A zero-emission hydrogen hybrid research vessel: Scripps Institution of Oceanography

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Acknowledgments: We are grateful for our visionary sponsors

The Hydrogen Hybrid Research Vessel is supported by a major grant from the **State of California**, passed as part of the California Budget Act of 2021, signed by Governor Gavin Newsome on 12 July 2021.

California's Hydrogen Hub, The Coastal Class Research Vessel is supported as a Tier 1 project by Californiia's **Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES)**

Major support for California's Hydrogen Hub has been awarded by the United Stated **Department of Energy** through the Office of Clean Energy Demonstrations

Vessel design and control engineering for the Coastal Class Research Vessel is supported by the U.S. **Office of Naval Research** under Award N00014-22-1-2765.

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 supported by the U.S **Department of Transportation Maritime Administration (MARAD)** Maritime Environmental and Technical Assistance (META) program.

Roger Revelle aboard R/V *E. W. Scripps*, Gulf of California Expedition, 1939

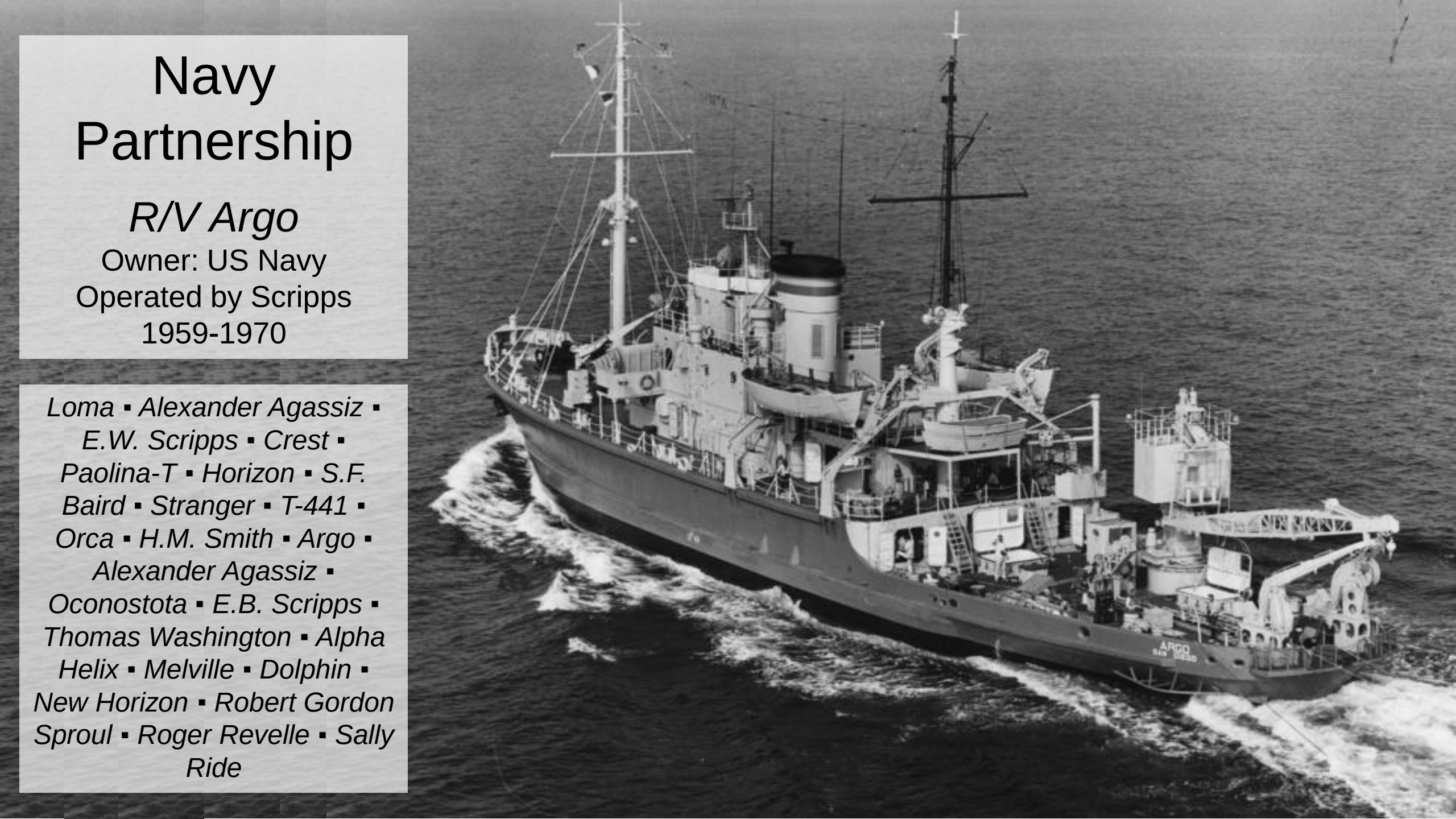
R/V *Alexander Agassiz*
1907-1917

Navy Partnership

R/V Argo

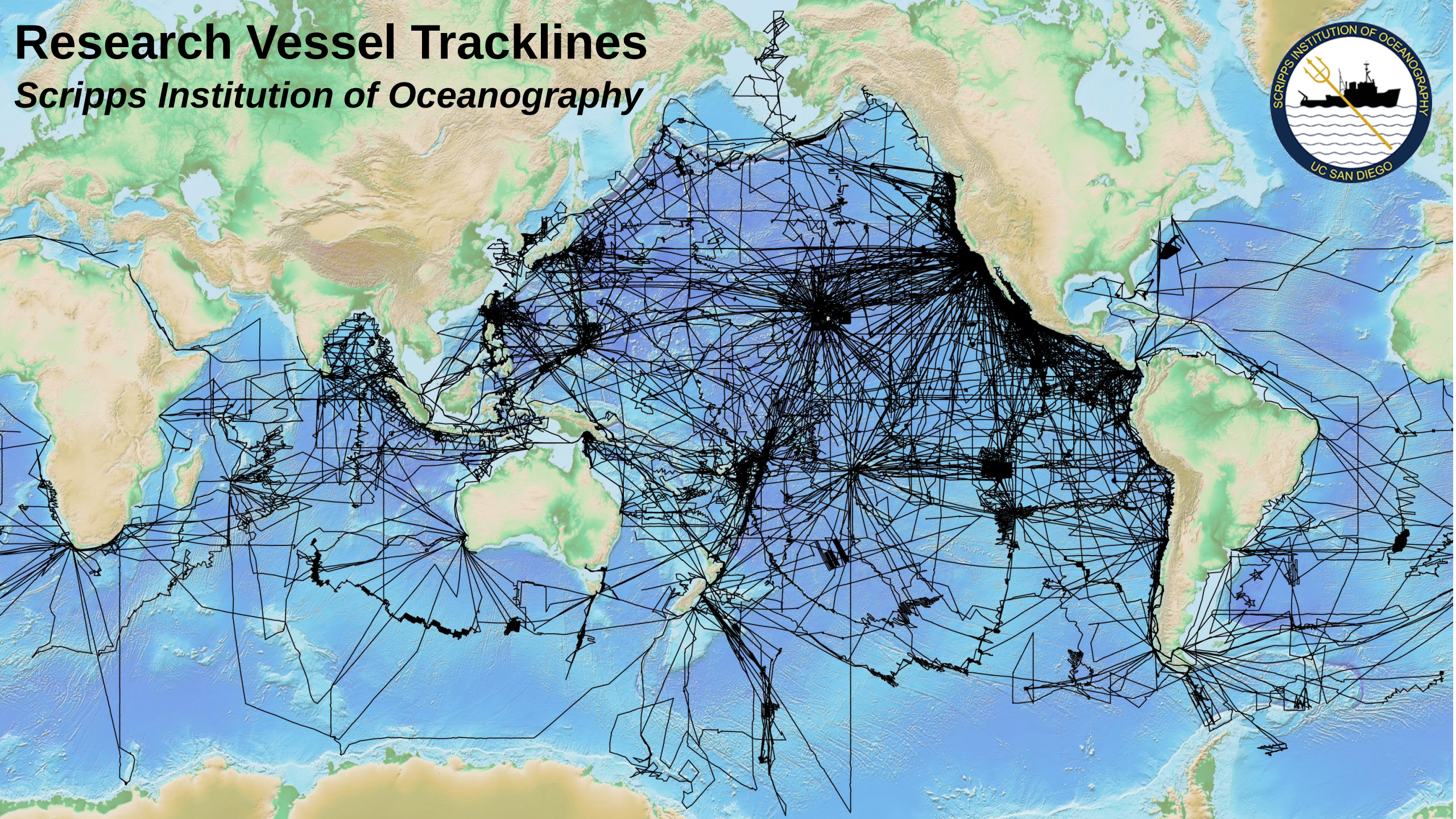
Owner: US Navy
Operated by Scripps
1959-1970

Loma ▪ Alexander Agassiz ▪ E.W. Scripps ▪ Crest ▪ Paolina-T ▪ Horizon ▪ S.F. Baird ▪ Stranger ▪ T-441 ▪ Orca ▪ H.M. Smith ▪ Argo ▪ Alexander Agassiz ▪ Oconostota ▪ E.B. Scripps ▪ Thomas Washington ▪ Alpha Helix ▪ Melville ▪ Dolphin ▪ New Horizon ▪ Robert Gordon Sproul ▪ Roger Revelle ▪ Sally Ride



Research Vessel Tracklines

Scripps Institution of Oceanography



United States Academic Research Fleet - 2024

Global Class
40 scientists, worldwide range


Atlantis


Roger Revelle


Thomas G. Thompson

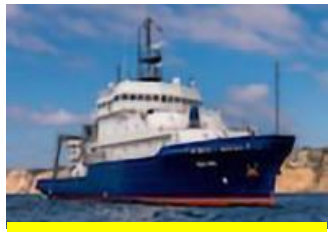

Marcus Langseth

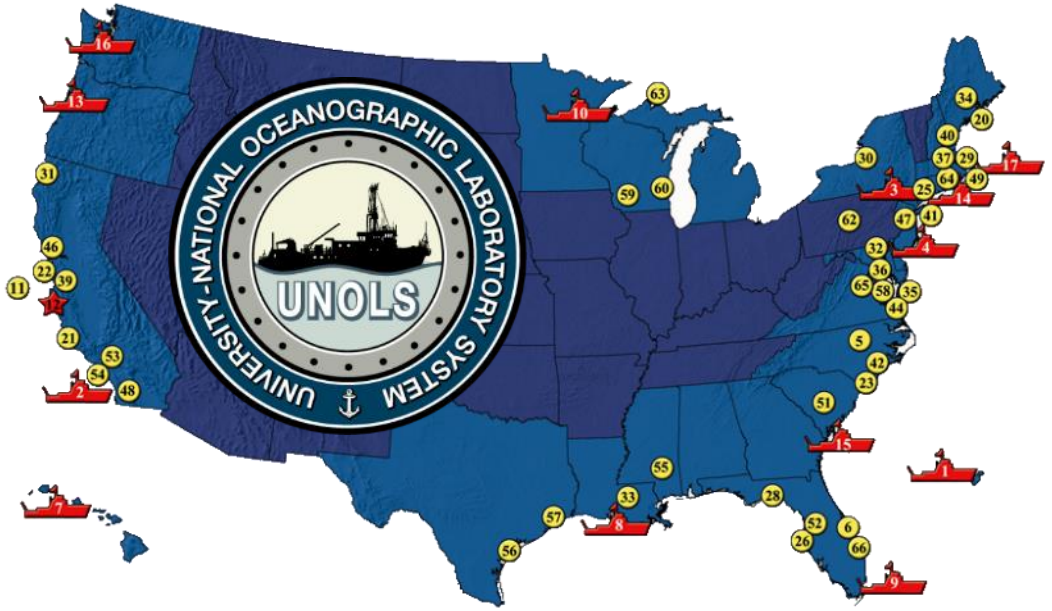

Sikuliaq

Ocean Class
24 scientists, oceanic range


Kilo Moana


Neil Armstrong


Sally Ride



Regional Class
20 scientists, continental shelf to abyssal plain


Endeavor


Atlantic Explorer


Hugh Sharp

Coastal Class
15 scientists, Coastal and local


Robert G. Sproul


Blue Heron


Rachel Carson


Savannah


Walton Smith


Pelican

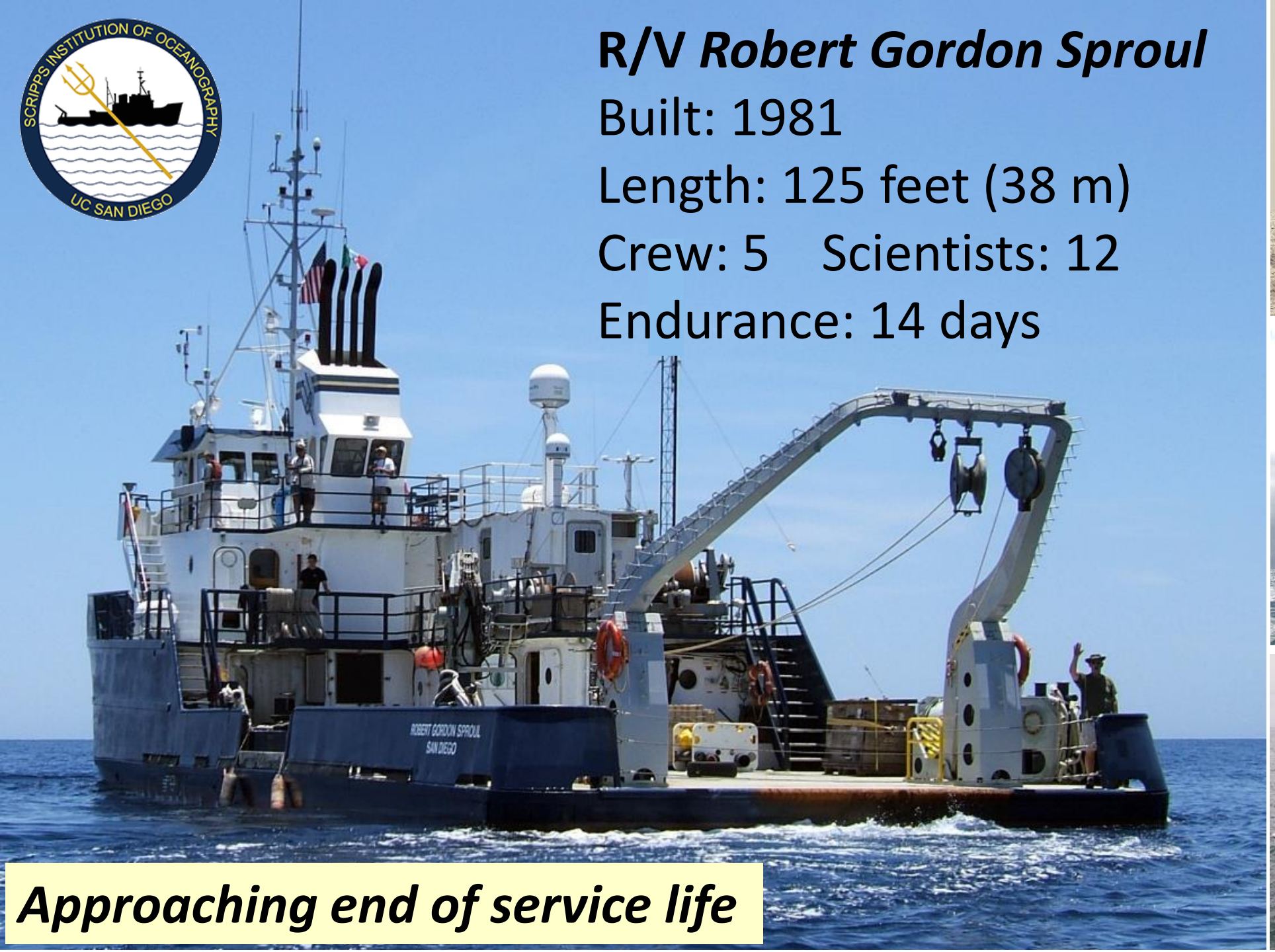
R/V *Robert Gordon Sproul*

Built: 1981

Length: 125 feet (38 m)

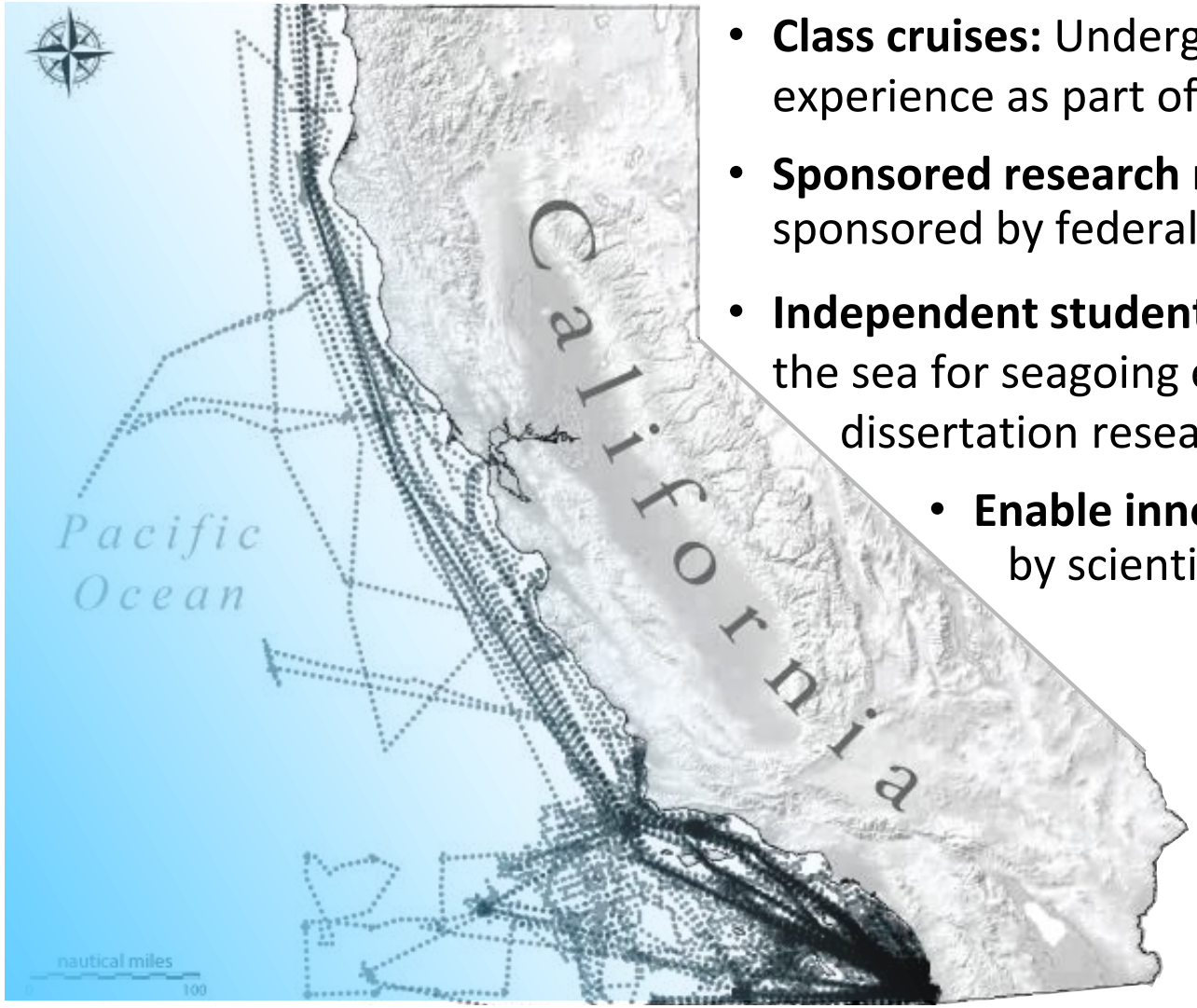
Crew: 5 Scientists: 12

Endurance: 14 days



Approaching end of service life

CCRV: An uncompromising research vessel -- with zero-emission capability



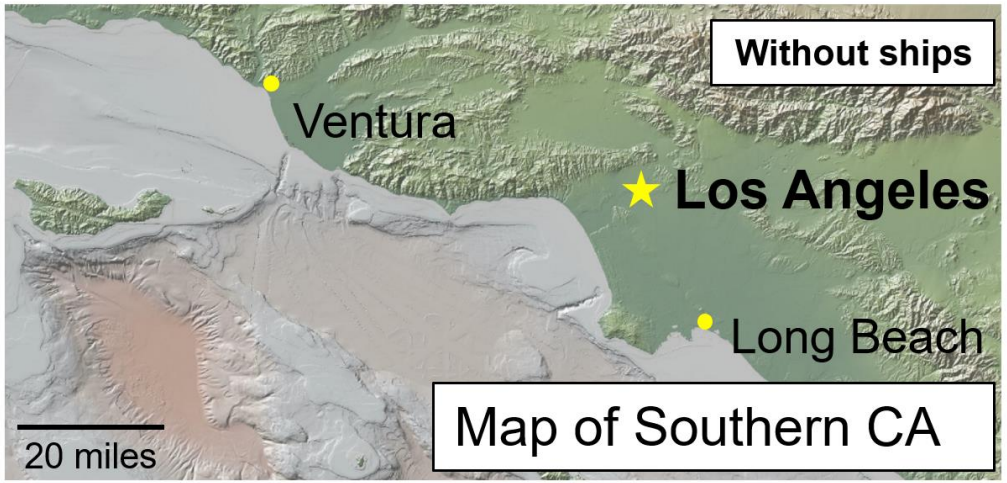
Mission tracklines of UC's Coastal Class Research Vessel

- **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	Marine Mammal Studies
Physical Oceanography	Oceanic Fisheries
Ocean Acoustics	Ocean Monitoring Moorings
Marine Biology	Harmful Algal Blooms
Pollution Detection	Ocean Ecosystems
Remotely-Operated Vehicles	Ocean Acidification
Autonomous Vehicles	Seabed Mapping

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

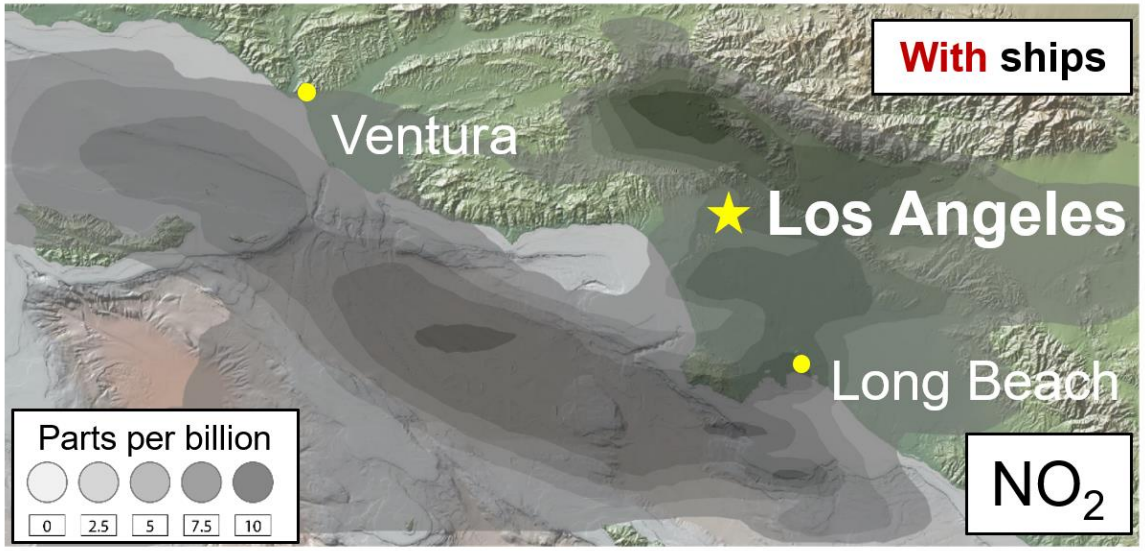
Ship fossil fuel emissions harm our health and environment

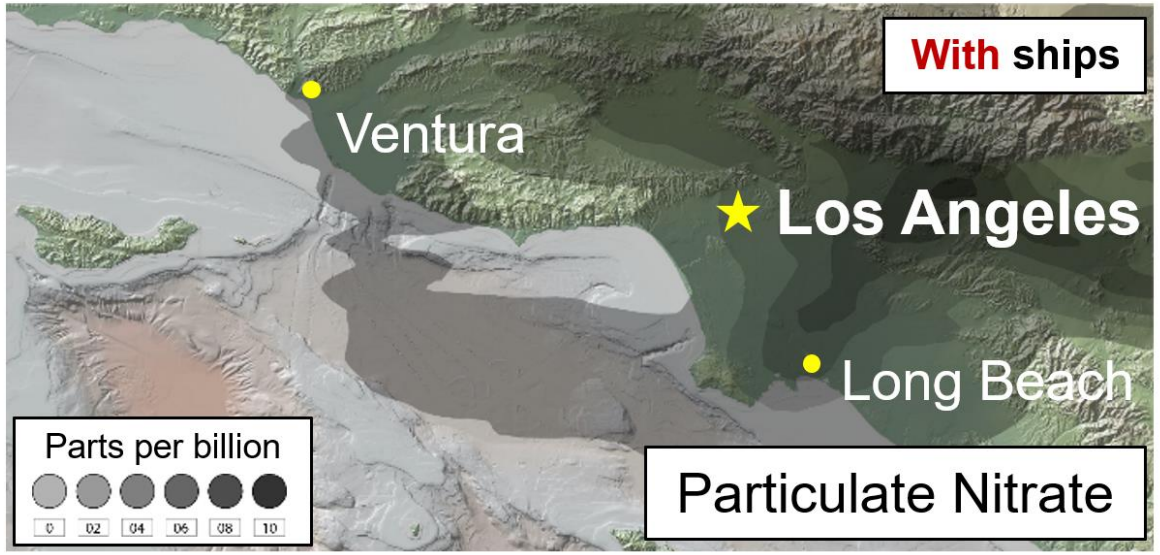


CARB recognizes diesel particulate matter as a **toxic air contaminant.**

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

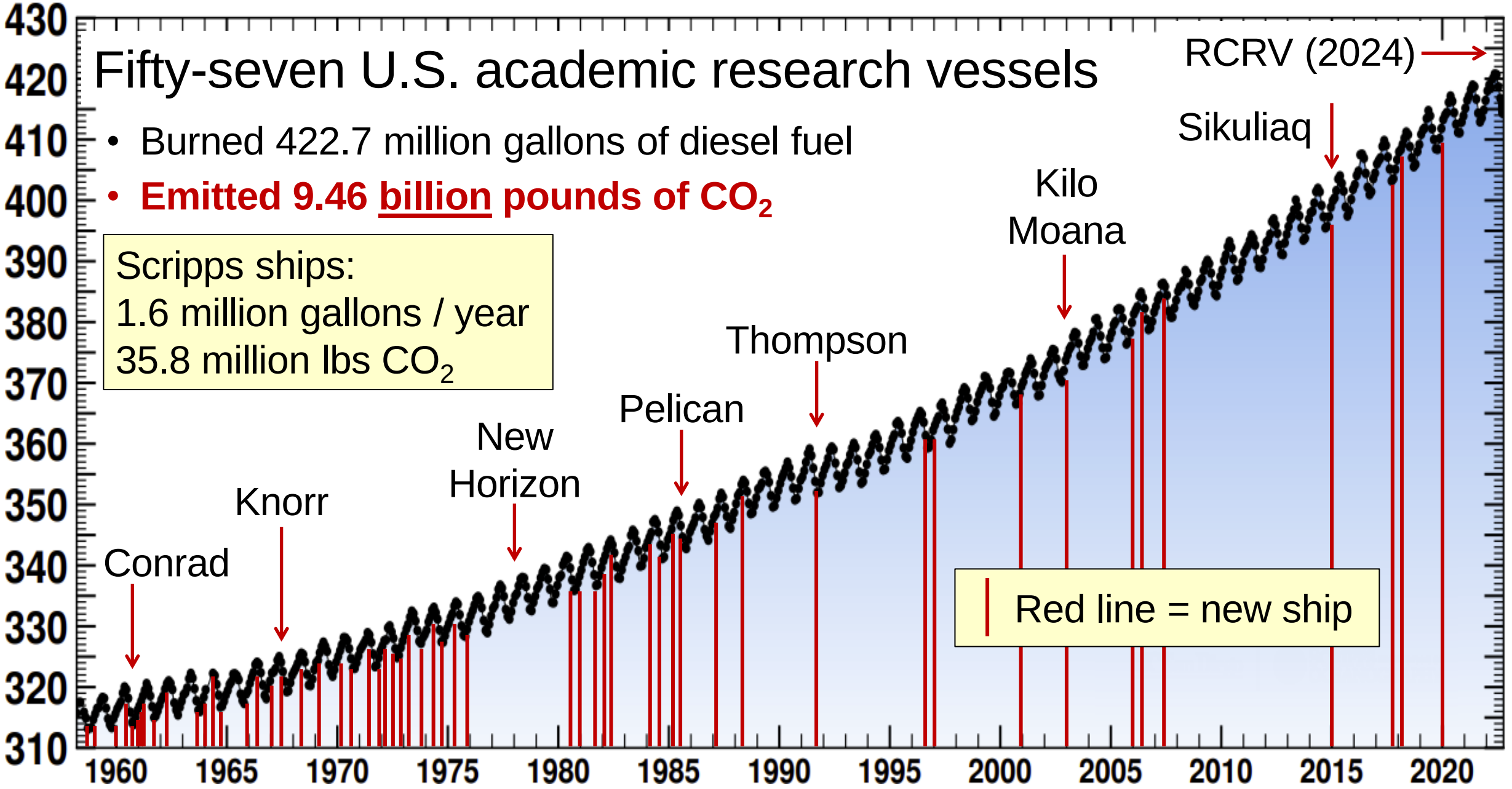
"…diesel exhaust still poses substantial risks to public health and the environment."





Dabdub et al., 2008, Air Quality Impacts of Ship Emissions in the South Coast Air Basin of California

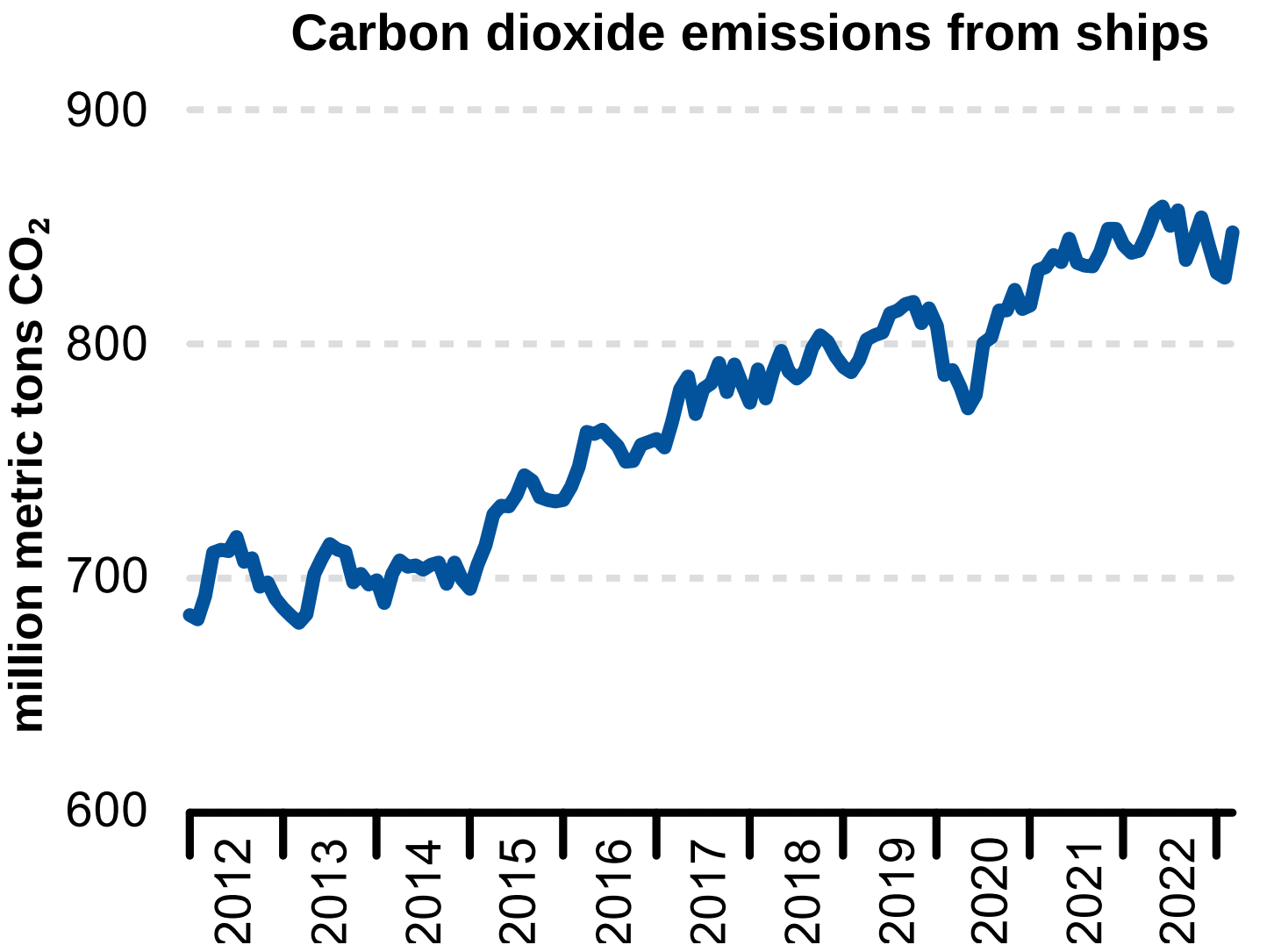
Ship fossil fuel CO_2 emissions contribute to global climate change



If ship emissions were a country…

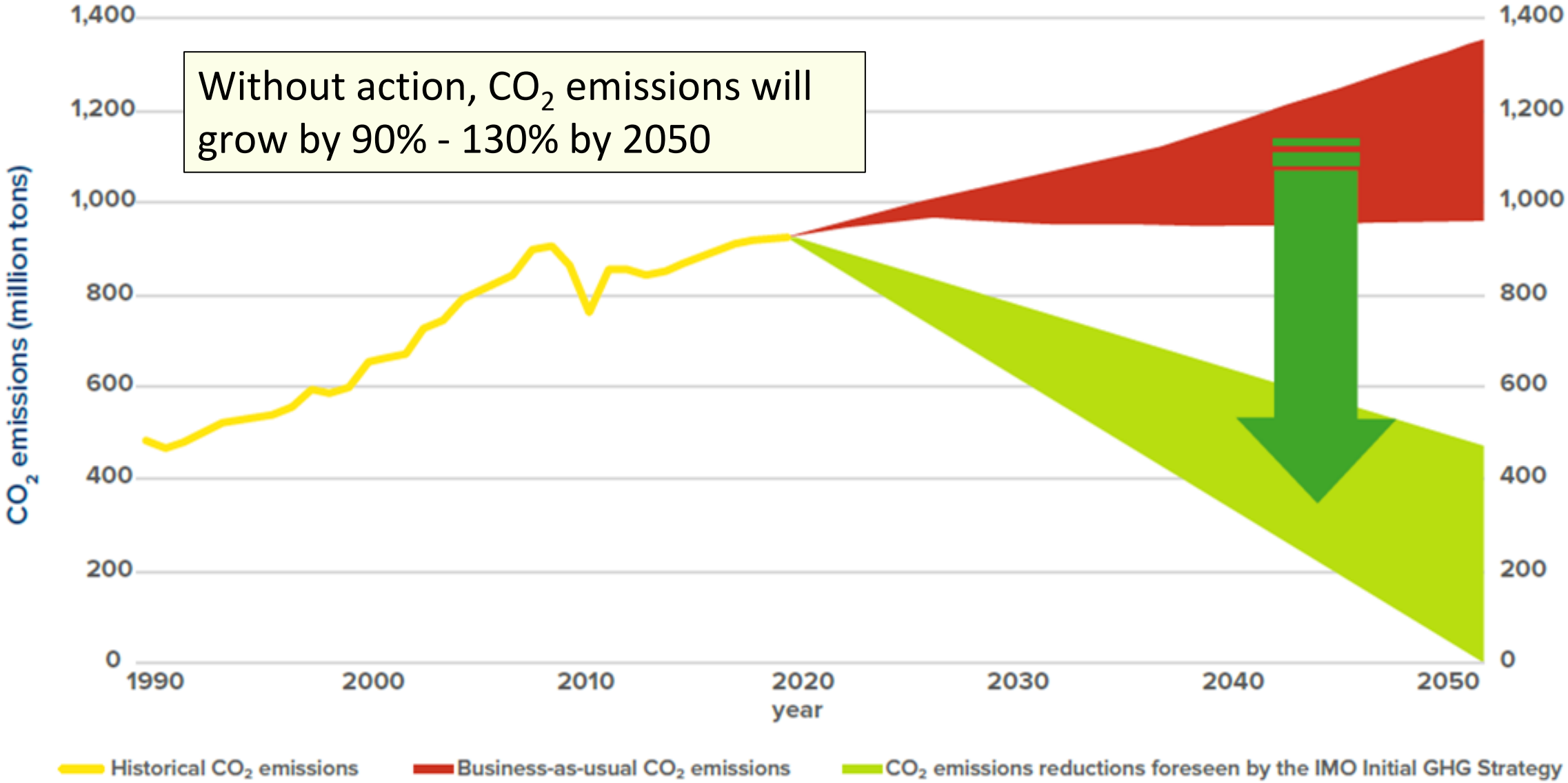
Worst global CO_2 emitters (million metric tons CO_2)

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



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

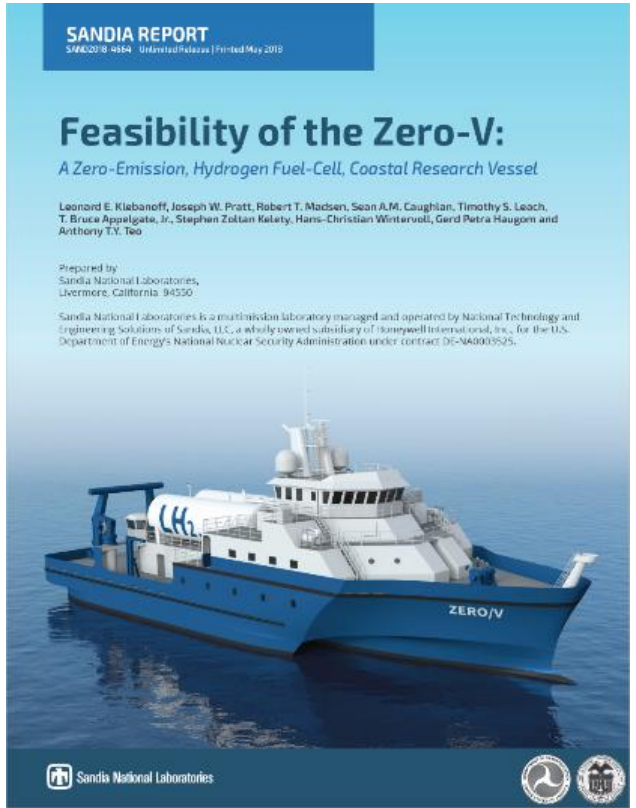
Feasibility Study: Can We Eliminate Ship Emissions?

2018 Study:

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

2020 Study:

Can a coastal research vessel use a hybrid approach to achieve zero emissions using hydrogen fuel cells or batteries, coupled with conventional propulsion?



Answer: Yes

Answer: Yes

Download the full reports:
maritime.sandia.gov

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

MARAD Maritime Administration

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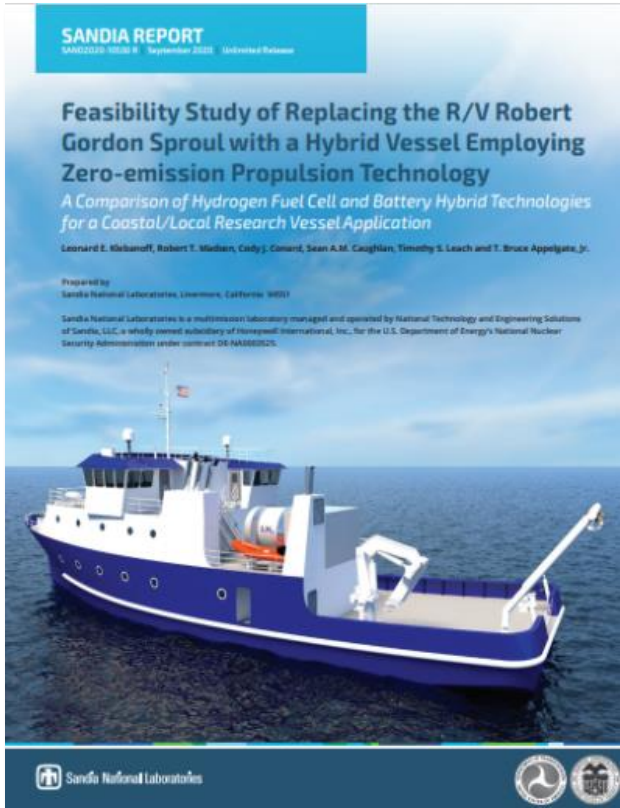
Sandia National Laboratories

Scripps Institution of Oceanography

DNV·GL



Benefits of a zero-emission vessel

Environmental benefits

- Reduce/eliminate criteria pollutant emissions
- Reduce/eliminate CO_2 emissions
- Replace fossil fuels with renewable green hydrogen
- Reduce/eliminate risk of oil spills

  Hydrogen fuel spill cleans itself up in < 30 seconds

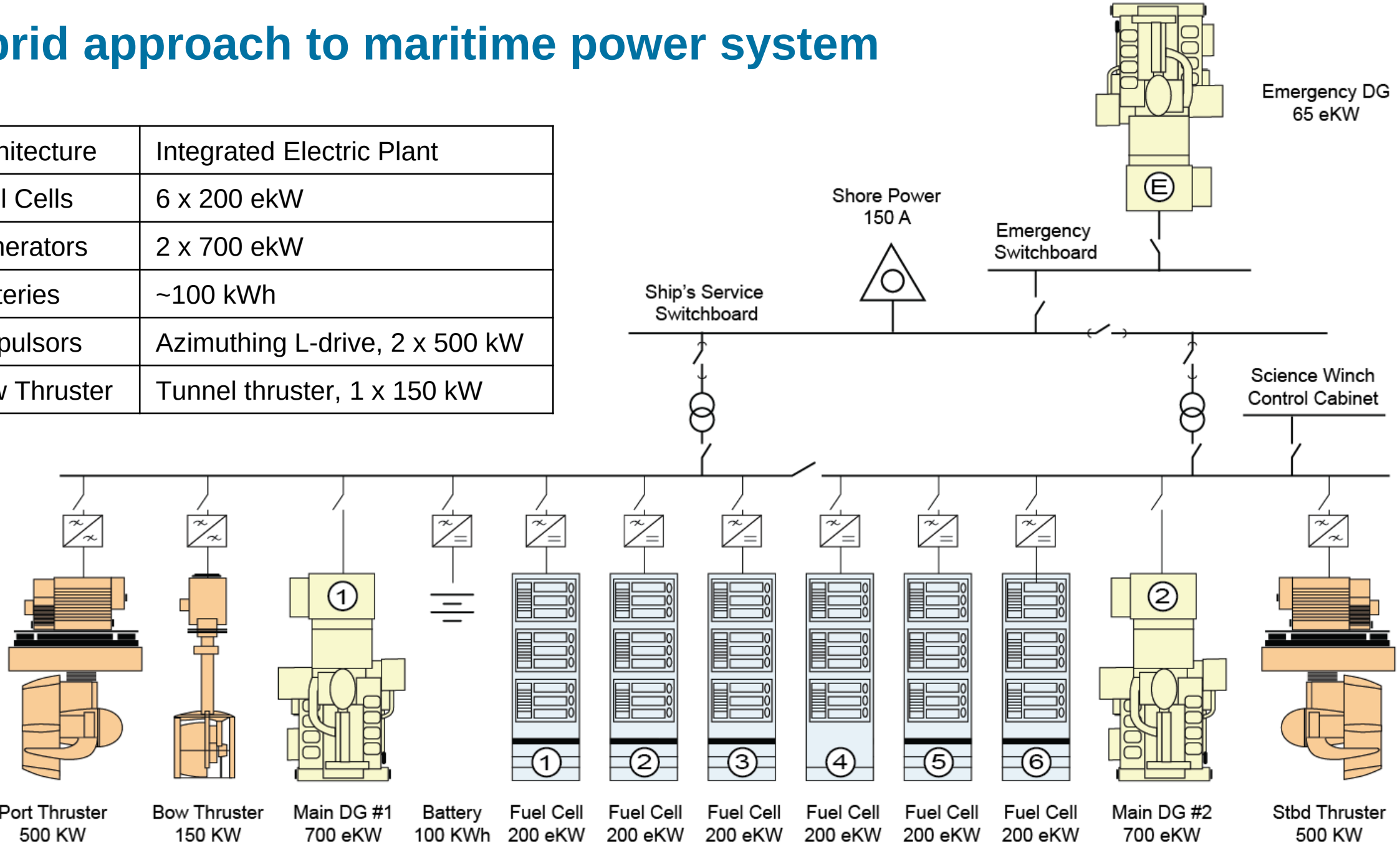
Scientific advantages

- Quiet: low underwater radiated sound = better acoustics
- Uncontaminated air and water samples
- Minimizes harm to physical & biological systems
- Makes own ultrapure water

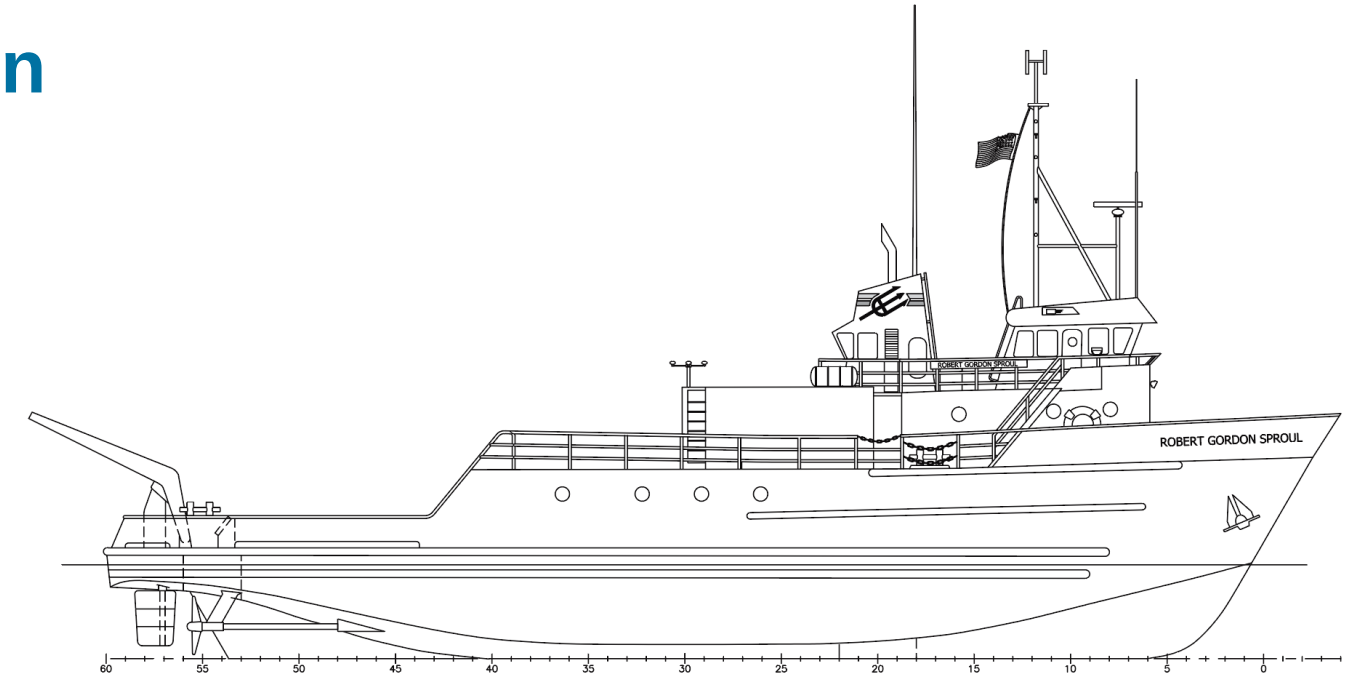
The Scripps Nimitz Marine Facility has pioneered the application of clean energy systems, including cold-iron berthing, solar power, and a containerized hydrogen fuel cell system to provide shore hotel load for *Robert Gordon Sproul.*

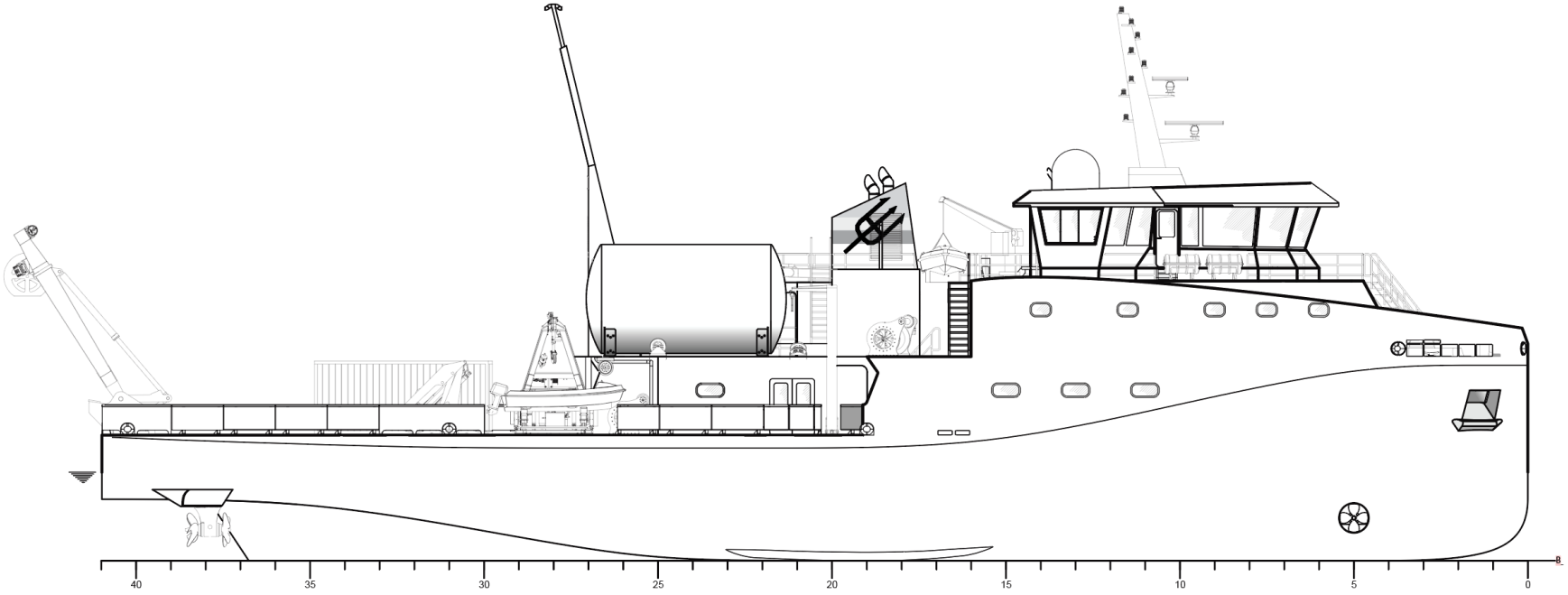
Hybrid approach to maritime power system

Architecture	Integrated Electric Plant
Fuel Cells	6 x 200 ekW
Generators	2 x 700 ekW
Batteries	~100 kWh
Propulsors	Azimuthing L-drive, 2 x 500 kW
Bow Thruster	Tunnel thruster, 1 x 150 kW



Comparison





Robert Gordon Sproul

Length: 38 m (125 ft)
Beam: 9.7 m (32 ft)
Crew: 5
Scientists: 12
Students: 30 (day trips)
Lab space: 44 m^2
Deck space: 168 m^2

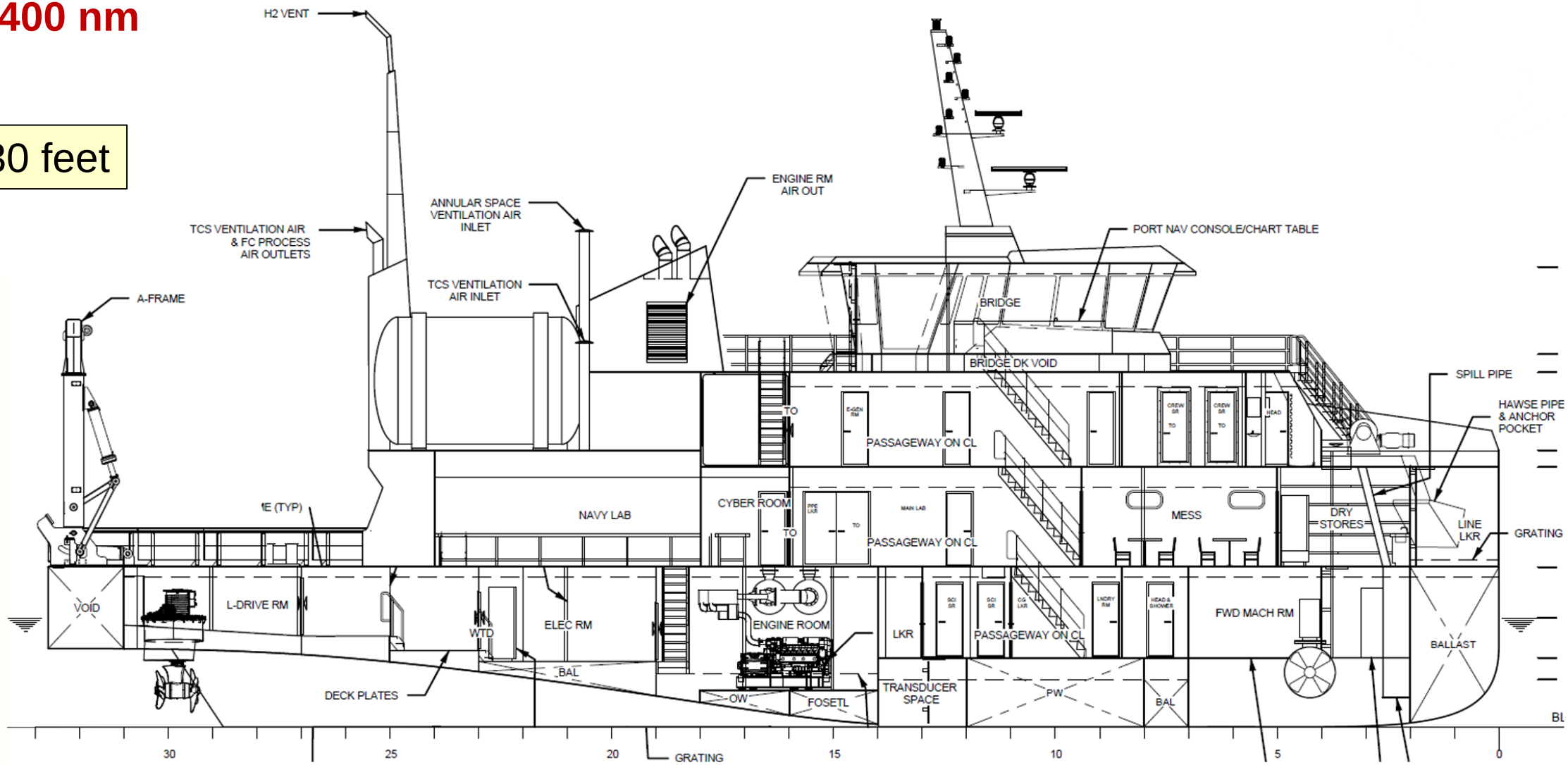
CCRV Hydrogen Hybrid

Length: 49.99 m (164 ft)
Beam: 11 m (36 ft)
Crew: 7 (US) / 9 (SOLAS)
Scientists: 16 (US) / 14
Students: 40 (day trips)
Lab space: 102 m^2
Deck space: 238 m^2

Inboard profile: Hybrid hydrogen/diesel concept

Range: 2,400 nm

Length: 130 feet



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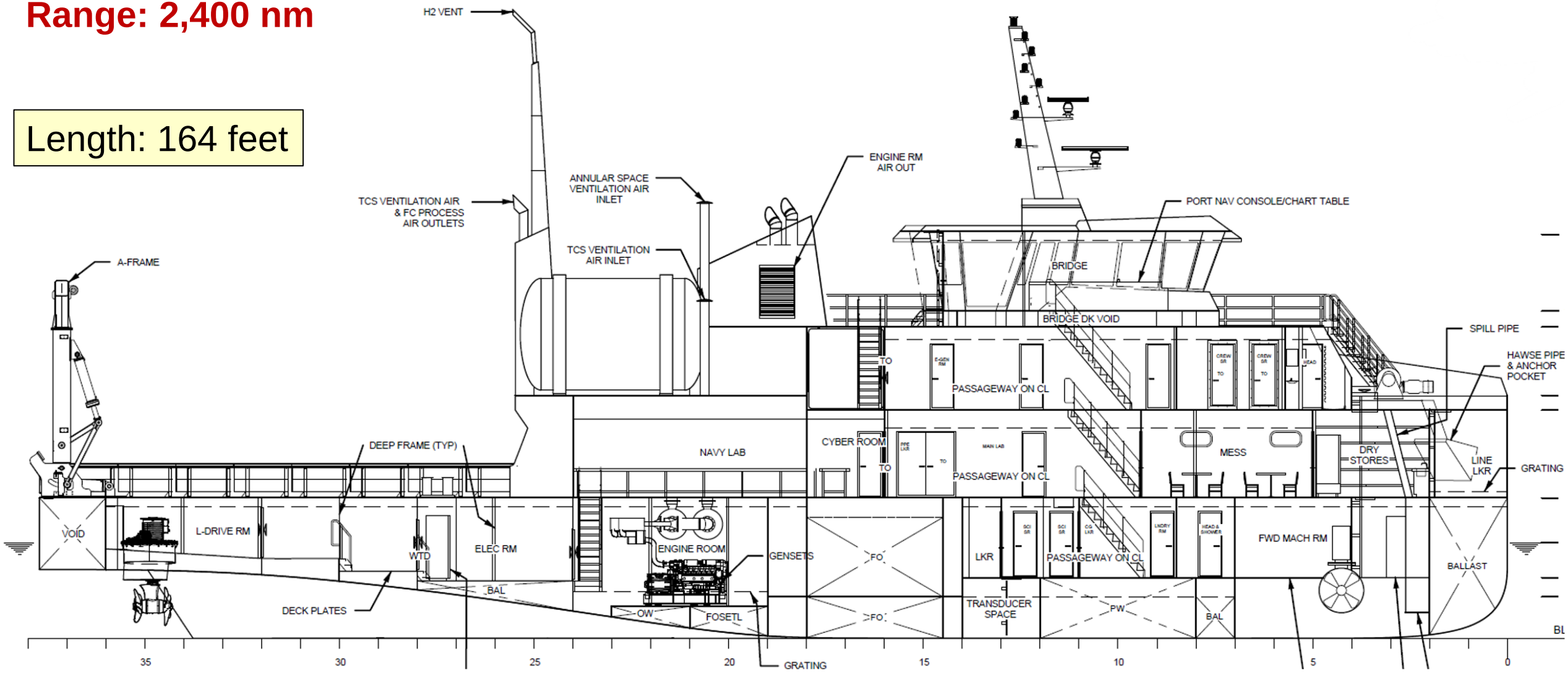
Inboard profile: Hybrid hydrogen/methanol concept

Range: 2,400 nm

Length: 164 feet



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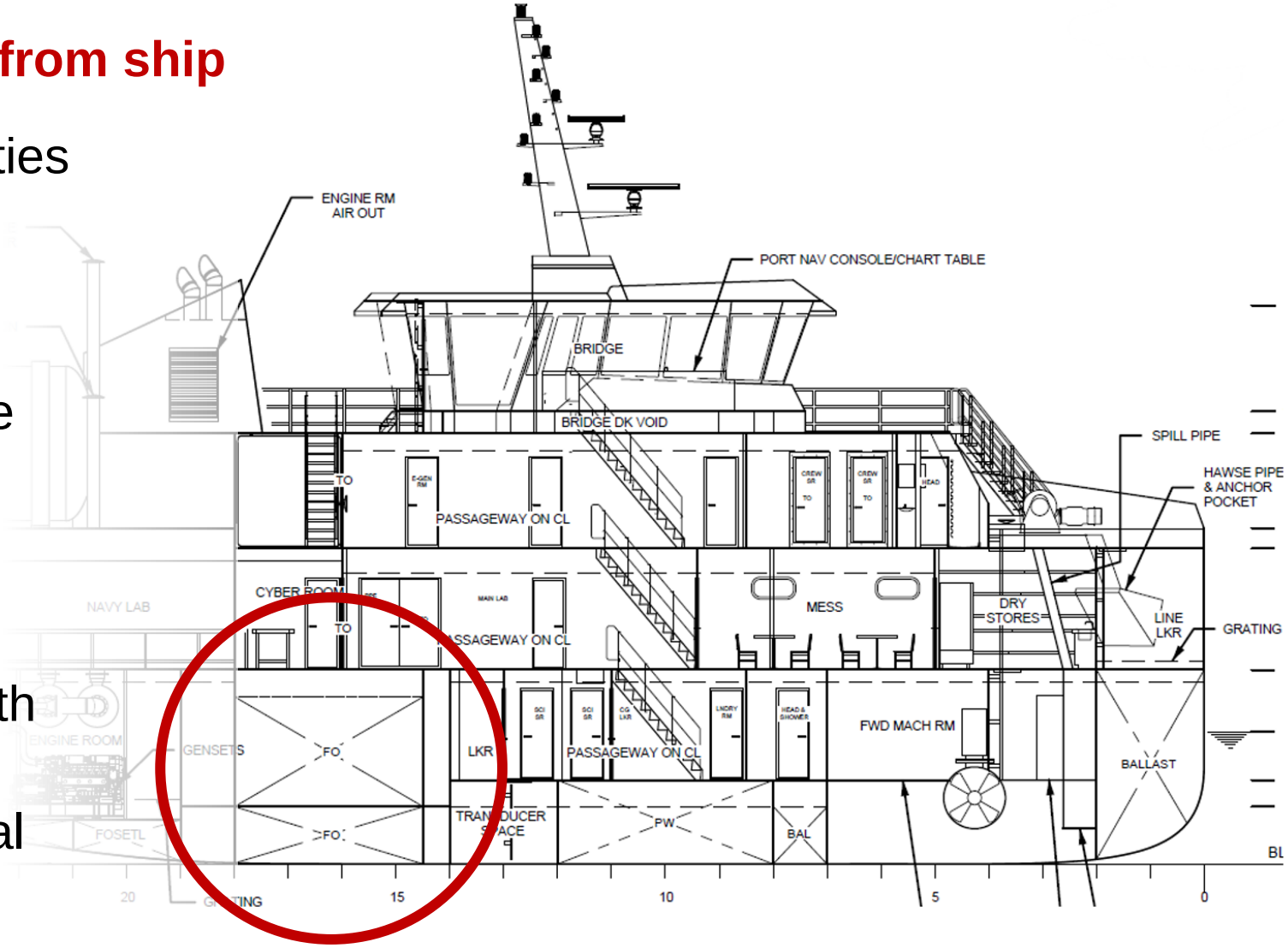
Methanol convertible concept

Hydrogen will remain as primary fuel

Objective: Eliminate diesel entirely from ship

- Methanol offers higher energy densities and easier storage than hydrogen
- Using green hydrogen as feedstock, methanol has low well-to-wake CO_2
- Hydrogen carried in methanol can be used in fuel cells for emission-free operation
- Methanol offers high technological readiness: 42 methanol-fueled and -ready Ocean Going Vessels built, with 240 more are on order
- Small-ship solutions are likely several years away



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Methanol convertible concept

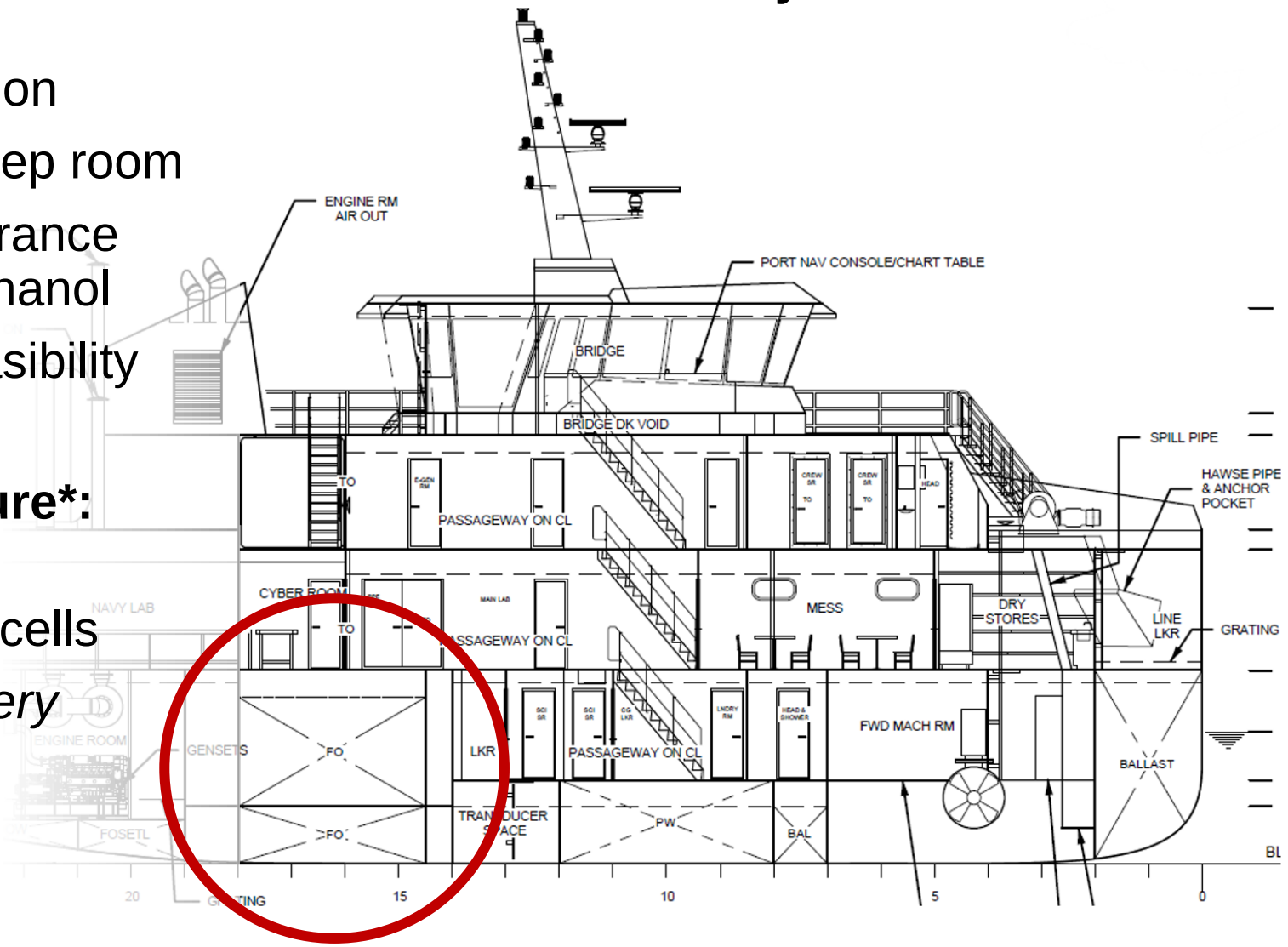
Design now with intent to replace diesel with methanol as secondary fuel

- 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 & confirm feasibility of arrangements

When methanol technology is mature*:

Replace diesel generators with either methanol combustion engines or fuel cells

** Anticipated within five years of delivery*



The initial design is for a hydrogen/diesel fueled hybrid. It will not be reviewed for, or approved for, carriage of methanol fuel or as a methanol-ready vessel. This reduces technical and regulatory risk.

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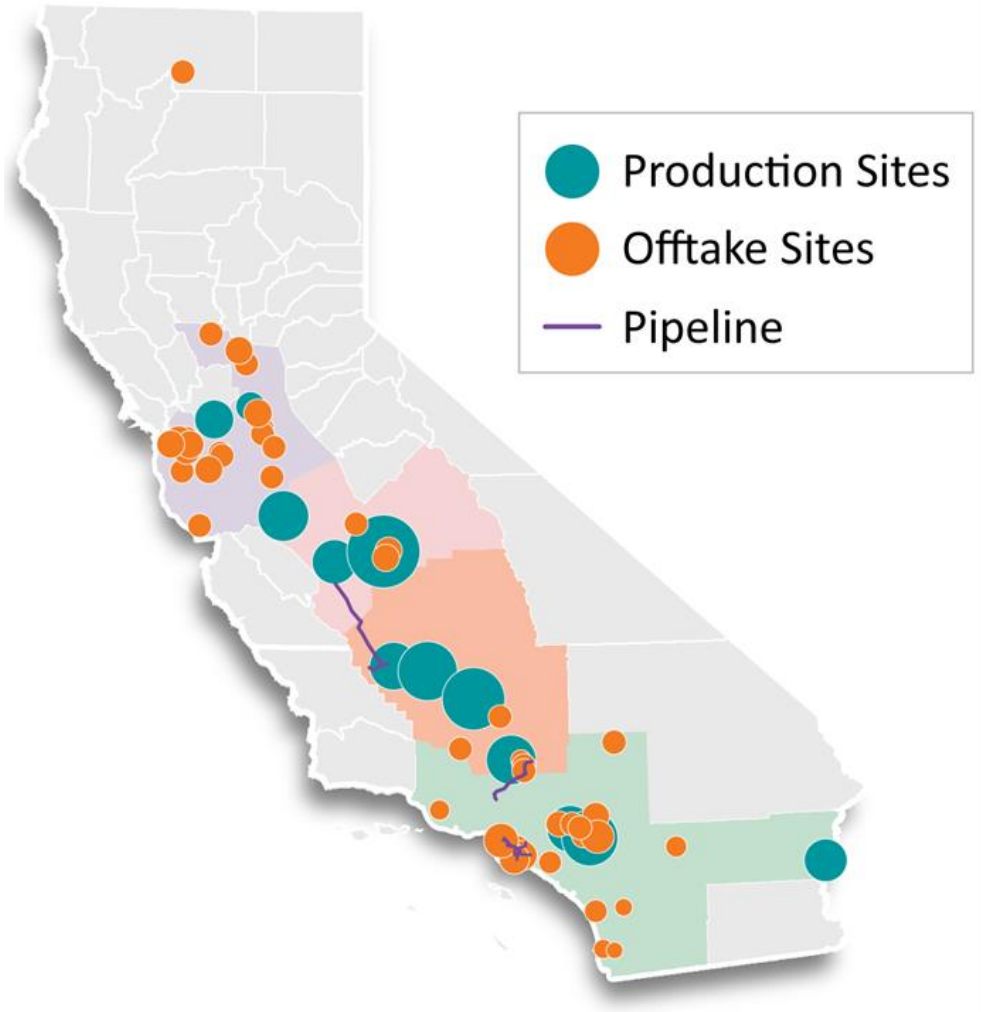
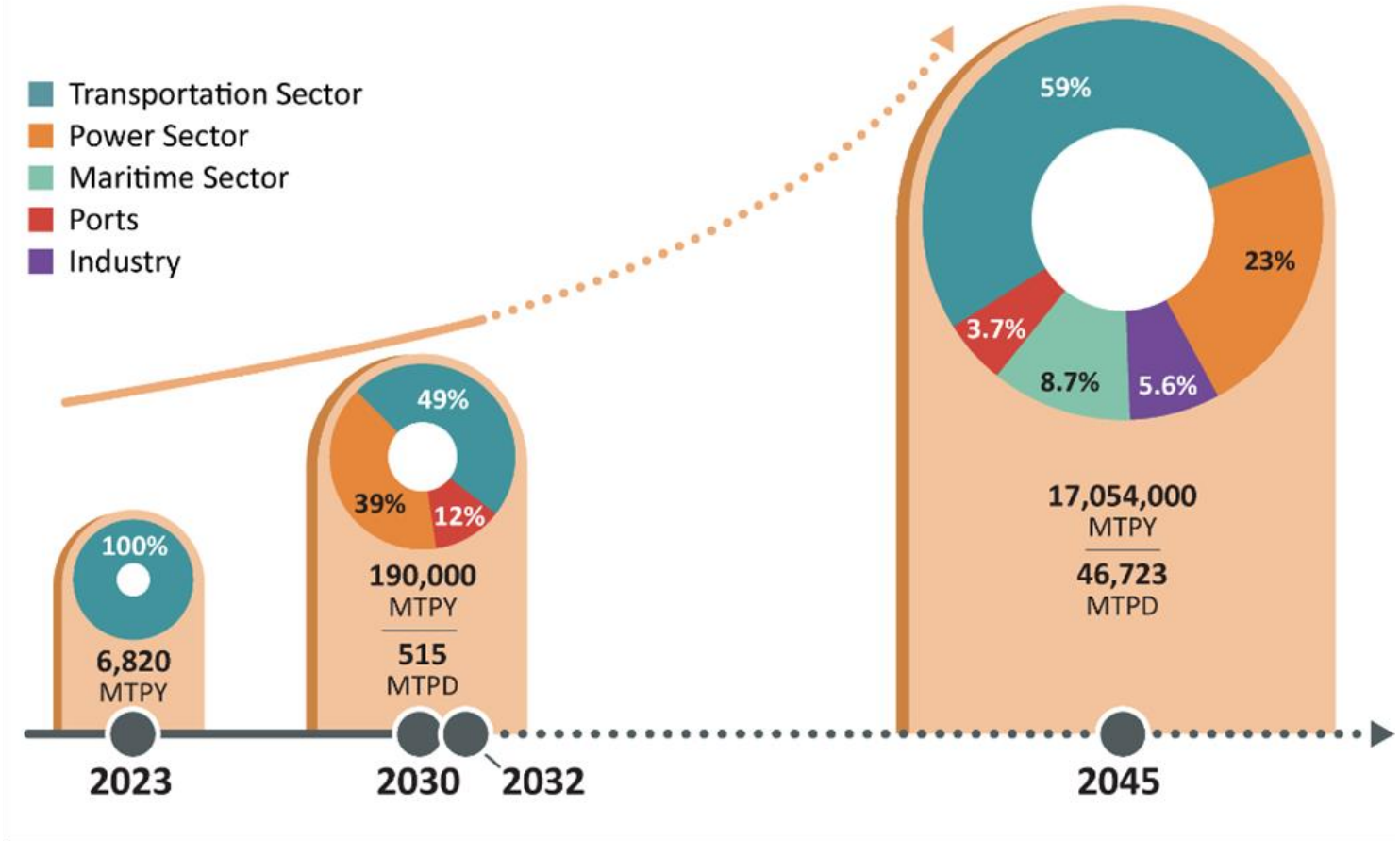
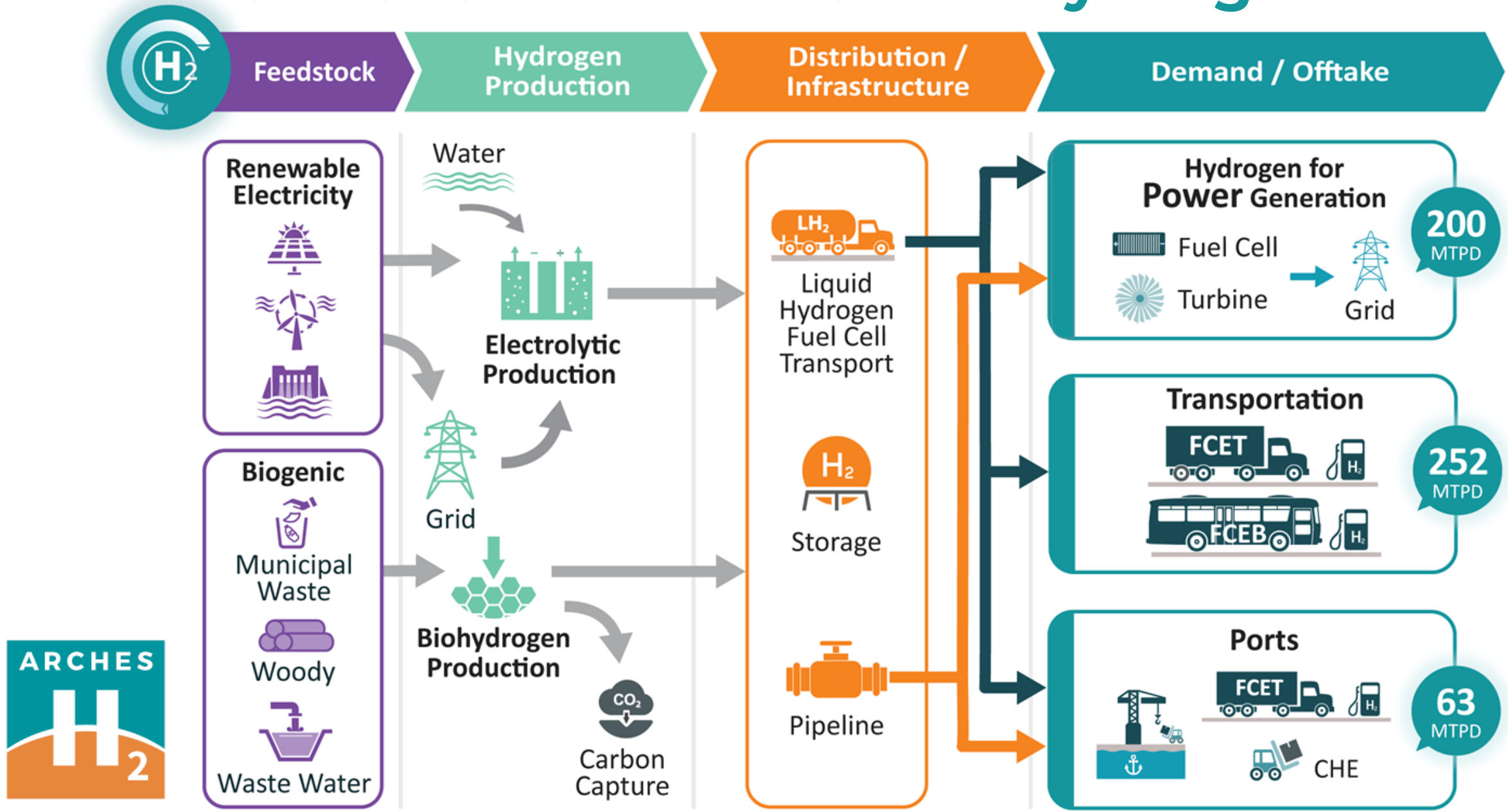
ARCHES Systems Approach Initiates Large Future Growth and Opportunities





ARCHES: California's Clean Hydrogen Hub



Bunkering liquid hydrogen

Existing methods of delivery and transfer can be easily adapted

- Based on safe, proven practices
- Trailer deliver and transfer to ship
- Currently used for filling LH_2 storage tanks across the USA
- Fueling procedures were informed by commercial vendors
- Each trailer provides 4,000 kg of LH_2
- Typical CCRV bunkering will require one trailer
- Full transfer in ~ 1 hour (similar to diesel)
- Existing methods for cryogenic fuel transfer can be applied to CCRV

Existing technology can be used

No installed shore infrastructure required

CCRV project timeline

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: Regulatory Approval In Principle, preparation of shipyard solicitation

Construction

- 2024: Solicitation for shipyards expected Q4
- 2025: Shipyard selection, conduct final design
- 2026: Vessel assembly

Commission and operate

- 2027: Commissioning & science verification trials
- 2028: Operational for science missions
- 2033: Green methanol conversion from diesel

Hydrogen-Hybrid Zero-Emission Research Vessel

Coming soon!

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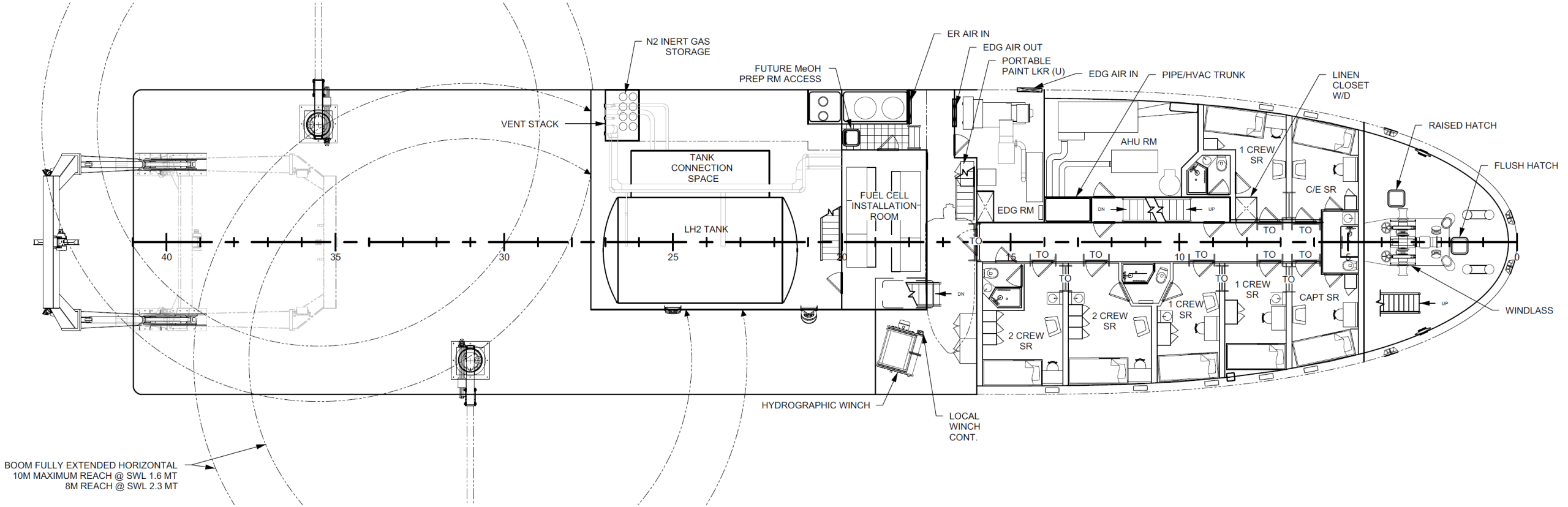
Bonus content follows

Vessel characteristics

Length overall	49.9 m (164 feet)
Beam	11.0 m (36 feet)
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	

CCRV: Upper Deck



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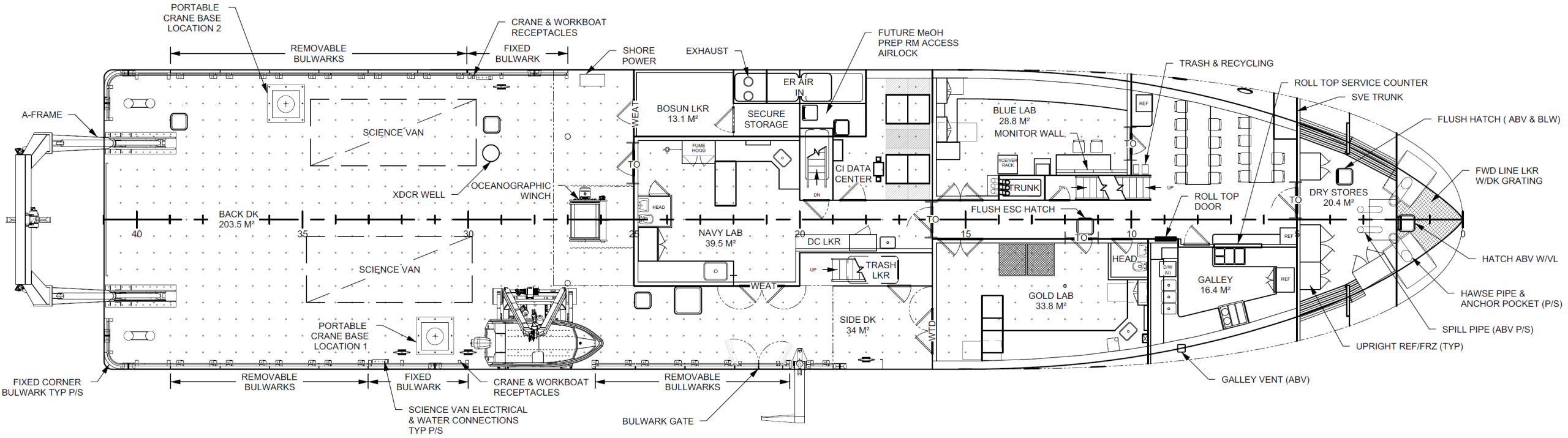
CCRV: Main Deck



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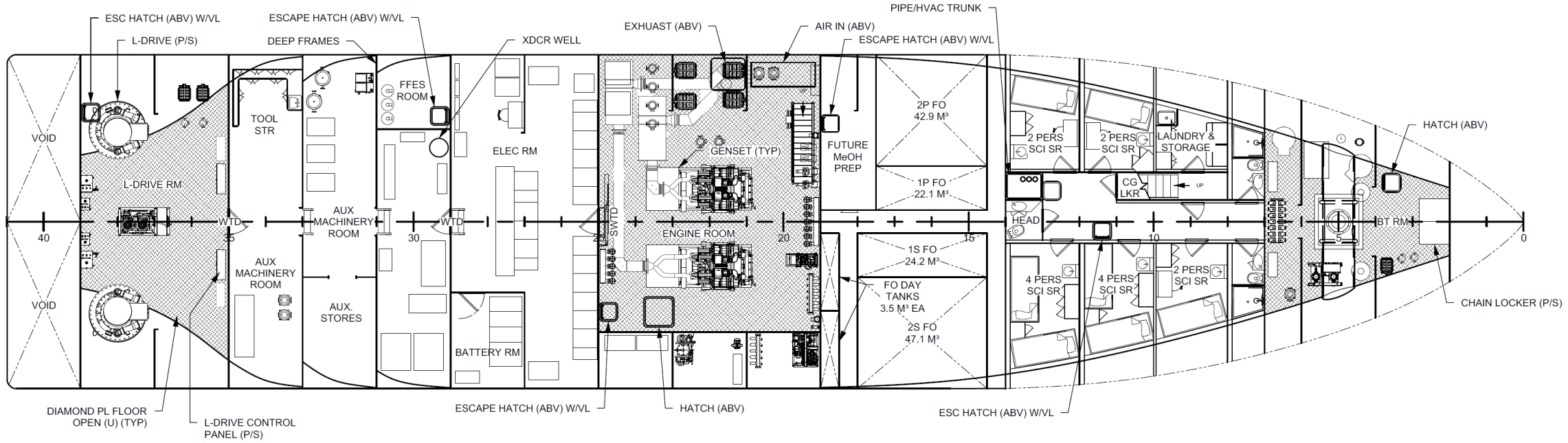
CCRV: Lower Deck



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