Propulsion Materials
Propulsion Materials Research Relevant to VT Goals

• Improve efficiency of advanced vehicles through innovative material solutions

• Critical enabler supporting Advanced Combustion, Thermoelectric, and Hybrid-Drive Systems
  – Material compatibility for Alternative Fuels
  – Materials for high efficiency CI/SI Engines
  – Thermoelectric materials
  – Materials for reliable high performance hybrid and EV drive systems

• Vehicle weight reductions and freight efficiency improvements through increased engine power density (hp/liter and hp/kg)
Material Research Role

Propulsion Materials Activities

Materials for Combustion Systems / High Efficiency Engines
- Turbocharger, Valve train, Fuel Injection, Structural Components Head/Block, Sensors, Materials/Fuel Compatibility

Materials for Exhaust and Energy Recovery
- DPFs, Catalysts, Thermoelectric Materials, Materials for high temperature structures

Materials for Electric and Hybrid Drive Systems
- High Temperature Power Electronics Materials, Solder Joints, Materials/Coolant Compatibility, And Materials for Electric Drive Motors

Materials By Design
- Materials Synthesis, Characterization, Multi-Scale Computer models, Testing Standards, and Coatings

VTP Team Collaborations

Advanced Combustion Engine
- LD 45%e @ $30/kW
- HD 55%e
- Biofuels

Hybrid Electric Systems
- 55kW @ $12/kW
- 300Whr @ $20/Whr

Fuels Technologies
- Petroleum Displacement
Materials will Be Key Going Forward

Vehicle systems to see the greatest percentage of material change as a result of proposed 2025 CAFE standards

- Powertrain: 49%
- Chassis: 22%
- Body exterior: 19%
- Interior: 4%
- Other: 6%

Source: 2011 WardsAuto/DuPont Survey of Auto Industry Challenges, conducted by Paramount Research

The auto industry’s current materials portfolio will need to be augmented to meet new 2025 fuel economy standards, according to a WardsAuto and DuPont Automotive survey conducted in late July. - Green Car Congress, October 5, 2011
Planning is Critical

Vehicle Technology Penetration
Years After Initial Significant Use

Food for Thought
- Design Process is about 4 years,
- For inclusion, new materials must be qualified before designs begin,
- New materials typically take 10+ years to develop

Materials Research Must be Focused on the Horizon
Objectives: identify technology gaps to be overcome such that advanced materials systems are available for heavy & light duty vehicles

- Lightweighting and Engine Efficiency Sub-Topic Areas:
  - Identify maximum potential reduction by vehicle class and time
  - Identify material requirements necessary to reach potential
  - Identify technical hurdles and gaps on the critical path
  - Identify time based cost targets

135 participants representing light duty vehicles (LDV) and heavy duty vehicles (HDV)

- OEMs (36)
- Material & Tier 1 suppliers (43)
- U.S. Government experts (8)
- Canadian government (4)
- Trade Organizations (5)
Workshop Considerations

Vehicle subsystems include:

- Structural systems:
  - Body structure
  - Chassis structures
  - Suspension and drivetrain systems
  - Engine and transmissions
  - Turbo-machinery
  - Exhaust and cooling systems

- Semi-structural and non-structural systems:
  - Appearance panels
  - Enclosures
  - Bumpers

- Materials considered:
  - Advanced high strength steels
  - Cast iron
  - Aluminum
  - Magnesium
  - Carbon fiber composites
  - Glass fiber composites
  - Unreinforced plastics
  - Advanced materials such as:
    - Titanium
    - MMCs
    - Ni-based alloys
## Draft Weight Reduction Goals for LDVs

<table>
<thead>
<tr>
<th>LDV Component Group</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>35%</td>
<td>45%</td>
<td>55%</td>
<td>60%</td>
<td>65%</td>
</tr>
<tr>
<td>Power-train</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>35%</td>
<td>40%</td>
</tr>
<tr>
<td>Chassis/suspension</td>
<td>25%</td>
<td>35%</td>
<td>45%</td>
<td>50%</td>
<td>55%</td>
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<tr>
<td>Interior</td>
<td>5%</td>
<td>15%</td>
<td>25%</td>
<td>30%</td>
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<tr>
<td><strong>Completed Vehicle</strong></td>
<td><strong>20%</strong></td>
<td><strong>30%</strong></td>
<td><strong>40%</strong></td>
<td><strong>45%</strong></td>
<td><strong>50%</strong></td>
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</table>
## Draft Weight Reduction Goals for HDVs

<table>
<thead>
<tr>
<th>Class 8 Tractor Component Group</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels and Tires</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Chassis/Frame</td>
<td>0%</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Drivetrain &amp; Suspension</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td>Misc.</td>
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<td>15%</td>
<td>25%</td>
<td>30%</td>
<td>35%</td>
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<tr>
<td>Accessories/Systems</td>
<td></td>
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<td></td>
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<tr>
<td>Truck Body Structure</td>
<td>15%</td>
<td>35%</td>
<td>45%</td>
<td>55%</td>
<td>60%</td>
</tr>
<tr>
<td>Powertrain</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Total Class 8 HDV</strong></td>
<td>6%</td>
<td>16%</td>
<td>22%</td>
<td>27%</td>
<td>31%</td>
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</table>

<table>
<thead>
<tr>
<th>Trailer (53 ft) Component Group</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels and Tires</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Chassis/Frame</td>
<td>0%</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Suspension</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td>Box/Other</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
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<tr>
<td><strong>Total Trailer</strong></td>
<td>3%</td>
<td>9%</td>
<td>13%</td>
<td>19%</td>
<td>23%</td>
</tr>
</tbody>
</table>

**Truck and Trailer Combined Totals**

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.8%</td>
<td>13.2%</td>
<td>18.0%</td>
<td>23.6%</td>
<td>27.4%</td>
</tr>
</tbody>
</table>
### Engine/Transmission Metric Synergies

**LDV and HDV – 2025 and 2050**

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight Reduction</strong></td>
<td>Baseline - LDV Baseline – HDV</td>
<td>25% lighter - LDV</td>
<td>40% lighter- LDV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15% lighter - HDV</td>
<td>20% lighter- HDV</td>
</tr>
<tr>
<td><strong>Power density</strong></td>
<td>LDV Baseline Midsize Car -2.7L 196 HP (73.4 HP/L)</td>
<td>10% augmented –LDV 2.4L 196 HP (81 HP/L)</td>
<td>30% augmented – LDV 1.9L 196 HP (104 HP/L)</td>
</tr>
<tr>
<td></td>
<td>LDT – 5L 308 HP (61 HP/L)</td>
<td>1.7L 139 HP (81 HP/L)</td>
<td>0.9L 98 HP (104 HP/L)</td>
</tr>
<tr>
<td></td>
<td>15L 475HP (32 HP/L)</td>
<td>4.3L 308 HP (71 HP/L)</td>
<td>3.5L 308 HP (78 HP/L)</td>
</tr>
<tr>
<td></td>
<td>- HDV baseline</td>
<td>30% augmented – HDV</td>
<td>40% augmented- HDV 9L 475HP (53 HP/L)</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>5% recovery – LDV</td>
<td>20% recovery – LDV</td>
<td>50% recovery – LDV</td>
</tr>
<tr>
<td></td>
<td>Turbo Machinery</td>
<td>Turbo / Thermoelectric(TEs)</td>
<td>Turbo/TEs/ Rankine Cycle</td>
</tr>
<tr>
<td></td>
<td>LDV Thermal Baseline 30% efficiency</td>
<td>LDV - 25% improvement (37% e)</td>
<td>LDV - 50% Improvement (45% e)</td>
</tr>
<tr>
<td></td>
<td>42% efficiency – HDV</td>
<td>42% efficiency – HDV</td>
<td>60% efficiency- HDV</td>
</tr>
<tr>
<td><strong>Exhaust Temperatures</strong></td>
<td>870 C - LDV 700 C- HDV</td>
<td>950 C - LDV 800 C - HDV</td>
<td>1000 C - LDV 900 C - HDV</td>
</tr>
<tr>
<td></td>
<td>(Exhaust Valve to Turbo Inlet)</td>
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</tr>
<tr>
<td><strong>Cylinder Peak Pressures</strong></td>
<td>Baseline – LDV ~ 50 bar 190 bar - HDV</td>
<td>75 bar - LDV gasoline 193 bar - LDV diesel 250 bar - HDV</td>
<td>103 bar - LDV gasoline 206 bar - LDV diesel 300 bar - HDV</td>
</tr>
</tbody>
</table>

*Background Graphic Courtesy of Daimler Trucks North America*
Current Material Limits

Peak Cylinder Pressure (PCP) BAR

- MG alloy
- AL Alloy
- MMCs
- Cast Iron
- CG Iron

Sub-component Limitations

7-25% (Based on 1999 study)
Expect 40-60%

Engine Materials Used

- V engine
- Inline engine
- 50% Goal
- 60% Goal

Based on 1999 study

Vehicle Technologies Program
Response to Workshop

- In 2012 three new Propulsion Materials Solicitation topics were released:
- Advanced Light-weight Cast alloy development for LD applications and High-strength Cast Alloys for HD application (two topics). Each topic includes:
  - ICME application and gap analysis
  - Alloy Development
  - OEM technology transfer path
  - Alloy validation
  - Component validation
- SBIR Topic: low-temperature catalysts materials targets:
  - 90% effectiveness at 150C
Prospective New Agreements in Each Technology Area are Evaluated On:

- Relevance to Vehicle Technologies Program Objectives
- Supported Team’s Priorities
- Potential for Co-funding from other VTP Teams
- Industry Support for Activity
- Perceived risk/benefit to program
- Mechanism for Technology Transfer

• Existing activities are evaluated annually
  - Identify activities that should be transitioned to other VTP Teams or Industry
  - Identify activities requiring changes in effort

• Approximately 15% of activities are retired each year

• Goal to migrate over 70% of portfolio to competitively awarded Solicitations by 2014
## Funding Direction

<table>
<thead>
<tr>
<th>Funding</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013 Request</th>
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<tbody>
<tr>
<td>Direct Funding</td>
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<td>8.5</td>
<td>10.6</td>
<td>10.9</td>
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<td>Solicitations</td>
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<tr>
<td>Total</td>
<td>5.9</td>
<td>9.5</td>
<td>10.7</td>
<td>11</td>
<td>13</td>
<td>13</td>
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<tr>
<td>Solicitations %</td>
<td>1.7%</td>
<td>10.5%</td>
<td>0.9%</td>
<td>0.9%</td>
<td>9.2%</td>
<td>37.7%</td>
<td>54.4%</td>
</tr>
</tbody>
</table>

![Pie chart showing funding distribution]

**Hybrid Electric Drive System Materials**: 51%
**Materials for High Efficiency Engines**: 16%
**Emissions / Durability**: 9%
**Fuels Compatibility**: 8%
**Materials by Design & Thermoelectric**: 16%
Thank You

www.vehicles.energy.gov

Jerry Gibbs
Propulsion Materials
Technology Development Manager
Vehicle Technologies Program
Email: jerry.gibbs@ee.doe.gov