low visibility). Shore support is needed to get precision down to centimetres.

In those areas we use local corrections, in other areas we use SBAS, with which we are down to 10 - 15 meters. With IALA DGPS, there are different stations installed, the accuracy depends on the distance from the stations.

This is why we invested in our own DGPS systems, which we use to achieve a much higher accuracy than the one of IALA DGPS.

I also have SBAS equipment and this performs in-between of the IALA DGPS (SBAS is better) and our own DGPS solutions (SBAS is worse).

Problem is that SBAS is not officially usable due to current status of IMO regulation. If this was possible, it would of course be useful to integrate those technologies in a single system.

2. Do you think that environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation should be defined? Do you bring on-board your own positioning system and if yes do you experience integration issues?

For navigation, I don't think there is need of new requirements. Those covered by regulation are sufficient. As mentioned own devices are brought in and currently there is no integration.

3. What key trends do you expect regarding the user requirements in the next years?

- In relation to regulatory process and main stakeholders behind regulations?
- What is the regulatory requirement followed by regulation (international regulation, national or local)? Do you follow IMO recommendations/standards?

I think that you might see something upcoming in the future, similarly to what happens in other segments with remote control vehicles or autonomous vehicles, you will see the same in maritime. You will see the need for new regulation as you will need also 24/7 availability and continuity of service, everywhere as navigation is global. This can be challenging as the owners of the various systems (US, China) could take on/off decisions on their GNSS or regional satnav systems due to political reasons.

In relation to technological and market developments:

- **E-Navigation** is likely to be introduced from 2015 to 2019. It is considered as a key opportunity to spread the use of multi-constellation GNSS since e-Navigation.
- In terms of user requirements, recommendation for e-Navigation does not go beyond the high level user need for data and system integrity, as per *IMO Strategy for e-Navigation*.
- *"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."*

I did not participate in the last e-nav conference but the problem is that the manufacturers cannot agree on a standard, they cannot make their mind of what system to use. E-Nav might come out not as planned, but rather as different regional standards with regards to the electronic parts. This would be a challenge for users.

The level of ambition has been too high in the beginning, resulting in too expensive standards and too complex user training requirements, so the concept might change and be revised.

- As part of the e-Navigation strategy, the Maritime community is strongly involved in the **development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "*multi-system shipborne navigation receiver*"** for which performance standards have been published in June 2015. "Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land based radionavigation.

My knowledge on this area is not sufficient.

- **IMO drafted Galileo receiver performance standards, approved in the Resolution MSC 233 (82**), which verses about the "adoption of the performance standards for shipborne Galileo receiver equipment". This resolution describes the performance standards, integrity checking, failure warnings, status indications and the protection for Galileo receiver equipment.

I am not aware of this, I would have presumed the standard was the same for GPS.

- **By IMO the development of combined Galileo/GPS/GLONASS performance standards was found to be unnecessary and the following work would be the development of a generic GNSS receiver standard based on Galileo standards**. However, no IMO resolution is found today describing generic GNSS receiver standards, there are still separate standards for GPS, Galileo and GLONASS. The most recent information in this matter is in the second session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), in 13 March 2015, when the performance standards for multi-system shipborne navigation receivers were endorsed and Draft Performance standards aiming to address the combined use of current and future radio navigation and augmentation systems were approved for adoption by MSC 95. The need to develop associated guidelines for Position, Navigation, and Time (PNT) data and integrity information was recognized, and the Sub-Committee requested MSC 95 to authorize further work to be finalized in 2017.

I think that this is not a challenge as the equipment will change slowly through the time, as the maritime market is price sensitive and quite conservative. As the equipment will be replaced slowly, there will be sufficient time to accommodate the changes in terms of technology used.

- **No existing GNSS is capable of meeting all operational requirements without the use of augmentation systems including SBAS**. Despite its theoretical capacity to fulfil IMO resolution A.1046 (27), there are no existing maritime standards for SBAS receivers. This does not prevent the maritime community from using SBAS (but not its integrity concept), but in order to spread its use as permanent and consolidated it would be **necessary to have specific regulation concerning the maritime users' needs**. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers in order to minimize implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and also the fact that SBAS have limited signal availability in northern latitudes.

We would like to use approved systems, but the problem is that if you want to use a global standard you will have an economic issue as compared to a local standard, as the local standard might need to be adapted to the local characteristics. E.g., certain areas might require higher accuracy than others. In other words, to us IMO global requirements are the baseline and the absolute minimum, then at the moment it is the users that use own solutions to go beyond the regulatory requirements when justified by the operational scenario.

MCMURDO

Interviewee: Robin George
Role: Marine Product Manager
Company: McMurdo – Orolia group

NOTE: the company focuses on SAR products, so the answer to the questions on requirements reflects the position on products such as EPIRBs, PLBs, AIS SART, etc.

Support material for consulting GNSS user requirements in Maritime.

Based on results of the report "ANALYSIS OF THE GNSS MARITIME USER REQUIREMENTS" for European GNSS Agency.

1. From the user perspective, do you currently find some challenges regarding GNSS user requirements in Maritime applications?

In light of:

- **Stated performance values:** There are huge discrepancies between stated performance values in various sources, e.g. for oceanic navigation where IMO A.915 quotes an accuracy of 10 m versus 1800 m for the US FRP...
- **Traceability:** The justification or traceability of the quoted requirements is missing, especially in IMO resolutions (IALA guidelines & Navguide, as well as the US FRP, make some attempts at putting the requirements in context).
- **Justification of requirements:** Some requirements are almost impossible to justify, e.g. accuracy for oceanic navigation, which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the manoeuvre. What is the average duration of a typical manoeuvre when entering a port (is it rather 15 minutes or 3 hours)?
- **Contradictions in regulations even by the same stakeholders:** The two major IMO resolutions on this subject contradict each other, and the only way to reconcile them is to consider that one applies for current requirements (A.1046) while the other deals with future requirements (A.915).
- **Missing requirements:** The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are not present.

  What is the importance of velocity requirements wrt position requirements? Are there any other important requirements?

  What is the accuracy requirements for port operation and how does it differ from ports?

To us, the main point is that IMO is not interested fast pace of innovation, they mostly focus on setting the minimum requirements. There are administrations in US that are more proactive and have introduced GNSS in PLBs; this is similar in some European countries, but the international level is requirements are quite low.

Moving to missing requirements, for SAR requirements should also include an expectation on the time required for the message to be received after transmission. For saving lives you need speed and accuracy of the response, and this is not taken into account.

In general, IMO hasn't really embraced the coming of MEOSAR satellites. There is no initiative to adopt it as part of the SOLAS framework.

2. Do you think that environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation should be defined? Do you bring on-board your own positioning system and if yes do you experience integration issues?

There should be a minimum performance requirement, so to ensure that antenna is protected from wave wash, etc. This aspect is addressed properly in EPIRB standards, not so much for PLBs and AIS SART devices.

3. What key trends do you expect regarding the user requirements in the next years?

- In relation to regulatory process and main stakeholders behind regulations?
- What is the regulatory requirement followed by regulation (international regulation, national or local)? Do you follow IMO recommendations/standards?

My interest is in the safety products, and these do not come up very much in discussion with the standardisation bodies. As an example, considering the return link of Galileo, there is work needed at standardization level (e.g. test plan standards, to verify if safety of life requirements are met by the product).

This standardization task is required by manufacturers to launch products on the market.

Issue is that this pace of innovation is difficult to be kept up with by standardization bodies, in particular for European standardization bodies. As manufacturers we want to innovate, and this issue is slowing things down.

Another point is the unwillingness to bring in major changes. As an example, we would also like to change the battery technology. We could introduce cheaper and more environmentally friendly products (rechargeable batteries), but the standard authorities don't acknowledge that this innovation is a good thing. Our feeling is that there is not very much interest in big changes, as they pose additional questions that require big efforts (e.g. in case of rechargeable batteries, it should be decided at regulatory/standardization level who would do it, how, how often…).

In relation to technological and market developments:

- **E-Navigation** is likely to be introduced from 2015 to 2019. It is considered as a key opportunity to spread the use of multi-constellation GNSS since e-Navigation.
- In terms of user requirements, recommendation for e-Navigation does not go beyond the high level user need for data and system integrity, as per *IMO Strategy for e-Navigation*.
- "*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.*"

The stakeholder does not have the full picture on the progress of the work related to position fixing.

Nevertheless, he mentioned that there are discussions at IMO through CIRM as what GNSS engine would take into account the information from different systems (WWRNS inclusion).

The point is that the core of e-navigation is reaching the objective of taking decision-making and workload out of the ship and to the ground. Eventually the ship will be connected to shore and everything that the ship does can be questioned from the shore.

- As part of the e-Navigation strategy, the Maritime community is strongly involved in the **development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "*multi-system shipborne navigation receiver*"** for which performance standards have been published in June 2015."Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land based radionavigation.

There is a lot of work being done on signal blocking and jamming at the moment.

That particular device is a black box that has to be used with other systems (interface to ships, charting and ECDIS systems).

The standard is there on paper but it doesn't really provide a method to test the method (testing standard)[4].

As long as this part is not published manufacturers will not be able to develop the product.

- **IMO drafted Galileo receiver performance standards, approved in the Resolution MSC 233 (82)**, which verses about the "adoption of the performance standards for shipborne Galileo receiver equipment". This resolution describes the performance standards, integrity checking, failure warnings, status indications and the protection for Galileo receiver equipment.

I am not that close to this file, but as far as I am aware of again there is a gap in standardization for equipment testing related to Galileo receiver equipment. [same as above].

- **By IMO the development of combined Galileo/GPS/ GLONASS performance standards was found to be unnecessary and the following work would be the development of a generic GNSS receiver standard based on Galileo standards**. However, no IMO resolution is found today describing generic GNSS receiver standards, there are still separate standards for GPS, Galileo and GLONASS. The most recent information in this matter is in the second session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), in 13 March 2015, when the performance standards for multi-system shipborne navigation receivers were endorsed and Draft Performance standards aiming to address the combined use of current and future radio navigation and augmentation systems were approved for adoption by MSC 95. The need to develop associated guidelines for Position, Navigation, and Time (PNT) data and integrity information was recognized, and the Sub-Committee requested MSC 95 to authorize further work to be finalized in 2017.

The stakeholder does not have strong views on this aspect.

- **No existing GNSS is capable of meeting all operational requirements without the use of augmentation systems including SBAS**. Despite its theoretical capacity to fulfil IMO resolution A.1046 (27), there are no existing maritime standards for SBAS receivers. This does not prevent the maritime community from using SBAS (but not its integrity concept), but in order to spread its use as permanent and consolidated it would be **necessary to have specific regulation concerning the maritime users' needs**. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers in order to minimize implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and also the fact that SBAS have limited signal availability in northern latitudes.

I have no strong views on this aspect. We focus on SAR products and SBAS there has the constraint of battery consumption, so value added is probably different [lower] than in other applications (e.g. navigation).

KONGSBERG

Interviewee: Carl Magne Rustand
Role: Product Manager Navigation
Company: Kongsberg

1. From the user perspective, do you currently find some challenges regarding GNSS user requirements in Maritime applications?

In light of:

- **Stated performance values:** There are huge discrepancies between stated performance values in various sources, e.g. for oceanic navigation where IMO A.915 quotes an accuracy of 10 m versus 1800 m for the US FRP...
- **Traceability:** The justification or traceability of the quoted requirements is missing, especially in IMO resolutions (IALA guidelines & Navguide, as well as the US FRP, make some attempts at putting the requirements in context).
- **Justification of requirements:** Some requirements are almost impossible to justify, e.g. accuracy for oceanic navigation, which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the manoeuvre. What is the average duration of a typical manoeuvre when entering a port (is it rather 15 minutes or 3 hours)?
- **Contradictions in regulations even by the same stakeholders:** The two major IMO resolutions on this subject contradict each other, and the only way to reconcile them is to consider that one applies for current requirements (A.1046) while the other deals with future requirements (A.915).

4 Note from VVA: this follow-up activity is usually taken care of by IEC

- **Missing requirements:** The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are not present.

  What is the importance of velocity requirements wrt position requirements? Are there any other important requirements?

  What is the accuracy requirements for port operation and how does it differ from ports?

There are no huge issues regarding the requirements for accuracy, the issues come more in terms of justification of regulation for using differential corrections could be improved.

2. Do you think that environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation should be defined? Do you bring on-board your own positioning system and if yes do you experience integration issues?

Yes, I agree that indeed the environmental / physical / radio electrical constraints applicable to the vessel ought to be defined.

The interviewee was rather surprised about the question and suggested that he hopes that users are not doing it, as they be using the positioning system of the vessel.

3. What key trends do you expect regarding the user requirements in the next years?

- In relation to regulatory process and main stakeholders behind regulations? What is the regulatory requirement followed by regulation (international regulation, national or local)? Do you follow IMO recommendations/standards?

In general, the IMO regulation supersedes the other ones in case of conflicts, but it is often the case that IMO sets minimum shared requirements and national frameworks define more stringent rules.

In relation to technological and market developments:

- **E-Navigation** is likely to be introduced from 2015 to 2019. It is considered as a key opportunity to spread the use of multi-constellation GNSS since e-Navigation.
- In terms of user requirements, recommendation for e-Navigation does not go beyond the high level user need for data and system integrity, as per *IMO Strategy for e-Navigation*.
- "*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.*"

There will be more combined use of more system. Both Glonass, GPS and Galileo will be used and also BeiDou, based also on the conditions of the different systems. I mean that the requirement is not only to go towards multiconstellation, but also towards the capability to choose which constellation to use in a certain moment based on the comparison of their performance.

- As part of the e-Navigation strategy, the Maritime community is strongly involved in the **development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "*multi-system shipborne navigation receiver*"** for which performance standards have been published in June 2015. "Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land based radionavigation.

The next development is really going to use more systems than GPS, very few at the present stage combine GPS and Glonass. It is very important that there is a standard on that, so that more systems will be used. Not only in combination but also by comparing the position provided by different systems.

e-Navigation also requires an harmonized HMI, today there are maybe 30 suppliers of equipment on the bridge, and they have different standards for example for turning on and off buttons, etc.. As HMI will be harmonized, GNSS will be more of a black box integrated in the system and provided through the interface, similarly in a sense to what happens in smartphones, where PNT data are provided through the operating system.

There is a big ongoing work to standardize alert systems on the bridge. The situation is a bit chaotic. Very often equipment start giving alerts an it is difficult for pilot and crew to deal with it. We want to harmonize alert into one common alert system, so all sensors (including GNSS) need to be aligned with IMO bridge alert standard (see IMO Resolution MSC.302(87)) Further to that, IEC is making now the detailed standard with performance test.

- **IMO drafted Galileo receiver performance standards, approved in the Resolution MSC 233 (82)**, which verses about the "adoption of the performance standards for shipborne Galileo receiver equipment". This resolution describes the performance standards, integrity checking, failure warnings, status indications and the protection for Galileo receiver equipment.

The stakeholder is not into the details of this. He suggested to contact his colleague Cato Eliassen (cato.eliassen@km.kongsberg.com) at Kongsberg Seatex, who will be available after March 16.

- **By IMO the development of combined Galileo/GPS/GLONASS performance standards was found to be unnecessary and the following work would be the development of a generic GNSS receiver standard based on Galileo standards**. However, no IMO resolution is found today describing generic GNSS receiver standards, there are still separate standards for GPS, Galileo and GLONASS. The most recent information in this matter is in the second session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), in 13 March 2015, when the performance standards for multi-system shipborne navigation receivers were endorsed and Draft Performance standards aiming to address the combined use of current and future radio navigation and augmentation systems were approved for adoption by MSC 95. The need to develop associated guidelines for Position, Navigation, and Time (PNT) data and integrity information was recognized, and the Sub-Committee requested MSC 95 to authorize further work to be finalized in 2017.

The stakeholder is not into the details of this. He suggested to contact his colleague Cato Eliassen (cato.eliassen@km.kongsberg.com) at Kongsberg Seatex, who will be available after March 16.

- **No existing GNSS is capable of meeting all operational requirements without the use of augmentation systems including SBAS**. Despite its theoretical capacity to fulfil IMO resolution A.1046 (27), there are no existing maritime standards for SBAS receivers. This does not prevent the maritime community from using SBAS (but not its integrity concept), but in order to spread its use as permanent and consolidated it would be **necessary to have specific regulation concerning the maritime users' needs**. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers in order to minimize implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and also the fact that SBAS have limited signal availability in northern latitudes.

The stakeholder agrees that the introduction of SBAS would indeed be useful for ship navigators once standardization and harmonization work will be finalised.

ACR ELECTRONICS

Interviewee: Chris Hoffman
Role: Director of Technology Strategy

NOTE: the company focuses on SAR products, so the answer to the questions on requirements reflects the position on products such as EPIRBs, PLBs, AIS SART, etc.

1. From the user perspective, do you currently find some challenges regarding GNSS user requirements in Maritime applications?

In light of:

- **Stated performance values:** There are huge discrepancies between stated performance values in various sources, e.g. for oceanic navigation where IMO A.915 quotes an accuracy of 10 m versus 1800 m for the US FRP...
- **Traceability:** The justification or traceability of the quoted requirements is missing, especially in IMO resolutions (IALA guidelines & Navguide, as well as the US FRP, make some attempts at putting the requirements in context).
- **Justification of requirements:** Some requirements are almost impossible to justify, e.g. accuracy for oceanic navigation, which is several orders of magnitude better than that of the nautical charts, or continuity requirements over a period of 15 minutes, irrespective of the type of vessel and of the manoeuvre. What is the average duration of a typical manoeuvre when entering a port (is it rather 15 minutes or 3 hours)?
- **Contradictions in regulations even by the same stakeholders:** The two major IMO resolutions on this subject contradict each other, and the only way to reconcile them is to consider that one applies for current requirements (A.1046) while the other deals with future requirements (A.915).
- **Missing requirements:** The environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation are not present.

  What is the importance of velocity requirements wrt position requirements? Are there any other important requirements?

  What is the accuracy requirements for port operation and how does it differ from ports?

The applications we work on are not too difficult in that perspective. We don't deal with navigation but rather safety products using positioning, where there are fairly limited international requirements (maybe too few).

2. Do you think that environmental / physical / radio electrical constraints applicable to the vessel and / or the operation / phase of navigation should be defined? Do you bring on-board your own positioning system and if yes do you experience integration issues?

The aspects that are not really well defined is the detection of interferences (you can think about the LightSquared vs. GPS case).

Moreover, also the front end of the receiver (antenna + amplifier) is quite weak so receivers are not very protected against interference.

Moving to other missing requirements, I would say that also cold start is a critical criterion for all those applications requiring to turn on the GNSS receiver only in particular circumstances (e.g. beacons).

The other requirement missing is performance in difficult environments, e.g. in the middle of the storm with limited sky visibility. In those cases, the receiver might be looking to a part of the sky, then due to a wave looking to another part losing previous satellites.

3. What key trends do you expect regarding the user requirements in the next years?

- In relation to regulatory process and main stakeholders behind regulations?
- What is the regulatory requirement followed by regulation (international regulation, national or local)? Do you follow IMO recommendations/standards?

In terms of future development, there has been RTCM work for GNSS receiver performance, but this has not materialised internationally. That's an area that will be further developed with time.

International level is usually the baseline and some countries just prefer to go for international IMO baseline standards, whereas some countries (e.g. US on GNSS) go for their own more demanding requirements.

Regarding GNSS from a manufacturer perspective (interested in testing & validation), regulation is quite easy to follow as there is just one key collection of standards (IEC 61108).

In relation to technological and market developments:

- **E-Navigation** is likely to be introduced from 2015 to 2019. It is considered as a key opportunity to spread the use of multi-constellation GNSS since e-Navigation.
- In terms of user requirements, recommendation for e-Navigation does not go beyond the high level user need for data and system integrity, as per *IMO Strategy for e-Navigation*.
- *"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."*

The stakeholder does not have strong views on this aspect as he is following e-Navigation from a distance.

- As part of the e-Navigation strategy, the Maritime community is strongly involved in the **development of "robust PNT" solutions (also called "resilient PNT"), an important component of which is the "*multi-system shipborne navigation receiver*"** for which performance standards have been published in June 2015. "Performance standards for multi-system shipborne navigation receivers", Resolution MSC 401(95)). Such a receiver will use two independent GNSS as a basis, and optionally additional sources such as SBAS or land based radionavigation.

The stakeholder does not have strong views on this aspect as he is following e-Navigation from a distance.

- **IMO drafted Galileo receiver performance standards, approved in the Resolution MSC 233 (82)**, which verses about the "adoption of the performance standards for shipborne Galileo receiver equipment". This resolution describes the performance standards, integrity checking, failure warnings, status indications and the protection for Galileo receiver equipment.

These are then defined in IEC 61108-3.

- **By IMO the development of combined Galileo/GPS/GLONASS performance standards was found to be unnecessary and the following work would be the development of a generic GNSS receiver standard based on Galileo standards**. However, no IMO resolution is found today describing generic GNSS receiver standards, there are still separate standards for GPS, Galileo and GLONASS. The most recent information in this matter is in the second session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), in 13 March 2015, when the performance standards for multi-system shipborne navigation receivers were endorsed and Draft Performance standards aiming to address the combined use of current and future radio navigation and augmentation systems were approved for adoption by MSC 95. The need to develop associated guidelines for

Position, Navigation, and Time (PNT) data and integrity information was recognized, and the Sub-Committee requested MSC 95 to authorize further work to be finalized in 2017.

There is work ongoing on that, again in the US. RTCM has a committee working on that, it is called RTCM Special Committee 131. That work goes quite slowly but my understanding is that once that this is finalised they will submit it to IEC for international approval.

There has been very recently (end of February) discussion within the 3rd Session of the Navigation, Communications and Search and Rescue Sub-Committee (NCSR 3) of MSC on a multiconstellation receiver at IMO, but it is not clear to me will be done exactly.

But I can see that they are a year or two away from defining a draft performance standard. Also the performance standards will be at very high level. That will require an IEC standard for design and testing. IMO is just going to set the requirement for performance (e.g. 10 meter), but then whether it is with 3 or 4 satellites, in clear sky or not, etc. this is usually left to IEC.

- **No existing GNSS is capable of meeting all operational requirements without the use of augmentation systems including SBAS**. Despite its theoretical capacity to fulfil IMO resolution A.1046 (27), there are no existing maritime standards for SBAS receivers. This does not prevent the maritime community from using SBAS (but not its integrity concept), but in order to spread its use as permanent and consolidated it would be **necessary to have specific regulation concerning the maritime users' needs**. This motivates the maritime community to wait for a combination of GPS and Galileo and respective hybrid integrated navigation receivers in order to minimize implementation costs. Their position is even more justified if we consider that there are other navigation aids and instruments onboard vessels already available, and also the fact that SBAS have limited signal availability in northern latitudes.

No strong views on this aspect. The company focuses om SAR products and SBAS has the constraint of battery consumption, so it is not of high interest.

4.7 USER CONSULTATION PLATFORM, MADRID, 2017

1st Galileo Assembly - User Consultation Platform – Transport- Maritime

Meeting Date	28.11.2017	**Time**	10:15 – 16:30
Meeting Called By	GSA – Manuel Lopez Martinez	**Location**	Madrid, INTA Dome
Minutes Taken By	Thiago Tavares	**Next Meeting Date**	N/A
Attendees	**GSA:** Manuel Lopez Martinez, GSA (Moderator) **Other participants:** 1. Michael Fairbanks, Tailor Airey (Chair) 2. Silvia Porfili, GSA (EEXP) 3. Carlos Armiens, JRC (ERNP) 4. Capt. Johan Gahnström, Intertanko (Tanker safe transport) 5. Ana Cezon Moro, GMV (GNSS Section Head) 6. Gergeli Mezo, RSOE (Inland waterways Emergency and Disaster information service) 7. Douglas Watson, Ericsson (Director – Business unit shipping) 8. Nikolaos P. Ventikos, Technical University of Athens (Head of Maritime Risk Group - Safety and Pollution) 9. David Fanego de la Bodega, Hispano Radio Maritima (Bridge integrator) 10. Pedro Gomez, INECO (Maritime SBAS software Rx) 11. Neil Jordan, OceanSignal Limited (SAR beacon Manufacturer) 12. Juan Defez, Direction General Marina Mercante España, (SAR authority) 13. Enrico Barro, Vitrociset (Skipper – Leisure Boating Business) 14. Simone Perugia, Thales Alenia Space Italia (System Engineer) 15. David Russels, VERIPOS (Services and Marine Systems) 16. Miguel Tortosa, EUTELSAT Communications 17. Laurent Jobey, SYRLINKS (SAR beacon Manufacturer) 18. Ivan Tesfai, RINA CONSULTING (Port Terminal Cyber Security) 19. Jose-Manuel Alvarez, ESSP (Service Development Manager) 20. Thiago Tavares, VVA		
Distribution (in addition to attendees)	UCP Plenary, GSA		

Organisation	Name	Signature
GSA	Manuel Lopez Martinez	
VVA	Thiago Tavares	

Agenda Items	Presenter
10h15-11h15 1. Round table with participants (5' presentation per member)	Manuel Lopez Martinez, GSA
11h15-12h45 2. User requirements presentation (by GSA) and discussion (all)	Manuel Lopez Martinez, GSA
12h45- 13h00 3. Emerging applications and new trends in R&D (inputs for FP9) Autonomous vessels and dynamic positioning	Manuel Lopez Martinez, GSA

14h00- 14h30 4. Emerging applications and new trends in R&D (inputs for FP9) - Timing for sensor fusion, Accident investigation, Bathymetry survey, SAR – new uses of RLS	Manuel Lopez Martinez, GSA
14h30-14h55 5. Common trends in transport / multimodal transport. Sensor fusion, Automation (manual/teleoperated/autonomous), UAVs to support operations (e.g. maritime surveillance, inspections, piloting, offshore operations)	Manuel Lopez Martinez, GSA
14h55-15h30 6. Inputs to European Radionavigation Plan (RN systems, augmentations and backs-up)	Carlos Armiens, JRC
15h30-15h50 7. Ideas for enhanced services for Galileo and EGNOS and GSC information services	Manuel Lopez Martinez, GSA
15h50-16h30 8. Panel report preparation	Manuel Lopez Martinez, GSA

SUMMARY

The European GNSS aims to keep a constant dialogue with the civilian community of users. With EGNOS fully operational and Galileo in Initial services it is necessary to continuously improve the services and plan future evolutions. A key driver for improvements and evolutions are user needs. The User Consultation Platform (UCP) took place on 28th of November during the 1st Galileo User Assembly in Madrid. It was organized as a forum for interaction between end users, user associations and representatives of the value chain such as receiver and chipset manufacturers, application developers, and the organizations and institutions dealing, directly and indirectly, with Galileo and EGNOS.

The Maritime panel gathered 20 participants, representing industry, research institutes, national authorities and European institutions with interest in maritime and inland waterways.

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

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

When it comes to R&D, it is important that projects sponsored by EU institutions are relevant and in line with what is requested by the market and supported by political framework to promote and support innovative technologies in the sector. Research on complementary terrestrial systems and sensor fusion (including timing) to promote resilience and redundancy is important. Autonomous vessels are another topic highlighted as one of the priorities. In addition to having a better understanding of resiliency for this application, more research is needed to develop different operation scenarios and collision risk models. The use of autonomous vessels for SAR operations should be investigated as well as the real accuracy requirements for SAR operations. The use of UAVs for support operations (i.e. maritime surveillance, inspections, piloting, offshore operations) should be further explored. For IWW, research is needed to define the potential use of data recording from the landside for accident investigation.

The panel discussion was concluded with some recommendations from the participants for enhancing Galileo Services and Galileo Service Centre user support. A rapid dissemination of maritime safety information through the proper channels was deemed essential to ensure the added value of Galileo services. In addition, participants reinforced that easy access to Galileo performance data is very important and they have suggested that Galileo Services could include the service monitoring for verification of performance for forensic investigation and geofencing services for safeguarding of marine protected areas.

MINUTES OF MEETING

10h15-11h15
Round table with participants

- Introduction of the different points of discussion in the agenda.
- All participants accepted the agenda.
- The Draft user requirements document has been shared with registered participants prior to meeting. The objective of the meeting is to receive the feedback from participants on the proposed user requirements.

PRESENTATION OF PARTICIPANTS:

- Manuel Lopez Martinez (GSA, https://www.gsa.europa.eu/). Manuel is Technology Officer for Maritime, IWW and SAR applications and Professor in System Engineering and Automation. The GSA is responsible for the operation, security, exploitation and marketing of Galileo and EGNOS services. Manuel is also the Moderator of the Maritime Section.
- Michael Fairbanks (Tailor Airey, http://www.taylorairey.com/home.html): Michael is a maritime expert with over twenty-five years' experience as a management consultant specialising in the operational, business, regulatory, policy and institutional aspects of air and marine transport infrastructure. He is the secretary of the European Maritime Radionavigation Forum and also the co-chair of the workshop.
- Johan Gahnström (Intertanko, https://www.intertanko.com/): the association represents the independent tanker owners around the world. The interest in the meeting is to understand if Galileo could fulfil the necessary requirements of the industry.
- Ana Cezon Moro (GMV, https://www.gmv.com/en/): GMV is a privately owned technological business group providing consultancy and engineering services in different fields, including maritime. Particular interest is in the integrity and safety context and to understand which are the user needs and their impact in the maritime requirements. GMV is implementing the SEASOLAS project which analyses a potential EGNOS Maritime Safety Service with new receivers on-board vessels that use future EGNOS V3 Dual Frequency Multi Constellation capabilities (EGNOS V3, L1 and L5 frequencies, GPS and Galileo). Within the scope of SEASOLAS, GMV is also developing a new integrity information concept at user level tailored for the maritime community.
- Gergeli Mezo (RSOE, http://www.rsoe.hu/home/index/english): RSOE operates Emergency and Disaster Information Service (EDIS) in Hungary within the objective to monitor and document all the events on the Earth which may cause disaster or emergency to IWW users. Particular interest is on position information and recording for IWW users.
- Douglas Watson (Ericsson, https://www.ericsson.com/en): the company is a system integrator and it is interested in autonomy and how those systems can affect logistics and transportation.
- Nikolaos P. Ventikos (Technical University of Athens, https://www.ntua.gr/en/): focused in research on autonomous ships and SAR. Interested in understanding how GNSS can be used in those maritime applications, including safety critical applications.
- David Fanego de la Bodega (Hispano Radio Maritima, http://www.hispanoradio.net/), is a system integrator for land based infrastructure and equipment to ship owners. Interested to learn more about on how to integrate Galileo in a solution to be provided to the customers.
- Pedro Gomez (INECO, https://www.ineco.com/webineco/en): engineering and consultancy firm with focus on the development of transport infrastructure. Currently working at the GNSS Service Centre. Interested to understand the needs and the expectations of the maritime users in relation to the Galileo centre and Galileo services.
- Neil Jordan (OceanSignal Limited, http://oceansignal.com/): company focused on design and manufacture of Satellite and Terrestrial Emergency Rescue Beacons based upon VHF/UHF, Iridium, DSC, AIS, GNSS and battery technologies. Main interest is on what Galileo can provide to support anti-spoofing, UAV and SAR.

- Juan Defez (Direction General Marina Mercante España, https://www.fomento.gob.es/MFOM/LANG_CASTELLANO/DIRECCIONES_GENERALES/MARINA_MERCANTE/) institutions responsible for organisation of the maritime operation and fleet in Spain. Interested in knowing more about positioning devices to reach as soon as possible the people during SAR operations.
- Carlos Armiens (JRC, https://ec.europa.eu/jrc/en): EU institutions focused on science and research development. Currently working on the finalisation of the ERNP. Interested to know more about backup systems to understand what happens if GNSS fails.
- Enrico Barro (Vitrociset, http://www.vitrocisetbelgium.com/) the company operates in Space & Telecom sectors providing turn-on key systems, software and services with strong emphasis in the satellite ground operations. Focus in the maritime domain is on leisure and recreational vessels. Interested in the possibility of having cooperative system in the maritime domain.
- Simone Perugia (Thales Alenia Space Italia, https://www.thalesgroup.com/en): the company designs, develops and constructs satellites in Italy. It serves telecommunications and navigation; remote sensing; manned systems, and space and orbital infrastructures; meteorology and scientific applications; launch, transport, and re-entry systems; and control centres. Interest is to know the benefits of Galileo to different services including the maritime sector and where the final users can benefit from Galileo.
- Silvia Porfili (GSA, EGNOS department - service engineering team, https://www.gsa.europa.eu/). EGNOS service engineering department focuses on the development of new services for applications in various user domains and is analysing the provision of EGNOS V3 dual frequency and multi-constellation (DFMC) service for maritime users. Also interested to understand under which conditions the EGNOS DFMC service could be attractive for the maritime sector.
- David Russels (VERIPOS, https://www.veripos.com/): the company provides global navigation and PPP services. Interested to understand what Galileo could provide in terms of accuracy, liability, system integrity.
- Miguel Tortosa (EUTELSAT, http://www.eutelsat.com/en/home.html): satellite operator providing coverage over the entire European continent, the Middle East, Africa, Asia and the Americas interested in synergies between the navigation systems in oceans.
- Laurent Jobey (SYRLINKS, http://www.syrlinks.com/): the company designs and manufactures products and services for the Space, Defence and SAR markets (e.g. GNSS receivers, AIS beacons, miniature distress beacons). Interested in time and frequency applications for the maritime sector.
- Ivan Tesfai (RINA CONSULTING, http://www.rinaconsulting.org/en/ltd): company focus in the provision of engineering services, including to support general maritime transportation, ports and harbours, alternative energy (such as offshore wind farms) and the development, operation and maintenance of all nearshore and offshore Oil & Gas facilities.
- Jose-Manuel Alvarez, ESSP (Service Development Manager): ESSP is specialized in the operations and service provision of safety-critical navigation satellite systems. ESSP is the current holder of the EGNOS Service Provision contract funded by the European Union with a clear mandate to help foster the use of satellite navigation within Europe, including the maritime sector.
- Thiago Tavares (VVA, http://www.vva.it/en/european-public-policy): VVA is a consulting firm with strong experience in market and economic analysis of Space and Transport sectors both for public and private clients. VVA (together with GMV) is currently implementing the SEASOLAS project which looks into the potential use of EGNOS for the maritime sector. Interested in understanding user needs for the maritime users in difficult environments such IWW and harbours.

11h15-12h45
User requirements presentation (by GSA) and discussion (all)

- Summary of UR document was presented.
- The document was produced based on the user requirements available in the literature (IMO, IHO requirements, requirements from the US Federal Radionavigation Plan, and previous projects).
- Objective of the session is to validate if the order of magnitude presented is sufficient or not.

COVERAGE NEEDS OF THE MARITIME USER COMMUNITY:

- A study was performed to check routes with high traffic – congested areas based on AIS data) – those that require more support from the maritime authorities.
- Some areas with high traffic are not covered by land infrastructure i.e. IALA beacons.
- EGNOS can provide solutions in areas where IALA beacons are not deployed or coverage is patchy and there is high traffic.
- In the Arctic Zone, cargo and fishing vessels are introducing a growth in specific areas and EGNOS services could bring safety to the operations in these harsh environments.
- The Suez Route (Mediterranean Sea) concentrates a very high SOLAS traffic (mainly cargo and tanker). Most of the areas traversed by these routes are outside the EGNOS Open Service.

MARITIME USER REQUIREMENTS:

Table of user requirements for navigation in different waters (i.e. classification as per IMO)

- User requirements considered are based on IMO, MARUSE project (GSA project), FRP, IHO (provides recommendation on the minimum accepted accuracy for navigation charts depending on the type of navigation).

COMMENTS FROM PARTICIPANTS:

- Institutional statutory requirements are the bare minimum. These requirements are broad and globally applicable. Real requirements may be more challenging and are likely to vary from place-to-place. If the maritime community decides that the current statutory requirements should be amended, e.g. more stringent performance is needed, then the IMO process must be followed.
- These statutory requirements often do not reflect the real more stringent operational requirements. These more stringent and local requirements could be reflected as guidelines to define what the service should deliver. Guidelines offer more flexibility and are easier to change.
- There are conflicts between requirements derived from different sources.
- The overall objective for the maritime community is to have a resilient PNT in an environment where electronic systems are becoming more and more dominant.
- Maintaining signals in space is also one of the challenges.
- Participants suggested to base the accuracy user requirements on the Category Zone of Confidence (CATZOC)[5] used by cartographers to highlight the accuracy of data used on charts.
- It was suggested to discuss with national cartographic institutes to understand which accuracies they use, however it also mentioned that the positioning accuracy does not necessarily need to be as precise as the cartographic.
- Some ports use RTK for positioning and for those, precision is higher than the 1 m proposed.
- For IWW, it has been said that 10 m is not enough. 2-3 m should be considered instead.

5 https://www.admiralty.co.uk/AdmiraltyDownloadMedia/Blog/CATZOC%20Table.pdf

- It was also highlighted that the interaction with users (such as the UCP workshop) is necessary.
- Non-performance requirements are very important (authentication, resilience – interference and anti-spoofing).
- For INTERTANKO, Integrity, Availability and Continuity are more important than accuracy (IMO accuracy should be sufficient for the specific industry).
- Leisure and recreational vessels (Vitrociset):
  - it is a very innovative market but users don't have clear requirements, they expect the industry to propose the options. For leisure market, 1m is necessary and GPS is not sufficient e.g. if you want to drive a boat in an empty space (parking).
  - Availability and continuity is not an issue.
  - The biggest problem is related to data communication and not navigation. Telecommunication operators should be involved.
  - For pure leisure application authentication is not needed (and in some cases, it is not wanted) but in the semi-regulated applications, authentication is needed by the authorities to know where the vessels are – to guarantee the position.
  - Managers of the protected areas are interested to ensure that boats don't go in these areas. Interest is to prevent the violation rather than give fines to the entering in the protected areas. Integrity is not essential for such enforcement. To prove the violation through forensic investigation, authentication of the signal is needed.
  - Coast authorities are considering the exchange of data between users and authorities in order to enlarge VTS capabilities for leisure boats for the future.
  - AIS class B – number of accidents should be checked to understand the risks. Big yachts are well organised and carry sophisticated navigation equipment and don't want to be regulated (smaller boats would like to be regulated, larger boats are already regulated – big yachts are bottlenecks).
- Timing is becoming more important, not only for navigation but for the operation and synchronisation of on-board systems such as engine management and radar. Applications have range of accuracy requirements from low performance ≤ 1 second for, e.g. synchronisation of lights through to high performance ≥1 micro second for time-stamping, measurements with high frame rates.
- Authentication is important for regulated applications with statutory, minimum requirements.
- Cyber security needs to be a priority e.g. jamming, spoofing.
- There is sometimes a mismatch of PNT requirements on board a single vessel for different applications in the same location, e.g. general navigation requirements are different to collision avoidance requirements. The mariner needs to be sure what level of service is provided and what applications are supported.
- For an increasing number of applications, it is not only position that is important but other parameters, such as rate of turn and the relative position of the bow and stern of the vessel.

CATEGORIES FOR NAVIGATION AND POSITIONING APPLICATIONS

- User requirements were divided by categories (IMO 915) to reflect different use cases.

COMMENTS FROM PARTICIPANTS:

- Participants approved the approach to categorise the applications and their required performances per type of operation (per order of magnitude i.e. 0.1m, 1m, 10m, noting that often intermediate (lower) levels of performance might be acceptable depending on local circumstances).
- It was suggested that one more stringent category with 0.01 m accuracy should be added to cover some specific applications requiring higher precision than decimetre accuracy.
- Fusion from different sensors is likely to be needed to meet the requirements of critical applications and provide redundancy and resilience.
- Category 1: for SAR, only GNSS is sufficient. For 2nd generation beacons, GNSS-independent location requirement is 30 m. Casualty analysis require a separate recording related to VDR.

- Category 2: "Port operations: Local VTS" – it should be clarified that the Local VTS relies on the signal received from the ships, the requirement of using augmentation for achieving higher accuracy should be to the ships and not the land infrastructure.
- Large vessels have 2 or more antennas that can be used to calculate rate of turn and lateral displacement.
- Positioning from antennas could be used as protection levels but problem could come from the errors in the antennas from the satellites. EGNOS could correct potential satellite errors and then the use of the relative position of the antennas could be used as a sort of protection level – alert if the positioning between antennas is not correct.

CONSULTATION PROCESS FOR INTERMEDIATE USER PERFORMANCES

- A consultation was done among different European port authorities to have their view on the need of intermediate performance levels for navigation and positioning operations in ports.
- Results indicate that most respondents tend to select the most stringent requirements but it sometimes does not represent the real needs.

COMMENTS FROM PARTICIPANTS:

- Question 2 – different replies could have been because the question was not clear. The concept "navigation in ports" is too general. Each operation need to be well defined for the questions.
- Question 5 – was an open question. Average duration for operation is 3h. For tankers – operations from 30 min and 7 h. Size of the ship and distance (could go to 80 km) are the most important parts. During the entire operation you need to be very focused. GPS not used, only Radar and sensors.
- Question 6 – continuity concept and variation might not be well understood by the users. It is suggested that the requirements are broken down in "minutes" which is more understandable for the users.
- Question 12 – "automatic collision avoidance" is referring to potential use in autonomous vessels.
- Trend is to go for more accurate systems (if available).
- CONCLUSION: order of magnitude is valid and it is aligned with the IMO guidelines MSC.1/Circ.1575 with multi-system and multi-sensors (document has been finalised). Concept differentiating Operational Requirements from Technical Requirements levels.

12h45-13h00, 14h00- 14h30
Emerging applications and new trends in R&D (inputs for FP9)

GENERAL

- Main challenges:
  - Resilient PNT.
  - Maintaining signal in space.
  - Cyber security.
- Main technical barriers:
  - Radio Frequency (RF) signal interference on vessels.
  - Regulation not keeping up with technology.
  - Data communications is critical.
- Technology trends:
  - Sensor fusion to provide resilient PNT.
  - Multi-constellation and multi frequency.
  - Authentication.
- EU should encourage Europe's industry to innovate and it should avoid developing EU services that compete with Europe's industry existing services e.g. Galileo CS.

COMPLEMENTARY TERRESTRIAL SYSTEMS

- Research on complementary territorial systems for resilience (backup) is necessary.

AUTONOMOUS VESSELS

- GMV participated in the EGUS project to identify the user requirements for autonomous vessels.
- Horizontal accuracy is an important parameter but horizontal alert limit (HAL) is the most important parameter.
- Requirements derive from expert consultation.
- Resistance to spoofing is also critical.
- Additional research to include different scenarios and collision risk models is necessary to augment the analysis already done to assess the requirements for autonomous navigation in realistic traffic situations.
- Better understanding of resilience requirements is also required.
- Key areas to be developed to enable autonomous vessels:
  - Accurate and more importantly robust/resilient anti-spoof navigation systems.
  - Accurate maps of ports and harbours, tidal areas and rivers with regular updates on moving sandbars and other potential underwater obstructions.
  - Monitoring and interconnectivity of all major and essential systems on board a vessel, from engines to cargo for preventive maintenance and ongoing in transit monitoring purposes.
  - Cost effective high data rate interconnectivity between the vessel and shore support facilities (both the vessel owners/operators and harbour and port authorities).

DYNAMIC POSITIONING

- The control system for dynamic positioning in a vessel uses a combination of sensors including GNSS, lasers, radar, wind detectors.
- Redundancy is very important (sensors and GNSS).
- Authentication is also important because spoofing is an issue.
- Signal interference is also an issue.
- High precision is needed.

OIL AND GAS POSITIONING SERVICES:

- Performance standards are set within the industry itself rather than by external bodies.
- Tenders for services to offshore oil and gas companies are strict in their requirements and require assurance that these requirements are met.
- Less than 10 cm, because the 10 cm in the surface is a much higher error in the seabed.
- GNSS is also used as a source of time, 1s is sufficient.

TIMING FOR SENSOR FUSION

- Resilient position navigation.
- Sensor integration.
- At the moment, only source of timing is GPS.
- Time is critical because multiple sensors depend on time – sensors that appear independent have a common point of failure through the source of timing.
- 1 microseconds precision and 50 Hz could be required.

IWW TRAFFIC MANAGEMENT

- Inland waterways environment is more challenge than open seas, even in coastal areas, due to the much tighter spaces and distances on most rivers and canals, the spacing between vessels and between vessels and the river banks can be quite tight.
- The spacing between vessels also leads to a secondary issue of interconnectivity between vessels, if one slows down for some reason, then so must the vessels behind it, thus you cannot just manage vessels in isolation from each other.
- A Mesh/grid mapping network would be required to leverage control. A solution of this type will ideally need to be seamless across international borders.

ACCIDENT INVESTIGATION ON IWW

- In case of accidents, bridge collisions, insurance between two ships can be an issue.
- AIS track is used to reconstitute the accident, if there are any problems in the positioning information, it could be an issue in court. Authorities need integrity of information.
- What is it missing for R&D: special service with the backup of the signal. For IWW, there is no recording equipment in the vessels. Only VHF and transponders are used. For IWW, shore-based AIS monitoring should be required and they should require the positioning of the vessel because the vessel themselves are not required to record data.
- Authorities distribute the augmentation messages through VHF.
- Insurance: if they use AIS positioning to report the position augmentation is necessary in this situation to ensure that the horizontal accuracy is below 10m.

BATHYMETRY SURVEY (IWW)

- Special surveys – use of RTK but requires special vessels and it is high cost.
- For areas that require regular surveys, unmanned vessels could be interesting – accuracy of 1m.

SAR – NEW USES OF RLS

- Initially, requirement was 120 m but in the final part of the rescue operation more precision could be needed. Nevertheless, it has been highlighted by participants that the original requirement of 100 m was a not a user requirement but a coding restriction.
- With GNSS, 30 m could be achieved. With multi-constellation, a 12m is easily reachable.
- EGNOS is not necessary – view of sight could be sufficient in most situations.
- 2nd Generation beacon includes 3.4 m as a requirement but it does not define ways to achieve it.
- If unmanned vessels would be used for SAR operations in rough seas, better than 1m accuracy would possibly be required (in case of autonomous distress unmanned vessels, especially in rough seas).
- There is considerable uncertainty in the real requirement for accuracy for SAR. More investigation is required to determine this.
- the proposed Galileo Return Link Service which start has been postponed to Q1 2019 is believed to be one of the most promising applications. It will be a key unique selling proposition (USP) for 406 MHz beacons and as such expected to have a high take up of RLS capable beacons over the next few years once the service is operational and people become aware of it.
- The further development of the Type 2 RLM Service with the ability to send messages over Galileo could be really significant, for example the ability to send weather warning or tsunami alerts or a host of other items of information to multiple devices or just one device would be a really great enhancement to the system, that is make it more than just a navigation system, turn it into an information service as well for non-SAR and SAR related usage.

- Main challenges:
  - Accuracy and data integrity are a clear priority. The user requires a position fix that they can trust the position being provided, this is critical for any autonomous system whether that be an unmanned vessel or a 406 MHz beacon.
  - After accuracy / integrity comes robustness of the system, it has to work under adverse conditions, in poor weather, when a ship is subject to violent motion, when part of the sky is masked by something or the receiver sensitivity is impaired or there is interference nearby.
  - Finally, and just as important as the two items above in many applications, is data resilience. The system has to be capable of withstanding spoofing and jamming and ideally should continue to function in these environments, but if not should at least be able to indicate that the position provided may not be reliable.
  - Cost of hardware.
  - Miniaturization of equipment for wearable electronics beacons.

- Main Technical barriers:
  - From a maritime perspective, apart from violent movement of a vessel and the ability to continue to track satellites when the antenna is moving all over the place, the only other real issue on a vessel is potential interference from nearby satellite systems that also operate in L Band (e.g. Inmarsat, Iridium etc). Clearly making the front end of Galileo receivers capable of coping with adjacent band interference is important as is making sure that any nearby signals do not leak into the GNSS frequency bands.
  - For other maritime applications, such as beacons and MOB devices, the key issues are different in that Time To First Fix (TTFF) is a critical parameter, followed by the ability for the Receiver to be able to cope with wave wash-over/scintillation effects and violent movement. These are issues that are not given much importance by many but which are critical in SAR applications.
  - Power consumption of GNSS receiver for embedded application (beacons) is a challenge.
  - Obviously critical are inland in urban environments, in buildings or in natural mountainous areas etc, Multi-path issues especially on the inland markets. River radars do rely for a great majority on the accuracy of GNSS compasses. Within urban areas multi pathing due to buildings, bridges etc. is still a big issue.

- Main Technology trends
  - GNSS integration to provide receivers that can operate on GPS, Galileo, EGNOS, Glonass and Beidou and importantly can operate in a multi-constellation and multi-frequency mode taking data from say one GPS satellite, one Galileo satellite and one Glonass satellite to obtain a 2D position.
  - From the perspective of battery powered devices continued reduction in power consumption. The use of multi-constellation GNSS modules has generated the need for increased processing capability, which in turn means higher currents, so we need to find ways to include this capability with minimal increase power consumption at the same time.
  - GNSS disciplined micro-atomic clock or ultra-stable oven controlled crystal oscillators (OCXO).
  - True integration into clothing etc. This has progressed over the last 5-6 years but yet to be made economically viable and reliable.

- Which EGNSS service(s) is the more relevant for the top 3 applications?
  - Galileo Open Service (OS) is the most important as consumers generally do not want to pay for anything, the question really becomes will OS be good enough for critical navigation applications? Or will it be necessary to upgrade to either the Commercial Service (CS) or maybe even the Public Regulated Service (PRS) in order to get the reliability, integrity and resilience needed and if so will people be prepared to pay for this and will such services (e.g. PRS) be available for these applications.
  - From a 406 MHz beacons perspective, clearly the other very important service is the Search and Rescue Service (SAR) that is additional payloads on the Galileo satellites and providing the RLS.

IN ADDITION TO THE ABOVE, PARTICIPANTS ANSWERED TO TWO QUESTIONS RELATED TO R&D FUNDING PRIORITIES

1. What size would you expect for R&D projects sponsored by EU Institutions?
   (x10k€, x100k€, 1 M€, xM€).

   a. Some participants indicated that focus should be on R&D projects between 100k€ and 1M€ while other participants indicated that if they are to leverage tangible work, the focus should be between €300k to €2-3M depending on the scope of the project and the numbers of participants. The size should also depend on the project. For application areas that already exist, getting to market quickly is important. However, some innovative application areas might require more time and resources.

2. How many R&D projects sponsored by EU Institutions would you expect per year?
    a. It is important that the EU sponsored R&D projects are relevant and in line with what is requested by the market.
    b. Some participants indicate From a Maritime perspective we would estimate that somewhere between 5 to 10 R&D projects a year would be target to aim for, however others indicate that 2 to 3 would be sufficient.

14h30-14h55
Common trends in transport / multimodal transport

SENSOR FUSION

- This is a major trend in the maritime sector.
- It is important to have a better understanding of resilience and on backup systems.

UAVS TO SUPPORT OPERATIONS (E.G. MARITIME SURVEILLANCE, INSPECTIONS, PILOTING, OFFSHORE OPERATIONS)

- It is already used in the sector for:
    - Platform inspections.
    - Piracy (security).
    - Off-shore operations.
    - Arctic navigation, looking for open tracks in the ice.
    - UAV for fishing identification e.g. tuna fishing.
- Could also be used for:
    - Environmental control - emission of exhaust gas.
    - Potentially also to support piloting.

14h55-15h30
Inputs to European Radionavigation Plan (RN systems, augmentations and backs-up)

- Carlos Amiens from JRC briefly presented the ERNP.
- Only focused on Radionavigation systems and only on technologies available in Europe.
- Radionavigation Systems recognised as part of WWRNS:
    - GPS, GLONASS, Galileo, Beidou – multi-constellation, single frequency and multi-frequency.
- Augmentation Systems:
    - IALA radiobeacons (GBAS), EGNOS (SBAS) and EDAS (internet).
    - AIS MT17/VDES.
- Back-up systems:
    - R-MODE (AIS+IALA radiobeacons).
- Sensor fusion:
    - Inertial systems: IMU.
    - Technologies for obstacle detection: Radar, Lidar, Cameras, ultrasonic sensors.
- Mapmatching technologies
- This is the first edition, but it will be updated regularly (every 3 years)
- The document will be published in one month and distributed with the group
- User survey will follow after the document will be published

There will be subsequent work on complementary systems

15h30-15h50
Ideas for enhanced services for Galileo and EGNOS and GSC information services

- General information about the GSC:
  - There is a website linked to GSC.
  - Technical Documents OS, SAR, EDAS are available.
  - Quarterly reports about performance of Open Service and SAR.
  - It provides information in relation to the status of the satellites.
  - User support website related to the status of EGNOS in real-time.
  - Helpdesk also available.

- Recommendations for enhancing EGNSS Services and GSC user support:
  - Easy access to Galileo and performance data.
  - Rapid dissemination of maritime safety information through the proper channels.
  - Service monitoring for verification of performance for forensic investigation. EGNOS data is recorded regularly, so it is possible to know the quality of the signal in the specific area. It could be used for post-accident investigation. However, it would be probably difficult to define the signal errors at local level. SOLAS vessels, on-board positioning recording is mandatory. Not the case for IWW.
  - Geofencing concept for areas (e.g. protected areas) which should not be entered, geofencing already possible with AIS however signal is not certified.

Conclusions

1. Highlights of our recommendations for the User Requirements document:

- Institutional statutory requirements are the bare minimum. If we need more stringent statutory requirements we need to follow the IMO process.

- These statutory requirements often do not reflect the real more stringent operational requirements. These should be reflected as guidelines to define what the service should deliver.

- The overall objective is resilient PNT.

- Non-performance requirements are very important:
  - Authentication.
  - Resilience:
    - Interference.
    - Anti-spoofing.

- Timing is becoming more and more important:
  - Low performance (1 second).
  - High performance (1 micro second).

- Applications can be grouped by order of magnitude performance requirements (0.01m, 0.1m, 1.0m, 10m) although it is possible for intermediate service levels to enable applications in some circumstances.

- Fusion from different sensors is needed to meet the requirements of critical applications and provide redundancy and resilience.

- Detailed updates in the user requirements document are required.

2. Identified R&D needs:
General:

- Main Industry's challenges:
  - Resilient PNT.
  - Maintaining signal in space.
  - Cyber security.

- Main technical barriers:
  - Radio Frequency (RF) signal interference on vessels.
  - Regulation not keeping up with technology.
  - Data communications is critical.
- Main technology trends:
  - Sensor fusion to provide resilient PNT.
  - Multi-constellation and multi frequency.
  - Authentication.

Research areas:

- Research on complementary terrestrial systems for resilience.
- Political framework for innovative technologies.
- Autonomous vessels:
  - Build on initial analysis to include different scenarios and collision risk models.
  - Better understanding of resilience.
- Timing for sensor fusion:
  - Determine timing requirements.
  - Investigate sensor integration.
- Accident investigation (IWW):
  - Data recording from land side.
- Search and Rescue:
  - Assess real requirements for accuracy.
- UAVs:
  - Explore the further use of UAVs to support maritime operations.

3. Recommendations for enhancing Galileo Services and Galileo Service Centre user support

- Easy access to Galileo performance data.
- Rapid dissemination of maritime safety information through the proper channels.
- Service monitoring for verification of performance for forensic investigation.
- Use geofencing for protected areas.

4. Answers to the EC questions asked

Which are the technologies/systems that can fulfil the requirements of your sector today?

- Radionavigation Systems recognised as part of WWRNS:
  - GPS, GLONASS, Galileo, Beidou – MC SF or MF.
- Augmentation Systems:
  - IALA radiobeacons, RTK (GBAS), EGNOS, PPP and EDAS (internet).
  - AIS MT17/VDES.

Out of these technologies, which is the primary PNT solution at the moment, what are the alternative technologies you are using as backup?

- Primary:
  - GPS, GLONASS, Galileo, Beidou – MC SF or MF.
- Backup systems:
  - R-MODE (AIS + IALA radiobeacons).

What is your perception for the evolution of your requirements and related primary and alternative PNT systems in the next 10/15 years?

- Sensor fusion:
  - Inertial systems: IMU.
  - Technologies for obstacle detection: Radar, Lidar, Cameras, ultrasonic sensors.

Actions					
ID	**Action Description**	**Responsible**	**Due Date**	**Status**	**Comments**
1.1	Update the Maritime User Requirement Document	MKD GSA			
1.2	Define improvements in Galileo Services based on UCP	GSC GSA/ MKD GSA			

[Include Reference if Actions are traced at another location]

Other Notes & Information

Annexes & Attachments
1. Presentation - User Consultation Platform Maritime and Inland Waterways Panel
2. Presentation - Summary of the results of discussions in the Maritime and Inland Waterways Panel

APPENDIX 5 ANALYSIS OF RELEVANT PAST PROJECTS

5.1 GALA WP1 -APPLICATIONS DEFINITION AND SIZING

"Data has been collected about the technical and non-technical aspects of the user needs of 92 applications found on a very wide variety of platforms, location and environments. In particular, such technical parameters as accuracy, integrity (risk, time to alarm, alarm threshold), availability, operating environment and coverage were addressed. This knowledge has been used to define a number of navigation services that collectively satisfy the majority of the applications addressed." (Extract from GALA executive summary)

Although GALA results are dating back to 2000, the user requirements have been produced by market specialists with an in depth knowledge of the applications, and validated through a number of iterations with Geminus. They do include maritime user requirements, both for Safety of Life (navigation) and non-safety of life (specialised operations) applications. Contrary to most other sources, GALA requirements contain a description of each application and of their *operating environment* (constraints).

5.2 MARNIS MARITIME NAVIGATION AND INFORMATION SERVICES

The EC co-funded project 'Maritime Navigation and Information Services' (MarNIS – 2004-2008) supported the EU ambitions by contributing to the E-Maritime concept.

The focus was placed on the improved exchange of information from ship to shore, shore to ship and between shore-based stakeholders, both on an authority and business level. The stakeholders included on the one hand the vessel itself, together with the ship owner, operator and agent, and on the other hand shore-based entities, including maritime authorities (e.g. Search and Rescue (SAR), coastal and port), related authorities (e.g. customs and immigration) and commercial parties within the port sector.

Of particular interest to user requirements is the study "**A critical look at the IMO requirements for GNSS**" which analysed the then current IMO user requirements as stated in resolutions A915 (22) and A953 (23), and compared them against the then current or planned GNSS.

According to this study ended in 2008, all existing systems have difficulties to comply with all IMO requirements:

GPS alone can only meet the requirements for the ocean navigation phase.

None of the systems comply with IMO requirements for integrity and continuity through the European Maritime Area – *though compliance with continuity requirements stated in A.1046 needs to be re-assessed*.

IALA DGPS has the required availability, but it only meets the continuity requirements at a few discrete zones throughout the EMA area.

EGNOS may achieve the required availability and continuity in most parts of the EMA, but unfortunately not without the additional ranging signals – *compliance with continuity requirements stated in A.1046 is to be re-assessed – Evolutions that will be implemented with EGNOS V3 would likely also deserve further assessment*.

Concerning Galileo, use in combination with GPS will increase integrity, availability and continuity of service at user level. The project has analysed the A.915(22), which provides specific integrity requirements, including integrity risk and horizontal alert limit. However, results are quite obsolete since the withdrawal of the Galileo SoL.

The IMO Resolution A.953 (23) has been also studied and commented. There was a particular non-compliance to navigation in port approaches and inland waterways due to a continuity requirement of 99.97% per 3h. However, Resolution A.1046 (27) changed this requirement to 15min for navigation in harbour entrances, harbour approaches and coastal waters, which is more easy to comply with GNSS, but its adequacy for the phase of navigation, dynamic and manoeuvrability of the craft and type of environment is still questionable. It also still leaves navigation in inland waterways with the most stringent requirement of 99.97% per 3h.

5.3 GEM

The GEM (Galileo Mission Implementation) project started in December 2003 and ended in December 2005.

GEM undertook activities complementary to the development and deployment of GALILEO in order to ensure its success. These activities include standardization for a wide range of applications (including maritime applications), certification and spectrum management. GEM built on several activities undertaken in earlier phases within projects like GALILEI, GALA and SAGA and was then continued within the GARMIS project.

In the Maritime domain, it contributed to the drafting of standards to support the recognition of Galileo as part of the World Wide Radio Navigation System (WWRNS) by the International Maritime Organization (IMO). The aim was to facilitate this recognition process, both in Europe and globally, and to initiate the development of standards necessary for Galileo to be deployed and utilised by the maritime sector.

This concerned in particular:

IMO receiver performance standards for Galileo OS and SoL, with draft receiver performance standards for:

- A combined Galileo-GPS receiver;
- An EGNOS receiver;
- A combined differential Galileo, DGPS, DGLONASS receiver.

Standards for Galileo maritime local components with the development of extensions to the RTCM SC-104 V2.3 and V3.0 to account for Galileo.

IEC test standards based on the Galileo receiver performance standards submitted to IMO.

5.4 GARMIS

The Galileo Reference Mission Support (GARMIS) project started in April 2005 and ended in June 2008.

GARMIS provided the Galileo Joint Undertaking (GJU) with engineering support for analysing a series of technical open issues and for optimising the Galileo and EGNOS documentation. The project addressed the following key areas of activities:

- Galileo and EGNOS mission consolidation and evolutions;
- Galileo, EGNOS, and combined Galileo-EGNOS signals and/or services Interface Control Documents (ICDs) development and validation;
- International standardisation of the Galileo signals and receivers in civil aviation, maritime applications, and Location Based Services (LBS);
- The definition and the development of a prototype Service Centre for Galileo.

GARMIS pursued in particular the Maritime standardisation activities undertaken with the GEM project.

5.4.1 IMO

Galileo receiver performance standards were drafted, supported and approved by IMO in the Resolution MSC 233 (82), which verses about the "adoption of the performance standards for shipborne Galileo receiver equipment". This resolution describes the performance standards, integrity checking, failure warnings, status indications and the protection for Galileo receiver equipment.

The development of combined Galileo/GPS/GLONASS performance standards was found to be unnecessary and the following work would be the development of a generic GNSS receiver standard based on Galileo standards. However, no IMO resolution is found today describing generic GNSS receiver standards, there are still separate standards for GPS, Galileo and GLONASS.

The most recent information in this matter is in the second session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR), in 13 March 2015, when the performance standards for multi-system shipborne navigation receivers were endorsed and Draft Performance standards aiming to address the combined use of current and future radio navigation and augmentation systems were approved for adoption by MSC 95.

The minimum specifications referred here are for multi-system shipborne navigation receivers, which use navigation signals from two or more Global Navigation Satellite Systems (GNSS), with or without augmentation, providing improved position, velocity and time data.

The need to develop associated guidelines for Position, Navigation, and Time (PNT) data and integrity information was recognized, and the Sub-Committee requested MSC 95 to authorize further work to be finalized in 2017.

5.4.2 IEC

A work on Galileo receivers has been adopted by IEC Technical Committee on Maritime Navigation and Radio Communication Equipment and Services.

5.4.3 IALA

GARMIS succeeded to have Galileo supported as part of the LRIT (Long Range Identification and Tracking) in IALA e-Navigation Committee.

5.4.4 RTCM

Many draft messages were proposed and presented both to Version 2 and Version 3 of the differential standard and the main remaining task left for accomplishment prior to voting was the interoperability test.

5.4.5 UPDATE OF NMEA 0183 VERSION 3.01

New Galileo sentences have been proposed and a revised proposal has been completed. The following work should focus on submitting an IEC PAS (Publicly Available Specifications) for Galileo data exchange messages to be included in new editions of interface standards.

5.4.6 LIAISON WITH EUROPEAN MARITIME RADIO NAVIGATION FORUM

Resources were dedicated to promote Galileo within the EMRF in particular to get support in the standardization processes.

5.5 STANDARDS

The STANDARDS project built from end 2008 to 2011 on GEM and GARMIS achievements. Its overall objectives were:

- To carry on the EGNOS and Galileo standardisation process already started in aviation, maritime and location based services with the objective to have fully established norms for the systems entry into operations;
- To develop a standardisation roadmap for other applications where the standardisation work has not yet fully started;
- To support the update of the Galileo OS and SoL services ICD to consider the latest Galileo programme evolutions and the needs of the different standardisation bodies;
- To support the Galileo SIS and Services ICDs consultation processes for obtaining from industry, operators, researchers and users' communities a useful feedback for the improvement of the documents;
- To continue supporting the strict configuration control of the Galileo and EGNOS high-level documents using the DOORS S/W tool already adopted by all Galileo stakeholders.

5.5.1 IMO

The IMO continuity requirement has been amended for port approach applications. While this update was important as the former requirement was too demanding compared to actual operations' risks and GNSS alone were not in position to meet this requirement, other maritime requirements may still need to be reviewed. For example, integrity performance values may be refined as values are often identical from one application to another in the resolution A915(22). Furthermore an IALA paper (e-NAV7/8/23) also requested in 2009 some performances adjustments. Beside this, following a quick review of IMO requirements compared to Galileo MRD performances, some gaps or clarifications may still be needed to ascertain Galileo fully complies to maritime navigation requirements (cf. Annex 1 of D-3110).

5.5.2 IEC

STANDARS contributed to the Final Draft International Standard (FDIS) IEC 61108-3 Ed.1 Standard published on June 2010. It covers maritime navigation and Radiocommunication equipment and systems, GNSS. Part 3 addresses Galileo – Receiver equipment – Performance requirements, methods of testing and required test results.

It also supported the IEC 61162-1 Ed.4 which covers maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 1: Single talker and multiple listeners, and the FDIS was issued on November 2010.

It prepared new sentences for Galileo, including the new sentences defined for IEC 61162-1 as well as a new sentence for Galileo almanac data for the NMEA 0183 Interface Standard and assisted the NMEA 2000 Standard for Serial-Data Networking of Marine Electronic Devices with the definition of new PGNs (Parameter Group Number) related to Galileo.

5.5.3 RTCM

STANDARDS supported the update of the RTCM Recommended Standards for Differential GNSS Service V2.3 and V3.1 to incorporate Galileo. It continued the work undertaken in GARMIS by updating the draft versions of RTCM V2 and V3 messages for Galileo receivers.

Interoperability tests of the proposed V2 and V3 Galileo messages were conducted and STANDARDS contributed to the preparation and adoption of final RTCM 104 V2.4 and V3.2 standards voting documents.

5.5.4 COORDINATION WITH IALA

STANDARDS participated in e-Nav meetings in view of the revision of the ITU-R Recommendation M.823 to include Galileo in differential GNSS Standards.

5.5.5 MARGINAL NAVIGATION USING GALILEO

This task aimed at studying the interrelated processes involved with provision of highly accurate and robust relative accuracy (± 5cm horizontal and vertical – or better) position services on the vessel. Marginal ships are severely limited for their manoeuvrability or accessibility, due to their size in relation to the sea-lanes, waterways and infrastructures they are required to use. Any ship therefore can be marginal. The major issues are Squat, Shallow water effect, Water Level & Density, Waterway - Bank effect and Interaction. The information needed to manage ships transition are mainly Tactical image, Path Prediction, Co-operative decision support, Strategic Image – Dynamic Slot Allocation, Dynamic path prediction, Dynamic Underkeel Clearance.

A major consideration is that though the marginal vessel will use special services for its passage from sea to berth, other vessels will use normal DGNSS or GNSS. This task addresses specific constraints of marginal navigation and establishes a standardisation roadmap.

When marginal navigation's requirements will be defined at IMO level, it is recommended to consider them with regards to Galileo specifications and to assess how far Galileo is able to respond to marginal situations.

5.6 MARUSE

The MARUSE project Report on Standardization and Certification in the Maritime Community, elaborated in 2006, summarizes the previous and ongoing work (at that time) of the standardization process, separating applications on 3 different situations: ports and open sea, and inland waterways and high precision applications.

5.6.1 PORTS AND OPEN SEA

During the GEM project time-frame, IMO NAV 50 confirmed that Galileo navigation service would meet all the requirements for oceanic, coastal, port approach and restricted waters operation. Galileo Open Service (OS) and – at a time where Safety of Life (SoL) was still considered - SoL can be used to meet all of the requirements for ship-to-ship coordination. This is specific to Galileo, since GPS (GPS SPS) does not meet the availability, continuity or integrity requirements. The GEM project developed a combined standard for the Galileo OS and SoL, draft standards for a combined Galileo-GPS receiver and for those using EGNOS, and an initial draft minimum performance standard for a DGNSS receiver including DGalileo, DGPS and DGLONASS. The last 3 standards were immature and had not been submitted to the IMO. It is important to highlight that Galileo certification and standardization is vital for all applications, given the fact that, without certification by IMO it would not be approved for use onboard vessels.

5.6.2 INLAND WATERWAYS

For this type of application, there are additional international bodies defining regulations, resolutions and standards, such as the European RIS (River Information Service) Platform, whose objective is to promote the harmonized implementation of RIS.

River information services means harmonized information services to support traffic and transport management in inland navigation, including, wherever technically feasible interfaces to other transport modes. RIS aim at contributing to a safe and efficient transport process and at utilizing the inland waterways to their fullest extent. RIS are already in operation in manifold ways.

Some important documentation is found in RIS directive 2005/44/EC on harmonized river information services on inland waterways in the Community, and also in the amending acts 2007/414/EC (RIS Guidelines) and 2007/415/EC (technical specifications for vessel tracking and tracing systems). They establish frameworks for the use of RIS and the development of its technical requirements, specifications and conditions to ensure harmonized, interoperable and open RIS besides also describing the principles and general requirements for planning, implementing and operational use of RIS and related services. The MARUSE project is recommending an intermediate value of accuracy and alert limit of 3m and 7.5m respectively, while the European RIS regulation keeps the values from IMO for general navigation (10m 95% accuracy) and propose 1m 95% accuracy for operations in locks and under bridges.

5.6.3 HIGH PRECISION APPLICATIONS

High precision applications are those which require additional levels of accuracy, integrity availability and continuity than those necessary for normal navigation and positioning requirements. Standardization and legislation processes only cover a part of high-end applications.

This type of application requires 3 hour continuity, as stated by IMO A.915 (22), because of their need to proceed to successful resolution without any interruption. However, most of these applications take place in fairways, rivers and inland waterways, and within ports, and thus can be served with local elements to provide the continuity requirement without putting impossible demands on the space segment service. These local elements can be IALA radiobeacon DGNSS, Galileo differential services, RTK, PPP, etc. The use of pseudolites has also been assessed.

The Sub-Committee at NAV 52 July 2006 noted that performance standards were intended for a stand-alone Galileo receiver and that there might be a future need for performance standards for combined GNSS receivers.

The MARUSE work has been undertaken a long time ago. Standardisation related activities have been pursued by the STANDARD project. Actions related to DGNSS are now undertaken by the LIONS project. Although focusing on SBAS

L1/L5, PROSBAS also provides an up to date situation with regards to the requirements analysis and applicable resolutions.

5.7 LIONS

LIONS is a three years project kicked-off in 2014, which completes EC efforts for Galileo standardisation undertaken through multiple past and currently on-going projects (STANDARDS, SUGAST, JASMIN, SAGITER, SALSA). LIONS specifically focuses on introduction of Galileo in D-GNSS technologies for various domains: Maritime, Airport vehicles, Aviation application (GBAS multi-constellation), Land management.

LIONS provides support to the standardisation process of local elements augmenting Galileo in view of their adoption in applications including maritime transport, inland waterways and offshore oil platform.

It also identifies standardisation needs and development/ update of high priority standards to augment Galileo as well as areas where additional standards for Galileo local augmentation are desirable.

A roadmap for further development of the maritime beacon DGNSS standards is under development and will involve the following standardisation bodies and procedures.

5.7.1 IMO MARITIME SAFETY COMMITTEE (MSC)

The MSC 114 (73) standard on maritime beacon receivers for DGPS and DGLONASS needs to be amended or revised in order to include DGalileo corrections. This standard basically refers to ITU-R M823 which also has to be revised in order to include DGalileo corrections.

5.7.2 RTCM SC104 DGNSS

However, prior to the revision of ITU-R M823 a revision of RTCM SC104 v2.3 also needs to take place. A new draft version 2.4 was proposed and even put out for ballot in 2008, but further progress has been hampered due to lack of support from the parties involved. The Version 3 standard on Multiple Signal Messages, however, covers Galileo signals.

5.7.3 IALA E-NAV COMMITTEE

Most maritime standardisation matters related to IMO and ITU are channelled through IALA, such that a future amendment or revision of ITU-R M823 will be handled by IALA.

5.7.4 IEC TC 80 WG 4A

A Galileo receiver test standard, IEC 61108-4, Ed.1, was adopted in 2009, and a revision of the IEC 61108-4 on maritime beacon receivers will also have to be undertaken after a revision of the IMO MSC 114 (73).

At time of writing the report, there is not yet relevant result for the user requirement analysis.

5.8 PROSBAS

5.8.1 USER REQUIREMENTS

The PROSBAS project (2012-2014) aimed at supporting the EC in the elaboration of the SBAS L1/L5 multi-constellation augmentation standard for the SIS ICD and User Receiver parts. It concerned both aeronautical and non-aeronautical domains, including especially the maritime domain.

It started by an analysis of requirements and ended with system prototyping and test. The Maritime user requirements issued from the IMO Resolutions A.915 (22) and A.1046 (27) were described from an EGNOS V3 point of view (EGNOS V3 Mission Guidelines Document – rev3), i.e. taking into account two navigation phases:

- Ocean waters;
- Navigation in harbour entrances, approaches and coastal waters (the most stringent phase).

IMO resolution A.1046(27)							IMO resolution A.915(22)			Associated applications
Accuracy			Service Continuity	Signal Availability	TTA (integrity warning)	Fix Interval	Alert Limit		Integrity risk	
H pos	V pos	Velocity					H pos	V pos		
<100m	N/A	N/A	N/A	> 99.8%	10s	2s	N/A	N/A	N/A	Ocean waters
<10m	N/A	N/A	> 99.7% / 15 min	> 99.8%	10s	2s	25m	N/A	10^{-5} / 3h	Navigation in harbour entrances, harbour approaches and coastal waters

The project made a critical analysis of these requirements. It is stressed that the requirements are clearly derived from aviation requirements different in many respects (e.g. environment, certification process). A consultation process has been held with professionals of the domain, including the EMRF representatives, Maritime institutions and manufacturers. It indicated that the Safety of Life concept as stated in the aeronautic domain is not wanted by mariners. It is thus understandable that mariners want to revise the resolution A.915(22). An example of revision lies in the continuity requirements: according to maritime fora, super-tankers can do an emergency stop in 14 minutes. In normal operations, they begin to reduce the speed of the ship 25 km away of the port; for such tankers having a continuity risk superior to 99.97% over 15 minutes means that the boat should not have a continuity breach of more than one second. This seems obviously too stringent with regard to the dynamic of the boat.

A reference environment has been studied for the different navigation phases, and allows comparison with already developed models or integrity work. In particular, several multipath error models have been defined for various type of environment (sea activity, structure of the ship, surrounding environment especially in harbour). The approach was to define maritime environments based on five criteria. See table below.

This characterization is mostly intended to serve as a base for performances study (mainly accuracy and integrity), but depending on results from test campaigns, it might become necessary to assess different assumptions for reference environments according to class of the ship and the surrounding environment.

The notion of integrity[5] in the maritime domain is taken from the IEC document 61108-4 for DGPS.

Applied to DGNSS, the GNSS receiver shall give a DGNSS integrity indication:

- If no DGNSS message is received within 10 s;
- While in manual station selection mode and the selected station is unhealthy, unmonitored, or signal quality is below threshold (acceptable < 10 % WER, unacceptable > 10 % WER);
- While in automatic station selection mode and the only available station is unhealthy, unmonitored, or signal quality is below threshold.

From a high-level point of view, there is no clear difference between integrity in maritime domain and in aviation: both domains rely on warning when no signal is available, a station/SV is unavailable / unhealthy or alarm limits are exceeded. The difference here lies in the target of protection levels: in maritime, protection levels are computed at system level, i.e. on signals not impacted by errors at user level. In aviation, protection levels are computed at user level.

PROSBAS considered a similar approach in service level B, i.e. to define protection levels for a ship, so at user level. In case these protection levels exceed alert limits (the alert limit value is to be defined for each phase of navigation), an alert is sent to the user within a limited amount of time.

Characterization of maritime environments

Environment	Criteria	Characterization
Open sea	Elevation mask (degree)	Low to medium
	Multipath condition	Can be high at low elevation
	Attenuation	Low
	Interference	Low
	User dynamic	Low
Coastal waters, harbour entrances and approaches	Elevation mask (degree)	Low to medium
	Multipath condition	Can be high at any elevation. Medium in average
	Attenuation	Low
	Interference	Low to medium
	User dynamic	Low

5 Integrity refers to the confidence the user is able to have in the calculation of the position. Integrity includes a system's capacity to provide confidence thresholds as well as alarms in the event that anomalies occur.

5.8.2 ADDED VALUE OF EGNOS

The main benefits of EGNOS are:

- **Accuracy backing DGPS**: EGNOS can complement DGPS in area where the latter service is not available. This difference is due to the fact that DGPS is a local system whose accuracy decreases as the ship moves away from the station, while EGNOS is a regional system capable of providing almost the same accuracy over a determined area;
- **Resistance to unintentional interference**: the availability of a navigation system is crucial in certain maritime operations. Due to the frequency in use, IALA DGPS is easily perturbed, with a loss of RTCM corrections reception;
- **Provision of integrity information**: In addition to corrections for a better accuracy, EGNOS also transmits integrity information to warn the user not to use a faulty satellite and to over-bind the system errors. This has been considered by the people consulted especially interesting for the maritime community in the frame of the performance standard development for multi-system ship borne navigation receivers.

5.8.3 CONCLUSIONS FROM THE PROSBAS CONSULTATION PROCESS

The maritime community is interested in the use of augmented systems, such as SBAS to complement local DGNSS, but not to replace it, for the following reasons:

- Decommission of DGPS would have financial and operational impacts, as mariners would have to change to other commercial services for accurate positioning;
- GNSS and SBAS can't be used when geo-satellites are not visible, and therefore need complementary systems such as DGPS;
- E-navigation concept includes SBAS utilization.

The reluctance towards the translation of aviation-based systems to maritime use comes from the differences of environment, behaviour, navigation culture, safety of life concept and its price of certification.

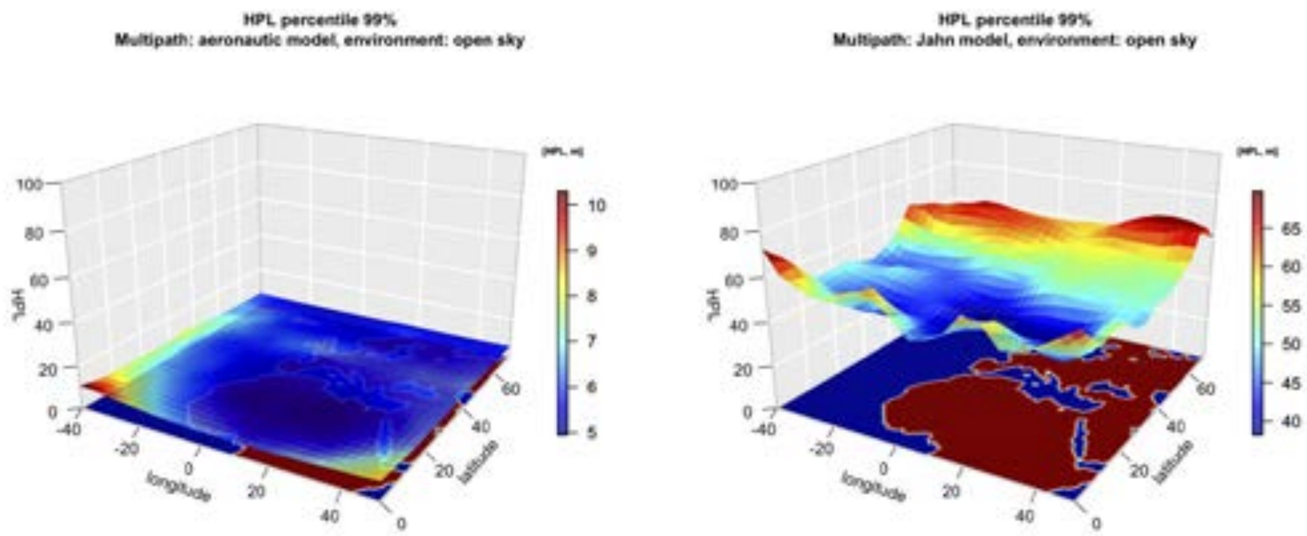
Concerning multipath errors, they consider that a suitable installation of the antenna and the use of adequate models can solve the problem.

5.8.4 NEED TO BETTER ASSESS MARITIME INTEGRITY REQUIREMENTS AND GET OPERATIONAL FEEDBACK

PROSBAS has analysed the suitability of EGNOS to meet the user requirements of the IMO resolutions A.1046(27) and A.915(22). PROSBAS has presented two services level (SLA and SLB). The first one (SLA) is the use of EGNOS as a DGPS-like and is based on resolution A.1046, the second one (SLB) is a "protection level based integrity" approach and based on resolution A.195(22). First simulation's results highlighted that use of EGNOS V3 (multi-constellation, dual frequency) associated with all available GNSS (Galileo, GPS, GLONASS and BEIDOU) allows to reach maritime user requirements for the two services level for ocean and coastal waters and harbour approaches and entrances.

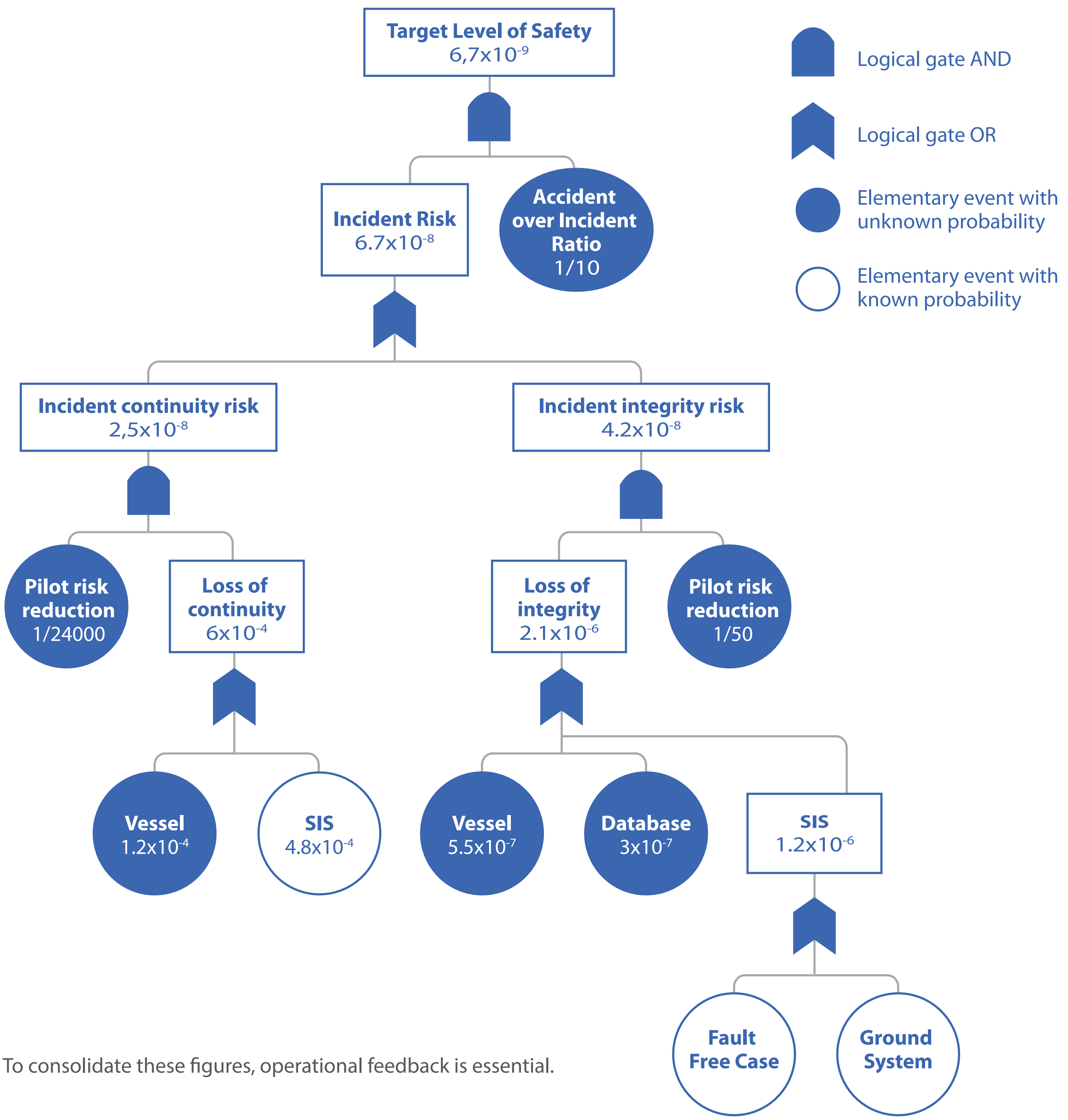
The figures below show that the EGNOS suitability is linked to the environment encountered during navigation phase. The usage of EGNOS for all navigation phases can only be assessed if a good knowledge of the electromagnetic and multipath environments is obtained. Thus, it is necessary to better appraise user operational environment and operational constraints. Technical analyses could be performed, but operational feedback to challenge and refine this characterisation is certainly necessary.

Figure 15: HPL in constrained environment and HPL in unconstrained environment



In addition, the EGNOS integrity concept relies on the monitoring of GNSS constellations and evaluation of the alarm condition when the Protection Limit (PL) exceeds the Alarm Limit (AL). PL computation is based on an over bound of the residual errors over the monitored area, mapped into the positioning domain. The calculation of SBAS protection level is standardized into the RTCA DO-229D. In the PROSBAS project, it has been identified that several items of the integrity algorithm at receiver level need to be adapted from the aviation to the maritime domain: the fault tree allocation, the scaling factor K, the suppression of vertical constraint, the redefinition of error models for multipath. Some values and solutions for each of these items have been proposed. It is now essential to validate them with operational feedback and through the definition of a concept of operations. In particular, we lack statistics regarding the degree of involvements of pilots in accidents. They do not exist. It is thus today not possible to quantify the probability for "Pilot Risk Reduction" in the fault tree allocation presented in the figure hereafter.

Figure 16: Fault Tree Allocation for the maritime phase "harbour entrance and approach, and coastal waters", over a period of 15 minutes, with proposed values



To consolidate these figures, operational feedback is essential.

5.9 MARSOL

MARSOL is a Working Group of experts established by ESA in 2014 to analyse the needs of the Maritime community in the field of GNSS and study how EGNOS can fit with those needs, in particular with regard to integrity.

It starts by analysing the needs of integrity as defined in the IMO resolutions A.1046(27) (2011) and IMO A.915(22) (2001, expected to be revised).

It considers how EGNOS can take account of the specificities of the maritime use in terms of concept of operations and sources of errors (e.g. shadowing, multipath, receiver noise, interference), confirms that errors models needed are different from those developed for aviation in particular concerning multipath characterization, it proposes and promotes EGNOS as a complementary system to local DGNSS and would envisage a potential revision of IMO 915(22) resolution.

5.10 MUNIN

Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) is a project that aims to develop an autonomous ship concept, described as a combination of automated decision systems with remote control via a shore based station. The navigation concept is based in:

An *Advanced Sensor Module (ASM),* responsible for the automated lookout, detecting objects and observing sea phenomena;

An *Autonomous Navigation System (ANS),* associated to ship operation and decision making by executing the tasks of avoiding collision and ensuring stability in harsh weather;

A *Shore Control Center (SCC),* where the human supervision is done, the drone ship's voyage is monitored and eventual problems are solved.

The tasks of GNSS in this future application concern mostly the Autonomous Navigation System and the Advanced Sensor Module, but the Shore Control Center also depends on it once satellite links are responsible for connectivity and data exchange between the SCC and the fleet.

Some specific issues are brought to light in the context of unmanned navigation: GNSS systems are intended to support the decision-making process in order to avoid dangerous situations and collisions. When the SCC uses GNSS, it is required to prevent collision at sea at any cost. If an accident arises from the SCC operators, they are liable for the damage. Therefore, GNSS use in this application must be very precise and reliable due to the legal obligations and liabilities involved.

Although full autonomy may be difficult to realize, the results from MUNIN will have direct applications in the short term:

Better navigation support and obstacle detection can reduce accidents by providing decision support for the officer of the watch.

Small object detection can provide valuable assistance in search and rescue operations.

Better maintenance strategies can reduce technical incidents and off-hire costs.

Improved ship-shore communication and coordination can be used to simplify pilotage, VTS operations and management of the ship. Thus, the expected results of MUNIN also provide a significant potential to make manned shipping safer and less stressful for the mariners in the near future.

APPENDIX 6 UPDATES FOLLOWING THE USER CONSULTATION PLATFORM 2018

As per EUSPA document reference GSA-MKD-AGR-UREQ-25028 available here.

APPENDIX 7 UPDATES FOLLOWING THE USER CONSULTATION PLATFORM 2020

As per EUSPA document reference EUSPA-MKD-AGR-UREQ-25028 available here.

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