Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

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Overview

Timeline	Partners
• Start: November 2004 • Finish: June 2010 • 85 % Complete	• BP • Ballard/AFCC • States of California & Florida • City of Taylor, MI • SMUD, Progress Energy & NextEnergy
Budget	**Barriers**
• Total Project Funding – DOE: $42M – Ford: $42M • Funding received in FY08 = $6.5M • Funding for FY09 = $3.2M	• Cost • Air Delivery System • Freezability • Range

Objectives

- Ford Motor Company Objectives
  - Gain vehicle operational data in differing climate conditions, to direct and augment future design efforts
  - Provide input to the industry-government efforts to define a future hydrogen economy
- BP Objectives
  - Establish an initial retail compatible hydrogen infrastructure to fuel a small fleet of fuel cell vehicles
  - Evaluate emerging hydrogen technologies that have the ability to meet DOE cost and performance targets
  - Explore cost and commercial feasibility of renewable-based hydrogen generation

2008 Completed Milestones

Gen II Fuel Cell Powertrain – June, 2008	- System achieved Ford's Implementation Ready milestone - Improved power output and lifetime verses Gen I - Achieved freeze start capability
700Bar Type III Hydrogen Storage System Validation – April, 2008	- Drive Cycle validation is statistically equivalent to 350Bar - System tested for 4,500+ miles - PWM valve control strategy confirmed - Achieved the Ford GTDS Implementation Ready milestone
Next Gen IPT Electric Drive – August, 2008	- Performance and durability assessment completed
Infrastructure Development	- SMUD station commissioned in March, 2008 - 700bar stationary site commissioned in July, 2008

2009 Scheduled Milestones

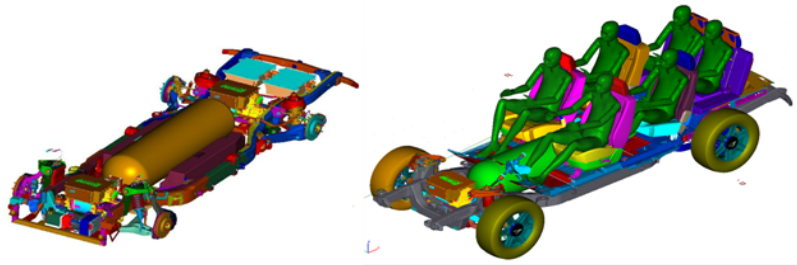
Demonstrate 700Bar Type III/Next Gen IPT/Gen II FC Powertrain in vehicle package – April, 2009	- Integration testing of vehicle's on-going - Beginning fuel economy testing - Freeze start evaluation on-going
Continue Gen I Focus Fleet Operation	- To drive EOL failure analysis - Fleet decommission scheduled for Dec, 2009 - Tear Down Analysis 1Q-2Q10

Approach

- 18 Ford Focus Hydrogen Fuel Cell Vehicles
  - Southern California (8)
  - Orlando, Florida (5)
  - Southeast Michigan (4)
  - Reykjavik, Iceland (1)

Hydrogen FC Focus

- Technology Demonstration Vehicles (TDVs):
  - Development of next generation fuel cell system on a commercially viable platform
    - Low temperature starting capability
    - Increased driving range
    - High pressure hydrogen storage

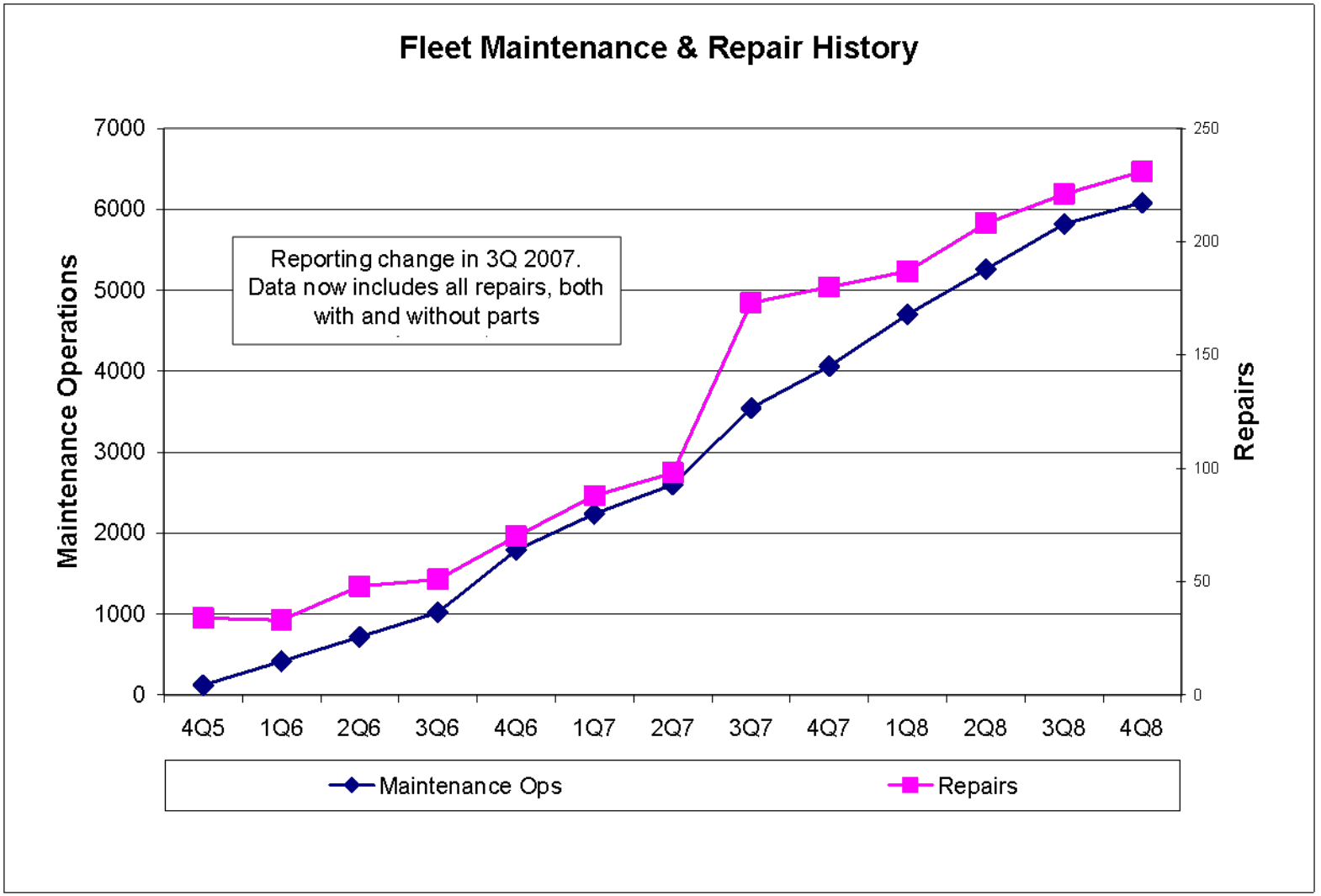


Designed Around Hydrogen Explorer

Technical Accomplishments / Progress / Results

- Focus Fleet
- Technical Demonstration Vehicles (TDVs)
- Data Analysis
- Infrastructure

DOE Focus Fleet Data



FC Technical Demonstration Vehicle Program

	Robustness Demonstrator Modified Focus	H2 Storage Upgrade 700 bar	Designed Around Hydrogen Demonstrator			Proposed Technology Path Demonstrator
Vehicle	TDV1	TDV 9	TDV 2	TDV3.2	TDV 4	TDV 7
Miles driven since oper.	30000	5270	26000	4700	500	11584
Hours	751	156	813	128	16	254
Platform	Mod Focus	Focus	Explorer	Explorer	Explorer	Edge HySERIES
Fuel Cell Powertrain	Gen I Modified	Gen I Carryover	Gen I - Alternate Package	Gen II Prototype	Gen II Production Intent	Series FC APU
Range (miles)	200	250	150	175	>300	225
H2 Storage (bar)	350	700	350 surrogate	350	700	350
STACK Life (miles)	30,000	15,000	45,000	45,000	45,000	NA
Unassisted Cold Start	2 °C	2 °C	< 0 °C	-15C	-15C	NA
Assisted Cold Start	2 °C	2 °C	-15 °C	N/A	N/A	NA
FE (mpg)	50	50	30	35	35	41

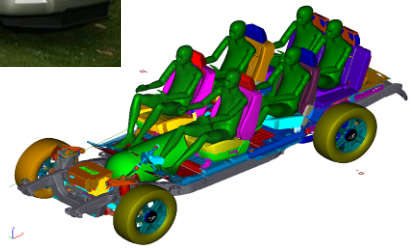
TDV1

- Purpose was to demonstrated 30K stack and FC durability
- Goal to improve FC life via
  - Anode Reactant Gas Humidity changes
  - Optimized internal FC water management

- Accomplishments
  - Stack polarization did not degrade significantly as mileage increased
  - Dynamic humidity modeled in vehicle
  - Thermal characterization of anode and cathode gases in vehicle system
  - Completed 30K miles in June, 2006

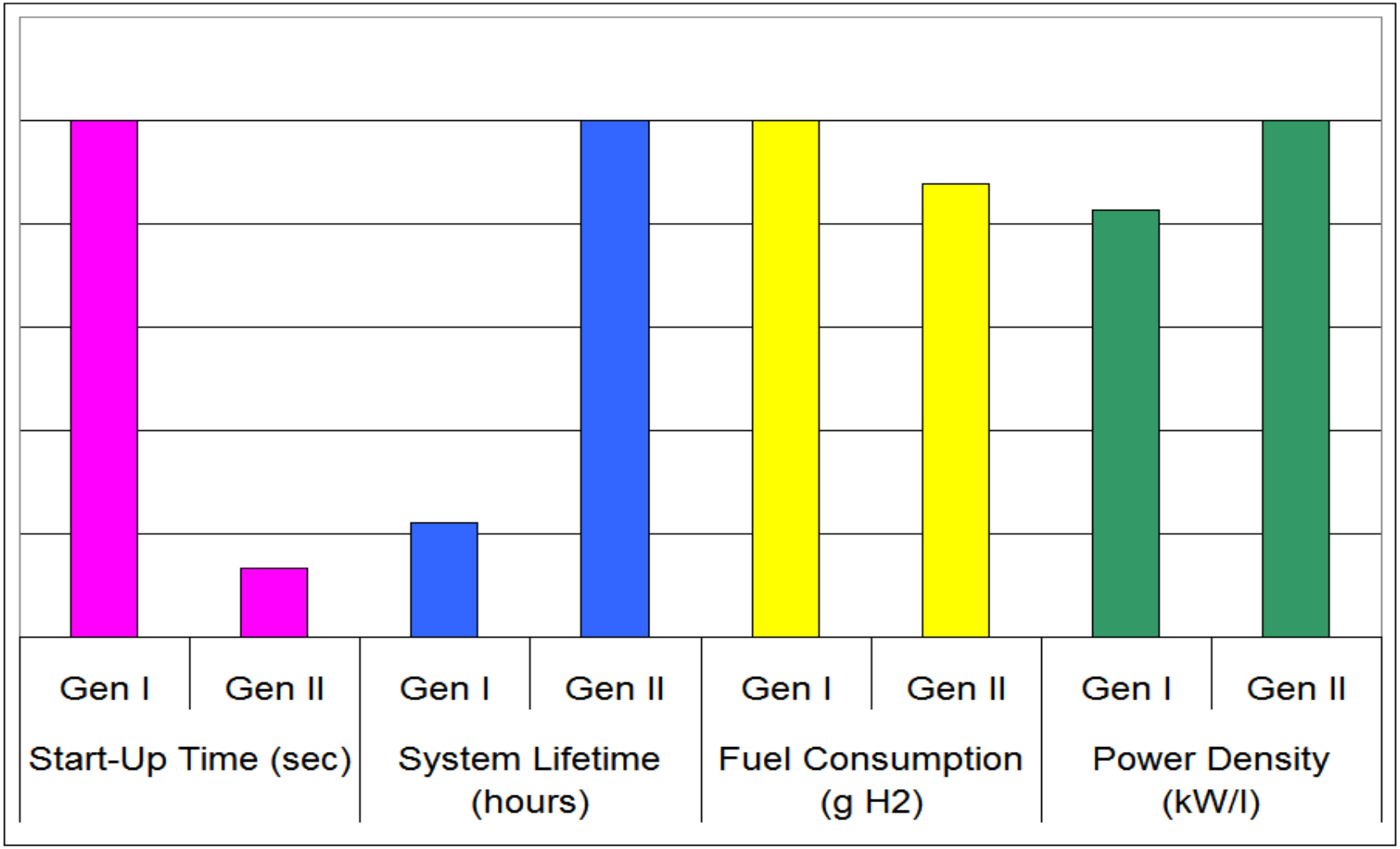
TDV

- TDV2
  - Launched in October, 2005
  - Accumulated 26,000 miles
  - Original stack, and is in good health
  - The vehicle has been used in many drive and media events.



- TDV3.2
  - Vehicle is assembled and commissioned
  - Vehicle was used for validation of reliable cold starts down to temperatures of -15^{o}C with a Gen II stack & system

Gen I vs. Gen II



Fuel Consumption as indicated over the FUDS Cycle

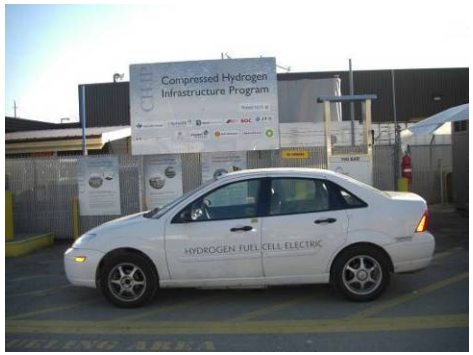
TDV

- TDV4
  - Build is complete, integration is on-going
  - Gen II prototype engine
  - Type IV 700bar Tank, 9.52kg usable hydrogen

- TDV7
  - Accumulated approximately 9500 miles
  - HySeries Powertrain
  - Evaluated by NREL in January, 2008
  - Significant learning on series hybridization
    and power-fade challenges

TDV 9

- Demonstrated new 700 bar technology through durability and real-world customer cycles
- Provides the capacity improvement pathway to the 300 mile driving range goal
- Improves volumetric density by about 1.5x while maintaining the same weight ratio
- Conducted successful fueling trials providing similar experience as 350 bar



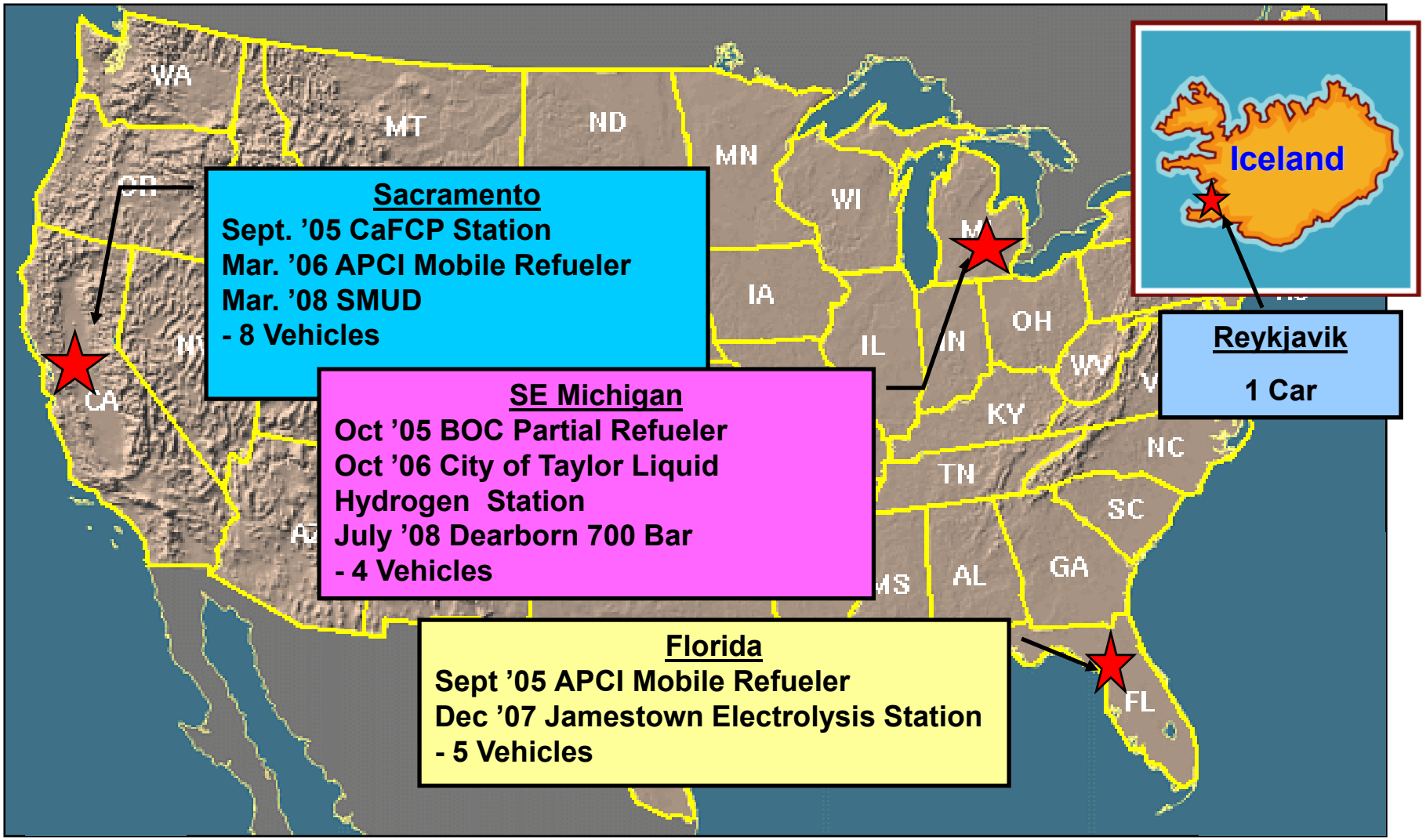
Data Analysis Results

- The fleet is showing reduced stack power
  - Some customers are aware of the power reduction but it has not affected their daily usage of the vehicle
  - Continuing to monitor stack power
  - Using this experience in new designs and tests
- Stack Degradation Workshop with NREL
  - Productive meetings and discussions held
  - Developed an alternative method for assessing stack health
    - Decision to discretely analyze stack beginning-of-life degradation and compare to mid/end-life degradation

Infrastructure Project Objectives & Approach

- Objectives
  - Provide safe, reliable, user- friendly hydrogen infrastructure
  - Install technology to meet cost targets
  - Test a variety of hydrogen delivery options
- Approach
  - Phase One
    - Install Mobile Refuelers
    - Install Delivered H2
  - Phase Two
    - Install On-site H2 Production
    - Commission 700 bar station in Dearborn, MI

Phase I Infrastructure Deployments



Station Timeline

	2005	2006	2007	2008	2009
Sacramento, CA Mobile Refueler					
SMUD, CA Sacremento Municipal Utility District					
Jamestown, FL Mobile Refueler					
Jamestown, FL Stationary Site w/electrolyzer					
City of Taylor, MI Temporary Station					
City of Taylor, MI Stationary Site, Liquid delivery					
Dearborn, MI 700 bar, Liquid delivery					

Dearborn 700 bar Hydrogen Station

Technology	Delivered CH2 & Liquid
Service Pressure, psig	5000/10000 (350/700 bar)
Total Capacity, kgs	**1500 gallon Liquid/300 kg CH2**
Usable @ 5000 and 10000 psig, kgs	1000
Utilities Required	Nitrogen, Electricity
Renewable	No
Data Collection	Automated
Grounding	No electrical connector (Vehicle connector for 10000 psi only)
Vehicle Interface	SAE J2600
Total Capacity	1000 kg

SMUD Station

- Commissioned in March, 2008
- Solar power electrolyzer
- Service Pressure = 6600psig
- Electrolyzer Production Capacity = 24kg/day
- Interfaces supported
  - Wireless
  - Non-comm
  - Wired
- Data collection on-going

Deployment Accomplishments

- Focus Fleet
  - Accumulated over 1,000,000 miles to date[1/]
  - Average stack life has exceeded original expectations by 100% on average
  - Additional geographic information is being collected from deployment of one vehicle to Iceland
- TDV4 completion
  - First full implementation of Gen II technology into a single platform

[1/] *Includes DOE and non-DOE Focus Fleet Vehicles*

Future Work

- Complete vehicle accumulation through 12/2009
- EOL failure analysis on key systems/components
- Final FE and freeze-start assessment (TDVs)
- For financial reasons, further work on TDVs have been cancelled/deferred
  - Continue Fuel Cell development through laboratory testing
- Submit Final Report

Summary

- Focus Fleet very successful with Gen I architecture
  - Data shows stack more reliable than anticipated
- Technical Demonstration Vehicles
  - Successful demonstration of 700bar H2 storage
  - Design Around H2 demonstrated
  - Freeze start capability demonstrated
- Infrastructure
  - Permanent 700bar station operational