



# Final Presentation

## The GSAB project



GRIMALDI DEEP SEA S.p.A.



KONGSBERG

# GSAB - Grimaldi Satellite Assisted Berthing



**Grimaldi Satellite  
Assisted Berthing**



Grimaldi Euromed S.p.A. – Prime Contractor



Radiolabs - Subcontractor



Kongsberg Discovery - Subcontractor



Kongsberg Maritime - Subcontractor



## Grimaldi Euromed S.p.A.

Grimaldi Euromed S.p.A. is a fully integrated multi-national logistics company specialized in maritime transport of cars, rolling cargo, containers, and passengers. More recently, it has also become a driving force behind the Motorways of the Sea and Short Sea Shipping concepts in the Mediterranean area by deploying a fleet of modern Ro/Ro (Roll on-Roll off) and Ro/Ro Passenger ships. The Euro-Med network now operates as many as 35 ships with a total loading capacity of up to 120,000 cars or up to 100,000 linear meters of rolling cargo. The core elements of its services are high frequency maritime links, strict quality standards in terms of punctuality and procedures, and compliance with its zero- damage level target. Starting from 2016 The Grimaldi Group is working on a target called “zero emission in port” in fact from 2020 to 2022 will be delivered 12 new vessels called “G5GG - Green”. Highly energy efficient and environmentally friendly hybrid mega-RoRo vessels with a transport capacity of 7,300 lane-meters each and equipped with the most innovative technologies available on the market. Grimaldi Euromed S.p.A. participates in various European research and development projects aiming at improved efficiency and environmental performance for their ships and those of other market actors operating in the EU (Motorway of the Sea) waters.



## Radioabs

Radiolabs is a non-profit research organization between Hitachi Rail, WestPole and Universities of Roma Tor Vergata, l'Aquila and Roma Tre being involved since 2011 into high integrity GNSS and multi-bearer TLC networks innovative projects for rail. They have contributed to the development and testing of the world's first SIL-4 Localization System put in operation and is currently involved with RFI and Hitachi for the adoption of GNSS positioning systems on the ERTMS in Italy. RAL was the prime contractor of Gate4Rail (Shift2Rail) developing a GNSS Automated Virtualized Test Environment based on digital twins of the system under test. An important facility is VIRGILIO a simulator with Hardware in the Loop for predicting and assessing performance of high integrity GNSS + IMU localization with different Augmentation Networks. RAL is the prime contractor of EMERGE and P-CAR – the pillars of a strategic initiative in Italy for the development and test of the PNT platforms for the connected and autonomous cars with Stellantis and other stakeholders. Radiolabs is a member of the Cluster of Transport in Italy and cooperates with important international research institutions such as the DLR in Germany and University of Stanford in the USA. Radiolabs has three laboratories located at the Universities of Roma Tor Vergata, l'Aquila and Roma Tre and a central laboratory at the headquarter in Roma.



**KONGSBERG**

## Kongsberg Discovery

Kongsberg Discovery is a leading international marine company specialising in the development and production of precision positioning, motion sensing and communication systems. The company is committed to providing products and solutions for safe navigation and operations at sea in the commercial offshore, maritime, hydro graphic and defence industries. Kongsberg has 124 employees as of 2020. As part of this industry, KD has been involved in infrastructure projects like DGNSS systems, AIS systems, EGNOS and Galileo. KD has been the prime contractor for the Galileo Sensor Stations and has managed and participated in numerous projects for the EU and ESA, a selection of projects is listed below. KD is fully owned by Kongsberg Maritime AS, a division of the Kongsberg Group ASA (KOG). KOG is an international high-technology enterprise widely known for its state-of-the-art products and services and enjoys a long-standing reputation in the world of business. KD has also been involved in EGNOS from the beginning, first as supplier of the sensor stations to the EGNOS testbed, and then as supplier of safety critical real-time software for EGNOS RIMS-B. Current activities include the H2H and MAREC projects. The MAREC project has provided tested the EGNOS Guidelines for maritime users and provided input to the standardisation process. The company's president Gard Ueland is the chairman of the European non-profit association Galileo Services involving about 180 leading European Satellite Navigation companies.



KONGSBERG

## Kongsberg Maritime

Kongsberg Maritime Integrated Solutions (KM) delivers systems for dynamic positioning and navigation, marine automation, safety management, propulsion, deck machinery and cargo handling, subsea survey and construction, maritime simulation and training, and satellite positioning. The solutions enhance efficiency and safety throughout the whole maritime technology spectrum and KM offers additional competence in providing turnkey engineering services within the shipbuilding and floating production sectors. Kongsberg Maritime is a wholly owned subsidiary of Kongsberg Gruppen (Kongsberg). The company was founded in 1814 and celebrated 200-years in business in 2014. Kongsberg is an international technology corporation that delivers advanced and reliable solutions that improve safety, security, and performance in complex operations and during extreme conditions. The Group is a customer focused organisation with a worldwide performance culture. Kongsberg works with customers in the global defense, maritime, oil and gas and aerospace industries. Over the last two decades the company has grown to become stock-listed organization of around 11 000 employees and an established international technology leader with a reputation for innovation, determination, and reliability.



# GSAB – Innovative Technology Solutions



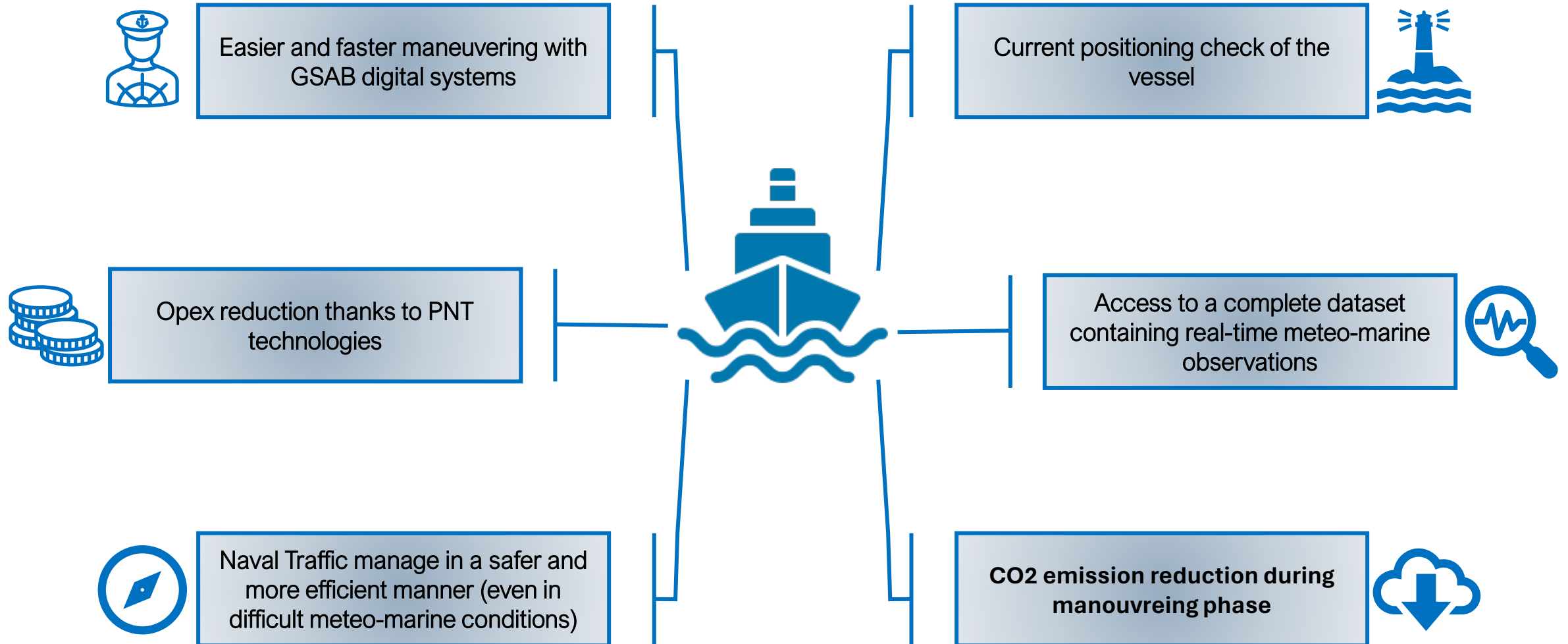
**GSAB** – Grimaldi Satellite Autonomous Berthing. Development and demonstration of a navigation support system in port water for the assisted berthing of a large car-carrier ship (200m) that allows to perform automatically high precision operations using advanced technologies for autonomous ships.

# GSAB – Main Targets





# GSAB – Grimaldi Expectations

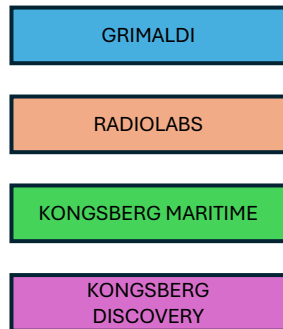
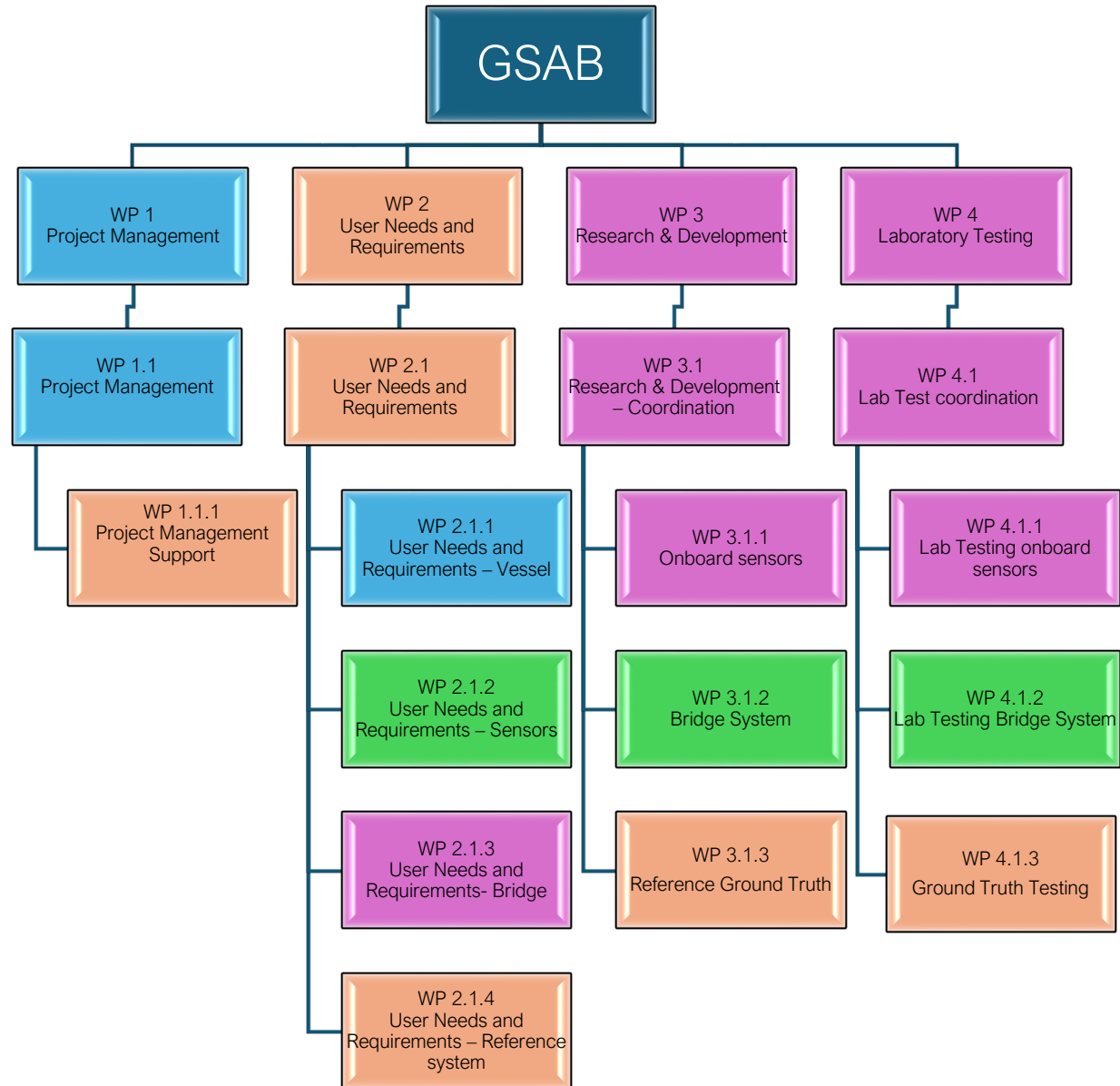


## GRIMALDI GROUP:

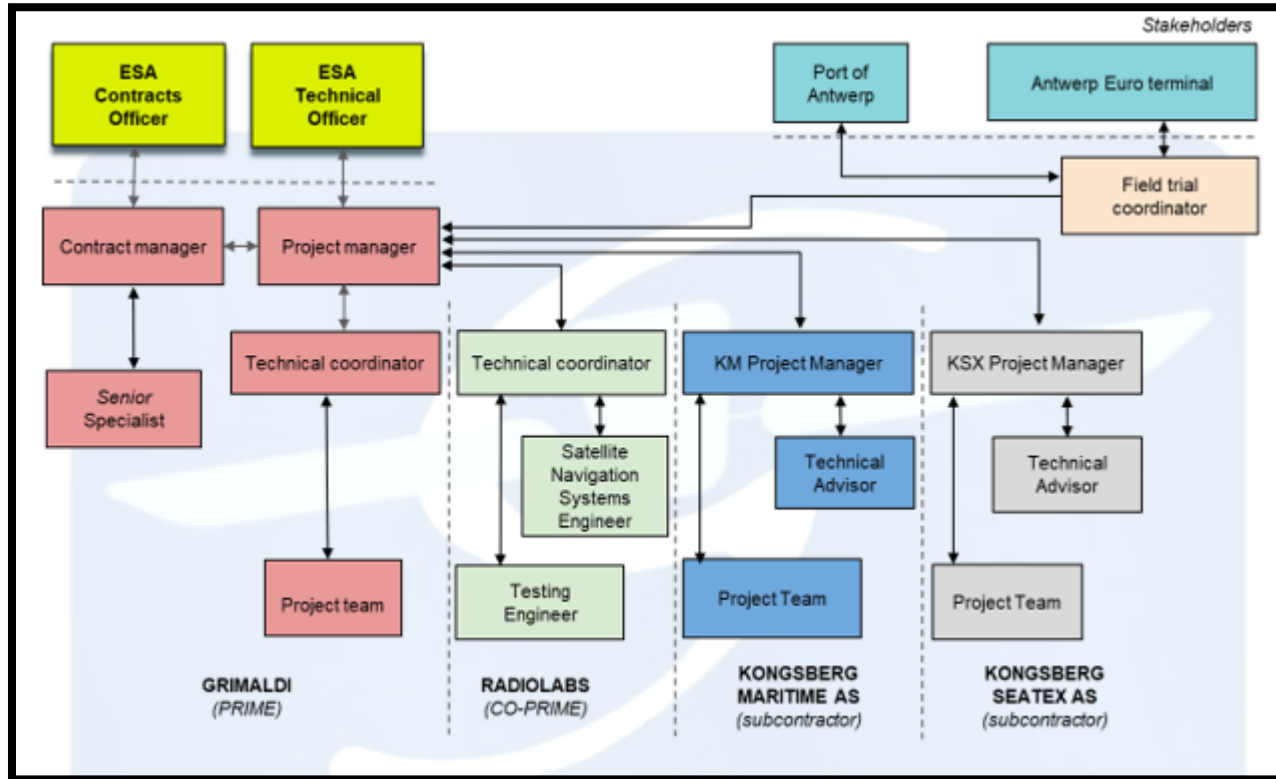
- EXTENDING THE VESSEL ICT ARCHITECTURE TO MATCH ALL REQUIREMENTS;
- EQUIPPING VESSELS BY DEDICATED DEVICES AND CAMERAS;
- APPOINTING A CAR CARRIER VESSEL AND COMMITTING TO RUN TRIALS IN ANTWERP PORT WATER.



# GSAB – WBS Structure



# GSAB – PMP Project Management Plan



- Consortium organisation, responsibility and activity management
- Configuration and data management
- Management Structure and Communication
- Subcontractor control
- Reporting and Project Schedule
- MPR
- Meetings - Meeting Plan
- Minutes of Meetings
- Progress Reports



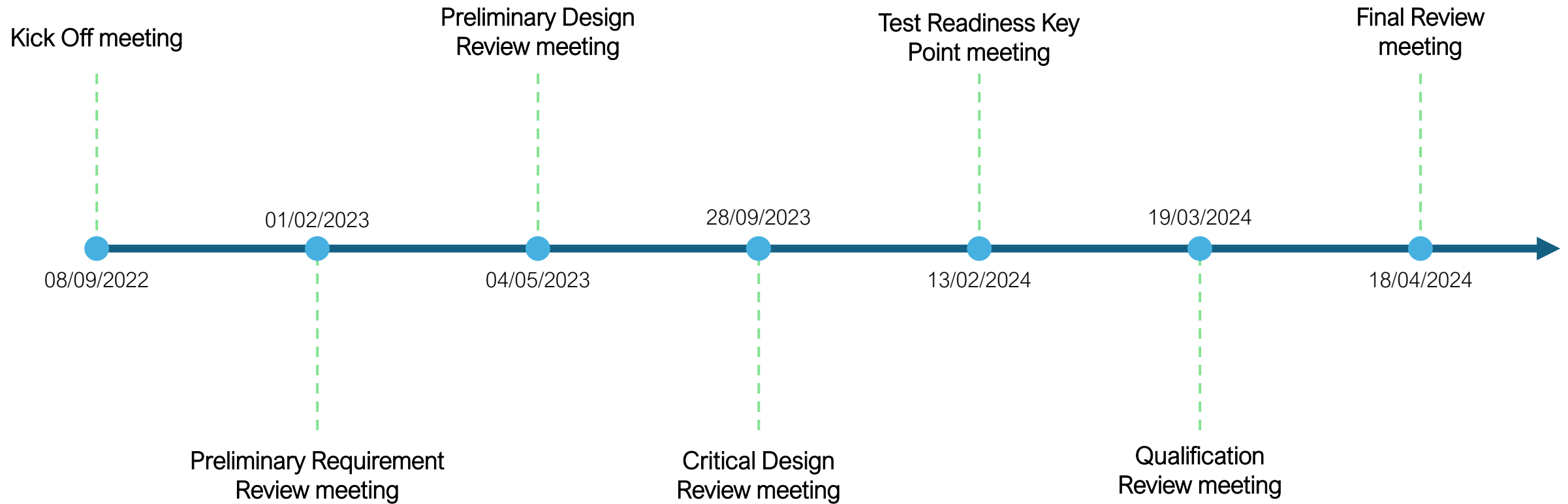
# GSAB – Gantt Chart

| GSAB MASS PROJECT SCHEDULE                     | Year 1 |    |       |    |    |     |    |    |     |     |     |     | Year 2 |     |     |     |     |     |
|------------------------------------------------|--------|----|-------|----|----|-----|----|----|-----|-----|-----|-----|--------|-----|-----|-----|-----|-----|
|                                                | M1     | M2 | M3    | M4 | M5 | M6  | M7 | M8 | M9  | M10 | M11 | M12 | M13    | M14 | M15 | M16 | M17 | M18 |
| Review meetings                                | KO     |    |       |    |    | PRR |    |    | PDR |     |     | CDR |        |     |     |     | QR  | FR  |
| WP1 – Project Management                       |        |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP 1.1 - Project Management                    | D.1.1  |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP2 - User Needs and Requirement               |        |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP 2.1 – User Needs and Requirements           | D.2.1  |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP3 – Research & development                   |        |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP 3.1 - Research & Development – Coordination | D.3.1  |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP4 – Laboratory Testing                       |        |    |       |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |
| WP 4.1 – Lab Test Coordination                 |        |    | D.4.1 |    |    |     |    |    |     |     |     |     |        |     |     |     |     |     |

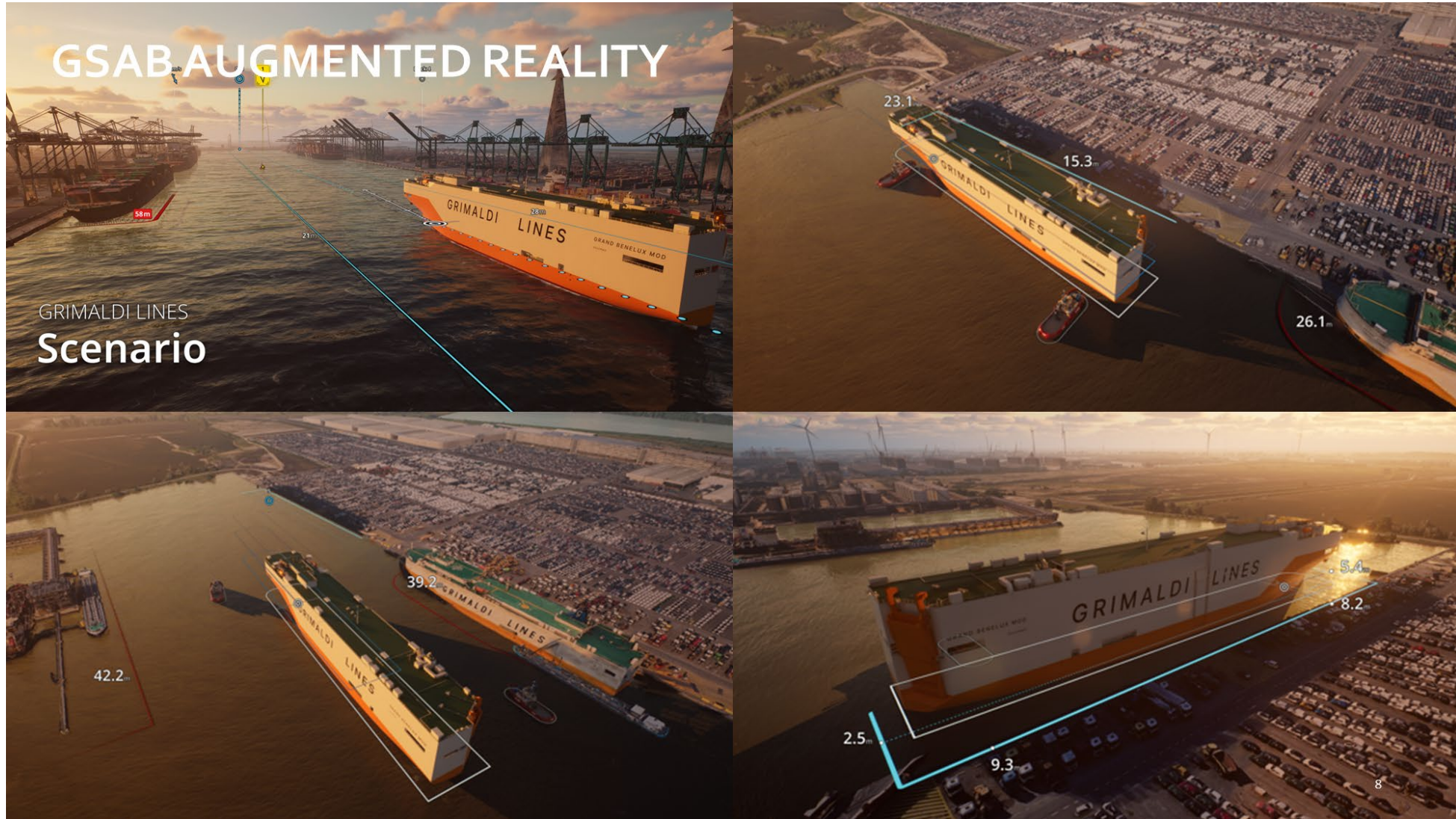
## GSAB Milestones– Development phase (18 months)

- **KO** (Kick Off)
- **PRR** (Preliminary requirement Review) T0+6
- **PDR** (Preliminary Design Review) T0+9
- **CDR** (Critical Design Review) T0+12
- **TRKP** (Test Readiness Key Point) T0+16
- **QR** (Qualification Review) T0+17
- **FR** (Final Review) T0+18

# GSAB – Updated Timeline



# GSAB – Grimaldi Scenario

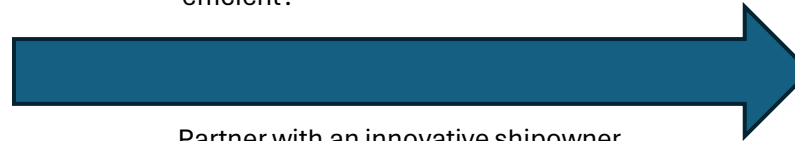




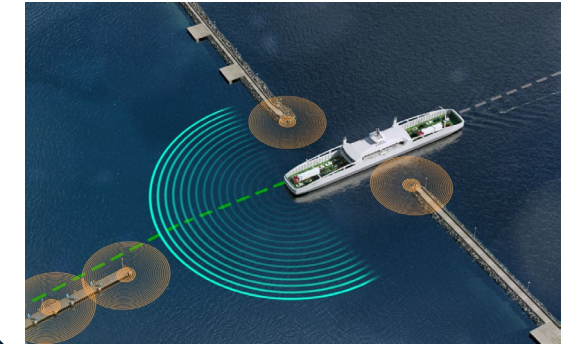
# GSAB – KONGSBERG MOTIVATION



How could we utilize the emerging technology from KONGSBERG's considerable investment into Remote & Autonomous solutions to make today's merchant fleet safer and more efficient?



Partner with an innovative shipowner to investigate how new technology could make berthing operations safer and more efficient





The Grimaldi satellite assisted berthing (GSAB) is focusing on the domain of assisted and autonomous shipping in the proximity of seaport.

KONGSBERG contribution to the project was as a technology provider. Investigating and prototyping products and systems for assisting berthing. This included:

- Integration and fusion of new sensors to provide accurate positioning and ranging data with high integrity.
- A system that suggest the best path for berthing based on all available relevant information sources.
- The use of augmented reality (AR) googles as an intuitive method of visualizing relevant berthing information.

With a corresponding result of:

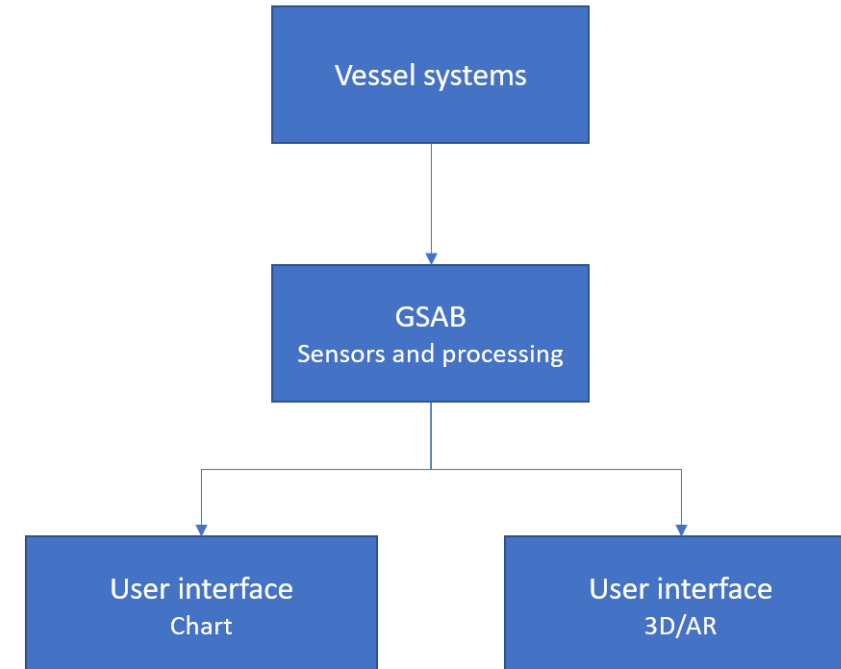
- Reduction of the time of entry and exit from a port.
- Reduction emitted pollutants due to increased efficiency.

Two KONGSBERG business areas were involved, KONGSBERG Maritime (KM) and KONGSBERG Discovery (KD).

- ✓ KM had responsibility of the onboard presentation of data on the bridge, as well as the assisted berthing path prediction module. KM owned the WP 2.1.3 User Needs and Requirements – Bridge, WP 3.1.2 Bridge System, WP 4.1.2 Lab Testing Bridge System.
- ✓ KD had responsibility of the onboard sensor system. KD owned WP 2.1.2 User Needs and Requirements – Sensors, WP 3/3.1 Research & Development, WP 3.1.1 Onboard Sensors, WP 4 Laboratory Testing, WP 4.1 Lab test – Coordination, WP 4.1.1 Lab testing Onboard Sensors

# GSAB – KONGSBERG TECHNICAL SOLUTION

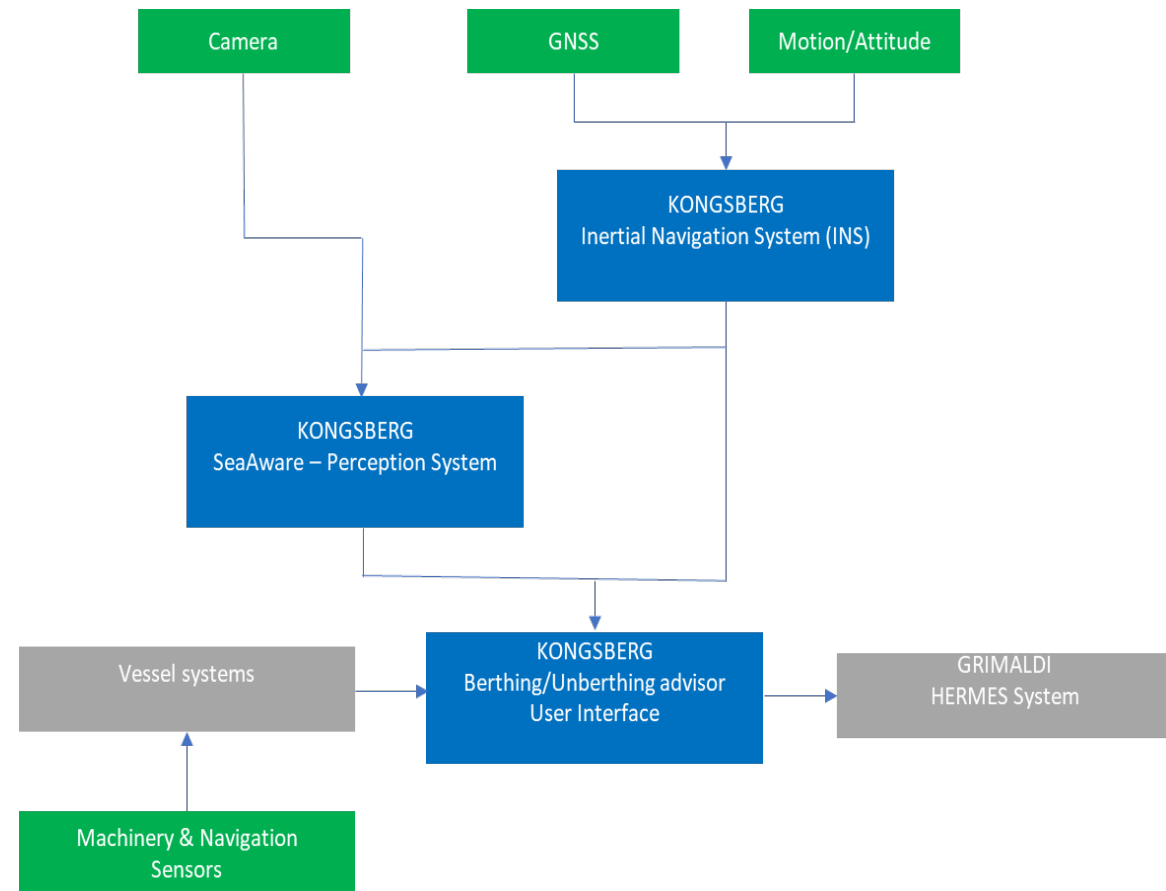
- ✓ The GSAB consists of a range of sensors and processing capabilities to produce advanced berthing and unberthing advisory assistance, moving towards an autonomous system.
- ✓ The output of the system will be presented to the operator in both a traditional electronic chart surface as a new ECDIS based application and in an 3D augmented reality platform.



# GSAB – KONGSBERG TECHNICAL SOLUTION

The system consists of different subcomponents responsible for different tasks

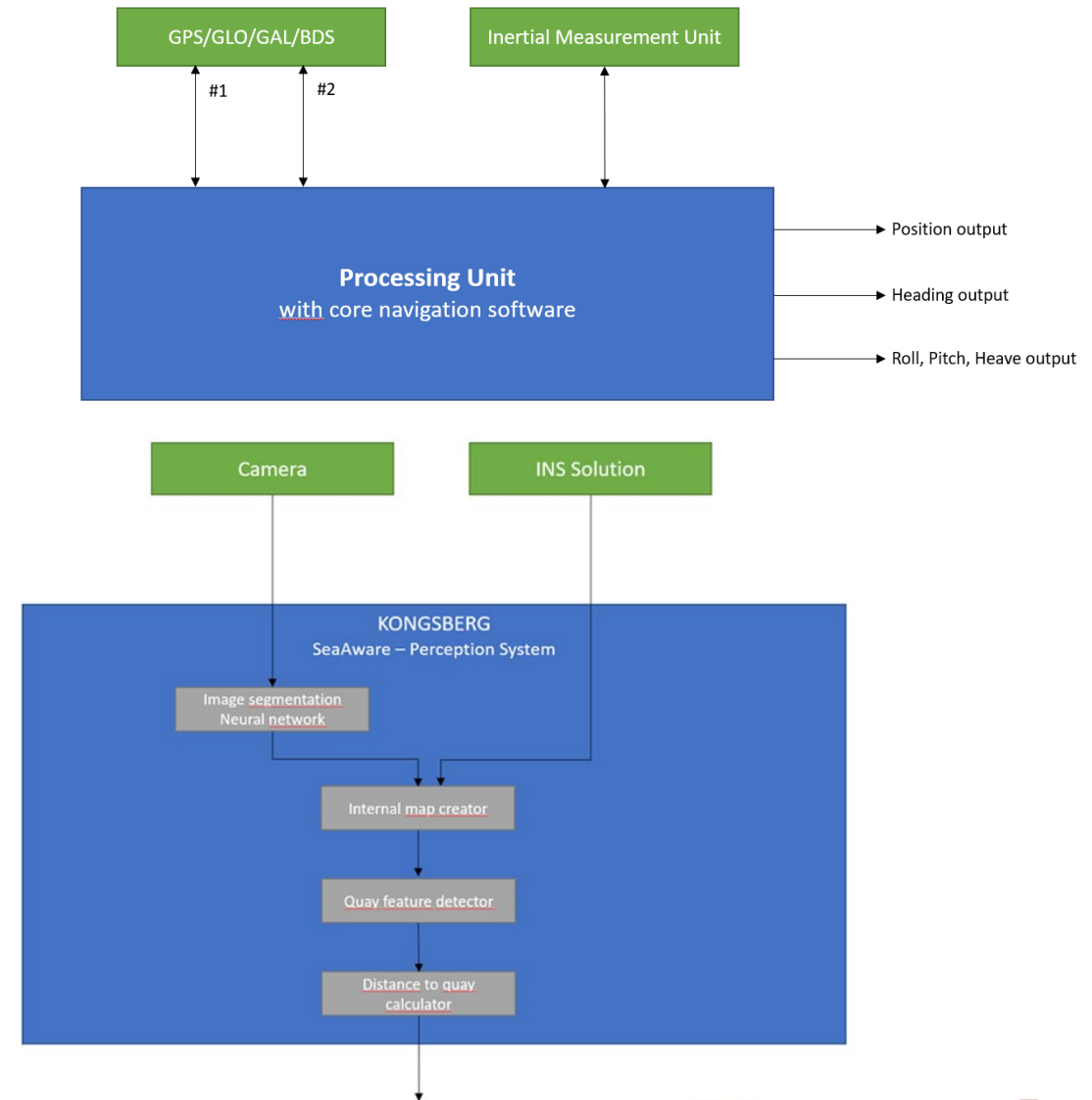
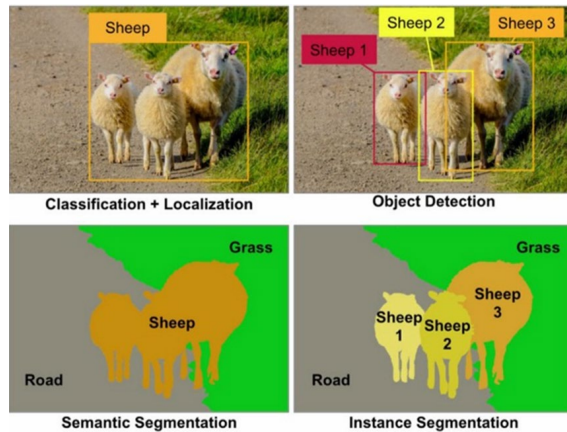
- **KONGSBERG - Inertial Navigation System**
  - Fusion of GNSS measurements with motion/attitude data from the KONGSBERG MGC to give the system robust and precise data regarding vessel location, velocities, and acceleration
- **KONGSBERG SeaAware – Perception System**
  - Camera based sensor for determining steel-to-steel distances from the vessel to any obstruction as well as distance to a quay
- **KONGSBERG Berthing/Unberthing advisor**
  - Determine the optimal path for a berthing operation based on available sensor input



# GSAB – KONGSBERG ONBOARD SENSORS

## The onboard sensor system

- Camera measurements are created through a trained image segmentation neural network which can differentiate between open waters, land, quay and other floating objects.
- To create steel-to-steel and distance to quay data, camera measurements are fused with INS measurements.





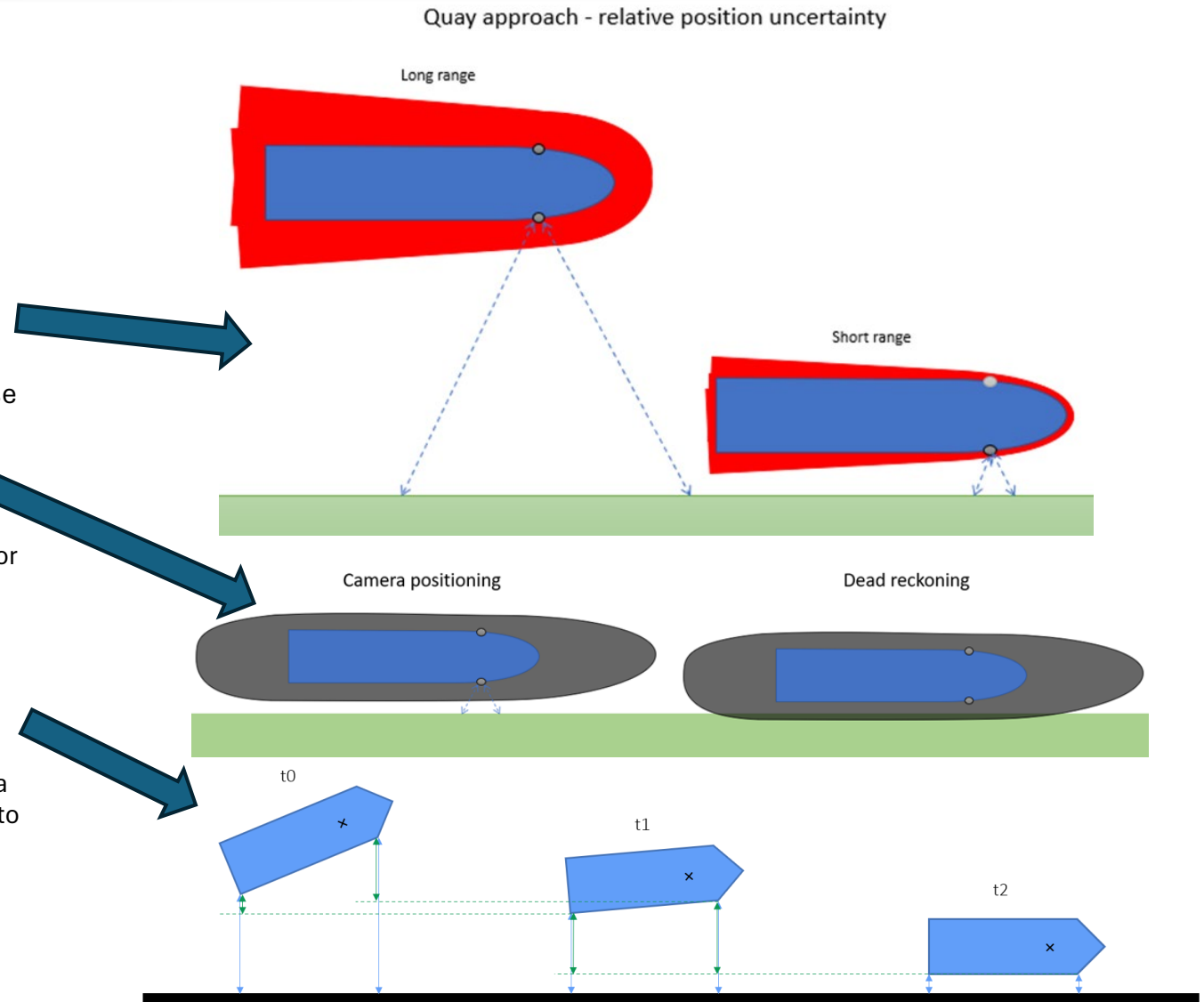
# GSAB – KONGSBERG ONBOARD SENSORS

- Over time we create an internal map of the surroundings based on all camera measurements
- Utilizing a high-resolution outline of the vessel we are able to create steel-to-steel distances.
- In addition, adding a quay feature detector we are able to create distances from the vessel to the quayside.



# GSAB – KONGSBERG ONBOARD SENSORS

- Uncertainties in the camera measurements are relative to the installation height and the distance to the object which is measured
- The cameras used are outwards facing to be able to be multi-purpose for general navigational Situational Awareness
  - This gives certain blindspot around the vessel underneath the cameras.
  - The unique relative positional accuracy of the Inertial Navigation System together with the internal map creation makes it possible for the system to continue to give updated distances even though it's entered the blind sectors.
- An online integrity monitoring algorithm was implemented which compares the relative changes of both the GNSS and camera-based measurements over time
  - Targeted integrity of the outputted data regarding localization was a Horizontal Alarm Limit of 2.5m, Integrity Risk  $10^{-5}$  in 3h and Time to Alarm (TTA) of 10s



# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

Testing of the onboard sensors was performed onboard the Ocean Space Lab in the Autonomous vessel test area of Trondheimsfjorden, Norway.

## OSL1 MAIN PARTICULARS

|           |          |
|-----------|----------|
| LENGTH    | 16,1m    |
| BREADTH   | 3.8m     |
| DRAFT     | 0.8m     |
| MAX SPEED | 45 knots |

| Device            | # | Characteristics                                                                                                                                                               |
|-------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| KCC 100 4D        | 2 | Marine grade camera clusters, designed for Machine Vision use. 2 clusters covers 360 degrees coverage.<br><br>Pixel accuracy: 2px RMS                                         |
| MGC R2 Compass    | 1 | Type approved gyro compass. High reliability with no rotational or mechanical wear-out parts.<br>Heading accuracy: 0.1dgr RMS sec.lat<br><br>Roll/Pitch accuracy: 0.02dgr RMS |
| K-INS             | 1 | GNSS receiver with MGC interface. Fuses GNSS and inertial data.                                                                                                               |
| SeaAware 100      | 1 | Interprets and fuses camera data together with AIS data and INS solution. Outputs distance to quay side as well as obstacles.                                                 |
| ProximityView 100 | 1 | 3D Augmented reality application. Possibility of overlaying data onto camera imagery.                                                                                         |
| AIS 300           | 1 | 4 <sup>th</sup> generation AIS class A mobile station                                                                                                                         |

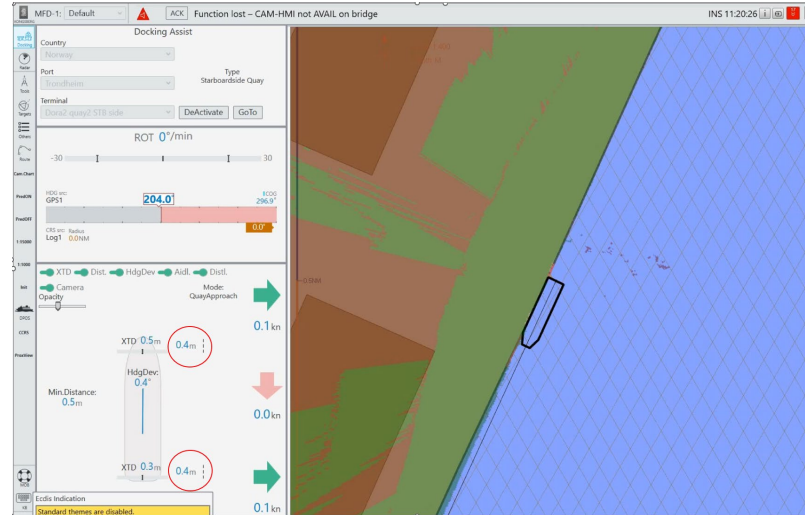


# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

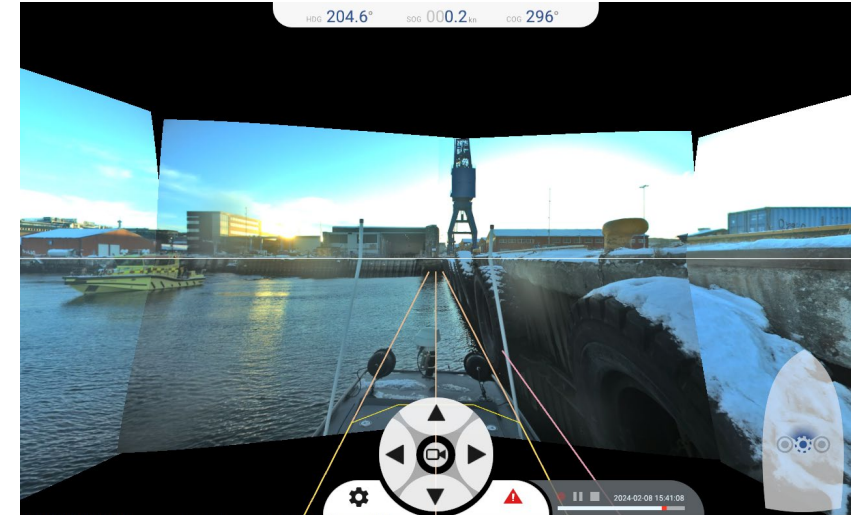
## Onboard sensor test campaign



Test quay for berthing scenarios – map location



Test quay for berthing scenarios – ECDIS



Test quay for berthing scenarios – ProximityView



# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

## Test objectives

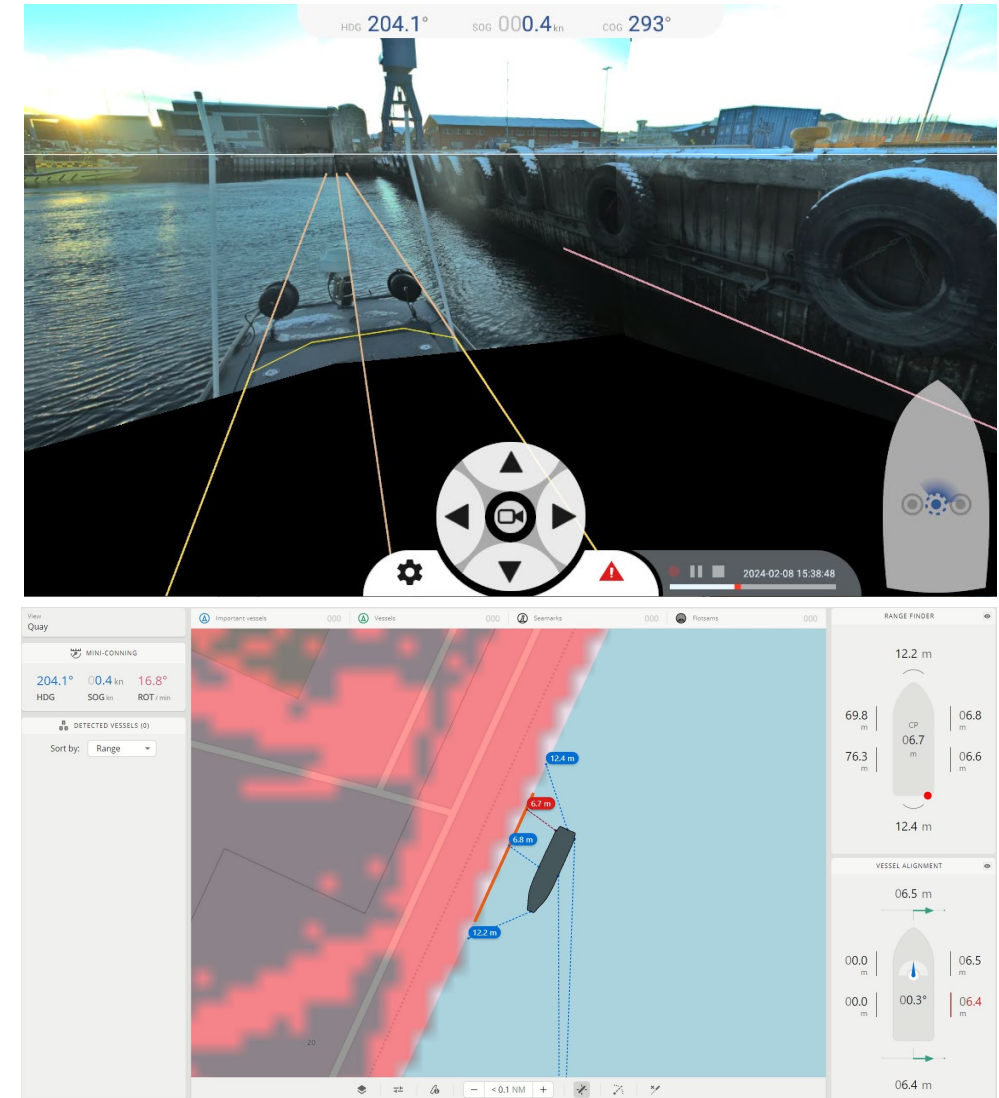
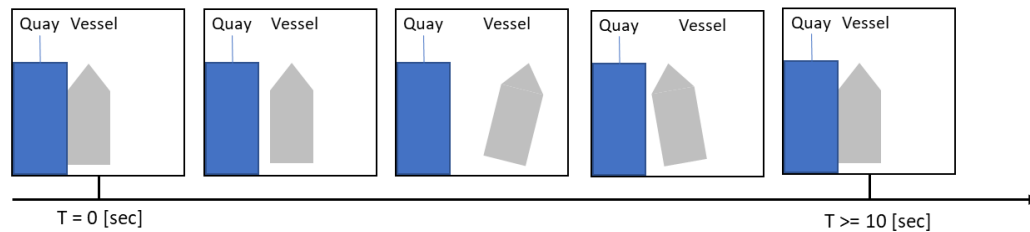
1. Verify that the absolute positioning accuracy of the GSAB system is better than 1m in the horizontal plane in port area
2. Verify that the relative camera solution is able to perform distance to quay measurements

## Test steps

Performed repeated berthing operations, and logging of the position output. The dataset collected includes data from when the vessel is pushing against the quay, ensuring a known sideways position of the vessel.

## Expected results

- Distance measured against the quay when the vessel is pushing against the fenders, should be in the range from -1.0 m to 1.0 m.
- Distance to quay measured in camera.
- ✓ Sensor data visible in the GSAB displays.



# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

## Actual results

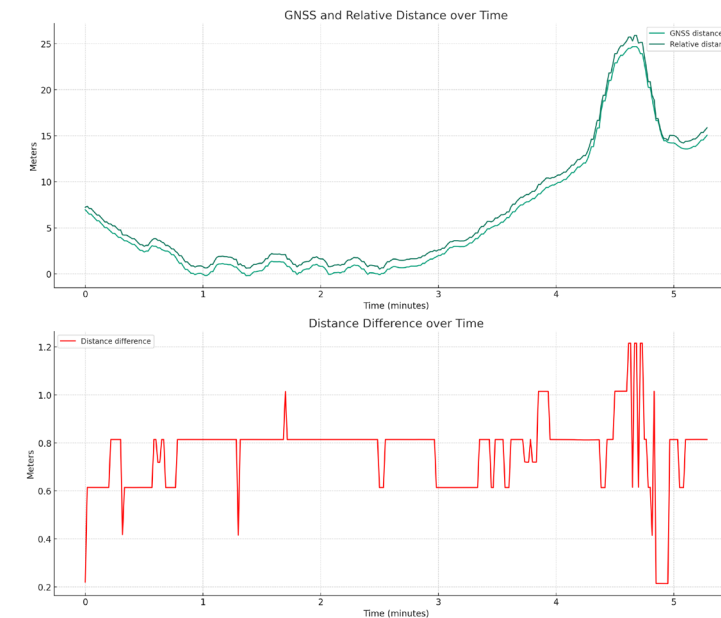
The plot shows two distances. A GNSS solution and a relative solution. The GNSS solution is based on the vessels position and heading, and a quay reference line in fixed geographic coordinates. The relative solution is the distance to the detected quay detected and estimated from camera images. The camera solution is in this case detecting the quay as the concrete structure, while the GNSS reference line is defined at the outside of the tire fenders.

The plot shows the relative distance measured by the camera, compared to the distance computed by GNSS solution.

- ✓ Distance measured against the quay when the vessel is pushing against the fenders, should be in the range from -1.0 m to 1.0 m.
- ✓ Distance to quay measured in camera.

## Passed/Failed

Passed



# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

## Test objective

Verify that the relative motion of the K-INS within a 10s timeframe is close to ground truth for validation of the online integrity scheme.

## Test steps

1. Position the vessel alongside the quay and push against the quay fenders.
2. Move the vessel out for a short period > 10 seconds
3. Position the vessel alongside the quay and push against the quay fenders.
4. Move the vessel out for a short period > 10 seconds
5. Position the vessel alongside the quay and push against the quay fenders.

Record position.

## Expected results

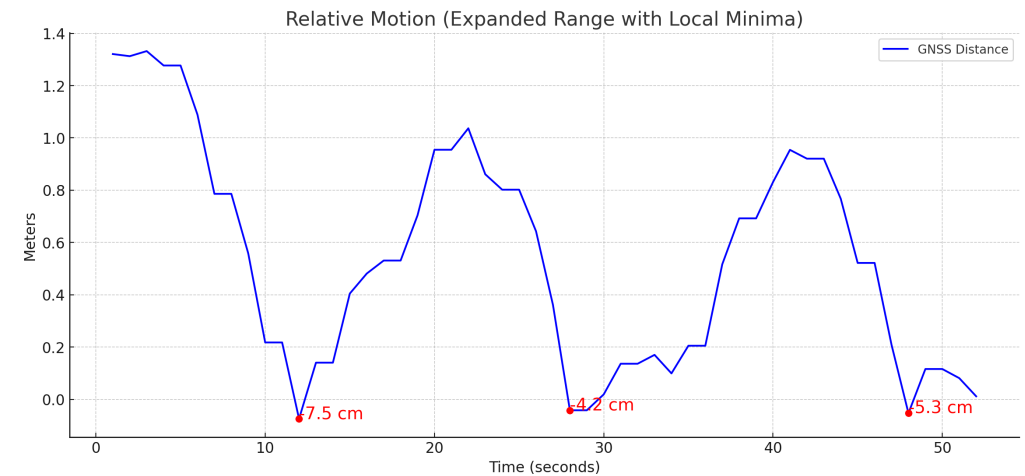
GNSS distance from the from the quay when pushing against the quay fenders, should not vary more than 10 cm between 1 and 3 or between 3 and 5.

## Actual results

The plot below shows the distance from the quay during this test. When pushing against the fenders, the distance varies from 4.2 to 7.5 cm. I.e., 3.3 cm variation, which is within the 10 cm limit.

## Passed/Failed

Passed



# GSAB – KONGSBERG ONBOARD SENSORS – TEST & TEST RESULTS

## Test objective

Verify that the online integrity scheme will alarm within 10s if the system is outside of the Integrity Horizontal Alarm Limit (HAL) 2.5m and Integrity Risk 10–5 in 3 h.

## Test steps

Performed repeated berthing operations, and logging of the position output and the online integrity check.

## Expected results

The expected results in this test, was that comparing the relative position of the vessel based on INS (GNSS + IMU) and the relative distance measurements made in the camera solution, was sufficient to detect when the system integrity.

## Actual results

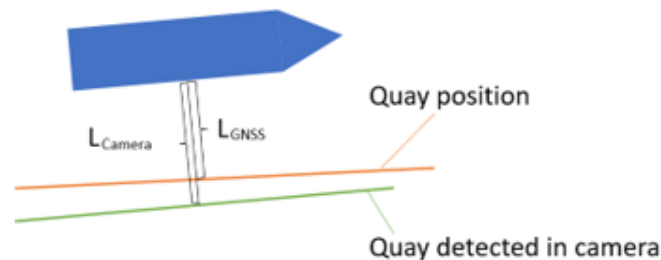
Comparing only relative position of vessel motion based on INS and Camera measurements, was not sufficient to capture absolute offsets integrated over time. An additional test with a prerequisite of known geographic position of the quay was therefore introduced to also compare the absolute quay position calculated from the camera measurement and vessel position, to the static configured quay position. Introducing this additional test, the integrity scheme was fulfilled and the test was successfully demonstrated. The system was performing within the integrity limit at all times, but an intentional error was introduced to the cameras configured mounting orientation to successfully trigger the alarm.

## Passed/Failed

Passed with comments

## Comment

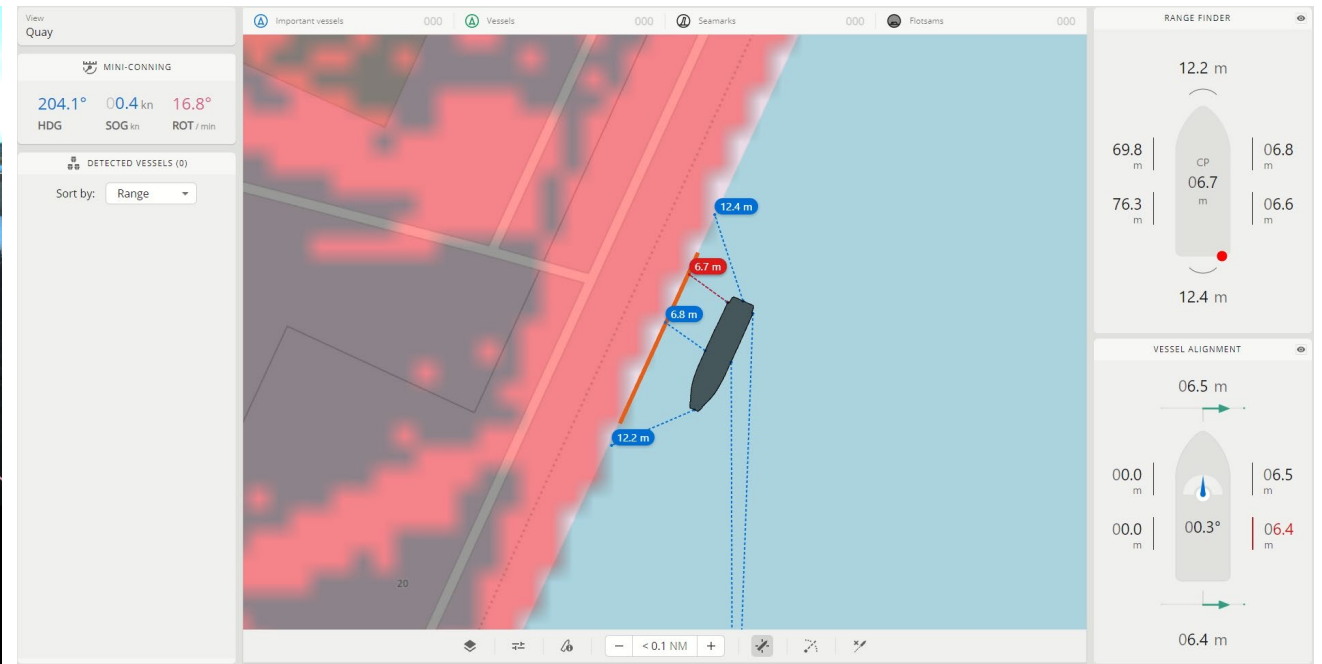
The original method was not enough to trigger the alert, but by adding a simple prerequisite of know geographic position of the quay, an additional integrity check could be added and successfully implemented.





# GSAB – KONGSBERG ONBOARD SENSORS – SUMMARY

In the GSAB project, Camera + GNSS + Attitude fusion have shown to be a viable solution for robust and accurate measurements relevant for assisting both human operators and as a sensor input for advanced digital solutions.



# GSAB – KONGSBERG Augmented Reality User Interface

## Test objectives

- **TC\_8:** Define through the test scenarios what information and guidance will be relevant to the user to optimize the use of the GSAB system and to avoid overload of information.
- **TC\_9:** Refine the user interaction to ensure that all necessary information and guidance is available to the user.
- **TC\_10:** Ensure that in the case of augmented reality (AR) headset, the user is still able to see through and work as normal.

## Tested

- Bridge Display with AR overlays
- AR user interface for head mounted devices

## Test methods

- User Centred Design Process
- Field Study
- Virtual Reality-Based Reconstructed Operations Scenarios” (VRROS)
- Collaborative Virtual Reality





# GSAB – KONGSBERG Augmented Reality User Interface

## Bridge wing



Bridge wing with AR graphics extending all the way to the users' position, with a fixed "display" over the bridge wing console.  
(Source: OCIL)

## Bridge



Bridge display with conning view with AR overlay on KMs camera cluster (KCC100 D) camera.  
(Source: OCIL)



Scenario model, showing the most critical steps & contexts in relation to the design cases  
(Source: OCIL)

## Process



(Sources: OCIL)

# GSAB – KONGSBERG Augmented Reality User Interface

## Test activities

| Date          | Category         | Topic                                                                                                                                                                                  | Participants                         | Participants                                                                                                                       |
|---------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| 2023-03-22    | Workshop         | Scenario walkthrough<br>Baseline development                                                                                                                                           | AHO (host)<br>Grimaldi<br>KM         | Design researchers.<br>Master + Operational<br>Management<br>Designers and engineers                                               |
| 2023-05-12-13 | Field study      | Field study to Grimaldi vessel in Antwerp                                                                                                                                              | Grimaldi (host)<br>AHO<br>KM         | Master & crew<br>Design researchers.<br>Innovation Manager                                                                         |
| 2023-09-05    | Workshop         | Setup & test of collaborative VR                                                                                                                                                       | KM (host)<br>AHO<br>Grimaldi         | Designer<br>Design Researcher<br>Operational manager                                                                               |
| 2023-09-15    | Workshop         | Field study results<br><br>Design review of new conning and AR user interface with navigation experts                                                                                  | KM (host)<br>AHO                     | Designers, Product<br>Advisors, and engineers<br>Design Researcher                                                                 |
| 2023-09-18    | Workshop         | Design review with masters                                                                                                                                                             | Grimaldi (internal)                  | Operational Manager<br>Three Masters                                                                                               |
| 2023-11-10    | Workshop         | Feedback from Grimaldi VR testing<br><br>Presentation of new designs and scenario model 2 based on Field study.<br><br>Review of new AR user interface design in VR                    | KM (host)<br><br>Grimaldi<br><br>AHO | Designers, System<br>Engineers, and Innovation<br>& Research managers<br>Masters + Operational<br>Management<br>Design Researchers |
| 2024-01-22    | Workshop (final) | Minimum sensor «pack» required and considerations for interface design.<br><br>Motion prediction discussion on needs vs possibility<br><br>VR session with feedback on the latest work | KM (host)<br><br>Grimaldi<br><br>AHO | Designers, System<br>Engineers, and Innovation<br>& Research managers<br>Masters + Operational<br>Management<br>Design Researchers |

## Test results

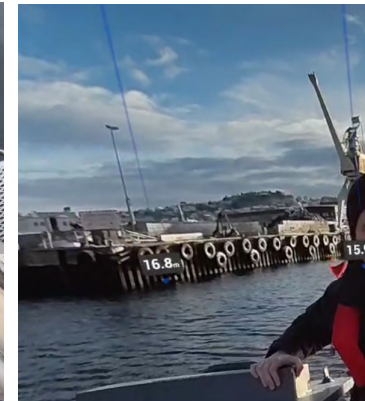
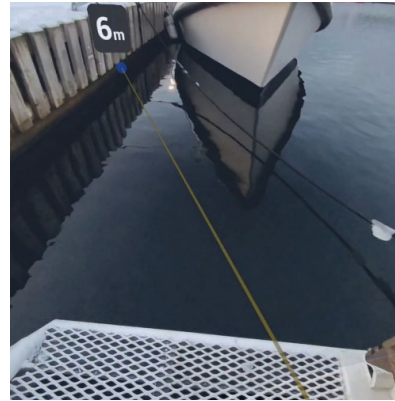
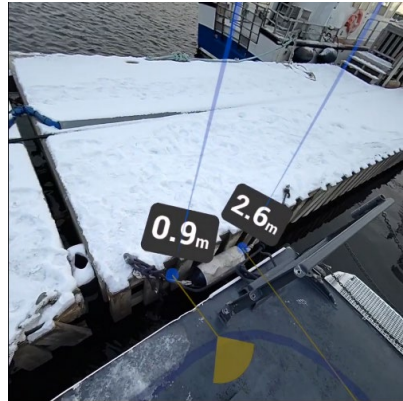
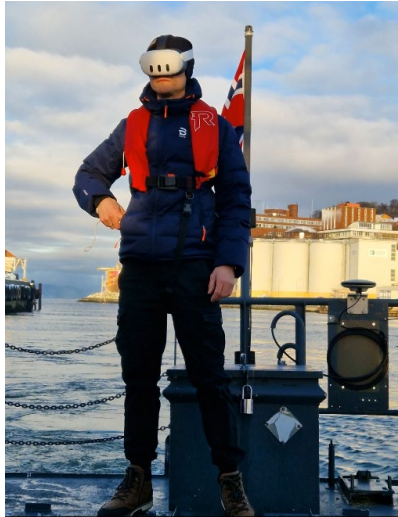
- ✓ **TC\_8: Define through the test scenarios what information and guidance will be relevant to the user to optimize the use of the GSAB system and to avoid overload of information.**
  - Relevant information has been derived from the design process in several steps, the scenario development process, the field study, a user centred design process, design reviews including the use of VR. The resulting design reflects both the process and the results.
  - The users centred design process has revealed that there is a limited amount of information needed, and that it can be presented in predefined layouts.
  - VR testing revealed that positioning of information also effects the amount of information that is both relevant and necessary.
- ✓ **TC\_9: Refine the user interaction to ensure that all necessary information and guidance is available to the user.**
  - The user interaction has been refined through the scenario model development, the field study, the user centred design process and the design reviews in 2D and VR, which included masters from Grimaldi, sailing on the actual vessels in the actual scenario.
  - Feedback from the users (masters) has been applied to the design to the possible within the project frame and without shifting towards physical in-situ testing.
- ✓ **TC\_10: Ensure that in the case of augmented reality (AR) headset, the user is still able to see through and work as normal.**
  - VR testing revealed that positioning of information effects the field of view towards the real world and towards instrument and devices.
  - By applying the principles of blocking graphics from overlaying certain areas and by positioning the essential graphics in a fixed position these issues are managed and becomes manageable, in theory. Further in-situ testing is needed to refine these principles.



# GSAB – KONGSBERG Augmented Reality User Interface. Live tests

View from inside AR goggles. Distance markers when berthing

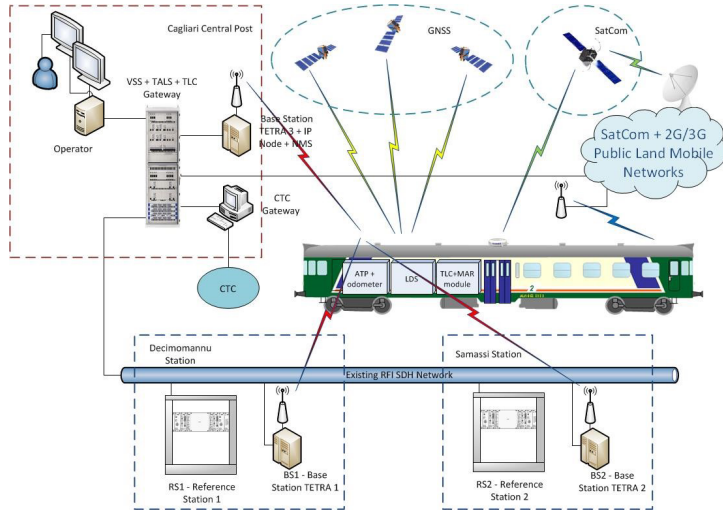
AR Headsets on



Test of «safety fence» when leaning over board



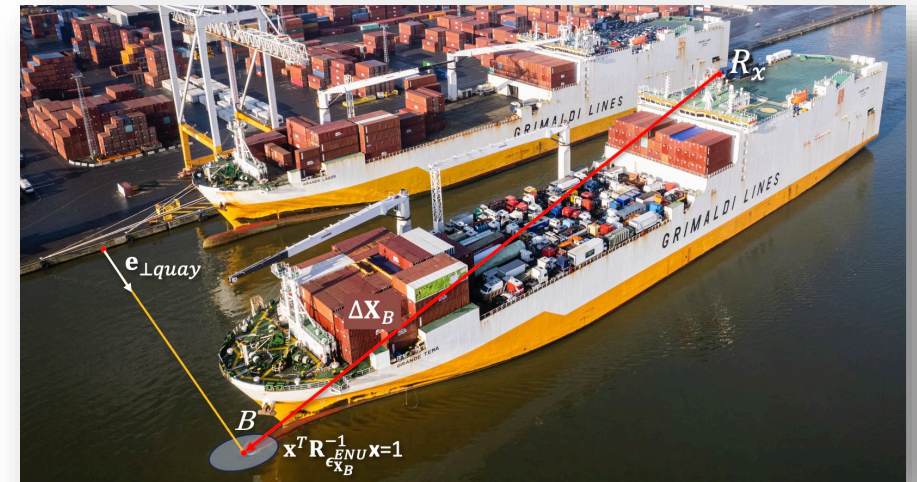
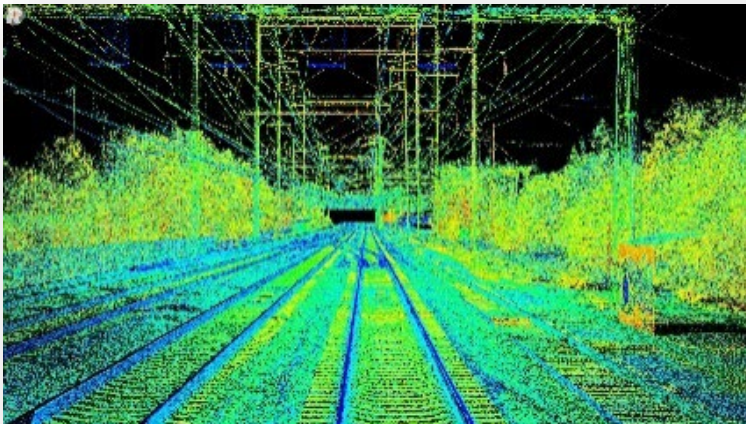
# GSAB – RADIOLABS MOTIVATIONS



How could RADIOLABS utilize the emerging technology from automotive and rail domains to maritime ones?



Partner with an innovative shipowner to investigate how to validate the autonomous berthing process



The Grimaldi satellite assisted berthing (GSAB) is focusing on the domain of assisted and autonomous shipping in the proximity of seaport.

RADIOLABS is a research facility that contribute to GSAB project by investigating and prototyping a reference ground truth for assisting berthing. This included:

- Definition of user and systems requirements
- Integration and fusion of GNSS, IMU, and LIDAR to provide accurate positioning and ranging data with high accuracy

With a corresponding result of:

- Validation of the GSAB berthing system

The RADIOLABS group located in Rome was involved in the project, having the following responsibility

- Project Management support in any administrative and financial aspects of the project
- Responsible for coordination of User needs definition and specification of the requirements at system and subsystem level
- Definition, design and implementation of the Ground Truth concept and methodology for its computation



# GSAB – RADIOLABS USER/SYSTEM REQUIREMENTS

User requirements (UR) was organized according to the GSAB Segments

System requirements (SR) was developed accordingly to user requirements

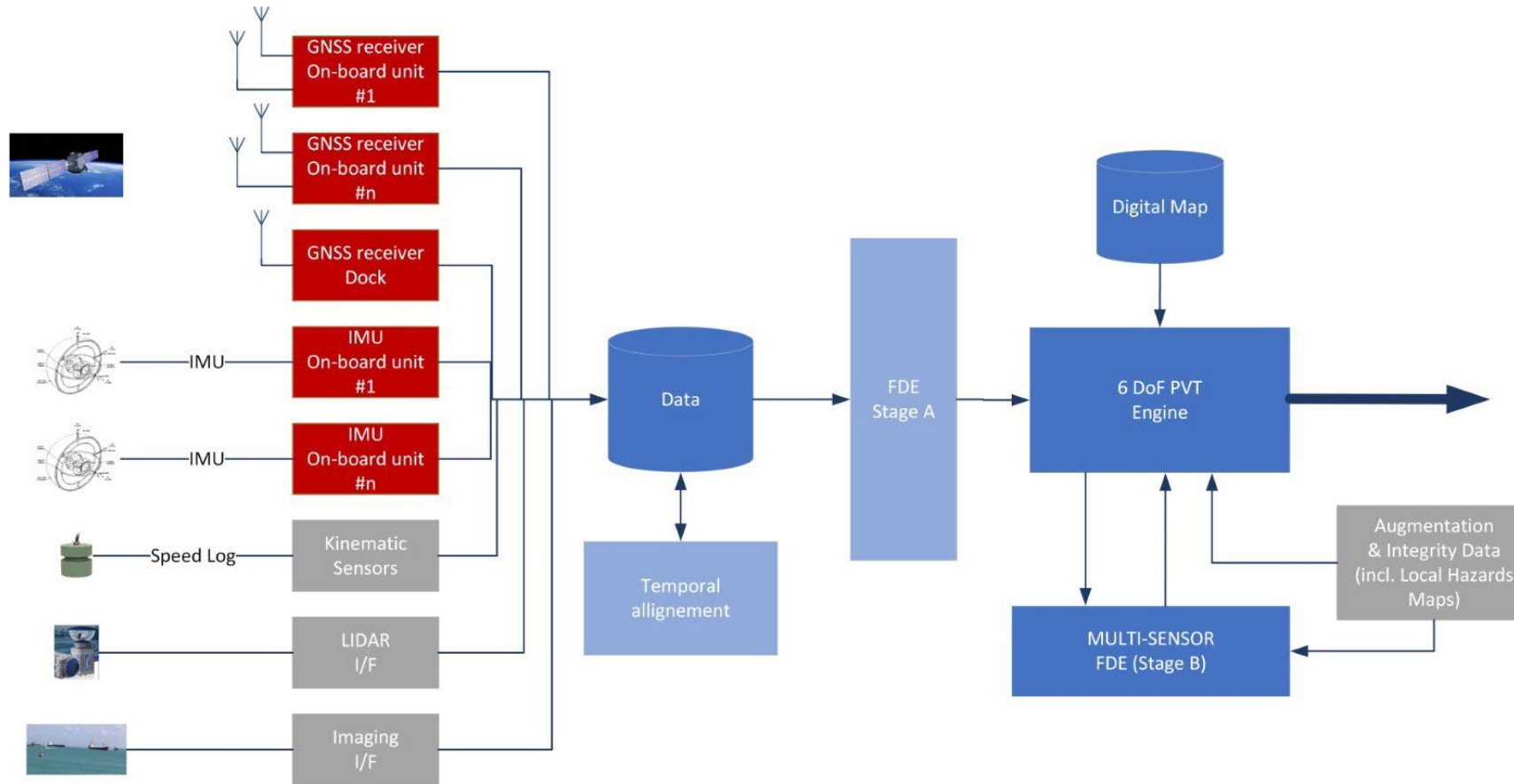
A track matrix was set up to show that dependencies among User and SR

| Requirement Identifier | Requirement denomination      | Requirement description                                                                                                                                               |
|------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UR-001                 | Assisted berthing             | Development and testing of an integrated system used for assisted increase in safety and efficiency of ship manoeuvres within port waters including the docking phase |
| UR-002                 | Advanced berthing system      | To develop a system that suggests the best path for berthing on the background experience in past events                                                              |
| UR-003                 | Berthing time forecast        | The system should be able to estimate the time of approach to the departure/arrival time.                                                                             |
| UR-004                 | Space optimization            | Optimization of space to manoeuvre                                                                                                                                    |
| UR-005                 | Traffic control               | Traffic control in near-port waters                                                                                                                                   |
| UR-006                 | Advanced Collision avoidance  | To develop a system capable to provide how many meters of distance from the berth to the hull of the ship in real-time                                                |
| UR-007                 | Awareness display             | Awareness display (on the ship), showing the real-time situation on the marine weather forecast in the last maritime mile                                             |
| UR-008                 | AR based awareness and advice | Explore and test how to achieve higher awareness and advice provided by the use of AR goggles/tablet                                                                  |
| UR-009                 | Time saving                   | Achieve improved efficiency for entry and exit from the port                                                                                                          |

| Requirement Identifier | Requirement denomination     | Requirement description                                                                                                                                                                                                              |
|------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| System REQ 1           | Open sea service support     | Connectivity between Ship-side and Shore-side (AET terminal) is supported to ensure continuity of service in the open sea scenario                                                                                                   |
| System REQ 2           | Visualization                | The GSAB System visualizes in real time all information available (from AIS, VTS, etc.)                                                                                                                                              |
| System REQ 3           | Alert notification           | The GSAB System notifies an alert in case of deviation from the recommended route                                                                                                                                                    |
| System REQ 4           | Alarm notification           | The GSAB System elaborates the current situation by generating a periodic deterministic and short timeframe (after proper boot procedure has completed)                                                                              |
| System REQ 5           | Positioning accuracy         | The GSAB System reaches a positioning accuracy of the vessels in port of 1 meter in the horizontal plane                                                                                                                             |
| System REQ 6           | Optimal route                | The GSAB System shall be able to generate an optimized route, considering waypoints, to approach the port and the mooring quay.                                                                                                      |
| System REQ 7           | Route constraints            | During the generation of the route, the GSAB System shall take into account the ship's dimensions, the direction to be maintained, the maneuvers needed to approach the quay and the physical and structural constraints of the port |
| System REQ 8           | Route information            | The GSAB System during the generation of the route shall take into account marine information, the information processed by advanced positioning systems                                                                             |
| System REQ 9           | Route Graphics visualization | The GSAB System must implement a graphical interface able to visualize: 1) the recommended route; 2) the current weather conditions; 3) the time of arrival on the quay; 4) deviations from the current route                        |
| System REQ 10          | Berth information            | The GSAB system relies on information about destination berth, its status of occupancy                                                                                                                                               |

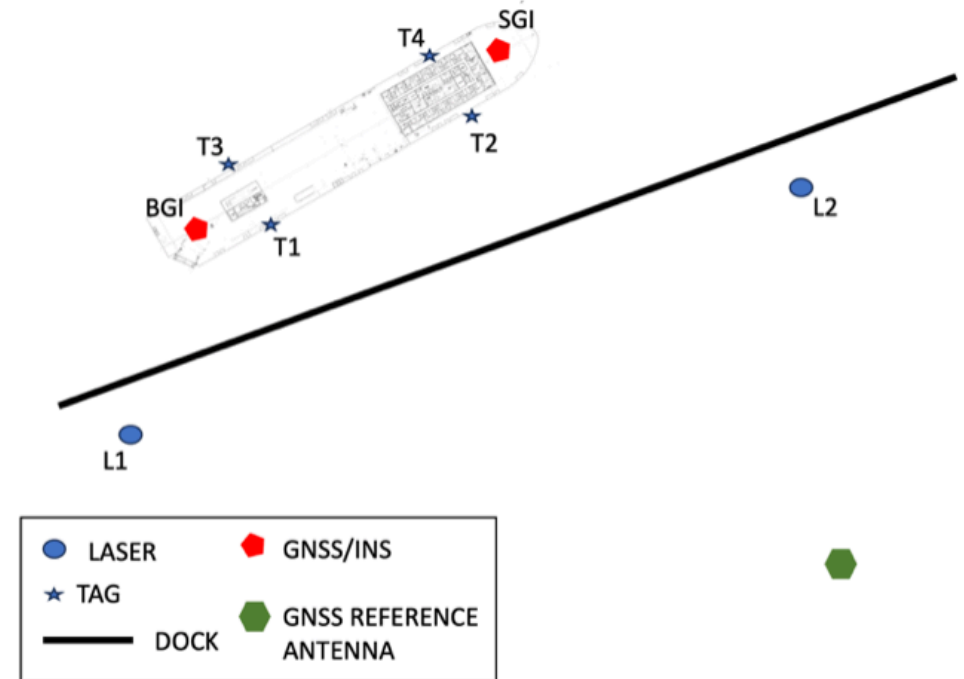


# GSAB – RADIOLABS RGT ARCHITECTURE

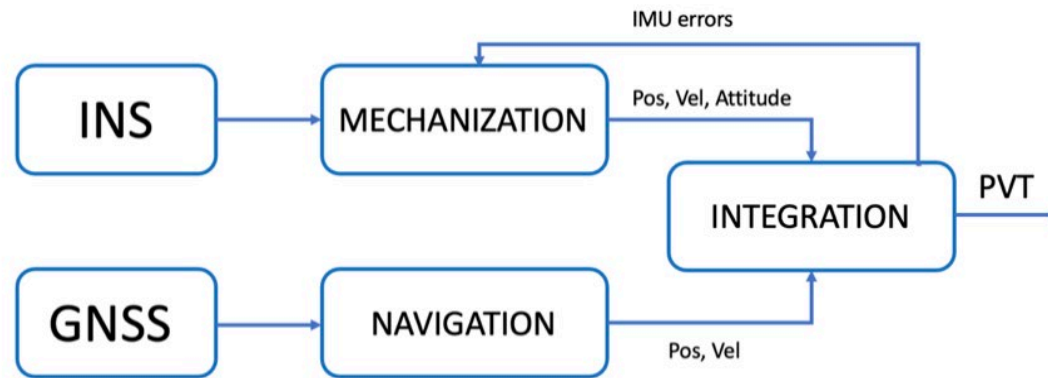


# GSAB – RADIOLABS RGT DEPLOYMENT

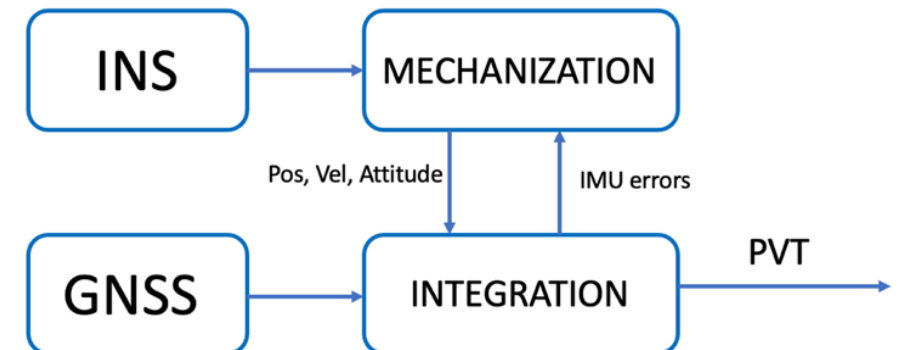
- ☐ Bow GNSS/INS system
  - 1 INS, 2 GNSS Antenna
  - 1 GNSS receiver
- ☐ Stern GNSS/INS system
  - 1 INS, 2 GNSS Antenna
  - 1 GNSS receiver
- ☐ 2 LIDAR on dock
- ☐ 1 GNSS Antenna and receiver on dock (ground/reference antenna).



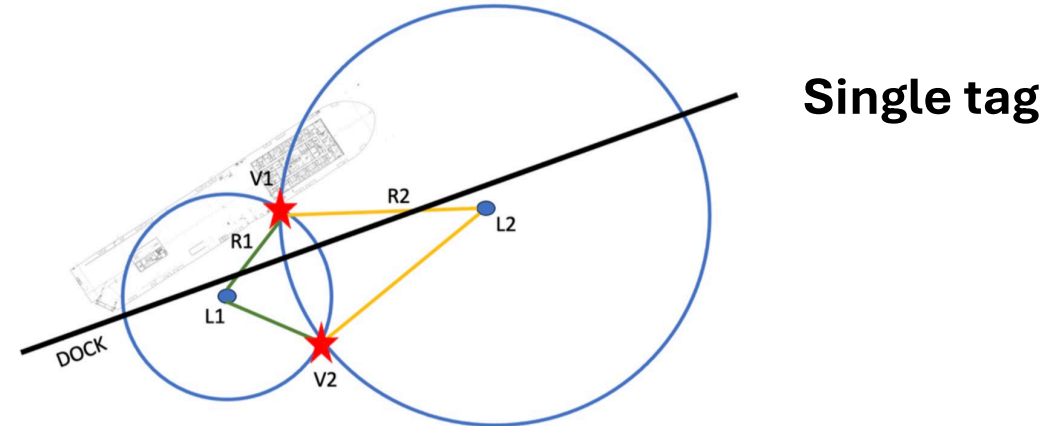
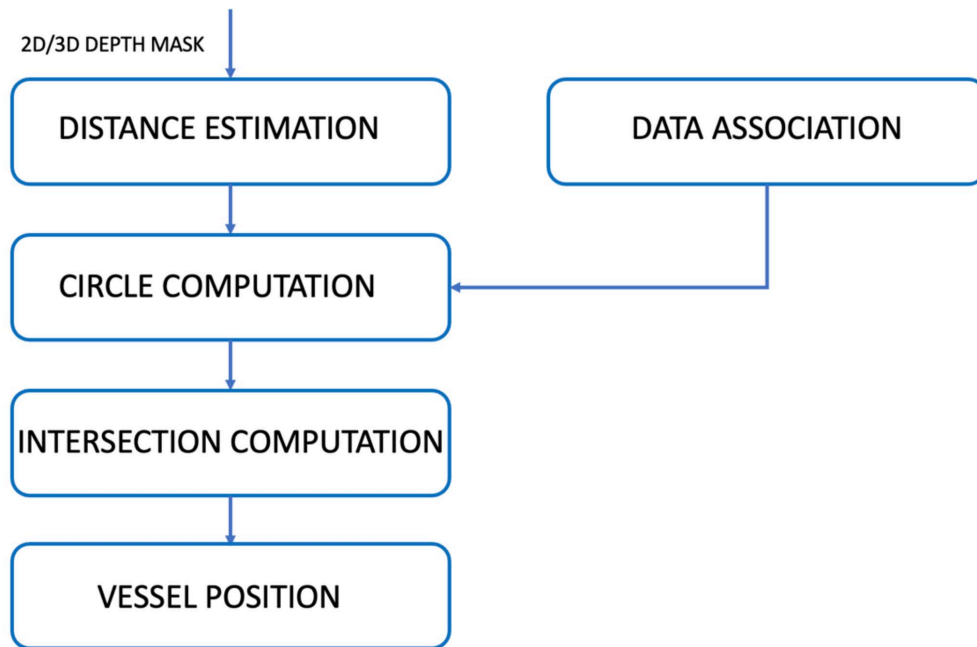
## □ Loosely-coupled algorithm



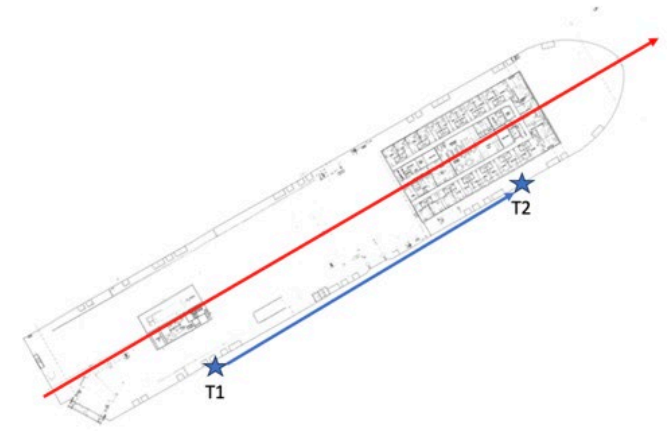
## □ Tightly-coupled algorithm



## LIDAR fusion algorithm

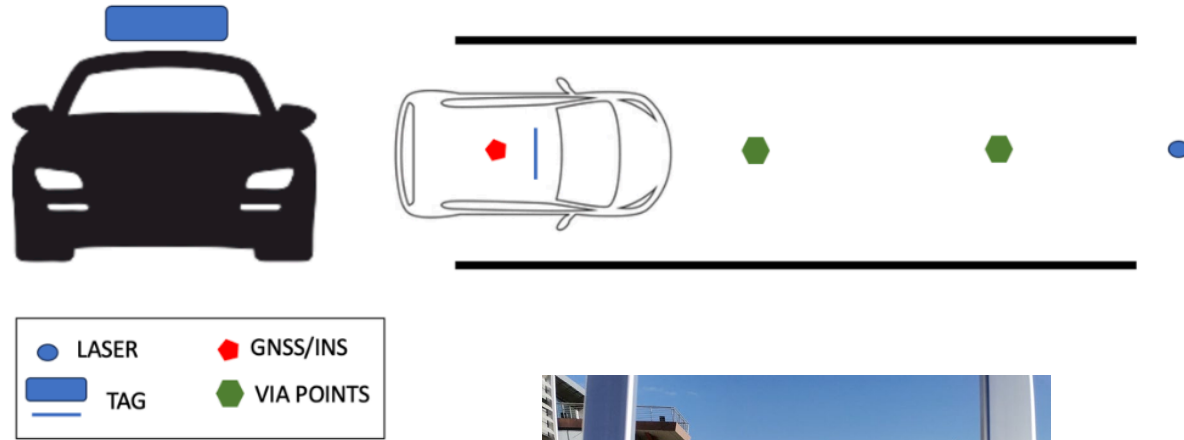


## Multiple tags

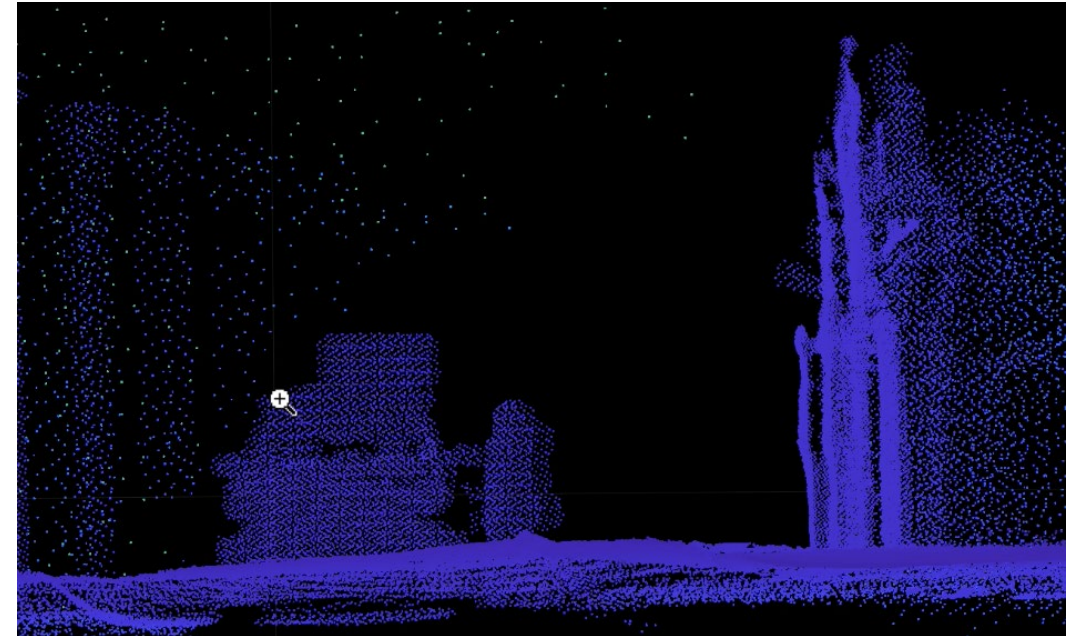
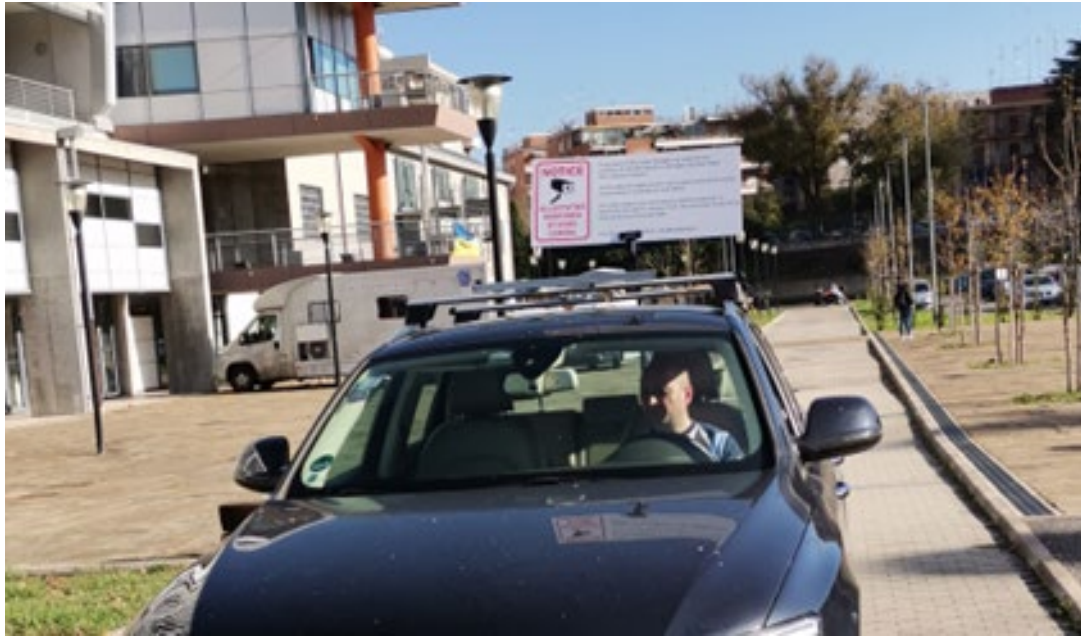




# GSAB – RADIOLABS RGT AUTOMOTIVE SCENARIO



# GSAB – RADIOLABS RGT LIDAR CLOUD POINT



# GSAB – RADIOLABS RGT TEST RESULTS

## Test objective

- Verify the reliability of Lidar in identify a tag in automotive set up
- Verify the max distance for identifying a tag in automotive set up

## Test steps

- Move the car to a via point and stop
- Retrieve data from LIDAR
- Repeat 1-2 until the last via point
- Post-processing:
- Extract the point clouds related to a via point
- Identify the tag in the point cloud
- Compute the distance from the tag

## Expected results

- Number of fault detection and exclusion events for LIDAR: < 50% of frames related to a stop event on a via point in the point cloud recordings of the tag
- Number of tags detected: 1
- Number of bad data association from LIDAR measurements: <10% of points in the frames related to a stop event on a via point.
- Number of position points rejected due to accuracy: <50% of points in the frames related to a stop event on a via point describing a tag

## Actual results

- Number of fault detection and exclusion events for LIDAR: < 50% of frames related to a stop event on a via point in the point cloud recordings of the tag
- Number of tags detected: 1
- Percentage of position points rejected due to accuracy or bad data association: <50% of points in the frames related to a stop event on a via point describing a tag

## Passed/Failed

Passed

## Comment

The overall results are promising and verify the effectiveness of the use of the LIDAR as a positioning measurement. However, the dimension of the tag and the number of tags needs to be adapted to maritime scenario.

| Via Point | Ground Truth [m] | Mean Value [m] | Estimate error [m] | # Frame tot | # Frame discarded | % of points discarded |
|-----------|------------------|----------------|--------------------|-------------|-------------------|-----------------------|
| 7         | 107,49           | 107,43         | 0,05               | 6           | 5                 | 60%                   |
| 6         | 92,97            | 93,03          | -0,06              | 7           | 4                 | 60%                   |
| 5         | 78,81            | 78,90          | -0,11              | 8           | 5                 | 50%                   |
| 4         | 52,63            | 52,53          | 0,10               | 8           | 3                 | 30%                   |
| 3         | 40,74            | 40,66          | 0,08               | 7           | 3                 | 10%                   |
| 2         | 29,26            | 29,29          | -0,03              | 9           | 4                 | 14%                   |
| 1         | 17,70            | 17,67          | 0,03               | 10          | 4                 | 10%                   |

The results in the table show that when the tag is well identified, the location estimate satisfies UR-022





## Article ESA Main Channel

[https://www.esa.int/Applications/Navigation/Navigating\\_the\\_sea\\_from\\_space\\_with\\_innovative\\_technologies](https://www.esa.int/Applications/Navigation/Navigating_the_sea_from_space_with_innovative_technologies)

## NAVISP Website

<https://navisp.esa.int/news/article/Navigating%20the%20sea:%20A%20partner%20ship%20between%20Space%20and%20Water>

## GRIMALDI Website

[https://www.grimaldi.napoli.it/pdf/pr\\_esa\\_grimaldi\\_agreement\\_1662658860.pdf](https://www.grimaldi.napoli.it/pdf/pr_esa_grimaldi_agreement_1662658860.pdf)

## Transport Cluster

[ESA e Gruppo Grimaldi: da Napoli ad Anversa la sfida delle navi a guida autonoma - Cluster Trasporti](#)

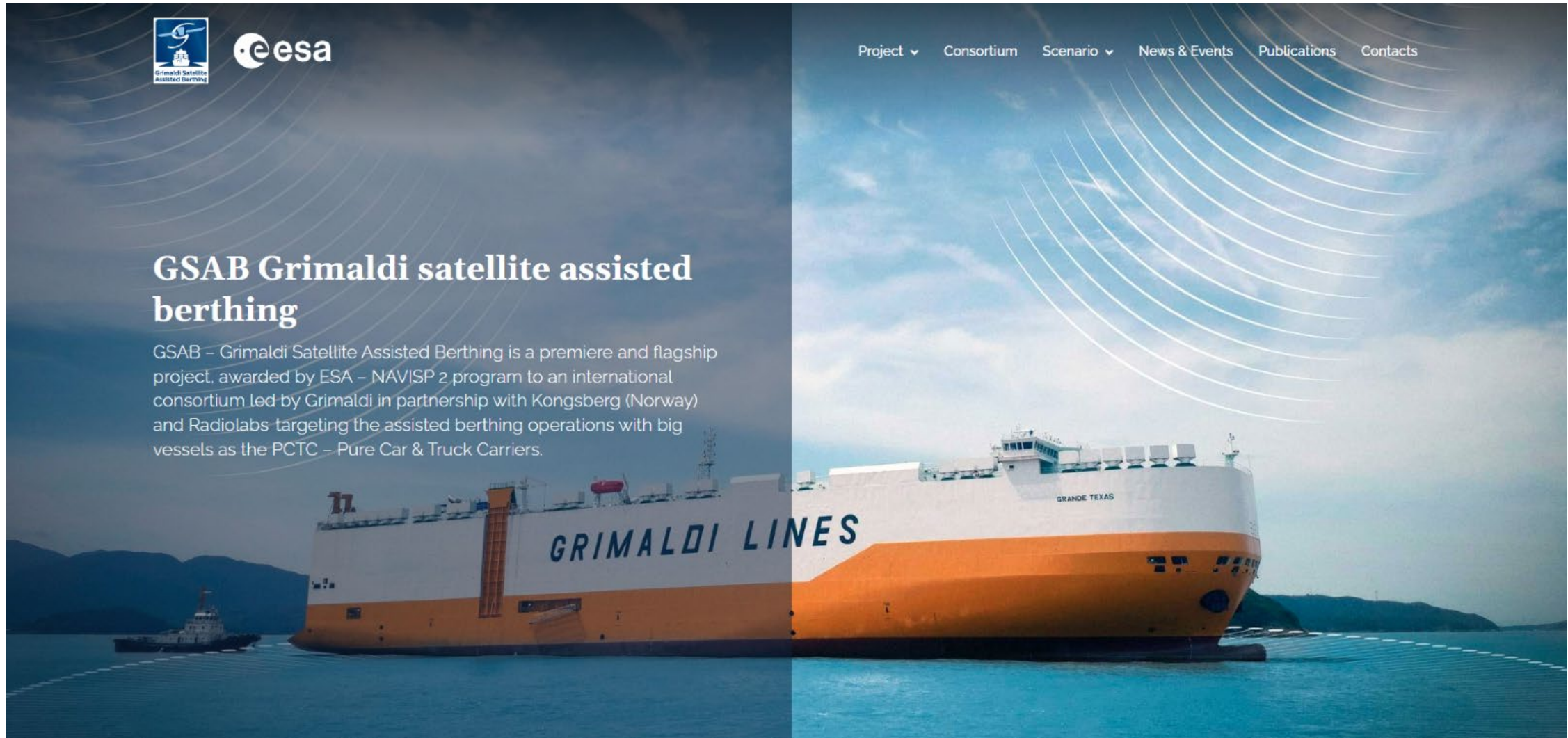
## GPS World

[ESA's NAVISP partners with Grimaldi Group - GPS World : GPS World](#)

## GSAB Web site

<https://gsab.grimaldi-app.com/>





# GSAB – CONCLUSIONS & ACHIEVEMENTS

GSAB results set the latest PNT technologies into a new product to navigate disruptive changes through a commitment between key stakeholders to creating the conditions for further actions in response to market take-off.

The proposed methodology integrates, in a single solution, functionalities and capabilities.

The integration of state of art technologies for data aggregation, processing, prediction, display and control is exploited by the proposed system resulting in a disruptive approach in the field of Autonomous Surface Ship management in a port scenario.

The following benefits have been analyzed respect the current state of art and competitor solutions:

- Saving in pilot call costs;
- Saving in insurances fees;
- Vessel stopping saving time;
- Saving in maintenance costs;
- Saving in fuel consumption costs;
- Benefit for Port Authority;
- Improve Safety;





# GSAB – FUTURE WORKS

## **GSAB2** already started!

GSAB2 – Grimaldi Satellite Assisted Berthing 2 is a premiere and flagship project, awarded by ESA – NAVISP 2 program targeting the assisted berthing operations with big vessels as the PCTC – Pure Car & Truck Carriers.

GSAB2, which is the evolution of the previous successful project GSAB, considered as a Best practice for the maritime sector, will demonstrate autonomy level 2 and will study the prerequisites for reaching autonomy level 3. GSAB2 will adopt the latest innovations on satellite-based multi-sensor technologies, previously studied and will contribute to improve the efficiency of manoeuvres in port and will continue to increase the safety while reducing CO2 emissions in line with the strategy of a greener and safer maritime transport. In addition GSAB2 will also develop advanced algorithms based on Artificial intelligence and interface the functions of the Ship Automation system.



Thanks to ESA NAVISP Element II Team  
for the support and cooperation

