Safe storage of hydrogen for power generation onboard naval vessels via LOHC

Engine as a Weapon XI
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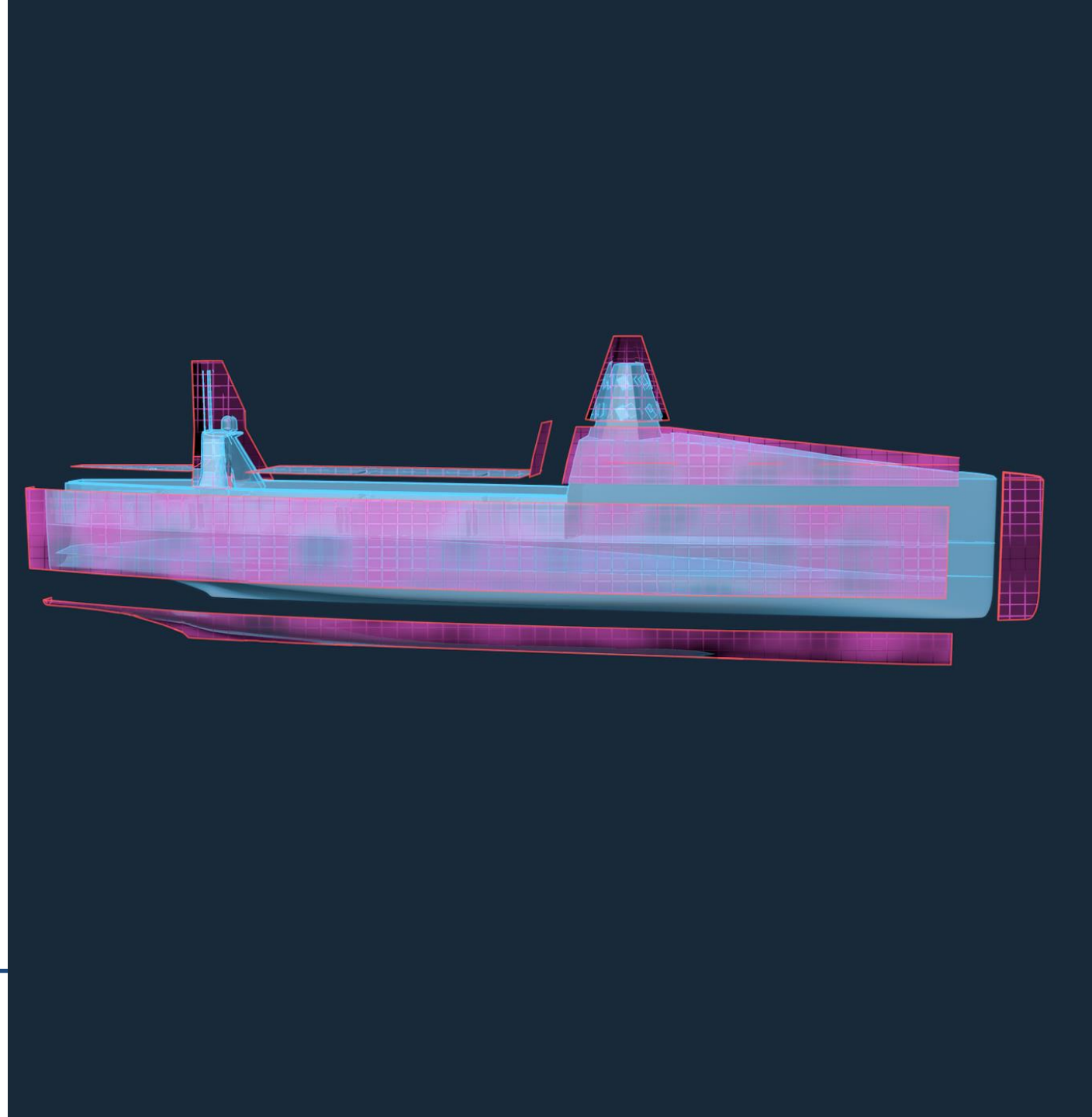

Introduction

- Maritime accounts for ~2-3% global GHG emissions [1,2].
- IMO strategy
  - 20 – 40% reduction by 2030 (2008 baseline)
  - 5 – 10% alternative fuels by 2030
  - 70 – 80% reduction by 2040 (2008 baseline)
  - Net Zero by ~2050

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[1] Sector by sector: where do global greenhouse gas emissions come from? - Our World in Data
[2] REVIEW OF MARITIME TRANSPORT 2023 - Chapter 3: Decarbonizing shipping

Introduction

- Difficulty in following commercial maritime future fuel.
- Hydrogen is key to creating any synthetic fuel.
- Focus on generation after next.
- How could hydrogen be used on a naval vessel?

Fuel Options

	Hydrogen, H_2	Liquified Natural Gas (LNG), CH_4	Ammonia, NH_3	Methanol, CH_3OH	LOHC, DBT	REFERENCE (MGO)
With Tank (Gross) Volumetric Energy Density (MJ/L)	2.7 – 7.9	13.2	11.5	14.2 – 15.1	6.85	27.3 – 31.0
General Storage Conditions	Cryogenic (or Pressurised)	Cryogenic	Cryogenic (or Pressurised)	Ambient	Ambient	Ambient
Space Requirement	7.7 – 15.7	3.2	3.4 – 6.4	2.3	4.2	1.0
Flash Point	-253°C	-162°C	-33°C	+12°C	~200°C	+61.5°C
Flammability Limits in air (vol%)	4.0 – 75.0	5.3 – 15.0	15.0 – 28.0	7.3 – 36.0	Not flammable	0.7 – 5.0
Minimum Ignition Energy in air (mJ)	0.02	0.29	8.0	0.14	Not flammable	20.0
Explosion Risk	Large flammability range with low ignition energy	Medium flammability range with reasonable ignition energy	Medium flammability range with high ignition energy	Medium flammability range with reasonable ignition energy	Not flammable	Small flammability range with high ignition energy
Toxicity	None	None	Highly toxic to humans and aquatic life	Toxic to humans, but very low-toxicity to aquatic life	Potentially toxic to aquatic life	Toxic to aquatic life
Combustion Emissions	**NOx**	**NOx & lower COx**	**NOx**	**NOx & lower COx**	**NOx**	**COx, NOx, SOx & PM**

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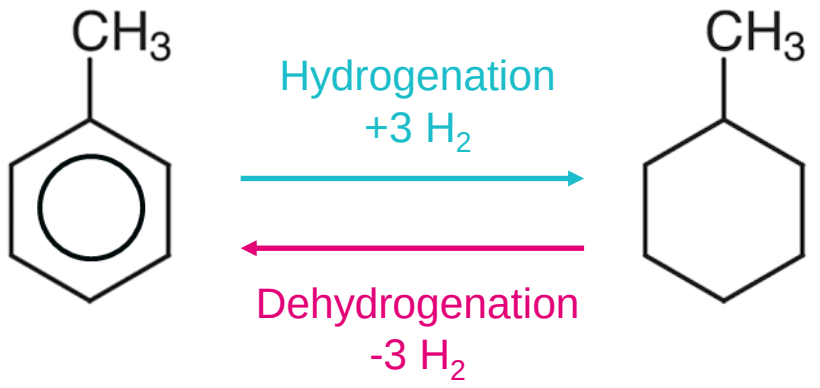
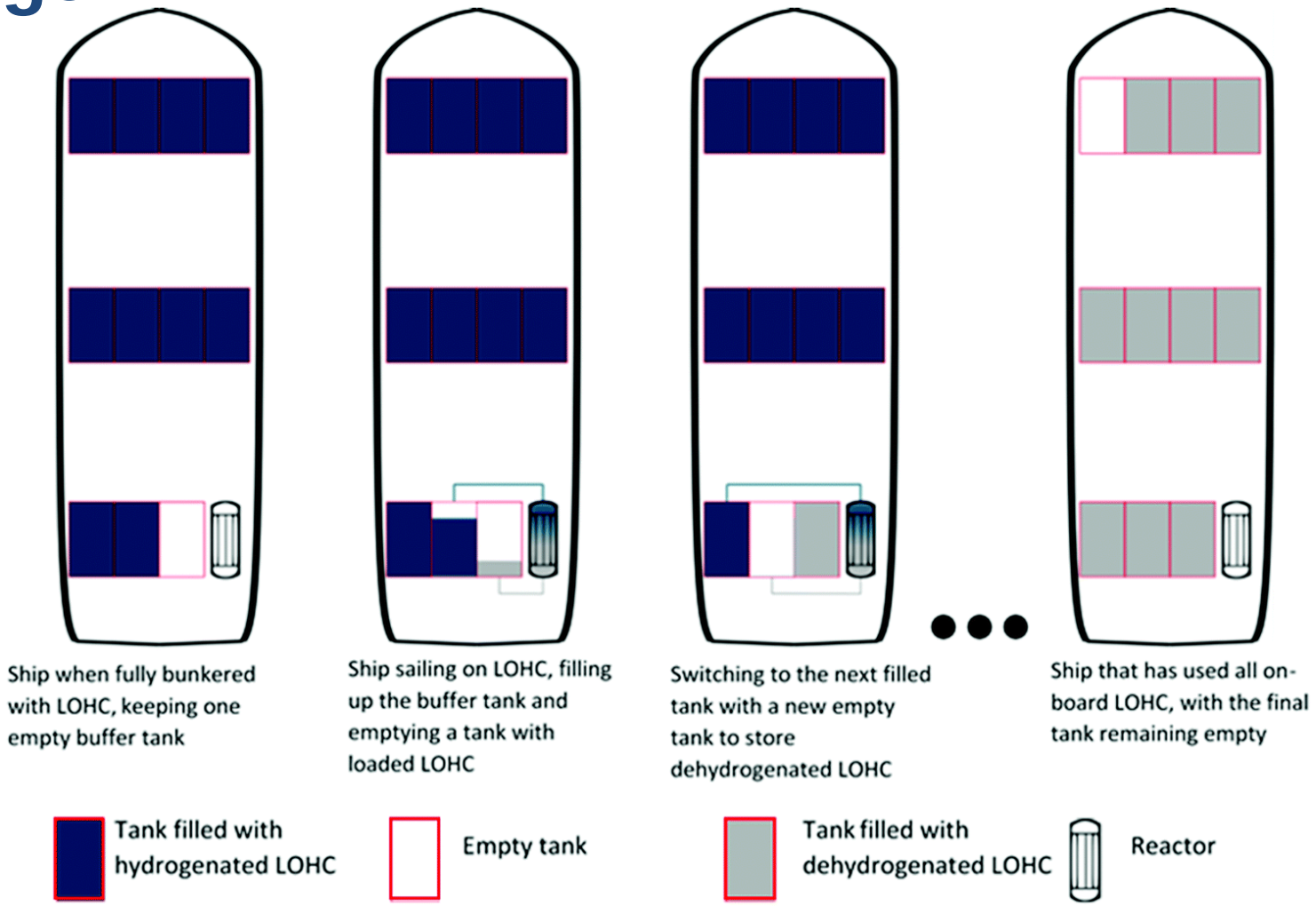
What is LOHC?

- LOHC is a carbon-based chemical that transports hydrogen.
- Generally aromatic compounds but anything with carbon-carbon double/triple bonds would work.
- Cyclic in nature, which means no carbon emissions at use.
- Plethora of potential research

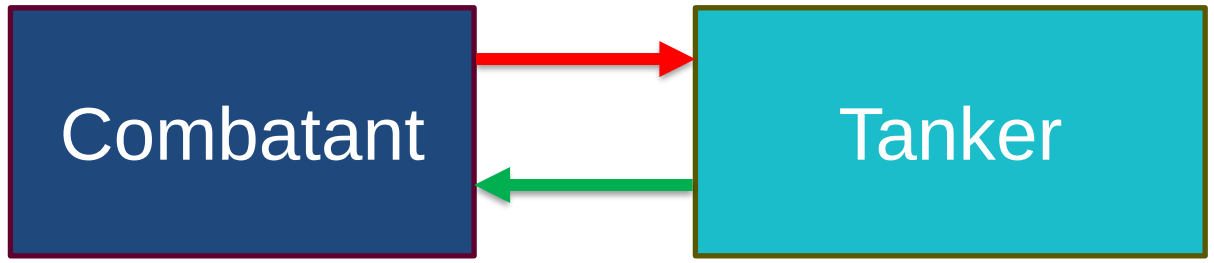


Cyclic fuel storage

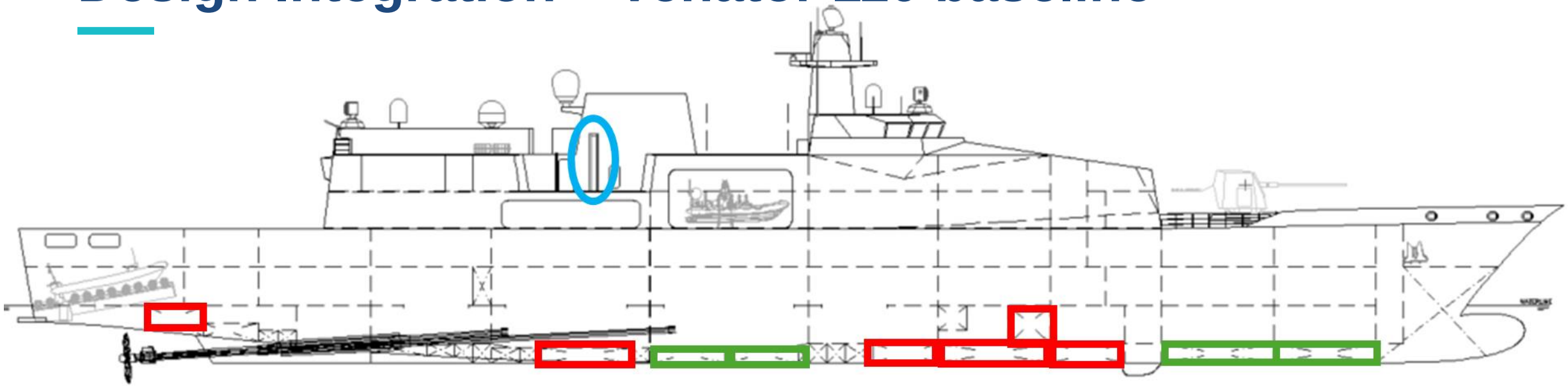


Challenges

- RAS of dehydrogenated form.
- Energy density reduction.
- Up to 25% energy stored to dehydrogenate.

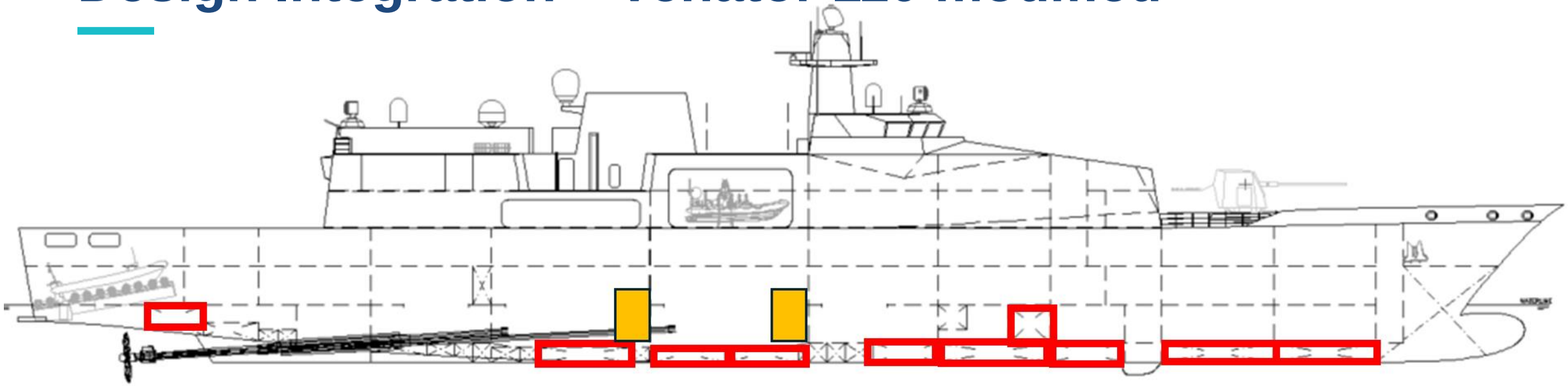


Design Integration – Venator 110 baseline



- Fuel tankage – currently 635 m^3 for F76
- RAS equipment – receive only
- Prime movers – diesel only

Design Integration – Venator 110 modified



- Increased fuel tankage – 860m^3 by repurposing ballast tanks – optimal size 40m^3
- Dehydrogenation equipment located near prime mover
- RAS equipment – send and receive
- Prime mover modifications or replacement

Conclusions

- LOHC can be safer than other future fuels.
- Repurpose ballast tanks for additional capacity.

- Requires supply chain to be created though.
- Require two-way RAS to refuel.
- Impact on range/endurance – reduction of ~3.4.
- Potential to be used for auxiliary power

- What requirements are willing to exchange in the future?

Thank you

Any questions or queries please email me at:
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