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MODEL-CENTRIC DESIGN AND DEVELOPMENT FOR ECO-FRIENDLY SHIPS

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Kevin Koosup Yum

Content

- SINTEF Ocean
- Model-Centric Design, Why?
- Main concepts for Model-Centric Design, What and How?
- Relataed Researches
- Conclusion

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Our role

Contract research
R&D-partner to industry and government

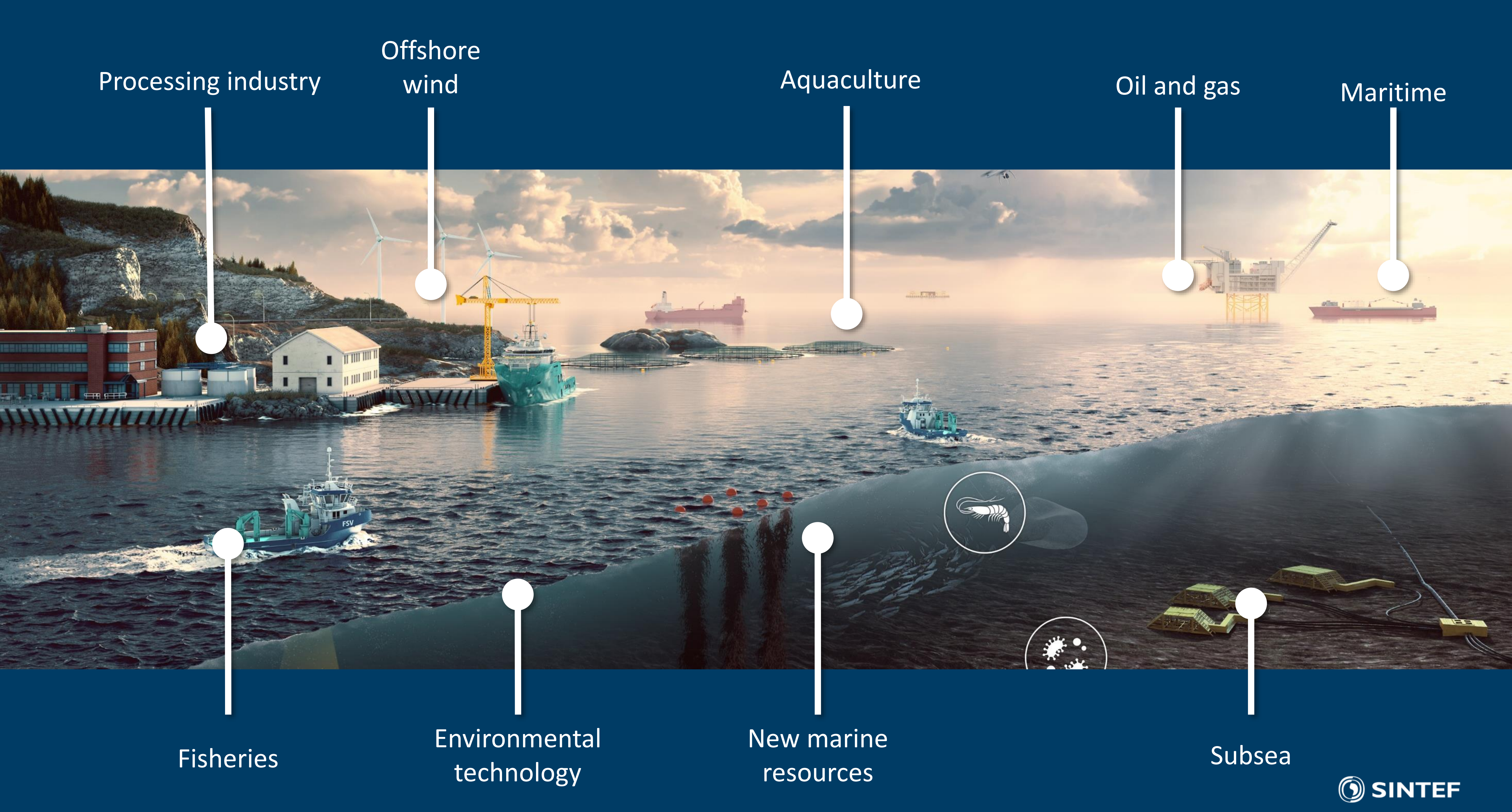
Laboratories and software
Testing, development and verification

Innovation
Develop new technology and knowledge

New ventures
Create new products and spin-offs

Sustainable development
Deliver environmentally friendly solutions

Social mission
Knowledge to social debate and politics


Processing industry
Offshore wind
Aquaculture
Oil and gas
Maritime
Fisheries
Environmental technology
New marine resources
Subsea

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World leading laboratories

Ocean laboratory

Plankton centre

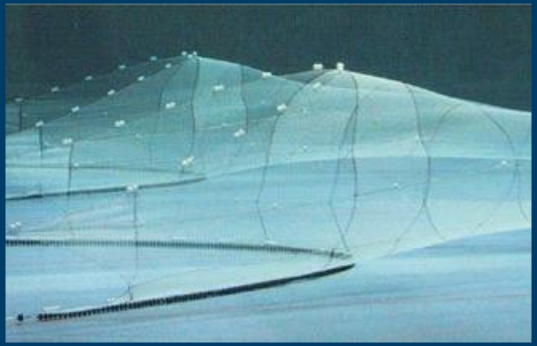
Towing tank

Oil laboratory

Robot laboratory

Full scale aquaculture site

Flume tank



Construction lab

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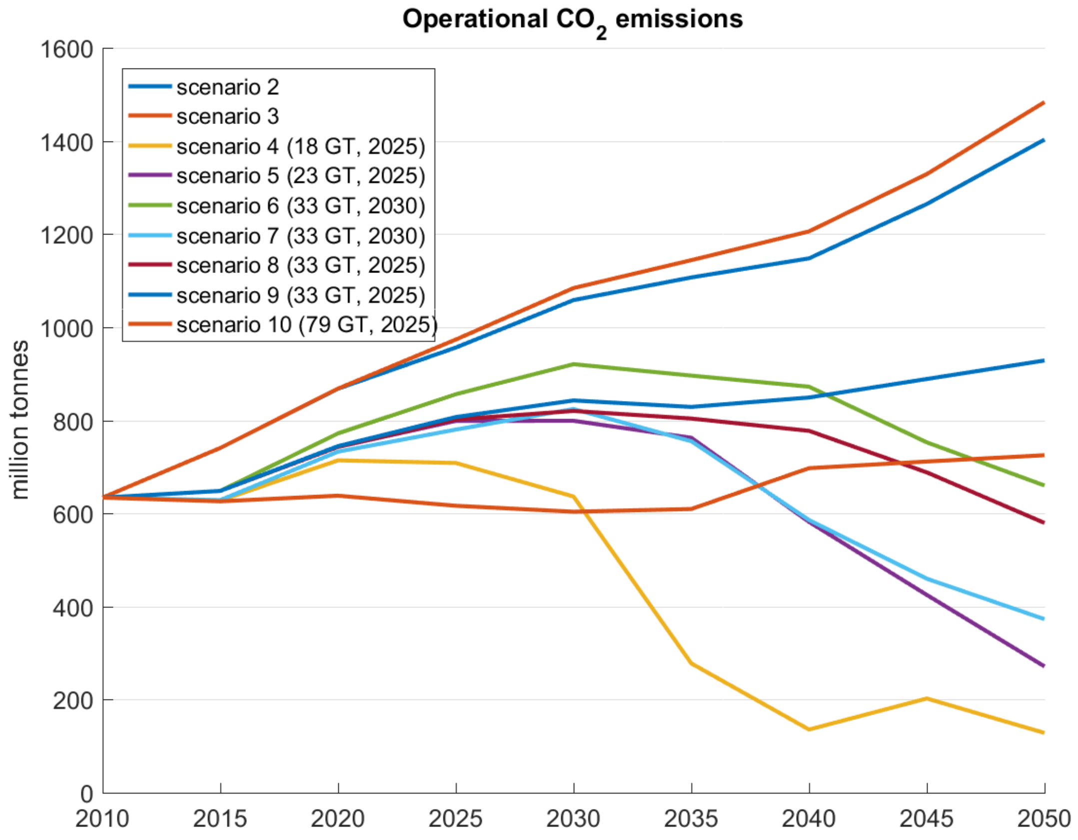
Model-Centric Design, Why? – Challenges ahead

- Disruptive changes in the industries
  - Digitalization
  - Autonomous shipping

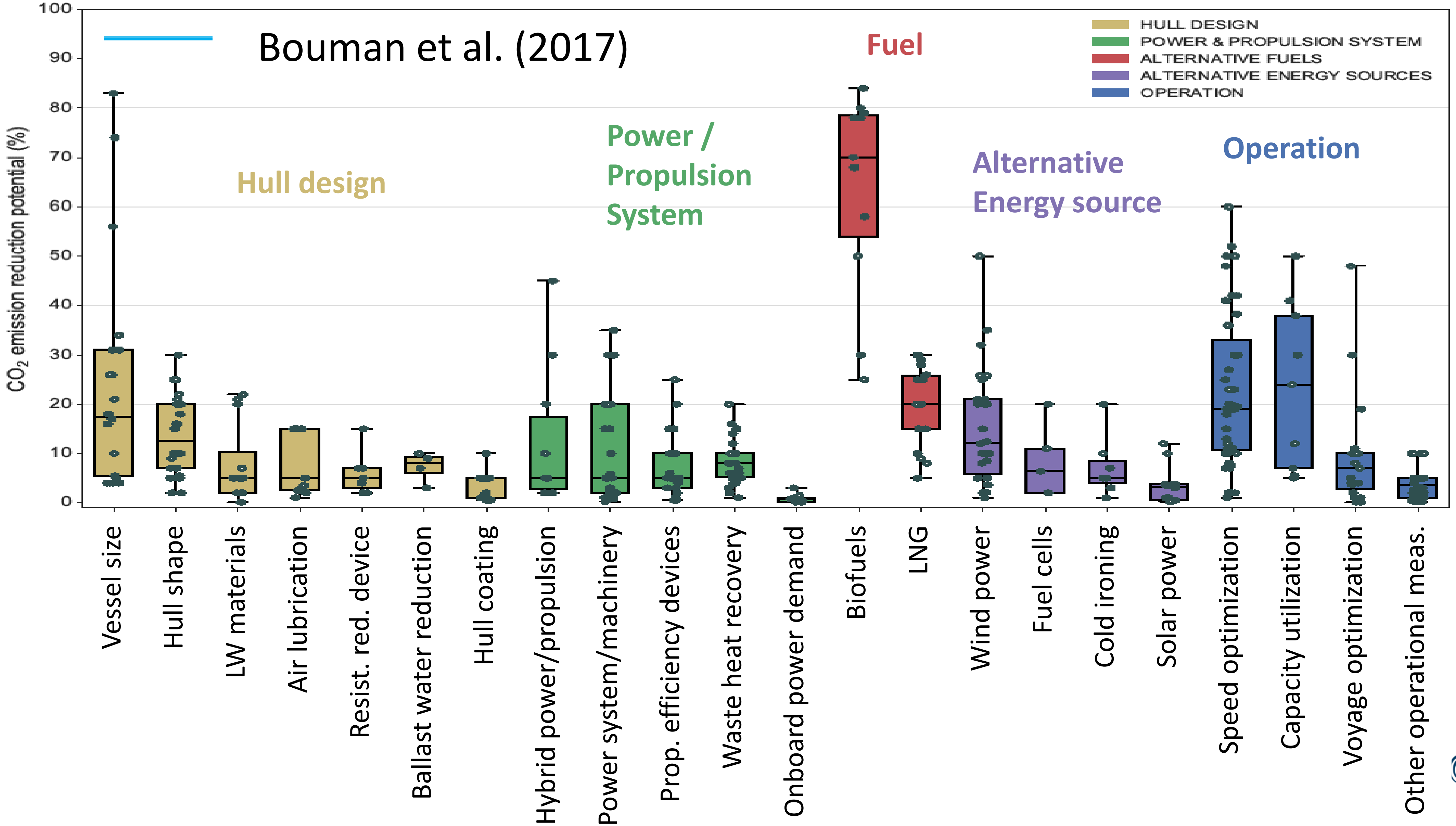
- Strenthening emission regulations
  - EEDI / EEOI
  - NOx regulations
  - Global Sulfurcap
  - Radical green house gas reduction

    (MEPC 72, 40% by 2035 & 70% by 2050, per transport work)



Smith et al. (2016)

Options for CO2 reduction



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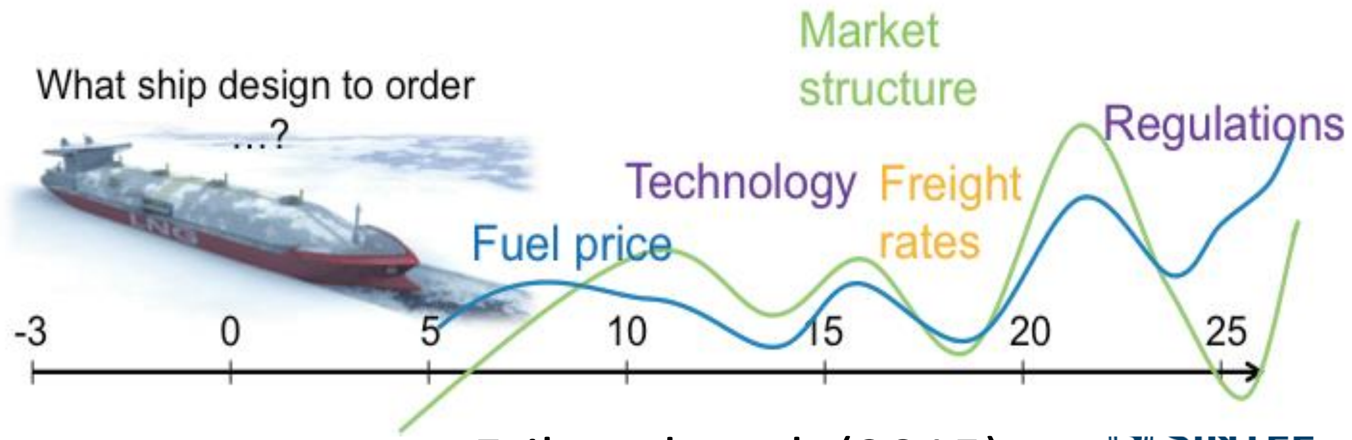
Model-Centric Design, Why? - Real Challenges

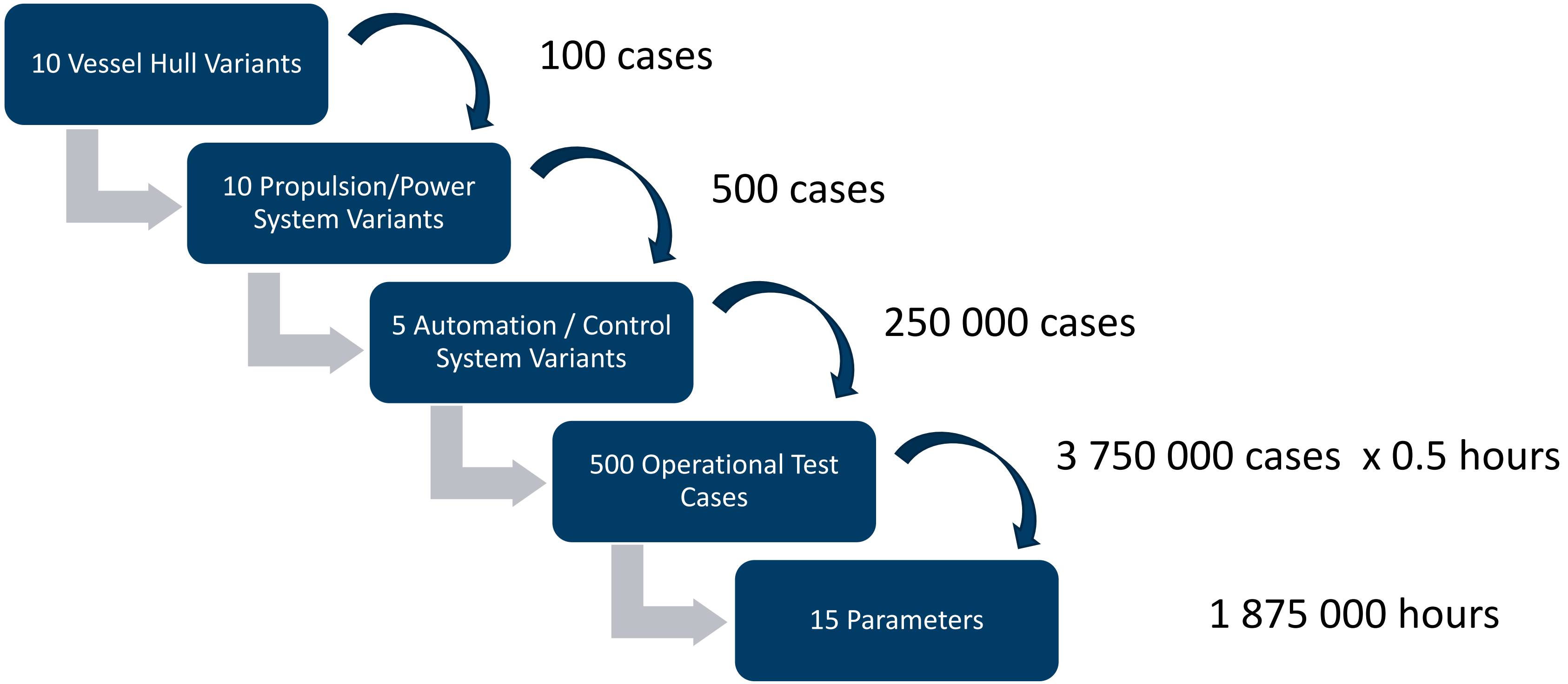
- Complexity
  - Combinations of the options
  - Operational profiles: mode, route and weather, speed
  - Market Scenarios



Erikstad et al. (2015)

Model-Centric Design, Why?

- Testing and Verification Challenges



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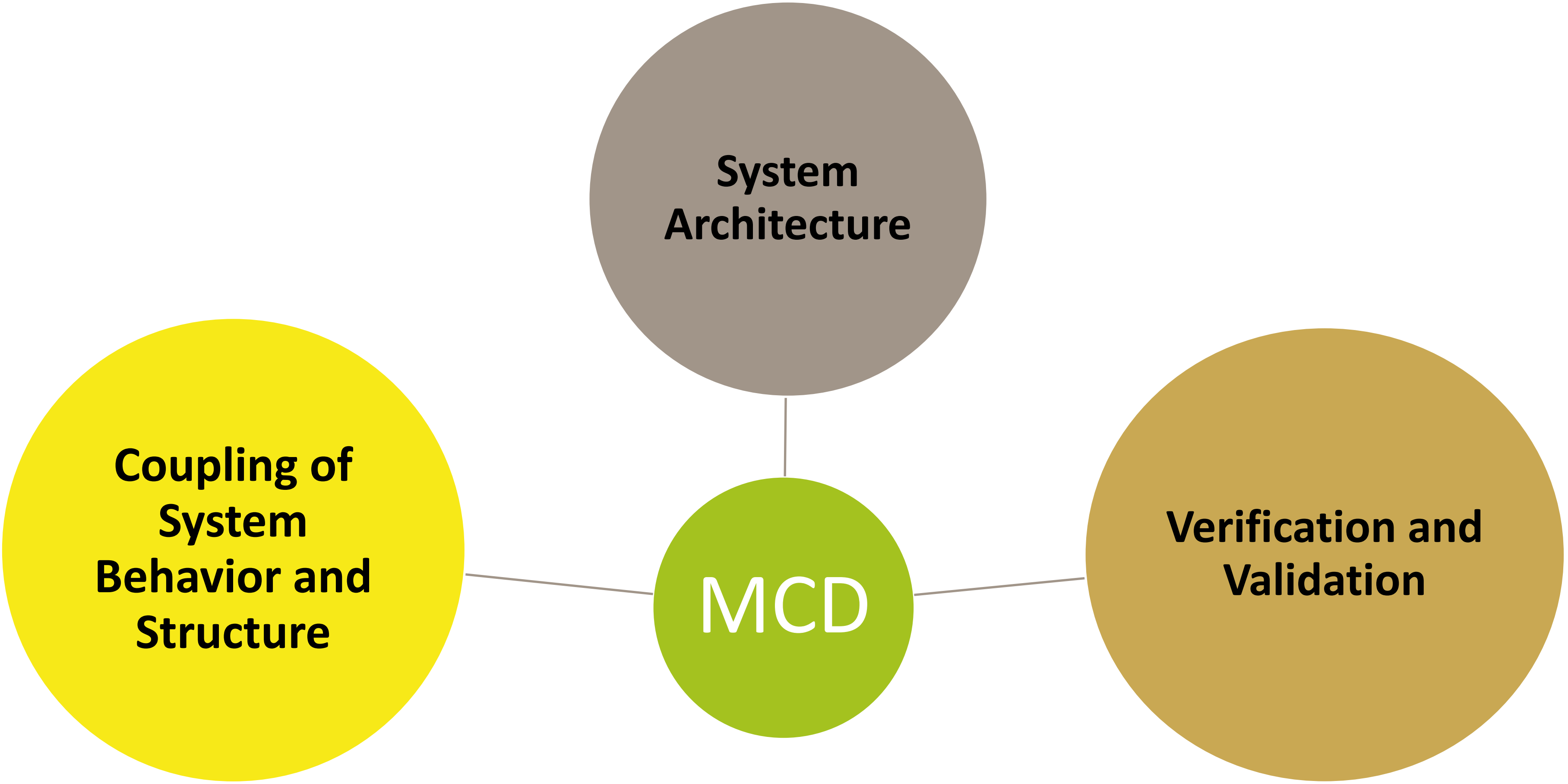
MAIN CONCEPTS

Model-Centric Design, What is it?



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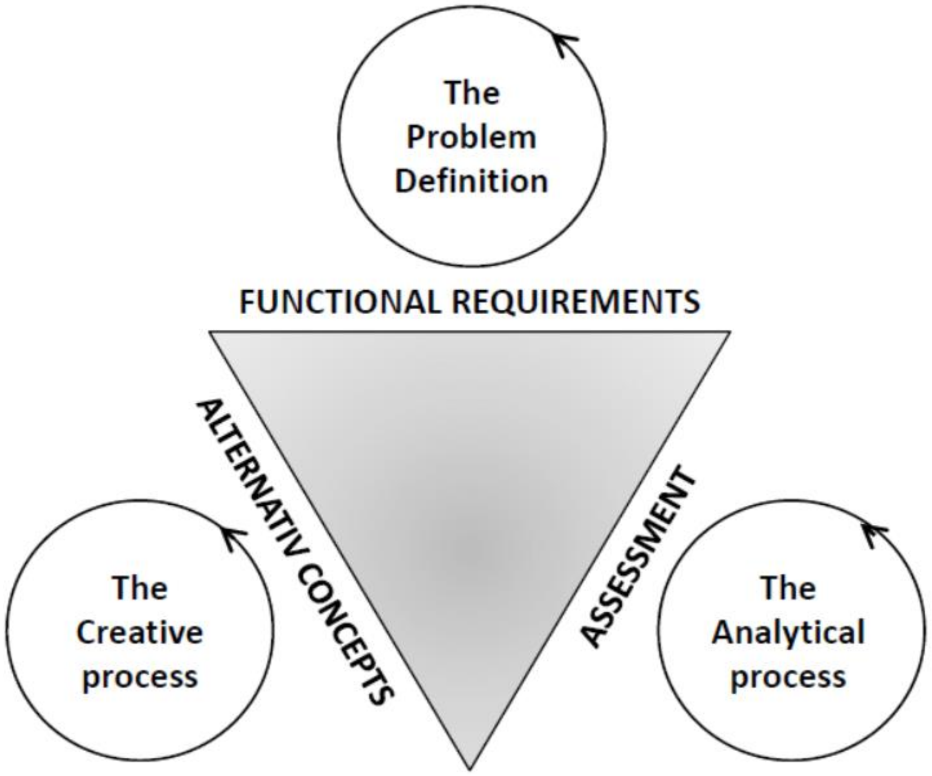
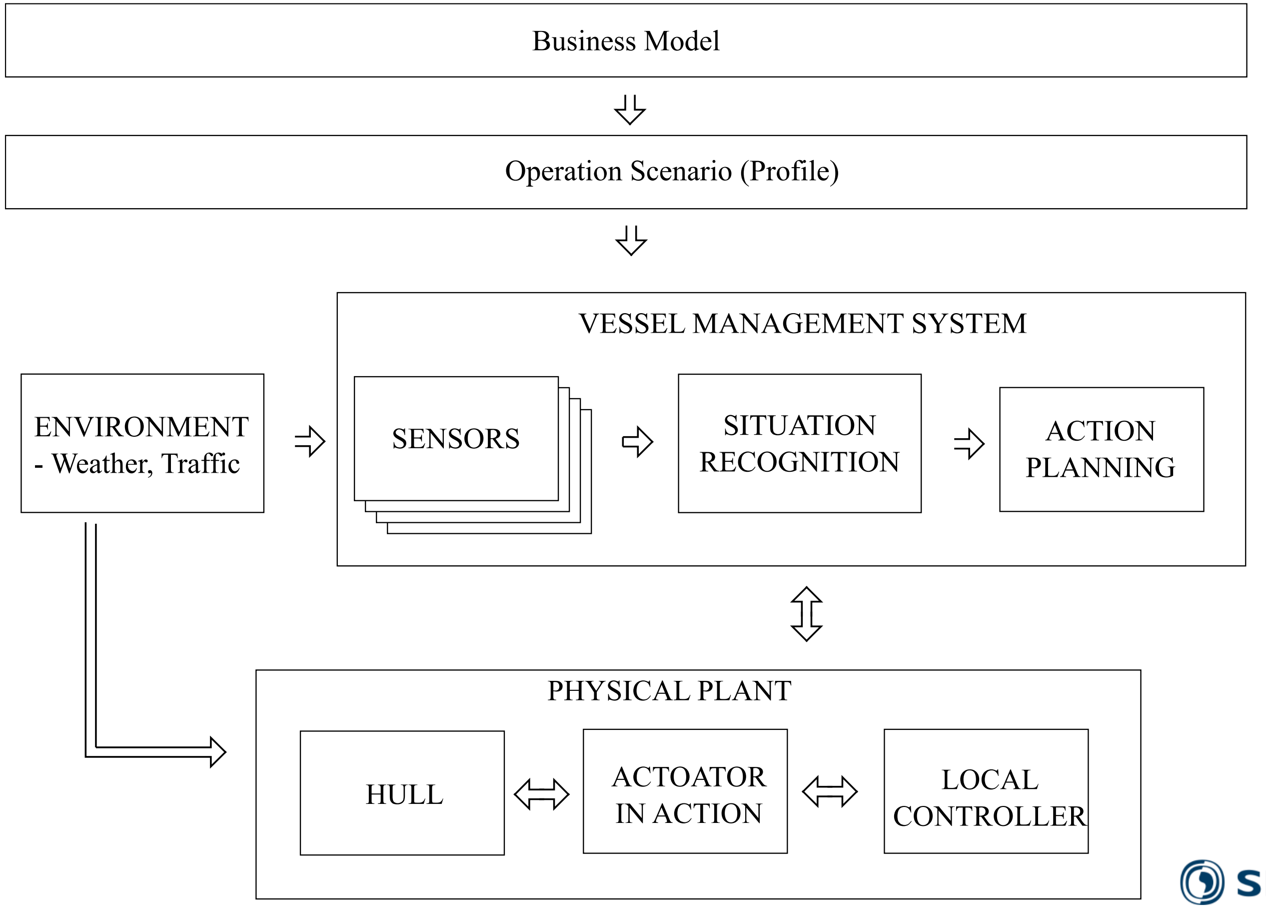
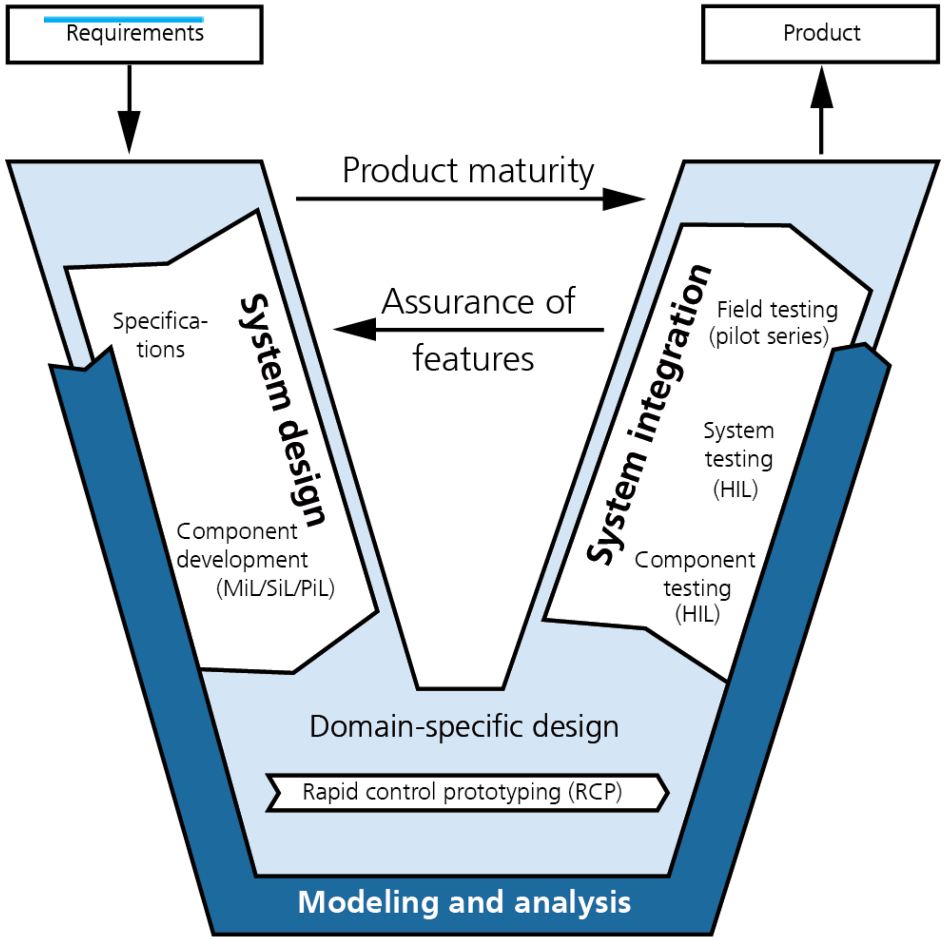
Tools for Analysis and Decision Support

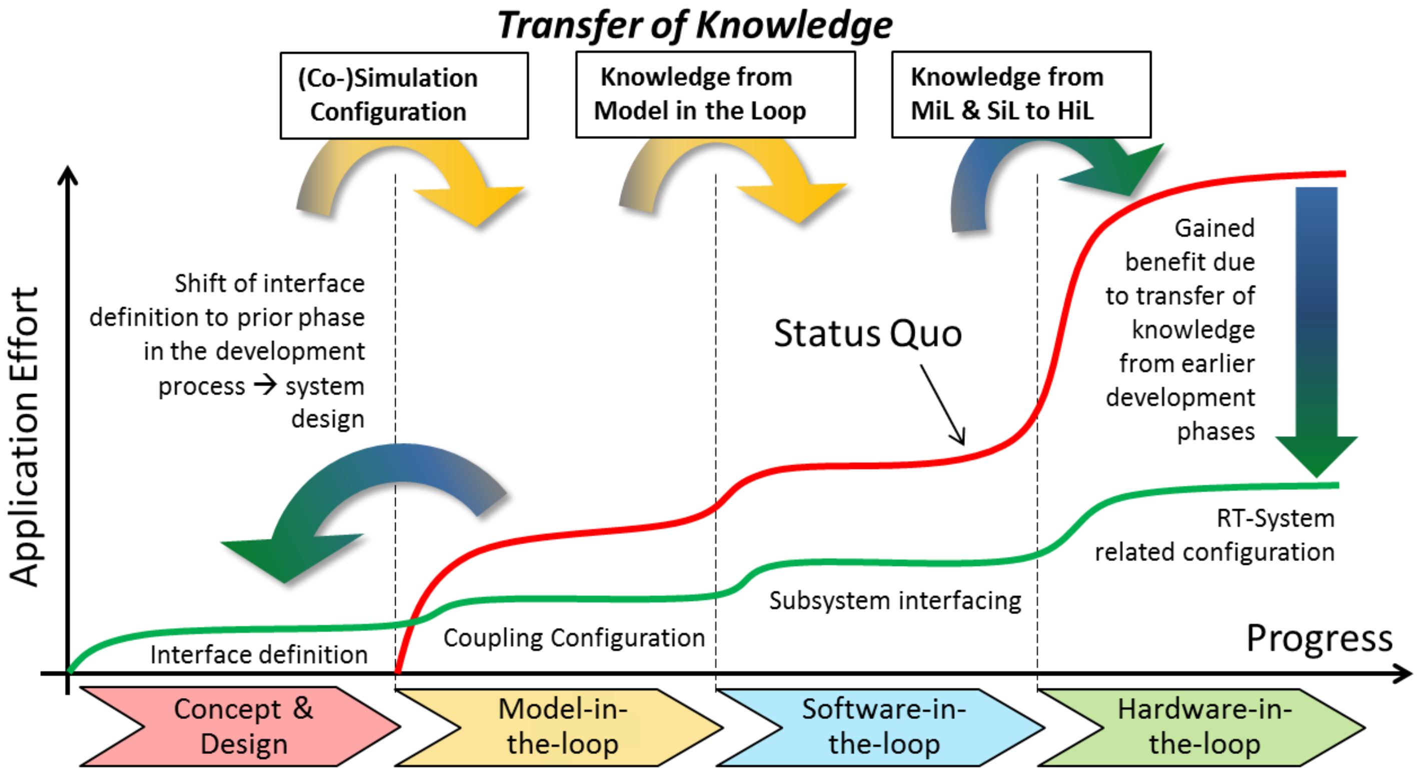
- Design Thinking and Systems Perspective Analysis





Development with X-in-the-Loop Testing

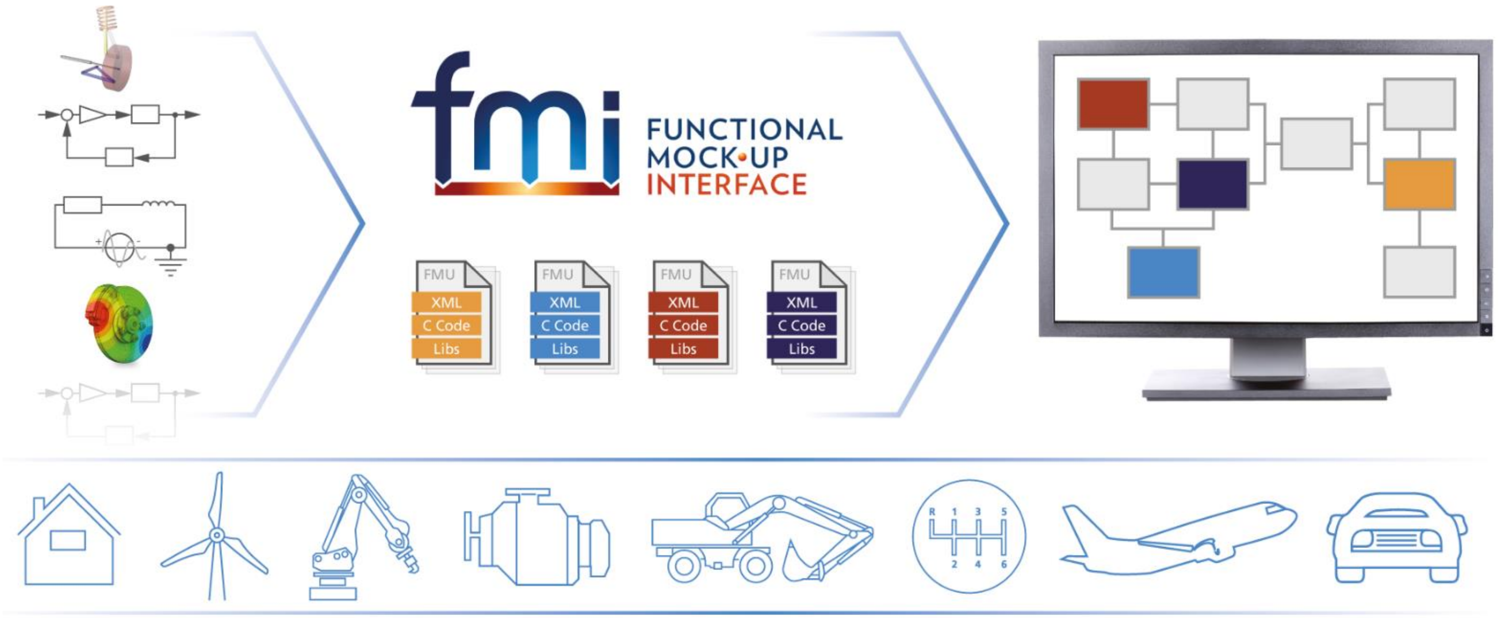




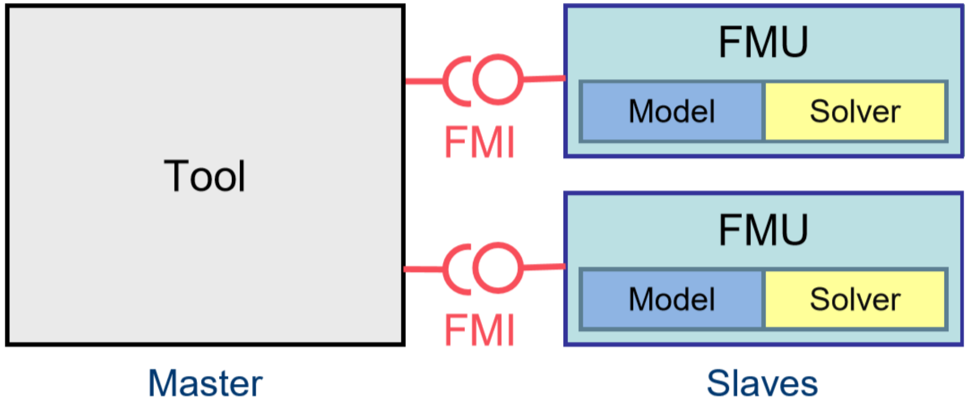
http://www.acosar.eu/overview.php

https://www.iem.fraunhofer.de/en/kompetenzen/unsereforschungsabteilungen/regelungstechnik/leistungsangebot/X-in-the-LoopEntwicklungs-undTestumgebungen.html

Co-simulation



- Simulation of heterogeneous systems
- Partitioning and parallelization of large systems
- Multirate integration
- Hardware-in-the-loop simulation



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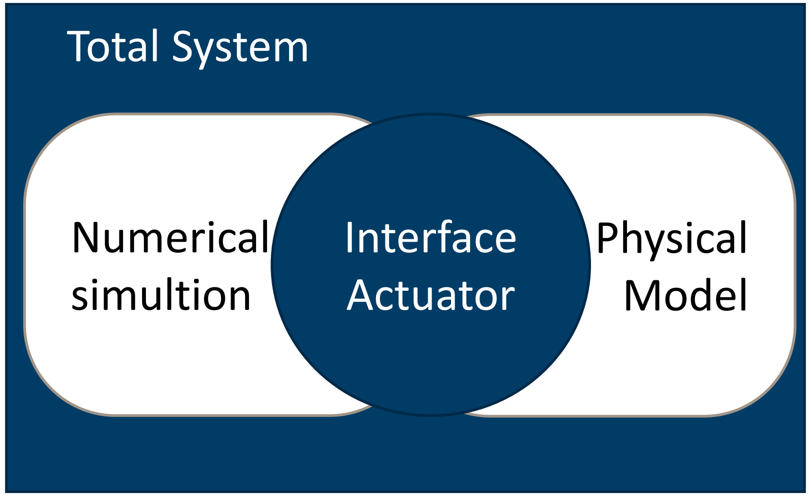
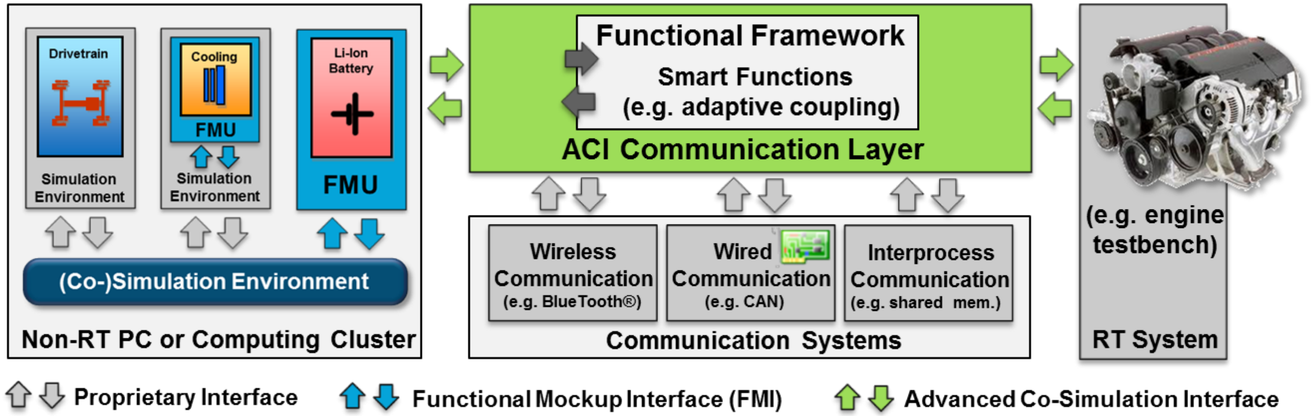
Real-time Testing with Hardware

- Hybrid Testing



- Standard Interface



http://www.acosar.eu/overview.php

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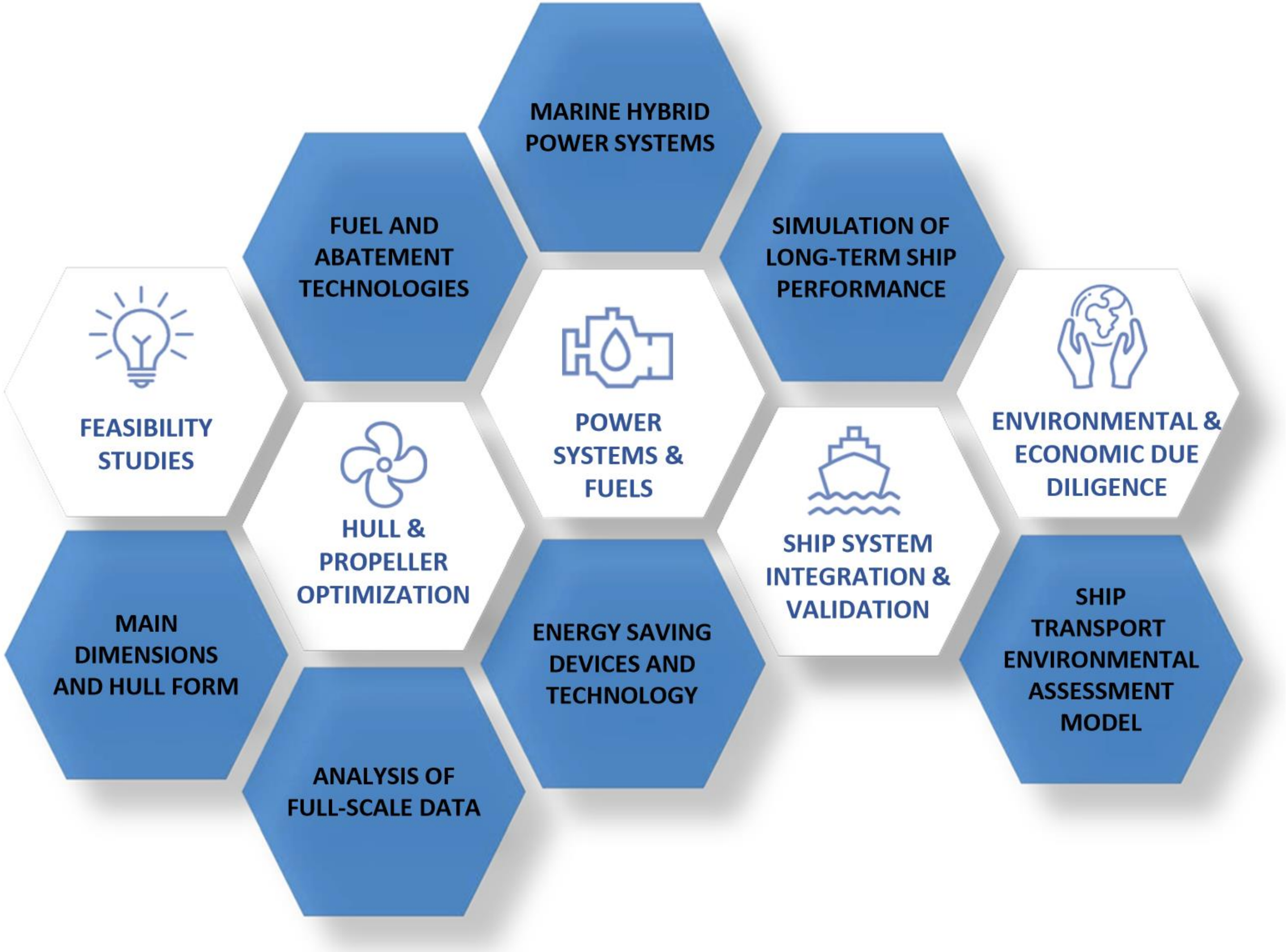
RELATED RESEARCH ACTIVITIES IN SINTEF OCEAN

SMART MARITIME - Center of Research Based Innovation

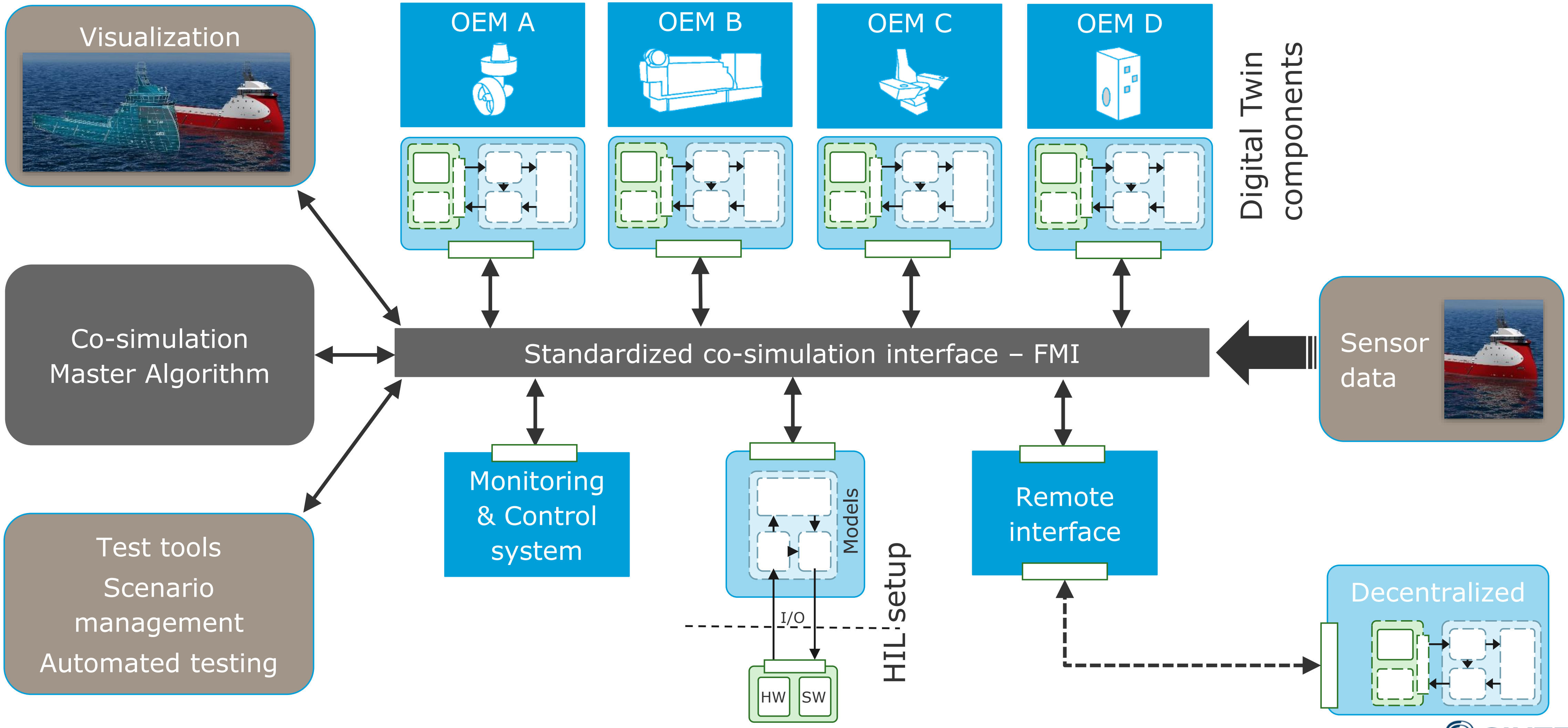
- Main goals
  - Strengthen the competitiveness of the Norwegian maritime industry
  - Improve energy efficiency and reduce emissions
- In brief
  - 17 Industry Partners
  - 30 Research Scientists / 10 Laboratories
  - Budget: 24 MNOK / year (~3 MUSD)
  - Period: 2015 – 2023
  - Hosted by SINTEF Ocean



Open Simulation Platform

Rolls-Royce NTNU JIP SINTEF DNV·GL

Open Ship Simulator Platform Project



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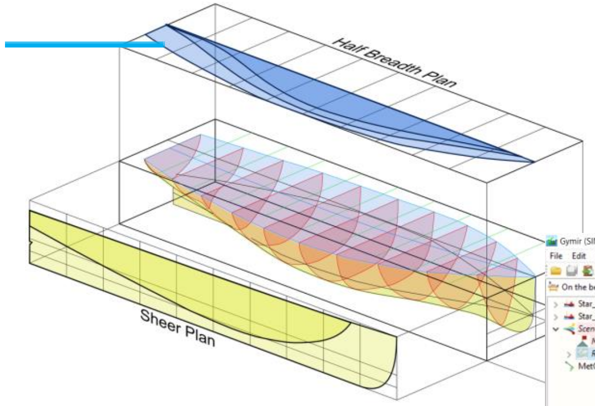
Longterm Ship Performance Simulator - GYMIR

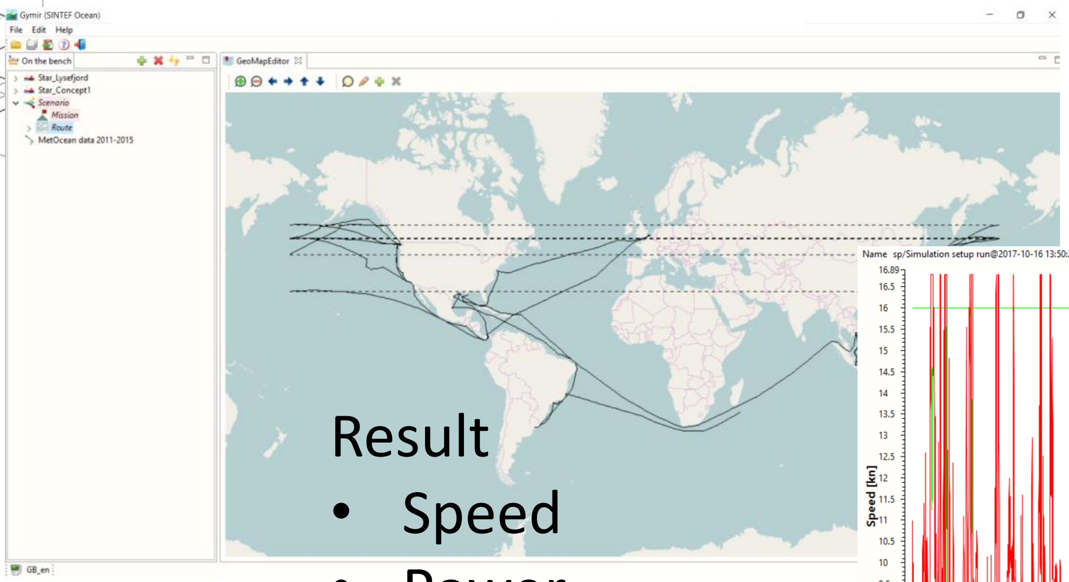
Input => Hull and propulsion information

Performance analysis in calm sea and seaway by ShipX



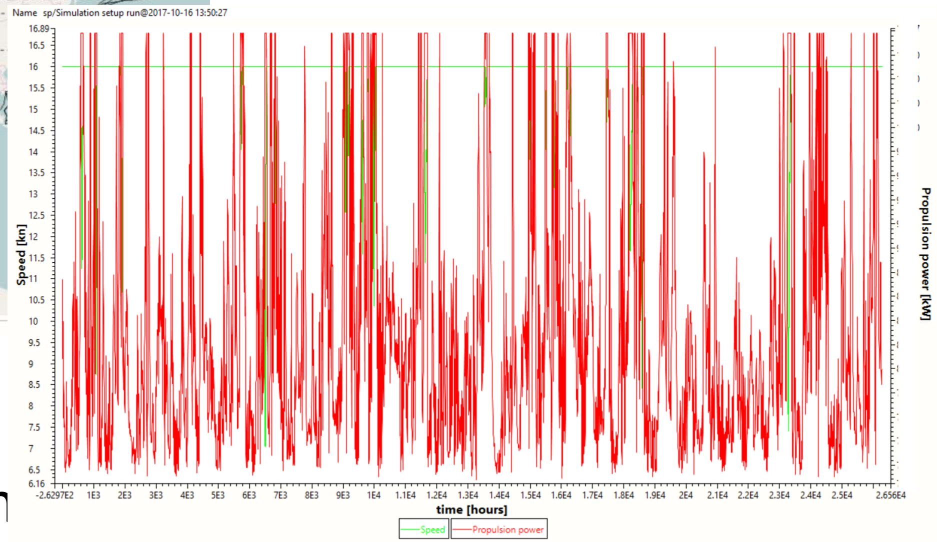
Simulation set up

- Routes
- Period
- Metocean data
- Speed policy

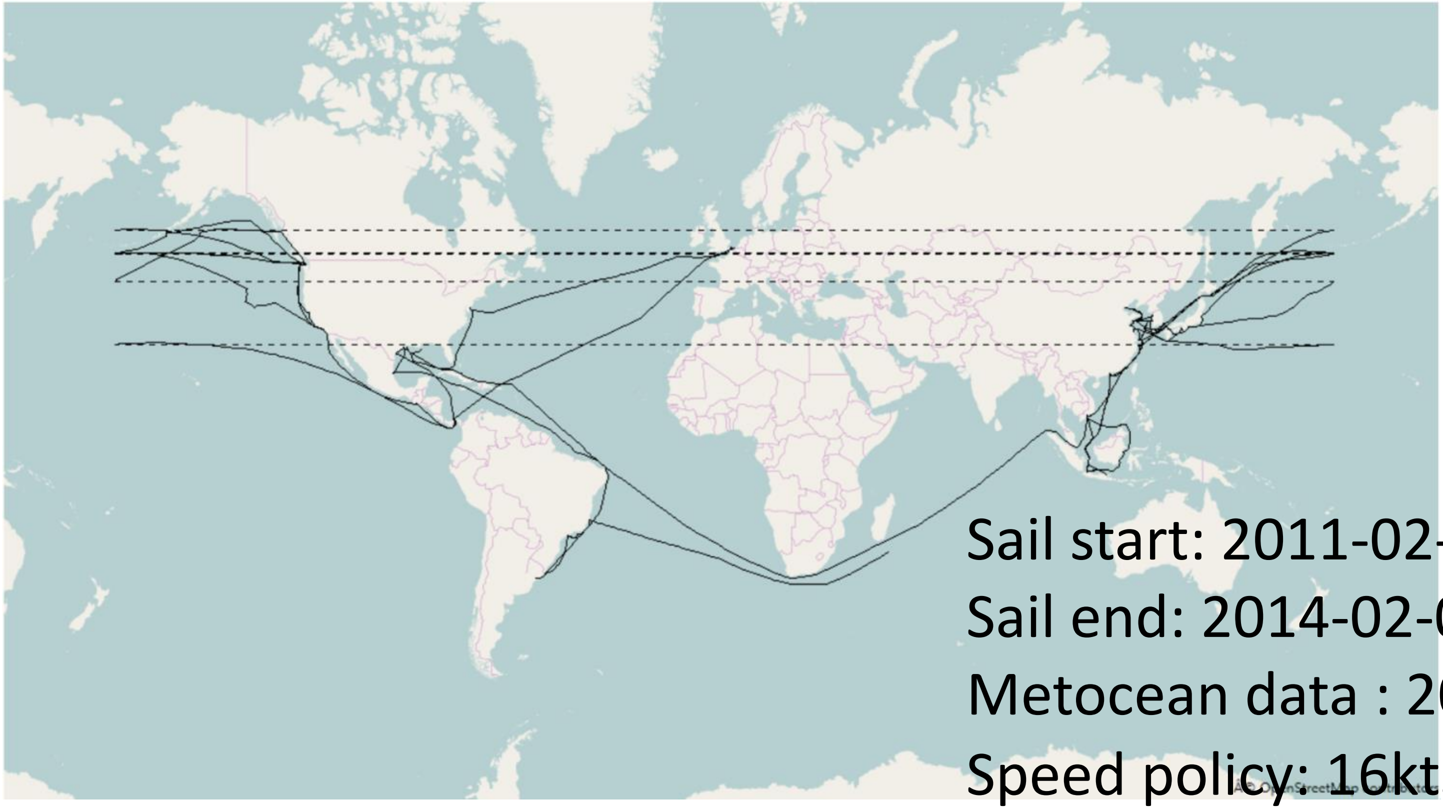


Result

- Speed
- Power
- Propeller speed
- Fuel consumption



55K Bulk Carrier Case



Sail start: 2011-02-01
Sail end: 2014-02-01
Metocean data : 2011 ~ 2014
Speed policy: 16kts target speed, limited by power

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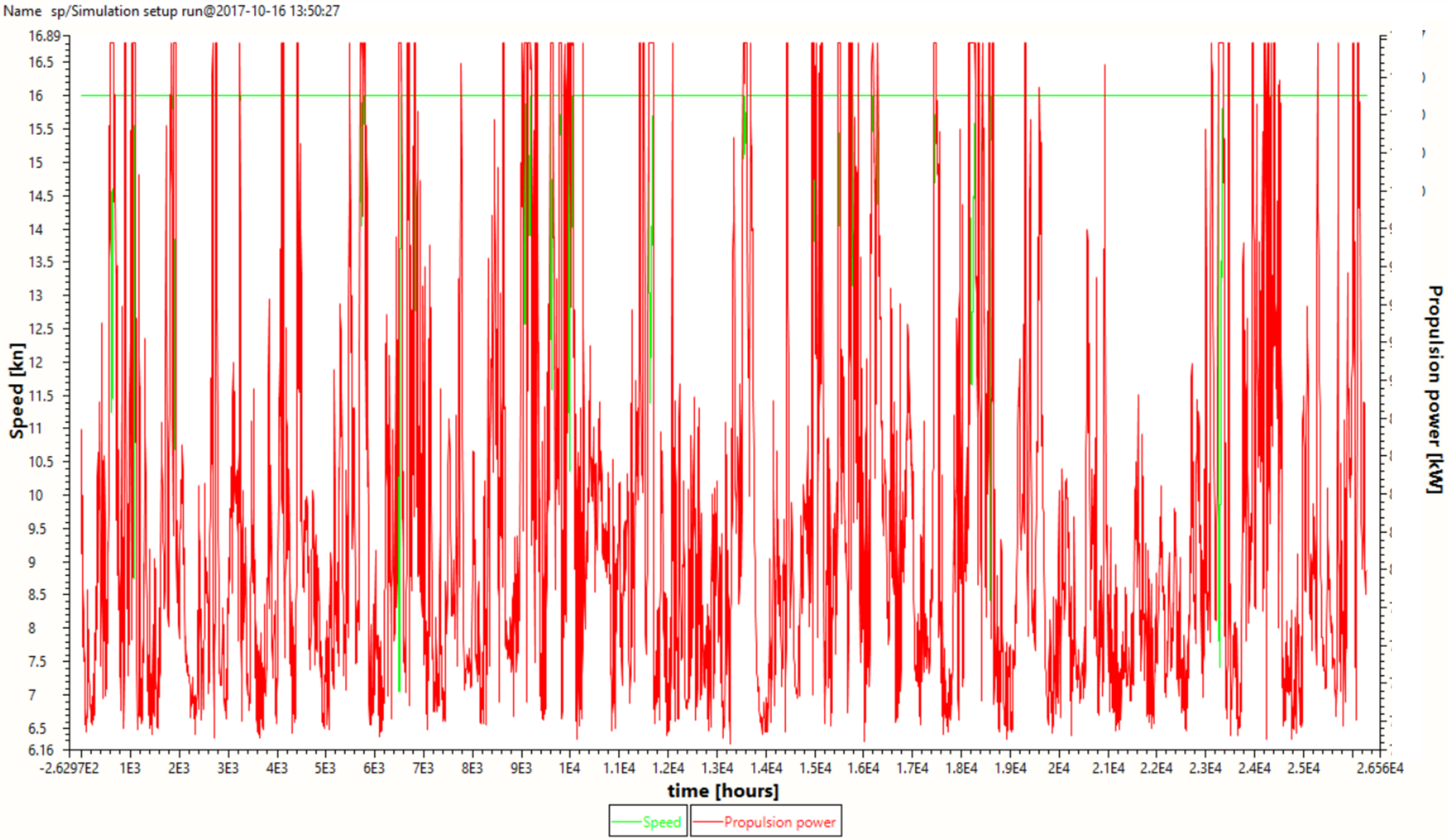
Result



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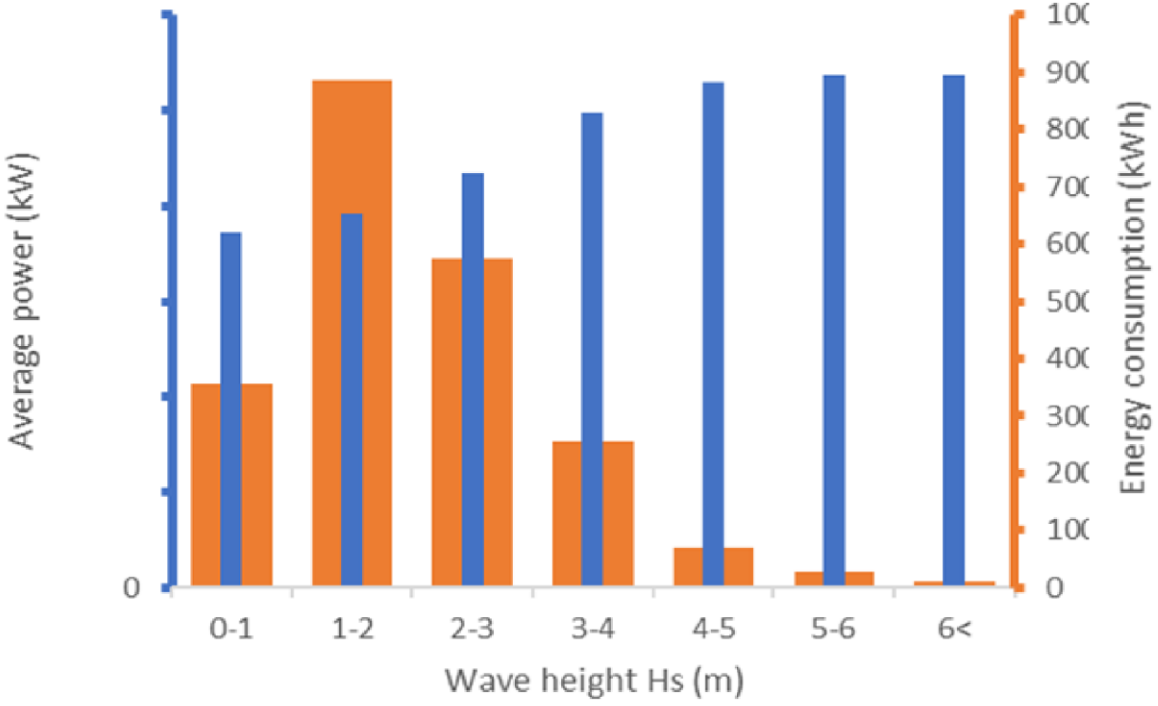
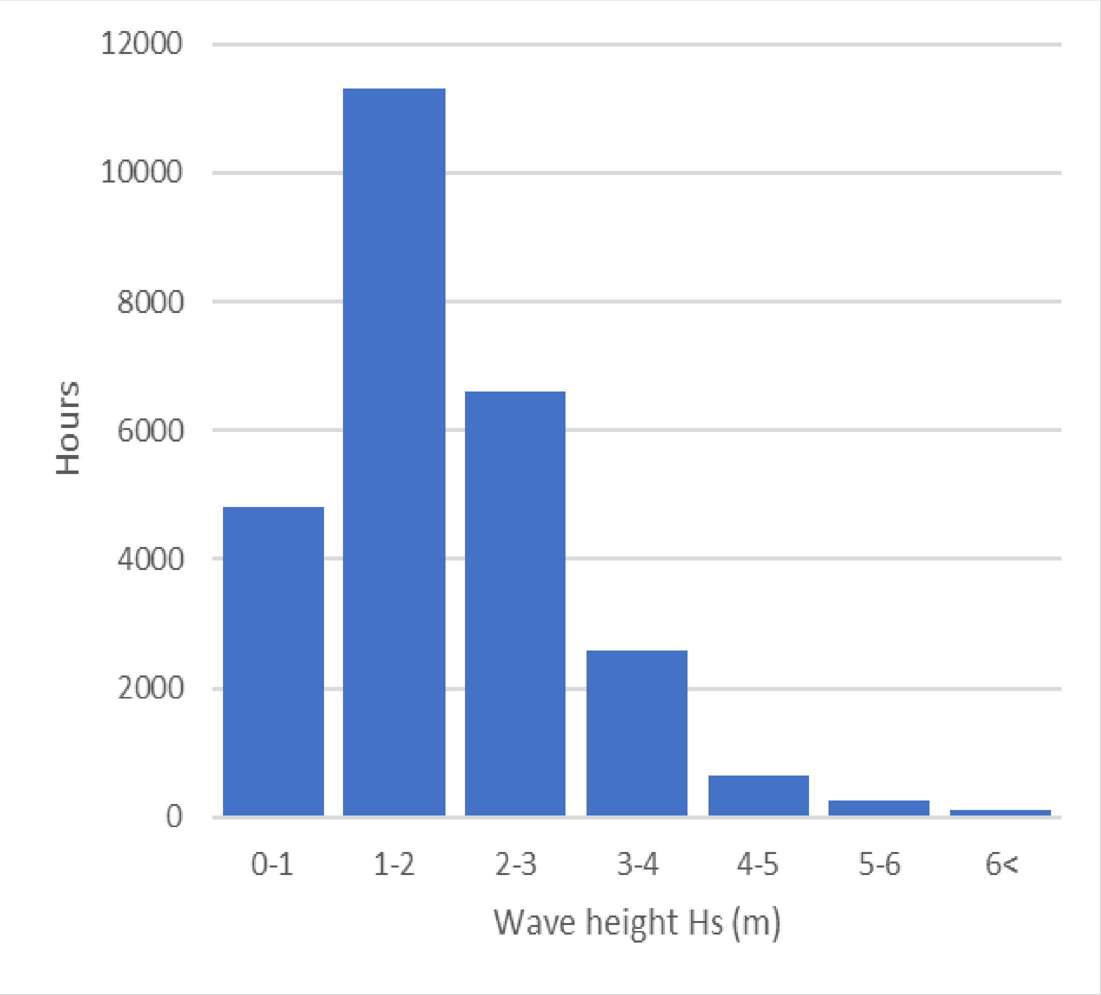
Result





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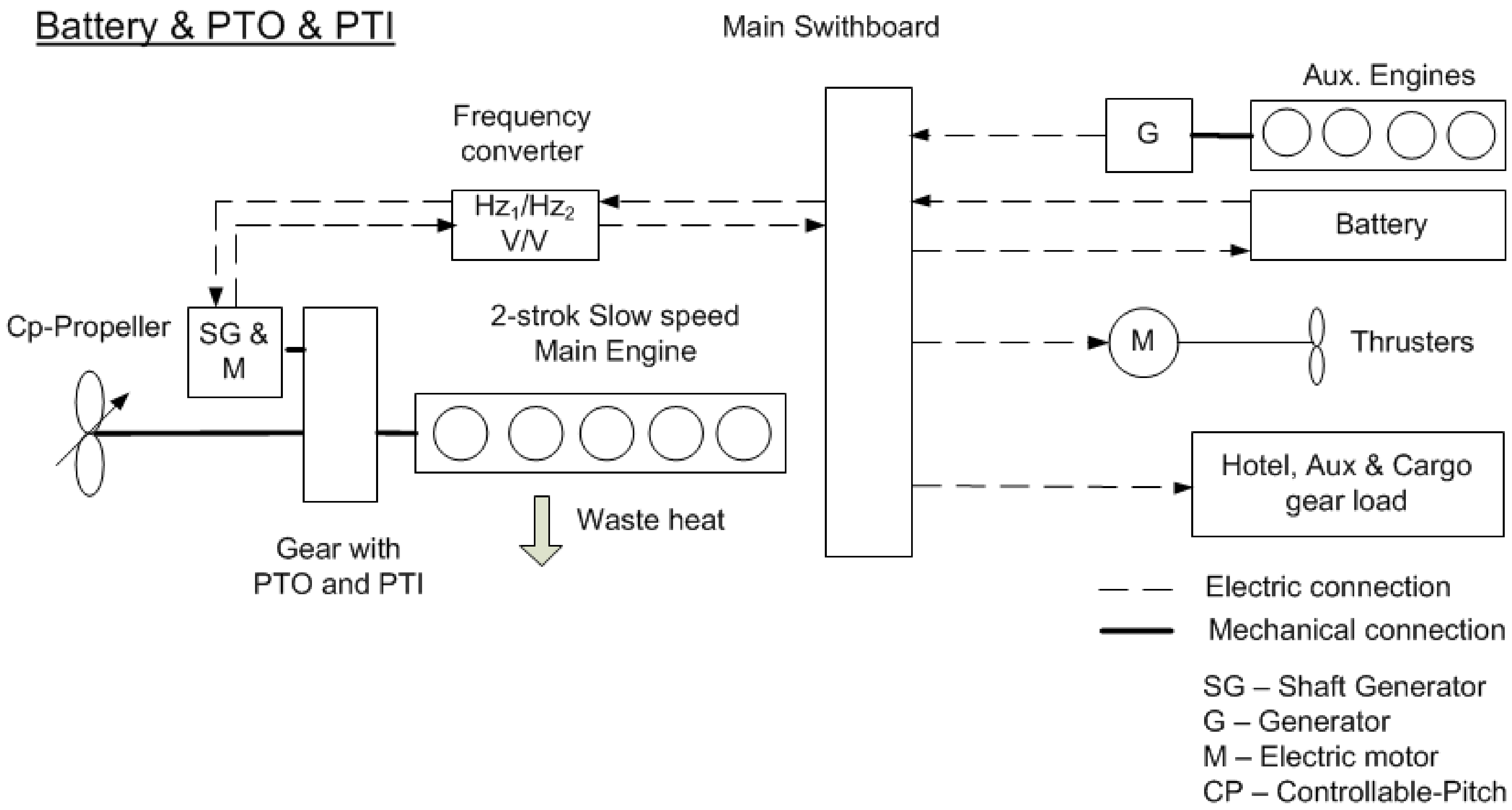
Case studies – Hybrid propulsion system for a VLCC



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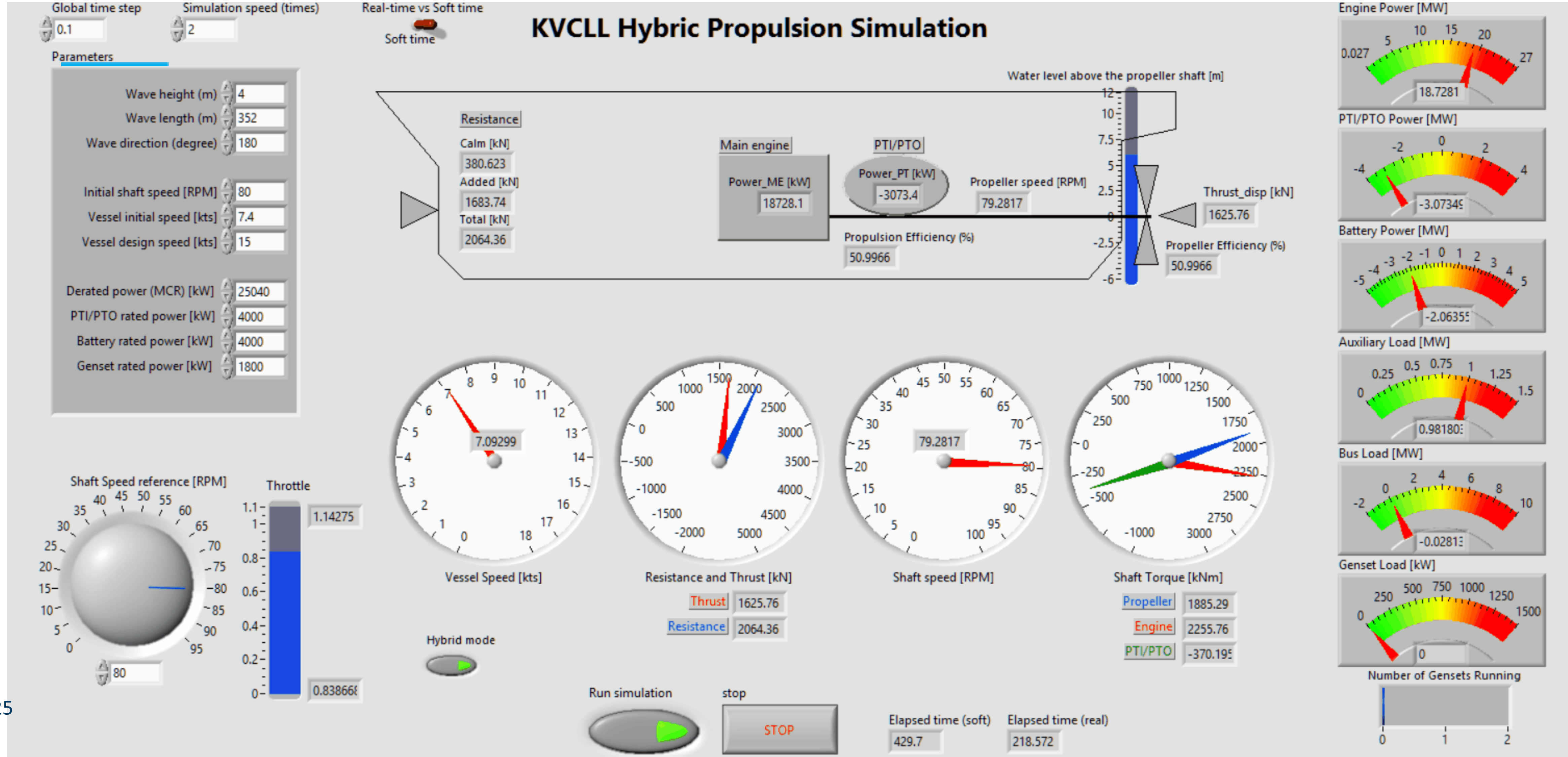
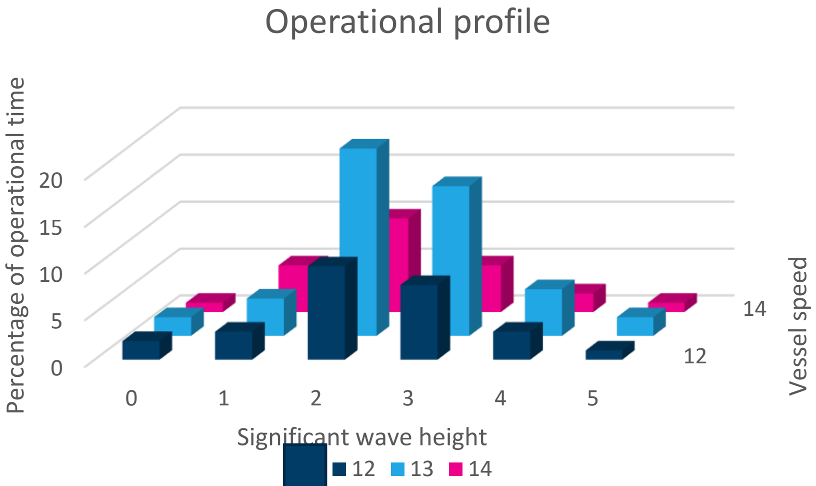
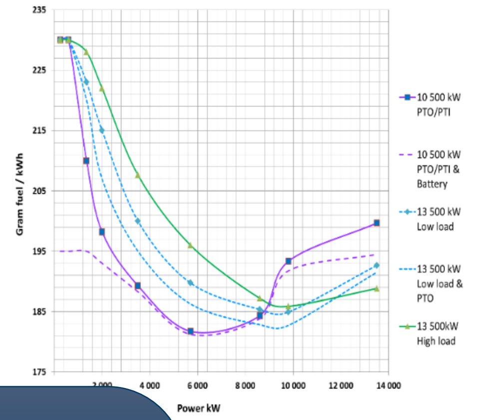

KVCLL Hybric Propulsion Simulation
Global time step
0.1
Simulation speed (times)
2
Real-time vs Soft time
Soft time
Parameters
Wave height (m) 4
Wave length (m) 352
Wave direction (degree) 180
Initial shaft speed [RPM] 80
Vessel initial speed [kts] 7.4
Vessel design speed [kts] 15
Derated power (MCR) [kW] 25040
PTI/PTO rated power [kW] 4000
Battery rated power [kW] 4000
Genset rated power [kW] 1800
Resistance
Calm [kN] 380.623
Added [kN] 1683.74
Total [kN] 2064.36
Main engine
Power_ME [kW] 18728.1
PTI/PTO
Power_PT [kW] -3073.4
Propeller speed [RPM] 79.2817
Propulsion Efficiency (%) 50.9966
Water level above the propeller shaft [m]
Thrust_disp [kN] 1625.76
Propeller Efficiency (%) 50.9966
Vessel Speed [kts] 7.09299
Resistance and Thrust [kN]
Thrust 1625.76
Resistance 2064.36
Shaft speed [RPM] 79.2817
Shaft Torque [kNm]
Propeller 1885.29
Engine 2255.76
PTI/PTO -370.195
Shaft Speed reference [RPM] 80
Throttle 1.14275 0.838668
Hybrid mode
Run simulation
stop
STOP
Elapsed time (soft) 429.7
Elapsed time (real) 218.572
Engine Power [MW] 18.7281
PTI/PTO Power [MW] -3.07349
Battery Power [MW] -2.06355
Auxiliary Load [MW] 0.981803
Bus Load [MW] -0.02813
Genset Load [kW] 0
Number of Gensets Running

Case studies – Hybrid propulsion system for a VLCC

Long-term Voyage simulation



Fuel/Emission Calculation



Power system modeling
Machine learning
Data analysis
Design of experiments
Surrogate modeling
Optimization
Verification

Configuration
Constraints
Objectives
Models

Design of Experiment
Dynamic Performance
Simulation
Surrogate Modeling
Optimization
Verification of the result

Power System Design

Case studies – Hybrid propulsion system for a VLCC

Speed [kts]	Frequency Speed
9	15%
11	50%
13	20%
15	15%

Hs	Scenario 1	Scenario 2	Scenario 3
0 m	5%	5%	5%
1 m	10%	10%	12%
2 m	10%	20%	45%
3 m	55%	55%	28%
4 m	20%	10%	10%

	Base [kg/m]	Optimum [kg/m]	P_{ME} [MW]	P_{PTI} [MW]	P_{Gen} [MW]	P_{Batt} [MW]
1	0.1641	0.1627 (↓0.85%)	24.93	1.884	1.802	1.079
2	0.1500	0.1492 (↓0.5%)	24.41	2.375	1.641	1.266
3	0.1352	0.1339 (↓0.96%)	23.93	3.554	1.239	2.606

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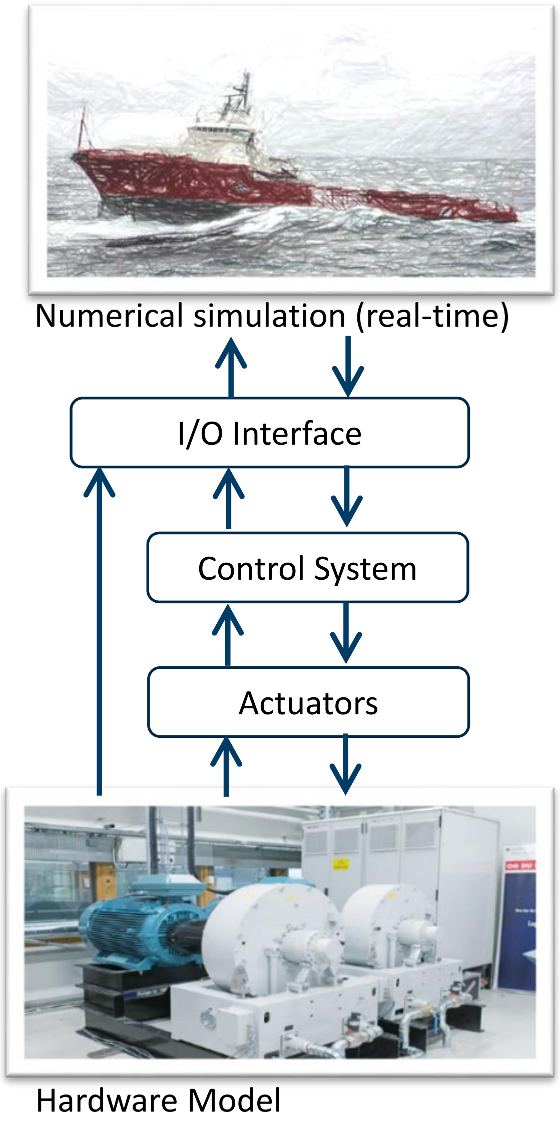
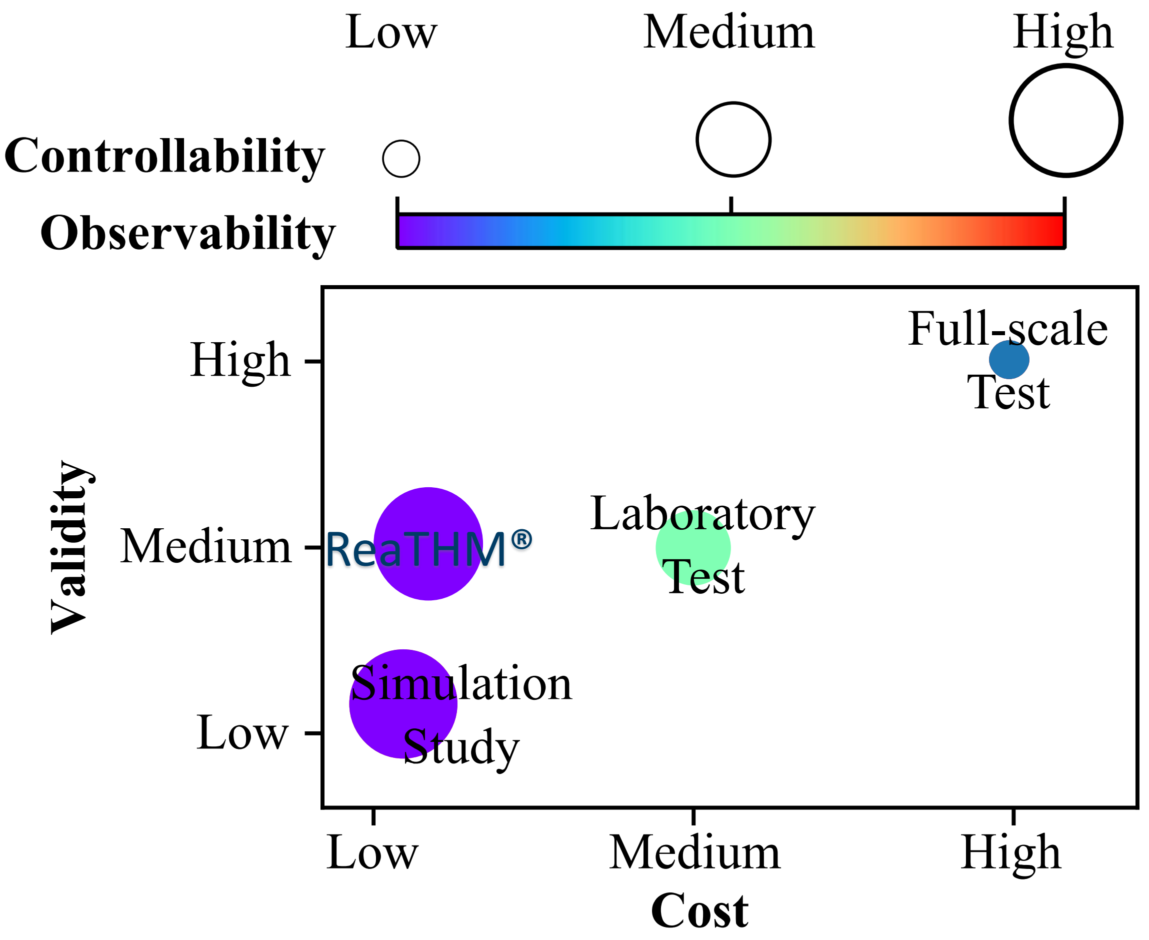
Real-Time Hybrid Testing of A Marine Power Plant





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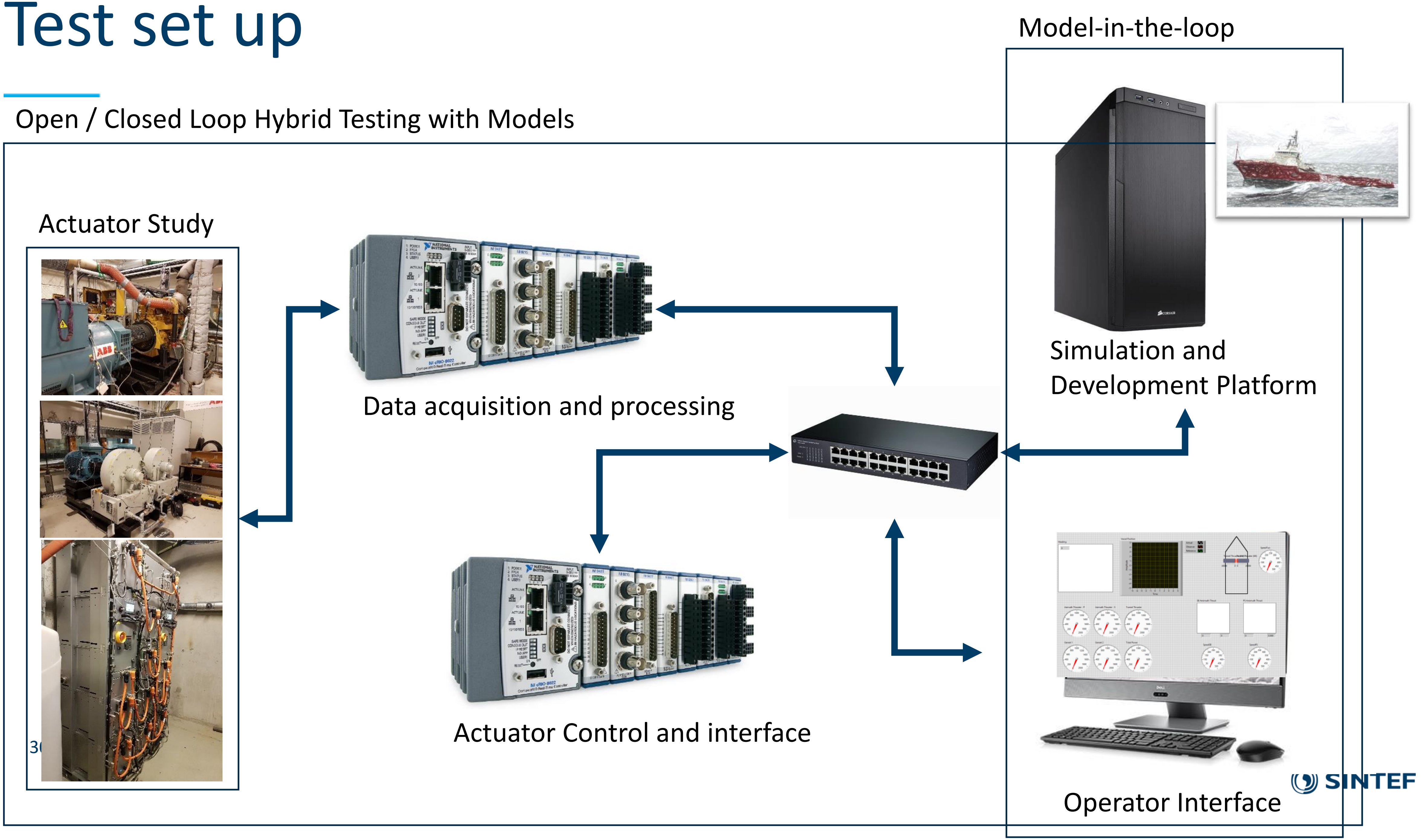
Hybrid Power Laboratory

- Application
  - Testing and Verification of Power and Energy Management System (Hybrid DC)
  - Prototyping of controllers for the power system
  - Real-time Hybrid Testing (ReaTHM) for a marine power system
  - X-in-the-Loop simulation and testing

- Future development
  - Marine fuel-cell test bed
  - Regenerative braking on the shaft

Test set up

Open / Closed Loop Hybrid Testing with Models



Conclusion

- Challenges ahead are immense in terms of its complexity and uncertainty.
- Design thinking and system perspective are crucial to overcome the challenges.
- X-in-the-Loop platform will be a central tool for the development of new vessels.

QUESTIONS?

Reference

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Teknologi for et bedre samfunn