Propulsion Materials Research Update

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Vehicle Technologies Program
Office of Energy Efficiency and Renewable Energy
Historical Evolution of Propulsion Materials Program

Automotive Propulsion Materials
- Automotive Project 1
- Automotive Project 2

Heavy Vehicle Propulsion Materials
- HD Vehicle Project 1
- HD Vehicle Project 2

Propulsion Materials
- PM Project 1 (Auto 1 + HD 2 + ...)
- PM Project 2 (Auto 2 + HD 4 + ...)
• Improve efficiency of advanced vehicles through innovative material solutions
• Critical enabler supporting combustion, Thermoelectric, and Hybrid-Drive Systems
  – Materials for HCCI / HECC engines
  – Material compatibility for Alternative Fuels
  – Materials for 45% thermal efficient LD engines
  – Materials for 55% thermal efficient HD CIDI engines
  – Thermoelectric materials
  – Materials for reliable high performance hybrid and EV drive systems
• Materials for Electric and Hybrid Drive Systems
  – Address materials issues impacting power electronics, motors, and other hybrid drive system components
• Combustion System Materials
  – Address materials issues impacting H2, HCCI, FFVs, and other light duty combustion regimes
• Materials for High Efficiency Engines
  – Address materials issues impacting high efficiency engines (valvetrains, rotating mass, fuel injectors, etc.)
• Materials for Exhaust and Energy Recovery
  – Develop materials for exhaust aftertreatment, turbo-machinery, and thermoelectric applications
• Materials by Design
  – Using advanced characterization and modeling techniques identify and develop new application specific materials
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,
- Electric Drive Motors, and Thermal Management

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

VTP Team Collaborations

Advanced Combustion Engine

Hybrid Electric Systems

Fuels Technologies
2007 Resource Allocation
$5.8M

- Hybrid Electric Drive System Materials: 9%
- Materials for High Efficiency Engines: 66%
- Materials by Design: 25%

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable
2008 Resource Allocation
$9.6M

- Hybrid Electric Drive System Materials: 10%
- Materials for High Efficiency Engines: 10%
- Materials by Design - ACE / Fuels: 10%
- Materials by Design - Characterization & Basic Research: 10%
- Materials by Design - HEVS: 59%
Propulsion Materials
Develops materials that meet projected operational performance parameters without exceeding cost constraints

Sample Performance Parameters
- Structural Strength
- High Temperature Tolerance
- Strength to Weight Ratio
- Thermal Conductivity
- Corrosion Resistance
- Manufacturability

Cost

Performance

Current Propulsion Materials
Aerospace Materials
Projected Propulsion Materials Requirements
Prospective New Agreements in Each Technology Area are Evaluated On:

- Relevance to Vehicle Technologies Program Objectives
- Supported Team’s Priorities
- 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 12% of activities are retired each year
• Current Projects
  – Materials for Electric and Hybrid Drive Systems
  – Combustion System Materials
  – Materials for High Efficiency Engines
  – Materials for Exhaust and Energy Recovery
  – Materials by Design

• Revisions to Project Portfolio
  – Combustion System Materials
    • To be incorporated into Materials for High Efficiency Engines.
• Projects are evaluated annually, using strategic objectives.
• Over 10% of projects are retired annually.
• New projects are selected in accordance with identified Office of Vehicle Technologies needs.
  – Advanced Combustion Engine Team
    • Internal Combustion Engine Materials
    • Thermoelectric Materials
    • Catalysts and After-treatment Materials
    • Materials for Engine Sensors
    • Materials for High temperatures and turbo-machinery
  – Hybrid Electric Systems Team
    • Power Electronics Materials
    • Materials for Energy Storage
  – Fuels Technologies Team
    • Alternative Fuels / Materials Compatibility
Thank You
• Following slides provide details about:
  - Activity duration
  - Activity funding to date
  - Activity projected end date

• Each Slide Represents the Activities within a Project Area
### Project 1: Materials for Electric and Hybrid Drive Systems (18516)

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
<th>End Date</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Carbon Foam Thermal Management (9237)</td>
<td>2002-2008, Ford and Michigan State, $1.5M</td>
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<td>2008</td>
<td>Materials Compatibility of Power Electronics (16306)</td>
<td>2007-2010, ORNL, $220k</td>
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<td>2009</td>
<td>Solder Joint Materials by Design (16305)</td>
<td>2007-2010, ORNL, $170k</td>
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<tr>
<td>2010</td>
<td>Modeling/Testing of Environmental Effects (16307)</td>
<td>2007-2010, ORNL, $225k</td>
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</tr>
</tbody>
</table>

1. Annual Merit Review  
2. Project Decision Point  
3. Critical Decision Point  
* = Project end dates TBD
# Project 2: Combustion System Materials (18517)

(All to be moved to 18518)

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<tbody>
<tr>
<td></td>
<td>Materials for HCCI Engines (11752)</td>
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<td>2005-2010, Eaton, $500K</td>
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<td></td>
<td>Hydrogen Compatible Materials (11754)</td>
<td>2005-2009, Ford/Westport, $1.1M</td>
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<td>NOx Sensor Development (8697)</td>
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<td>2002-2012, Ford, $2M</td>
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<td></td>
<td>Fuel Injector Holes Project (9440)</td>
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<td>2002-2013, Siemens/Cummins/Imagineering, $1.1M</td>
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<td></td>
<td>Integrated Surface Modification (14708)</td>
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<td>2006-2007, NIST, $200k</td>
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### Project 3: Materials for High Efficiency Engines (18518)

**Annual Merit Review**  2. Project Decision Point  

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
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<th>End Date</th>
<th>Funding Agency</th>
<th>Amount</th>
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<tbody>
<tr>
<td>2006</td>
<td>Joining of Advanced Materials by Plasticity (9010)</td>
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<td>2003-2008, ANL/Ohio State</td>
<td>$700K</td>
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<td>2006</td>
<td>Mechanical Reliability of Piezo Stack Actuators (13329)</td>
<td>✔️</td>
<td>2006-2010, ORNL</td>
<td>$605K</td>
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<td>2006</td>
<td>Materials for High Pressure Fuel Injectors (16303)</td>
<td>✔️</td>
<td>2006-2010, ORNL/Caterpillar</td>
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<td>2006</td>
<td>Valve Train Materials (9128)</td>
<td>✔️</td>
<td>2002-2008, ORNL/ANL/Caterpillar</td>
<td>$367K</td>
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<td>2006</td>
<td>Materials for Advanced Valves (16304)</td>
<td>✔️</td>
<td>2007-2010, ORNL/Caterpillar</td>
<td>$245K</td>
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<td>2006</td>
<td>NDE of Engine Components (9089)</td>
<td>✔️</td>
<td>2002-2008, Caterpillar/ANL/ORNL</td>
<td>$1.2M</td>
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<tr>
<td>2006</td>
<td>Materials Testing with ACERT Engine (15050)</td>
<td>✔️</td>
<td>2007-2011, Caterpillar</td>
<td>$800K</td>
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<td>2006</td>
<td>Fatigue Enhancements by Shock Peening (15054)</td>
<td>✔️</td>
<td>2007-2010, PNNL/Cummins</td>
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<td>2006</td>
<td>Tailored Materials for Advanced CIDI Engines (15055)</td>
<td>✔️</td>
<td>2007-2010, PNNL/Caterpillar</td>
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<td>2006</td>
<td>Compact Potentiometric NOx Sensor (17058)</td>
<td>✔️</td>
<td>2007-2010, ANL</td>
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<td>2006</td>
<td>Low Cost Titanium Cofunding (11139)</td>
<td>✔️</td>
<td>2004-2010, PNNL/DuPont/ATI-Allvac</td>
<td>$100K</td>
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1. Annual Merit Review  2. Project Decision Point  

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[Image of project timeline and critical decision points]
Project 4: Materials for Exhaust and Energy Recovery (18519)

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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<tr>
<td>2006</td>
<td>Catalyst Characterization (9130)</td>
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<td>2008</td>
<td>Durability of PM Filters (10461)</td>
<td>Cummins, $1.2M</td>
<td>2004-2007</td>
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**Project 5: Materials by Design (18865)**

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<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
<th>Sponsor(s)</th>
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<td>2006</td>
<td>Catalyst Microstructures (9105)</td>
<td>Ford/Cummins/UQP</td>
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<td>2006</td>
<td>Life Prediction of Engine Components (9110)</td>
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<td>2006</td>
<td>Mechanical Reliability of Thermoelectrics (14957)</td>
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<td>2007</td>
<td>Erosion of Materials by Nanofluids (15529)</td>
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<td>2007</td>
<td>Nanocrystalline Machining Project (10460)</td>
<td>ORNL/Purdue</td>
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<td>2007</td>
<td>Materials by Design – HTML (16418)</td>
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<td>2007</td>
<td>Materials by Design – Thermoelectrics (16308)</td>
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<td>2007</td>
<td>IEA Annex on Materials for Transportation (16710)</td>
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<td>Integrated Surface Modification (16226)</td>
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<td>2008</td>
<td>Diamond-Based Thermoelectrics Materials (16309)</td>
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<td>2008</td>
<td>Nanocoatings: Superhard Coatings (13721)</td>
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<td>Nanocoatings: Residual Stress (13723)</td>
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Annual Portfolio Turn Over

<table>
<thead>
<tr>
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<th>2007</th>
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• Electric Propulsion System with a 15-year life capable of delivering at least 55kW for 18 seconds, and 30kW continuous at a system cost of $12/kW peak.

• Internal combustion engine powertrain systems costing $30/kW, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.

• Electric drivetrain energy storage with 15-year life at 300 Whr per vehicle with discharge power of 25 kW for 18 seconds and $20/kW.
• Develop and demonstrate an emissions compliant engine system for Class 7-8 highway trucks that improves the engine system fuel efficiency by 20% (from approximately 42% thermal efficiency today to 50%) by 2010.

• Develop technologies which will achieve a stretch thermal efficiency goal of 55% in prototype engine systems by 2013, leading to a corresponding 10% gain in over-the-road fuel economy over the 2010 goal.

• By 2010, identify and validate fuel formulations optimized for use in advanced combustion engines exhibiting high efficiency and very low emissions, and facilitating at least 5% replacement of petroleum fuels