



Progress report: Construction of a zero-emission hydrogen hybrid research vessel at Scripps Oceanography

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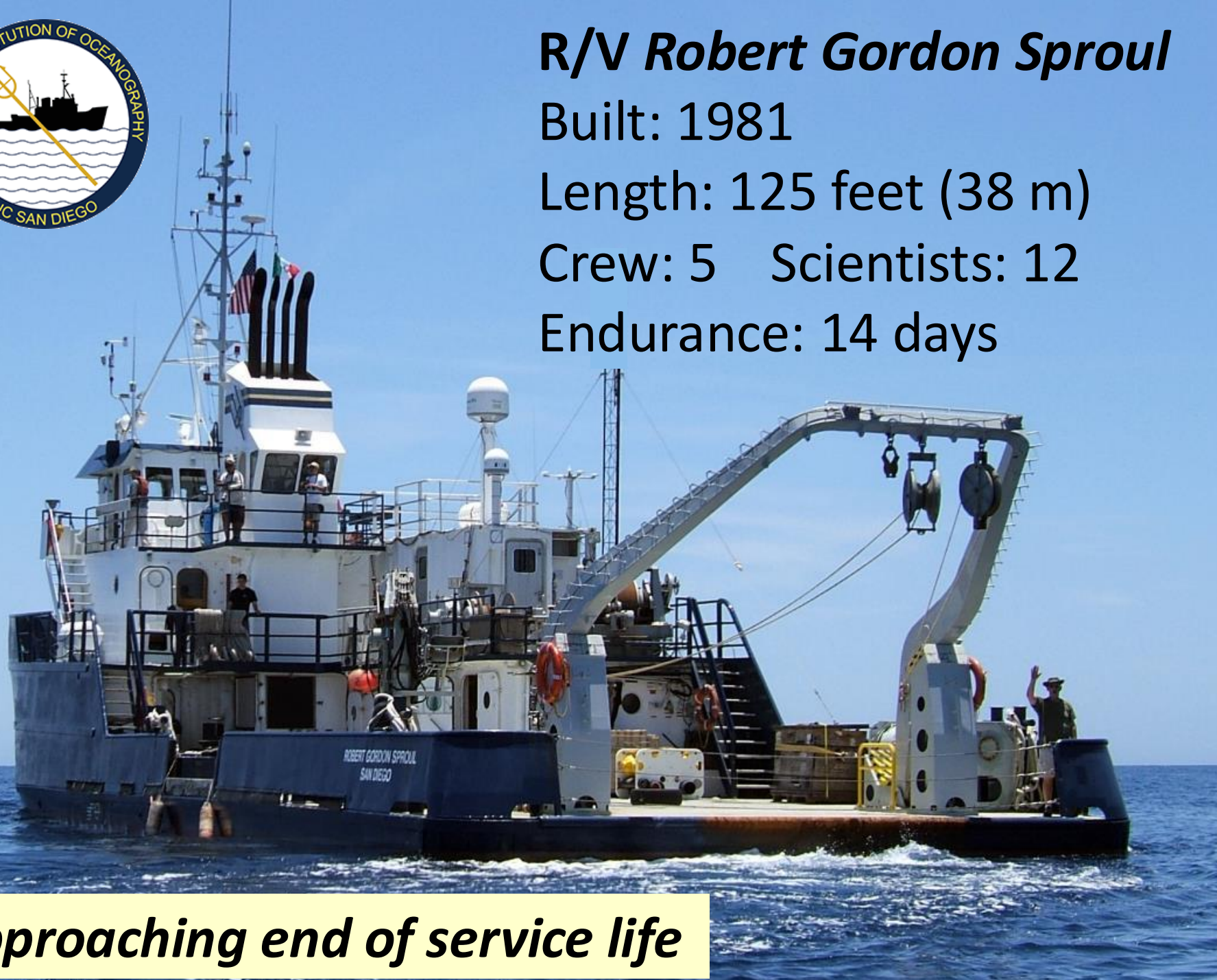
R/V *Robert Gordon Sproull*

Built: 1981

Length: 125 feet (38 m)

Crew: 5 Scientists: 12

Endurance: 14 days



Approaching end of service life

Sally Ride



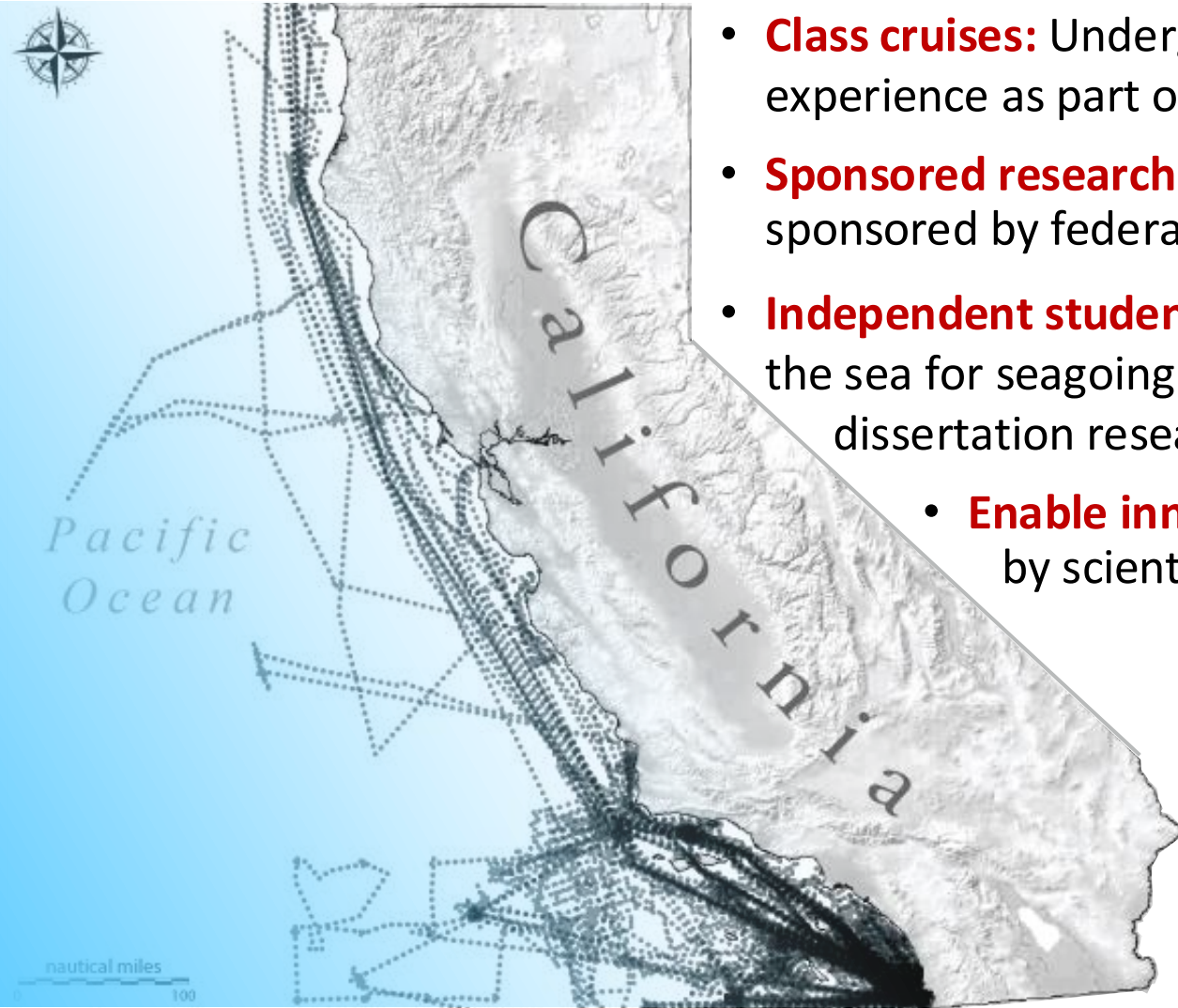
Roger Revelle



Beyster



Scripps Coastal Class Research Vessel (CCRV): A vital asset for California



- **Class cruises:** Undergraduate and graduate courses rely on practical seagoing experience as part of the Scripps curriculum.
- **Sponsored research missions:** Conducted by established research scientists, sponsored by federal agencies (NSF, ONR, NOAA, NASA etc).
- **Independent student research missions:** Provide graduate students access to the sea for seagoing experiments and to acquire data as part of their dissertation research.
- **Enable innovation:** Deploy new sensors and instruments developed by scientists and engineers for testing and demonstration.

Geology and Geophysics
Physical Oceanography
Ocean Acoustics
Marine Biology
Pollution Detection
Remotely-Operated Vehicles
Autonomous Vehicles

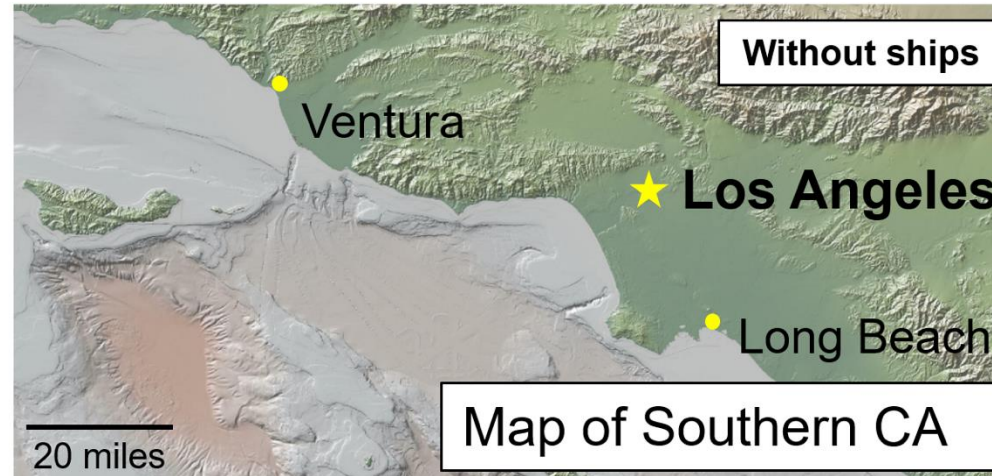
Marine Mammal Studies
Oceanic Fisheries
Ocean Monitoring Moorings
Harmful Algal Blooms
Ocean Ecosystems
Ocean Acidification
Seabed Mapping

Mission tracklines of UC's Coastal Class Research Vessel

Each year: 35+ unique missions, 90+ days at sea, 750+ participating students, scientists, engineers and technicians

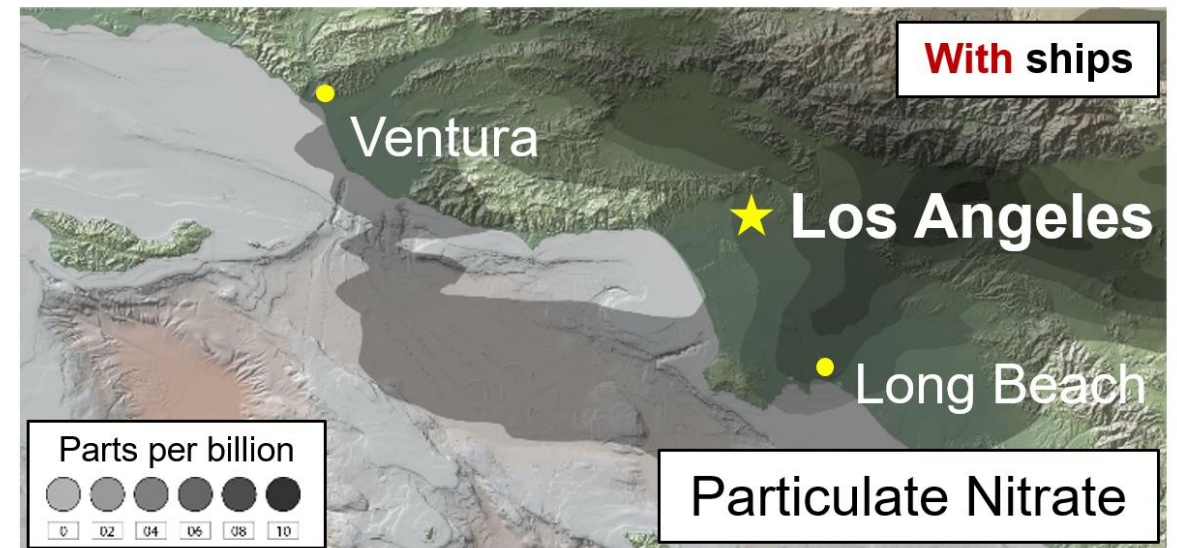
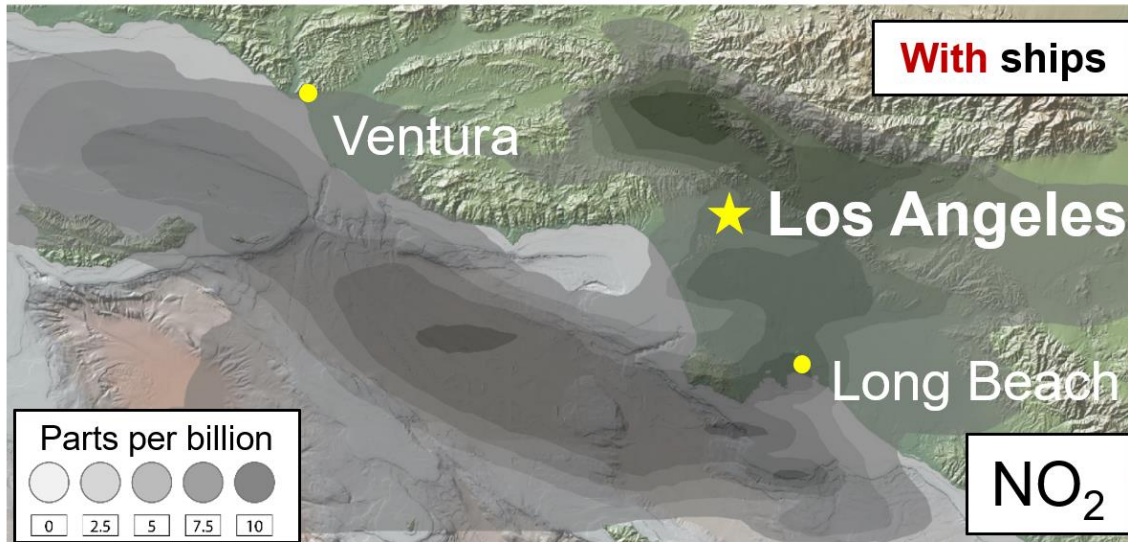
Ship fossil fuel emissions harm our health and environment

Positive (dark) values show higher concentration due to ship emissions



CARB recognizes diesel particulate matter as a **toxic air contaminant.**

“...diesel exhaust still poses substantial risks to public health and the environment.”



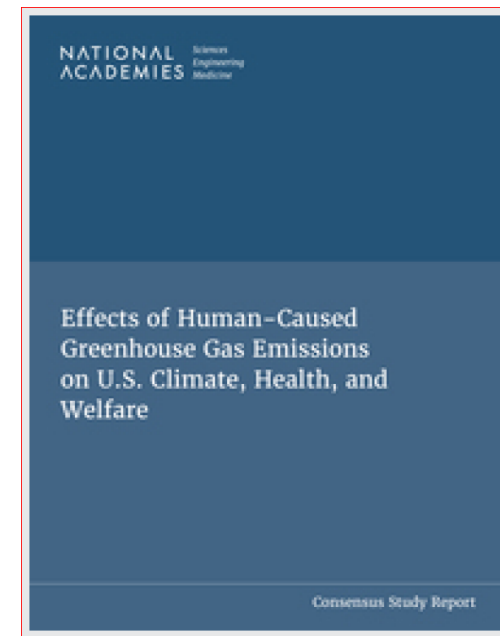
Imperative for reducing greenhouse gas emissions

2025 Report: US National Academies of Science

The evidence for current and future harm to human health and welfare created by human-caused GHGs is beyond scientific dispute.

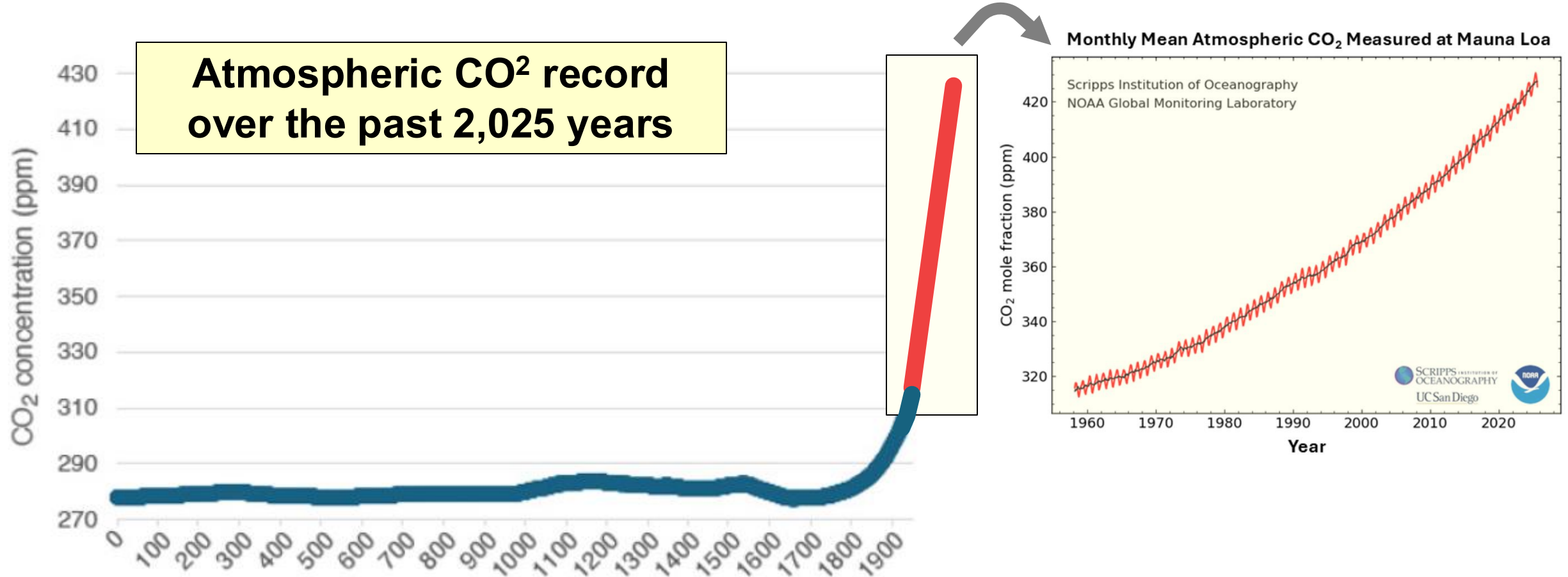
The U.S. EPA's 2009 finding that the human-caused emissions of greenhouse gases (GHGs) threaten human health and welfare was accurate, has stood the test of time, and is now reinforced by even stronger evidence.

- Emissions of GHGs from human activities are increasing the concentration of these gases in the atmosphere.
- Improved observations confirm unequivocally that GHG emissions are warming Earth's surface and changing Earth's climate.
- Human-caused emissions of GHGs and resulting climate change harm human health.
- Climate change from human-caused emissions of GHGs harm the welfare of our societies.
- Continued emissions of GHGs from human activities will lead to more climate changes and their impacts on human health and welfare.



National Academies of Sciences, Engineering, and Medicine. 2025. *Effects of Human-Caused Greenhouse Gas Emissions on U.S. Climate, Health, and Welfare*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/29239>.

Imperative for reducing greenhouse gas emissions



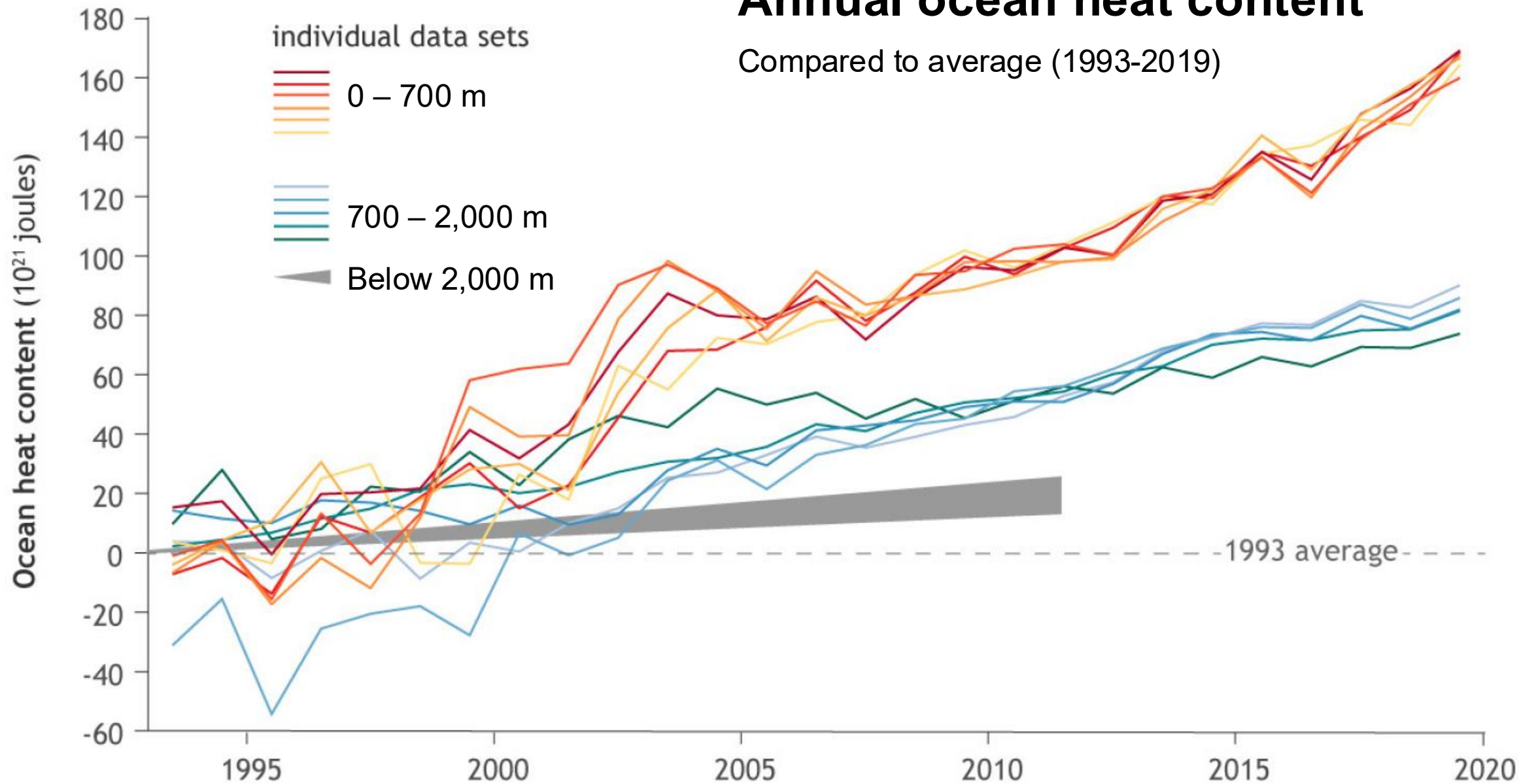
Year 0000 – 1960
275 ppm – 318 ppm

Year 1960 – 2025
318 ppm – 430 ppm

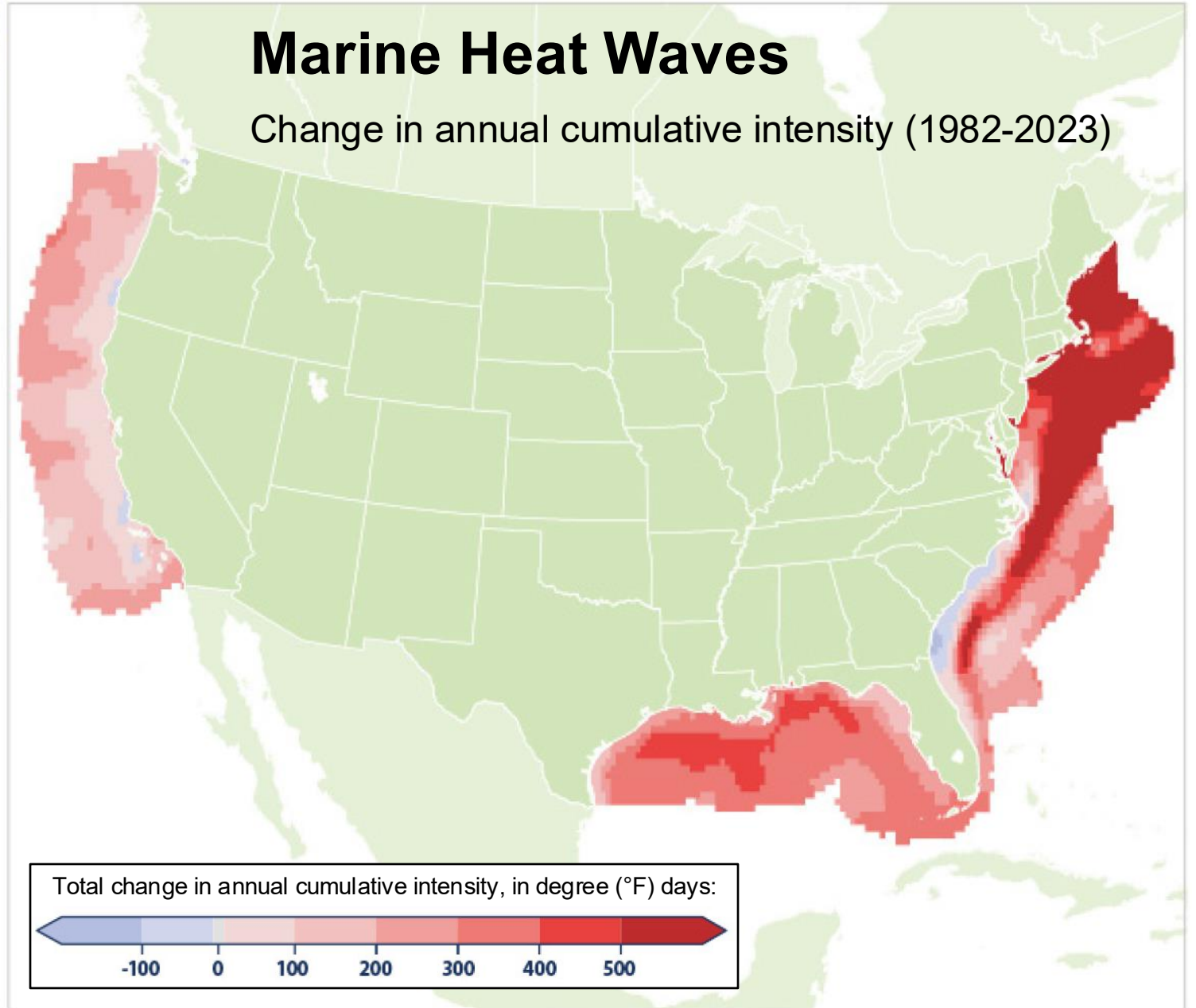
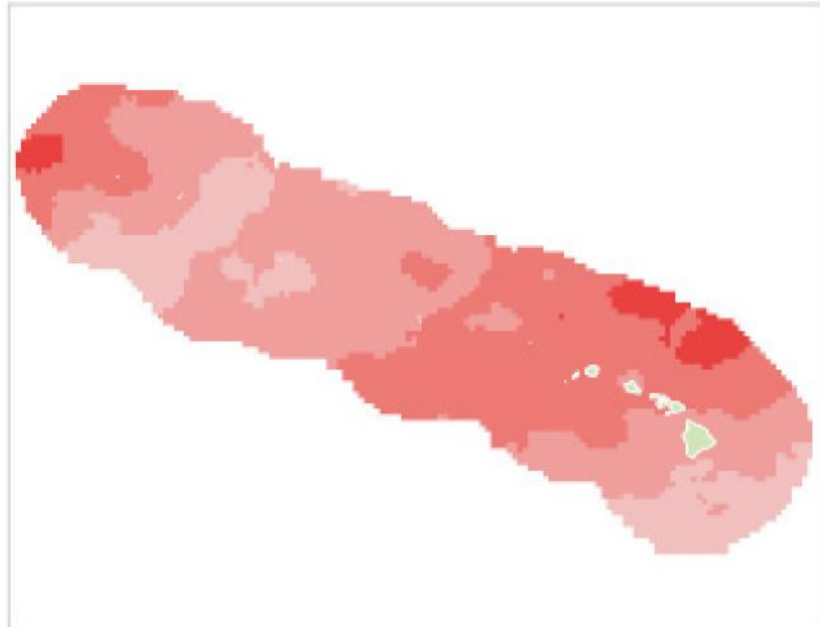
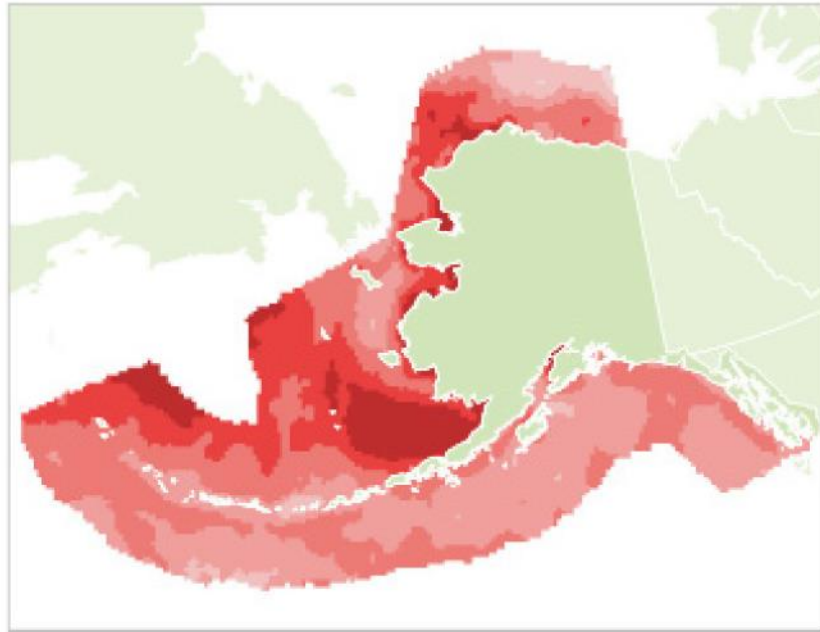
Imperative for reducing greenhouse gas emissions

Annual ocean heat content

Compared to average (1993-2019)



Imperative for reducing greenhouse gas emissions



Can We Eliminate Emissions From Research Vessels?

2018 Feasibility Study:

Is it possible to build a zero-emission research vessel that does not use fossil fuels, with existing technology that is available commercially now?

2020 Feasibility Study:

Is it possible to build a hybrid research vessel to achieve significant (but not total) zero-emission operations, coupled with a diesel-electric plant?

Answer: Yes

Answer: Yes

Download the full reports:
maritime.sandia.gov

This work was supported by the U.S. Department of Transportation, Maritime Administration



SANDIA REPORT
SAND2018-0864 - Unclassified Release | Printed May 2018

Feasibility of the Zero-V:

A Zero-Emission, Hydrogen Fuel-Cell, Coastal Research Vessel

Leonard E. Klebanoff, Joseph W. Pratt, Robert T. Madsen, Sean A.M. Caughlan, Timothy S. Leach, T. Bruce Applegate, Jr., Stephen Zoltan Kalaty, Hans-Christian Wintervoll, Gerd Petra Haugom and Anthony T.Y. Teo

Prepared by
Sandia National Laboratories,
Livermore, California 94550

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Sandia National Laboratories



SANDIA REPORT
SAND2020-1030-R - September 2020 - Unclassified Release

Feasibility Study of Replacing the R/V Robert Gordon Sproul with a Hybrid Vessel Employing Zero-emission Propulsion Technology

A Comparison of Hydrogen Fuel Cell and Battery Hybrid Technologies for a Coastal/Local Research Vessel Application

Leonard E. Klebanoff, Robert T. Madsen, Cody J. Conrad, Sean A.M. Caughlan, Timothy S. Leach and T. Bruce Applegate, Jr.

Prepared by
Sandia National Laboratories, Livermore, California 94550

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.



Sandia National Laboratories



Comparing Hybrid Variants: Zero Emissions Range

Zero Emissions Range

Hydrogen hybrid has nine times better range than the battery hybrid

Cruise Speed	Zero Emissions Range (NM)	
	Battery Hybrid	Hydrogen Hybrid
9 knots	37	330
10 knots	25	234

Hydrogen hybrid is better than battery hybrid

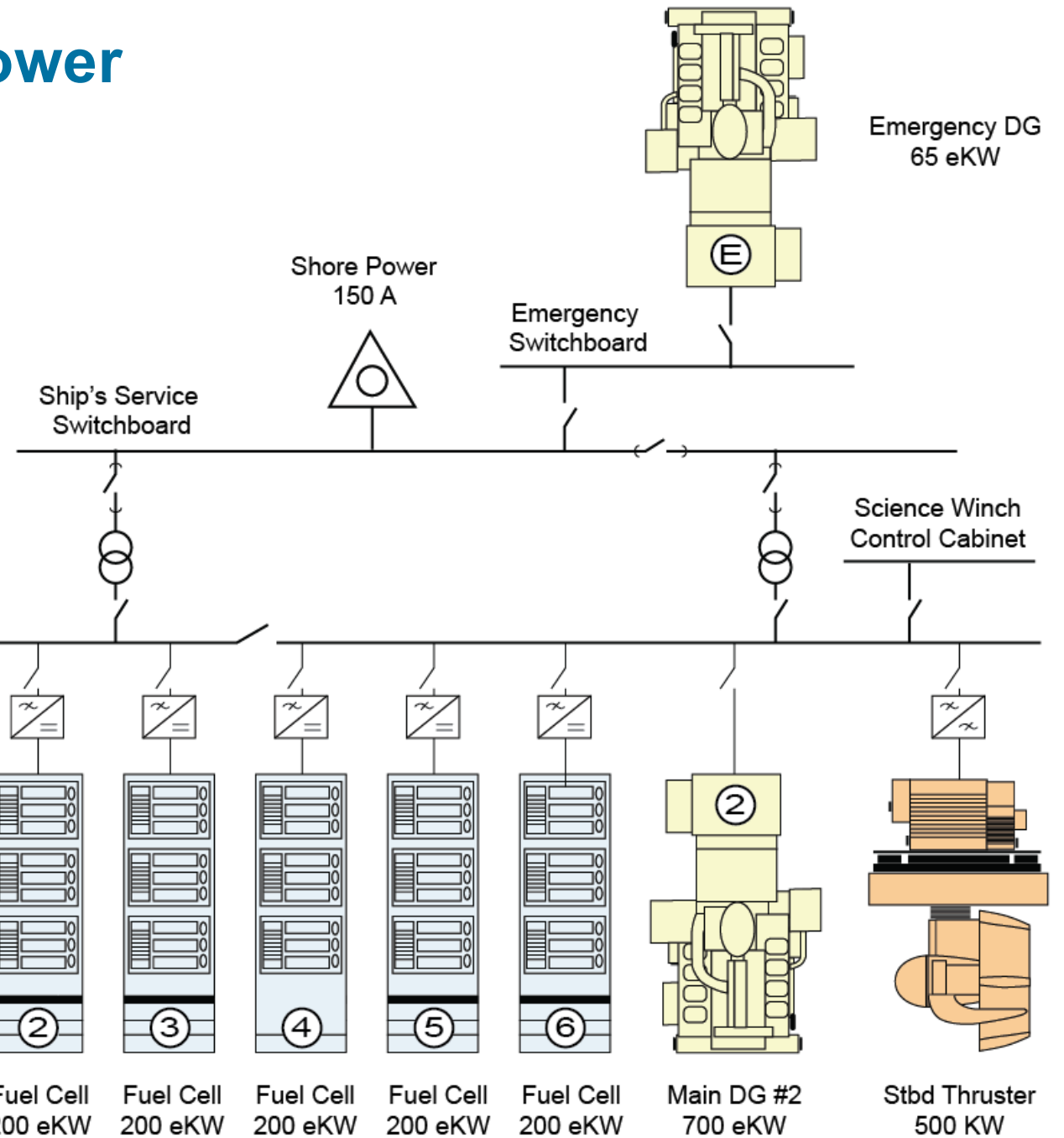
Compared to batteries, the Hydrogen Hybrid offers:

- ✓ 9x better zero-emission range & endurance
- ✓ 9x reductions in NOx, HC, PM and GHGs
- ✓ Fast fueling times – similar to diesel
- ✓ Better suited for ocean-going ships with long missions

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

Hybrid approach to maritime power

Architecture	Integrated Electric Plant
Fuel Cells	6 x 200 ekW PEM
Generators	2 x 700 ekW
Batteries	178 kWh
Propulsors	Azimuthing L-drive, 2 x 500 kW
Bow Thruster	Tunnel thruster, 1 x 150 kW



Port Thruster
500 kW

Bow Thruster
150 kW

Main DG #1
700 ekW

Battery
100 kWh

Fuel Cell
200 ekW

Fuel Cell
200 ekW

Fuel Cell
200 ekW

Fuel Cell
200 ekW

Fuel Cell
200 ekW

Fuel Cell
200 ekW

Main DG #2
700 ekW

Stbd Thruster
500 kW

CCRV project to date

Preliminary engineering, design, review, and construction preparation

- 2021: Scripps issued RFI and RFP for design
- 2022: Preliminary engineering and design
- 2023: Engineering review, HAZID workshop
- 2024: ABS Approval In Principle, USCG Preliminary Approval for Alternative Design under SOLAS)
- 2025: Solicitation for shipyard, shipyard selection

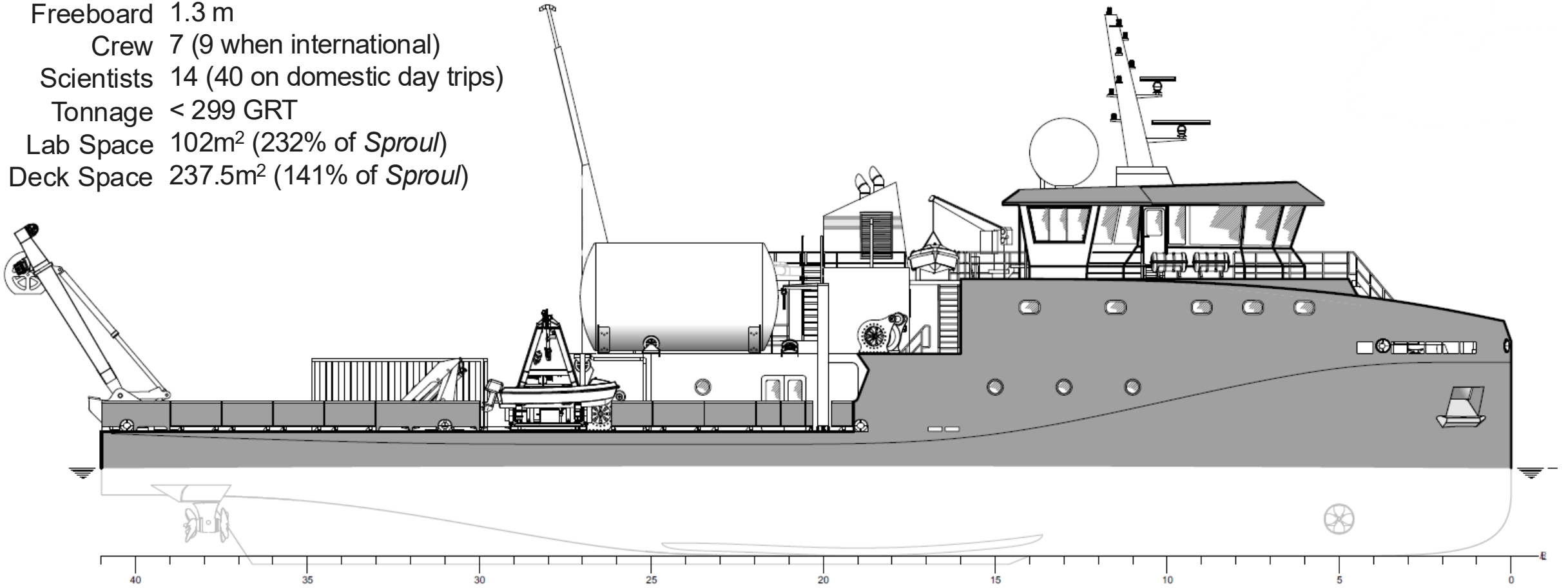
Next...

- Final design
- Vessel assembly
- Commissioning & science verification trials
- Operational for science missions (target 2029)
- Conversion from diesel to methanol engines



Elements of Design

LOA 49.9 m
Beam 11 m
Freeboard 1.3 m
Crew 7 (9 when international)
Scientists 14 (40 on domestic day trips)
Tonnage < 299 GRT
Lab Space 102m² (232% of *Sproul*)
Deck Space 237.5m² (141% of *Sproul*)



Elements of Design

Range (hydrogen)	400 nm
Range (diesel)	6,500 nm
Range (methanol)	2,400 nm
Endurance	11 days
Cruising speed	10 knots
Azimuthing thruster power	Two L-Drives, 500 kW each
Crew berths	US: 7 International: 9
Scientist berths	US: 16 International: 14
Students	40 (on day trips)
Station keeping	Dynamic positioning
Main crane	2,400 lbs SWL
Stern A-Frame	21,000 lbs SWL
Side Frame	10,000 lbs SWL
Winches	Trawl, CTD/Hydro
Scientific instrumentation:	ADCPs, multibeam echosounder, subbottom profiler, midwater imaging sonar, flow-through seawater system, broadband internet, motion reference system



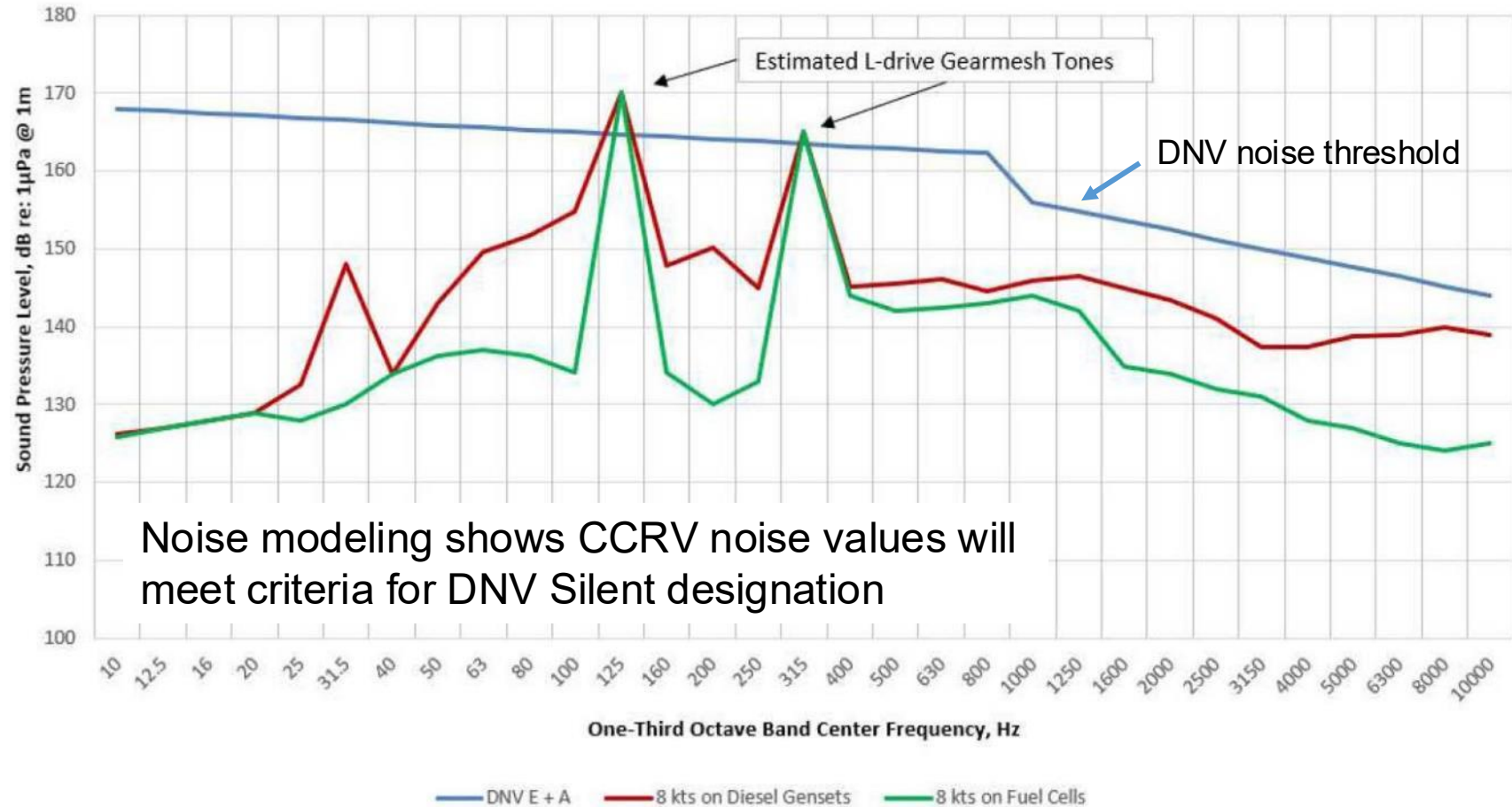
75% of missions can be zero-emissions using hydrogen --- **fossil free**

Hydrogen power is quiet power

Underwater Radiated Noise

- No propeller cavitation at 8 knots & below.
- Sonar self-noise is expected to be well controlled for sonar operations at 8 kts.
- L-drive gear mesh tones (100-400 Hz) are well below the lowest operating frequency for the sonar transducers (~2 kHz for sub-bottom profiler)

CCRV Underwater Radiated Noise Prediction at 8 kts



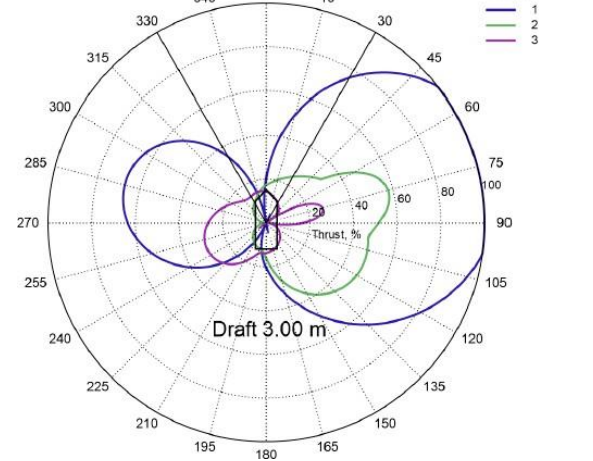
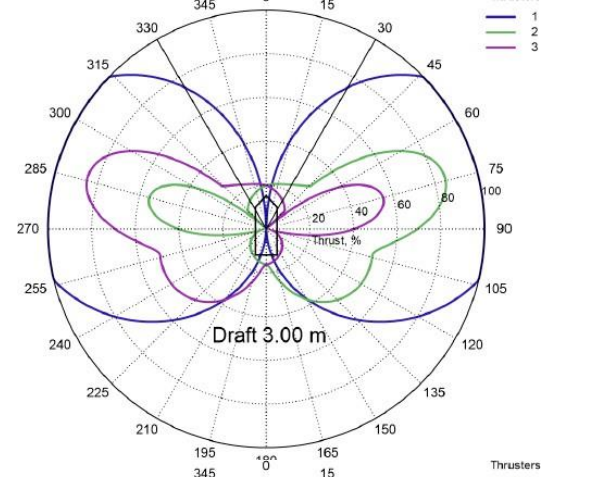
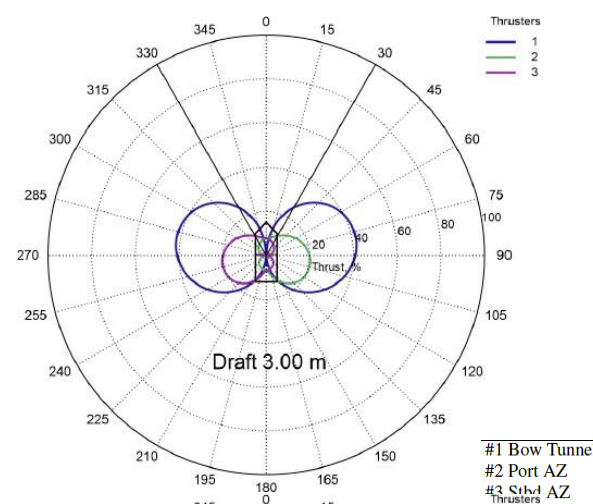
DNV underwater noise limits are Silent-A in the higher frequencies and Silent-E below 1,000 Hz.

Position Keeping

Thrusters

- 1
- 2
- 3

- #1 Bow Tunnel
- #2 Port AZ
- #3 Stbd AZ



Nominal Operating Condition

- No current
- 14 kts wind
- Wind & wind-driven waves rotating
- ✓ **Able to maintain position**

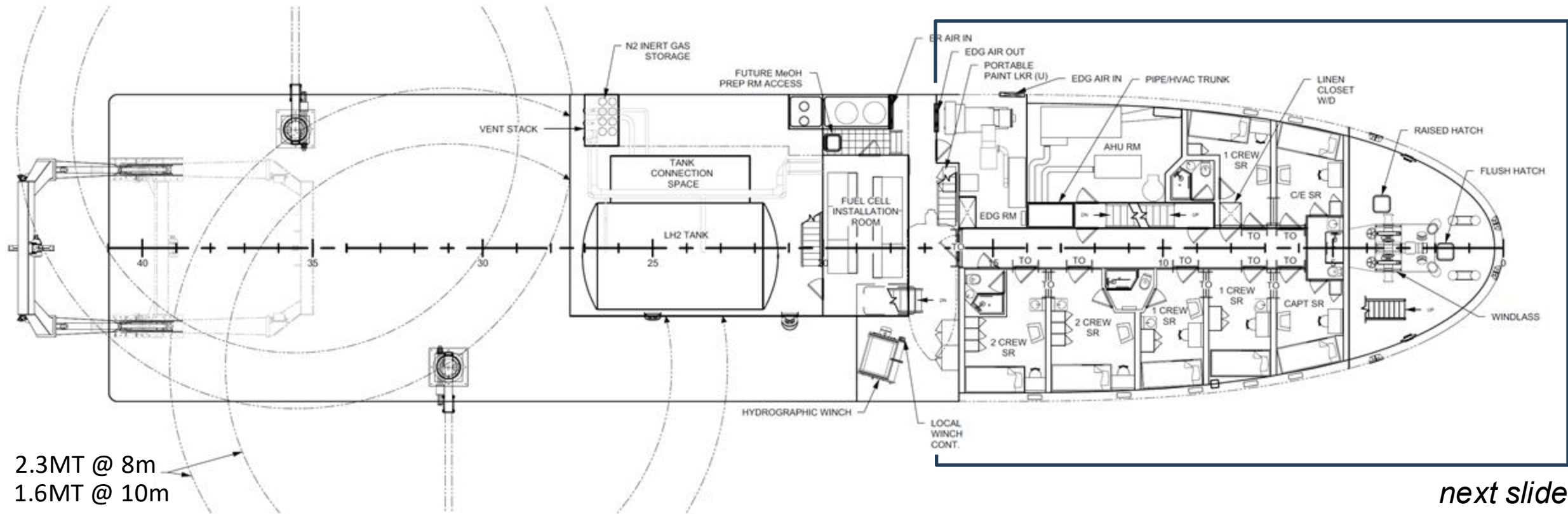
Challenge Condition

- 2 knots current
- 30 kts wind
- Wind & wind-driven waves rotating
- ✓ **Able to maintain position**

Challenge Condition

- 1 knots current
- 25 kts wind
- Wind & wind-driven waves rotating
- ✓ **Able to maintain position**

CCRV: Upper Deck



next slide

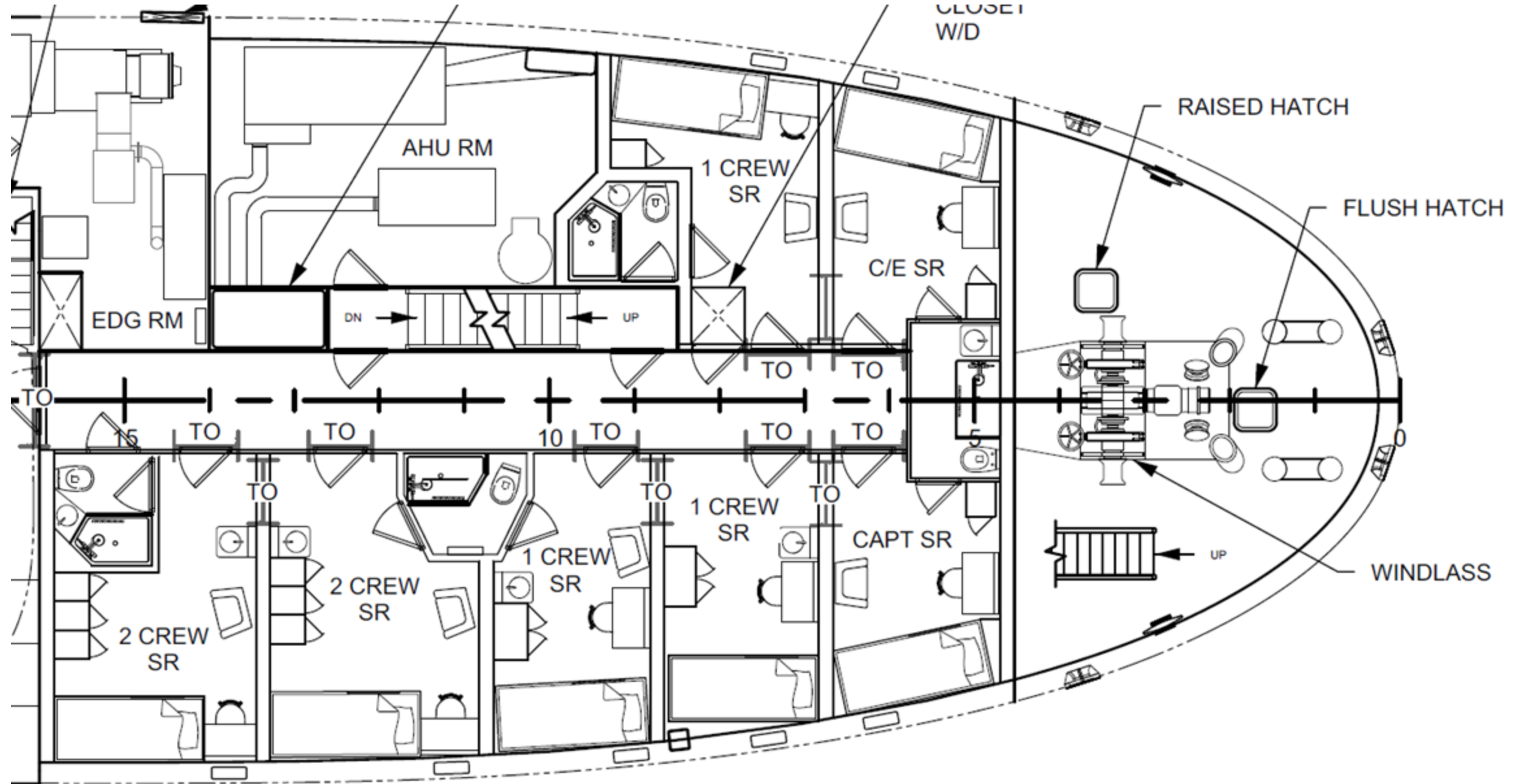
Overboard handling systems

- | | |
|--------------------|----------------------------|
| A-Frame | Transom centerline |
| Hydrographic winch | Upper deck, aft house stbd |
| Main crane (1) | Relocatable port or stbd |

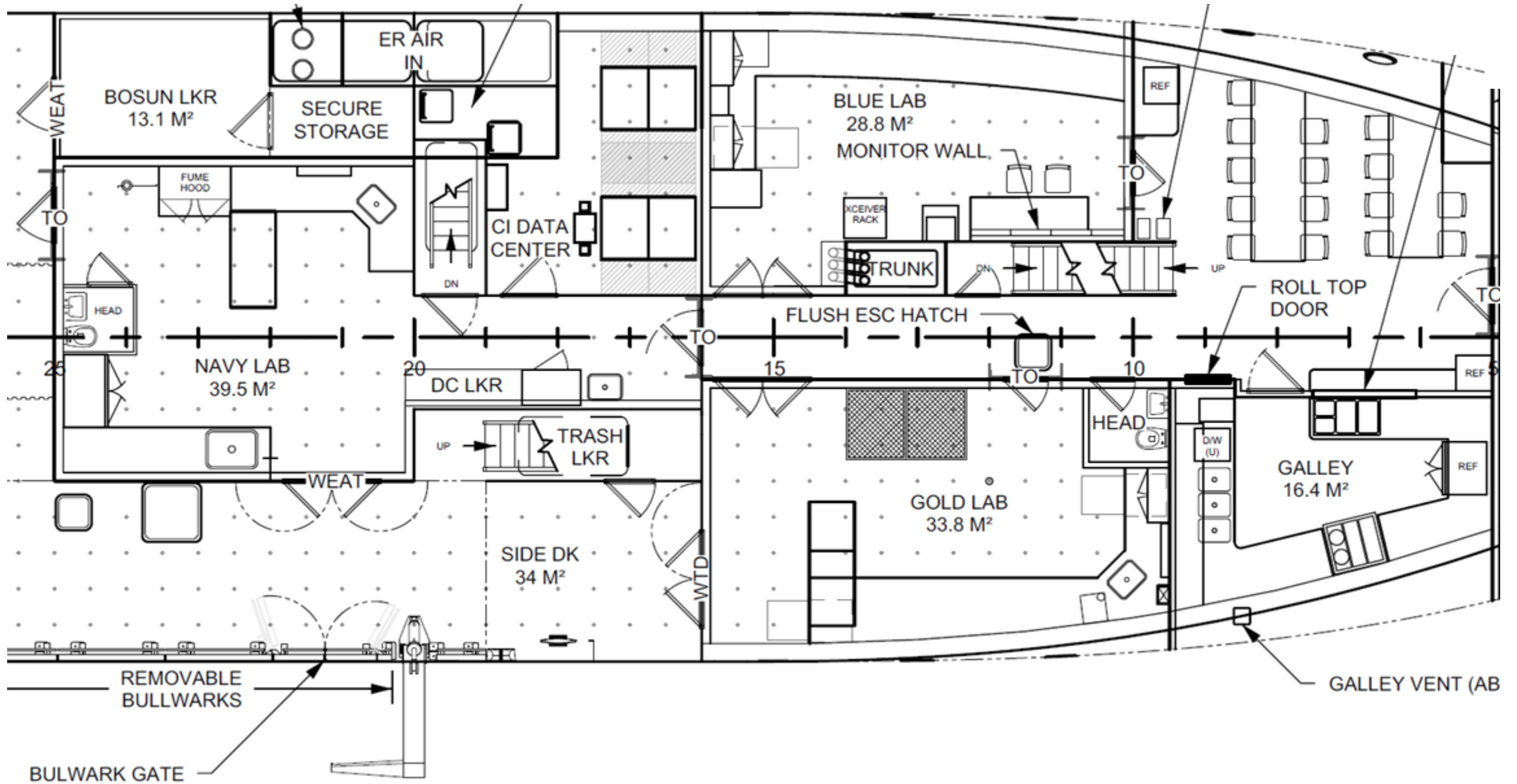
Primary power system

Six Ballard FCwave, proton exchange membrane (PEM) fuel cell power modules, 200 kW per module

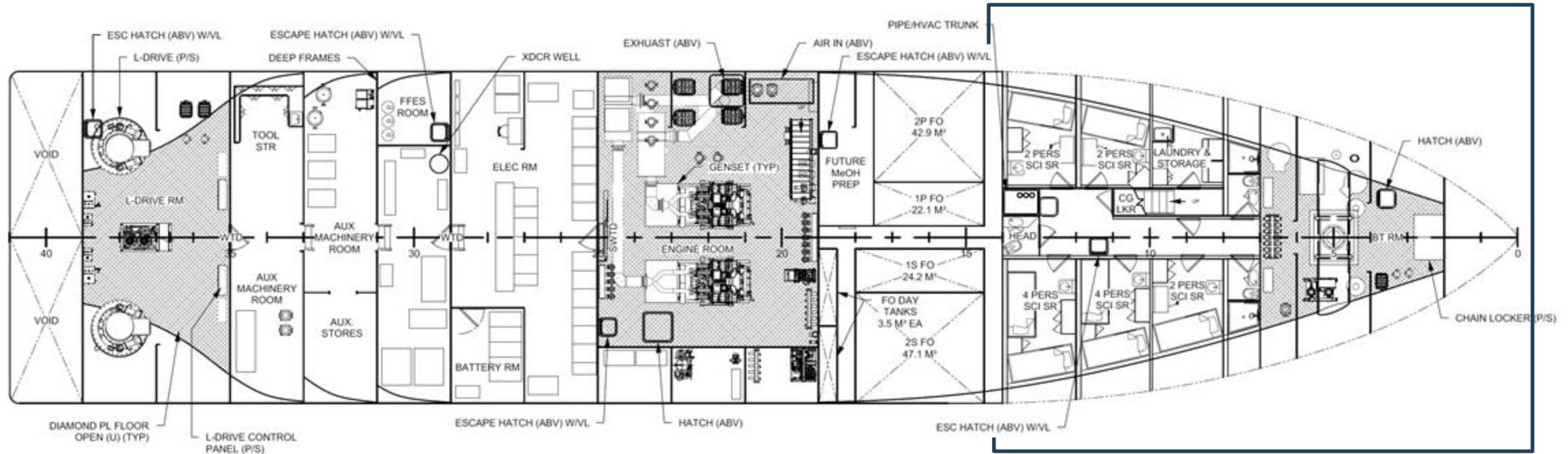
CCRV: Upper Deck – Crew Berthing (9)



CCRV: Main Deck – Scientific Laboratories



CCRV: Lower Deck



next slide

Propulsion

Thrusters: twin steerable 500 kW L-drives (Veth VL-700i-CR) with contra-rotating fixed-pitch propellers with integrated permanent magnet motors.

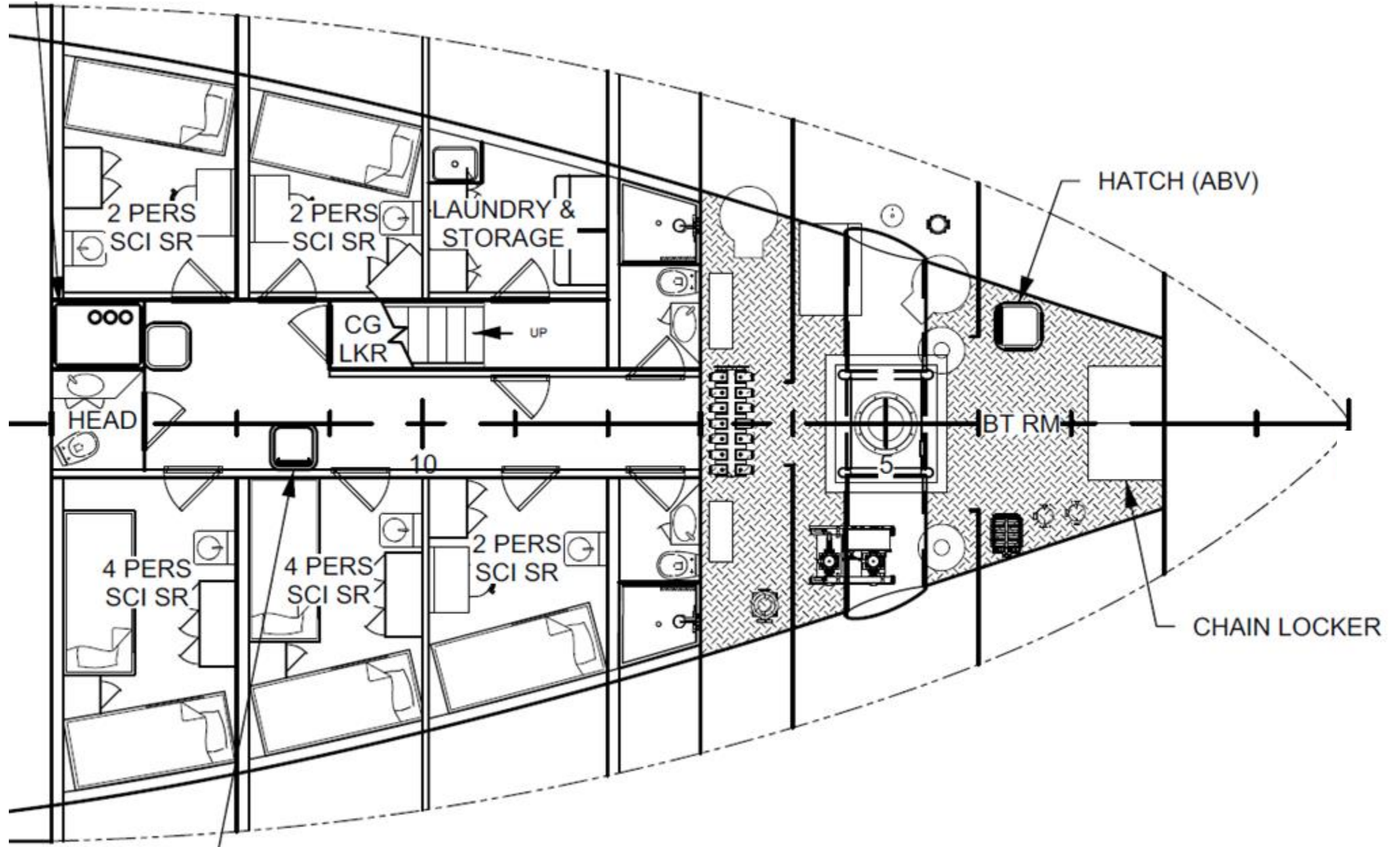
Bow thruster: tunnel thruster, 320 kW Schottel (STT 170 FP) with a fixed-pitch propeller

Secondary Power

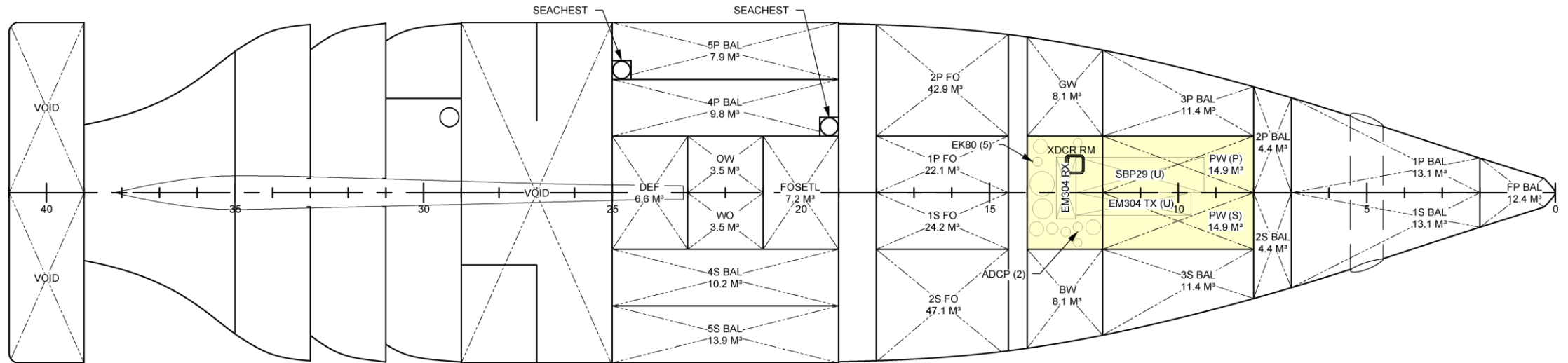
Diesel engines: Two variable speed, 700 kW diesel engines, Tier 4, compliant with California Air Resources Board (CARB) Commercial Harbor Craft Rules, with Diesel Particulate Filter

Note: Design supports a straightforward repower to methanol when technically feasible

CCRV: Lower Deck – Scientific Berthing (14)



CCRV: Tanks & Transducer Room



Acoustics suite

Kongsberg EM 304 MKII, 1° x 2°

Sub-Bottom Profiler (SBP) Kongsberg SBP29 6°x14°

Kongsberg/Simrad EK80 18, 38, 70, 120, 200

ADCP RDI Ocean Surveyor 75, 150 kHz

Sound Velocity Sensor (SVS) Teledyne SVP70

Acoustic Release Airmar CS229, 12kHz

Sonar Synchronization Unit (SSU) K-Sync

Kongsberg Remote Control Unit

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
- Hazards will be mitigated in detailed design



Alternative fuel vessel: Lessons learned (so far)

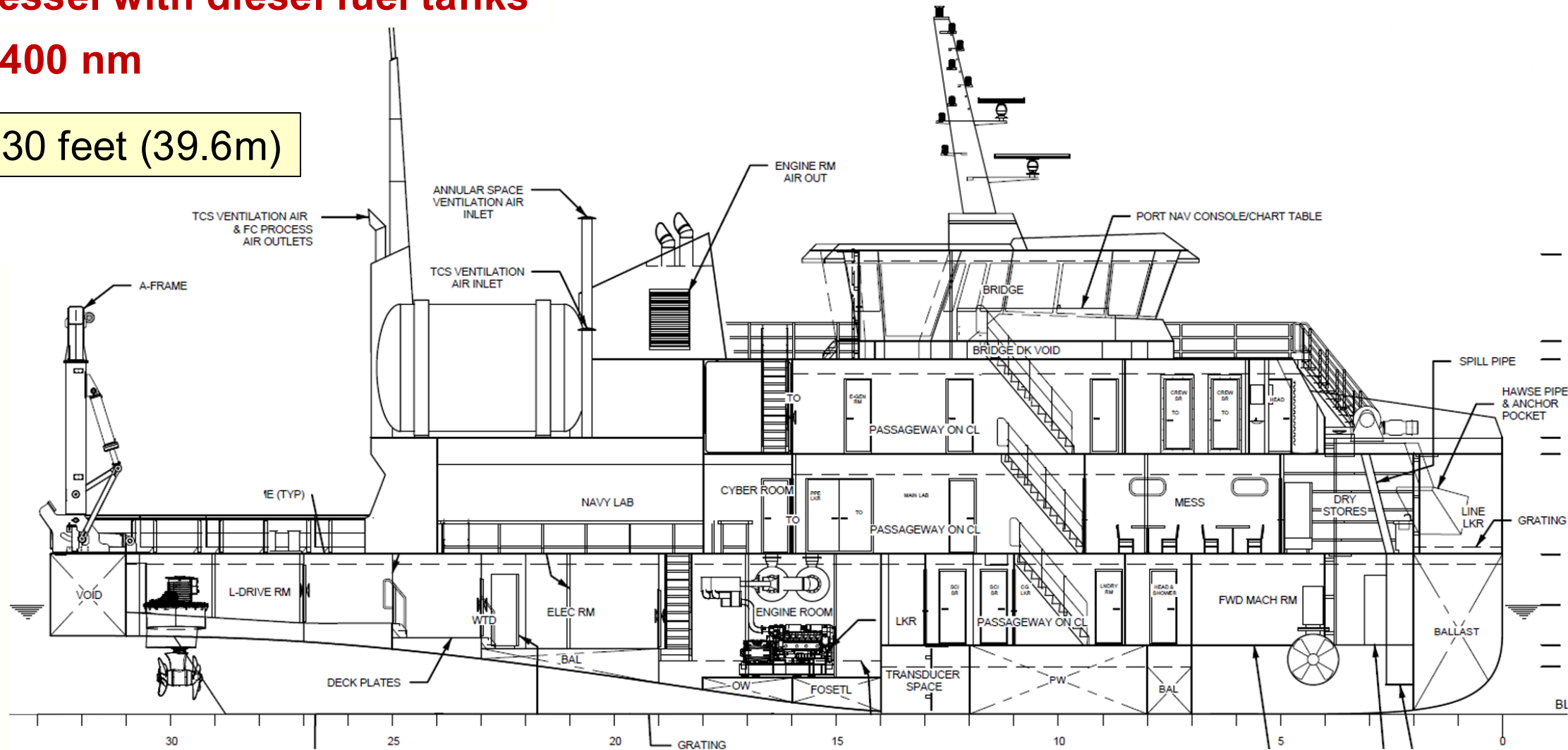
- **Tanks:** LH2 cryogenic tank, methanol tanks (cofferdams around the fuel storage tanks and a future methanol preparation room). **Cryogenic tank is expensive.**
- **Bunkering:** shore delivery system needs to be designed, built & integrated with ship bunkering system
- **Safety:** HAZID workshop identified 89 separate hazards, assessed potential consequences, and evaluated existing safeguards of the hydrogen gas system
- **Firefighting:** Multiple systems needed, 1) clean agent (Novec) in engine room and emergency generator spaces, 2) water mist system to protect battery room and fuel cell room with fixed fire extinguishing and cooling, and 3) dry chemical powder system for the hydrogen bunkering stations
- **Impacts to design:** deck space and scientific equipment (hydrogen tank taking up 01 deck, methanol tanks added 10 meters to work deck length, separate spaces for diesel generator room and fuel cell room)
- **Additional capital cost:** 2024 estimate ~30% additional cost for hydrogen-specific engineering, design, hardware, and vessel modifications
- **Crewing:** Power plant requires engineering staff of three licensed engineers with advanced knowledge and skills (existing vessel sails with a single diesel mechanic).

Alternative fuel vessel: Lessons learned (so far)

Coastal vessel with diesel fuel tanks

Range: 2,400 nm

Length: 130 feet (39.6m)



Tankage: Coastal vessel with diesel fuel tanks...

Alternative fuel vessel: Lessons learned (so far)



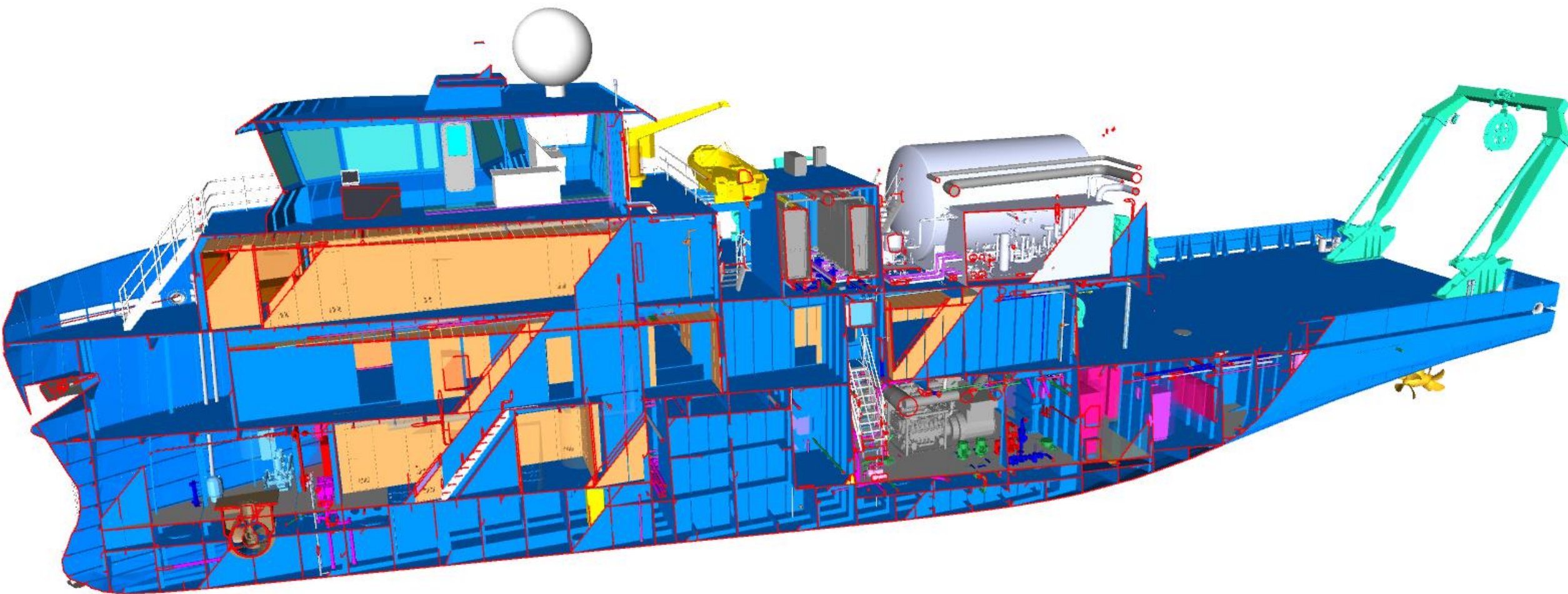
Bunkering: Not so different

Existing methods of delivery and transfer can be easily adapted

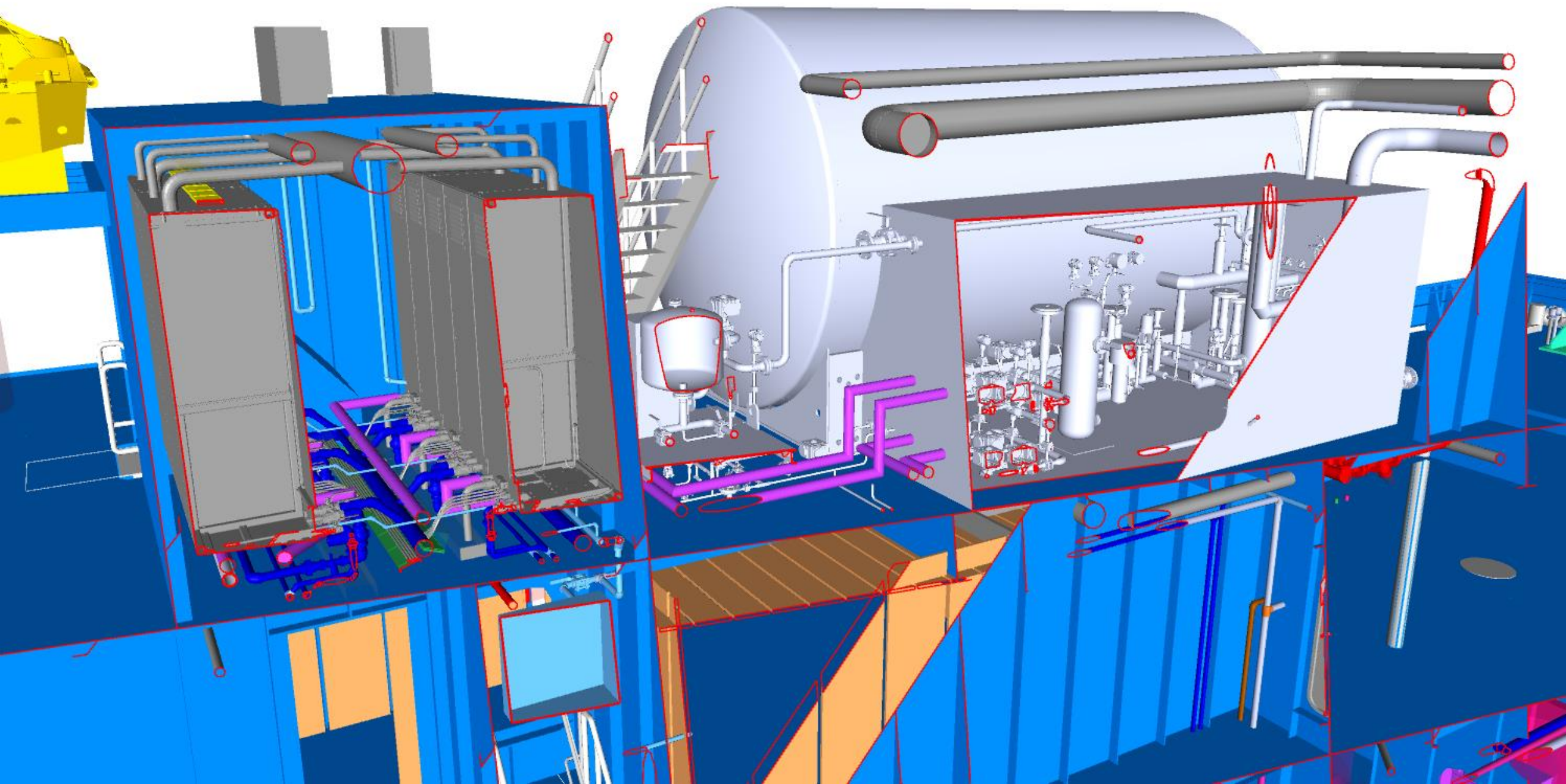
- Based on safe practices used now
- Trailer delivery pierside
- Each trailer provides 4,000 kg of LH₂
- Typical CCRV bunkering will require one trailer
- Full transfer in ~ 1 hour (similar to diesel)

New cryogenic pump technology enables transfers that are quiet and minimize incidental release of hydrogen

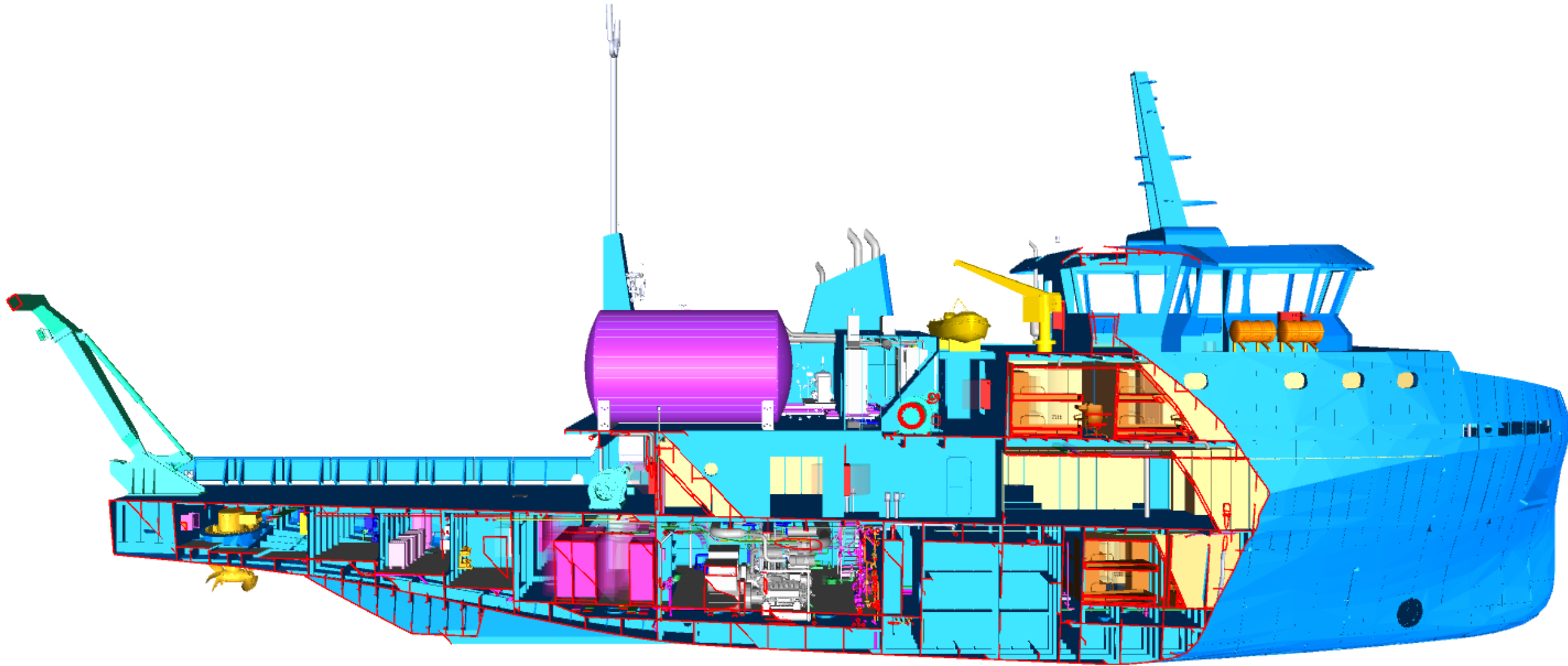
3D Model



3D Model



3D Model – The engine room of the future?





Hydrogen-Hybrid Zero-Emission Research Vessel



Coastal Class Research Vessel (CCRV)