Development of a Containerized 100 kW Fuel Cell System for Maritime Applications

Lennie Klebanoff

Sandia National Laboratories

Presentation to the H_2@Ports Workshop

Marines' Memorial Club & Hotel, San Francisco CA

September 11, 2019

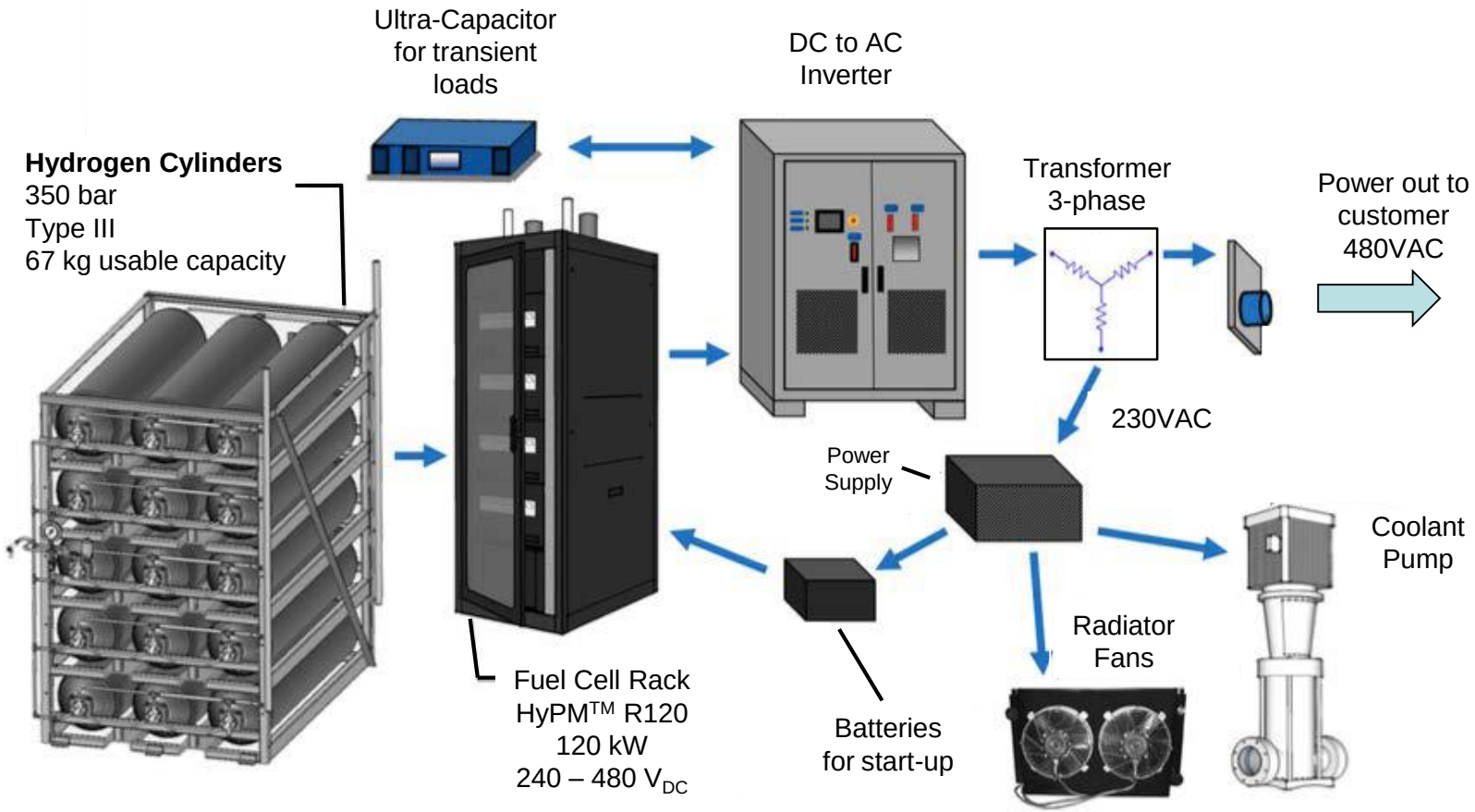
Overall Project Objectives

-- Develop a fuel-cell system for the marine environment that will reduce emissions and be a viable alternative to diesel-based systems.--

- ✓ **Lower the technology risk** of port fuel-cell deployments by gathering performance data of H_2-PEM fuel cells in the marine environment.
- ✓ **Lower the investment risk** by understanding capital and O&M costs for this application.

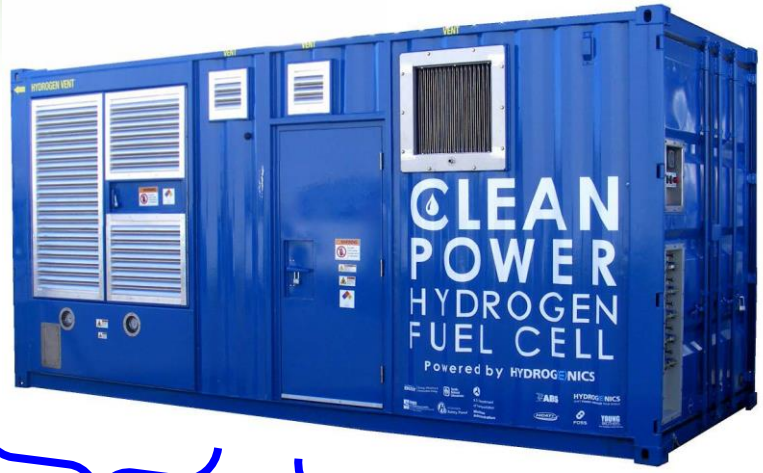
- ✓ **Enable easier permitting and acceptance** of H_2-FC technology in maritime applications by engaging the USCG and ABS.
- ✓ **Engage potential adopters/end users** of hydrogen fuel cells to enable more widespread acceptance of the technology.

Essential MarFC Components



--diagram courtesy of Hydrogenics

Final MarFC Embodiment



20-foot ISO Container

Length: 19'10.5"; Width: 8'0"

Height: 8'6"; Weight: ~ 25,000 lbs

H_2 storage

power generation

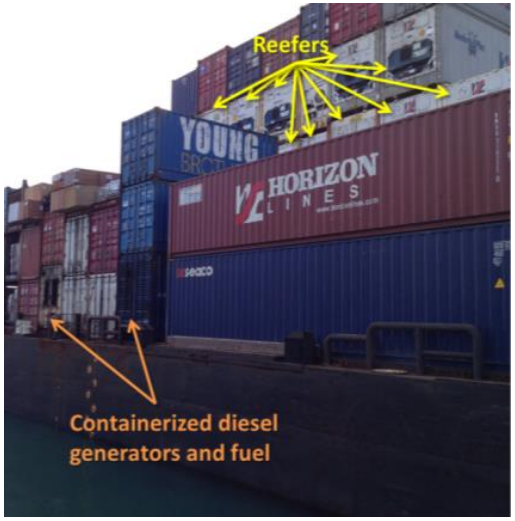
Key Early Dates:

5/2014 Design Review, Hydrogenics

9/2014 USCG gives Design Basis Letter

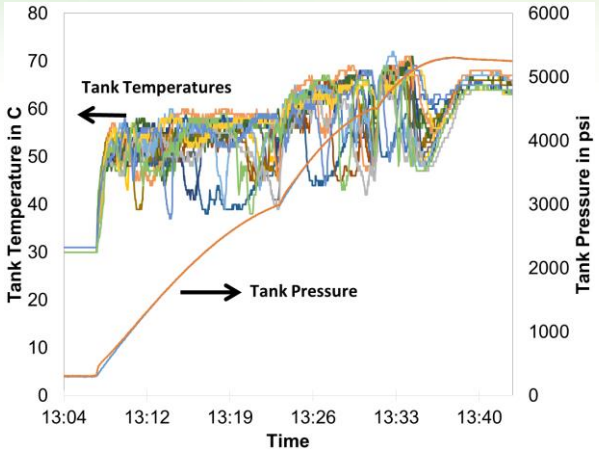
6/2015 Factory Acceptance Testing

First Deployment: Supply Power to Refrigerated Containers (Reefers), Young Brothers, Honolulu HI

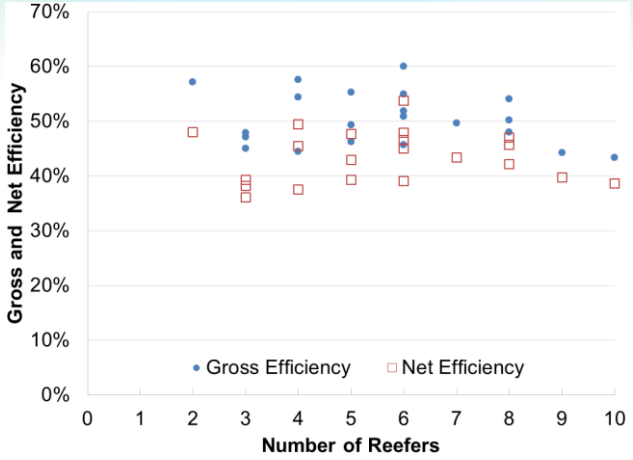


Deployment from 8/4/2015 – 6/8/2016

Sandia Analyzed Deployment Data Including.....



Component pressure and temperature



System energy efficiency

Hardware durability in the marine environment

Table 4: Probability modeling results which show that the only expected outcome that could result in persona jet flame following a full release of hydrogen. The probability of a release causing a jet flame that has potenti injury is 0.000957, or about once in every five years of continuous operation.

Scenario	End State	Probability (Average events per year)	Contribution to PLL[a]
0.01pct Release	No Ignition	0.65369087	0.00%
0.1pct Release	No Ignition	0.11390703	0.00%
1pct Release	No Ignition	0.04529515	0.00%
10pct Release	No Ignition	0.02346609	0.00%
100pct Release	No Ignition	0.01865201	0.00%
0.01pct Release	Jet fire	0.00236179	0.00 %
10pct Release	Jet fire	0.00120451	0.00 %
100pct Release	Jet fire	0.00095740	100.00 %
10pct Release	Explosion	0.00058109	0.00 %
100pct Release	Explosion	0.00046188	0.00 %
0.1pct Release	Jet fire	0.00041155	0.00 %
1pct Release	Jet fire	0.00016365	0.00 %
0.1pct Release	Explosion	0.00000000	0.00 %
0.01pct Release	Explosion	0.00000000	0.00 %
1pct Release	Explosion	0.00000000	0.00 %

[a] PLL: Potential Loss of Life

Hydrogen safety and risk analysis

MarFC Repair, Upgrade and Testing by Hydrogenics

Based on the deployment the prior year
in Honolulu, Hydrogenics repairs/upgrades the unit,
Completed ~ 2/2018:

	Improvement
1	Fix inverter
2	Operator interface
3	Battery duration
4	Extended run testing at factory
5	H2 detectors, filters
6	Coolant water thermocouple
7	Battery charger
8	Coolant line pressure
9	FC rack pressure transducer
10	DI water tank and monitor
11	Upgrade internal cooling fans
12	Notification email system
13	Monitor power at plugs
14	Fix tank temperature jump issue
15	Modify rack to allow single module failure
16	Modify generator for sub-zero operation

Ruggedized System Display

Improved ABB Inverter

Site Requirements for MarFC Deployment

A site may have specific insurance/indemnification requirements.

All H_2 providers have requirements for refueling or H_2 storage that must satisfy NFPA 2 (Hydrogen Technologies Code), NFPA 55-2016 Compressed Gases and Cryogenic Fluids Code (2016) and their own requirements.

<u>Considerations Include Distances to:</u>

Lot Lines
Overhead Power Lines
Intakes (HVAC, compressors)
Wall Openings (operable and inoperable)
Other Flammable Gas Storage
Parked Vehicles
Ignition Sources (welding)
Others.....

The Scripps Institution of Oceanography (SIO)

Project Team Visited SIO on 8/17/2018

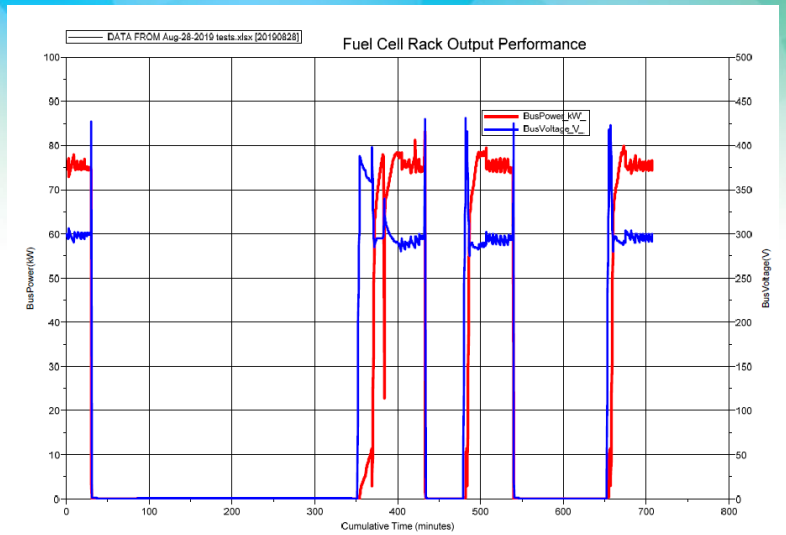
R/V Robert Gordon Sproul
docked at Nimitz Marine Facility

1. SIO wants to use the MarFC unit to provide shore power for the Research Vessel *(R/V) Robert Gordon Sproul* when in port at the Nimitz Marine Facility, San Diego CA.

2. "The Sproul" is typically in Port for 1 week, goes out for 2-3 days, and then comes back.

3. While in Port, the Sproul requires 480 VAC 3-phase shore power 24 hours per day.

4. Average power ~ 30 kW. During the day, the power can peak to ~ 50 kW, during the evening, the power load ~ 15 kW. These are within the 100 kW MarFC capability to provide (with the MarFC unit upgraded to provide 480 VAC).



Modified unit undergoing power testing now

The SIO Nimitz Marine Facility location is in full compliance with relevant NFPA and H_2 supplier requirements for H_2 storage and delivery. ✓

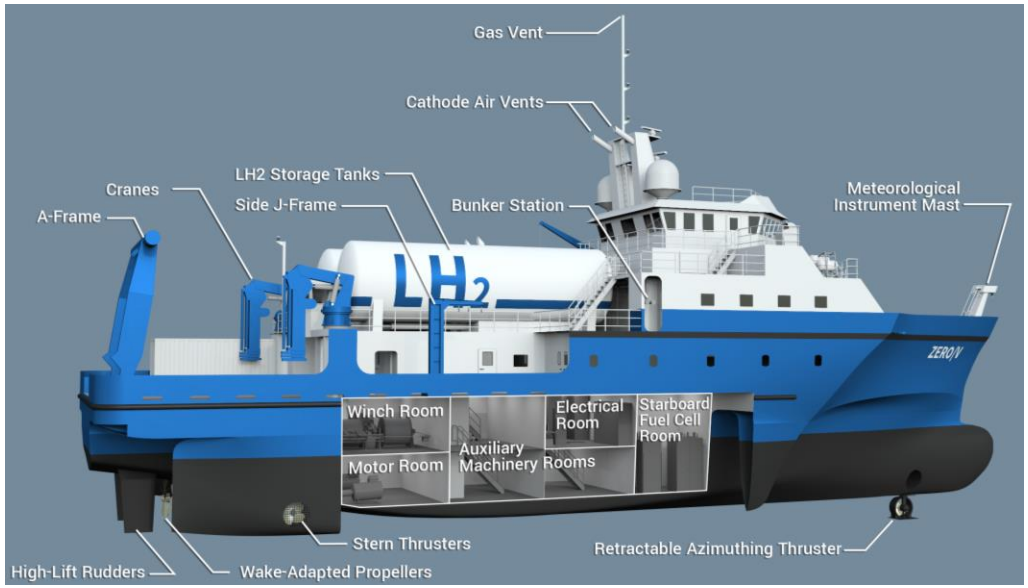
Also satisfied Scripps terms and conditions. ✓

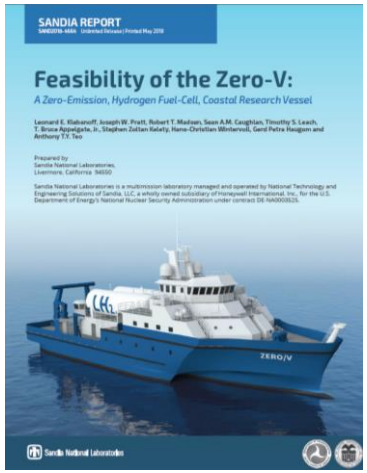
Deployment scheduled for 6 months starting ~ 11/1/2019.

We are particularly excited about the SIO deployment because….

Scripps is the largest oceanographic institution in the United States, with 186 professors, researchers and project scientists, 329 graduate students. There is a large educational exposure in a project with Scripps.

Through the "Zero-V Project", in which the feasibility of a H_2/Fuel Cell ocean-going research vessel was established, Scripps understands hydrogen and wants to pursue such a vessel in the future:

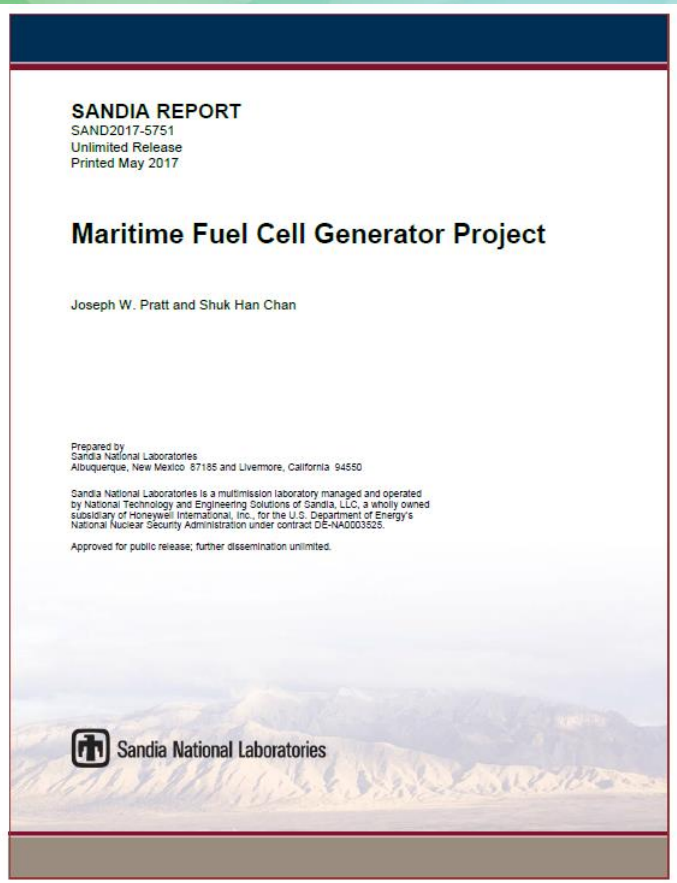




maritime.sandia.gov

Thanks to our partners and colleagues:

- **DOE:** Pete Devlin, Shuk Han Chan
- **MARAD:** Sujit Ghosh
- **Sandia National Labs:** Lennie Klebanoff, Joe Pratt, Jon Zimmerman, Myra Blaylock, Chris LaFleur, David Rose, Bruce Balfour, Jill Micheau, Landon Daft, Lynn McClellan, Billy Thomas.
- **Hydrogenics:** Ryan Sookhoo, Nader Zaag, Will Cook, Maximilian Muller, Ruslan Kosyan, Norm Freeman
- **Young Brothers:** Glenn Hong, Nami Ohtomo, Gavin Calimpong, Dave Holland, Chris Martin
- **Foss Maritime:** Susan Hayman
- **Hydrogen Safety Panel:** Nick Barilo, Dave Farese, Don Frikken, Glenn Scheffler
- **United States Coast Guard:** Thane Gilman and Tim Meyers
- **American Bureau of Shipping**: Prasae Mantravadi, Michael Wasicek
- **California Fuel Cell Partnership:** Jennifer Hamilton
- **Hawaii Natural Energy Institute**: Mitch Ewan; **U.S. Hybrid/Hickam Station:** Rusty Hughes, Abas Goodarzi
- **Air Liquide:** Dwight Zuck, Jorge Lopez
- **Air Products:** Chris Kretz
- **Linde:** Jeff Earl, James Lohan
- **IGX Group:** Delisa Leighton
- **Curtin Maritime**: Martin Curtin, Boomer Sisneros, Marley Schroepfer
- **Port of Long Beach:** Christine Houston
- **Scripps Institution of Oceanography:** Bruce Appelgate, Paul Mauricio, Andrea Lupu


SANDIA REPORT
SAND2017-5751
Unlimited Release
Printed May 2017

Maritime Fuel Cell Generator Project

Joseph W. Pratt and Shuk Han Chan

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

maritime.sandia.gov

Special Thanks To Our Sponsors:

Sujit Ghosh, MARAD

Pete Devlin, DOE FCTO

The U.S. Department of Transportation (DOT), Maritime Administration (MARAD) through MARAD's Maritime Environmental and Technical Assistance (META) program and the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Office.

Lennie Klebanoff

(925) 294-3471

lekleba@sandia.gov

Thank You!!