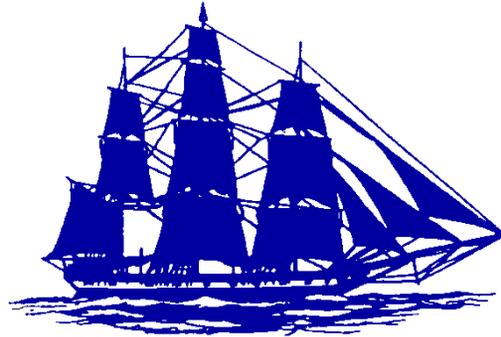


# Center for the Commercial Deployment of Transportation Technologies (CCDoTT)



*Seaworthy Systems, Inc.*

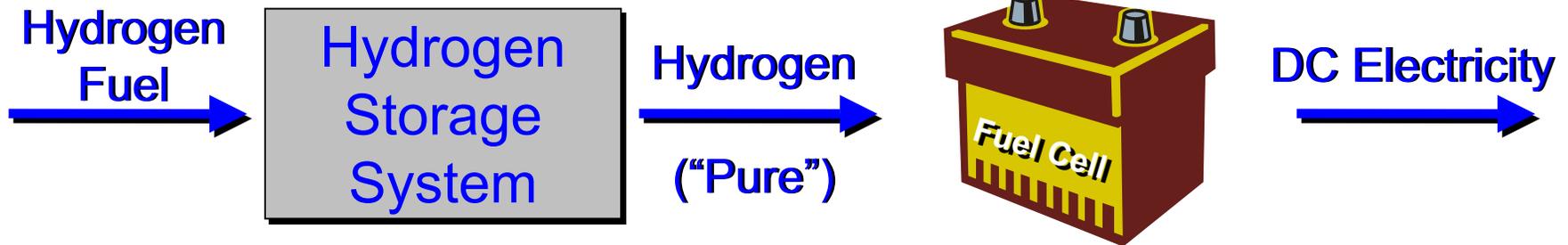
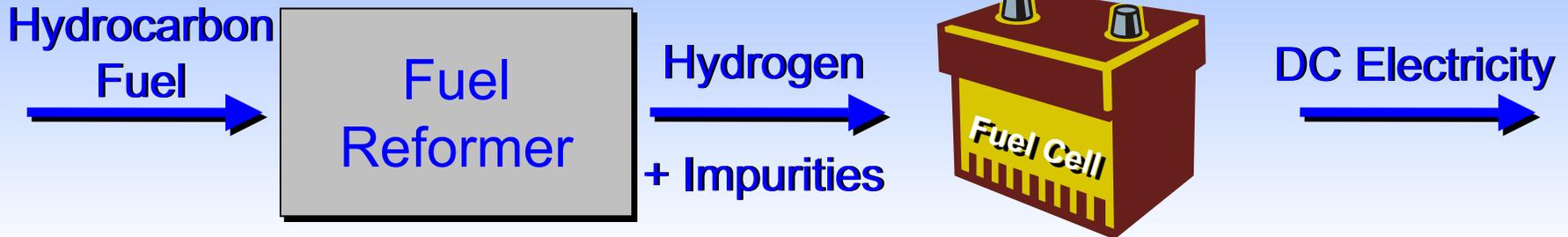
**Matt Winkler**

in conjunction with



## Hydrogen Fuel Cell Technology Adapted for Commercial Marine Operation

# There Are Two Types Of Hydrogen-Fuel Systems

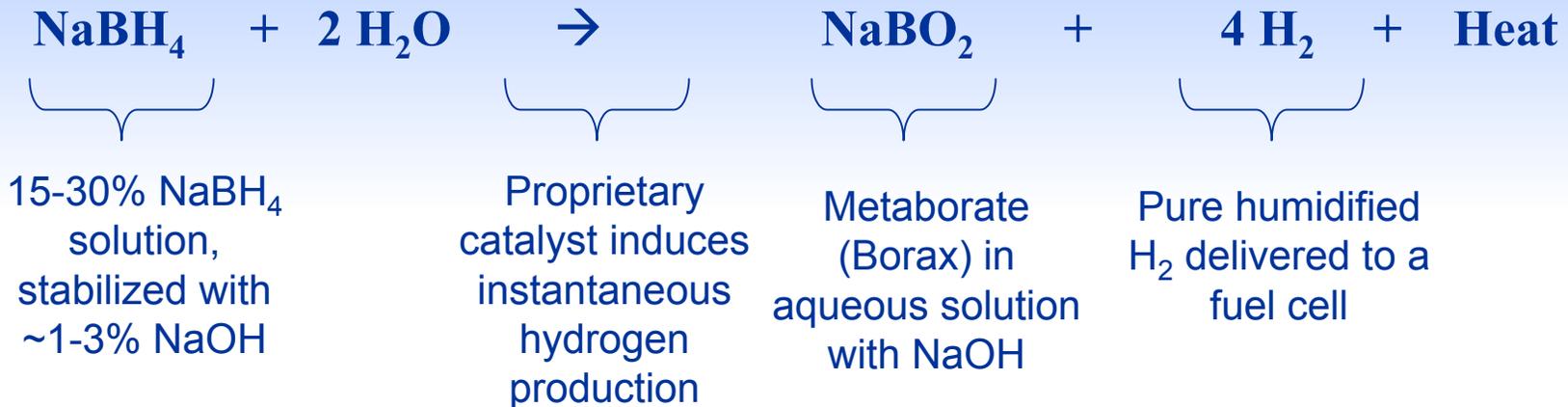


- Compressed hydrogen gas
- Cryogenic liquid hydrogen
- Metal hydride solids
- Water
- Chemical hydride in water (*Hydrogen On Demand™*)



# How Millennium Cell's Hydrogen On Demand™ System Works

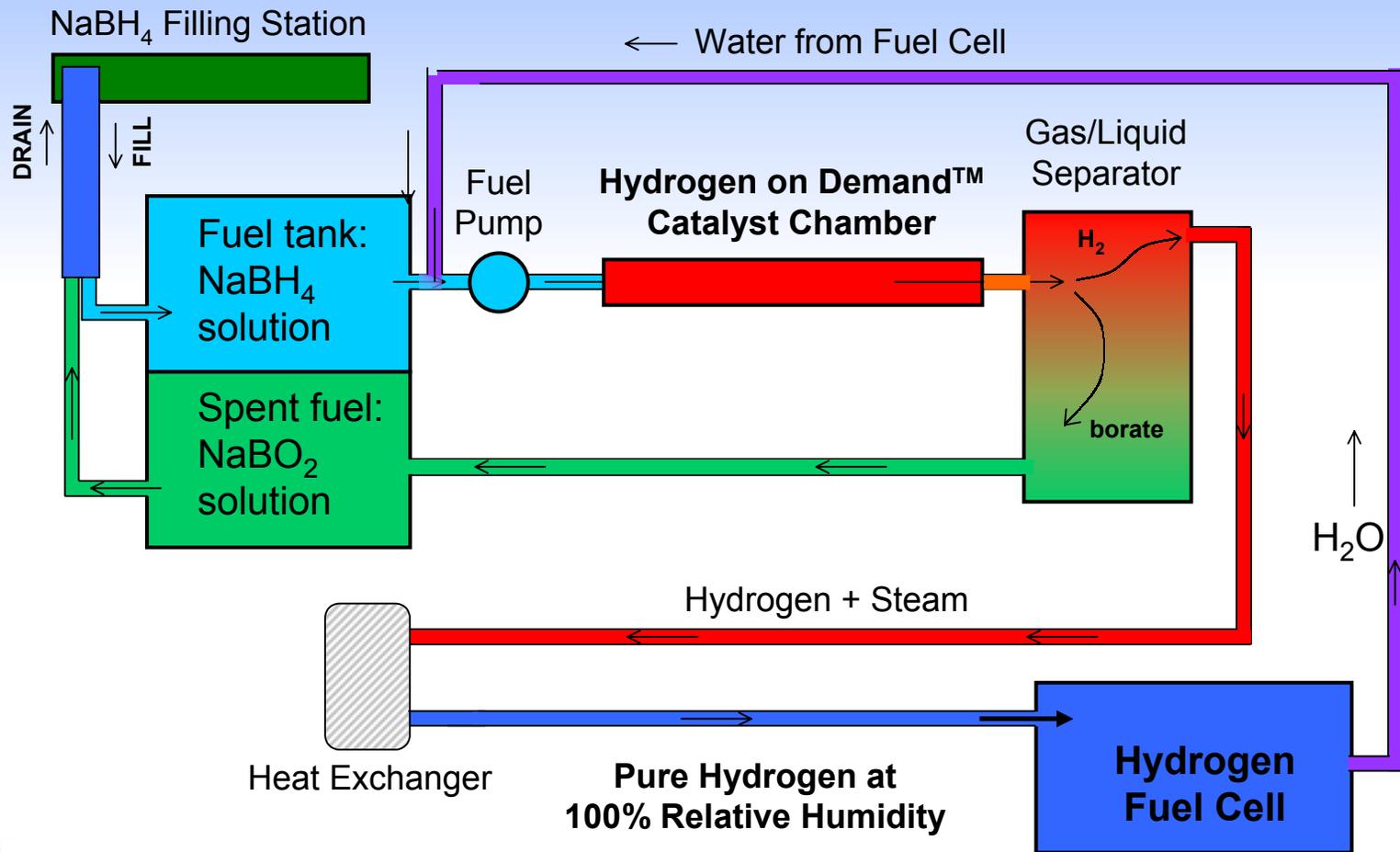
## On-Board Energy-Releasing System:



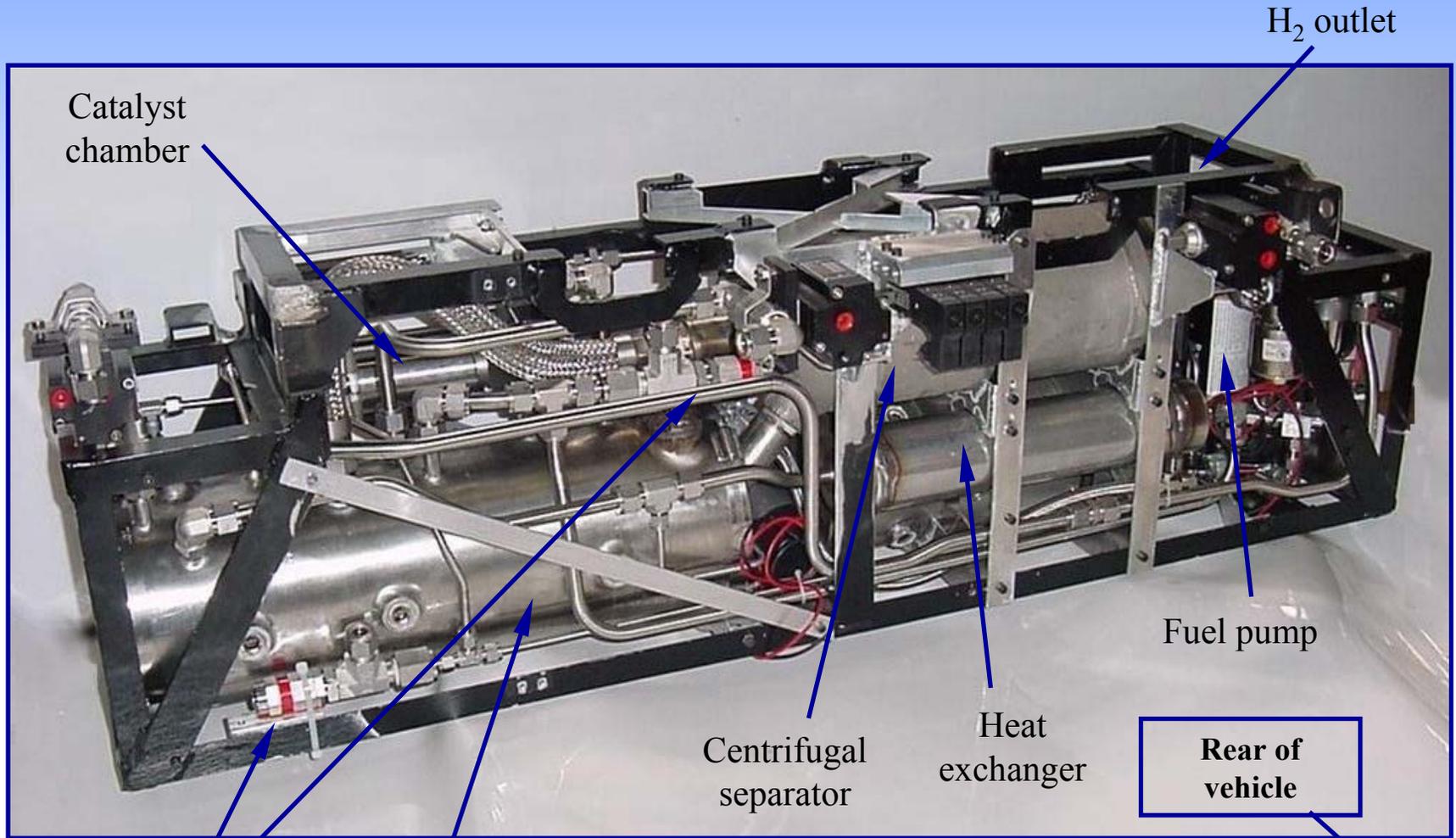
- Fuel is a room temperature, ambient pressure liquid
- Generated H<sub>2</sub> is pure and at 100% relative humidity
- Borax solution is a warm “ecologically-friendly” water-based solution



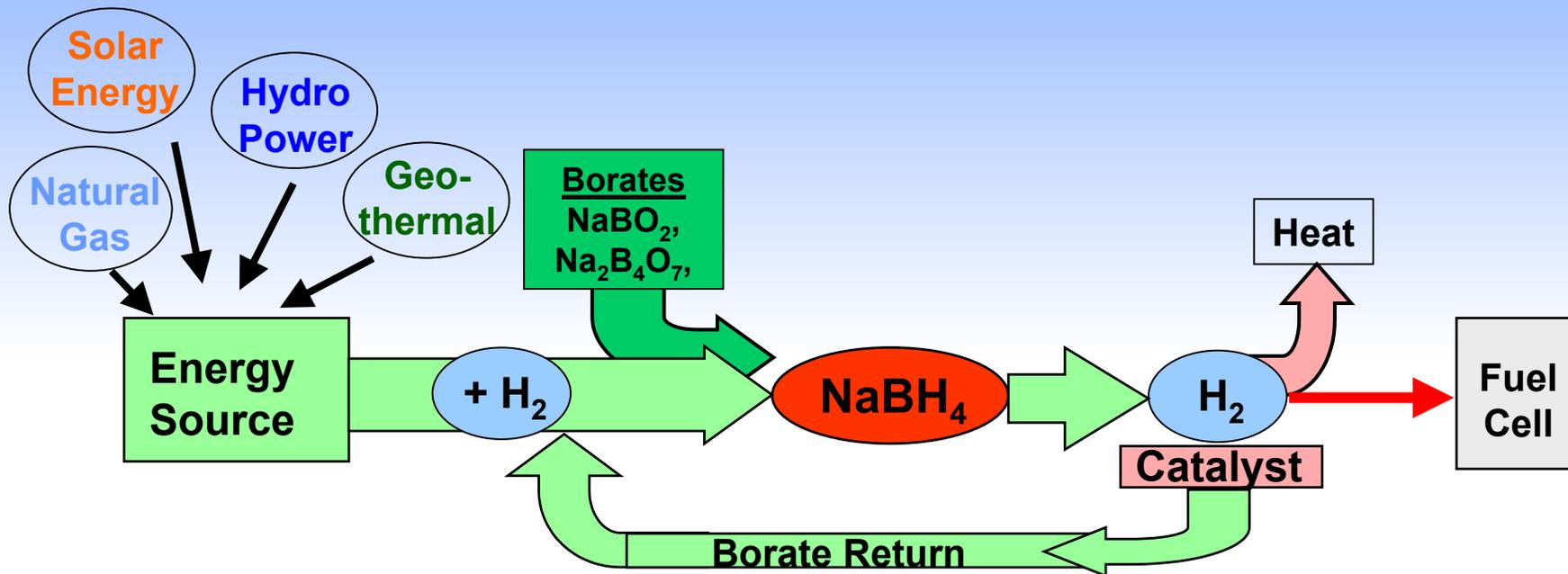
# Hydrogen On Demand Schematic



# Chrysler Town and Country Natrium HOD system



# Process Development Approach To Deliver Economic H<sub>2</sub> Via NaBH<sub>4</sub>



**Well-To-Wheels Efficiency Targeted At 15-20%**



# Hydrogen On Demand™ Summary

- **Safe**
  - ◆ Non-flammable
  - ◆ Ambient pressure
- **Lowest weight and volume**
  - ◆ A sodium borohydride-based hydrogen generator offers a solution that is significantly more compact than any other hydrogen fuel alternative.
- **Flexible arrangement options**
  - ◆ This pressure-less liquid enables a wide choice of tank locations and configurations.
- **Low complexity**
  - ◆ Minimal system integration is required to couple a sodium borohydride-based storage solution to a fuel cell or engine.



# Hydrogen On Demand Generating System Demonstration – Phase I

CCDoTT FY2001 Program Element 2.16  
Subcontract No. DTMA91-97-H0007

## Completed Phase I Tasks:

- Literature review
- Evaluate existing commercially viable mobile hydrogen-based technologies
- Conduct safety analyses for shipboard support systems
- Review existing/emerging regulatory codes and requirements for shipboard applications of gaseous fuels
- Develop concept design for shipboard hydrogen-on-demand fuel system and support systems



# Phase I Findings

- Literature addressing the status of hydrogen fuel and future for H<sub>2</sub> economy is optimistic and abundant
- Hydrogen fuel technologies exist as prototypes in many applications, from automotive to power generation
- RECIP engines can be modified for H<sub>2</sub> combustion
  - ◆ Modification is complicated, costly and must overcome:
    - ▶ Pre-ignition and flashback
    - ▶ Breakdown of lubricating oil
    - ▶ Volumetric losses, e.g. larger engines for equal power



# Phase I Findings (Continued)

- Among power sources, the fuel cell is most adaptable to hydrogen fuel
  - ◆ Fuel cells are more widely available than hydrogen fueled engines
  - ◆ Fuel cells emit only water vapor and heat
  - ◆ RECIP engines produce oxides of nitrogen (NOx), regardless of fuel type burned
- A battery-powered electric-drive boat is the best match for any initial HOD marine application
  - ◆ Low-output HOD/fuel cell system is suitable for auxiliary power production
  - ◆ Operation is clean, reliable, virtually silent and non-polluting
  - ◆ HOD/Fuel cell systems can be dropped in to replace existing DG set-based battery-charging system



# Phase II: Proof of Concept

CCDoTT FY2002 Program Element 2.25

Subcontract No. S07-265502SEA

- A 3kW HOD/fuel cell system will be installed in a purpose built DH30 water taxi from Duffy Electric Boat
- Duffy/Herreshoff 30 water taxi characteristics:
  - ▶ 22 passenger capacity
  - ▶ 8.5 knot maximum speed
  - ▶ 15 kW, 96 VDC battery powered electric motor propulsion system
  - ▶ HOD/fuel cell system will replace conventional 7 kW DG set and related battery charging equipment
- The DH30 water taxi will serve the public in Newport Beach, CA, after HOD/fuel cell system installation, operating 10-12 hours/day in commercial service



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# Phase II Proof of Concept

- The Duffy / Herreshoff 30 Electric Drive Water Taxi



# Phase II Proof of Concept

- Other design and operating considerations:
  - ◆ One tank (50 gallons) of 15 wt% NaBH<sub>4</sub> solution will extend boat endurance 21 hours and range by 110 nautical miles
  - ◆ Physical modifications to hull structure and arrangement and impact on weights, trim and stability are minimal
  - ◆ Under normal conditions, battery charging will draw 9 Amps/Hr
  - ◆ NaBH<sub>4</sub> and NaBO<sub>2</sub> tanks will be built into the boat and filled/emptied weekly

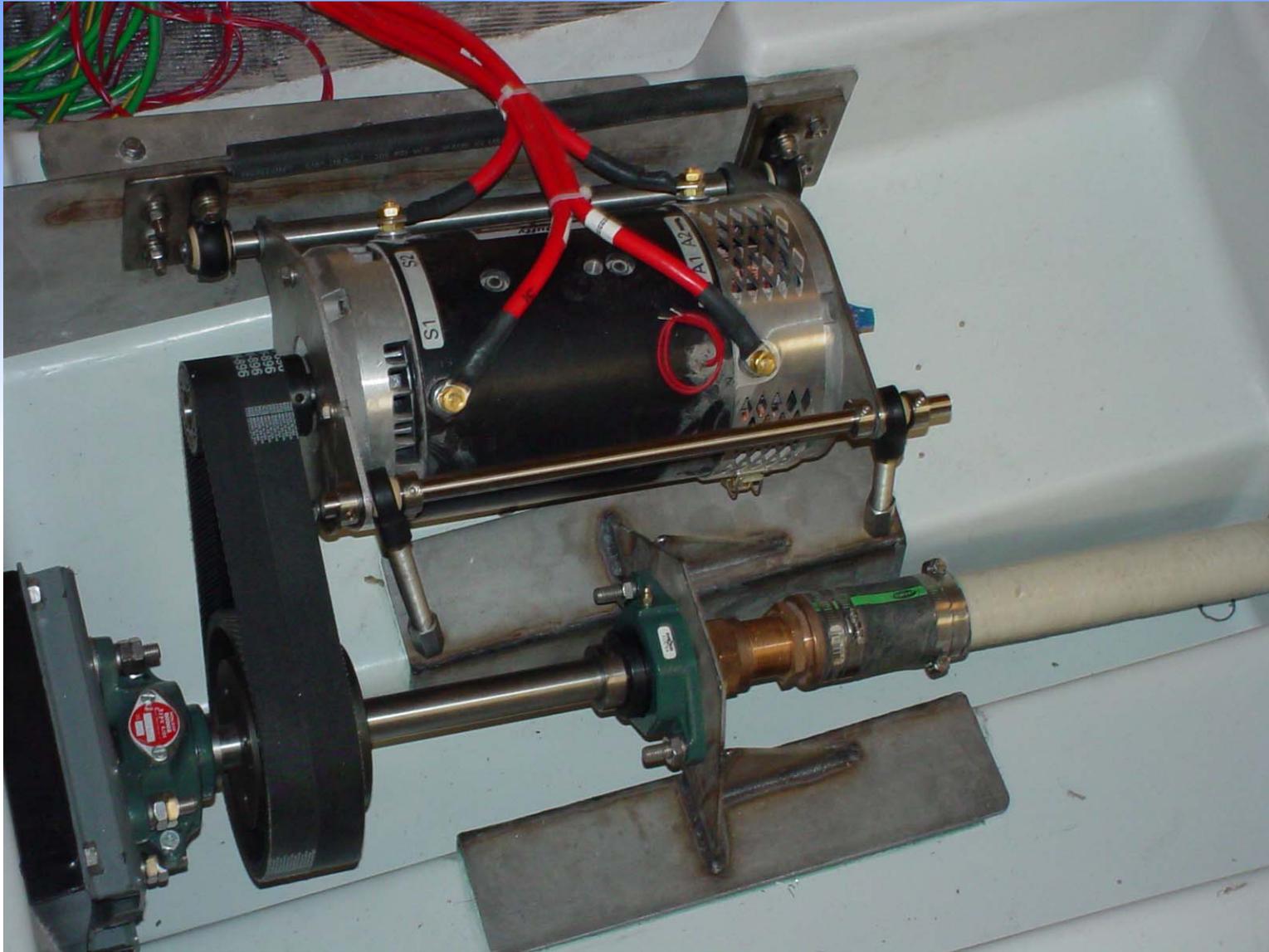


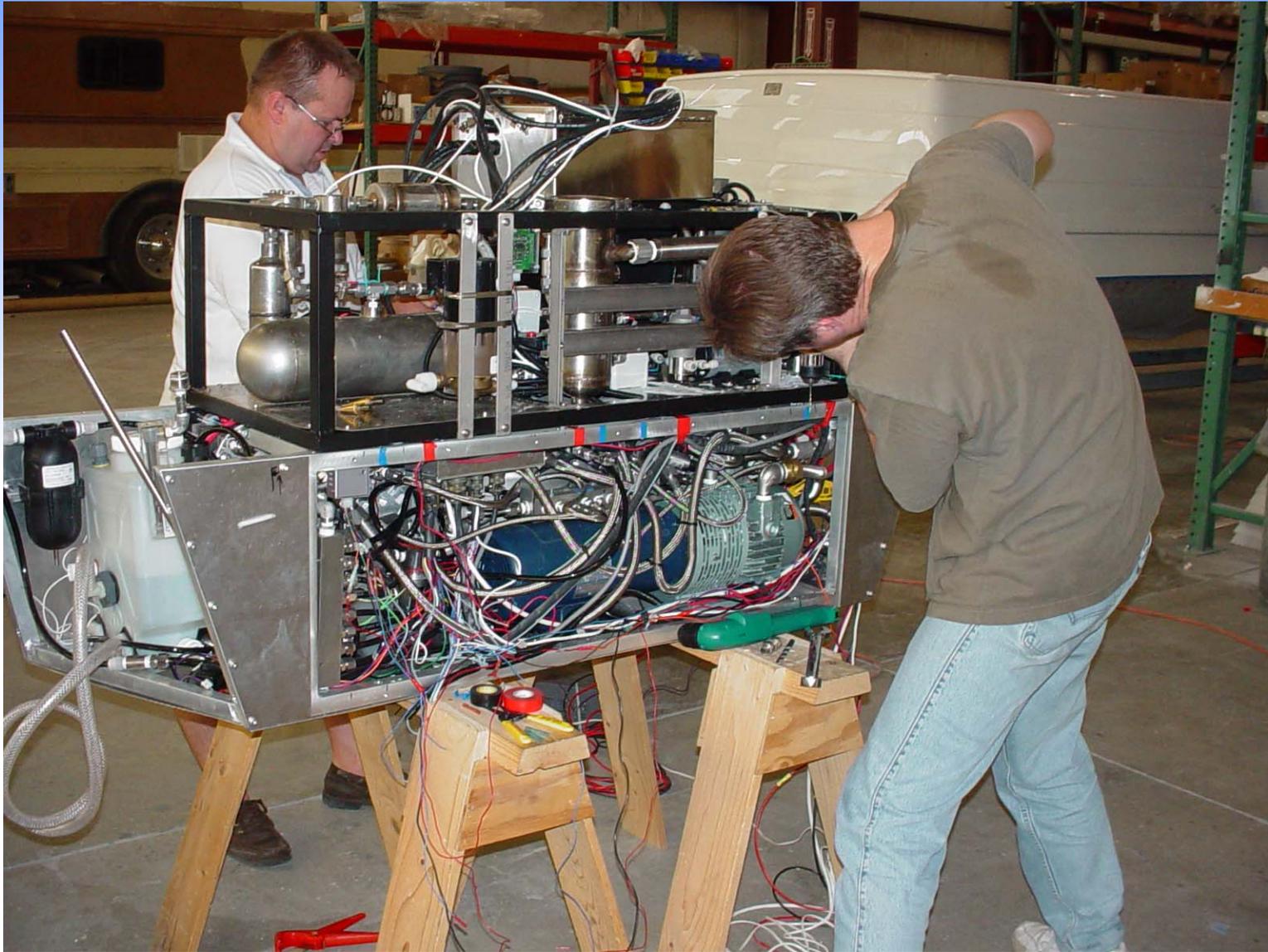
# Phase II Schedule

1. Detail design, specification and materials purchase 9/1/02 – 3/31/03
2. HOD/fuel cell assembly and shop testing 4/1 – 5/31/03
3. DH30 construction and HOD/fuel cell system installation and commissioning 6/1 – 8/14/03
4. HOD/fuel cell system endurance testing and final report preparation 8/15 – 9/30/03

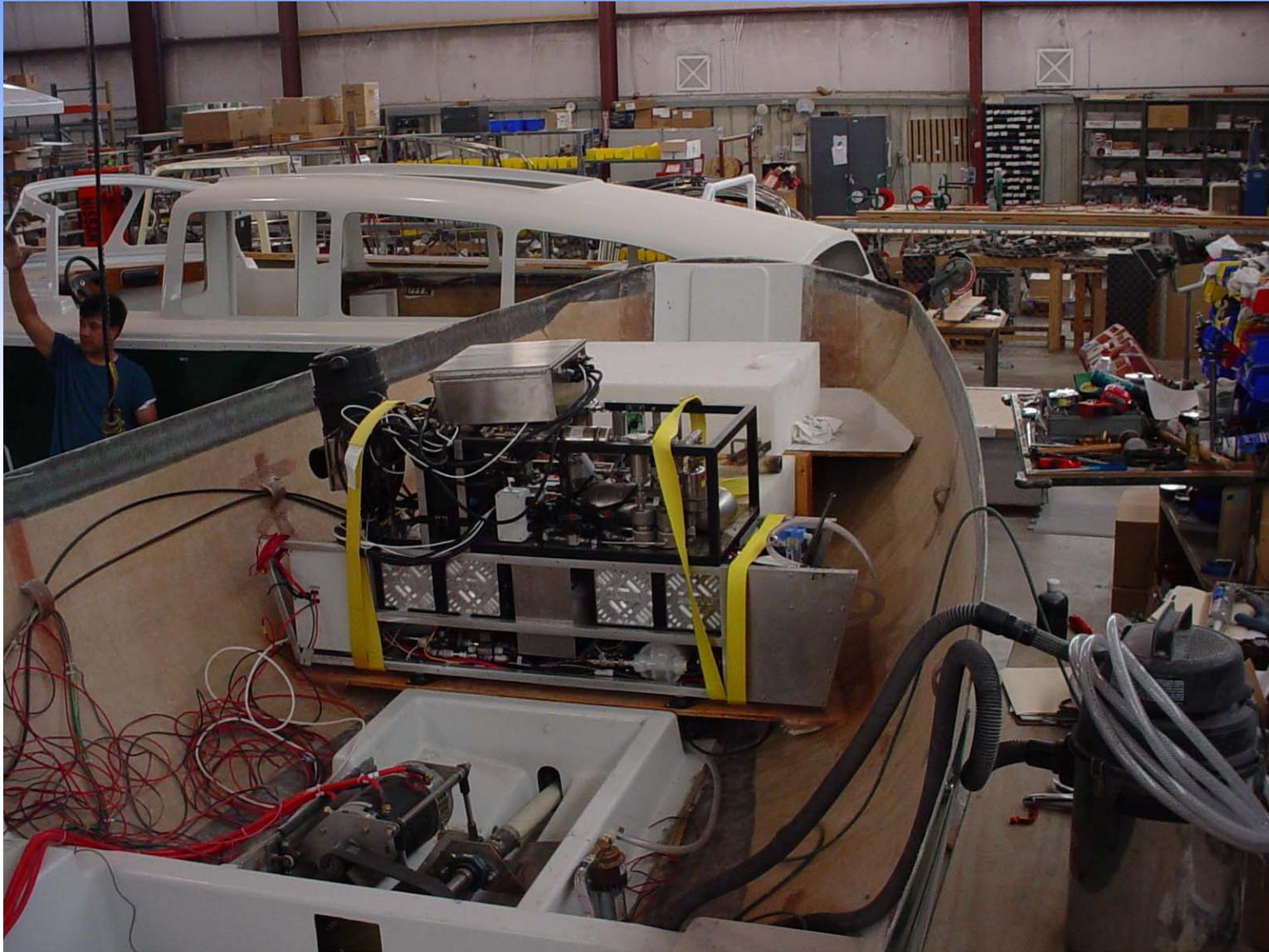








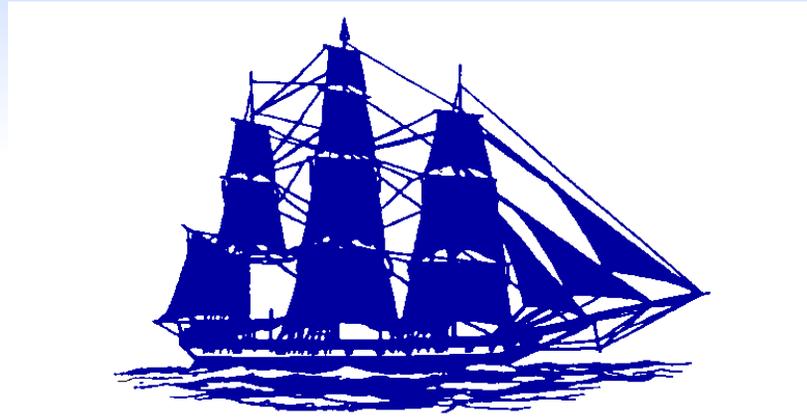








# Thank You for Your Attention



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**Duffy** Electric Boat Company

**ANUVU**  
Incorporated

