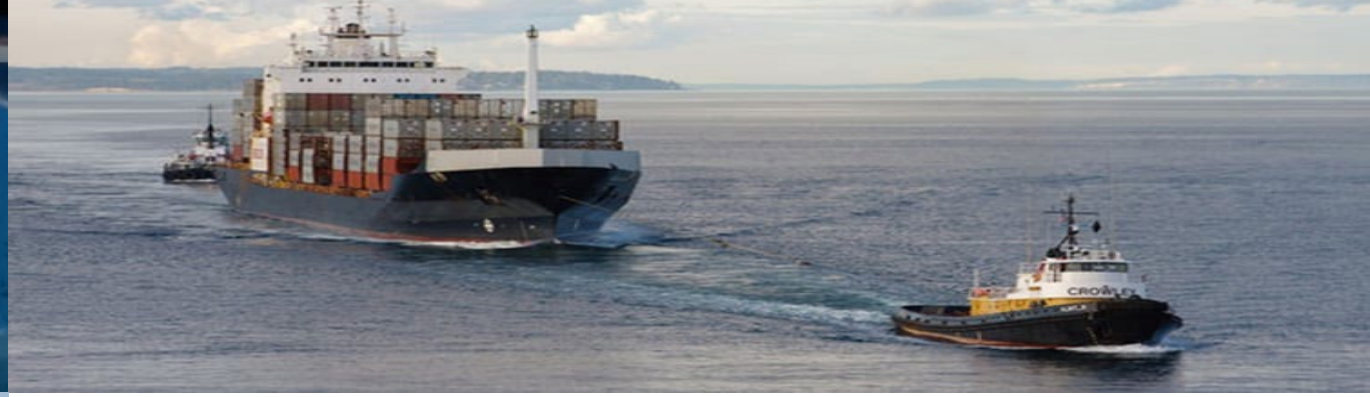


Smart Shipping: Perspectives & Challenges

"anticipating the massive introduction of sensing, actuation, computation, and communication technology"

Prof.dr. Rudy Negenborn

R.R.Negenborn@tudelft.nl

Researchlab Autonomous Shipping
Department of Maritime and Transport Technology
Delft University of Technology

Interreg 2 Seas Mers Zeeën

NWO

Connecting EU Insights

RESEARCHLAB AUTONOMOUS SHIPPING

RESEARCHLAB AUTONOMOUS SHIPPING

- *Adaptive* control, coordination & health monitoring
- *Human-machine intelligence* interaction
- *Real-time* optimization of transport and logistics (e.g. construction materials, mobility solutions)
- *Experimental validation* using high-fidelity simulations with real-life data and actual vessels (fleet of ~20 vessels)


The Green Village

EUROPESE UNIE
Europees Fonds voor Regionale Ontwikkeling
Mede gefinancierd in het kader van de respons van de Unie op de COVID-19-pandemie.

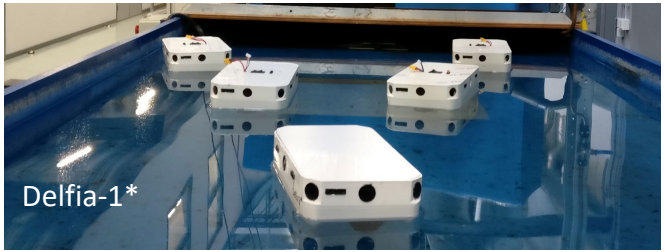
THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

NWO

provincie Zuid-Holland

Interreg 2 Seas Mers Zeeën

Interreg North Sea Region
European Regional Development Fund
EUROPEAN UNION


Delfia-1*

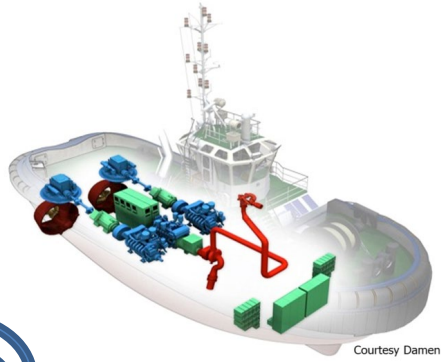

SeaBAX

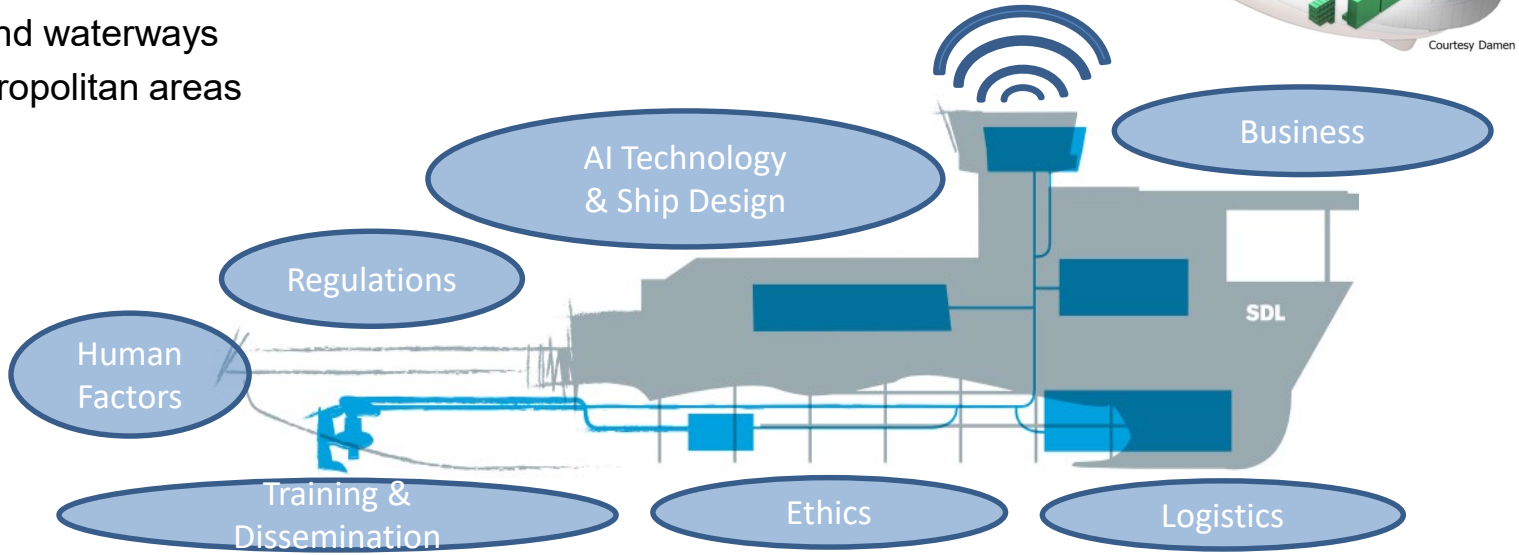

Vera Cruz


GeoXYZ

Multi-disciplinary approaches enabling green and autonomous transport

- on the open oceans
- in crowded port areas
- in inland waterways
- in metropolitan areas





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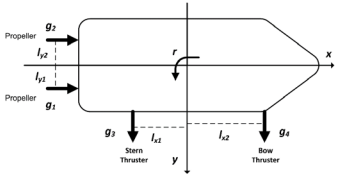
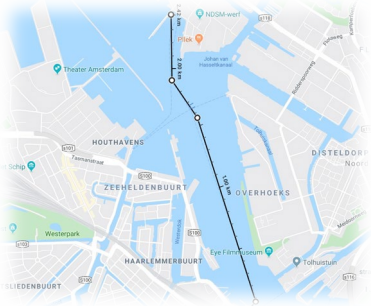
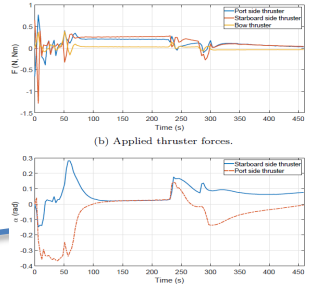
Single Autonomous Vessel

- Machine Vision & Situational awareness
- Adaptive Predictive Manoeuvring Control
- Predictive Thrust Allocation & Energy Management
- ....

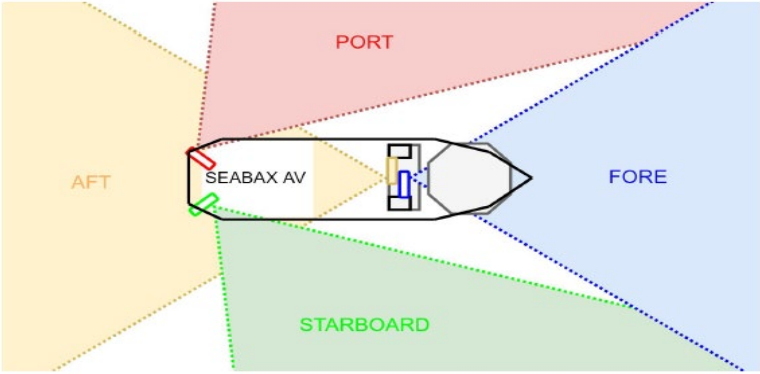


$$\mathbf{x}(k+1) = f(\mathbf{x}(k),\mathbf{u}(k),\mathbf{d}(k))$$
$$\mathbf{y}(k+1) = g(\mathbf{x}(k+1))$$
$$\mathbf{u}(k) = c(\mathbf{y}(k))$$
$$\max J(\mathbf{y}(k+1),\mathbf{u}(k))$$





In collaboration with AMS & MIT Roboat

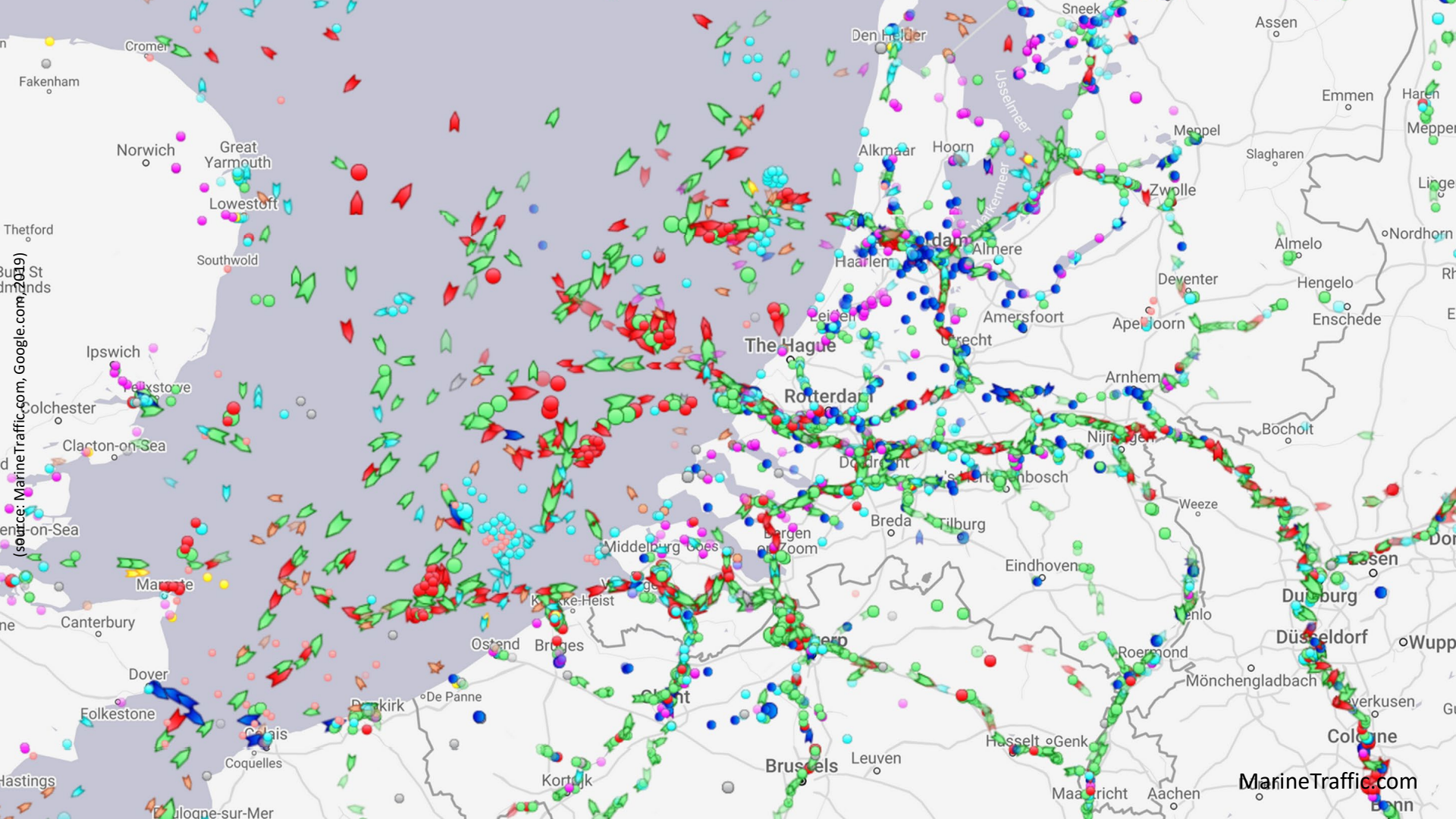


M. Hepworth, 2020; A. Haseltalab, V. Garofano et al., "Model Predictive Trajectory Tracking Control and Thrust Allocation for Autonomous Vessels," IFAC world congress 2020.

TU Delft

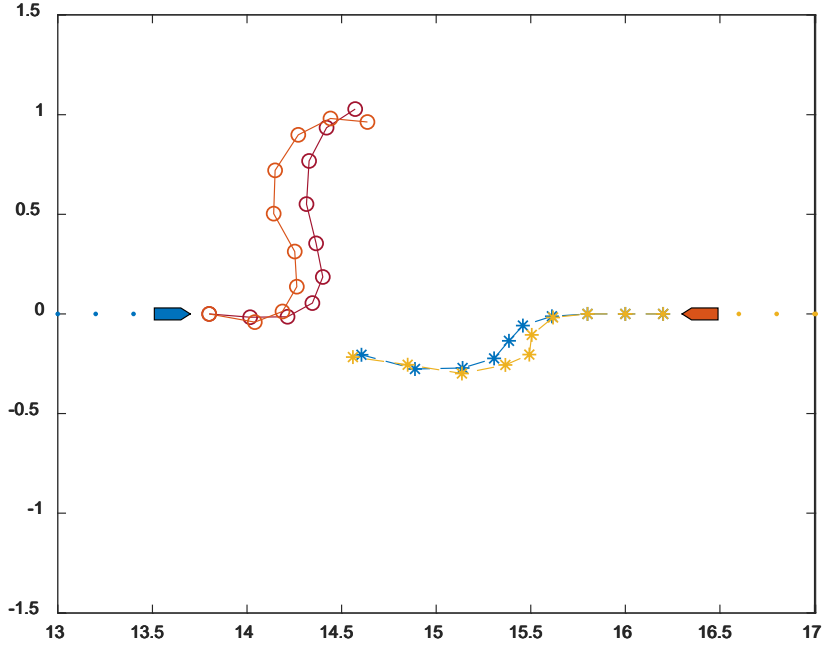
FASTI FIELD LAB AUTONOMOUS SAILING TECHNOLOGY

OPZuid Europees Innovatieprogramma Zuid-Nederland

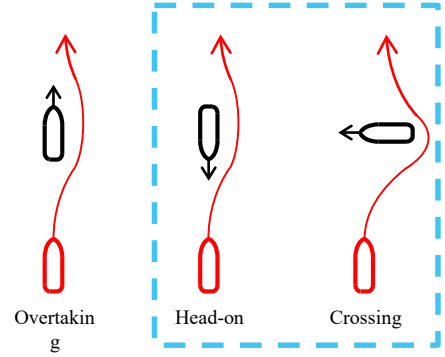

(source: MarineTraffic.com, Google.com, 2019)
Cromer
Fakenham
Norwich
Great Yarmouth
Lowestoft
Thetford
Southwold
Ipswich
Colchester
Clacton-on-Sea
Margate
Canterbury
Dover
Folkestone
Calais
Coquelles
Hastings
Boulogne-sur-Mer
Ostend
Bruges
De Panne
Kortrijk
Brussels
Leuven
Middelburg
Goes
Bergen op Zoom
Breda
Tilburg
Eindhoven
Den Helder
Alkmaar
Hoorn
Haarlem
Leiden
The Hague
Rotterdam
Amsterdam
Almere
Amersfoort
Utrecht
Dordrecht
Nijmegen
Arnhem
Apeldoorn
Deventer
Zwolle
Meppel
Sneek
Assen
Emmen
Slagharen
Almelo
Hengelo
Enschede
Nordhorn
Bocholt
Weeze
Venlo
Roermond
Mönchengladbach
Hasselt
Genk
Maastricht
Aachen
Essen
Duisburg
Düsseldorf
Wuppertal
Leverkusen
Cologne
Bonn
IJsselmeer
Markermeer
MarineTraffic.com

Multi-vessel interactions

"What if ships could talk?"



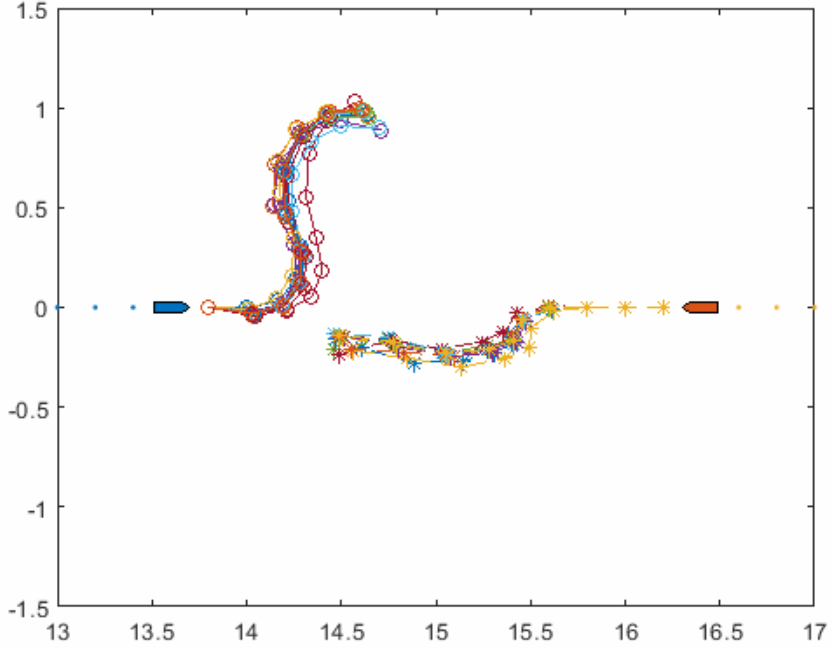
And / Or (?):
COLlision
REGulation**S**
Compliant
Collision
Avoidance



Distributed Model Predictive Control Made Easy, Springer, 2015

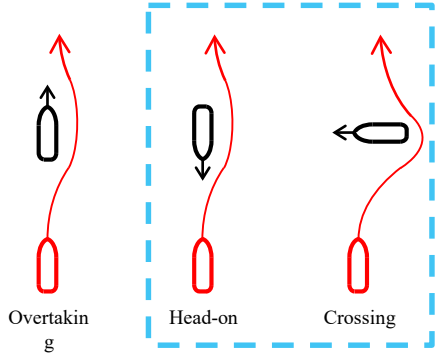
Multi-vessel interactions

"What if ships could talk?"



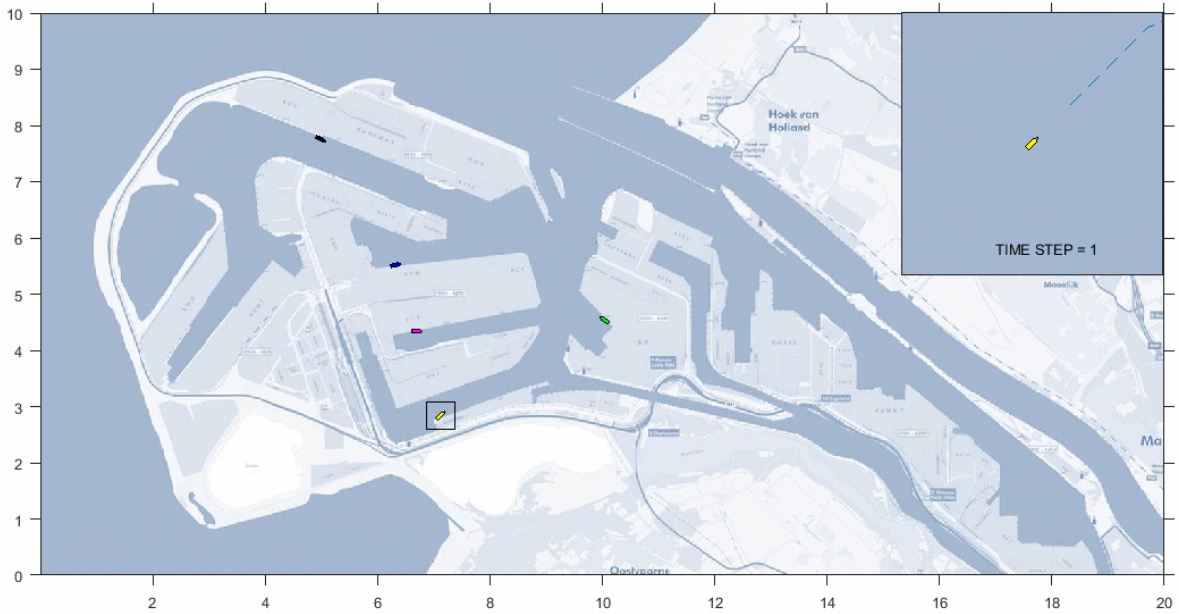
Distributed Model Predictive Control Made Easy, Springer, 2015

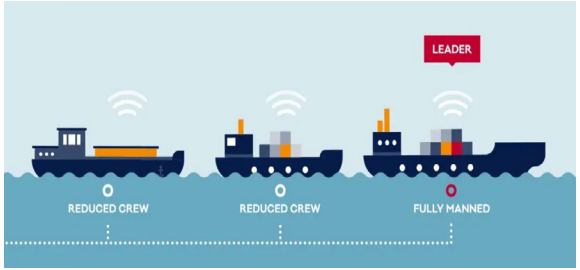
And / Or (?):
COLlision
REGulation**S**
Compliant
Collision
Avoidance



RESEARCHLAB AUTONOMOUS SHIPPING

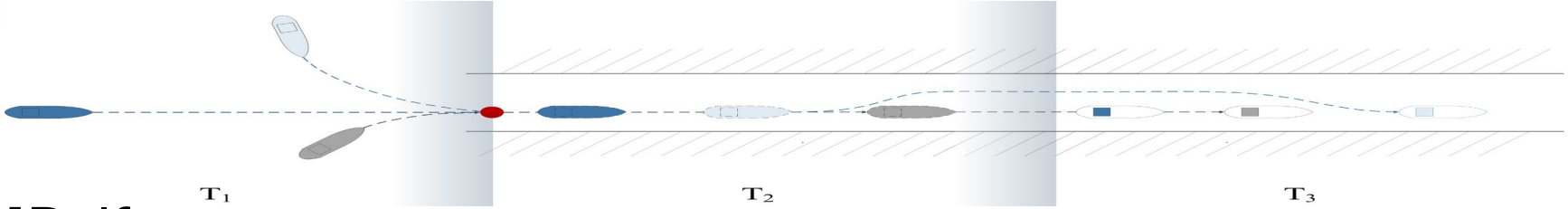
Fuel-Efficient Vessel Train Formations





NOVIMAR VESSELTRAIN

Horizon2020
European Union Funding
for Research & Innovation



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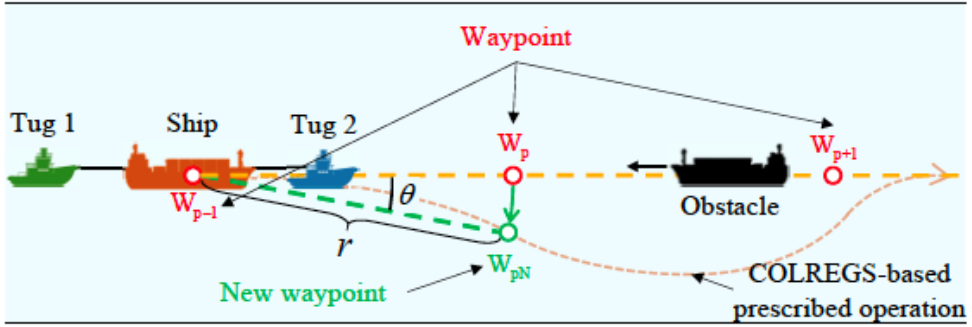
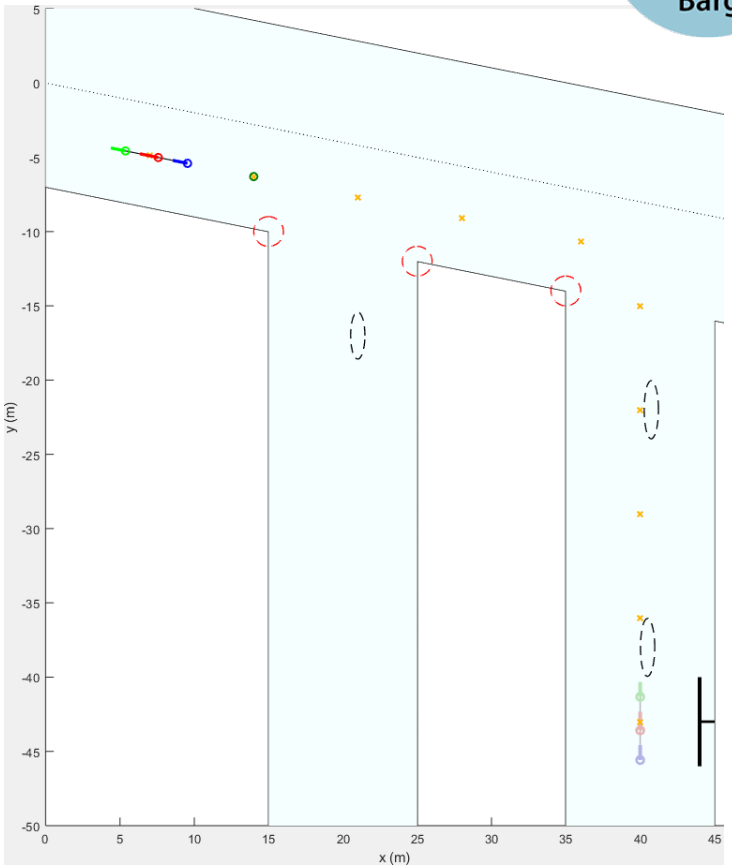
Distributed model predictive control for vessel train formations of cooperative multi-vessel systems, Chen, Hopman, Transportation Research Part C: Emerging Technologies, vol. 92, pp. 101-118, July 2018.

Horizon2020
European Union Funding
for Research & Innovation

AUTO Barge

Object manipulation: Multi-Tug Ship Towing





Cooperative multi-agent control for autonomous ship towing under environmental disturbances, Du, Reppa, *IEEE/CAA Journal of Automatica Sinica*, 2021.

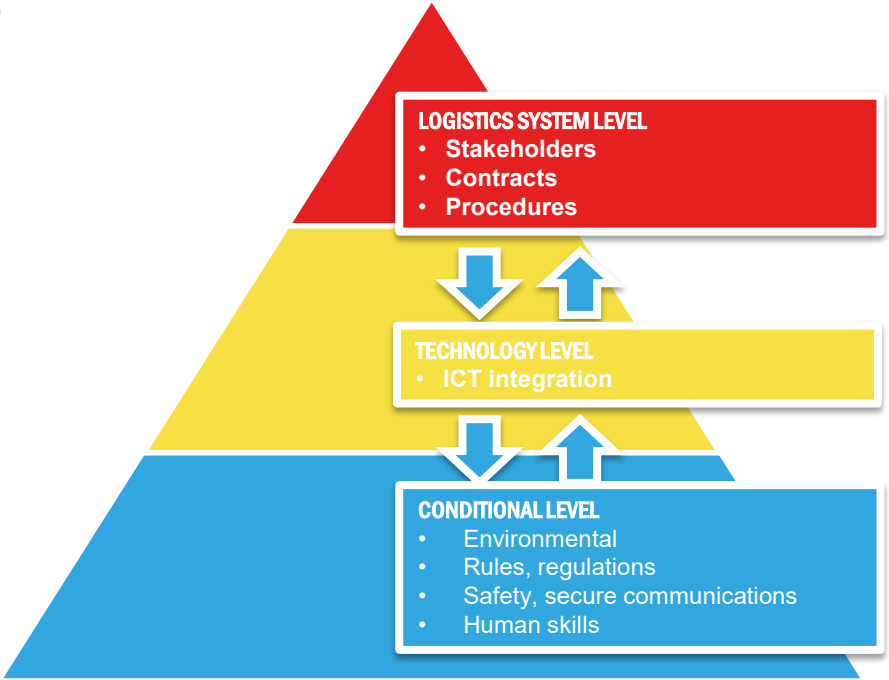
Human and(/or?) machine intelligence in the port area?

Smart Logistics: Putting things in perspective

NOVIMOVE

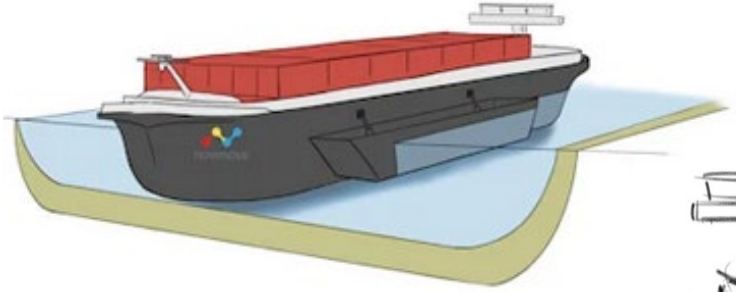
Smart & sustainable waterways

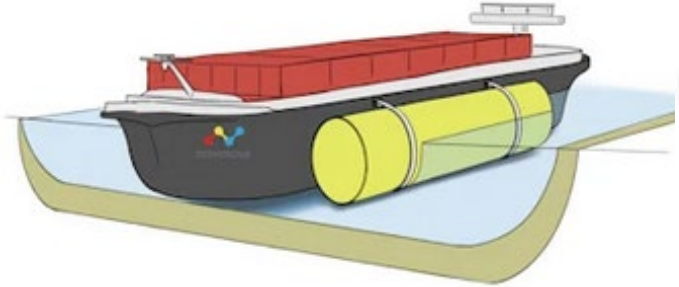
Make better use
of the capacity of
inland fleet and infrastructure,
and increase IWT
reliability and competitiveness

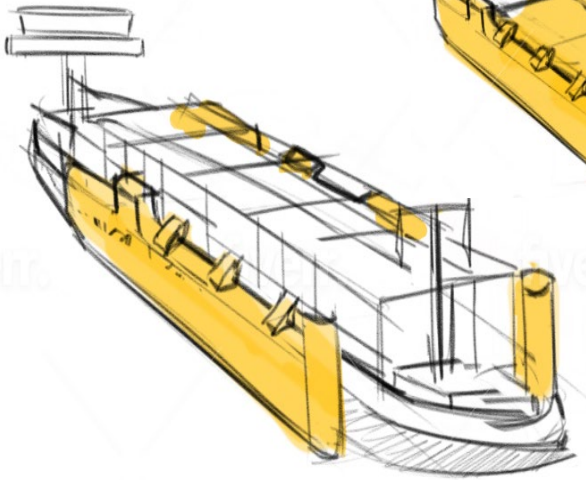


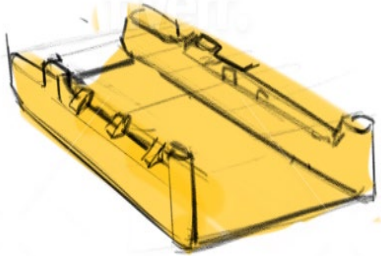
Funded by the Horizon H2020 Programme of the European Union under grant agreement No 858508

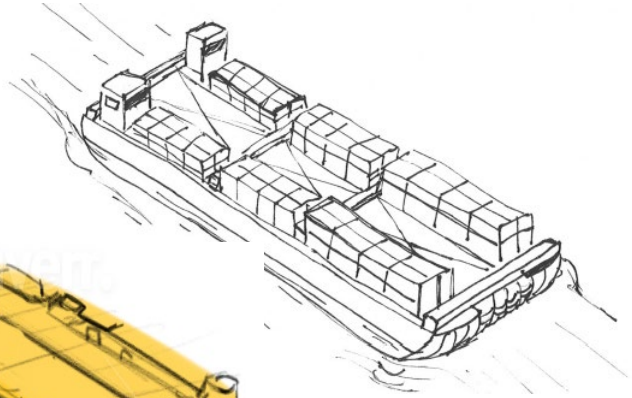
From Climate-Resilient Ship Concepts …











(Artist impressions)

Including new GNSS-empowered smart navigation systems

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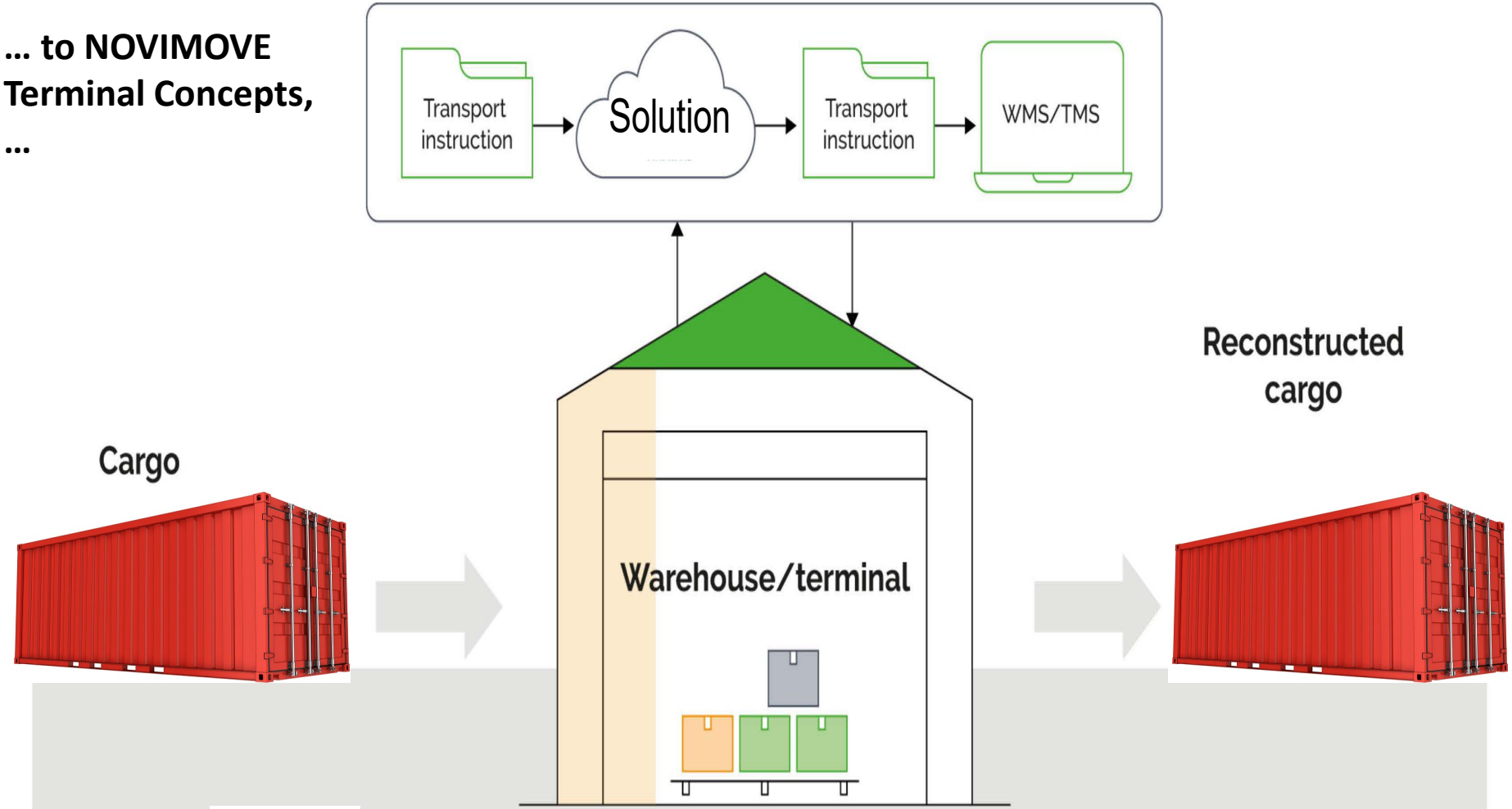
… to NOVIMOVE Terminal Concepts, …



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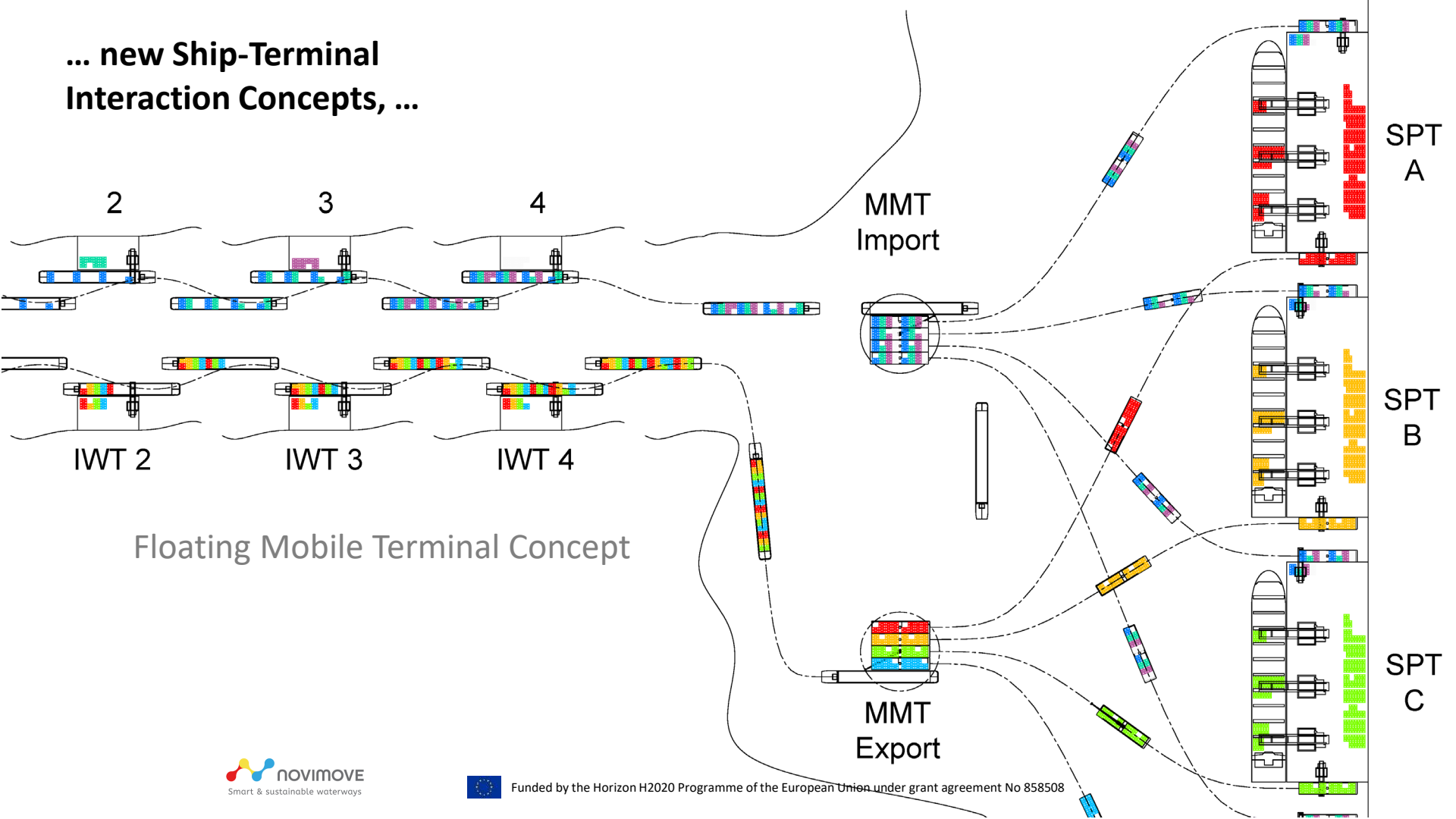
… new Ship-Terminal Interaction Concepts, …



Floating Mobile Terminal Concept

novimove
Smart & sustainable waterways

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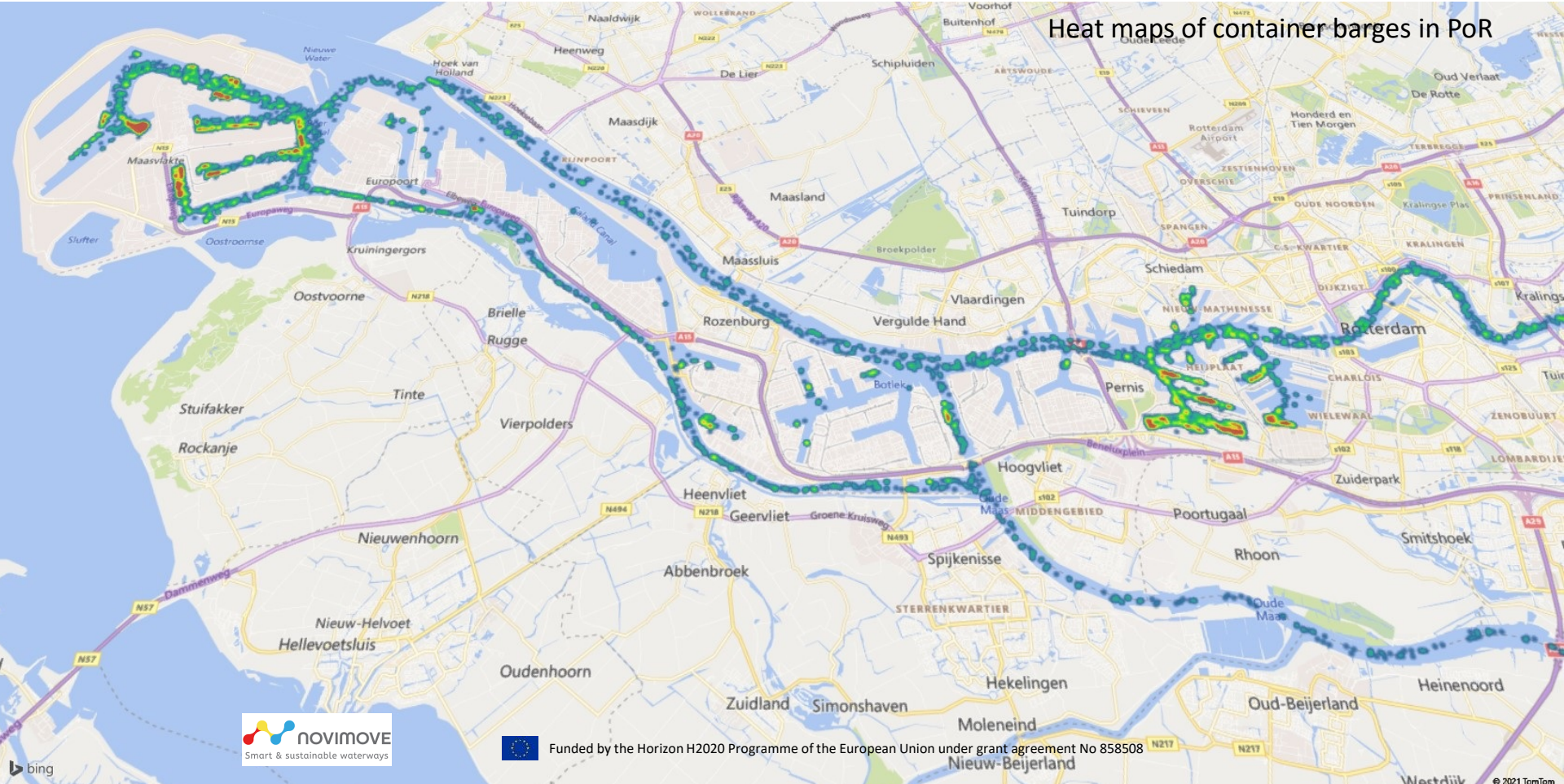
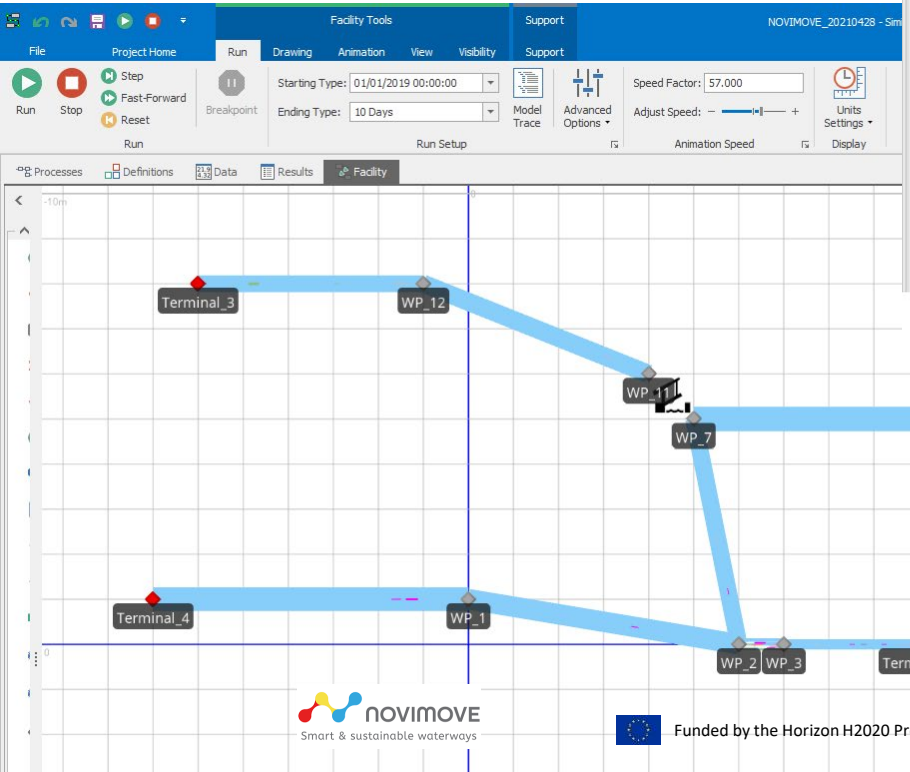
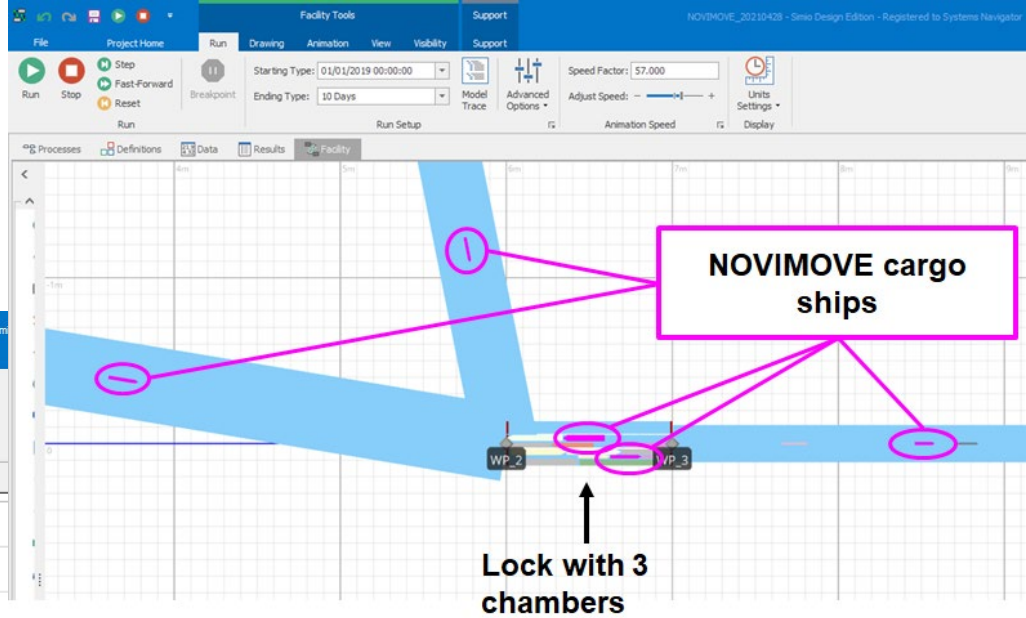
… and analysis of current situation …



… versus innovation impact analysis for future situation …





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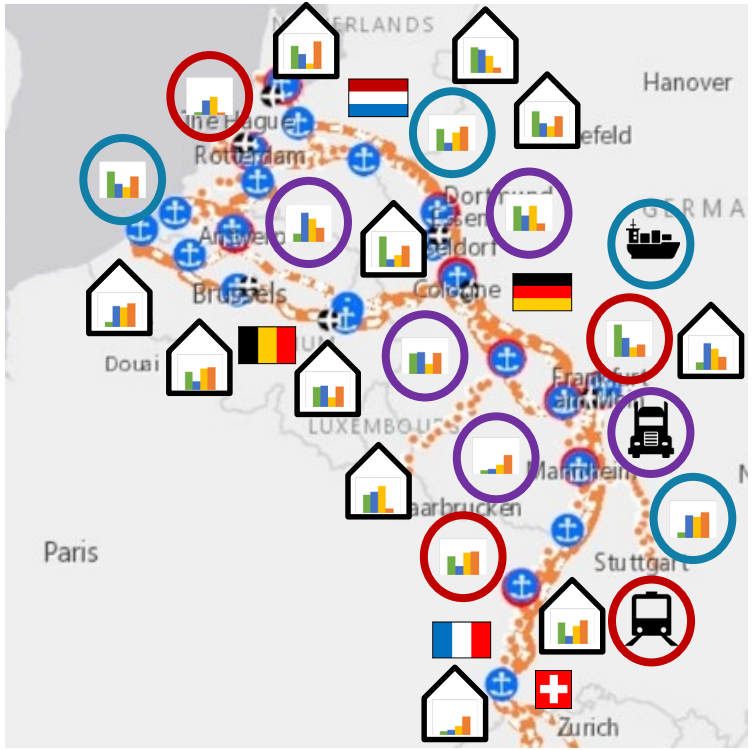
… with focus on the Rhine-Alpine Corridor …



- Assess the impact of the innovations on the corridor transport network
- Very complex system
  - High number of ports/terminals
  - 5 countries
  - 3 different transport modes
  - Many operators with various objectives
  - Numerous shippers exhibiting different behavior
  - Relations between these actors

… to move from science towards application.

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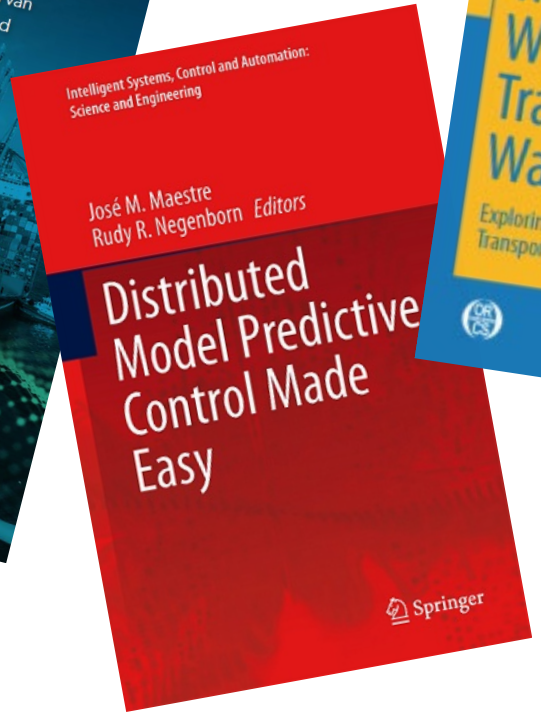
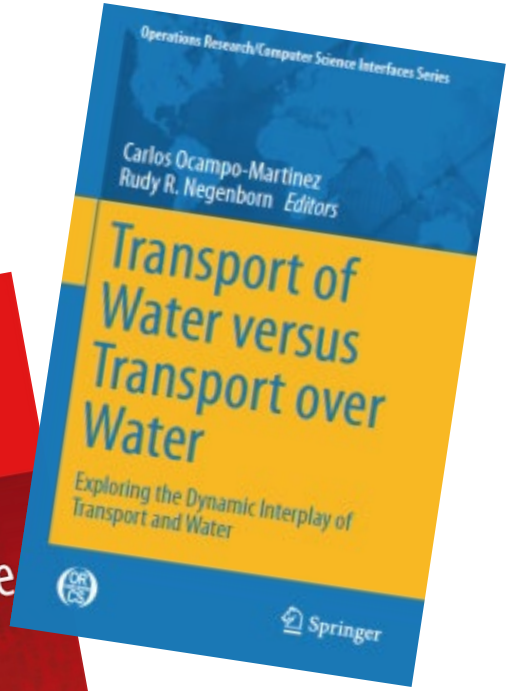
SMART PORT
Smart ships and the changing maritime ecosystem
How digitalization and advanced automation of barges, service vessels and sea ships create new opportunities and challenges for the maritime industry


KOERSEN OP AI
Maritieme ambities op het gebied van Artificial Intelligence in Nederland
NL AI Coalitie


Intelligent Systems, Control and Automation: Science and Engineering
José M. Maestre
Rudy R. Negenborn Editors
Distributed Model Predictive Control Made Easy
Springer


Operations Research/Computer Science Interfaces Series
Carlos Ocampo-Martinez
Rudy R. Negenborn Editors
Transport of Water versus Transport over Water
Exploring the Dynamic Interplay of Transport and Water
Springer

TU Delft

Become a member of the
“Joint IWT Smart Logistics / Smart Shipping Project Initiative”

NOVIMOVE
Smart & sustainable waterways

PLATINA3
IWT policy platform

LASTING
POWERED BY WATERBORNE

IW-NET

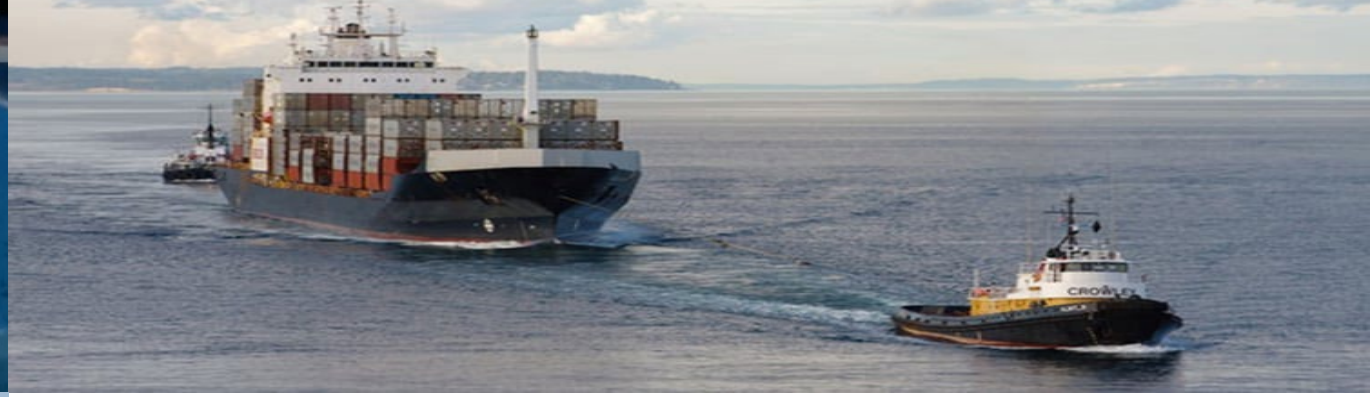
AUTOSHIP
Autonomous Shipping Initiative for European Waters

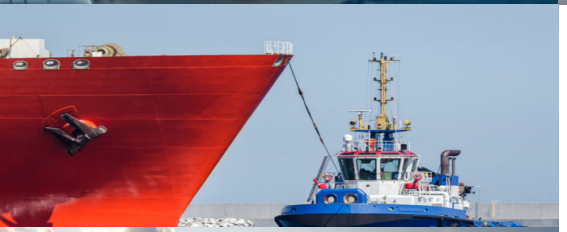
Aegis

ENTRANCE

AUTO Barge

BOOSTLOG





Smart Shipping: Perspectives & Challenges

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A. Coraddu, F. Schulte, D.L. Schott, *et al.*

Researchlab Autonomous Shipping
Department of Maritime and Transport Technology
Delft University of Technology