Road Mapping Engine Technology for Post-2020 Heavy Duty Vehicles

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DTNA / DDC Super Truck Team
Agenda

- Total operating costs
- CO2 Regulatory
- Truck requirements
- Supertruck Technology elements
  - Downsizing
  - Combustion System
  - Parasitics
  - Integrated Powertrain Optimization
  - Transient control
- Summary Roadmap
Fuel Economy Is Still King

• Fuel Economy Is Expected To Continue To Be #1 Priority From Our Trucking Customers.

• Yet, Their Profitability, If Not Survival Depends Keenly In Knowing and Anticipating Total Truck Life Cycle Operating Costs, Including Reliability /Up-Time, Durability, and Payback Duration For Newer, Higher Complexity Technology.

• Cyclical Fuel Market Trends – Future Optimized NO\textsubscript{x}/BSFC Variable Engine Maps Would Adjust Dynamically To DEF/Fuel Price Ratios While Ensuring Regulatory Compliance.

![Weekly U.S. No 2 Diesel Ultra Low Sulfur (0-15 ppm) Retail Sales by All Sellers](image1)

![Combined On-road Fuel and DEF Consumption vs. Engine out NO\textsubscript{x}](image2)

Source: U.S. Energy Information Administration
CO₂ Regulatory Activities for Heavy Duty Markets

**USA**
Legislation Finalized September 2011
- Reduction target between 6 and 23% depending on vehicle class
- (2017 compared to 2010)
Engine targets based on FTP-, SET-cycle tests
Separate vehicle targets based on „bin mapping“ method for 5 technologies.

**Europe**
EC Ordered 2 studies:
- Policy Options
- Measurement procedure of HDV fuel consumption
ACEA proposes simulation based approach similar to Japanese legislation extended by vehicle improvements.

**Japan**
Legislation in Place Since 2006
- Reduction target 12.2% 2015 compared to 2002 (target tightening expected)

<table>
<thead>
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<th>Category</th>
<th>Target Consumption ( \text{km} / \text{L} )</th>
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<tr>
<td>9</td>
<td>9.97</td>
</tr>
<tr>
<td>10</td>
<td>4.15</td>
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**China**
Legislation Targeted To Be Finalized by End of 2012
Proposal for standardized fuel consumption
Chassis dyno test for base type vehicles. Simulation allowed for variants.
C-WHVC (Chinese version). Vehicle class specific target values.
Super Truck Technology Elements

Enhanced high pressure fuel injection system

Optimized Combustion Including VVT

Aerodynamics

Exhaust Heat Recovery & turbocharging

Optimized Aftertreatment

Hybrid Transmission Concepts

Super Truck Technology Elements

Predictive Torque & Auxiliary Management

Next Generation Controller

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Engine Technology Forged To Meet Future Requirements

- Reduced Gas and Fluid Parasitics, Optimized Engine/Vehicle Aerodynamics & Cooling
- Reduced cruise load
- Reduced Weight & Space Claim, Higher BMEP / lower ISFC, Optimized Exhaust Thermal Signature, Freight Efficiency

**Supertruck Targets**
- 50% eff = 0.167 kg/kWhr
- 55% eff = 0.152 kg/kWhr

**Thermal Efficiency vs BSFC**

<table>
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<th>Engine Thermal Efficiency (%)</th>
<th>BSFC (kg/kWhr)</th>
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<tr>
<td>55% eff</td>
<td>0.152</td>
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</tbody>
</table>
Perennial Combustion System Levers

- Combustion Chamber
  - Piston / Head / Liner Shape & Robustness Refinement
  - Increased Compression Ratio & Cylinder Pressure
  - Thermal Coatings & Focal Point Cooling

- Injection
  - Evolutionary Nozzle Geometry
  - Optimized Hydraulic Flow
  - Dynamic Rate Shaping
  - Increased Injection Pressure
  - Multiple Injection
Parasitic Management

- Smarter Use Of Optimized Accessories And Pumps
- Increased Flexibility In Component Outputs
- Tighter Control of Emission Constituents
- Self-Learning Feedback Control System
Integrated Powertrain Performance Metrics

- Load Response
- Drive Time
- Driveability
- Low Speed Maneuvering
- NVH
- Thermal/Mechanical Stress
- Surge Margin
- Emission Compliance

Max. Acceleration
Max. Power
Traction Force
Post-2020 Powertrain Optimization

- Optimized Powertrain Interface
  - Torque
  - Cooling & Heating Flows
  - Data Exchange
- Engine - Exhaust Aftertreatment Thermal Marriage
- Turbo Compounding
  - Mechanical
  - Electrical
- Waste Heat Recovery System
Transient Road Mapping

• Factorial Increase In Calibration Space
• Multiple Performance Targets
• Cost Function That Minimizes Emissions And Fuel Consumption
• Optimizes Engine Operation In Real-time
• Use of Neural networks
• Predictive Control In Vehicle

Performance targets
- Torque
- Drivability
- Durability
- Fuel economy
- NOx / PM / NMHC
- NO/NO₂ ratio
- NH₃ storage
- Urea consumption
- SCR efficiency
Summary Supertruck Technology Road Map

- Advanced, fully integrated powertrain
- Hybrid Concepts
- Real time control
- Increased turbocharger efficiency
- Improved Air/EGR
- Improved Aftertreatment / thermal management
- Improved combustion Including Variable Valve timing
- Increased P max
- Downsizing
- Downspeeding

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