Model-based systems engineering for marine industry

Realize innovation.

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Agenda

- The marine industry is evolving
- Model-based systems engineering for marine applications
- The voice of our customers
- Conclusion

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The marine industry is evolving

New and stringent regulations

Fiercer competition

Global economic downturn

Streamlined processes

Which implications for marine systems design?

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New and stringent regulations

- Reduce NOx emissions and noise (ECA)
- Reduce CO2 emissions (EEDI)

Fiercer competition

- Improve performances and energy flow
- Increase ship cargo capacity
- Improve NVH comfort

Global economic downturn

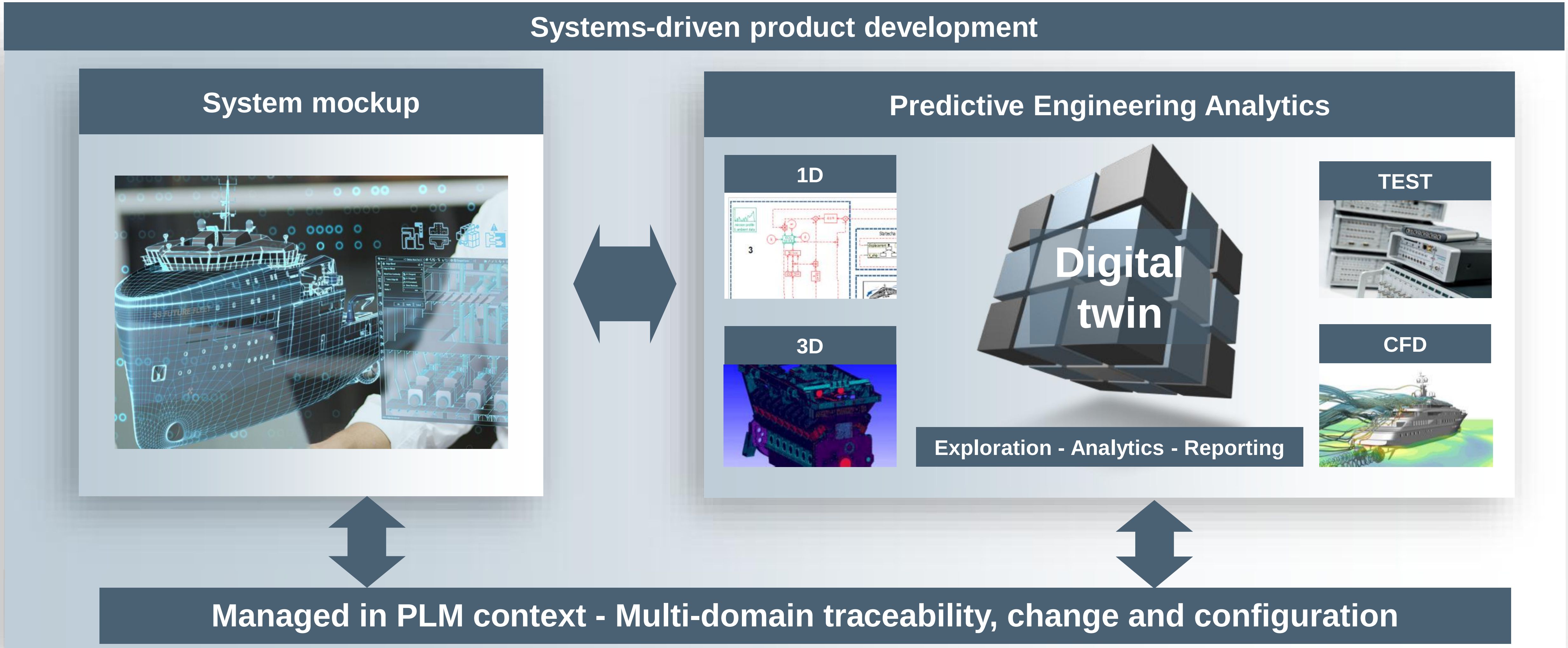
- Reduce ship fuel consumption
- Reduce development costs

Streamlined processes

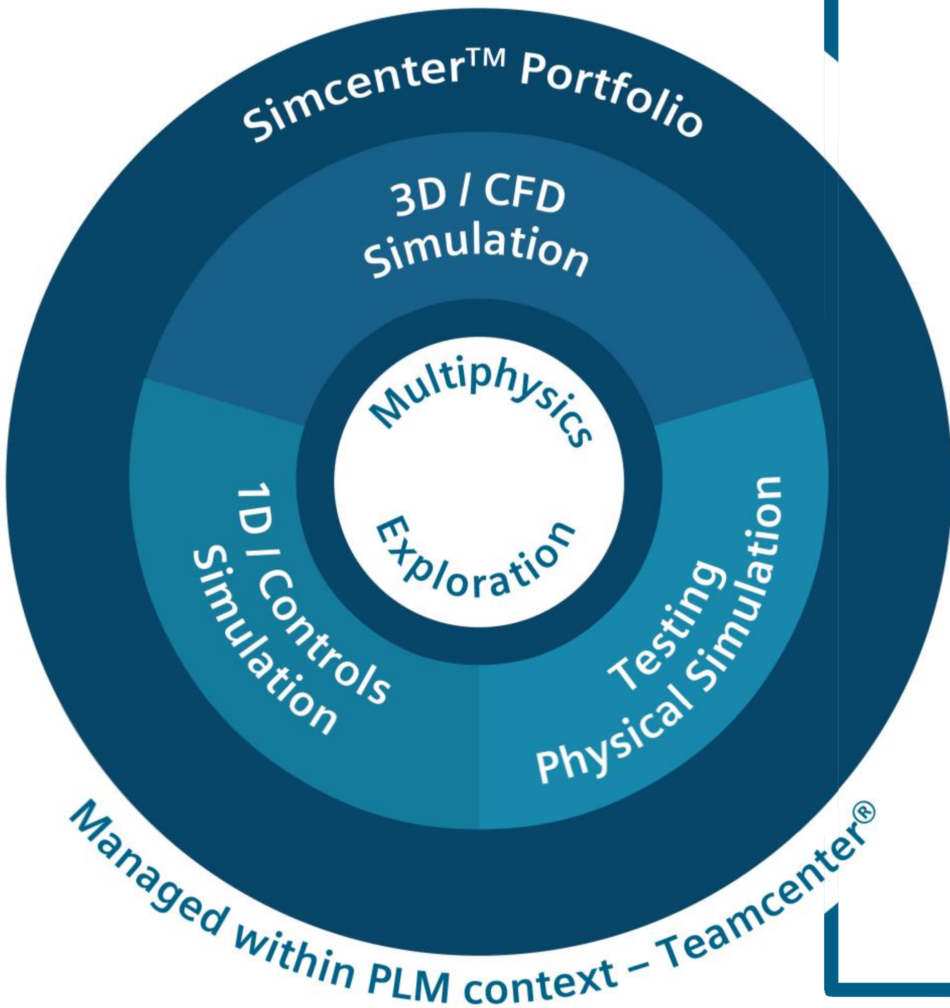
- Adapt design process to system complexity
- Improve collaboration between suppliers and integrator

One constant. Addressing these engineering challenges …
… without compromising time-to-market, quality and cost

Predictive Engineering Analytics
Role in systems-driven product development



Introducing Simcenter™ Portfolio for Predictive Engineering Analytics



Simcenter™

Simcenter™ Portfolio for Predictive Engineering Analytics

LMS Imagine.Lab

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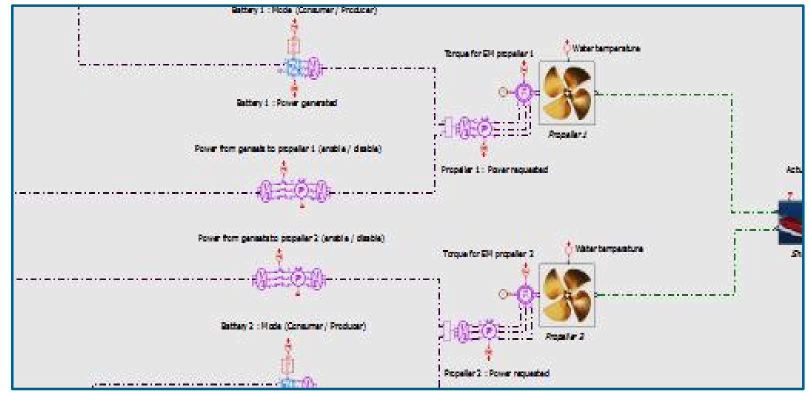
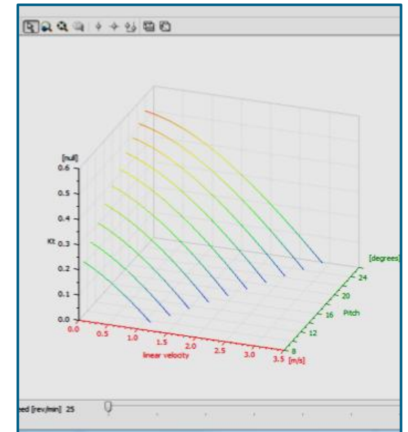
LMS Imagine.Lab Amesim

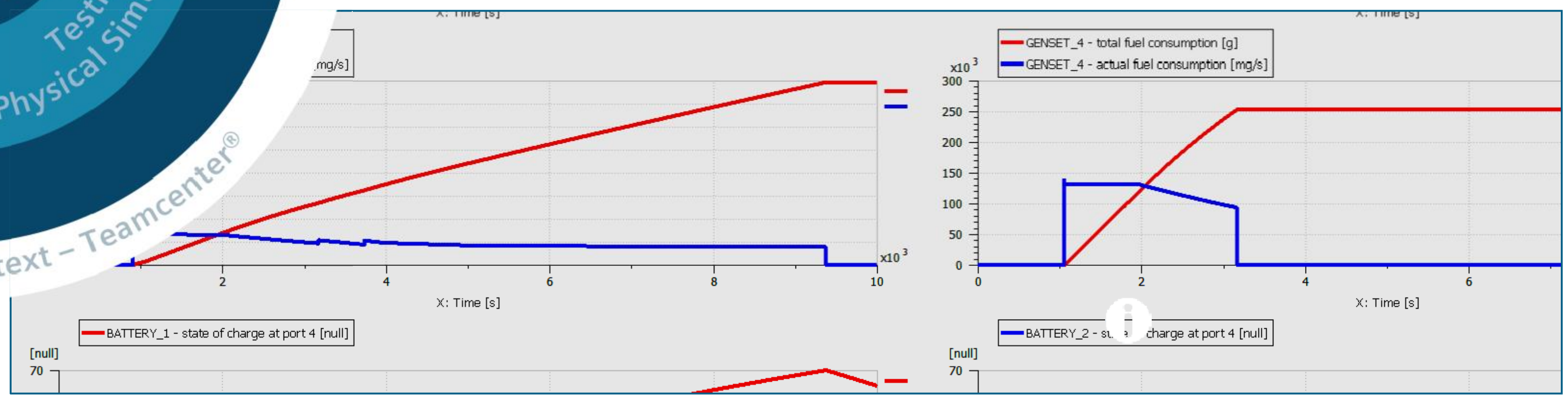




(4) K_T or K_P:

K_T From previous calculation

$K_P = CP = K_Q \times 2\pi$



LMS Imagine.Lab System Synthesis

Simcenter™ Portfolio for Predictive Engineering Analytics
LMS Imagine.Lab

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Industry specific

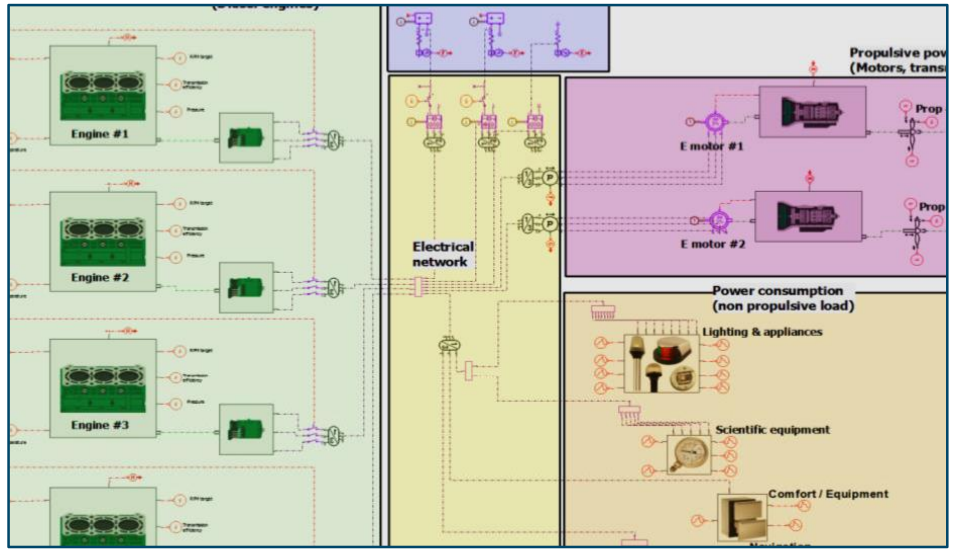
- Powertrain
- Propulsion System
- Thermal Systems
- Electrical Systems
- Engine Equipment
- Fuel Systems
- Pumps & Compressors
- Electro-Hydraulic Valves
- Fluid Actuation Systems
- Heat Exchangers
- Recovery Systems
- Control Systems

Pre-Design

Systems Sizing & Integration

Performance Balancing

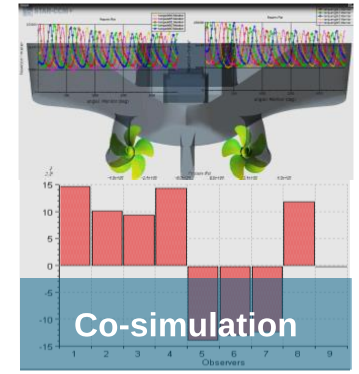
Controls Validation



Scalable Simulation

Connecting “Mechanical” – “Controls”

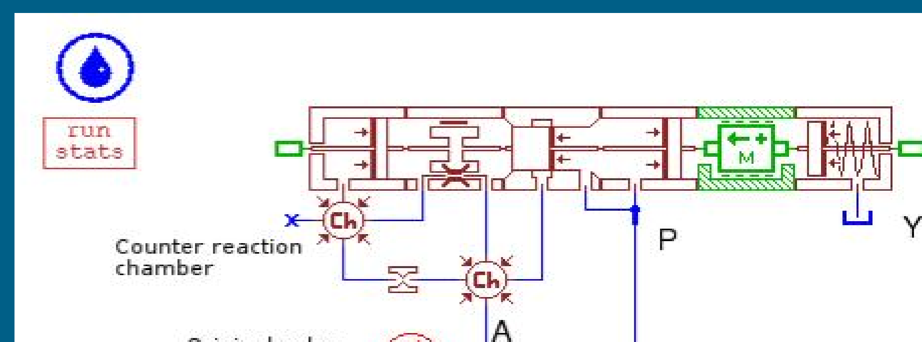
Model reduction for real-time



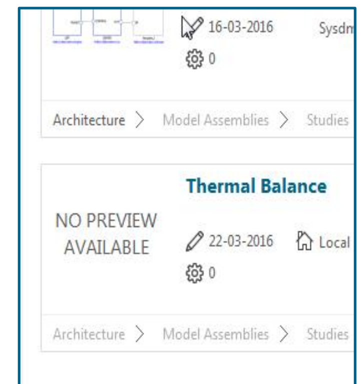
Open & customizable

>30 Libraries

>4,000 Multi-physics Models



Hydraulics
Pneumatics
Thermal
Electrical
Mechanical
Signals



Process & data management

Engineering services – LMS & CD-adapco

Experience and global talent for valued customer partnerships

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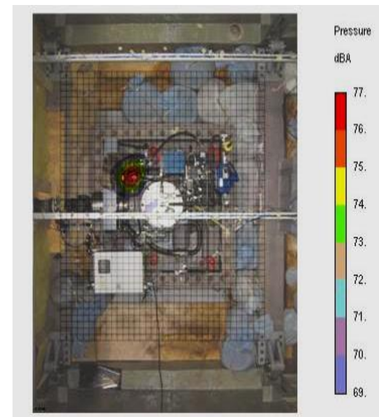
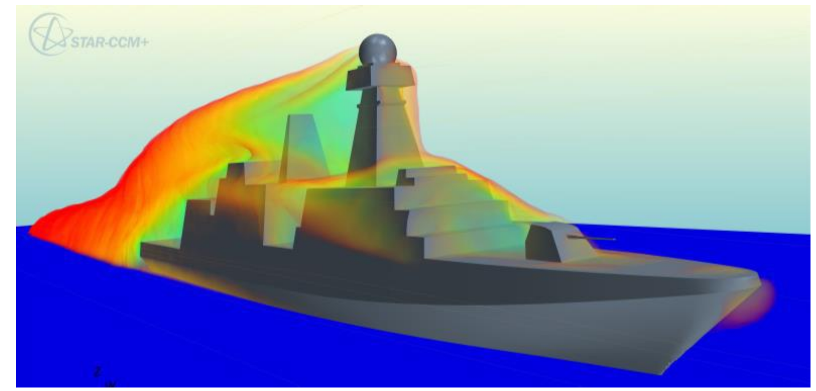
CD-adapco Engineering





LMS Engineering

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Agenda

The marine industry is evolving

Model-based systems engineering for marine applications

The voice of our customers

Conclusion

Model-based systems engineering for marine applications

CHALLENGE:

Design optimal and energy efficient architecture and balance the key ship attributes

LMS Imagine.Lab value proposition

- Optimize ship energy flow at system level
- Assess new architectures performance
- Enable analysis of several scenarios
- Design ship subsystems and components
- Test control strategies (supervisor, engine …)

Mechatronic system simulation capabilities
Plant modeling

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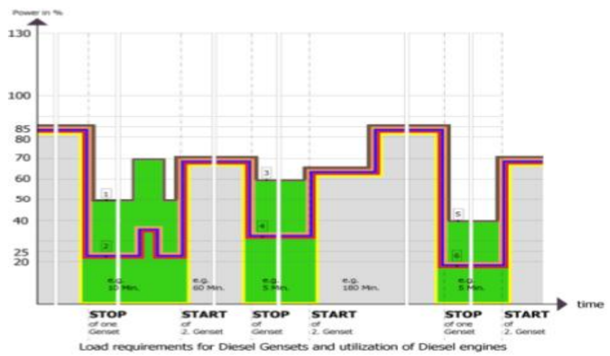
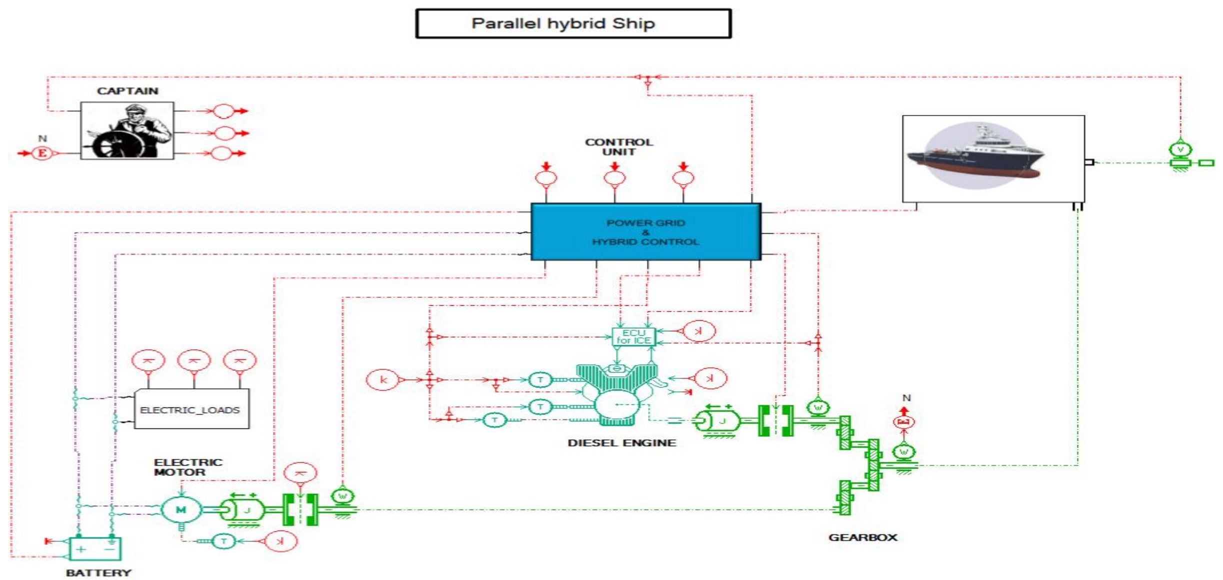
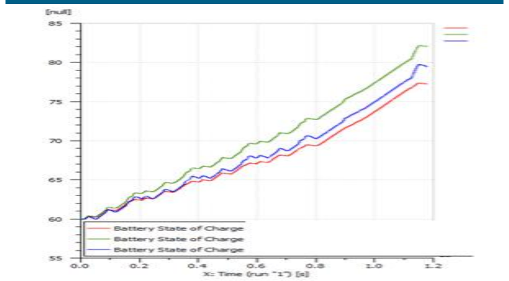
Scenarios



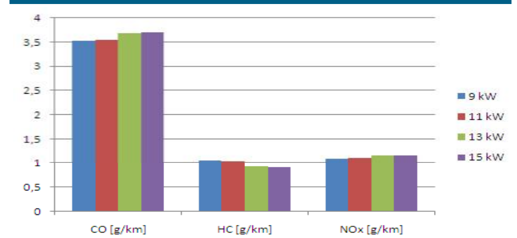
Ship model – synthesis and analysis



Fuel consumption



Pollutant reduction

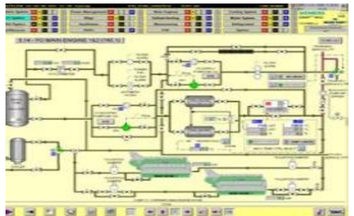


Sub-systems models and tools







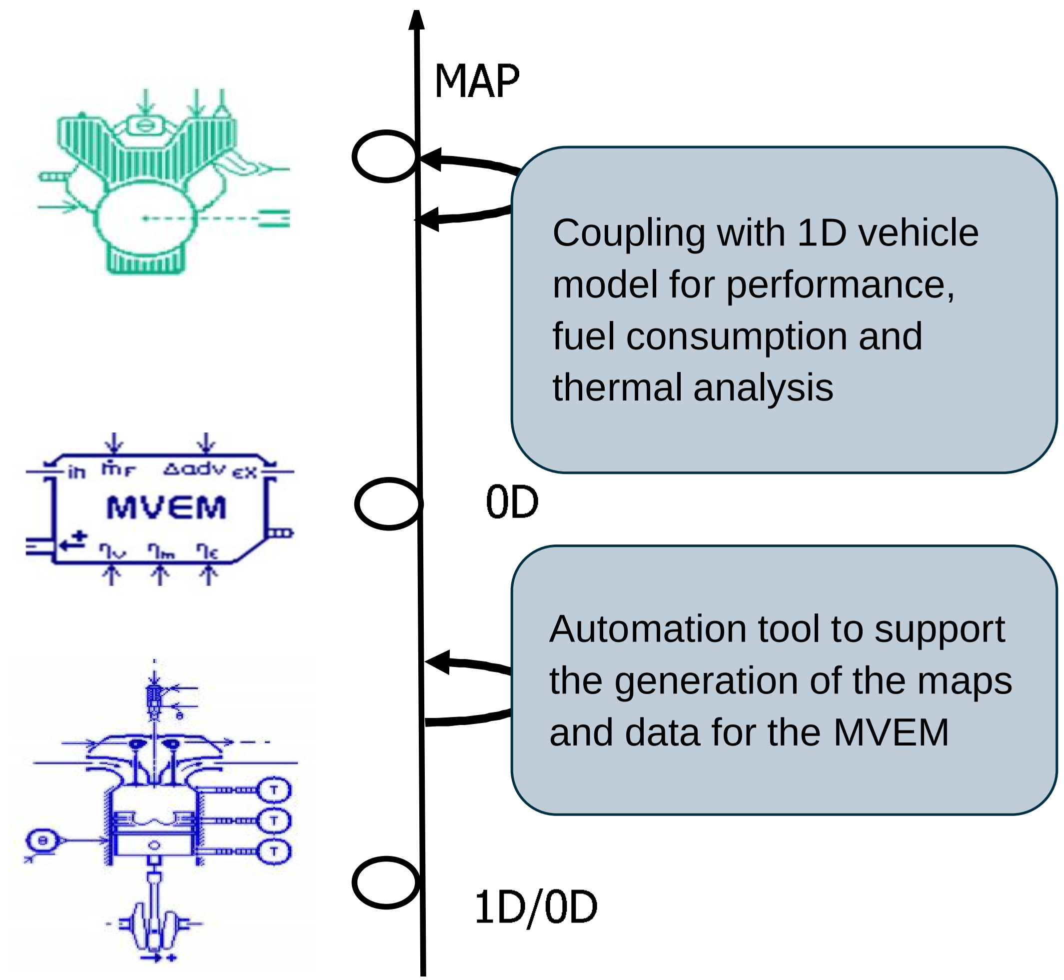


Energy storage | Engine | Transmission | Thermal | Electrics | Propellers | Monitoring

Solution portfolio
Internal combustion engine simulation

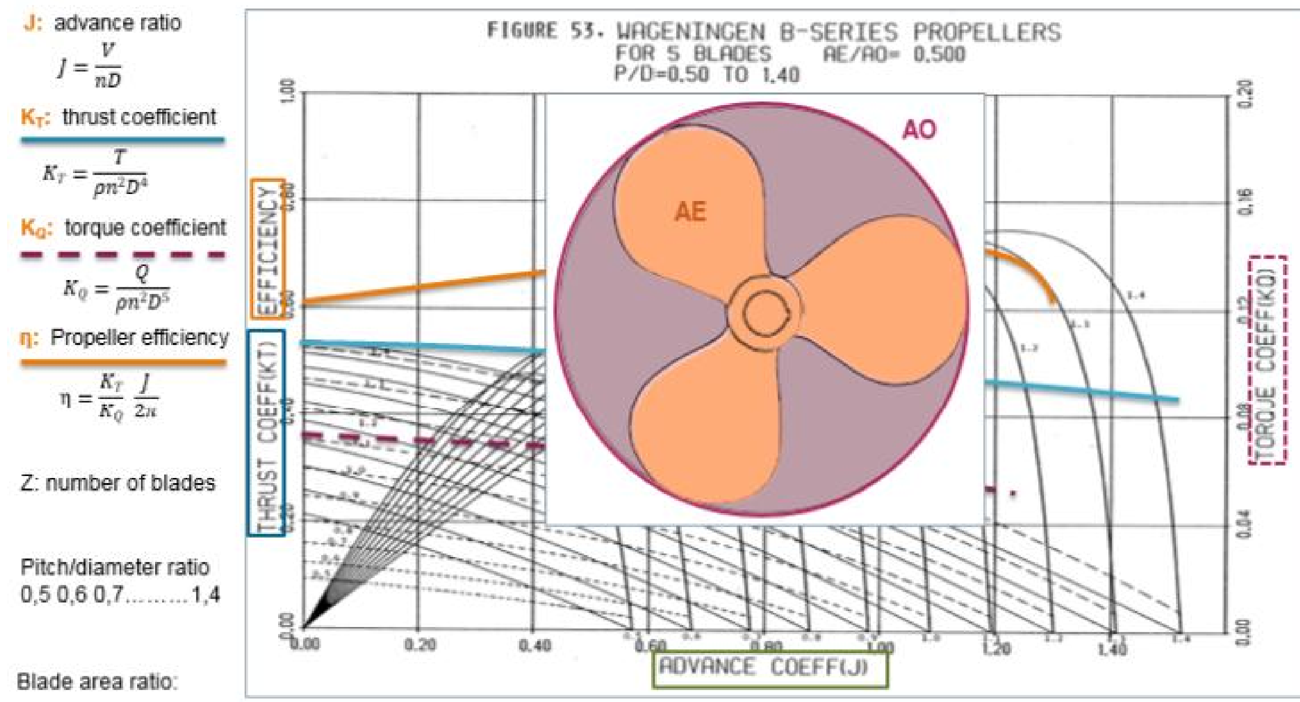
- **Modeling level** dedicated to complete engine and vehicle simulation
- **Tabulated static models** for fuel consumption on driving/working cycle, real-time export
- **Mean value models** for dynamic torque transient analysis, integration of waste heat recovery system, engine controls
- **Crankshaft-based level** with physical combustion models for emissions and combustion analysis, actuators integration and sensitivity analysis (SA, VVT, injection…)

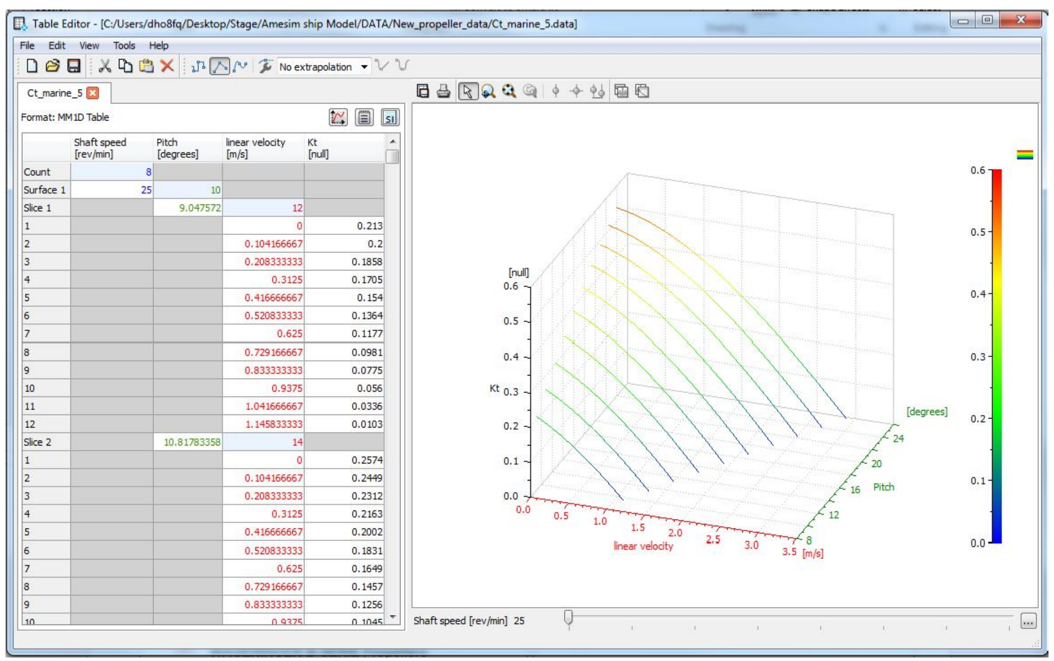
Physical content

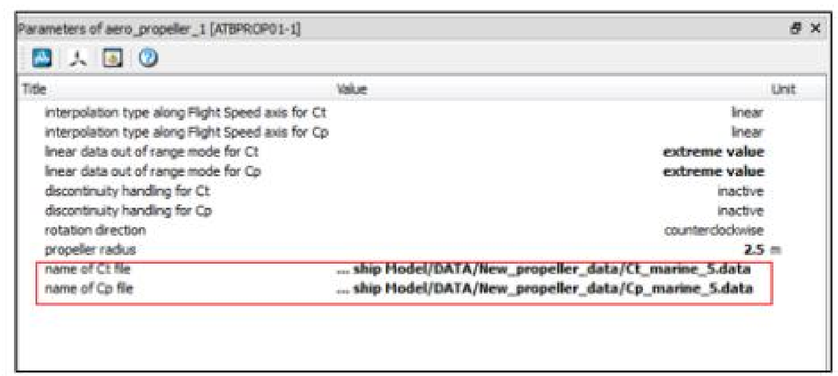


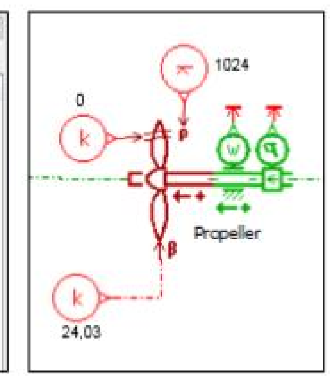
- **B-SERIE WAGENINGEN propeller type**: Based on efficiency, trust coefficient and torque coefficient

- **Map-based model:** pitch/diameter ratio, blade area ratio, number of blades as model inputs



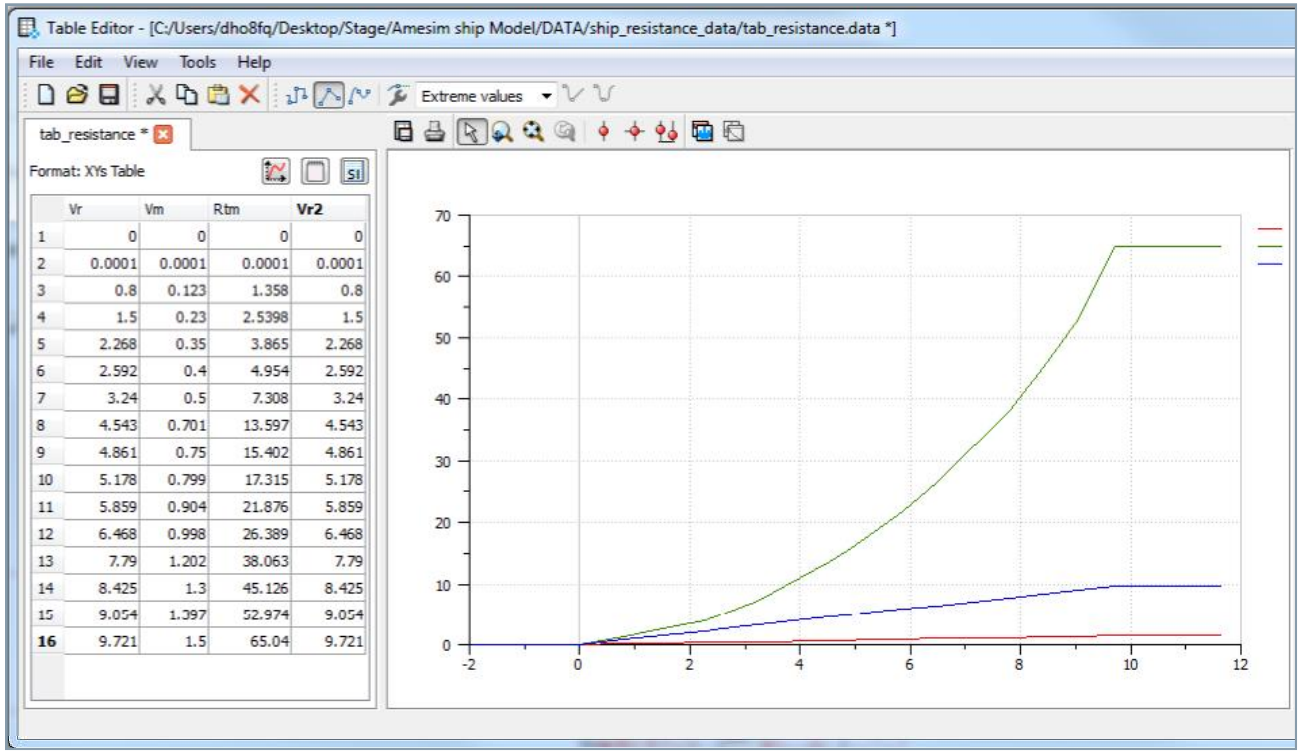






Different calculation methods:

- Statistic
- Numerical
- Experimental



	Vr	Vm	Rtm	Vr2
1	0	0	0	0
2	0.0001	0.0001	0.0001	0.0001
3	0.8	0.123	1.358	0.8
4	1.5	0.23	2.5398	1.5
5	2.268	0.35	3.865	2.268
6	2.592	0.4	4.954	2.592
7	3.24	0.5	7.308	3.24
8	4.543	0.701	13.597	4.543
9	4.861	0.75	15.402	4.861
10	5.178	0.799	17.315	5.178
11	5.859	0.904	21.876	5.859
12	6.468	0.998	26.389	6.468
13	7.79	1.202	38.063	7.79
14	8.425	1.3	45.126	8.425
15	9.054	1.397	52.974	9.054
16	9.721	1.5	65.04	9.721

Map-based model (experimental method ITTC78):

Vessel speed, resistance coefficients and wetted surface area as model inputs

Solution portfolio
Electric components detailed design

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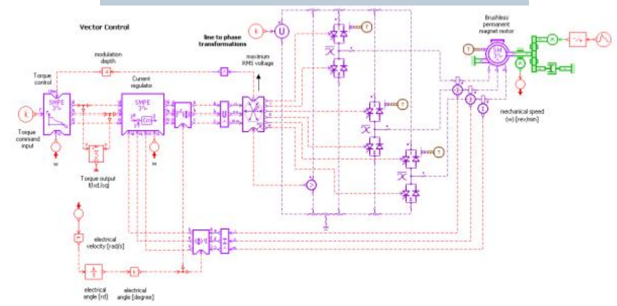
Features

- Scalable models for Machine, Converters and Storage Systems
- Most common machine technology (DC, IM, SM, SRM,…) with dedicated control blocks
- Battery (Li-Ion, NiMh) and ultra-capacitor pre-calibrated models,
- Battery parameter identification tool

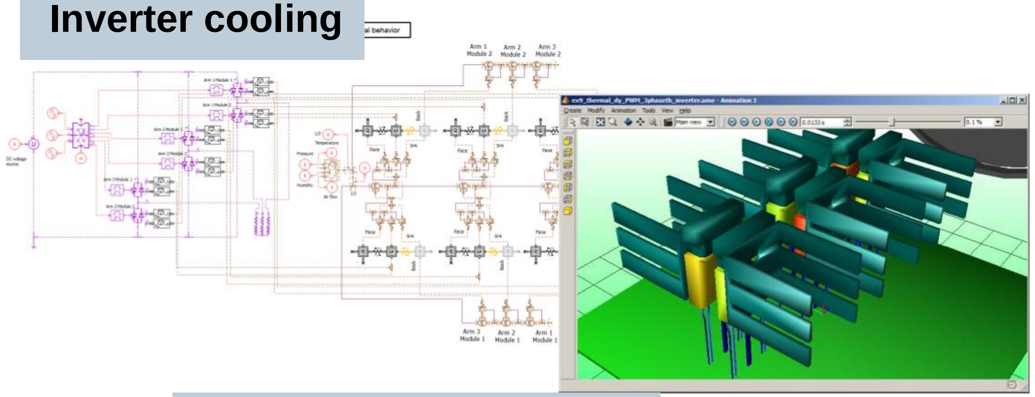
Benefits

- From architecture and technology early comparison up to subsystem detailed design
- Easy machine close-loop control setup and validation
- Battery Management system validation and cooling system design

PMSM vector control



Inverter cooling



Battery identification tool

Fluid simulation: scalable component modeling

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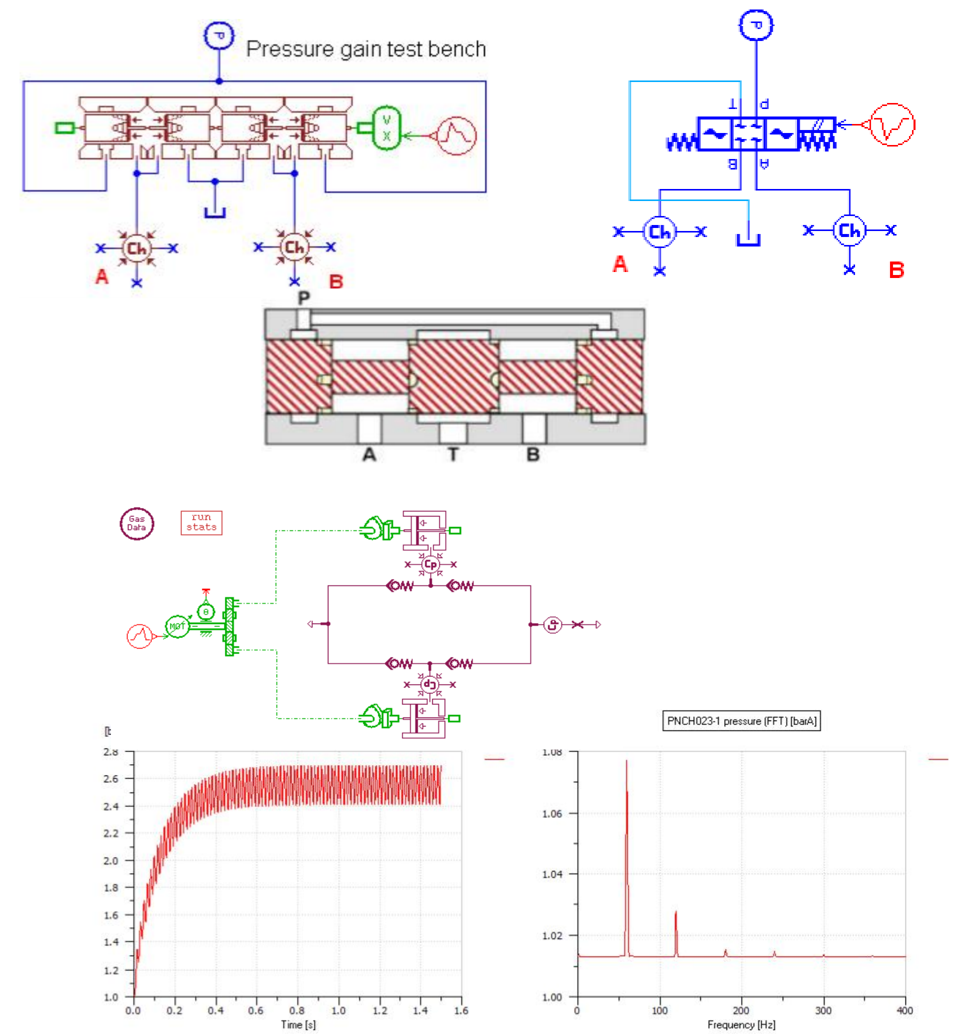
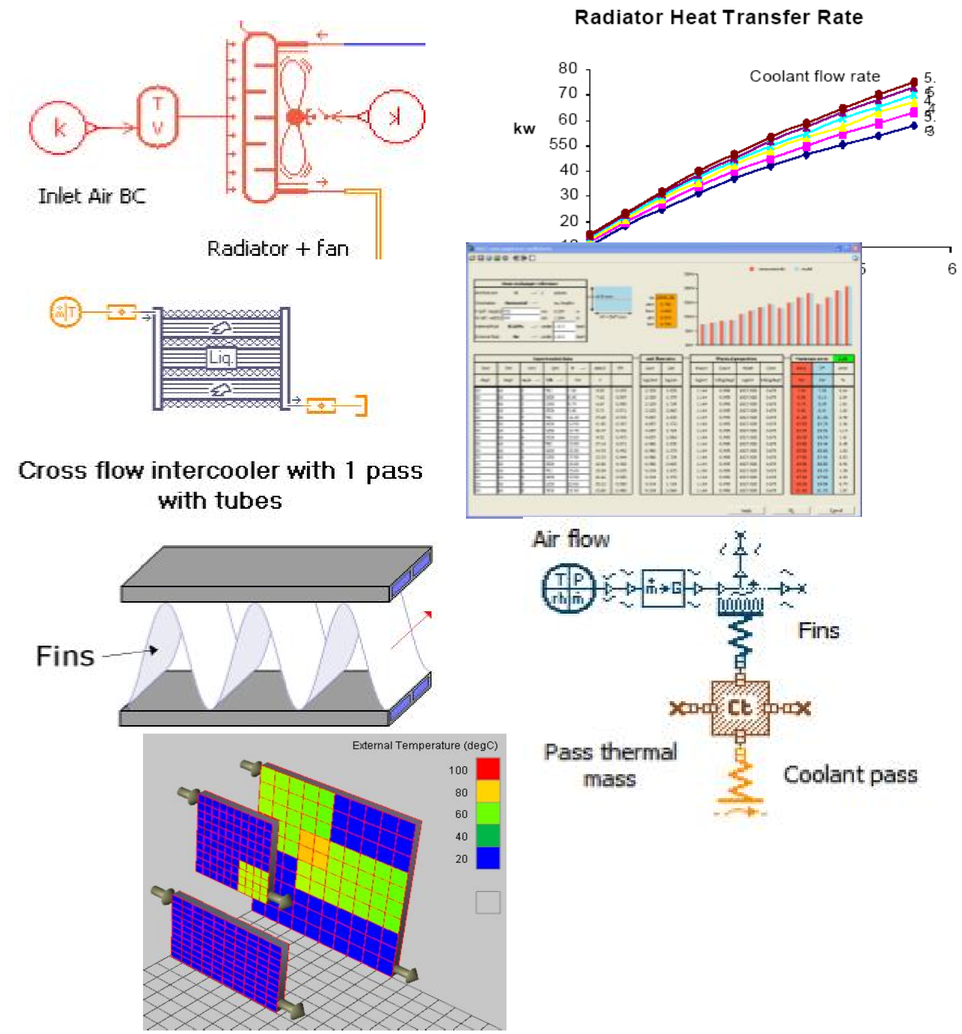
- **Level of modeling adaptable** to available input data and dynamics to be represented (quasi static, slow or fast transient)
- **Functional** (data from catalogues or measurements) or **geometrical** models for system, sub-system and component level simulation
- **4 families of components**: pumps and compressors, valves, actuators and fluid network



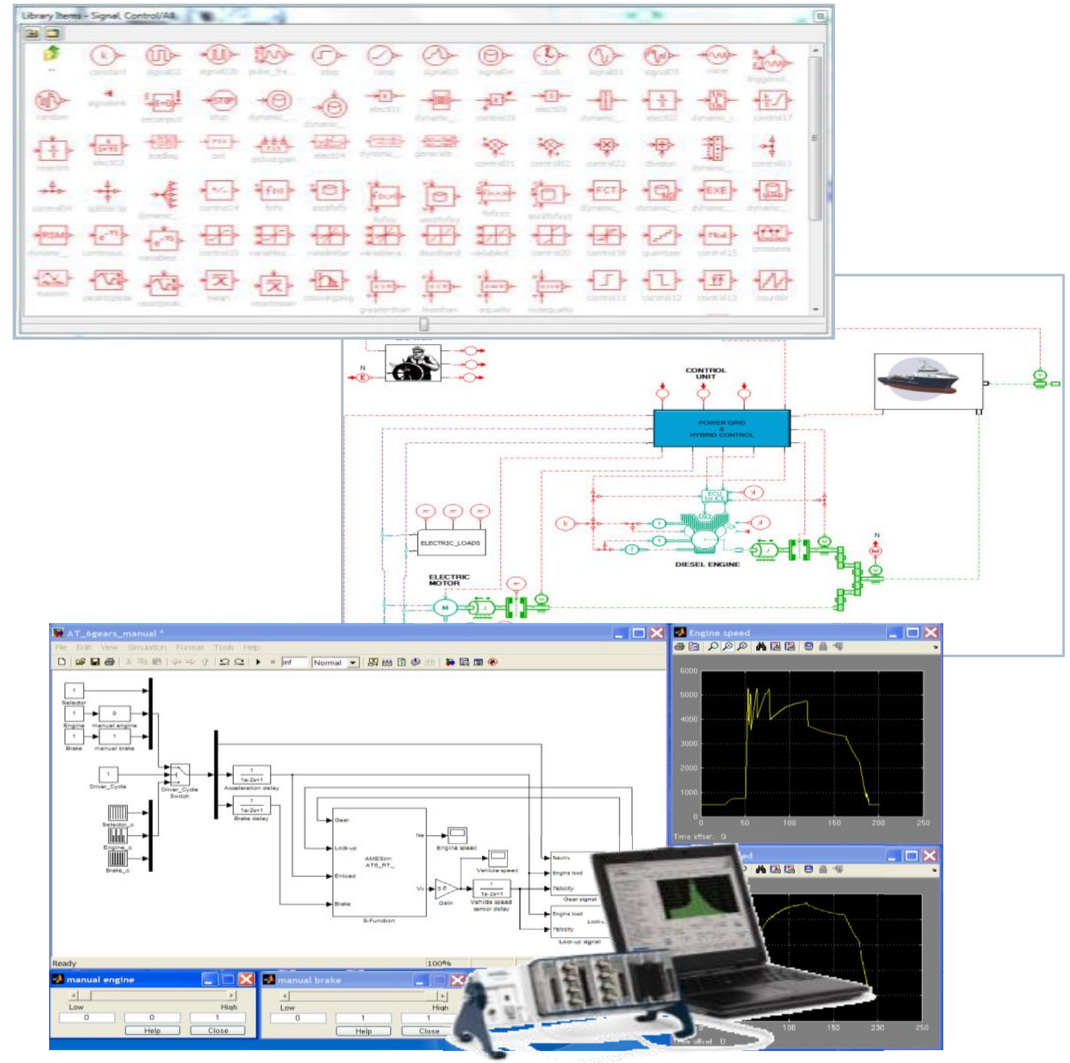
- **Prediction of flow rates, pressure and temperature**: oil circuit for actuation and transmission, engine cooling, two-phase flow systems (HVAC, Rankine…)
- **Scalable heat exchanger modeling**: functional (based on Qexch maps or effectiveness or regression with respect to tests) or detailed geometry (based on tubes and fins sizing and calibration)
- **3D interactive animation window** (stack view and results) for heat exchanger staking



Solution portfolio
Link with controls

SIEMENS

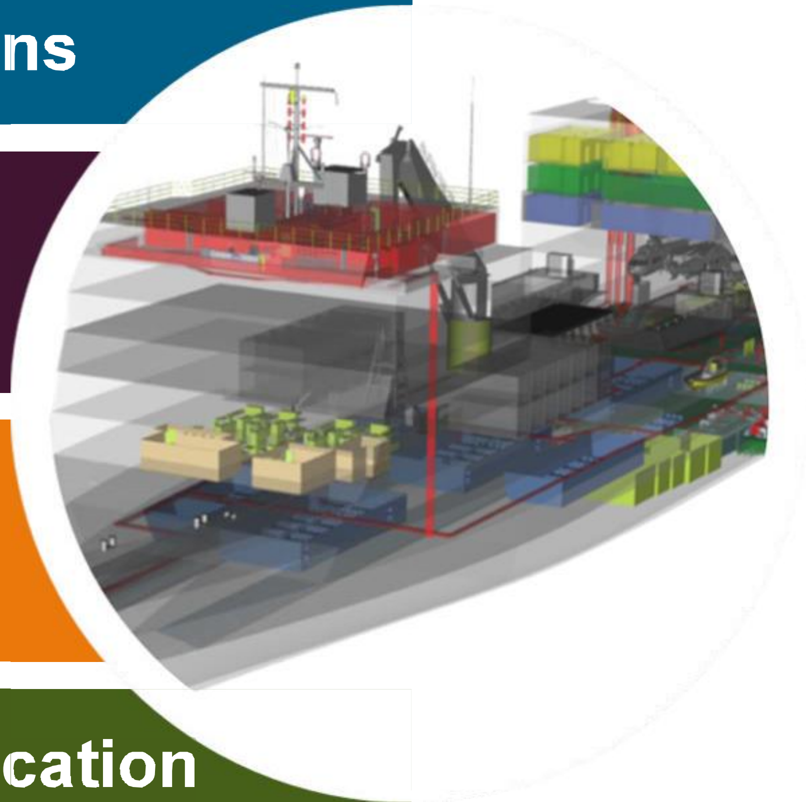
- Embedded signal, control and observer library
- Full **interfaces** with Matlab/Simulink and LabVIEW
- **Blackbox** option allows to provide standalone plant models to Simulink
- **Import** of **C-coded** control logics
- **Code export** to all major hardware-in-the-loop platforms: dSPACE, LabVIEW RT, VeriStand , xPC, Opal-RT…



Supports the SW V&V process through **MiL, SiL or HiL** methodologies

Examples of typical applications

1. Compare several propulsion system architectures for lower fuel consumption and NOx emissions
2. Optimize waste heat recovery system for diesel-electric vessel propulsion
3. Design, optimize and validate ship engine subsystems and components
4. Control algorithm development and verification for optimal power consumption and ship operation



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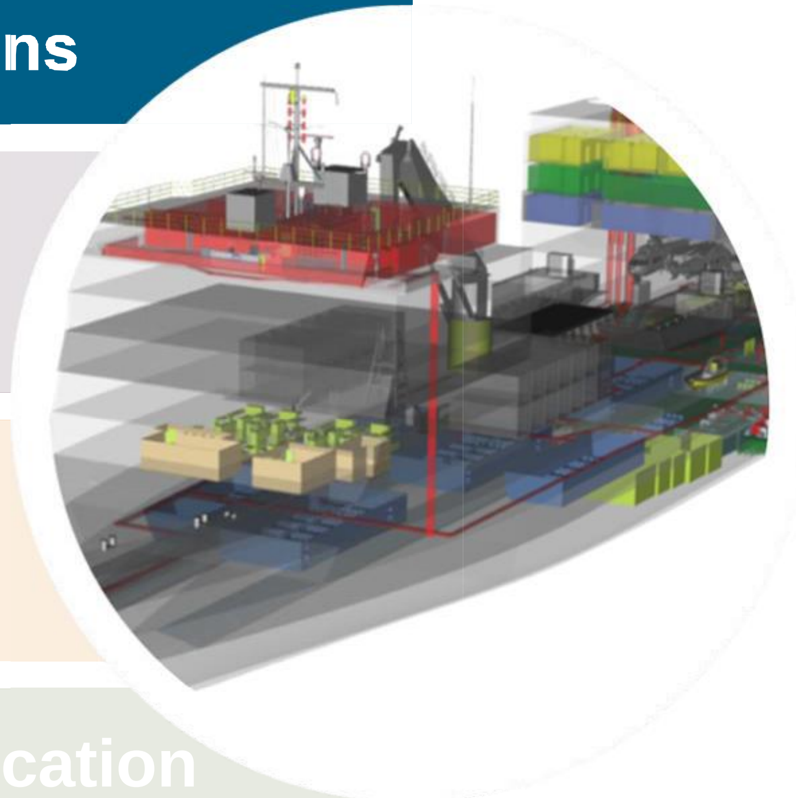
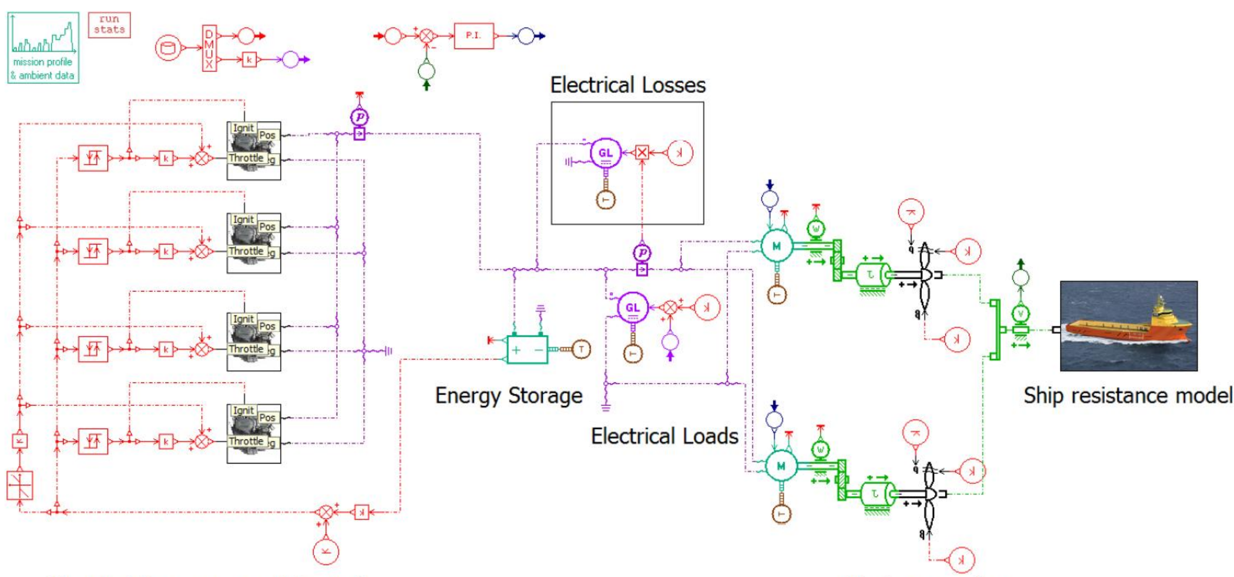
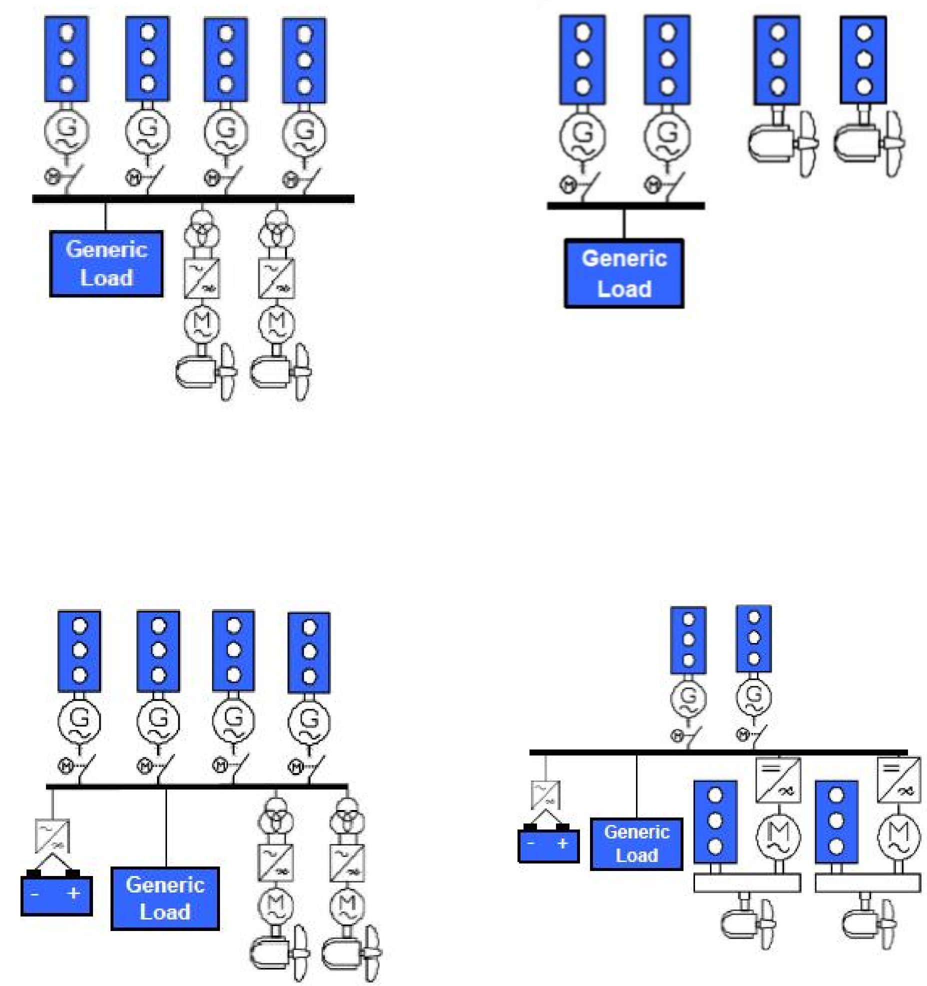


Application #1 - Ship energy management

Objective:

- Select the most efficient propulsion architecture in terms of fuel consumption and pollutant emissions for a specific load case



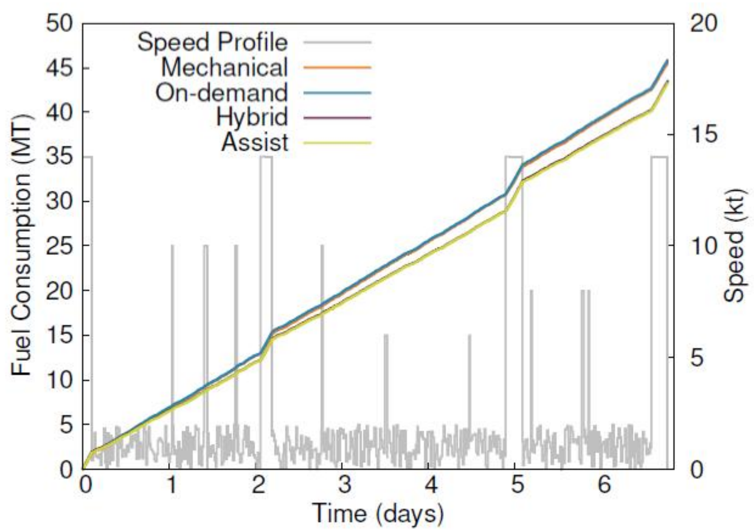


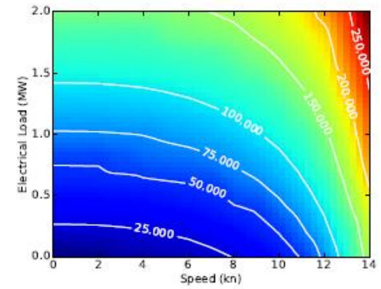
Application #1 - Ship energy management

Results:

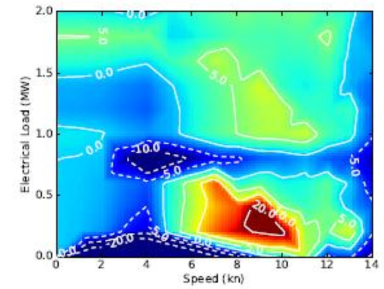
- Quasi-static and dynamic interactions between electrical and propulsion sub-systems properly identified

- Ideal architecture selected for minimum fuel consumption and NOx emissions over a mission profile (OSV based in Denmark in that case)

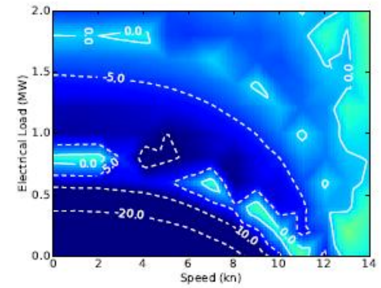




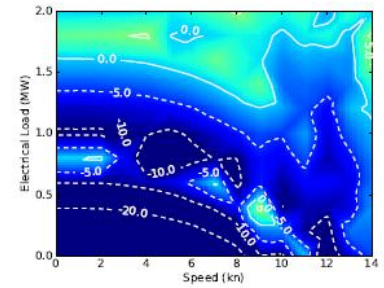
(a) On-demand absolute fuel consumption in g/s.



(b) *Mechanical* fuel consumption relative (%) to *on-demand*.



(c) *Hybrid* fuel consumption relative (%) to *on-demand*.



(d) *Assist* fuel consumption relative (%) to *on-demand*.

Examples of typical applications

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1 Compare several propulsion system architectures for lower fuel consumption and NOx emissions

2 **Optimize waste heat recovery system for diesel-electric vessel propulsion**

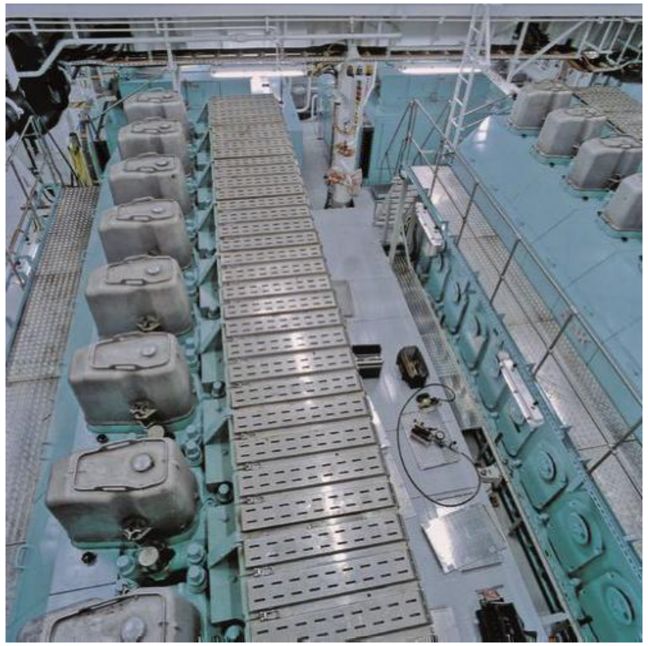
3 Design, optimize and validate ship engine subsystems and components

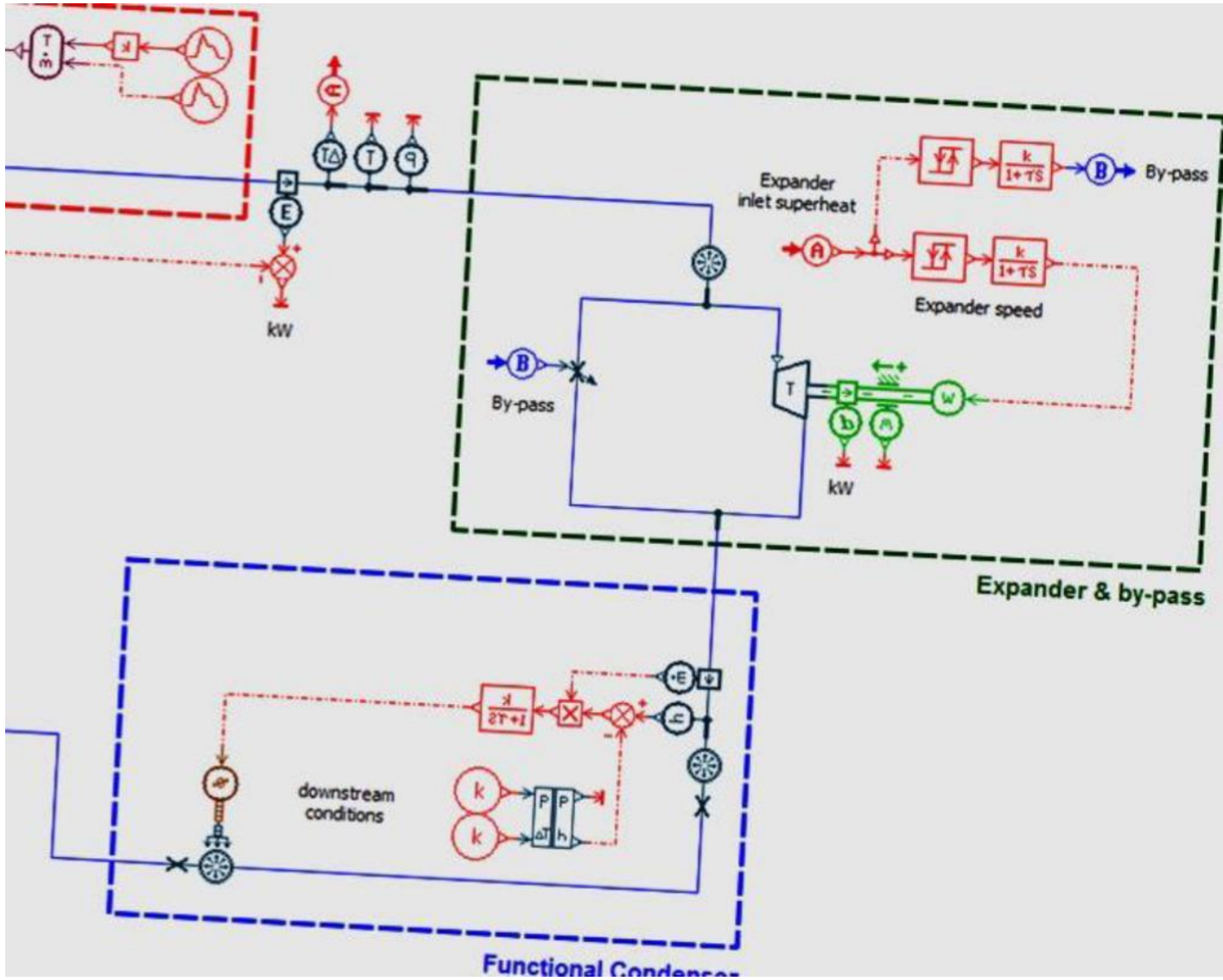
4 Control algorithm development and verification for optimal power consumption and ship operation

Application #2 - Waste heat recovery

Objectives:

- Evaluate virtually the potential of waste heat recovery systems based on Rankine Cycle principle for a specific ship

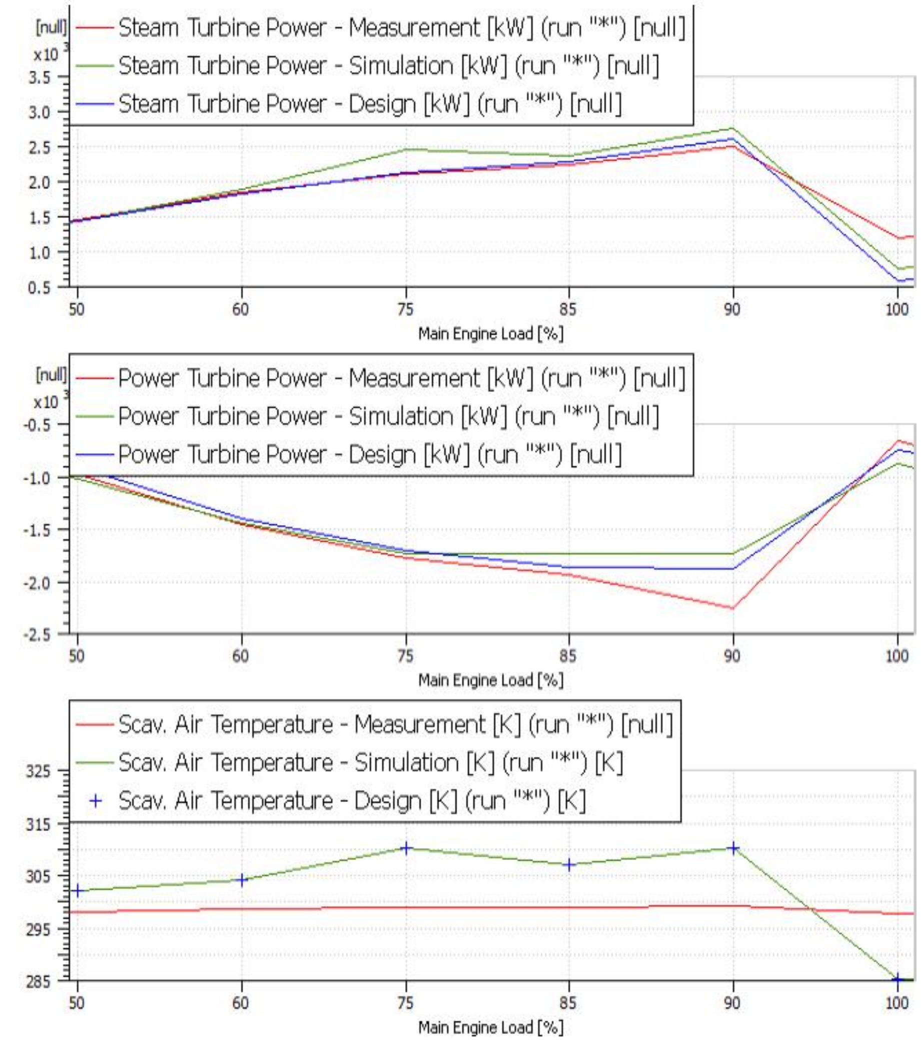




Application #2 - Waste heat recovery

Results:

- Various designs and organic fluids investigated
- Cycle efficiency, pressure and temperature level evaluated
- Control system requirements defined
- Impact of Rankine on fuel economy assessed for specific scenarios and conditions

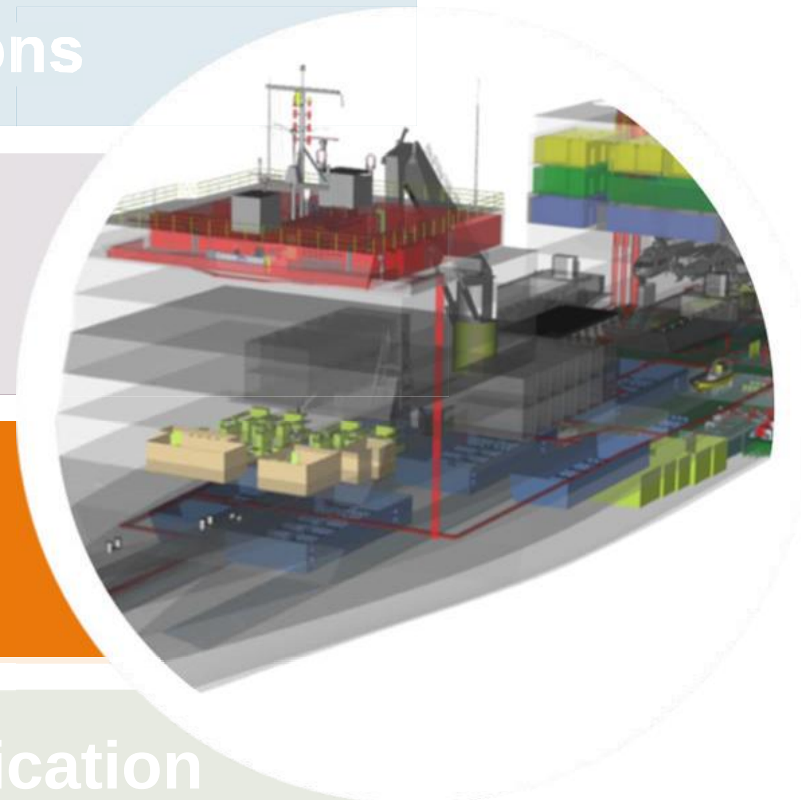


Steam

Component	Measured	Model	Unit
LP Mass Flow	3.7	3.2	kg/s
LP Pressure	3.5	3.3	bar
LP Temperature	136.6	122.2	°C
HP Mass Flow	3.3	3	kg/s

Examples of typical applications

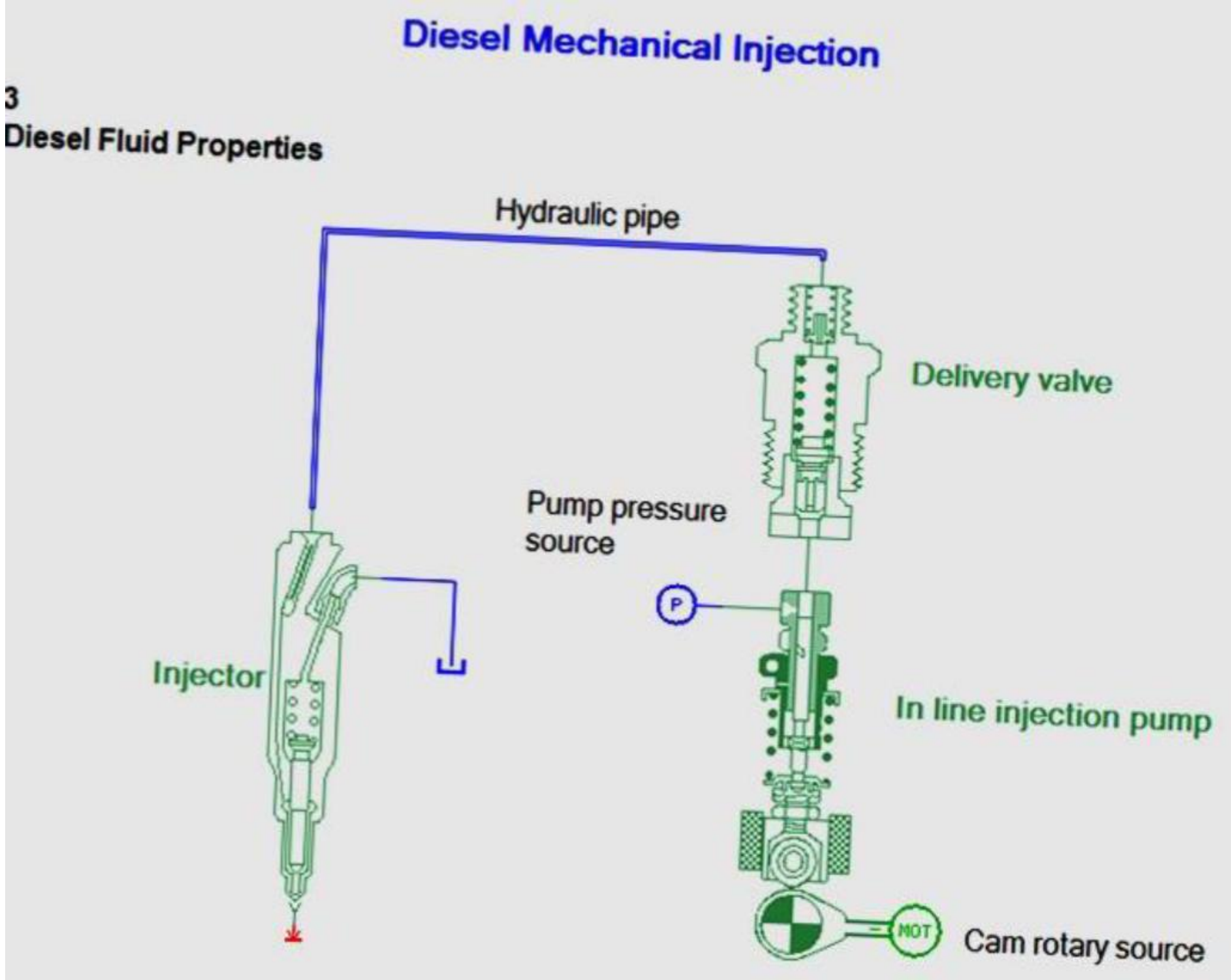
1. Compare several propulsion system architectures for lower fuel consumption and NOx emissions
2. Optimize waste heat recovery system for diesel-electric vessel propulsion
3. **Design, optimize and validate ship engine subsystems and components**
4. Control algorithm development and verification for optimal power consumption and ship operation



Application #3 - Engine fuel injection system design

Objectives:

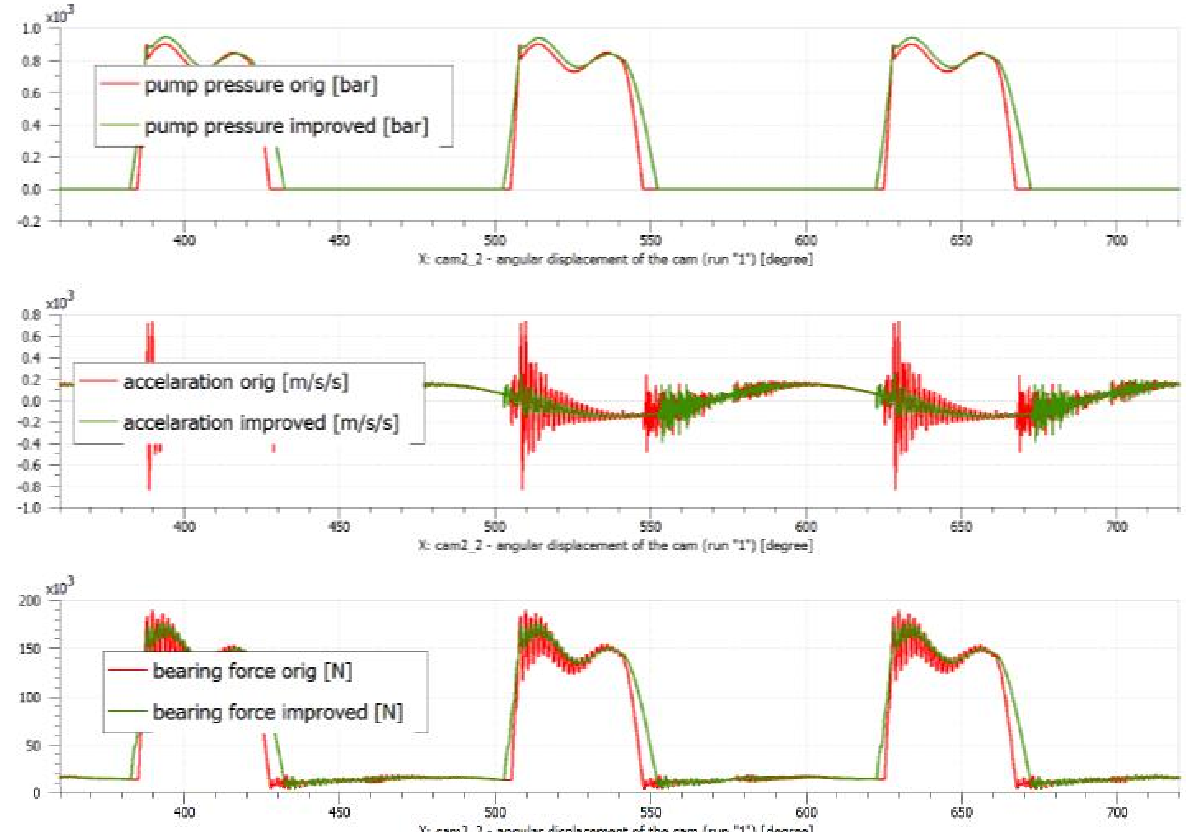
- Deal with increasing pressure levels, to improve the combustion process, emissions while managing the impacts on NVH
- Operate repeatable injections of small and precise fuel amounts
- Adapt systems for alternative fuels: HFO, LPG, CNG

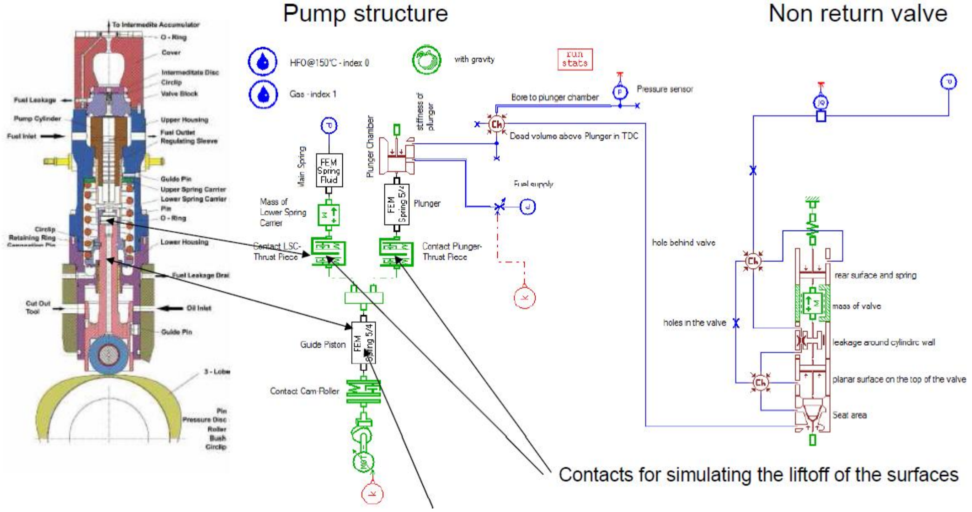


Application #3 - Engine fuel injection system design

Results:

- Facilitated component selection for best fuel system performances
- Improved fuel system NVH and mechanical characteristics design





Examples of typical applications

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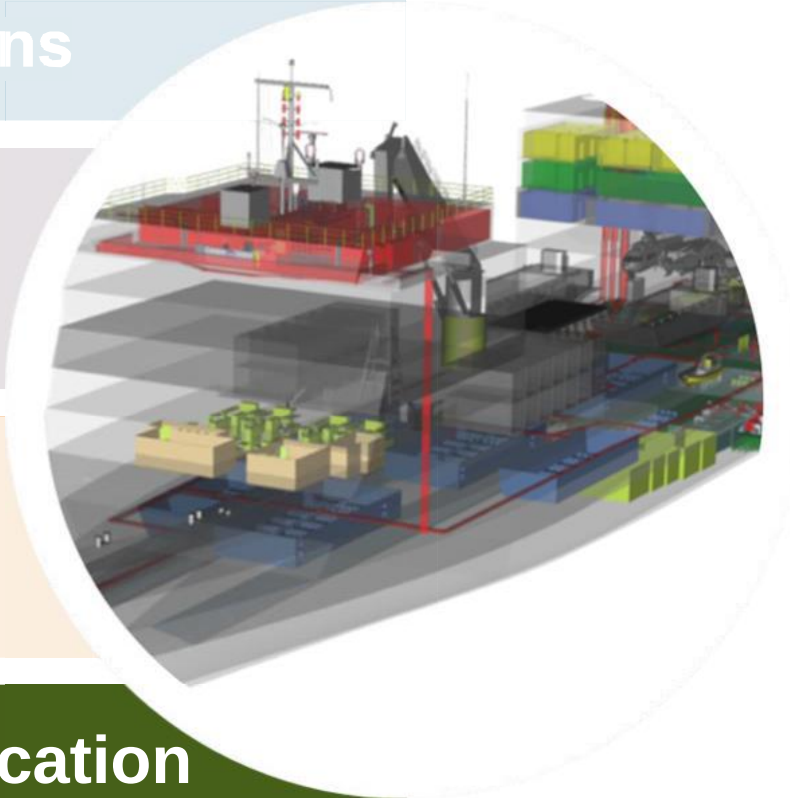
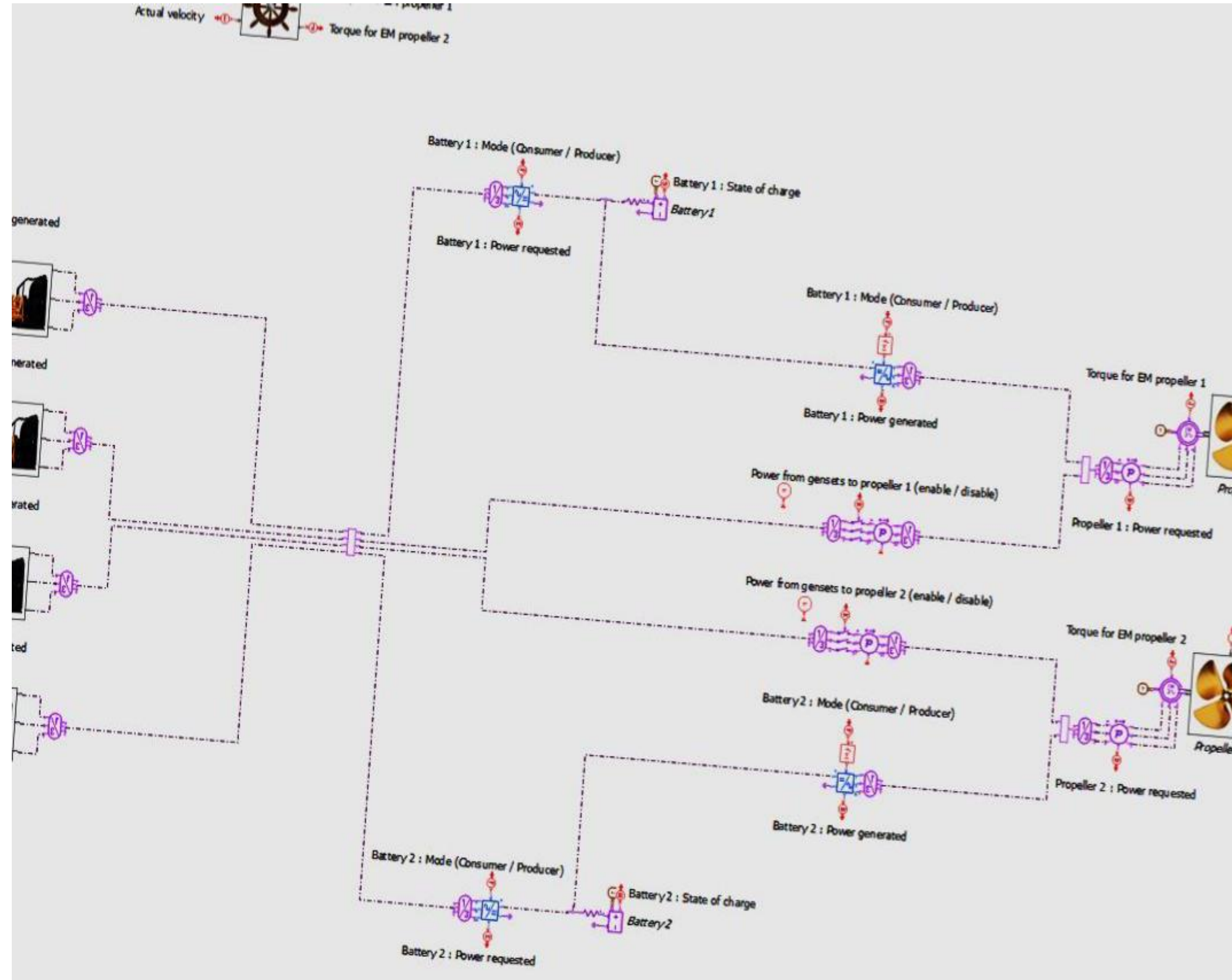


Objective:

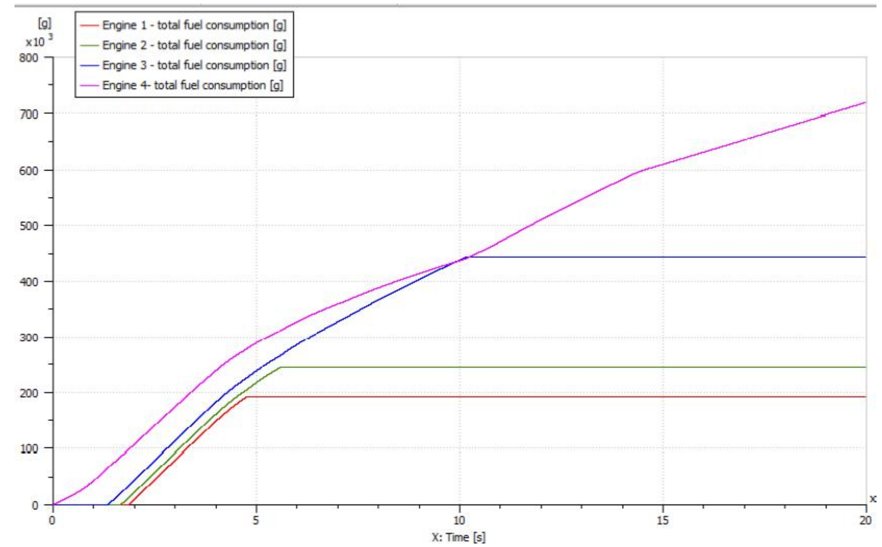
- Develop and validate a control strategy defining the number of engines in operation, based on power requirements and operating conditions

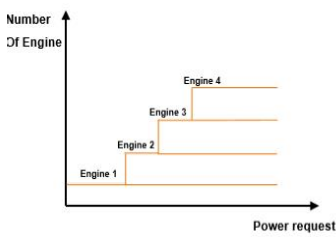


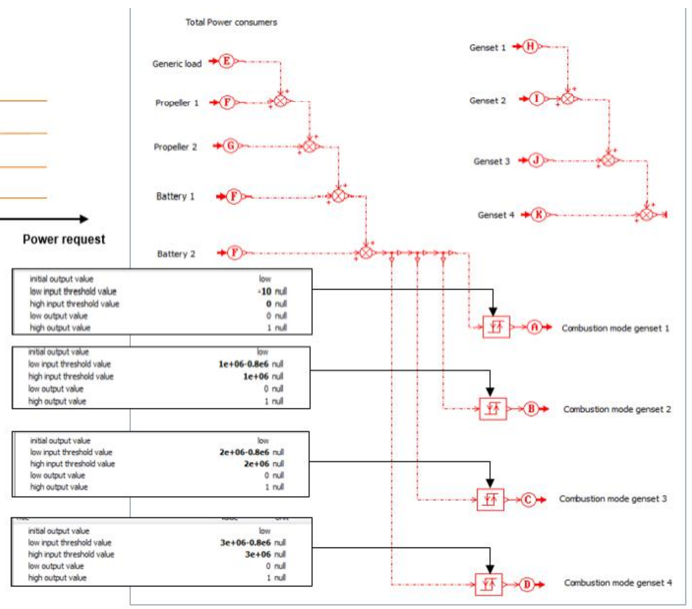
Application #4 - Control strategy development and validation

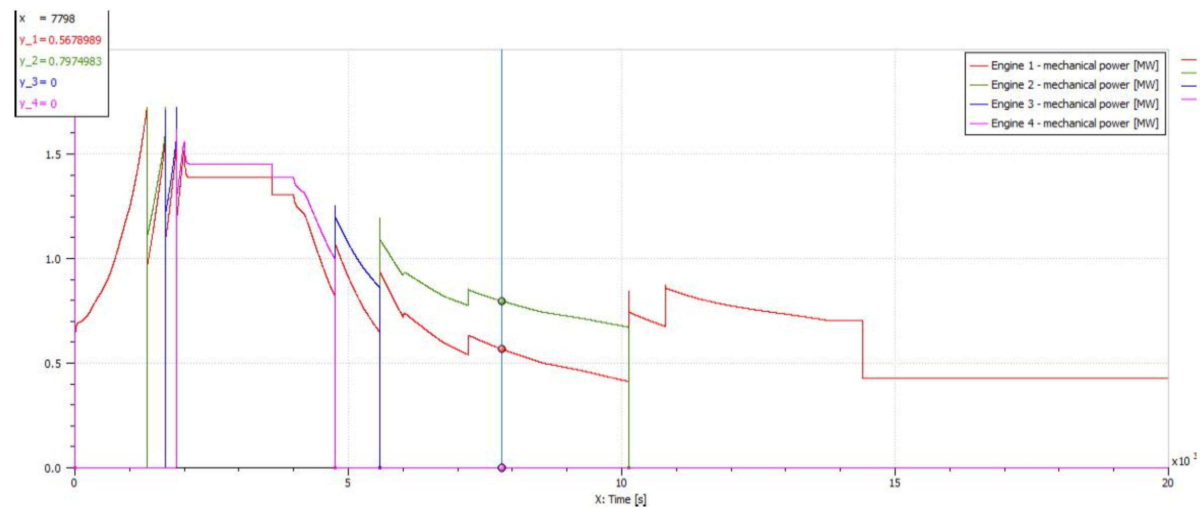
Results:

- Impact of engine mode control strategy on fuel consumption determined
- Control strategy virtually validated under several operating conditions (water and wind conditions, ship load, in port …)









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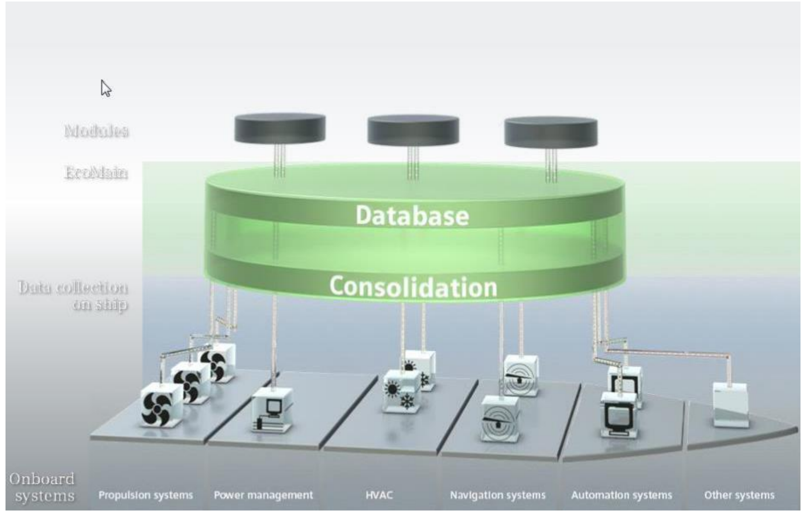
Agenda

- The marine industry is evolving
- Model-based systems engineering for marine applications
- **The voice of our customers**
- Conclusion

Siemens Marine

Monitoring ship energy efficiency with LMS Imagine.Lab and LMS Engineering



- **Good predictability of the systems behavior under changing ambient conditions**
- **Helped on-board personnel in their decisions and operations in an efficient way**
- **Relied simulated values to do the right decisions at the right time**

"LMS Imagine.Lab Amesim and Engineering services enabled us to provide our customers a system which can simulation the real world in a perfect way. We wouldn't have been able to do this with other solutions."

Key Tigges, Senior Naval Architect

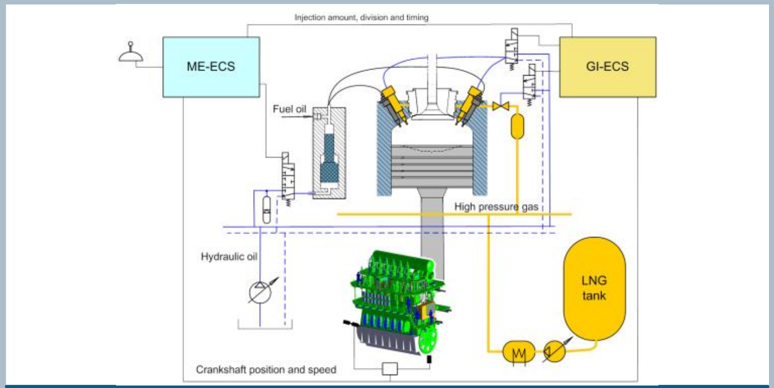
MAN Diesel & Turbo

Accelerating the development of dual-fuel engines with LMS Imagine.Lab Amesim

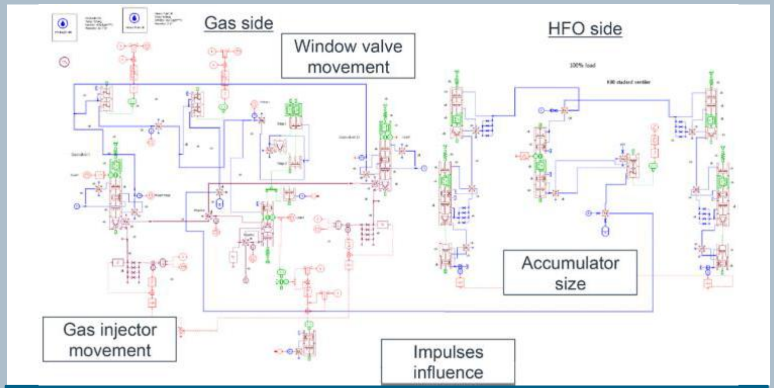
SIEMENS

- **Reduced development time for new fuel injection systems by a factor of five**
- **Lowered testing costs**
- **Simplified training process for new research engineers**

Along the model-based systems engineering approach



View of dual-fuel engine operating on LNG



Model with gas and injection systems

- Adapting HFO fuel systems to gas injection constraints
- Quickly applying design changes by modifying parameters of off-the-shelf components

"Using LMS Amesim, development time has been reduced by a factor of five."

Mikkel Thamsborg, R&D Project Manager

Agenda

- The marine industry is evolving
- Model-based systems engineering for marine applications
- The voice of our customers
- **Conclusion**

Model-based systems engineering solutions
Unique value proposition for marine applications

SIEMENS

Virtually assess various ship propulsion and auxiliaries architectures

Study the influence of control strategies on key ship attributes

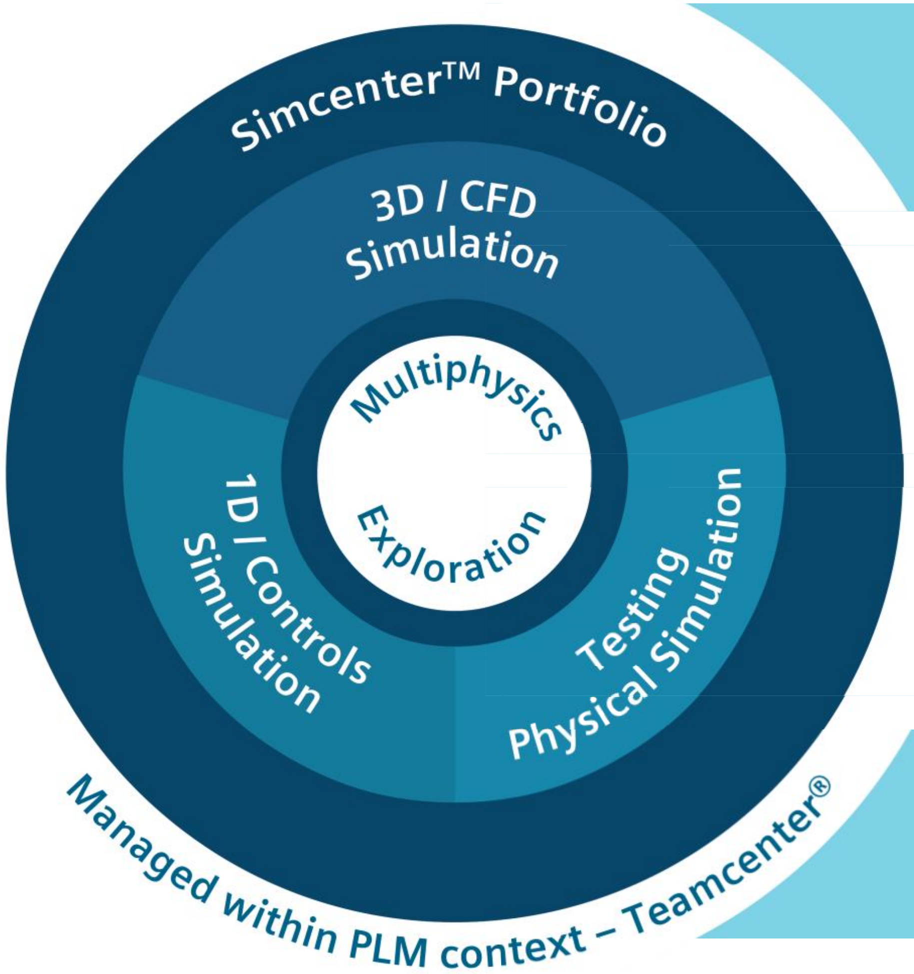
Find the best comprise to fit both regulations and market requirements

Reduce development cost during sub-systems design and analysis, with fewer prototypes

Reduce time-to-market with virtual system integration and increase reusability through knowledge capitalization

Explore how the Simcenter portfolio can help you optimize designs and deliver innovations faster, with greater confidence

SIEMENS



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