Super Truck – 50% Improvement In Class 8 Freight Efficiency

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DTNA and DDC Super Truck Team
Super Truck Cross Functional Work Stream

- Engine Downsizing & Hybrid
- Waste Heat Recovery
- Aerodynamics
- Powertrain Integration
- Energy Management
- Parasitic Losses
- Weight Reduction

50% Increase in Freight Efficiency

Predictive Technologies
Super Truck Program Objectives

2 50% improvement in freight efficiency
2 Measured in ton-miles/gallon
2 Baseline: 2009 Cascadia with DD15 engine
2 Engine goal: 50% brake thermal efficiency
2 Base engine – 47%
2 Parasitics – 48%
2 Waste heat recovery – 50%

**Thermal Efficiency vs BSFC**

- 50% eff = 0.167 kg/kWhr
- 55% eff = 0.152 kg/kWhr

**Engine Thermal Efficiency (%)**

<table>
<thead>
<tr>
<th>BSFC (kg/kWh)</th>
<th>0.230</th>
<th>0.220</th>
<th>0.210</th>
<th>0.200</th>
<th>0.190</th>
<th>0.180</th>
<th>0.170</th>
<th>0.160</th>
<th>0.150</th>
<th>0.140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Thermal Efficiency (%)</td>
<td>35.0</td>
<td>40.0</td>
<td>45.0</td>
<td>50.0</td>
<td>55.0</td>
<td>60.0</td>
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**Supertruck Design Complete**

**Supertruck Targets Set (Component Level)**

**SuperTruck Shortlist Defined**

**Supertruck Specification Complete (target conflicts resolved)**

**Submit Final Scientific / Technical Report**

**Supertruck Program Complete**
Roadmap: Vehicle-Side Technologies

Freight Efficiency Improvement (FEI)

- **Aerodynamic Drag Reduction**
- **Rolling Resistance Reduction**
- **Intelligent Controls**
- **Weight Savings**
- **Other Regen.**
- **Braking Regen.**

Categories:
- **External Aerodynamics**
- **Tires**
- **Energy Mgt.**
- **Powertrain Integration**
- **Materials**
- **Hybrid**
- **Idle Reduction**
- **Parasitic Losses**
External Aero: Wind Tunnel and CFD Study

Design Option 1

Design Option 2
Idle Reduction Technologies

**Objective:** 4% Freight Efficiency Improvement over baseline (*main engine idling*)

**Solid-Oxide Fuel Cell APU**

*Image shown with permission from Delphi Corporation*

**Results:** SOFC-APU installed & tested on Cascadia, fuel measurement

**Characteristics:**
- Enables full-engine off operations

**NEXT STEPS:** evaluation / selection of preferred SuperTruck concept based on representative test cycles

**Hybrid System**

**Results:** concept defined, preliminary energy calculations completed

**Characteristics:**
- Fast on/off time
- No dedicated added weight
Horsepower Rating Criteria

Over the past 20 years, ratings drifted higher, resulting in higher speed on grades, fewer shifts and increased driver satisfaction.

Balancing driver satisfaction vs. fuel economy is an interesting challenge.
2009 Engine Performance at Higher NOx
Combustion System Investigations

- Evaluating various 2-step piston bowls
- Results vary by bowl shapes, but overall 2-step bowls show significant smoke reduction, but no bsfc improvement.
- Follow-on: heads with higher swirl level are being procured to quantify potential impact.
Aftertreatment Development

- Aftertreatment focused on next generation materials
- Lower dP and improved DEF-SCR efficiency
- New DOC material for reduced back pressure
- New DPF material for lower pressure drop while maintaining soot storage capability
- New DEF-SCR for higher efficiency
- All hardware at canner
- Testing will be initiated shortly
Parasitic Reduction – 4% bsfc

- Multiple systems being optimized.
  - Kit and engine friction, and “smarter” accessory loads
- Progress to date
  - 1.5% improvement demonstrated in test cell and on vehicle.
  - Parts on order to allow demonstration of an additional 1.5%
  - Feasibility study underway for further improvements of >1%
- Partnered with Massachusetts Institute of Technology (MIT)
Predictive Controls

- Increasingly complex calibration
  - More degrees of freedom
  - Additional actuators
  - Vehicle integration
  - Refined optimizations

- More stringent requirements
  - Control stability
  - Transient response
  - Fuel economy
  - Urea consumption
  - Emissions
  - Life-cycle cost
  - Durability
  - Diagnostics
Control System Features

- Develop a **map-less, predictive, empirical** engine controller
- Reduce calibration and controller complexity
- Include an on-board fuel efficiency optimizer

Calibration Constraints
- Drivability
- Durability
- Fuel economy
- Life-cycle cost
- NOx / PM / NMHC / CO₂
- OBD
- Exhaust temperature
- GPS / Route / Traffic info.

- Easier to calibrate (mitigate control complexity)
- Remain optimized through transient operation.
Controller fully operational – validation and development in transient test cell

Preliminary vehicle testing initiated
Waste Heat Recovery

- Approx. 55% of fuel energy is “waste heat”
- Waste heat recovery
  - Turbocompound – being evaluated
  - Rankine cycle – recover energy from EGR and/or exhaust gases
    - 5% BSFC improvement targeted.
    - Significant technical challenges
      - Heat exchangers, expander, compressor, packaging, engine integration, etc
- Development Partners
  - Oak Ridge National Laboratory
  - Daimler Advanced Engineering Group
Simulation and Packaging

- Multiple simulation tools being used
- Performed at ORNL and Detroit
- Component testing @ Daimler Research
- Packaging studies underway
Rankine System – Major Components

**Evaporator**
Transfer exhaust and/or EGR energy to working fluid.

**Pump**
Hermetically sealed Diaphragm pump

**Working Fluid**
Ethanol
Low environmental impact. Suitable thermodynamic properties

**Condenser**
Rejected heat will be released under hood

**Expander**
Handle 2-phase flow, high speed operation for electricity generation
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