



**GHENT
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Full scale manoeuvring tests with a SFAZ vessel

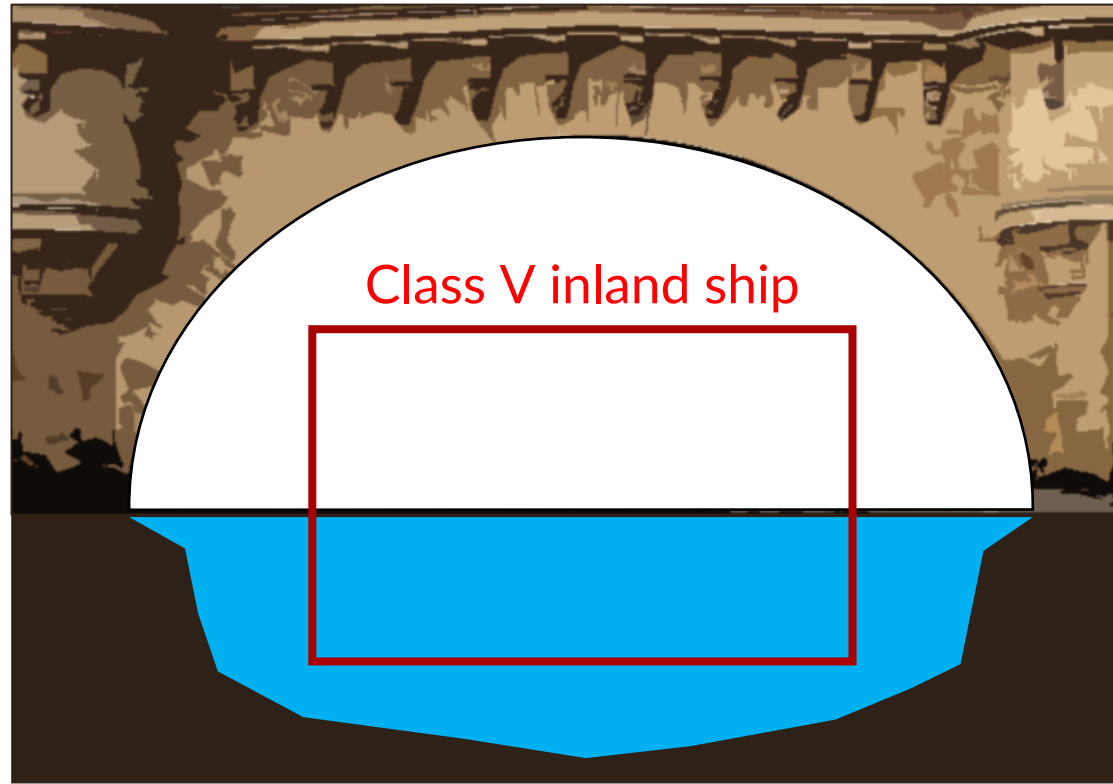
Mansuy, M., Delefortrie, G., Candries, M., Alliot, A., Mesnil, L., Alliot, I.,

Overview

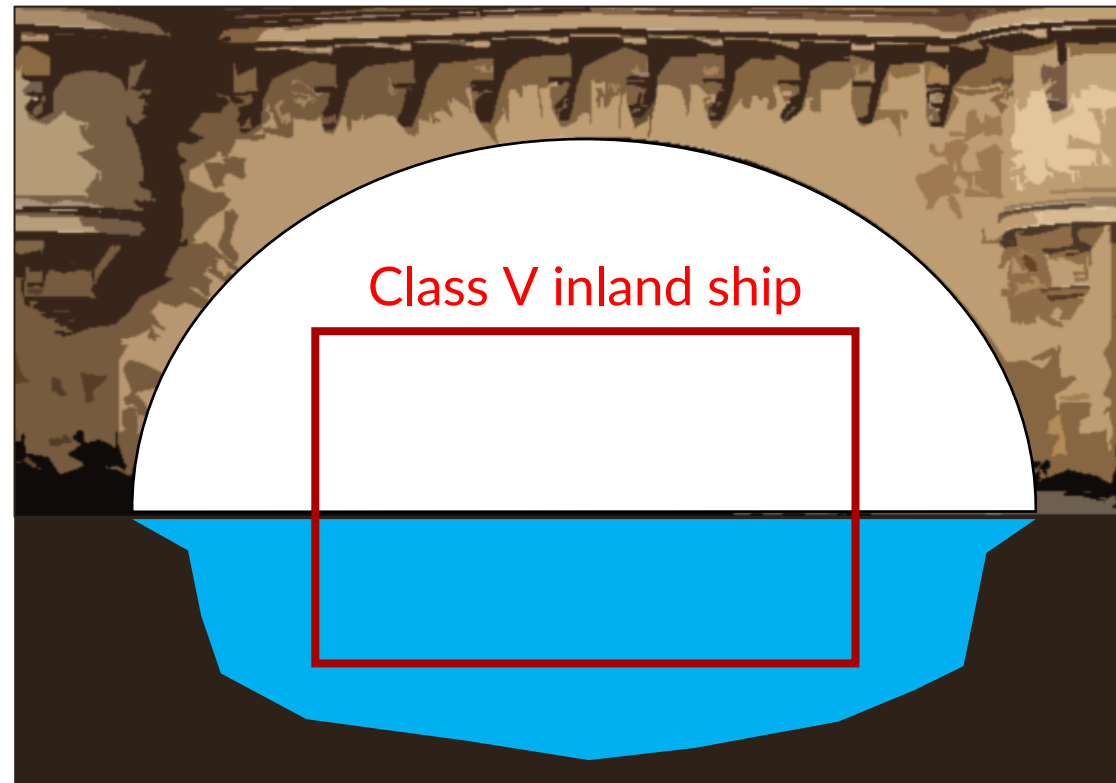
- **What is a SFAZ ?**
- Digital twin
- Full scale trials
- Data processing and analysis
- Further outlook
- Conclusions

What is a SFAZ ?

Ship – bottom interaction

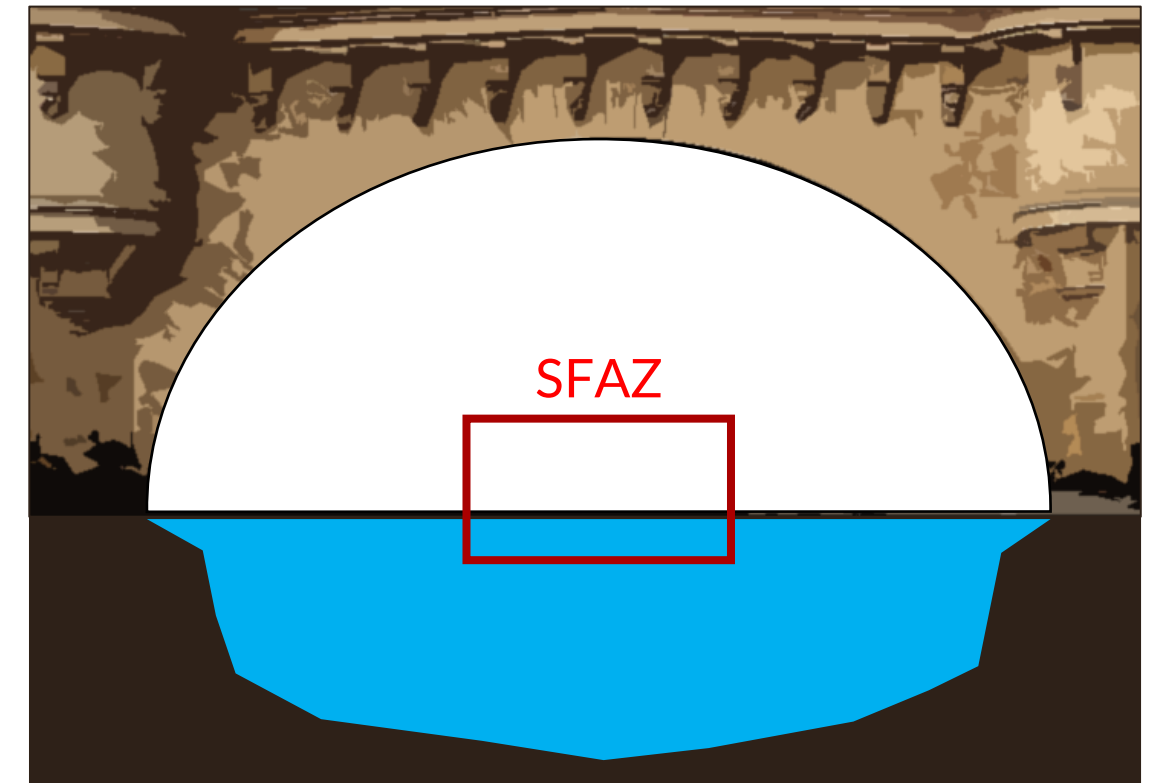
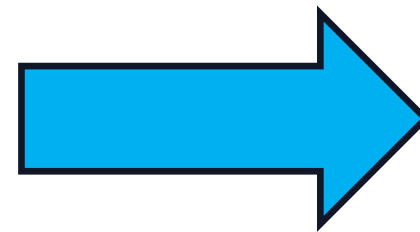


Ship – bottom interaction Small, Flexible, Automated, Zero-emission (SFAZ) vessels



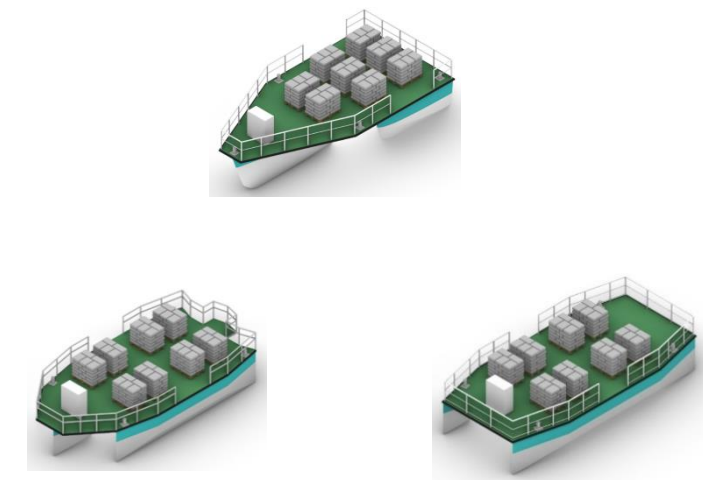
Sustainable transport solutions
in urban areas

FOREMAST project



Benefits:

- Reducing road congestion
- Optimizing last mile deliveries
- Lowering emissions (green power)
- Improving overall accessibility
- Increasing IWT competitiveness



FOREMAST stands for Freight vOlumes transfer from Road to waterborne transport, using zeroEMission, Automated, Small, and flexible vessel (SFAZ) protoTypes



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To examine the techno economic aspects of SFAZ vessels in smart, competitive and green transport systems.

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To undertake focused research in SFAZ design and solution components in line with vessels research

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To test and demonstrate the SFAZ vessel concept in the FOREMAST Living Labs

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To accelerate the wider deployment of SFAZ vessels

Consortium

36
months

9
countries

16
partners

3
Living Labs

inlecom

ITA INNOVA
INSTITUTO TECNOLÓGICO DE ARAGÓN

hb HOUT & BOUW
OPLEIDINGSCENTRUM

connecta
systems

ABB

vltn

SEAFAR

P&E
P&E LOWLANDS BV

ciRcoE
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UNIVERSITY

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Living Labs

Living Lab

1

Ghent, Belgium

will develop and test a sustainable SFAZ vessel solution in the Ghent region.

Living Lab

2

Caen, France

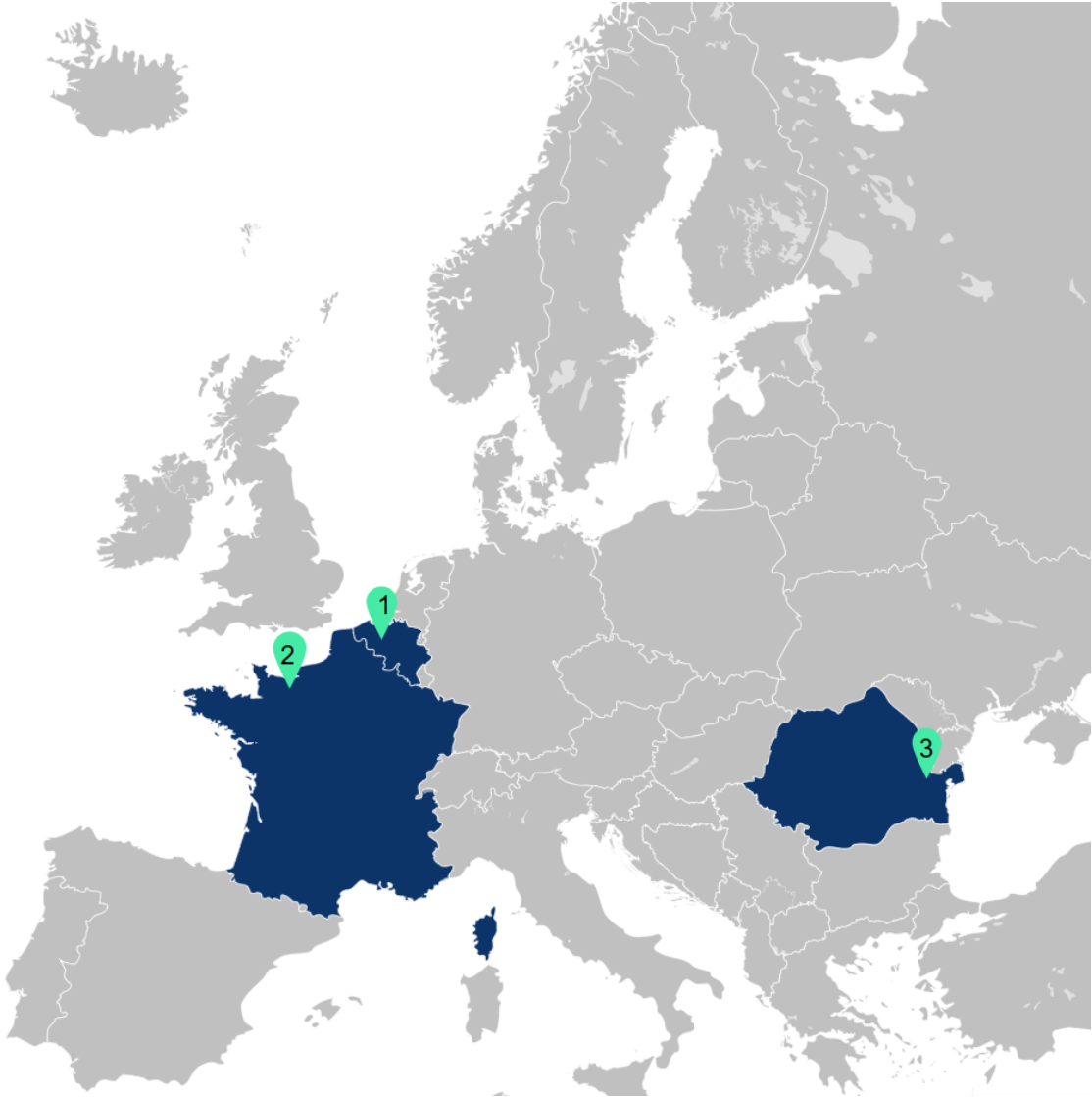
will develop and test a new innovative catamaran vessel design and prototype, reflecting the SFAZ concept in Caen and Le Havre, France.

Living Lab

3

Galati, Romania

will develop an optimised SFAZ concept addressing the specific inland and Black Sea coastal navigation areas located in South- Eastern Romania.



3



Overview

- What is a SFAZ ?
- **Digital twin**
- Full scale trials
- Data processing and analysis
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Digital twin

Digital twin: Comprehensive virtual representation of the vessel and its environment

- **Design Phase:** Early optimization of hull and propulsion
 - Reduces development time and costs
 - Improves overall design quality
 - Virtually testing control algorithms



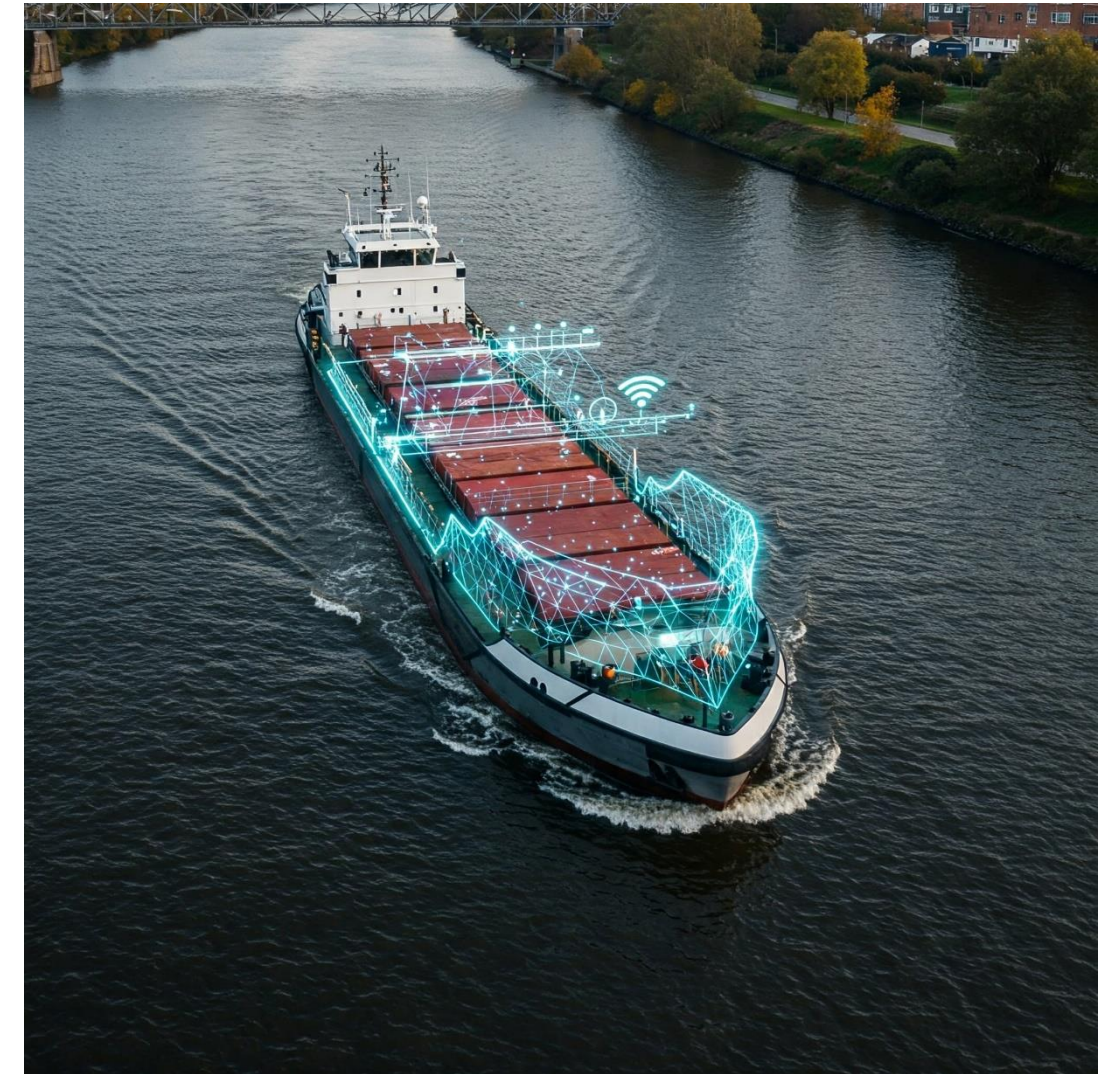
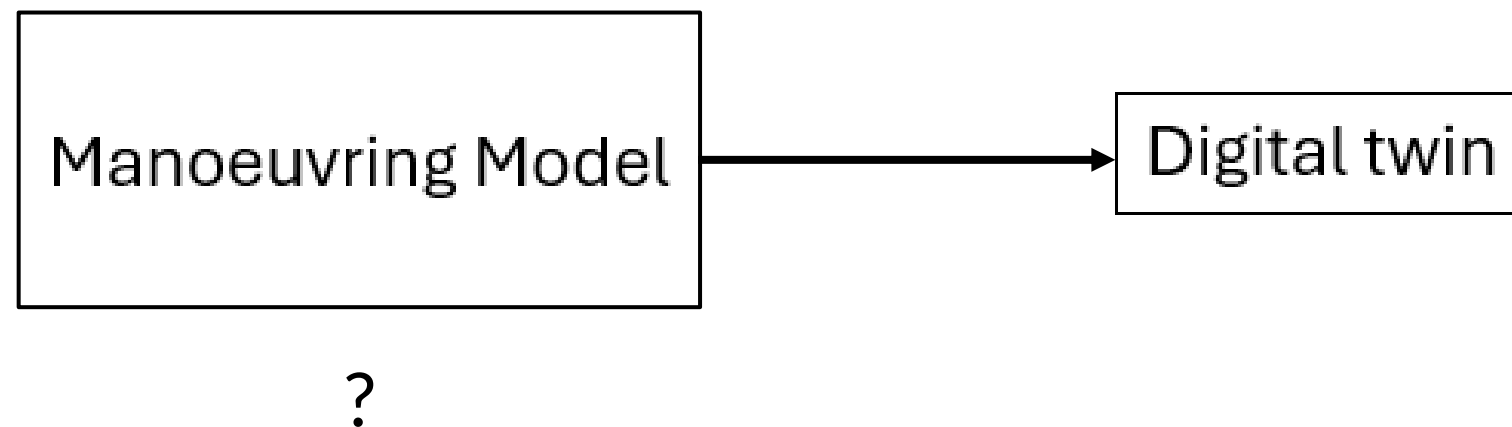
Digital twin: Comprehensive virtual representation of the vessel and its environment

- **Design Phase:** Early optimization of hull and propulsion
 - Reduces development time and costs
 - Improves overall design quality
 - Virtually testing control algorithms
- **Operational Phase:** Integrates real-time sensor data
 - Continuous performance monitoring
 - Predictive maintenance
 - Optimized route planning
 - Supports decision-making, crew training, safety, efficiency, and sustainability
 - Predicting future ship motion under different control inputs or environmental conditions

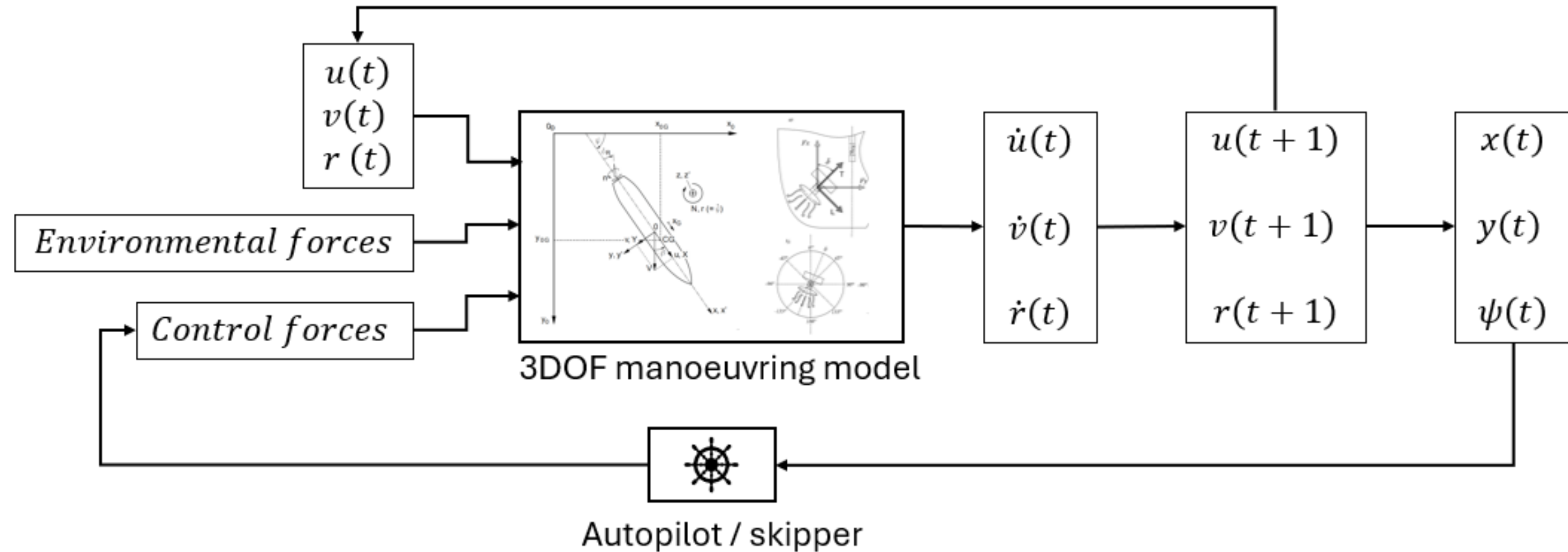


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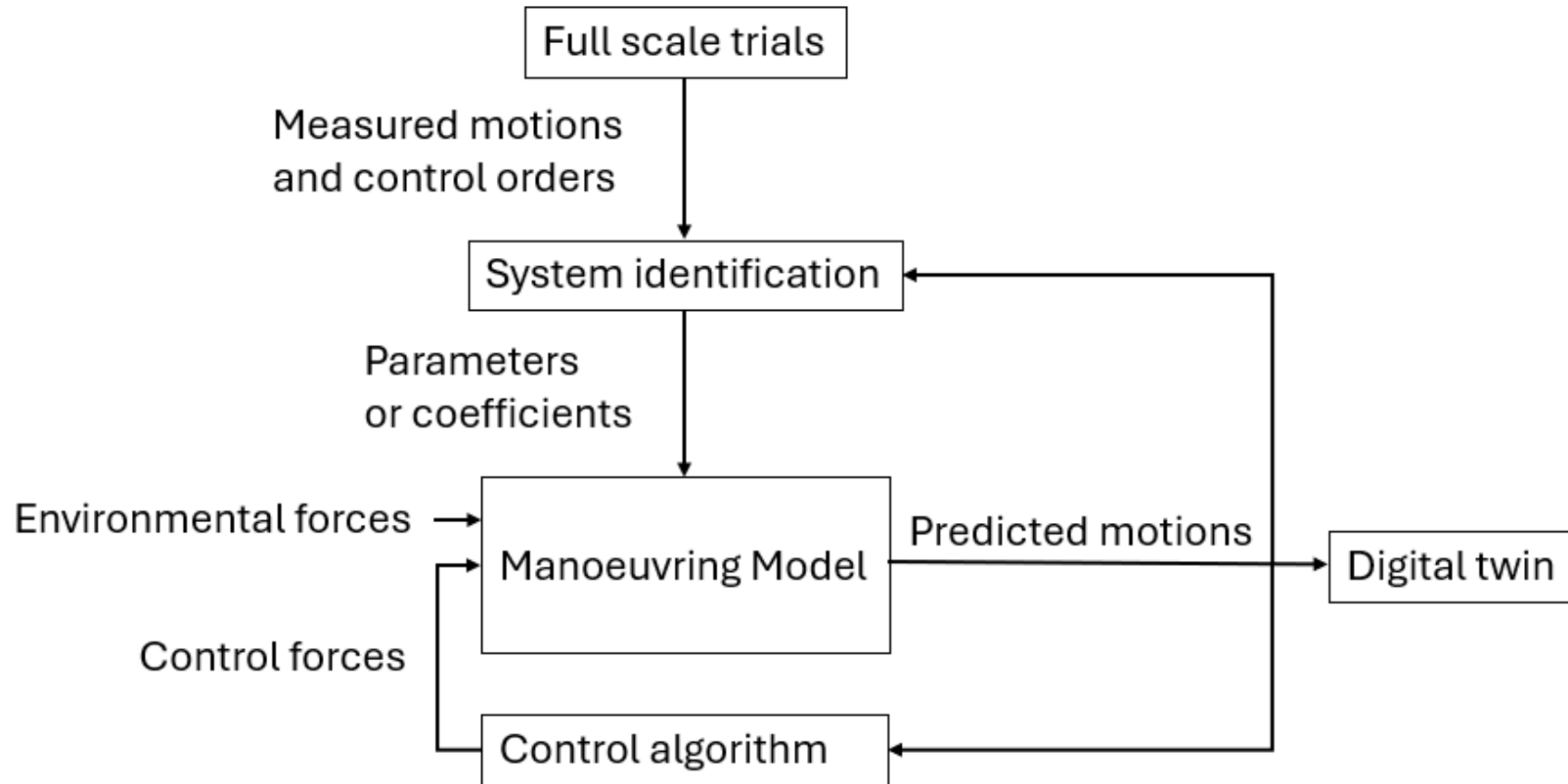


Manoeuvring model



- **Advantages :** no need for extensive model tests to identify a small number of coefficients
- **Drawbacks :** limited accuracy

Manoeuvring model



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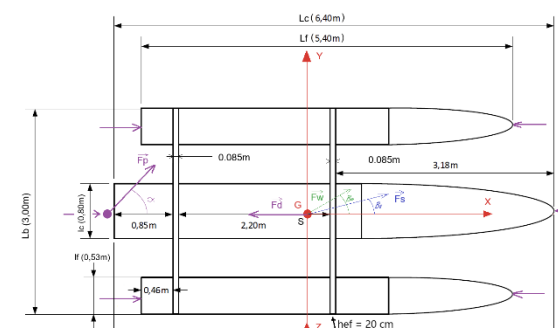
Full scale trials

The living lab in Caen



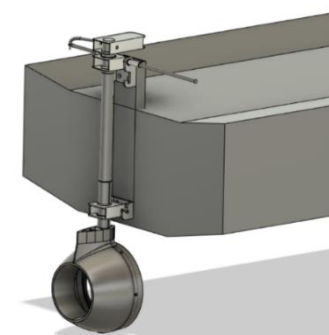
Main dimensions:

$L = 6 \text{ m}$
 $B = 3 \text{ m}$
 $T = 0.2 \text{ m}$



Propulsion/steering:

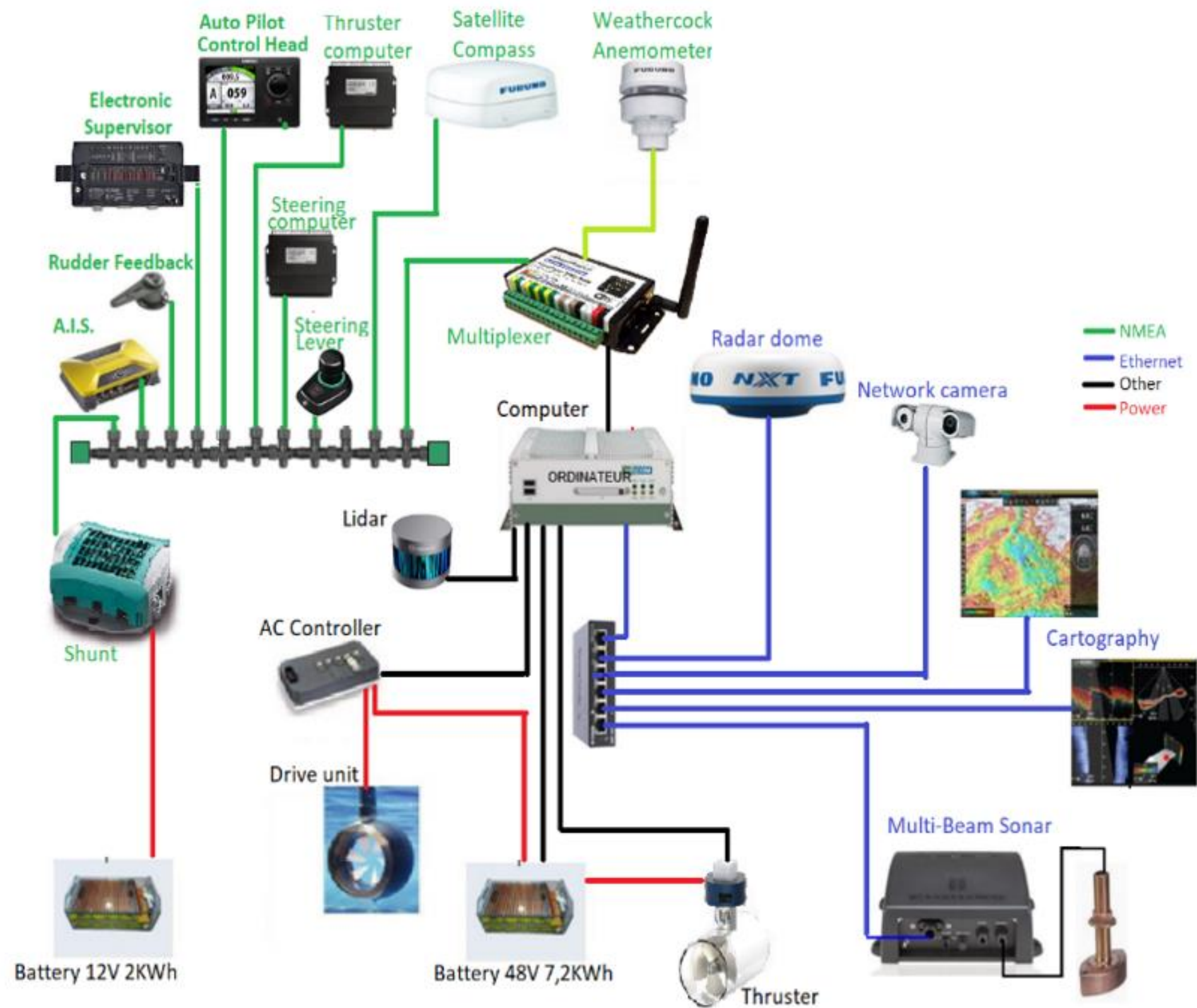
electric driven thruster
(RIM 6kW Hy.G Motors)



NEAC vessel



Ship instrumentation



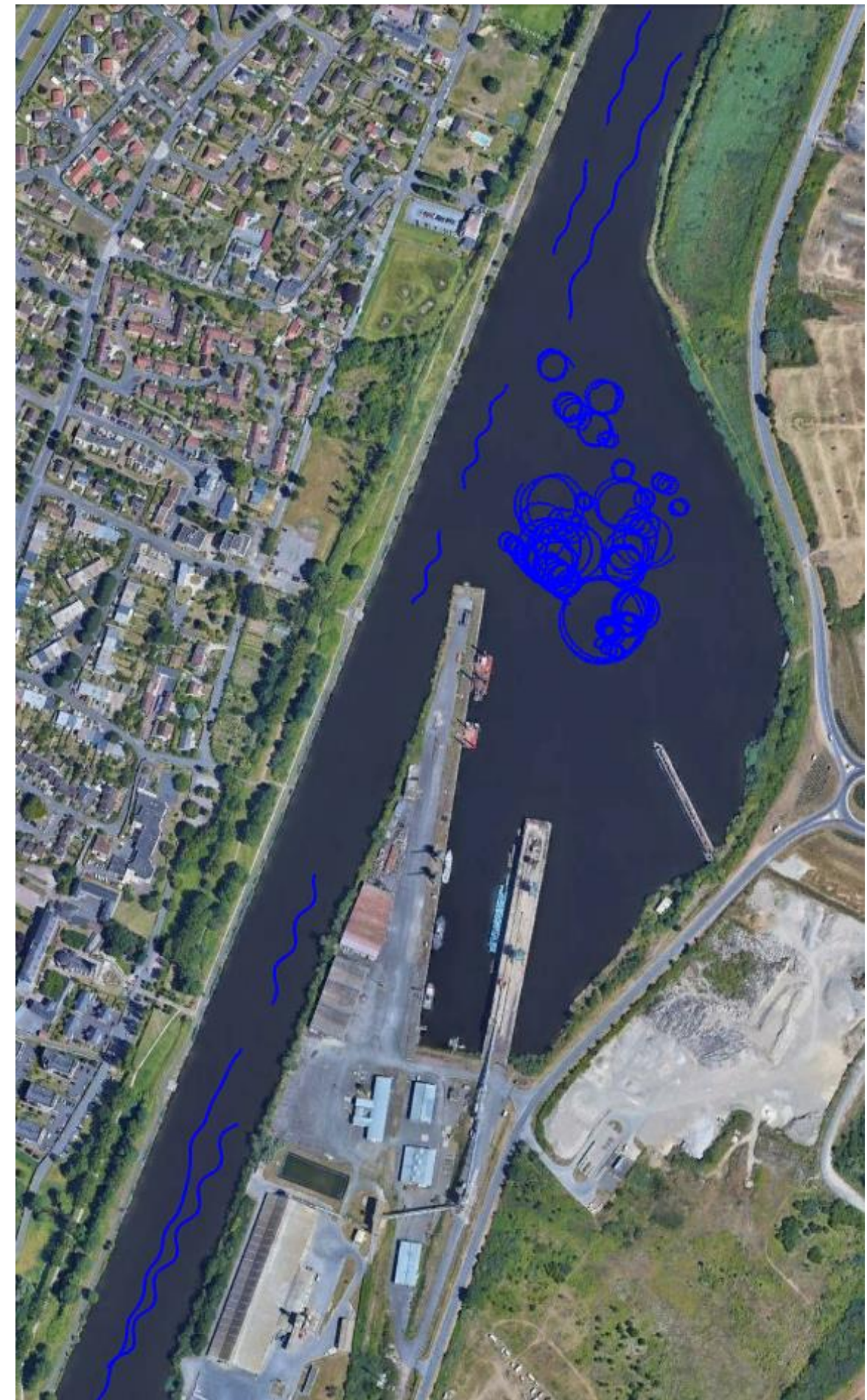
Environment: the Caen Canal



- Small tidal range (70-80 cm), low current velocities (< 0.1 m/s), depth of 10 m, width 100 m
- Controlled environment is suitable for manoeuvring trials and autonomous vessel research

Test protocol

- **Standard manoeuvres**
⇒ Vessel characteristics (ITTC Guidelines)



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- **Accuracy challenges**
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⇒ final protocol executed in 3 days



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⇒ discrepancies between protocol settings vs pilot commands



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- **Manual thruster control**
⇒ discrepancies between protocol settings vs pilot commands
- **Environmental/Operational Constraints** (weather, traffic, power)
⇒ variable loading conditions
⇒ difficult to plan testing days in advance
⇒ test location based on test type
⇒ NEAC team very flexible



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Data processing and analysis

Pre-processing

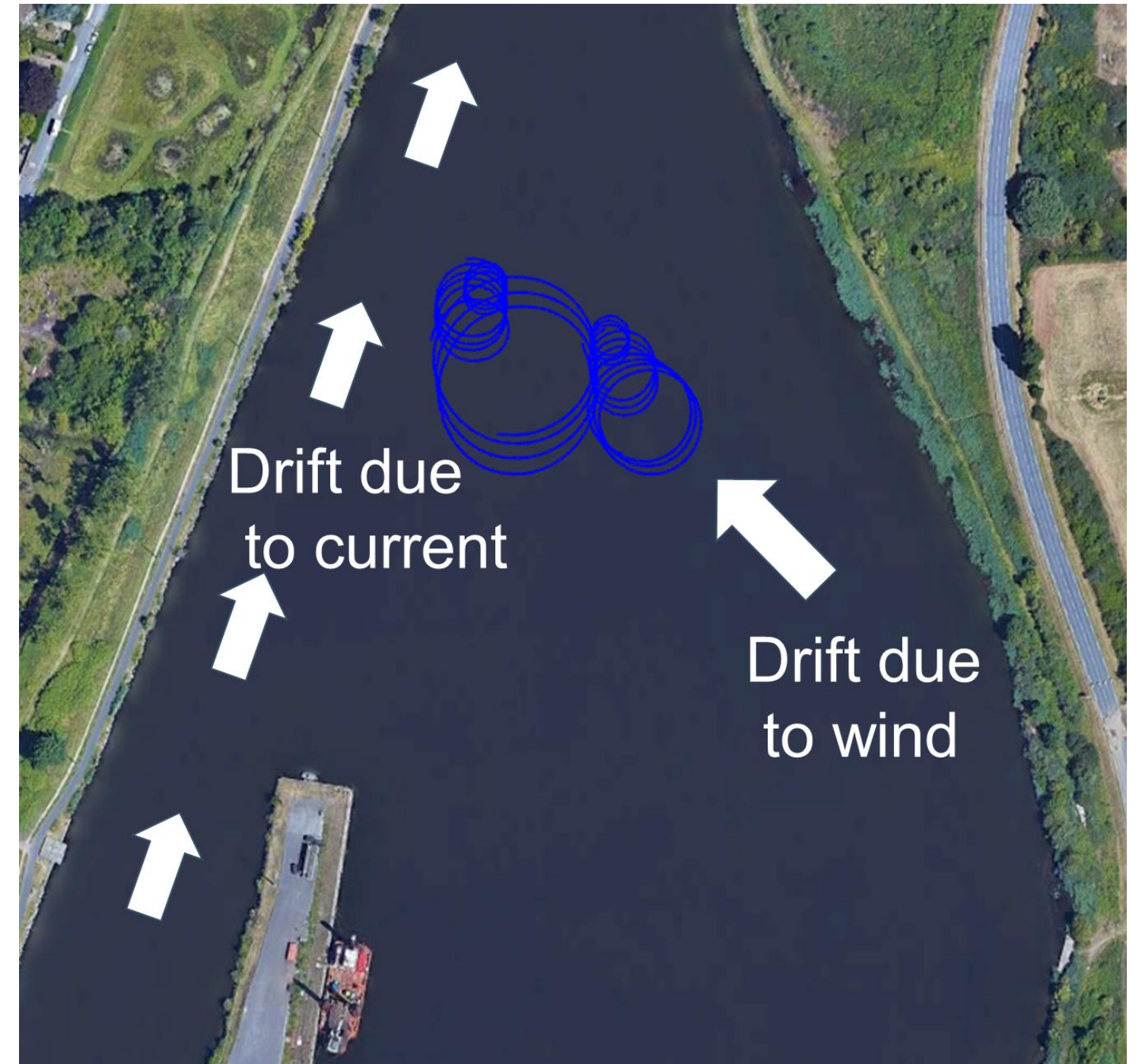
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Pre-processing

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- **Noise reduction:** low-frequency focus

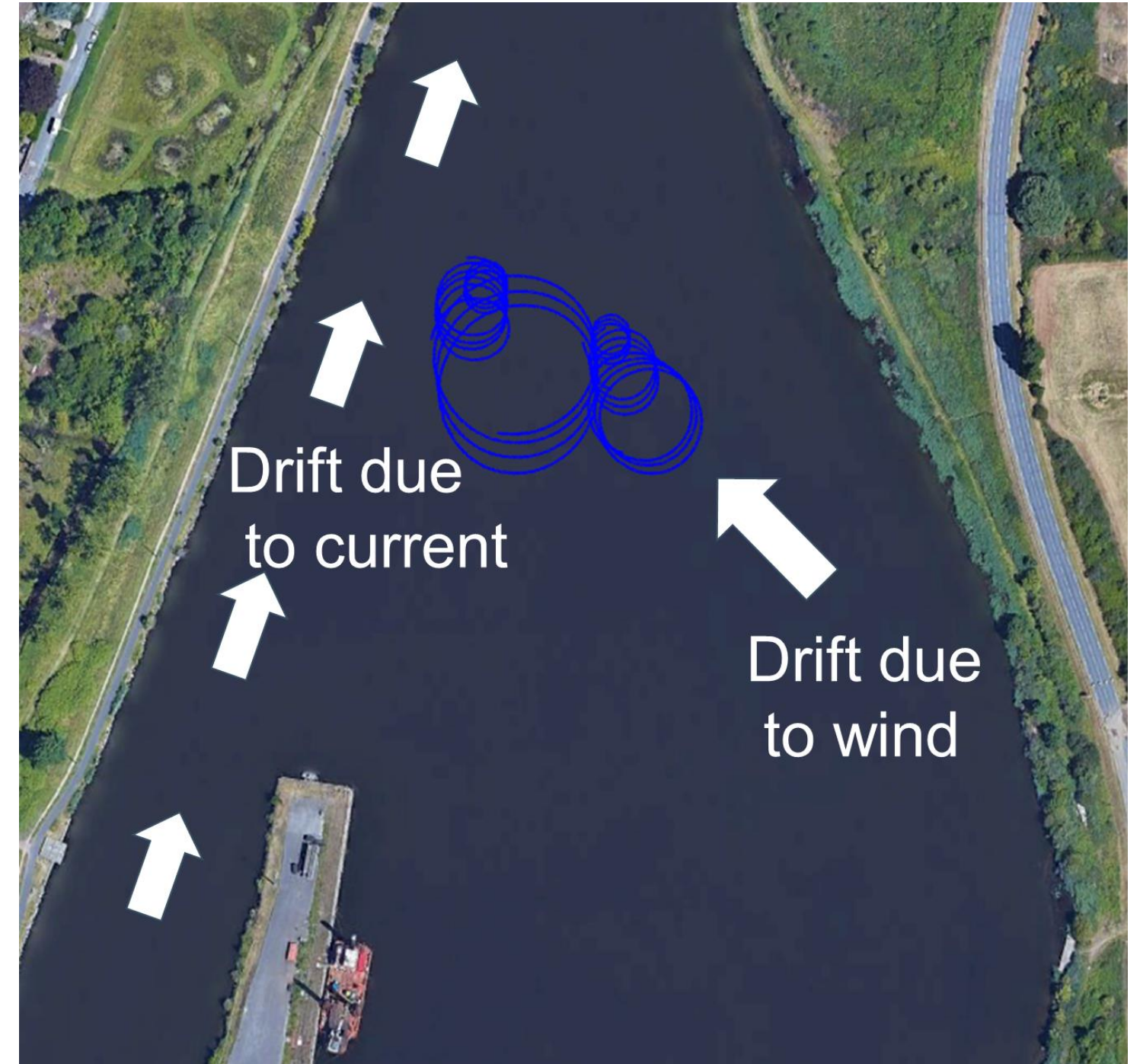
Pre-processing

- **Data:** Synchronized & resampled, filled blanks
- **Noise reduction:** low-frequency focus
- **Wind sensitivity** (large superstructure, small draft = drift) and **current influence** (small currents = noticeable drift):



Pre-processing

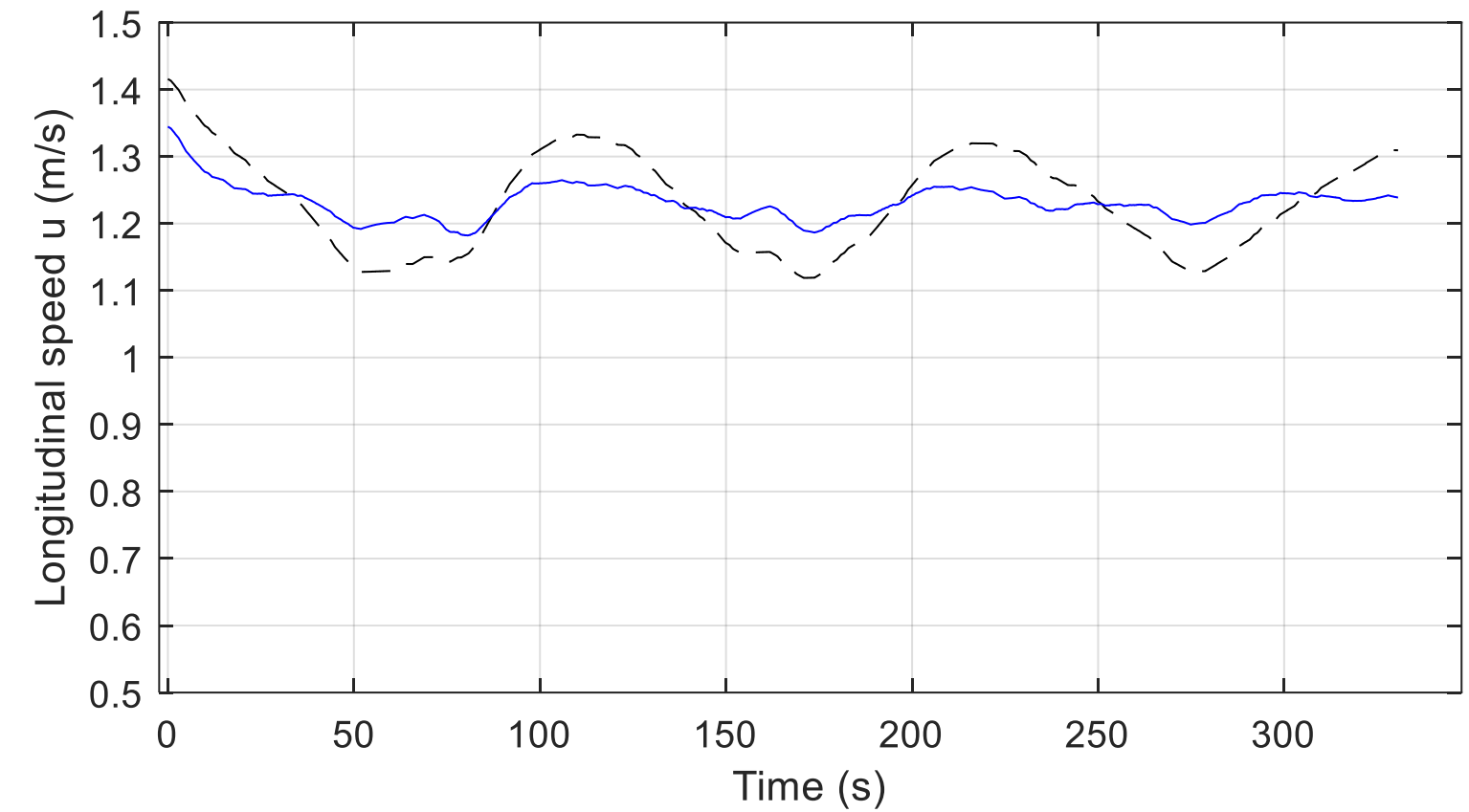
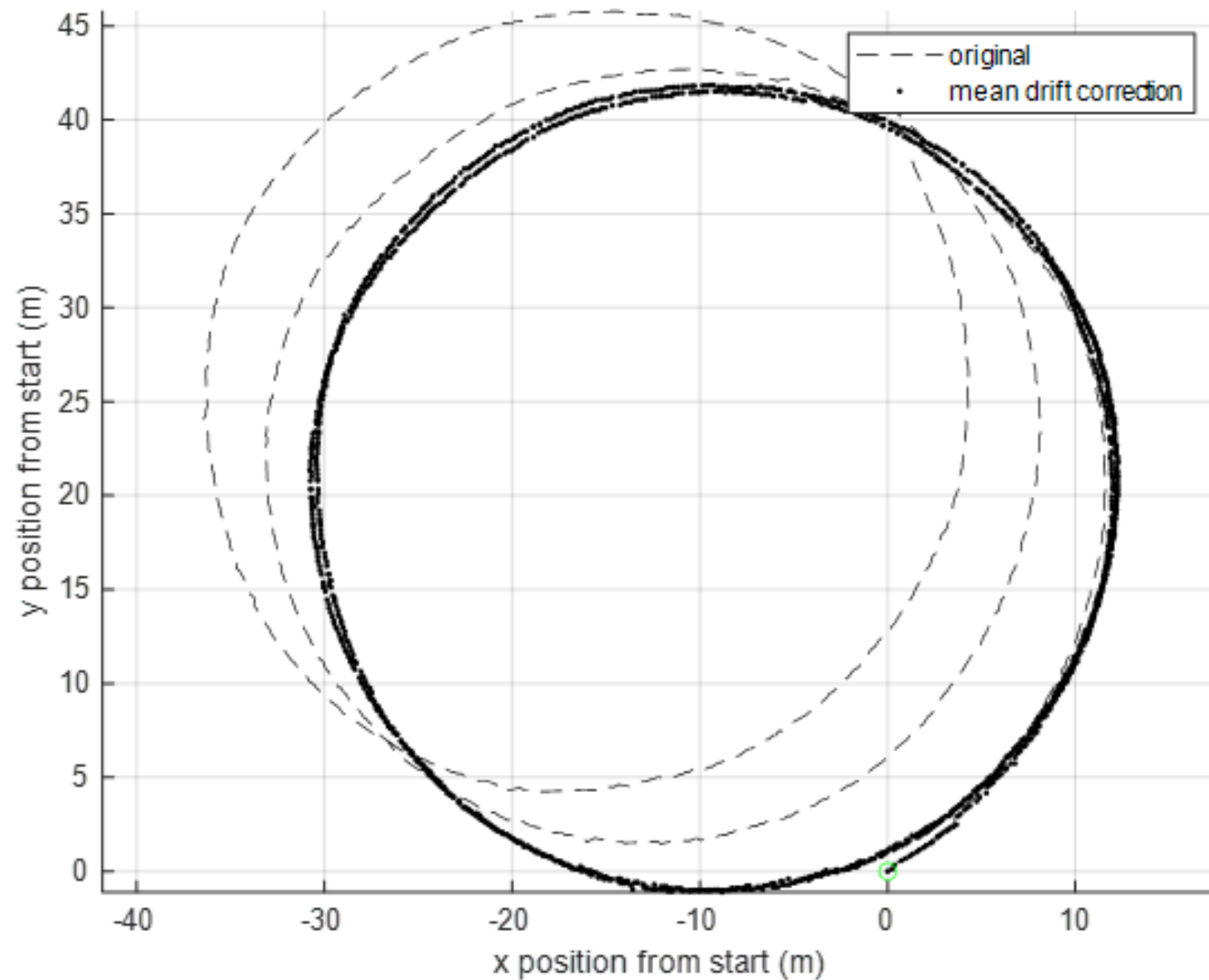
- **Data:** Synchronized & resampled, filled blanks
- **Noise reduction:** low-frequency focus
- **Wind sensitivity** (large superstructure, small draft = drift) and **current influence** (small currents = noticeable drift):
 - ⇒ advanced correction (varying disturbances)
 - using relative wind and vessel motion **was not successful**
 - ⇒ Simplified ITTC drift correction (heading comparison)
 - ⇒ Assuming uniform drift **was successful**



Drift correction

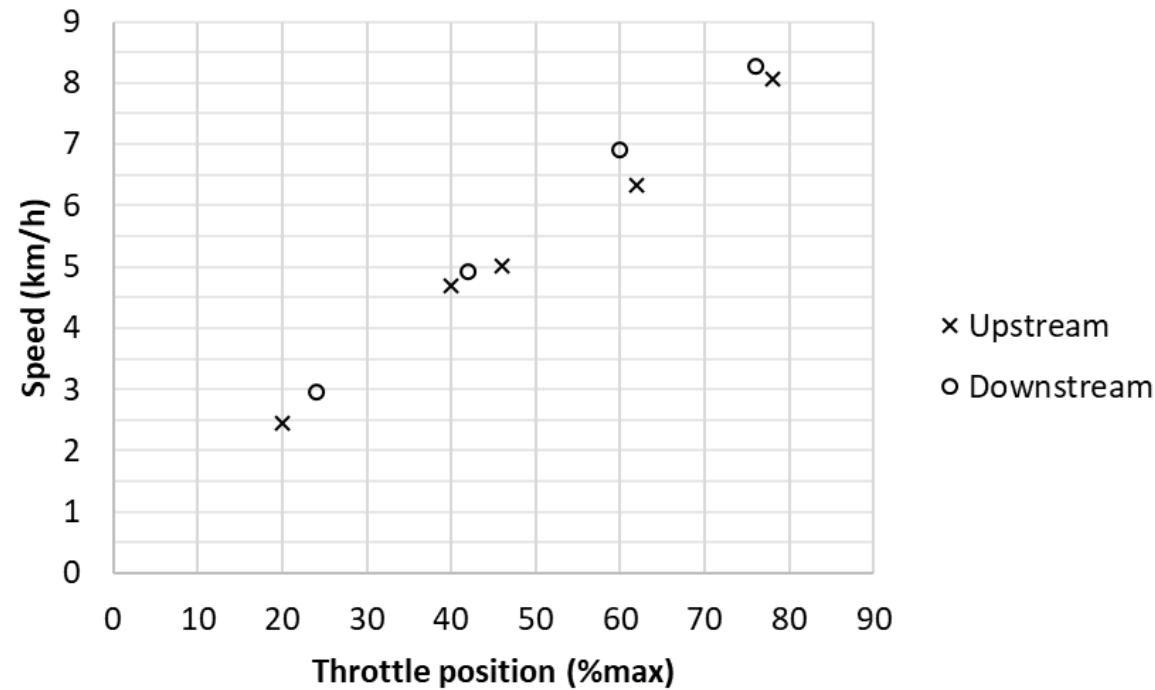
Ex: 10° turning circle to starboard side - 40% throttle

Trajectory and measured longitudinal velocity before (dashed line) and after (full line) drift correction:

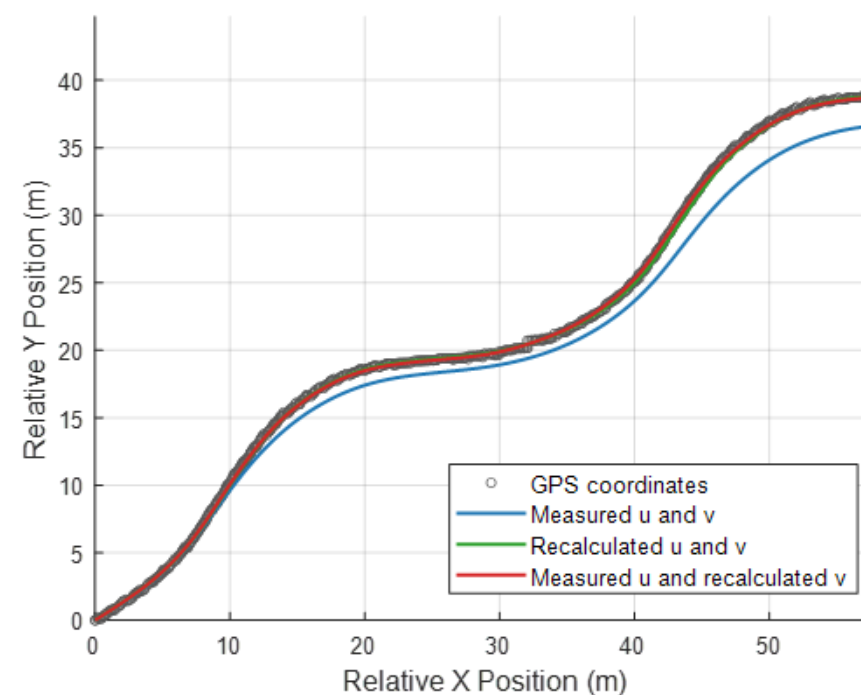


Extraction of manoeuvring characteristics

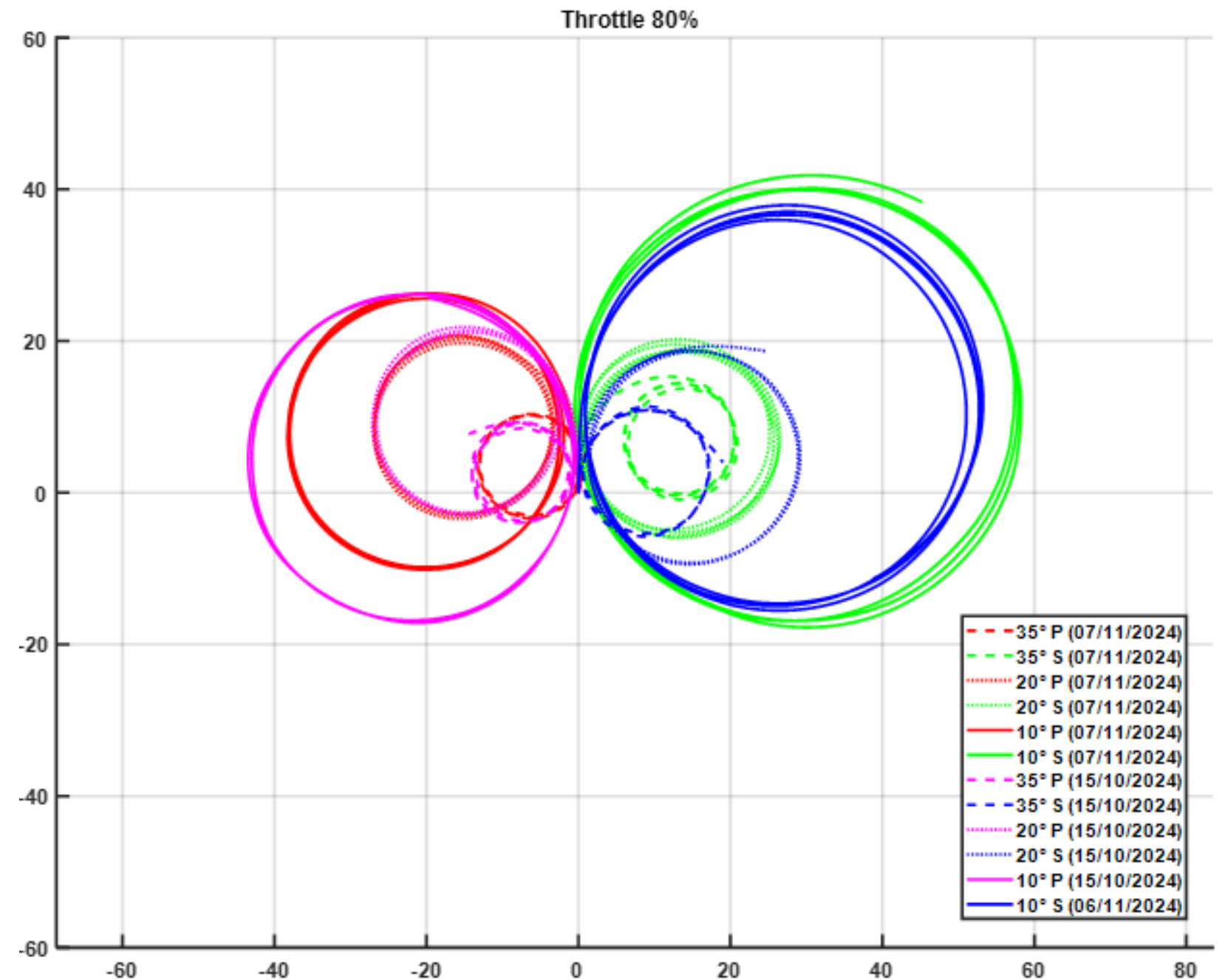
- Acceleration tests: speed vs throttle (resistance)



- Zigzag tests: course-keeping ability

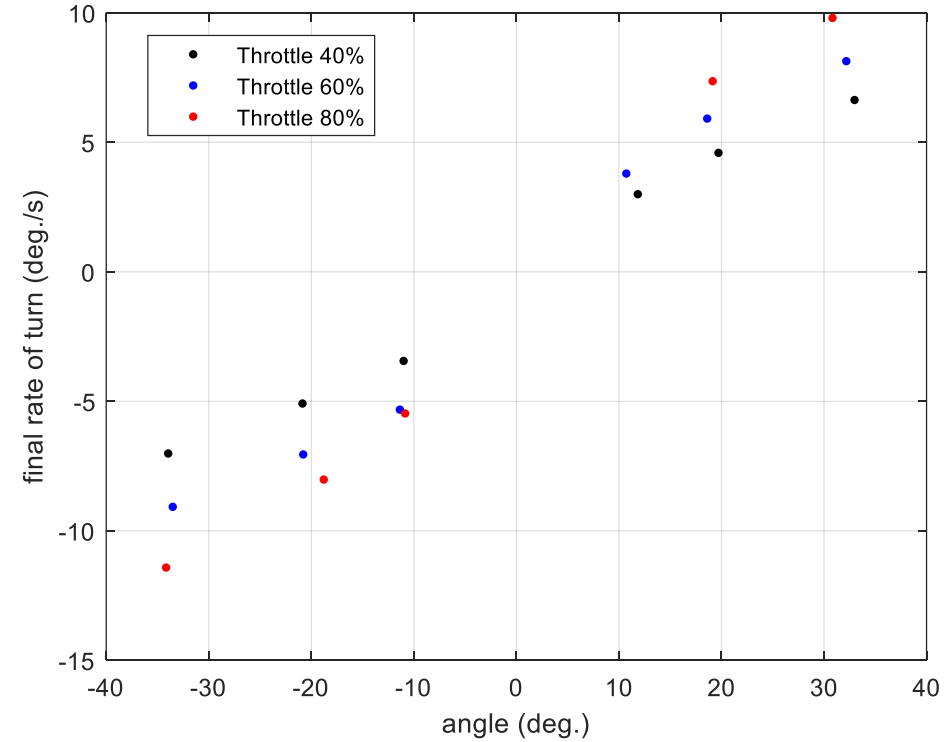
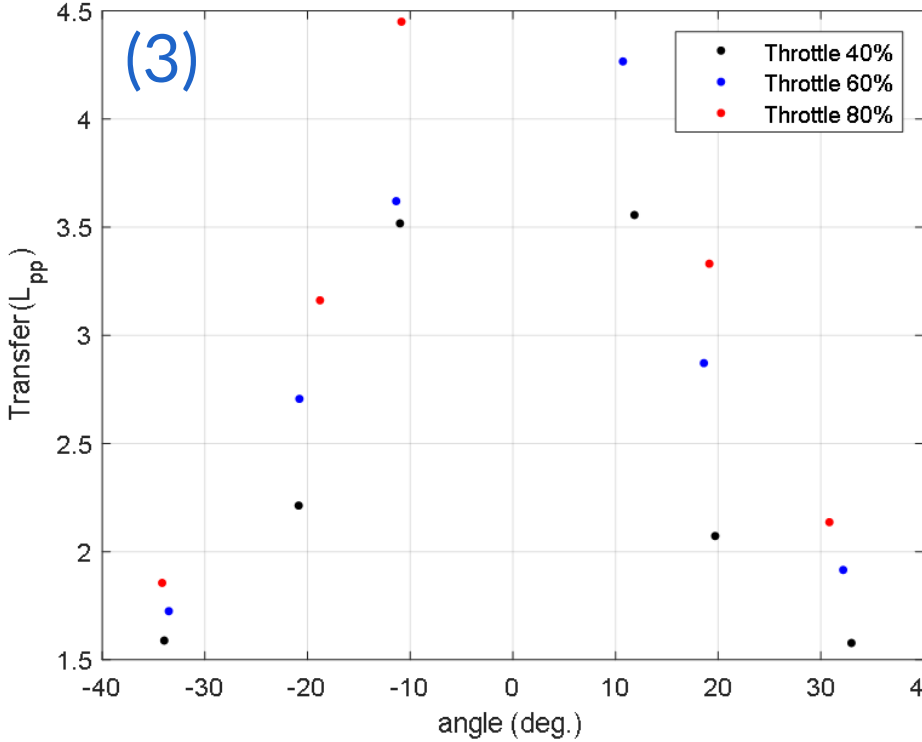
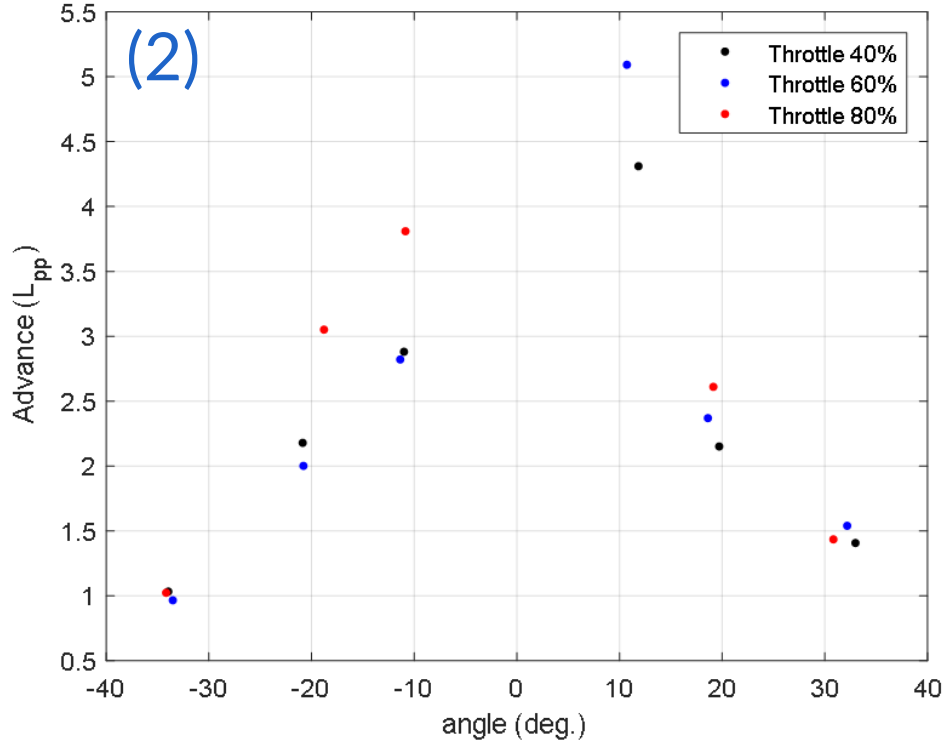
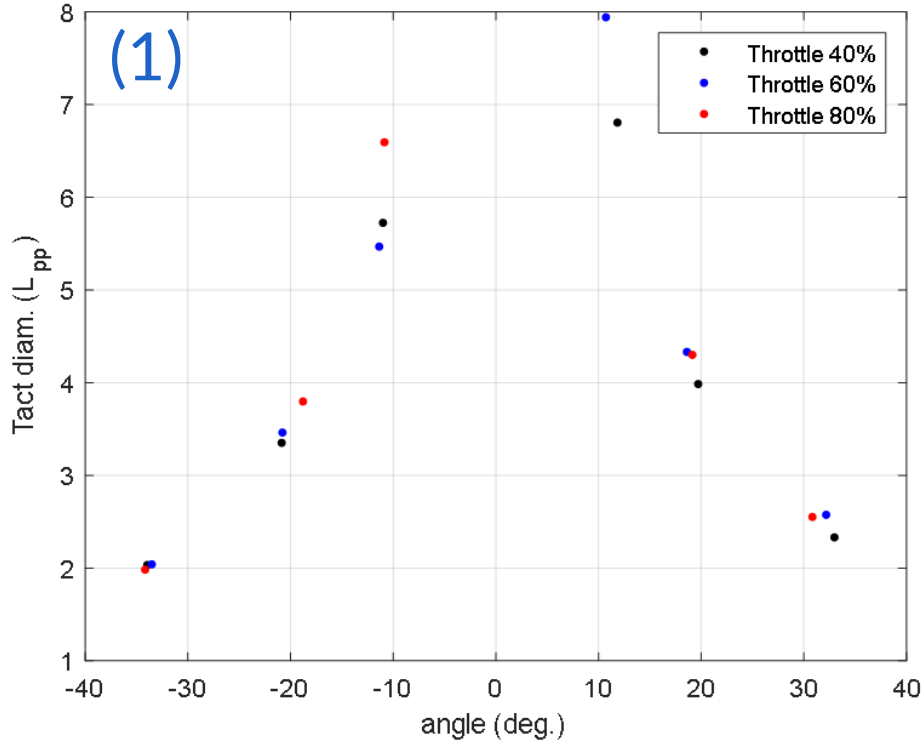
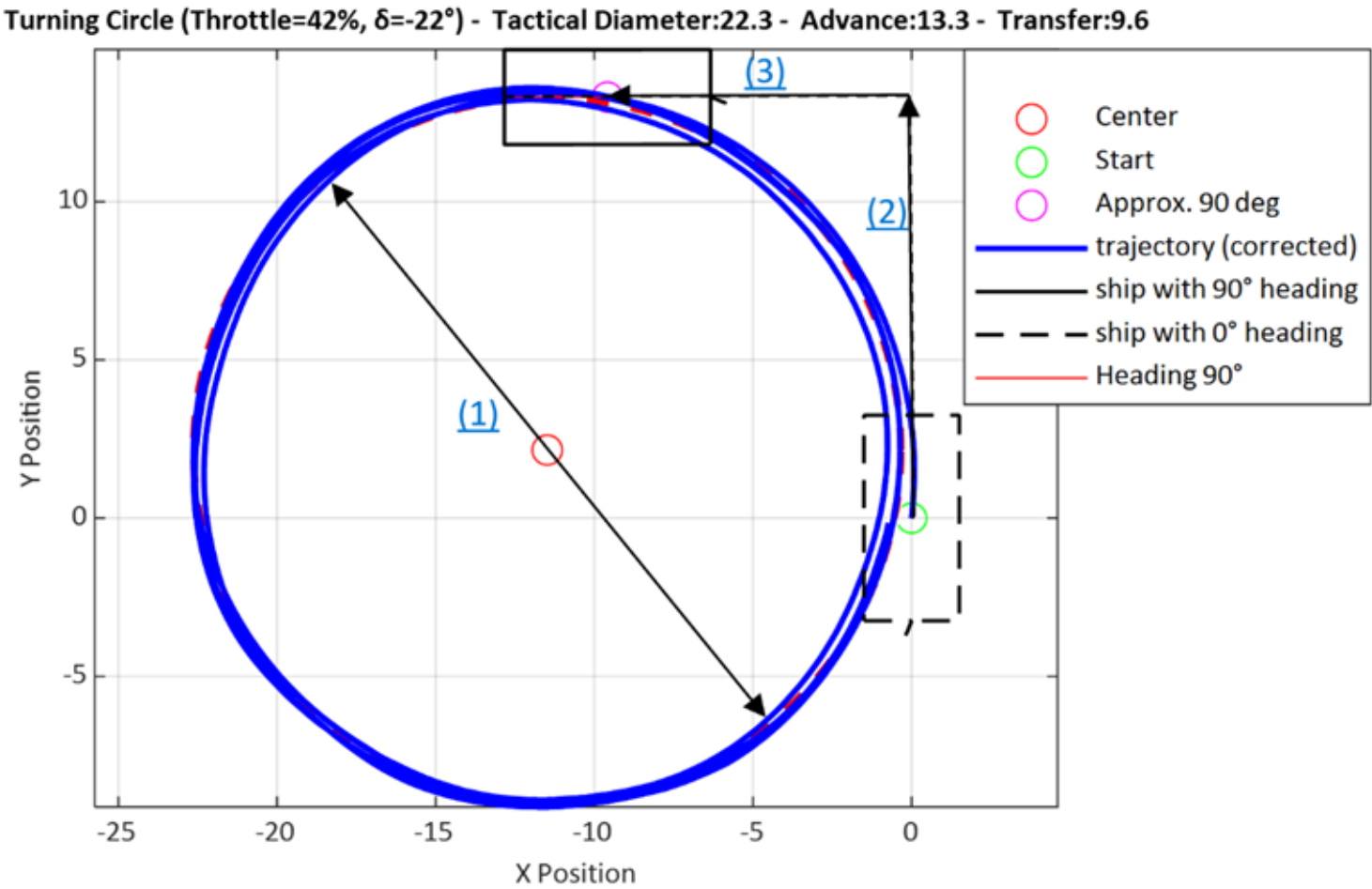


- Turning circles: turning ability



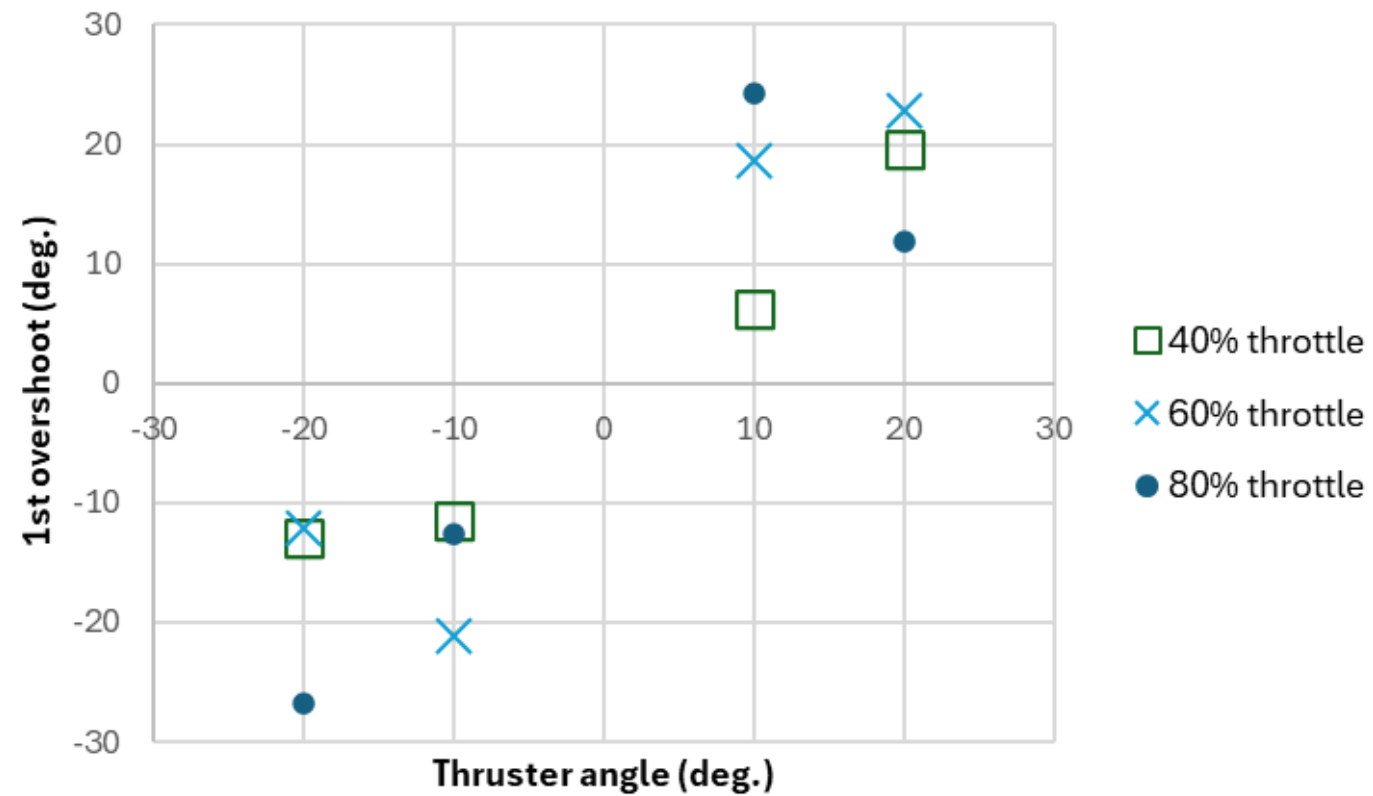
Extraction of manoeuvring characteristics

– Example turning circles 10°/20°/35° :

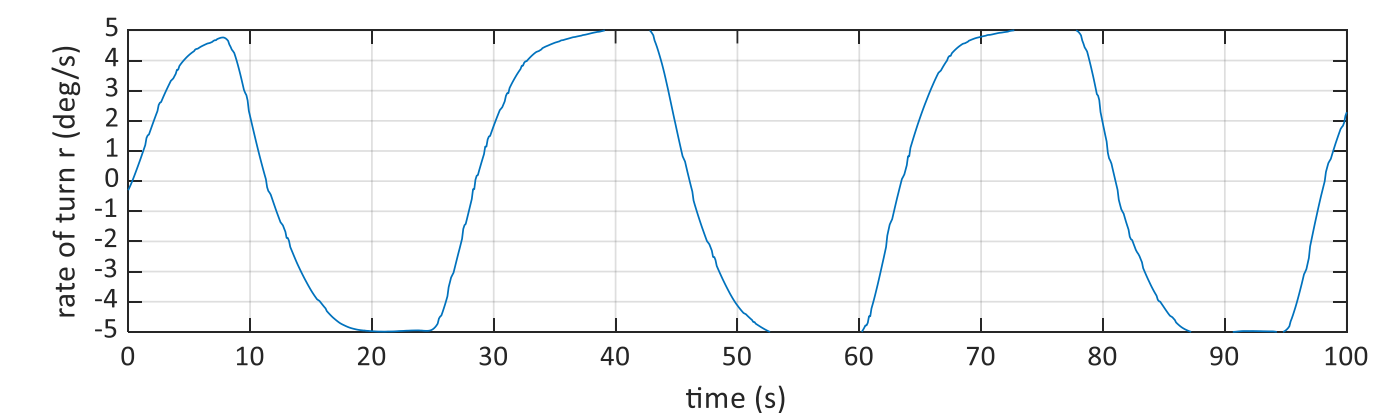
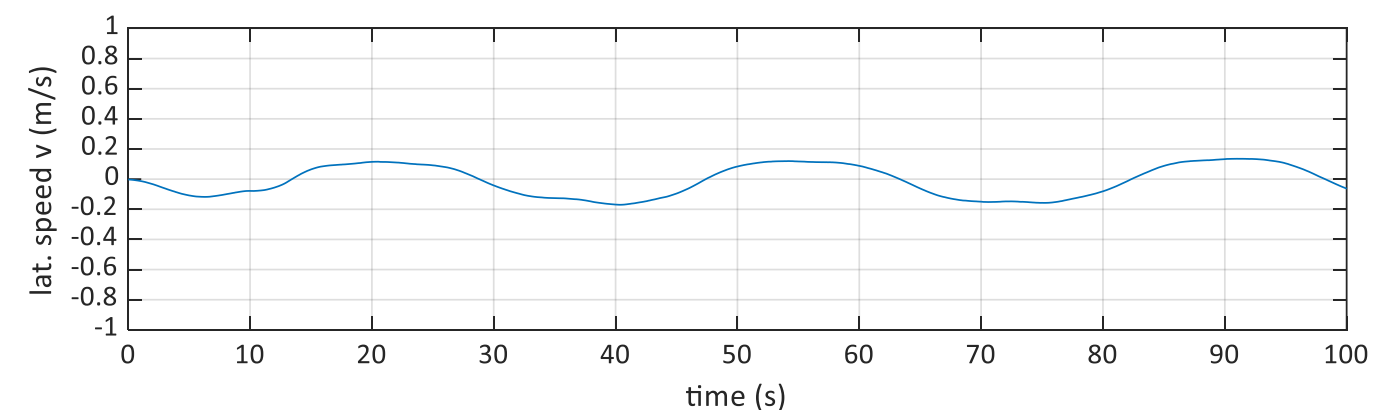
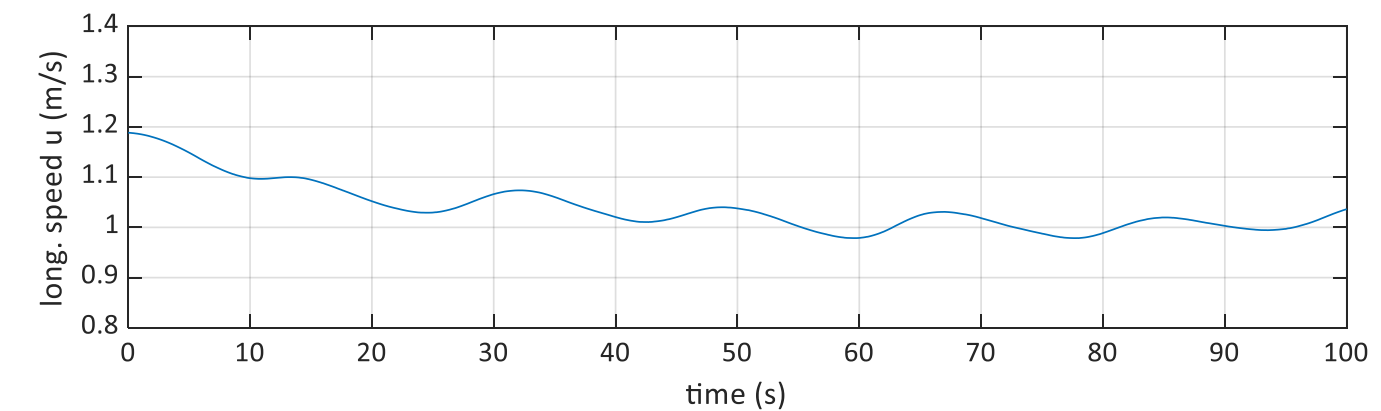
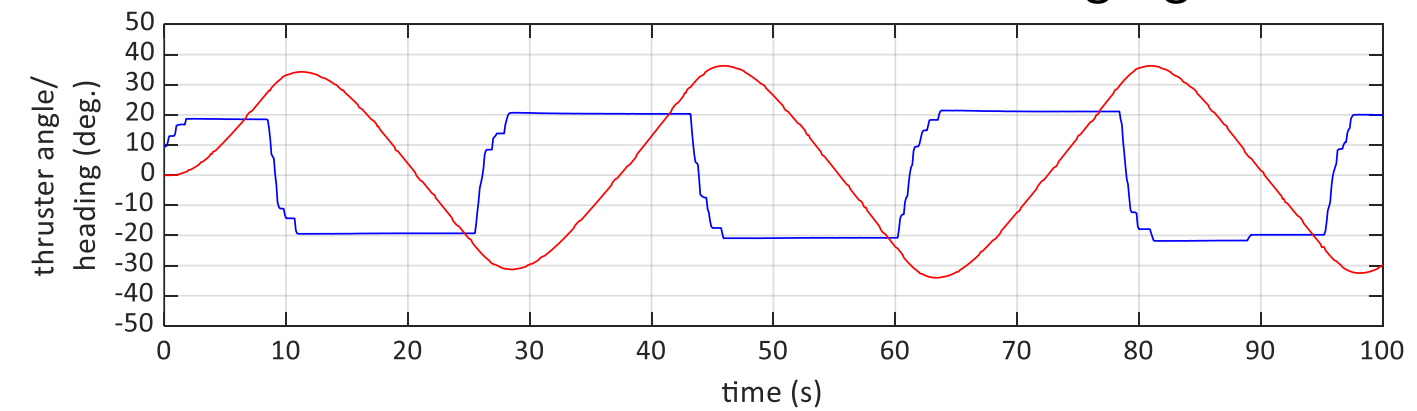


Extraction of manoeuvring characteristics

- Example zigzag 10°/10° and 20°/20°:



zigzag 20°/20°



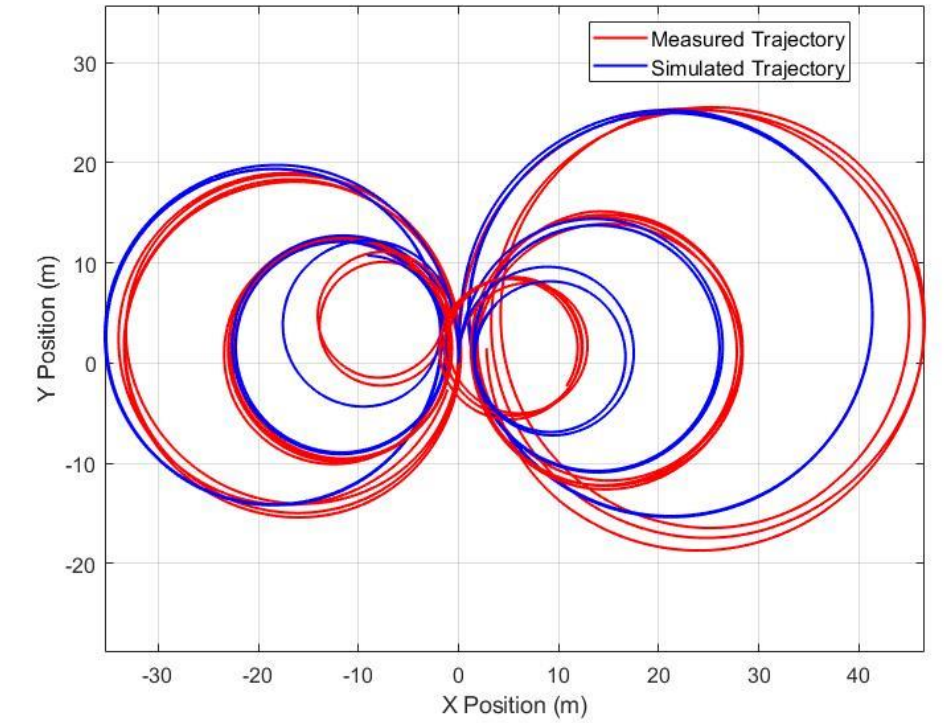
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Further outlook

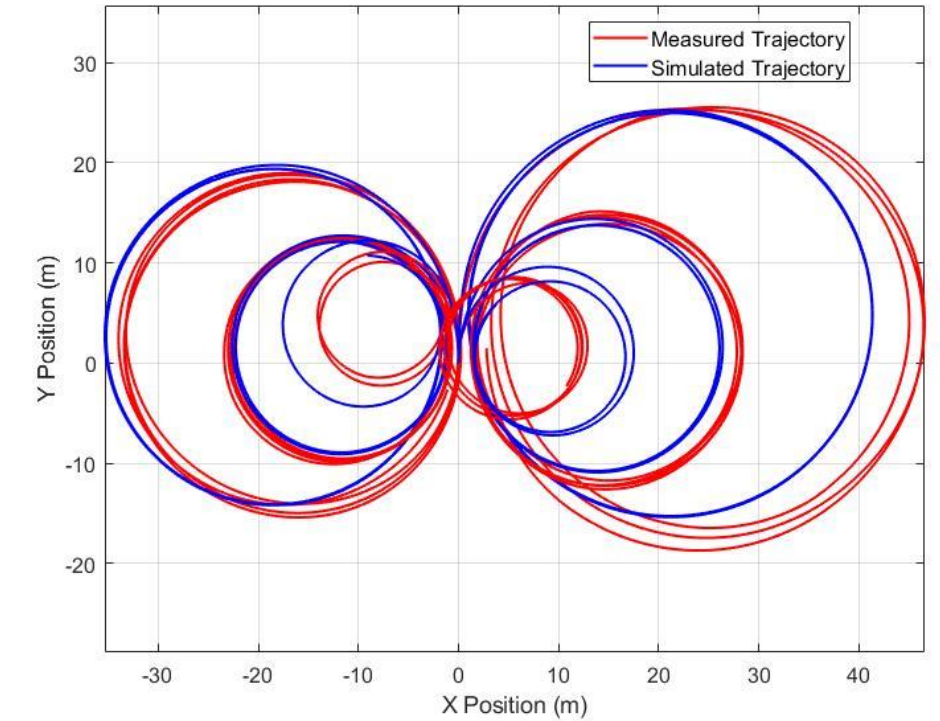
Further outlook

- Simplified 3DOF Manoeuvring Model (incl. environmental factors)



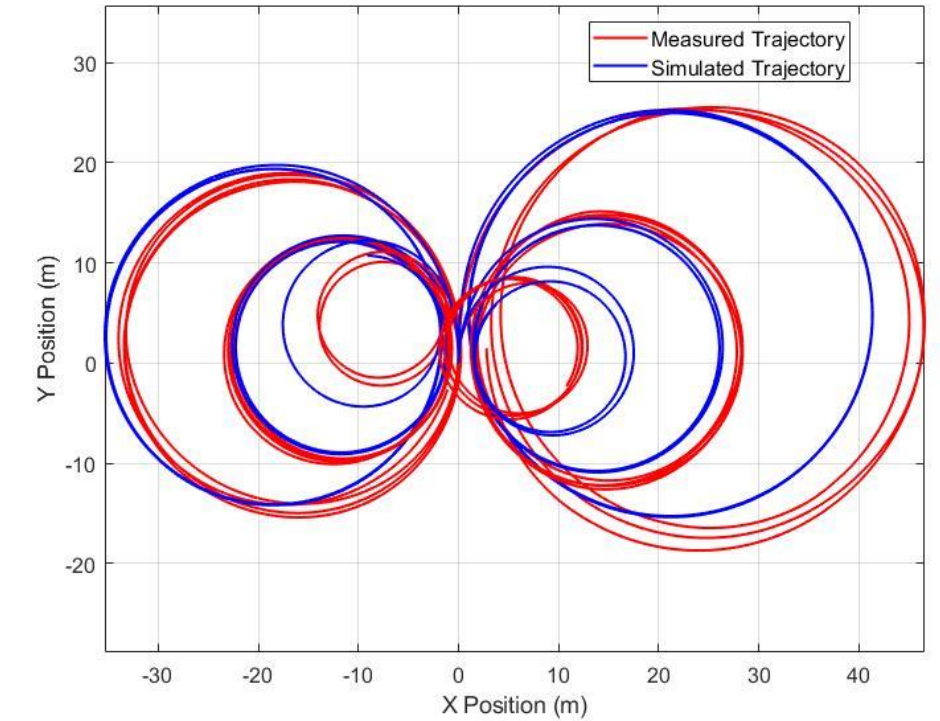
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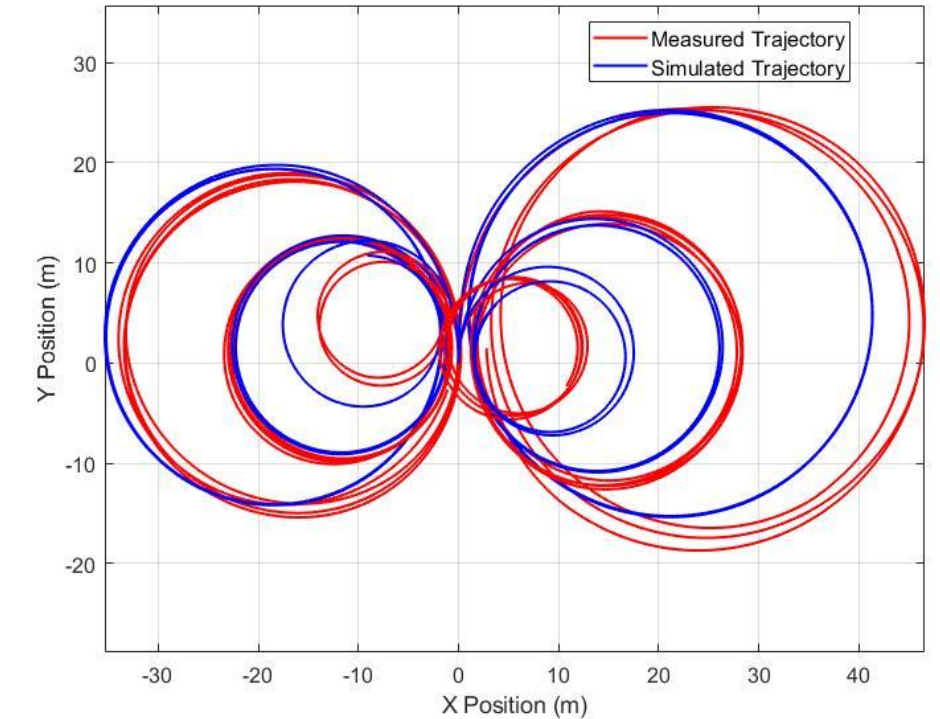
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- Integrate model into control system (autonomous navigation, vessel train)
- Model for logistical/economic planning



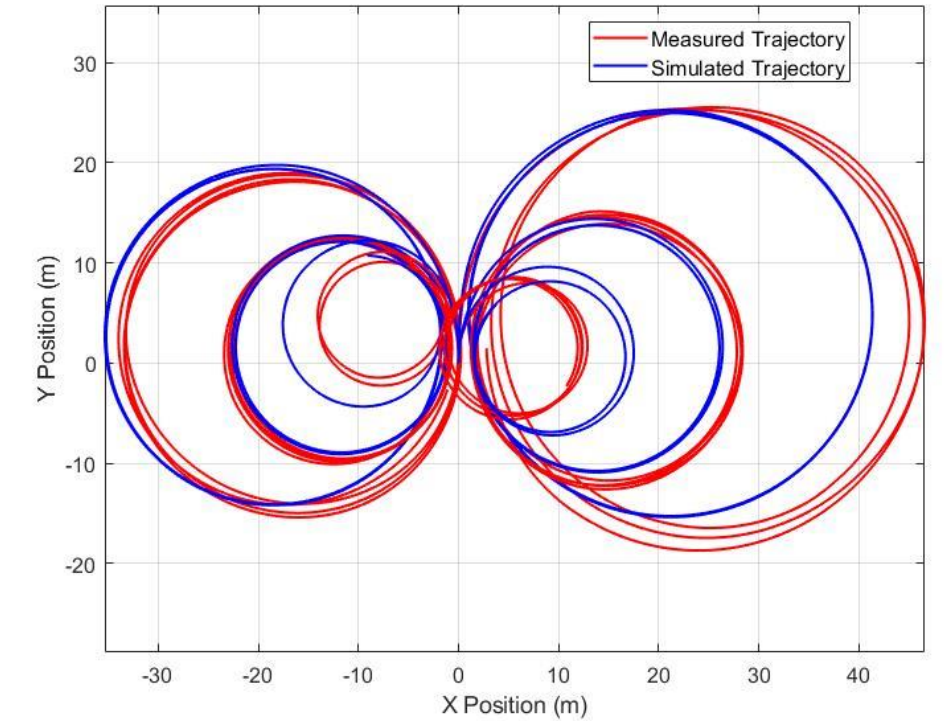
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- Apply methodology to second vessel in Gent (LL in Belgium)



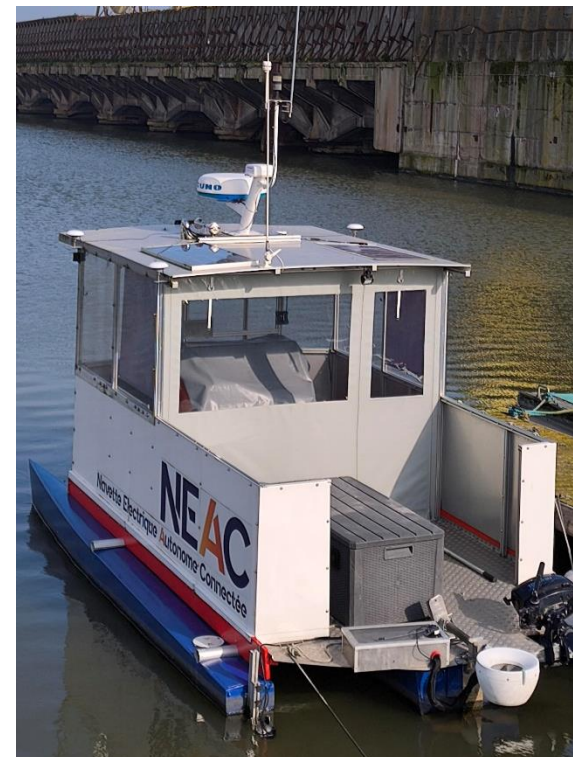
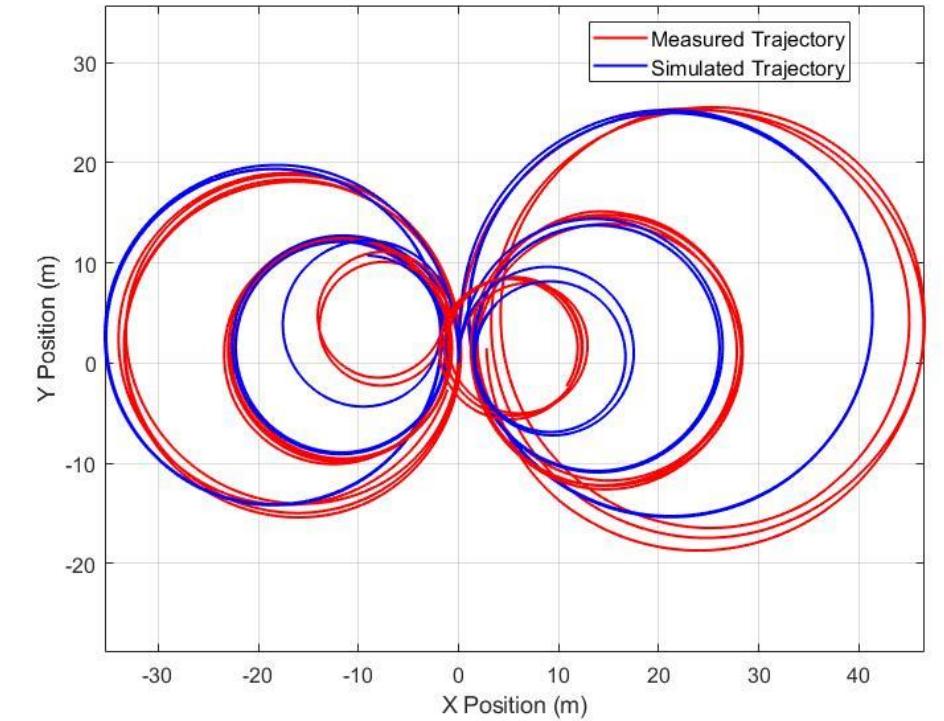
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- Apply methodology to second vessel in Gent (LL in Belgium)
- Low-speed manoeuvres (automated mooring)
- RTK measurements (coefficient sensitivity)



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⇒ revitalize inland waterways
- SFAZ prototype full scale trials (turning circle, zigzag, acceleration) successfully completed
⇒ practical and cost-effective

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⇒ practical and cost-effective
- Key manoeuvring characteristics identified
⇒ ready to develop a manoeuvring model
- Future Work: develop a simplified 3DOF manoeuvring model with focus on environmental factors
⇒ practical SFAZ motion prediction with balanced efficiency and accuracy

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FOREMAST

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