KU LEUVEN

Use of Uncertainty Zones for Vessel Operation in Inland Waterways

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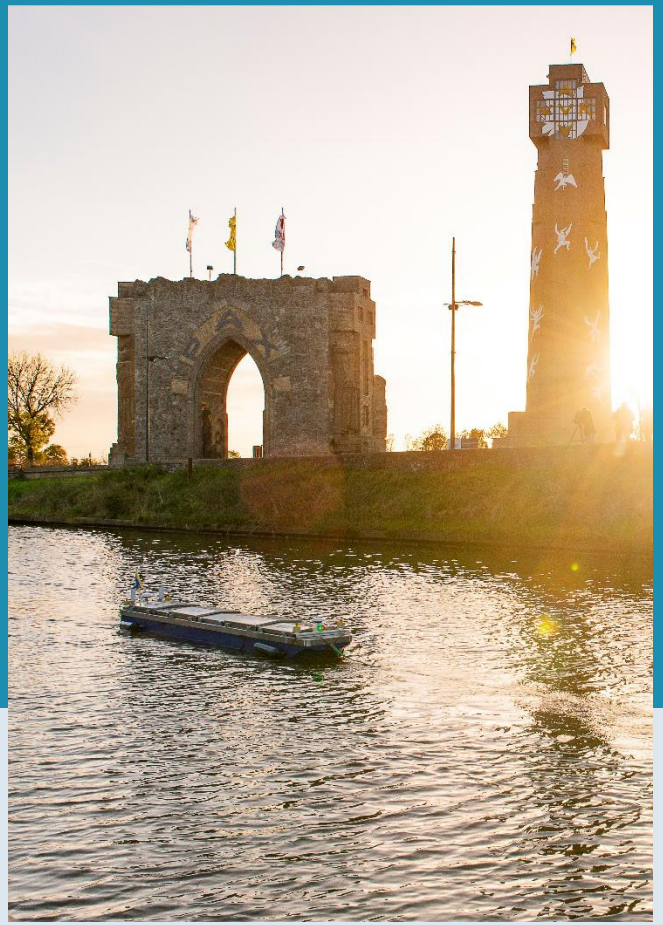


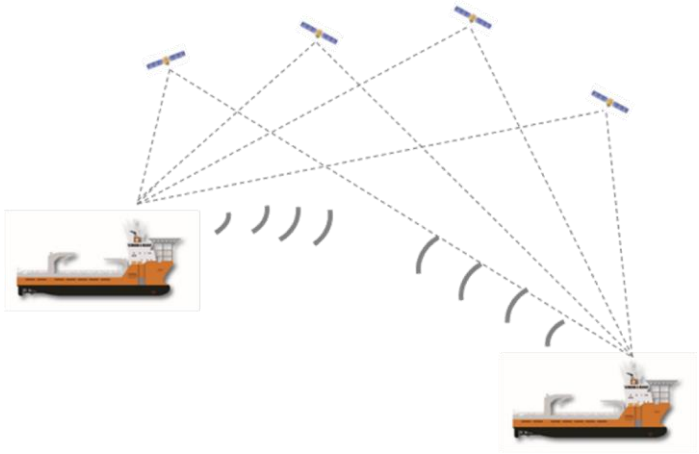
Intelligent Mobile Platforms
Faculty of Engineering Technology

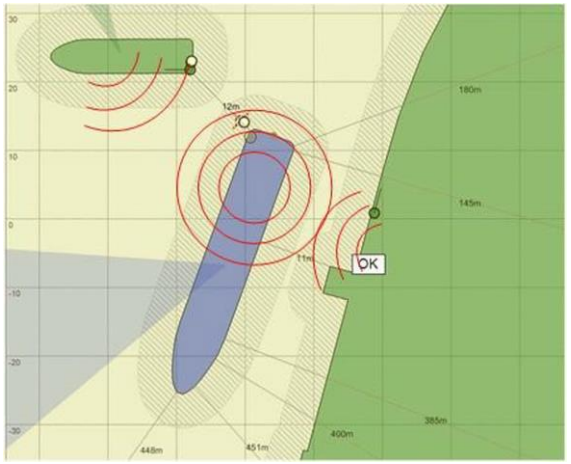
Overview

- H2H project
- W+ scale model
- H2H approach
- Future work

H2H project

- H2020-IA (Nov 2017 - Nov 2020)
- GNSS based marine autonomy
- H2H module
  - Relative positioning & velocities
  - Geometry of vessels





images courtesy of Kongsberg Seatex

KONGSBERG SINTEF KU LEUVEN

KU Leuven use case: Inland shipping

HULL TO HULL

- Single handed sailing:

Regular sailing

Docking

Lock passing

Scale model “Cogge”

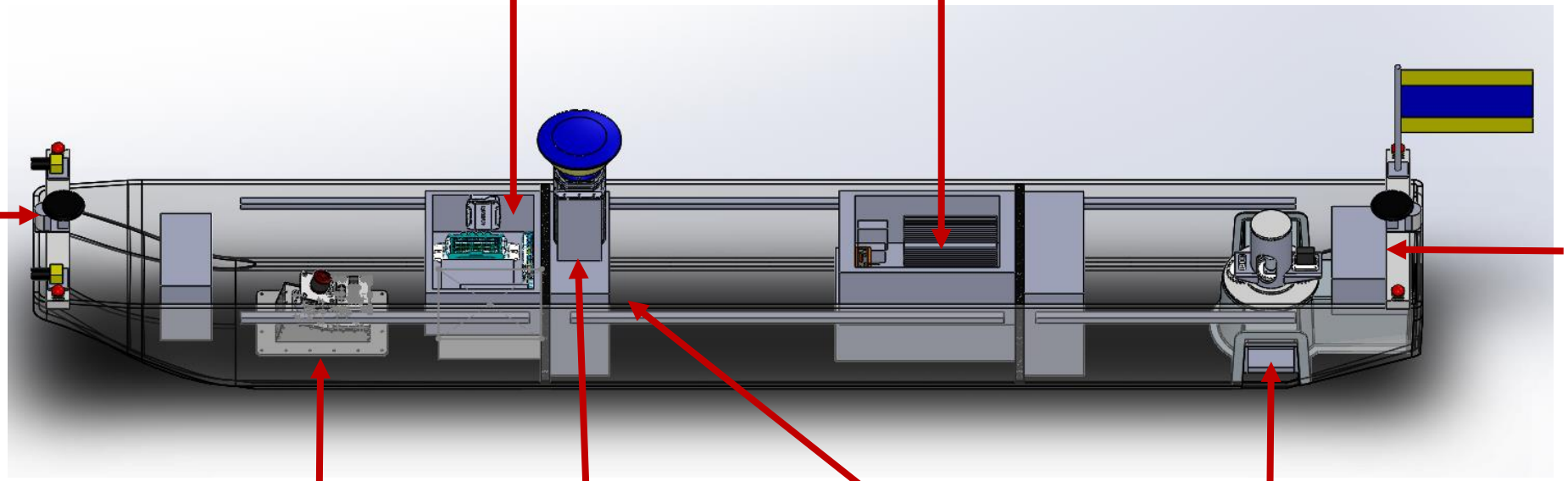
- Based on the CEMT1
- Full sized vessel: 400 – 650 tons, 38m length, 6.6m breadth.
- Scale Model: 1/8 scale, 425kg, 4.8m length. 0.64m breadth.
- Hull made of fiberglass epoxy mixture.

Scale model “Cogge”

Power System Box

Sensor & IPC Box

Bow Sensor Bar: camera, nav-lights, GNSS antenna, E-stop

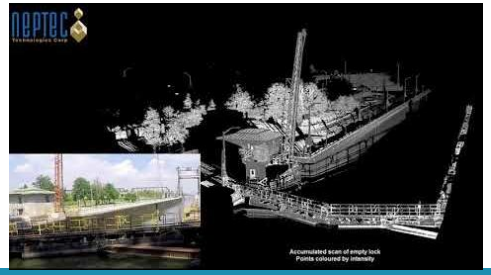


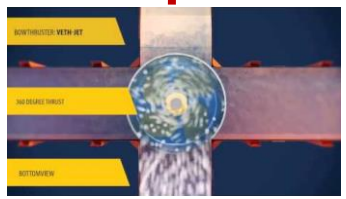
Stern Sensor Bar: light, GNSS antenna, E-stop, flag

LIDAR

Power System Box

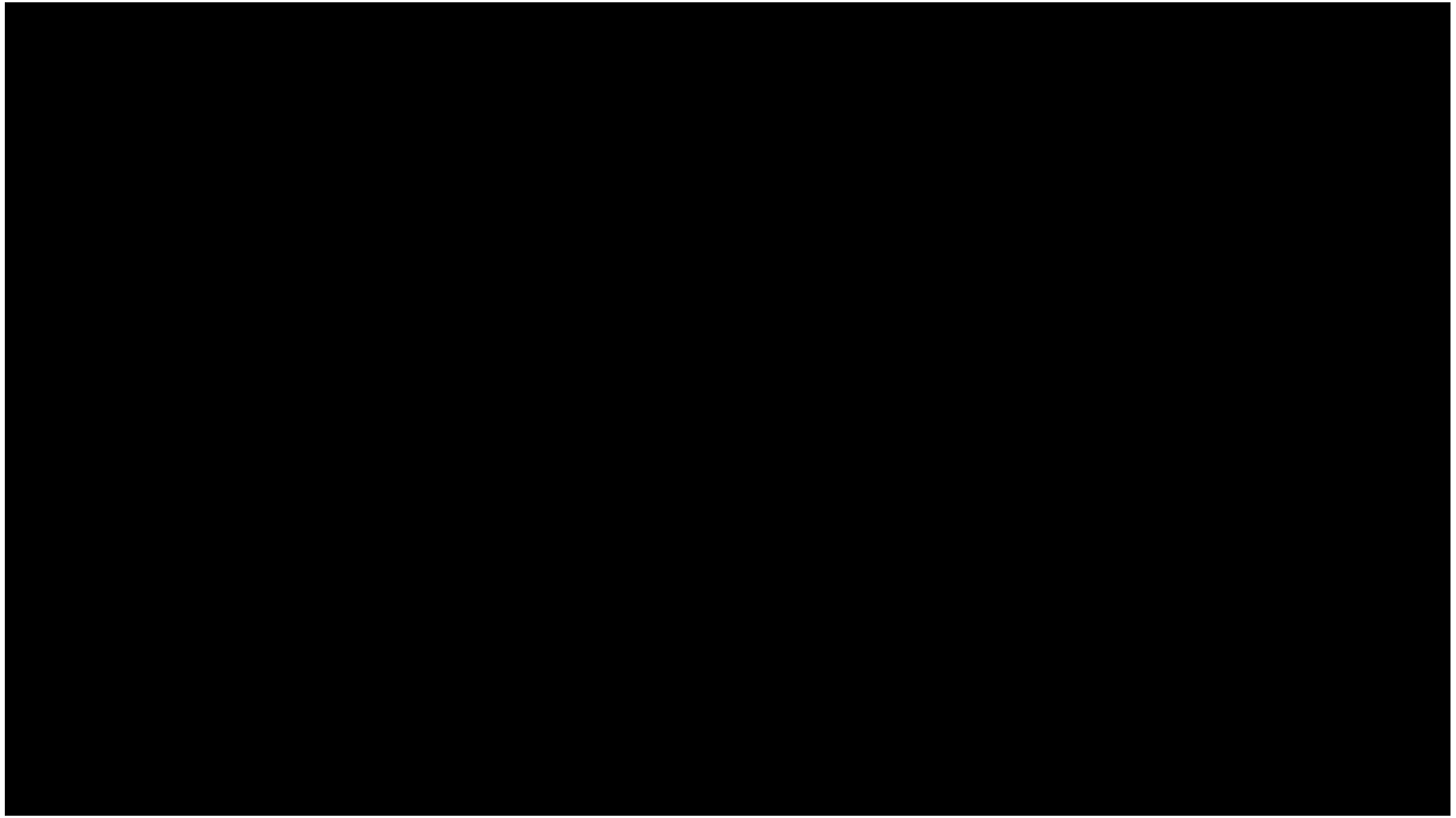
Bow Thruster





4-Channel Thruster

Cogge

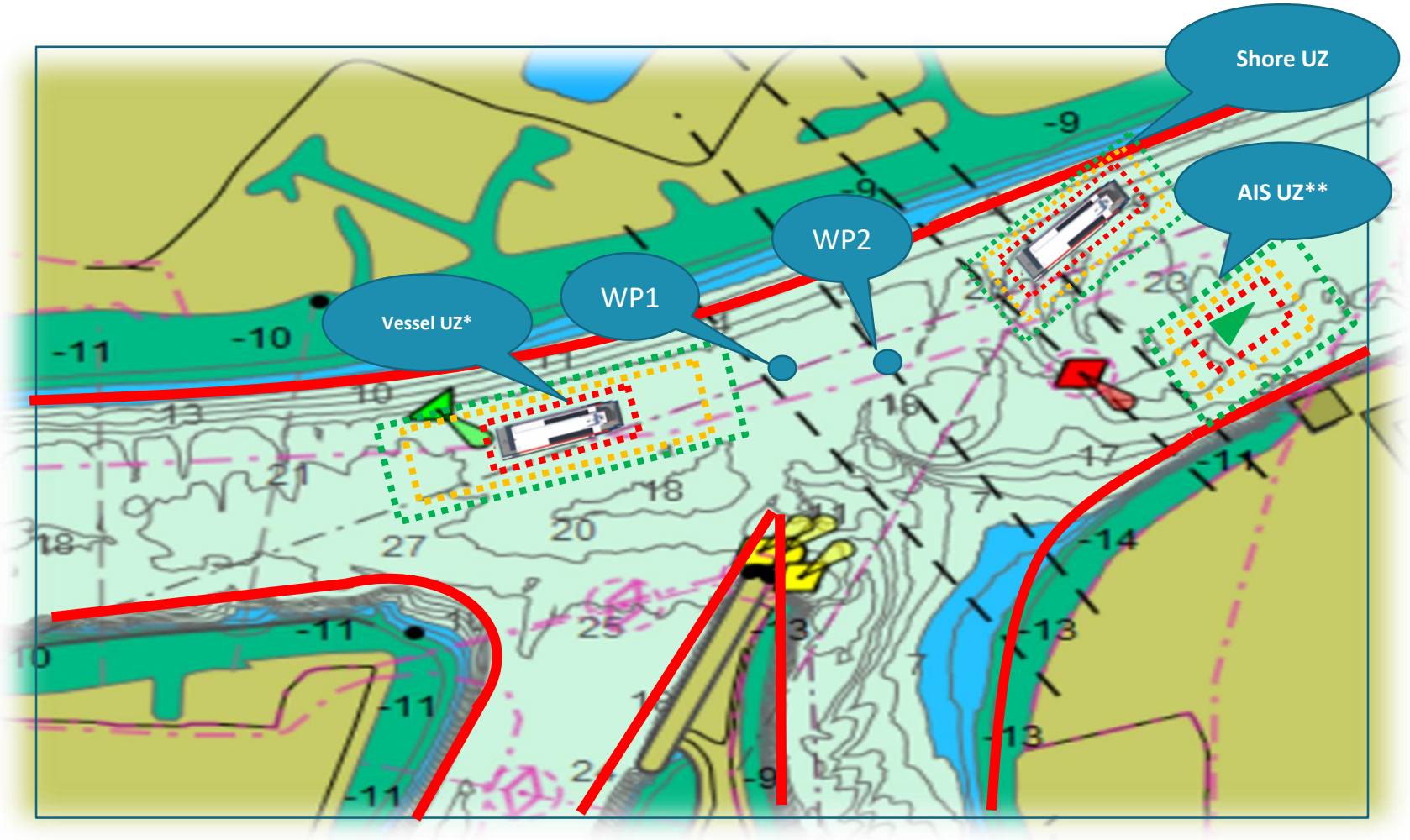


H2H Visualization Vessel Module

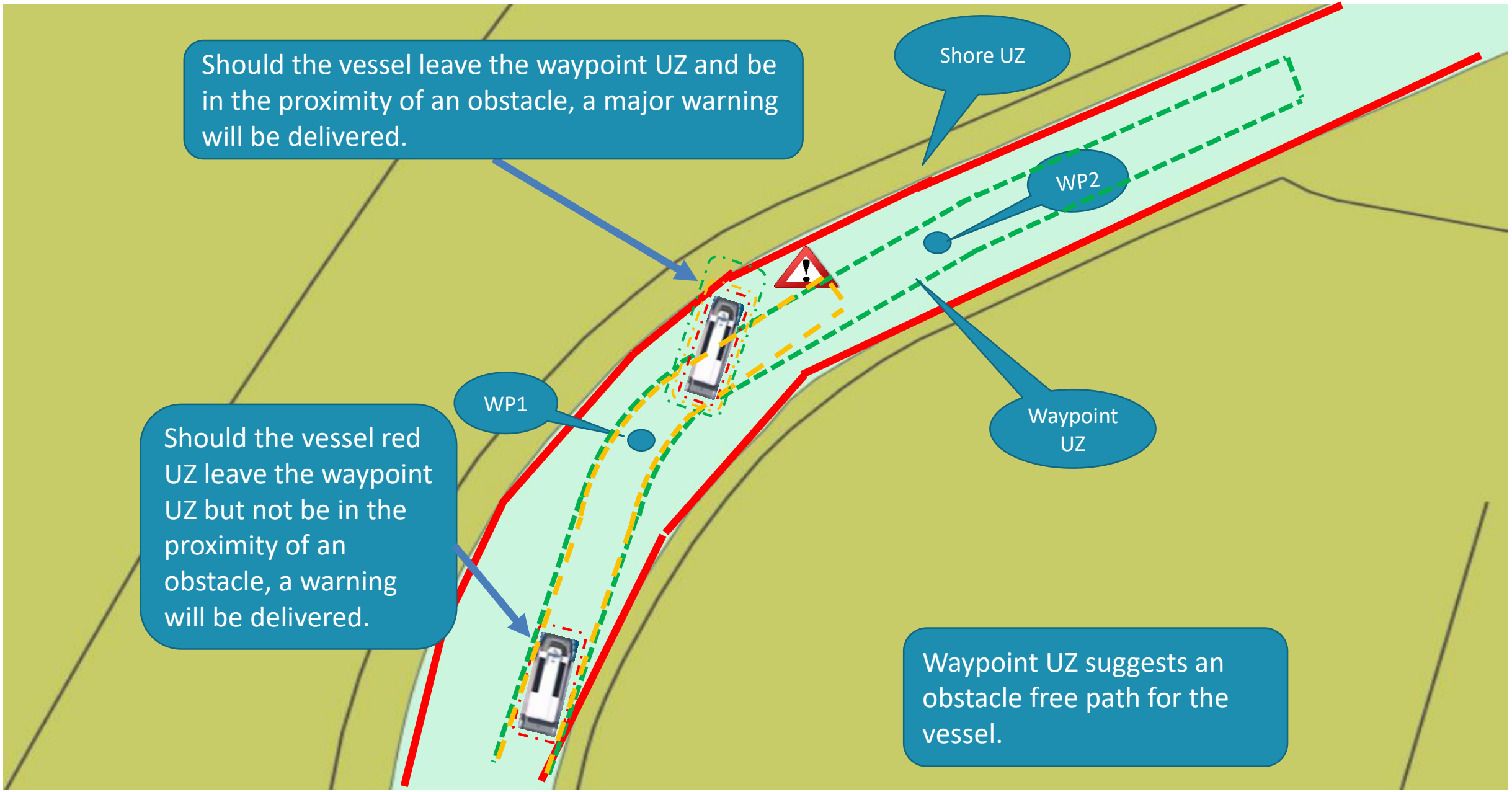
H2H Shore Module

H2H inland visualisation

- Augmented ECDIS
- Static Uncertainty zones (red).
  - Vessels
  - Shore - obstacles
- Dynamic Operational zones
  - Tracking zone (green)
  - Danger zone



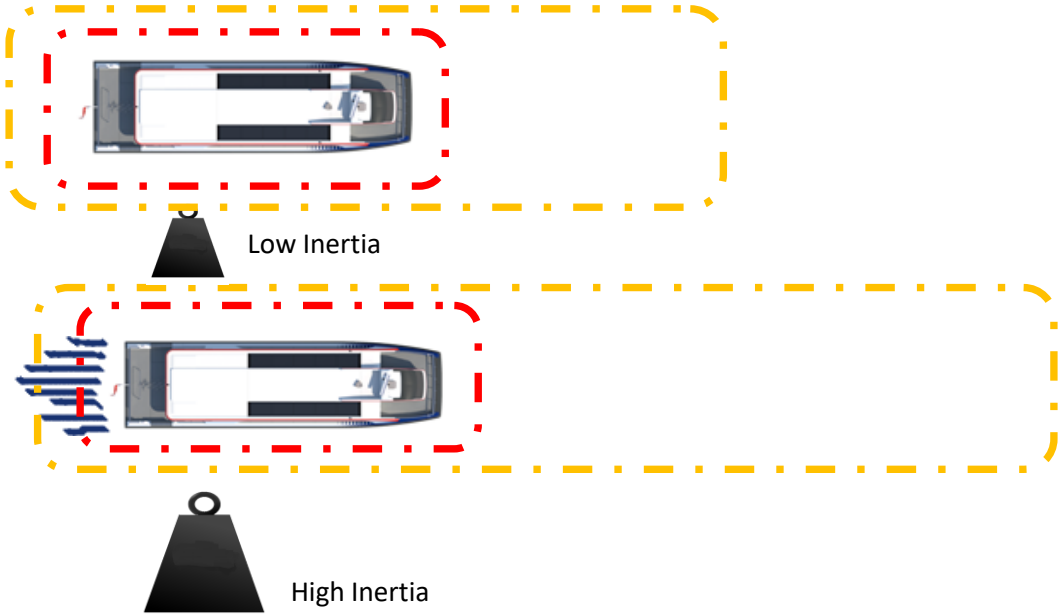
*H2H Vessel
**Non H2H Vessel


Should the vessel leave the waypoint UZ and be in the proximity of an obstacle, a major warning will be delivered.
Shore UZ
WP2
WP1
Waypoint UZ
Should the vessel red UZ leave the waypoint UZ but not be in the proximity of an obstacle, a warning will be delivered.
Waypoint UZ suggests an obstacle free path for the vessel.

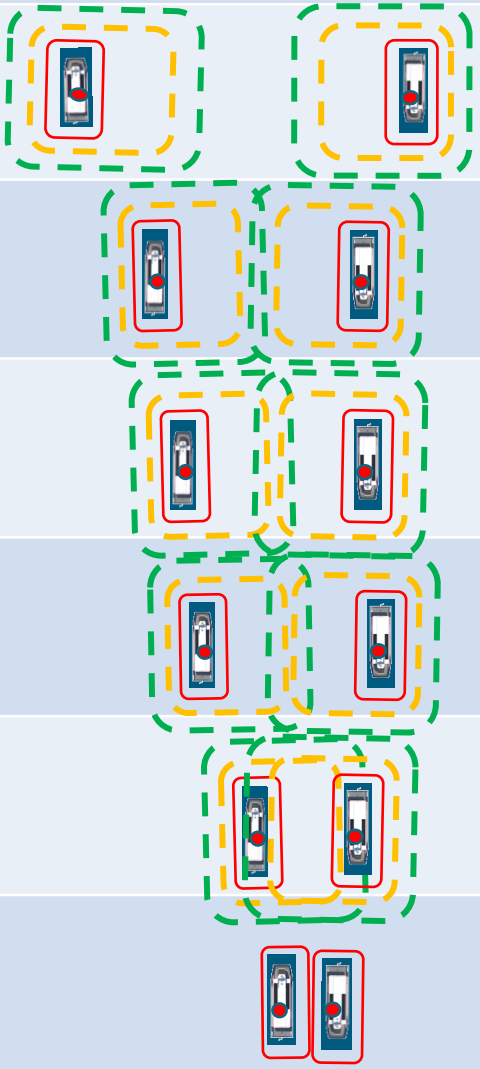
Operational Zones

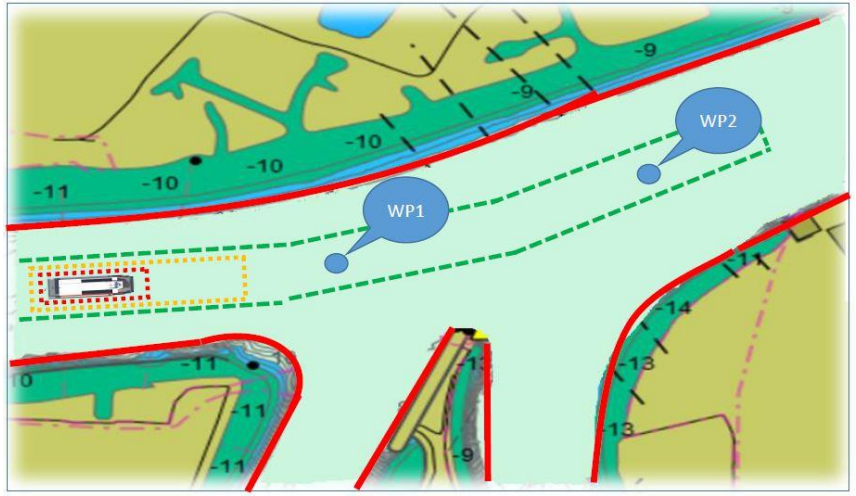
- Vessel dynamics, sensor and map accuracy, which will predict large stopping distance (high speed, large mass), will generate a larger OZ and vice versa.
- In the diagram below, it is assumed that the vessels are travelling in a straight line, hence the box-shaped operational zone. Should the vessel be turning, the proximity zone will change shape accordingly based on the rate of turn.

Dynamic OZ for different vessel dynamics

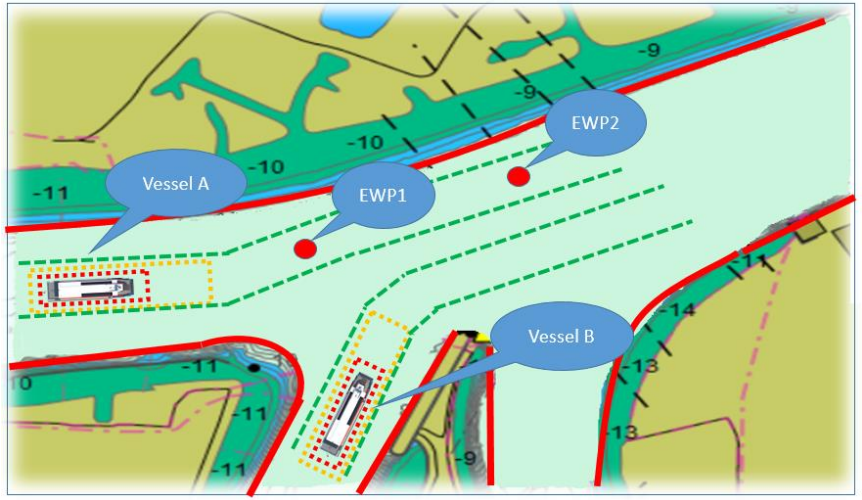


UZ Procedure for Sailing

Warnings H2H module	UZ Intersection	UZ Situation
1. No warning	None	
2. Start tracking the object in the green zone	Green – Green	
3. Raise L1 warning and suggest evasive maneuver	Green – Orange	
4. Raise L2 warning for collision if no action is taken	Orange – Orange	
5. Raise L3 warning for collision is imminent if no action taken by both vessels	Orange – Red	
6. Collision has happenend	Red – Red	

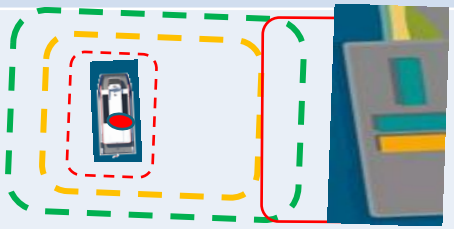
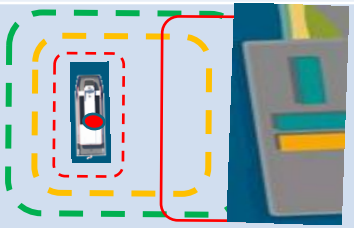
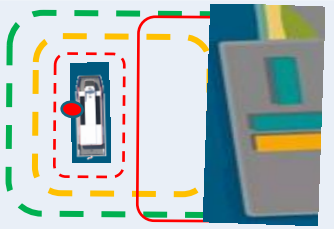
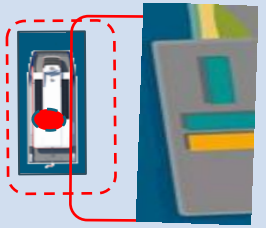


General sailing with waypoints



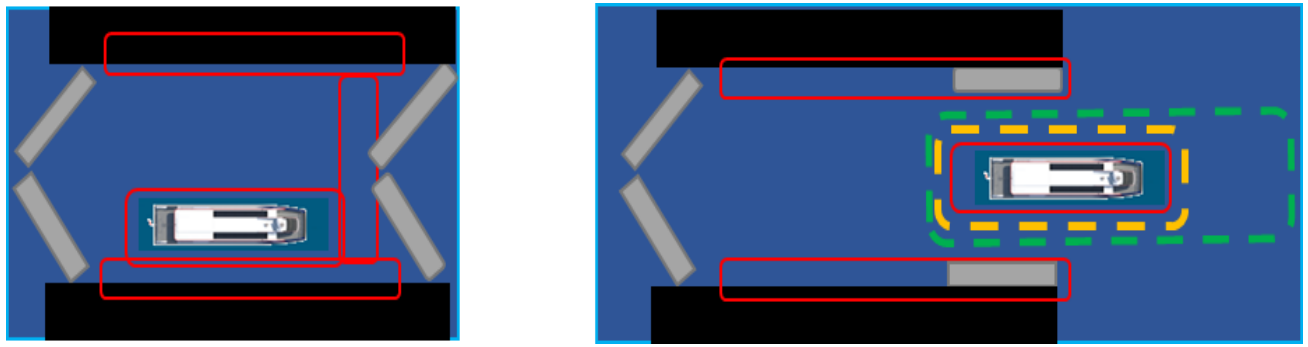
Sailing with H2H object detected

UZ Procedure for Docking/Lock Passing*

Warnings H2H module	UZ Intersection	UZ Situation
1. No warning	None	
2. Velocity and heading suggestions for efficient docking	Green – Red	
3. Suggest gradual deceleration	Orange – Red	
4. Docking complete (Contact sequence)	Red – Red	

*Similar conventions for lock passing

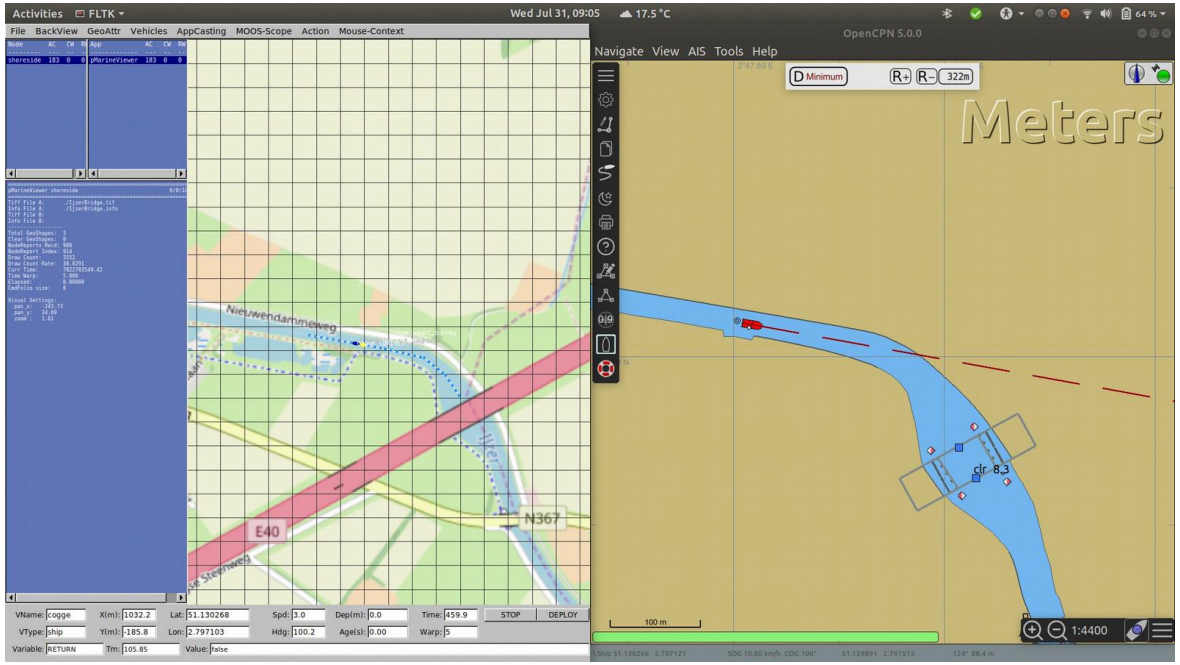
Lock Approach Procedure



Lock Docking and Departure

OpenCPN viewer

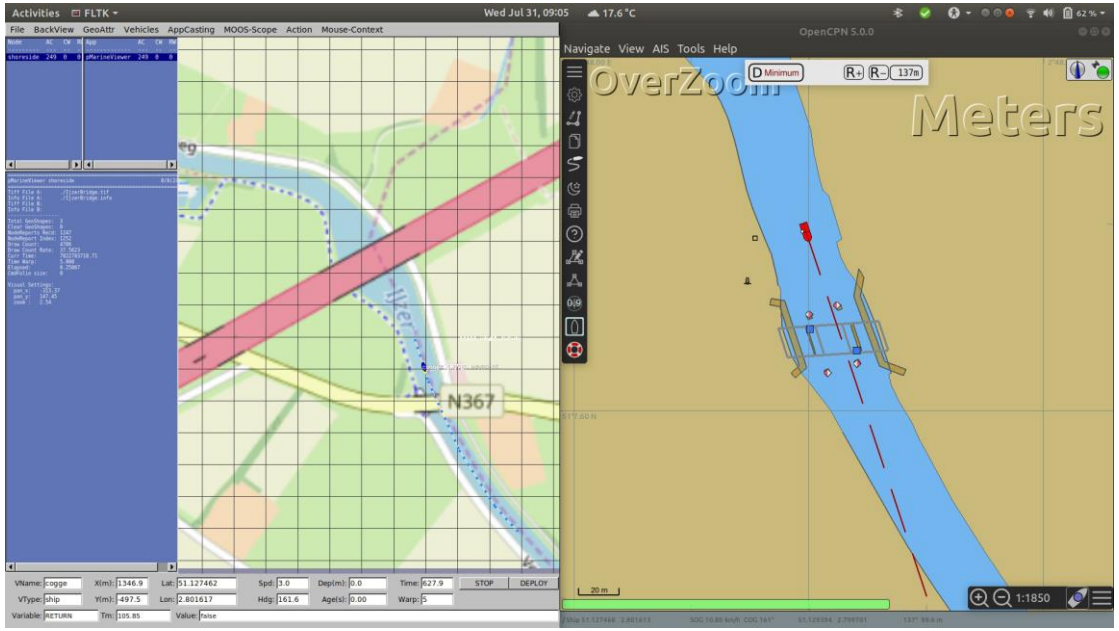
- Parallel with pMarineViewer (MOOS-IVP)
- Realtime streaming of GNSS data
- Uses (I)ENC vector charts
  - much more detailed
  - includes critical objects
  - zoom, navigate, plan routes, ...
- Bi-directional communication
  - set absolute waypoints from OpenCPN
  - dynamically update waypoint behavior



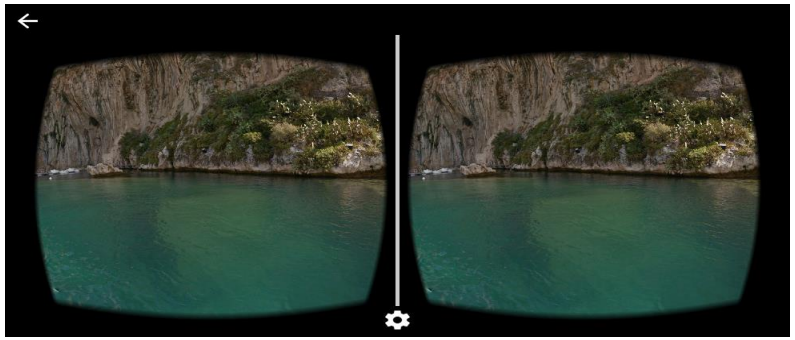
Simulate trajectory to check waypoint-feasibility before real life test

OpenCPN viewer

- e.g. concrete obstacles in trajectory area under bridge
  - Critical for Inland waterway routes
- Retrieve data (absolute coordinates) from chart features using GDAL



Use case scenarios



Realistic View from Camera System

SCENARIO 1

Remote Control for the Vessel

H2H Visualization on the Screen

SCENARIO 2

SCENARIO 3

Expected outcomes of experiments

- Different scenarios of sailing with/without H2H
  - Safety
  - Energy
  - Execution time

Future work

HULL TO HULL

- Setup remote control center
- Integration of H2H modules with remote control center
- OpenCPN based dynamic maps for display of UZ
- Perform H2H inland experiments with different users

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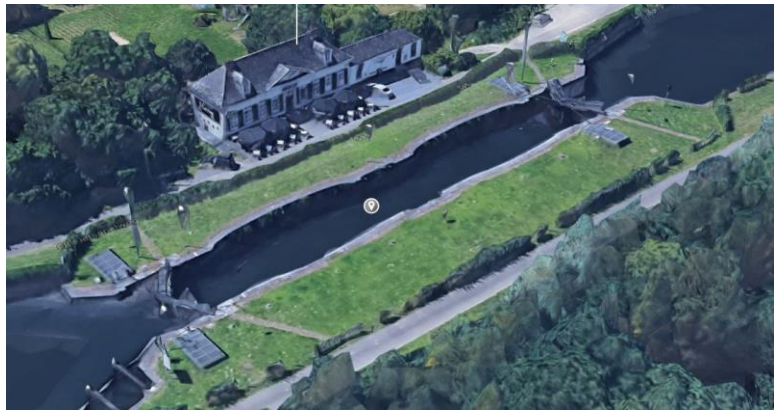
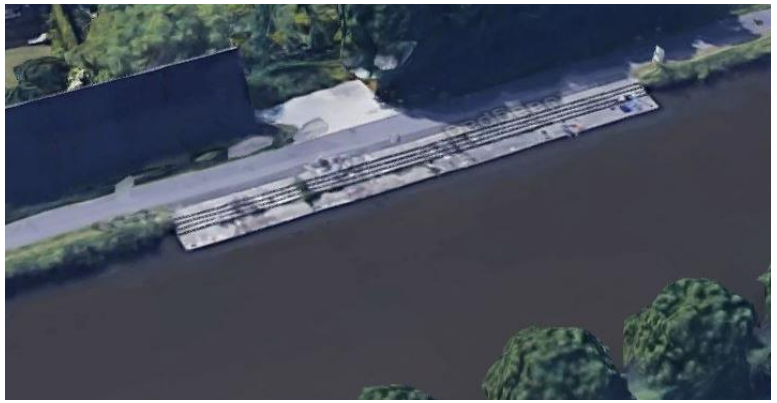
Questions

Thank you

Testing locations in Leuven, BE



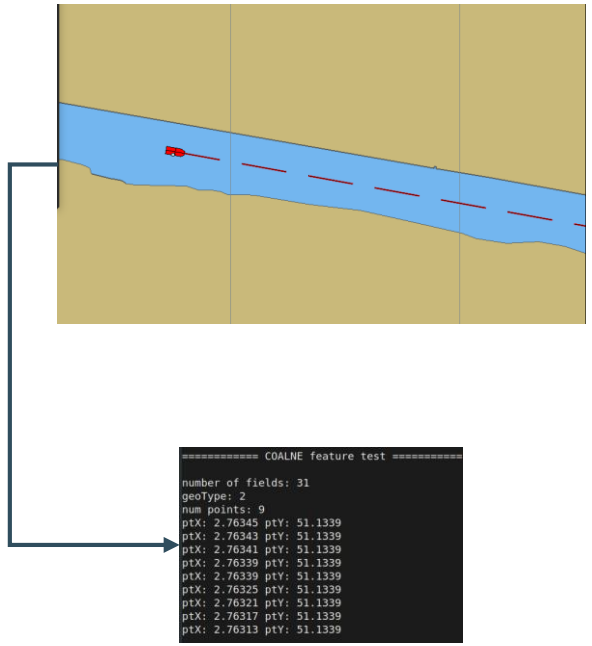
Tildonk Lock (Image taken from Google Maps)



Dock on the Vaart (Image taken from Google Maps)

GDAL

- Translator library for raster and vector geospatial data formats that (released under an X/MIT OSL)
- Example:
  - Capture absolute coordinates for part of shore (COALNE object, +-10 meter)



All features in ENC charts have absolute coordinates that can be utilized in obstacle avoidance algorithms

Modeling of error and uncertainty

courtesy of Kongsberg Seatex

- We saw previously that total uncertainty for an arbitrary point on the hull can be modelled as:
- $\varepsilon_{hull} = \varepsilon_{sensor} + \varepsilon_{installation} + \varepsilon_{3Dmodel}$

- Assuming independent errors and sensors for position and orientation:
- $\sigma^2_{hull} = \sigma^2_{position} + \sigma^2_{orientation} + \sigma^2_{installation} + \sigma^2_{3Dmodel}$