Institute of Machine Components and Methods of Development

Application of the Arcadia Method on a Bulk Carrier with Siemens Teamcenter PLM Integration

Capella Days Online 2024

by IME @TU Graz

CapellaDays ONLINE 2024

Agenda

- **Introduction** | *Research at IME*
- **Context** | *Decarbonization & Digitalization of the Maritime Industry*
- **Example** | *Bulk Carrier System Model Integration Into Siemens Teamcenter*
- **Summary** | *Outlook*

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Institute of Machine Components and Methods of Development

Workshop Presenters

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- Head of R&D and Product Development at *ANTEMIA GmbH*
- Experience in automotive industry, SE, MBSE
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Introduction | Research at IME

Institute of Machine Components and Methods of Development (IME)

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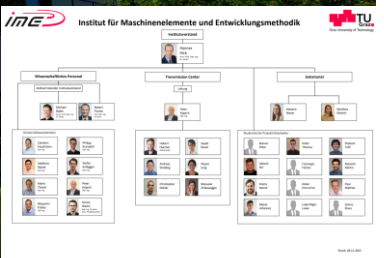
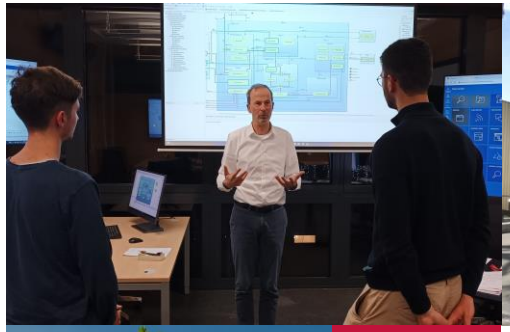
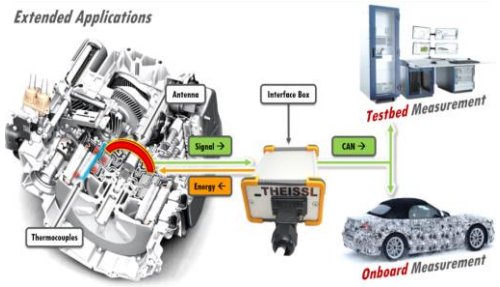


Introduction | Research at IME

Institute of Machine Components and Methods of Development (IME)

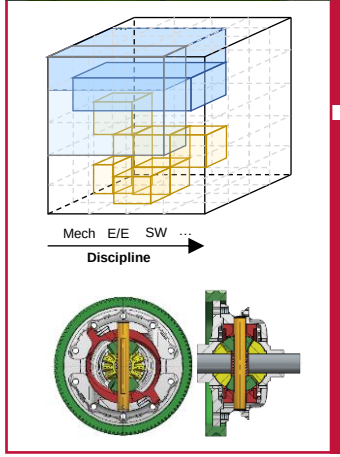


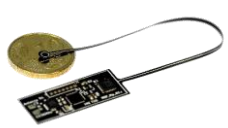
System design



System verification & validation

System integration

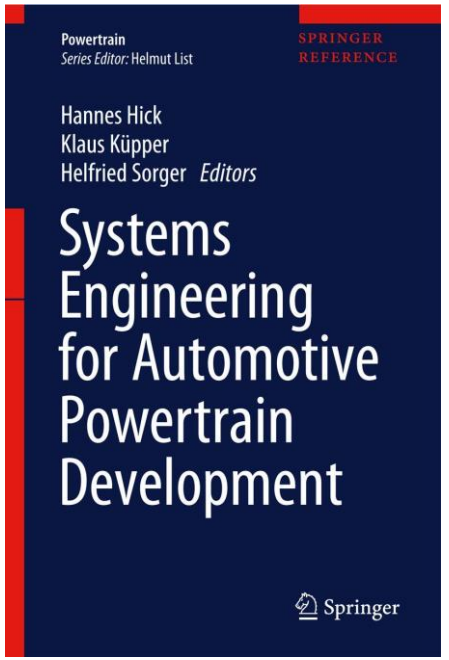




Mechanics

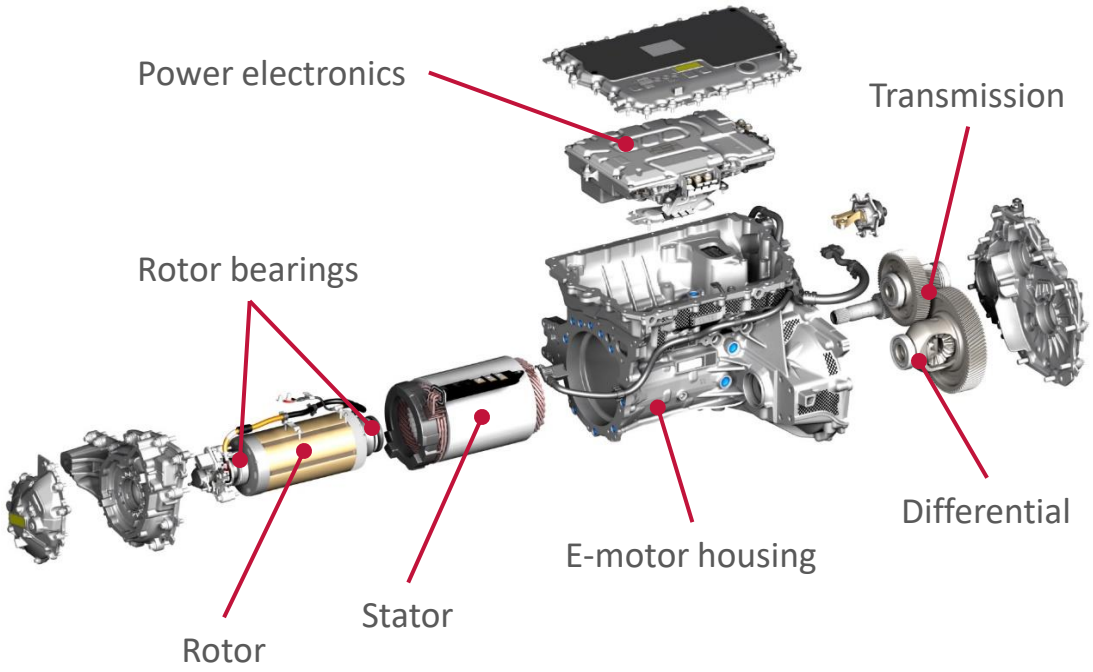
Electrics/electronics

Software

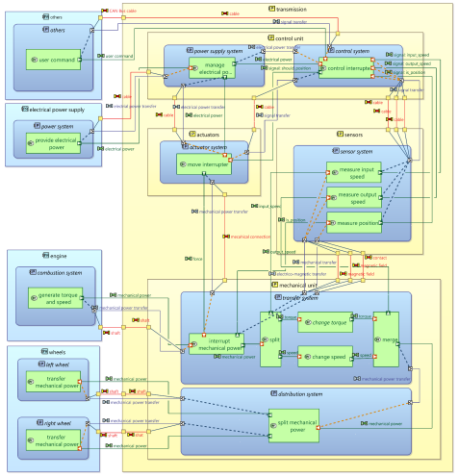


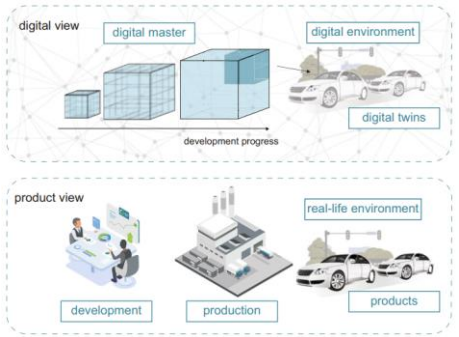
Research at IME

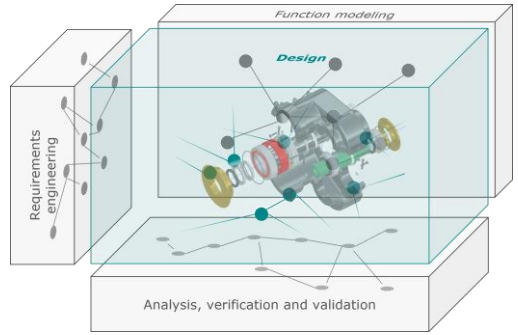
Machine components

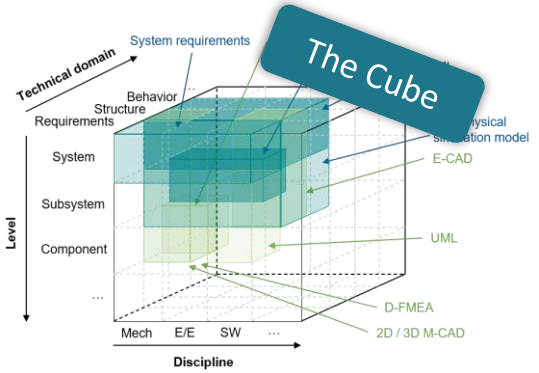


Methods of development





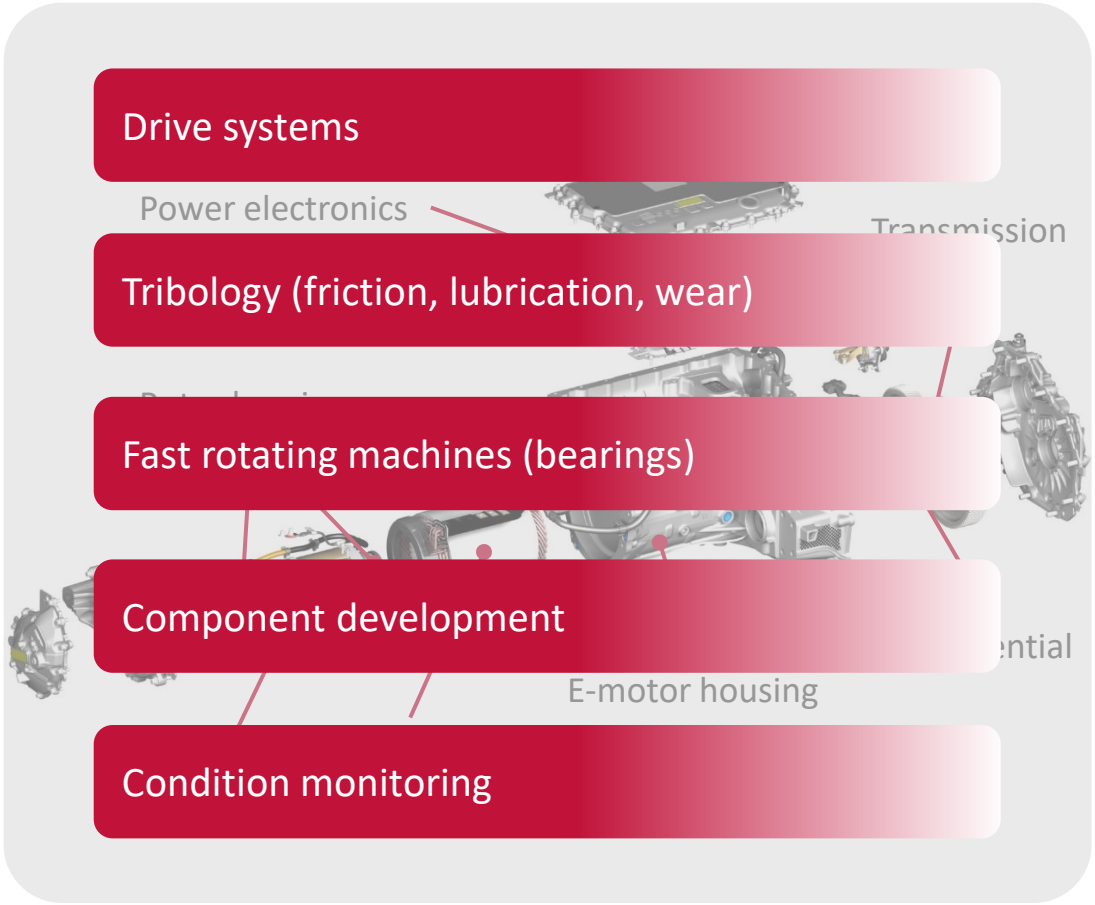




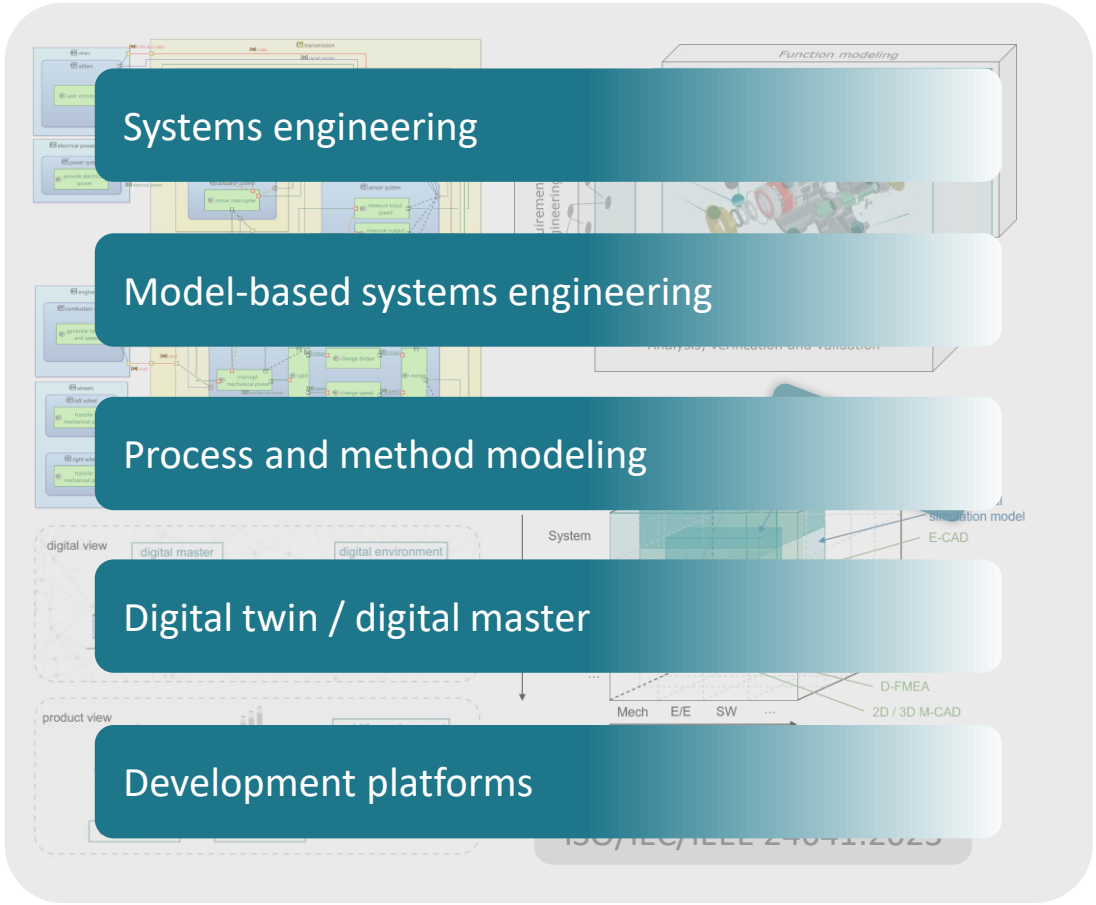
Referenced in ISO/IEC/IEEE 24641:2023

Research at IME

Machine components



Methods of development



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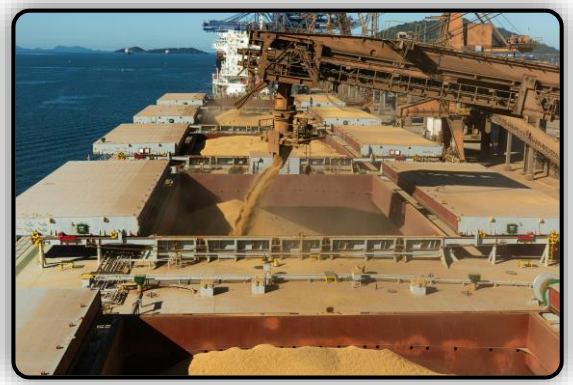
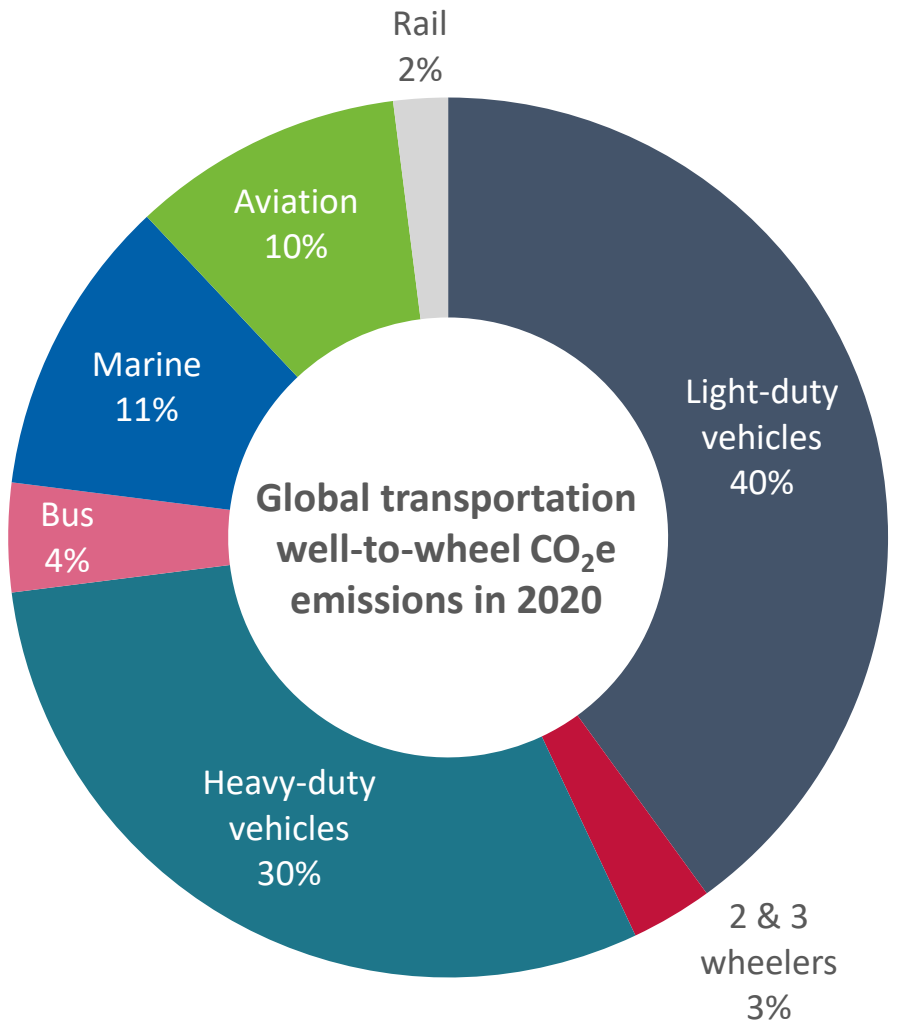
The Maritime Industry

Container ship

Bulk carrier

Wheat transport in bulk

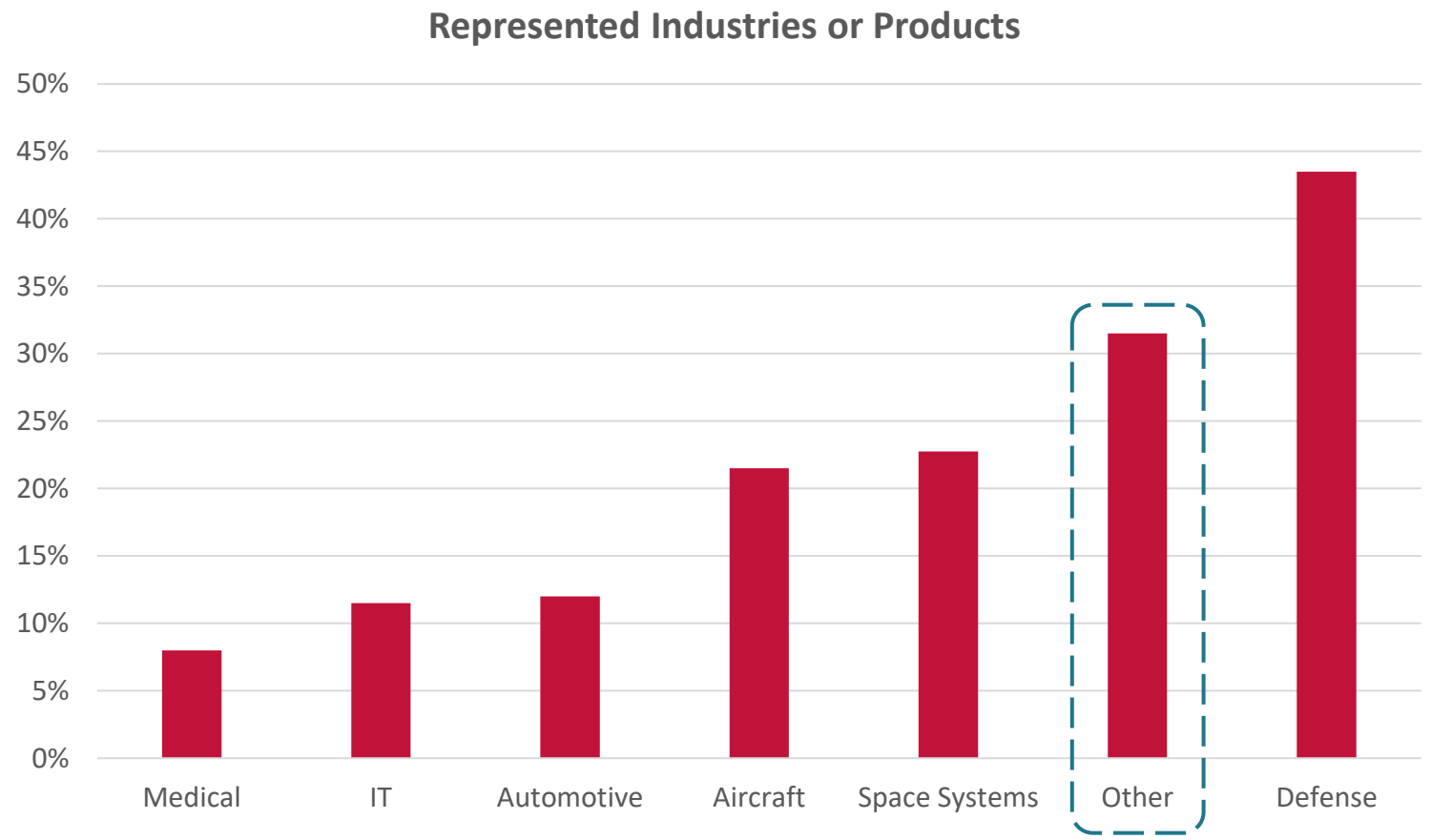




Source: International Council on Clean Transportation (2021). *VISION 2050: A strategy to decarbonize the global transport sector by mid-century*

Source: Cloutier, R. (2019). *2018 MBSE Survey Results*. At: Proceedings of the 2019 INCOSE MBSE Workshop

The MBSE Industry in Numbers



Industries represented in a 2018 MBSE Survey

What about **MBSE** in the **maritime industry**?

Challenge of Marine Shipping

On-time
vs.
environment
vs.
market demands

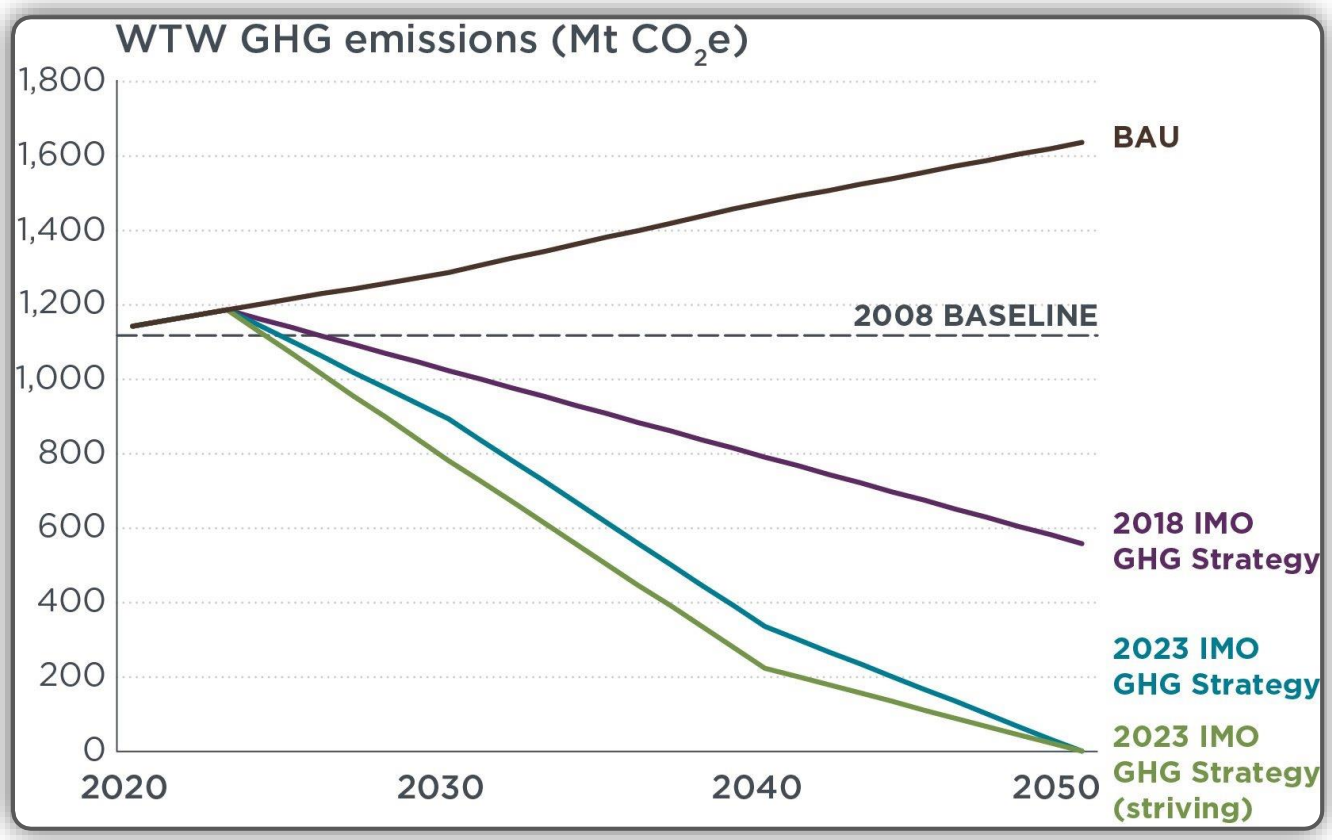
Decarbonization
vs.
legislation
vs.
cost

Transportation of **goods**,
resources, **passengers**

Source: International Maritime Organization (IMO). (2023). *2023 IMO Strategy on Reduction of GHG Emissions from Ships*
Source: Comer, B., & Carvalho, F. (2023). *IMO's Newly Revised GHG Strategy: What It Means for Shipping and the Paris Agreement*

2023 IMO GHG Strategy

- Reduce the total annual GHG emissions from international shipping
- **2050:** Net-zero GHG emissions

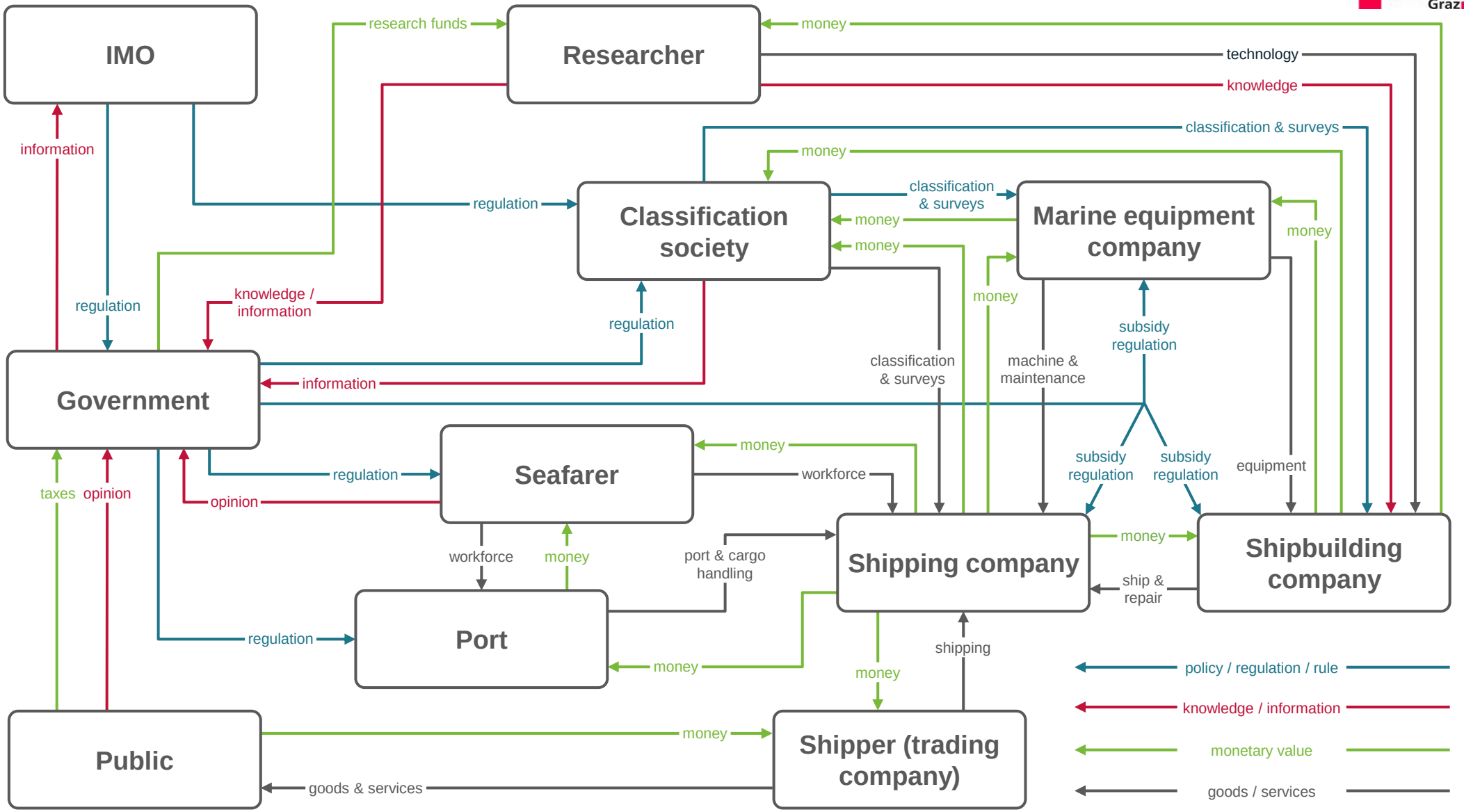


No measures (= BAU) → **climate targets** not reached!

Source: Hiekata et al. (2020). *Systems analysis for deployment of internet of things (IoT)*

Context | Decarbonization & Digitalization of the Maritime Industry

Stakeholder Value Network



Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

Technical Solutions

Low- and zero-emission alternative fuels and propulsion technologies

Energy-saving technologies

Operational measures

control system
- optimized routing and navigation
- optimized cargo loading/unloading
- slow steaming

wind-assistance devices (WADs)

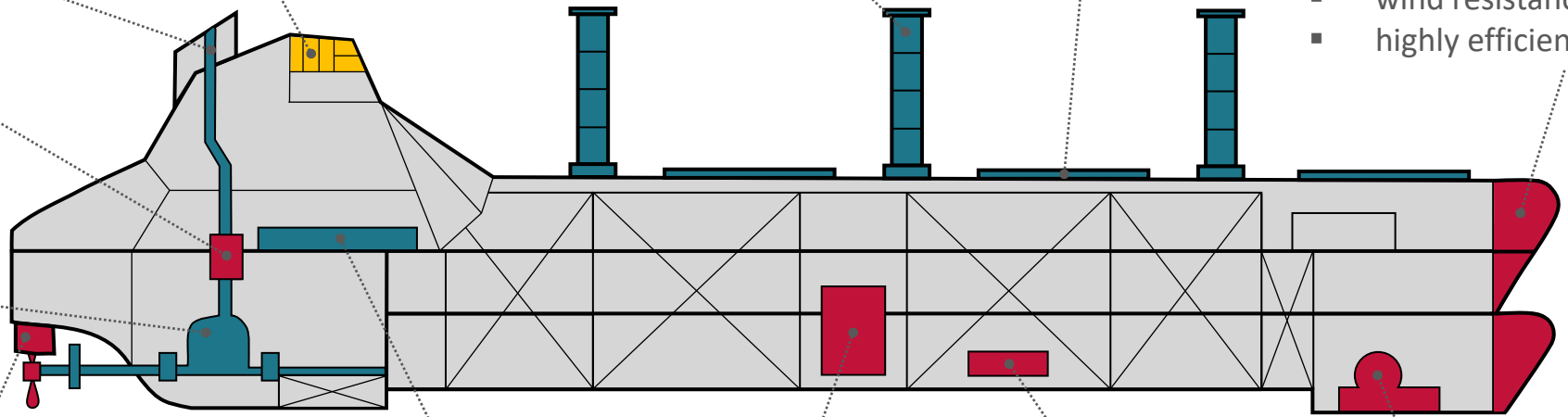
solar power

energy-efficient vessel type
- wind resistance reduction
- highly efficient bow shape

onboard CO_2 capture

waste heat recovery power generation

highly efficient engine and alternative fuels



propulsion improving devices (PID)
- gate rudder
- energy saving ducts
- highly efficient propeller

battery

highly efficient cargo handling system

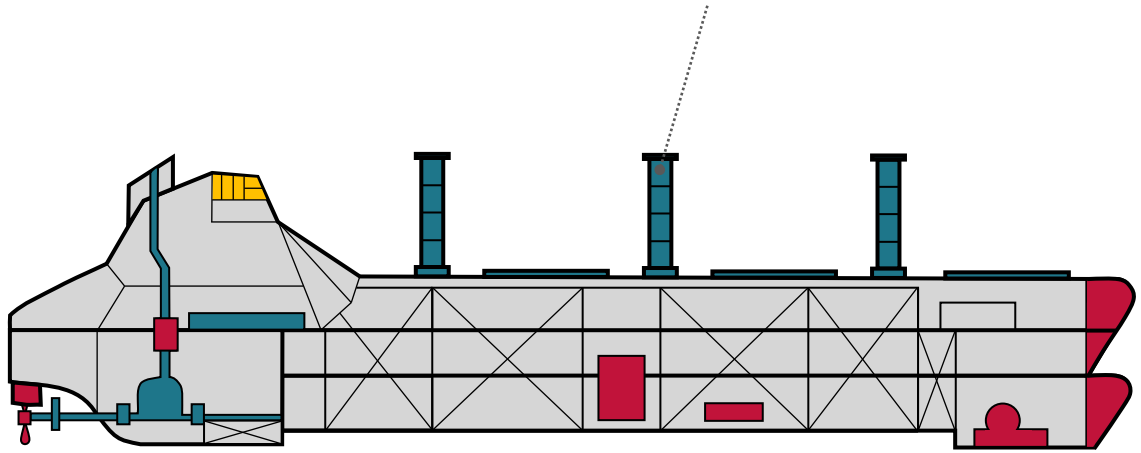
low friction paint

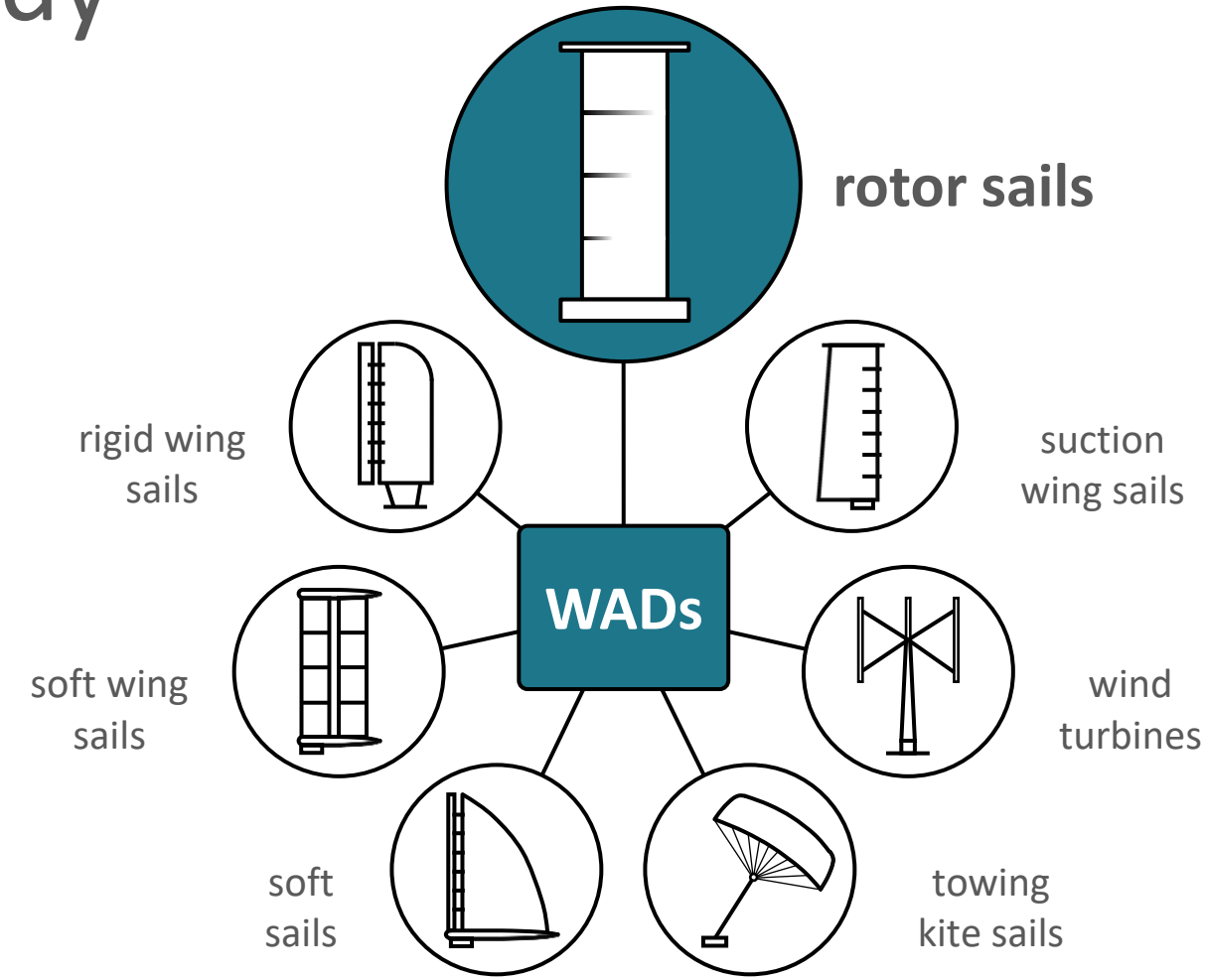
air lubrication system

Source: Det Norske Veritas (DNV). (2023). *Energy Transition Outlook 2023 - Maritime Forecast to 2050*

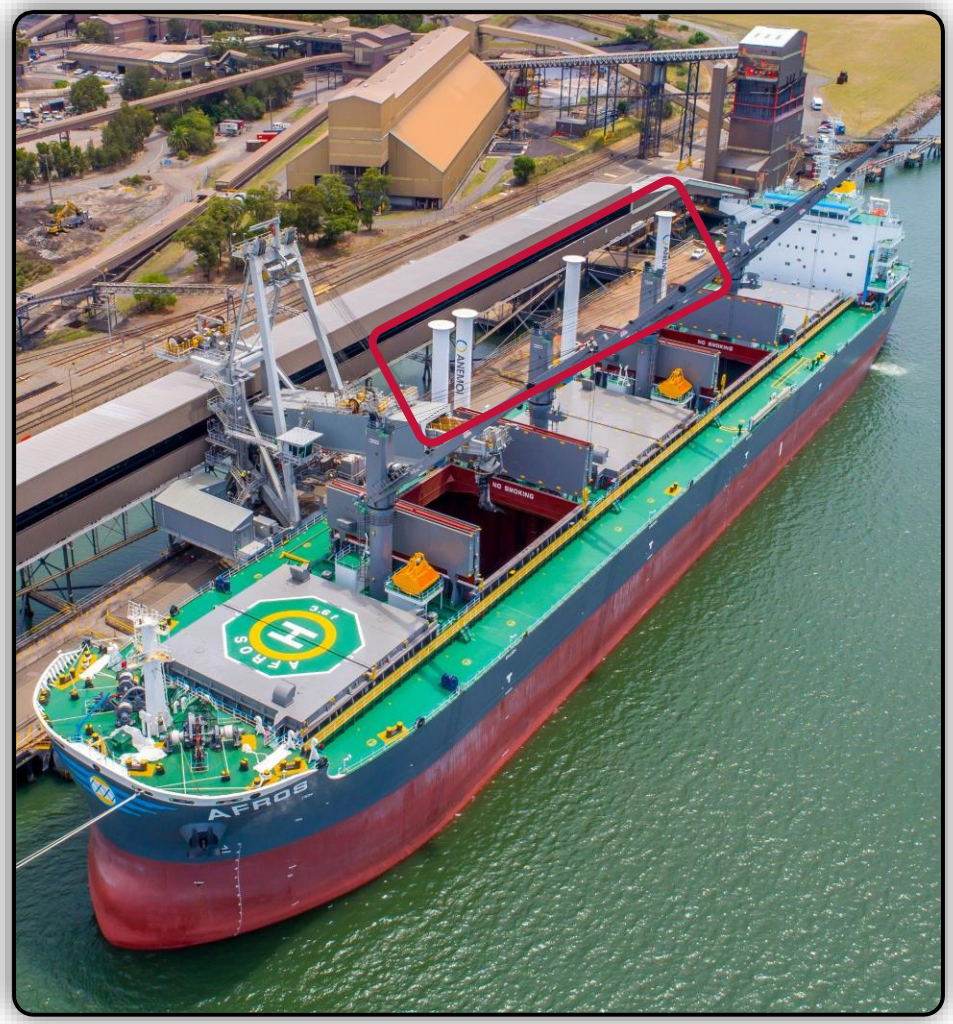
Focus of the Case Study

wind-assistance devices (WADs)

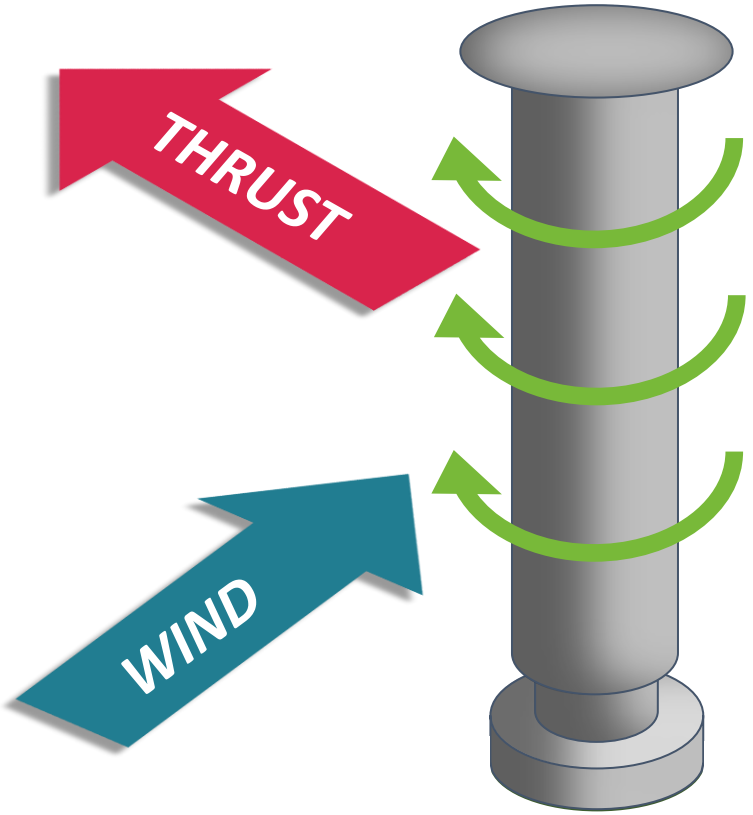




Bulk Carrier With Flettner Rotor Sails



Source: M/V Afros - The world's first rotor sail bulk carrier - Anemoi (anemoimarine.com)



Forward thrust generated through the **Magnus effect**!

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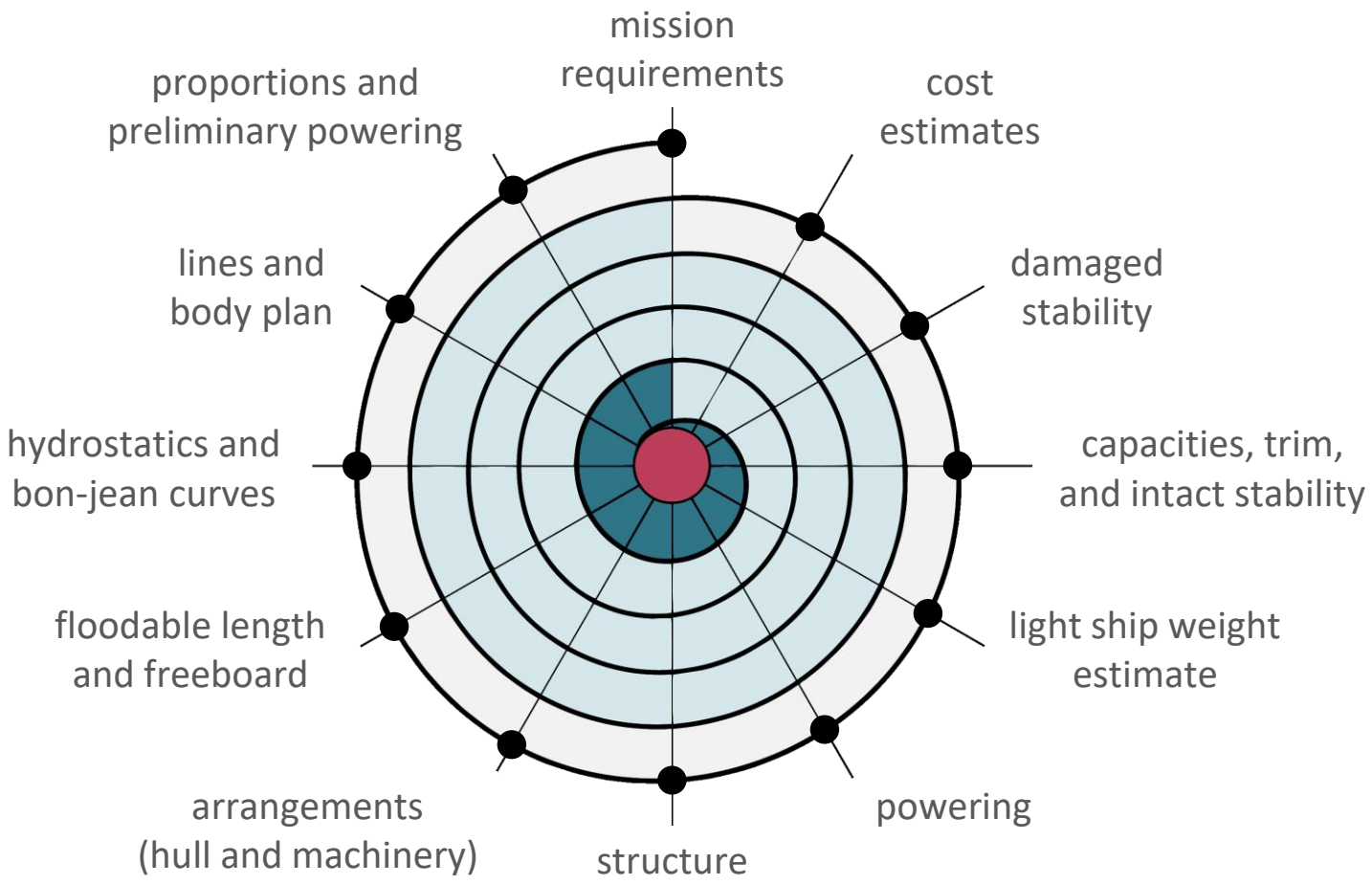
Ship Development Process – Design Spiral

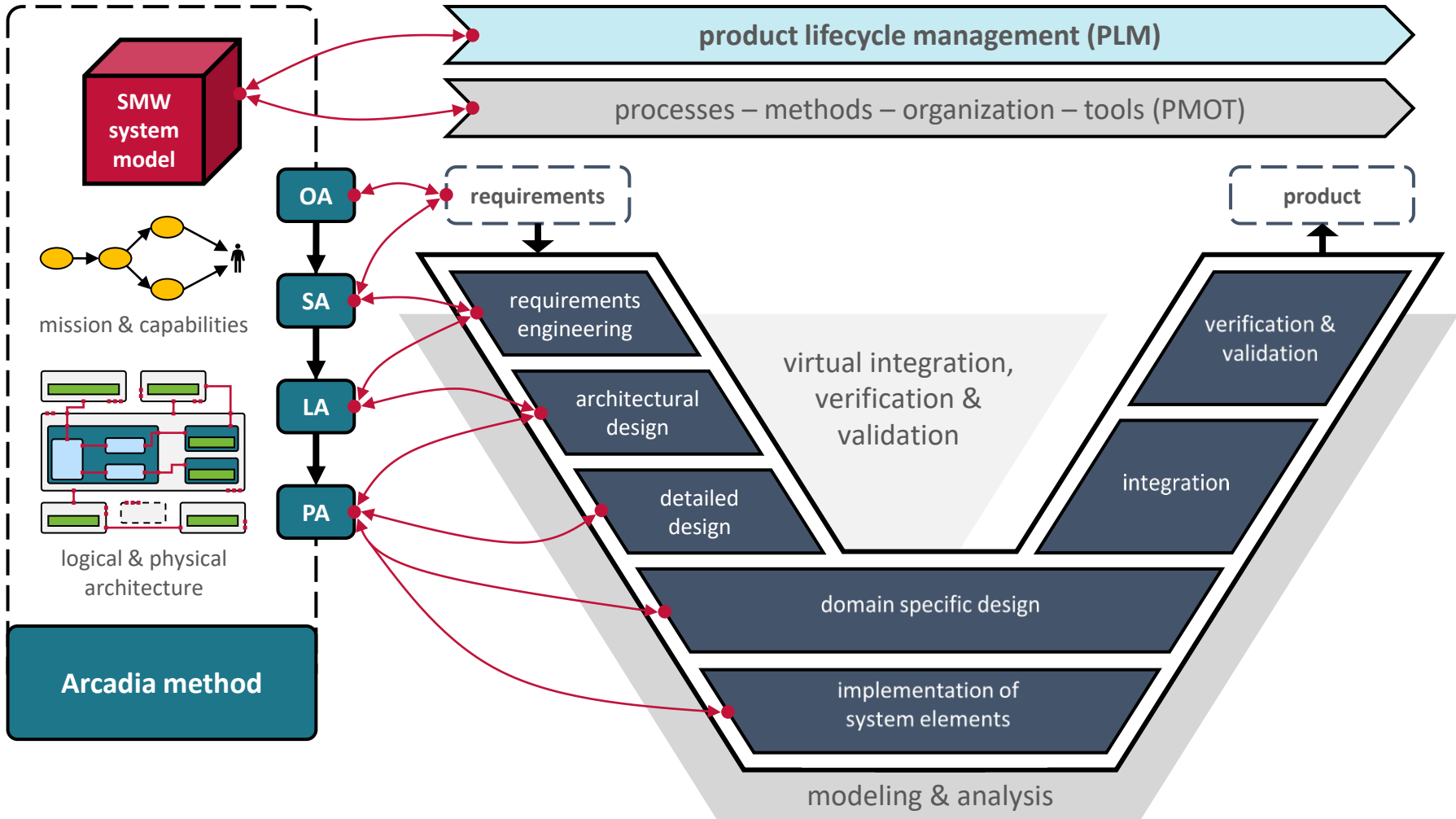


- Concept design
- Preliminary design
- Contract design
- Detail design

Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

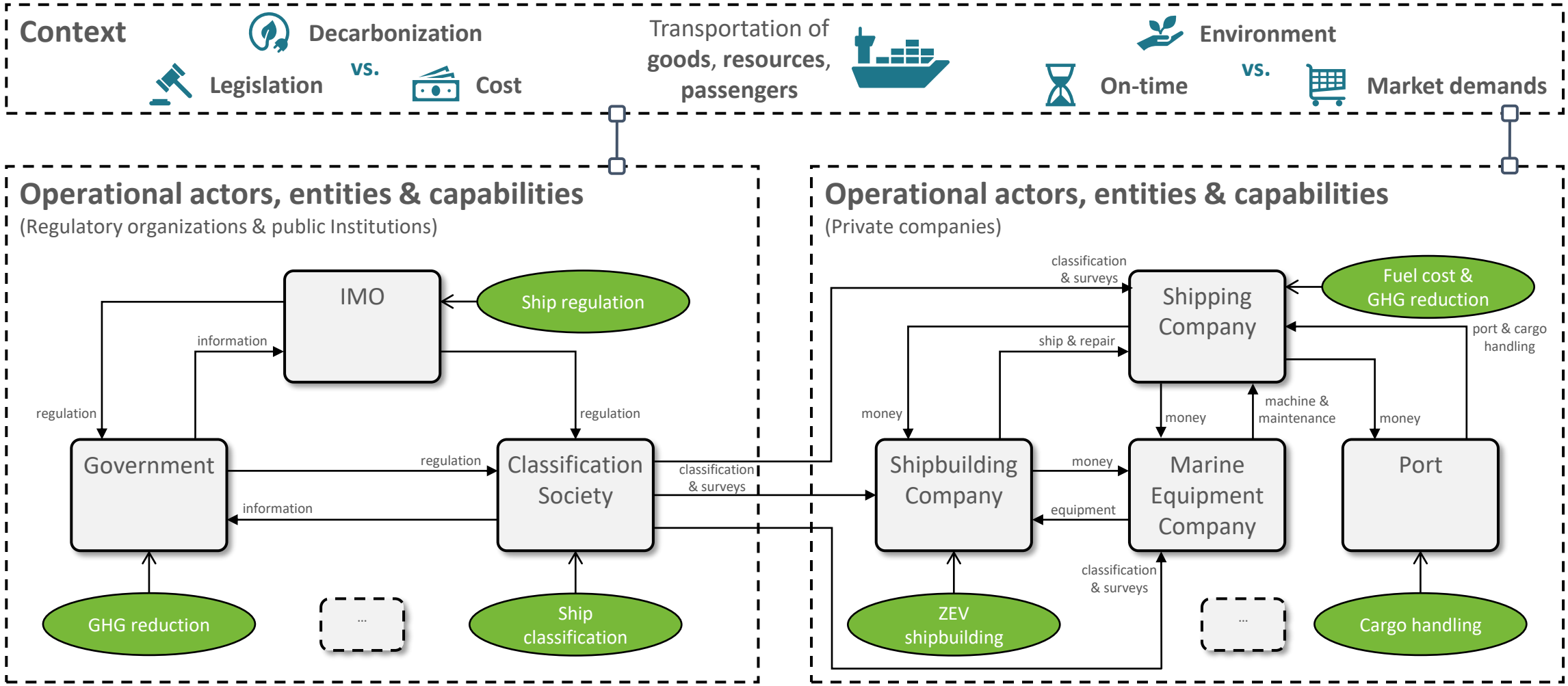
MBSE With Arcadia/Capella

Integration of the **Arcadia** method and the **SMW** system model into the **V-model**, **PLM** and **PMOT**



Operational Analysis

Operational analysis → System analysis → Logical architecture → Physical architecture



*Not all artifacts shown

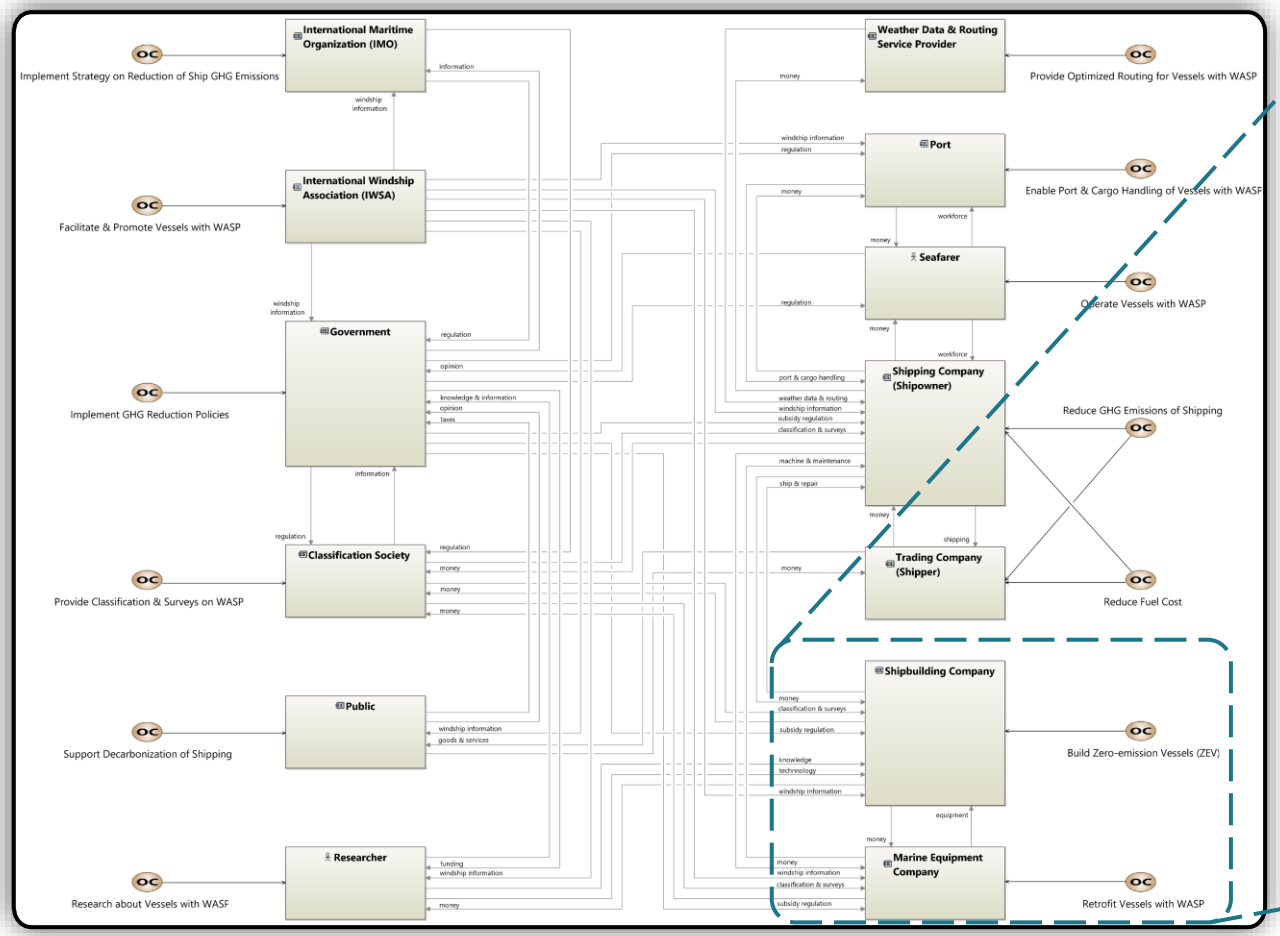
ZEV = Zero-emission vessel
IMO = International Maritime Organization

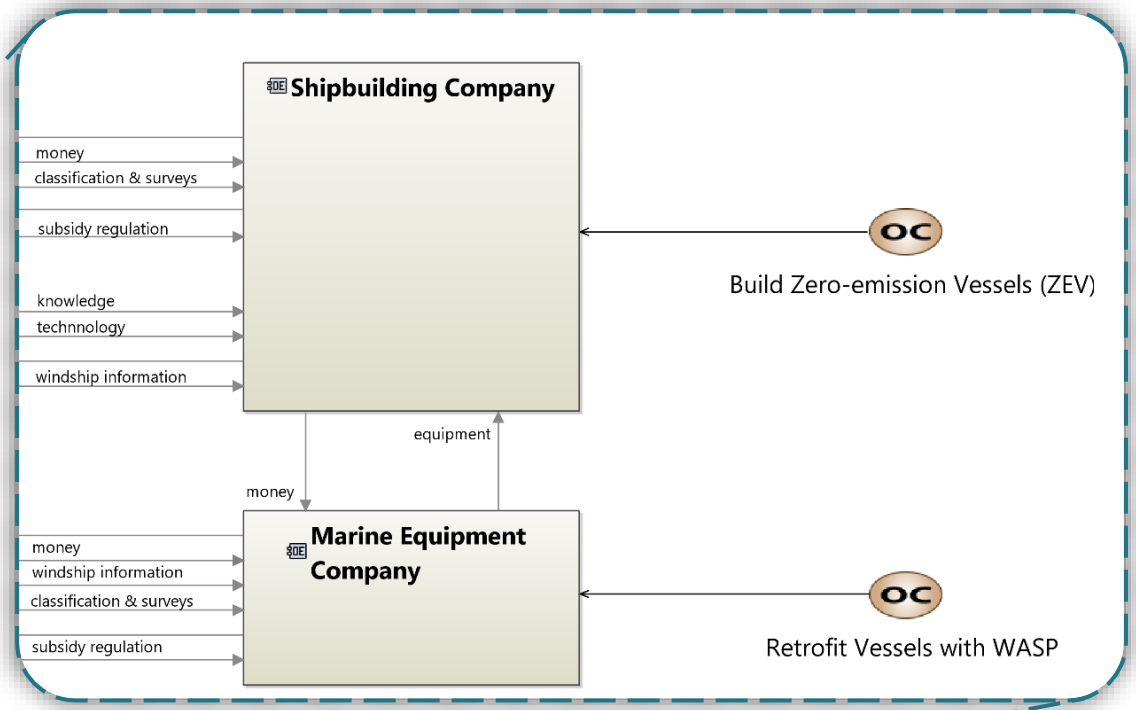
Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

Operational Analysis

Operational analysis → System analysis → Logical architecture → Physical architecture

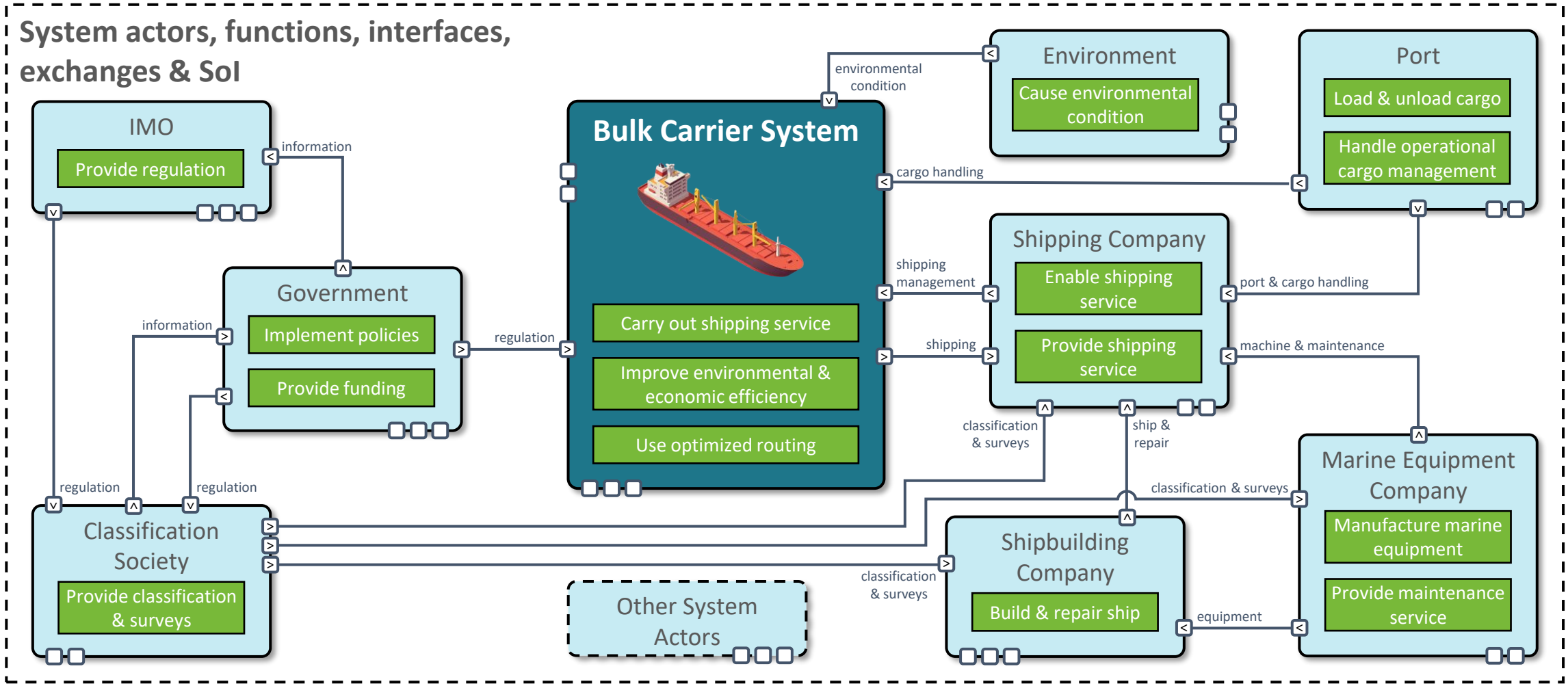




Analyze the **operational context** & **stakeholder interactions**!

SMW Screenshot

System Analysis



*Not all artifacts shown

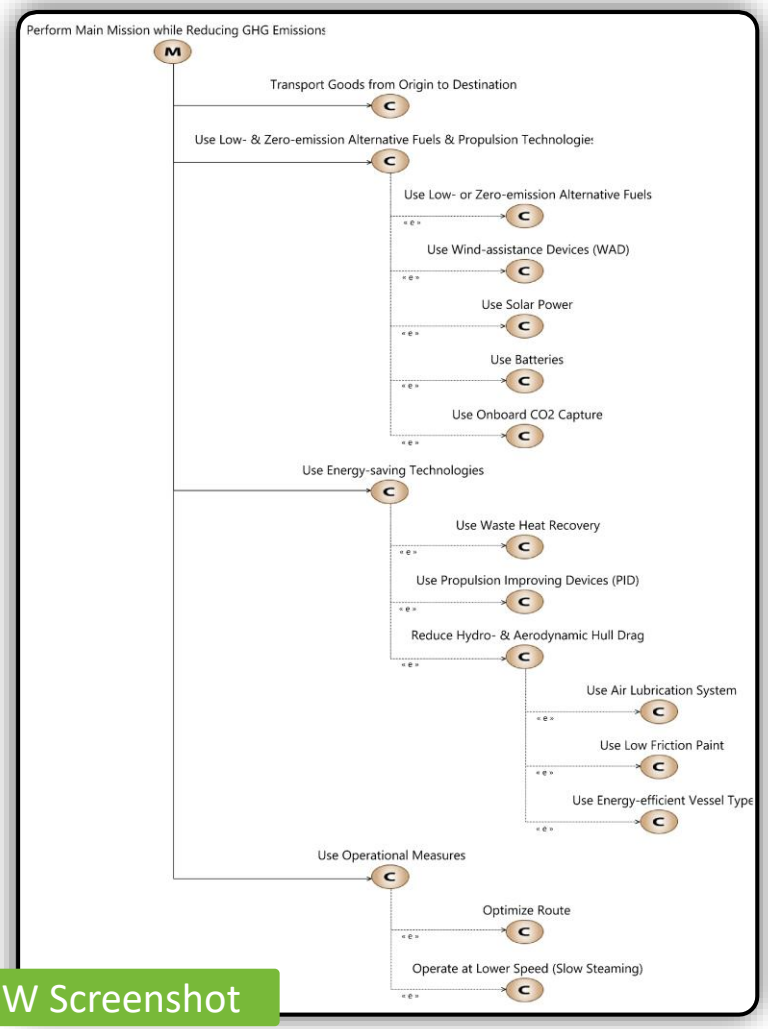
SoI = System-of-Interest

Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

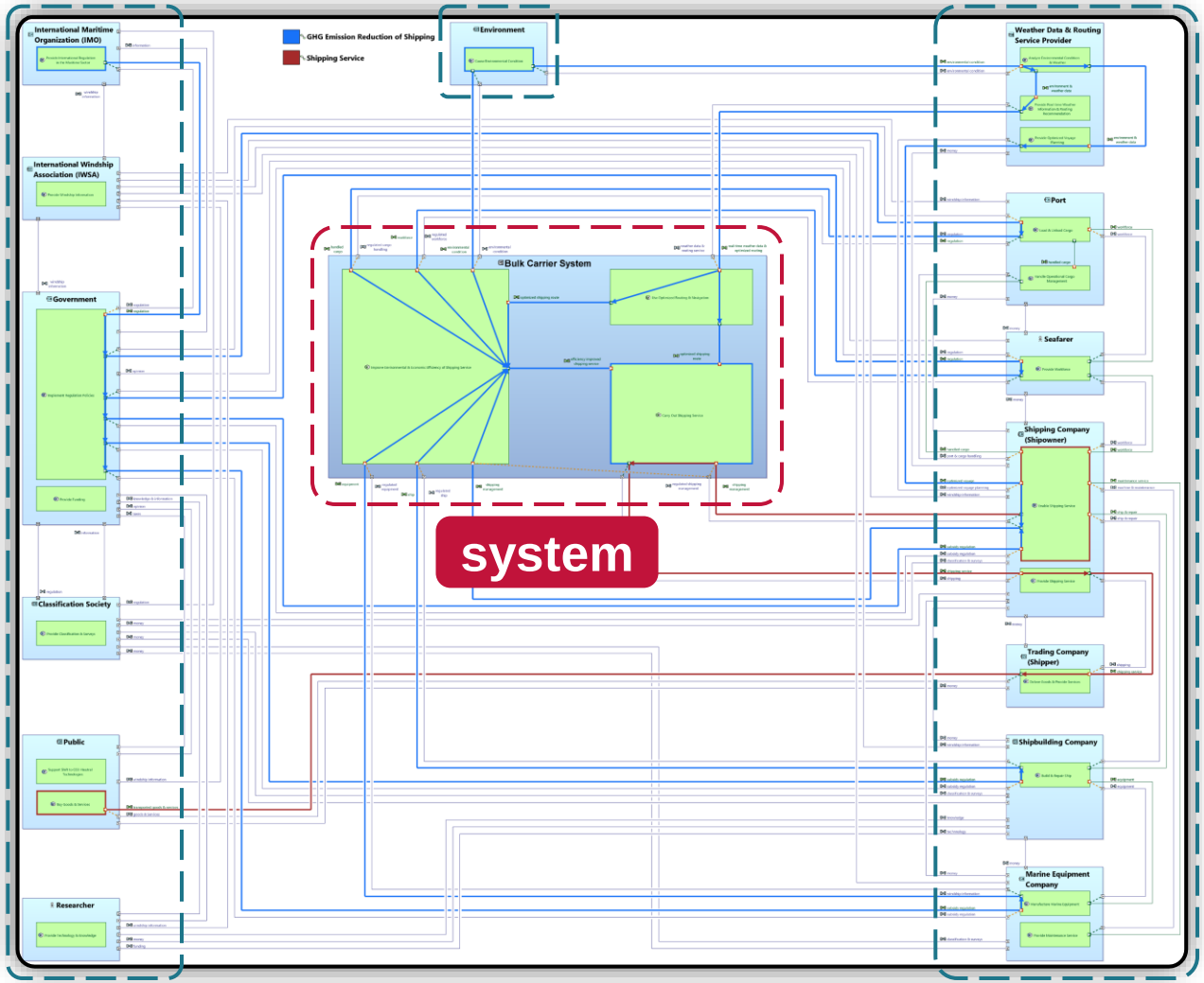
System Analysis

Operational analysis → **System analysis** → Logical architecture → Physical architecture



SMW Screenshot

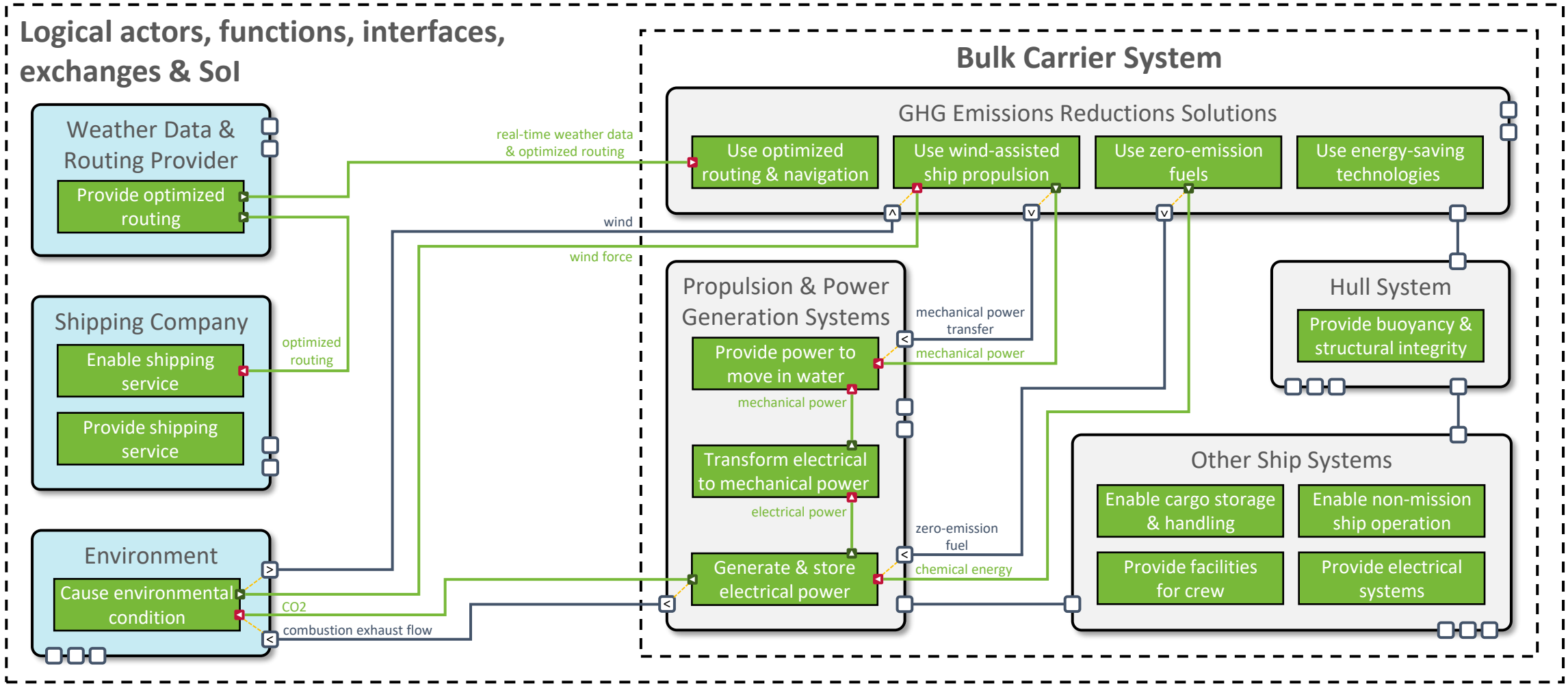
system actors



system

Logical Architecture

Operational analysis → System analysis → **Logical architecture** → Physical architecture



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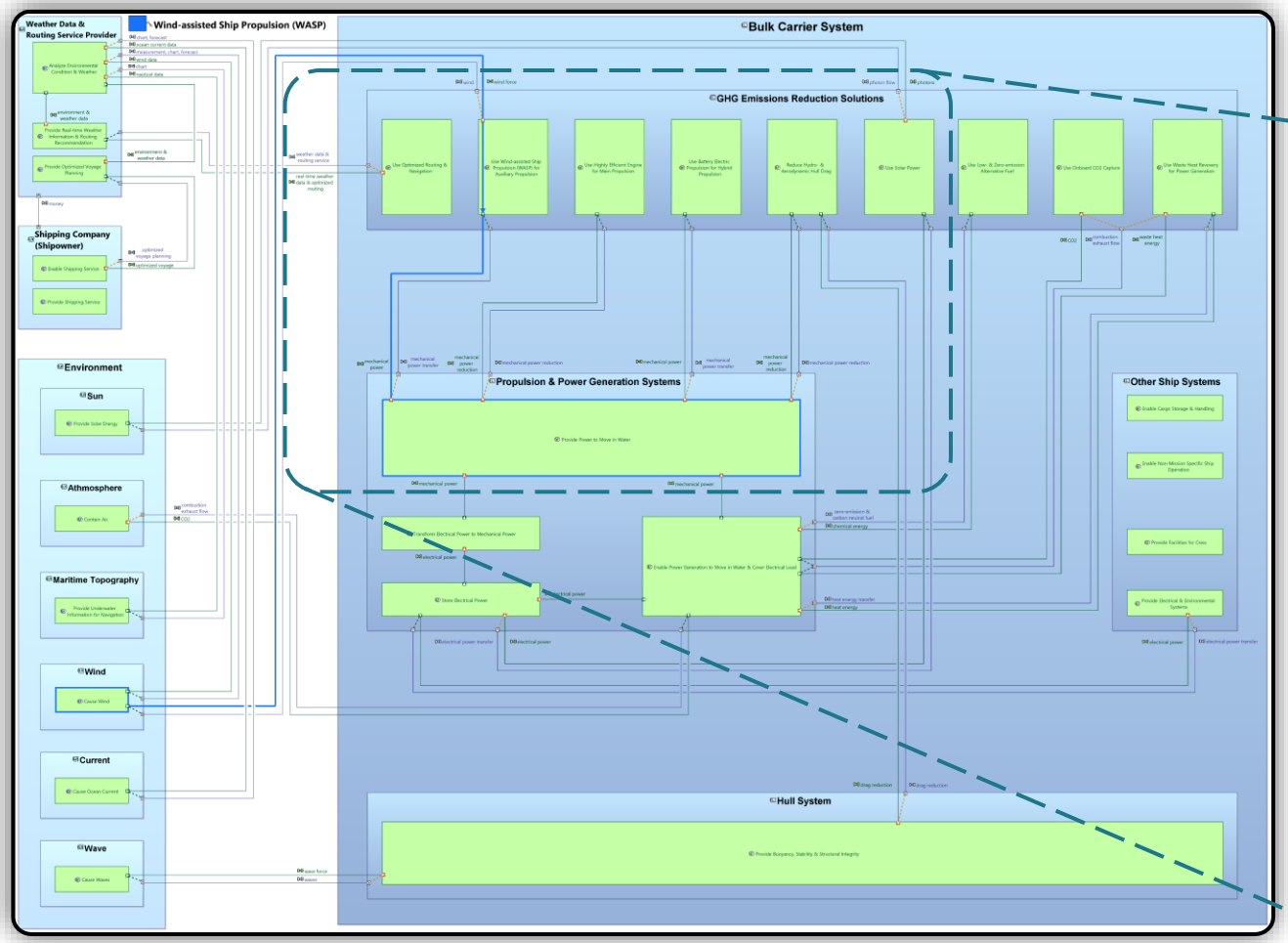
Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

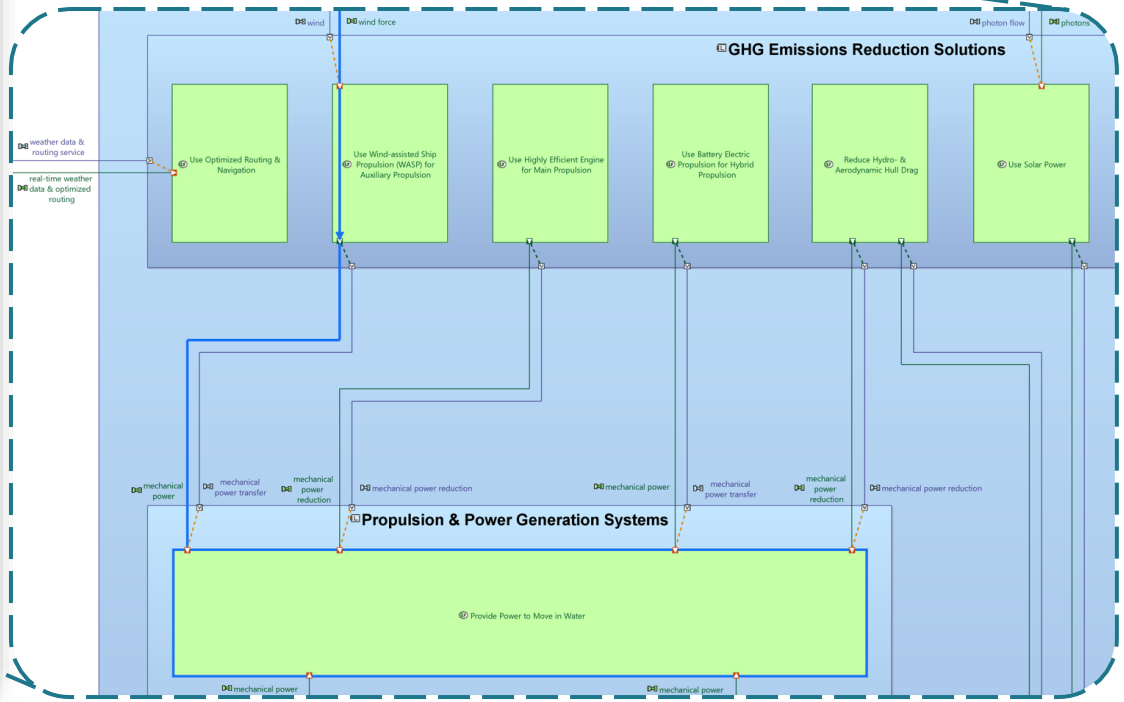
Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

Logical Architecture

Operational analysis → System analysis → **Logical architecture** → Physical architecture

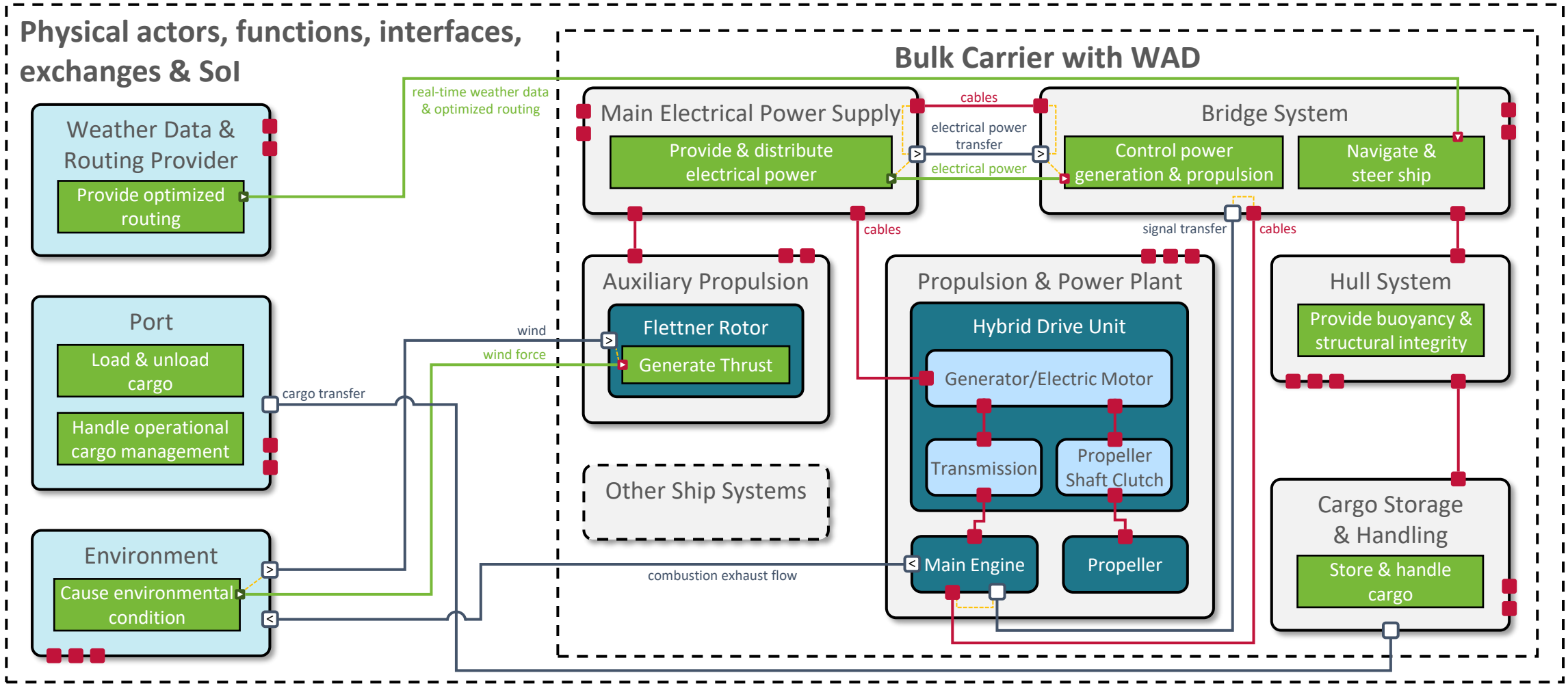


Logically **integrate** GHG emissions reduction solutions!



SMW Screenshot

Physical Architecture



*Not all artifacts shown

WAD = Wind-assistance device

Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

Physical Architecture

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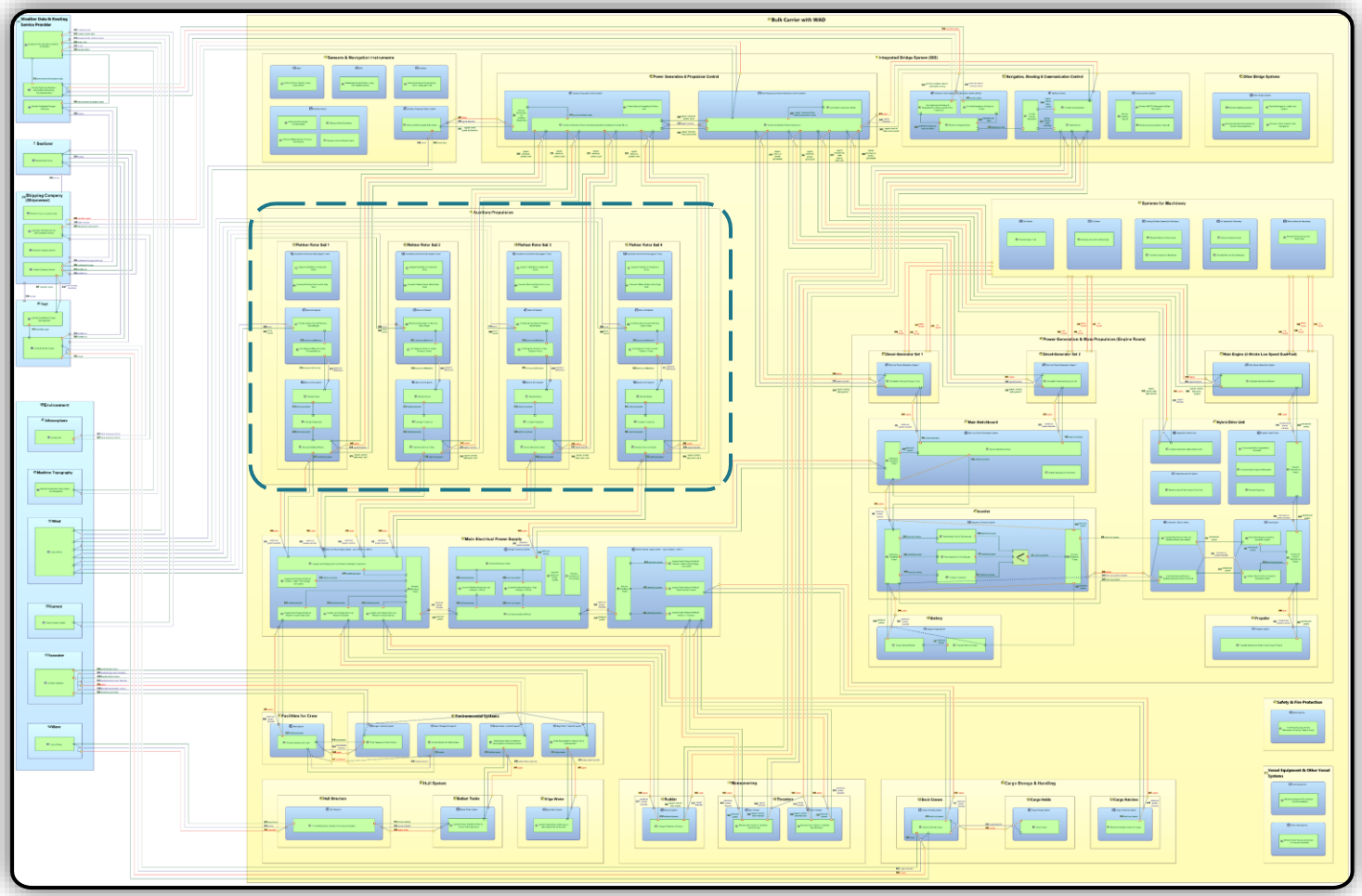

- Model and connect all relevant **subsystems** & **functions**
- Consider **physical actors**
- Define **interfaces** & **exchanges**

The essential step for further **discipline** development!

SMW Screenshot

Source: Dreier, M. (2024). MBSE in the Maritime Industry: Enabling Digital Transformation for CO_2 Reduction through Wind-assisted Ship Propulsion

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

Physical Architecture

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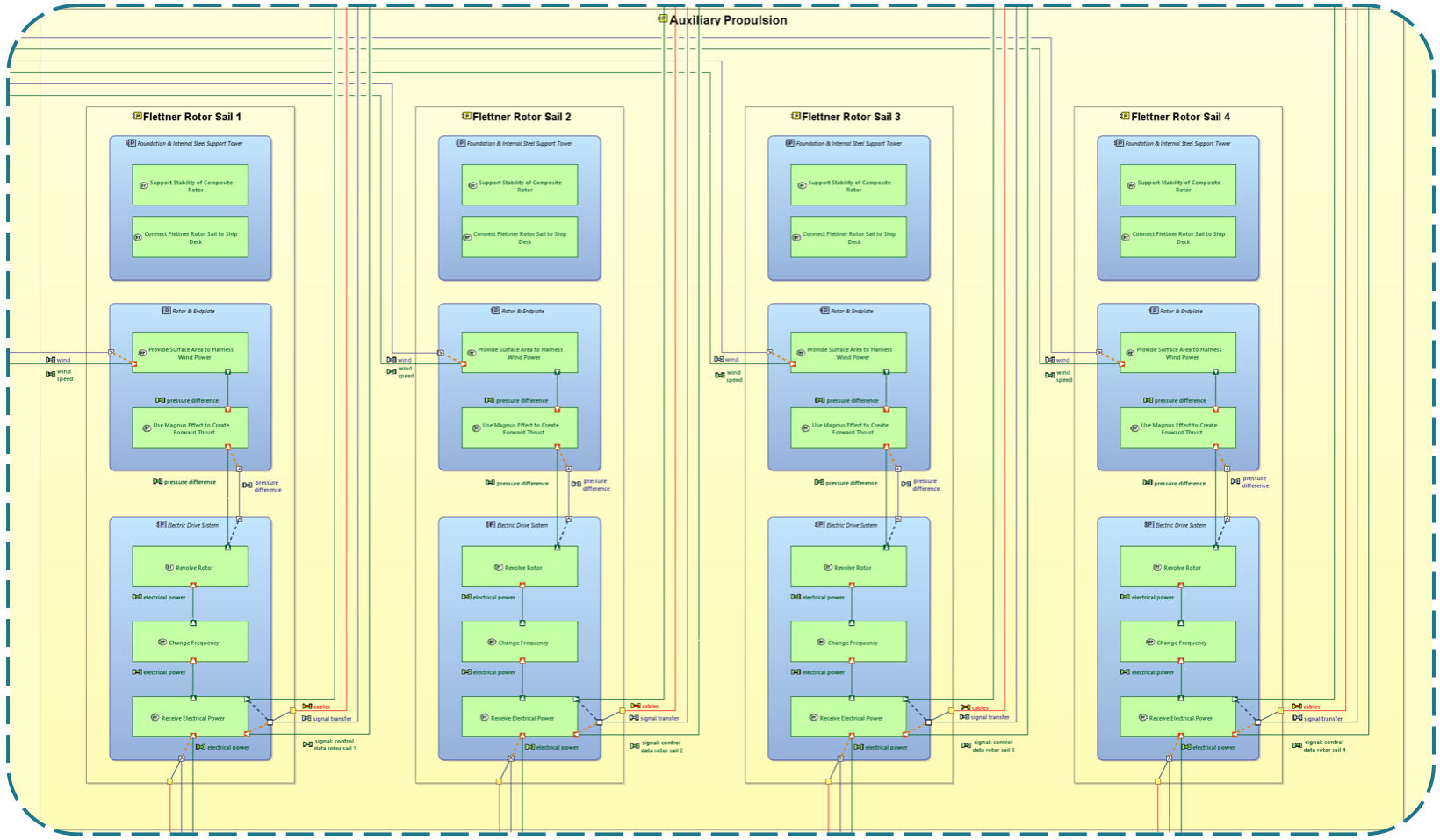


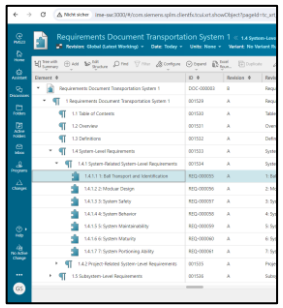
- **Auxiliary propulsion** subsystem integrated in bulk carrier system
- **Structural**, **hierarchical**, & **functional** view

The basis for **integration**, **V&V**!

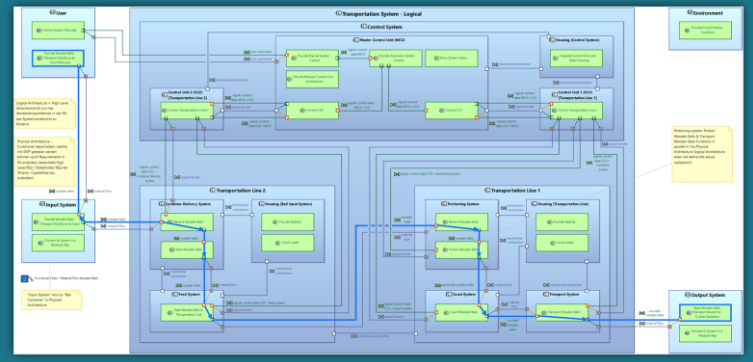
SMW Screenshot

Product Development With MBSE and PLM

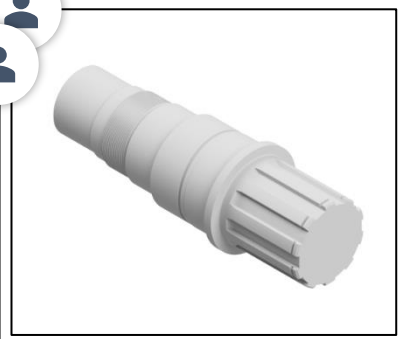
Knowledge share



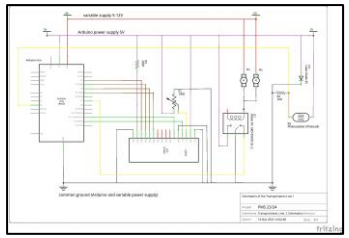
Requirements and test engineering



System architecting with *SMW*

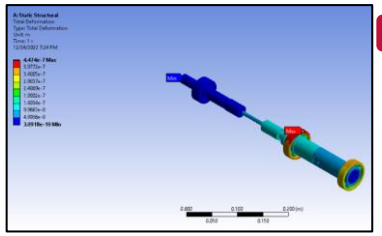


Mechanical design and modeling



E/E circuit design

Coding



Virtual verification

Data management

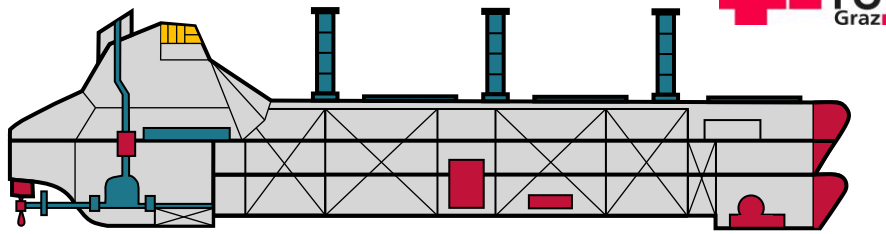
Workflows

Roles & permissions

PLM with *Teamcenter*

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

SMW Architecture Workflow



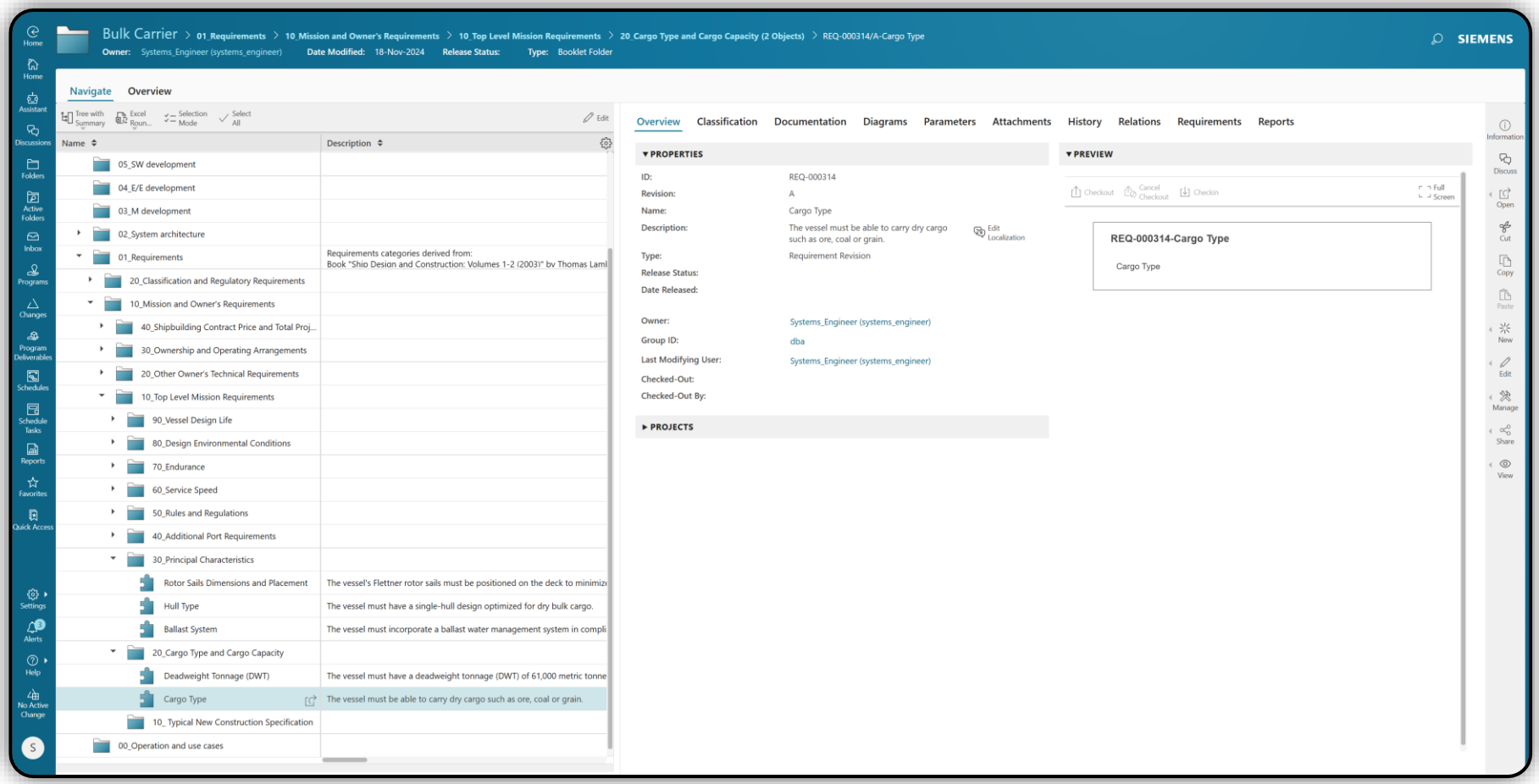
1. SMW architecture creation
   - Operational analysis
   - System analysis
   - Logical architecture
   - Physical architecture
2. Architecture upload to Teamcenter
3. Review of architecture
4. Release of architecture
5. Requirements and test cases creation
   - Creation of requirements and test cases in the maritime context
6. Linking of system artifacts
   - System architecture components linked with requirements and test cases in Teamcenter

SYSTEM MODELING WORKBENCH

TEAMCENTER

Example | Bulk Carrier System Model Integration Into Siemens Teamcenter

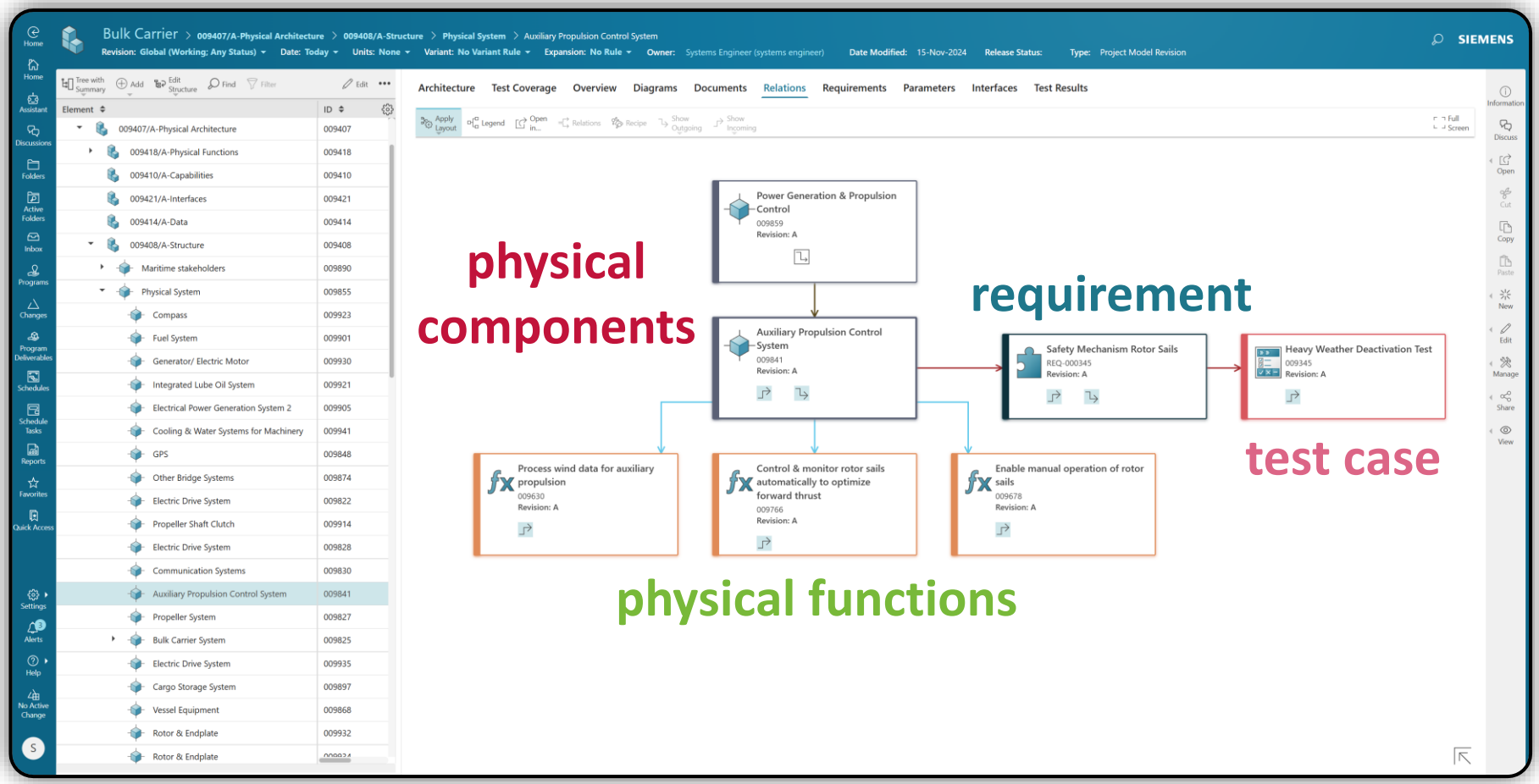
Requirements & Test Cases



Create your **RQs** and **test cases** and link them with **system artifacts!**

Teamcenter Screenshot

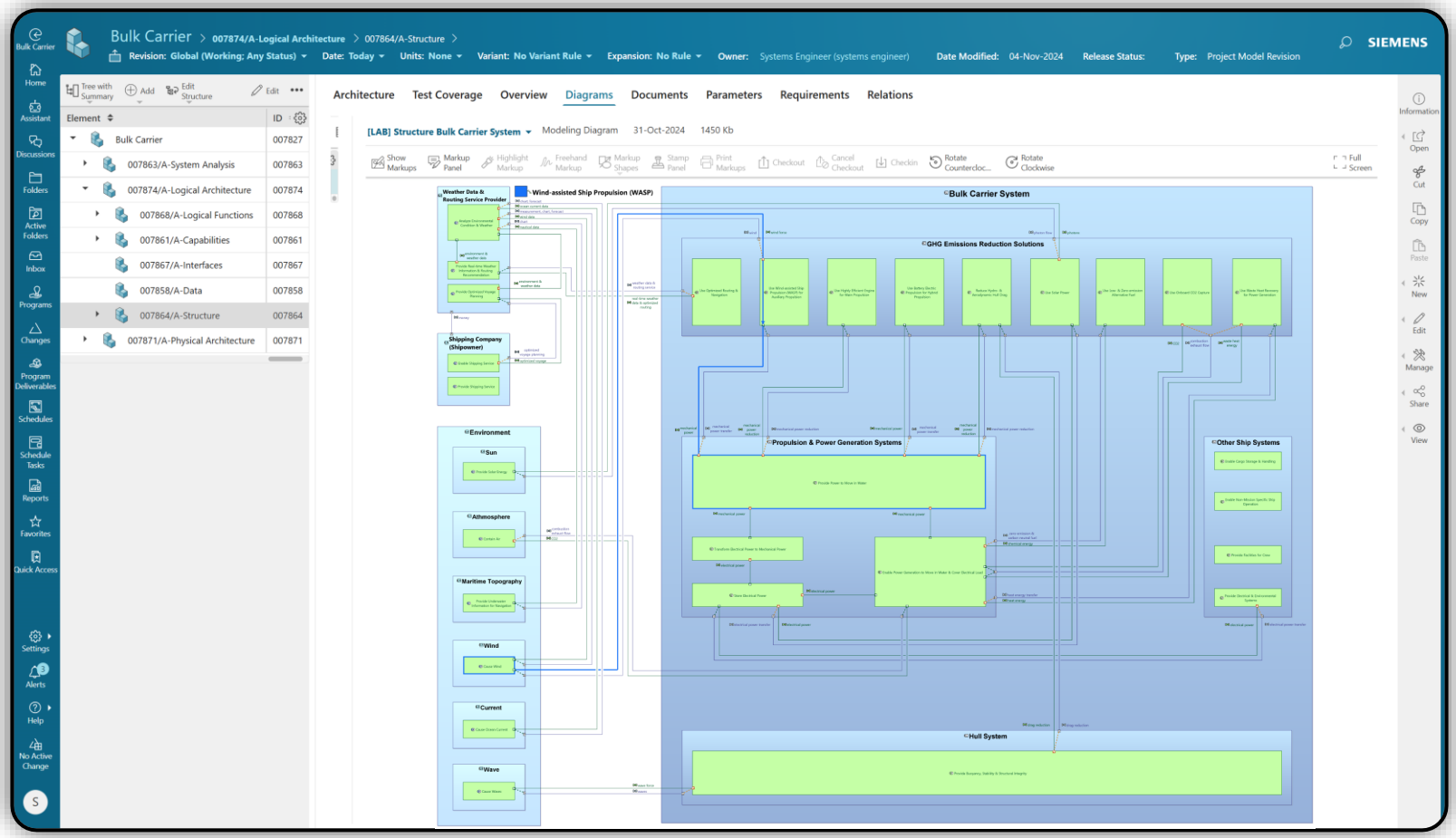
Requirements & Test Cases



Teamcenter Screenshot

Manage your **artifacts traceability** in Teamcenter!

Architecture in Teamcenter



- Bringing the disciplines together early in development using the **system architecture**
- Realized by an comprehensive **PLM** approach
- Do not just “document” what has already been built!

Teamcenter Screenshot

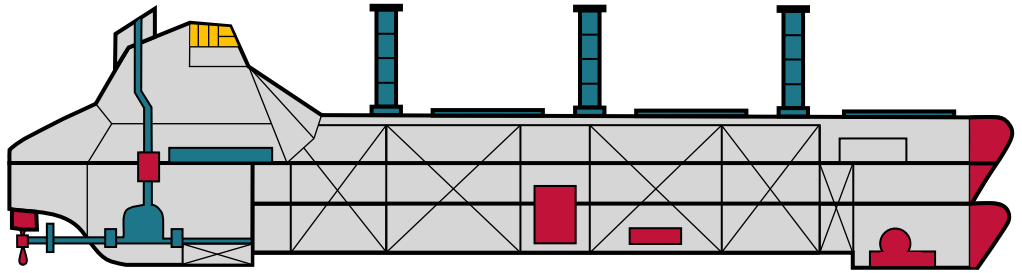
Agenda

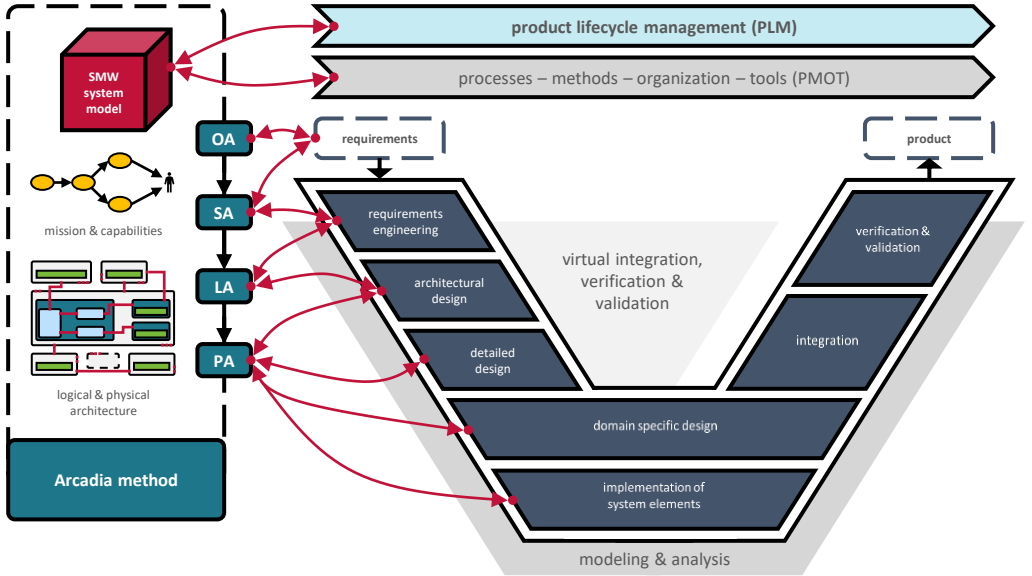
- **Introduction** | *Research at IME*
- **Context** | *Decarbonization & Digitalization of the Maritime Industry*
- **Example** | *Bulk Carrier System Model Integration Into Siemens Teamcenter*
- **Summary** | *Outlook*

Institute of Machine Components and Methods of Development

Outlook

- International shipping must reduce its GHG emissions (IMO 2023 strategy)
- Retrofit the existing fleet with GHG reduction solutions e.g., WADs
- New methodologies needed for developing zero-emission vessels (ZEVs)
- Modernized development approach in ship design with Arcadia and the V-model
- MBSE in the maritime industry is a must!





Thank you!

Institute of Machine Components and Methods of Development

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