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

Since Last Review

- **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

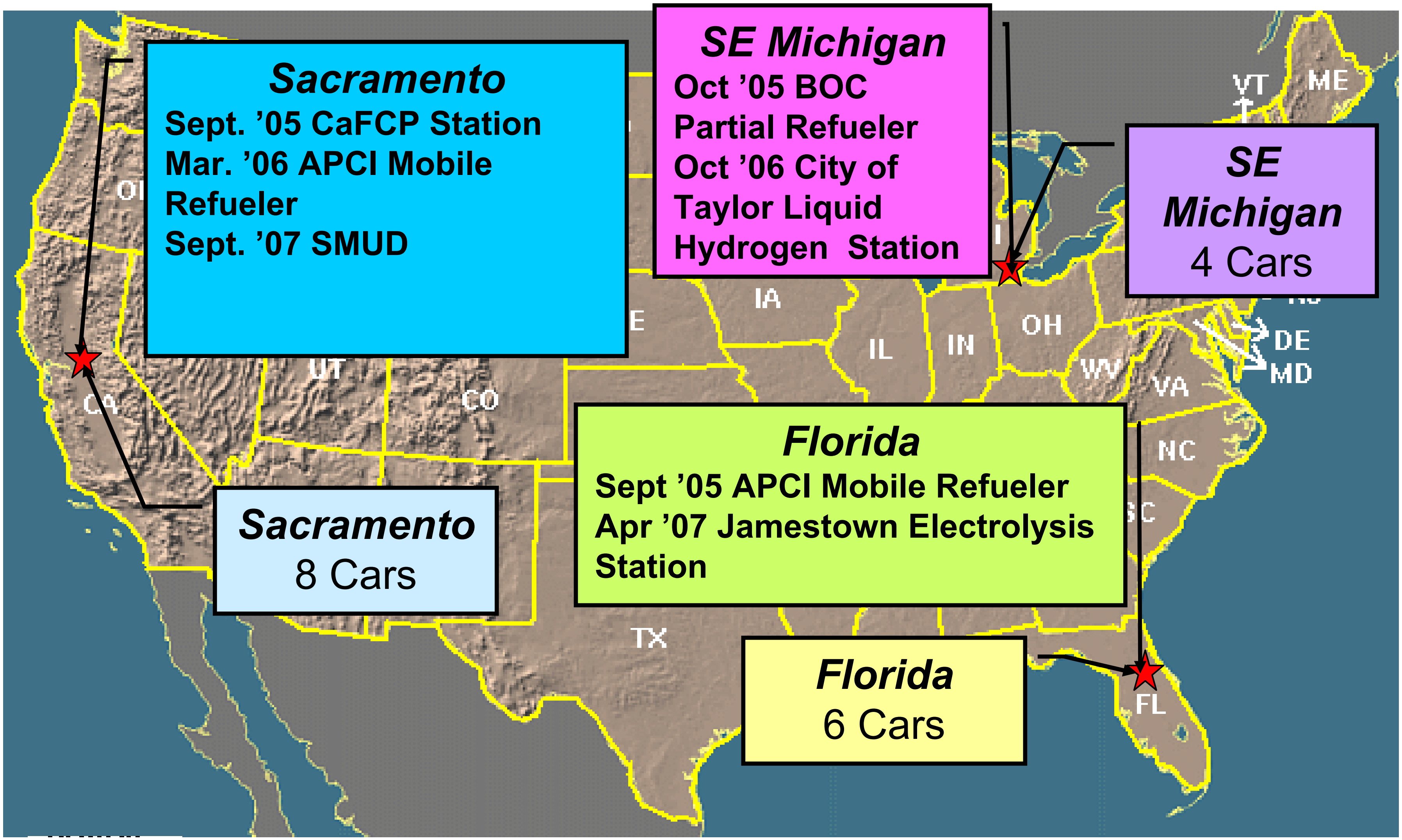
Current Project Objectives

- 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

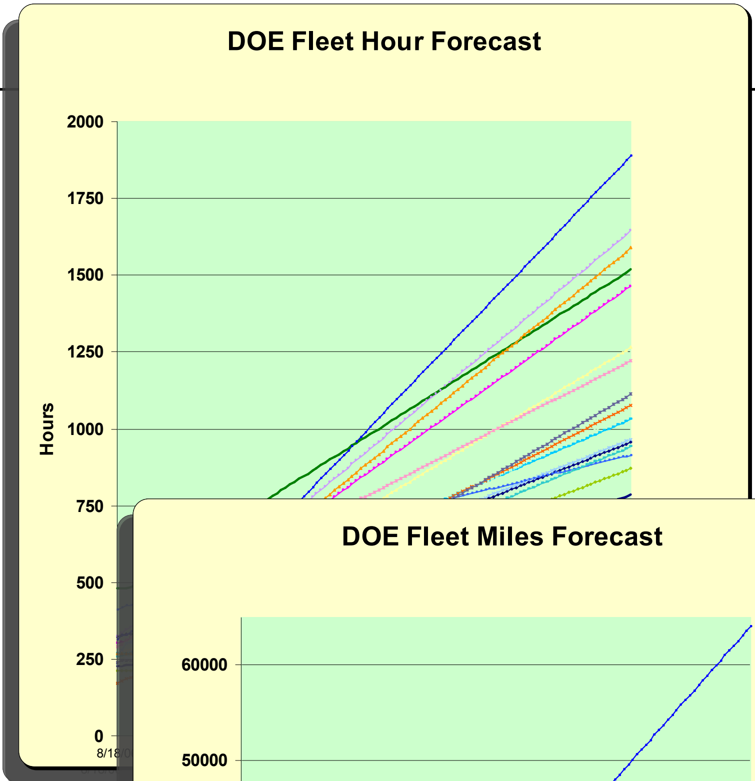
2007 Phase 1 Deployments

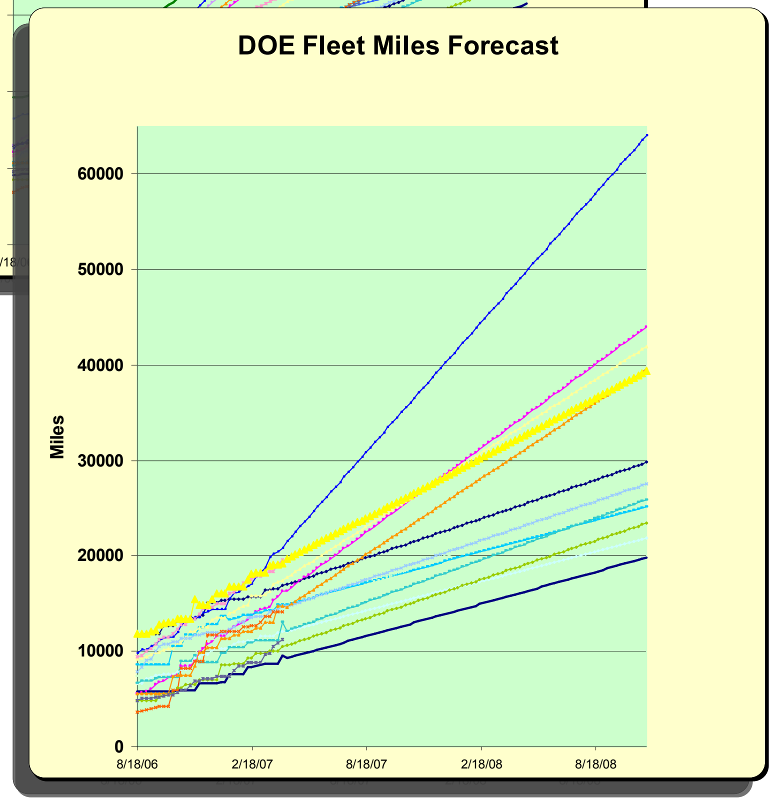


Technical Accomplishments/ Progress/Results

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***

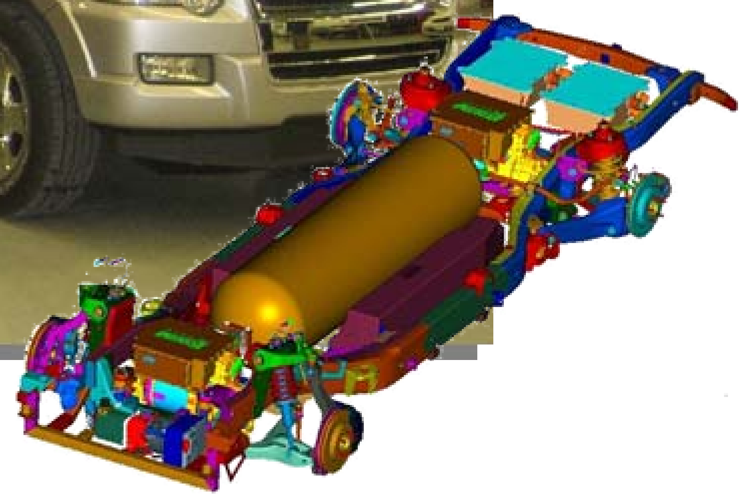
Robustness Demonstrator

- 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

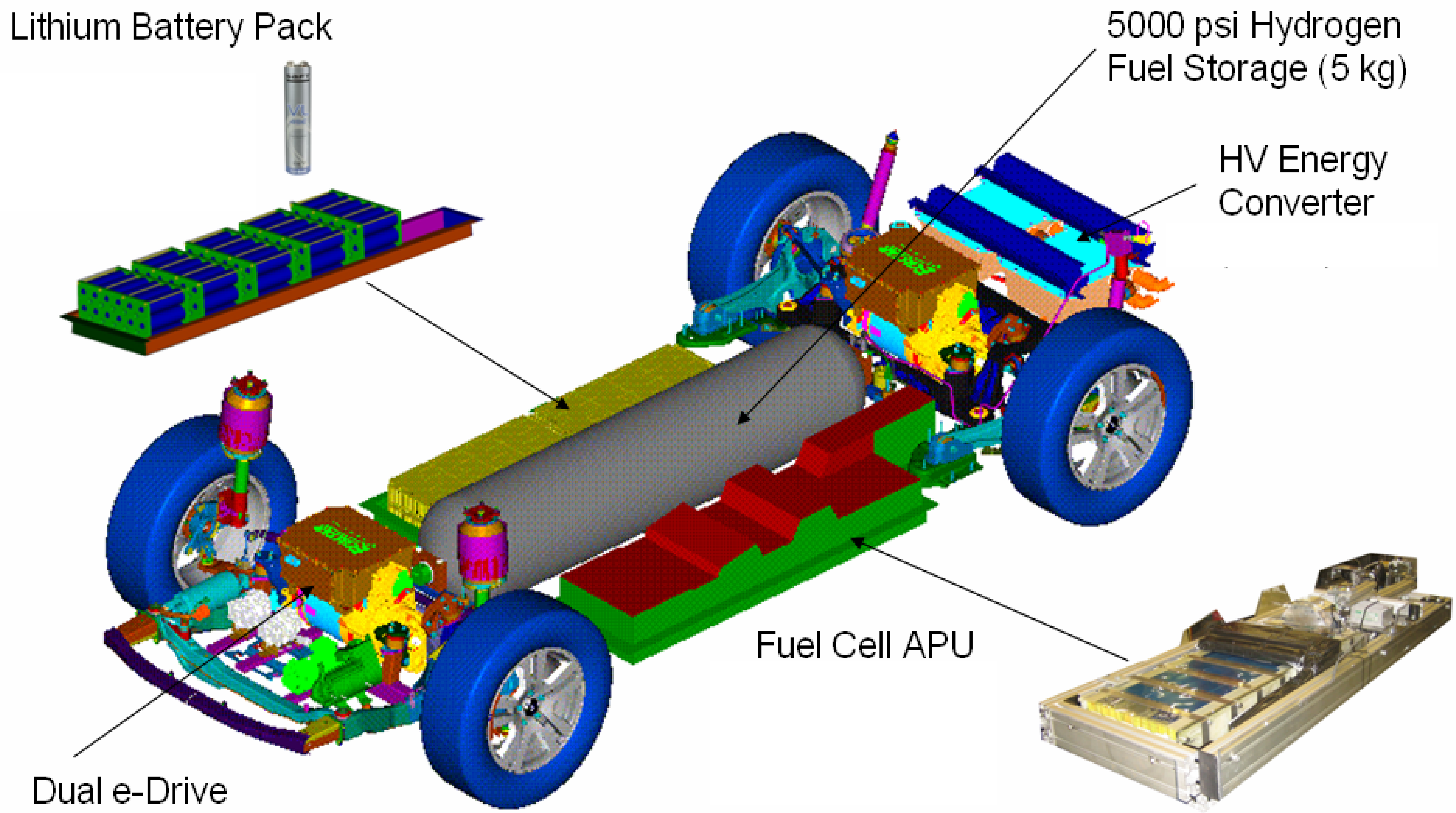


Designed Around Hydrogen Accomplishments

- 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

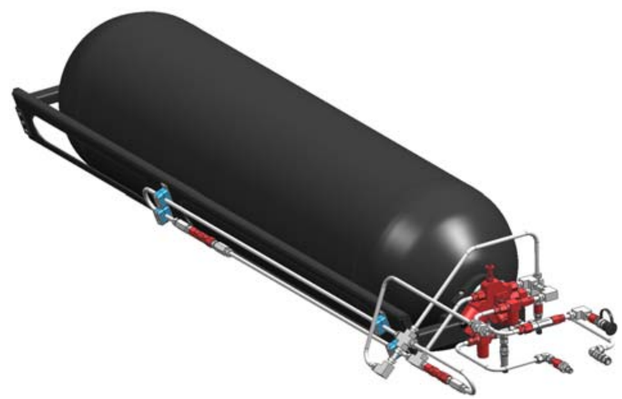
Flexible Series Hybrid

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

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

Technical Accomplishments

Technology	Liquid Delivered
Service Pressure	6600 psig
Total Capacity	2149 kgs
Fill Types	Wireless RF Wired Comm 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 Wired Comm 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.

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