Input paper: ENG20-3.1.2.1

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM **X** ENG **□** PAP **□** Input

**□** DTEC **□** VTS **□** Information

Agenda item [[1]](#footnote-2) 3.1

Technical Domain / Task Number 2 …………………………………

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GNSS & EO requirements for Automated inland waterways navigation

# Summary

The paper shows the requirements for GNSS and Earth Observation services that have been obtained in the AVIS project. The process that was carried out to identify the different navigation operations in inland waterways is shown. This led to the definition of several groups of operations according to the needs of these operations. The requirements vary according to the operation group and automation level. The process to obtain the requirements involves a review of the state of the art, both in terms of current regulations and projects, and a technical analysis carried out by the project consortium.

## Purpose of the document

The objective of this paper is to make IALA ENG Committee members aware of the progress of the AVIS project in identifying GNSS and Earth Observation requirements for autonomous navigation on Inland Waterways.

# Background

The information provided in this paper comes from the results obtained in the AVIS project (<https://www.gmv.com/en-es/communication/press-room/press-releases/space/gmv-leads-avis-project-optimize-navigation-autonomous>). The Automated Vessels on European Inland Waterways (AVIS) project is fully funded by the European Union. The main objective of the project is to analyse how EU Space Data (EGNSS and Copernicus Earth Observation) can be used for Automated Vessels on European IWW. In order to do this analysis, a safety prototype will be defined, designed and implemented, and will be used in pilots´ demonstrations in different EU IWW important corridors.

AVIS is formed by a consortium led by GMV, which has a wide experience in GNSS and Earth Observation systems. Together with GMV, a group made up of some of the most important experts in the inland waterways sector are working in coordination to carry out the best possible study. This experience is brought to the consortium by national inland authorities and private companies such as WSV, TRESCO, BM, HAC, RSOE and EY.

# Introduction

Inland waterway transport has long been an integral part of the global transport system and serves as an important mode of transport for goods, cargo and people. In recent years, technological advances have significantly transformed inland waterway transport and initiated a new phase in terms of efficiency, sustainability and safety.

Global Navigation Satellite Systems (GNSS) play an essential role in precisely determining a vessel's position on inland waterways. Furthermore, Earth Observation technologies are identified as potential solutions for providing alerts to the navigation and update the electronic nautical charts. Looking ahead, the integration of European Global Navigation Satellite System (EGNSS) and the Copernicus program offers additional layers of precision and reliability in navigation. These advancements not only contribute to the safety of inland waterway transport but also open doors to innovative solutions and increased efficiency in the maritime industry.

The AVIS project seeks how to use EU Space Data to contribute to autonomous navigation in inland waterways. In this sense, it is essential to be able to make an analysis on the identification of requirements for EGNSS and Copernicus services for safe navigation. The process of defining requirements requires an in-depth study of the state of the art of inland waterways operations and current technology. Therefore, the process is based on reviewing the different inland operations, analysing their characteristics, reviewing the state of the art of other projects and regulations. With all this, the aim is to identify user needs that will lead to user requirements.

It is important to note that autonomous navigation requires a sensor fusion solution beyond just GNSS and Earth Observation technologies. However, AVIS project is mainly focused on EGNSS and Copernicus, so requirements for other sensors are not developed.

## Automated Navigation and Automation Levels.

Inland waterways navigation operations are varied and may have different requirements. Additionally, when considering performing these operations autonomously, the requirements may also vary. There are several levels that identify the degree of automation of the operation, i.e., they express whether the operation is performed with greater or lesser automation. There are several references or criteria to identify these different levels of automation. Specifically, for the AVIS project, we based ourselves on the levels established by the CCNR [1]. The definition of the levels can be seen in the following figure.

A blue and white list of information

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1. CCNR International definition of levels of automation [1]

In the case of AVIS, an analysis was made of the levels of automation currently in use and those expected to be achievable in the medium term. This analysis was carried out by putting together the knowledge provided by the experts that make up the consortium together with the outputs obtained from a round of expert consultations.

After the analysis it was established that the target Automation Level (AL) is AL 3, which would be one in which the vessel is capable of performing all the manoeuvres needed for navigation autonomously, but in which crew are still required to monitor and act in case of failure of any system.

AVIS decided to analyse all operations and requirements from two points of view, which are from a lower level of automation (AL0 - AL2) to a higher level of automation (AL3).

# Inland waterways Navigation operations assessment

The navigation operations of Inland waterways are varied. If analysed from a standardization point of view, there are 4 operations that can be identified. The different navigation operations for Inland AIS [2] are Navigation medium term ahead and Navigation short term ahead. On the other hand, the operations for Inland ECDIS [3] are Information Modus and Navigation Modus. The following table presents a brief description of these operations:

1. Existing Inland Waterways navigation operations

|  |  |
| --- | --- |
| **Navigation Operation** | **Brief description** |
| Navigation medium term ahead | Is the navigation phase in which the skipper observes and analyses the traffic situation looking some minutes up to an hour ahead and considers the possibilities of where to meet, pass or overhaul other vessels |
| Navigation short term ahead | Is the decision phase in the navigation process. In this phase traffic information has relevance for the process of navigation, including collision avoidance measures if necessary. |
| Information Modus | In the information mode, Inland ECDIS equipment acts as an electronic atlas and serves to guide and to provide information about the waterway. |
| Navigation Modus | Inland ECDIS in navigation mode is defined by the “use of the Inland ECDIS for conning the vessel for overlaid radar image”. Inland ECDIS in navigation mode must fulfil the requirements of ES-TRIN regarding the minimum requirements and the conditions for installation and is subject to type approval. |

In addition to these standardized operations, a set of different operations are identified which, although not standardized, are considered to be of common application in inland waterway navigation. All the operations identified are considered relevant for autonomous navigation, however, after analysis it is noted that GNSS and Earth Observation are not all able to add a great added value.

Therefore, the project decided to focus only on those where GNSS and Earth Observation can provide the highest impact.

From this, the operations selected are:

* 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

For all operations, a series of qualitative parameters are identified to characterize them. Thanks to this characterization work, it is possible to have a generic vision of possible needs for navigation. With this, it was concluded that several navigation operations share features and needs. It was therefore decided to define several groups of requirements, including operations that share common features. In this way, the analysis of the requirements is more understandable, since requirements are not posed for each specific operation, but for the whole group of operations that have the same needs.

Specifically, 3 Groups of needs were identified, which are defined as follows:

|  |
| --- |
| 1. **Group 1. General Navigation needs**: This group is characterized by having a general navigation need that can be considered as a basis for any navigation operation. That is to say, all those minimum necessities that are going to be needed simply for the fact of navigating Inland Waterways. The other groups add additional needs on top of the needs this group already has. This group is formed by the following IWW operations:    1. ECDIS Navigation, Information Modus    2. ECDIS Navigation, Navigation Modus    3. Track Guidance Assistants in Inland Navigation    4. Remote shipping 2. **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 Depth Below the Transducer (DBT), DPT (Depth NMEA code), dist. to ship and Closest Point of Approach (CPA). Also is identified the use of an echo sounder to have this type of information. This group is formed by the following operations:    1. General navigation on free-flowing rivers    2. Navigation on small narrow channels    3. Congestion controlled rivers and canals 3. **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:    1. Bridge passing |

This idea of grouping needs is similar to other approaches that have already been used in IMO guidelines. For example, IMO MSC.1/Circ.1575 [4] defines Application Grades of PNT-DP. Figure 2 shows the definition of these grades.

A screenshot of a computer

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1. IMO Application Grades of PNT-DP [4]

Therefore, 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 among different institutions and thus facilitate standardization activities. Table 2 shows the relationship between the defined requirement groups and the IMO grades

1. 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 |

# User needs identification

In order to derive the requirements, several steps are performed. One is to review the state of the art of current requirements for both autonomous and non-autonomous navigation. This step was carried out by reviewing the most relevant current regulations, as well as projects that have studied some aspect relevant to the requirements. During the process it was reviewed both IMO and IALA requirements as well as the current standards for Inland Waterways (IWW). The relevant projects considered were LAESSI, SciPPPer, DIWA, GSALOT3TRANS-SC10.

Along with this, an identification of needs that each group may have was carried out. The needs are considered at a higher level of abstraction than a requirement which is a step prior to the requirements. Therefore, a need identifies that aspect which is demanded without specifying the degree to which it is required. For example, a need may be to know the position of the vessel, while a requirement specifies that the position of the vessel must be known with a certain accuracy. The following table shows all the requirements identified for automated navigation in IWW.

1. User needs identification

|  |  |  |
| --- | --- | --- |
| **User needs group** | **need** | **justification** |
| Group 1 | own vessel position, course, speed, RoT and heading parameters | basic need for navigation |
| info about other vessels | needed for situational awareness |
| dynamic real time ENC | needed as a quality enhancement over the static ENCs |
| fairway info parameters (NtS, berth occupancy, lock&bridge operating times...) | needed for practical skipper operations during navigation |
| safe fairway indication parameters | needed to position own vessel correctly in the waterway |
| 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) |
| path generation parameters | needed to calculate optimal tracks to follow (for TGAIN operation) |
| steering code parameters (e.g. XTE) | needed to optimally follow the ideal path (during TGAIN operation) |
| engine (propulsion) code parameters | needed to optimally control the progression along a path |
| extra remote control parameters | needed to allow remote controlled vessels (e.g. cameras) |
| to be able to provide a confidence level in the solution | good integrity monitoring leads to safe sailing |
| to be resilient to external factors that degrade the navigation performance | resilience leads to safe sailing |
| to provide a solution during the whole operation | continued availability is needed for safe sailing along the complete trip |
| 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 |
| 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. |
| Group 2\* | vertical info under water | needed for safe sailing with correct under keel clearance |
| water current parameters | needed to correctly anticipate upcoming turns in the waterway, especially during the use of TGAIN |
| distance & CPA info to other targets | needed for even more precise situational awareness |
| Group 3\* | vertical info above water | needed for safe passage underneath bridges |
| high accuracy horizontal info | needed for safe passage through bridge openings |

\* Includes the needs from Group 1.

Note that the needs identified include a wide variety of aspects for automated navigation, however, from the AVIS project only those needs that can be satisfied, totally or partially, with the use of GNSS or Earth Observation are derived into requirements.

# User Requirements for automated Inland Waterways navigation

## User requirements for GNSS services

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

* Temporal quality of PNT data: service availability and continuity, data update frequency.
* Accuracy of PNT data: absolute precision of data.
* Data integrity: reliability, latency and data integrity monitoring (time to alert, integrity risk).

User requirements for temporal quality of PNT data are similar for each requirement parameter for GNSS services, regarding to continuity and availability. Therefore, the continuity and availability requirements have the same values for all the Requirement Groups and all the automation levels identified. The requirements obtained are:

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% |

1. 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 differ within the automation levels and among the different Groups identified. Requirements are defined for several parameters that are relevant for IWW navigation. These parameters are:

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

Regarding integrity, it can be characterized by several parameters, like data integrity risk, alert limit, and time to alert. This document identifies user requirements for PNT data integrity with the integrity level, according to MSC.1-Circ.1575.

The following are the requirements that have been extracted after all the analysis of the state of the art. 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.

**Horizontal position (Lat/Long)**

1. 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 |

1. 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 |

1. 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 |

1. 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 |

1. 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 |

1. GNSS requirements – Horizontal Position | TBA

|  |  |  |  |
| --- | --- | --- | --- |
| **Time Between Authentications (TBA) [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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a level of integrity

AI-generated content may be incorrect.

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.

**Vertical position (Height)**

Vertical positioning is relevant to bridge passing, so in this case, the requirements only apply to Group 3 operations where the operation of passing under a bridge is included.

1. GNSS requirements – Vertical Position | Accuracy

|  |  |  |  |
| --- | --- | --- | --- |
| **Accuracy [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 | 0.1m | 0.1m |

1. GNSS requirements – Vertical 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 | N/A | N/A |
| Group 2 | N/A | N/A |
| Group 3 | 10-5 | 7,2x10-6 |

1. GNSS requirements – Vertical Position | Time to Alert

|  |  |  |  |
| --- | --- | --- | --- |
| **Time to Alert [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 |

1. 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 |

1. 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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a level of integrity

AI-generated content may be incorrect.

1. 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.

**Speed over ground (SOG)**

1. 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 or 1 km/h whichever is greater | 1% of actual speed or 0.2 km/h whichever is greater |
| Group 2 | 1 km/h | 0.2 km/h |
| Group 3 | 0.5 km/h | 0.2 km/h |

1. 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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a level of integrity

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1. 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.

**Course over ground (COG)**

1. 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° |

1. 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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a course over ground

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1. 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.

**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.

1. 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° |

1. 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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a level of integrity

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1. 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.

**Rate of turn (ROT)**

1. GNSS requirements – ROT | Accuracy

|  |  |  |  |
| --- | --- | --- | --- |
| **Accuracy [deg/s]** | | **At identified automated level in D1.1. AL0 - 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 |

1. GNSS requirements – ROT | Update frequency

|  |  |  |  |
| --- | --- | --- | --- |
| **Update frequency [Hz]** | | **At identified automated level in D1.1. AL0 - 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 |

By performing an analysis similar to the one performed in IMO MSC.1-Circ.1575, it is obtained the following diagram:

A diagram of a level of integrity

AI-generated content may be incorrect.

1. 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.

## User requirements for Earth Observation services

This analysis is approached from two different perspectives taking into account the Copernicus services. 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.

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.
* **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 Mean Absolute Error (MAE) or Root Mean Square Error (RSME).

For alerts, in short term, it is interesting to take advantage of one of the 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. 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 temporal resolution, since it will never be possible to update this alert at a frequency higher than the time frequency of the ad-hoc service.

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

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, 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.

**River edge**

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

1. 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 |

**River depth/bathymetry**

River depth is measured as underwater depth of a waterbody. Looking at the characteristics offered by Copernicus services, it can be seen that they mainly meet the needs of Group 1 needs. The spatial and temporal resolution of Copernicus satellites makes the fulfilment of user requirements for Group 2 and 3 challenging. It is observed that the particular needs of Groups 2 and 3 might not be directly satisfied by Earth Observation services. The only service that potentially could provide additional information for Group 2 are river depth/bathymetry.

1. 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 |

1. 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 |

**Water speed**

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

1. 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 |

**Object detection**

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

1. 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 |

**Floods forecasting**

Currently, this service is provided near-real time, with a delay of 6 days. The real-time data is only available to European Flood Awareness System (EFAS) partners. In the requirement from the Copernicus services, the forecasting time of 15 days for flood prediction refers to the period over which flood forecasts are made, spanning from the current day up to 15 days into the future.

1. Copernicus requirements – Floods forecasting | Group 1

|  |  |  |  |
| --- | --- | --- | --- |
| **Requirement** | | **AL0-AL2** | **AL3** |
| Provide alerts | forecasting time | 15 days | 15 days |

# References

1. International definition of levels of automation. 2022. CCNR. https://www.ccr-zkr.org/files/documents/AutomatisationNav/DefinitionAutomatisation\_en.pdf
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3. ES-RIS 2021/1 PART I STANDARD ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEM FOR INLAND NAVIGATION). Version 2.4, 07/12/2018.
4. IMO MSC.1/Circ.1575, Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing. 06/2017.

# Acronyms

|  |  |  |  |
| --- | --- | --- | --- |
| AIS | Automatic Identification System | HMI | Human-Machine Interface |
| CCNR | Central Commission for the Navigation of the Rhine | IWW | Inland Waterways |
| COG | Course Over Ground | MAE | Mean Absolute Error |
| CPA | Closest Point of Approach | MSC | Maritime Safety Committee |
| DBT | Depth Below the Transducer | PNT | Positioning, Navigation and Timing |
| DPT | Depth NMEA code | RIS | River Information Services |
| ECDIS | Electronic Chart Display and Information Systems | ROT | Rate Of Turn |
| EFAS | European Flood Awareness System | RSME | Root Mean Square Error |
| EGNSS | European GNSS | SOG | Speed Over Ground |
| ENC | Electronic Navigational Charts | TBA | Time Between Authentications |
| GNSS | Global Navigation Satellite System | TGAIN | Track Guidance Assistant for Inland Navigation |
| HDT | Heading |  |  |

# Action requested of the Committee

The Committee is requested to:

1. To review the input paper
2. To provide feedback, if considered, to the authors.
3. To be able to make a presentation in next ENG20 committee to share the information provided in this paper.

1. Leave open if uncertain [↑](#footnote-ref-2)