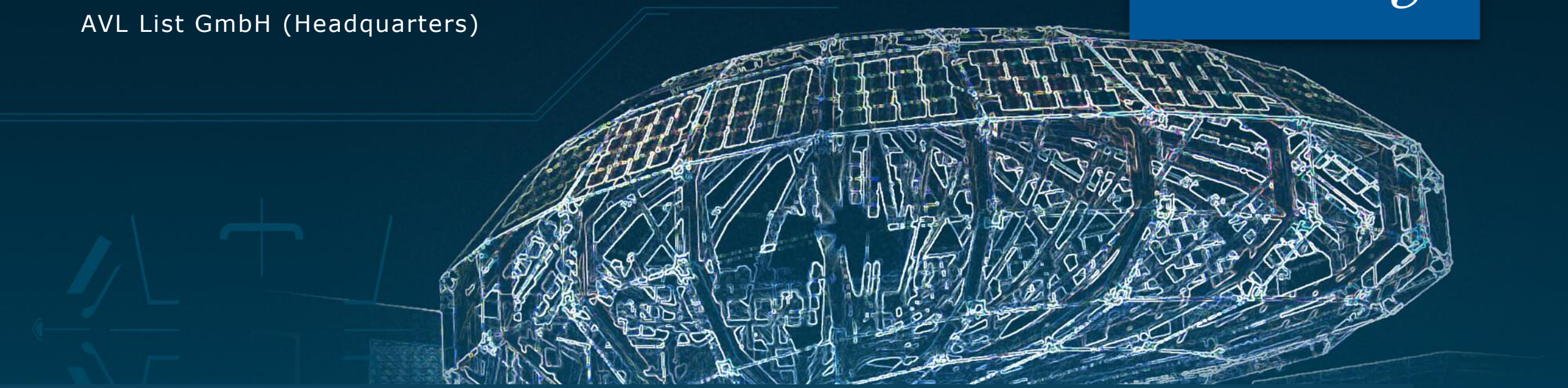
AVL List GmbH (Headquarters)



Getting the Best Out of Electrification Through Good System Integration

11th CIMAC CASCADES

Dr. Klaus Hadl,
Robert Strasser

Agenda

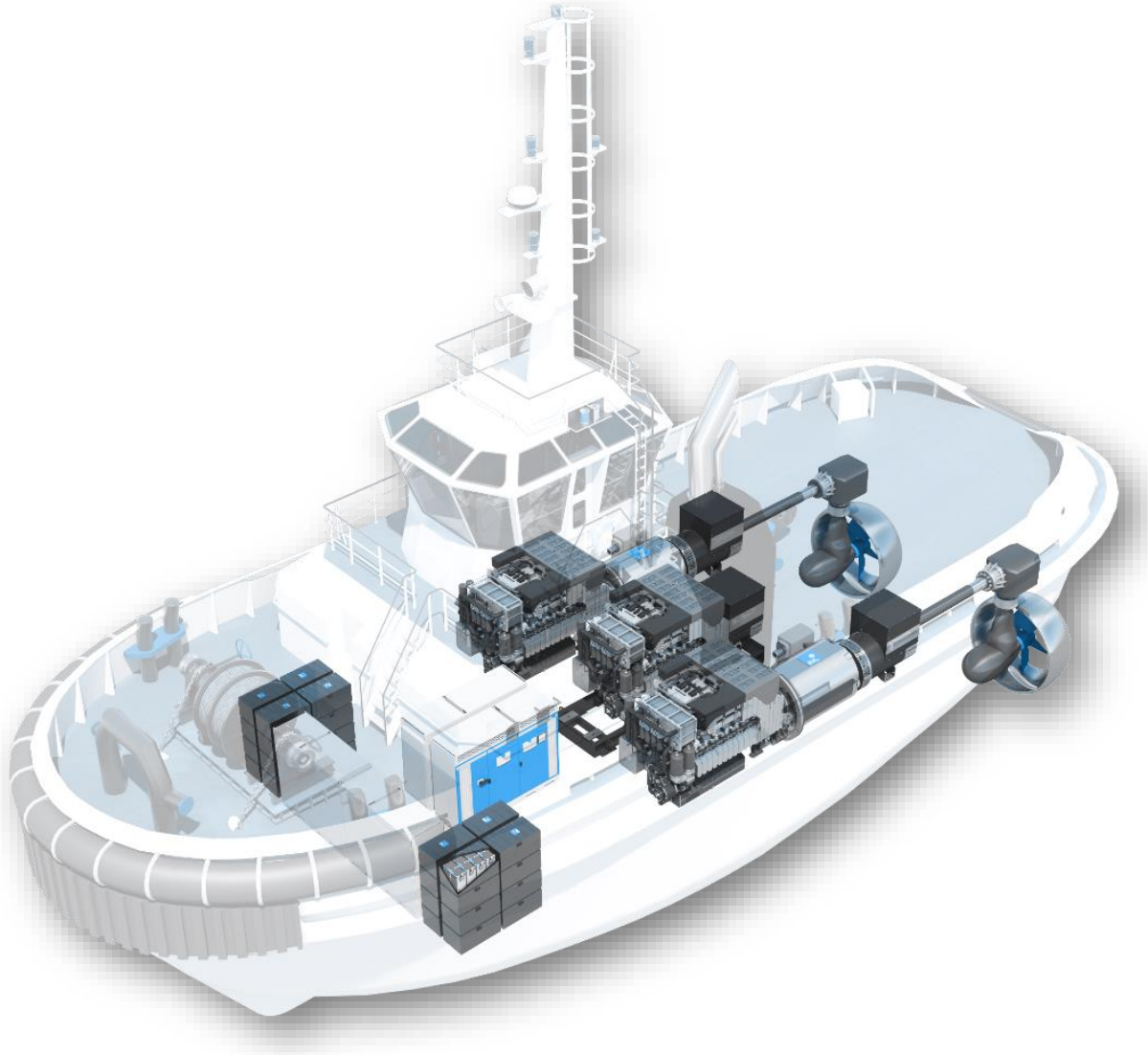
- Hybridization & Electrification of Ships
- Virtual System Integration & System Simulation
- Use Case: Hybrid Tug Boat

Agenda

- Hybridization & Electrification of Ships
- Virtual System Integration & System Simulation
- Use Case: Hybrid Tug Boat

Hybridization & Electrification of Ships
Motivation for Maritime Applications

Environmental Responsibility	Emission free missions, pure electric operation, e.g. ferries
Legislation	Focus of public & politics, new local legislation, e.g. inland shipping
Efficiency Improvement	Sweet spotting, part-load operation, e.g. tug boats



Hybridization & Electrification of Ships
Motivation for Maritime Applications

Environmental Responsibility	Emission free missions, pure electric operation, e.g. ferries
Legislation	Focus of public & politics, new local legislation, e.g. inland shipping
Efficiency Improvement	Sweet spotting, part-load operation, e.g. tug boats
Component Protection	Peak shaving, e.g. dredging ships with sudden load steps
Transient Behavior	Manoeuvring & dynamic positioning, e.g. OSV
Redundancy of Propulsion & Energy System	Safety, reliability, availability
Acoustic & Thermal Signature	Defense applications
Silence & Comfort	Luxury yachts

Hybridization & Electrification of Ships
Examples of Maritime Applications

Fully Electric Ferry

Hybrid Offshore-Supply Vessel

Hybrid Tug Boat

Hybrid Yacht

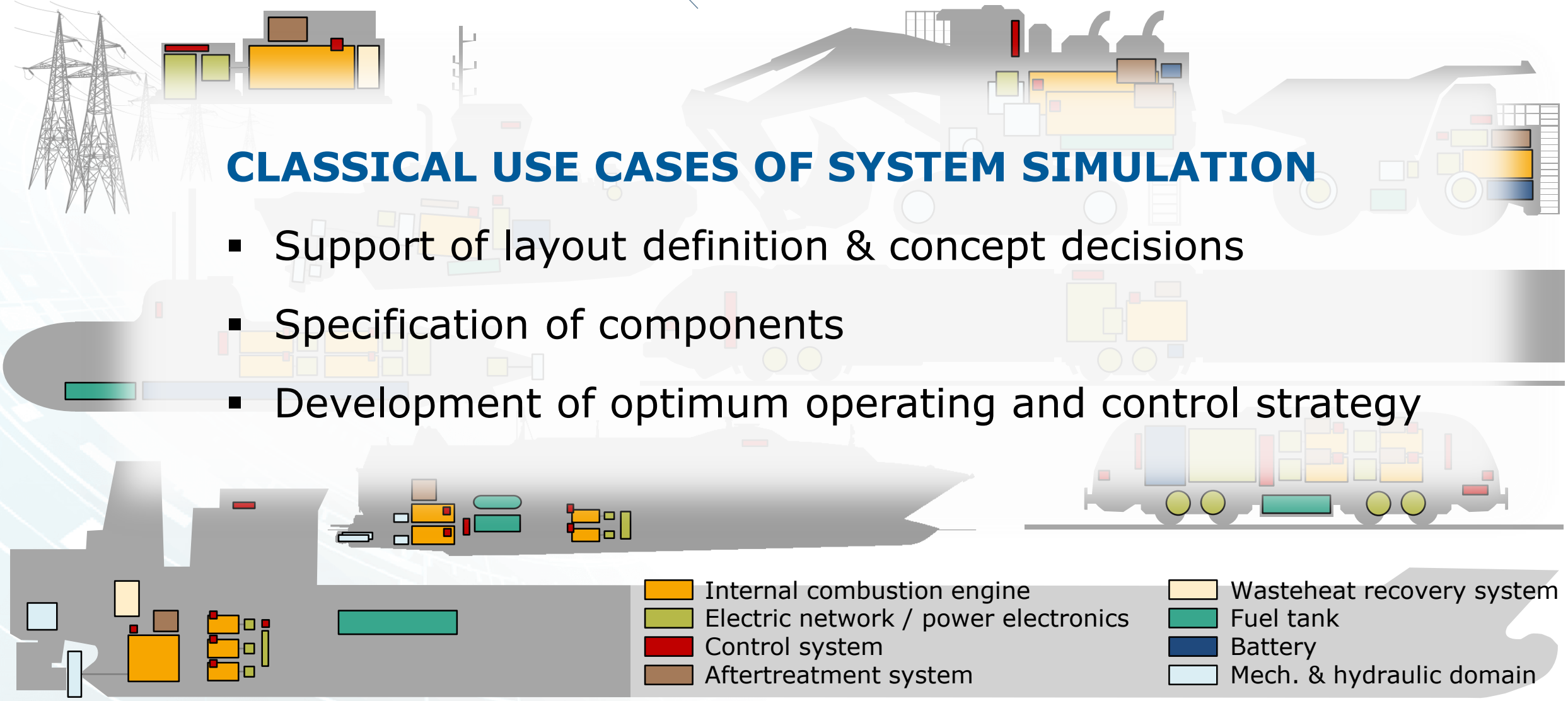
Agenda

- Hybridization & Electrification of Ships
- Virtual System Integration & System Simulation
- Use Case: Hybrid Tug Boat

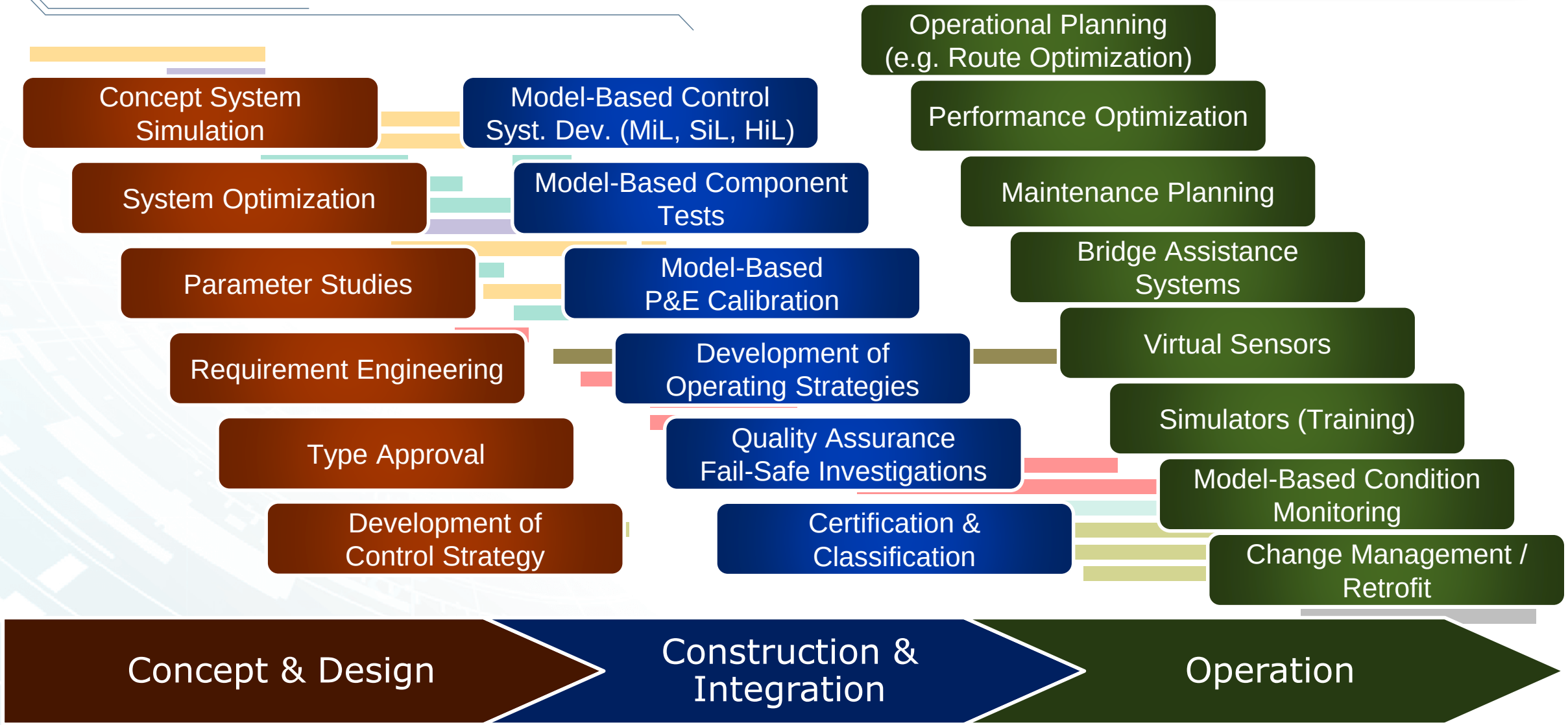
Virtual System Integration & System Simulation: System Complexity

CLASSICAL USE CASES OF SYSTEM SIMULATION

- Support of layout definition & concept decisions
- Specification of components
- Development of optimum operating and control strategy



Virtual System Integration & System Simulation: Use Cases



Virtual System Integration & System Simulation: Co-Simulation

Modelling Tool	AVL CRUISE™ M	
Simulation Tool		AVL Model.CONNECT™
Co-Simulation Platform		

AVL CRUISE™ M: Wide range of Modelling and Simulation applications!

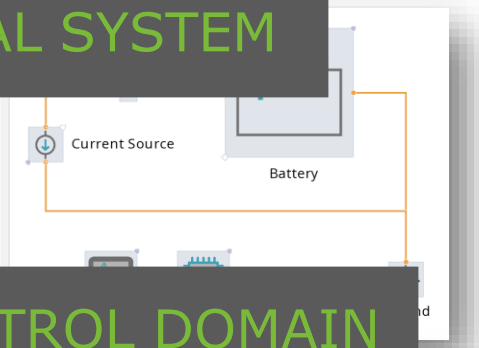
Requirements for Co-Simulation Platform

- Supporting industry standards such as FMI
- Integration of testing world, virtual testbeds
- Local & distributed co-simulation
- Advanced coupling & synchronization techniques
- Elimination of co-simulation errors

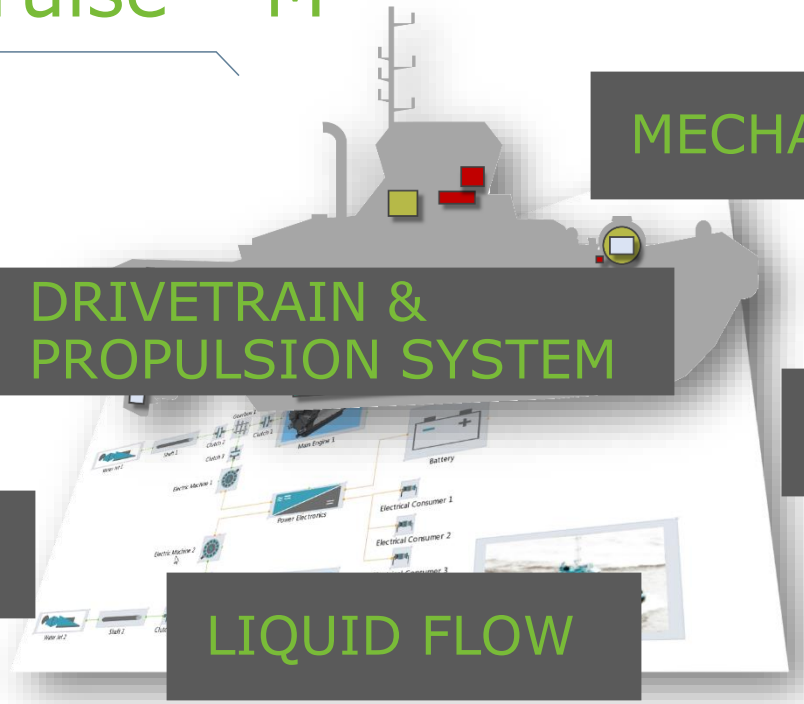
Virtual System Integration & System Simulation: AVL Cruise™ M

AVL CRUISE™ M
MULTI-DISCIPLINARY SYSTEM SIMULATION

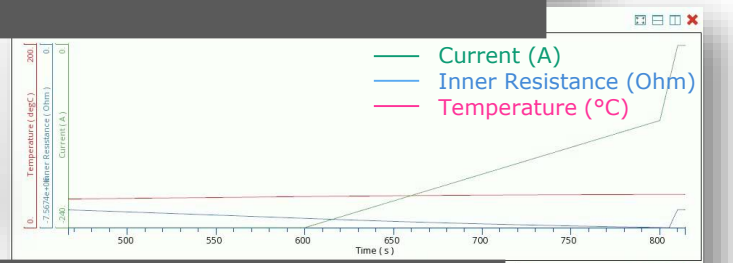
MECHANICAL SYSTEM



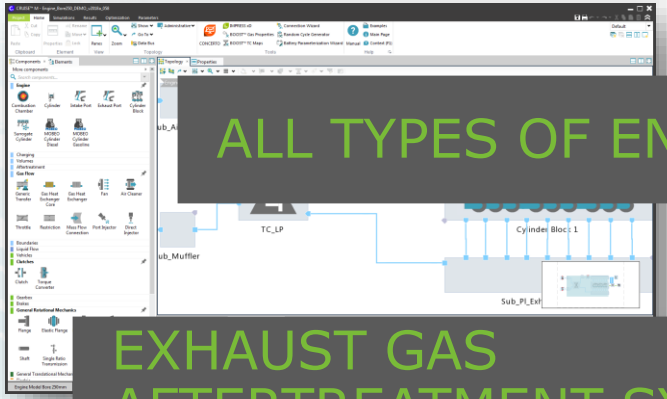
DRIVETRAIN & PROPULSION SYSTEM



CONTROL DOMAIN



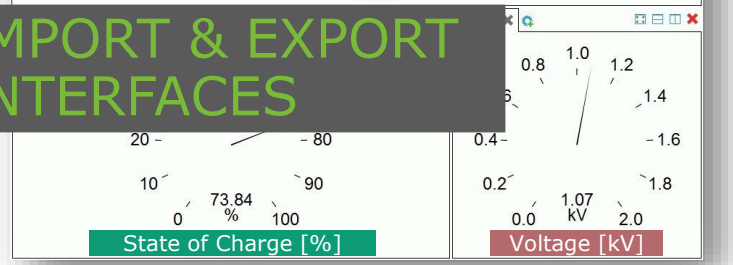
ALL TYPES OF ENGINES

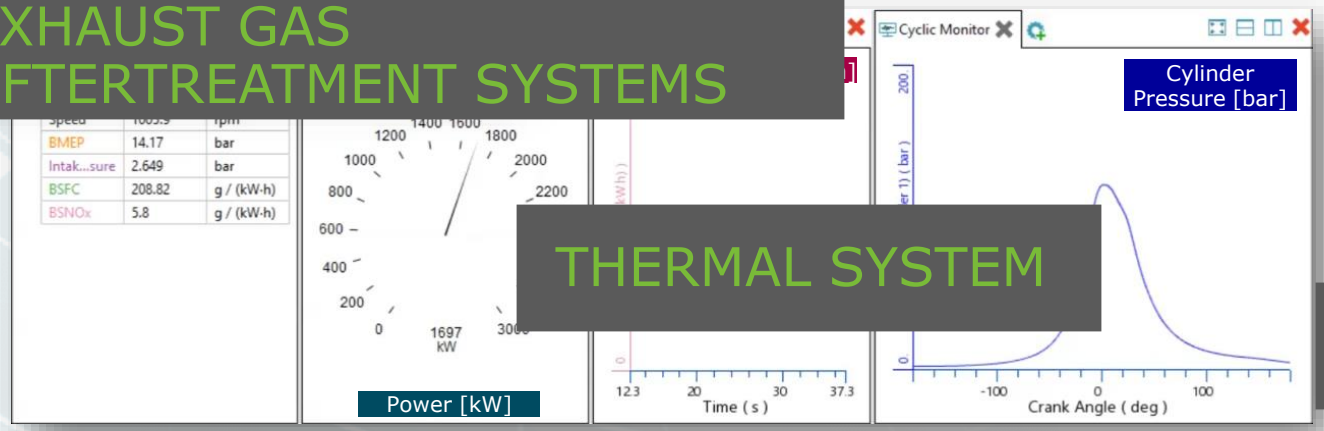


LIQUID FLOW

EXHAUST GAS AFTERTREATMENT SYSTEMS

IMPORT & EXPORT INTERFACES

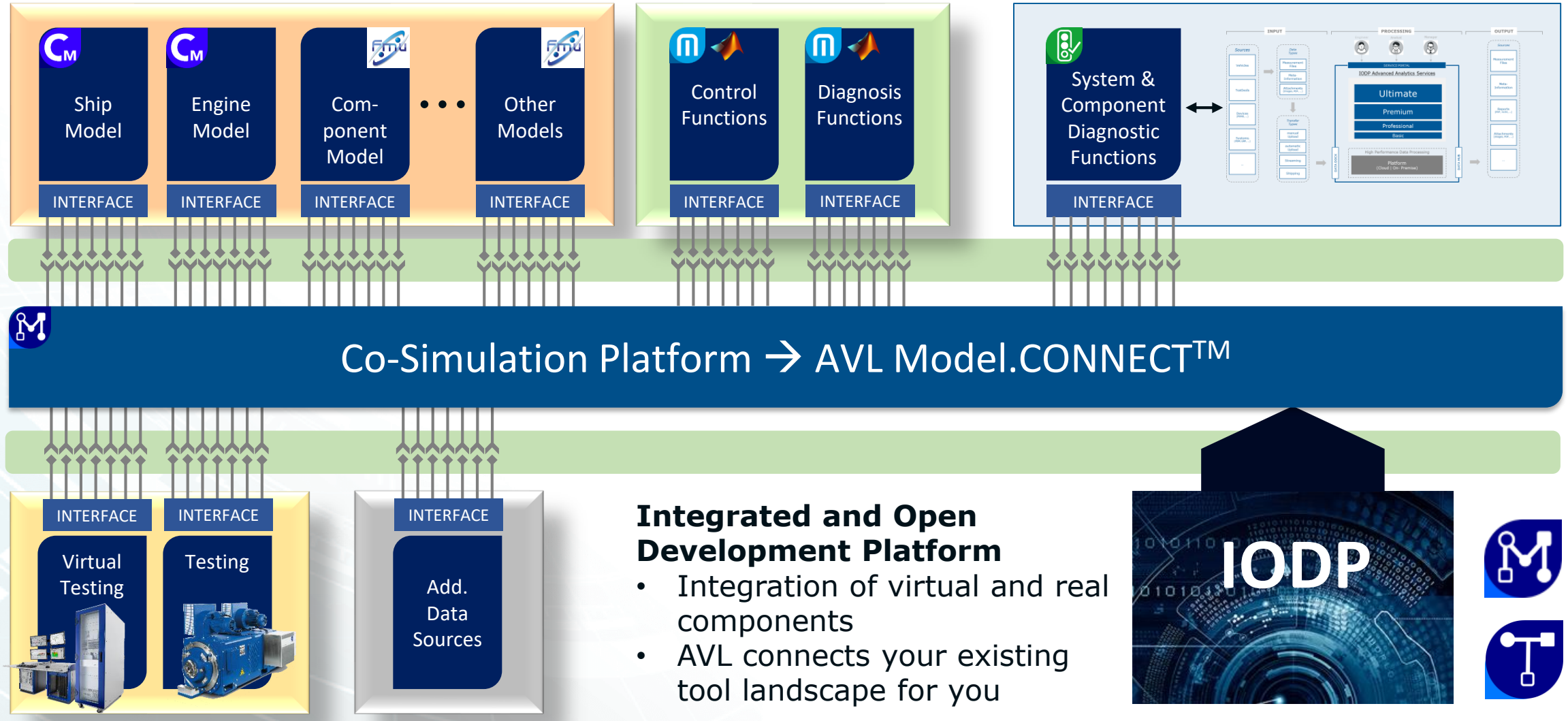




THERMAL SYSTEM

ELECTRIC DOMAIN & FUEL CELL

Virtual System Integration & System Simulation: Platform Architecture

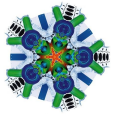


Integrated and Open Development Platform

- Integration of virtual and real components
- AVL connects your existing tool landscape for you

Agenda

- Hybridization & Electrification of Ships
- Virtual System Integration & System Simulation

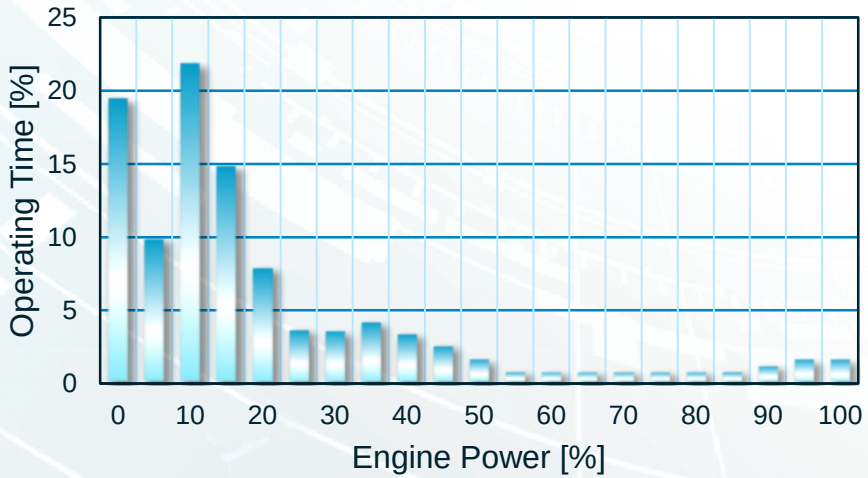


- Use Case: Hybrid Tug Boat

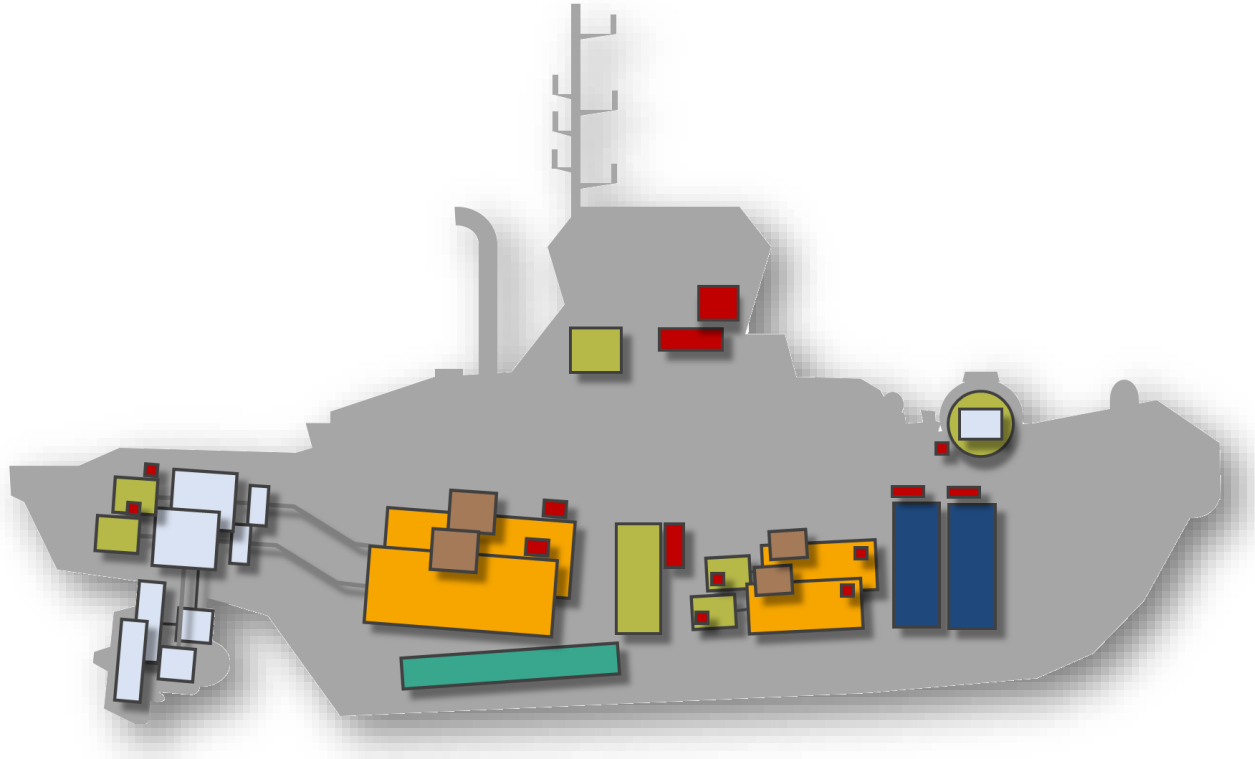
Use Case: Hybrid Tug Boat
Introduction Hybridization Example

OBJECTIVES OF PROJECT

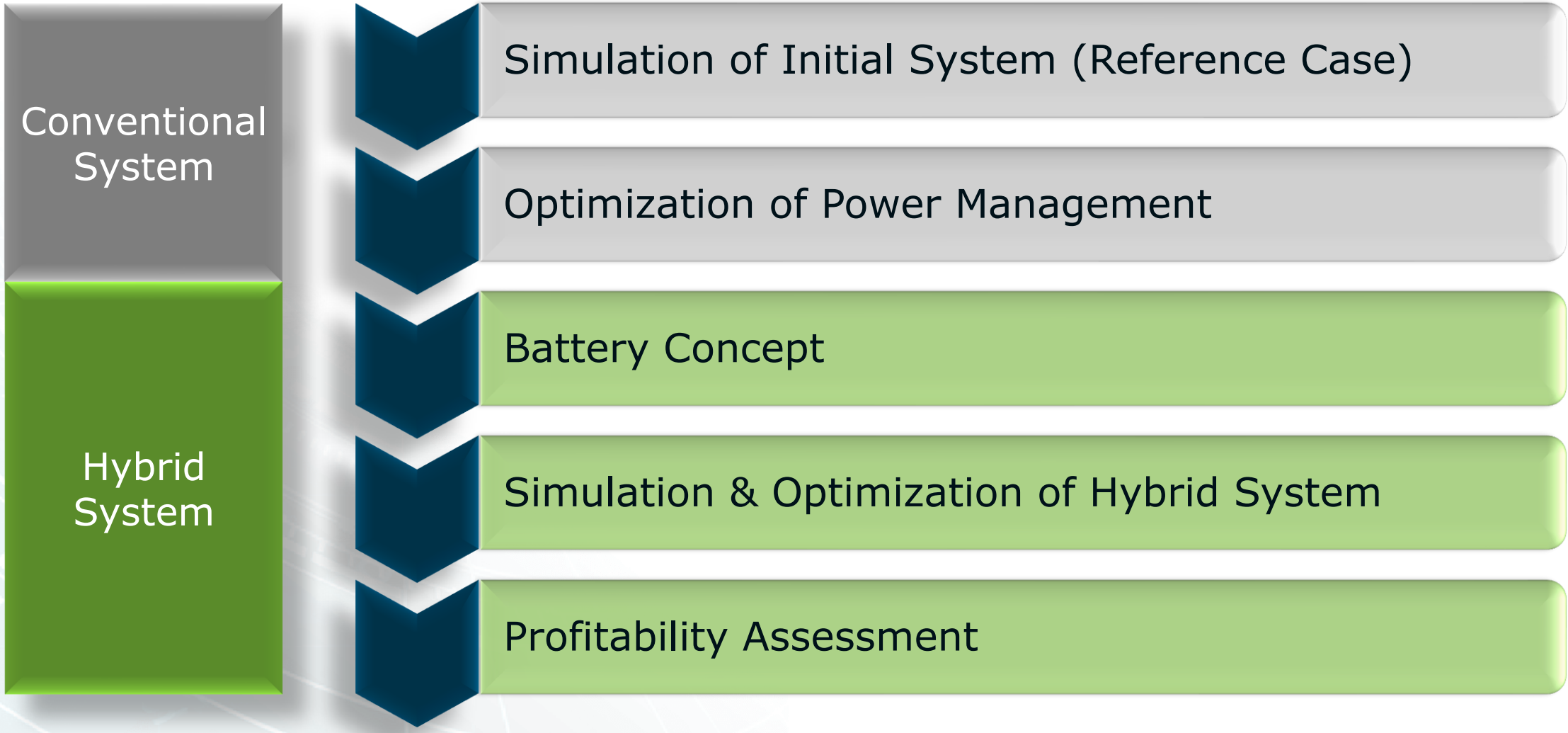
- Definition of hybrid concept
- Specification of components (engine, e-machines, batteries etc.)
- Optimization of operating strategy for given operating profile/duty cycle



High system complexity

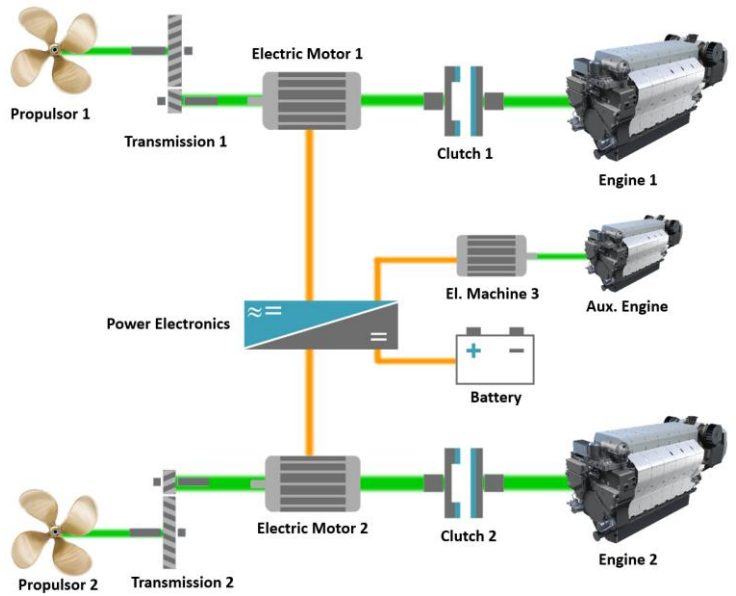


Use Case: Hybrid Tug Boat
Flow Chart– Concept Investigations



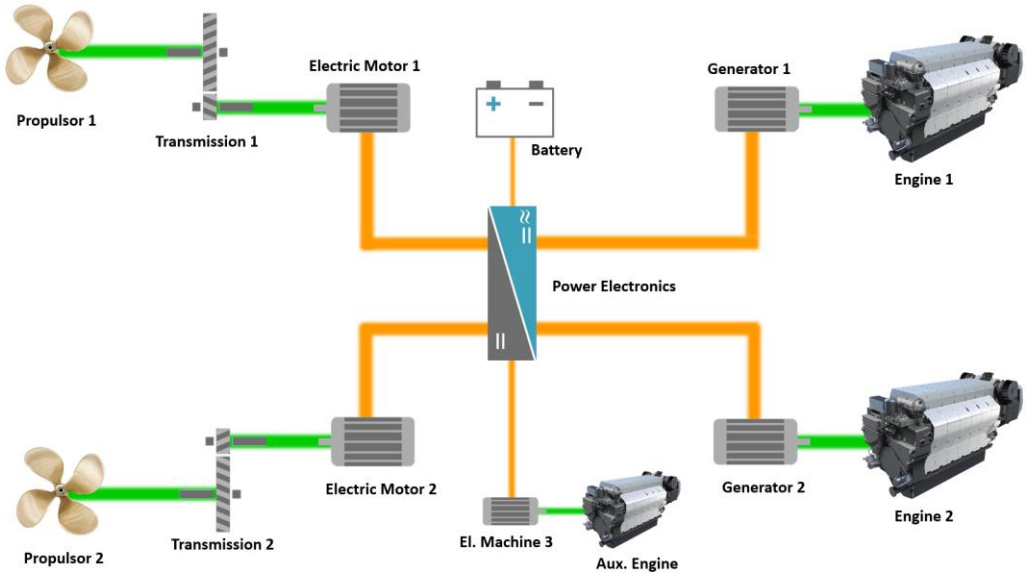
Use Case: Hybrid Tug Boat
Concept Investigations Hybrid System

DIESEL/GAS-MECHANIC CONCEPT



- Diesel/gas-mechanic propulsion system
- Parallel hybrid concept with clutch
- Additional e-motors & battery
- Option: onshore plug-in

DIESEL/GAS-ELECTRIC CONCEPT



- Diesel/gas-electric propulsion system
- ICE as genset
- Battery as additional energy source
- Option: onshore plug-in

Use Case: Hybrid Tug Boat
Battery Concept: Cell Chemistry Comparison

Active Material		Voltages Nominal	Specific Energy		Specific Power	Safety	Perfor-mance	Life Span	Cost
Lithium Cobalt Oxide ($LiCoO_2$)	LCO	3.6 V	150 – 200 Wh/kg						
Lithium Manganese Oxide ($LiMn_2O_4$)	LMO	3.7 V	100 – 150 Wh/kg						
Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)	NMC	3.6 V	150 – 220 Wh/kg						
Lithium Iron Phosphate ($LiFePO_4$)	LFP	3.3 V	90 – 120 Wh/kg						
Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$)	NCA	3.6 V	200 – 260 Wh/kg						
Lithium Titanate Oxide ($Li_4Ti_5O_{12}$)	LTO	2.4 V	30 – 110 Wh/kg						

low  high

Use Case: Hybrid Tug Boat
Battery Concept: AVL Battery Test Center

AVL Battery Test Center

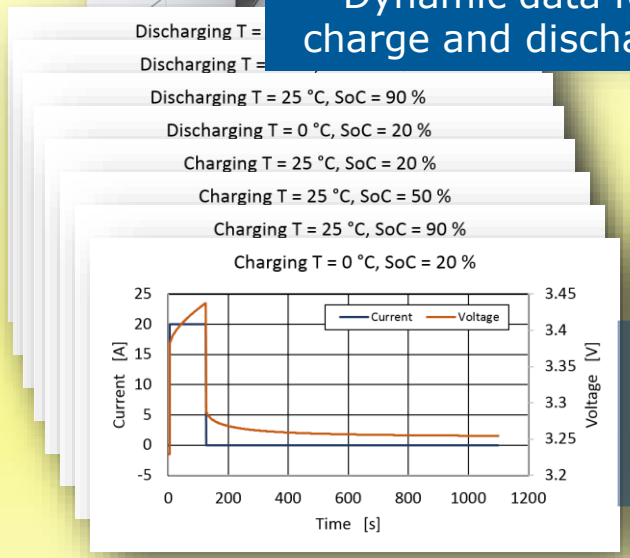
AVL Battery Test Center:

- Equipment for different cell types
- Cell validation
- Hardware in the loop test facilities for battery controls calibration
- Durability test cells
- Calendric ageing test cells

Use Case: Hybrid Tug Boat
Simulation & Optimization

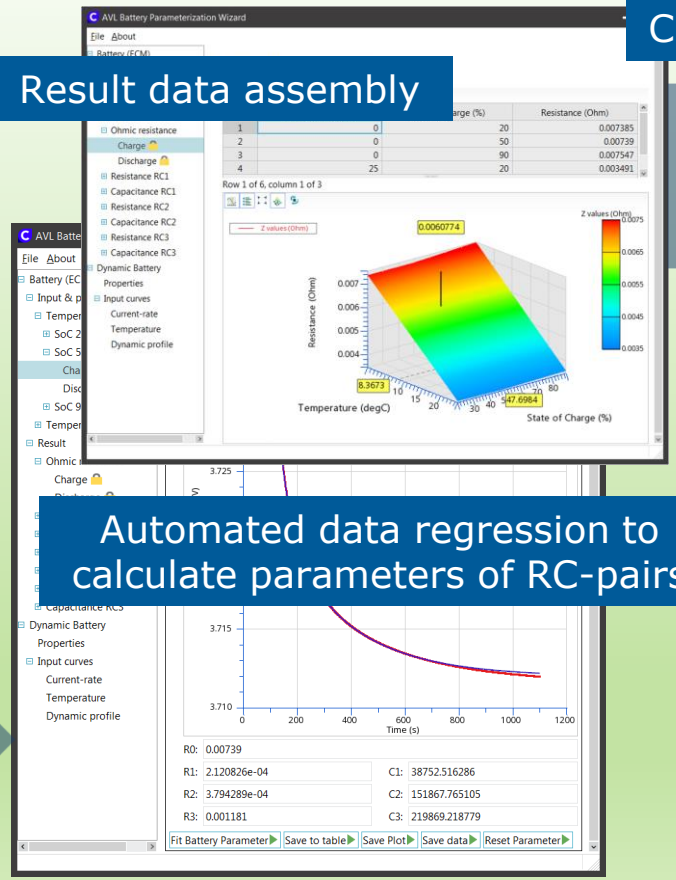
Battery & Cell Testing

Dynamic data for charge and discharge



Battery Parametrization Wizard

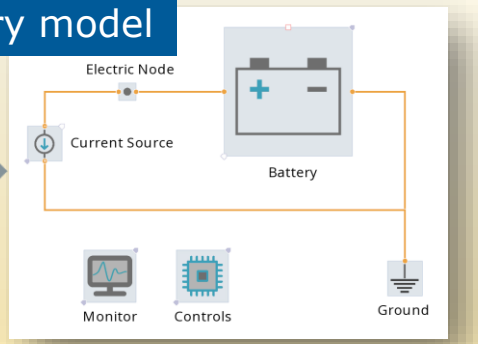
Result data assembly

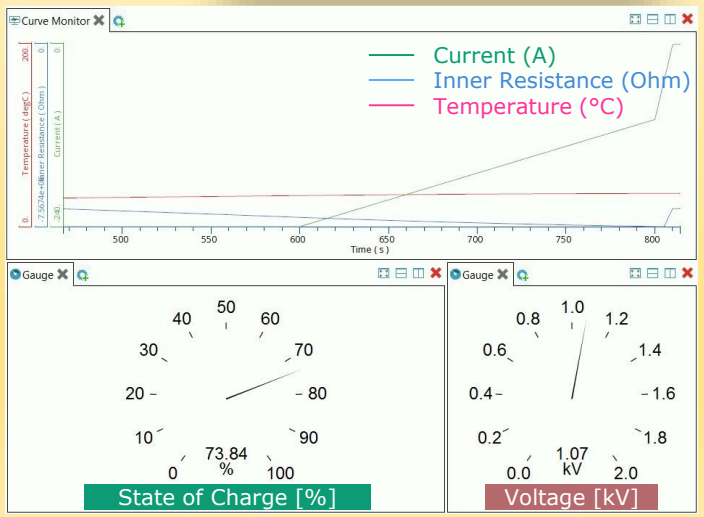


Automated data regression to calculate parameters of RC-pairs

Battery Model

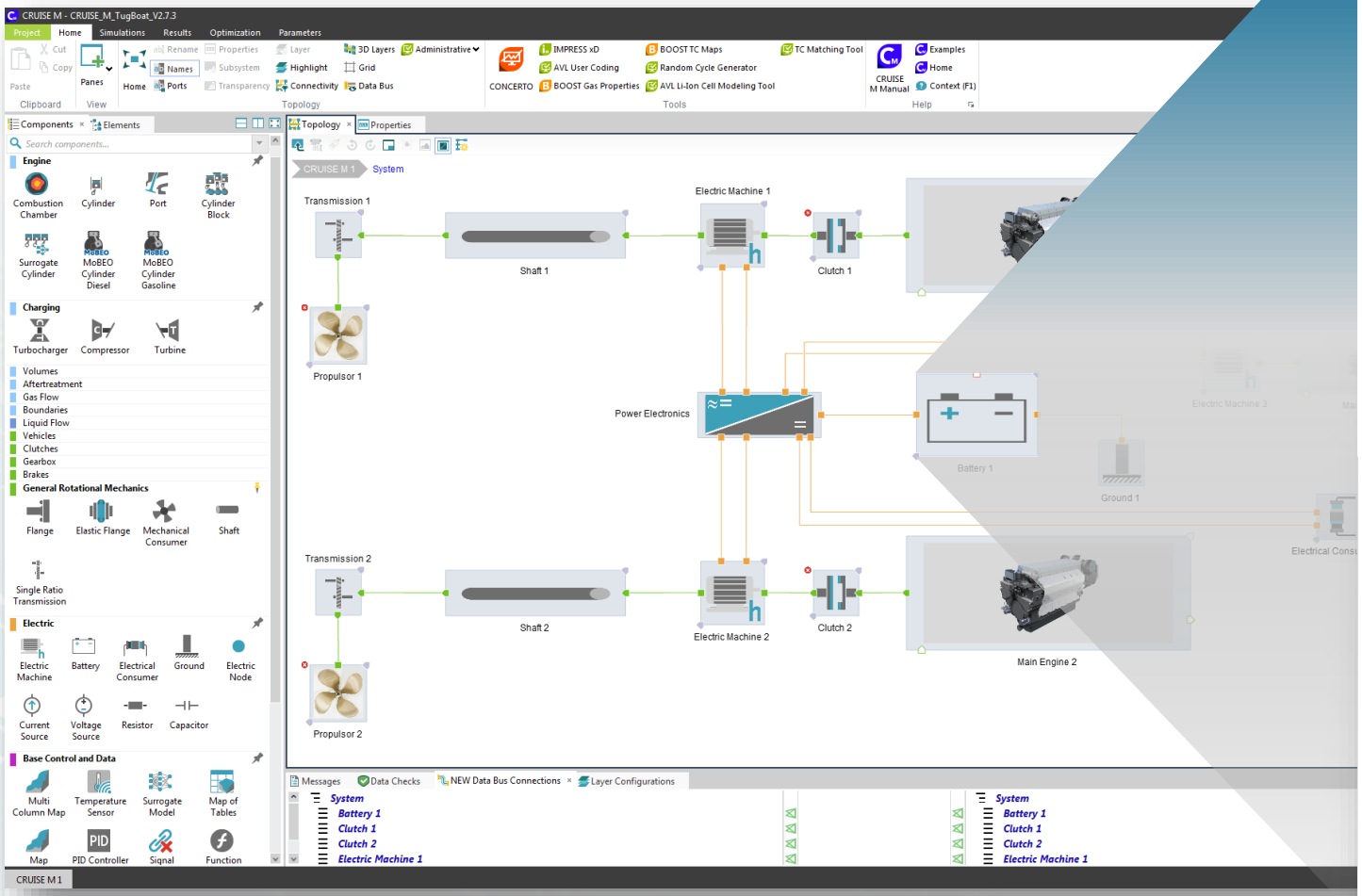
Direct transfer to CRUISE M battery model

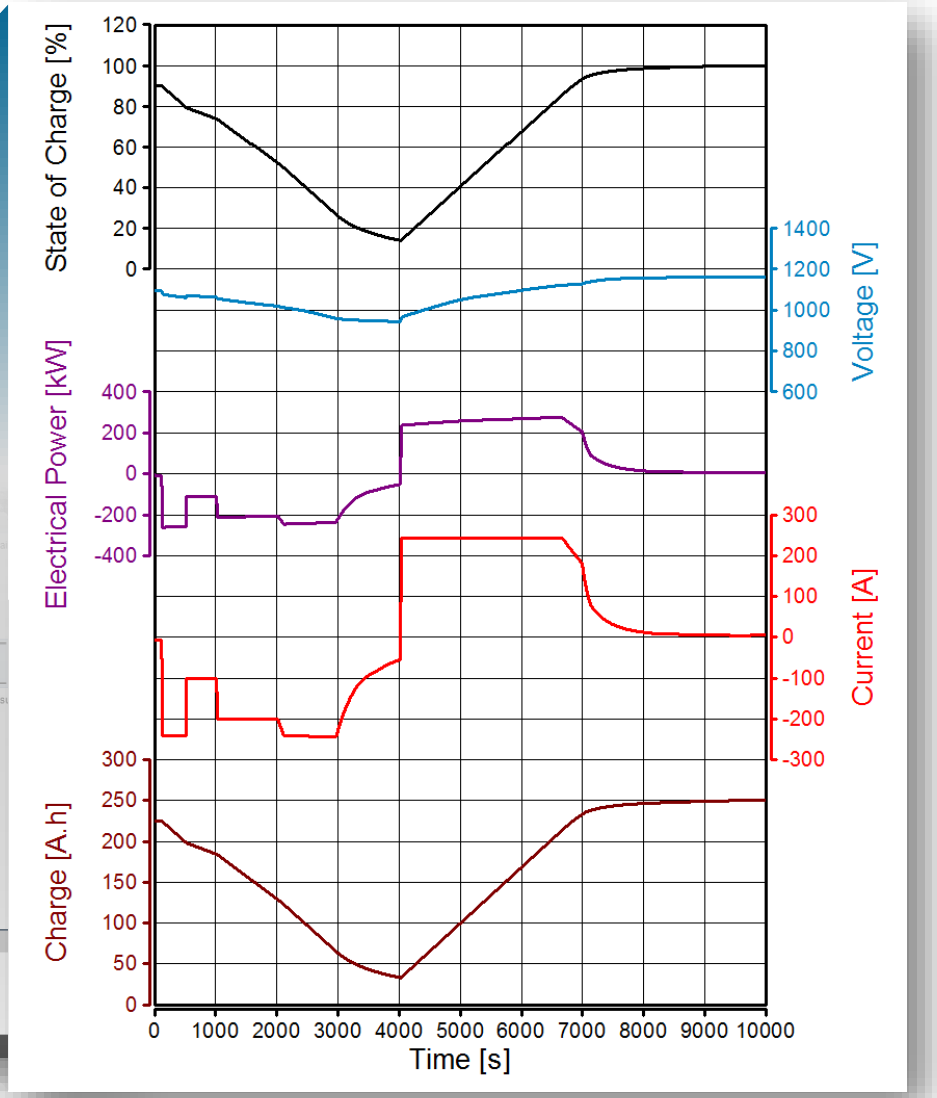




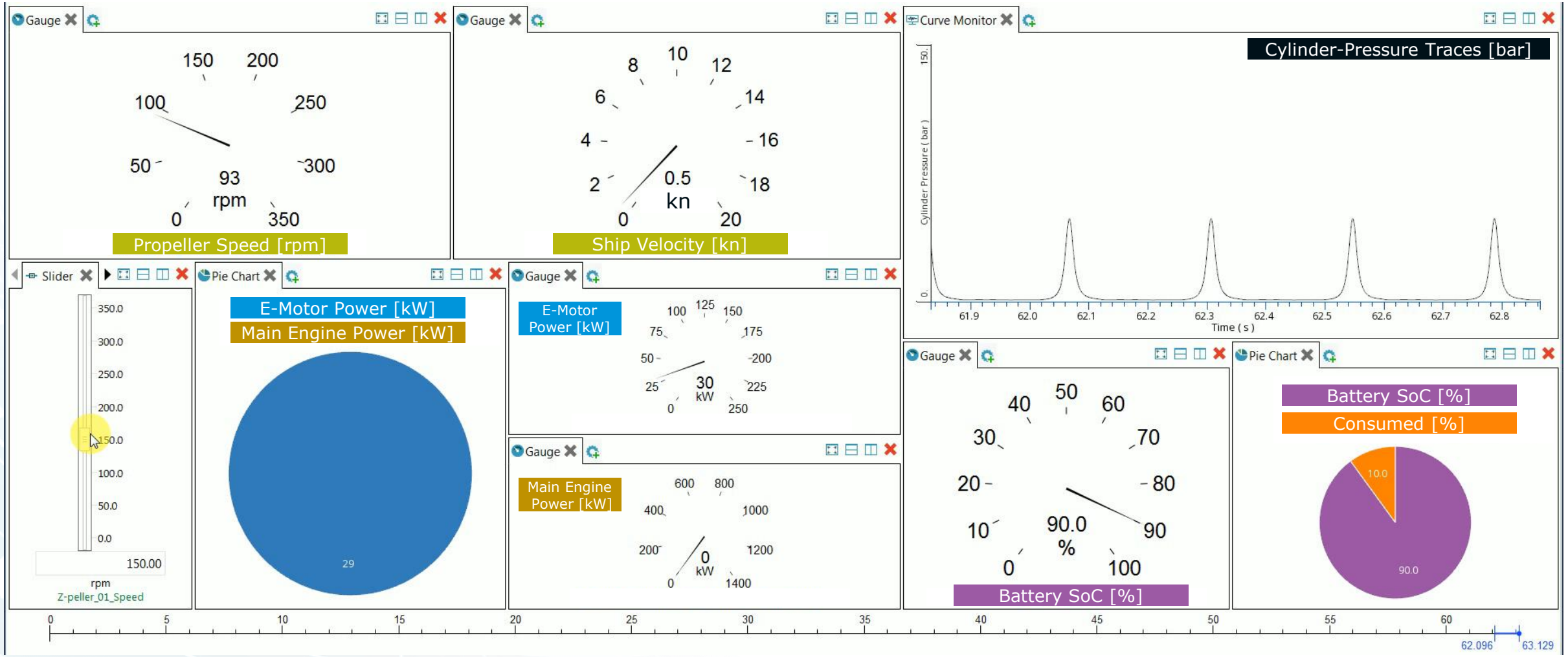
Use Case: Hybrid Tug Boat
Simulation & Optimization: Battery Model

AVL CRUISE™ M





Virtual System Integration & System Simulation: Simulation for Hybridization



AVL CRUISE™ M

Use Case: Hybrid Tug Boat
Results of the Investigation

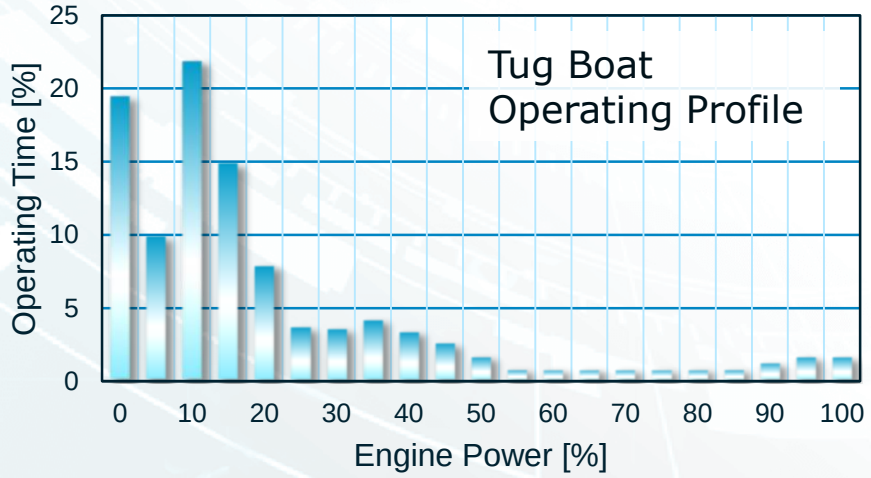
BOUNDARY CONDITIONS

2 x 1800 kW for propulsion and
450 kVA of auxiliary engine

Operating profile

Fuel cost (LSMGO 310 €/mt)
Electricity cost (2.55 Ct/kWh)

Battery capacity: 246 kWh



CONCLUSIONS

Diesel-mechanical system with parallel hybrid configuration and clutch:
fuel saving potential ~ 7%

Diesel-electric system with batteries:
fuel saving potential ~ 4%

Cheap onshore power during docking, plug-in charging of batteries: **reduction of energy cost up to 30%**
(→ „smart charging concepts“)

Operating profile has major influence on fuel saving potential

System simulation is a valuable tool for optimizing numerous variants under different boundary conditions

Intelligent hybrid management system & predictive control system

Conclusions

- **Hybrid & electric solutions**: attractive to reduce the environmental impact of the operation of various maritime applications.
- **System simulation**: valuable instrument to investigate and optimize the operation of vessels.
- The high added value of system simulation as part of the virtual system integration results from the **integrative and consistent application of models** in the entire development process and also in the operation of a system.
- Innovative platforms allow the **integration of virtual and real components**. (AVL's Integrated and Open Development Platform)
- In the future, virtual system integration & model-based development methods will be increasingly used. AVL deals with various **virtual approaches for maritime applications**, to **give a valuable contribution to the design, construction and operation of maritime applications**.


Thank You
AVL
www.avl.com