Sustainability in ship operations in the shipping 4.0 era

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Who we are

DANAOS and Research

- ✓ Fleet of 76 container ships
- ✓ Ranking among the top in the Greek shipping business.
- ✓ Strong invest in research and innovation
- ✓ Best-of-breed maritime software
- ✓ Participation in a number of EU projects (40+), funded under different EU research programs, with a strong motivation to apply innovation and creative thinking across all aspects of maritime operation.
- ✓ Member of FRANZ EDELMAN academy and winner of the homonymous award in 2012 (the highest worldwide distinction in applied operation Research).

Websites:

- https://danaosrc.com/
- https://www.danaosshipping.gr/
- https://www.danaos.gr/

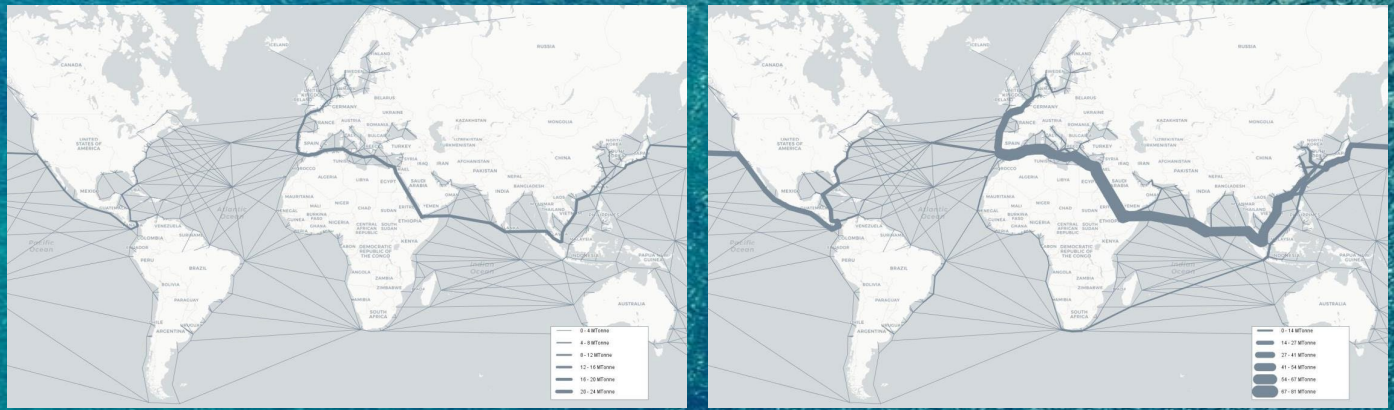
Running Projects

Introduction - Main topics

- Updated outlook on drivers and regulations (safety, emissions, etc)
- Infrastructure to shift towards carbon-neutral operational blueprint
- Shipping in the era of digitalization; Technological advancements. Gap Analysis (SOTA & BEYOND)
- Evaluation of possible solutions through simulation frameworks

Decarbonization of the maritime sector -
Motivation & Rationale

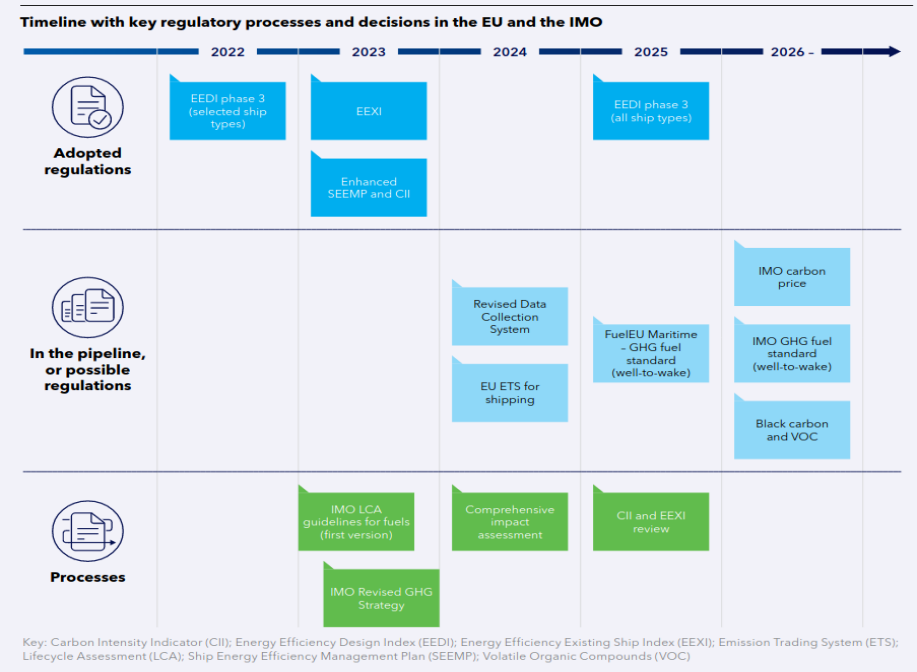
- The 2022 IMO mandated report for emissions reduction - Decarbonization of the shipping industry
- Well to Wake holistic supply chain optimization for GHG emissions reduction
- Growth of international trade, projected to almost double by 2035 and growing at a rate of approximately 3% per year until 2050 (ITF, 2017)
- Replace manual procedures concerning core & third party modules of the industry (shipowners, ports, suppliers, chartererers) with automated administrative workflows (Layer of transparency)



CO_2 emission across global shipping in 2015 (left) & 2035 (right)

Decarbonization of the maritime sector - Outlooks & Drivers

Regulatory measures and GHG emissions reduction (%)



	Technical requirements		Market-based measure
Ambition	**Newbuild requirements**	**Operational requirements (gradually increasing)**	**Carbon price**
IMO ambitions	Currently adopted EEDI requirements: up to 30% reduction depending on ship type ▪ From 2035: 50% to 80% reduction depending on ship type ▪ From 2040: 90% reduction	Currently adopted CII and EEXI requirements ▪ 2030: 40% reduction ▪ 2050: 75% reduction	ETS allowance prices for ships when operating in Europe ▪ 2023–2030: USD 22/tCO_2 to 95/tCO_2 ▪ From 2030: up to USD 135/tCO_2
Decarbonization by 2050	Currently adopted EEDI requirements: up to 30% reduction depending on ship type ▪ From 2035: 50% to 80% reduction depending on ship type ▪ From 2040: 90% reduction	Currently adopted CII and EEXI requirements ▪ 2030: 40% reduction ▪ 2050: 100% reduction	ETS allowance prices for ships when operating in Europe ▪ 2023–2030: USD 14/tCO_2 to 150/tCO_2 ▪ From 2030: up to USD 250/tCO_2

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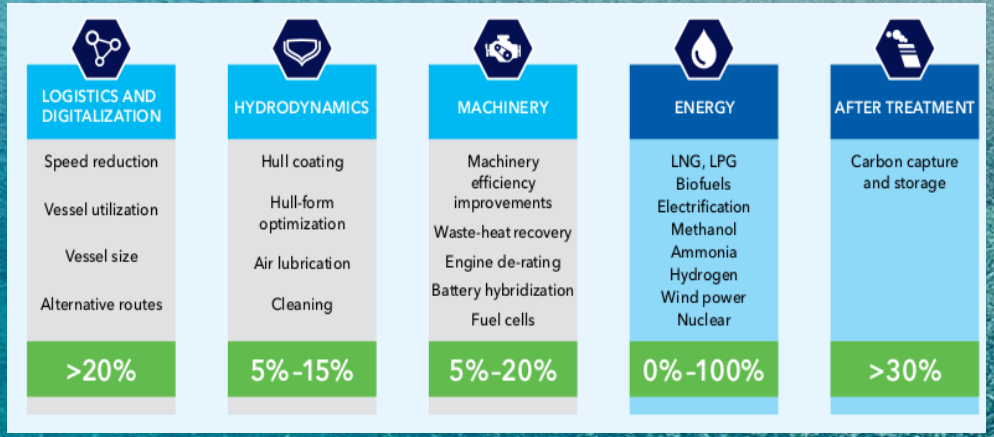
Decarbonization of the maritime sector -
Outlooks & Drivers

GHG emission-reduction potential of technologies



Current SOTA - Company infrastructure

DANAOS Functionality:

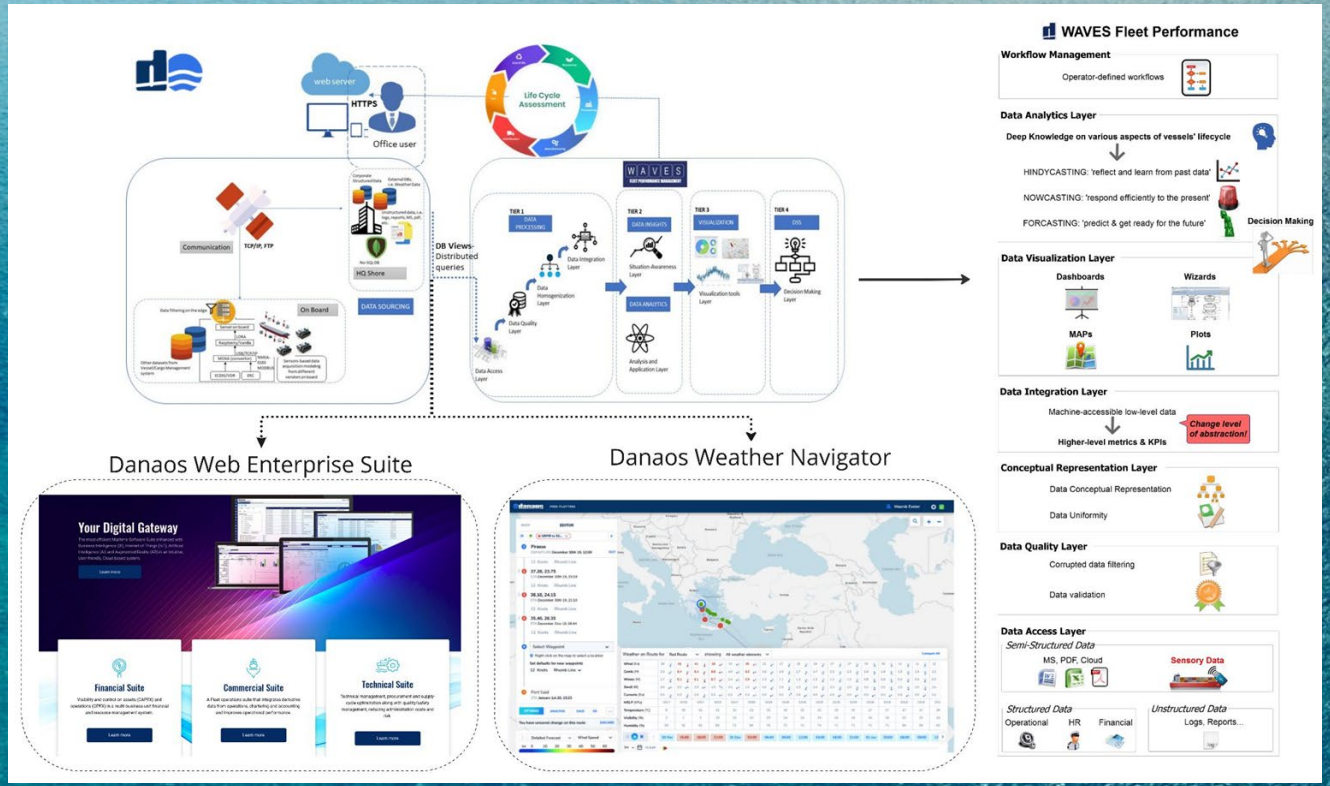
- Data acquisition network - Reporting : (***Danaos Application Suite / Waves***)
- Weather Routing Optimization: (***Weather Navigator***)
- Voyage Estimation – (Crewing, Cargo Handling, Bunkering, Freight): (***Danaos Application Suite***)
- Visualization - Causal Analysis - Predictive Maintenance - Post Voyage Analysis: (***WAVES***)

EU proposals heritage:

Involved in numerous EU projects concerning mitigation measures to reduce the environmental footprint of the vessel by replacing key components (structural, machinery) of the vessel and running simulations to evaluate the performance.

- ENGIMONIA
- ORC4SHIP
- AIRCOAT

Current SOTA - Company infrastructure



Tech trends & Beyond SOTA - Digital Twins for green shipping

A Digital Twin constitutes:

- Virtual holistic representation of the vessel that spans its life-cycle
- Updated from near to real-time data, utilizing simulation, machine learning and reasoning
- Decision-making, sensing and control actuation.

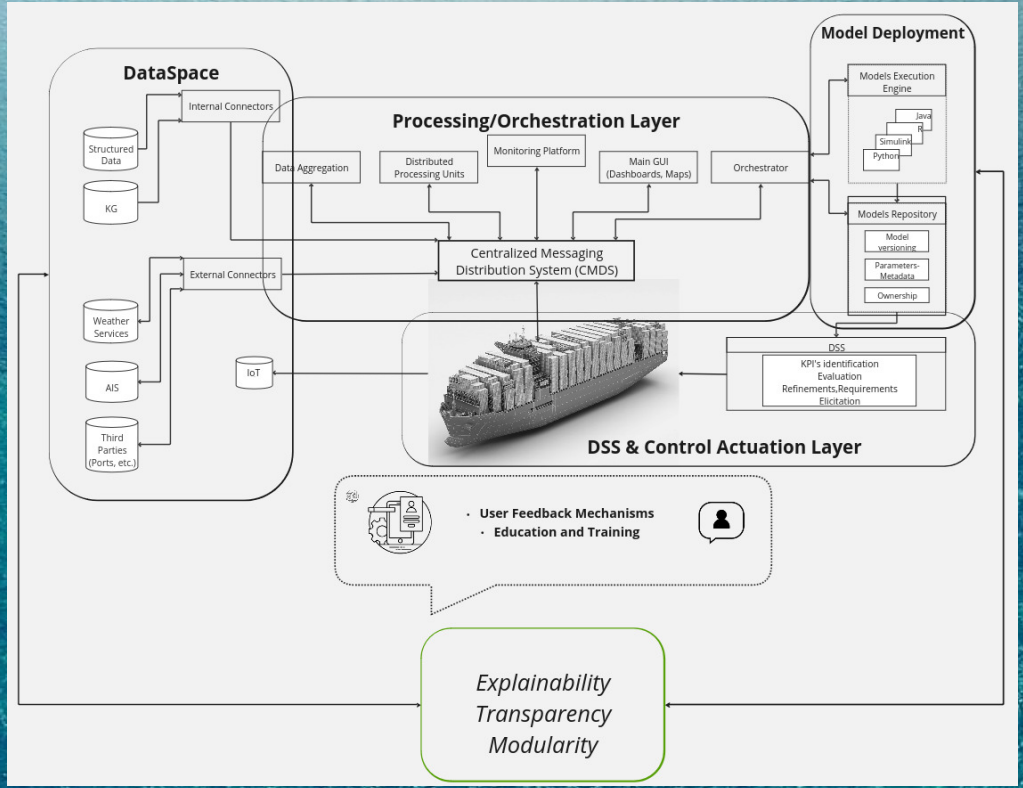
By combining core structural properties of traditional MIS and digital twins, organizations can gain a better insight of their internal operations and pave the way for a fully automated and fault tolerant decision making procedure, facilitating towards a carbon neutral operational blueprint.

Tech trends & Beyond SOTA - Digital Twins for green shipping

Main components:

- DataSpace
- Models Repository
- DSS
- Control Actuation Layer

More here: "***Enabling digital twins in the maritime sector through the lens of AI and industry 4.0***"

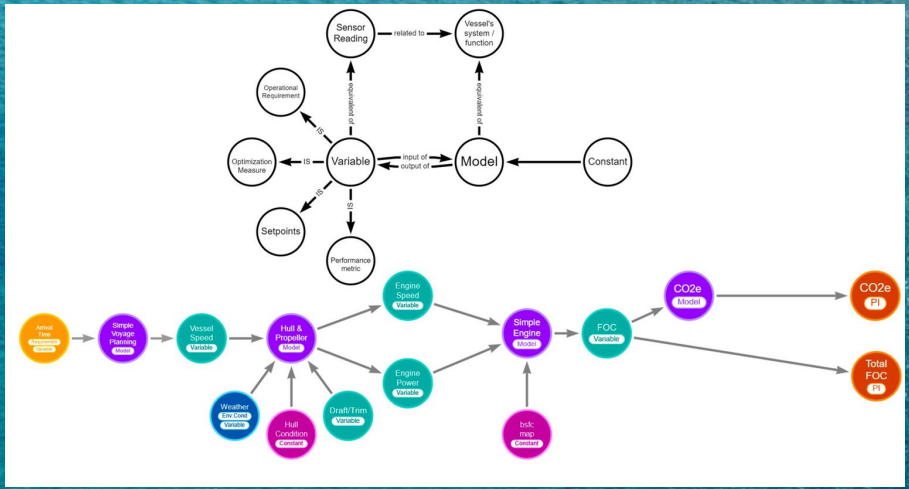


Holistic representation of the envisaged DT framework

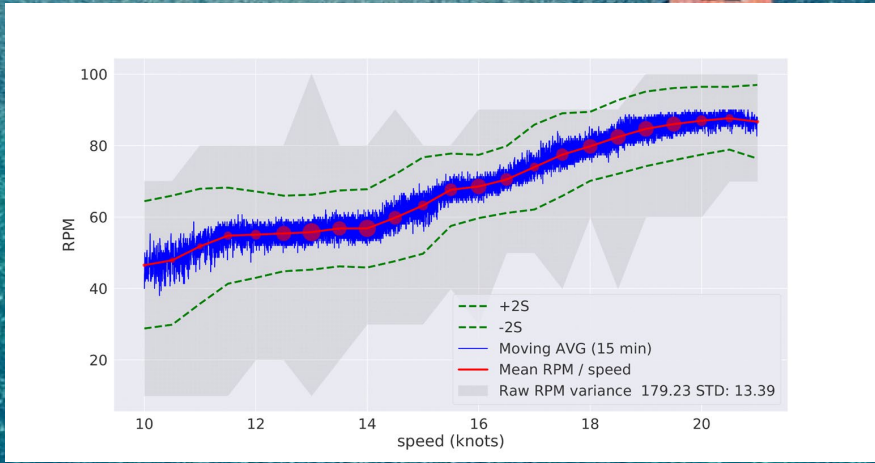
Tech trends & Beyond SOTA - Digital Twins for green shipping

Standardized Data Processing

KG - Semantic Annotation of Data Sources with KPIs - Data Cleansing Procedures etc



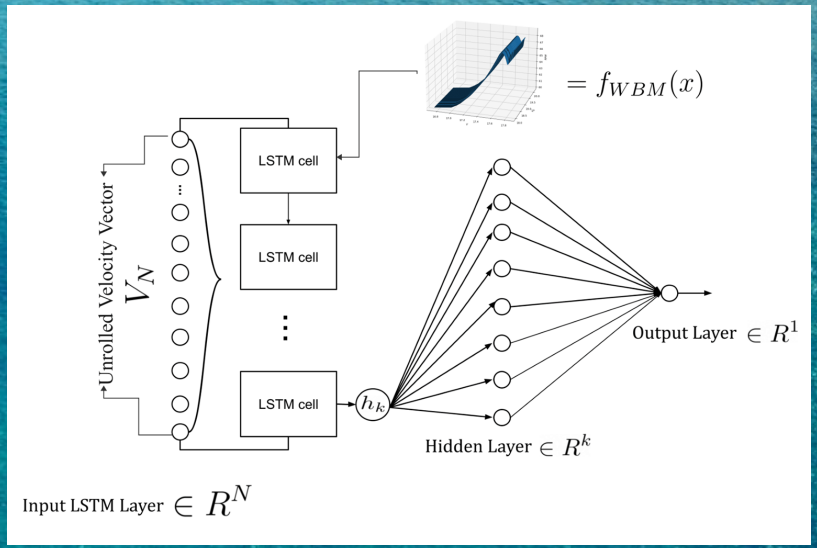
Data Cleansing Example Visualization



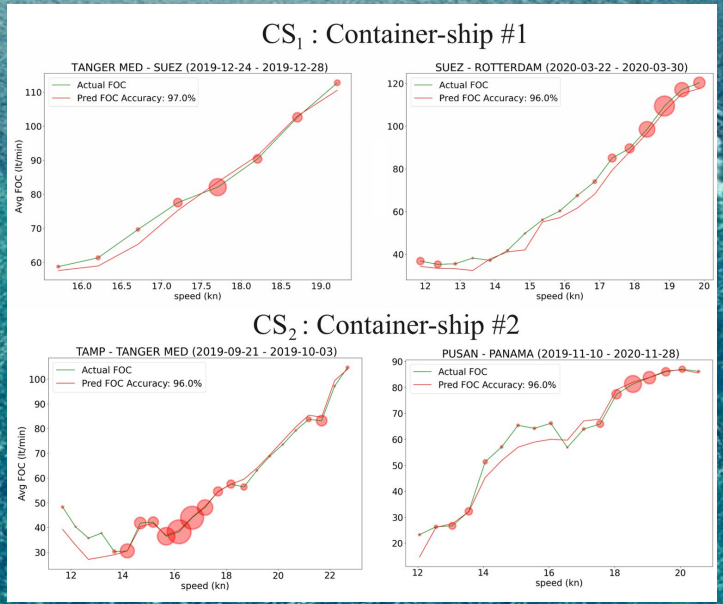
Tech trends & Beyond SOTA - Digital Twins for green shipping

Simulation models - Prominent Example

Physics informed or GBM for FOC approximation



Experimental results - Accuracy



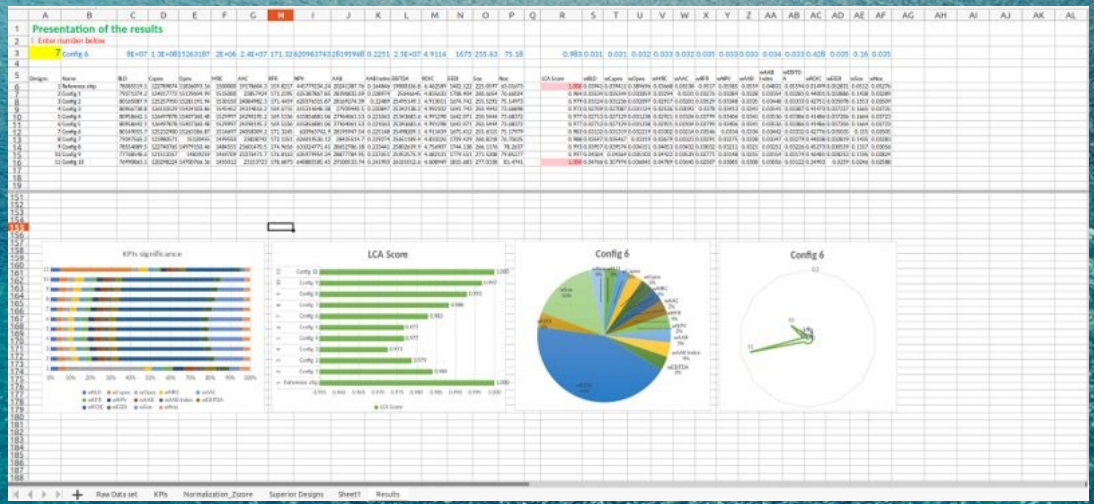
Tech trends & Beyond SOTA - Static Life Cycle Assessment (LCA)

Multi- constraint optimization

Table 3: Features - KPI's - Calculation

Features	Indicators	Calculation
F_t		
SFOC	CO_2	$P * SFOC * EF_{CO_2}$ (1)
DWT	NOX	$P * SFOC * EF_{NOX}$
AUX/E	SOX	$P * SFOC * EF_{SOX}$
STW	OPEX	
DRFT	CAPEX	
M/E	EEOI($\frac{gr}{ton*mile}$) [1]	$FOC*EF_{CO_2}/M_c*Dist$
Pr_p	FOC	see section 3.1.4
Pr_d	$EEDI_{required}$	$a * b^{-c}$
F_t	$EEXI_{required}$	$(1 - Z/100) * EEDI_{ref}$
RPM_{ME}	$CII_{required}$	$(100-Z)/100*CII_{Ref}$ (1)
P	AER	$FOC*EF_{CO_2}/DWT*Dist$

KPI Calculation

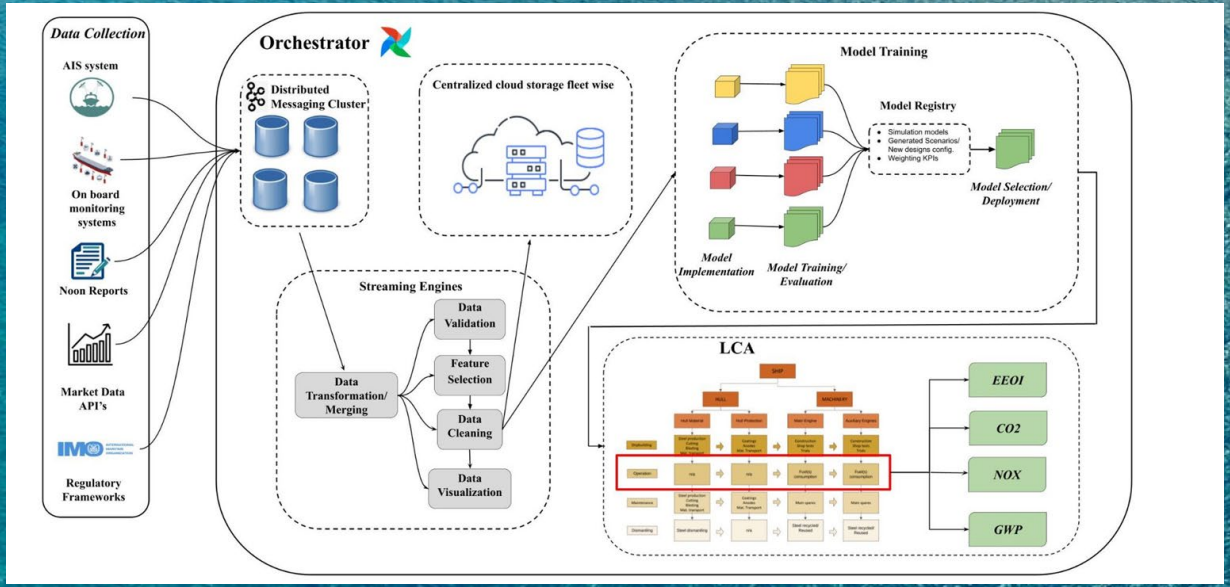


Evaluation of possible scenarios (Financial & Environmental assessment)

Tech trends & Beyond SOTA - Dynamic LCA

DLCA - "Static LCA extension; *Beyond SOTA*"

- Employ an LCA ecosystem; Updated from real time information (operational data, market analysis, regulatory frameworks)
- Dynamic Weighting factors (depending on current vessel state, tech trends & new regulations)
- Utilization of automated workflows to generate appropriate scenarios (retrofitting, new design, operational /CII optimization) depending the vessel & the desired outcome)

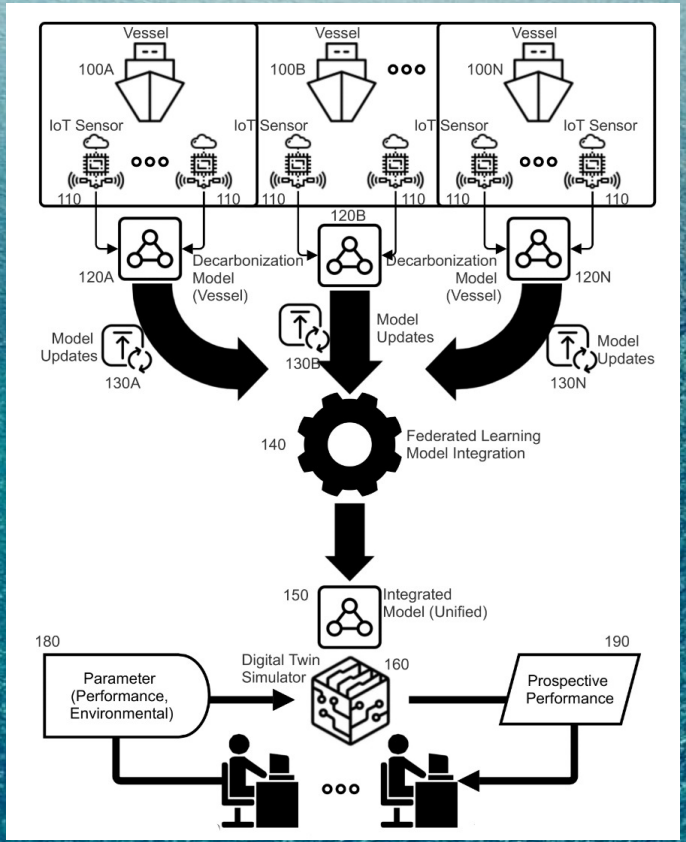


Envisaged DLCA pipeline

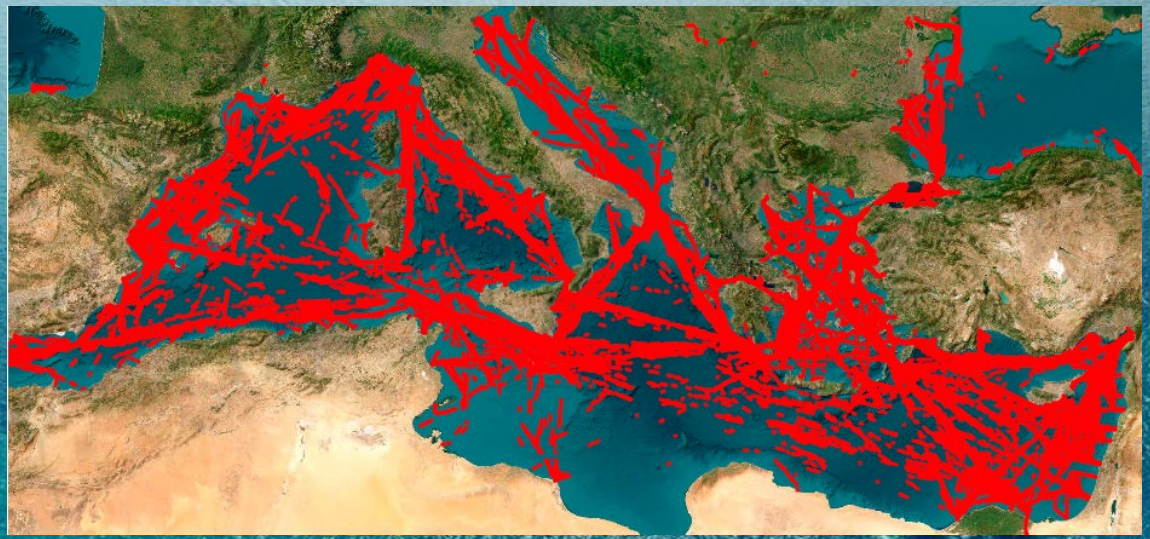
Tech trends & Beyond SOTA - Federation in the maritime sector

Main concepts and advantages:

- Exploitation of multiple datasets
- User engagement
- Model interoperability
- Transferability



Tech trends & Beyond SOTA - Trajectory Mining



Main concept

- Build a dense network of clusters containing historical routes
- Clusters correspond to different inherent attributes describing the routes (heading, speed adopted, traffic, regulatory compliance (ECA, SECA, CII, etc))
- Query the most “optimal” route utilizing this network based on a set of constraints

More here: “***Trajectory Mining and Routing: A Cross-Sectoral Approach”***

Conclusions & Future steps for shipping

The feasibility of international shipping decarbonization depends on:

- **The formulation of possible decarbonisation pathways, that will result to the required CO2 emission reduction ranging from 82-95% by 2035.**
- **Required reductions could be realised via alternative fuels and renewable energy.**
- **Technological measures are available to increase the energy efficiency of ships and could yield a substantial part of emission reductions.**

Additionally:

- **Government intervention can help to accelerate the commercial viability and technical feasibility of certain measures**
- **Financial incentives are essential to reduce the price gap between conventional and more sustainable fuel options.**

Thank you for your attention!

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