



Scripps zero-emission hydrogen hybrid research vessel

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Presentation Overview

Why zero-emission ships?
Feasibility of zero emissions
Zero-emission hybrid power
Coastal class research vessel

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.



This 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.



This material is based upon work supported by the U.S Department of Transportation Maritime Administration (MARAD) Maritime Environmental and Technical Assistance (META) program.

Download the full reports:
maritime.sandia.gov





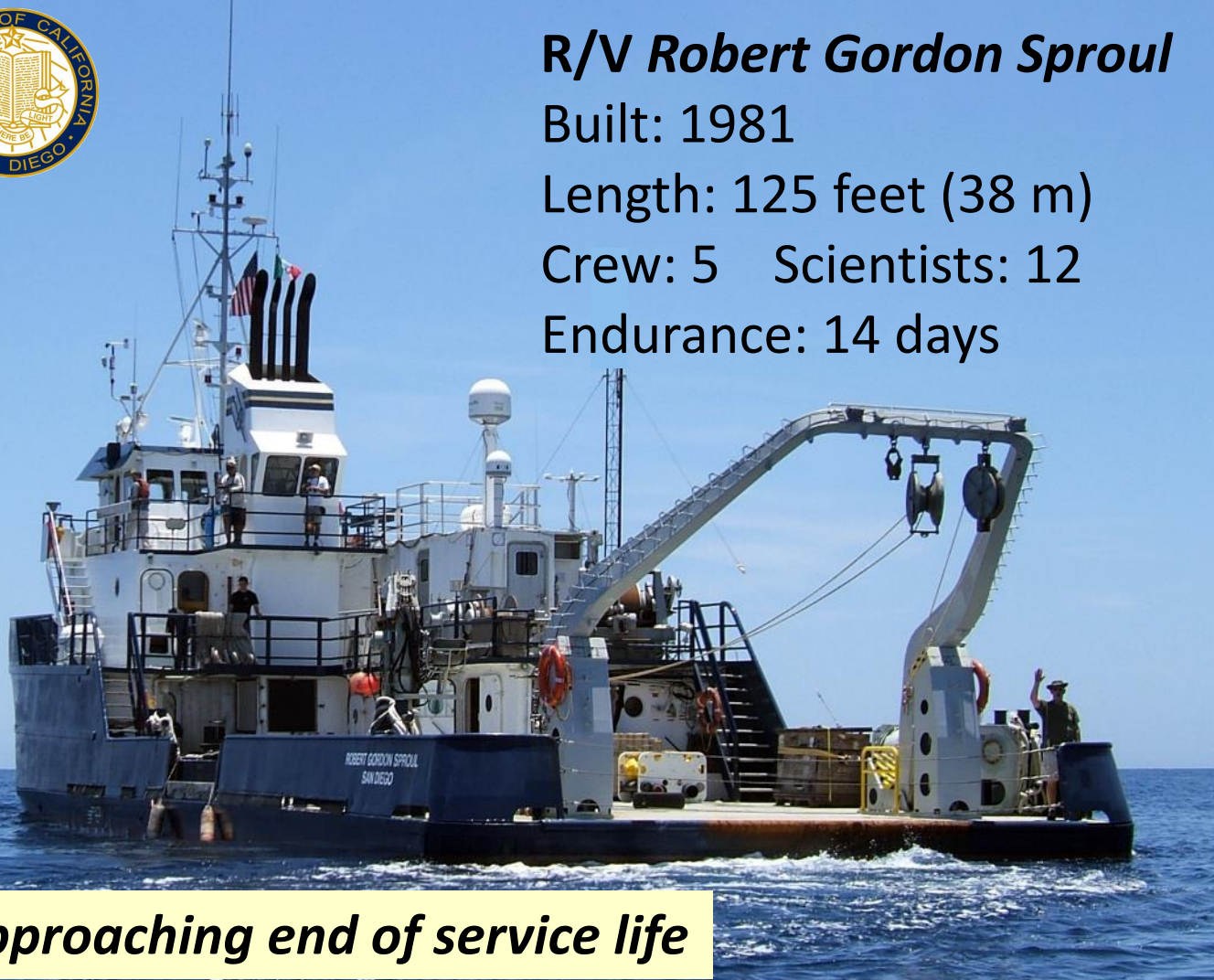
R/V Robert Gordon Sproul

Built: 1981

Length: 125 feet (38 m)

Crew: 5 Scientists: 12

Endurance: 14 days



Sally Ride



Roger Revelle

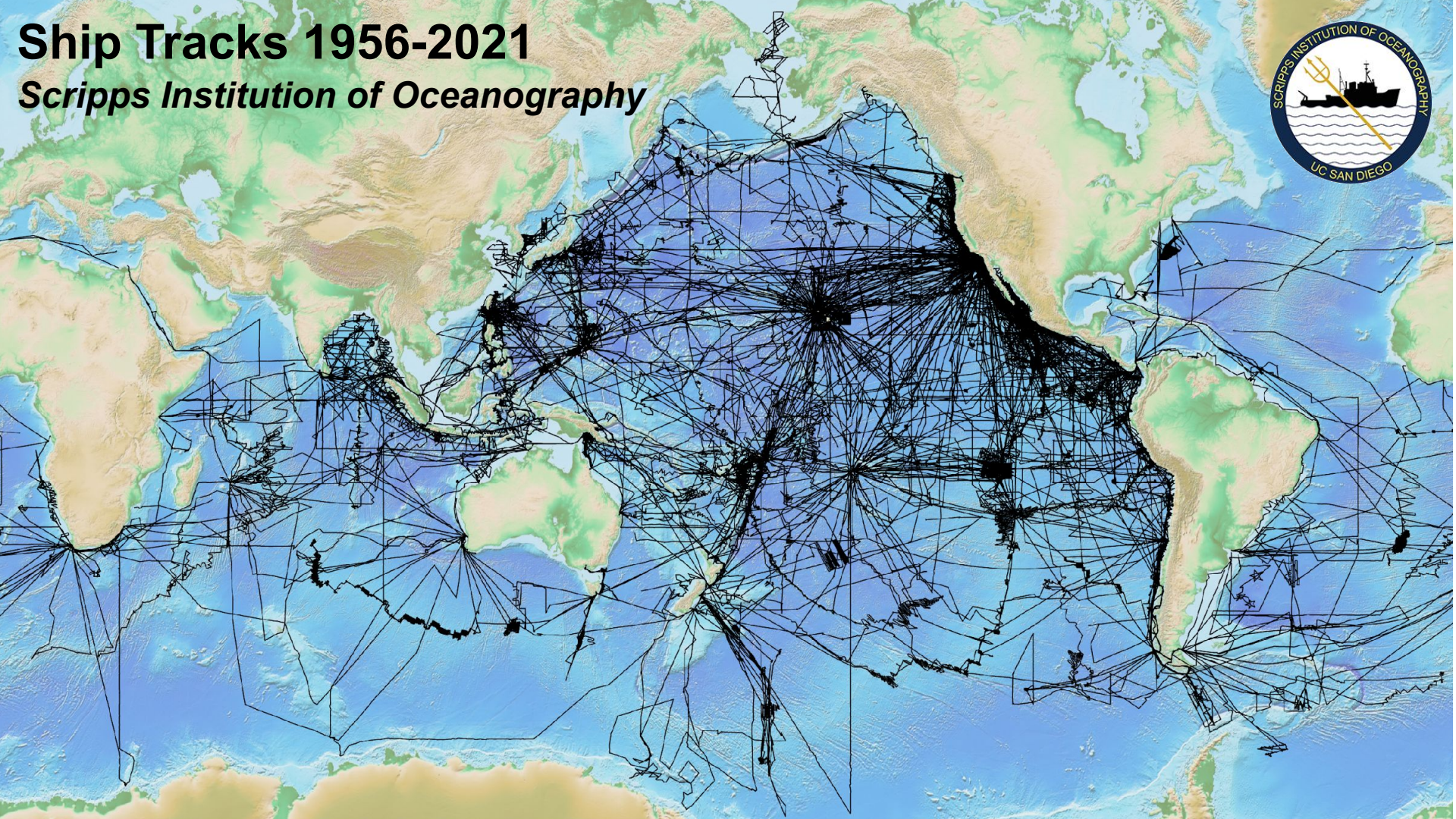
Beyster



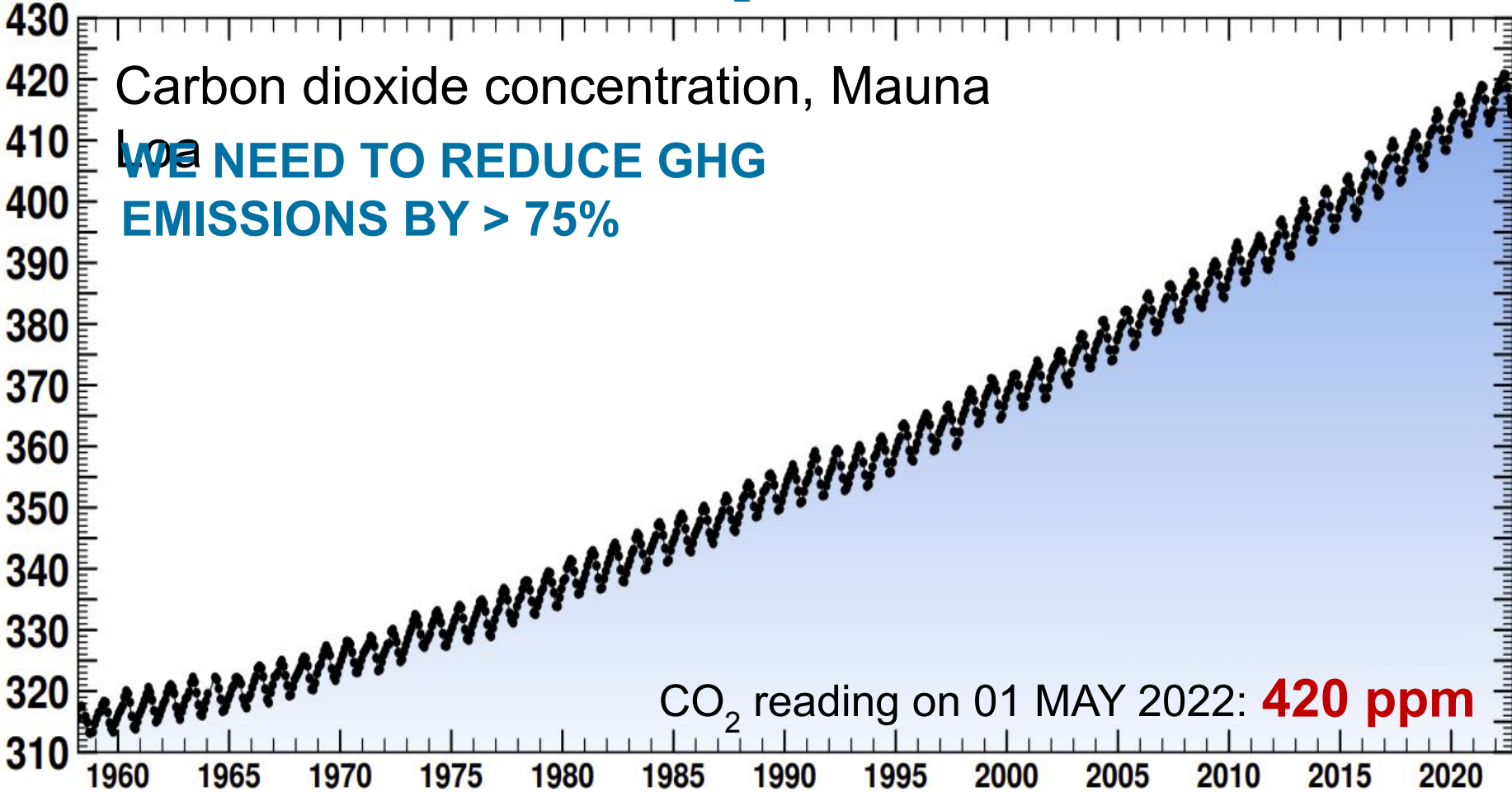
Approaching end of service life

Ship Tracks 1956-2021

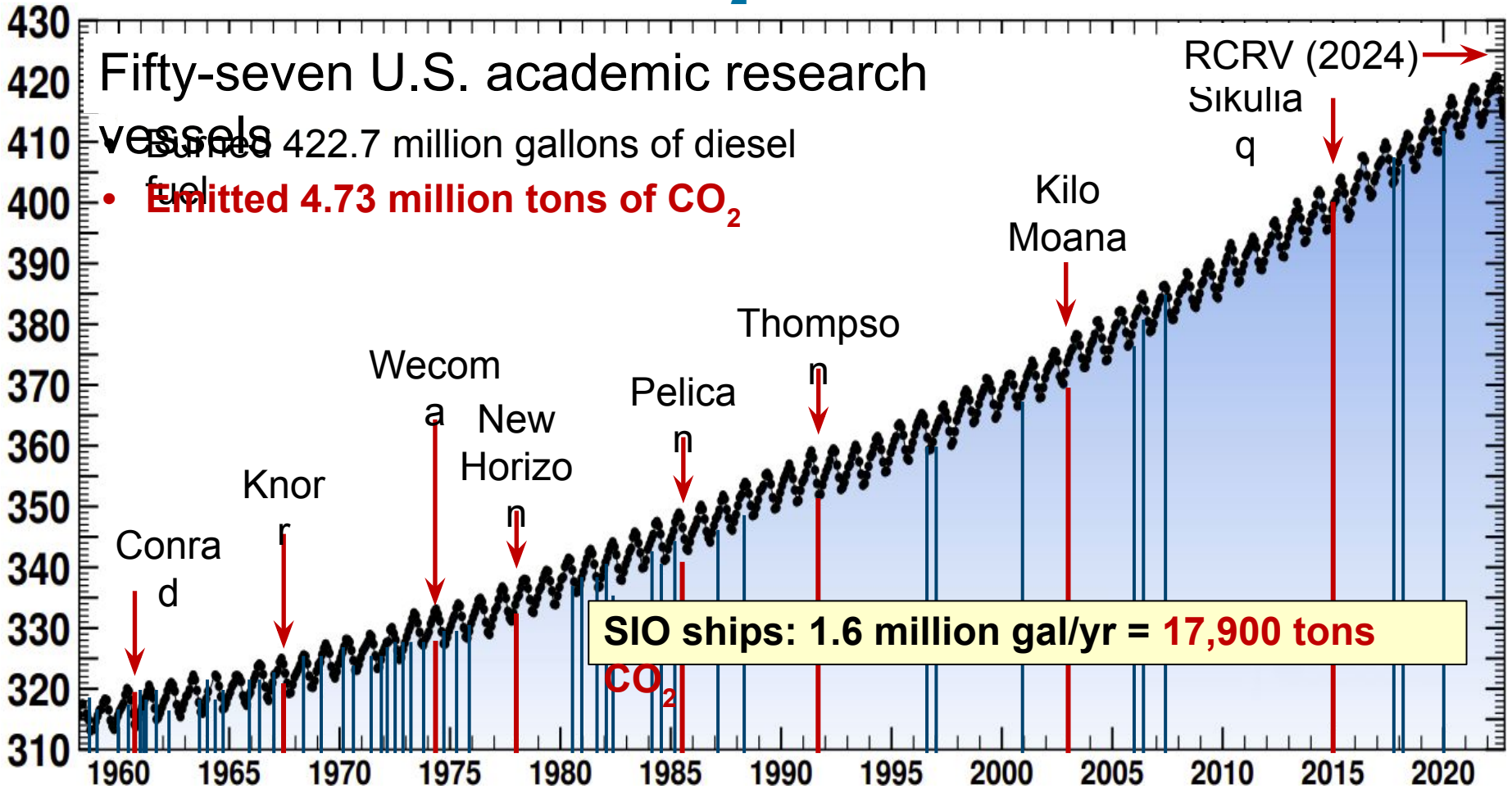
Scripps Institution of Oceanography



Ships pollute the Earth with CO₂ (a greenhouse gas)



Ships pollute the Earth with CO₂ (a greenhouse gas)



Fifty-seven U.S. academic research

vessels burned 422.7 million gallons of diesel

• Emitted 4.73 million tons of CO₂

Ship Tracks 2009-2016

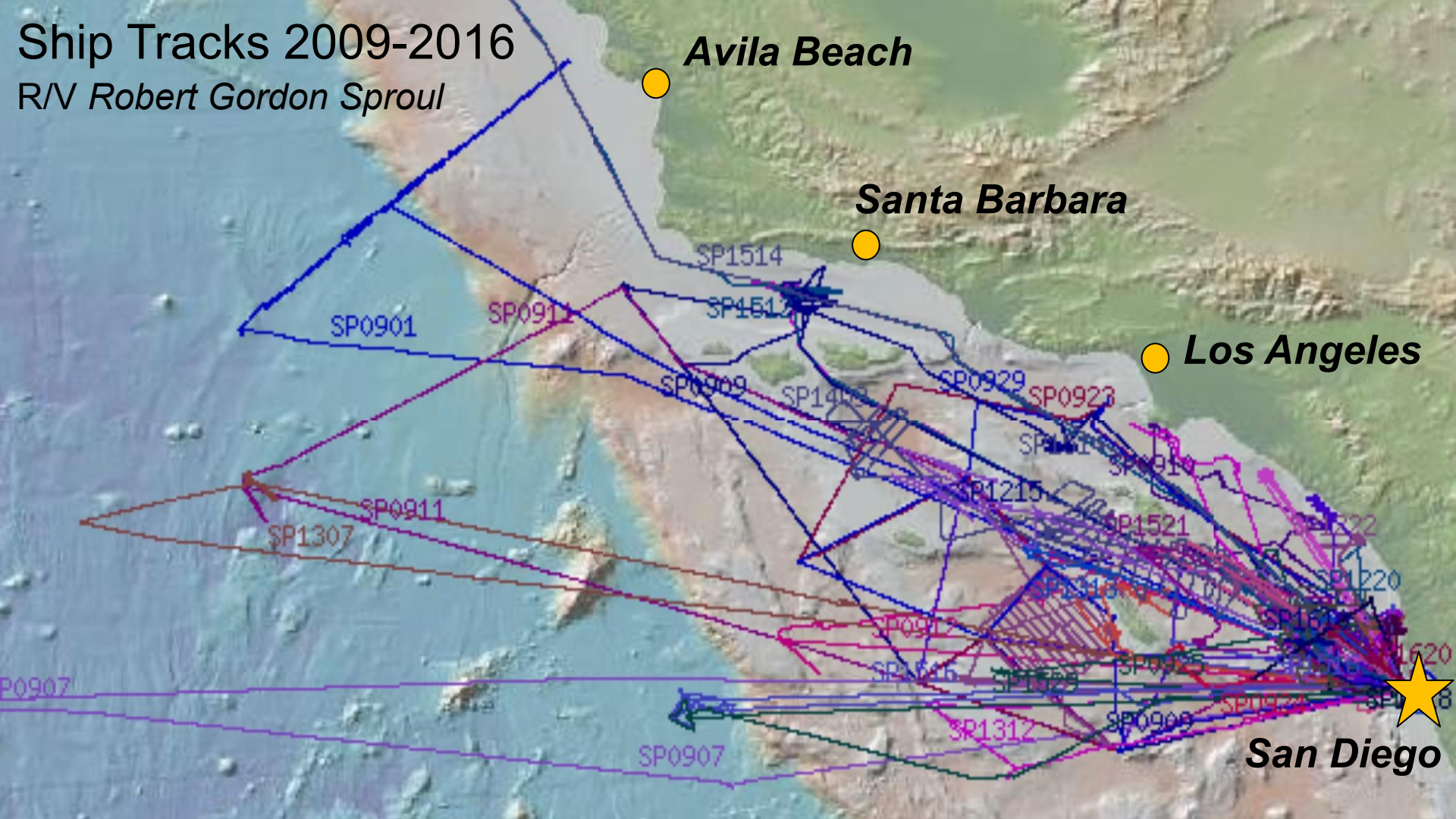
R/V Robert Gordon Sproul

Avila Beach

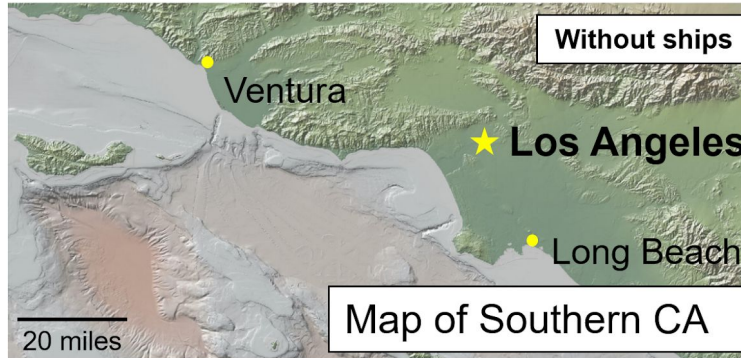
Santa Barbara

Los Angeles

San Diego



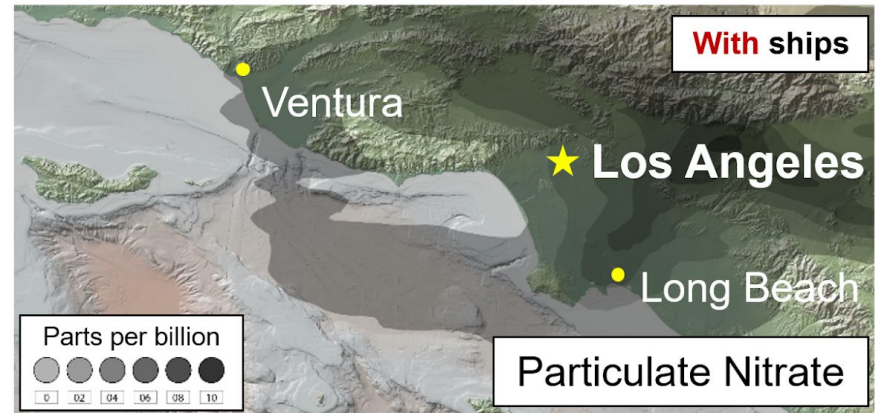
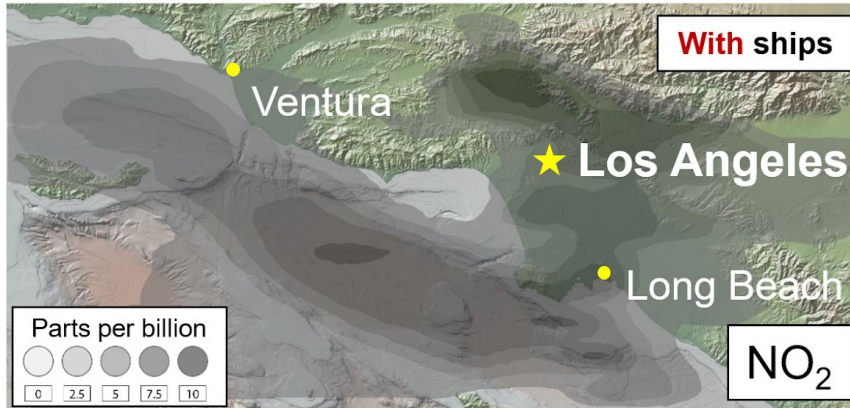
Ship Emissions Pollute All of Southern California



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.”



WHY A ZERO-EMISSION VESSEL?

University of California mission: Carbon neutrality by 2025

Scientific advantages

- Quiet: low underwater radiated sound = better acoustics
- Sample uncontaminated air and water
- Protects physical / biological systems
- Makes own ultrapure water

Environmental benefits relative to fossil fuels

- H₂ will be derived from renewable sources
- No criteria pollutants, no greenhouse gas emissions
- **Hydrogen fuel spill cleans itself up in < 30 seconds**
- Quiet operations = low impact on marine wildlife
(also better for humans!)



Solar power



Hydrogen fuel cell

Feasibility Study: Can We Eliminate Ship Emissions?

SANDIA REPORT

5/NOV/2019 4884 Unrated Release | Printed May 2019

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 Appelgate, Jr., Stephen Zoltan Kelety, Hans-Christian Wintervoll, Gard Petra Haugson and Anthony T.Y. Teo

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Sandia National Laboratories is a multimission 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



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?

Answer: Yes

Download the full report:
maritime.sandia.gov

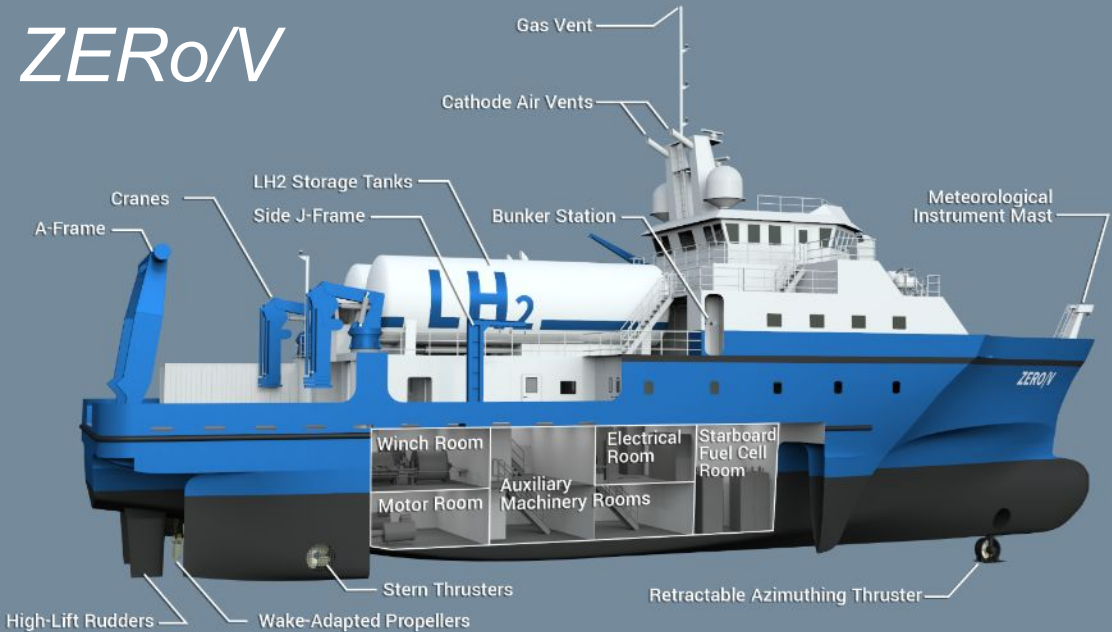
This work was supported by the U.S. Department of Transportation, Maritime Administration



A zero-emission research vessel is feasible NOW using existing technology



ZERoV



- Oceanographic research vessel for coastal / regional operations
- Uses clean hydrogen: **No fossil fuels!**
- Zero emissions: **Clean / no GHGs!**
- Carries no diesel: **No oil spills!**
- All-electric propulsion: **Quiet!**
- **FEASIBLE** with existing technology
- Outstanding scientific capabilities
- Advanced instrumentation
- Designed for California's educational and R&D needs

The zero-emission research vessel (ZERoV) concept vessel has a range of 2,400 nm with berths for up to 20 scientists, supporting general-purpose missions.

A bold, transformative game-changer



What about a coastal vessel?

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

Goals of 2020 study:

Design one hull, and use it to compare four different power systems:

- **Baseline Vessel:** conventional diesel-electric propulsion.
- **Battery Hybrid Vessel:** diesel-electric plus lithium-ion battery bank.
- **H₂ Hybrid Vessel:** diesel-electric plus H₂/Fuel Cell
- **All Hydrogen Vessel:** 100% H₂/Fuel Cell propulsion



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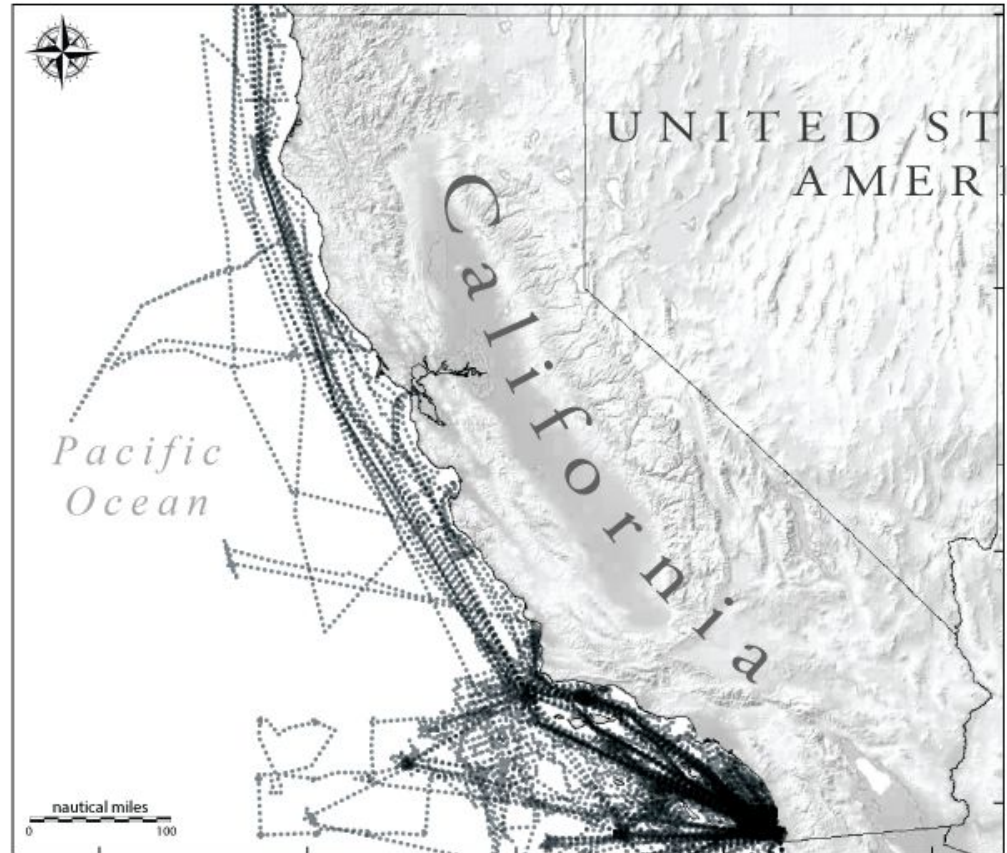
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Science mission requirements, along the entire CA Coast

Cruise speed	10 knots
Max speed	11 knots
Range	2,400 nm
Endurance	10 days
Students	30 (min) 40 (desired)
Crew berths	5 (singles preferred)
Science berths	12 (min)
Stationkeeping	Dynamic positioning
Lab area	340 ft ² (min)
Deck sockets	UNOLS compliant
Main crane	2,400 lbs SWL
Stern A-Frame	21,000 lbs SWL
Side Frame	10,000 lbs SWL
Winches	Trawl, CTD/Hydro
Sewage holding	2,000 gal (min)
Portable vans	2 (min)
Scientific instrumentation: sonar suite, GPS, motion reference, satcom broadband, network	

Historical Range



Science instrumentation

General multi-purpose research vessel

- High frequency ADCP
- Medium frequency ADCP
- 12kHz transducer
- Expendable bathythermograph
- GPS/GNSS x2
- Multibeam sonar
- Sub-bottom profiler
- Sonar synchronization unit
- Fisheries imaging sonar
- USBL positioning system
- Meteorological system sensors
- Underway seawater system sensors
- Portable transducer pipe string
- Universal acoustic deck box

Hybrid Variants: Battery vs Hydrogen

Hydrogen hybrid is better than batteries

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

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

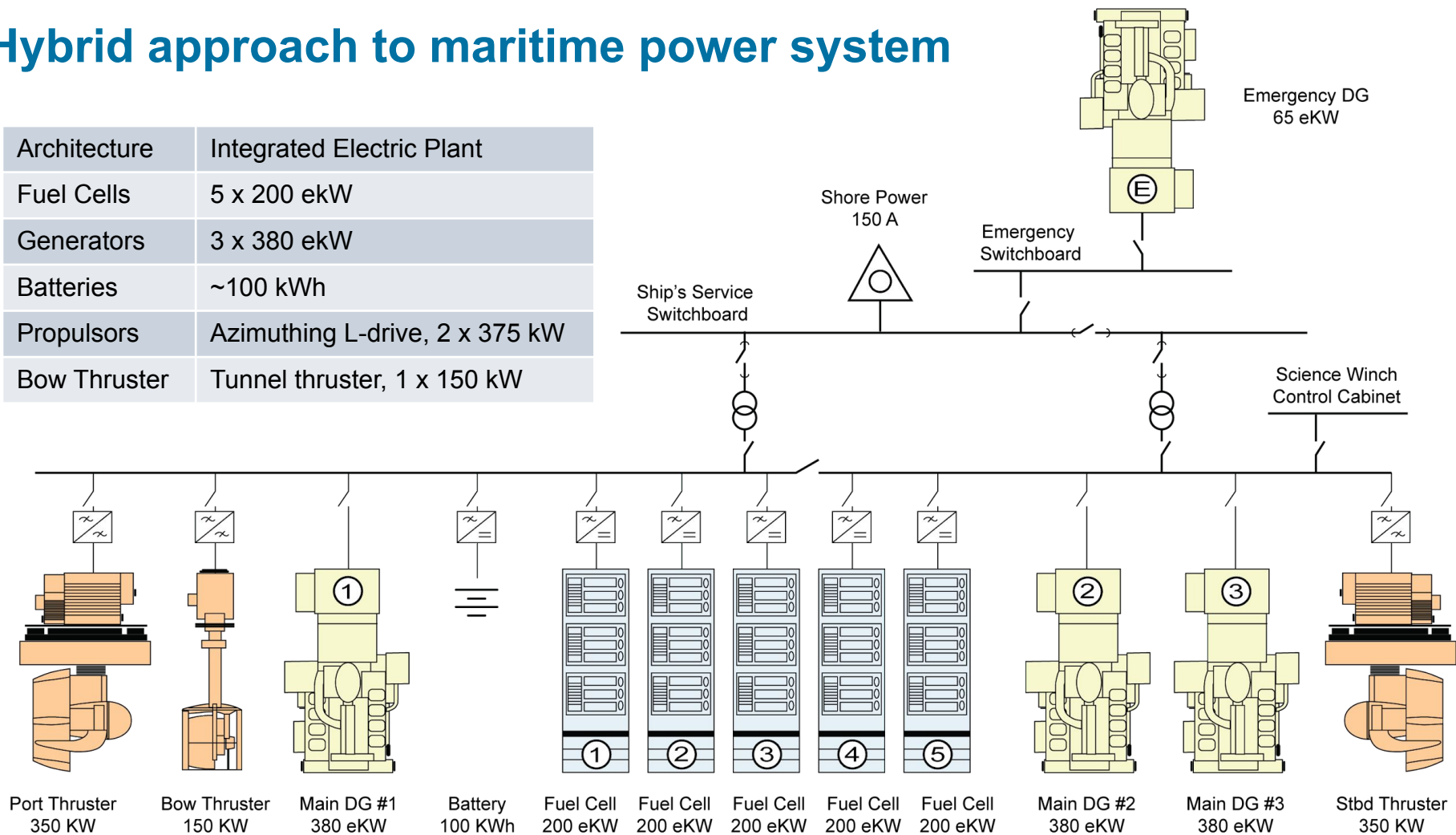
Compared to batteries, the Hydrogen Hybrid offers:

- ✓ 9x better zero-emission range & endurance
- ✓ Commensurate reductions in NOx, HC, PM and GHGs
- ✓ Better suited for ocean-going ships with long missions

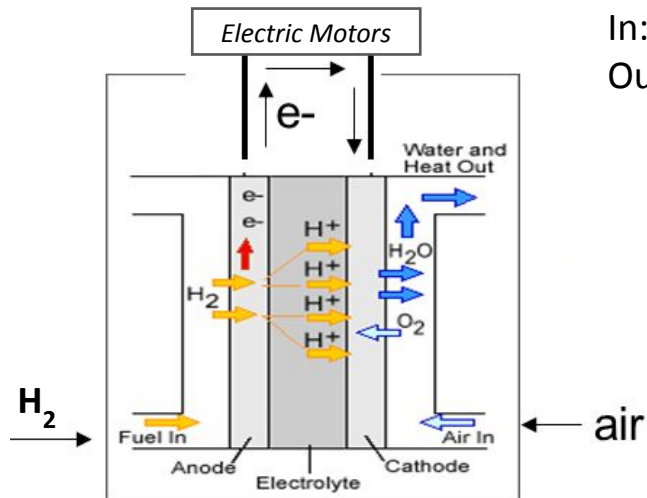


Hybrid approach to maritime power system

Architecture	Integrated Electric Plant
Fuel Cells	5 x 200 ekW
Generators	3 x 380 ekW
Batteries	~100 kWh
Propulsors	Azimuthing L-drive, 2 x 375 kW
Bow Thruster	Tunnel thruster, 1 x 150 kW



Hydrogen fuel cells produce ZERO GHG or criteria emissions



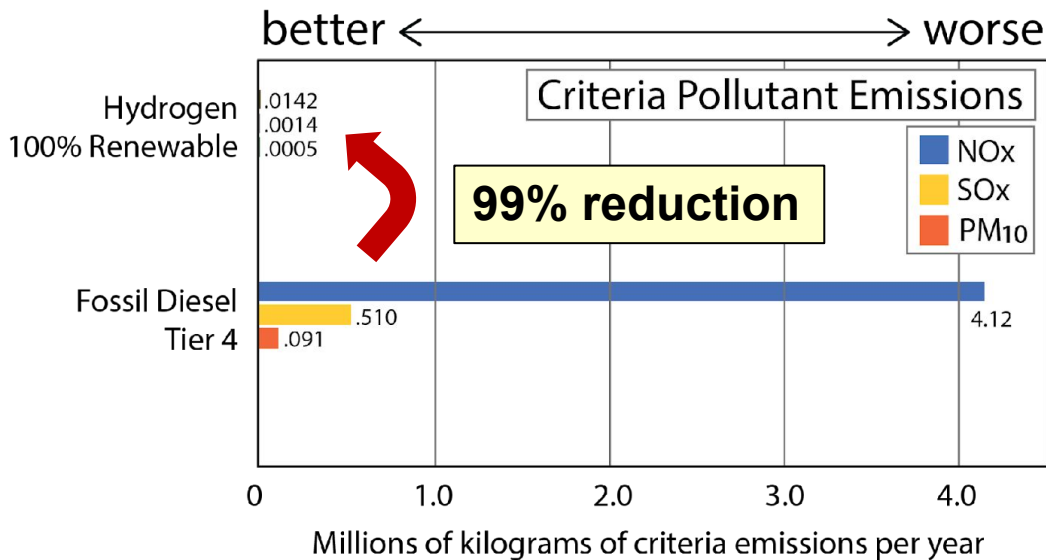
- Commercially available
- More energy efficient than diesel generators
- No emissions at the point of use
- Eliminates fuel spills, greatly reduces noise
- Emissions only arise from H₂ production/delivery

In: H₂ and air
Out: Electricity
Waste Heat
Warm humidified air

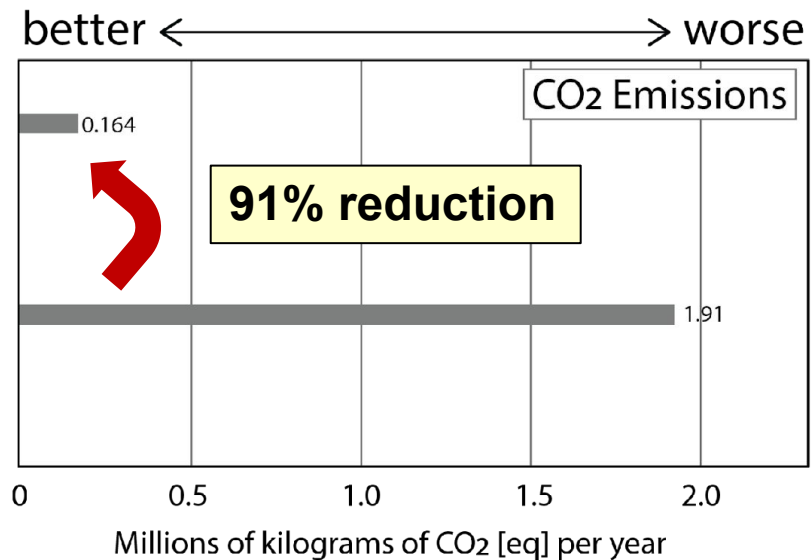


Emissions: Total impact from H₂ production and delivery

Well-To-Waves Criteria Emissions
(1,000 MT / year)



Well-to-Waves Greenhouse Gas Emissions
(1,000 MT CO₂ equivalent / year)



Criteria pollutant emissions can be reduced using LH₂. Dramatic reductions in GHG can be achieved with **renewable** LH₂. Renewable LH₂ is available now from commercial gas suppliers.

Fuel and bunkering: Safe and available at scale



Existing methods of LH₂ delivery

- Safe, proven practices
- Applicable to ship bunkering
- No major new shore infrastructure needed

Liquid hydrogen delivery at Emeryville, CA H₂ Station



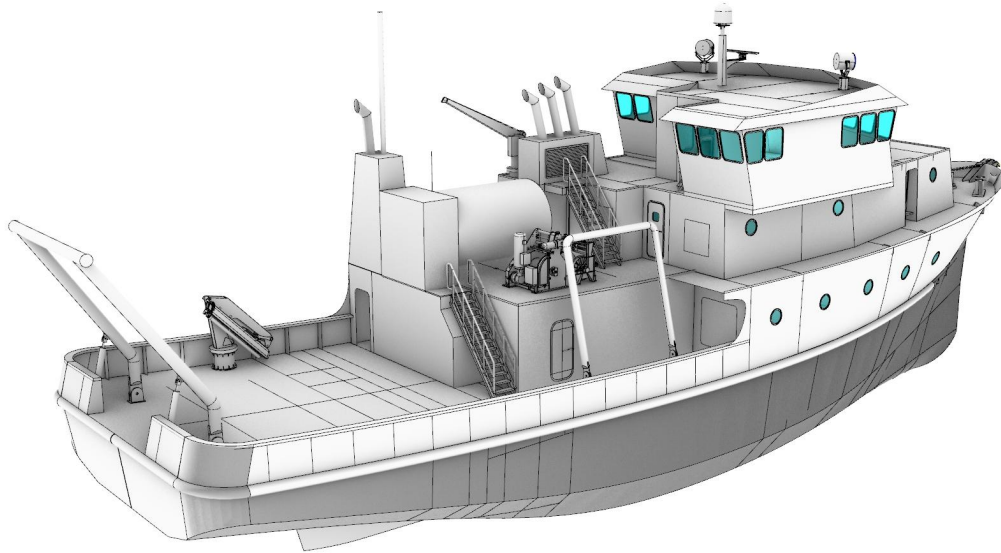
Hydrogen is readily available at scale

- Mature supply chain
- LH₂ bunkering will require one trailer
- Full fuel transfer in < 4 hours

Decarbonizing requires clean hydrogen

- New **green hydrogen** production facility near San Diego coming on line 2023
- Electrolysis from solar, wind and nuclear electricity – no fossil fuels involved

The San Diego Union-Tribune



Jul 23, 2021

UC SAN DIEGO RECEIVES \$35 MILLION IN STATE FUNDING FOR NEW CALIFORNIA COASTAL RESEARCH VESSEL

First-of-its-kind hydrogen-hybrid vessel will be vital to education and research

California Budget Act of 2021

On 12 July 2021, Governor Newsom signed SB 129, which contained one-time appropriations to Scripps, for a hydrogen hybrid research vessel

Design & Construction Timeline

Phase I: Detailed engineering, design, review, and prep

- 2021: Establish project office at Scripps, issue RFI and RFP for design (complete)
- 2022: Development of detailed vessel engineering and design (underway)
- 2023: Final engineering review and construction prep

Phase II: Construction

- 2024: Keel laying and construction

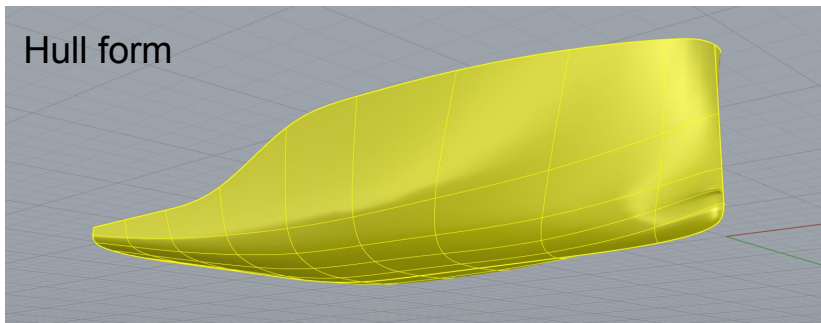
Phase III: Commission for service

- 2026: Christening, sea trials, delivery, verification
- 2027: Begin regular operations in Q1



Design Refresh

Hull form





Any questions?