




# Hydrogen Fuel Cell Vehicle & Infrastructure Demonstration Program Review

Ford Motor Company
Research & Advanced Engineering

May 17, 2007

# Overview

## Timeline

- Project start:
  Nov. 17, 2004
- Project end:
  Jun. 2009
- 50 % complete

## Barriers Addressed

- Vehicles
- Storage
- Hydrogen Refueling Infrastructure
- Maintenance and Training Facilities
- Codes & Standards

## Budget

- $88 mil project
  - DOE $44 mil
  - Ford $44 mil
- FY06: $7.2 mil
- FY07: $6.1 mil

## Partners

- BP America
- Ballard
- States of California & Florida
- City of Taylor, MI
- SMUD, Progress Energy & NextEnergy

# Vehicle Project Objectives

***To gain FCV operational data in differing climate conditions to direct and augment future design efforts***

***<u>Since Last Review</u>***

- **Continue Vehicle Operation**
- **Collect and report operational data**
- **Maintain fleet & survey customers**
- **Design & build four Phase II concept vehicle**

# Infrastructure Project Objectives


## Previous Project Objective

- Provide safe, reliable user friendly hydrogen infrastructure
- Install technology to meet cost targets
- Establish an initial infrastructure network to fuel small fleets across a metropolitan area

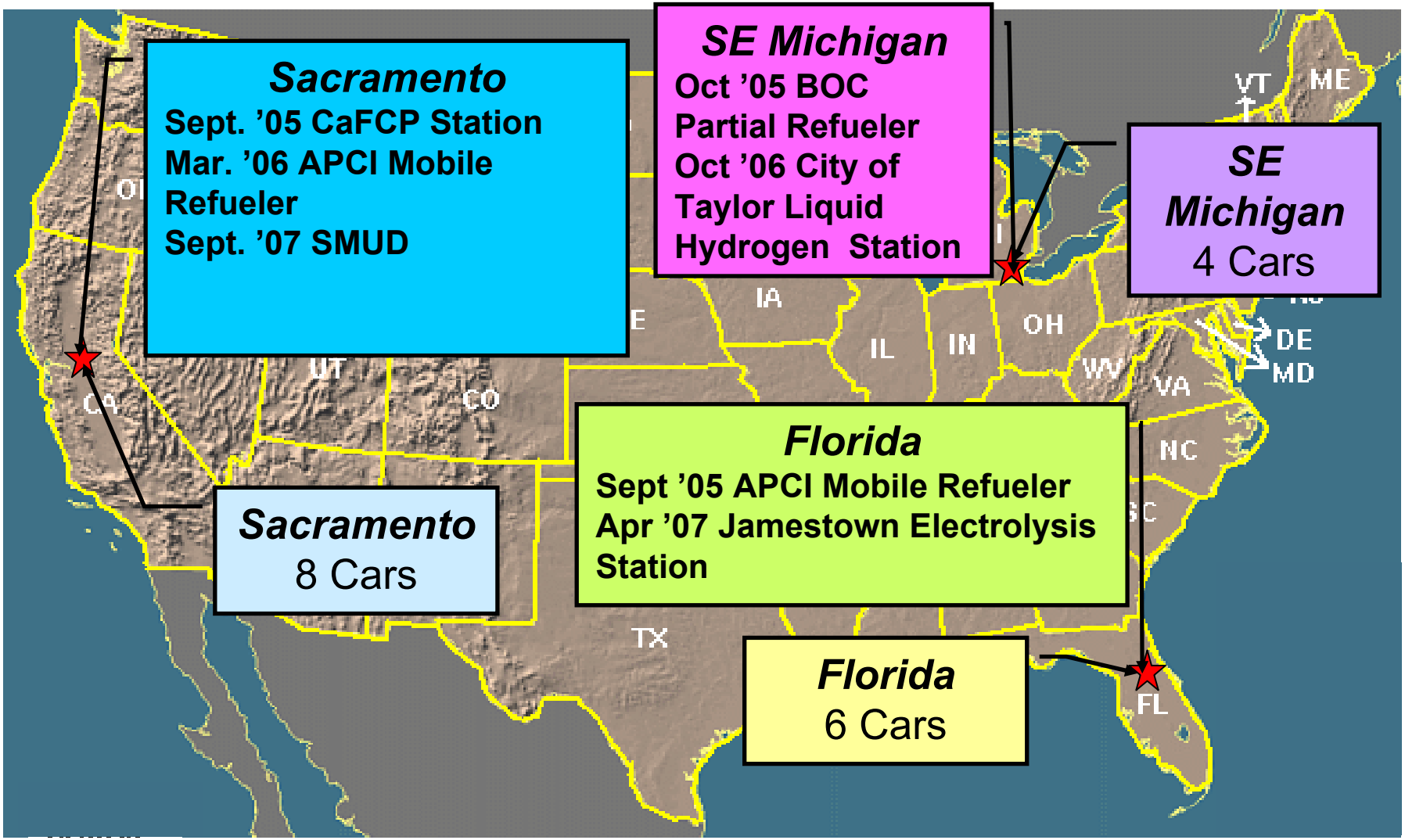
## Current Project Objectives

- Provide safe, reliable user friendly hydrogen infrastructure
- Install technology to meet cost targets
- Test a variety of hydrogen delivery options

# Vehicle Approach

- Two demonstration components
  - Phase 1: developed technology installed in contemporary (Focus) vehicles for real world use
  - Phase 2: controlled in-house demonstration of extended range, durability, hydrogen pressure and operating temperature
- Fleet vehicles in three differing geographic/climatic regions
- Automated data collection methodologies for effective data analysis

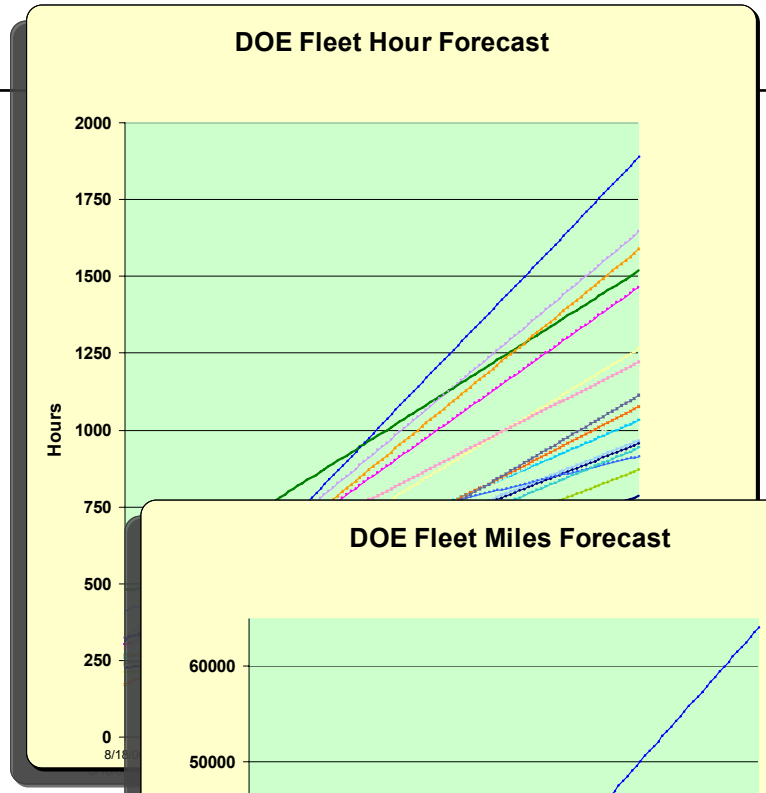
# 2007 Phase 1 Deployments

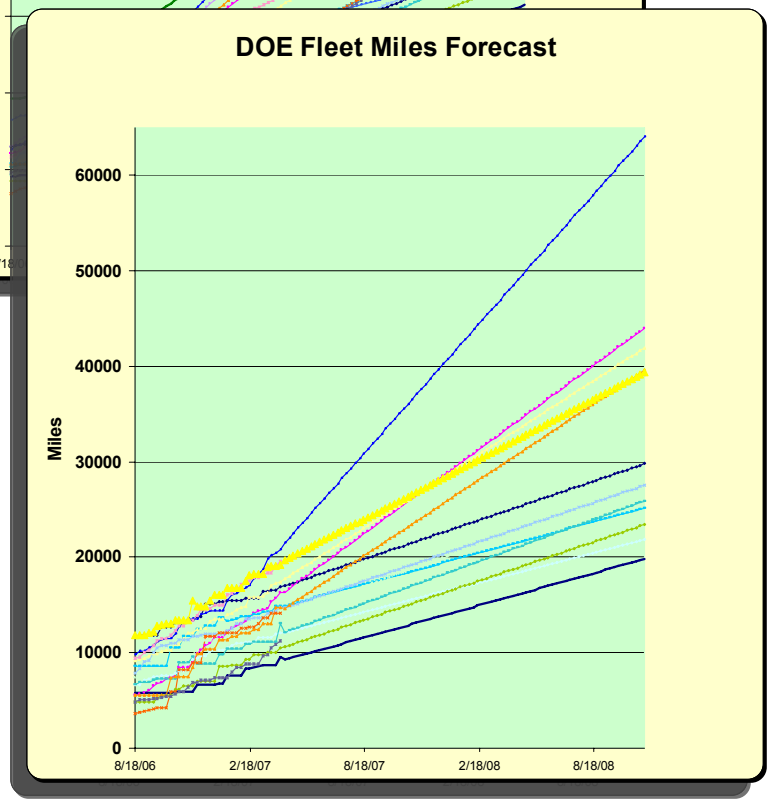


# Technical Accomplishments/ Progress/Results

## Phase I Fleet

- Accumulated 274,000 miles vs. 324,000 mile target to date
- Operated 9593 hours vs. 13590 hr target to date and 27000 hr end of program target
- Projected end of program vehicle miles/hours
  - 820 to 1525 Hour
  - 20000 to 64000 miles



# Phase II Ford Controlled Engineering Prototypes

| Vehicle Attributes | H2 Storage Upgrade | Robustness Demonstrator | Designed Around Hydrogen Demonstrator | Flexible Series H2 Hybrid |
|---|---|---|---|---|
| Fuel Cell Generation | Gen 1 | Gen 2 (Stage 1) | Gen 2 (Stage 2) | APU |
| Number of Vehicles | 1 | 1 | 5 | 2 |
| Timing | 2 Q '07 | 1Q '06 | 4Q '06 | 4Q '06 |
| Range (miles) | 240 | 200 | >300 | 300 |
| Hydrogen Storage (bar) | 700 | 350 | 350 | 350 |
| Unassisted Cold Start | 2 °C | 2 °C | < 0 °C | -15 °C |
| Assisted Cold Start | 2 °C | 2 °C | -15 °C | -25 °C |
| Fuel Efficiency (mpg) (*normalized to Focus) | 50 | 50 | 50 | 40-70 |

In bench Test

Complete

Operating

Operating

# Hydrogen Storage Upgrade


| | | | 700 bar Project |
|---|---|---|---|
| 1 | **Target Vehicle** | vehicle | Focus - TDV9 |
| 2 | **Approx. Cylinder Size** | mm | 573 x 972 |
| 3 | **Useable Storage Capacity** | Kg | 5 |
| 4 | **Driving Range** | miles | 250 @ 50 mpg |
| 5 | **Total System Weight** | Kg | 132 |
| 6 | **Cylinder Development Status** | *Status/Timing* | ***Certification Done*** |
| 7 | **Valve Development Status** | *Status/Timing* | ***Certification Done*** |
| 8 | **PRD Development Status** | *Status/Timing* | ***Certification Done*** |
| 9 | **Bonfire Test Status** | *Status/Timing* | ***Complete*** |
| 10 | **CR System Assembly Status** | *Status/Timing* | ***Complete*** |
| 11 | **CR System Testing Status** | *Status/Timing* | ***Underway*** |

# Robustness Demonstrator


- Demonstrated improved stack lifetime and reliability
- Completed 30,000 mile dynamometer endurance test
- No stack performance or durability issues
- Stack polarization data shows no appreciable signs of deterioration

# Robustness Demonstrator Accomplishments

- Developed an advanced humidity sensor
- Developed an advanced gas conditioner
- Characterized FCS interface (RH, DP, P, T)
- Improved Humidification of Anode
- Applied next gen H2 pump
- Completed a 30,000 mile durability test

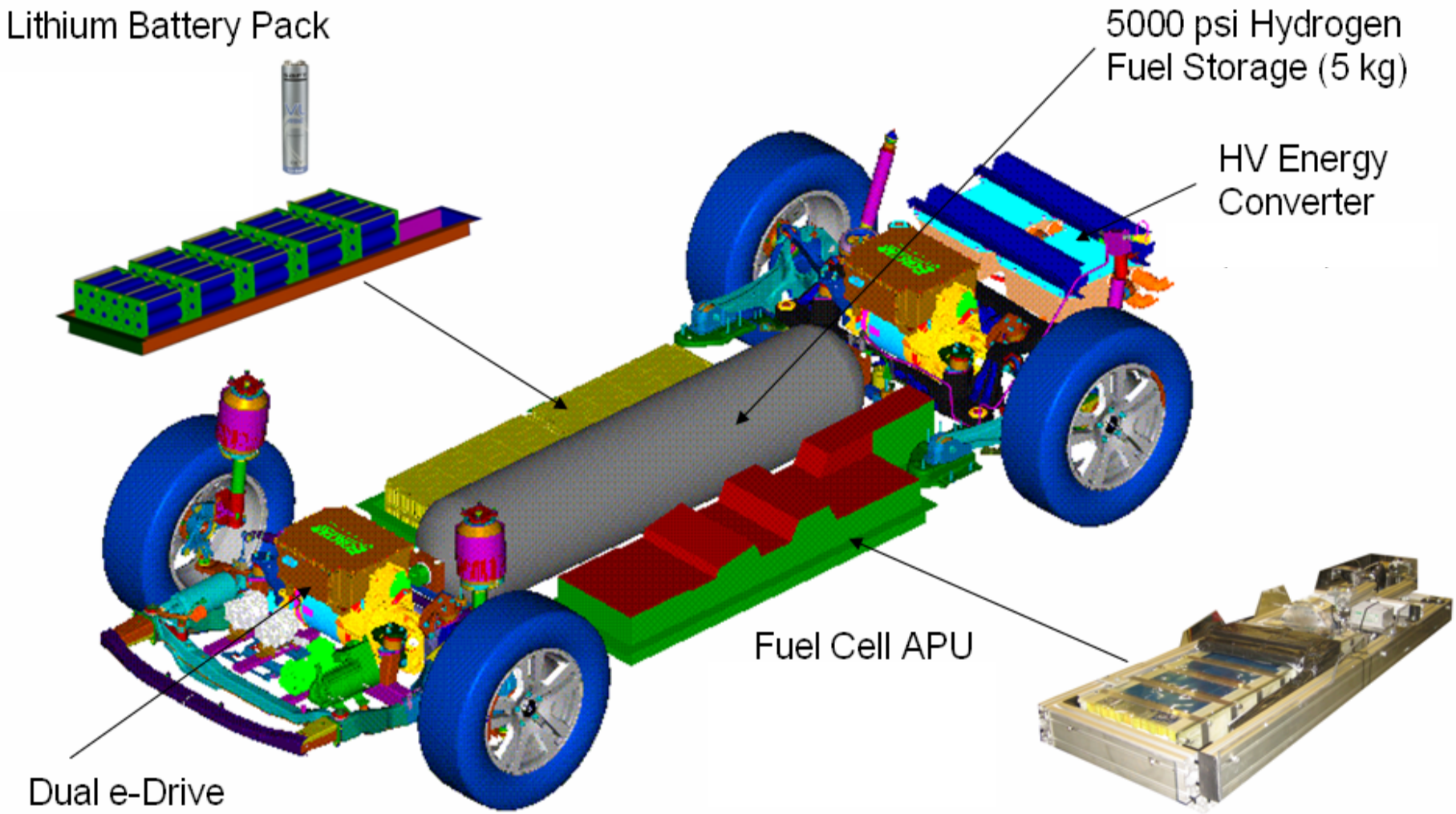
# Designed Around Hydrogen

# Designed Around Hydrogen Accomplishments

- Hydrogen Storage Architecture for 350 miles range
- Underhood Fuel Cell Stack
- NVH better than base ICE
- 17,000+ miles of real world road use in 2006
- 1556 miles distance record for 24 hr run at DDC
- Displayed at 2006 LA Auto Show

# Flexible Series Hybrid

# Flexible Series Hybrid Powertain



# Lessons Learned- Vehicles

- **Hydrogen Fuel storage packaging continues to be a significant challenge**
- **Vehicle architecture can be designed to accommodate consumer demands, but not without significant compromise & cost**
- **A 98%+ uptime is not sufficient to meet commercial targets/ standards**
- **Economic viability remains uncertain**


# Infrastructure Approach


THEN -2006

NOW-2007

- **Phase One**
  - **Install Mobile Refuelers**
  - **Install H2 Delivered Stations**
- **Phase Two**
  - **Install On-site H2 Production**
  - **Install 700 bar (if feasible)**
- **Station Locations**
  - Orlando, Florida
  - Sacramento, CA
  - Taylor, MI
  - Dearborn, MI (TBD)

# Station Timeline

| California | Open | Planned | Decommission |
|---|---|---|---|
| Sacramento Mobile Refueler | Oct 2005 | | Dec 2007 |
| SMUD | | Sep 2007 | Sept 2009 |
| **Florida** | | | |
| Jamestown Mobile Refueler | Sep 2005 | | July 2007 |
| Jamestown Stationary Site w/electrolyzer | Apr 2007 | | Sept 2009 |
| **Michigan** | | | |
| City of Taylor Temporary Station | Oct 2005 | | Jan 2007 |
| City of Taylor Stationary Site (Liquid delivery) | Oct 2006 | | Sept 2009 |
| Dearborn (700 bar) (liquid delivery) | | TBD | Sept 2009 |

# Technical Accomplishments

**City of Taylor Station**
**Dept. of Public Works**
**Opened Oct. 18, 2006**

| | |
|---|---|
| Technology | Liquid Delivered |
| Service Pressure | 6600 psig |
| Total Capacity | 2149 kgs |
| Fill Types | Wireless RF<br>Wired Comm<br>Non-Comm |
| Safety Training | 40 emergency responders/ 25 fleet operators |
| Data Collection | Obtaining fueling data from vehicles |

# Jamestown Station
# Oviedo, Florida
# Progress Energy Site
# Opened April 2007

# Technical Accomplishments

| | |
|---|---|
| Technology | Electrolysis |
| Service Pressure | 6600 psig |
| Total Capacity | 24 kgs/day |
| Fill Types | Wireless RF<br>Wired Comm<br>Non-Comm |
| Safety Training | 90 emergency responders/ 60 fleet operators |
| Data Collection | On-site electronic data collection |

**BP/SMUD/DOE**
**Renewable Energy Station**
**Sacramento, California**
**Planned Station Opening Sept 07**

# *Technical Accomplishments*


- Completed Site Design
- Completed Legal Agreements
- Completed 6 Community Outreach meetings
- Completed CEQA process
- Completed HAZID Review
- Initiated permitting process

# Safety Implementation

*Hydrogen for Transport is committed to no accidents, no harm to people, no damage to the environment*

- **Project Management**
  - ✓ **Managerial Gate Approvals**
  - ✓ **Management of Change**
  - ✓ **Pre-Construction Safety Induction for Contractors and Suppliers (Injury and Incident Free training)**
  - ✓ **Advanced Safety Audits**
  - ✓ **Integrity Management Standard**

- **Adherence to relevant safety codes for example:**
  - ✓ **NFPA 52**
  - ✓ **SAE J2600**
  - ✓ **SAE J2601(planned)**
  - ✓ **ASME B31.3**

# Safety Implementation

*Hydrogen for Transport is committed to no accidents, no harm to people, no damage to the environment*

- **Collaborative system safety assessments, reviews and plans**
  - ✓ **HAZID / QRA**
  - ✓ **HAZOP**
  - ✓ **pHSSEr approach**
  - ✓ **BP-Global Alliance safety training for contractor and supplier**
  - ✓ **Emergency Response Plan**
- **H2 Safety Training**
  - ✓ **Contractors**
  - ✓ **Fleet operators**
  - ✓ **Station operators**
  - ✓ **Emergency Responders**


# Lessons Learned

- **Station Loading/Vehicle Volumes**
  - Difficult to justify building several multi-million dollar stations to fuel four or less vehicles a couple of times per week (load too small).
  - Need substantial numbers of cars per station (DOE and industry should work together to guarantee substantial station loading)
- **Limited Supply Base**
  - Results in high cost of equipment (even though we are coming down the learning curve).
  - Small suppliers can add unnecessary complexity and significant cost to projects due to their financial challenges. Need a better way to vet privately owned small companies.
- **Permitting**
  - Footprint of distributed production stations may be too large for most urban area retail sites
  - Permitting hydrogen at retail stations is challenging for a variety of reasons including unrelated local issues with existing retail stations
- **Developing Codes & Standards**
  - New safety codes that emerged mid-stream of a project added cost and time delays (for example NFPA 52 flame and gas detection requirement)
  - New ASTM test methods must be developed to ensure hydrogen quality guidelines are met (for example, SAE J2719 sulphur and CO levels)

# Future Work: 2007 Work Plan

## Upcoming Events:

- Continue Phase I vehicle operation
- Operate Orlando and City of Taylor Stations
- Evaluate 700 Bar Vehicle Performance
- Begin third Phase II Designed Around Hydrogen Concept Vehicle
- Install SMUD Renewable Hydrogen Station
- 700 bar station to support Phase II- TBD

# Summary

- Vehicles:
  - Program remains on track, Phase I vehicles performing well
  - Phase II vehicles are proving viability of improved durability, greater range and commercially acceptable designs
- Infrastructure
  - In late 2006 began evaluation of liquid hydrogen station and early 2007 began operations of distributed electrolysis production station.
  - In 2007 will install and operate renewable hydrogen station.
  - In 2007 will complete assessment of feasibility of 700 bar fueling.

# Research and Advanced Engineering