USER REQUIREMENTS FOR AUTOMATED NAVIGATION

AVIS

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Code:	AVIS-D2.1
Version:	1.0
Date:	30/09/2024
Internal code:	GMV 25781/24 V1/24

DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	30/09/2024	58	First version prepared for T0+8 delivery

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1. INTRODUCTION

1.1. PURPOSE

The present document is the "User Requirements for Automated Navigation" document for the AVIS project. The main purpose of this document is to task is to identify the user requirements for the safe navigation in inland waterways where automated, remotely and manually piloted vessels will co-exist.

1.2. SCOPE

The present document has been organized as follows:

- Chapter 1. gives an introduction to the document, including purpose and scope of the plan.
- Chapter 2. provides the list of project applicable and reference documents.
- Chapter 3. provides the list of terms, definitions and acronyms used throughout the plan.
- Chapter 4. describes the methodology used for this document.
- Chapter 5. reviews the state of the art information
- Chapter 6. identifies the user needs for the automated navigation
- Chapter 7. identifies the user requirements for EGNSS and Copernicus services
- Chapter 8. provides update recommendations for the EUSPA report
- ANNEX I (Chapter 9.) identifies other requirements not applicable to EU-services

2. REFERENCES

2.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 2-1: Applicable documents.

Ref.	Title	Code	Version	Date
[AD.1]	SERVICE CONTRACT CONTRACT NUMBER – MOVE/D3/2022-501 – MOVE/2022/OP/0029 for "Study with pilot projects on EU Space Data for automated vessels on European inland waterways"	Contract number: MOVE/D3/2022-501 – MOVE/2022/OP/0029	-	10 May 2023
[AD.2]	Study with pilot projects on EU Space Data for automated vessels on European inland waterways Tender Specifications	Call for tenders MOVE/OP/2022/0029 MOVE/D3/FV-2022-501	-	10 May 2023
[AD.3]	AVIS Technical Proposal	GMV 11852/23 V1/23	1.0	13 July 2023

2.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X].

Table 2-2: Reference documents.

Ref.	Title	Code	Version	Date
[RD.1.]	IMO Resolution A.915(22), Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)			11/2001
[RD.2.]	IMO Resolution A.1046(27), Worldwide Radionavigation System			11/2011
[RD.3.]	IMO Resolution MSC.401(95), Performance Standards for Multi-System Shipborne Radionavigation Receivers			06/2015
[RD.4.]	IMO MSC.1/Circ.1575, Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing			06/2017
[RD.5.]	P. Zalewski, A. Bak, and M. Bergmann, Evolution of Maritime GNSS and RNSS Performance Standards. Remote Sens https://doi.org/10.3390/rs14215291			2022
[RD.6.]	IALA website: https://www.iala-aism.org/about-iala/			07/2024
[RD.7.]	IALA Guideline G1112, Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz		1.1	05/2015
[RD.8.]	Vessel Tracking and Tracing Standard for Inland Navigation		1.2	02/2019
[RD.9.]	ES-RIS 2021/1 PART I STANDARD ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM FOR INLAND NAVIGATION)		2.4	12/2018
[RD.10.]	R. Strenge, M. Sandler and M. Hoppe, Driving Assistance Systems for Inland Vessels based on High Precision DGNSS (Research Project LAESSI), 34th PIANC World Congress, 7 -11 May 2018, Panama City, Panama			

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Ref.	Title	Code	Version	Date
[RD.11.]	DIWA_SuAc_3_3_Final_Draft_Report_v0.8		0.8	
RD.12	EUSPA EO and GNSS Market Report, EUSPA	ISBN 978-92-9206-079-4	1.0	2024
RD.13	Precise GNSS based positioning for automated inland vessel navigation, Ralf Ziebold, Anja Hesselbarth, Christoph Lasse, Jörg Zimmermann, Jürgen Alberding, Conference: Autonomous Inland and Short Sea Shipping Conference (AISS) Duisburg		1.0	January 2020
RD.14	IALA Recommendation R1022: PROVISION OF GNSS AUGMENTATION SERVICES FOR MARITIME NAVIGATION APPLICATIONS		1.0	June 2021
RD.15	IALA Standard S1030: RADIONAVIGATION SERVICES		1.0	May 2018
RD 16	IMO Circular MSC.1/Circ.1638 OUTCOME OF THE REGULATORY SCOPING EXERCISE FOR THE USE OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS)			June 2021
RD.17	Electronic Chart Display and Information System for Inland Navigation. Danube Commission (Draft, not yet adopted)		2.3	2024

3. TERMS, DEFINITIONS AND ABBREVIATED TERMS

3.1. DEFINITIONS

There are no definitions that apply to this document.

3.2. ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 3-1 Acronyms

Acronym	Definition
AIS	Automatic Identification System
AISS	Autonomous Inland and Short Sea Shipping Conference
AOI	Area Of Interest
AVIS	Automated Vessels on European Inland Waterways
CCNR	Central Commission for the Navigation of the Rhine
CEMS	Copernicus Emergency Management Service
CESNI	European committee for drawing up standards in the field of inland navigation
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
COG	Course Over Ground
CPA	Closest Point of Approach
CTW	Course Through the Water
DBT	Depth Below the Transducer
DGNSS	Differential GNSS
DPT	Depth NMEA code
ECDIS	Electronic Chart Display and Information Systems
EFAS	European Foot & Ankle Society
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European GNSS
ENC	Electronic Navigational Charts
EUSPA	European Union Agency for the Space Programme
GNSS	Global Navigation Satellite System
GOVSATCOM	EU GOVernmental SATellite COMmunication
HAL	Horizontal Alert Limit
HAS	High Accuracy Service
HDT	Heading
HMI	Human-Machine Interface
IALA	International Association of Lighthouse Authorities
IEC	International Electrotechnical Commission
IECDIS	Inland ECDIS
IHO	International Hydrographic Organization
IMO	International Maritime Organization

Acronym	Definition
ISM	International Safety Management
ISO	International Organization for Standardization
ITU	International Telecommunication Union
IWW	Inland Waterways
LNG	Liquefied Natural Gas
MAE	Mean Absolute Error
MASS	Maritime Autonomous Surface Ships
MSC	Maritime Safety Committee
MSG	Meteosat Second Generation
MSI	Maritime Safety Information
NFS	Near Field Sensor
NMA	Navigation Message Authentication
NRT	Near Real-Time
OSNMA	Open Service Navigation Message Authentication
PIANC	World Association for Waterborne Transport Infrastructure
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
PVT	Position, Velocity and Time
RIS	River Information Services
RNSS	Regional Navigation Satellite Systems
ROC	Remote Operating Center
ROT	Rate Of Turn
RSME	Root Mean Square Error
RTCM	Radio Technical Commission for Maritime Services
SOG	Speed Over Ground
SOLAS	Safety of Life at Sea
STW	Speed Through Water
TGAIN	Track Guidance Assistant for Inland Navigation
UCP	User Consultation Platform
VDES	VHF Data Exchange System
VHF	Very High Frequency
VHR	Very High Resolution
VTS	Vessel Traffic Services
VTT	Vessel Tracking and Tracing
XTE	Cross-Track Error

4. CONTEXT AND METHODOLOGY

In this document produced in AVIS WPx2100 "User Requirements"

The high-level methodology for the work performed is:

- Step 1: **review all the available background information** including info from relevant projects (e.g. LAESSI project, SciPPPer project, GSALOT3TRANS-SC10, etc.) in relation with minimum positioning, navigation and timing requirements for IWW and also for autonomous vessels as well as regarding potential needs on Earth Observation data. The information coming from the different MASS trials/testbeds can also represent a relevant input for this task. Additionally, a review of the state-of-the-art aspects in relation with bathymetric requirements will be done. This will be complemented also with the review of UCP outcomes. Finally a review of the existing requirements for maritime and IWW (Section 5.).
- Step 2: to identify the **user needs** to perform the different automated operations for the IWW Navigation Operation scenarios defined in WP1000 (Section 6.).
- Step 3: to derive the **user requirements** for GNSS and Copernicus Services (Section 7.).
- Step 4: to provide recommendations to update the EUSPA report (Section 8.).

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5. REVIEW OF THE STATE OF THE ART INFORMATION FOR PNT REQUIREMENTS AND ALERTS

This chapter describes the state of the art of requirements of inland navigation operations which are relevant to the project. Position, navigation and timing (PNT) data are essential for ship navigation, especially for future applications such as assisted, automated or autonomous navigation. To ensure safety, this PNT data must meet certain accuracy, integrity, availability and continuity requirements. However, factors such as atmospheric disturbances or intentional interference can affect the accuracy and availability of PNT data. Therefore, the integrity and security of PNT data becomes a critical issue that needs to be addressed. These requirements are primarily derived from standardization organizations, existing regulations and research projects.

The most important operational requirements for radio navigation systems include position accuracy, availability, continuity and integrity. Modern maritime and inland navigation applications and automated solutions increasingly depend not only on position data from a single reference point (e.g. GNSS antenna location), but also on accurate speed, heading and rate of turn (ROT) information as well as measurements from other external sensors (such as AIS, radar, etc.).

In 5.1.1.4 the current IMO Resolution for Alert Management (MSC.302(87)) is mentioned. It overrules other IMO documents. In chapter 5 of this document copies of tables of IMO documents published before the adoption of the Alert Management Resolution are cited/included. In those cases, it has to be considered that the terminology "alert", "alarm" and "warning" is the legacy terminology of standards before the publication of MSC.302(87) in May 2010. So the meaning of such wording has to be seen in context with the original IMO document and before implementation of new functionality be crosschecked with experts regarding the terminology and priority used in MSC.302(87) to ensure the harmonization within alert management on ships worldwide.

5.1. REVIEW OF EXISTING MARITIME REQUIREMENTS APLICABLE FOR IWW

International maritime requirements are defined by regulations, resolutions, directives and guidelines from various organizations, including the International Maritime Organization (IMO), the International Association of Lighthouse Authorities (IALA), the International Hydrographic Organization (IHO), the International Telecommunication Union (ITU), the International Electrotechnical Commission (IEC), the Radio Technical Commission for Maritime Services (RTCM) and the European Commission (EC).

This analysis focuses on the GNSS requirements as set out in the most widely recognized sources. Some of these sources are several decades old and may need to be updated. In addition, there are known inconsistencies in the performance values given in the various documents. Therefore, no direct comparison is attempted in this analysis. Instead, the GNSS performance requirements from the most relevant sources are listed to provide an overview.

5.1.1. IMO REQUIREMENTS

The International Maritime Organization (IMO), a specialized agency of the United Nations (UN), serves as the global regulatory authority for the safety, security, and environmental performance of international shipping. The IMO establishes requirements for radionavigation systems and performance standards for shipborne equipment.

The following IMO Resolutions and Guidelines apply

- IMO Resolution A.915(22), GNSS,
- IMO Resolution A.1046(27), Worldwide Radionavigation System,
- IMO Resolution MSC.302(87), alert management, and
- IMO PNT Guidelines MSC.1/Circ.1575, PNT Data Processing

A key regulation concerning the maritime and inland waterway (IWW) use of GNSS is the IMO Resolution A.915(22) titled "Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)" [RD.1.].

5.1.1.1. IMO RESOLUTION A.915(22), GNSS

IMO Resolution A.915(22) outlines the minimum user requirements for general navigation as follows:

Table 5-1 Minimum maritime user requirements for general navigation

Phase of Navigation	System Level Parameters[1]				Service Level Parameters			
	Absolute Accuracy	Integrity			Availability (per 30 days) [%]	Continuity(over 3 hours) [%]	Coverage	Fix interval [s]
	Horizontal [m]	Alert Limit [m]	Time to Alarm [s]	Integrity Risk (per 3 hours)				
Ocean	10	25	10	10^{-5}	99.8	N/A	Global	1
Coastal	10	25	10	10^{-5}	99.8	N/A	Global	1
Port approach and restricted waters	10	25	10	10^{-5}	99.8	99.97	Regional	1
Port	1	2.5	10	10^{-5}	99.8	99.97	Local	1
Inland waterways	10	25	10	10^{-5}	99.8	99.97	Regional	1

The resolution A.915(22) specifies also more detailed operational requirements for positioning applications, in particular with regard to accuracy. This table below contains a summary of requirements from several tables in the Guideline A.915(22). The performance values for various applications, which could be relevant to inland navigation, are listed in the table below.

Table 5-2 Minimum performance user requirements for positioning (extract)

Application	System Level Parameters					Service Level Parameters			
	Absolute Accuracy		Integrity			Availability (per 30 days) [%]	Continuity (over 3 hours) [%]	Coverage	Fix interval [s]
	Horizontal [m]	Vertical [m]	Alert Limit [m]	Time to Alarm [s]	Integrity Risk (per 3 hours)				
Hydrography	1 - 2	0.1	2.5 - 5	10	10^{-5}	99.8	N/A	Regional	1
Local VTS	1	N/A	2.5	10	10^{-5}	99.8	N/A	Local	1
Law enforcement	1	1	2.5	10	10^{-5}	99.8	N/A	Local	1
Container/ cargo management	1	1	2.5	10	10^{-5}	99.8	N/A	Local	1
Automatic docking	0.1		0.25	10	10^{-5}	99.8	99.97	Local	1

Dredging	0.1	0.1	0.25	10	10^{-5}	99.8	N/A	Local	1
Construction works	0.1	0.1	0.25	10	10^{-5}	99.8	N/A	Local	1
Cargo handling	0.1	0.1	0.25	1	10^{-5}	99.8	N/A	Local	1

5.1.1.2. IMO RESOLUTION A.1046(27), WORLDWIDE RADIONAVIGATION SYSTEM

The IMO resolutions on the global radionavigation system and the performance standards for the individual GNSS subsystems define the mandatory parameters that manufacturers must meet for shipborne receivers in order to obtain certification by the IEC and the classification societies [RD.5.]. The most important of these resolutions is IMO Resolution A.1046(27) entitled "Worldwide Radionavigation System" [RD.2.]. The operational requirements set out in this resolution must be met by GNSS either independently or with the help of supplementary systems such as IALA beacons and EGNOS.

The IMO Resolution A.1046 (27) operational requirements for different phases of general navigation can be found in the Table below.

Table 5-3 IMO Resolution A.1046(27) performance requirements

Phase of Navigation	System Level Parameters				Service Level Parameters		
	Absolute Accuracy (95%) [m]	Integrity			Availability [%]	Continuity (over 15 minutes) [%]	Fix interval [s]
		Alert Limit [m]	Time to Alarm [s]	Integrity Risk [%]			
Ocean	≤ 100	N/A	As soon as practicable by MSI	N/A	> 99.8	N/A	2
Harbor entrances, harbor approaches and coastal waters	≤ 10	N/A	10	N/A	> 99.8	≥ 99.97	2

GNSS satellite signals are very weak and susceptible to unintentional and intentional radio interference, such as jamming and spoofing. Improved jamming immunity can be achieved by integrating measurements from two or more independent or frequency-diverse radio navigation systems. Improved spoofing immunity can be achieved by services as Galileo OSNMA (not yet standardized at IMO level). To ensure that ships have robust positioning equipment, IMO Resolution MSC.401(95) establishes performance standards for multi-system shipborne radio navigation receivers [RD.3.]. These standards allow the combined use of existing and future radionavigation and augmentation systems to provide position, velocity and time (PVT) data with the accuracy specified in IMO Resolution A.1046(27).

Resolution MSC.401(95) specifies that the multi-system radio navigation receiver on board a ship shall, as a minimum, determine position, course over ground (COG), speed over ground (SOG) and time information. In addition, the multi-system equipment should be designed to include integrity monitoring for each PVT source used.

5.1.1.3. IMO PNT GUIDELINES MSC.1/CIRC.1575, PNT DATA PROCESSING

In 2017, the IMO Maritime Safety Committee adopted MSC.1/Circ.1575 entitled "Guidelines for Shipborne Position, Navigation, and Timing (PNT) Data Processing". The aim of these guidelines is to increase the safety and efficiency of shipping by improving the provision of position, navigation and timing data. They outline the achievable performance levels of PNT data in terms of accuracy, integrity, continuity and availability. The guidelines also list various data sources, including different sensors and services that contribute to combined PNT data processing (PNT-DP), as shown in the figure below.

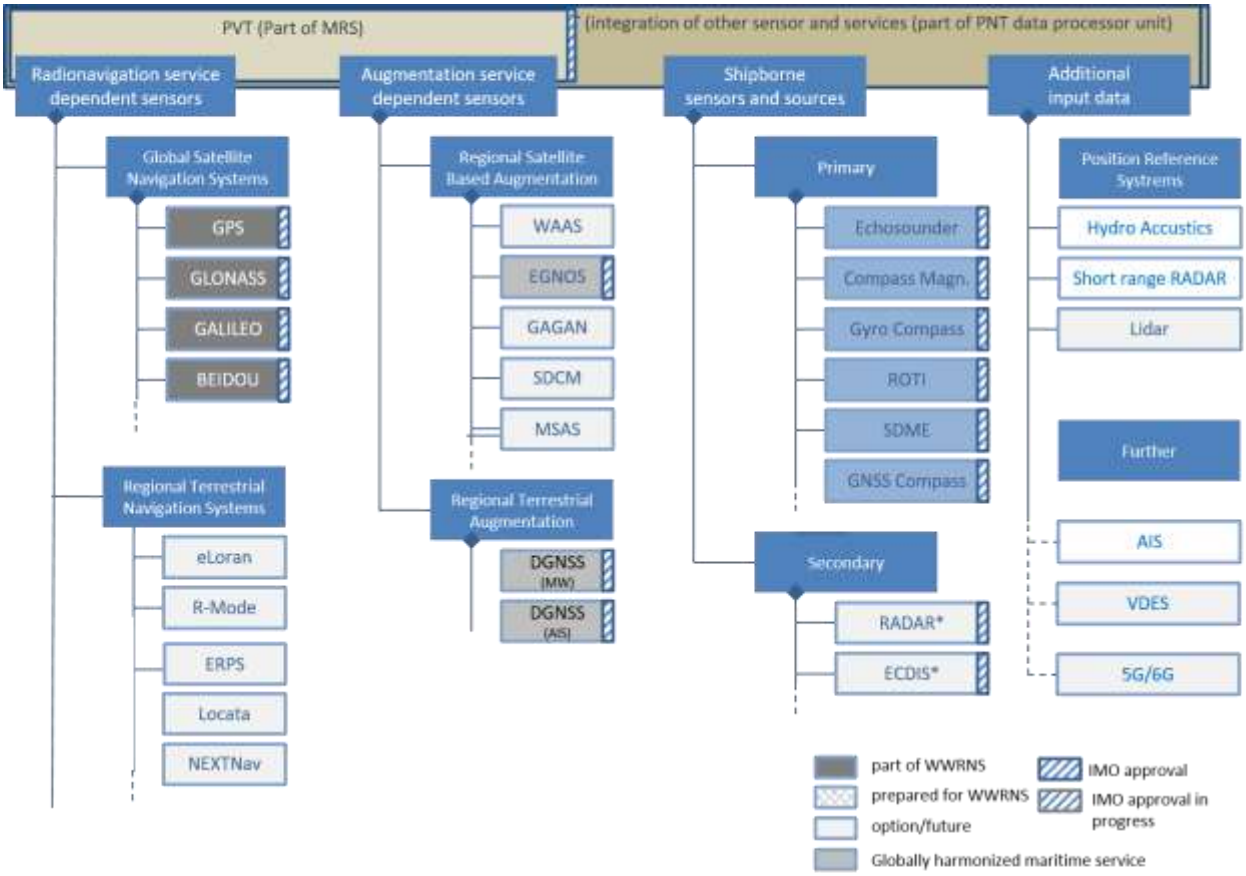

Figure 5-1 IMO PNT Guidelines MSC.1/Circ.1575 – PNT-DP input data sources

The relevant navigation parameters were determined in order to meet the navigation operations identified in document D1.1 (Table 6-1 Key Aspects or the description the navigation operations – Navigation Parameters). An analysis showed that the provision of PVT Data (Position, Velocity, Time) no longer meets the requirements of the future navigation operation. In the future, parameters such as rate of turn (ROT) or course over ground (COG) will be required to allow ships to navigate the waterway automatically or autonomously.
The IMO has defined requirements for such data in resolution MSC.1/Circ.1575 in order to better classify the large number of navigation parameters [RD.4.].

The requirements on data output of PNT-DP are specified by:

- the application grade of PNT-DP defining the amount and types of output data; and
- the supported performance level of provided PNT data regarding accuracy and integrity.

The MSC.1/Circ.1575 Guidelines specify the requirements of PNT-DP data output by defining application grades as well as accuracy and integrity performance levels.

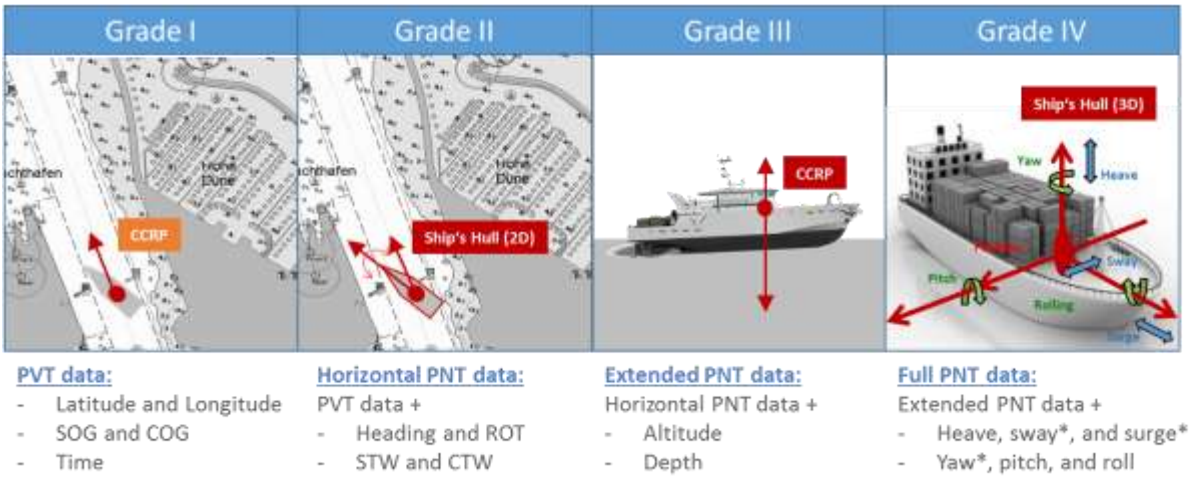

Figure 5-2 IMO PNT Guidelines MSC.1/Circ.1575 – application grades of PNT-DP

The following application grades have been defined by IMO:

Table 5-4 IMO PNT Guidelines MSC.1/Circ.1575 – application grades and PNT data requirements

Application Grade	Description	PNT data requirement
Grade I	position and movement of a single onboard point (e.g. antenna location of a single GNSS receiver)	horizontal position (latitude, longitude), SOG, COG, and time
Grade II	horizontal attitude and movement of ship's hull	heading, rate of turn, STW and CTW in addition to Grade I
Grade III	vertical position of a single onboard point and depth	altitude, and depth in addition to Grade II
Grade IV	ship's position and movement in three-dimensional space	heave, pitch, and roll (and may be surge, sway, and yaw with higher performance) in addition to Grade III

Further, the PNT Guidelines set generic performance requirements for each PNT output data in terms of accuracy and integrity as follows:

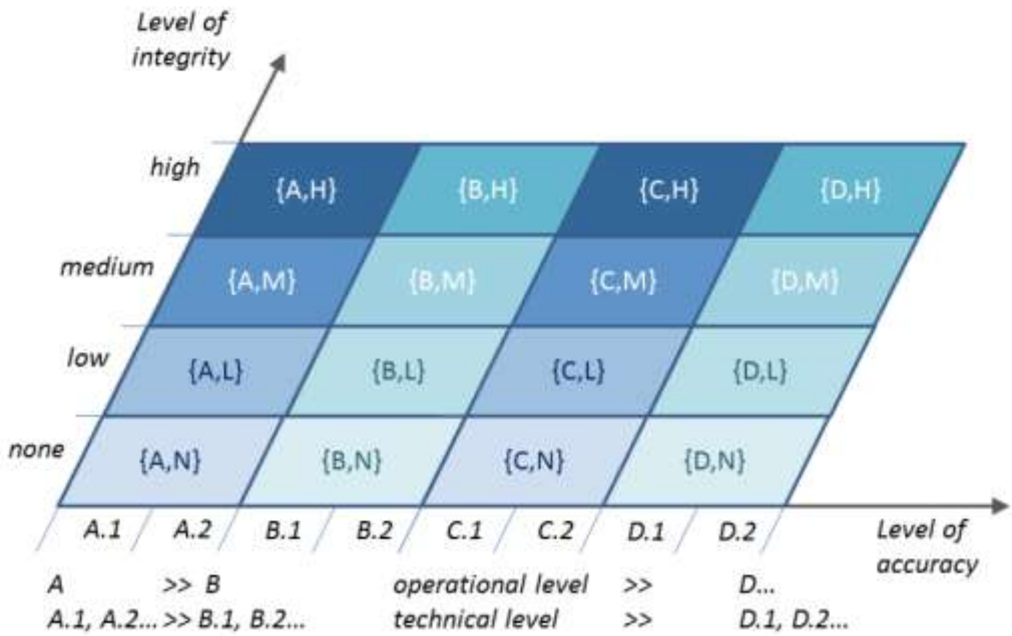

Figure 5-3 IMO PNT Guidelines MSC.1/Circ.1575 – generic performance level for each PNT output data in relation to accuracy and integrity

The operational accuracy performance levels are defined based on existing performance standards (Resolutions A.1046(27) and A.915(22)):

Table 5-5 IMO PNT Guidelines MSC.1/Circ.1575 – accuracy performance requirements

Accuracy Level	Absolute Accuracy (95%) [m]
A	≤ 100
B	≤ 10
C	≤ 1
D	≤ 0.1

The provided integrity information is categorized depending on the applied principles of integrity evaluation:

Table 5-6 IMO PNT Guidelines MSC.1/Circ.1575 – integrity performance requirements

Integrity Level	Integrity Evaluation Principle
none	unavailable
low	plausibility and consistency checks of data provided by single sensors, systems, services, or sources

medium	consistency checks of data provided by different sensors, systems, services, and sources with uncorrelated error parts as far as possible
high	estimated accuracy (protection level)

Accuracy and integrity levels should be defined for all PNT data of the supported application grade or a combination of them.

5.1.1.4. IMO RESOLUTION MSC.302(87), ALERT MANAGEMENT

During the revision of IMO Resolution MSC.252(83) for Integrated Navigation Systems it was identified that with the increasing number of equipment on the navigation bridge of vessels the harmonization of alerts is a main task for the IMO. The inconsistency of the priority of alerts and its presentation starts more and more confusing the masters and the bridge team. Therefore, IMO decided to harmonize all so far called "alarms" by a kind of a high level "umbrella standard". IMO resolution MSC.302(87) "ADOPTION OF PERFORMANCE STANDARDS FOR BRIDGE ALERT MANAGEMENT "is adopted in May 2010 and is a high-level standard. Its hierarchy is defined in clause 3.6 and 3.7 of the application of the resolution.
"3.6 In case of conflict with alert requirements of existing performance standards, the present Performance standards will take precedence.
3.7 These Performance standards should apply for all alerts presented on, and transferred to, the bridge."

This leads into the situation that currently a lot of Performance standards need revision because the terminology "alert" with its priorities has to be aligned with IMO Resolution MSC.302(87). Standardisation organisations like IEC and ISO are already considering MSC.302(87) accordingly in case they revise their testing standards.

Main topic for consideration are the following definitions (MSC.302(87):

Alert
Alerts are announcing abnormal situations and conditions requiring attention. Alerts are divided in four priorities: emergency alarms, alarms, warnings and cautions. An alert provides information about a defined state change in connection with information about how to announce this event in a defined way to the system and the operator.

Emergency alarm
Highest priority of an alert. Alarms which indicate immediate danger to human life or to the ship and its machinery exits and require immediate action.

Alarm
An alarm is a high-priority alert. Condition requiring immediate attention and action by the bridge team, to maintain the safe navigation of the ship.

Warning
Condition requiring immediate attention, but no immediate action by the bridge team. Warnings are presented for precautionary reasons to make the bridge team aware of changed conditions which are not immediately hazardous, but may become so if no action is taken.

Caution
Lowest priority of an alert. Awareness of a condition which does not warrant an alarm or warning condition, but still requires attention out of the ordinary consideration of the situation or of given information.

5.1.2. IALA REQUIREMENTS

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a non-profit international trade association dedicated to the worldwide standardization of aids to navigation for shipping. Its aim is to ensure safe, efficient and cost-effective shipping while protecting the environment. To achieve this, the IALA has formed several technical committees that develop best practices that are published as IALA standards, recommendations, guidelines and model courses [RD.6.].

To improve the accuracy and integrity of GNSS positioning for maritime navigation applications, the IALA Radiobeacon medium frequency DGNSS system is used worldwide. The performance requirements for this system are described in IALA Guideline G1112, "Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 - 325 kHz" [RD.7.].

The IALA Guideline G1112 summarizes the maritime positioning performance requirements based on IMO Recommendations A.915(22) and A.1046(27) see chapter 5.1.1:

Table 5-7 IALA Guideline G1112 maritime positioning performance requirements

Phase of Navigation	System Level				Service Level	
	Absolute Horizontal Accuracy (95%) [m]	Integrity			Availability (2 years) [%]	Continuity (over 15 minutes) [%]
		Alert Limit [m]	Time to Alarm [s]	Integrity Risk [%]		
Ocean	≤ 100	N/A	N/A	N/A	≥ 99.8	N/A
Harbor entrances, harbor approaches and coastal waters	≤ 10	25	10	10^{-5}	≥ 99.8	99.97

5.2. REVIEW OF EXISTING REQUIREMENTS FOR IWW

The European Committee for Drawing up Standards in the Field of Inland Navigation (CESNI) is a pivotal organization dedicated to enhancing safety, efficiency, and environmental sustainability in inland waterway transport. Established by the Central Commission for the Navigation of the Rhine (CCNR) in 2015, CESNI's primary mission is to develop and harmonize technical standards that govern various aspects of inland navigation. These standards include vessel construction and equipment, professional qualifications, information technologies, and operational procedures.

CESNI brings together experts from member states, international organizations, and industry stakeholders to collaborate on creating unified regulations and guidelines. This collaborative approach ensures that the standards reflect the latest technological advancements and best practices, promoting interoperability and safety across European inland waterways. By setting high standards for vessel safety, environmental protection, and crew competencies, CESNI plays a crucial role in fostering a reliable and sustainable inland navigation sector, ultimately supporting the broader goals of economic growth and environmental preservation in Europe.

The following two CESNI standards were identified as relevant when considering requirements for the project.

- VTT Standard
- Inland ECDIS Standard

Although the rules of European inland waterway navigation are made up by decrees with legal force in each country at the national level, the VTT and Inland ECDIS rules of international waterways are harmonized and CESNI standards are accepted. Individual police regulations (mainly discounts) may occur on the smaller, national waterways. For example: Using navigation chart along the Danube is mandatory, but Inland ECDIS is not mandatory (a hard copy map can also be used). In case a vessel use IECDIS, CESNI standard is applicable.

5.2.1.VTT STANDARD

The concept of River Information Services (RIS) has emerged from several European research projects aimed at improving the safety and efficiency of inland navigation. The European Commission, the Central Commission for the Navigation of the Rhine (CCNR) and the Danube Commission have recognized the need for automatic data exchange between ships and between ships and shore for identification and tracking purposes and have supported these initiatives.

In the maritime sector, the International Maritime Organization (IMO) has introduced the Automatic Identification System (AIS) and required that all seagoing vessels on international voyages covered by Chapter 5 of the SOLAS Convention be equipped with AIS by the end of 2004. The Guidelines and Recommendations for River Information Services (RIS Guidelines 2002) of PIANC and CCNR highlight Inland AIS as an important technology.

In 2003, the European RIS Platform established an expert group for tracking and tracing. This group's primary task is to develop and maintain a harmonized vessel tracking and tracing standard across Europe for inland navigation. Given the mixed traffic areas, it is essential that standards and procedures for inland shipping are compatible with those defined for seagoing navigation.

To meet the specific needs of inland navigation, AIS has been further developed into the Inland AIS Standard, ensuring full compatibility with IMO's maritime AIS and existing inland navigation standards [RD.8.].

Table 5-8 Overview of accuracy requirements dynamic data

Required accuracy	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 organization service	10 m [1]	1 km/h	5°	5°
Lock planning long term	100 m – 1 km	1 km/h	-	-
Lock planning short 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	-	-	-

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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.

5.2.2. INLAND ECDIS STANDARD

The Inland ECDIS standard defined the positioning performance requirements for normal operation conditions as follows [RD.9.]:

- The average position estimation shall not deviate more than **5 meters** from the true position and shall cover all systematic errors.
- The standard deviation **σ shall be less than 5 meters** and shall be based on random errors only.
- The system shall be capable to detect deviations of more than 3σ within 30 seconds.

5.3. REVIEW FROM OTHER RELEVANT PROJECTS

The following section shows the various requirements that have been developed in different projects in the context of automation in inland navigation. In the projects, various technical navigation aspects and situations on inland waterways were examined and evaluated. The most important projects in relation to PNT requirements are presented below.

5.3.1. LAESSI

The LAESSI (Guiding and Assistance Systems to Improve Safety of Navigation on Inland Waterways) project aimed to develop efficient navigation assistance functions for inland waterway transport in Germany. A primary objective was to create a bridge collision warning system that alerts the skipper when the vessel, particularly the wheelhouse or radar mast, is at risk of not safely passing under a bridge [RD.10.]. Additionally, the project developed other assistance functions, such as a track guidance assistant and a berthing assistant, along with the associated conning display.

In the LAESSI project the following PNT requirements have been defined **Error! Reference source not found.**:

Table 5-9 LAESSI PNT accuracy and integrity requirements for inland navigation assistant functions

Application	System Level Parameters				
	Absolute Accuracy			Integrity	
	Horizontal[m]	Vertical [m]	Heading [°]	Time to Alarm [s]	Integrity Risk
Bridge collision warning	0.2	0.1	0.3	4	10×10^{-5} (per 2 minutes) 30×10^{-5} (per 8 minutes)
Track control	0.3	-	0.17	2	0.55×10^{-5} (per 3 hours)

Berthing	0.1	-	0.07	6	$18x10^{-5}$ (per 10 minutes)
Conning	0.2	-	0.1	6	$18x10^{-5}$ (per 1 hour)

5.3.2.SCIPPPER (2018 – 2022)

Locking is one of the most frequent and at the same time most critical navigation operation in inland shipping. A common scenario on German waterways is the entry of an 11.40 m wide ship into a 12 m wide lock chamber. The time it takes a ship to enter and exit a lock can have a significant impact on the overall journey time to its destination. Automating this process should both facilitate shipping traffic and speed up the lock process.

The aim of the SciPPPer (Lock Assistance System based on PPP and VDES for Inland Navigation) project was to develop a navigation assistance system that enables an inland vessel to enter and exit a lock automatically. The automatic lock process was divided into five different phases as shown in figure Figure 5-4. Each of these phases has different requirements for the PNT data.

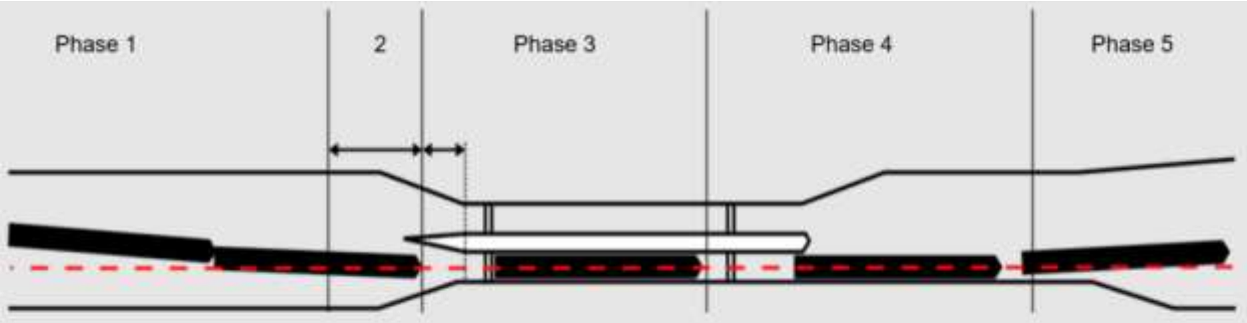


Figure 5-4 Phases of locking process defined in scippper project

Table 5-10 Summary of the requirements for the accuracy of position determination

PNT – requirements derived from SciPPPer project					
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**
Position accuracy bow transverse GNSS [cm]	10	-	-	10	10
Position accuracy stern transverse GNSS [cm]	10	10	-	-	10
Longitudinal GNSS position accuracy [cm]	10	10	10	10	10
Result. Directional accuracy [°/m]	11,45	11,45	-	-	11,45
Longitudinal velocity GNSS [cm/s]	10	10	-	-	10
Transverse speed GNSS [cm/s]	1	1	-	-	1

AVIS project is funded by the European Commission. Results are property of the European Commission.

Time to Alarm PNT Unit [s]	10s (Pos.) 2s (head)	10s (Pos.) 2s (head)	10s (Pos.) 2s (head)	10s (Pos.) 2s (head)	10s (Pos.) 2s (head)
Positioning accuracy bow transverse NFS [cm]	-	1	1	1	-
Positional accuracy bow longitudinal NFS [cm]	-	-	10	-	-
Position accuracy tail NFS [cm]	-	-	1	1	-
Result Directional accuracy [°/m]	-	-	0,573	0,573	-
Longitudinal speed NFS [cm/s]	-	-	1	-	-
Transverse speed NFS [cm/s]	-	1	1	1	-
Time to Alarm NFS [s]	1s	1s	1s	1s	1s
Rotation speed [degrees/min] Standard rate of turn indicator	0,3	0,3	0,3	0,3	0,3
Typical longitudinal speed [m/s]	0,7-1,25	0,3-0,7	<0,3	0,3-0,7	0,7-1,25
Typical transverse velocity [m/s]	0,1	0,05	0,05	0,05	0,1
Integrity risk	10e-5	10e-5	10e-5	10e-5	10e-5
Time to Alarm Kalman filter [s]	1	0,5	0,5	0,5	1
Availability in 30d [%]	90	90	90	90	90
Continuity 15min (open sky)	>99.97%	>99.97%	>99.97%	>99.97%	>99.97%
Update rate [Hz]	10	10	10	10	10

5.3.3. DIWA

Activity 3 (Technical Developments) of the Masterplan Digitalisation of Inland Waterways (DIWA) project, is focusing on 5 topics. During one of the studies, Sub-Activity (SuAc) 3.3 "Smart Sensoring including Positioning, Navigation and Timing (PNT)" is covering existing devices and classifying the sensors according to the identified business developments in Activity 2 and SuAc 3.1. These business developments and the "New Technologies" are part of the digitalization of inland waterways.

Looking at Position, Navigation and Time systems four grades, see Figure 5-2 IMO PNT Guidelines MSC.1/Circ.1575 – application grades of PNT-DP, are identified for different requirements in usage:

- Grade A supports the description of position and movement of a single onboard point (e.g. antenna location of a single GNSS receiver);
- Grade B ensures that horizontal attitude and movement of vessel's hull are unambiguously described;
- Grade C provides additional information for vertical position of a single onboard point and depth; and
- Grade D is prepared for the extended need on PNT data e.g. to monitor or control vessel's position and movement in three-dimensional space.

5.3.4. GSALOT3TRANS-SC10

One of the main objectives of this project was to analyse requirements for autonomous MASS navigation. It does not study the particular case of IWW, but makes a very deep study on how to establish requirements for MASS.

Therefore, in terms of requirements, this project can be a very interesting reference to take into account. The requirements that were established are shown in the following table:

Table 5-11 Requirements derived from GSALOT3TRANS-SC10

Performance Parameter		Ocean Navigation	Coastal Navigation	Port Navigation
Horizontal accuracy (95%)		<10 m	<3-5 m	<1 m
Continuity Risk (over 15 min)		N/A	$3x10^{-4}$	$3x10^{-4}$
HAL		<25 m	<7,5-12,5 m	<2,5 m
Time To Alarm		<8 s	<6 s	<6 s
Integrity Risk	**Over 3 hours**	10^{-5}	$7,2x10^{-6}$	$7,2x10^{-6}$
	Over 15 min	$8,33x10^{-7}$	$6x10^{-7}$	$6x10^{-7}$
	Per sample	$1,39x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$
Availability		99,8%	99,8%	99,8%

5.4. REQUIREMENTS AUTONOMUS SHIPS (MASS)

The different granulation of levels of automation in shipping from the excerpts showing that there are several approaches possible to define the levels of automation and autonomy for operation of ships.

The IMO defines there requirements for maritime autonomous surface ships in ***MSC.1/Circ.1638 as follows:***

The degrees of autonomy identified for the purpose of the scoping exercise were:

- Degree one: Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
- Degree two: Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

Figure 5-5 IMO requirements for maritime autonomous surface ships

The Class NK has defined the grades of automation and autonomy for maritime surface ships as follows:

Table 1 Automation levels according to Sheridan [1) 2)]

Automation level	Definition
1	The human operator performs all tasks without support from the control system.
2	The system offers a complete set of action alternatives, and the operator selects and executes one of those alternatives.
3	The system suggests a small number of effective action alternatives to the operator. The operator decides whether to execute one of the small number of alternatives or not, and the action is executed by the operator.
4	The system offers one suggestion to the operator. The operator decides whether to execute that suggestion or not, and the action is executed by the operator.
5	The system suggests one the most effective action to the operator. If the operator approves the suggestion, it is executed by the system.
6	The system offers one suggestion to the operator. If the operator does not veto the suggestion within a certain time, the system executes that suggestion.
6.5	The system presents one suggestion to the operator, and simultaneously executes that suggestion.
7	The system decides and executes all actions automatically and informs the operator of the actions taken.
8	The system decides and executes all actions automatically and informs the operator of the action taken if requested by the operator.
9	The system decides and executes all actions automatically. The actions executed are reported to the operator only if the system judges reporting to be necessary.
10	The system decides and executes all actions automatically.

—36—

Figure 5-6 Class NK grades of automation and autonomy for maritime autonomous surface ships

Source: ClassNK "Guidelines for Automated/Autonomous Operation of ships Design development, Installation and Operation of Automated Operation Systems/Remote Operation Systems".

The Class DNV (Det Norske Veritas) has developed MASS Guidelines applicable for seagoing and inland waterway ships (CLASS GUIDELINE, DNV-CG-0264, Edition September 2021, Autonomous and remotely operated ships) There in are the basics for DNV's classification rules for inland waterways ships and the general approach:

1. **Safety and Design Standards**: DNV sets rules to ensure ships are safe and well-built, covering everything from the materials used in construction to the ship's overall design, like how strong the hull needs to be.

2. **Types of Ships**: Different types of ships, like cargo ships, tankers, or passenger vessels, have specific rules. For inland waterway ships, DNV provides specialized guidelines to meet the unique needs of these environments.

3. **Special Features**: Ships can get additional certifications for special features, like using alternative fuels (e.g., LNG or ammonia) or having backup propulsion systems to improve safety.

4. **Regular Updates**: DNV regularly updates these rules to include new technologies and meet updated international safety standards.

The Guidelines focus in the Objectives on:

to provide guidance for:

1) safe implementation of novel technologies in the application of autonomous and/or remote controlled vessel functions
2) recommended work process to obtain approval of novel concepts challenging existing statutory regulation and/or classification rules

The guideline covers four types of concepts:

— *Decision supported navigational watch*

This concept is based on enhanced decision support systems supporting an on-board officer in charge of the navigational watch in performing tasks for the navigation function. The incentive for such a concept may be to cover tasks conventionally done by the crew with advanced technology (e.g. look-out), or it may be for the purpose to enhance the safety and facilitate the officer in performing the navigation function.

— *Remote navigational watch*

This concept is based on the tasks, duties and responsibilities of an officer in charge of the navigational watch being covered by personnel in an off-ship remote control centre. This concept assumes that no crew is available on board to support the remote personnel in performing the navigation function and the radio communication function as defined in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) code.

— *Remote engineering watch assisted by personnel on board*

This concept is based on the tasks, duties and responsibilities of an officer in charge of the engineering watch being covered by personnel in an off-ship remote control centre. For this concept, it is assumed that crew is available on board to perform certain defined tasks and assist the remote personnel as needed.

— *Remote engineering watch*

This concept is based on the tasks, duties and responsibilities of an officer in charge of the engineering watch being covered by personnel in an off-ship remote control centre. This concept assumes that no crew is available on board to support the remote personnel in performing the marine engineering function.

The above concepts may be linked to the degrees of autonomy used by IMO for their scoping exercise of maritime autonomous surface ships (MASS):

1) ships with automated processes and decision support
2) remotedly controlled ships with seafarers on board
3) remotely controlled ships without seafarers on board
4) fully autonomous ships.

Figure 5-7 Class DNV guideline concepts covered

The guideline is using different categorizations for the degrees of automation for respectively the navigation functions and the engineering functions.

The technical guidance for the navigation functions in Sec.4 is based on a categorization in line with what is established in the vehicle automation industry (see Sec.4 [3]).
A simpler categorization is used for the engineering functions in Sec.5, distinguishing between systems providing automatic support and systems performing automatic operation.

Overview of Bureau Veritas (BV) classification for inland waterway vessels:

- **Safety and Design**: BV has specific rules to ensure that inland waterway vessels are built and maintained to high safety and design standards. These rules cover everything from the ship's structure to its machinery and equipment.
- **Updated Standards**: The rules, known as **NR217**, are regularly updated to include the latest safety and environmental standards, with the most recent version applying to vessels built after June 2021.
- **Specialized Services**: BV also offers additional services like checking the condition of older ships, assessing hull thickness, and providing guidelines for modern, eco-friendly propulsion systems like LNG.
- **Global Presence**: BV has a strong global network, making them a reliable partner for shipowners worldwide, helping them stay compliant with local and international regulations.

Lloyd's Register provides comprehensive classification rules for Maritime Autonomous Surface Ships (MASS) operating on inland waterways. These rules, updated as of July 2023, cover various aspects of ship classification, including the structural integrity, machinery, and safety systems specifically designed for autonomous operations. Key areas include:

1. **Structural Requirements**: Ensuring the hull and superstructure are robust enough to handle the specific conditions faced in inland waterways, such as varying water levels and potential collisions with floating debris.
2. **Machinery and Equipment**: Guidelines for the installation and maintenance of machinery that ensures the vessel's autonomous operations are reliable and safe.
3. **Control and Communication Systems**: Requirements for the integration of advanced control systems that allow for remote operation and monitoring of the vessel, ensuring that it can operate without a crew onboard.
4. **Safety Protocols**: Enhanced safety measures tailored for autonomous ships, such as redundancy in critical systems and emergency response mechanisms.

Lloyd’s Register also updates these regulations periodically to incorporate the latest technological advancements and operational experiences, ensuring that MASS remains compliant with evolving safety and operational standards. These rules are a vital part of the regulatory framework supporting the safe deployment of autonomous vessels on inland waterways

In Safety4Sea are 6 Levels mentioned (https://safety4sea.com/report-6-levels-of-automation-in-shipping/)

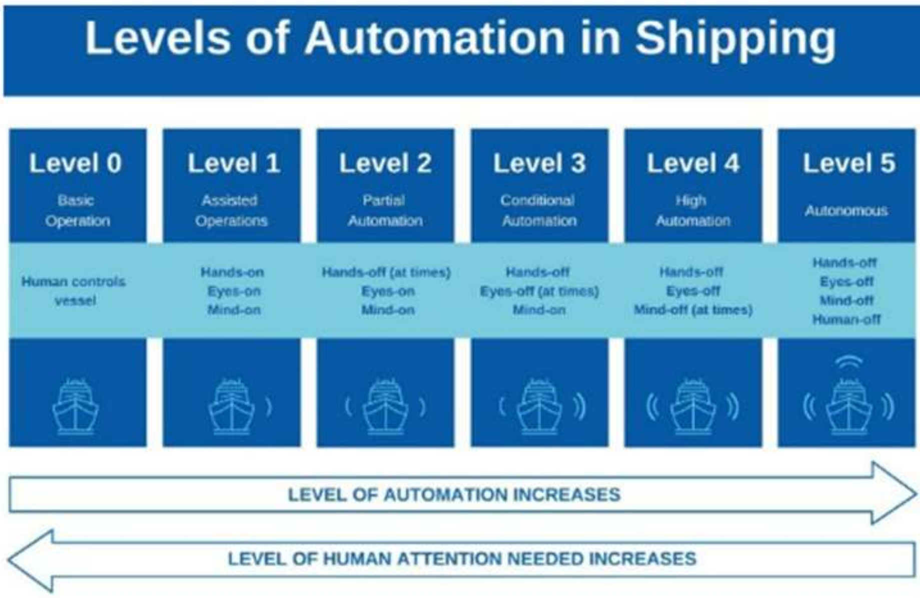
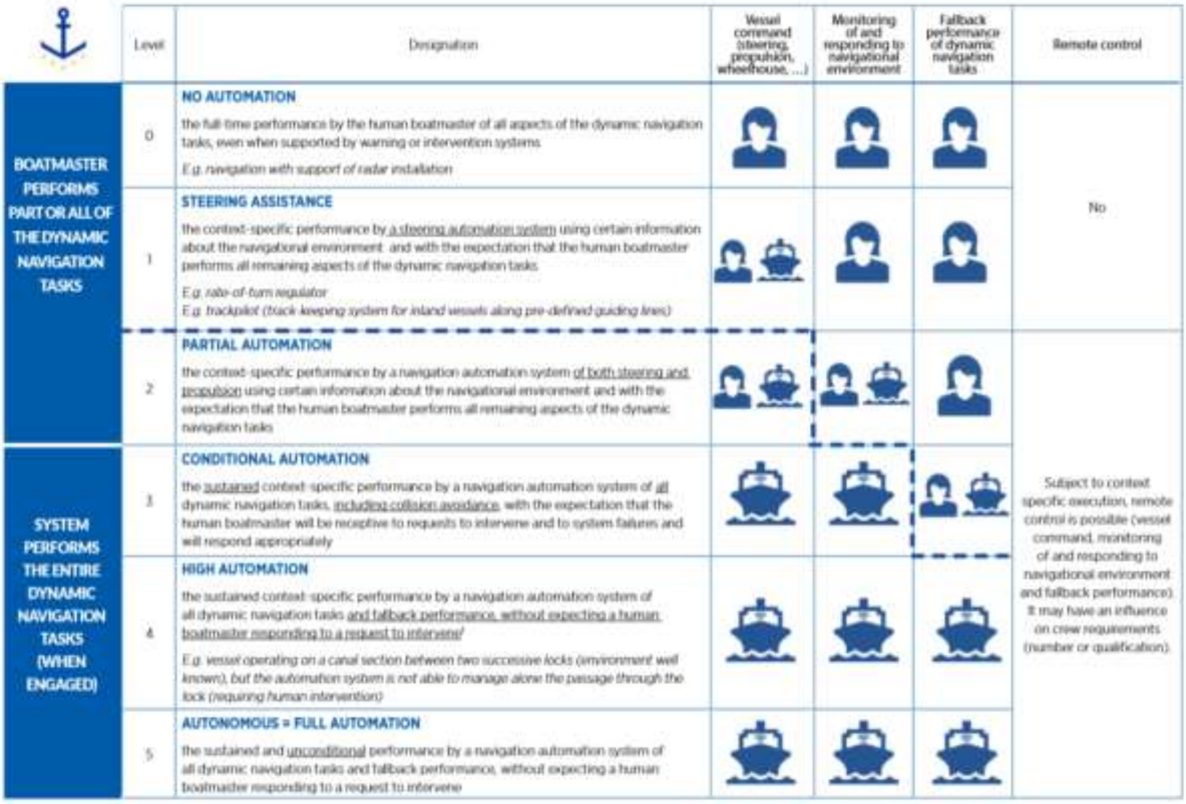


Figure 5-8 Safety4Sea levels of automation

Furthermore, CCNR adopted the first international definition of the various levels of automation in inland navigation (see next figure).



AVIS project is funded by the European Commission. Results are property of the European Commission.

Figure 5-9 CCNR international definition of levels of automation in inland navigation, Ref : cc/cp (18)20

These levels of automation offer a good starting point for the prioritization of work. In the short term, the CCNR considers it necessary to work on minimum requirements and/or recommendations for inland navigation guidance aids corresponding to level 2 of the definition (automated navigation system for both steering and propulsion). In parallel with the automation itself, the CCNR also intends to work on the conditions for operating an automated vessel from a central facility for the remote control and monitoring of vessels. In the medium term, work could start on systems that fall under level 3 of the definition. With this in mind, the CCNR has drawn up this vision as an instrument for directing and coordinating the work to be carried out in the period 2022 to 2028 and beyond.

Steering assistance equipment compatible with CCNR Level 1 (AL1) are already commercially available in the market (e.g. Tresco’s TrackPilot) despite AL1 and AL2 are still not regulated. Products compatible with AL2 or higher are not in the market at this current stage. AL2 is mainly propulsion control and object detection by multiple sensors (including sensor fusion). AL3 uses the result of AL2 to do object avoidance.

5.5. CONCLUSION ON REQUIREMENTS FOR PNT – DATA IN IWW

The PNT (Positioning, Navigation, and Timing) requirements for ships navigating inland waterways typically involve using GNSS or DGNSS to determine the vessel's position, speed, course over ground, heading, and other navigation parameters. These requirements vary significantly depending on the specific applications and phases of navigation, necessitating different levels of accuracy, integrity, availability, and continuity. This report aims to comprehensively analyze and classify these requirements for inland navigation. It takes into account existing maritime standards and regulatory requirements for individual systems (e.g., ECDIS, AIS) used onboard. Additionally, it evaluates and analyzes results from research and development projects to include applications ranging from driver assistance systems to advanced automation and autonomous shipping.

5.6. REVIEW FROM EUSPA USER CONSULTATION PLATFORM

EUSPA spearheads the User Consultation Platform (UCP[1]), a systematic consultation process involving stakeholders utilizing position, navigation and time services and technologies. With the aim to gather and analyse user needs and requirements, the UCP ensures timely inputs into the development of user-centric space data services within the European Space Programme. In the 2022 EUSPA User Consultation Platform (UCP) for inland waterway navigation, stakeholders provided valuable insights into the EO and GNSS requirements for enhancing navigation and positioning within the sector. As stated into the UCP, the integration of EO and GNSS technologies is pivotal for the advancement of maritime applications, including inland waterways, fisheries, and aquaculture, as they have become primary means of navigation in these fields.

For GNSS, the key requirements identified were resiliency and trustworthiness, which are ensured by the integrity of position data. This integrity is critical for safety-critical applications, as it guarantees a very low probability of position error exceeding a certain threshold. The authentication of GNSS data is also crucial, with Galileo's OS-NMA providing a function that allows receivers to verify the authenticity of GNSS information. The availability of high-accuracy solutions like the HAS of Galileo, operational since January 2023, offers free-of-charge, high-accuracy PPP corrections worldwide, positioning Galileo as the most precise satellite navigation system.

For EO, the main drivers for applications in maritime and inland waterways include the need for Very High-Resolution imagery with meter-level or submeter-level resolution, and the availability of historical data to enable change detection or identify trends. The ability to cover large-scale areas is essential for applications such as Metocean and ship route navigation. Additionally, there is a demand for faster data provision and more user-friendly HMI or dashboards.
These requirements are essential for ensuring safe and efficient navigation within inland waterways and other maritime applications. The insights from the UCP and the detailed analysis of user requirements shape the evolution of the European Union's satellite navigation systems and the Earth Observation system, influencing the development of future GNSS services tailored to the specific needs of inland waterway navigation.

In summary, the EO and GNSS requirements for IWW are geared towards ensuring the provision of detailed, reliable, and timely data to support the complex demands of inland waterway navigation. These technologies contribute to the safety, efficiency, and sustainability of IWW operations, and their continuous evolution is shaped by the feedback and needs of the user community.

5.6.1. EARTH OBSERVATION REQUIREMENTS

EO plays a crucial role in enhancing the safety and efficiency of IWW. The EO requirements for IWW focus on the acquisition of high-resolution imagery that is capable of providing detailed information about the waterways. The need for VHR imagery, with meter-level or submeter-level resolution, is paramount for tasks such as monitoring water levels, detecting potential obstructions, and managing traffic along the waterways.

Another critical requirement is the availability of historical EO data, which enables authorities and stakeholders to perform change detection analysis, identify trends, and make informed decisions regarding waterway maintenance and development. This historical data is also valuable for environmental monitoring and assessing the impact of navigation on ecosystems.

For large-scale applications such as Metocean conditions and ship route navigation, EO systems must have the capability to cover extensive areas, potentially spanning several hundreds of square kilometres. This ensures comprehensive monitoring and supports the planning of optimal navigation routes.

Lastly, the EO data provision needs to be timely, with near-real-time availability being ideal for operational decision-making. Moreover, user-friendly interfaces, such as intuitive dashboards and HMI, are required to facilitate the accessibility and interpretation of EO data by end-users.

[1] User Consultation Platform | EU Agency for the Space Programme (europa.eu)

The table below shows the identified requirements for EO in IWW at the UCP 2022:

Table 5-12 Identified requirements for EO in IWW at the UCP 2022

ID	**EUSPA-EO-UR-MAR-0002**
Application	Inland Waterways Navigation
Users	▪ Waterways and Shipping Administration ▪ Commercial shipping companies (freight and passenger) ▪ Harbour master ▪ Non-commercial, recreational tourism e.g. fishing, sailing, canoeing ▪ Local authorities ▪ Wildlife protection organisations
User needs	
Operational scenario	Determining fairways Mapping embankments, barrages, locks. Provide overview for VTS Centre of complete traffic situation (professional and leisure boats). On inland waterways, there is a mandatory carriage requirement using AIS transponders on professional vessels. In principle, this enables the provision of a traffic situation image in the corresponding VTS centres. However, the Inland Authority (e.g. WSV) is also responsible for leisure boat navigation, which is not subject to this AIS equipment obligation. It can be assumed that in the future, requirements will be set for the monitoring of recreational shipping. Since these will not have a corresponding transponder at present and presumably not in the future, the question arises how they could be monitored. The equipment along the waterways with optical sensors seems to be very costly and difficult due to different weather conditions. Thus, detection via an EO system would be of great advantage here. However, it can be assumed that due to the small targets, reliable detection with a sufficient update rate will be difficult to realise.
Size of area of interest	Size of AOI depends on the application scenario: for rescue operations it will be the route towards the operational arena as well as the operational arena, for platforms the surrounding sea area and the route connection to land, for shipping the route between port of departure and port of destination, etc. Weather data are usually collected with a resolution in the km range (e.g. MSG Seviri - at 1 km or 3 km. This is sufficient to allow predictions in the AOI.
Scale	Commercial shipping in the range of ECDIS scale: ▪ Harbour conditions 1:4,000 - 1: 21,999 ▪ Berthing conditions 1:>4,000 ▪ Recreational tourism in the range of 1:4,000 - 1:21,999 Commercial shipping routes are usually well explored and mapped. Therefore, for commercial shipping especially elements usually not captured in those maps and occurring as short-term or seasonal obstacles are of interest. The dimension of these obstacles can range from a few meters (e.g. single obstacles, sandbank) to larger areas (e.g. ice building). Accordingly, the spatial resolution has to start in the meter range (VHR).

	For recreational users, the spatial resolution depends on the size/width of the waterway and can also start in the meter range. For applications related to the conditions of the waterway (e.g. erosion, impact of weather events, maintenance work) spatial resolution starts also in the meter range
Frequency of information	The temporal resolution for the commercial shipping and the obstacle detection starts with NRT monitoring of obstacles (e.g. another ship stranded in front of the ship) and can go up to daily/weekly observations (e.g. ice building). For recreational users, most information is not time critical except e.g. the availability of weather information (extreme weather events) and harbor place availability. For local authorities the temporal resolution varies as well, from NRT observation of blockages effecting immediately any traffic and the safety of the waterway users up to observations over time (e.g. erosion).
Other (if applicable)	Specific requirements are related to the aspects effecting the safety of goods and lives. Therefore, reporting on related aspects like obstacles has to be available and reliable (avoiding false positives and false negatives). For recreational utilization, all services related to safety of life have to be reliable as well (especially weather, flooding, fire risk).
Service Provider offering	
What the service does	Enables safe navigation through inland waterways using most accurate and timely information available. Sediments and natural erosion are continuously changing, e.g. Wadden islands in the Netherlands and Germany (ferries operate regular services, coastguard interventions). Supports the preservation and maintenance of the waterways and related surroundings for commercial shipping, recreational use, environmental and wildlife protection.
How the service works	EO imagery can be used to monitor riverbank erosion and to detect/perform maintenance activities by authorities. EO imagery (radar, optical) can be used for singular object detection as well as for continuous monitoring of various aspects throughout the seasons (e.g. sandbank detection in summer, ice building in winter, sedimentation and erosion, protected zones, maintenance work).
Service Provider Satellite EO Requirements	
Spatial resolution	1 meter/ The size of leisure boats
Temporal resolution	6 hours
Spectral range	N.A.
Other	For safe routing on fairways it is absolutely necessary to include immediate warnings on obstructions, i.e. accident detection in real-time by other means other than satellite imagery.
Service Inputs	
Satellite data sources	▪ Aerial/VHR satellite data

	▪ Other satellites beyond Sentinels may be required, depending on the spatial resolution (meter range) as well as the temporal resolution (especially NRT detection of objects), to allow NRT detection of obstacles (e.g. Cosmo-SkyMed). ▪ Data received from aerial or satellite monitoring will have to be complemented by in-situ/ground measurements, e.g. water gauges regarding water levels, local observations from authorities, water samples to determine the water quality, specific harbour information (invasive species), etc.
Other data sources	▪ AIS Data ▪ Sentinel-1 (object detection, ice monitoring, deformation mapping, flood monitoring) ▪ Sentinel 2 (Maritime Monitoring CMEMS) ▪ Sentinel 3 (altimetry for narrow rivers and small lakes)

5.6.2. GNSS REQUIREMENTS

GNSS are indispensable for precise positioning and navigation within the IWW sector. The GNSS requirements for IWW emphasize the need for resiliency and trustworthiness, particularly in safety-critical applications. The integrity of the position data provided by GNSS is a top priority, ensuring that the risk of significant position errors is minimized.

Authentication of GNSS data is another essential requirement, allowing users to confirm the authenticity of the information received. Services like Galileo's OS-NMA provide the capability for GNSS receivers to verify the source and integrity of the navigation data, enhancing the overall trust in the GNSS solutions.

High accuracy solutions are also a significant demand in the IWW sector. The HAS of Galileo, for instance, offers free-of-charge, high-accuracy PPP corrections globally, which is particularly beneficial for IWW navigation where precision is critical for avoiding collisions and ensuring smooth vessel operations.

The table below shows the identified requirements for GNSS in IWW at the UCP 2022:

Table 5-13 Identified requirements for GNSS in IWW at the UCP 2022

Category 1++			
General navigation (SOLAS); Inland waterways falls under Category 1++. Category 1++ differs from 1+ in that the horizontal accuracy is 3m.			
ID	Description	Type	Source
EUSPA-GN-UR-MAR-0101	The PNT solution shall provide 3m horizontal positioning accuracy (95%)	Performance (Accuracy Horizontal)	MARUSE + UCP 2017
Category 2			
Casualty analysis in Port approach, restricted waters and inland waterways falls under Category 2, which is characterized by having 1 m horizontal accuracy requirement			
ID	Description	Type	Source

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EUSPA-GN-URMAR-0120	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability % per 30 days)	Resolution IMO A.915(22) - 29/11/2001[RD3]
EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) - 29/11/2001 Regulation (EC) No415/2007
EUSPA-GN-UR-MAR-0140	The vertical positioning accuracy is not applicable for Category 2 applications	Performance (Accuracy Vertical 95 %)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0170	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001 (not mandatory for the applications in IMO resolution A.1046 [RD6])
EUSPA-GN-UR-MAR-0180	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity –Integrity risk per 3 hours)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0190	The PNT solution shall have regional coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0200	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval in seconds)	Resolution IMO A.915(22) - 29/11/2001
Category 2+++			
Bridges operations in inland waterways falls under Category 2+++. This category presents the same requirements as of those in category 2, except for the horizontal accuracy, which varies from 1 to 2m, the vertical accuracy must be of 0.1m, and the alert limit, which needs to be between 2.5 and 5m in the horizontal axis.			
ID	Description	Type	Source
EUSPA-GN-UR-MAR-0184	The PNT solution shall have an integrity risk smaller than 10-5 per 2 minutes (LAESSI bridge warning)	Performance (Integrity – Time to Alarm)	[RD44]"A critical look at the IMO requirements for GNSS[RD44]"within the scope of MarNIS FP6 project
EUSPA-GN-UR-MAR-025	The PNT solution shall provide 1 to 2 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001 [RD3]
EUSPA-GN-UR-MAR-0260	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001

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USPA-GN-UR-MAR-0270	The PNT solution shall provide a 2.5 to 6m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001 Regulation (EC) No 415/2007 [RD30]
Category 3			
Bridge collision warning systems, automatic guidance, mooring assistance**,** and conning systems in Inland Waterways falls under Category 3. This category is characterised by having 0.1m horizontal accuracy requirement.			
ID	Description	Type	Source
EUSPA-GN-UR-MAR-0280	The PNT solution shall have a 99.8% availability over any 30-day period	Performance (Availability, % per 30 days)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR)-MAR-029	The PNT solution shall provide 0.1 m horizontal positioning accuracy	Performance (Accuracy Horizontal, 95%)	Resolution IMO A.915(22) - 29/11/2001
USPA-GN-UR-MAR-0300	The PNT solution shall provide 0.1 m vertical positioning accuracy	Performance (Accuracy Vertical, 95%)	Resolution IMO A.915(22) - 29/11/2001
USPA-GN-UR-MAR-0310	The service continuity (% over 3 hours) is not applicable to Category 3 applications	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001
USPA-GN-UR-MAR-0320	The PNT solution shall provide a 0.25 m horizontal alert limit	Performance (Integrity - Alert limit)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0330	The PNT solution shall have a time to alarm smaller than 10s	Performance (Integrity – Time to Alarm)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0332	The PNT solution shall have a time to alarm smaller than 6s (LAESSI IWW applications)	Performance (Integrity – Time to Alarm)	RD44"A critical look at the IMO requirements for GNSS"within the scope of MarNIS FP6 project
EUSPA-GN-UR-MAR-0340	The PNT solution shall have an integrity risk smaller than 10-5 per 3 hours	Performance (Integrity –Integrity risk, per 3 hours)	Resolution IMO A.915(22) - 29/11/2001
USPA-GN-UR-MAR-0343	The PNT solution shall have an integrity risk smaller than 10-5 per 10 minutes (LAESSI mooring assistance)	Performance (Integrity – Integrity risk, per 10 minutes)	RD44"A critical look at the IMO requirements for GNSS"within the scope of MarNIS FP6 project
USPA-GN-UR-MAR-0344	The PNT solution shall have an integrity risk smaller than 10-5 per 1 hour (LAESSI conning display)	Performance (Integrity – Integrity risk, per 1 hour)	RD44"A critical look at the IMO requirements for GNSS"within the scope of MarNIS FP6 project
SPA-GN-UR-MAR-0350	The PNT solution shall have local coverage	Performance (Coverage)	Resolution IMO A.915(22) - 29/11/2001

EUSPA-GN-UR-MAR-0360	The PNT solution shall provide independent position fixes at least once per second	Performance (Fix interval, in seconds)	Resolution IMO A.915(22) - 29/11/2001

6. IDENTIFICATION OF THE USER NEEDS FOR AUTOMATED OPERATIONS IN IWW

For the identification of the user needs, we analyse the selected navigation operations from the deliverable D1.2 Section 7.2 that are the following:

- ECDIS Navigation, Information Modus
- ECDIS Navigation, Navigation Modus
- Track Guidance Assistants in Inland Navigation
- Remote shipping
- General navigation on free-flowing rivers
- Navigation on small narrow channels
- Congestion controlled rivers and canals
- Bridge passing

From those navigation operations, as starting point, an assessment of the qualitative parameters identified in deliverable D1.1 is performed. This assessment has the objective to find if some of these operations could have similar user needs. This idea arises from seeing how several operations have similar qualitative parameters. If several operations have similar qualitative parameters, this means that they might have similar requirements. This could result in having to identify the same needs and requirements for several operations. This would lead to repeated information that would complicate the tracking and understanding of the document. Therefore, it was concluded that if various operations could be grouped into groups of requirements, it could simplify the understanding of the analysis, leaving requirements easier to understand and having a better overall perspective of the requirements and needs. The following table, which information is extracted from D1.1 document, shows all the parameters identified for the selected operations.

Table 6-1 Qualitative parameters of the selected operations

	ECDIS Navigation, Information Modus	ECDIS Navigation, Navigation Modus	Track Guidance Assistants in Inland Navigation	Remote shipping	General navigation on free-flowing rivers	Navigation on small narrow channels	Congestion controlled rivers and canals	Bridge passing
Horizontal Accuracy	A	B-C	B-C	B-C	B-C	C	B-C	D
Vertical Accuracy	-	-	-	-	-	-	-	D
Integrity	-	H	H	H	H	H	H	H
Availability	M	H	H	H	H	H	H	H
Continuity	M	H	H	H	M	H	H	H
Coverage	G	G	G	G	G	G	G	G-R
Fix Interval	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec
Protection Level	A	B-C	B-C	B-C	B-C	C	B-C	D
Time to Alert	L	M	M	M	M	M	M	H
Lat/Long	X	X	X	X	X	X	X	X
Height				X				X

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SOG		X	X	X	X	X	X	X
COG		X	X	X	X	X	X	X
HDT		X	X	X	X	X	X	X
ROT		X	X	X	X	X	X	X
DBT,DPT					X	X	X	
dist. to ship					X	X	X	
CPA					X	X	X	
Environmental conditions/ seasons	L	M	M	H	M	M	H	H
Maneuvering	L	M	M	H	M	H	H	H
Automation	0	0	1-2	2	1-2	1-2	1-2	1
Security need	L	H	H	H	H	H	H	M
Criticality	L	M	M	M	M	M	M	H
GNSS receiver	X	X	X	X	X	X	X	X
AIS mobile			X		X	X	X	X
Radar		X	X	X	X	X	X	X
I-ECDIS nav mod	X	X	X	X	X	X	X	
Heading sensor		X	X	X	X	X	X	X
TGAIN			X		X	X	X	
ROT sensor		X		X	X	X	X	X
Processor	X	X						X
Extra display		X			X			X
Extra comm.				X				
Echo sounder					X	X	X	
Standardized	Y	Y	N	N	N	N	N	N
Current feasibility of EGNSS use	H	H	M	M	M	M	M	L
Current feasibility of Copernicus use	L	L	L	M	L	L	L	L

Note: *Details of the meaning of the letters are included in document D1.1 from which the information in this table is taken.*

After reviewing the table, we can identify that from the selected operations we can found three main groups of needs. Those groups are the following:

- Group 1. General Navigation needs: This group is characterized by having a general navigation needs that can be considered as a basis for any navigation operation. This group is formed by the following IWW operations:
  - ECDIS Navigation, Information Modus
  - ECDIS Navigation, Navigation Modus
  - Track Guidance Assistants in Inland Navigation
  - Remote shipping
- Group 2. Need of having additional information of the vessel surroundings: This group is characterized by having a special need of having more information of what is happening near the vessel. This group of operations includes as navigation parameters DBT,DPT, dist. to ship and CPA. Also is identified the use of an echo sounder to have this type of information. This group is formed by the following operations:
  - General navigation on free-flowing rivers
  - Navigation on small narrow channels
  - Congestion controlled rivers and canals
- Group 3. High accuracy and integrity needs in horizontal and vertical positions: This group is characterized by having a special need in terms of accuracy for the horizontal or vertical component. This need of higher accuracy is also related with a higher criticality for the operation. This group is formed by the following operation:
  - Bridge passing

Since the user needs to be assessed in this section are focused on automated operations, a special attention is derived to the automated level. In the case of the first qualitative analysis performed in D1.1, an identification of the current achievable level of automation is described. Then, throughout the project execution, a consultation campaign has been performed (outcomes included in D7.4) in which it is consulted the automated level expected for the operations in a near future. This feedback is of a high relevance since it indicates the level in which to assess the user needs for the automated operations in a near future.

From the analysis of the interviews, we can see that there is a certain variability in the responses depending on the geographic area of the interviewee. This suggests that expectations may vary depending on the characteristics of the different waterways. Respondents related to canals that present more challenges to navigate show a lower expectation than those related to more easily navigable canals. For example, in the Romanian area the bridges are higher, and ships pass under them with a greater clearance. Therefore, from their point of view, they can expect more autonomous navigation in that operation compared to other interviewees in countries, like the Netherlands for example, where the bridges are lower and there is little clearance between the ship and the bridge.

With all this, analysing the average response we can see that for most of the operations to be analysed the expected autonomous level would be level 3. This level is higher than the levels currently available on the market, which range from level 0 to level 2. Therefore, it is a message that stakeholders expect innovation in terms of the autonomous level. This expectation would also fit with the level of achievable technological development that is foreseen to be reasonable.

Therefore, for the analysis of user needs and requirements, it has been decided to focus on level 3, as it is assessed as the next reasonably achievable level in a near future.

Taking therefore into account that it is decided to analyse all operations with an autonomous level 3, it is interesting to relate the different operations, and therefore requirement groups with the IMO Circ.1575 Grades. This relationship can help to make better use of state-of-the-art information. In addition, having traceability between need groups and other classifications such as those used in IMO helps to better understand between different institutions and thus facilitate standardization activities. Table 6-2 shows the relationship between the defined requirement groups and the IMO grades introduced in Section 5.1.1.

Table 6-2 Relationship between user needs groups and IMO Circ.1575 Grades

User needs group	IWW Operations	IMO Circ.1575 Grades
Group 1	ECDIS Navigation, Information Modus	I
	ECDIS Navigation, Navigation Modus	II
	Track Guidance Assistants in Inland Navigation	II
	Remote shipping	III
Group 2	General navigation on free-flowing rivers	III
	Navigation on small narrow channels	III
	Congestion controlled rivers and canals	III
Group 3	Bridge passing	III - IV

Once the groups are identified, the next step is to analyze different specific user needs and how they may apply depending on the group of user needs.

Table 6-3 User needs identification

User needs group	need	justification	IWW stakeholders	Potential contribution from EU data services to requirements
Group 1	own vessel position, course, speed, RoT and heading parameters	basic need for navigation	boat master + monitoring authority	Horizontal Position accuracy Vertical position accuracy Speed accuracy Course accuracy
	info about other vessels	needed for situational awareness	boat master	N/A
	dynamic real time ENC	needed as a quality enhancement over the static ENCs	boat master	River edge River Depth/Bathymetry Data/alerts from: CMEMS, CLMS, C3S, CEMS
	fairway info parameters (NtS, berth occupancy, lock&bridge operating times...)	needed for practical skipper operations during navigation	boat master	N/A
	safe fairway indication parameters	needed to position own vessel correctly in the waterway	boat master	River Edge Object detection
	route planning parameters	needed for planning optimal route to destination (e.g. weather forecast, IWW nautical charts, water levels, lock operating times, notices to skippers, other traffic & own vessel parameters such as cargo load, max. height, max. keel depth, max. width & average speed)	boat master + shipping company	River Edge River Depth/Bathymetry Water speed Data/alerts from: CMEMS, CLMS, C3S, CEMS

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	path generation parameters	needed to calculate optimal tracks to follow (for TGAIN operation)	boat master	N/A
	steering code parameters (e.g. XTE)	needed to optimally follow the ideal path (during TGAIN operation)	boat master	N/A
	engine (propulsion) code parameters	needed to optimally control the progression along a path	boat master + shipping company	N/A
	extra remote control parameters	needed to allow remote controlled vessels (e.g. cameras)	remote boat master + ROC	N/A
	to be able to provide a confidence level in the solution	good integrity monitoring leads to safe sailing	boat master	Integrity
	to be resilient to external factors that degrade the navigation performance	resilience leads to safe sailing	boat master	Robustness
	to provide a solution during the whole operation	continued availability is needed for safe sailing along the complete trip	boat master	Continuity
	to provide alerts within a specific time and react accordingly	a good warning/alarm-HMI prevents unwanted (autonomous) vessel behaviour and leads to safer sailing	boat master	Integrity
	To Authenticate positioning data to be able to have spoofing alarms	Some functionality is needed to authenticate that position data is correct to prevent an autonomous ship from making decisions based on false position information.	Boat master	Authentication
Group 2*	vertical info under water	needed for safe sailing with correct under keel clearance	boat master	River Depth/Bathymetry Data/alerts from: CMEMS, CLMS
	water current parameters	needed to correctly anticipate upcoming turns in the waterway, especially during the use of TGAIN	boat master	Water speed Data/alerts from: CMEMS, CLMS
	distance & CPA info to other targets	needed for even more precise situational awareness	boat master	N/A
Group 3*	vertical info above water	needed for safe passage underneath bridges	boat master	Vertical position
	high accuracy horizontal info	needed for safe passage through bridge openings	boat master	Horizontal Position accuracy

* Includes the needs from Group 1.

7. IDENTIFICATION OF USER REQUIREMENTS TOWARDS FUTURE NAVIGATION OPERATIONS

This section describes the user requirements for the EU services (EGNSS and Copernicus). These requirements are derived from the needs identified in the previous section. It should be noted that the values provided in this section are the result of research into the available references together with a technical and rational analysis of the references. Therefore, the values provided are considered as the best starting point for establishing autonomous navigation requirements, but it is identified that there is a need for projects that specifically validates the requirements in order to make a finer adjustment in terms of the standardization of these requirements. In the context of AVIS, part of this validation could be considered as part of the implementation of the pilots.

7.1. USER REQUIREMENTS FOR GNSS SERVICES

Requirements of PNT data for GNSS services of ship navigation operation are determined according to section No.5 and No.6. Parameters of requirements are analysed by the navigation operation groups defined in section No.6, and by the actual (identified automated level in D1.1) and foreseen (from interviews) CCNR automation level.

The user requirements of PNT data for GNSS services can be approached from several perspectives:

- Accuracy of PNT data: absolute precision of data
- Temporal quality of PNT data: service availability and continuity, data update frequency
- Data integrity: reliability, latency and data integrity monitoring (time to alert, integrity risk)
- Multi-constellation support: interoperability (utilize more GNSS constellations) and multiple frequency bands (to enhance performance in challenging environments)
- Integration with onboard systems: easy integration of GNSS data with on board navigation systems, and the ability to fuse data with other sensor data.

The last two perspectives are related more to GNSS device manufacturers than to GNSS services.

Data integrity can be characterized by several parameters, like data integrity risk, alert limit, and time to alarm. This document identifies user requirements for PNT data integrity with the integrity level, according to MSC.1-Circ.1575. The assessment performed on the IMO MSC.1-Circ.1575 showed that in some cases, the approach of qualifying the integrity may be not enough for the future evolution of the autonomous levels. The integrity levels defined might not reflect a correct increase in the integrity needs through the different autonomous level.

Currently, for the non-autonomous navigation a high level of integrity is needed. However, in the analysis it is identified that potentially a higher level of autonomy requires a higher level of integrity. Hence, with the current definition of integrity levels it is not find room to express a potential increase in the integrity needs, since the starting point is already the maximum integrity level available.

User requirements for temporal quality of PNT data are similar for each requirement parameter for GNSS services, regarding to continuity and availability. However, there are differences in the update frequency between the requirements of individual PNT data. These differences will be detailed in the following sub sections of PNT data. The "GUIDELINE FOR SHIPBORNE POSITION, NAVIGATION AND TIMING (PNT) DATA PROCESSING" is used as the basis for evaluating these requirements.

Table 7-1 GNSS requirements - Continuity

Continuity % over 3 hours [%]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	99.97%	99.97%
	Group 2	99.97%	99.97%
	Group 3	99.97%	99.97%

Table 7-2 GNSS requirements - Availability

Availability % per 30 days [%]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	99.8%	99.8%
	Group 2	99.8%	99.8%
	Group 3	99.8%	99.8%

In terms of PNT data accuracy, user requirements are different even in automation level and identified navigation operation groups.

The performance requirements of the following parameters are detailed in the document:

- Horizontal position (Lat/Long)
- Vertical position (Height)
- Speed over ground (SOG)
- Course over ground (COG)
- Heading (HDT)
- Rate of turn (ROT)

The following parameters are identified previously in Section 6, but since they are mathematical computations using the data they receive, do not add any new information for GNSS services requirements. Therefore, for the next parameters there are not defined specific requirements and would apply the general requirements of the previous parameters:

- Closest point of approach (CPA)
- Distance to ship

The following subsections show the user requirements for GNSS services that have been derived for the aforementioned parameters.

7.1.1.HORIZONTAL POSITION (LATITUDE, LONGITUDE)

Table 7-3 GNSS requirements – Horizontal Position | Accuracy

Accuracy [m]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	10 m	5 m
	Group 2	5 – 10 m	1 m
	Group 3	1-3 m	0.1 m

Table 7-4 GNSS requirements – Horizontal Position | Integrity Risk

Integrity Risk (per 3 hours) [-]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	10^{-5}	$7{,}2x10^{-6}$
	Group 2	10^{-5}	$7{,}2x10^{-6}$
	Group 3	10^{-5}	$7{,}2x10^{-6}$

Table 7-5 GNSS requirements – Horizontal Position | Time to Alarm

Time to Alert [s]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	10 s	6 s
	Group 2	10 s	6 s
	Group 3	10 s	6 s

Table 7-6 GNSS requirements – Horizontal Position | Alert Limit

Alert Limit [m]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	25 m	12.5 m
	Group 2	12.5 m – 25 m	2.5 m
	Group 3	2.5 m – 7.5 m	0.25 m

Table 7-7 GNSS requirements – Horizontal Position | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	1 Hz	1-2 Hz
	Group 2	1 Hz	1-5 Hz
	Group 3	1 Hz	10 Hz

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Table 7-8 GNSS requirements – Horizontal Position | TBA

Time Between Authentications (TBA) [s]		At identified automated level in D1.1. ALO - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	10 s	6 s
	Group 2	10 s	6 s
	Group 3	10 s	6 s

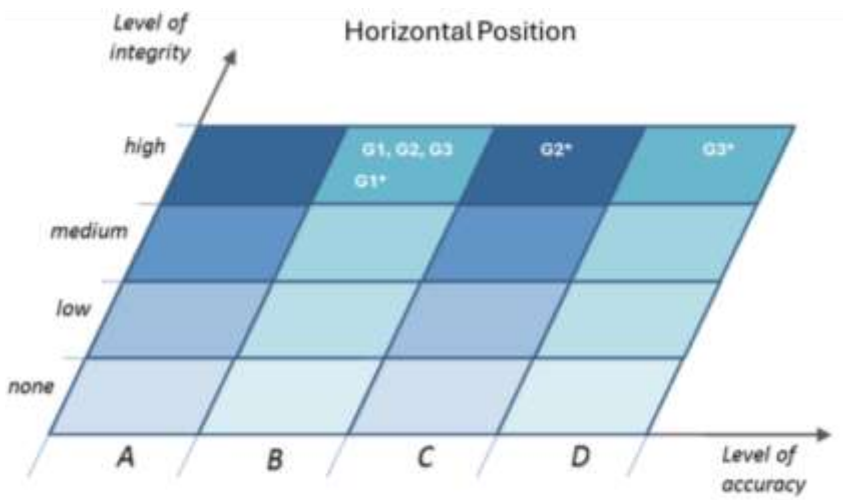

Figure 7-1 IMO Circ.1575 performance level for Horizontal Position requirements

Note: G1, G2, G3 refer respectively to Group 1, Group 2 and Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

7.1.2. VERTICAL POSITION (HEIGHT)

Table 7-9 GNSS requirements – Vertical Position | Accuracy

Accuracy [m]		At identified automated level in D1.1. ALO - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	N/A
	Group 2	N/A	N/A
	Group 3	0.1m	0.1m

Table 7-10 GNSS requirements – Vertical Position | Integrity Risk

Integrity Risk (per 3 hours) [-]	At identified automated level in D1.1. ALO - AL2	At automated level foreseen AL3

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Navigation operation group	Group 1	N/A	N/A
	Group 2	N/A	N/A
	Group 3	10^{-5}	$7{,}2 \times 10^{-6}$

Table 7-11 GNSS requirements – Vertical Position | Time to Alarm

Time to Alarm [s]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	N/A
	Group 2	N/A	N/A
	Group 3	10 s	6 s

Table 7-12 GNSS requirements – Vertical Position | Alert Limit

Alert Limit [m]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	N/A
	Group 2	N/A	N/A
	Group 3	0.25 m	0.25 m

Table 7-13 GNSS requirements – Vertical Position | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	N/A
	Group 2	N/A	N/A
	Group 3	1 Hz	10Hz

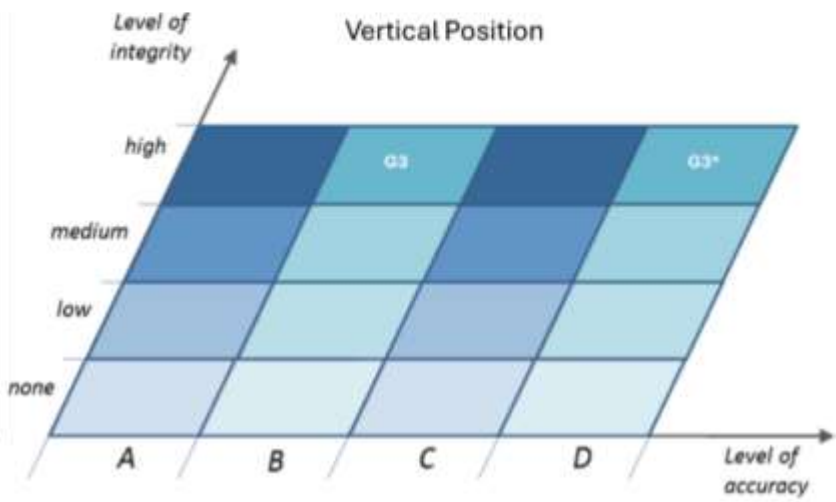

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Figure 7-2 IMO Circ.1575 performance level for Vertical Position requirements

Note: G3 refer to Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

Note that that in general Group 1 does not require any accuracy requirement in the vertical position. However, Group 1 includes remote control operations which would require precision in the vertical position. For this particular operation, the vertical precision requirements are considered to be the same as those described for Group 3.

7.1.3.SPEED OVER GROUND (SOG)

Table 7-14 GNSS requirements – SOG | Accuracy

Accuracy [km/h]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	2% of actual speed	1% of actual speed
	Group 2	1 km/h	0.2 km/h
	Group 3	0.5 km/h	0.2 km/h

Table 7-15 GNSS requirements – SOG | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	1 Hz	1-2 Hz
	Group 2	1 Hz	1-5 Hz
	Group 3	1 Hz	10 Hz

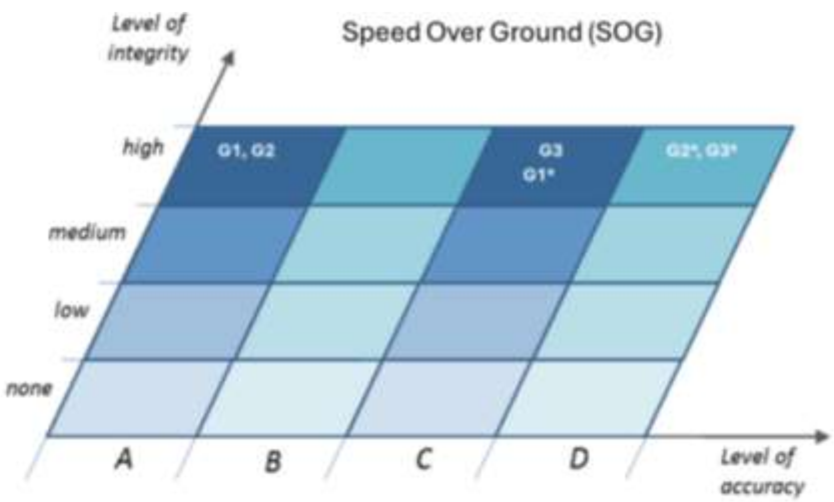

Figure 7-3 IMO Circ.1575 performance level for SOG requirements

Note: G1, G2, G3 refer respectively to Group 1, Group 2 and Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

7.1.4.COURSE OVER GROUND (COG)

Table 7-16 GNSS requirements – COG | Accuracy

Accuracy [deg]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	2°	0.3°
	Group 2	1°	0.17°
	Group 3	1°	0.07°

Table 7-17 GNSS requirements – COG | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	1 Hz	1-2 Hz
	Group 2	1 Hz	1-5 Hz
	Group 3	1 Hz	10 Hz

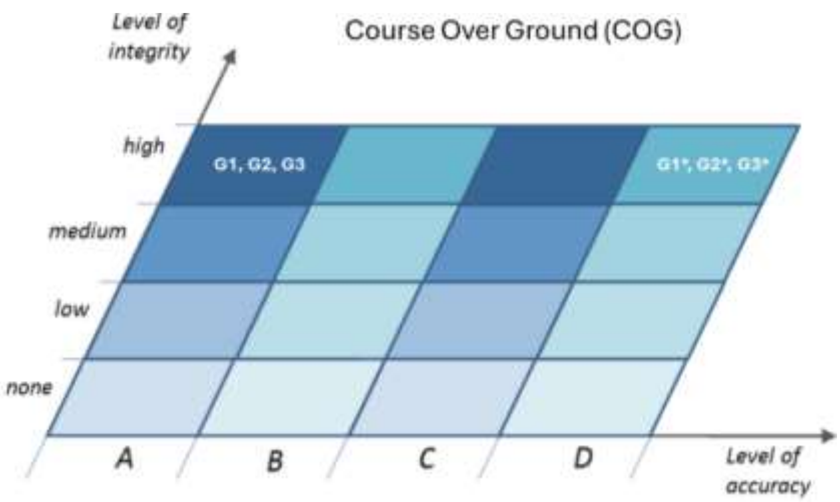

Figure 7-4 IMO Circ.1575 performance level for COG requirements

Note: G1, G2, G3 refer respectively to Group 1, Group 2 and Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

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7.1.5.HEADING (HDT)

In inland navigation, it is common to use a GNSS receiver with two antennas as a source for obtaining heading. This is because it is a more affordable solution than using other sensors that offer adequate accuracy. These requirements are therefore also covered as requirements for GNSS services.

Table 7-18 GNSS requirements – Heading | Accuracy

Accuracy [deg]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	2°	0.3°
	Group 2	1°	0.17°
	Group 3	1°	0.07°

Table 7-19 GNSS requirements – Heading | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	1 Hz	1-2 Hz
	Group 2	1 Hz	1-5 Hz
	Group 3	1 Hz	10 Hz

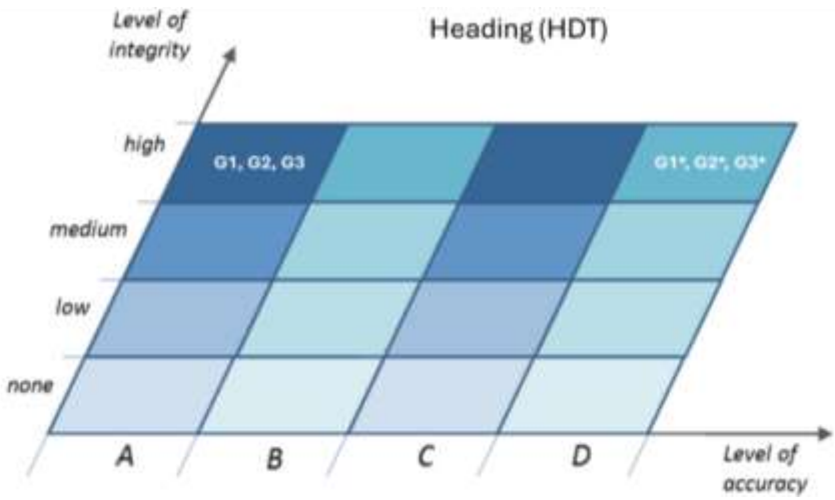

Figure 7-5 IMO Circ.1575 performance level for Heading requirements

Note: G1, G2, G3 refer respectively to Group 1, Group 2 and Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

7.1.6.RATE OF TURN (ROT)

In inland navigation, it is common to use a GNSS receiver with two antennas as a source for obtaining rate of turn. This is because it is a more affordable solution than using other sensors that offer adequate accuracy. These requirements are therefore also covered as requirements for GNSS services.

Table 7-20 GNSS requirements – ROT | Accuracy

Accuracy [deg/s]		At identified automated level in D1.1. ALO - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	greater of 1 °/min or 5% indicated	1 °/min
	Group 2	greater of 1 °/min or 5% indicated	0.5°/min
	Group 3	greater of 1 °/min or 5% indicated	0.3°/min

Table 7-21 GNSS requirements – ROT | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. ALO - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	2 Hz	2 Hz
	Group 2	2 Hz	2-10 Hz
	Group 3	2 Hz	10 Hz

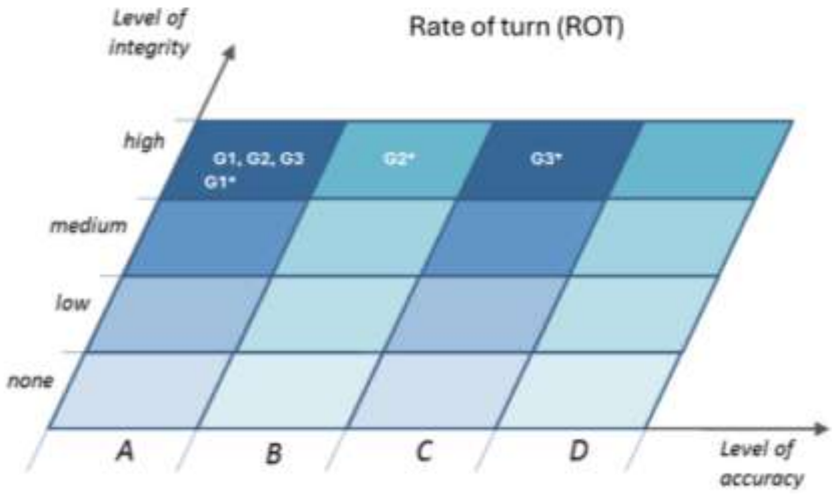

Figure 7-6 IMO Circ.1575 performance level for ROT requirements

Note: G1, G2, G3 refer respectively to Group 1, Group 2 and Group 3. The asterisk "*" is used to indicate the user need group for CCNR Automation level 3.

7.2. USER REQUIREMENTS FOR EARTH OBSERVATION SERVICES

This analysis is approached from two different perspectives taking into account the Copernicus services described through the deliverable D1.2. On the one hand, requirements for different Copernicus services in order to update nautical charts are proposed. On the other hand, there are requirements in cases where Copernicus can be used to provide alerts.

Considerations on the possibility to update the Nautical charts

In order to update nautical charts, it is necessary to obtain images with high resolution and accuracy. Although this is further developed in D2.2, the current Copernicus technology appears to be insufficient to provide information for updating nautical charts that can be used directly for Inland navigation. Therefore, we would like to emphasize that the requirements of Earth Observation related to the updating of the nautical charts are provided considering a future evolution of the Earth Observation capabilities in which improved performance is provided.

The Earth Observation requirements for updating the nautical charts can be defined by the following parameters:

- **Temporal resolution**: The temporal resolution of a satellite in orbit is the revisit time of the satellite to a particular location.
  - Sentinel-2: Each Sentinel-2 satellite has a revisit time of 10 days, but with the two satellites in the constellation, the combined revisit time is 5 days[2]. Sentinel-2 satellites are optical in nature and presence of cloud may increase the effective revisit time.
  - Sentinel-1A: This satellite has a revisit time of 12 days globally, but over Europe, it can be as frequent as 6 days. This satellite can operate effectively in cloudy condition.
  - When used together, the combined revisit time can be less than 5 days, depending on the specific location and the overlap of their observation schedules.

- **Service error**: It is the magnitude that represents a comparison between the final value obtained from an earth observation product and the value considered as real. Depending on the service used, it can be for discrete values, metrics as precision or recall, or for continuous values, metrics as MAE or RSME.

Looking at the characteristics offered by Earth observation's services, it can be seen that they mainly meet the needs of Group 1 needs. As a general rule, it is observed that the extra needs of Groups 2 and 3 might not be directly satisfied by Earth Observation services. The only services that potentially could provide additional information for Group 2 are river depth/bathymetry and water speed. In this case we can see that Copernicus can help and therefore there may be a difference in the requirements for these services. For this reason, the requirements are focused on requirement Group 1, since for the other requirement groups the requirements are the same and do not change. The only probable exception is in the River depth/bathymetry and water speed services, which are specifically analyzed for Group 2 as well.

It should be noted that the services described in deliverable D1.2 such as Copernicus Platform will offer data that might be used at the time of the technical implementation to derive proposed ad-hoc services. In other cases, for example, they could be used as final services. It must be considered that all this may vary at the time of technical definition of the services.

Considerations on the possibility of providing alerts

For alerts, we plan to take advantage, in short term, of one of the interesting features of Copernicus, which is to have access to historical data. By doing a data analysis, apart from being able to extract information from a particular image, it can also have added value to compare river conditions with historical river conditions. In that sense, each of the ad-hoc services proposed in Copernicus would not only give a snapshot type value but could also provide an alert if there has been a noticeable change with respect to the historical data.

To process alerts based on historical data, it is necessary to define a parameter setting the frequency at which they can be updated. We call this parameter "deviation from historical data alert update frequency". It should be noted that this parameter is closely related to the time resolution, since it will never be possible to update this alert at a frequency higher than the time frequency of the ad-hoc service. However, in some cases this alert frequency may be looser than the temporal resolution.

[2] User Guides - Sentinel-2 MSI - Resolutions - Sentinel Online - Sentinel Online (esa.int)

- **Deviation from historical data alert update frequency**: Frequency at which alerts for deviation from historical data can be updated.

Similarly, associated with this frequency would be the requirement to provide an alert if there is a significant deviation of the measurements offered by a Copernicus service from its historical average. In this sense, the first proposal of the AVIS project is that it should be just a traffic light type alert (red light or green light). So that there is an alert or not for each of the services. Therefore, there is another parameter that is the service alert threshold, that actually defines when there is an anomalous deviation. This value has to be assessed in detail for each particular navigation areas of each river. Therefore, it is considered out of the scope of the project to define specific thresholds, and specific analyses will have to be performed for each river considering its specific characteristics. However, for the pilot execution, there will be potentially defined possible thresholds for the zones where the pilots are executed.

To better understand the potential applications of Copernicus services, a use case is presented that could currently be considered to take advantage of Copernicus. Considering that today there is a greater potential in the part of generating Copernicus alerts, it is considered that it would be interesting to provide alerts when global anomalies are detected that may affect the river conditions.

One of the advantages of Copernicus is its global scale, at which information can be obtained. In this sense, it is possible to monitor effects, even at a scale beyond the river of interest, and identify anomalies that could affect the current conditions of a river. In order to implement something like this, combined use would be made of, among others, services such as river edge, river depth and object detection.

These types of events are more difficult to monitor and detect with local sensors, so there is a great advantage in using Copernicus services to alert on them.

As conclusion of AVIS assessment, it is identified that the Earth Observation features of updating nautical charts is long-term oriented while the feature of providing alerts could be potentially applied in short-term.

With all these considerations, the following services, included in the following subsections, are defined as the most potential, where satellite image information will be adopted as long as the data proposed by Copernicus Platform to build the solutions and on which it is interesting to establish requirements.

7.2.1. RIVER EDGE

River Edge is measured as the boarder of water surface in a river.

Table 7-22 Copernicus requirements – River edge | Group 1

Requirement		AL0-AL2	AL3
Update Nautical charts	Temporal resolution	1 week	3 days
	Service Error	10 cm	5 cm
Provide alerts	Deviation from historical data alert update frequency	1 week	3 days

7.2.2. RIVER DEPTH/BATHYMETRY

River depth is measured as underwater depth of a waterbody

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Table 7-23 Copernicus requirements – River depth/bathymetry | Group 1

Requirement		AL0-AL2	AL3
Update Nautical charts	Temporal resolution	1 week	3 days
	Service error	10 cm	5 cm
Provide alerts	Deviation from historical data alert update frequency	1 week	3 days

Table 7-24 Copernicus requirements – River depth/bathymetry | Group 2

Requirement		AL0-AL2	AL3
Update Nautical charts	Temporal resolution	3 days	2 days
	Service error	5 cm	5 cm
Provide alerts	Deviation from historical data alert update frequency	3 days	2 days

7.2.3. WATER SPEED

Water speed is measured as speed of surface water in the river

Table 7-25 Copernicus requirements – Water speed | Group 1

Requirement		AL0-AL2	AL3
Update Nautical charts / Broadcast navigation information	Temporal resolution	1 week	3 days
	Service error	2 km/h	1 km/h
Provide alerts	Deviation from historical data alert update frequency	1 week	3 days

7.2.4. OBJECT DETECTION

Here object detection is used as a general umbrella for detection of foreign objects like boats, ships and floating ice.

Table 7-26 Copernicus requirements – Object detection | Group 1

Requirement		AL0-AL2	AL3
Update Nautical charts	Temporal resolution	3 days	3 days
	Service error	2 m	2 m
Provide alerts	Deviation from historical data alert update frequency	3 days	3 days

7.2.5. FLOODS FORECASTING (EFAS/GLOFAS)

We would like to highlight this service because, although it is not a previously defined ad-hoc service, it is a Copernicus service that fits the characteristics of providing alerts. In this case, it is a flood forecast service.

Currently, this service is provided near-real time, with a delay of 6 days. The real-time data is only available to EFAS partners.

Table 7-27 Copernicus requirements – Floods forecasting | Group 1

Requirement		AL0-AL2	AL3
Provide alerts	forcasting time	15 days	15 days

8. UPDATE RECOMMENDATIONS FOR EUSPA REPORT

The contractor shall update the requirements for the operations of interest presently in the EUSPA report on user needs and requirements and add new requirements where applicable.

The following requirements for Port approach and restricted waters are to be reviewed in the upcoming UCP process and report:

Table 8-1 UCP requirements to be reviewed

ID	Description	Type	Source
EUSPA-GN-UR-MAR-0130	The PNT solution shall provide 1m horizontal positioning accuracy	Performance (Accuracy Horizontal 95 %)	Resolution IMO A.915(22) - 29/11/2001 Regulation (EC) No415/2007
EUSPA-GN-UR-MAR-0150	The service continuity (% over 3 Hours) is not applicable to Category 2 applications.	Performance (Continuity - % over 3 hours)	Resolution IMO A.915(22) - 29/11/2001
EUSPA-GN-UR-MAR-0160	The PNT solution shall provide a 2.5m horizontal alert limit	Performance (Integrity – Alert limit)	Resolution IMO A.915(22) - 29/11/2001

They are to include the following requirements including their sources:

- IMO resolution A.915 indicates for Port approach and restricted waters a horizontal accuracy of 10 m.
- IMO resolution A.915 indicates for Port approach and restricted waters a continuity over 3 hours of 99.8%
- IMO resolution A.915 indicates for Port approach and restricted waters an alert limit of 25m

In addition, it should be noted that bridges operations as an operational scenario are not mentioned in the IMO resolution and minimum requirements, but are influenced by the following frameworks:

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

- The ISM Code requires that shipboard operations, including navigation, are planned and executed safely. GNSS data is essential for developing these plans, particularly for pollution prevention and safety during bridge transits.

- MSC.1-Circ.1638 (Maritime Autonomous Surface Ships - MASS):
  - This document discusses the implications of autonomous ships on current regulations. For MASS, GNSS would be even more critical as it would provide the necessary positioning and timing information for remote control centers and autonomous decision-making systems.
- COLREG 1972 (International Regulations for Preventing Collisions at Sea):
  - While not directly related to GNSS, COLREGs are essential for navigation safety, and GNSS data helps in complying with these regulations, especially when visibility is poor or when navigating close to bridges.

The frameworks above do not explicitly set out minimum requirements and performance levels. The current requirements for Bridges operations stem from the previous iterations and presentations made during the UCP events(Presentation from WSV via: 14._michael_hoppe_euspa_space_week_3dpositioning.pdf (europa.eu); MoM 2020 UCP event via UCP "Maket Segment" Panel Minutes (europa.eu); MoM 2022 UCP event via: euspa-mkd-um-mom-a21628_0.2_ucp2022-maritime_inland_waterways_fisheries_and_aquaculture_session_mom.pdf (europa.eu)).

Our proposition is to further reinforce the framework set out in the UCP by integrating the above regulatory frameworks in the description of requirements for bridge operations.

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9. ANNEX I: OTHER REQUIREMENTS

Throughout the development of the document, some requirements necessary for maritime navigation are identified that, however, cannot be required from EU services. Therefore, this annex includes those requirements that are not applicable to either GNSS or Earth Observation services.

9.1.1. DEPTH (DPT,DBT)

Table 9-1 Other requirements – Depth | Accuracy

Accuracy [m]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	0.15 - 0.2 m
	Group 2	0.15 - 0.25 m	0.05m
	Group 3	N/A	0.15 - 0.2 m

Table 9-2 Other requirements – Depth | Update frequency

Update frequency [Hz]		At identified automated level in D1.1. AL0 - AL2	At automated level foreseen AL3
Navigation operation group	Group 1	N/A	1 Hz
	Group 2	1 Hz	2-5 Hz
	Group 3	N/A	2-5 Hz

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