DoE SuperTruck Program
Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks

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Presenter: Scott Newhouse
Peterbilt Motors Company

Project ID: ARRAVT081
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Relevance - Program Objectives
(DoE Vehicle Technologies Goals)

**Objective 1**: Engine system demonstration of 50% or greater BTE in a test cell at an operating condition indicative of a vehicle traveling on a level road at 65 mph.

**Objective 2**

a: Tractor-trailer vehicle demonstration of **50% or greater freight efficiency improvement** (freight-ton-miles per gallon) over a defined drive cycle utilizing the engine developed in Objective 1.

b: Tractor-trailer vehicle demonstration of **68% freight efficiency improvement** (freight-ton-miles per gallon) over a defined 24 hour duty cycle (above drive cycle + extended idle) representative of real world, line haul applications.

**Objective 3**: Technology scoping and demonstration of a 55% BTE engine system. Engine tests, component technologies, and model/analysis will be developed to a sufficient level to validate 55% BTE.

Baseline Vehicle and Engine: 2009 Peterbilt 386 Tractor and Cummins 15L ISX Engine
Relevance - American Recovery and Reinvestment Act (ARRA) Goals

- Create and/or Retain Jobs

- Spur Economic Activity
  - Greater Than $40M Total Spend To Date

- Goals Align With VT Multi-year Program Plan 2011-2015
  - Advanced Combustion Engine R&D (ACE R&D):
    - 50% HD Engine Thermal Efficiency By 2015 (Ref: VT MYPP 2.3.1)
  - Vehicle And Systems Simulation And Testing (VSST):
    - Freight Efficiency Improvement of 50% by 2015 (Ref: VT MYPP 1.1)

- Invest In Long Term Economic Growth
  - Commercial Viability Assessment
  - Adopt Technologies into Product Plans to Meet GHG and CO2 Regs

Projections

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Time Equivalent</td>
<td>75.5</td>
<td>85</td>
<td>70</td>
<td>45</td>
</tr>
</tbody>
</table>

States: Indiana, Texas, Michigan, Wisconsin, Tennessee, Illinois, California
### Overview - Schedule and Budget

**Budget**
- DoE Share: $38.8M (49%)
- DOE Spend To-Date: $20.2M
- Contractor Share: $40.3M (51%)

**4 Year Program:** April 2010 to April 2014

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2011</td>
<td>2012</td>
<td>2013</td>
</tr>
<tr>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
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<tr>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
</tr>
</tbody>
</table>

#### Objective 1 – Engine Demo.
50% or Greater BTE Engine Demonstration

#### Objective 2a - Drive Cycle Vehicle Demo.
Vehicle Demonstration of 50% or Greater Freight Efficiency Improvement

#### Objective 2b – 24 hour Duty Cycle Vehicle Demon.
Vehicle Demonstration of 68.5% or Greater Freight Efficiency Improvement

#### Objective 3 – 55% BTE Engine
55% BTE Engine Demonstration

Program Close-Out
Peterbilt Participants

- Contract Lead - Cummins
- Suppliers
  - Modine – Cooling Module
  - Eaton – Transmissions
  - Bendix – Brakes and Suspension
  - Dana – Drivetrain
  - Bridgestone & Goodyear – Fuel Efficient Tires
  - Alcoa - Wheels
  - Delphi – Solid Oxide Fuel Cell APU
  - Bergstrom – eSHVAC
  - Garmin – 3D Map and Display
  - Exa – CFD Analysis
- OEM
  - Utility Trailer Manufacturing
- End User
  - US Xpress
Comprehensive Approach with Enabling Technology

- Idle Management (APU)
- Enhanced Tractor and Trailer Aerodynamics
- Transmission/Axle Technology
- Weight Reduction
- Highly Efficient Engine/Aftertreatment
- Route Performance Management
- Next Generation LRR Tires
- Driver Display with Fuel Economy Tools
## Approach – Freight Efficiency Path to Target Original Plan

<table>
<thead>
<tr>
<th>Technology</th>
<th>Drive Cycle Vehicle Demonstration</th>
<th>24 Hour Duty Cycle Vehicle Demonstration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freight Efficiency Improvement (%)</td>
<td>Freight Efficiency Improvement (%)</td>
</tr>
<tr>
<td>Vehicle Aerodynamics</td>
<td>14%</td>
<td>24%</td>
</tr>
<tr>
<td>Engine</td>
<td>25.5%</td>
<td>27%</td>
</tr>
<tr>
<td>Transmission/Axles</td>
<td>3.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Rolling Resistance</td>
<td>3.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Route Performance Management</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Idle Management</td>
<td>N/A</td>
<td>10%</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52%</strong></td>
<td><strong>73.5%</strong></td>
</tr>
<tr>
<td><strong>Target</strong></td>
<td><strong>50%</strong></td>
<td><strong>68.5%</strong></td>
</tr>
</tbody>
</table>
**Approach – Freight Efficiency Path to Target**

- **Demo #2 Goal**: 78%
- **Demo #1 Goal**: 60%

**Graph Details**
- **X-axis**: Various factors such as Aerodynamics, Engine, Transmission/axle, Tire Rolling Resistance, Route Management, Idle Management, Vehicle Weight, Demo #1 2012 AMR Status, Demo #2 2012 AMR Status.
- **Y-axis**: Freight Efficiency Improvement (%)
- **Legend**:
  - 24hr duty cycle
  - Drive Cycle

**Status**
- Demo #2 2012 AMR Status: 78%
Overview - Program Barriers

- Underhood Cooling with Waste Heat Recovery
- Vehicle and Engine System Weight Reduction
- Engine Downspeed (Reduced Engine Speed)
  - Powertrain Components
  - Vibration/Customer Acceptance
- Trailer Aerodynamic Devices that Meet Operational Requirements
- Vehicle and Powertrain Communication Speed

★ = To Be Validated on Demonstrator Truck
## DoE SuperTruck Program

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<th>2010</th>
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</tr>
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<tbody>
<tr>
<td>1Q</td>
<td>2Q</td>
<td>3Q</td>
<td>4Q</td>
</tr>
<tr>
<td><img src="image" alt="Funding Approval" /></td>
<td><img src="image" alt="Cummins Hardware Devo and Lab Testing" /></td>
<td><img src="image" alt="50% BTE Engine Demonstration" /></td>
<td><img src="image" alt="50% Freight Efficiency Demo" /></td>
</tr>
</tbody>
</table>

- **2010**
  - 1Q: Funding Approval
  - 2Q: Cummins Hardware Devo and Lab Testing
  - 3Q: 50% BTE Engine Demonstration
  - 4Q: 50% Freight Efficiency Demo

- **2011**
  - 1Q: Baseline Truck Model 386
  - 2Q: Integrated Tractor-Trailer CFD Analysis
  - 3Q: Set Duty Cycle and Baseline Testing
  - 4Q: Truck #1 Definition and Design

- **2012**
  - 1Q: Truck #1 Model 587 Mule
  - 2Q: WHR System Calibration
  - 3Q: Demo 1 Build Model 587
  - 4Q: Truck 1.5

- **2013**
  - 1Q: Demo 2 Build NGP
  - 2Q: 50% Freight Efficiency Demo
  - 3Q: 68% Freight Efficiency Demo
  - 4Q: USX Driver Feedback
587 Engineering Mule –
Technical Progress

• Successful Packaging of Technologies
• No Increase in Frame Length
Truck/Trailer Weight – Technical Progress

Baseline

Pounds

-3000
-2000
-1000
0
1000
2000
3000

WHR/2010 Emissions
Aero Devices
Idle Systems
Truck Savings
Trailer Savings
Net Weight Difference
**Truck/Trailer Weight – Technical Progress**

- WHR/2010 Emissions
- Aero Devices
- Idle Systems
- Truck Savings
- Trailer Savings
- Net Weight Difference

Actual Part Weights

“Production” Part Weights

Baseline

- 3.5% FTMPG
- 6.5% FTMPG
Trailer Development – Technical Progress

- Trailer Build Complete
- Preliminary Aerodynamic Road Test Complete
- End Customer Input In Process
Aerodynamic Improvements – Technical Progress

Progress Since Last Review
- 7% Increase on Demo 1
- 3% Increase on Demo 2

Cd's Shown Are Adjusted to SAE J1252 Baseline Using
% Average Deltas From 0 and 6 Degree CFD Runs
Aerodynamics - Approach

SuperTruck/SuperTrailer
46% Improvement As Shown
49% With Camera Cab Mirrors

Equivalent Aerodynamics

Advanced Concept With SuperTrailer
With Camera Cab Mirrors
49.6% Improvement
Milestones and Technical Accomplishments

• March 2011 to March 2012 – **Technical Accomplishments**
  – Path to Target Analysis for Engine and Vehicle Efficiencies
  – Aerodynamic Components Fabricated and Initial Testing
  – Initial Vehicle Tests of Cummins Waste Heat Recovery
  – Initial Testing of Advanced Transmission
  – Performance Assessment of SOFC APU

• March 2012 to March 2013 – **Future Work**
  – Engine Calibration and Optimization Work
  – Vehicle Testing of Advanced Transmission
  – Testing of Tractor – Trailer Aerodynamics Solution
  – Build and Test Vehicle Demonstration 1 (Objective 2a)
  – Design Freeze Vehicle Demonstration 2 (Objective 2b)
  – Initial Calibration of Second Generation of SOFC APU
Summary

• Program Remains On Schedule
  – Meeting the ARRA and DoE VT MYPP goals
• Roadmaps Updated for Freight Efficiency and 50% Engine Efficiency
• Vehicle Packaging and Integration Proceeding Without Major Issues
• Build and Test of Sub-Systems Are On The Planned Cummins Waste Heat Recovery Vehicle Test (Objective 2a)
• Advanced Transmission Dynamometer and Vehicle Test (Objective 2a)
• Solid Oxide Fuel Cell 2nd Design Iteration Lab Tests (Objective 2b)