Heavy-Duty Powertrain Development
Current Status and Future Opportunities

Detroit, Sep.29th 2010
Rakesh Aneja
Daimler Trucks is globally positioned w/ truck and components plants

- Detroit
- Mannheim
- Wörth
- Gaggenau
- Rastatt
- Stuttgart
- Kassel
- Molsheim
- Istanbul
- Aksaray
- Tramagal
- East London
- São Paulo
- Atlantis, Cape Town
- Portland
- Portland
- Saltillo
- Santiago
- High point
- Mount Holly, Cleveland, Gastonia, Gaffney
- Detroit Trucks North America
- Detroit Diesel
- Western Star
- Freightliner
- saltillo
- Santiago
- Japanese
- Kawasaki
- Japanese
- Fuso
- Japanese
Global Heavy Duty Engine Platform
Clean Sheet Design

<table>
<thead>
<tr>
<th>Attribute</th>
<th>DD13</th>
<th>DD15</th>
<th>DD16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Market</td>
<td>LTL, Reg. Dist., Vocational</td>
<td>Truck Load</td>
<td>Specialized Hauling, O/O, Vocational</td>
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<tr>
<td>Displacement (l)</td>
<td>12.8</td>
<td>14.8</td>
<td>15.6</td>
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<tr>
<td>HP Range (hp)</td>
<td>350 – 500</td>
<td>455 – 560</td>
<td>475 – 600</td>
</tr>
<tr>
<td>Torque Range (ft-lb)</td>
<td>1250 – 1650</td>
<td>1550 – 1850</td>
<td>1750 – 2050</td>
</tr>
</tbody>
</table>

2 DD13,15,16 worldwide HD engine platform (NAFTA + EU + Japan)
- Amplified Common-Rail Fuel System
- Turbo-Compounding
- DOHC w/ integral engine brake
The Age of Criteria Pollutant Emissions Reduction

<table>
<thead>
<tr>
<th>Year</th>
<th>PM [g/ hp-hr]</th>
<th>NOx [g/ hp-hr]</th>
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<tbody>
<tr>
<td>1988</td>
<td>10.7</td>
<td></td>
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<tr>
<td>1990</td>
<td>6.0</td>
<td></td>
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<tr>
<td>1991</td>
<td>5.0</td>
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<td>1994</td>
<td>4.0</td>
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<td>1998</td>
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<tr>
<td>2004</td>
<td>1.2</td>
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<tr>
<td>2007</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>0.2</td>
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</table>
Near-Zero Emissions Today
DD1x Series Equipped with BlueTec Emissions Control
• The light bar indicates the level of fluid in the DEF tank.
• Low DEF levels will trigger a decrease in engine performance.
• The use of improper fluid will trigger a decrease in engine performance.
• In the empty and ignored state, if the diesel tank is refilled without filling the DEF tank, vehicle speed will be limited to 5 mph until DEF is detected in the tank.
Fuel Economy Progression

Detroit Diesel HD Engine Economy
Historical Progression from EPA98 to EPA2010*

Emission Year-to-Year Fuel Economy % Change

-4%
-2%
+3%
+3%

EPA98 (pre-EGR)  EPA04  EPA07  EPA07 DD15  EPA10 DD15

* Not including DEF

“…[BlueTec fuel economy] slightly better than our pre-EGR trucks…”
– Steve Duley, VP Purchasing – Schneider National
The Age of CO₂ - Fuel Economy Improvement Scenarios

- Fuel economy improvements will be introduced very quickly
- Life Cycle Costs will continue to drive efficiency improvement, but legislation begins to play a role
- DoE Super Truck project with a 50% improvement target [in ton-miles/ gallon] will help accelerate introduction of innovative technologies

**Scenarios for FE Improvement**

**Columbia S60 EPA07**

**Cascadia DD15**

**FE Demonstrator**

**DoE SuperTruck**

50% Improvement in Freight Efficiency
- 20% Engine
- 30% Vehicle

**DTNA/ DDC**

+ Suppliers
+ Customers

**Business Case & Competition**

**Regulation Impact**

Fuel Consumption (%)
DDC/ DTNA DoE SuperTruck Technologies

ENGINE & POWERTRAIN

- Combustion
- Fuel Injection
- Air/ EGR
- Controls
- Waste heat recovery
- Auxiliary components
- Powertrain: Engine downsizing, hybridization, transmission optimization

VEHICLE

- Aerodynamics
- Driveline optimization
- Predictive power management
- Weight reduction
- Idle reduction
- Driver feedback
- More freight efficient vehicle concepts (e.g., 60 ton vehicles)
- Navigation and route planning
SuperTruck Technical Road-Map/ Interaction Matrix

- Next Generation Controller:
  - On board optimizer

- Powertrain Controls:
  - Engine Cycle Simulations
  - Energy management, Predictive controls

- Transmissions & Axles

- Hybrid Development

- Vehicle Tests & Demonstrations
  - Cooling Package Optimization

- DTNA
  - Packaging & Weight Optimization
  - Driving Behavior & Coaching

- Engine Tests
  - Engine Cycle Simulations
  - Prototype Development

- Drivetrain Analysis
  - Vehicle Simulations
  - Maps, MVM

- Energy Management
  - Gear Ratios
  - Transmission String
  - Brake Power

- 3D In-Cylinder Combustion Simulations
  - Hardware, Adv.
  - Performance Testing

- Reactive Flow Simulations
  - High NOx Eff., Low DP ATS
  - Temperatures & Flow Rates
  - Brake Power

- Prototype Testing
  - Prototype Development
  - Brake Power

- Thermodynamic Simulations
  - Exhaust Heat Recovery

- Engine Tests Maps, MVM
  - NOX Levels & Exit Temp.
  - Backpressure

- Combustion Development
  - Parasitic Reduction

- Detroit Diesel
  - Next Generation Controller
  - Vehicle Tests & Demonstrations

- Detroit Diesel
  - DTNA

- Cooling Package Optimization
  - Drive Load Reduction:
    - Lightweight, Tires, Efficiencies

- Aerodynamics

- Anti Idling

- Drive Load Reduction:
  - Lightweight, Tires, Efficiencies
Analytical Model Requirements for HD Vehicle Fuel Efficiency

Vehicle Simulation Software

Fuel consumption optimization

Engine Fuel Map
- Gear and axle ratios
- Transmission efficiency (per gear)
- Axle efficiency
- Inertias
- Mass
- Tire rolling resistance
- others

Component Characteristics (lookup table)

Vehicle Characteristics: $C_dA$
- Drag ($C_dA$) from
  - lookup table or measurements
  - analysis (CFD)

EcoFeatures: system characteristics

Route profile
- Real routes with driver model

Trip Activity

Vehicle Configuration
Efficiency Improvement: Predictive Technology

RunSmart Predictive Cruise™ - Freightliner Cascadia with DD15

1. Collects Information
A GPS locator, digital mapping device, vehicle load and set speed comprise the essential data.

2. Calculates Efficiency
Road grade and curvature are calculated for 1.2 miles ahead of truck’s location.

3. Adjusts Performance
Engine speed adjusts within a maximum 6% of set speed to create optimal efficiency.

Incline – Run Smart PCC anticipates the incline ahead and builds up momentum beforehand.

Crest – Run Smart PCC anticipates the crest of the hill and begins decreasing speed.

Decline – Run Smart PCC anticipates the decline and utilizes the truck’s momentum to maintain optimal speed.
Changes in Technologies and Regulations Drive changes in Development Processes

**Yesterday**
- Stand alone development

**Today**
- Definition of modules and platform architectures
- Integration via standardized interfaces

**Tomorrow**
- Engineering Cycle Management in entire vehicle platforms
Summary

- DDC’s new global Heavy Duty Engine Platform includes the latest technology for fuel efficiency and emissions control and is well-positioned for future regulatory and customer demands.
- In the next decade commercial vehicle development focus changes from criteria pollutant reduction to CO2 reduction in terms of freight efficiency.
- Freight efficiency improvements require not only engine advancements but also powertrain and vehicle improvements and optimized system integration.
  - Vehicle modeling tools are key to understand technology trade-offs and to maximize improvements.
- Global application of engines requires further technology development (e.g. to manage fuel variation).

Freight Efficiency - Which Solution?
Thank You