"Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration"

Mr. Dan Hennessy
DELPHI
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Sponsor: U.S. DOE – Hydrogen, Fuel Cells and Infrastructure Technologies

DOE Technical Development Manager: Dimitrios Papageorgopoulos
DOE Project Manager: David Peterson, Ph.D.
Partners: PACCAR, TDA Research, Inc , & Electricore

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Project ID:
ARRAH2002

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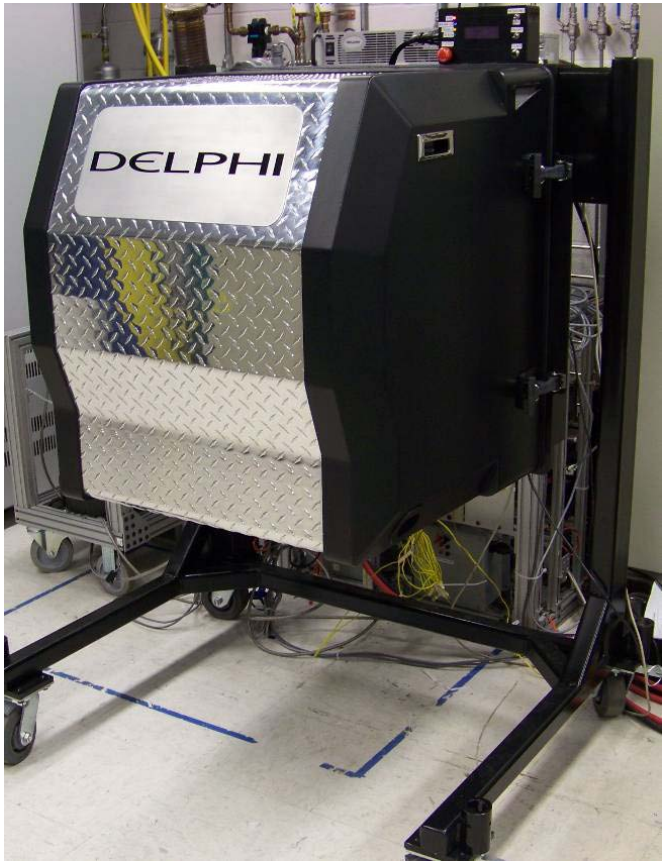
Agenda

- Overview
- Objectives
- Milestones
- Approach
- Technical Accomplishments and Progress
- Future Work
- Summary



Overview

Timeline

- August 2009
- January 2012
- 28% Complete

Budget

- Total project funding
  - DOE - $2,400,000
  - Delphi - $2,400,000
- $ 605,976 received in CY09
- $ 1,631,524 planned in CY10

Barriers

- Barriers to address:
  - System Vibration Robustness
  - Packaging / size (Form factor)
  - System Weight
  - System Cost
  - System Manufacturability
  - System durability / reliability

Partners

- PACCAR, TDA Research Inc., and Electricore Inc.

Relevance: Objectives

- DOE's support of Solid Oxide Fuel Cells Development will:
  - Provide immediate job creation / retention during the Development Phase
    - Jobs created / retained in New York State: 5
  - Spur / support Delphi's continued investment in the Fuel Cell Technology
  - Accelerate the commercialization and high volume manufacture of SOFC Technology
  - Augment the US's long term energy policy by enabling the development and commercialization of alternate fuel technologies (bio-fuels, etc.)

Relevance: Solid Oxide Fuel Cells Market Opportunities

- Solid Oxide Fuel Cells Provide:
  - Ultra-clean, near zero emissions
  - High-quality, reliable power
  - High fuel efficiency
  - Fuel flexibility
  - Low noise

Residential Power
Stationary CHP Power Units

Commercial Power
Stationary Power Units

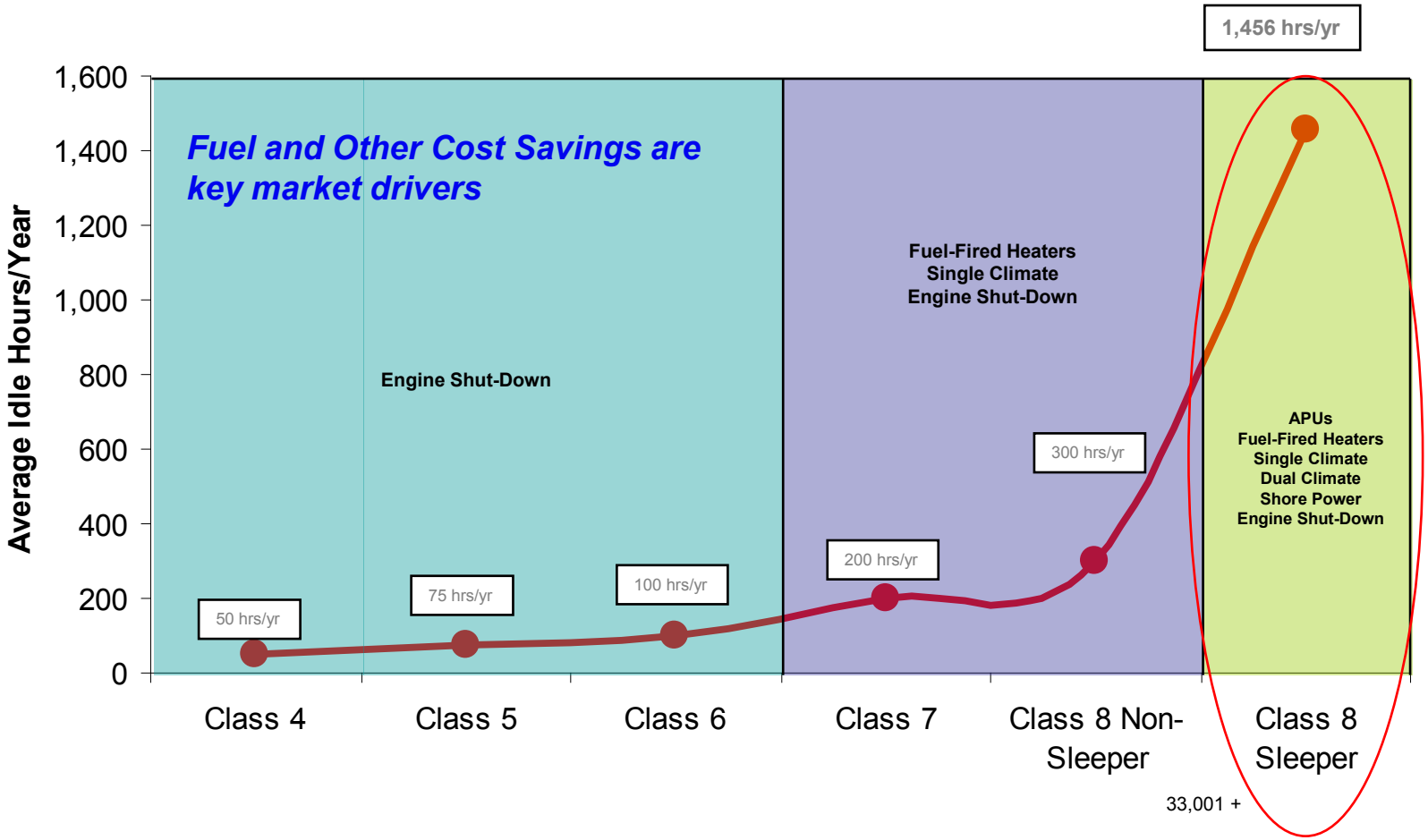
Heavy Duty Trucks
Auxiliary Power Units

Recreational Vehicles
Auxiliary Power Units

Military
Auxiliary & Mobile Power Units

Clean Coal Power Plant
Advanced Power Systems

Relevance - Heavy Duty Truck Market Idling Time



Relevance - Heavy Duty Truck Market Drivers

Increasing Cab Electrical Loads

Truck load profiles identify potential power requirements of 2.5kW and 4.0kW

In-Cab Appliances Include

- CB Radios
- Cell Phones
- Televisions
- Refrigerators
- Stereos
- Lamps
- DVD / VCR Player
- Computer
- Microwave
- Coffee Maker
- Electric Blankets
- Electric AC / Heater

Approach - Objectives

Complete a 30-month contract with the DOE EERE:

1. Define System Specifications and Commercial Requirements
   1. Define Subsystem requirements
   2. Develop subsystem requirements document
2. Design, Build and Test the Diesel APU system
   1. Verification testing of APU subsystems
   2. Form and packaging re-design
   3. APU System vibration analysis
3. One year vehicle demonstration and data analysis

Meeting these objectives will dramatically increase both the technical and commercial viability of fuel cell APU technology

Approach - Safety

Project Safety Plan:

- As an initial task, Delphi has reviewed, updated and provided DOE with a comprehensive “Safety Planning Guidance for Hydrogen Projects” document.
- As is the case for all Delphi’s test facilities, Delphi’s Metro Park test facility is required to meet Delphi’s stringent safety requirements which are in alignment with the Safety Planning Guidance documentation specified by DOE.

Approach – 2010 Milestones

Month/Year	Milestone and Go/No-Go Decisions (Immediate)	Complete
April 2010	**Milestone Review #1:** Requirements Document complete	**75%**
July 2010	**Milestone Review #2:** SOFC APU System Design Release Go / No Go	**20%**
October 2010	**Milestone #3:** System Integration APU Complete	**0%**
December 2010	**Milestone #4:** In-house Tests Complete Go / No Go .	**0%**

Approach

Phase 1:
OEM input Collection

- Delphi worked with PACCAR to establish the APU Application Specifications and specific Commercial requirements.
- Information was compiled into Delphi's "House of Quality" that then established the various Subsystem Requirements

Phase 2:
Design/Build/Test

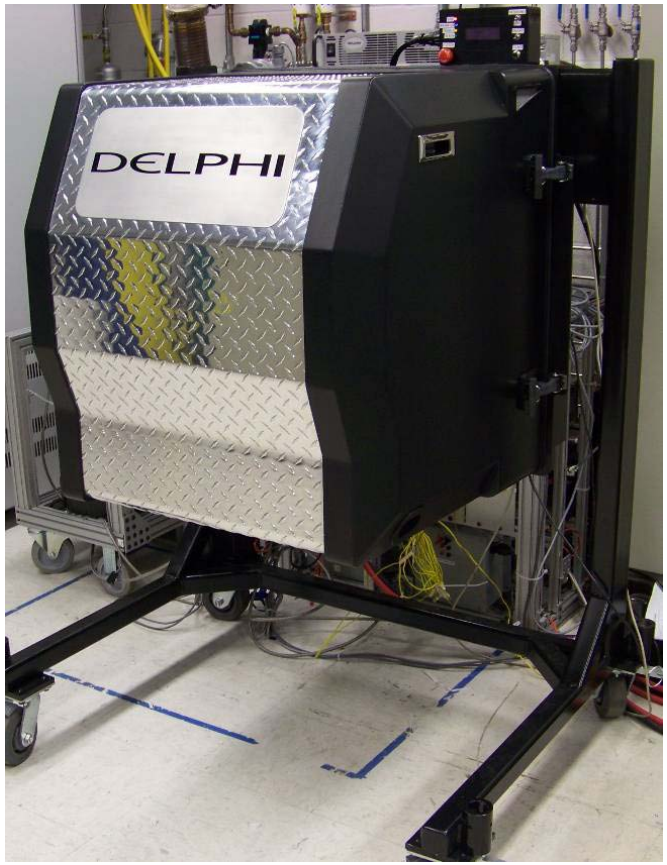
- 2010 Phase 2 effort is design and component verification period
- Late Phase 2 work will include system testing: both bench top and vehicle.
- Additional Desulfurizer development will be performed during this phase.

Phase 3:
Site Demonstration / Analysis

- During 2011, the APU System will be demonstrated on a Class 8 vehicle, as part of a controlled vehicle fleet.
- The data gathered during the demonstration will be analyzed and reported.

Technical Accomplishments and Progress

Major Design Efforts in Level B APU Development



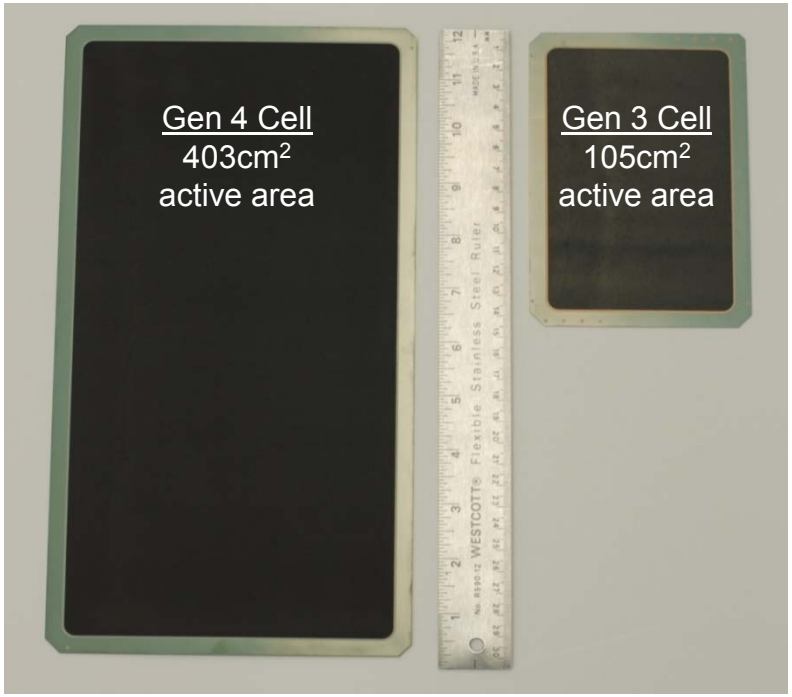
- Incorporated Next Generation Stack Design with increased active area
- Integrated Next Generation Endothermic Reformer
- Integrated Reformate Desulfurizer with Serviceability Enhancements
- Enhanced Heat Exchanger with recycle cooling
- Simplified Integrated Component Manifold
- Revised packaging based on customer feedback
- Demonstrated System Vibration Robustness
- Reduced System Weight
- Improved System Manufacturability
- Demonstrating System Durability / Reliability

Technical Accomplishments and Progress

SOFC APU Development – Stack / Cell

Integration of the larger cell/stack into the system will:

- Enable higher system power output
- Reduce air flow management complexity
- Reduce overall system costs



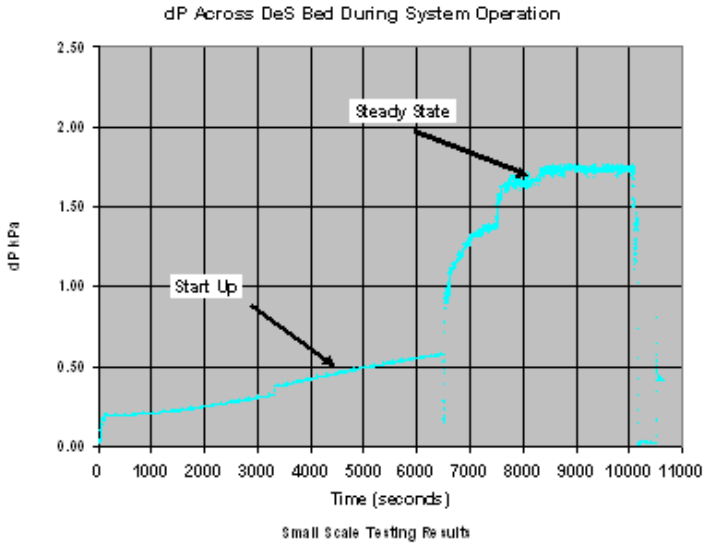
Technical Accomplishments and Progress

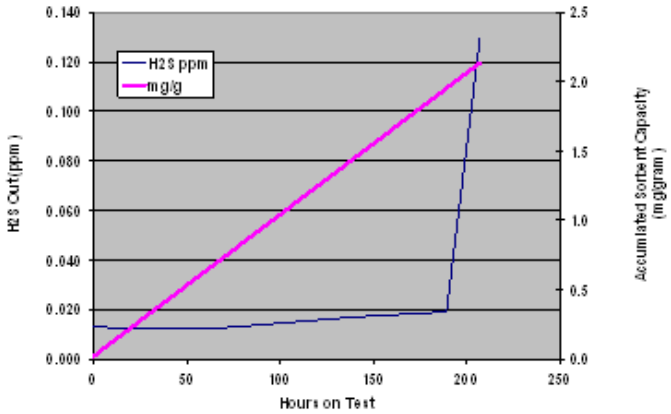
SOFC APU Development - Desulfurization Subsystem

- Delphi has modified the previous Desulfurization Subsystem to improve the pressure drop and interior flow pattern for better distribution.
- Design modifications are being made for increased manufacturability and reduced cost.
- High volume absorbent manufacturing processes are being developed.
- Specific enhancements for overall durability and robustness were incorporated in the revised design including internal outlet filtering.

Technical Accomplishments and Progress

- Sorbent Bed for H2S Removal from the Reformate
  - 4.6 liter Sorbent Bed
  - Removes H2S to below 10 ppbv
  - Functional life of 6 months at normal APU operating conditions
  - Sorbent cartridge is readily exchanged for fresh sorbent
  - Function has been demonstrated under steady state operating conditions on an APU system
    - » Pressure drop requirements are met
    - » H2S is removed to less then 0.010 ppm





Technical Accomplishments and Progress

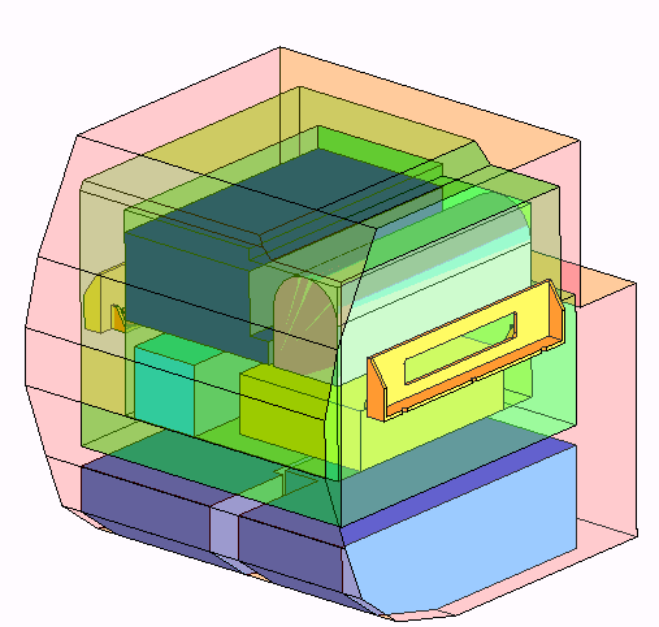
SOFC APU Development – Heat Exchanger w/ recycle cooling

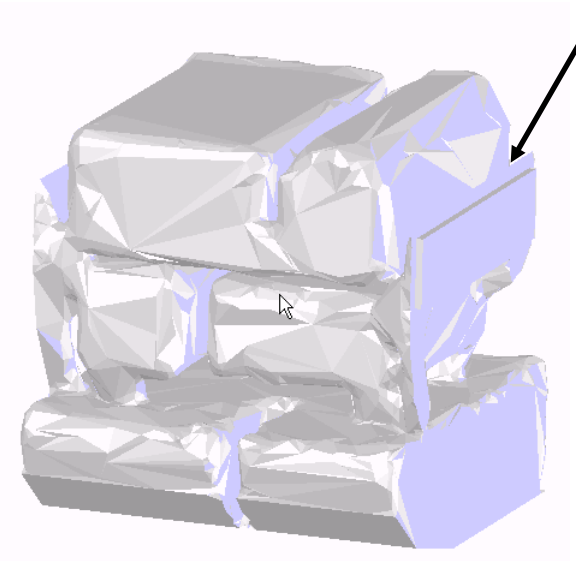
- The Heat Exchange subsystem has been enhanced to address functional and manufacturability concerns
- A more robust and cost effective design was developed based on a similar proven productive unit.

Technical Accomplishments and Progress

SOFC APU Development: Vibration Analysis of Chassis

•Optimization shows where connections to truck frame should be
• Indicates that APU should tie back to the fixed supports





Shows the bottom components tied all together,

It also shows area of support needed

Technical Accomplishments and Progress

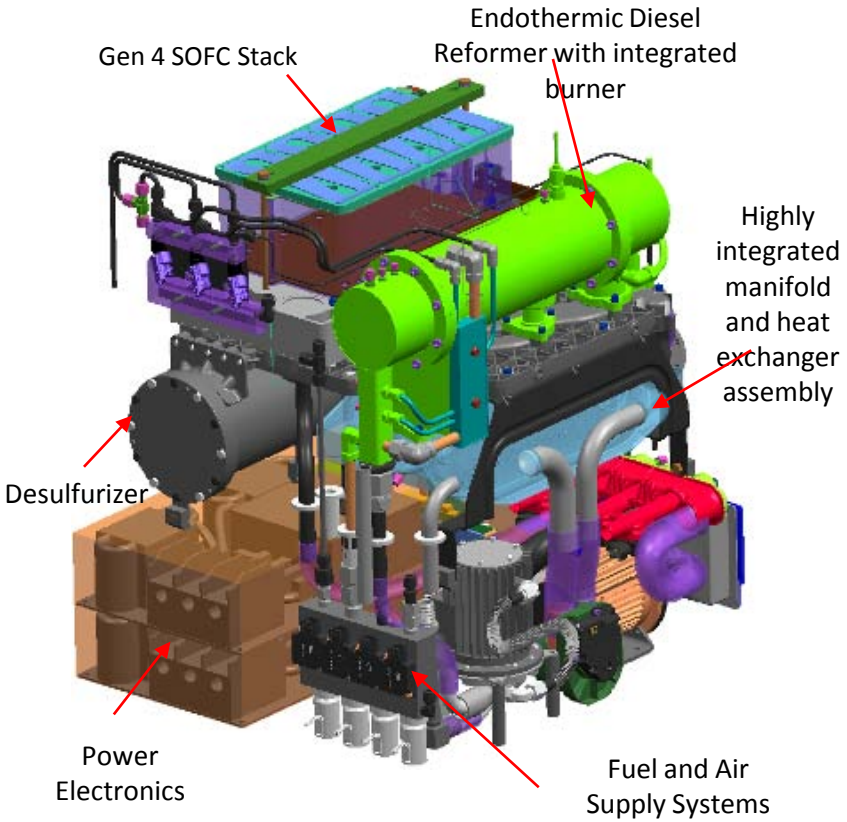
SOFC APU Vibration Schedule Development

- With assistance of PACCAR, Delphi developed a vehicle level vibration schedule specific to the Class 8 Truck application.
- System and subsystems will be tested prior to on vehicle testing.

Technical Accomplishments and Progress

SOFC APU Development – Hot Zone Packaging / Layout

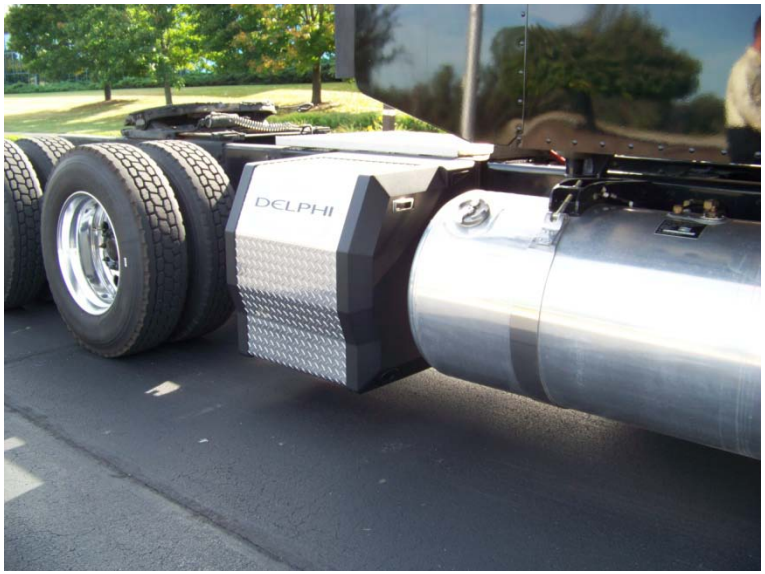
- A major effort has been undertaken to repackage the Hot Zone components / subsystems to incorporate specific commercial requirements (Width, length, height, mass)
- The Structural framing is being modified to meet a vibration threshold requirement.



Technical Accomplishments and Progress

SOFC APU Development – Vehicle Interface

- Vehicle mounting requirements being developed based on environmental and vehicle assembly requirements
- Initial mounting concept has been evaluated on vehicle



Collaborations

Delphi has teamed with OEM' PACCAR Incorporated to define system level requirements for a Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for the commercial trucking industry and TDA Research, Inc. for desulfurization guidance and material/production development. As well as Electricore Inc, to help with the overall program management.

PACCAR
KENWORTH Peterbilt
DAF Foden Trucks

PACCAR, Mt. Vernon, WA

TDA Research

Wheat Ridge, CO

ELECTRICORE
POWERING THE FUTURE

Electricore Inc, Valencia, CA

Future Work

2010

- Design system components based on the Customer commercial requirements
- Procure prototype parts
- Build both mule (subsystem) and demonstration units
- Test Demonstration Unit prior to availability for on Vehicle Demonstration

2011

- One year demonstration test Initiated

Summary

- **Primary Market Drivers**
  - Anti-Idling Legislation
  - Emissions Legislation
  - Increasing Heavy Duty Truck Cab Electrical Loads
  - Transportation Fuel Cost

- **Delphi is:**
  - **Near Completion of the Application Specifications and Commercial Requirements Documentation**
  - **Initiating System and subsystem modeling and designs**
  - **Meeting Timing and Budget forecast**
  - **Committed to Introducing SOFC Diesel Technology in Full Scale Production for Heavy Duty Truck Applications**