2022 Annual Merit Review
Cummins/Peterbilt SuperTruck II

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Project ID:ACE102

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Overview

Timeline
- Begin: 10/1/2016
- End: 9/30/2022
- 92% complete

Barriers
- Engine Efficiency ≥ 55% BTE
- Freight Efficiency ≥ 100% FTE
- Cost effective solutions

Budget
- Total Project: $40M
- $20M DoE + $20M Partners
- Total Spent: $39M
  - $19.5 = Partners
  - $19.5 = DoE

Partners
- Cummins – Powertrain
- Eaton - Transmission
- Peterbilt - Vehicle
- Bridgestone – Tires
- Walmart – Customer counsel
Demonstrate a minimum of 55% BTE at a 65 mph cruise, on an engine dynamometer test stand
  ▪ Same engine systems also demonstrated in vehicle, operating on real world drive cycles

Achieve a minimum of 125% Freight Ton Efficiency (FTE).
  ▪ FTE = MPG*Tons of Freight

Track, promote and report on cost effective solutions
  ▪ Prioritize solutions that have ~3-year payback period
  ▪ Utilize customer counsel for understanding payback variables
Relevance: Energy Consumption

- Approximately 20% of U.S. transportation petroleum goes to the production of heavy truck fuel. Proposed improvements would save more than 400 million barrels of oil per year.*
  - Reduce imports and improve energy security
  - Reduce the cost of moving goods
- Heavy Truck GHG emissions account for a CO2 equivalent 420.7 MMT per year (35th edition of the Transportation Energy Data Book).
  - Improve air quality
  - Protect the public health and environment

## Milestones by Quarter

<table>
<thead>
<tr>
<th>FY 2021</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Freight Efficiency Demonstration Engine Build</td>
<td>Ready the engine for final calibration</td>
</tr>
<tr>
<td>Begin Freight Efficiency Demo Chassis Build</td>
<td>Begin assembly and population of the frame system</td>
</tr>
<tr>
<td>Complete Freight Efficiency Demo Engine Calibration</td>
<td>Prepare the engine, WHR system, and 48V mile hybrid system for the demonstration vehicle</td>
</tr>
<tr>
<td>Complete engine installation into FTE Demo chassis</td>
<td>Installation of the engine into the freight efficiency demonstration vehicle</td>
</tr>
</tbody>
</table>
## Milestones by Quarter

<table>
<thead>
<tr>
<th>FY 2022</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Freight Efficiency Demo Truck Build</td>
<td>![Green Check] Truck built and ready for calibration</td>
</tr>
<tr>
<td>Complete on road calibration</td>
<td>![Green Check] Adjustments to powertrain and active aero for demo vehicle</td>
</tr>
<tr>
<td>Completion final freight efficiency demonstration</td>
<td>Demo route and performance tests</td>
</tr>
<tr>
<td>Complete final report</td>
<td>Full system final report</td>
</tr>
</tbody>
</table>
Program Level Milestones

All proposed future work is subject to change based on funding levels

- **50% BTE** Base engine
- Final Cd confirmed
- Mild hybrid demo in Mule vehicle
- **55% BTE** demo on dyno
- Demo vehicle & trailer mated
- Complete vehicle testing

2018 2019 2020 2021 2022
Technical Approach

- Reduce Work/Mile on test route
  - Vehicle aerodynamics & tire improvements
  - Reduce losses in engine and accessories
    - Enable engine-off-coasting (EOC) to reduce motoring losses
    - Electrify accessories for EOC
  - Enable 48V hybridization to minimize brake losses
- Enable high Engine + WHR efficiency
  - Maximize efficiency on test route
  - Advanced Cycle Efficiency Manager (ACEM) to favor high load engine operation
- Maximize freight capacity via weight reduced powertrain/truck/trailer
Accomplishment- Demo Powertrain

- Demo Powertrain delivered and installed in Demo chassis
- Successful Integration of the following sub-systems:
  - 48V mild hybrid with Electrification Thermal Management, M/G, Power Electronics, and DC/DC
  - Transmission integral WHR turbine expander and gearbox
  - Cooling module integration of WHR Condenser with 48V fans and topping radiator
  - Advanced Cycle Efficiency Manager
  - 6x4 Disconnect axle system
- Key activities for success:
  - Mule development
  - Electrical buck used for controls integration
  - Powertrain installation and startup prior to cab set
  - Final integration with cab and startup
Program Schedule

2021

1Q 2Q 3Q 4Q

- Complete BIW
- Build/Populate Chassis
- Build Interior Parts
- Exterior Parts Development
- Peterbilt Work Continue

2022

1Q 2Q 3Q 4Q

- Troubleshoot, Calibration
- ePower Steering, Chassis Height Control Validation
- Road Release
- Test Prep, Test
- Demonstrate > 125% FTE
- Trailer
- Hood Set
- Chassis Fairings
Technical Approach: Path to Target

- Aerodynamics
- Transmission/Axle
- Downspeeding
- Lightweighting
- Route Management
- Rolling Resistance
- Engine
- Mild Hybrid/Solar
Technical Approach: Path to Target

• 55% Engine Efficiency
  – Dyno Demonstration Complete ✓!

• Goals vs. 2009 Baseline
  – Goal: 56% Aerodynamic Drag Reduction
    – 63% Achieved +
  – Goal: 3800lb Weight Reduction
    – 4700lb Achieved ✓+
  – Goal: 30% Reduced Rolling Resistance
    – 33% Achieved ✓+
Technical Approach: Applied Technologies

- Active Extenders
- Aerodynamic Body
- Forward-Looking Yaw Sensor
- 6x4/6x2 Disconnect Tandems
- Cameras/Displays
- MMC Brake Drums
- Lightweight Chassis
- Chassis Height Control
- 48v ePower Steer
- Low Crr Tires
- Advanced Cycle Efficiency Manager
- 24.5” Aluminum Wheels
- Mild Hybrid Driveline
- 48v eHVAC
- High Efficiency Engine/Transmission
Technical Progress: Chassis and Powertrain Systems

48v ePower Steer
- Reduced Engine Parasitics
- Control During Engine-Off Coast
  - Functional Prototype In Operation
  - Final Software Available End of May ’22

Chassis Fairings
- Improved Aerodynamic Closeouts
- Lightweight Construction
  - Completed March ‘22
  - Final Installation Expected April ‘22
Technical Accomplishments: Chassis Systems

Cooling Module and 48v Fans

- Waste Heat Condenser
- Radiator and HVAC Condenser
  - Installed and Operational March ‘22
Technical Accomplishment: Lightweight/Aerodynamic Trailer

Trailer

- Solar Panels Integrated
- Light Weight Construction
  - 1500lb Weight Reduction
  - 500lb Overweight
- Aerodynamics
  - Modified Commercial Tail
  - Previous: Trailer Sail Plates
    - Maturity Not Yet Ready
- Delivered Feb ‘22
Technical Progress: Active Aerodynamics

• Dynamic Sleeper Extender
  – Pneumatically Controlled Surface
  – Input from Roof-Mounted Yaw Sensor
  – High Yaw Drag Mitigation (Trailer Gap)
    – Installed and Validated March ‘22
Technical Accomplishments: Cab

• Cab Body in White 🔄 MAGNA
  – Facilitates Aerodynamic Layout
  – Lightweight Design
  – Cab set Dec ‘21

• Vehicle Completed Technologies
  – Interior Trim 🔄 POINT INNOVATION
  – Driver Seat
  – Wiper System 🔄 Valeo
  – Roof and Outer Body Panels 🔄 RMC
  – Windshield and Side Glass 🔄 PILKINGTON
  – 48V HVAC 🔄 Bergstrom

Camera System

Cab Interior
2022 Vehicle Schedule Summary

3Q-4Q21
- Cab Trim

4Q21-1Q22
- Cab Set/Troubleshoot

1Q-2Q22
- Complete Outer Body Demonstration Testing
Collaboration: Walmart Application

Data Collection
- Road Grade
- Max Elevation
- Major vs. Local Roads
- Duty Cycle
  - Long & Short Term
  - % Time at Speed, Load
- Aftertreatment
  - Regeneration
  - Maximum Soot
  - DPF Out Temp/Parameters

NREL Data Collection and Analysis (2017)

<table>
<thead>
<tr>
<th>Location</th>
<th>Trucks</th>
<th>OEM</th>
<th>Engine</th>
<th>Total Mileage</th>
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</thead>
<tbody>
<tr>
<td>Loveland, CO</td>
<td>8</td>
<td>Peterbilt 579</td>
<td>Cummins ISX15</td>
<td>40,895</td>
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<tr>
<td>Sanger, TX</td>
<td>24</td>
<td>Peterbilt 579</td>
<td>Cummins ISX15</td>
<td>131,605</td>
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<tr>
<td>Grove City, CO</td>
<td>17</td>
<td>Brand X</td>
<td>Brand Y</td>
<td>101,238</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Brand X</td>
<td>Cummins ISX15</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td></td>
<td></td>
<td>273,738</td>
</tr>
</tbody>
</table>
Program Summary

- **Powertrain**
  - Powertrain development in mule vehicle completed and system installed in Demo
  - Cummins has achieved the *engine 55% BTE objective*

- **Vehicle**
  - Aerodynamic System, Weight Reduction, Tire CRR Ahead of Target
  - Demonstration Tractor and Trailer Initial Build Completed
  - Final Troubleshooting and Calibration to be Completed in Q2 2022
  - Final Demonstration Testing will begin in July 2022

- Cummins and Peterbilt will exceed the *125% Freight Efficiency objective*
Proposed Future Research

- Demonstrate >125% FTE improvement
  - Freight Efficiency Demonstrator is built
  - Complete on-road testing and confirm Freight Efficiency objective in Q3

- Testing planned beyond
  - Use local Texas Route developed by NREL from Walmart duty cycle data to demonstrate technology applicability
  - Test SuperTruck II Demo performance vs. current production baseline vehicle

- Complete Final Report

- The project will complete this fiscal year, with no follow-on funding/work expected

All proposed future work is subject to change based on funding levels
THANK YOU!

QUESTIONS