Hydrogen-Hybrid Zero-Emission Research Vessel

UNOLS Spring Council
17 April 2024
Bruce Appelgate

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

Acknowledgments: We are grateful for support and collaboration

Research vessels operated by Scripps Institution of Oceanography are part of the US Academic Research Fleet, a major facility supported by the National Science Foundation under awards that include OCE-1827444, OCE-1827415, OCE-1827383, OCE-1923051, and OCE-1823600.

Material presented here is based upon work supported by the Office of Naval Research under Awards N00014-22-1-2765 and N00014-16-1-2745. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the Office of Naval Research.

Zero-emission feasibility studies have been supported by the U.S Department of Transportation Maritime Administration (MARAD) Maritime Environmental and Technical Assistance (META) program.

Major funding for the zero-emission hydrogen hybrid Coastal Class Research Vessel has been provided by the State of California through SB 129, signed by Governor Gavin Newsom in 2021.

Hydrogen-hybrid zero-emission research vessel

Oceanographic research vessel for coastal / regional operations

75% of missions can be zero-emissions using hydrogen --- **fossil free**

When using hydrogen:

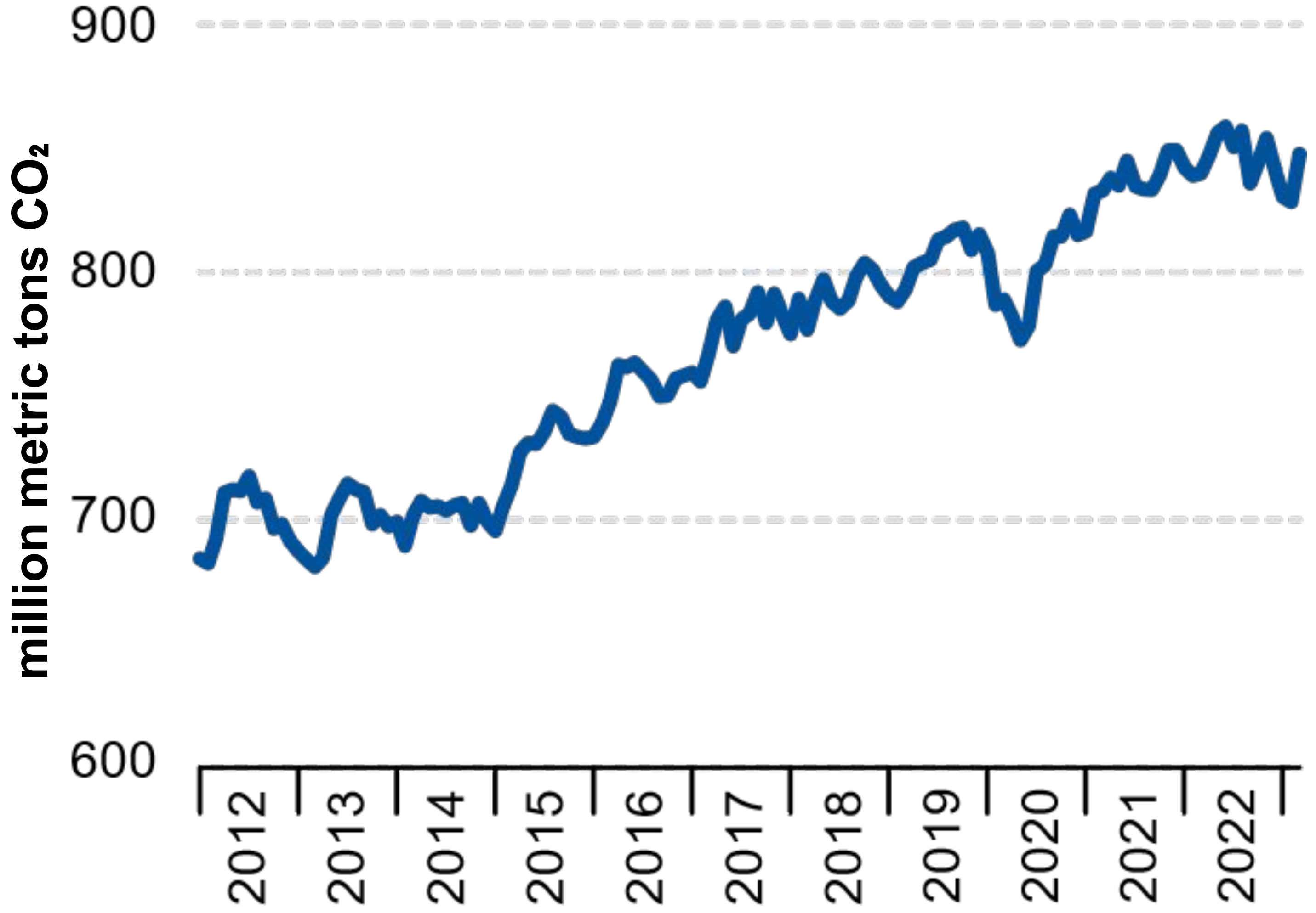
- Uses clean hydrogen: **No fossil fuels!**
- Zero emissions: **Clean / no GHGs!**
- All-electric propulsion: **Quiet!**
- **Feasible** with existing safe technology
- Outstanding scientific capabilities
- Designed for University of California's educational and R&D needs

If ship emissions were a country…

Worst global CO_2 emitters (million metric tons CO_2)

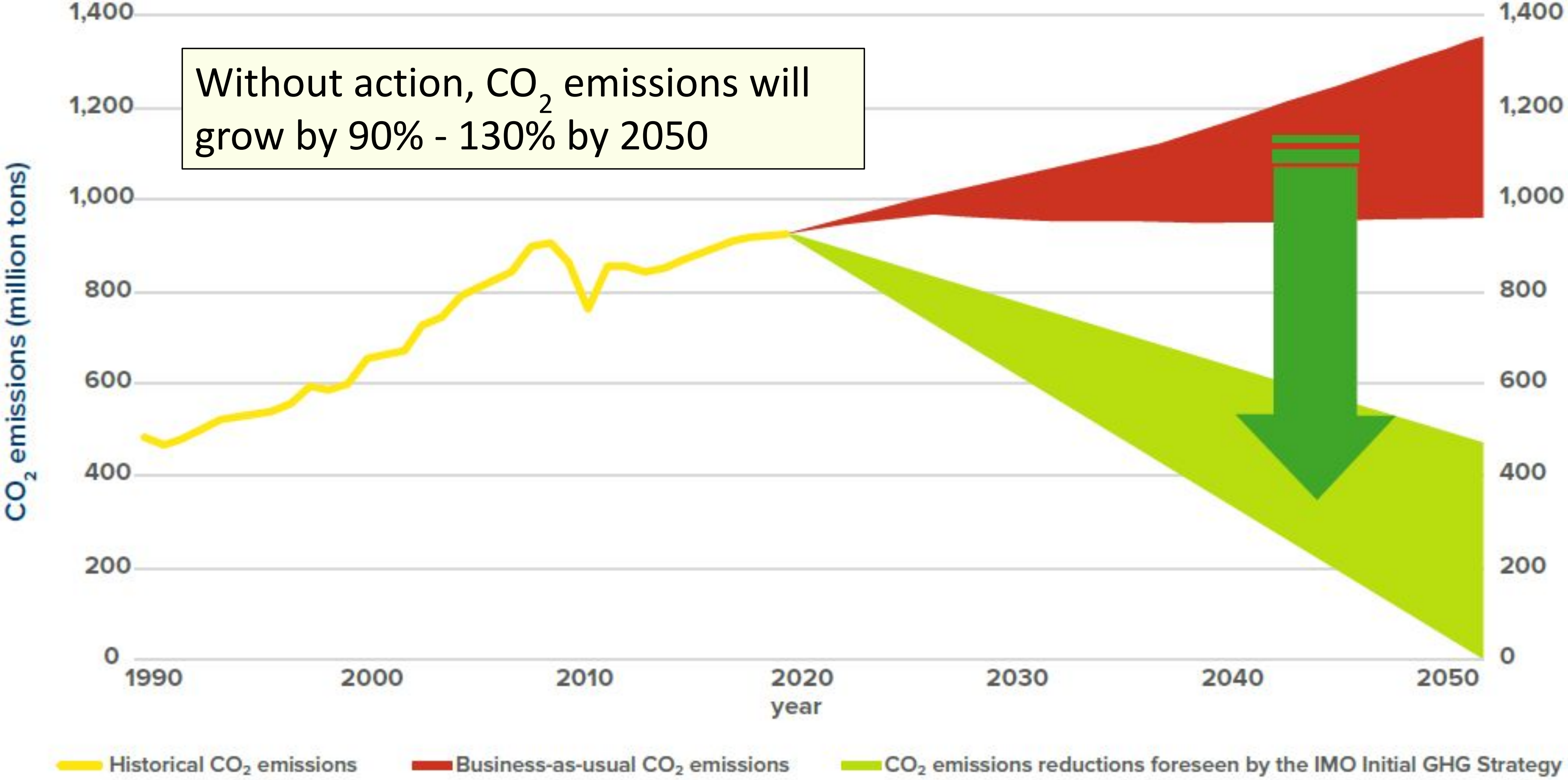
1. China 11,680
2. United States 4,535
3. India 2,412
4. Russia 1,674
5. Japan 1,062
6. **Ships 850**
7. Iran 690
8. Germany 637
9. South Korea 621
10. Saudi Arabia 589

Carbon dioxide emissions from ships



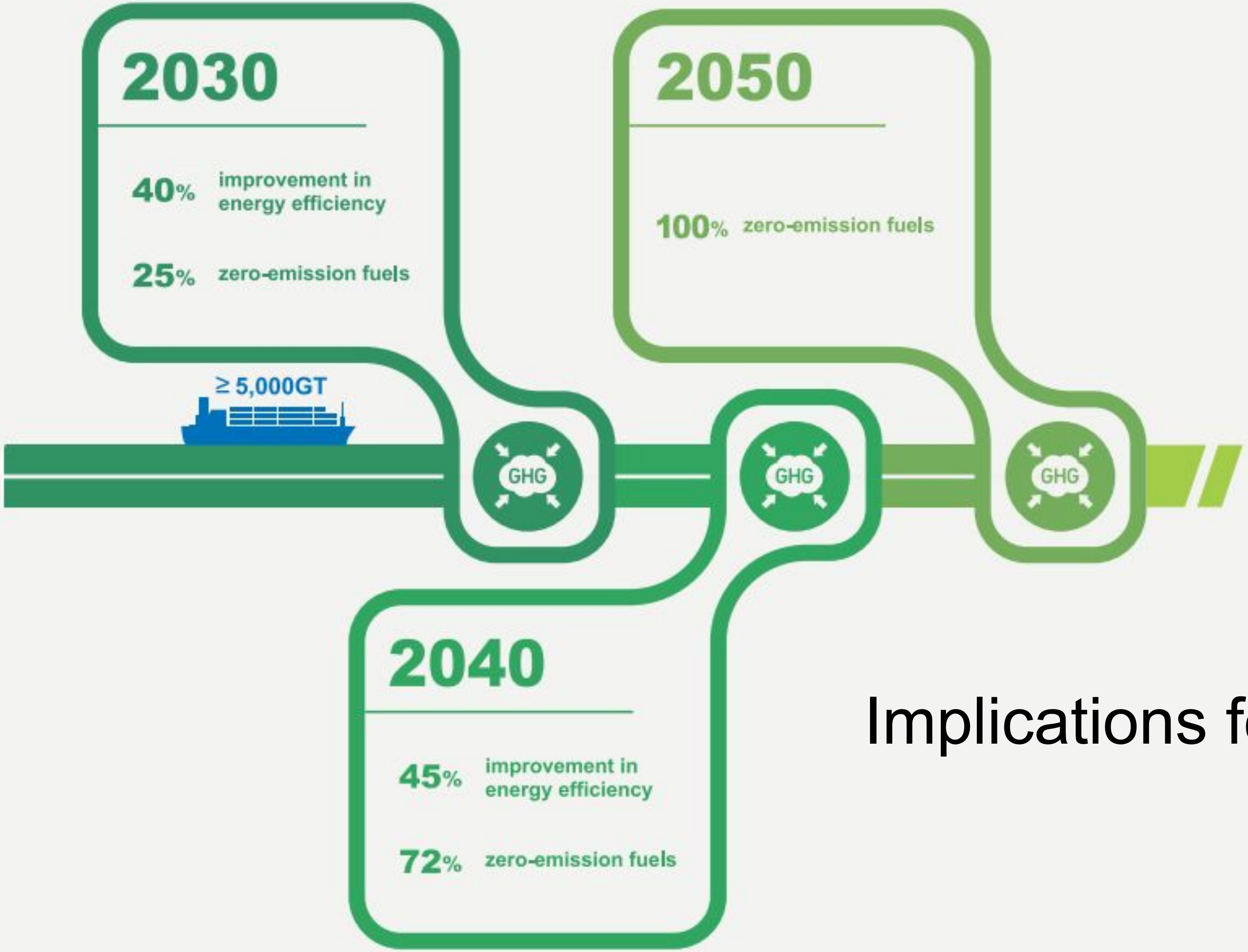
Source: EDGAR - Emissions Database for Global Atmospheric Research

Maritime CO2 emissions are bad -- and hard to decarbonize



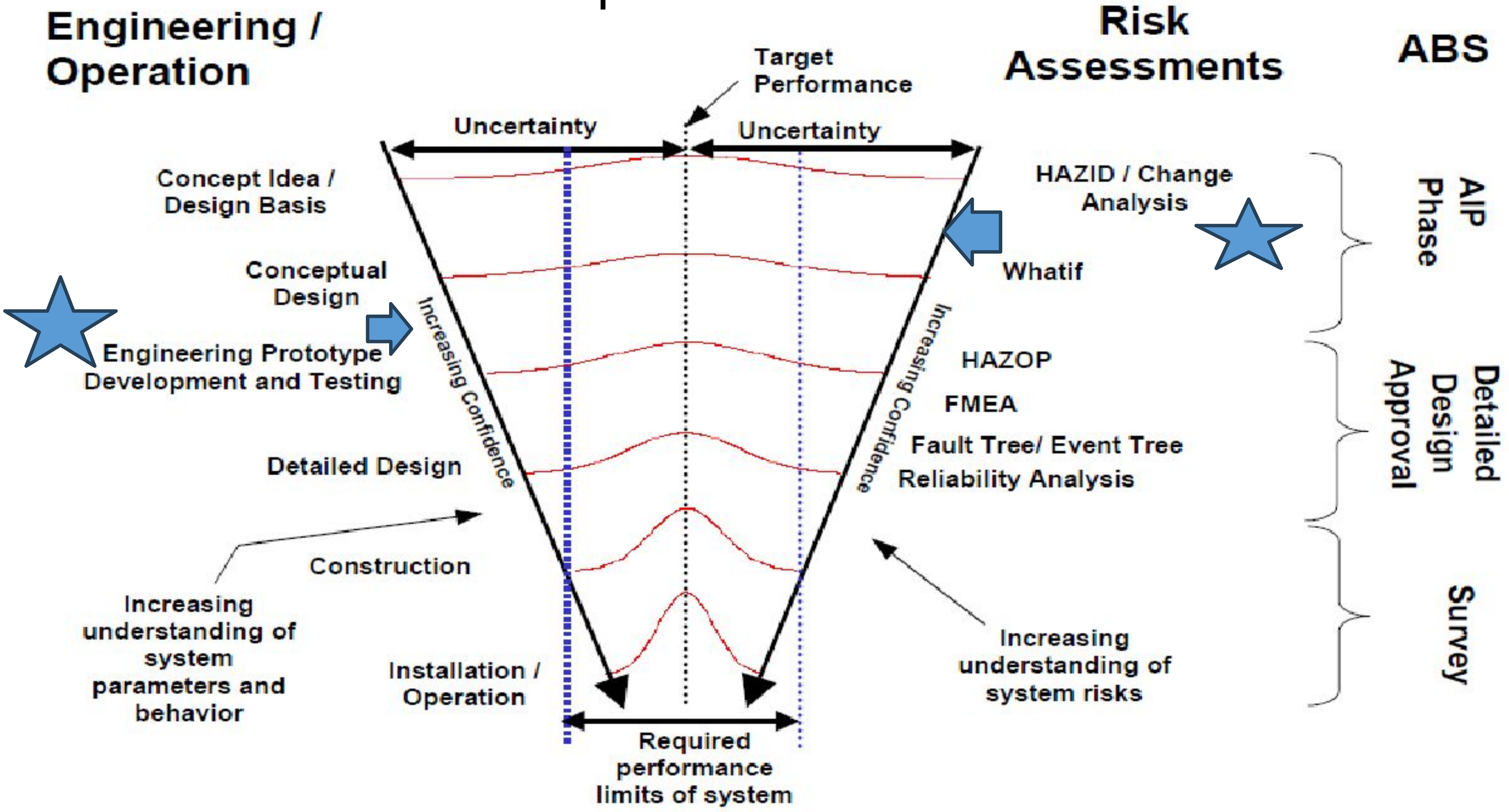
Source: IMO (2020), IMO (2018b) World Bank, 2021, Summary for Policymakers and Industry: Charting a Course for Decarbonizing Maritime Transport

Pathway to zero emissions: The 2023 IMO strategy



Implications for ARF?

Concept Evolution



CCRV project timeline

Preliminary engineering, design, review, and construction preparation

- 2021: Scripps issued RFI and RFP for design
- 2022: Development of preliminary vessel engineering and design
- 2023:Engineering review, HAZID workshop and regulatory Approval In Principle (AIP)

Construction

- 2024:Shipyard selection and preparation
- 2025:Keel laying, begin construction
- 2026:Construction

Commission and operate

- 2027:Commissioning & science verification trials
- 2028:Operational for science missions

SCRIPPS INSTITUTION OF OCEANOGRAPHY Glosten Sandia National Laboratories

Risk Assessment: Hydrogen gas system *Hazard Identification Workshop (HAZID)*

- 40 participants (25 in-person)
- USCG, ABS, ONR, NAVSEA, Sandia National Laboratory, Ballard Fuel Cells, Chart, Glosten, Siemens Energy, Scripps
- Identified 89 hazards, assessed potential consequences, and evaluated existing safeguards of the hydrogen gas system
- Highly experienced multi-discipline team used a structured brainstorming technique

Approval in Principle:
Major step towards classification society acceptance

From ABS statement:

- *proposed novel concept design complies with the intent of ABS Rules and other codes*
- *although said design may not yet be fully evolved - concept appears to have technical feasibility from both safety of personnel and environment*

ABS

Task – T2519213 / T2519217 / T2519221 / T2514721 / T2514726 / T2530965
Approval in Principle (AiP) of
"SCRIPPS INSTITUTE OF OCEANOGRAPHY"
CN.: YY289053, Coastal Class Research Vessel
Flag: United States of America

Attention: Mr. Robin Madsen / Glosten Associates Inc. (WCN: 241638)

The documents shown in the attached list are reviewed in accordance with the applicable requirements of the following:

- ABS Rules for Building and Classing Marine Vessels, 2023
- ABS Guide for Fuel Cell Power Systems for Marine and Offshore Applications
- ABS Guide for Hybrid Electric Power Systems for Marine and Offshore Applications
- ABS Guide for Use of Lithium-Ion Batteries in the Marine and Offshore Industries
- IMO Interim Guideline for the Safety of Ships Using Fuel Cell Power Installations, MSC.1/Circ.1647, 15 June 2022.
- USCG Policy letter 02-19 Design Guidance for Lithium-Ion Battery Installations Onboard Commercial Vessels
- IMO International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code)
- IMO International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- ABS Guidance Notes on Review and Approval of Novel Concepts, 2017
- 46 CFR, Chapter I, Subchapter S
- International Code on Intact Stability (IS Code), 2008 (2020 Edition)

Please note our review is based on the following conditions:

1. Our review of the drawings in the attached list is for "Approval in Principle". The purpose of the review for "Approval in Principle" is to investigate the feasibility of the conceptual design and identify any major deficiencies that would prove problematic in a full ABS review of the design for classification. The proposed design concept is in principle acceptable.

2. The primary objective of this review is to establish compliance in principle with the applicable ABS Rules and Guides, insofar as they relate to the details submitted (Annexure 1), that when all other requirements have been met the vessel will be eligible to be classed with the notations as below:

   +A1, ABCU, DPS-0, LFFS(FC-E-Hydrogen), ESS-LiBATTERY, HYBRID IEPS

3. Please note that before the final approval can be granted, the proposed design will need to be verified against the Rules, Guides, Regulations and Standards applicable at the time that the contract for construction is signed or the keel is laid, as applicable.

4. Based on our review, a list of comments generated during the review has been compiled and is enclosed herewith for your information (Annexure 2). These

Ready to solicit for final design & shipyard construction

Complete (as of 15 April 2024):

- *Request for Proposal*
- *Preliminary Design*
- *Technical Specification*
- *3D Model*
- *Sample Contract*

SHIPBUILDING CONTRACT

FOR

CONSTRUCTION

OF

OCEANOGRAPHIC RESEARCH VESSEL

UNDER HULL NUMBER ___

BETWEEN

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

on behalf of THE UNIVERSITY OF CALIFORNIA, SAN DIEGO

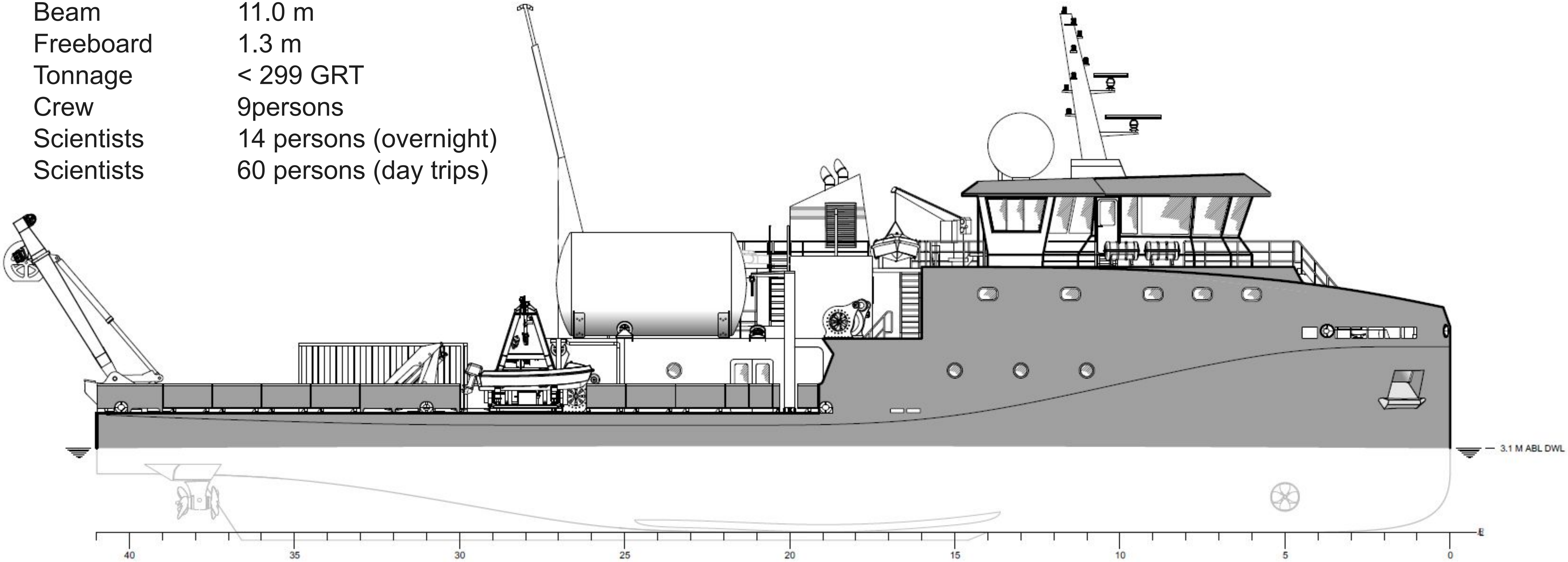
SCRIPPS INSTITUTION OF OCEANOGRAPHY

AND

[BUILDER]

Vessel characteristics

LOA	49.99 m
Beam	11.0 m
Freeboard	1.3 m
Tonnage	< 299 GRT
Crew	9persons
Scientists	14 persons (overnight)
Scientists	60 persons (day trips)



75% of missions can be zero-emissions using hydrogen --- **fossil free**

Methanol convertible concept: Plan for the future

Design now with intent to replace diesel with methanol as secondary fuel

Hydrogen will remain as primary fuel

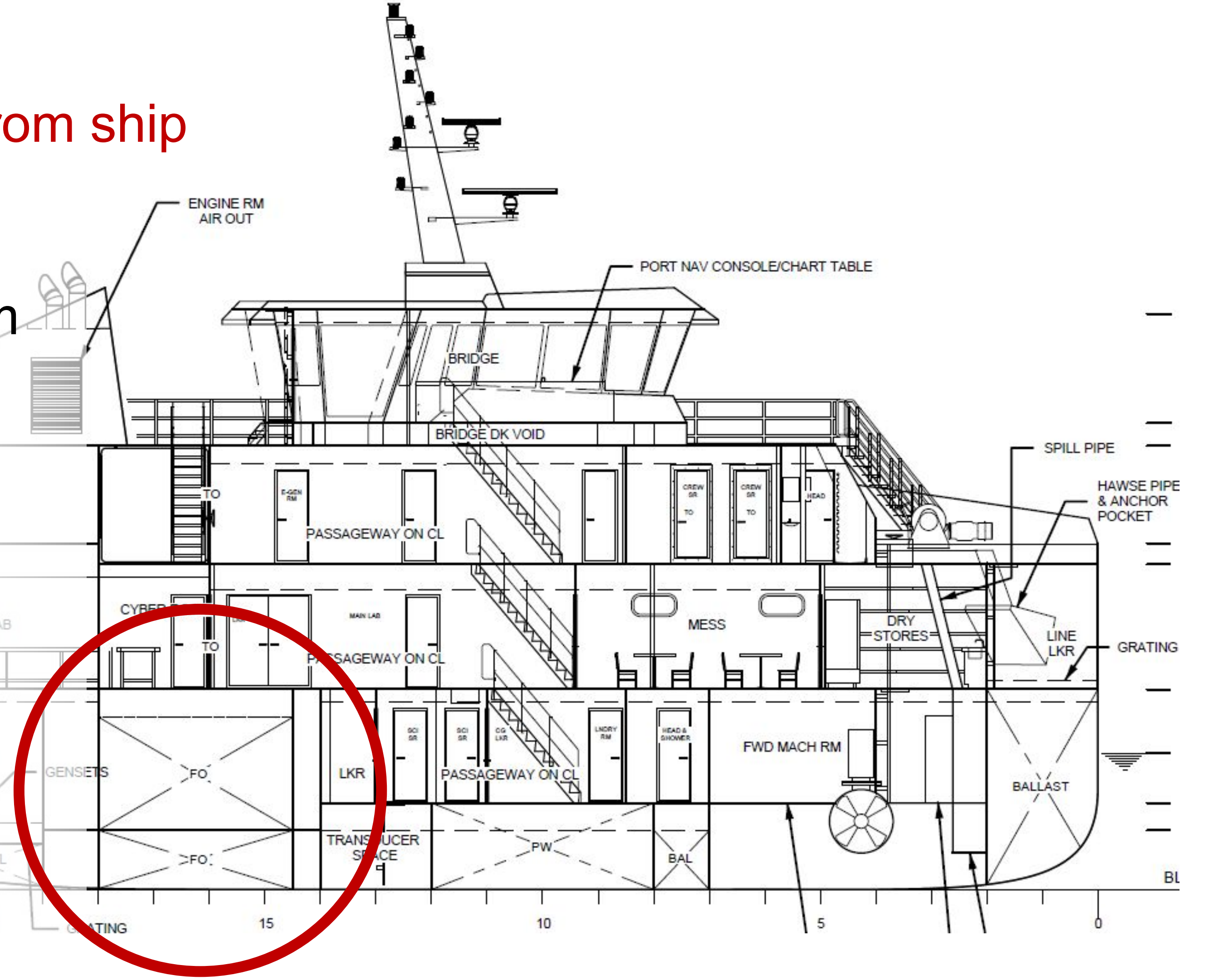
Design objective: Eliminate diesel entirely from ship

- Limit invasiveness of future conversion
- Include space for future methanol prep room
- Install fuel tanks sized to meet endurance requirement after conversion to methanol
- Ensure vessel stability

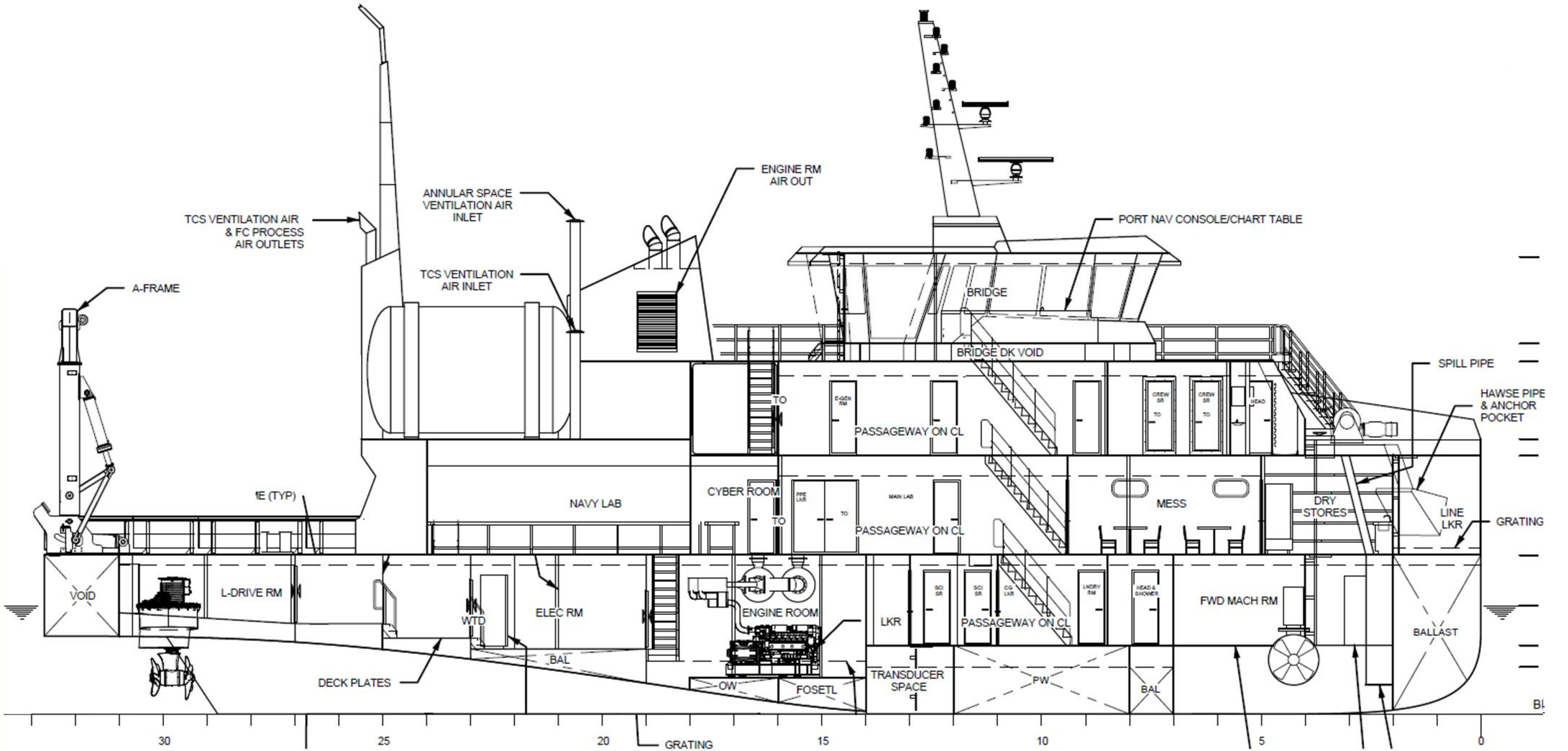
When methanol technology is mature*:

Replace diesel generators with methanol combustion engines or fuel cells

** Anticipated within five years of delivery*



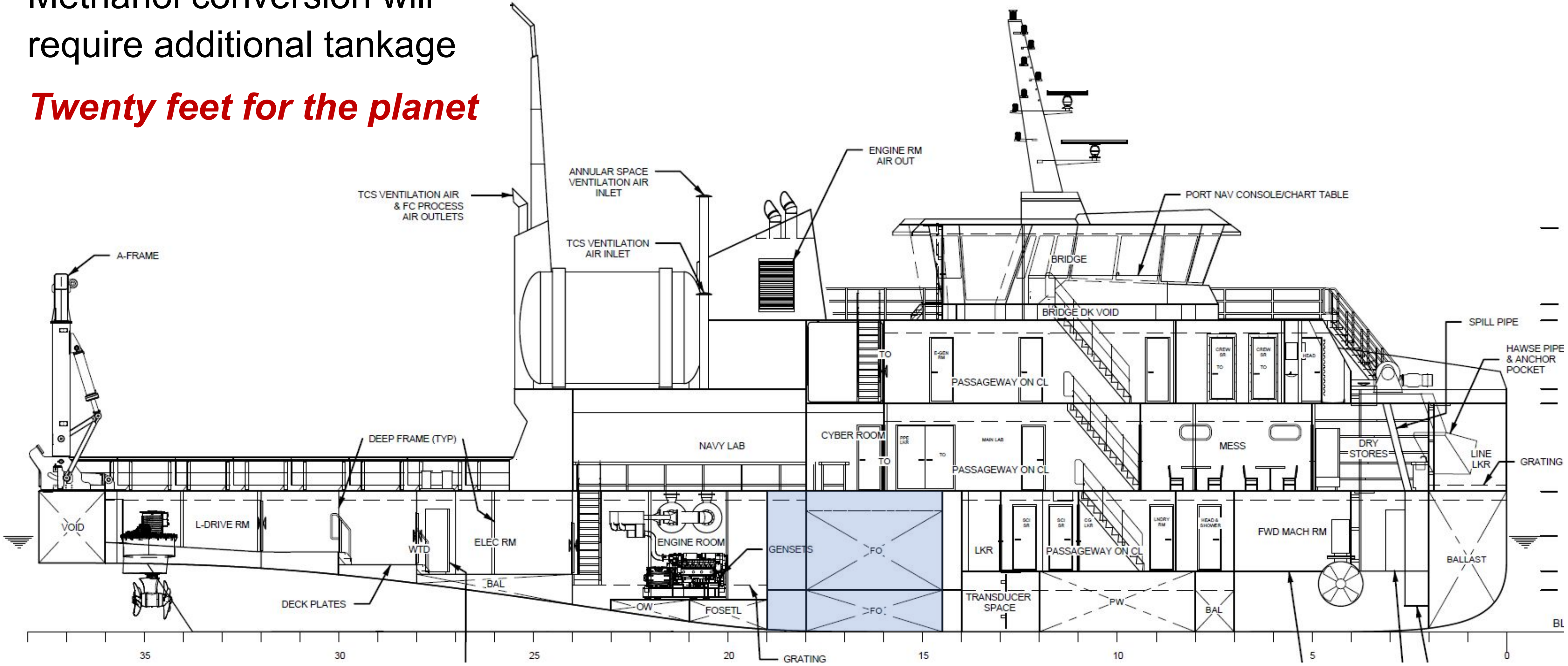
Inboard profile



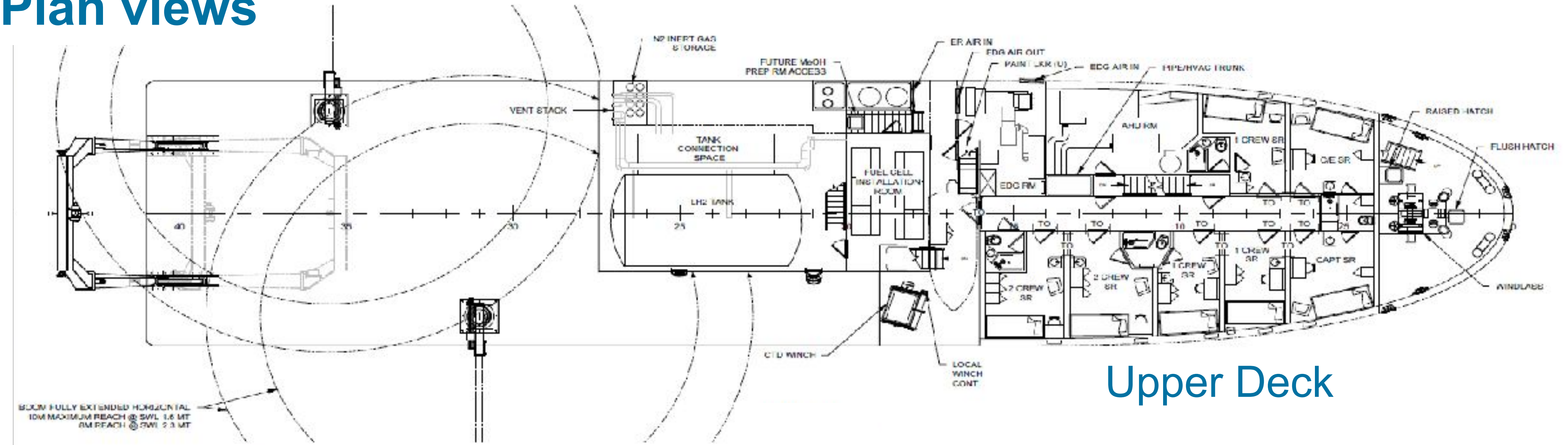
Inboard profile

Methanol conversion will require additional tankage

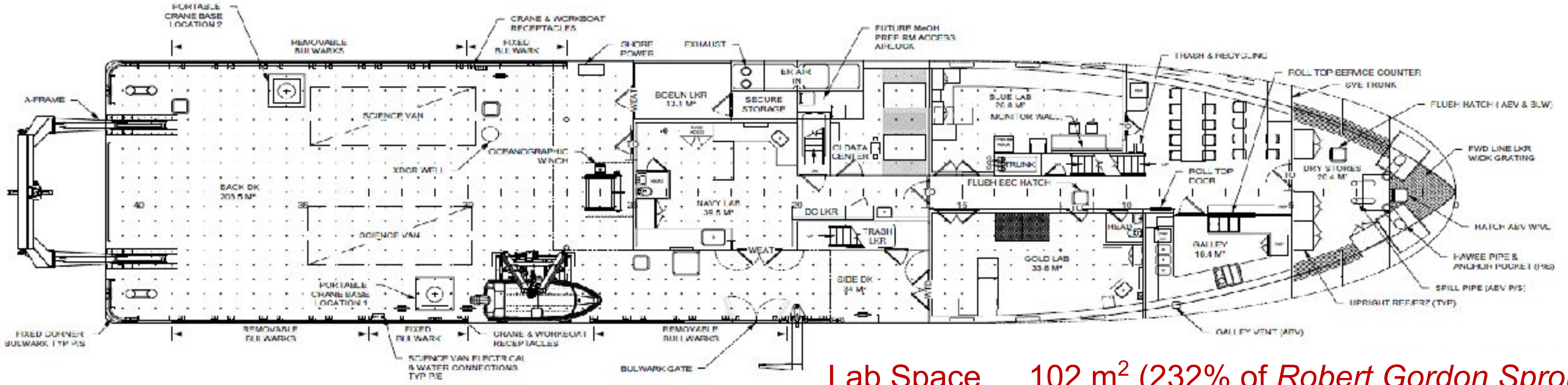
Twenty feet for the planet



Plan views



Upper Deck



Main Deck

Lab Space 102 m^2 (232% of *Robert Gordon Sproul*)

Deck Space 238 m^2 (141% of *Robert Gordon Sproul*)

Vessel performance

Scientific sonars

Multibeam bathymetry

- EM 304 MKII (1x2 degree)

Multibeam subbottom

- SBP 29 (6 x 14 degree)

ADCP

- Teledyne RDI Ocean Surveyor
  75 & 150 kHz

Fisheries

- Kongsberg/Simrad EK80

18, 38, 70, 120, 200 kHz

Mooring/Acoustic Modem

- Airmar CS229 12kHz
- Teledyne UTS9500 universal acoustic release system

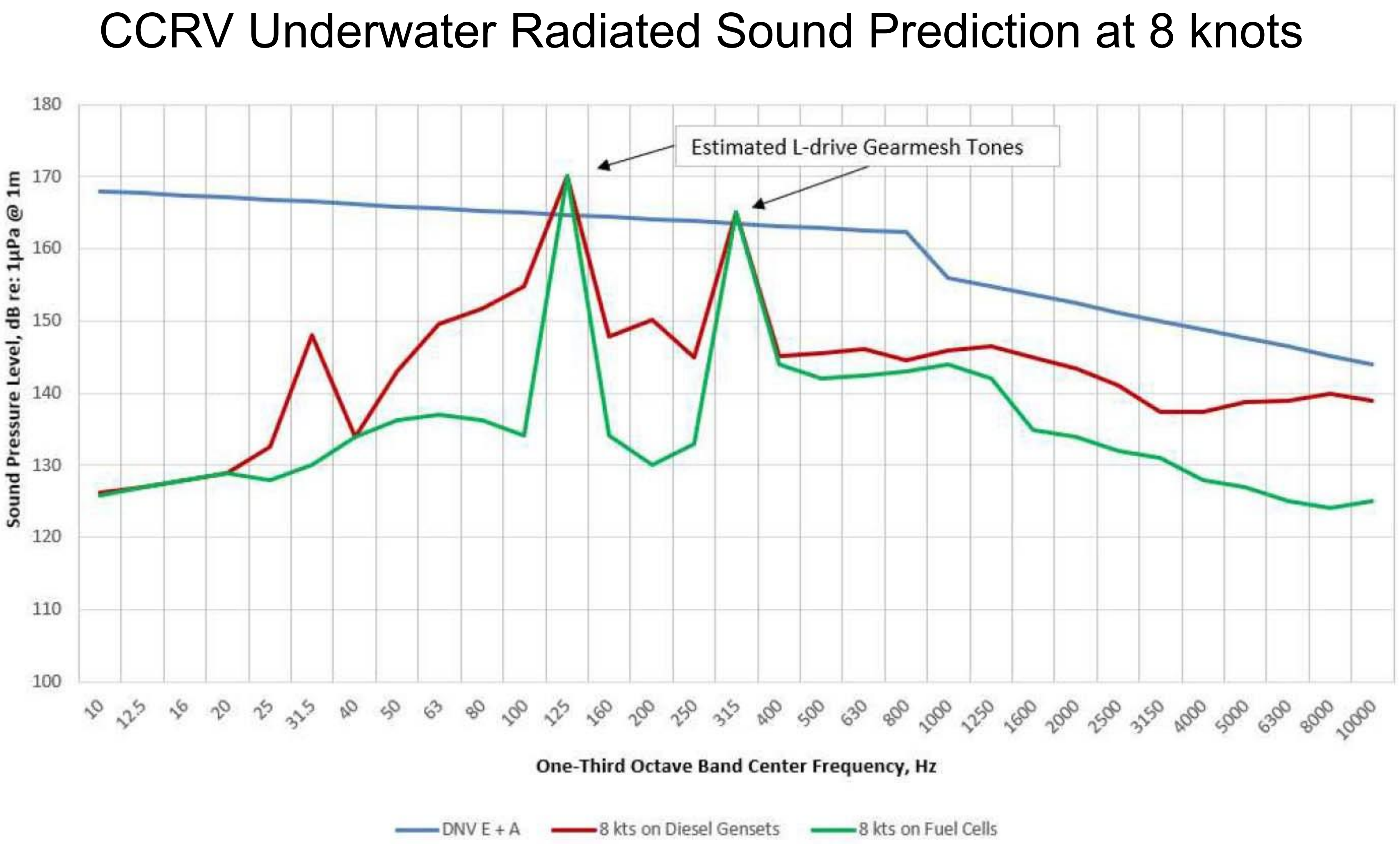
Sonar Synchronization

- Kongsberg Ksync

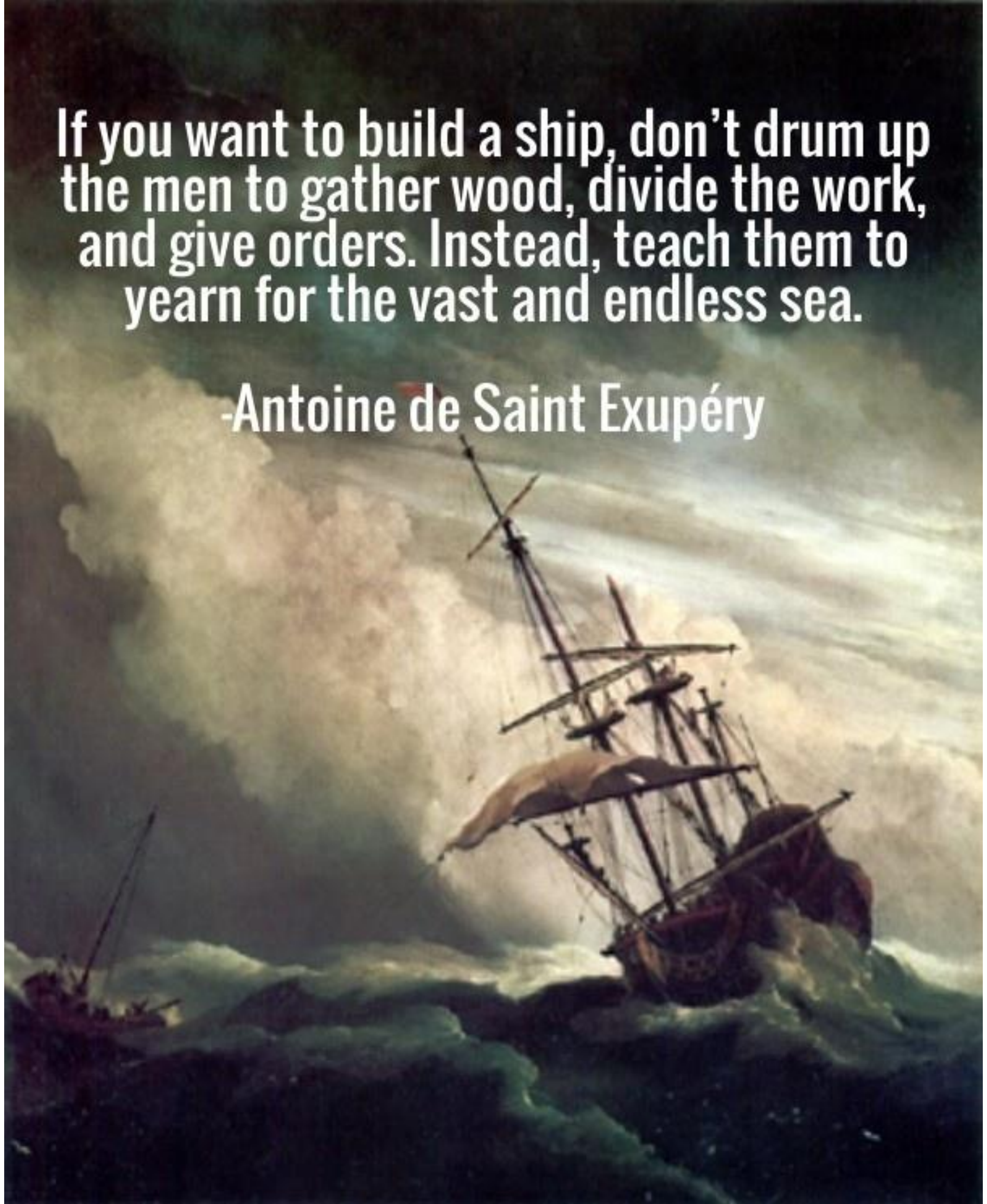
	Requirement	Design Capability
Cruise Speed	10 kts	10 kts
Range	2,400 nm at cruise	>6,000 nm, diesel
H_2 operation	Requirement: All one-day missions Objective: Support two successive one-day class cruises	>2 days
Endurance	1 days	11 days (limited by food)
Stationkeeping	Maintain position at best heading	30 kts wind, 2 kts current
Underwater Noise	Requirement: None Objective: Minimize as practicable	Not assessed
Design Life	30 years	30 years

Underwater radiated sound

- Propellers not cavitating at 8 knots
- Sonar Self-Noise is expected to be well controlled for sonar operations at 8 knots
- L-drive gear mesh tones (100-400 Hz) are well below the lowest operating frequency for the sonar transducers (~2 kHz for subbottom profiler)



DNV underwater noise limits are Silent-A in the higher frequencies and Silent-E below 1,000 Hz.


If you want to build a ship, don't drum up the men to gather wood, divide the work, and give orders. Instead, teach them to yearn for the vast and endless sea.
-Antoine de Saint Exupéry