Heavy-Duty Powertrain and Vehicle Development
A Look Toward 2020

Detroit, October 4, 2011
Mark Groeneweg
Overview of Daimler Trucks Brands

DTNA

New Addition to the Family
The Age of Criteria Pollutant Emissions Reduction (past)

<table>
<thead>
<tr>
<th>Year</th>
<th>PM [g/hp-hr]</th>
<th>NOx [g/hp-hr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>0.60</td>
<td>10.7</td>
</tr>
<tr>
<td>1990</td>
<td>0.25</td>
<td>6.0</td>
</tr>
<tr>
<td>1991</td>
<td>0.10</td>
<td>5.0</td>
</tr>
<tr>
<td>1994</td>
<td>0.01</td>
<td>4.0</td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>2007</td>
<td>0.01</td>
<td>0.2</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0.2</td>
</tr>
</tbody>
</table>
What will the future look like?

There is the prediction of possibilities ....
Next winner of the Super Bowl
Winning lottery numbers
Precise timing and extent of market behavior

But .... this is not the way Engineers work...
What will the future look like?

Certainty of recurring change
- Seasons
- Day/Night
- Economy (Up & Down)

Certainty of linear change
- Fuel prices
- Globalization
- Engineering genius

We can fear or embrace change.... ultimately, the smartest & the fastest will prevail
What do we know for sure?
Certainty of cycles

The economic cycle of our industry

Gearing up
Capacity planning
Product cycles
R&D spending

It went down – it goes up – it will go down again..... eventually
What else do we know for sure?
Certainty of “linear” change

Fuel price increase
Environmental requirements
Globalization
Progress in information technology and electronics
What are the consequences for the industry?

More fuel efficient trucks
Enhanced safety features offering
Reduction of chance for human operation error
Increased competition and chances for technology development
New markets
Growth beyond unit sales

What are the consequences for the ‘engine’?
Real World Fuel Efficiency Improvement – Systems Viewpoint

![Diagram of engine and aftertreatment features affecting fuel efficiency](image)

**Engine & Aftertreatment Features that Impact FE**
- Pressure Drop - Internal Geometry/substrate Geometry
- Control Algorithms and Sensors
- Friction Losses - Fluid, Oil, Motor Pumps, Valve Trains/Valve Train Control
- Coolant System Efficiency - Coolant Circulation, Coolant Flow
- Basic Combustion - Piston Rings, Bolts, Nozzle/Geometry, Valve Events, Oil Suction/Drain

**Powertrain (Component and Integration) Impact to FE**
- Powertrain Controls - Shift Points, Torque Rating, Speed Limiting
- Transmission, Mechanical Losses - Friction / Drive / Direct Drive
- Axle Mechanical Losses - Friction / Wear
- Engine Displacement and Torque Curve Match to Trans / Axle Radius / Vehicle Speed & GVW

**Installed Impact to FE (External to Engine/ATS Design)**
- Accessory Loads - Air System / Electrical / HVAC
- Air Filter & Intake - Pressure Drop/Temperature
- Charge Air Cooler - Pressure Drop / Eff.
- Fuel System - Restriction / Temperature
- Engine Mount NVH / Battery Charging - Accelerative Load (Time Speed)
- Cooling System - Fan Flow / Valve Flow / Wear / Coolant Consumption
- Exhaust System - Pressure / Temperature / Losses

**1st law energy balance**

- **Exhaust** 25%
- **Drive Train** 4%
- **Rolling Resistance** 2%
- **Aerodynamic Drag** 21%
- **Ambient and Residual** 5%
- **EGR Cooler** 8%
- **Engine Coolant** 12%
- **Charge Air Cooler** 10%
- **Auxiliary Loads** 4%
Comprehensive System Development

Example: Super Truck Program

50% Improvement In Freight Efficiency
The age of CO$_2$ begins

USA: GHG/ FE Regulation signed August 2011

Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Principle</td>
<td>Separate engine (test bench) and vehicle standard (simulation)</td>
</tr>
<tr>
<td>Separated engine standard</td>
<td>Cost effective GHG optimization jeopardized</td>
</tr>
<tr>
<td>Simulation Input Data</td>
<td></td>
</tr>
<tr>
<td>Segmentation / Cycles</td>
<td>Weight oriented (G/M) segment approach</td>
</tr>
<tr>
<td>Limits / Flexibilities</td>
<td>15 regulatory classes (engines &amp; vehicles). No credit exchange vehicle &amp; engine</td>
</tr>
<tr>
<td>Metrics</td>
<td>g/ ton-mile</td>
</tr>
</tbody>
</table>

Paradigm Shift by Daimler

Simultaneous Emissions, Fuel Consumption, and CO$_2$ Reduction

- Daimler EPA 2010 product has resulted in 8% lower fuel consumption (and CO$_2$) and >90% lower emissions (nitric oxides and particulate matter), compared to model-year 2004-06 products.

- Driven by:
  1. Regulatory Requirements
  2. Competition
  3. Business Case
  4. Internal Daimler Goals

Real world fuel consumption reductions vs. regulatory announcement.
Electronics and controls (r)evolution

Predictive Engine Control With On-Board Fuel Efficiency Optimization

Why Predictive Controls?

- Factorial increase in calibration space
- Multiple performance targets
Competition for talent continues....

Global workforce is a fact...

Innovative workplaces produce innovation.....

Nurturing interest in science and math is required...
In Summary...

1. “Linear” change will define certain aspects of the future.
2. Advances in technology are a certainty – today’s trends in technology make the future visible.
3. Globalization in emissions regulation will be a driving force for real efficiency progress – if done correctly.
4. Freight efficiency improvements require not only engine advancements but also powertrain improvement, vehicle improvements and optimized system integration.
5. Exciting times continue for the commercial vehicle industry.
6. YOU are at the front line of technology development.

Our engineers are the ‘engine’ that will propel us into the future of commercial vehicles.