MOSES


50 years
1972 - 2022
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Preliminary Hazard Analysis for an Innovative Container Feeder Concept

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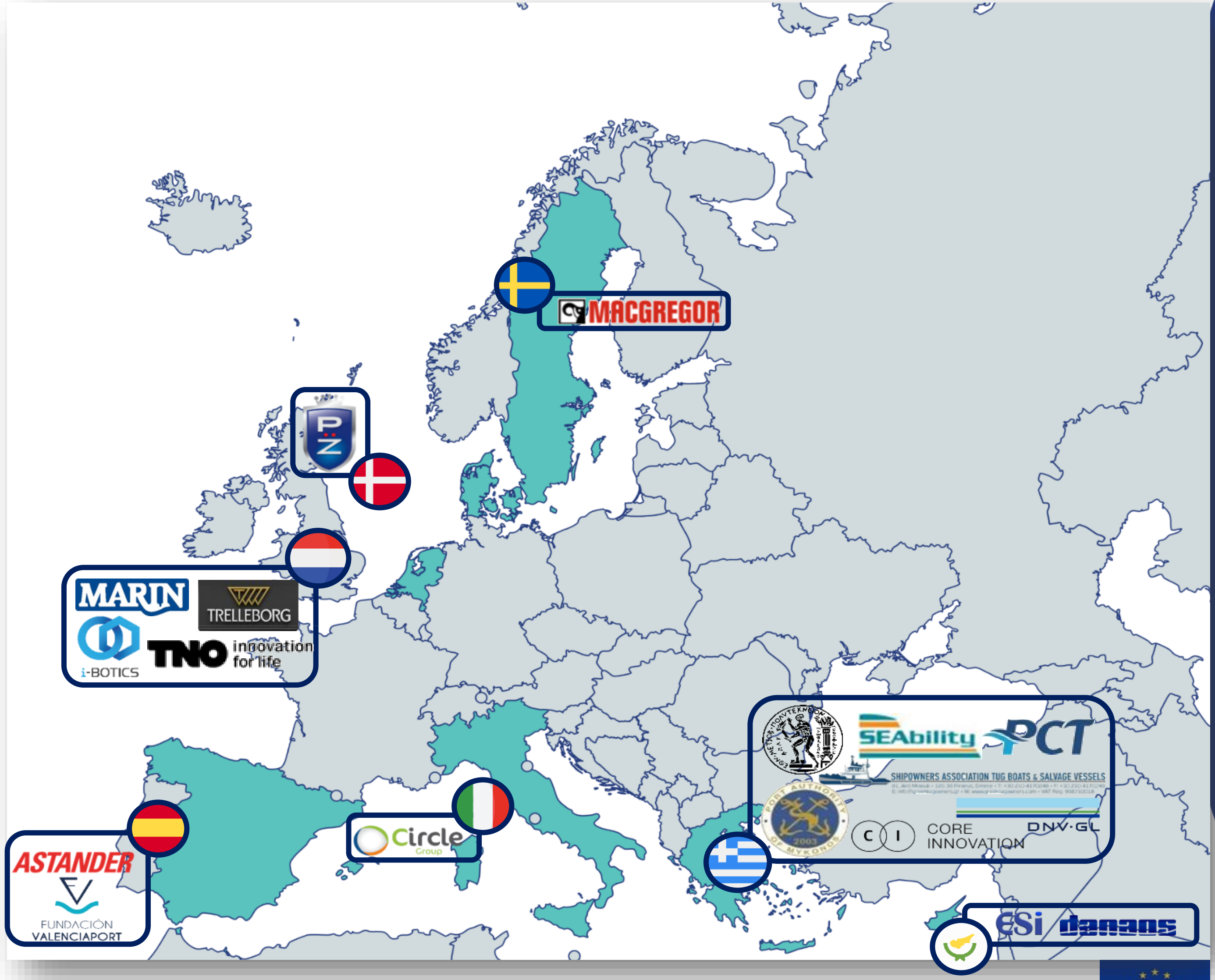
The MOSES project

Auto**M**ated Vessels and Supply Chain **O**ptimisation for Sustainable Short **SE**a **S**hipping

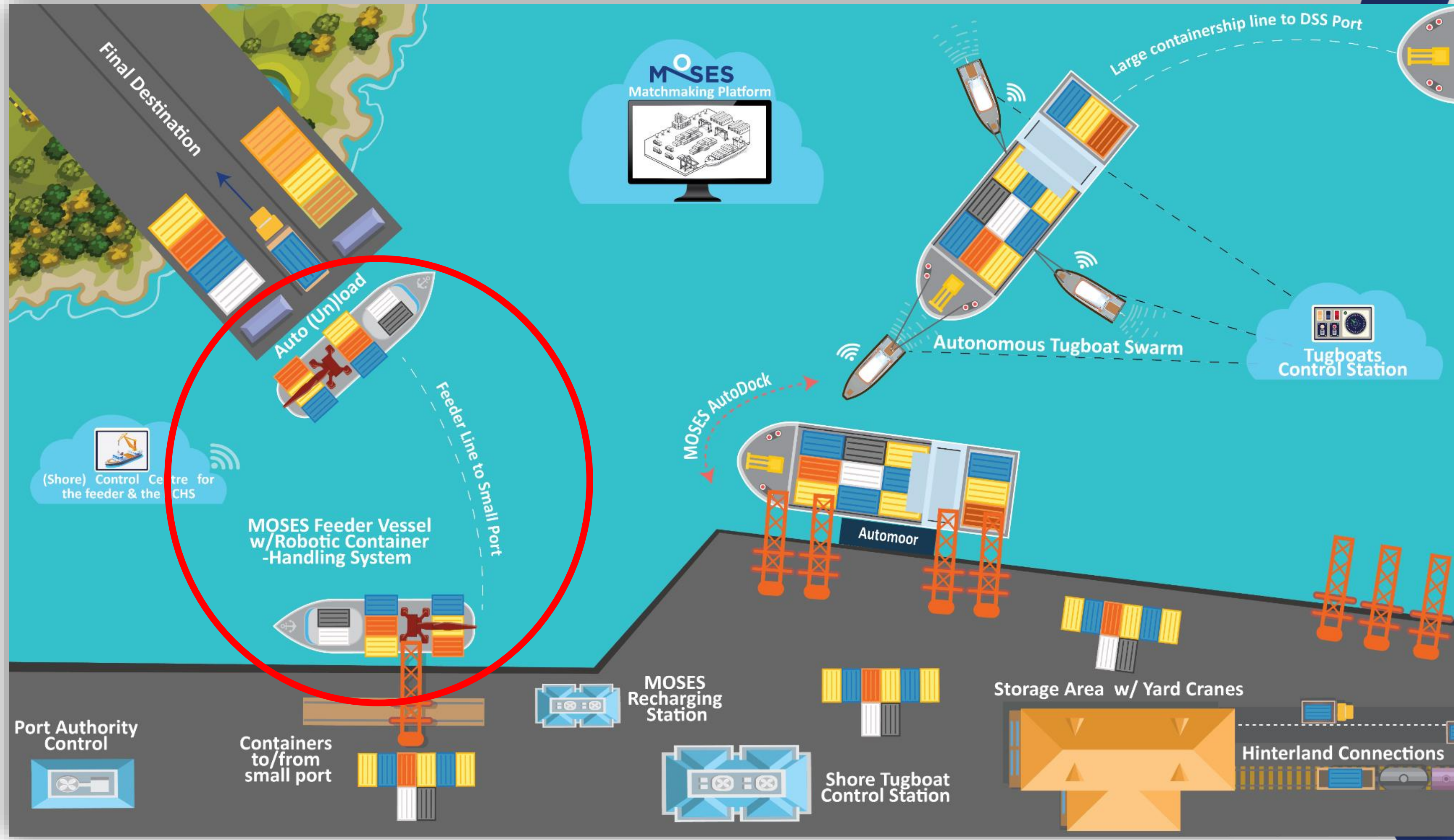
Significantly **enhance the SSS component** of the European container supply chain by **stimulating sustainable feeder services** to ports with limited or no infrastructure!



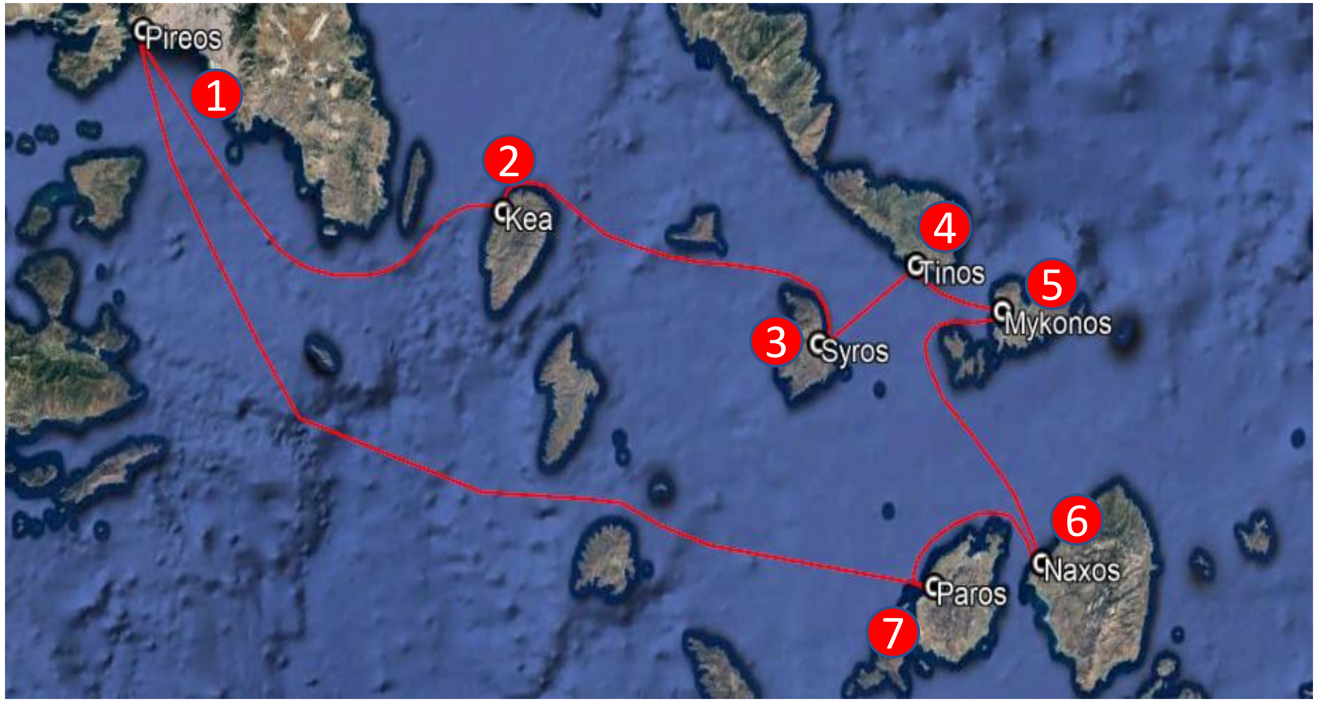
The MOSES project – Innovative Feeder

Innovations

- **Environmentally sustainable** propulsion for minimal emissions during **sailing**, (near) zero emissions **in port**
- **Highly-automated cargo handling** for independence from the availability of port services
- Envisioned future **autonomous functionalities**
- Based on a **different business model** → Direct container transport from terminals to small, non-feeder ports



The MOSES Innovative Feeder – Use cases



Eastern MED-Greece

Decongest Piraeus container terminal and integrate small Greek ports into the container supply chain

Western MED-Spain

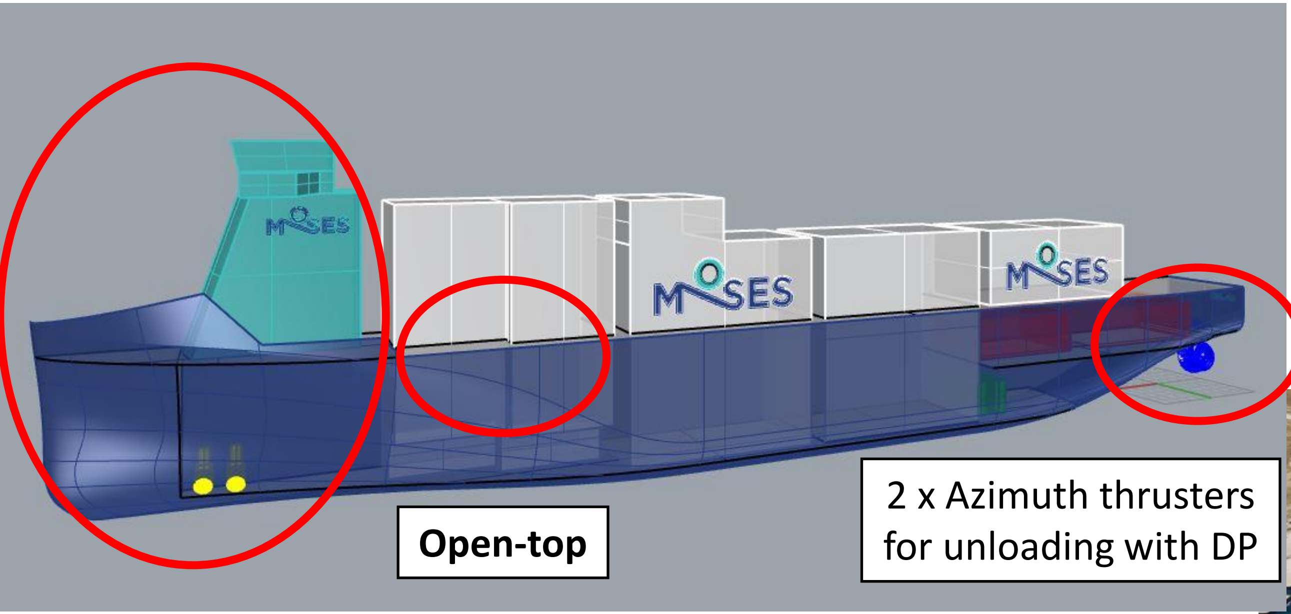
Decongest truck transport traffic in Valencia port and connect two Sagunto and Gandia satellite ports

Differences in operational context:

- Expected container demand → Capacity
- Round trip distance → Range and service speed

The MOSES Innovative Feeder – Greek I

Length, L_{BP} = 80 m
Capacity = 177 TEU
Design speed (T_{summer}) = 10 kn
Range = 266 nm



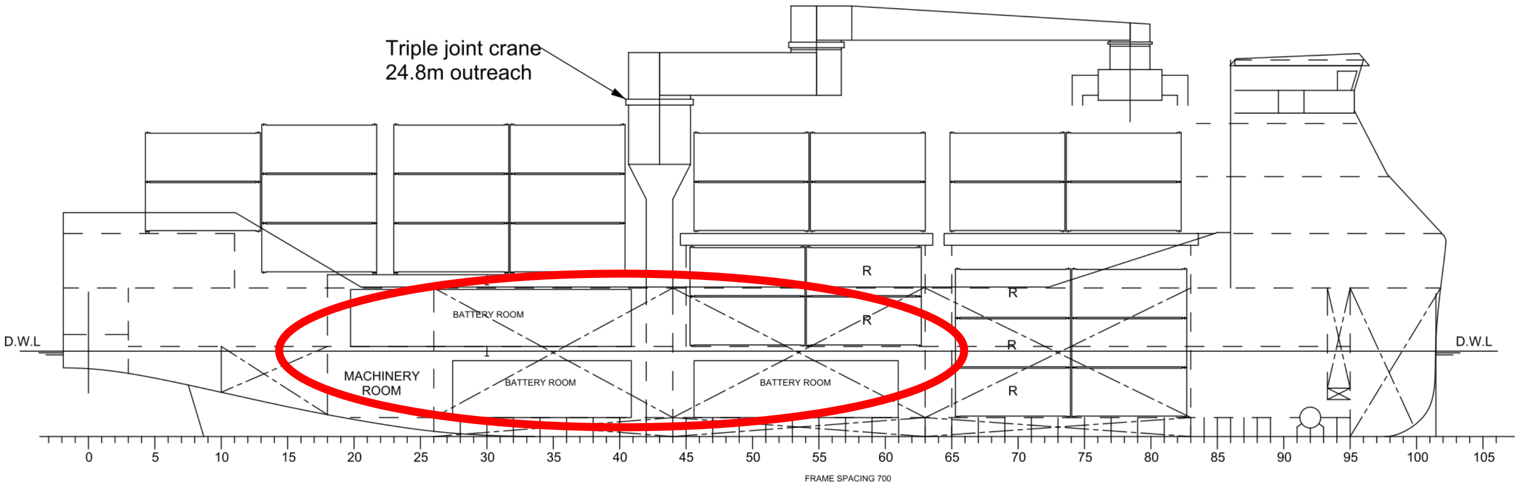
Open-top

2 x Azimuth thrusters
for unloading with DP

Bridge at fore for better visibility
Forecastle for preventing water ingress
(IMO Open-top Containerships guidelines (1994)

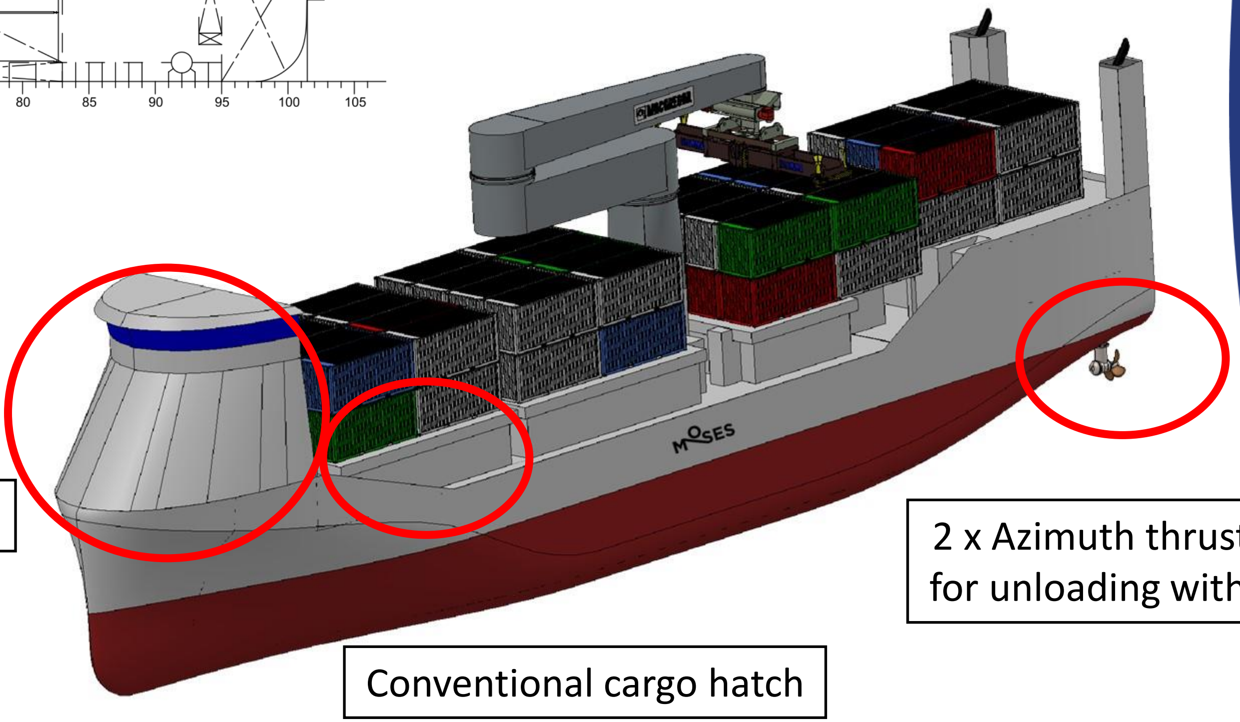
- Hybrid, methanol Internal Combustion Engine (ICE) and batteries
- Fully battery powered

The MOSES Innovative Feeder – Greek II



Length, L_{BP} = 71 m
Capacity = 106 TEU
Design speed (T_{summer}) = 10 kn
Range = 266 nm

- Hybrid, methanol Internal Combustion Engine (ICE) and batteries
- Fully battery powered

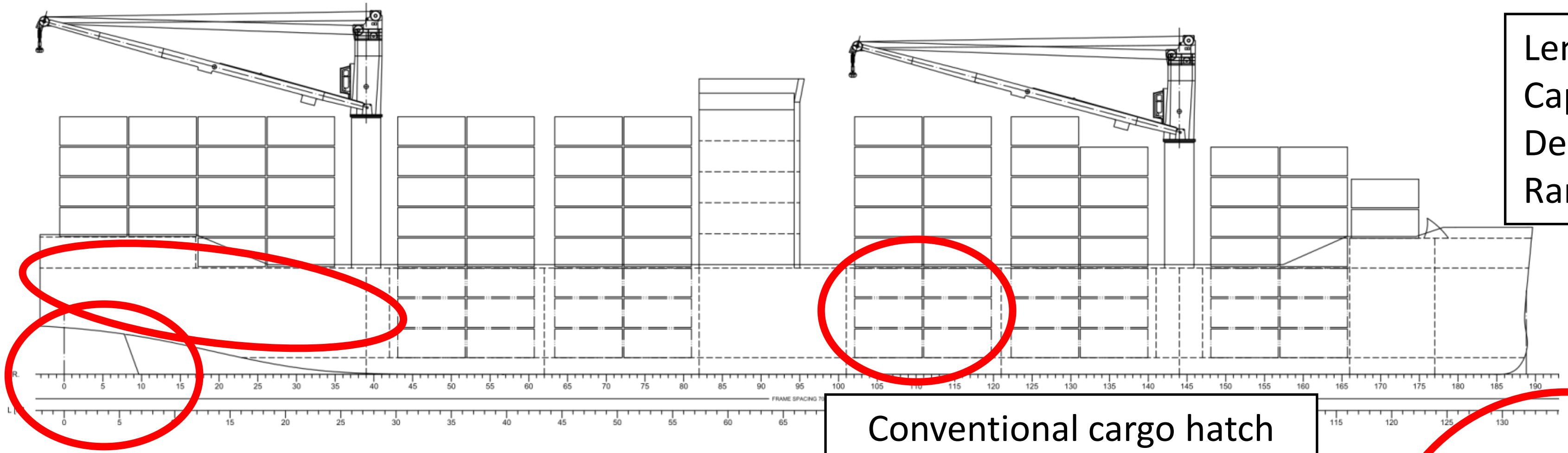


Bridge at fore for better visibility

Conventional cargo hatch

2 x Azimuth thrusters for unloading with DP

The MOSES Innovative Feeder – Spanish

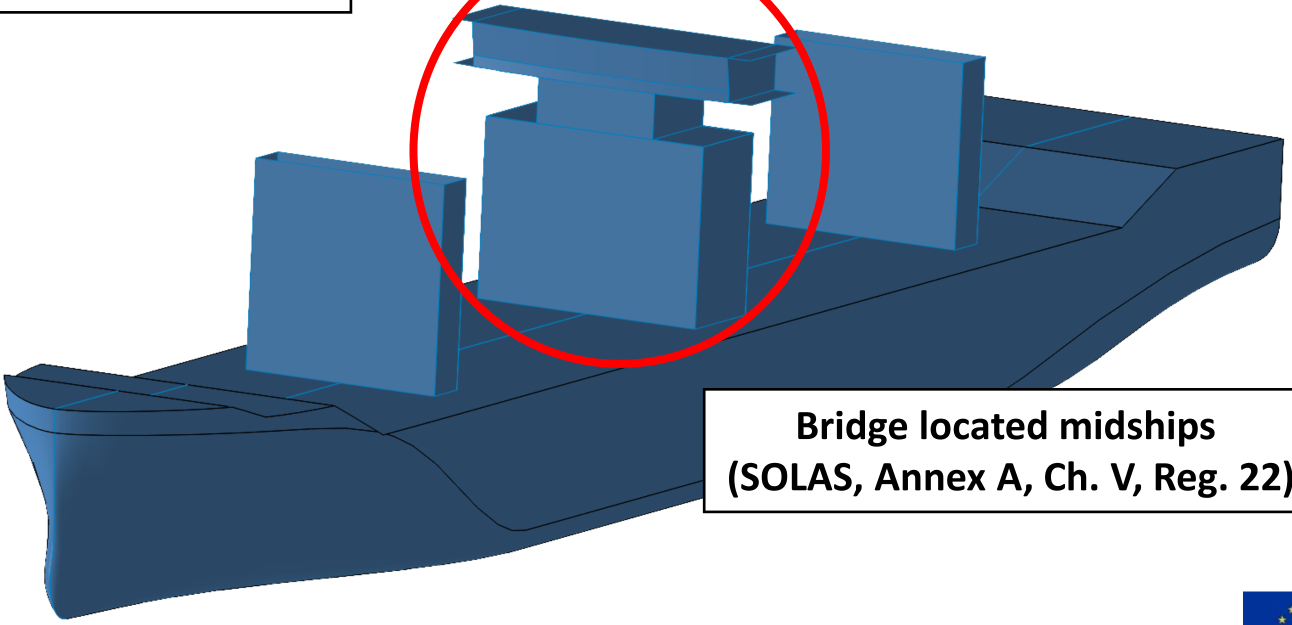


Conventional cargo hatch

Length, L_{BP} = 132 m
Capacity = 670 TEU
Design speed (T_{summer}) = 5 kn
Range = 85 nm

- Hybrid, methanol Internal Combustion Engine (ICE) and batteries
- Fully battery powered

- 2 x Azimuth thrusters for unloading with DP
- **Selected for sailing at 10 kn for additional power in bad weather conditions**



Bridge located midships (SOLAS, Annex A, Ch. V, Reg. 22)

The need for risk assessment in design

The maritime industry is currently searching for solutions to decrease emissions and increase efficiency for achieving sustainability goals

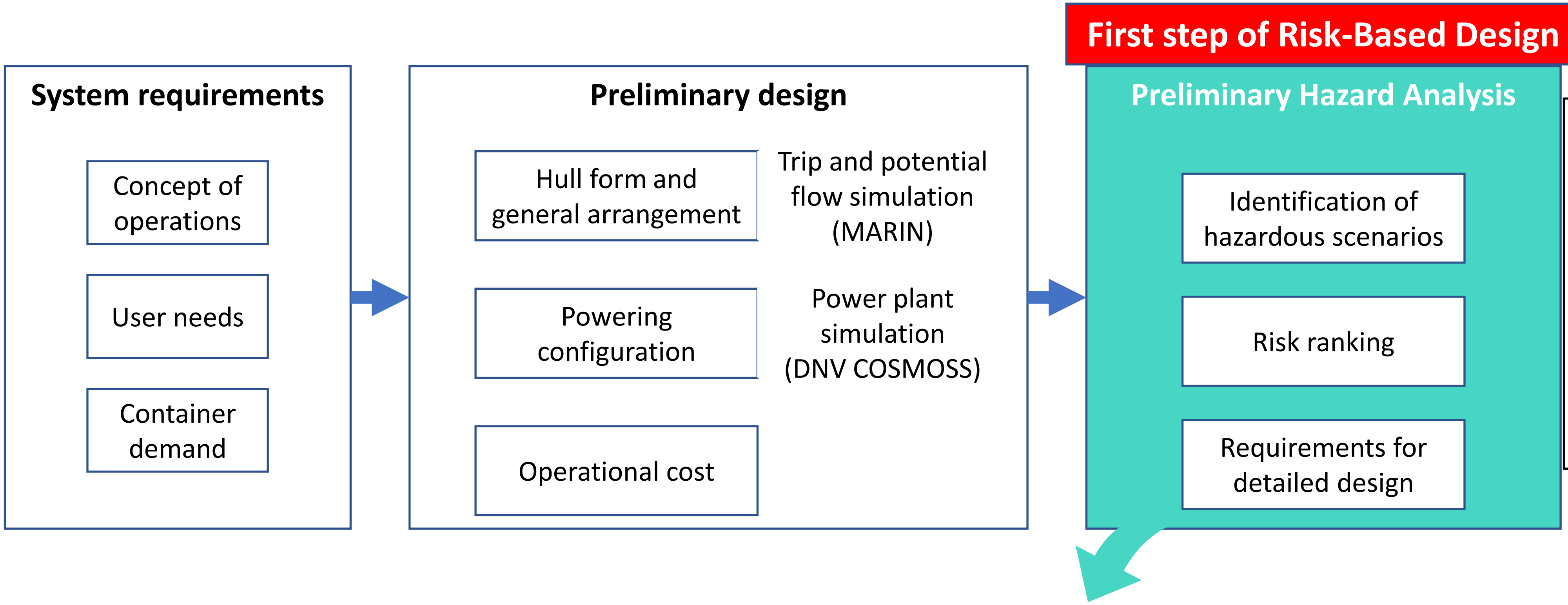
New vessel designs with innovations related to powering configurations and automation

- Design requirements for innovative solutions may not yet be in place
- **Risk-based design approaches** (see, e.g., Papanikolaou 2009; Lloyd’s, 2016) can provide evidence for approving safe operation

Risk assessment techniques applied from the early design stages - Examples:

- Autonomous, small passenger ferry - Preliminary Hazard Analysis (PHA) for risk-reducing measures (Thieme et al., 2019)
- Systems Theoretic Process Analysis (STPA) for autonomous ships at different autonomy levels (Ventikos et al., 2020)
    - Autonomous inland waterways ship - Hazard Identification (HAZID) that integrates safety and (cyber)-security (Bolbot et al., 2021)

Hazard analysis methodology



First step of Risk-Based Design

System requirements

- Concept of operations
- User needs
- Container demand

Preliminary design

- Hull form and general arrangement
- Powering configuration
- Operational cost

Trip and potential flow simulation (MARIN)

Power plant simulation (DNV COSMOSS)

Preliminary Hazard Analysis

- Identification of hazardous scenarios
- Risk ranking
- Requirements for detailed design

Typically used in the early stages of system design (Rausand 2011) for “**establishing the initial system safety requirements (SSRs) for design from preliminary and limited design information**” (Ericson 2005).

1. **Brainstorming expert sessions** → Hazards, hazardous events, worst case consequences, risk reducing measures
2. **Separate expert assessments for each hazardous event** → Frequency and consequence severity indices (FI, SI)
3. **Average of assessments** → Calculation of risk index (RI) for each hazardous event
4. Documentation in worksheet

Hazard analysis methodology

FI	Frequency	Definition	F (per year)
4	Frequent	Likely to occur several times per year	1
3	Reasonably probable	Likely to occur several times in the ship's lifetime	0,1
2	Remote	Likely to occur once in the ship's lifetime	0,01
1	Extremely remote	Unlikely to occur during the ship's lifetime	< 0,01

Matrices adapted from the IMO FSA Guidelines (2015)

The SI does not need to include damages in all categories

SI	Severity	Safety	Environment	Property	Supply chain
0	None	No injuries	No pollution	No damage to equipment, ship	No disruption
1	Minor	Single or minor injuries	Minor (local) pollution	Local damage to equipment, ship	Minor delays
2	Significant	Multiple or severe injuries	Significant pollution	Non-severe damage to ship	Significant delays
3	Severe	Single fatality or multiple severe injuries	Severe pollution, contained locally	Severe damage to ship	Severe delays
4	Catastrophic	Multiple fatalities	Severe pollution, not contained	Total loss	Cargo delivery disrupted

Four different RIs have been calculated

FI	Frequency	Severity (SI)			
		1	2	3	4
		Minor	Significant	Severe	Catastrophic
4	Frequent	5	6	7	8
3	Reasonably probable	4	5	6	7
2	Remote	3	4	5	6
1	Extremely remote	2	3	4	5

No acceptability criteria have been used – comparative ranking

High-Risk

Preliminary Hazard Analysis – Scope

System component

- Engine and propulsion machinery
- Fuel/energy storage system
- Cargo space
- Accommodation superstructure

Operational phases

- Sailing (open sea, shipping lane, port manoeuvring)
- Cargo operations during (un)loading at berth

Types of hazards

System complexity

Market volatility and variability

Extreme weather

Energy source

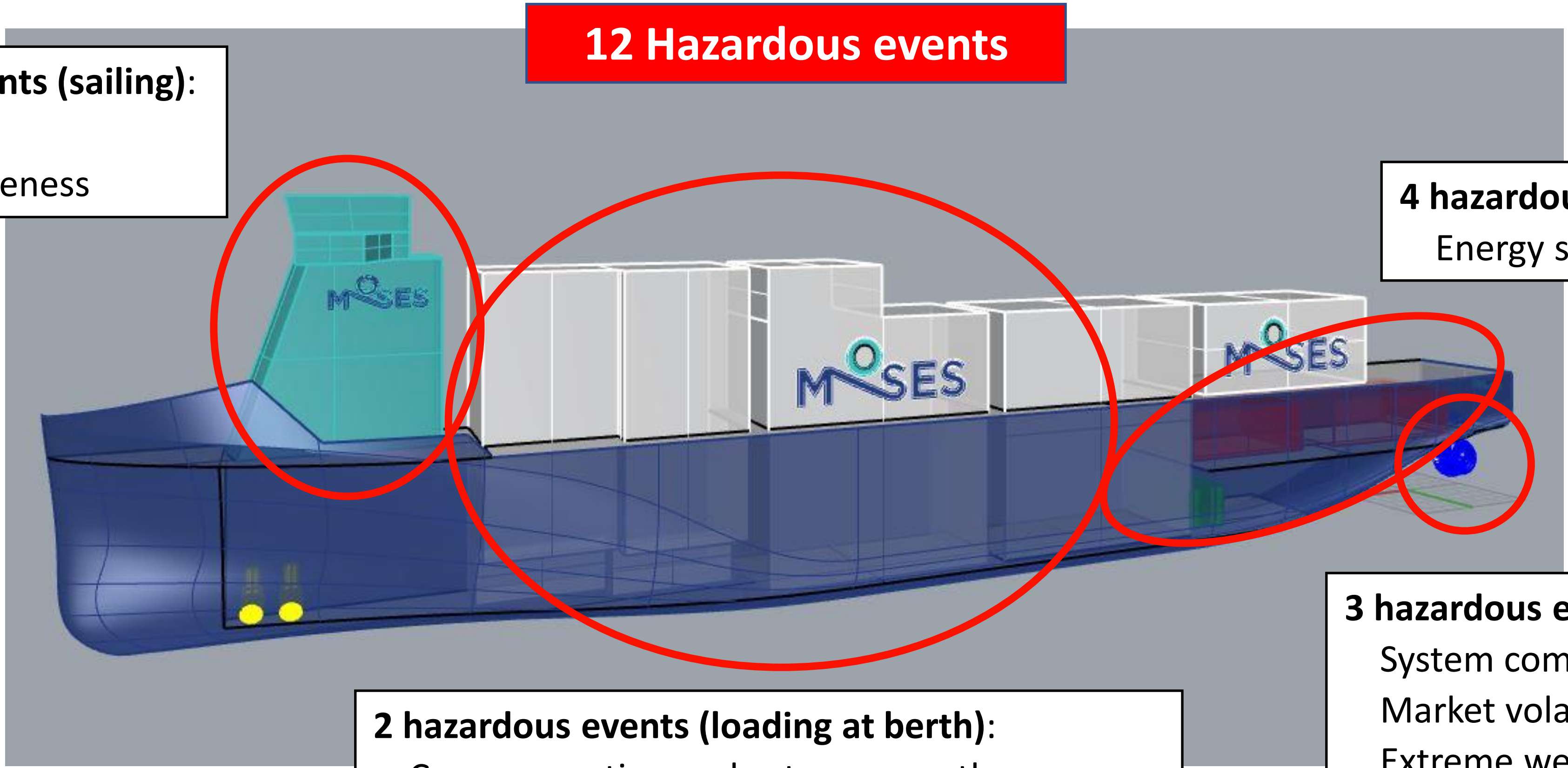
Crane operation

Evacuation

Situation awareness

Preliminary Hazard Analysis – Results

12 Hazardous events



2 hazardous events (sailing):
- Evacuation
- Situation awareness

4 hazardous events (sailing):
- Energy source

2 hazardous events (loading at berth):
- Crane operation and extreme weather

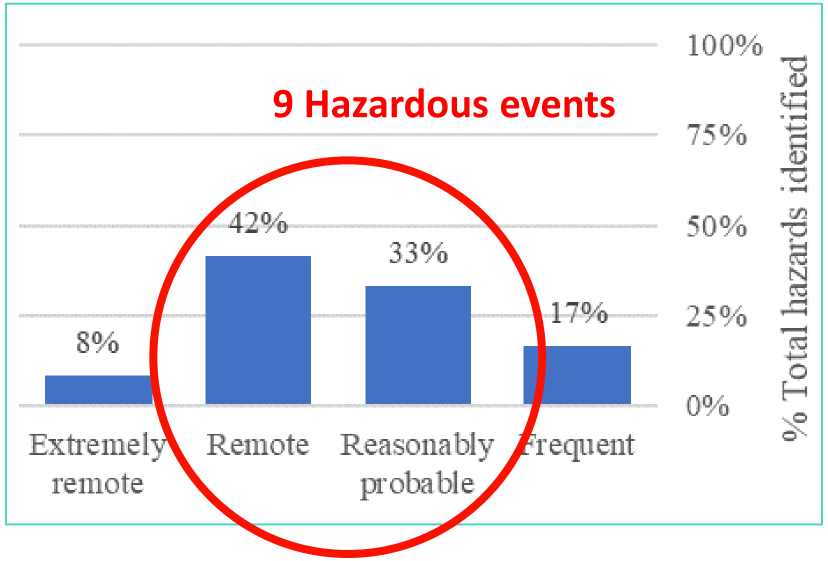
1 hazardous event (sailing):
- Water ingress in extreme weather conditions

3 hazardous events (all, sailing):
- System complexity
- Market volatility/variability
- Extreme weather

*** Hazards apply for all three concept designs**

Preliminary Hazard Analysis – Results

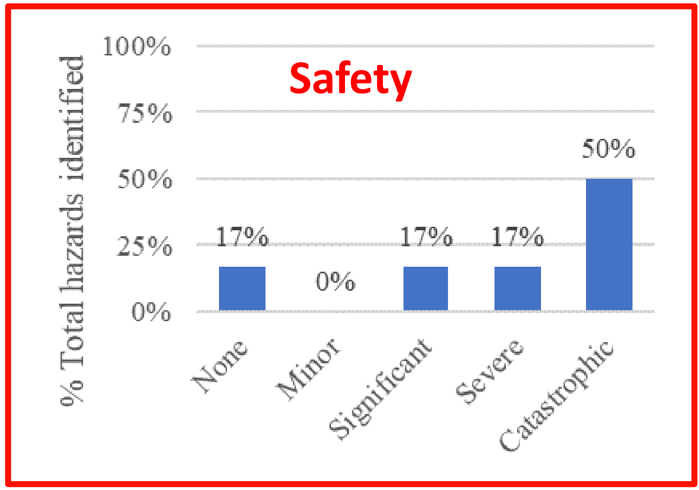
Frequency

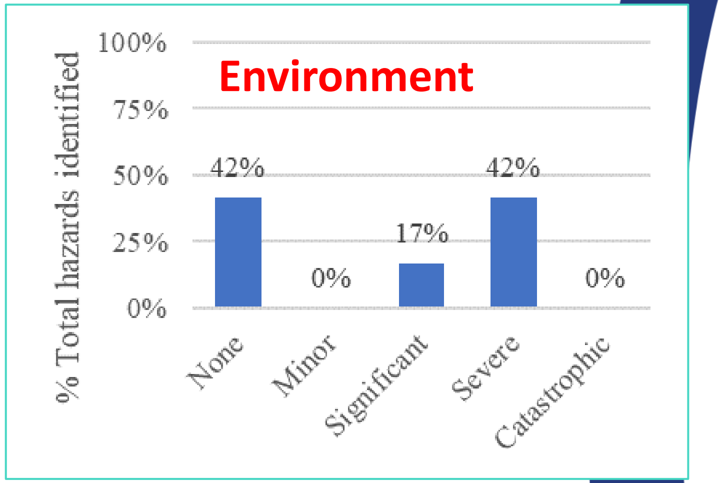


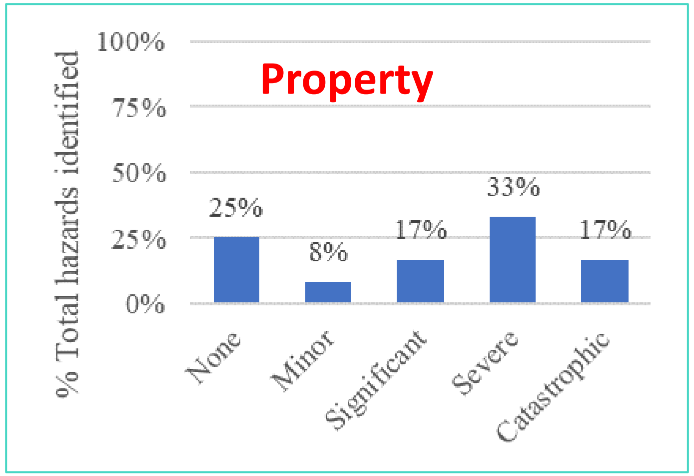
Most frequently expected:

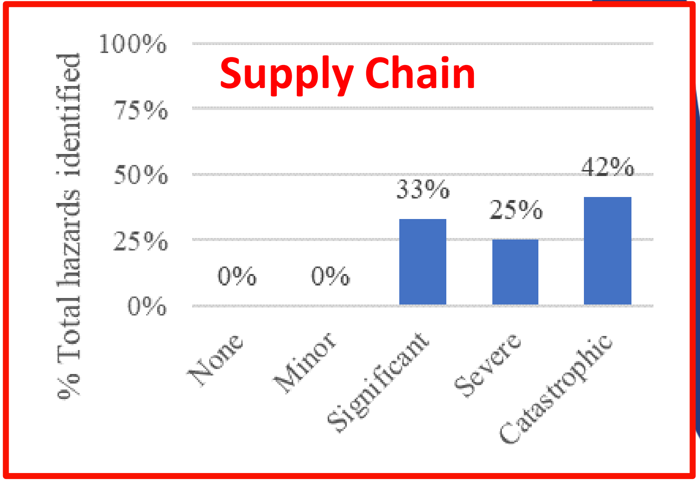
- Position of the container crane on board impedes operation of port cranes
- Water accumulates in cargo hold in harsh weather conditions due to open top design

Consequence severity



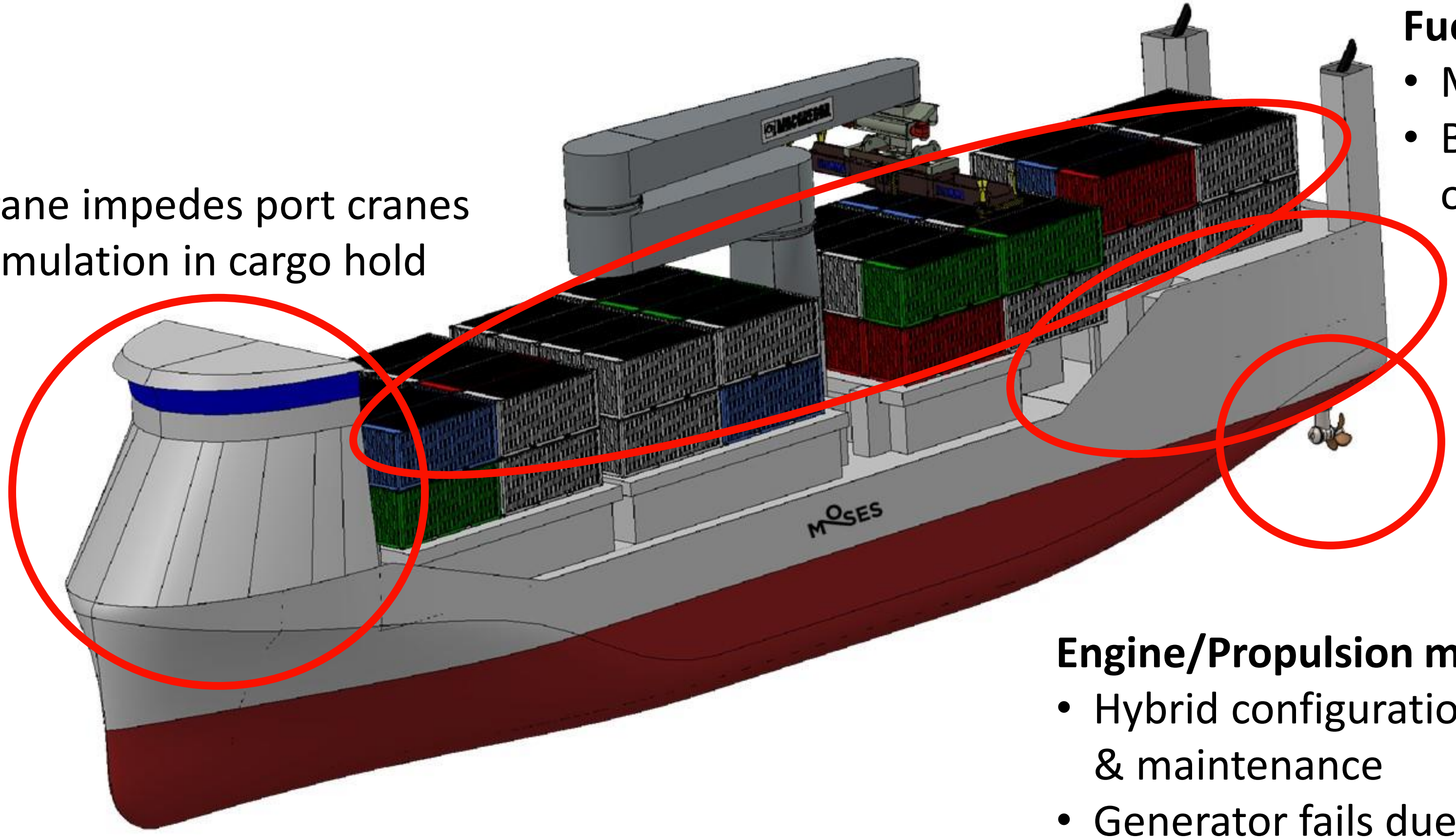






Preliminary Hazard Analysis – Results

9 High risk events / system component



Cargo space:
- Onboard crane impedes port cranes
- Water accumulation in cargo hold

Fuel/Energy storage:
- Methanol leakage
- Batteries overheating

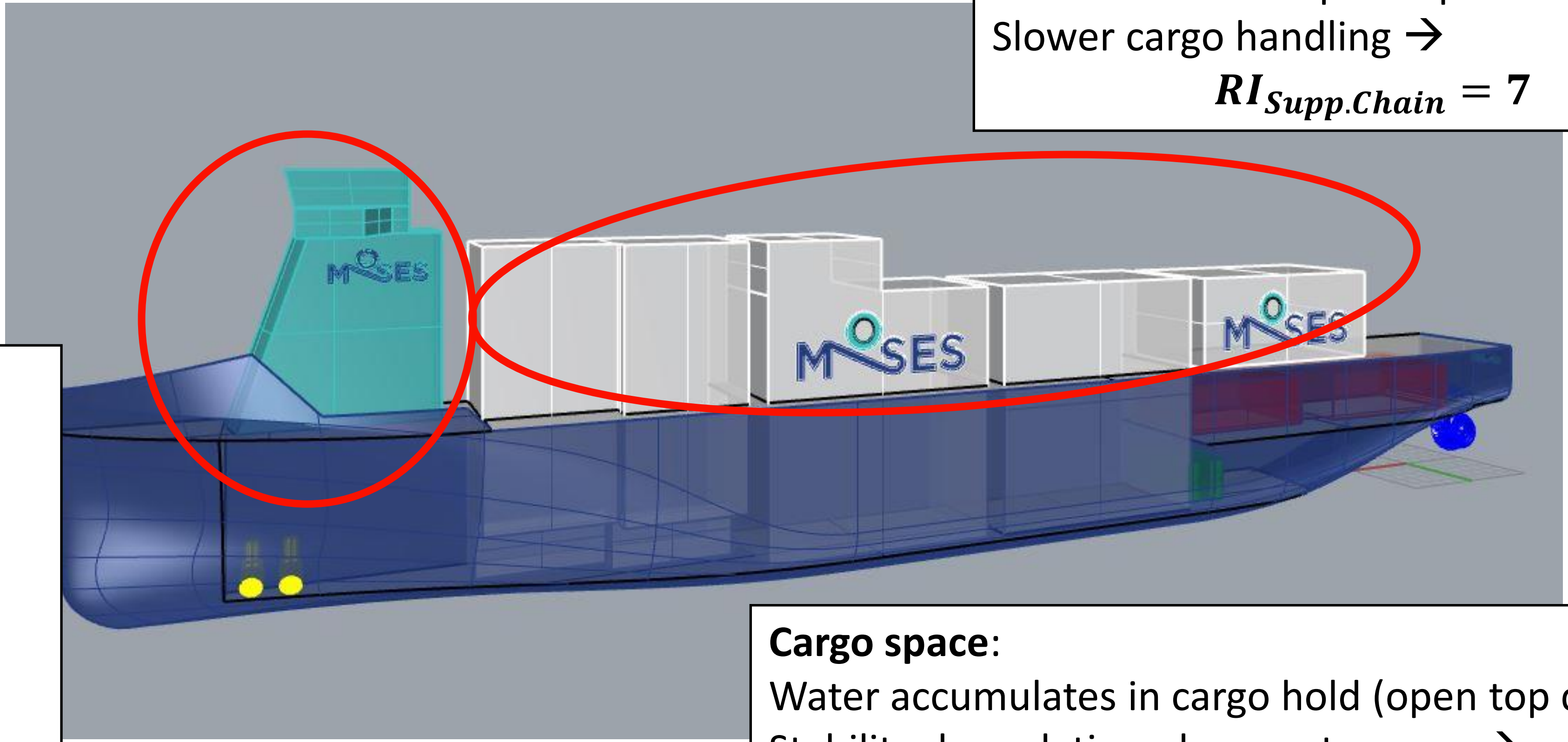
Accommodation:
- Mustering process takes too long
- Limited visual monitoring of the cargo space

Engine/Propulsion machinery:
- Hybrid configuration operation & maintenance
- Generator fails due to load variations in extreme weather
- Design speed too specific

*** Hazards apply for all three concept designs**

Preliminary Hazard Analysis – Results

3 Highest risk events / system component



Cargo space:
Onboard crane impedes port cranes →
Slower cargo handling →
$$RI_{Supp.Chain} = 7$$

Accommodation:
Limited visual monitoring of the cargo space →
Fire, cargo shift/loss not detected →
$$RI_{Safety} = 7$$

Cargo space:
Water accumulates in cargo hold (open top design) →
Stability degradation, damage to cargo →
$$RI_{Safety} = RI_{Property} = RI_{Supp.Chain} = 8$$

*** Hazards apply for all three concept designs**

Considerations for more detailed design

Engine and Propulsion Machinery Requirements

Hazard	**Hazardous event**	**Risk reducing measure**
Hybrid configuration is complex	Technical failures cannot be handled by the crew onboard	**Optimal manning** related to automation level
Extreme weather conditions	Generator system fails due to inability to cope with load variations	The battery system, the power and battery management systems should be designed to **cope with transient loading** efficiently and safely, providing **sufficient power redundancy** in different conditions

Considerations for more detailed design

Fuel/ Energy Storage System Requirements

Hybrid (Methanol ICE + batteries)

Methanol-related risks are covered extensively by:

- Interim Guidelines for the Safety of Ships using Methyl/Ethyl alcohol as fuel (IMO 2020) – **double wall piping, fuel handling system isolation**
- Class notations and Guidelines (ABS, 2022), (DNV, 2019) – **bunkering connections**

Additional risk reduction:

- **Optimal manning level** to avoid methanol leakage near hot surfaces in Engine room

Hybrid and fully Electric

- **Fire-proof** battery room (Class standards)
- **Detailed risk assessment** for the system arrangement

Fully Electric

- Energy storage requirements (**23-37 MWh**) > 4 x battery capacity on Yara Birkeland (NRP, 2021)
- Likely occurrence of hazardous situations not covered by Class requirements

Considerations for more detailed design

Accommodation Superstructure Requirements

- Bridge **360^0 visibility and sensors** for monitoring cargo space
- **Relative position to machinery, fuel handling, and batteries →** requirements from DNV LFL class notation and IMO IGF Code
- **Relative position to LSAs →** detailed risk analysis for crew access and compliance with IMO Evacuation Analysis (SOLAS Reg. III/31.1.4)

Cargo Space Requirements

- **Crane position optimization** and detailed risk assessment in accordance with, e.g., class notation Crane (DNV, 2017)
- **Safe cargo operations without with DP →** additional hazard identification
- **Water accumulation in cargo hold** covered by:
  - **Hatchcoverless Class notation** (DNV, 2017)
  - Model testing and Intact and Damage stability assessment – **IMO Interim Guidelines for Open-top Containerships (1994)**
  - **IACS rules**: Open top container holds – Water supplies, – Ventilation, – Bilge Pumping (2022)

Conclusions

Issues covered by existing international regulations and class rules:

- Methanol as fuel and batteries as energy source
- Evacuation effectiveness with respect to the position of the accommodation superstructures
- Stowage of the onboard crane during sailing
- Water accumulation in cargo holds in extreme weather due to open-top design

More detailed risk assessment required for:

- Optimal manning as a function of the targeted automation level
- Situation awareness from the bridge
- (Un)loading without using mooring lines through DP
- Handling load variations in extreme weather conditions

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Thank you for your attention!

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A typical container feeder

Small feeder: 300 – 1000 TEU

Feeder: 1000 – 2000 TEU

Feedermax: 2000 – 3000 TEU

Typically geared: 1/3 of very small ships (100 – 499 TEU) and 60% of feeders (1500 – 2499 TEU)

Max service speed 20 kn – slower than large container ships

Bridge typically positioned aft