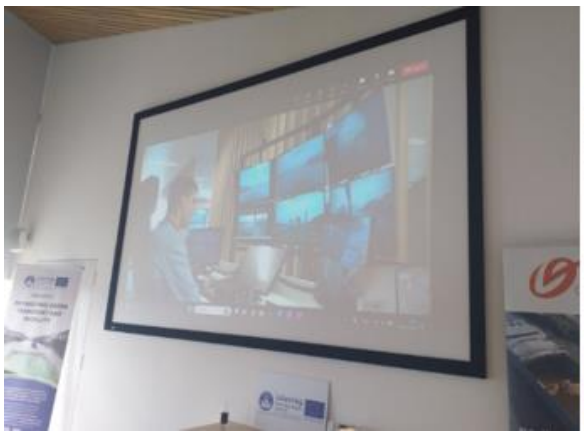

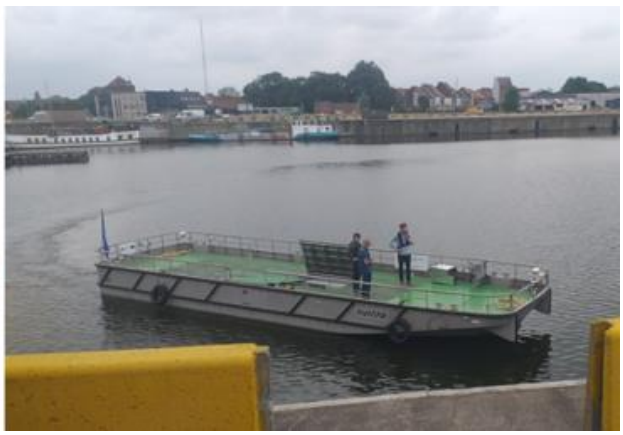

# *Report of the assessment of performance of urban freight vessels: AVATAR-vessel*

*Within the framework of the Interreg NSR project AVATAR work package 5*

AVATAR is a project co-funded by the
Interreg North Sea Region programme 2014-2020

# Colophon

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*See also: AVATAR website and Linkedin*

*Project partners AVATAR:*

# 1. Introduction

The massive under-exploitation of inland waterways (IWW) in the North Sea Region (NSR), especially in and around urban environments, provides opportunities for technological innovations. The AVATAR project aims to deploy (highly) zero-emission automated vessels that can do regular trips between the urban consolidation centers outside of a city and inner city hubs.

The AVATAR project aims to tackle challenges of city freight distribution by developing, testing and assessing adequate technologies and business models for urban (highly) autonomous zero-emission Inland waterway transport (IWT) solutions. Through this, the project unlocks the economic potential of urban vessels and corresponding waterways, increases available solutions for full-cycle automation and sets up a sustainable supply chain model for urban goods distribution and waste return.

This report gives a description of the new developed AVATAR-vessel and gives insights in the (limited) assessment results.

An important output of the AVATAR project was the completion of the AVATAR vessel. Completion of the AVATAR vessel was foreseen in the year 2022, but due to several reasons full completion (e.g. delay in delivery of components) was only possible in June 2023. This proved also the need of planning the final AVATAR event by the end of June 2023, making it possible to showcase the new AVATAR vessel. On the other hand, it was not possible to perform a lot of sailing tests with the new AVATAR vessel (implying also that less test results were available for the analyis and comparison of the different vessels in the project).

# 2. Description of the development of the AVATAR-vessel

Project partners Opleidingscentrum Hout en Bouw, E. Van Wingen NV and SEAFAR cooperated in the development of a new urban test vessel with a capacity of 25 ton, zero-emission and highly automated.

In January 2022, the hull of the new AVATAR vessel arrived in Ghent.

Figure 1: Arrival of the hull of the AVATAR vessel in Ghent (January 2022)

© Opleidingscentrum voor Hout en Bouw vzw - Peter Geirnaert

In a next step, the team of E. Van Wingen co-developed the new AVATAR vessel with the appropriate engine and equipment. SEAFAR has also been involved in this development and in the automation part. The necessary equipment has been built in and communication between software of SEAFAR and E. Van Wingen was set up. All in order to be able to steer the AVATAR vessel (located in Ghent) from the SEAFAR remote control center in Antwerp.

Figure 2: Installing engine and equipment on the AVATAR vessel by E. Van Wingen and SEAFAR

(c) SEAFAR

E. Van Wingen (in cooperation with OHB and SEAFAR): completion of the new AVATAR vessel. Following steps took place (based on Final AVATAR report):

- Completion of mechanical installation on board
- Installation and settings of steering gear
- Alignment of drive shaft
- Installation of all marine accessories like sailing lights, anodes, etc. , safety/life equipment
- Installation of water tanks water transfer system (pumps, piping and valves)
- Programming (PLC, MMI, can bus interfaces, …)
- Bilge pump installation
- Review and installation of water seal propeller drive shaft
- Manufacturing and installation of protection covers outside installed equipment
- Mechanical construction allowing further electric installation (allowing fixation of cable trays, etc.)
- Assisting first water launch
- Life tests of all equipment installed
- Repairs and corrections after testing
- Setting up and testing internet platform for online monitoring and for documentation management

**Based on** *Geirnaert, P., Hörteborn, A., Kia, G., Pang, Y., Pauwels T., Santen, V. and J.P. Van Wingen (2023): Development of an open source vessel – Guidelines how to set up a conceptual approach of an open source fleet, publication in the framework of AVATAR, a project co-funded by the INTERREG North Sea Region programme 2014-2020 (ERDF)* an overview is given of the activities of SEAFAR:

> *SEAFAR technology has been installed on the new AVATAR vessel in order to control the new AVATAR vessel (in Ghent) from the SEAFAR remote control center in Antwerp. Succesful tests and demonstrations took place in June 2023 (also during the final AVATAR event).*
>
> *The interfaces have been installed onboard the vessel and the connections were done with the SEAFAR system. Some of the controlled parts include the engine, rudder, bow and thruster, lights and the horn. Seamless transmission of environmental data captured from the vessel's surroundings to the remote operation center stands as a pivotal function.*
>
> *To be able to remotely sail a vessel, different elements are involved. One element is the control system. The control system should be able to receive commands from the remote operation center and transfer the command to the relevant module on the vessel. The interfaces are installed onboard the vessel and the connections are done with Seafar system. Some of the controlled parts include engine, rudder, bow and thruster, lights and the horn.*
>
> *Seamless transmission of environmental data captured from the vessel's surroundings to the remote operation center stands as a pivotal function. This data, a crucial element for remote operation, finds its purpose in being rendered comprehensible to the remote captain. The foundation for this synchronization relies on a network connection that is not only robust but unwaveringly stable.*

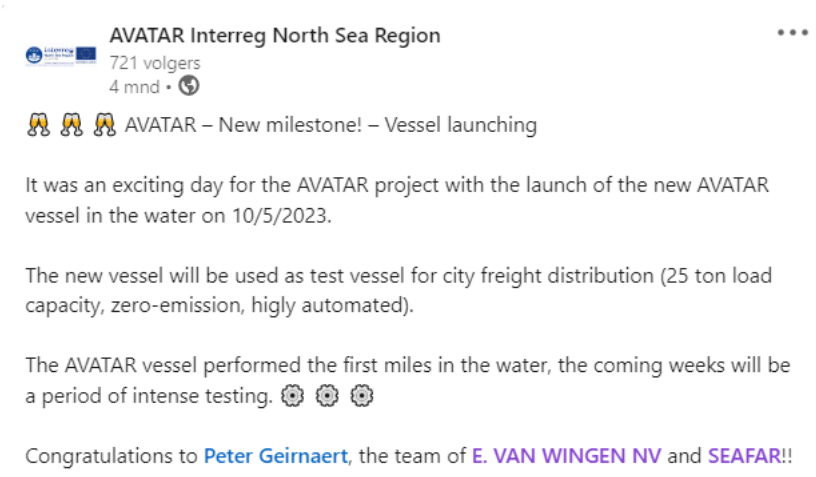
*With this objective in mind, Seafar has installed network infrastructure directly on board the vessel. This dedicated network apparatus serves as the faciliy through which the collected data from an array of sensors all the way to the remote operation center.*

*Central to this implementation is the utilization of 4G/LTE technology, notably employed within the AVATAR project. This technology forms the bedrock of communication, promising efficiency and reliability. It ensures that the data are transferred to the remote operation center for translation into a coherent narrative for the remote captain's informed decision-making. The fusion of technology, network solution, and precision engineering converges within this system, forming a crucial bridge between the vessel's immediate reality and the remote captain's distant perspective.*

*The received data should be provided to the remote captain to make the decisions and steer the vessel. We have considered one of the stations at Seafar headquarter in Antwerp for this purpose. However, considering the special design of AVATAR navigation system, modifications were required in the remote station. For example, the interface for the control device was considered and improved in a way to translate the command from captain to navigation methodology onboard the vessel.*

The new vessel has been launched in the water on 10/5/2023.

Figure 3: AVATAR vessel launching, message on AVATAR Linkedin




Source: AVATAR Linkedin,
https://www.linkedin.com/feed/update/urn:li:activity:7062403589763158017/

Figure 4: AVATAR vessel launching, picture


Source: AVATAR Website, https://northsearegion.eu/avatar/news/avatar-new-milestone-vessel-launching/

# 3. Testing the AVATAR-vessel

Project partners Urban Waterway Logistics, Opleidingscentrum Hout en Bouw, E. Van Wingen NV and SEAFAR cooperated in the development of a new urban test vessel with a capacity of 25 ton, zero-emission and highly automated. This vessel is part of a fleet of urban vessels that is being used for test sailings of city freight distribution. During the AVATAR final event, the project partners demonstrated the possibilities of remotely operating the AVATAR vessel in the dock in Ghent from the advanced Remote Operation Center in Antwerp. To show this, a live video connection has been established. On top of this , project partner RISE is monitoring the vessel performance data that will be shown on a dashboard.

SEAFAR technology has been installed on the new AVATAR vessel in order to control the new AVATAR vessel (in Ghent) from the SEAFAR remote control center in Antwerp. Successful tests and demonstrations took place in June 2023 (also during the final AVATAR event). OHB took care of the realization of the hull of the AVATAR vessel. The team of E. Van Wingen took care of the installation of the necessary equipment of the AVATAR vessel. In general, AVATAR project partners were confronted with delays related to the Corona impact but also as a result of the geopolitical situation. Besides the delivery delays, AVATAR project partners were also confronted with increasing prices.

A live demonstration was provided in the afternoons of the AVATAR final event. The captain at Seafar headquarter remote operation center in Antwerp has remotely sailed the vessel in

Gent, the final event venue. The demonstration started by safety check, going through the list of control system elements. Then, the captain started sailing the vessel to a specific point and returning to the starting point.

The demonstrations were successful. The video footprint was collected by a drone flying above the vessel. The video call with remote operation center was also recorded.

Figure 4: Remote control center in Antwerp


Source: POM Oost-Vlaanderen

Figure 5: AVATAR-vessel sailing in Ghent, remotely controlled by SEAFAR from Antwerp


Source: POM Oost-Vlaanderen

During the AVATAR project period several test sailings with freight took place with the Green Wave. An overview is included below. Test sailings with the Green Wave served as inspiration for the further development of the AVATAR-vessel.

**Test sailing Green Wave (project partner OHB): 15/11/2022**

On 15/11/2022, a test sailing took place with the Green Wave, characteristics:

- ⇨ 20 ton of goods (sand on pallets, in bags of 25kg) + other material
- ⇨ From: Oostvlaamse Bouwmaterialen, Nieuwevaart 143, 9000 Gent
- ⇨ Destination: Coupure Rechts 627, Ghent
- ⇨ Distance with truck 5km
- ⇨ Included in report: **20 ton = 20.000 kg**
- ⇨ Alternative: using 2 trucks
- ⇨ Avoided CO2: 2 trucks x (2x5km) x 112 gram CO2 per km = 2240 gram = **2,24 kg CO2**

Figure 6: Test sailing Green Wave on 15/11/2022


Source: Peter Geirnaert

**Test sailing Green Wave (project partner OHB): 6/7/2022**

- ⇨ 20 ton of goods (tiles, parquet, spray plaster; on pallets)
- ⇨ From: Oostvlaamse Bouwmaterialen, Nieuwevaart 143, 9000 Gent
- ⇨ Destination: Recolettenlei 43, 9000 Gent
- ⇨ Distance with truck 6 km
- ⇨ Included in report: **20 ton = 20.000 kg**
- ⇨ Alternative: using 2 trucks
- ⇨ Avoided CO2: 2 trucks x (2x6km) x 112 gram CO2 per km = 2.688 gram = **2,68 kg CO2**

See also here: https://northsearegion.eu/avatar/news/avatar-test-green-wave-in-ghent/

Figure 7: Test sailing Green Wave on 6/7/2022 (a)

(c) Tom Pauwels - Loading of the Green Wave (preparations)

Figure 8: Test sailing Green Wave on 6/7/2022 (b)

(c) Tom Pauwels - Loading of the Green Wave

Figure 9: Test sailing Green Wave on 6/7/2022 (c)

c) Tom Pauwels - sailing towards city center of Ghent


(c) Sandra Leroy - Unloading the Green Wave in the city of Ghent

**Test sailing Green Wave (project partner OHB): 15/11/2021**

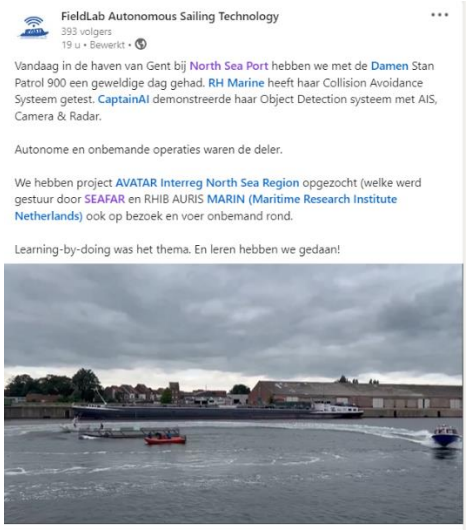
- ⇨ 25 ton of goods (sand on pallets, in bags of 25kg) + other material
- ⇨ From: Oostvlaamse Bouwmaterialen, Nieuwevaart 143, 9000 Gent
- ⇨ Destination: Coupure Rechts 627, Ghent
- ⇨ Distance with truck 5km
- ⇨ Included in report: **25 ton = 25.000 kg**
- ⇨ Alternative: using 2 trucks
- ⇨ Avoided CO2: 2 trucks x (2x5km) x 112 gram CO2 per km = 2240 gram = **2,24 kg CO2**

**Test sailing Green Wave (project partner UWL):**

- ⇨ Several test sailings took place with in total 85 tons of goods (85.000 kg)
- ⇨ From: Transhipment location Everstein
- ⇨ Destination: Coupure, Ghent
- ⇨ In the reference scenario, the vessel sails to the container terminal in Avelgem, from where trucks leave to the destination (in this case the centre of Ghent). Distance from Avelgem to the destination of the construction materials (Coupure Ghent) is 50 km one way. As such, 50 km of transport with truck is avoided.
- ⇨ Included in report: **85 ton = 85.000 kg**
- ⇨ Alternative: using 8 trucks
- ⇨ Avoided CO2: 8 trucks x (2x50km) x 112 gram CO2 per km = 89.600 gram = **89,6 kg CO2**

On 20/9/2023, test sailings with the AVATAR-vessel took place, in cooperation with other vessels (e.g Damen and Marin). During the test sailings, collision avoidance and object detection was tested.

Figure 10: Test sailing on 20/9/2023



Source: https://www.linkedin.com/posts/fieldlab-autonomous-sailing-technology_vandaag-in-de-haven-van-gent-bij-north-sea-activity-7110313797222813698-VWDK?utm_source=share&utm_medium=member_desktop

A checklist overview of the components and good operation has been delivered by E. Van Wingen on 30/6/2023. An overview is included in Figure 11.

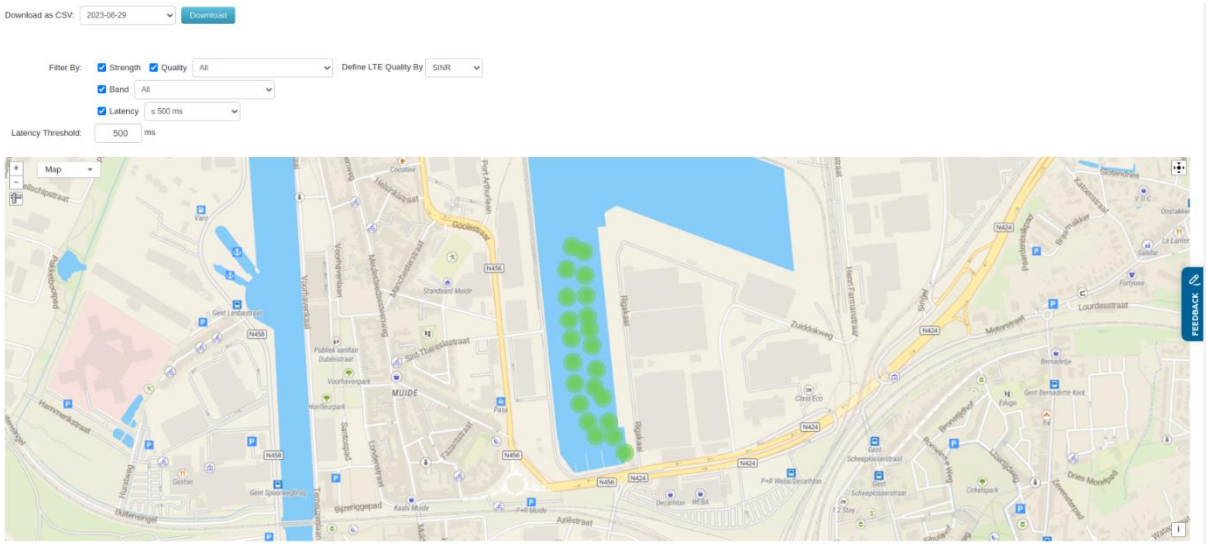
Figure 11: Checklist overview of the components of good operation

| Category | Topic | Action | Result | Problems | Risks | Solution |
|---|---|---|---|---|---|---|
| Elctrical installation | Cabling | Measuring connections | OK | | | |
| | 24 V battery system | Charge 24 V battery | OK | | | |
| | | Receive data from 24 V battery | OK | | | |
| | | Receive data from 24 V battery charger | OK | | | |
| | | Control 24 V battery charger with PLC | Not tested yet | | | |
| | 102 V battery system | Receive data from 102 V battery via shunt | OK | Incorrect values | Incorrect perception of state of charge | Calibration needed |
| | | Receive data from 102 V battery via control box | OK | | | |
| | | Charge 102 V battery | OK | | | |
| Local control | Propulsion | Control with throttle | OK | | | |
| | | Read feedback data from motor on HMI | OK | Certain values are not scaled correctly | | Fix with conversion in software |
| | Rudder | Control with steering wheel | OK | | | |
| | | Read position of rudder on analog meter | OK | Slight deviation from reality | Incorrect perception of rudder position | |
| | Thrusters | Control with joystick | OK | | | |
| | | Read feedback data from thrusters on HMI | NOK | Not possible with current protocol converter | | |
| | Bilge pumps | Turn on with button on HMI | OK | | | |
| | Ballast pump | Turn on with button on HMI | OK | | | |
| | Navigation lights | Turn on with button on HMI | OK | | | |
| | Horn | Turn on with button on HMI | OK | | | |
| Remote control | Propulsion | Control from Seafar control centre | OK | Calibration was needed but solved | | |
| | | Receive feedback data from motor | OK | | | |
| | Rudder | Control from Seafar control centre | OK | Calibration was needed but solved | | |
| | | Receive position feedback from rudder | OK | | | |
| | Thrusters | Control from Seafar control centre | OK | Still issues with reliability | Loss of control of thrusters | Contact with supplier |
| | | Receive feedback data from thrusters | NOK | | | |
| | Bilge pumps | Control from Seafar control centre | OK | | | |
| | Ballast pump | Control from Seafar control centre | OK | | | |
| | Navigation lights | Control from Seafar control centre | OK | | | |
| | Horn | Control from Seafar control centre | OK | | | |
| | Cameras | Send data from ship to Seafar | OK | | | |
| | 4G | Send data from ship to Seafar | OK | | | |
| | GPS | Send data from ship to Seafar | OK | | | |
| | LIDAR | Send data from ship to Seafar | OK | | | |
| | AIS | Send data from ship to Seafar | OK | | | |
| | VHF | Send data from ship to Seafar | OK | | | |

Source: E. Van Wingen

For the purpose of testing, SEAFAR has provided network data (see Figure 11). These network data are also presented in CSV-data containing exact location data.

Figure 11: Screenshots position AVATAR-vessel during test sailing on 29/6/2023




Source: SEAFAR

Figure 12: Recorded data AVATAR-vessel during test sailing on 29/6/2023

A16: Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-65.0,17.0,-9.0,,10,206,2023-06-30 13:37:10,51.07467,3.738066,

| | A |
|---|---|
| 1 | WAN name,Type,Cell ID,Carrier,Band,LTE - RSRP,LTE - SINR,LTE - RSRQ,Latency,MNC,MCC,Time,Latitude,Longitude,Altitude |
| 2 | Cellular,gobi,0,,,,,,,2023-06-30 13:35:10,,, |
| 3 | Cellular,gobi,0,,,,,,,2023-06-30 13:35:20,,, |
| 4 | Cellular,gobi,0,,,,,,,2023-06-30 13:35:30,,, |
| 5 | Cellular,gobi,0,,,,,,,2023-06-30 13:35:40,,, |
| 6 | Cellular,gobi,0,,,,,,,2023-06-30 13:35:50,,, |
| 7 | Cellular,gobi,0,,,,,,,2023-06-30 13:36:00,,, |
| 8 | Cellular,gobi,0,,,,,,,2023-06-30 13:36:10,,, |
| 9 | Cellular,gobi,0,,,,,,,2023-06-30 13:36:20,,, |
| 10 | Cellular,gobi,0,,,,,,,2023-06-30 13:36:30,,, |
| 11 | Cellular,LTE,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-67.0,16.0,-10.0,,10,206,2023-06-30 13:36:40,,, |
| 12 | Cellular,LTE,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-65.0,13.0,-10.0,,10,206,2023-06-30 13:36:50,,, |
| 13 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-67.0,15.0,-11.0,,10,206,2023-06-30 13:37:00,51.07466,3.738082, |
| 14 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 20 (800 MHz),-44.0,23.0,-6.0,,10,206,2023-06-30 13:37:00,51.07466,3.738082, |
| 15 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 1 (2100 MHz),-67.0,18.0,-7.0,,10,206,2023-06-30 13:37:00,51.07466,3.738082, |
| 16 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-65.0,17.0,-9.0,,10,206,2023-06-30 13:37:10,51.07467,3.738066, |
| 17 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 20 (800 MHz),-45.0,22.0,-9.0,,10,206,2023-06-30 13:37:10,51.07467,3.738066, |
| 18 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 1 (2100 MHz),-68.0,17.0,-9.0,,10,206,2023-06-30 13:37:10,51.07467,3.738066, |
| 19 | Cellular,LTE-A,33045,Orange Belgium (BE),LTE Band 3 (1800 MHz),-66.0,16.0,-11.0,,10,206,2023-06-30 13:37:20,51.074646,3.738048, |

Source: SEAFAR

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