CIMNE
30 years

Challenges on computational models for ship design and navigation: Ongoing projects at CIMNE MARINE

Julio García-Espinosa

OUTLINE

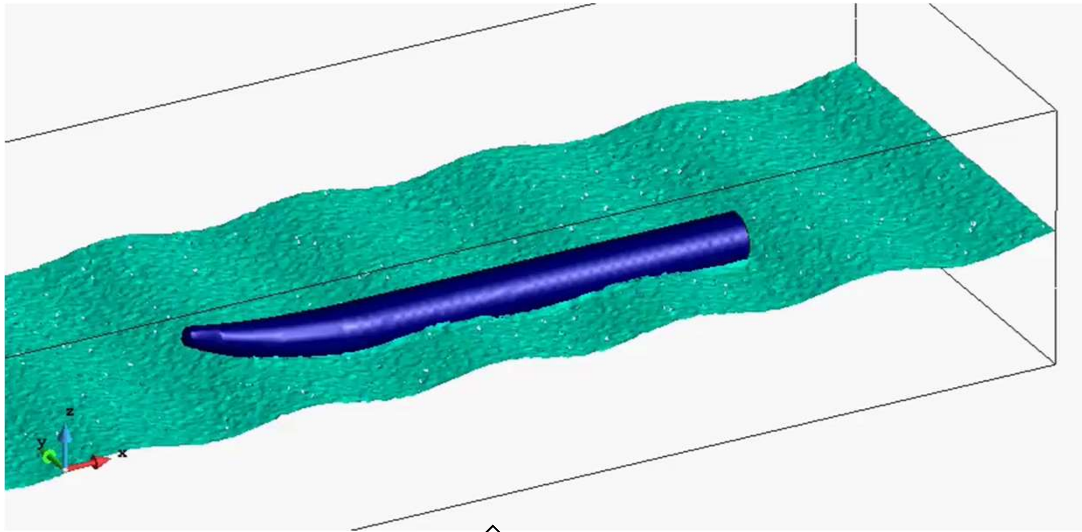
- Some completed projects
- On-going projects
  - Fibreship
  - Nice-Ship
  - STM Validation

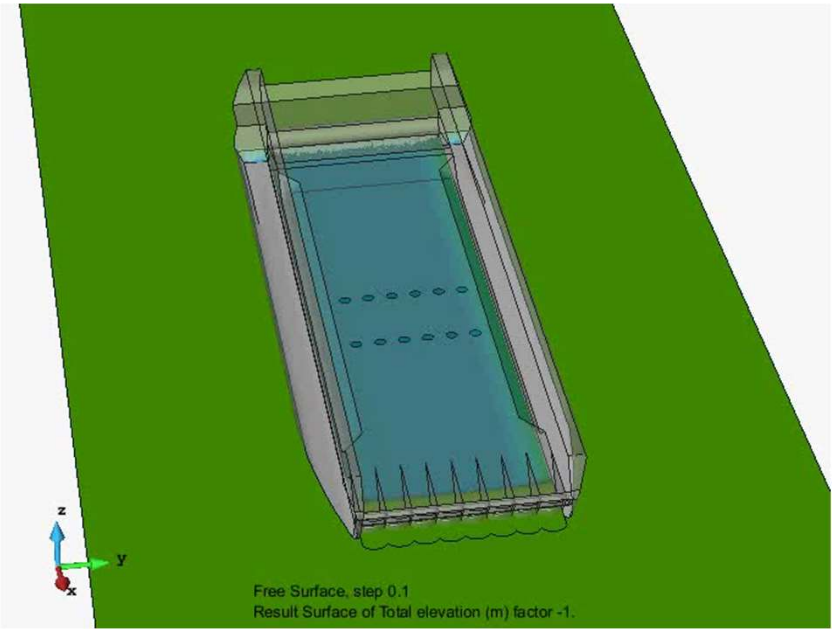
CIMNE
30 years

CIMNE MARINE SOME PAST PROJECTS

CIMNE MARINE: SOME COMPLETED PROJECTS

Evaluating performance of the air cushion and seals of a SES T-Craft in waves (M-SES). 2009-2012. ONR Global.

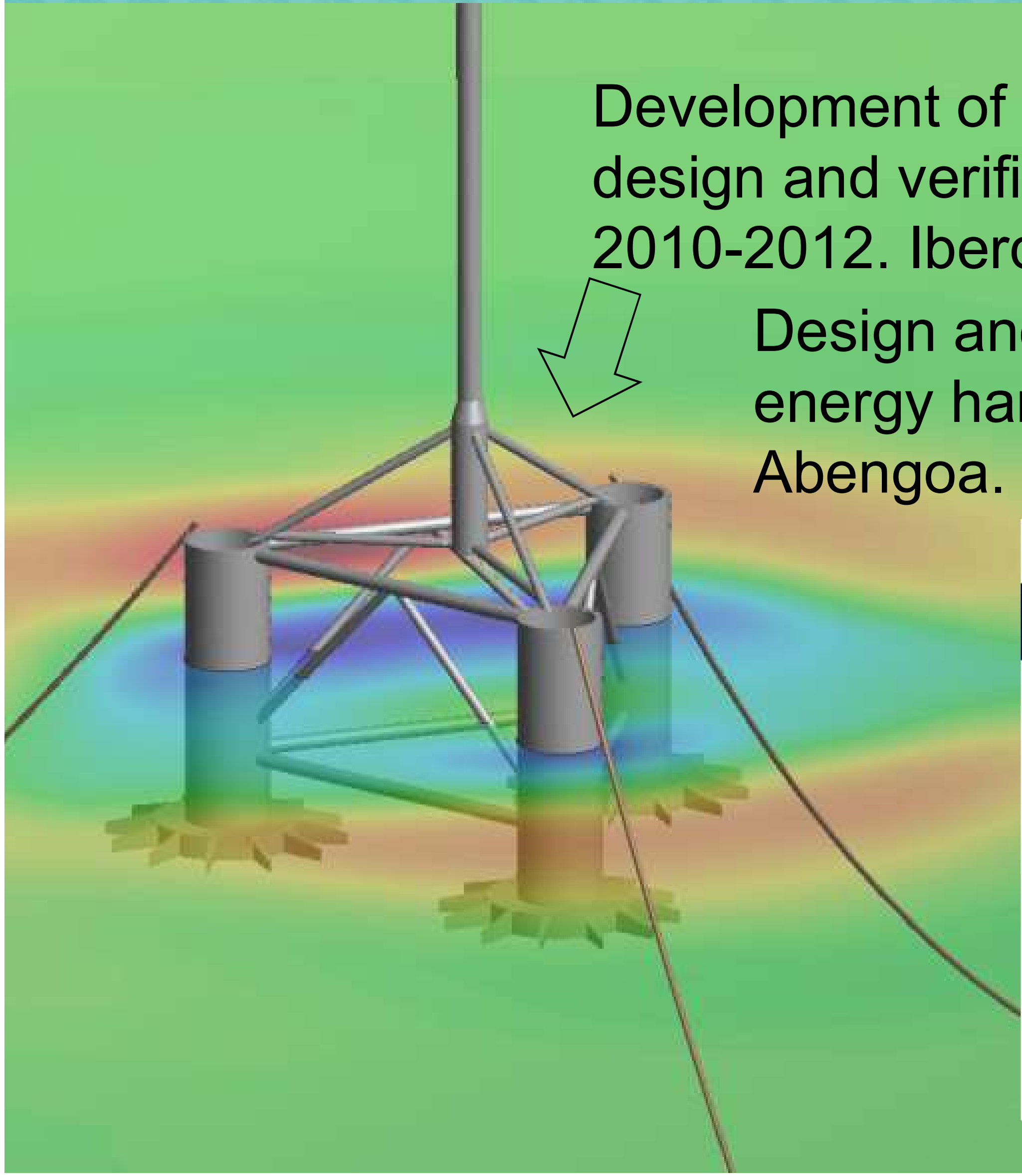




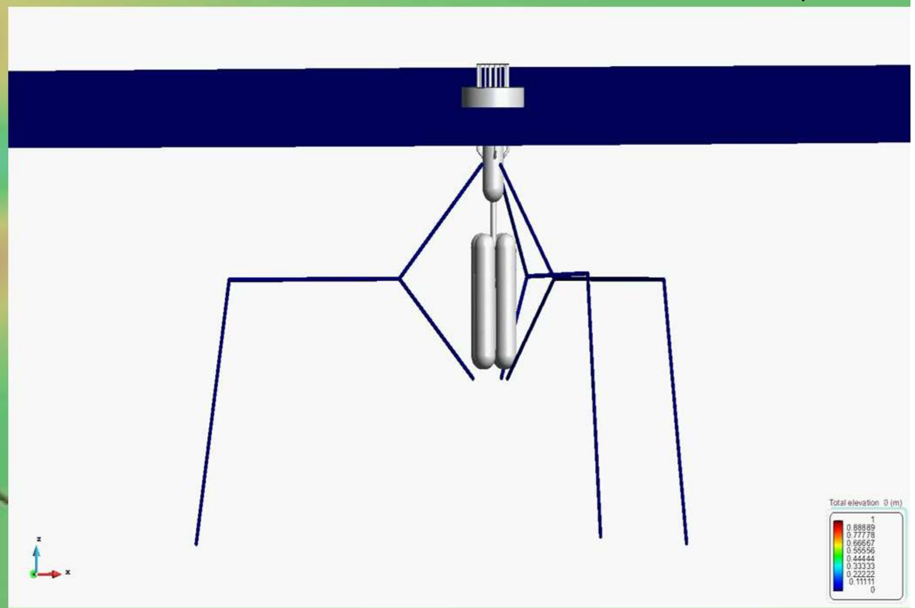
Advanced numerical simulation and performance evaluation of wave adaptive modular vessels in spray generating conditions (WAM-V). 2012-2014. ONR Global.

CIMNE MARINE: SOME COMPLETED PROJECTS

Development of a software environment for design and verification of marine wind turbines. 2010-2012. Iberdrola.

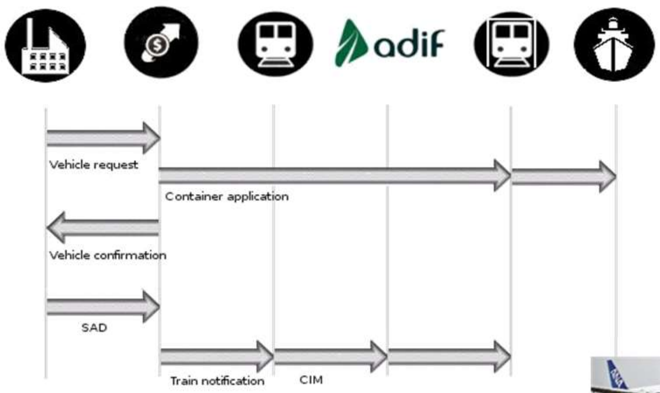


Design and assessment of wave energy harnesing devices. 2012-2015. Abengoa.



CIMNE MARINE: SOME COMPLETED PROJECTS

Multimodal interoperatibility e-services for Logistics and environmental sustainability (MIELE). 2010-2013. MOS 2010-EU-21105-S

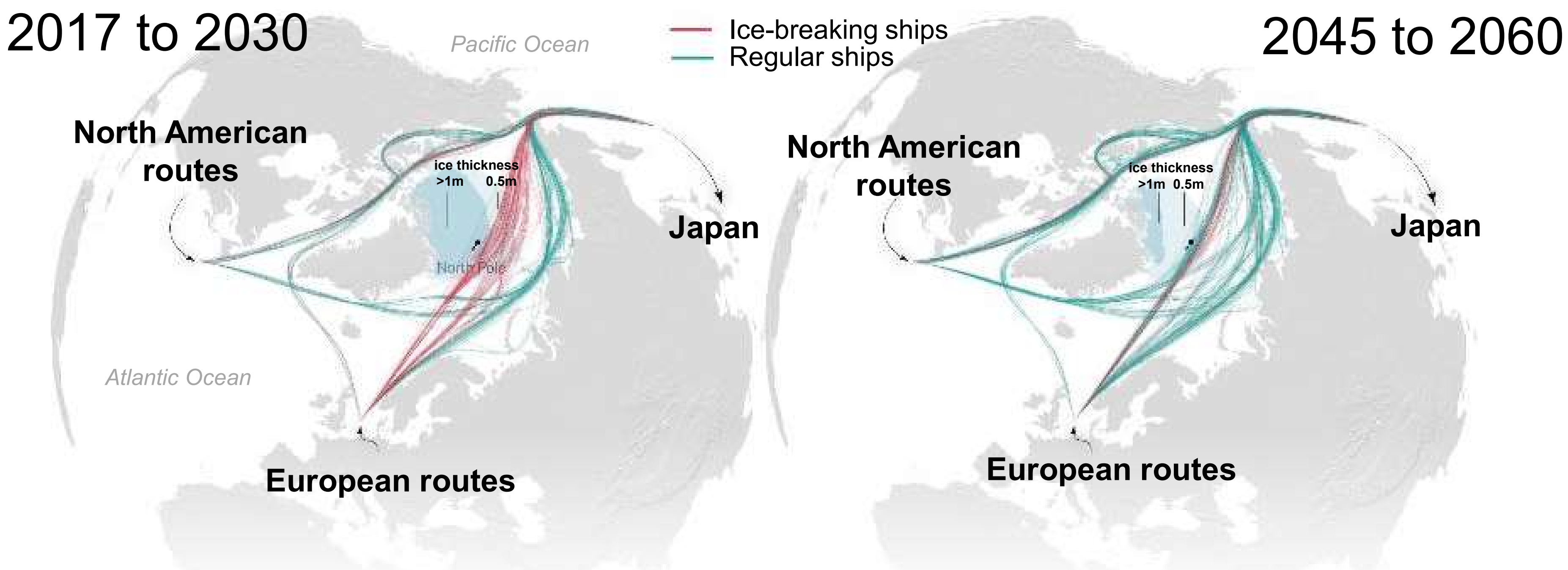


CIMNE®
30 years

CIMNE MARINE ON-GOING PROJECTS

NICE-SHIP

CIMNE MARINE: NICE-SHIP PROJECT



- Until now, exploitation of the vast stores resources in the far north has largely been confined to the land. But current retreating of sea ice is enabling an expansion northwards of commercial fisheries and, in time, it will facilitate the exploitation of the mineral and hydrocarbon resources in the Arctic Circle.
- De-icing of the existing ice masses in the far north region allows Arctic trade routes to remain open for longer periods of time. Sailing by northern routes could reduce by 20-30% the journey times and with similar savings in fuel consumption and greenhouse gas emissions.
- While nobody disputes today that the exploitation of those opportunities must be properly managed in order to preserve the delicate Arctic environment, it is undeniable that reality of today is that commercial activity and economic development in the Arctic is increasing rapidly.

Picture retrieved from: https://www.nytimes.com/interactive/2017/05/03/science/earth/arctic-shipping.html

CIMNE MARINE: NICE-SHIP PROJECT

- The potential development of the Arctic and Antarctic regions evidence the need for new procedures for estimating the forces that ice exerts on ice-breakers, polar ships and marine structures, and in general, the need for having advanced computational tools able to help naval architects to design the new generation of vessels to operate in polar regions.
- The NICE-SHIP (2016 - 2019) project aims to developing a new generation of computational methods, based on the integration of innovative semi-Lagrangian particle-based and discrete element models for the analysis of the operation of a vessel in an iced sea.

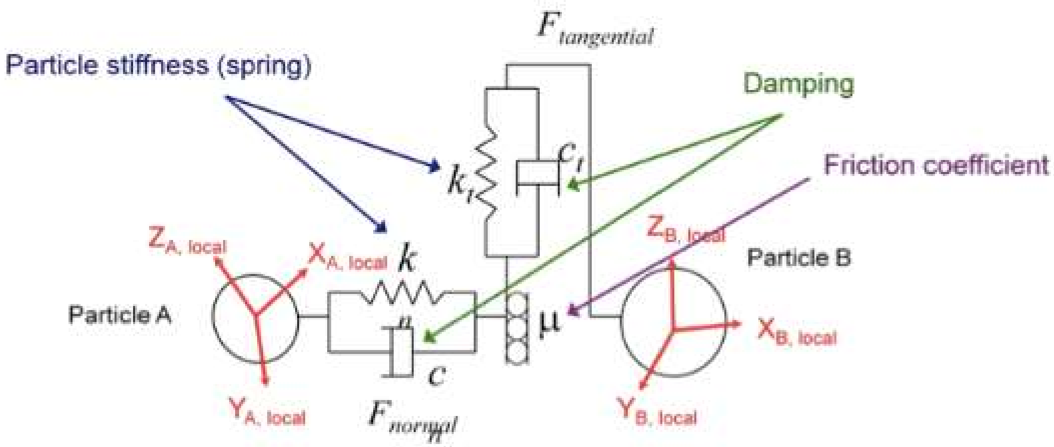
Scenario 1: Icebreaking performance in level ice

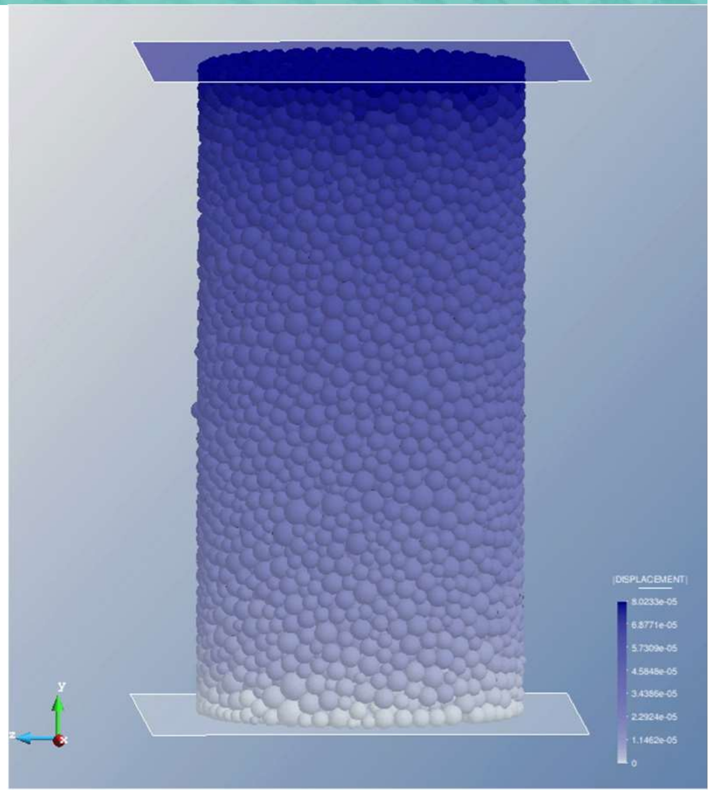
Scenario 2: Navigation of ships in brash ice (and broken ice)

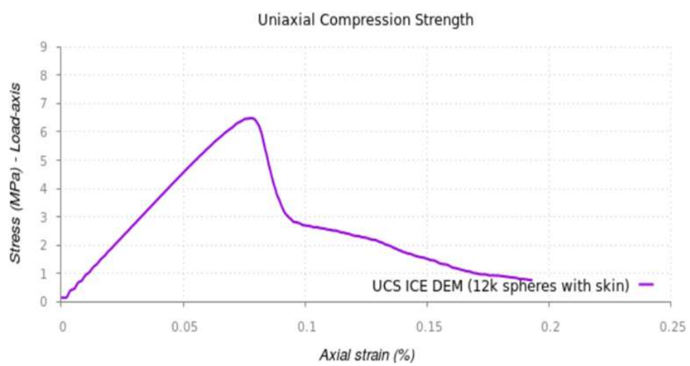
CIMNE MARINE: NICE-SHIP PROJECT MODELLING ICE MECHANICS

Discrete Element Method

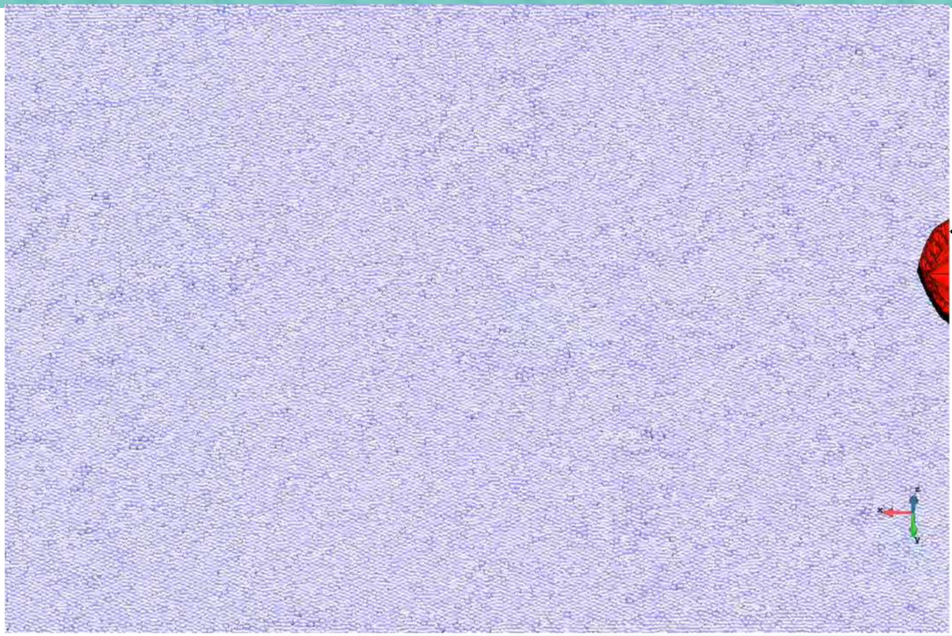
- Material represented by a collection of spherical (ellipsoidal) particles (not micro, usually cms).
- Rigid particles, soft contacts.
- Adequate contact laws yield desired macroscopic material behaviour (local contact problem).
- Contact surfaces (for forces integration) based on weighted Voronoi diagram.
- Contact interaction takes into account friction, cohesion, and the possibility of breakage of cohesive bonds.
- Dynamics based on standard equations of motion.





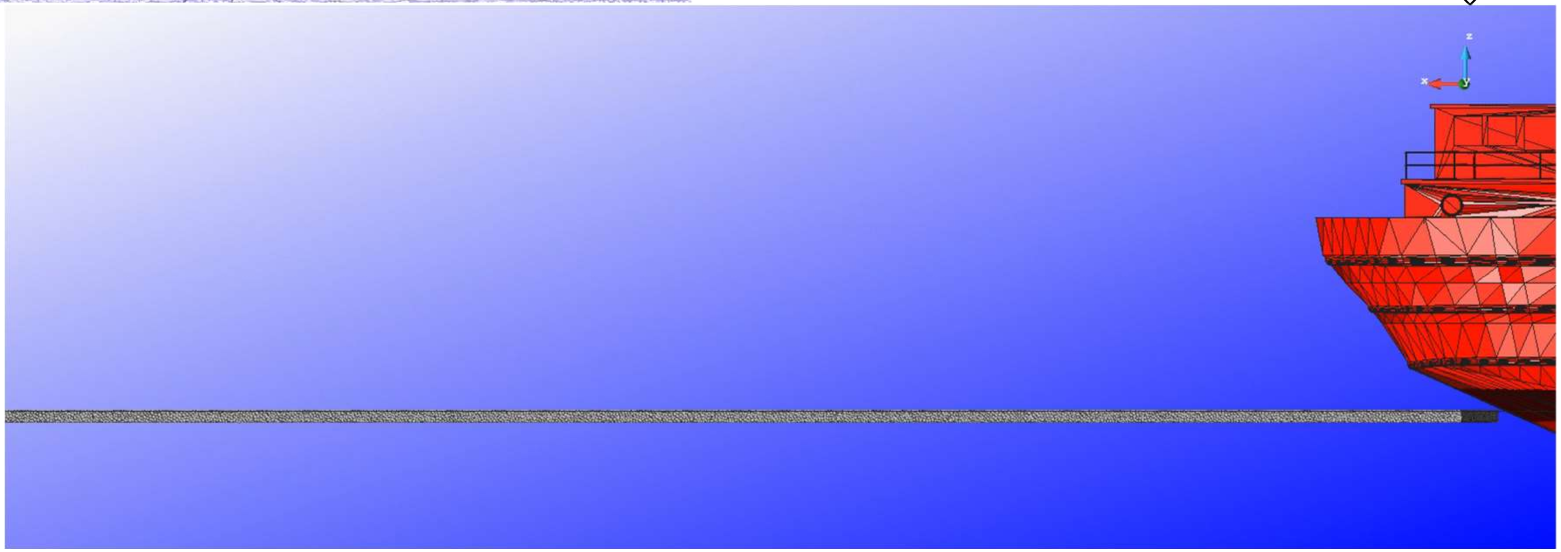


CIMNE MARINE: NICE-SHIP PROJECT
SCENARIO 1 (PRELIMINARY TESTS)



Soft ice. 1 meter thick. 1 element in thickness.

Hard ice. 1 meter thick. 6 elements in thickness.



CIMNE MARINE: NICE-SHIP PROJECT
SEMILAGRANGIAN MODEL FOR INCOMPRESSIBLE NAVIER-STOKES

Lagrangian governing equations: $d_t U_\lambda = A_\lambda \quad d_t X_\lambda = U_\lambda$

Integration along trajectory: $$\frac{U_\lambda(X_\lambda^{n+1}) - U_\lambda(X_\lambda^n)}{\Delta t} = A_\lambda(X_\lambda^{n+1})$$

Lagrangian splitting: $$\begin{cases} \dfrac{U_\lambda^*(X_\lambda^{n+1}) - U_\lambda(X_\lambda^n)}{\Delta t} = 0 \rightarrow U_\lambda^*(X_\lambda^{n+1}) = U_\lambda(X_\lambda^n) \\ \dfrac{U_\lambda(X_\lambda^{n+1}) - U_\lambda^*(X_\lambda^{n+1})}{\Delta t} = A_\lambda(X_\lambda^{n+1}) \end{cases}$$

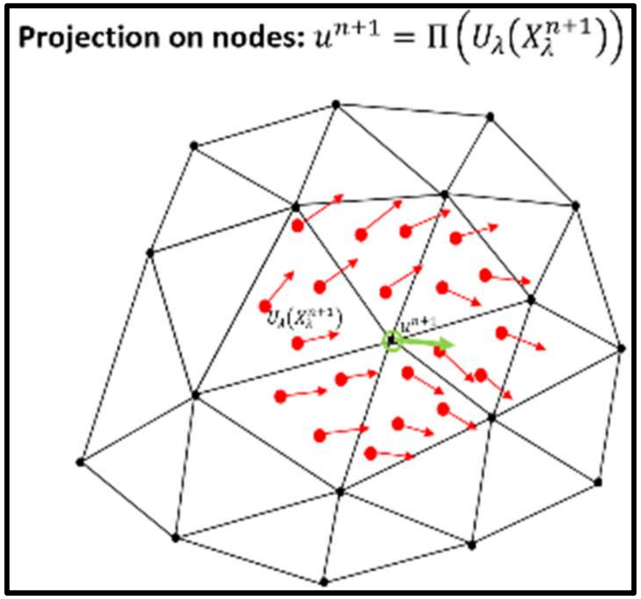
Projection onto background FE mesh:

$$\frac{\Pi\left(U_\lambda(X_\lambda^{n+1})\right) - \Pi\left(U_\lambda^*(X_\lambda^{n+1})\right)}{\Delta t} = \Pi\left(A^{n+1}(X_\lambda^{n+1})\right)$$

$$u^{n+1} = \Pi\left(U_\lambda(X_\lambda^{n+1})\right)$$

Lagrangian → Eulerian

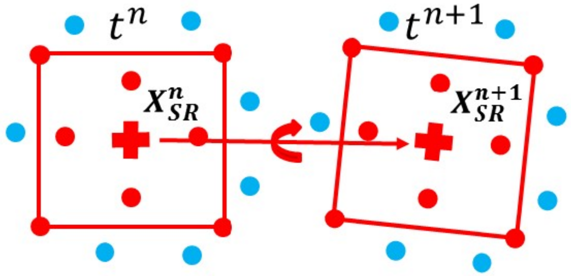
$$\frac{u^{n+1} - \mathrm{u}^*}{\Delta t} = a^{n+1} = -\frac{1}{\rho}\nabla P^{n+1} + \nu \Delta u^{n+1}$$



CIMNE MARINE: NICE-SHIP PROJECT
A SEMI-LAGRANGIAN METHOD FOR SOLID TRANSPORT IN FLUIDS

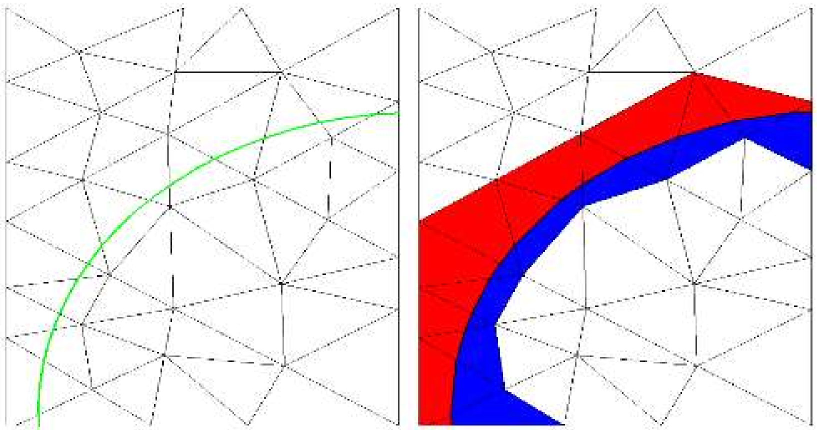
Step 1. The movement of the ice block can then be calculated explicitly using pressure and fluid stresses acting on the boundary in the Lagrangian transport step. Fluid particles trajectories and velocities are imposed using the ice block information.

$$\mathbf{F}_e = \int_{\Gamma} (p \cdot \mathbf{n}) d\Gamma + \int_{\Gamma} (\mathbf{n} \cdot \boldsymbol{\tau}) d\Gamma$$



Step 2. Once the translation and rotation of the ice block is evaluated, the interface of the solid mesh with the fluid mesh can be calculated.

Step 3. Then, the FE space can be enriched, by creating new DOFs on each of the interface elements for the pressure field (the original shape functions are split in two independent functions across the interface) and then statically condensing the new unknowns.

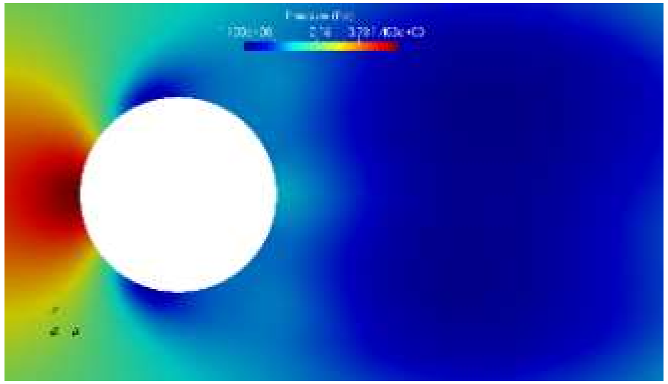


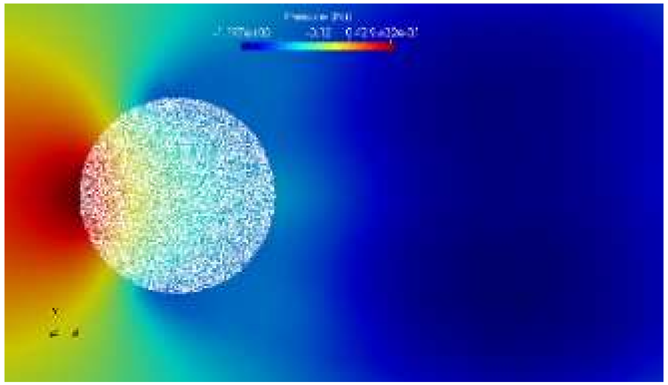
(left) Ice block interface over the mesh, (right) resulting enriched finite elements at the interface of the ice block

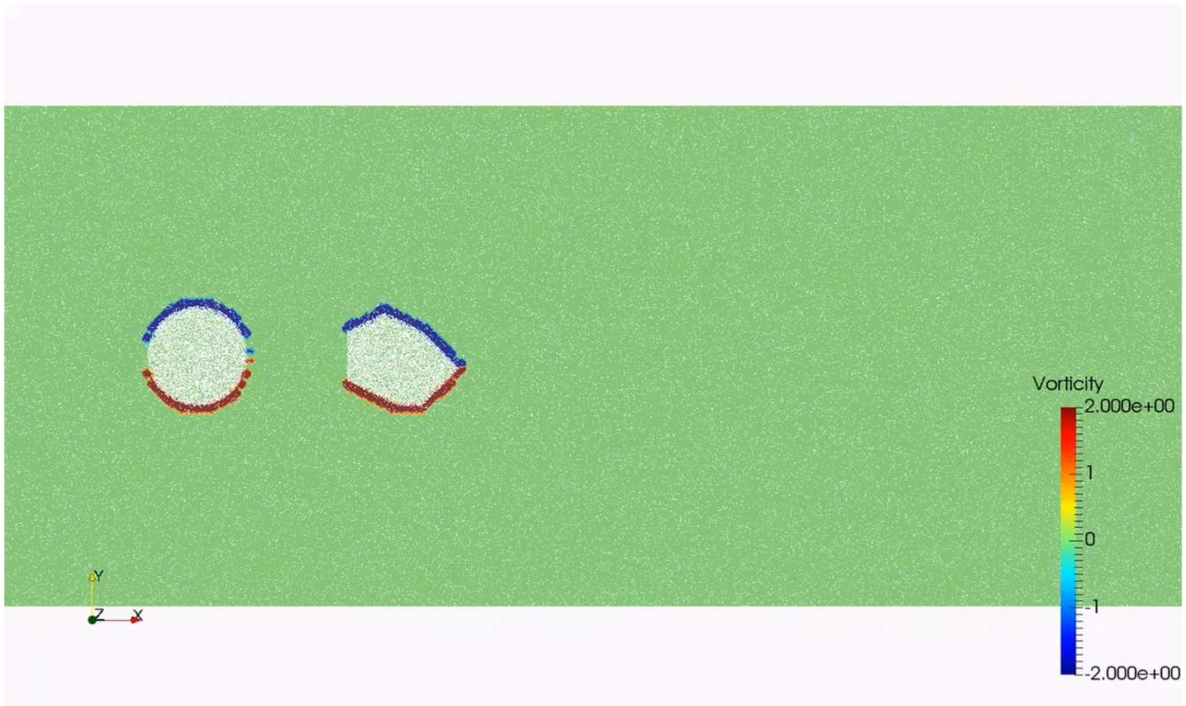
CIMNE MARINE: NICE-SHIP PROJECT
A SEMI-LAGRANGIAN METHOD FOR SOLID TRANSPORT IN FLUIDS

Proofs of concept

- 2D flow around a circular cylinder.
- Transport of two solid blocks within an uniform flow.





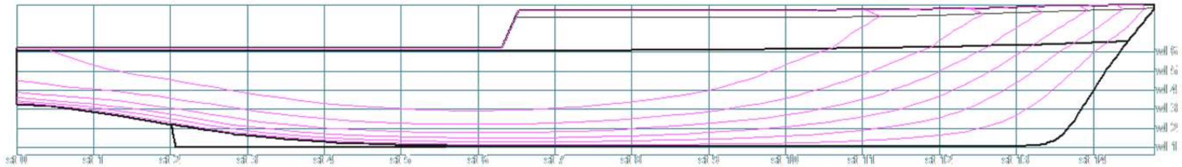


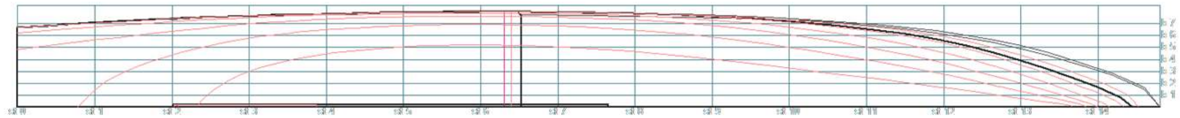
CIMNE MARINE: NICE-SHIP PROJECT SCENARIO 2 (PRELIMINARY TESTS)

Patrol ship in ice covered waters (brash ice)

Patrol ship

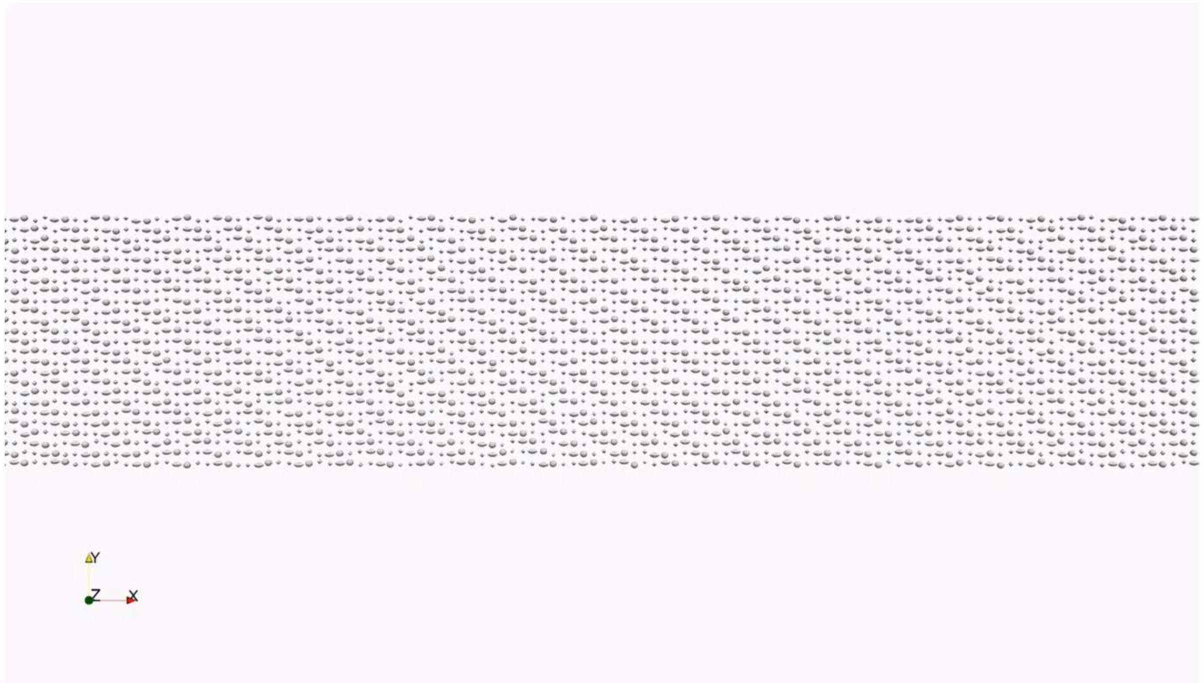
- Length: 75.5 m / 79.8 m
- Draft: 4.0 m
- Beam: 12.6 m / 13.2 m
- Displacement: 1813 t
- Velocity: 8kn





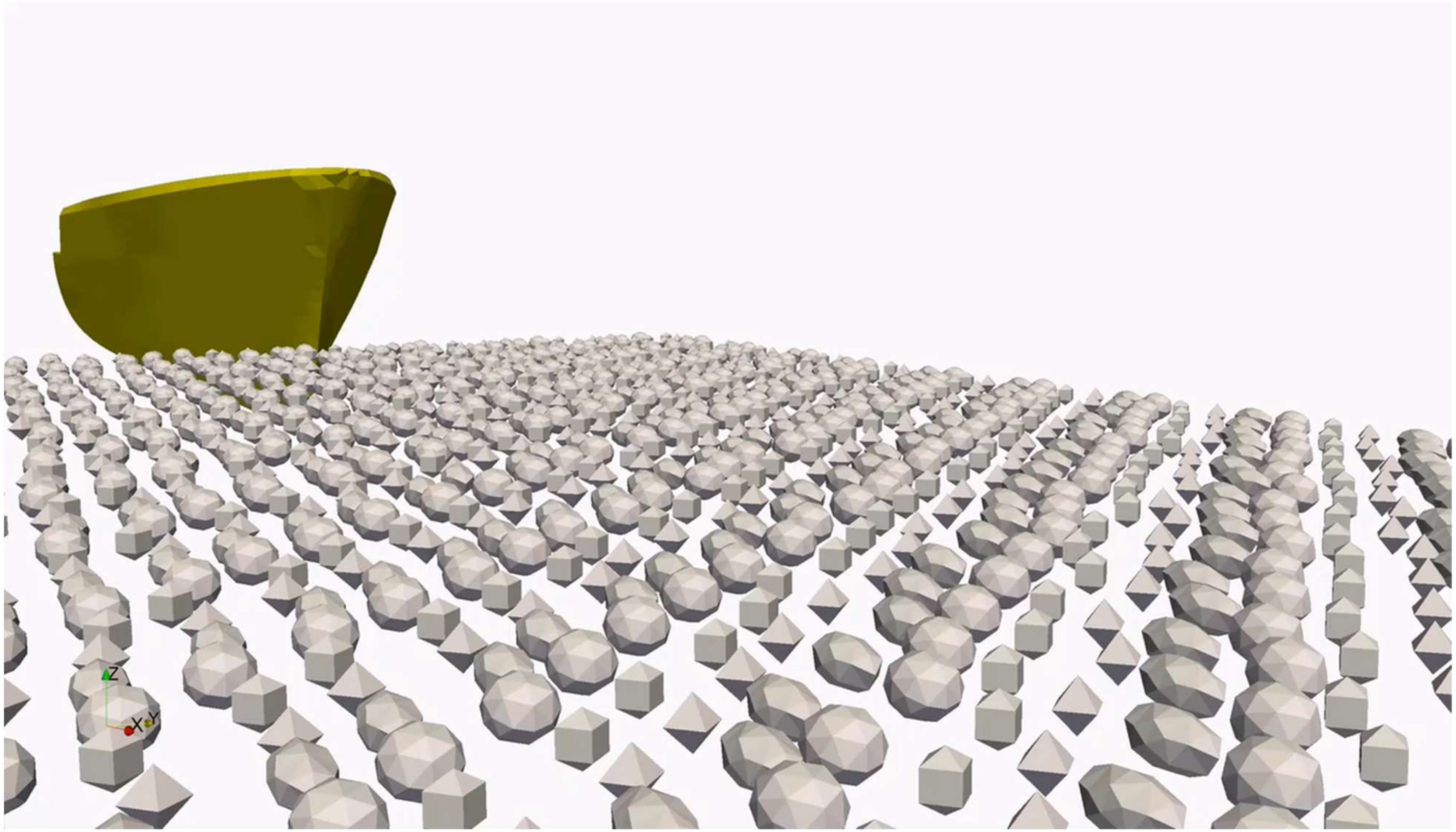
Ice covered waters

- Brash ice channel of 25 m wide
- Ice blocks of average size 0.5 m
- 300 x 25 ice blocks



CIMNE MARINE: NICE-SHIP PROJECT
SCENARIO 2 (PRELIMINARY TESTS)

Patrol ship in ice covered waters (brash ice)



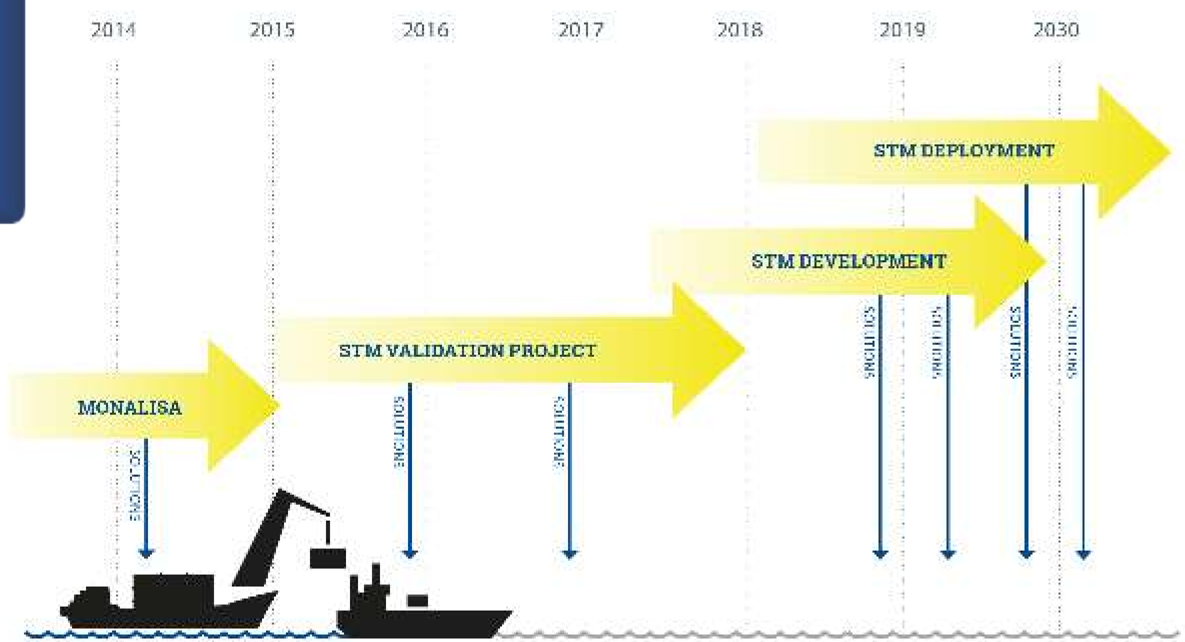
CIMNE 30 years

CIMNE MARINE ON-GOING PROJECTS

STM VALIDATION

STM
SEA TRAFFIC MANAGEMENT

STM past, present and future



- STM validation project is the second step in a long-term project aimed at developing and deployment of a Sea Traffic Management system connects and updates the maritime world in real time.
- STM-services allow personnel on-board and on shore to make decisions based on real-time information. These services enable more just-in-time arrivals, right steaming, reduced administrative burden and decreased risk related to human factors.
- Example of services are route optimization services, ship to ship route exchange, enhanced monitoring or port call synchronization.

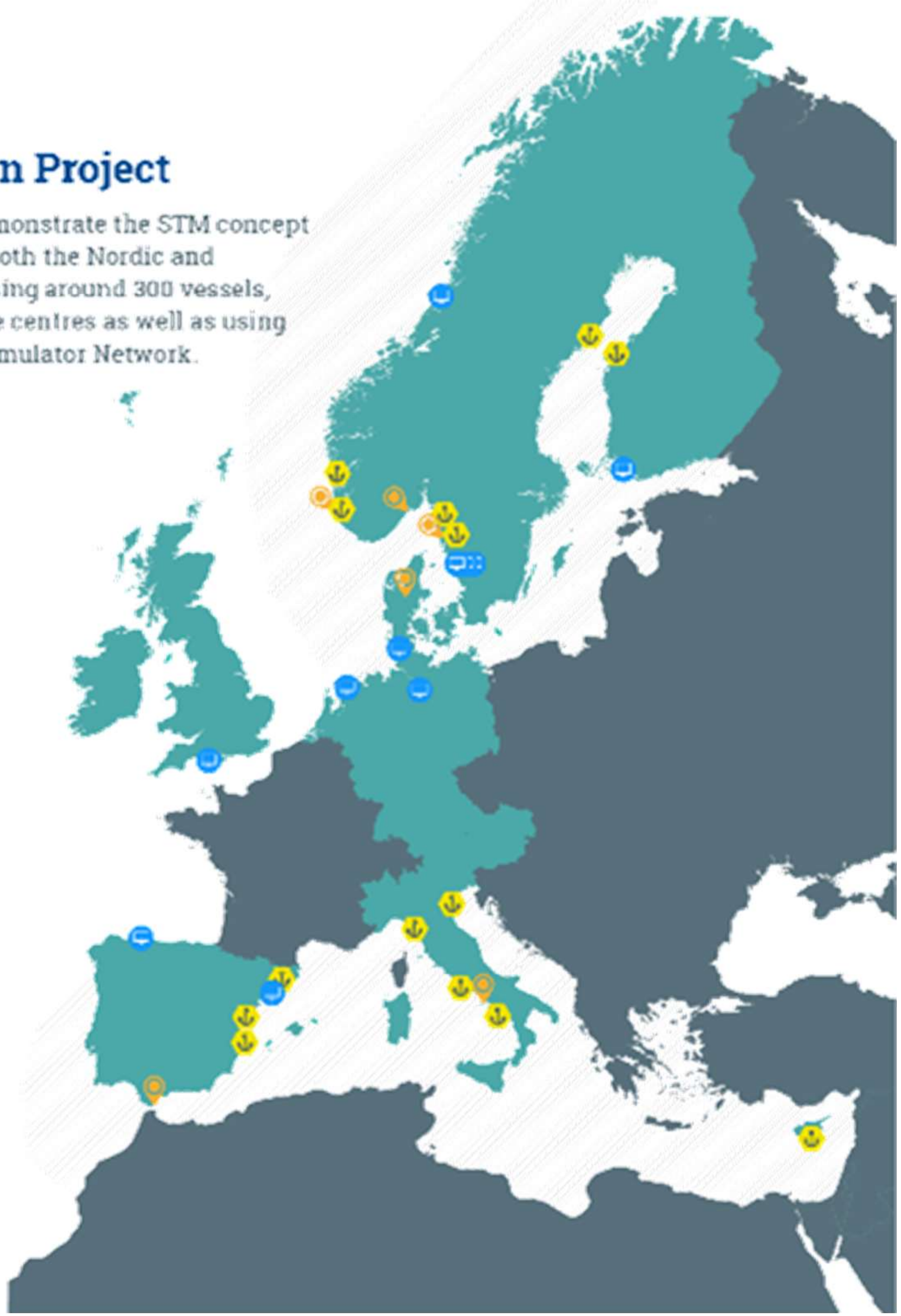
Co-financed by the European Union
Connecting Europe Facility

STM
SEA TRAFFIC MANAGEMENT

STM Validation Project

The STM Validation Project will demonstrate the STM concept in large-scale test beds in both the Nordic and Mediterranean Seas, encompassing around 300 vessels, 14 ports and 6 shore based service centres as well as using the European Maritime Simulator Network.

- Simulation centre in European simulation network (EMSN)
- Port CDM Port
- Shore centre
- Test bed for STM services
- Country with project partner(s)



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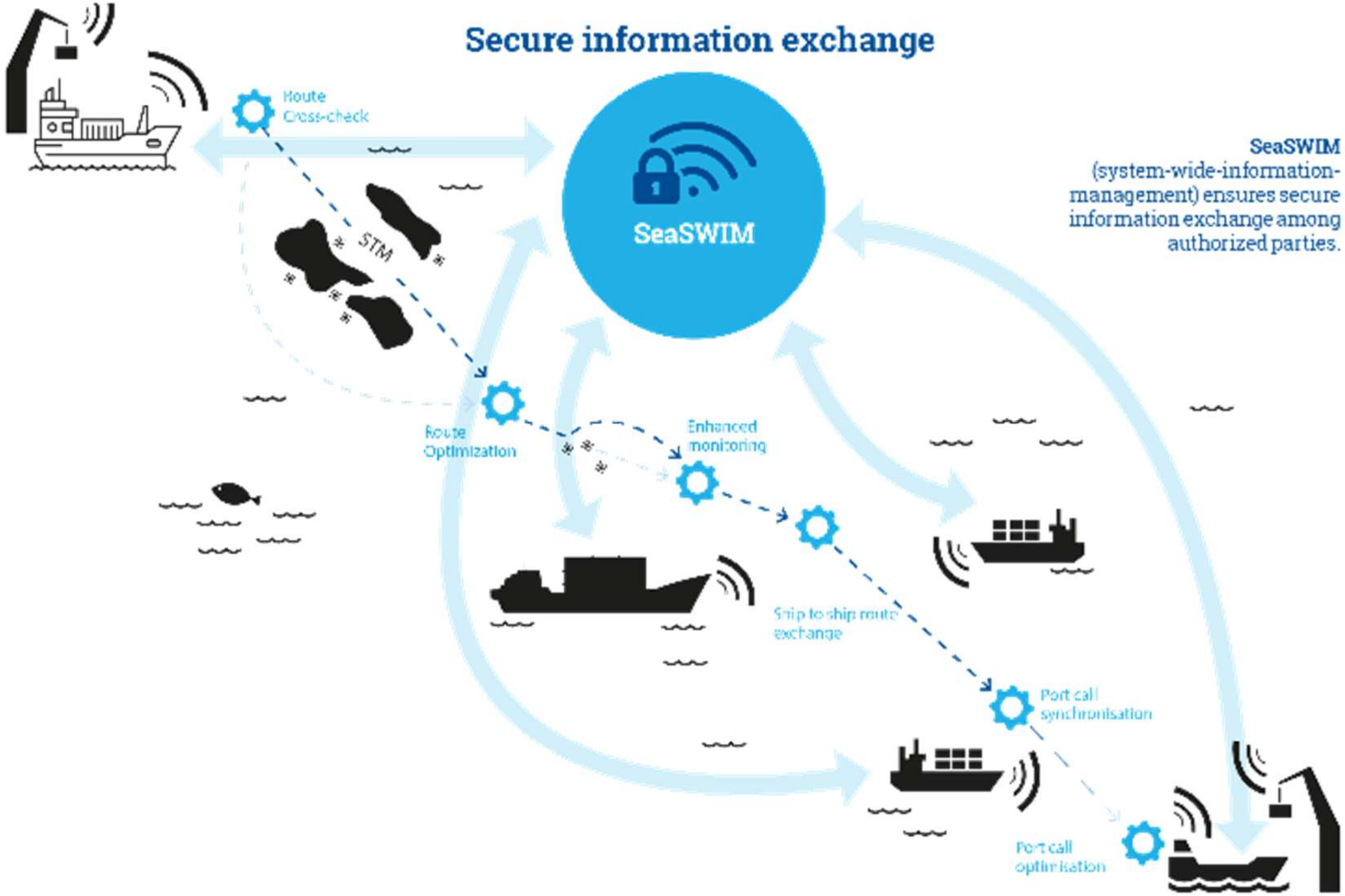
Secure information exchange



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STM
SEA TRAFFIC MANAGEMENT

STM Validation Project

OVER 50 PARTNERS INVOLVED

CO-FINANCED BY THE EUROPEAN UNION

PRIVATE, PUBLIC AND ACADEMIC SECTOR INVOLVED

43 MILLION EURO BUDGET

13 SIMULATION CENTRES

13 COUNTRIES

RUNS FROM 2015 UNTIL THE END OF 2018

6 SHORE CENTRES

300 TESTSHIPS IN NORDIC AND MEDITERRANEAN SEA

13 PORTS

SWEDISH MARITIME ADMINISTRATION

COORDINATED BY THE SWEDISH MARITIME ADMINISTRATION

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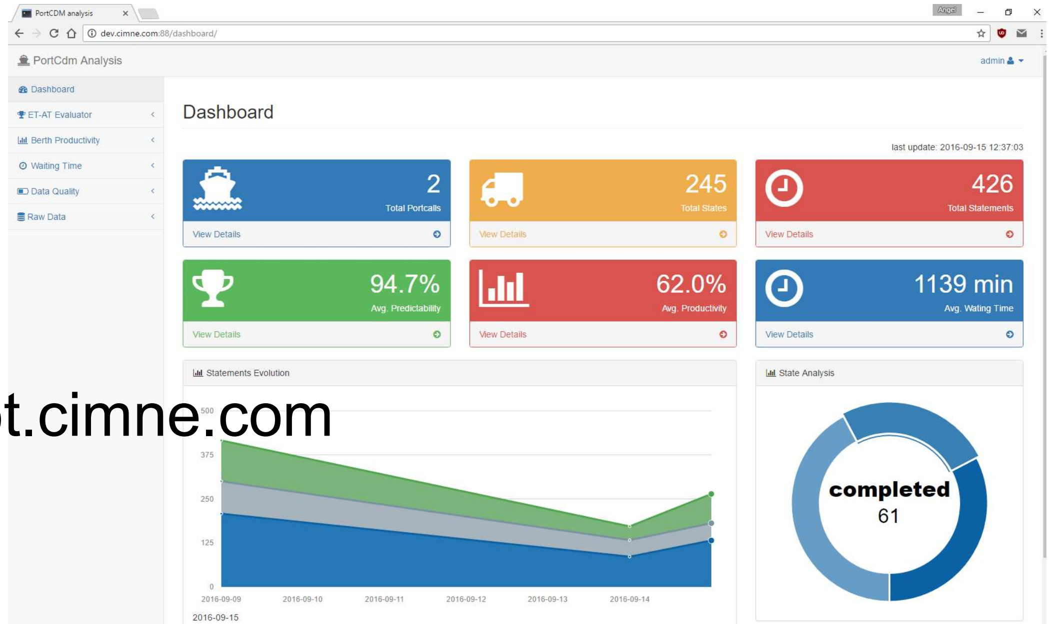
Connecting Europe Facility

STM
SEA TRAFFIC MANAGEMENT

Port Collaborative Decision Making (PortCDM)

CIMNE has developed different analysis solutions for the PortCDM service. Tasks:

- To develop a solution for analysis of the data collected in PortCDM systems in order to validate the concept.
- The PortCDM concept has been translated into key performance indicator (KPIs) to enable PortCDM to be measured.
- The quantitative data collected on the systems currently deployed at ports has been used to calculate the KPIs.



http://pcdmgot.cimne.com

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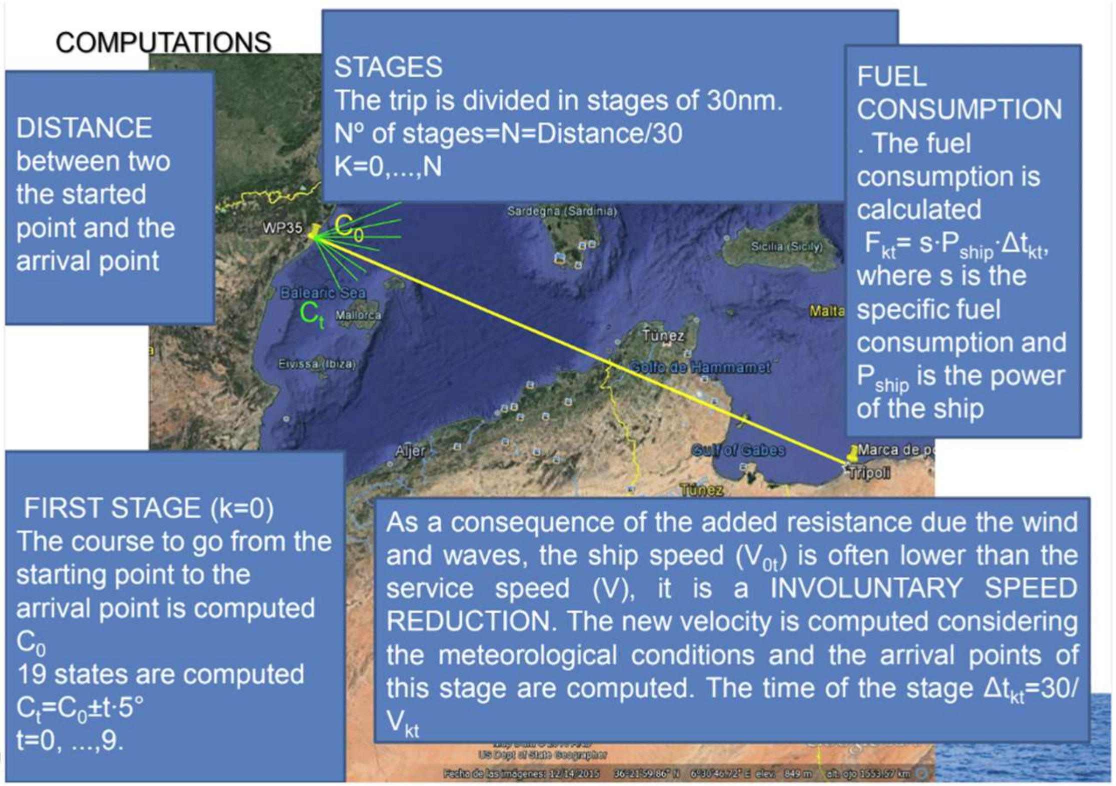
Route Optimization Service (ROS)

CIMNE has developed the ROS. It evaluates the best route considering: weather forecast/surface currents (speed reduction and IMO safety guidelines), fuel consumption, traffic congestion (statistical prediction), no-go areas (protected, draft restrictions, …), conflicts with other ships routes etc.



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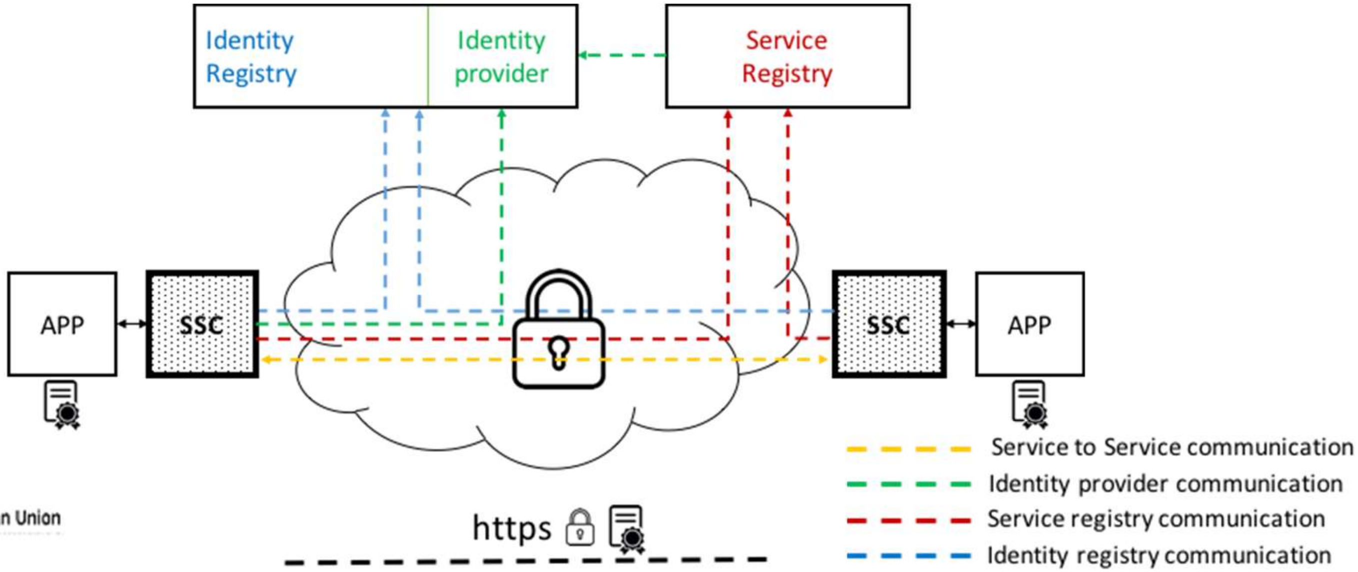
Sea System Wide Information Management (SeaSWIM)

- SeaSWIM is a set of open industry standards and best practices, providing an environment where different services can interoperate over organizational boundaries.
- CIMNE has worked in the implementation of the SeaSWIM Connector (SSC); an interface to reach STM and its connected actors and services.
- SSC take in account the communication flow between the core services of the SeaSWIM (identity registry and identity provider, service registry) and the rest of application services deployed in the infrastructure.
- SSC functionalities help the use of safe communication channels and authentication standards implementing the general requirements of the STM infrastructure.



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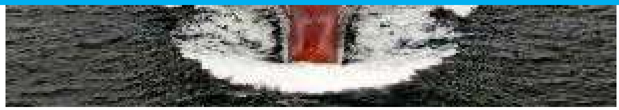
CIMNE
30 years

CIMNE MARINE ON-GOING PROJECTS

FIBRESHIP

This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement Nº 723360

The main objective of the FIBRESHIP project (2017-2020) is to enable the building of the complete hull and superstructure of large-length seagoing and inland ships in FRP materials. In order to achieve this objective, the project will audit innovative FRP materials, elaborate new design and production guidelines, generate efficient inspection methodologies and develop new analysis tools.



30%

- **Fuel Reduction (10-15%)**
- **Lower Greenhouse gas emissions**
- **Better Stability/Safety**
- **Increase cargo capacity (12%)**
- Underwater Noise Reduction

\+

- Reduced maintenance & life cycle costs (30%)
- Immune to corrosion
- **Continuous Structural Health Monitoring (safety)**
- Aesthetic improvements
- **Recycling rate (up to 75%)**

FIBRESHIP
INTEGRAL COMPOSITE SHIP

This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement Nº 723360

Project development will focus in three vessel categories that have been targeted as the most promising for the final project market orientation

CATEGORY I
Light Commercial Vessels

Representative
Container Vessel

- RoRo vessel
- Car Carrier
- Multi-purpose
- Freezer Vessel
- LNG
- Wood Transportation
- .....

COMPASS
Lloyd's Register

CATEGORY II
Passengers transportation & Leisure

Representative
ROPAX

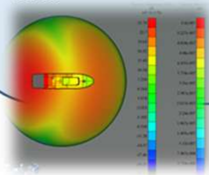
- Ferries
- Passenger vessel
- Megayacht
- .....

SOERMAR S.A.
RINA

CATEGORY III
Special Services

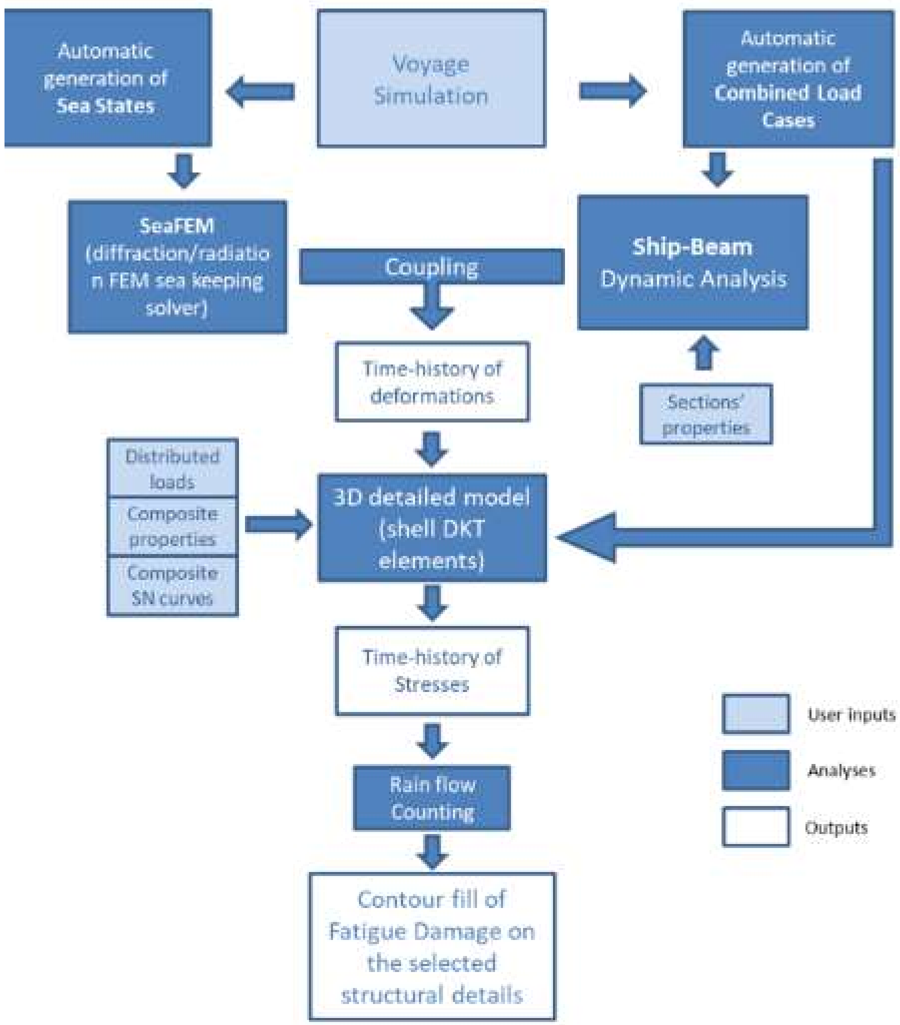
Representative
Fishing Research Vessel

- Fishing vessel
- Seismic Vessel
- Supply vessel
- Rescue vessel
- ......



TSI
BUREAU VERITAS

This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement Nº 723360



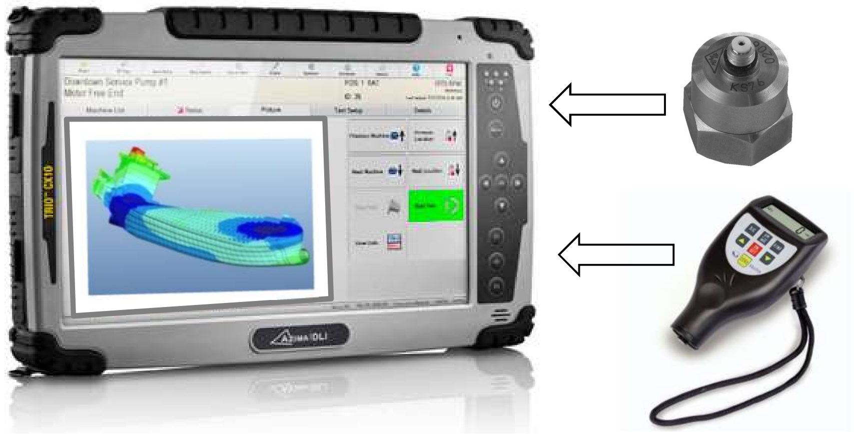
Development of a coupled Seakeeping-FEA analysis tool (structural health monitoring)

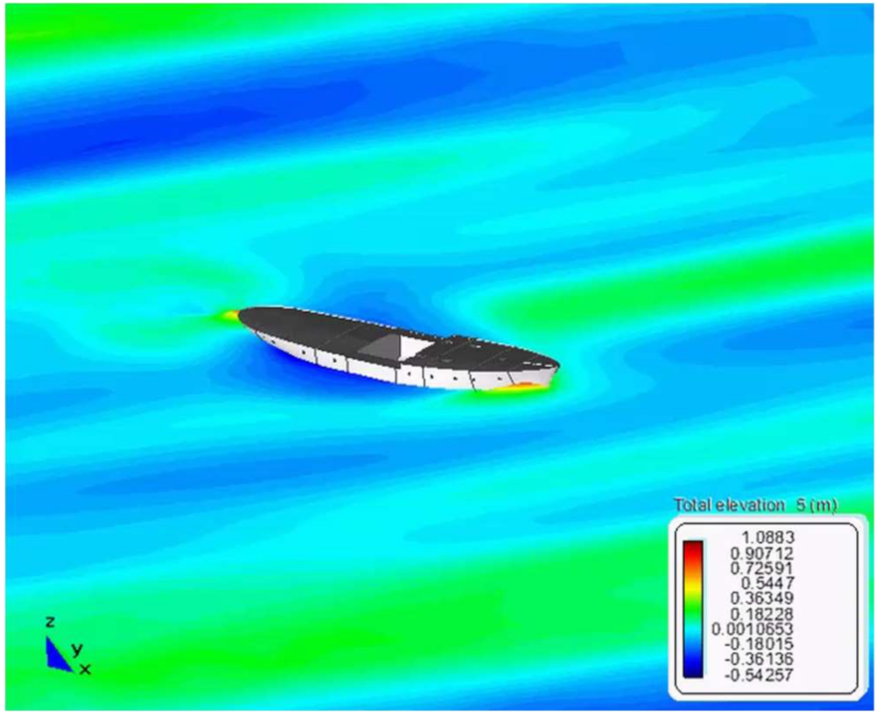
- **Hull girder model**: Simple 3D dynamic beam coupled with FEM seakeeping solver. It allows to analyse quickly long time series of the coupled problem.
- **3D detailed model**: Complete 3D FEM model (fatigue) uses the information obtained from the hull girder model to generate boundary conditions for the local detailed analysis of the ship structure. Fatigue model evaluates damage by obtaining the quasi-static stiffness at discrete cycle intervals.
- **IFEM model:** Structural Health monitoring + Topology-based optimization tool.

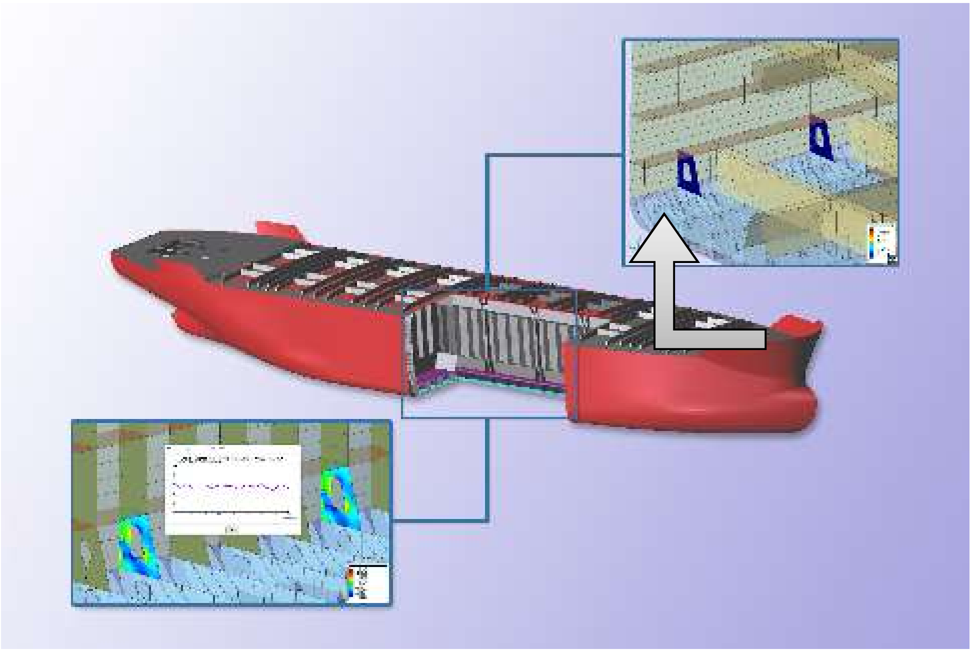
FIBRESHIP

INTEGRAL COMPOSITE SHIP

This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement Nº 723360







IFEM model: Structural Health monitoring + Topology-based optimization tool: Find the damage patern that macthes the vibration modes (local and global) monitored in different selected areas of the ship.

FIBRESHIP

INTEGRAL COMPOSITE SHIP

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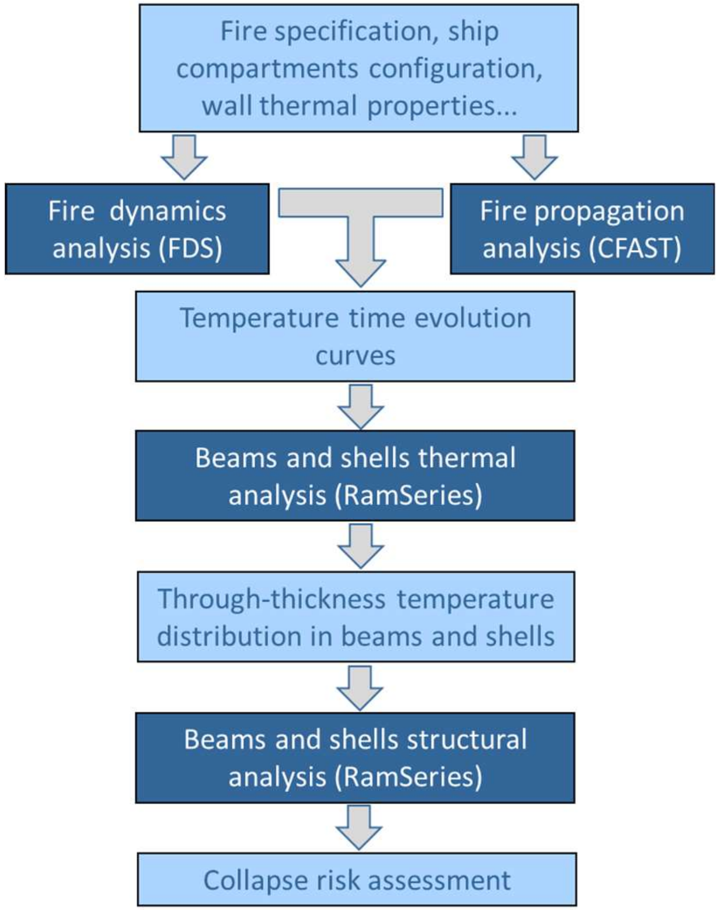

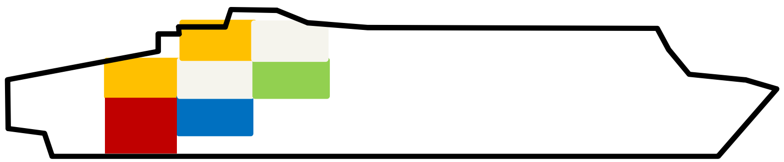

Development of thermo-mechanical behaviour analysis and collapse assessment tools for laminated composite structures

Fire dynamics analysis. Local analysis of a fire scenario will be modelled using a CFD model thus providing detailed information on fire development and local structure degradation (coupling with FEM model + pyrolysis model)

Fire propagation analysis. Fire propagation scenarios (involving a number of compartments) will be modelled with a zone fire model to simulate the fire propagation and evaluate the global collapse of the structure (coupling with FEM model + pyrolysis model)

FIBRESHIP
INTEGRAL COMPOSITE SHIP

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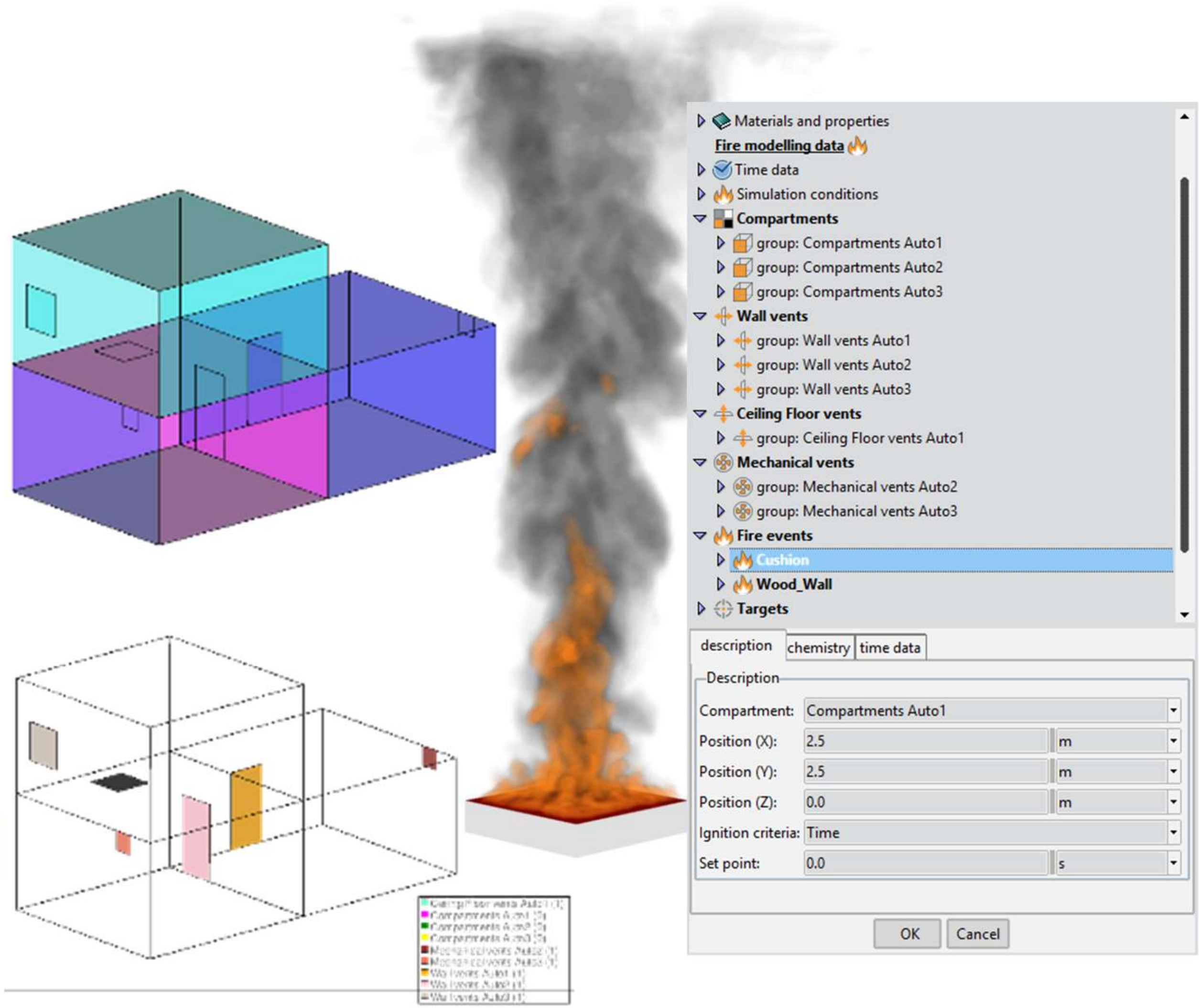

Left: preliminary test on intumescent coatings. **Right**: development of the fire dynamics simulation and collapse analysis tool

FIBRESHIP
INTEGRAL COMPOSITE SHIP

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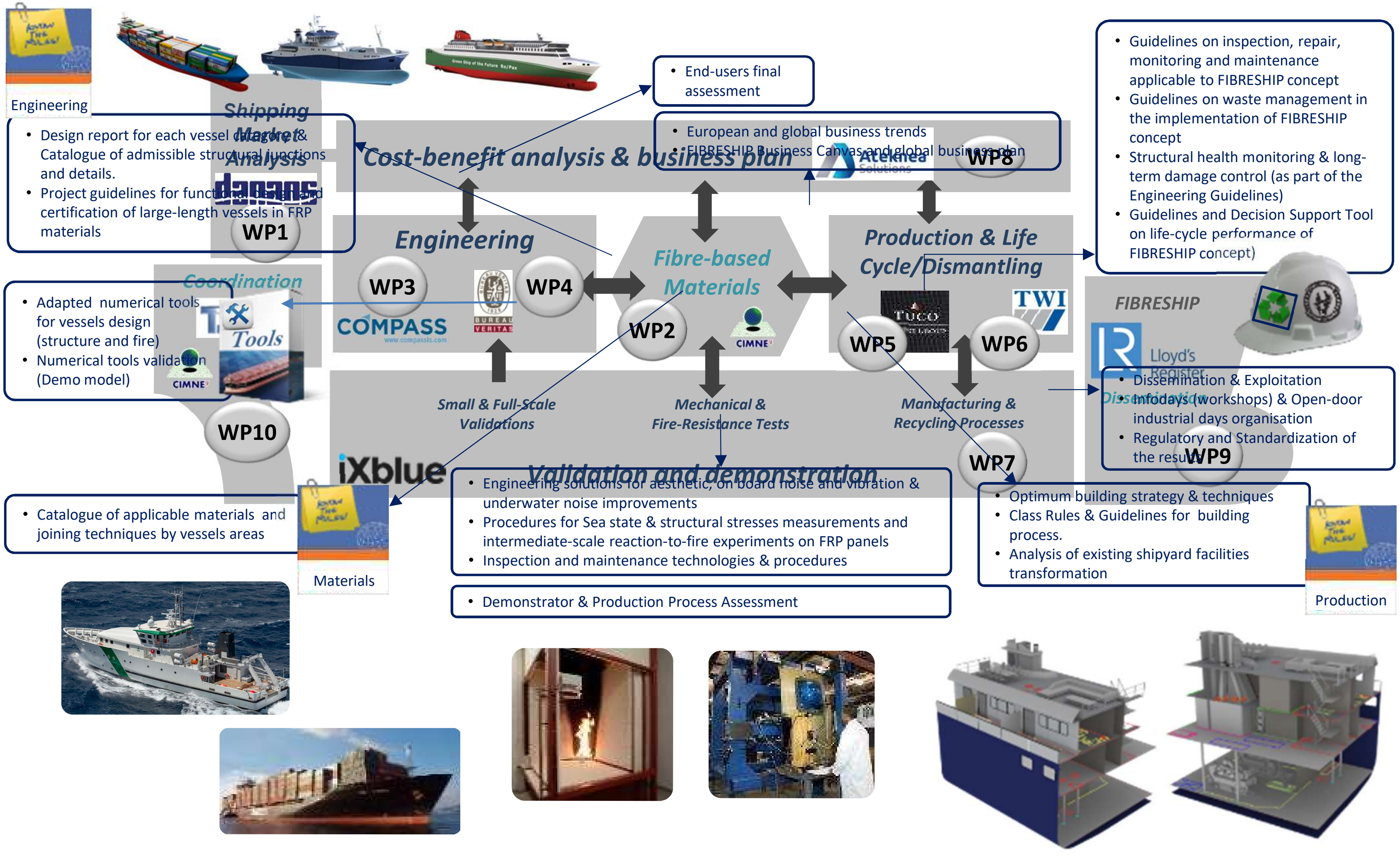

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