



Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project



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Overview

<p style="text-align: center;">Timeline</p> <ul style="list-style-type: none">• Start: November 2004• Finish: December 2009• 100 % Complete	<p style="text-align: center;">Partners</p> <ul style="list-style-type: none">• BP• Ballard/AFCC• States of California & Florida• City of Taylor, MI• SMUD, Progress Energy & NextEnergy
<p style="text-align: center;">Budget</p> <ul style="list-style-type: none">• Total Project Funding<ul style="list-style-type: none">– DOE: \$33M– Ford: \$33M• Funding received in FY09 = \$3.2M• Funding for FY10 = \$0.7M	<p style="text-align: center;">Barriers</p> <ul style="list-style-type: none">• Cost• Freeze start• Range• Infrastructure

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

2009 Completed Milestones

<p>Demonstrated 700 bar Type IV/Next Gen IPT/Gen III FC Powertrain in vehicle package</p>	<ul style="list-style-type: none">- Successful integration testing of vehicles- Conducted fuel economy testing- Freeze start evaluation complete
<p>Concluded Gen I Focus Fleet Operation</p>	<ul style="list-style-type: none">- Review EOL failure analysis- Fleet decommission complete- Tear down analysis

Approach

1. Fleet Demonstration

18 Ford Focus Fuel Cell Vehicles

- Southern California (8)
- Orlando, Florida (5)
- Southeast Michigan (4)
- Reykjavik, Iceland (1)

2. Technology Advancement

Technology Demonstration Vehicles

- Fuel Cell Durability
- Increased operating range
- Cold start capabilities

2005-2009 Focus FCEV Vehicle Demonstration Program



2006-2009 DOE Technology Demonstration Vehicle (TDV) Program



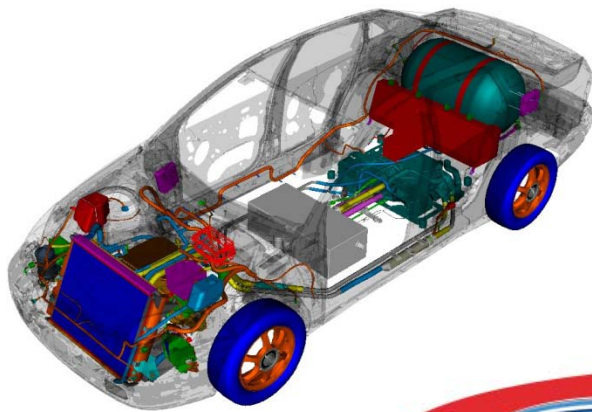
Technical Accomplishments & Progress

1. Fleet Demonstration Accomplishments
2. Technology Demonstration Accomplishments
3. Infrastructure Demonstration Accomplishments

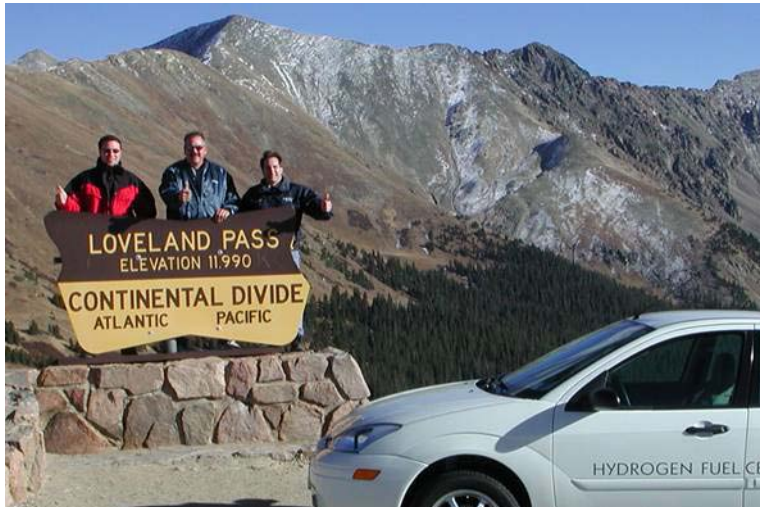
2005 Focus Fuel Cell Electric Vehicle



- 4 Passenger Sedan
- Curb Mass: 1600 kg (3520 lbs)
- Fuel Cell: Ballard Mark 902 FC STACK
- Peak Power: 65 kW (87hp)
- Powertrain: Integrated AC Induction
- Hybridized
- Series Regenerative Braking
- 50 Mi/Kg H₂
- Range: 200 mi/320 km
- Max speed: 80+ mph/128+ kph
- Fuel: 350 bar Compressed Hydrogen
- Emissions: Zero



2005 Focus Fuel Cell Electric Vehicle



14,000 Ft Altitude Testing



Mud Bath / Salt Water Fording



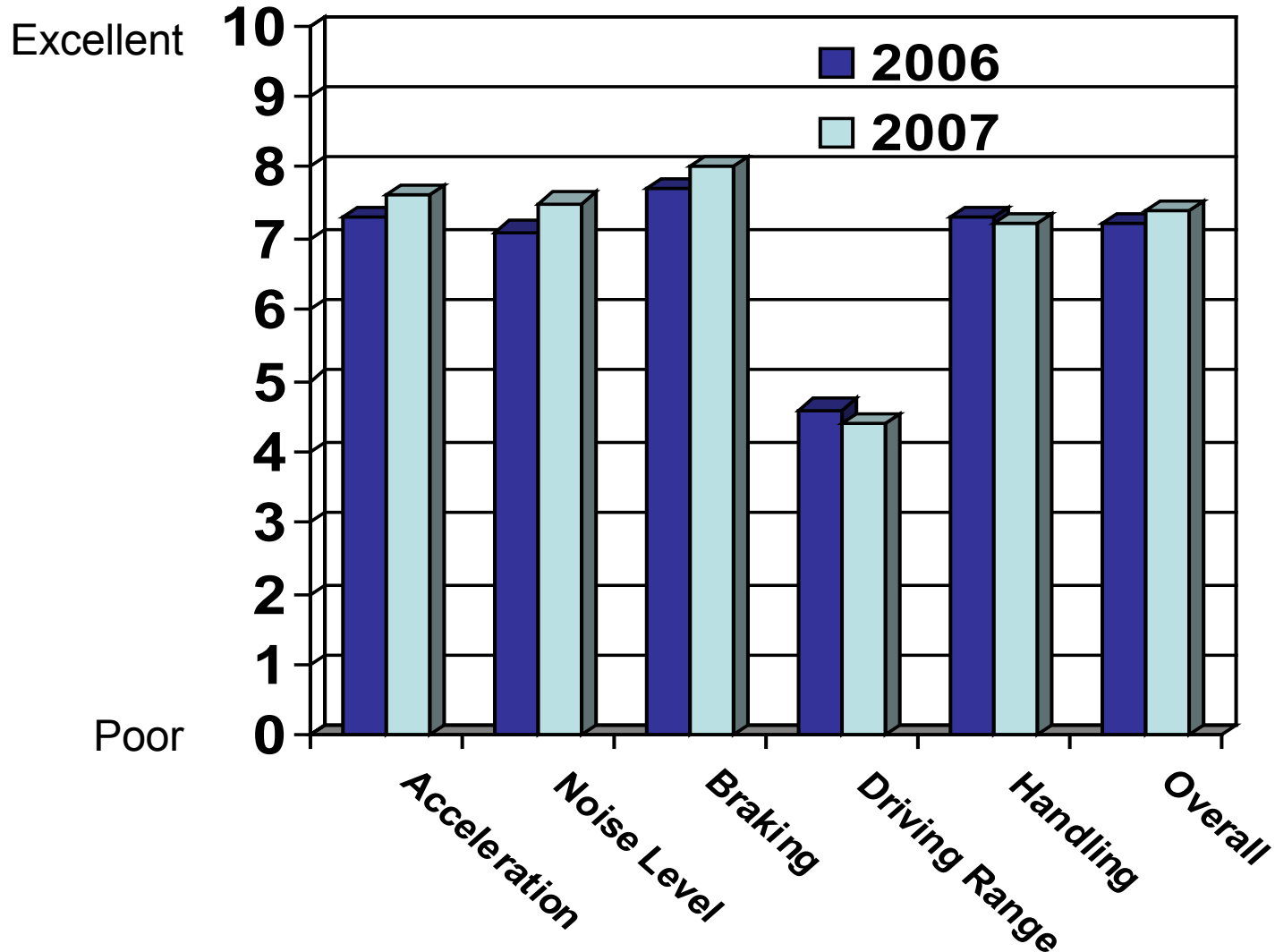
Sault Ste Marie Brake Testing -18 C



Cobblestone Roads

Focus Fuel Cell Customer Feedback

How would you rate the vehicle's performance?



Focus Fuel Cell Customer Feedback

I drive the car without hesitation and am very impressed by it.

It has plenty of speed for getting down the highway

I feel safer driving this vehicle than a gasoline vehicle. It is incredibly safe.

It has great pick up off the line.

It handles very well.

The car attracts a lot of attention and is fun to drive.

The car has been very reliable and a great addition to our fleet.



Fleet Demonstration Accomplishments

- **Focus Fuel Cell Fleet Milestones**

- ✓ Accumulated over **1,300,000 miles to date** ^{1/}
- ✓ Successful in-field operation past the original 36-month target with all vehicles in the field over 48 months
- ✓ Demonstrated 50% higher fuel economy than gasoline vehicles
- ✓ Confirmed >1000 hours fuel cell durability using on-road data
- ✓ Validated vehicle fueling time of 5 minutes or less for a 5 kg tank
- ✓ Fleet had a 94% up-time for user operation and availability
- ✓ High customer satisfaction and feedback



^{1/} Includes DOE and non-DOE Focus Fleet Vehicles

Technology Demonstration Vehicles

Vehicle Attributes	Robustness Demonstrator	700 bar Demonstrator	Designed Around Hydrogen Demonstrator			Plug-In Technology Demonstrator
Vehicle	TDV 1	TDV 9	TDV 2	TDV 3.2	TDV 4	TDV 7
Platform	Modified Focus	Focus	Explorer	Explorer	Explorer	Edge HySERIES
Fuel Cell Generation	Gen 1 modified	Gen 1 carryover	Gen 1	Gen 2	Gen 3	Series FC APU
Range (miles)	200	250	150	175	>300	225
Hydrogen Storage (bar)	350	700	350	350	700	350
STACK Life Target (miles)	30,000	15,000	45,000	45,000	45,000	n/a
Unassisted Cold Start	2° C	2° C	<0° C	-15° C	-15° C	n/a
Assisted Cold Start	2° C	2° C	-15° C	n/a	n/a	n/a
Fuel Efficiency (mpge)	50	50	30	35	40	41

TDV 1 Accomplishments

Demonstration Objective	TDV 1
Next Generation Fuel Cell	▲
Over 300 Mile Range	
700 bar Hydrogen Storage	
STACK Life (30,000 mile)	X
Unassisted Cold Start < 0°C	
Fuel Efficiency (mpg) (*normalized to Focus)	X
FCS Peak Noise (dBA)	

▲ Advancements, improvements or new concepts

Accomplishments

- Developed a novel humidity sensor
- Developed a novel gas conditioner
- Characterized fuel cell stack interfaces
- Improved Humidification of Anode
- Applied next generation H2 recirculation blower
- Demonstrated improved stack lifetime and reliability
- Completed 30,000 mile dynamometer endurance test
- No stack performance or durability issues
- Thermal characterization of anode and cathode gases



TDV 9 Accomplishments

Demonstration Objective	TDV 9
Next Generation Fuel Cell	
Over 300Mile Range	▲
700 bar Hydrogen Storage	X
STACK Life (30,000 mile)	
Unassisted Cold Start < 0°C	
Fuel Efficiency (mpg) (*normalized to Focus)	X
FCS Peak Noise (dBA)	

▲ TDV9 demonstrated progress toward this objective, extending range in the same vehicle packaging allowance.



Accomplishments

- Demonstrated new 700 bar technology through durability and real-world customer cycles
- Provided the capacity improvement pathway to the 300-mile driving range goal
- The high-pressure system improves volumetric density by about 1.5x while maintaining the same weight ratio
- Successful fueling trials have been conducted providing experience that is similar to the Focus Fuel Cell Vehicle fleet with 350 bar systems
- Achieved industry certification and Ford's internal validation

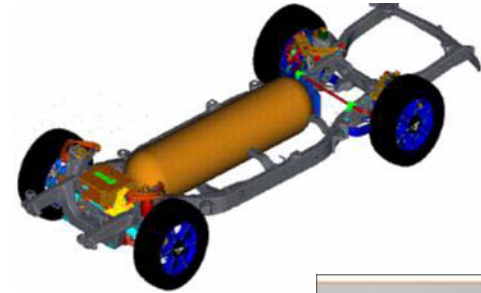
TDV 2 Accomplishments

Demonstration Objective	TDV 2
Next Generation Fuel Cell	
Over 300 Mile Range	X
700 bar Hydrogen Storage	
STACK Life (30,000 mile)	
Unassisted Cold Start < 0°C	
Fuel Efficiency (mpg) (*normalized to Focus)	X
FCS Peak Noise (dBA)	X

Accomplishments

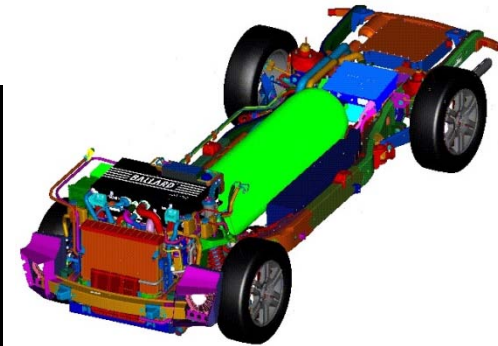
- Under hood packaged stack and system
- Full electric All Wheel Drive
- Improved vehicle current control
- Hydrogen Storage Architecture for extended range
- NVH treatment for silent operation
- 1556 miles distance record for 24 hr run on test track
- Demonstrated Technology in hundreds of drives for government and public officials
- Displayed at 2006 LA Auto Show
- TDV2 is still in operation in Iceland with in excess of 25,000 operating miles

“Designed Around Hydrogen”



TDV 3.2 and 4 Accomplishments

Demonstration Objective	TDV 3.2	TDV 4
Next Generation Fuel Cell	X	X
Over 300 Mile Range		X
700 bar Hydrogen Storage		X
STACK Life (30,000 mile)		
Unassisted Cold Start < 0°C	X	X
Fuel Efficiency (mpg) (*normalized to Focus)		X
FCS Peak Noise (dBA)		



Accomplishments

- Demonstrated unassisted freeze start capability (greater than 40 freeze starts conducted)
- Cold start time significantly reduced
- Improved Efficiency to nearly 40 miles/kg
- Fuel cell system Lifetime of 2000+ hours
- Improved power output: 90 kW peak
- 700 bar fuel storage of 9.5kg H₂ for a feasible range over 300 miles with no compromise vehicle package



TDV 7 Accomplishments

Demonstration Objective	TDV 7
Next Generation Fuel Cell	▲
Over 300Mile Range	▲
700 bar Hydrogen Storage	
STACK Life (30,000 mile)	▲
Unassisted Cold Start < 0°C	
Fuel Efficiency (mpg) (*normalized to Focus)	X
FCS Peak Noise (dBA)	X



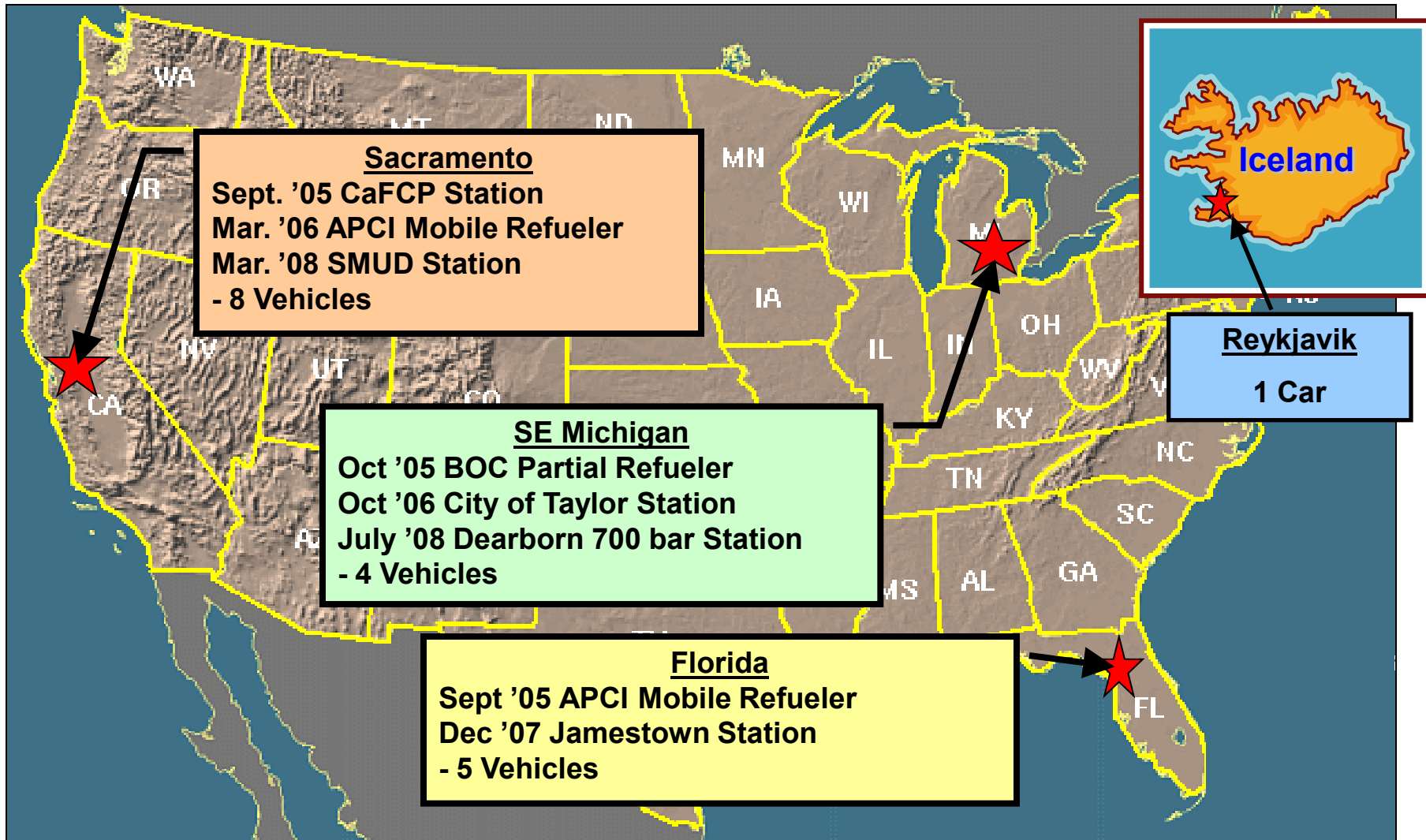
▲ TDV 7 utilized a specially designed, smaller fuel cell stack based on the Mk902 stack technology that was used to generate power at two fixed levels during operation. Using the plug-in feature daily, the average range can be extended.

Accomplishments

- NVH & Freeze Start improvements
- Reduction of FCS weight
- Modular FC APU design
- Less reliance on H2 Infrastructure
- Reduce System complexity
- Flexible Vehicle Design
- Increased Fuel Economy

- **5 passenger crossover**
- **Overnight Home Recharging**
- **25 mile range on Li-Ion Battery**
- **Uncompromised Interior Package**
- **Electric AWD Vehicle Controls**
- **Curb Mass: 2450 kg**
- **Fuel Cell: 35 kW Auxiliary Power Unit (APU)**
- **Powertrain: 130 kW Dual Electric Drives**
- **Regenerative Braking**
- **41 Mi/Kg H₂**
- **Range: 225 mi combined range (battery/APU)**
- **Fuel: 350 bar Compressed Hydrogen**
- **Emissions: Zero**

Infrastructure Demonstration



Infrastructure Accomplishments

Location	Dearborn, MI	Taylor, MI	Jamestown, FL	SMUD, CA
Technology	Liquid Delivered	Liquid Delivered	Electrolysis	Electrolysis
Service Pressure	13,200 psig	6,600 psig	6,600 psig	6,600 psig
Daily Capacity	60 kgs/day	96 kgs/day	24 kgs/day	24 kgs/day
Fill Types	Wireless RF Wired Comm Non-Comm	Wireless RF Wired Comm Non-Comm	Wireless RF Wired Comm Non-Comm	Wireless RF Wired Comm Non-Comm
Safety Training	100 emergency responders/fleet operators	40 emergency responders 25 fleet operators	90 emergency responders 60 fleet operators	200 emergency responders/fleet operators
Data Collection	Obtained fueling data from vehicles	Obtained fueling data from vehicles	On-site electronic data collection	On-site electronic data collection



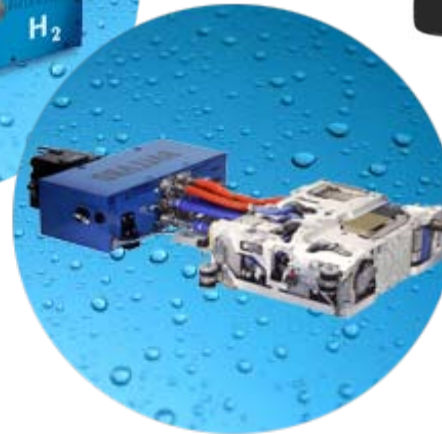
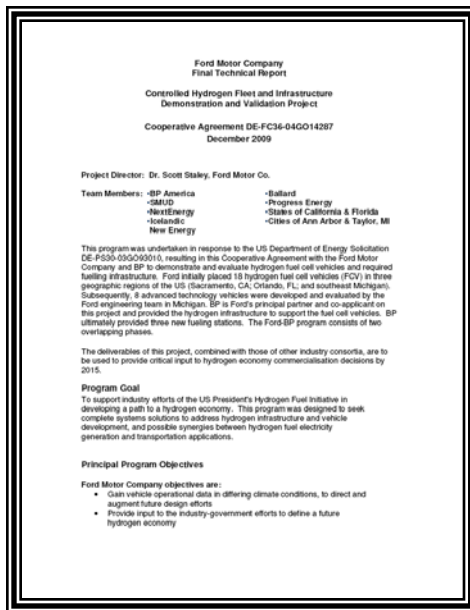
Collaborations and Coordination

Thanks to our Project Partners and Customers ...



Future Work

- Submitted final report
- Completed decommission and deployment of vehicles
- Continue internal research of hydrogen and fuel cell system technology to progress towards commercial viability



Summary

This project addressed the following technical barriers identified in the Technology Validation Program Plan:

- 1. Lack of Fuel Cell Vehicle Performance and Durability Data**
 - ✓ Submitted 270 gigabytes of operational data
 - ✓ Developed predictive analysis of fuel cell degradation with NREL
 - ✓ Exceeded lifetime expectancy of the fuel cell stack
- 2. Hydrogen Storage**
 - ✓ Demonstrated 350 bar with high reliability in the field
 - ✓ Developed advanced 700 bar storage system to optimize capacity
- 3. Lack of Hydrogen Refueling Infrastructure Performance Data**
 - ✓ Implemented multiple customer stations and trained over 500+ personal
- 4. Maintenance and Training Facilities**
 - ✓ Created new Technician Repair Order System for 3 external facilities
- 5. Codes and Standards**
 - ✓ Conducted 4 annual C&S conferences and no reported safety incidents

HYDROGEN
FUEL CELL

