PROTON
THE LEADER IN ON SITE GAS GENERATION.

Hydrogen By Wire – Home Fueling System

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Organization: Proton OnSite

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Project ID
#PD067

Overview

Timeline

- Project Start: 22 Sep 2010
- Project End: 14 Aug 2012
- Percent complete: 90%

Barriers

- Barriers addressed
  - G: Capital Cost
  - H: System Efficiency

Table 3.1.4. Technical Targets: Distributed Water Electrolysis Hydrogen Production [a, b, c]

Characteristics	Units	2003 Status	2006 Status [c]	2012 Target	2017 Target
Hydrogen Cost	$/gge	5.15	4.80	3.70	<3.00
Electrolyzer Capital Cost [d]	$/gge $/kW	N/A N/A	1.20 665	0.70 400	0.30 125
Electrolyzer Energy Efficiency [f]	% (LHV)	N/A	62	69	74

Budget

- Total project funding
  - DOE share: $1,000,000
- Planned Funding for FY12
  - DOE share: $500,000

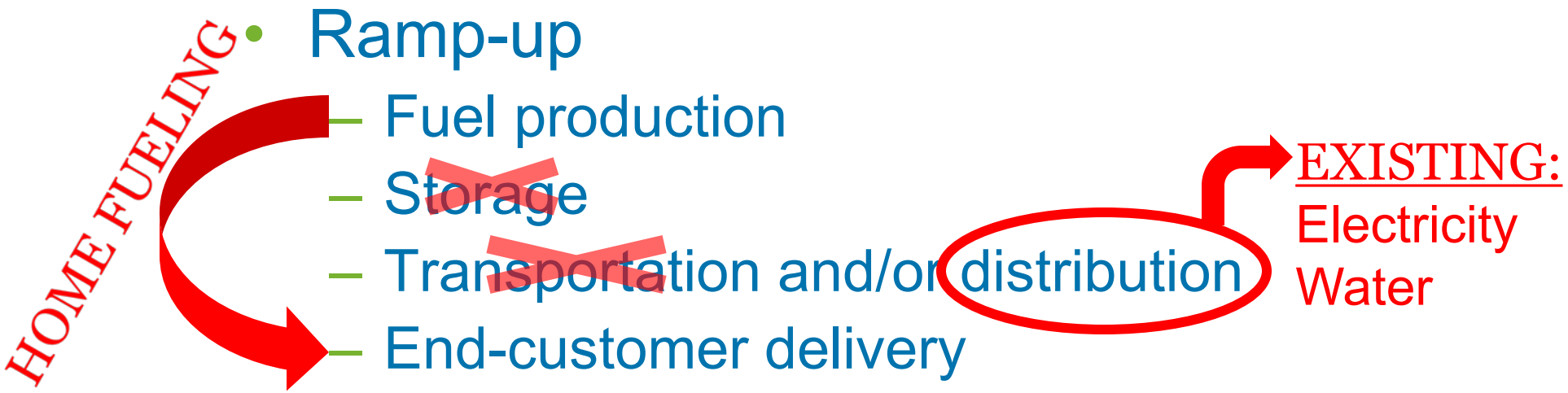
Partners

- Oak Ridge National Lab
- Industry component suppliers

Relevance
Hydrogen Fueling Pathways

- Continuum of options
  - Large, centralized plants
    - Requires transportation or distribution of fuel
  - Neighborhood fueling stations
    - Compatible with medium-to-large scale PEM Electrolysis
    - Generates fuel closer to end-user
    - Can be renewable
  - Home-based fueling
    - Compatible with small scale PEM Electrolysis
    - Generates fuel in the end-user's garage
    - Can be renewable
- Each generation scale will have its place

Relevance
Fueling Infrastructure Challenges



- Pace with parallel ramp-up of related vehicles

Relevance
Advantages of Hydrogen Home Fueling

Vehicle Type	Range (Miles)	Empty to Full Refueling / Charging Time (Hours)
Plug-in Hybrid Electric (PHEV)	40	4 to 6 (@110V)
Battery Electric Vehicle (BEV)	100	8 to 16 (@110V)
Compressed Natural Gas (CNG)	200-300	* 8 to 16 (potential <6h)
Fuel Cell Hybrid Electric Vehicle (FCV)	300	* 1 to 6 (Targets of study)

Comparison of Residential Fueling Charge Time and Vehicle Range (J. Schneider et. al, NHA 2009)

Relevance
Project Objectives

- Develop enabling technologies
  - 350-bar differential pressure electrolysis
    - Cell stack
      - Overboard seal
      - Cross-cell seal, membrane support
    - Fueling system

- Demonstrate prototype operation
  - 350-bar hydrogen generation
  - Fueling capability

Approach
Task Breakdown

- Task 1: Prototype System Design/Fabrication
  - System and key component design
  - Safety analysis
  - Procurement, fabrication, and acceptance testing
- Task 2: Prototype Stack Design
  - Requirements definition
  - Cell hardware design
  - Stack embodiment hardware design
- Task 3: Prototype Component Verification
  - Cell and stack component verification
- Task 4: Prototype System Testing
  - Stack fabrication and assembly
  - Integrated stack/system testing

Technical Accomplishments

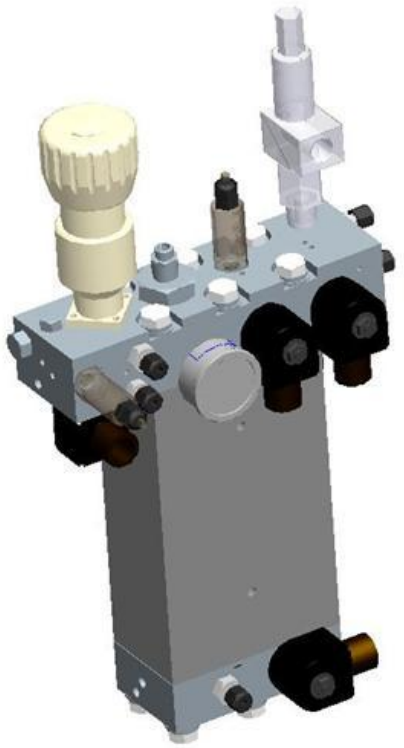
Task	Task Description	Progress Notes	Completion
1.0	System Design / Fabrication	• Completed component procurement. • Completed fabrication. • Completed hydrogen phase separator fabrication and proof test. • Completed system checkout.	100%
2.0	Stack Design	• Completed full-scale pressure testing. • Completed prototype and final design of cell and stack components.	100%
3.0	Component Verification	• Completed verification of stack embodiment hardware. • Completed verification of cell flow fields. • Completed verification of gas diffusion at full differential pressure.	80%
4.0	Integrated Testing	• Completed system power supply and pump testing. • Integrated cooling and data acquisition equipment.	10%

Technical Accomplishments
Task 1.0: System Design/Fabrication

- Prototype system completed fabrication and checkout

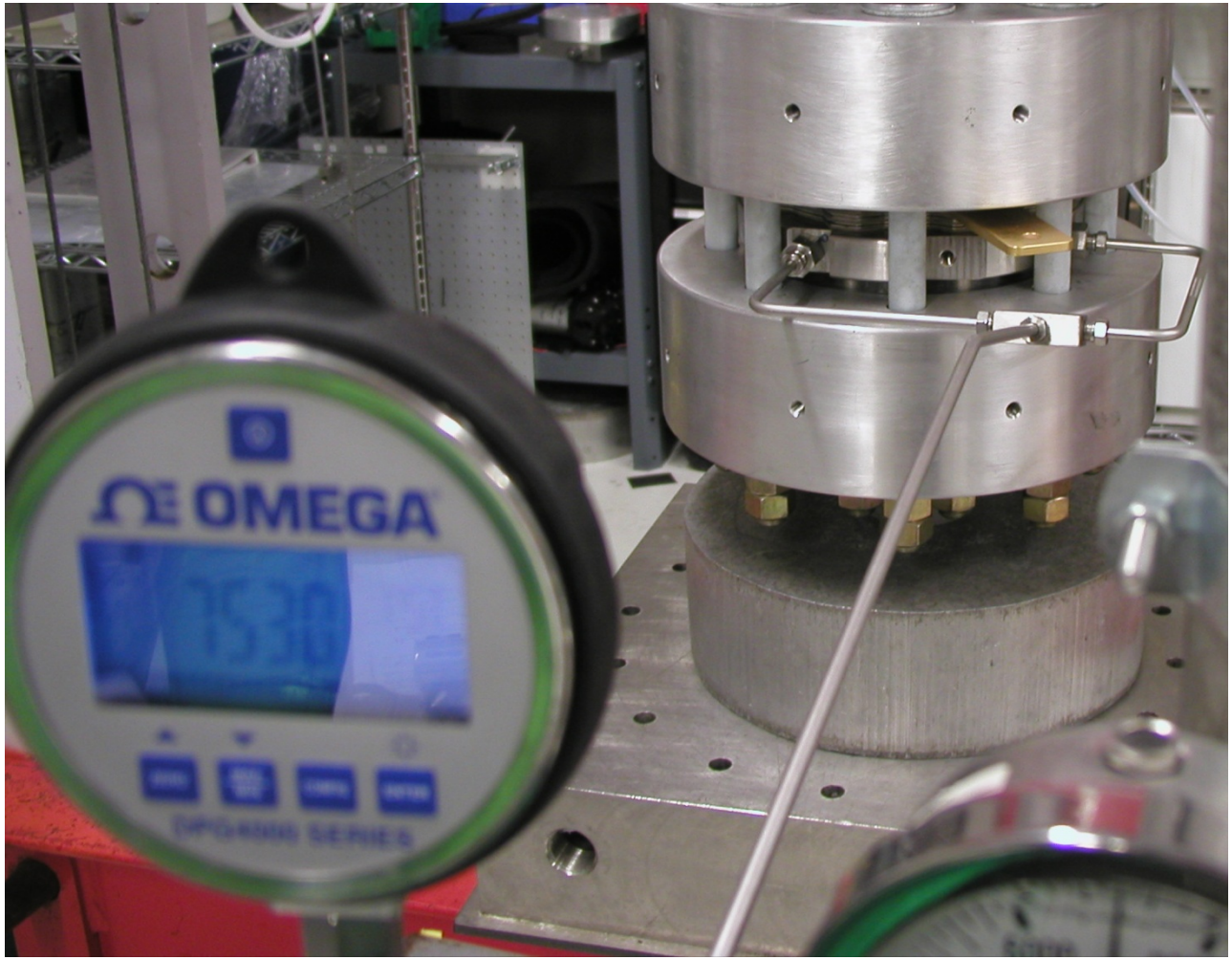
Technical Accomplishments
Task 1.0: System Design/Fabrication

- High pressure phase separator design refinement and prototype fabrication completed
  - Proof pressure test >7,500 psig completed



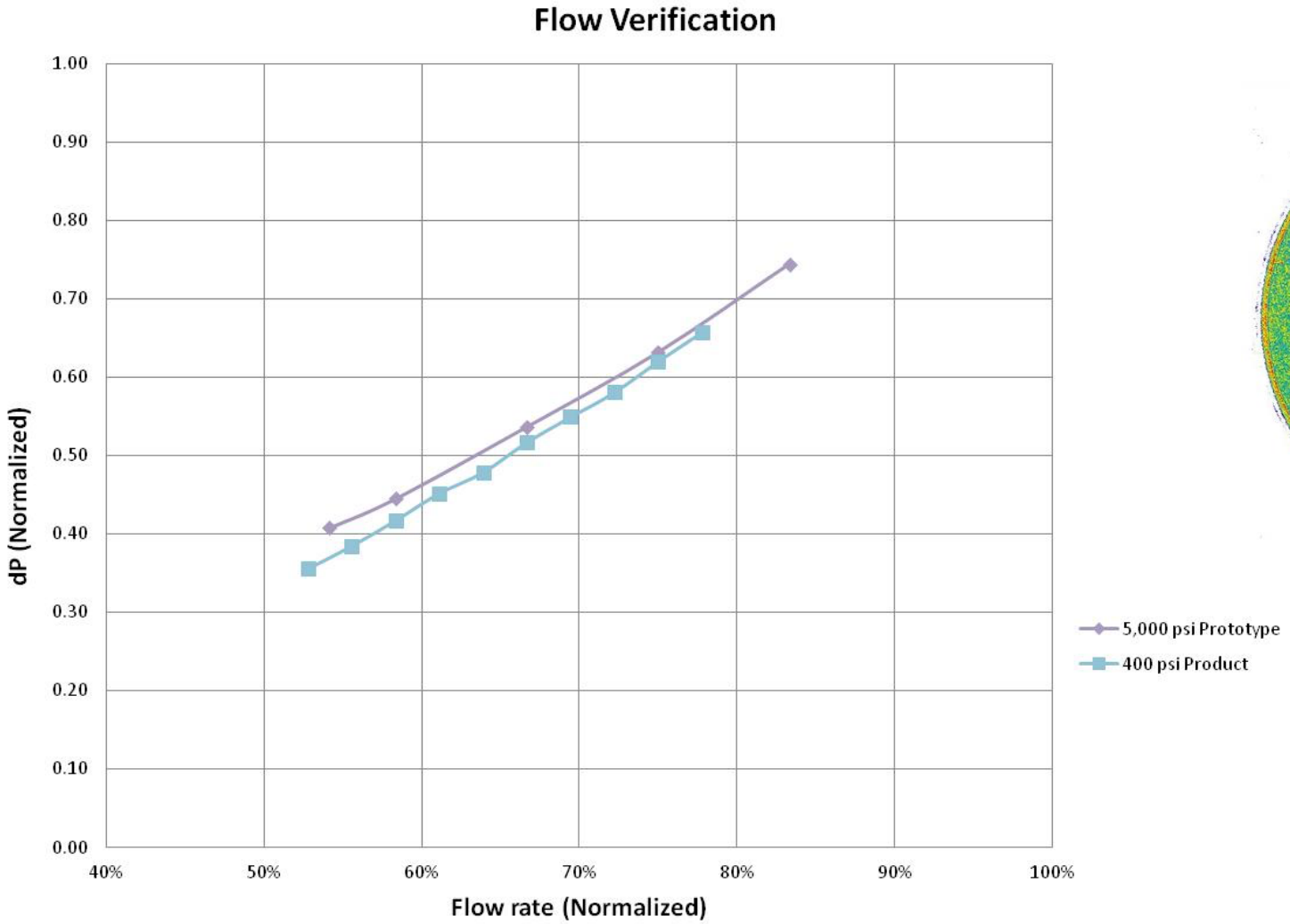
Technical Accomplishments
Task 2.0: Stack Design

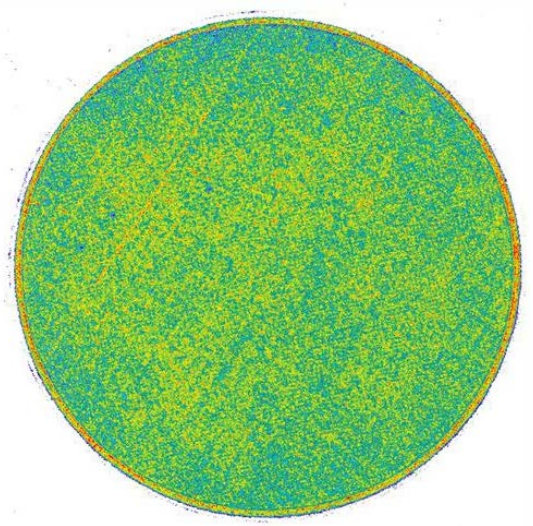
- Full-scale pressure testing—proof >7,500 psig



Technical Accomplishments
Task 3.0: Component Verification

- Flow field optimization complete

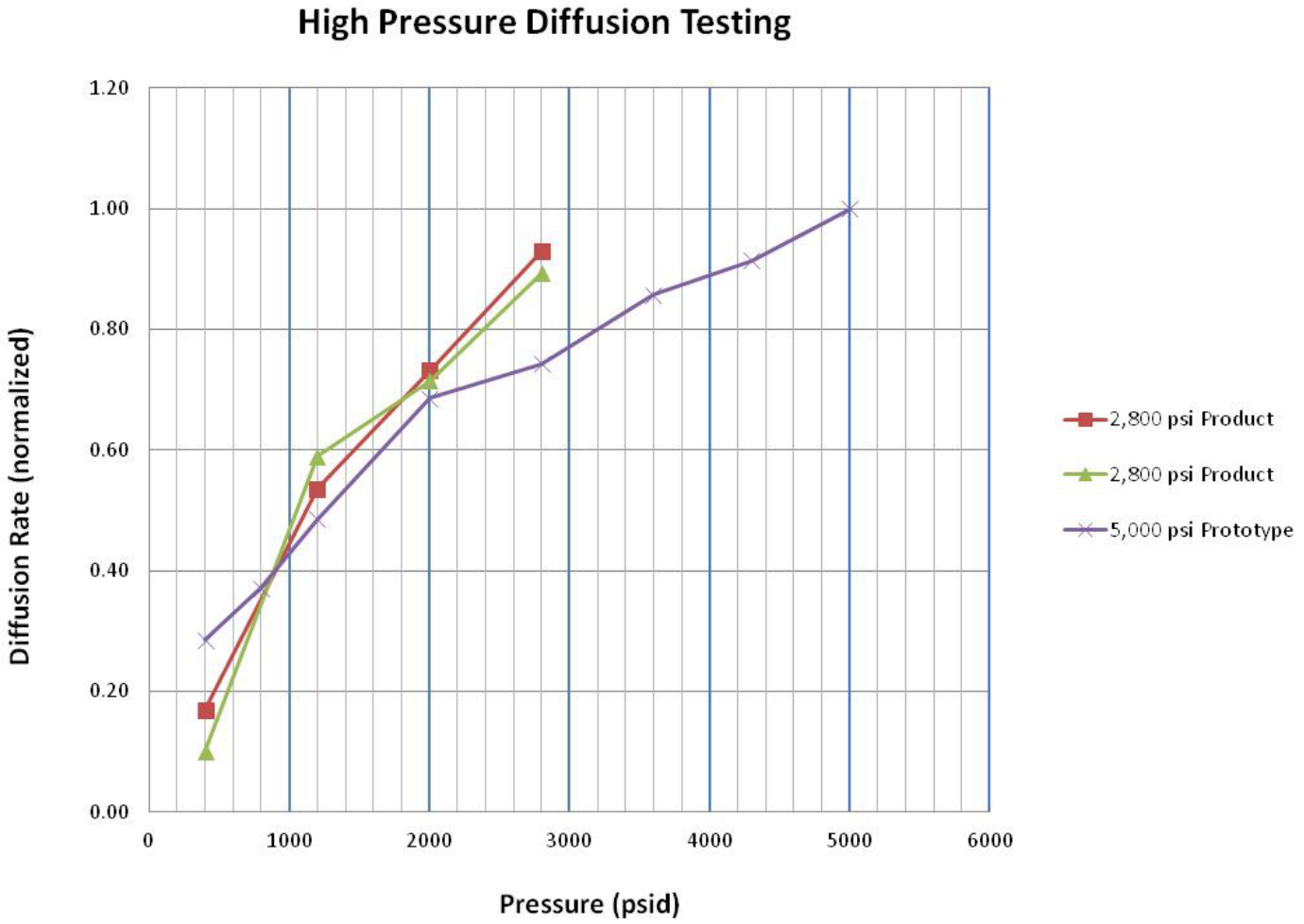




Contact pressure: Results uniform and within design specifications.

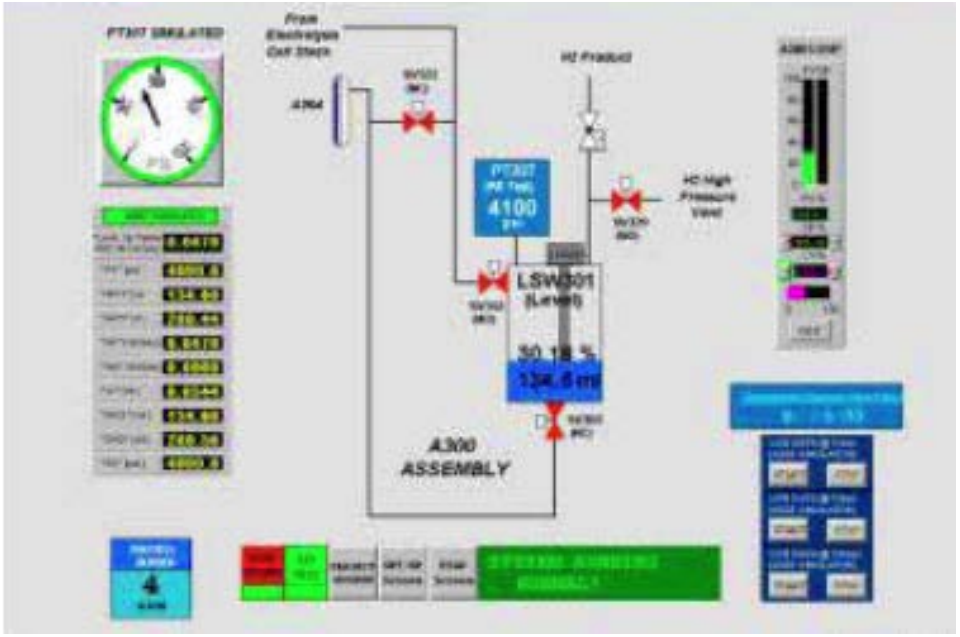
Technical Accomplishments
Task 3.0: Component Verification

- Cross-cell diffusion testing completed at 5000 psid



Technical Accomplishments
Task 4.0: Integrated Testing

- High pressure phase separator simulation created
  - Simulates input/output flow rates, rate of pressurization
  - Utilized to tune operating algorithm



- System ready for operation
- Stack installation anticipated soon!

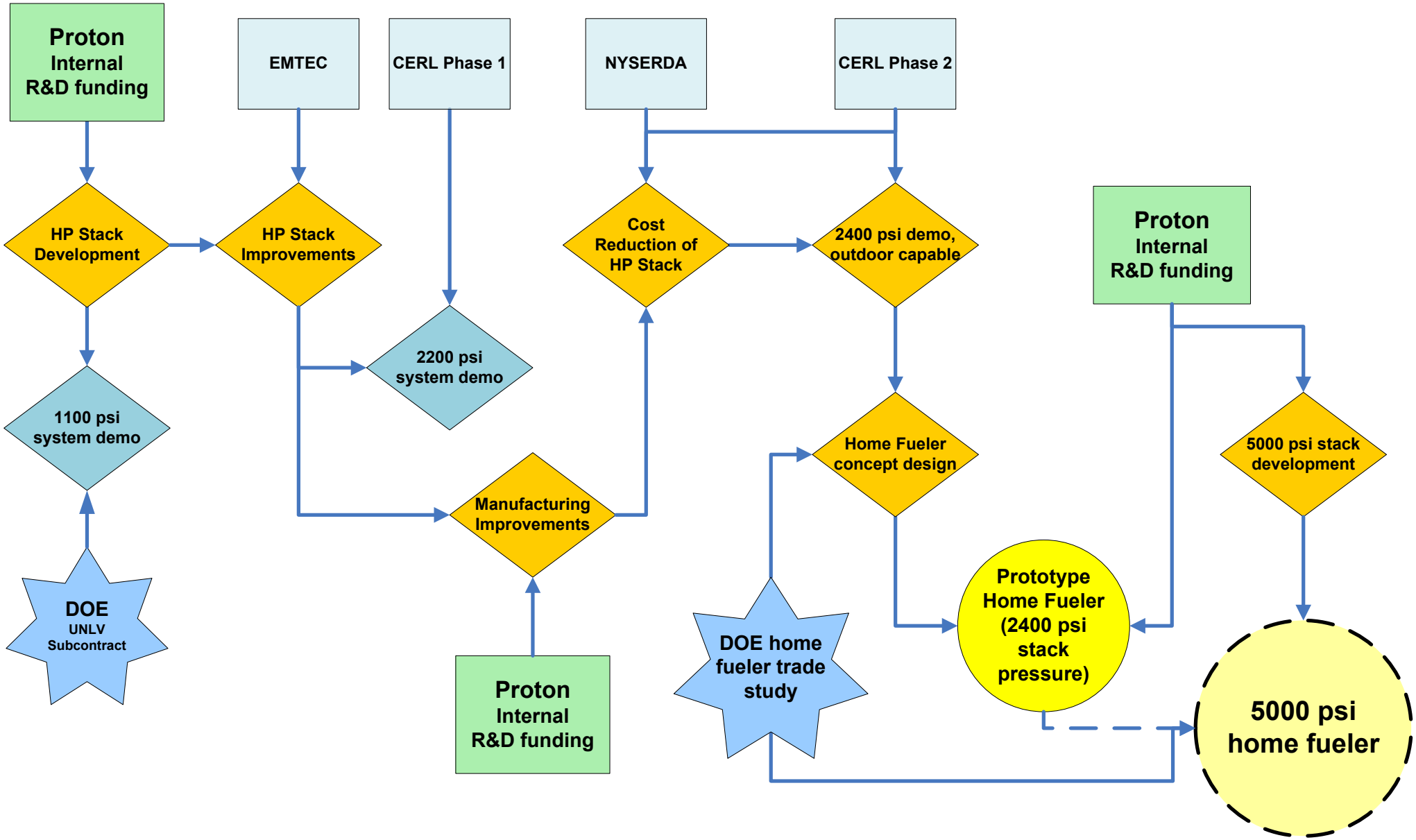
Collaborations

- Oak Ridge National Laboratory
  - Collaborated on analyzing durability of metallic and coated separator materials
- Industry component suppliers
  - Collaborated to identify appropriate components for pressure, temperature, and fluid compatibility requirements.

Future Work

- Integrated operational testing
- Scale up cell count to increase total output
- Optimize system packaging for siting requirements and cost effectiveness

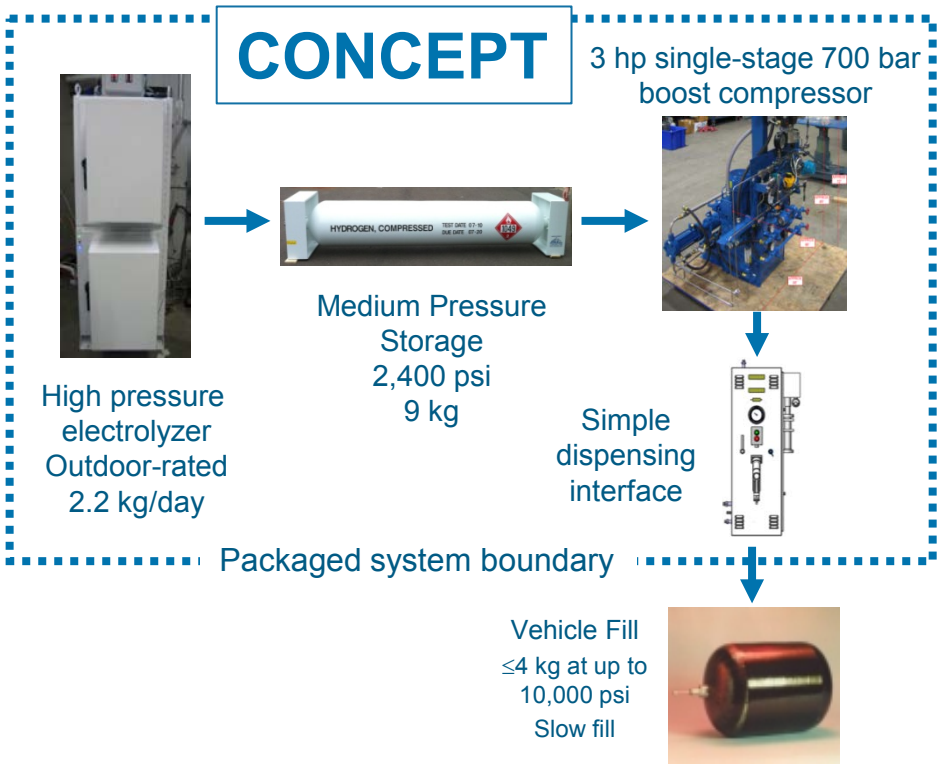
Future Work: Home Fueler Roadmap

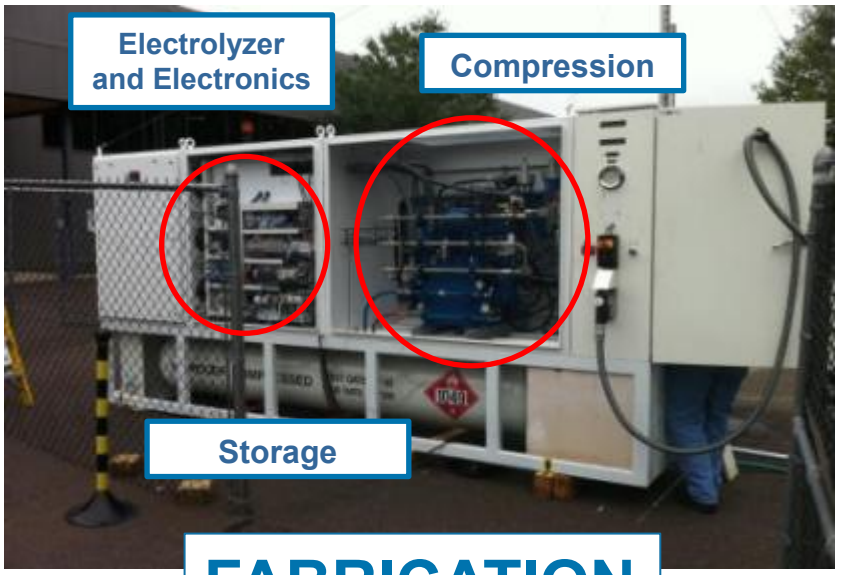


Future Work: 700-bar Fueling Comparison

HOGEN® NF Small-Scale 10,000 psi Fueler

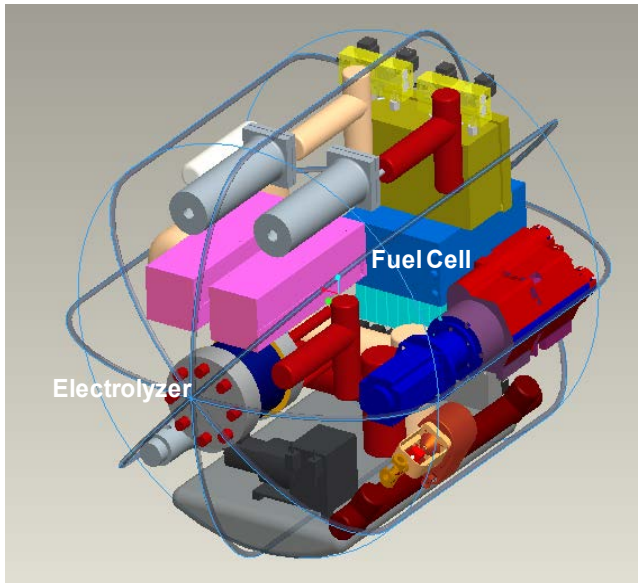
- Electrochemical compression to 2,400 psi, 2.2 kg/day production
- 10,000 psi slow-fill fueling capability
- Qualified for GM vehicle fueling





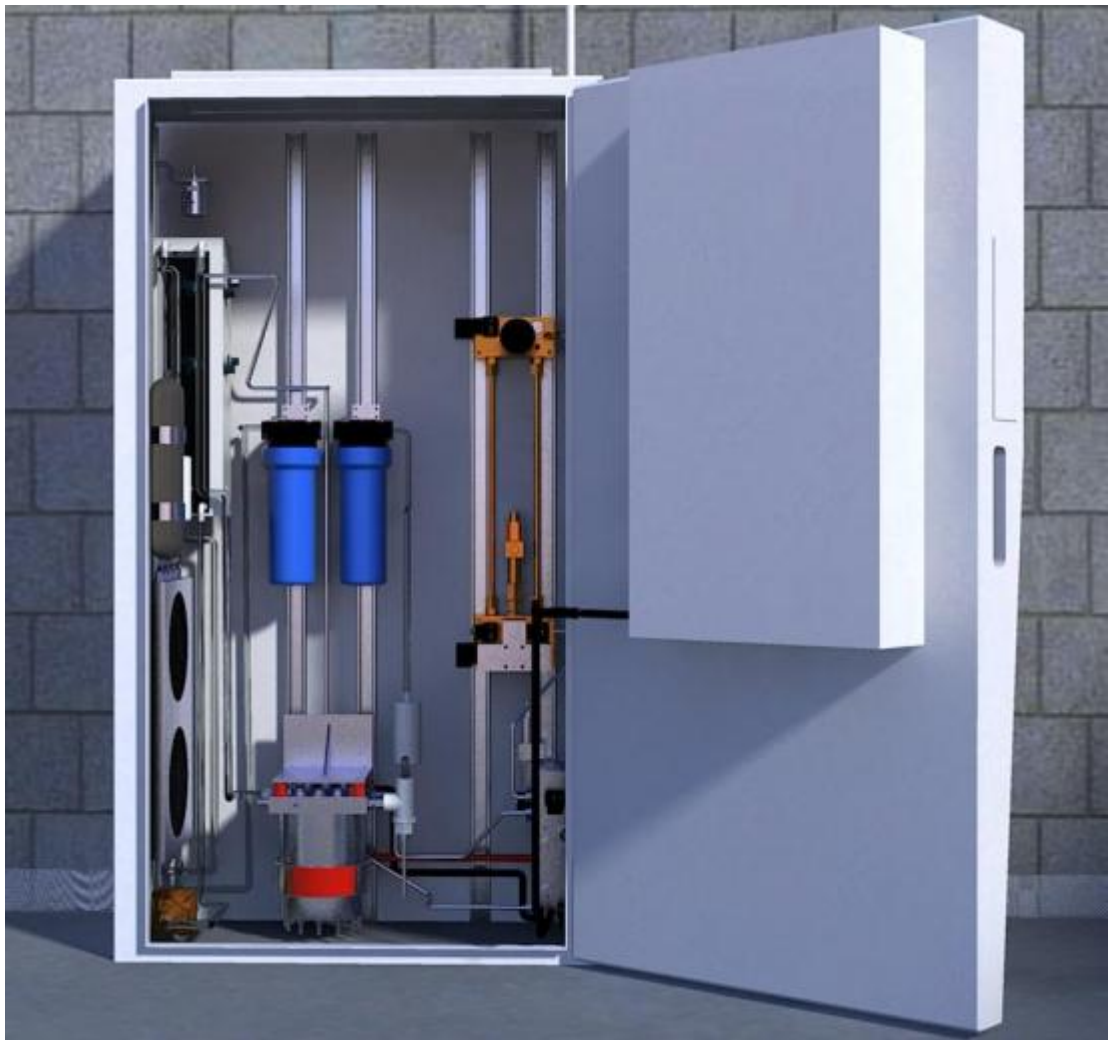
Future Work: Undersea Energy

- U.S. Navy Office of Naval Research
  - Parallel related development
  - Balanced pressure version of cell stack
  - Applied to air independent energy storage need



Future Work
Product Package Development

- Physical Size – 2’ x 3’ x 5’



Summary

- **Relevance:**
  - Home fueling is a viable pathway on the continuum of options. Home fueling grows organically with vehicle introduction. PEM electrolysis technology is ideal for small footprints and easy maintenance.
- **Approach:**
  - Execute development of key enabling technologies including PEM electrolysis cell stack and balance-of-plant components for 5,000 psi operation. Draw upon *Proton's experience with commercial products* to inform the design and safety analysis.
- **Technical Accomplishments:**
  - Completed prototype system fabrication and checkout. Completed full-scale cell pressure testing. Completed cell stack design and component fabrication.
- **Collaborations:**
  - ORNL supported analysis of metallic separator durability.
- **Proposed Future Work:**
  - Integrated testing of cell stack in system. Packaging optimization and fueling demonstrations.