# 21st Century Truck Partnership

...safely and cost-effectively move larger volumes of freight and greater numbers of passengers...

# Project Quad Sheets

...dramatically reducing the dependency on foreign oil...

DOE (full)
DOT (full)
EPA (full)

21CTP-004
February 2007

This document includes quad sheet project summaries for the majority of activities relevant to 21CTP goals and objectives. This document includes a complete set of quad sheets from DOT, a complete set of quad sheets from EPA, and a complete set of quad sheets from DOE.

(February 13, 2007)

# 21st Century Truck Partnership
# Project Quad Sheets
# February 2007

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## U.S. Department of Energy Projects

**Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.**

*Program Area: Advanced Combustion*

A-1. (CAT) Heavy Truck Diesel Engine (Heavy Truck Clean Diesel, HTCD)
A-2. (CMI) Heavy Truck Diesel Engine
A-3. (DDC) Heavy Truck Diesel Engine
A-4. Advanced Engine and Aftertreatment System R&D (CRADA with International)
A-5. Advanced Start-of-Combustion (SOC) Sensor (TIAX Project)
A-6. ANL-SNL Collaborative Research on Heavy-Duty Injector Spray Characteristics
A-7. Application of Wide Spectrum Voltammetric Sensors to Exhaust NOx Measurement (Streamline Project)
A-8. Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines
A-9. Emission Control Strategies for Off-Highway Engines (CRADA with John Deere)
A-10. Enabling High Efficiency Clean Combustion
A-11. Exhaust Energy Recovery
A-12. High CR, Atkinson-Cycle Engine Using Low-Pressure DI and Pneumatic EVA Enabled by Ionization Current and Forward-Backward Mass Air Flow Sensor Feedback (MSU Project)
A-13. Low Temperature Combustion Demonstrator for High Efficiency Clean Combustion
A-14. Low-Cost Fast-Response Actuator for Variable Compression Ratio Engines (VCR Actuator)
A-15. NOx Control and Measurement Technology for Heavy-Duty Diesel Engines (CRADA with Cummins)
A-16. On-Board Engine Exhaust Particulate Matter Sensor for HCCI and Conventional Diesel Engines (UTA Project)
A-17. Precompetitive Catalysis: Sulfur and Thermal Deactivation Effects on Transient LNT Chemistry, Capacity and Regeneration
A-18. Real-Time Control of Diesel Combustion Quality (CRADA with DDC)
A-19. Stretch Efficiency -- Thermodynamic Analysis of New Combustion Regimes
A-20. The Development of a Robust Accelerometer-Based Start of Combustion Sensing System (Westport Project)
A-21. Variable Valve Actuation (Delphi Project)

*Program Area: Heavy Vehicle Systems – Parasitic Loss Reduction*

A-22. ANL-NOx Sensor Development

*Program Area: Materials Technologies – Heavy Vehicle Propulsion Materials*

A-23. Advanced Machining and Sensor Concepts
A-24. Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers
A-25. Catalyst Characterization
A-26. Catalyst via First Principles
A-27. Characterization of Catalyst Microstructures and Deactivation Mechanisms
A-28. Deformation in Ceramics
A-29. Durability of Diesel Engine Materials
A-30. Durability of Particulate Filters
A-31. Engineered Surfaces for Diesel Engine Components
A-32. Evaluation of Materials via ACERT Engine
A-33. Fabrication of Small Diesel Fuel Injector Orifices
A-34. Fatigue Enhancements by Shock Peening

A-35. Friction and Wear Reduction in Diesel Engine Valve Trains
A-36. HDIR Surface Treatment
A-37. High Toughness Materials
A-38. IEA Annex on Materials for Transportation Applications
A-39. Integrated Surface Modification
A-40. Life Prediction for Diesel Engine Components
A-41. Lightweight Valve Train Materials (Titanium)
A-42. Low Cost Manufacturing of Precision Diesel Engine Components
A-43. Materials for Exhaust Aftertreatment
A-44. Materials for HECC/HCCI Engine Components
A-45. Mechanical Behavior of Ceramic Materials
A-46. Mechanical Reliability of Piezo-Stack Actuators
A-47. Microstructural Changes in NOx Trap Materials
A-48. Nanocrystalline Materials by Machining
A-49. Non Destructive Evaluation of Diesel Components
A-50. NOx Sensor Development (CRADA with Ford)
A-51. Processing and Characterization of Structural and Functional Materials for Heavy Vehicle Applications
A-52. Testing Standards
A-53. Thermoelectrics Modeling
A-54. Titanium Engine Components
A-55. Titanium Machining Consortium
A-56. Titanium Turbocharger Development
A-57. Walker Process for Stress Relief

*Program Area: Materials Technologies – High Strength Weight Reduction*

A-58. Laser Surface Texturing of Materials

**Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displ**

*Program Area: Fuels Technologies-Advanced Petroleum Based Fuels*

A-59. LLNL APBF: Kinetic Modeling of Combustion of Practical Hydrocarbon Fuels
A-60. NREL APBF: Biodiesel Effects on NOx Emissions: Engine vs. Chassis Test Cycles
A-61. NREL APBF: Diesel Particulate Filter (DPF) Performance with Biodiesel Blends
A-62. NREL APBF: Fuels for Advanced Combustion Engines (FACE)
A-63. ORNL APBF: Diesel Range Fuel Effects in a Single Cylinder HCCI Engine
A-64. ORNL APBF: Fuel Property Effects on Diesel High Efficiency Clean Combustion
A-65. ORNL APBF: Fuels and Lube Constituent Effects on Emissions Control Aging
A-66. ORNL APBF: Gasoline-Range Fuel Effects on HCCI
A-67. SNL APBF: High Efficiency Clean Combustion (HECC) with Conventional and Unconventional Diesel Fuels

**Hybrids: Develop drive unit with 15 year life and cost of $50/kW peak power.**

*Program Area: Heavy Vehicle Systems – Parasitic Loss Reduction*

A-68. Advanced Hybrid Propulsion and Energy Management System for Mine Haul Trucks

**Hybrids: Develop technology to achieve 60% fuel economy improvement while meeting emission standards**

*Program Area: Heavy Vehicle Systems – Heavy Hybrids*

A-69. Advanced Heavy Hybrid Propulsion System Program: Caterpillar Inc.

A-70. Advanced Heavy Hybrid Propulsion System Program: Eaton/International Truck

A-71. Advanced Heavy Hybrid Propulsion System Program: GM-Allison

A-72. Advanced Heavy Hybrid Propulsion System Program: Oshkosh

**Idle Reduction: Develop 5 kW diesel fuel ICE APU at $200/kW.**

*Program Area: Clean Cities – Idle Reduction Deployment*

A-73. Pony Pack APU/Truck Fleet Demo

**Idle Reduction: Develop codes and standards for on-board and off-board electrification technologies**

*Program Area: Heavy Vehicle Systems – Idle Reduction*

A-74. National Idling Reduction Plan

**Idle Reduction: Develop fuel cell APU at 5-30 kW on diesel fuel at delivered cost of $400/kW by 2012**

*Program Area: Heavy Vehicle Systems – Idle Reduction*

A-75. Diesel Fueled SOFC for Class 7/Class 8 On-Highway Truck Auxiliary Power

A-76. Solid Oxide Fuel Cell (SOFC) Development for Auxiliary Power in Heavy Duty Vehicle Applications

**Idle Reduction: Other idle reduction activities.**

*Program Area: Clean Cities – Idle Reduction Deployment*

A-77. Greater Sacramento Clean Air Coalition Truck Stop Electrification

A-78. New York State Research & Development Authority Truck Stop Electrification

*Program Area: Heavy Vehicle Systems – Idle Reduction*

A-79. Caterpillar MorElectric Technology Idle Reduction Demonstration

A-80. Espar Idle Reduction Technology Demonstration

A-81. Schneider National Cab Heating & Cooling

**Other 21CTP Research Areas**

*Program Area: Health Impacts*

A-82. Health Impacts of Engine Emissions

A-83. ORNL APBF: Watt Road Environmental Laboratory

*Program Area: Heavy Vehicle Systems – Heavy Hybrids*

A-84. Characterization of Long-Haul Heavy Vehicle Duty Cycles

*Program Area: Heavy Vehicle Systems – Parasitic Loss Reduction*

A-85. 21st Century Locomotive (System) Technology

**Parasitic Losses: Reduce aerodynamic drag by 20%**

*Program Area: Heavy Vehicle Systems – Aerodynamics*

A-86. Aerodynamic Drag (Includes Spray from Rolling Tires)

A-87. DOE Consortium on Heavy Vehicle Aerodynamic Drag

A-88. Heavy Vehicle Drag and Safety: Spray from Rolling Tires

A-89. Heavy Vehicle Drag Estimation Using Commercial CFD Tools

A-90. TMA - Test, Evaluation, and demonstration of practical devices and systems to reduce aerodynamic drag of tractor-Semitrailer combination-unit trucks

**Parasitic Losses: Reduce essential power loads by 50%**

*Program Area: Advanced Combustion*

A-91. Demonstration of Air-Power-Assist Engine Technology For Clean Combustion and Direct Energy Recovery In Heavy Duty Application

A-92. Very High Fuel Economy, Heavy Duty, Constant Speed, Truck Engine Optimised via Unique Energy Recovery Turbines and Facilitated by High Efficiency Continuously Variable Drivetrain

*Program Area: Heavy Vehicle Systems – Idle Reduction*

A-93. Systems Analysis for Heavy Vehicles

*Program Area: Heavy Vehicle Systems – Parasitic Loss Reduction*

A-94. Advanced Brake Systems and Undercarriage Aerodynamic Flow

A-95. Advanced Electric Systems and Aerodynamics for Efficiency Improvements in Heavy Duty Trucks

A-96. Autothermal Diesel Reformer

A-97. Boundary Layer Lubrication Mechanisms - A Systems Approach

A-98. Caterpillar-Parasitic Energy Loss Reduction and Enabling Technologies for Class 7/8 Trucks

A-99. Cooling Fan and System System Performance and Efficiency Improvements

A-100. Cummins CRADA: Diesel Engine Underhood Thermal Analysis

A-101. EATON - Efficiency Improvement Through Reduction of Friction and Wear in Powertrain Systems

A-102. Efficient Cooling in Engines with Nucleate Boiling

A-103. Erosion of Advanced Radiator Materials

A-104. Heat Transfer in Nanofluids

A-105. Nanofluids for Thermal Control Applications

A-106. Parasitic Energy Loss Mechanisms - Impact on Vehicle System Efficiency

A-107. Regenerative Shocks/Tires for Recovery of Parasitic Energy Losses

A-108. Residual Stresses and Adhesion in Coating Systems

A-109. Super Hard Coating Systems

A-110. Superhard Coatings For Advanced Vehicle Systems Applications

A-111. Truck Essential Power Systems Efficiency Improvements for Medium-Duty Trucks

A-112. Underhood Thermal Control: Coupled-Simulation with 3-D CFD Code and 1-D Network Model

*Program Area: Materials Technologies – Heavy Vehicle Propulsion Materials*

A-113. Advanced Tribological Coatings

**Parasitic Losses: Reduce Tare Weight by 15-20%**

*Program Area: Heavy Vehicle Systems – Parasitic Loss Reduction*

A-114. System Optimization of an UltraLight Electric Transit Bus

*Program Area: Materials Technologies – High Strength Weight Reduction*

A-115. Advanced Composite Cab Structures

A-116. Advanced Composite Structural Chassis Components

A-117. Advanced Composite Support Structures

A-118. Advanced Materials for Friction Brakes

A-119. Advanced Superplastic Forming Development for Heavy Vehicle Structures
A-120. Application of Carbon Fiber for Large Structural Components
A-121. Application of Superplastically Formed (SPF) Aluminum for Truck Body Panels
A-122. Attachment Techniques for Heavy Truck Composite Chassis Members
A-123. Basic Studies of Ultrasonic Welding for Advanced Transportation Systems
A-124. Carbon Fiber SMC Hood
A-125. Counter Gravity and Pressure Assisted Lost Foam Magnesium Casting
A-126. Development of Magnesium Powertrain Components
A-127. Development of Technologies for the Application of Magnesium Metal Matrix Composites for Heavy Vehicles
A-128. Effects of Ice Clearing Treatments on Corrosion of Heavy Vehicle Materials and Components
A-129. Equal Channel Angular Extrusion of Soft Ferromagnetic Materials
A-130. Equal Channel Angular Extrusion Processing of Alloys for Improved Mechanical Properties
A-131. Friction Stir Joined Aluminum Sheet Materials for Heavy Vehicle Cab Structures
A-132. Friction Stir Joining and Processing of Advanced Materials - PNNL
A-133. Friction Stir Welding and Processing of Advanced Materials - ORNL
A-134. High Conductivity Carbon Foam for Thermal Control in Heavy Vehicles
A-135. Hybrid Composite Materials for Weight Critical Structures
A-136. Improved Friction Tests for Engine Materials
A-137. Integrated Approach for Development of Energy-Efficient Steel Components for Heavy Vehicle and Transportation Applications
A-138. Inventory of Heavy-Duty Truck Lightweighting Candidates
A-139. Joining of Advanced Materials by Plastic Deformation
A-140. Lightweight Stainless Steel Bus: Manufacturing, Cost, and Crashworthiness
A-141. Rapid, Low-Cost Tooling Development
A-142. Thermomechanical Processing of Ti and Ti-6Al-4V sheet and Plate

**Safety: Develop and implement advanced technologies for high performance crash avoidance.**

*Program Area: Materials Technologies -- High Strength Weight Reduction*

A-143. Advanced Brake Systems for Heavy Vehicles
A-144. Research on Next Generation Truck Brake Materials

# (CAT) Heavy Truck Diesel Engine (Heavy Truck Clean Diesel, HTCD)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Demonstrate the technologies required to improve fuel efficiency and comply with the 2007 & 2010 (.2g/bhp-hr NOx, 0.01 g/bhp-hr PM) on-highway emission standards for Heavy Duty Trucks. Thermal efficiency improvement from a baseline of 43% to 50% is targeted. The approach will include the evaluation of HCCI systems and multiple emissions paths including NOx and PM aftertreatment systems to meet the 2010 emission requirements. Novel approaches will be evaluated to improve engine thermal efficiency including reducing engine friction, improving airflow through the engine, and improving BSFC/emissions trade-offs through developing advanced fuel systems and combustion system optimization.

## Current FY Focus

This project was completed at the end of FY2006.

**Duration** 8/21/2000 through 12/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $5100K / $5100K FY06 = $1679K / $1679K FY07 = $0K / $0K

## Accomplishments

A diesel engine system capable of 50% thermal efficiency while meeting 2010 on-highway truck emissions levels was identified using simulation. The resulting system includes the following high efficiency components: high efficiency aftertreatment; reduced friction piston rings; reduced flow restrictions; reduced heat rejection components; high efficiency air systems; turbo-compound system; compact high efficiency cooling system; optimized combustion system; high pressure injection system; variable intake valve actuation; increased cylinder pressure limits; and increased compression ratio. A demonstration engine capable of reaching high efficiency while meeting the 2010 on-highway truck emissions was built and tested. The engine included all the afore mentioned high efficiency components except for the reduced heat rejection components and 1 of the 3 high efficiency air system components. The test results for the engine showed the engine reached a peak efficiency of 47.5%. At the 2010 emissions levels, the efficiency achieved was 47%. This represents an improvement of 10-12% over the baseline engine.

## Significant Future Milestones

The Heavy Duty Truck Engine Program at Caterpillar concluded at the end of FY2006.


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**Partners** Caterpillar

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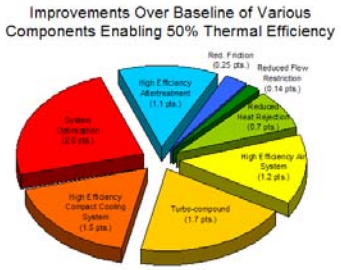


| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18624 / 8873 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-1 |

# (CMI) Heavy Truck Diesel Engine

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

To develop integrated combustion and aftertreatment systems to meet progressive emission and thermal efficiency goals that will ultimately achieve 2010 EPA emission standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr particulate matter at a 50% maximum thermal efficiency. These goals will be achieved through the development of advanced combustion systems including PCCI and LQHCCI techniques, advanced fuel injection systems, advanced air management systems including EGR, waste heat recovery techniques, and aftertreatment technologies. Laboratory development of the various systems will be followed by single-cylinder testing and then multi-cylinder testing. The Phase I goal is to demonstrate 45% brake thermal efficiency (BTE) at 2002 EPA emissions. The Phase IIA goal is to demonstrate 45% BTE at 2007 EPA emissions. The Phase IIB goal is to demonstrate 50% BTE at 2010 EPA emissions.

## Current FY Focus

This project was completed at the end of FY2006

**Duration** 7/19/2000 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $4000K / $4000K FY06 = $2685K / $2685K FY07 = $0K / $0K

## Accomplishments

Phase I goal successfully completed in Q2 of 2002 with the demonstration of 45% brake thermal efficiency from a heavy duty diesel engine (Cummins' ISX) while meeting 2002 U.S. EPA emissions.
Phase IIA goal successfully completed in Q2 of 2004 with the demonstration of 45% brake thermal efficiency from a heavy duty diesel engine (Cummins' ISX) while meeting 2007 U.S. EPA emissions.
Phase IIB goal successfully completed in Q2 of 2006 with the demonstration of 50% brake thermal efficiency from a heavy duty diesel engine (Cummins' ISX) while meeting 2010 U.S. EPA emissions when assuming the addition of a NOx reduction aftertreatment system (urea SCR and NOx adsorber). Demonstrated performance of an organic Rankine cycle waste heat recovery system.

## Significant Future Milestones

The Heavy Duty Truck Engine Program at Cummins Inc. concluded at the end of FY2006.


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**Partners** Cummins

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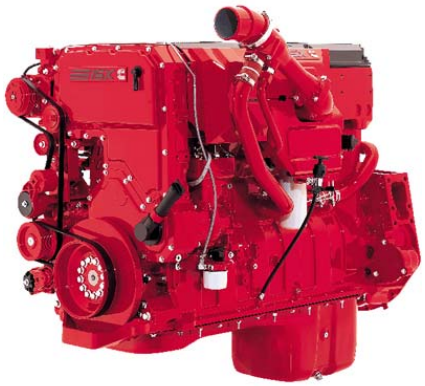

# (DDC) Heavy Truck Diesel Engine

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Demonstrate advanced engine component, sub-system and system technologies, feasible for subsequent product development and eventual commercialization, which are capable of achieving a brake thermal efficiency of 50% at EPA 2010 emissions regulations and explore advancements in engine combustion systems using high-efficiency clean combustion (HECC) techniques to minimize cylinder-out emissions.

## Current FY Focus

Consolidate and refine the demonstrated thermal efficiency milestone with the integrated controls system. Utilize the results of this system-based effort to identify the foundation for the next generation of combustion based thermal efficiency improvements. Work will focus on four technical activities including advanced low-temperature combustion, flexible precise fuel injection, air and exhaust gas recirculation, and transient control technologies.

**Duration** 9/20/2000 through 3/31/2009

**Gov't Funding/Industry Cost Share**

FY05 = $2100K / $2100K FY06 = $2950K / $2950K FY07 = $2000K / $2000K

## Accomplishments

Demonstrated integrated experimental and analytical technologies capable of achieving 50.2% thermal efficiency at EPA 2010 emissions regulation at a single operating condition in a multi-cylinder engine configuration. Experimentally demonstrated a brake thermal efficiency of 48.4% at EPA 2010 emissions regulations level at a single operating condition in a multi-cylinder engine test-bed environment. An additional 1.8%-point thermal efficiency improvement was demonstrated via analytical evaluation of potential engine system enhancements including reduced pumping losses, adaptive breathing cycles and reduced parasitic losses. Experimentally demonstrated greater than 45% thermal efficiency at several over-the-road representative operating conditions. Experimentally demonstrated EPA 2010 emissions over steady-state and transient operation (FTP and over-the-road), enabled by the multiple-mode, low emissions combustion concept (stretch project goal). Validated the effectiveness of NZ-50 technologies by demonstrating 8.2% over-the-road fuel economy improvement to meet the stretch project goal.

## Significant Future Milestones

Successfully wrap up the remaining technical activities of the current budget period, including the consolidation and refinement of the demonstrated thermal efficiency milestone and the development of the integrated controls system.


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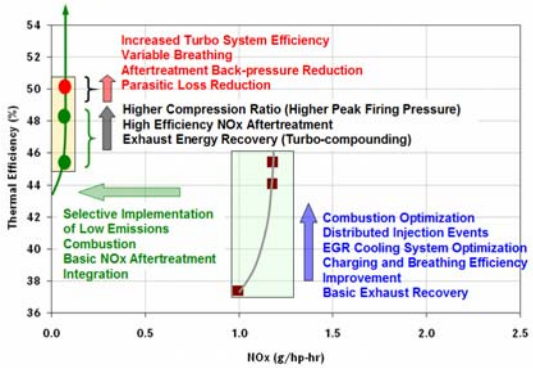
Figure 3: NZ-50 Thermal Efficiency Roadmap - Key Technical Building Blocks

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| 18624 / 8886 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-3 |

# Advanced Engine and Aftertreatment System R&D (CRADA with International)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Examine effects of HC chemistry on NOx adsorber regeneration
- Study NOx adsorber desulfation
- Explore advanced combustion regimes and thermodynamic cycles using infinitely variable intake and exhaust valve timing.

## Current FY Focus

- Commission camless research engine
- Examine desulfation time, temperature, and species effects on engine-aged NOx adsorber samples in DRIFTS and powder reactors

**Duration** 9/30/2000 through

**Gov't Funding/Industry Cost Share**

FY05 = $225K / $K FY06 = $225K / $K FY07 = $250K / $K

## Accomplishments

- Developed in-pipe injection strategies for rated load and road load conditions, studied HC preferences via HC speciation
- Desulfurized NOx adsorber on engine at road-load condition
- Evaluated iso-octane, toluene, and 1-pentene reductants on engine/NOx adsorber system, confirming rank order of various HC families in NOx adsorber regeneration
- Removed camless research engine from vehicle and installed in ORNL engine cell

## Significant Future Milestones

- Examine limits of over-expansion as means to higher efficiency


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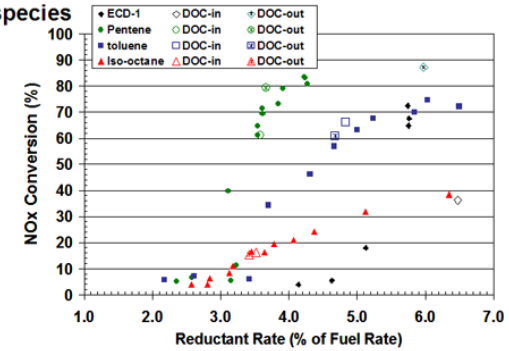
**Regeneration study with pure compounds confirms rank order of HC species**



# Advanced Start-of-Combustion (SOC) Sensor (TIAX Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop a Start-of-Combustion (SOC) sensor toward commercial readiness. The sensor must provide adequate SOC event capture to control an HCCI engine in a feedback loop, and meet the sensor system cost, durability, and software efficiency (speed) targets. The technical approach is to develop the sensor processing algorithms so that the accelerometer-based combustion sensor can identify SOC reliably. In addition, prototyping will be done to work toward a sensor system which is durable enough to meet all conditions of the engine operating regime and still provide accurate data for the life of the engine.

## Current FY Focus

The focus of the HCCI SOC project this coming year (2007) is to work to set up a multi-engine testbed to test engine-to-engine repeatability. In parallel, advanced algorithms and sensor combinations will be developed to build upon the SOC work already performed. Following those tasks, one engine will be converted to run HCCI, and the sensors and algorithms previously developed will be tested.

**Duration** 10/2/2006 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $10K / $3K FY07 = $195K / $65K

## Accomplishments

New project start for FY2007.

## Significant Future Milestones

The objective of Phase I is to determine if the accelerometer based SOC sensor can provide adequate SOC event capture to control an HCCI engine in a feedback loop, and if the sensor system can meet cost, durability, and software efficiency (speed) targets. In Phase I, the sensor must provide enough discernable signal resolution at low load conditions (where the lowest signal-to-noise ratio exists) so SOC may be readily identified to the required accuracy. Reliable algorithms for identification of SOC from the reconstructed pressure trace must be developed to meet accuracy and speed specifications. Processing code efficiency (response time of control system) must be rapid enough that control decisions may be made and implemented. Interface with the HCCI actuation/control mechanism (VVT/FI, etc) must be rapid and robust to allow the control mechanisms an opportunity to change engine conditions. Sensor(s) must be durable enough to meet all conditions of the engine operating regime and still provide accurate data for the life of the engine. The sensor and algorithm must also demonstrate "technology robustness" in application across engines of the same type (same model, different serial number) as a measure of production and commercial feasibility.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**Congressional Information** Massachusetts 8th
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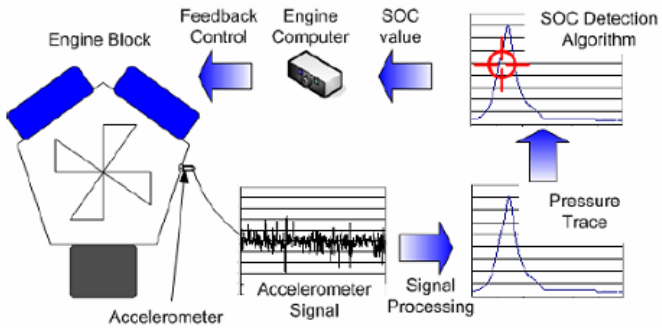


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|---|---|---|---|---|---|
| 18623 / 15939 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-5 |

# ANL-SNL Collaborative Research on Heavy-Duty Injector Spray Characteristics

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Study the mechanisms of spray atomization by making detailed, quantitative measurements in the near-nozzle region of sprays from heavy-duty injectors.
- Provide near-nozzle data that is crucial for the development of accurate spray models.
- Compare the data measured using the x-ray technique with existing data measured using conventional techniques at Sandia National Laboratory.

## Current FY Focus

**Duration** 10/1/2001 through 9/30/2004

**Gov't Funding/Industry Cost Share** *Total Funding Level = $500K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Fuel system based on the Sandia design was constructed and successfully tested.
- Time-resolved mass distribution of sprays from three different nozzle geometries were measured for a heavy-duty injection system.
- Preliminary analysis of the x-ray data shows striking differences in the mass distributions from the different nozzle geometries.

## Significant Future Milestones

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| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Advanced Combustion | Exploratory R and D | DOE | 3/15/2005 | A-6 |

# Application of Wide Spectrum Voltammetric Sensors to Exhaust NOx Measurement (Streamline Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Development of an effective engine exhaust NOX sensor based on voltammetric gas sensor technology. The sensor will be developed for application to passenger vehicle or heavy truck applications.

## Current FY Focus

The first phase will consist of sensor fabrication and packaging, calibration, and verification of instrumentation performance.

**Duration** 10/2/2006 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $10K / $3K FY07 = $126K / $74K

## Accomplishments

New project start for FY2007.

## Significant Future Milestones

Fabrication of NOx-tailored thick-film hybrid sensing elements and associated protective packages. {1/30/2007}
Demonstration that consistent electrochemical spectra (signatures) can be generated at NO and NO2 concentrations found in engine exhaust. {5/30/2007}
Demonstration of rapid operation and response of the instrumentation. {6/30/2007}


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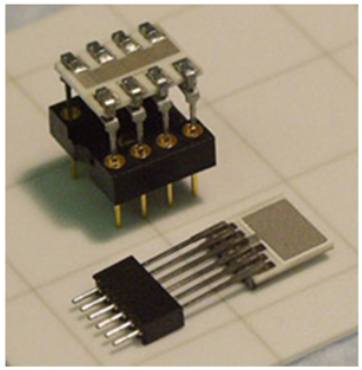
DOE374 FINAL

Geometric flexibility of sensing elements



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18623 / 15938 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-7 |

# Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop a low emissions and highly efficient combustion concept that is production feasible for both 2010 on-highway and 2014 off-highway applications.

## Current FY Focus

Overall objective is to develop clean combustion technologies that achieve the highest possible brake thermal efficiencies. The approach Caterpillar and its partners are using is a form of homogeneous charge compression ignition.

**Duration** 9/16/2005 through 12/31/2008

**Gov't Funding/Industry Cost Share**

FY05 = $1400K / $1400K FY06 = $1369K / $1369K FY07 = $1780K / $1780K

## Accomplishments

Phase 2 optical diagnostic experiments complete on diesel and gasoline fuels
Single cylinder engine fuels testing on low cetane fuels
Validated CFD HCCI model completed and in use for combustion development
New cooling system methodology developed for selective cooling
Preliminary controls architecture developed/validated on multi-cylinder engine
Transient operation demo'd on multi-cylinder engine with cylinder balancing and fuel trim strategies
Prototype fuel injection system developed and tested on single cylinder engine demonstrating ultra-low smoke emissions
Advanced multi-cylinder engine with compression ratio flexibility developed and tested demonstrating benefits for emissions, efficiency and controls

## Significant Future Milestones

Continue optical engine tests to further develop fundamental understanding. Refine and validate improved CFD submodels. Additional fuels effects testing to discern fuel property effects. Refinement of advanced cooling development process and validation with iron tests. Improvements to advanced fuel system capability and demonstration of benefits on multi-cylinder engines. Refinement of control strategies and implement on advanced multi-cylinder engines.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**Partners** Caterpillar, Inc., IAV Automotive Engineering Inc., Sandia National Laboratories, ExxonMobil, Woodward Governor Compan

**Congressional Information** Illinois 18th
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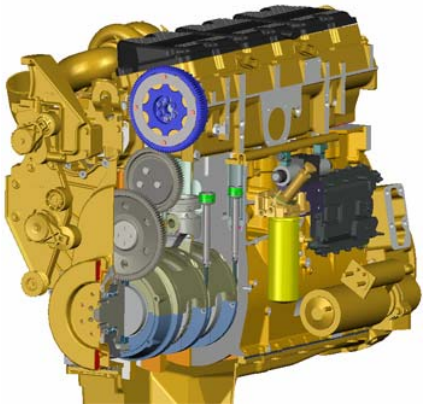

# Emission Control Strategies for Off-Highway Engines (CRADA with John Deere)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Achieve final Tier 4 PM and NOx emission levels with fuel consumption at 215 g/kWh or less
- Minimize heat rejection penalty

## Current FY Focus

- Investigate the influence of rail pressure and urea-SCR dosing on the formation and chemistry of particulate matter.
- Explore reformer technology to lower NOx emissions

**Duration** 9/30/2003 through

**Gov't Funding/Industry Cost Share**

FY05 = $300K / $300K FY06 = $300K / $300K FY07 = $K / $K

## Accomplishments

- Achieved Interim Tier 4 NOx emissions and final Tier 4 PM emissions.
- Identified NH4 emissions as a potential challenge for urea-SCR catalysis during low space velocities
- Evaluated Honeywell PM sensor

## Significant Future Milestones

- Evaluation of particulate formation and chemistry as a function of rail pressure and urea-SCR dosing
- Establish Delphi reformer for LNT investigation
- Addition of EGR and advanced intake geometry for added emission reduction capability and engine efficiency improvements


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**Partners** ORNL, John Deere

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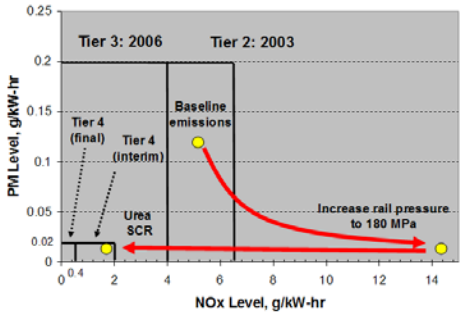
DOE341 FINAL

**High Rail Pressures and urea-SCR Enabled Interim Tier 4 Emission Levels of NOx and PM**

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|---|---|---|---|---|---|
| 18626 / 8861 | Advanced Combustion | Exploratory R and D | DOE | 6/13/2006 | A-9 |

# Enabling High Efficiency Clean Combustion

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop state of the art diesel combustion technology into commercially viable light and heavy duty engines which are capable of providing significantly improved thermal efficiency while achieving ultra low NOx and particulate emissions. The engines developed will be fully compliant with the EPA 2010 heavy duty on-highway emissions standard of 0.2 g/hp-hr NOx and 0.01 g/hp-hr particulate or the EPA Tier II Bin 5 light duty automotive emissions standard of 0.07 g/mile NOx and 0.01 g/mile particulate. The approach will utilize new low temperature combustion modes which are capable of reaching much lower emissions levels than conventional diffusion controlled diesel combustion. The engine's thermal efficiency will be improved by 10% or more through the use of this new combustion technology.

## Current FY Focus

Work will continue toward the completion of Phase II program goals with a focus on combustion development and enabling technology development. Planned work includes the completion of the multi-cylinder demonstration of PCCI combustion with next generation turbochargers and controls, single-cylinder evaluations of high pressure and advanced multi-pulse injections on the ISX engine, and completion of the transient evaluation of ISX high pressure injection and advance air handling recipe. Work will also include a biodiesel fuel study of PCCI combustion utilizing the ISB single-cylinder engine.

**Duration** 9/30/2005 through 12/31/2009

**Gov't Funding/Industry Cost Share**

FY05 = $1586K / $1586K FY06 = $1271K / $1271K FY07 = $4000K / $4000K

## Accomplishments

Engine system simulations were completed to define air handling requirements to achieve desired in-cylinder conditions for PCCI combustion.
Air handling equipment including turbomachinery, EGR components and required valves were designed and procured for multi-cylinder engine test.
Unique software was developed to support air handling and fuel system controls.
Preliminary multi-cylinder steady state engine tests were completed validating models and showing desired 10% improvement in fuel economy while meeting 2010 emission requirements.
The ISB PCCI engine was tested successfully in a transient environment, showing compliance with 2010 emissions and 10% improvement in fuel economy relative to baseline.
Special fuel blends were developed by BP and tested at Oak Ridge National Lab and in the Cummins ISB single-cylinder research engine to determine effects of basic fuel parameters on PCCI combustion.

## Significant Future Milestones

Complete multi-cylinder demonstration of PCCI combustion with next generation turbochargers and controls.
Finalize single cylinder evaluation of high pressure injection on the ISX engine.
Complete transient evaluation of ISX high pressure injection, advance air handling recipe.
Conduct biodiesel fuel study of PCCI combustion utilizing the ISB single cylinder engine.
Conduct single-cylinder engine studies of advanced, multi-pulse injection systems.


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**Partners** Cummins Inc., ORNL

**Congressional Information** Indiana 9th
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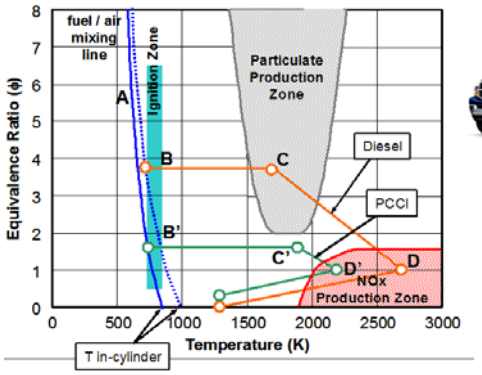

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| 19042 / 13914 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-10 |

# Exhaust Energy Recovery

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

To improve engine fuel efficiency by 10% through the recovery of waste heat energy, reduce the need for additional cooling capacity in Class 8 Trucks, and provide conditioning (cooling) for combustion charge air.

## Current FY Focus

Current work is to optimize WHR cycle for best performance, finalize heat exchanger and turbine designs, create dynamic system model, develop model-based controls, test turbine-generator and bearings at BNI, bench test heat exchanger at Modine, and start-up test cell.

**Duration** 10/1/2005 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $620K / $620K FY06 = $300K / $300K FY07 = $1000K / $1000K

## Accomplishments

Identified the prime path working fluid for the Rankine cycle system – R245fa.
Performed thermodynamic cycle analysis to predict performance across engine duty cycle. Identified the optimum arrangement of heat exchangers and system components within planned engine system architectures to provide the maximum amount of power recovery with a minimum of system complexity and expense.
Identified supporting technologies to enhance the recovery of waste heat energy using common electric power engineering components. Recovered waste heat energy will be converted to electricity. More efficient electrically driven parasitics (such as coolant pumps, fans, etc.) will be explored to most effectively utilize the recovered electric power.

## Significant Future Milestones

Create specifications for prototype hardware and control software.
Perform subcomponent testing of prototypes and verify model predictions for their performance.
Perform model-based simulation of integrated systems for vehicle-level performance prediction across operating duty cycles.
Define expected hardware performance in-vehicle.
Start laboratory-based, integrated system testing.


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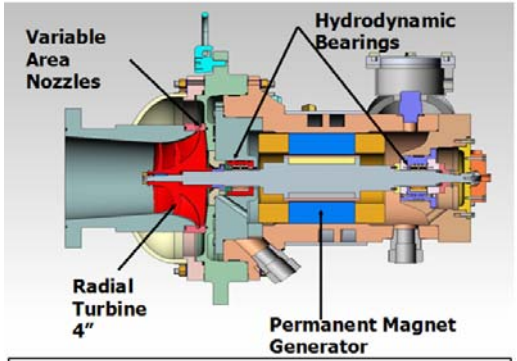


Waste Heat Recovery Turbine/Generator

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|---|---|---|---|---|---|
| 18625 / 13908 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-11 |

# High CR, Atkinson-Cycle Engine Using Low-Pressure DI and Pneumatic EVA Enabled by Ionization Current and Forward-Backward Mass Air Flow Sensor Feedback (MSU Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

The objective of this project is to integrate and demonstrate a number of advanced technologies for high efficiency clean combustion targeted to achieve an in-vehicle fuel economy improvement of 20% over baseline port fuel-injected gasoline engines currently in production. The proposed engine concept employs a high-compression-ratio, modified Atkinson combustion cycle that uses low-pressure direct injection system and electronically-controlled pneumatic valve actuation which are enhanced and enabled by combustion sensing ionization feed-back control for knock and combustion stability control and a forward-backward mass air flow sensor system for precise air-fuel ratio control. The concepts will be tested in a single-cylinder engine.

## Current FY Focus

Variable valve timing and controls will be of particular interest in 2007, as will integration of the knock and ionization detection system. The Atkinson Cycle – Enabled by Variable Valve Timing Project will be completed in 2007. It is planned to finalizing the firing optical piston design. The metal engine version is nearly complete with only the intake manifold fabrication remaining.

**Duration** 7/1/2005 through 6/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $200K FY06 = $252K / $252K FY07 = $221K / $221K

## Accomplishments

Demonstration of Motored Optical Engine
Demonstration of Fired Optical Engine
Presentation of high-speed imagery and Molecular Tagging Velocimetry (MTV) results from both Motored and Fired Optical Engines, and technical assessment of these results
Presentation of Computational Fluid Dynamics (CFD) modeling results compared with high-speed imagery and Molecular Tagging Velocimetry (MTV) data
Presentation of results from testing and demonstration of Electronically-controlled Pneumatic Valve Actuation (EPVA) system installed on Fired and Motored Engine cylinder heads
Presentation of results from testing and demonstration of Forward-Backward Mass Air Flow Sensor (FBMAFS) at both a bench-scale and integrated into a completed engine management system

## Significant Future Milestones

The overall goal of this project is to demonstrate a running HECC single cylinder engine that exhibits an average of 15% increase in fuel economy over a broad range of operating conditions, with the same or improved performance as compared to an equivalent PFI production engine.


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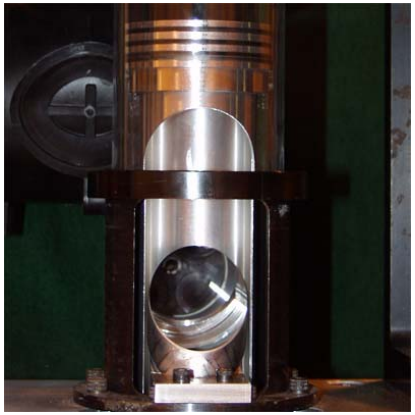

# Low Temperature Combustion Demonstrator for High Efficiency Clean Combustion

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop an engine with an application of Homogeneous Charge Compression Ignition (HCCI), which possesses conventional power density, the ability to operate in HCCI mode over transient emissions cycles, is compatible with current emissions control devices, meets US10 emissions, and provides a 10% fuel efficiency improvement when compared to current technology.

## Current FY Focus

Phase II of project consists of procurement and demonstration of functionality of individual components on the engine designed in Phase I. The engine, based on the ITEC 6.4L V8 platform was redesigned to support a low-temperature or homogeneous charge compression ignition (HCCI) combustion mode for high efficiency and low emissions targeting 2010 federal emission standards using standard diesel fuel. The engine is designed to operate in HCCI mode up to 12.6 bar brake mean effective pressure (BMEP).

**Duration** 9/23/2005 through 2/28/2009

**Gov't Funding/Industry Cost Share**

FY05 = $1190K / $1190K FY06 = $1050K / $1050K FY07 = $850K / $850K

## Accomplishments

The key technologies implemented and function tested to date consists of engine build items: A custom charge air cooler (CAC) and intake heater bypass system. Three sets of new injector nozzles providing better atomization and mixing. Piston with a reduced compression ratio. An injector bench test unit and calibration procedure used to validate new injector drivers and map injector characteristics prior to engine installation. Control system development items including: Stand alone processor, with crank angle based data acquisition was implemented with flexible control over custom injector drivers. Software was developed to provide combustion diagnostics based on cylinder pressure feedback control, allowing for control over start of combustion and torque. The control system has control over EGR, VNT and CAC/ intake heater bypass.

## Significant Future Milestones

Commission control system on engine. Engine controls will include FIE and VVA hardware with cylinder pressure feedback software. Controls are to run stable under steady-state conditions.
Demonstration of 2010 emissions targets at target engine rating. Conduct engine testing under steady-state at target points.


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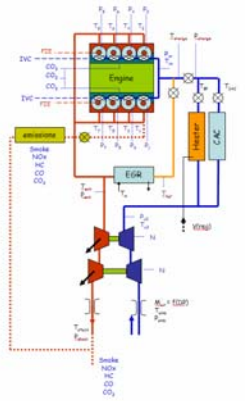


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| 19042 / 14716 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-13 |

# Low-Cost Fast-Response Actuator for Variable Compression Ratio Engines (VCR Actuator)

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Demonstrate through prototype development and testing a VCR actuator system having a fast cycle-resolved response for spark-ignition (SI), diesel (CDI) and homogenous charge compression ignition (HCCI) engines; reliability as required for mass production; low cost; and low parasitic power consumption on the engine.

## Current FY Focus

Phase II will focus on demonstrating a fast cycle-resolved response; reliability; low cost; and minimal parasitic power load on the engine to drive the actuator system. Operation of the actuator system should be imperceptible to the driver.

**Duration** 9/30/2005 through 8/31/2008

**Gov't Funding/Industry Cost Share**

FY05 = $120K / $36K FY06 = $47K / $14K FY07 = $300K / $338K

## Accomplishments

Hydraulic pressure requirements were greatly reduced by work performed under the contract. Pressure requirements were reduced by 86% to an estimated 314 psi. The reduction in pressure significantly relaxes the demands that will be placed on the hydraulic system.

## Significant Future Milestones

In Phase II an optimized actuator system will be built and installed in a mule vehicle for testing. Objectives of Phase II include demonstrating a fast cycle-resolved response; reliability; low cost; and minimal parasitic power load on the engine to drive the actuator system.


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**Partners** Envera

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| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
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| 18623 / 14724 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-14 |

# NOx Control and Measurement Technology for Heavy-Duty Diesel Engines (CRADA with Cummins)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Develop efficient diesel-engine systems with improved emissions characteristics.
- Improve efficiency and control of engine-catalyst systems
- Reduce barriers to diesel market penetration

## Current FY Focus

- Develop analytical techniques to quantify oil dilution
- Characterize effects of degrading mechanisms on specific catalyst reactions.

**Duration** 9/30/1998 through

**Gov't Funding/Industry Cost Share**

FY05 = $475K / $550K FY06 = $390K / $500K FY07 = $450K / $K

## Accomplishments

- Characterized nature of LNT-catalyst regeneration via CO and impact of the WGS reaction.
- Assessed effectiveness of specific regeneration strategies.
- Characterized fuel effects on engine-managed reductant generation.
- Developed unique analytical tools for providing unprecedented detail of catalyst chemistry.

## Significant Future Milestones

- Characterize catalyst degradation effects and pathways


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**Partners** ORNL, Cummins

**Congressional Information** Tennessee 3rd
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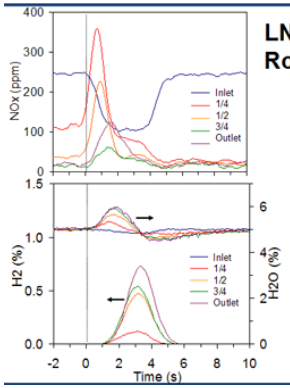


**LNT Regeneration with CO and Role of the Water-Gas Shift Reaction**

NOx Release occurs:
- at regen inception
- on timescale similar to oxidation
- at catalyst front

WGSR Produced Hydrogen occurs:
- late in regen
- in back ¾ of catalyst

CO appears to regen LNT directly

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
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| 18621 / 10030 | Advanced Combustion | Applied Research | DOE | 7/13/2006 | A-15 |

# On-Board Engine Exhaust Particulate Matter Sensor for HCCI and Conventional Diesel Engines (UTA Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Refine and complete development of an on-board particulate matter sensor, bringing it to a point where it can be commercialized and marketed. This novel particulate matter sensor concept will detect and quantify the carbonaceous fraction of particulate matter emissions in engine exhaust, with millisecond response time. The developed sensor will enable new diagnostic techniques to control the engine-out particulate emissions, control regeneration of the diesel particulate filter (DPF), and/or signal failure of the DPF.

## Current FY Focus

Phase 1 will focus on demonstrating that either of the methods for compensating the velocity dependence of the sensor signal yields a PM sensor system that is accurate and durable.

**Duration** 10/2/2006 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $15K / $11K FY07 = $123K / $97K

## Accomplishments

New project start for FY2007.

## Significant Future Milestones

In Phase 1 a single-cylinder diesel engine will be used to evaluate two methods to account for the velocity dependence of the PM sensor signal. The first will use an external by-pass circuit that maintains a constant flow velocity past the sensor, which is independent of engine operating conditions. The second uses a pitot tube type velocity probe in the exhaust to measure exhaust velocity. The use of the measured velocity in an available correlation function will be examined in both methods. Filter measurements of particulate mass emissions are used as a reference standard. Phase 1 shall demonstrate that either of the methods for compensating the velocity dependence of the sensor signal yields a PM sensor system that is accurate and durable. This means that the accuracy, as determined by comparison with filter measurements, is comparable to our previous measurements of approximately +/- 20% when tested in the single cylinder engine over a range of flow velocities. Durability should be such that it should not experience failure and maintain its accuracy for at least 1000 hours of run time without maintenance.


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**Partners** University of Texas at Austin, Cummins Inc.

**Congressional Information** Texas 10th
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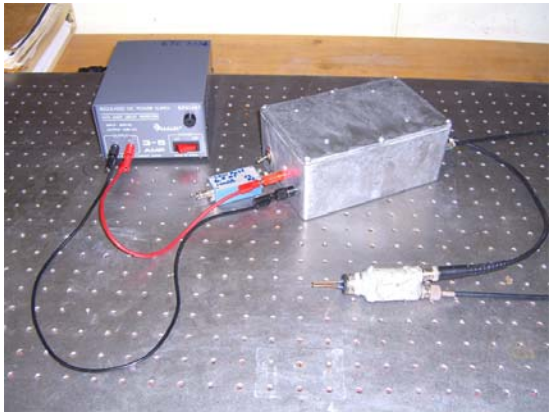

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| 18623 / 15940 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-16 |

# Precompetitive Catalysis: Sulfur and Thermal Deactivation Effects on Transient LNT Chemistry, Capacity and Regeneration

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Develop a fundamental understanding of deactivation mechanisms
- Form of sulfur groups and their formation rates and stability
- De-S temperature and its products
- Dependence on levels and temperature of sulfation/desulfation

## Current FY Focus

- Determine what sites sulfur impacts and its dependence on temperature and sulfation level
- Focus on using low levels of sulfur for model catalyst evaluation

**Duration** 9/30/2002 through

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $K FY06 = $175K / $K FY07 = $175K / $K

## Accomplishments

- Identified three sulfate forms on LNT: forms converge to one stable sulfate with time or mild heating; stable sulfate has largest impact on nitrate storage; unstable forms not shown to desulfate at lower temperatures
- Demonstrated initial sulfates only impact conversion at 400C; total capacity impacted at 200, 300 and 400C; sulfates do not INITIALLY block fast storage sites at 200 and 300C

## Significant Future Milestones

- Verify sulfates form near Pt then migrate during rich phase
- Correlate sulfate species to desulfation temp. and products


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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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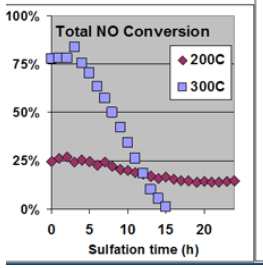
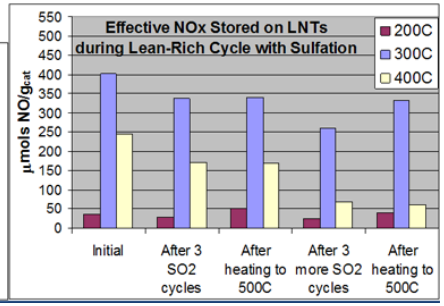
DOE275 FINAL

**Sulfation at 200 & 300C does not Initially Impact $NO_x$ Conv.**

- Sulfates migrate to less active sites; once those are full, conversion drops
- 400C initially affected



# Real-Time Control of Diesel Combustion Quality (CRADA with DDC)

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Investigate pathways for achieving high efficiency clean combustion (HECC) for 2010 and beyond heavy-duty diesel engines, emphasizing advanced control approaches.

## Current FY Focus

- Install prototype 2007 and 2008 DDC Series 60 engines at ORNL.
- Explore boundaries of HECC operation.
- Down select potential on-board sensor technologies for inclusion in future experiments.

**Duration** 10/1/2003 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $K FY06 = $0K / $375K FY07 = $K / $K

## Accomplishments

- Installation of 2007 engine is complete.
- Installation of 2008 engine is ongoing. Engine is expected to be operational by the end of this FY.
- Initial exploratory experiments have been performed on the 2007 engine to identify and characterize potential regions of HECC operation.

## Significant Future Milestones

- Finalize installation of 2008 engine and advanced controller.
- Initiate mapping of HECC boundaries on 2008 engine.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Craig Savonen, Detroit Diesel Corporation
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**Partners** ORNL, DDC

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Kevin Stork, U.S. Department of Energy
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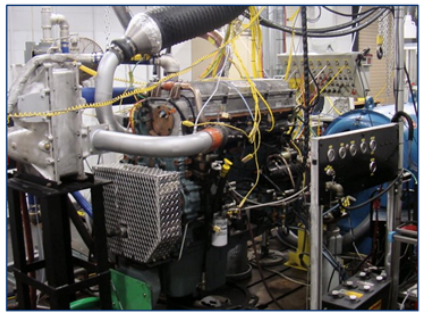
DOE254 FINAL

### 2007 Prototype DDC Series 60 Engine at ORNL

- Advanced engine controls.
- Performance measurements.
- In-cylinder pressure measurements and combustion analysis.
- Advanced exhaust characterization capabilities for gaseous & particulate emissions.



# Stretch Efficiency -- Thermodynamic Analysis of New Combustion Regimes

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Research and identify advanced approaches to combustion engines with the potential to achieve 60% efficiency, emphasizing mitigation of inherent combustion losses

## Current FY Focus

- Analyzed several scenarios for their impact on combustion irreversibilities including rates of heat release, EGR, and preheating.

**Duration** 9/30/2004 through

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $K FY06 = $185K / $K FY07 = $250K / $K

## Accomplishments

- Close collaboration with University of Wisconsin and Texas A&M to define theoretical limits of ICE engine efficiency
- Multiple publications and presentations on: identification of key ICE efficiency losses; comparison of losses for HCCI vs. conventional SI combustion; assessment of preheating, phased work extraction, EGR for reducing irreversibility; clarification of limits for utilizing ICE combustion irreversibility

## Significant Future Milestones

- Identification of potential realistic efficiency benefits for ICE cycle compounding and combustion staging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Ron Graves, Oak Ridge National Laboratory
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**Partners** ORNL, University of Wisconsin, Texas A&M

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Gurpreet Singh, U.S. Department of Energy
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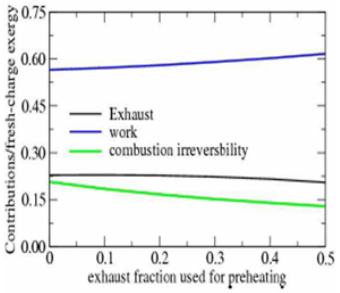
DOE255 FINAL

**Example theoretical availability analysis for advanced engine concept with constant volume preheating**




- Reduced combustion irreversibility
- Slightly increased piston work
- Slight reduction in exhaust losses
- Indicates in-cylinder heat recovery is possible option for improved efficiency

# The Development of a Robust Accelerometer-Based Start of Combustion Sensing System (Westport Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Complete the development of a robust accelerometer-based SOC combustion sensing system. Specifically, techniques to deal with lack-of-robustness will be developed. The work is divided into three distinct phases. The phases will cover engine to engine variation, sensor to sensor variation, and the final phase will demonstrate the accelerometer-based SOC measurement system in a test cell.

## Current FY Focus

The primary focus in the first year of the project work is to develop engine to engine compensation methods to allow the system to be implemented on engines of the same family and displacement but with different engine blocks and accessories. Once the concept is proven to work from engine to engine, the work will shift toward a focus of reducing the sensor to sensor variation.

**Duration** 9/30/2006 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $15K / $14K FY07 = $215K / $196K

## Accomplishments

New project start for FY2007.

## Significant Future Milestones

The focus of this project is to complete the development of a robust accelerometer-based SOC combustion sensing system. Specifically, techniques to deal with lack-of-robustness will be developed. In the first phase of work, methods will be developed to compensate for engine-to-engine variation. The main tasks in the first stage are to identify the critical parameters that influence engine-to-engine variation in the accelerometer sensor signal, develop engine-to-engine compensation techniques, using data collected from two engine configurations, and verify on paper that the robustness compensation techniques will meet performance requirements.


**Principal Investigator** Richard Ancimer, Westport Power Inc.
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**Partners** Westport Power Inc.

**Congressional Information** N/A (Canada)
N/A


**Technical Development Manager/Project Manager** Roland Gravel, U.S. Department of Energy
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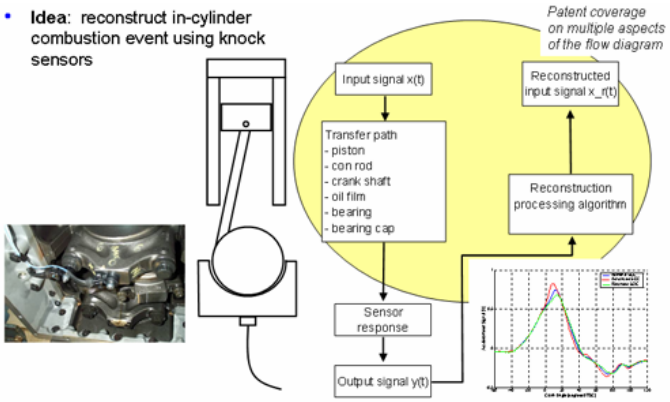
DOE377 FINAL

- **Idea**: reconstruct in-cylinder combustion event using knock sensors




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18623 / 15941 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-20 |

# Variable Valve Actuation (Delphi Project)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

The objective of this project is to develop and demonstrate an optimal, cost effective diesel Variable Valve Actuation (VVA) system for advanced, low temperature combustion processes. Flexible control of the valve event is a significant enabler for advanced mode diesel combustion (AMDC.) VVA is expected to enable expansion of the operating load and speed range of the AMDC and enhance effectiveness of the aftertreatment catalysts. A viable VVA technology is expected to reduce the penalty in fuel consumption related to extremely low emission standards.

## Current FY Focus

Phase II activities: The selected variable valve actuation system will undergo a detailed analysis and the VVA system design will be finalized. A candidate single cylinder engine representative of typical operating environments will be identified for integration of the selected VVA technology. Alternatively, a multi-cylinder test platform may be utilized for integration. Prototype VVA system validation shall be performed in the virtual lab (simulation) and on a motored VVA validation fixture. Limited engine verification testing may be performed if existing funding permits.

**Duration** 9/7/2005 through 8/16/2008

**Gov't Funding/Industry Cost Share**

FY05 = $230K / $77K FY06 = $134K / $45K FY07 = $210K / $257K

## Accomplishments

The required valve lift and actuation requirements have been determined in conjunction with work performed by an OEM.

Four candidate valve actuation systems were identified and a selection made for the optimal variable valve actuation device. The VVA was selected based on performance, packaging, manufacturability, and control flexibility.

## Significant Future Milestones

Perform detailed analysis and finalize the VVA system design.

The VVA system will be validated in the virtual lab and in a single cylinder test platform.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**Partners** Delphi Automotive Systems

**Congressional Information** Michigan 9th
Joe Knollenberg

**Technical Development Manager/Project Manager** Roland Gravel, U.S. Department of Energy
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Jason Conley, National Energy Technology Laboratory
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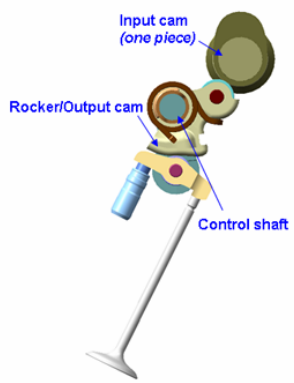
DOE372 FINAL



# ANL-NOx Sensor Development

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop a fast-response low-cost Nox sensor based on ion-mobility measurement for heavy-vehicle combustion and emission control. (CRADA with Cummins)

## Current FY Focus

- Evaluate the sensor performance in an exhaust line of a single diesel engine combustion system.

**Duration** 2/1/2005 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $139K / $K FY06 = $25K / $5K FY07 = $K / $K

## Accomplishments

- Conducted laboratory tests to evaluate sensor performance in high moisture environment
- Conducted laboratory tests to evaluate the temperature effect on sensor performance

## Significant Future Milestones

- Complete sensor tests in an actual exhaust line environment
- Determine the go/no-go decision


**Principal Investigator** Shuh-Haw Sheen, Argonne National Laboratory
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**Partners** ANL

**Congressional Information** Illinois 13th
Judy Biggert


**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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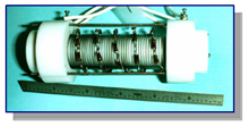
DOE118 FINAL-R1

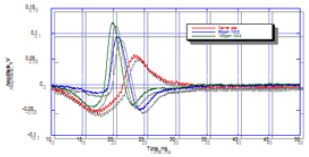
### Laboratory Prototype

- Needle-plate spark-discharge ionization source
- Withstands extreme conditions (i.e., corrosive environments, high temperature and pressure)
- PPM sensitivity with wide dynamic

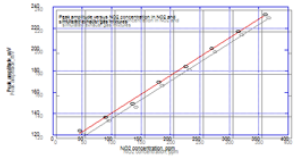


### Laboratory Test Results

Typical Negative Ion Spectra



Peak Amplitude versus $NO_2$ Concentration



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18497 / 11514/17817 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Applied Research | DOE | 1/23/2007 | A-22 |

# Advanced Machining and Sensor Concepts

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Investigate new Ti machining technologies to increase the productivity and reduce the cost of component fabrication

## Current FY Focus

High speed drilling (over 180 m/min) technique to increase the hole making productivity, new TiC-Ni3Al tool material, and finite element chip and tool thermal modeling

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $K FY06 = $57K / $K FY07 = $K / $K

## Accomplishments

1.High speed drilling of Ti-6Al-4V exceeding 180 m/min cutting speed demonstrated (0.5 s to penetrate a 6.35 plate). (July 2005)2.Finite element modeling of Ti turning validated with experiments and accurate prediction of drilling temperature achieved (July, 2005).

## Significant Future Milestones

BorgWarner Turbo Ti compressor wheel drilling (Sep 2006)
Drilling and turning process modeling and tool design (Sep 2007)


**Principal Investigator** Albert Shih, University of Michigan
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**Partners** University of Michigan

**Congressional Information** Michigan 15th
John Dingell

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE061 FINAL

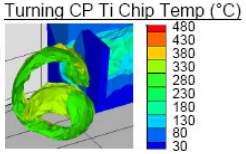
**Comparison of drilling speed (m/min)** (* Machining Data Handbook, Metcut Research Associates, Inc.)

| Drill | Al Alloys | Cast Iron | Ti-6Al-4V |
|---|---|---|---|
| HSS standard* | 43~105 | 27~49 | 9 |
| Carbide standard* | 245 | 60~90 | 46 |
| This Study: Carbide Spiral | | | 183 |

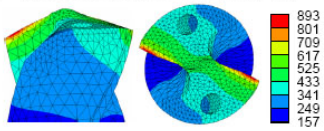
Comparison -- High speed turning and milling of Al alloys 600~4500 m/min.

**Sample FEM Machining Modeling**

Turning CP Ti Chip Temp (°C)




Drilling of Ti-6Al-4V tool temp (°C)

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|---|---|---|---|---|---|
| 18521 / PM 9278 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 8/15/2005 | A-23 |

# Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

This ORNL/CAT CRADA has been focused on commercialization of the new CF8C-Plus cast austenitic stainless steel to replace SiMo cast iron for advanced diesel exhaust manifolds and turbochargers. This is necessary to increase engine-out temperatures to improve engine efficiency.

## Current FY Focus

Caterpillar is focused on upgrading turbochargers from cast ironto cast stainless. Direct comparison of CF8C-Plus (MetalTek) and KN2 (Diado) stainless steels is in progress at ORNL to support turbo supplier needs.

**Duration** 10/1/2001 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $160K / $160K FY06 = $190K / $190K FY07 = $185K / $185K

## Accomplishments

- R&D 100 Award for developing CF8C-Plus, 2003.
- Creep strength, fatigue and aging resistance prove CF8C-Plus stainless is far superior to SiMocast iron >600oC; CF8C-Plus and KN2 stainless are being directly compared for turbocharger casing application.
- MetalTekInternational cast a 6,700 lb gas-turbine end-cover of CF8C-Plus steel, and now has melted >10,000 lb for various commercial applications.

## Significant Future Milestones

Complete creep testing of new CF8C-Plus Cu/W for more strength >800oC, (Feb., 2006)
Test properties of prototype components made of CF8C-Plus or –Plus Cu/W in support of diesel exhaust components, or other parts made by trial-licensee foundries for commercial applications.


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Mike Pollard, Caterpillar Inc.
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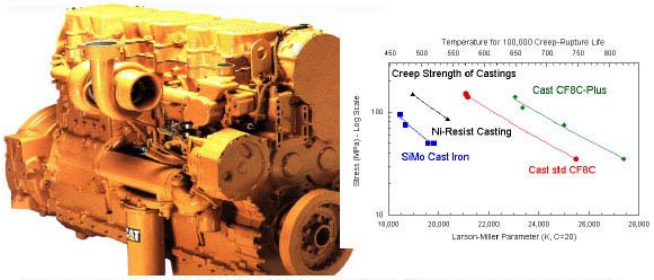
**Partners** ORNL, Caterpillar

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
(202) 586-9837, james.eberhardt@ee.doe.gov


DOE023 FINAL




Creep strength at 600-850°C makes CF8C-Plus stainless a dramatic upgrade from SiMo cast iron for thin-walled exhaust manifolds and turbocharger casings

# Catalyst Characterization

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop highly efficient catalyst devices capable of meeting EPA regulations with a minimal negative impact on fuel efficiency. Developing tools for state of the art characterization on diesel catalysts, both from reactor and engine testing, allowing validation of testing techniques.

## Current FY Focus

Measurement & characterization of the surface features of diesel catalysts, including correlating these attributes directly to fuel economy measurements.

**Duration** 10/1/2002 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $200K FY06 = $172K / $K FY07 = $220K / $K

## Accomplishments

- Characterized the size and location of light elements on the catalyst surface that had previously not been observed (9/04).
- Measured the particle size and distribution of Pt on the surface of the catalyst non-destructively with Raman and X-ray diffraction and correlated the measurements to TEM data (9/03).

## Significant Future Milestones

Characterization of the active elements on the surface of a engine aged catalyst as a function of time to quantify the degradation mechanisms and allow direct comparison of washcoats. (9-06)


**Principal Investigator** Thomas Watkins, Oak Ridge National Laboratory
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Roger England, Cummins Inc.
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**Partners** ORNL, Cummins

**Congressional Information** Tennessee 3rd
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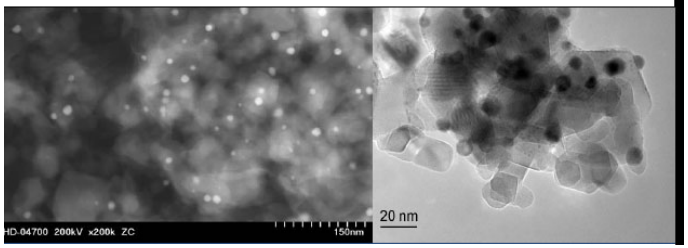
DOE026 FINAL

**TEM** allows resolution of particles of specific active elements and provides size & distribution statistics, which have been directly correlated to X-ray diffraction and Raman measurements.

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|---|---|---|---|---|---|
| 18519 / PM 9130 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-25 |

# Catalyst via First Principles

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop highly efficient catalyst devices capable of meeting EPA regulations with a minimal negative impact on fuel efficiency. Task goal is to demonstrate that we can examine "computationally complex but experimentally simple" system by both first principle theoretical models and experimental work to forecast improvements to obtain optimum catalyst systems

## Current FY Focus

Our focus has been on the computational and experimental study of supported Pt and Re clusters. The theoretical efforts, which are based on the Density Functional Theory (DFT), have so far been focused on the oxidation behavior of Pt nanoclusters. The experimental studies have been focused on synthesis and characterization of Pt and Re nano catalyst systems.

**Duration** 10/1/2004 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $300K / $K FY06 = $242K / $K FY07 = $195K / $K

## Accomplishments

- We have synthesized computationally complex but experimentally simple Pt and Re nanoclusters, carbonylated Re clusters, and decarbonylated Re clusters on commercial alumina.
- We have also synthesized sol-gel and mesoporous molecular sieve alumina. We are using these supports to synthesize carbonylated, decarbonylated, and nanoclusters of Pt and Re to understand the impact of substrate morphology by computational and experimental methods.
- We have completed theoretical studies of oxidation behavior of Pt nano-clusters.

## Significant Future Milestones

- Complete the synthesis of carbonylated, decarbonylated, and nanoclusters of Pt and Re using sol-gel and mesoporous molecular sieve as support materials. Evaluate these catalysts for their CO, Nox, and hydrocarbon oxidation efficiency (9-06). Synthesized catalysts based on insights from theoretical models (9/07) .
- Use experimentally observed structures as input for theoretical models of Pt or Re clusters on alumina (9-06). Investigate the adsorption of several atomic and molecular species relevant to CO oxidation, including O, O2, CO, and CO2, on the Pt and Pt oxide nanoclusters (9-07)


**Principal Investigator** Chaitanya Narula, Oak Ridge National Laboratory
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W. Shelton, ORNL/B.C. Gates, UC Davis/W. Schneider, Univ. Notre Dame (formerly Ford)

**Partners** ORNL, University of California-Davis, Notre Dame

**Congressional Information** Tennessee 3rd
Zach Wamp

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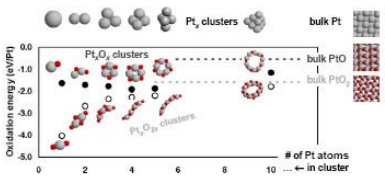
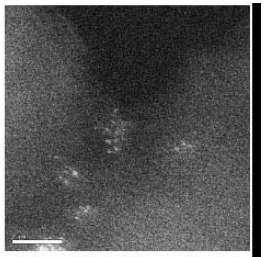



Oxidation energies of the $Pt_xO_x$ (filled circles) and $Pt_xO_{2x}$ (open circles) clusters. In stick-and-ball representations red spheres represent O atoms, and grey spheres represent Pt atoms.



ACEM HAADF-STEM image of 2% Pt/$\gamma$-$Al_2O_3$. Pt atoms in Pt-nanoclusters can be seen.

# Characterization of Catalyst Microstructures and Deactivation Mechanisms

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop highly efficient catalyst devices capable of meeting EPA regulations with a minimal negative impact on fuel efficiency. Task goal is to utilize ultra-high resolution imaging and spectroscopy capabilities of the ORNL aberration-corrected electron microscope (ACEM) to characterize "real"and "model"diesel and automotive catalyst systems to better understand mechanisms controlling aging and poisoning behavior of exhaust emission reduction catalyst materials.

## Current FY Focus

Study model metal cluster systems of known cluster size on oxidesupports to develop capability to reliably characterize our experimental andreal catalysts at sub-Angstrom resolutions. Use ACEM to characterize series of real-world catalysts (supplied by Ford Research Lab) to determine aging behavior mechanisms.

**Duration** 10/1/2004 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $190K / $K FY06 = $156K / $K FY07 = $200K / $K

## Accomplishments

- ORNL ACEM installed and demonstrated using model heavy metal cluster system to provide sub-Ångstrom imaging that allowed confirmation of presence of clusters containing 3 metal atoms in triangular configuration.
- Studies of real-world Lean NOx trap and diesel particulate NOx-reduction catalysts with ACEM confirmed atomic-level dispersions of Pt on baria-alumina-magnesia and ceria-zirconia components in washcoats, and allowed further characterization of these materials as a result of agingtreatments.

## Significant Future Milestones

Using ACEM imaging capabilities, unambiguously characterize for the first time the morphology of one or more nanometer or sub-nanometer metal particles in model catalyst system, and use the capability thus developed in the characterization of nano-dispersed catalyst particles in real automotive and diesel exhaust catalyst systems, to better understand aging mechanisms. (September, 2007)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**Partners** ORNL

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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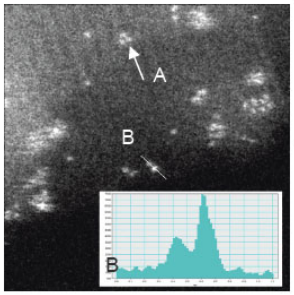
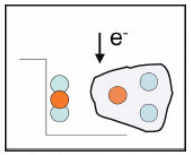
DOE021 FINAL




Cartoon showing arrangement of atoms in "dimer" B.

A: Tri-Re cluster seen in top view.
B: "Dimer" is actually a tri-Re cluster anchored to a ledge on the alumina, and imaged edge-on. Inset intensity profile confirms twice the intensity for lower "atom," indicating presence of 2 atoms.

**ACEM annular dark-field image of tri-rhenium carbonyl clusters on γ-alumina support material.**

# Deformation in Ceramics

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Develop processing technology for producing dense, nanocrystalline ceramics in bulk and coating forms.
- Optimize nanocrystalline ceramics for applications in both advanced sensor and wear-resistant applications.

## Current FY Focus

- Develop processing technology for thin bodies and coatings
- Explore feasibility of more conventional powder processing methodologies for fabricating nanocrystalline ceramics.

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $95K / $K FY06 = $82K / $K FY07 = $K / $K

## Accomplishments

- Demonstrated feasibility of fabricating thin components of dense zirconia with < 60 nm grain sizes.
- Developed powder processing based on granulation technology, which is more robust and more amenable to commercial production.

## Significant Future Milestones

Complete initial optimization of fabrication of dense nanocrystalline ceramics using granulation technology.(December 2005).
<Project now completed 2006>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James Adair, Pennsylvania State University
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**Partners** ORNL, Penn State

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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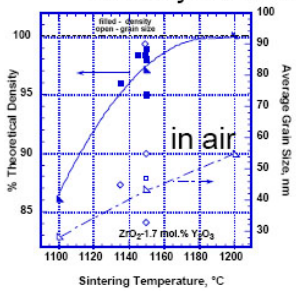
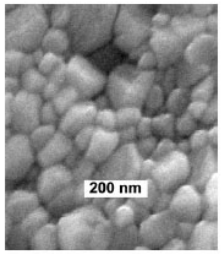
DOE064 FINAL

Combination of novel pressure-less sintering and colloidal processing approaches yield dense, nanocrystalline zirconia ceramics



# Durability of Diesel Engine Materials

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Quantify, model, and prevent surface damage in diesel engine components like EGR valve actuators and fuel injector plungers that must operate in low S fuels.

## Current FY Focus

Test the durability of advanced materials and surface treatments, and develop a multi-stage model for the initiation and propagation of scuffing in fuel injectors.

**Duration** 10/1/2001 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $180K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Applied thermal oxidation to greatly reduce the wear of titanium alloys for use in diesel engine components. (3/2005)
- Based on test data, developed a multi-stage scuffing model that includes the role of surface finish and lubricant films in the localized initiation and propagation of surface damage. (9/2005)

## Significant Future Milestones

Project will be completed in FY 2005. Planned follow-on effort to enhance energy-efficiency of valve train components (valve seats and guides) through the use of advanced materials.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J. Qu (ORNL) and J.J. Truhan (UT)

**Partners** ORNL, University of Tennessee

**Congressional Information** Tennessee 3rd
Zach Wamp

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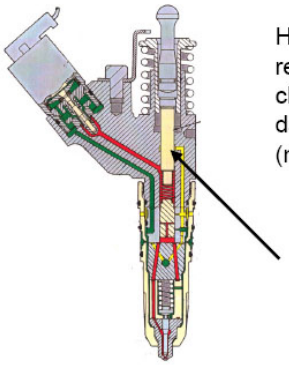


High-performance fuel injectors require precise plunger-bore clearances (cannot tolerate scuffing damage) and must avoid seizure (maintain low sliding friction).

*Courtesy of Cummins Engine Co.*

# Durability of Particulate Filters

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop highly efficient catalyst devices capable of meeting EPA regulations with a minimal negative impact on fuel efficiency. Minimize fuel consumption required for regeneration of particulate filters by determining the effect of regeneration imposed thermal stresses on ceramic filter life.

## Current FY Focus

Understand the critical material properties for life prediction and determining the stresses induced in porous cellular ceramics during operation.

**Duration** 10/1/2002 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $300K / $300K FY06 = $250K / $250K FY07 = $320K / $320K

## Accomplishments

- NASA CARES Life Model implemented at Cummins.
- Cordierite material properties determined independent of cellular structure.
- Impact of environment on material strength and crack growth rates was established.

## Significant Future Milestones

- Collect filter thermal fatigue data to validate thermal and structural life models. (9-06)
- Refine Life Prediction methodology for porous cellular ceramics. (9-06)
- Quantify growth rate of radial cracks in DPFs subjected to an arbitrary loading schedule. (3-07)


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**Partners** ORNL, Cummins

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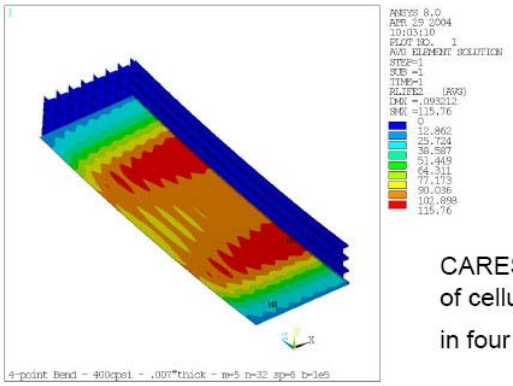


CARES Model
of cellular ceramic
in four point flexure

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18519 / PM 10461 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-30 |

# Engineered Surfaces for Diesel Engine Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop high density, low thermal conductivity metallic coatings based on amorphous steels and quasicrystal materials for use asthermal barrier coatings in HCCI engine designs.

## Current FY Focus

Develop coating properties and spray parameters for coating of engine components

**Duration** 10/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $75K FY06 = $30K / $K FY07 = $0K / $K

## Accomplishments

- Initial diffusion study of quasicrystal coatings shows capability to operate at expected engine temperatures.
- Thermal conductivity of amorphous steel coating shown to be stable at expected engine temperatures.
- Spray parameters to coat initial piston design for single cylinder engine test has been completed.

## Significant Future Milestones

Demonstration of initial engine durability of amorphous steel coating to be completed by end of FY 2005


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**Partners**

**Congressional Information** Illinois 18th
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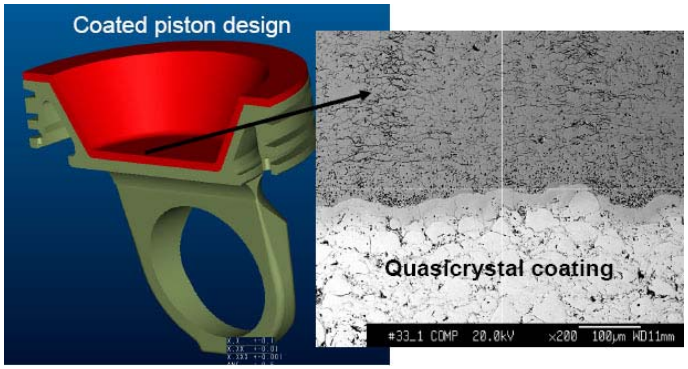

# Evaluation of Materials via ACERT Engine

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

The ACERT Engine provides a state-of-the-art computer controlled evaluation platform for advanced components utilizing advanced materials and new combustion regimes for improved engine performance and efficiency. (CRADA with Caterpillar). Improve efficiency by reducing parasitic, frictional, and thermal losses utilizing advanced materials. Improve combustion efficiency

## Current FY Focus

Install 2007 ACERT engine and perform baseline experiments.
Investigate the influence lightweight-fast response turbocharger and valvetrain systems.

**Duration** 10/1/2006 through

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $300K / $300K

## Accomplishments

Caterpillar has delivered a C15 ACERT engine and 600HP dynamometer for installation at ORNL
A test cell has been procured for dynamometer and engine installation

## Significant Future Milestones

Complete engine installation and complete base lining activities. 9/2007
Evaluation of combustion performance associated with materials changes.
Improvements in engine efficiency and transient response associated with advanced turbocharger systems and materials
Achieve efficiency improvements through reductions in parasitic and thermal losses via lightweight materials
Significant recovery of exhaust thermal energy

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**Partners** ORNL, Caterpillar

**Congressional Information** Tennessee 3rd
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DOE359 FINAL

**Delivered:**
- 2004 C15 ACERT engine (shown)
- 600HP Motoring
- Dynamometer

**Awaiting:**
- Open controller
- 2007 ACERT

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
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| 18518 / 15050 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-32 |

# Fabrication of Small Diesel Fuel Injector Orifices

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop micro-orifice fuel injector fabrication processes to improve fuel atomization leading to improved combustion, better efficiency, and reduced in-cylinder formation of diesel particulates/emissions. Electroless Ni and proprietary vapor deposition coating processes are being developed to uniformly coat the inner surfaces of production nozzles to reduce the orifice size from 200 µm to 50 µm. Demonstrate improvements in fuel efficiency and emissions with flow visualization and engine tests

## Current FY Focus

Fabrication of micro-orifice nozzles for flow visualization and engine emission studies. Non-destructive characterization of Ni coatings applied to commercial injectors, and investigations of fuel deposit formation on steel and electroless nickel coatings.

**Duration** 10/1/2006 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $250K / $28K FY07 = $250K / $62K

## Accomplishments

1. Demonstrated ability to produce adherent, uniform, smooth 50 µm Ni-P coatings on commercial heavy-duty injector orifices;
2. Developed a non-destructive x-ray imaging technique to image Ni-P coatings applied to interior surfaces of commercial nozzles;
3. Characterized superior deposit formation properties of Ni-P coatings.

## Significant Future Milestones

1. High-speed flow visualization studies of micro-orifice nozzles (ANL-APS – x-rays & US-EPA)
2. High-rate nickel vapor deposition of Ni coatings on commercial nozzles
3. Lifetime durability studies
4. Fabrication of multi-size micro-orifices to control spray penetration.


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**Partners** ANL

**Congressional Information** Illinois 13th
Judy Biggert

**Technical Development Manager/Project Manager** Rogelio Sullivan, U.S. Department of Energy
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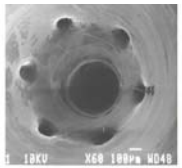
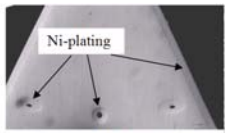
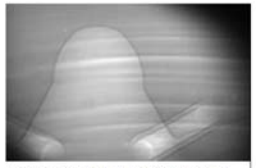





Cross-section of plated 6-orifice nozzle



Phase contrast image of Ni-coating (dark outlined regions) in the sac and orifices of a plated nozzle

# Fatigue Enhancements by Shock Peening

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

PNL will investigate improvements to fatigue performance on propulsion materials components, especially for fuel systems, cylinder heads, and engine blocks.

## Current FY Focus

PNNL and Cummins will focus on evaluating waterjet and laser shock peening as manufacturing methods to increase the fatigue performance of aluminum and steels that are used for fuel systems. PNNL will also focus on developing a modeling methodology and analytical tools to evaluate the stress fields and redistribution of these stresses before and after these low plasticity peening operations. This will involve developing NDE tools for simulating dynamic loading on parts by acoustic wave propagation and strain quantification. It is expected by Cummins and PNNL that these new tools will have applicability to other material systems within the engine, and once developed and proven, will significantly decrease development and implementation time of advanced materials and processes for future engines.

**Duration** 10/1/2006 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $300K / $300K

## Accomplishments

## Significant Future Milestones

Establish the modeling approach and create an initial version of a model to predict stress re-distribution in fuel injector components as a result of LSP processing. 9/2007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**Partners** PNNL, Cummins

**Congressional Information** Washington 4th
Doc Hastings


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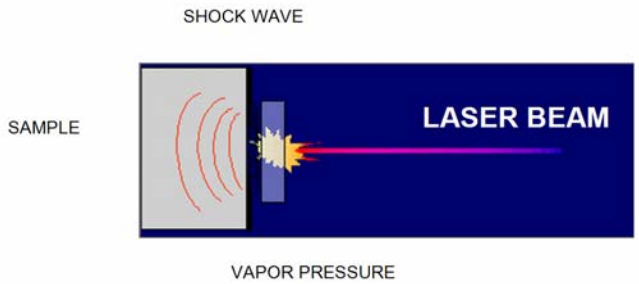


Laser Shock Peening of Sample to Improve Fatigue Life

# Friction and Wear Reduction in Diesel Engine Valve Trains

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Depending on engine design and operating conditions, between 5 and 20% of the friction losses in an internal combustion engine are attributable to rubbing between valve train components. Therefore, reduction in valve train friction can improve overall engine efficiency. The objective of this project is to develop methodology to characterize durability and help select promising new valve train materials and surface treatments for use in the next generation of fuel efficient, low-emissions diesel engines. In addition to building a high-temperature repetitive impact testing system and establishing cost-effective laboratory test methods, candidate materials and surface treatments will be investigated and their wear mechanisms will be modeled. Methods to reduce valve guide friction by surface engineering will also be investigated.

## Current FY Focus

To design and begin construction of a laboratory-scale exhaust valve materials testing system that will apply a combination of mechanical impact, high-temperature, and simulated engine gas environments. The fixture design was based on the dimensions of production diesel valves supplied by an engine manufacturer, but the apparatus will also permit testing of relatively simple coupons in order to pre-screen new materials, coatings, surface treatments.

**Duration** 10/1/2005 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $195K / $K FY07 = $130K / $K

## Accomplishments

Designed and began construction of the high-temperature, repetitive impact valve durability testing system.

## Significant Future Milestones

Complete construction of the high-temperature valve wear tester (3/07);
Complete first matrix of tests to compare traditional and advanced valve/valve seat materials at high temperature, in controlled-atmosphere, and with repetitive impact conditions. Submit report or journal article on the results. (03/07)
Complete baseline tests of current exhaust valve materials and identify primary wear mechanisms (9/07);
Prepare an analysis of the basic mechanisms that operate as valve/valve seat materials degrade in service and correlate them with basic material properties and metallurgical structure. Submit report or journal article describing the analysis. (09/07)
Develop the basis for a model that aids in the selection of materials for use in combined mechanical, thermal, and chemically-active environments. (3/08)


**Principal Investigator** Peter Blau, Oak Ridge National Laboratory
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**Partners** ORNL, Caterpillar

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE150 FINAL

**Heat-resistant specimen holder for the new high-temperature valve material testing system showing a production valve in position.**

# HDIR Surface Treatment

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Use High Density Infrared (HDI) technology to produce wear and corrosion resistant coatings on iron-based materials for heavy-duty vehicle applications.

## Current FY Focus

Coatings based on hard metal compositions applied onto iron-based parts appear to have the best potential for use in heavy-duty vehicles.

**Duration** 10/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $70K / $K FY06 = $K / $K FY07 = $0K / $K

## Accomplishments

1.Refined processing of hard metal coatings. (September 2004)
2.Demonstrated improved wear resistance for hard metal coatings on cast iron, low alloy steel and tool steel. (September 2004)

## Significant Future Milestones

Complete investigation of the relationship between processing parameters, microstructural development, and wear resistance. (September 2005)


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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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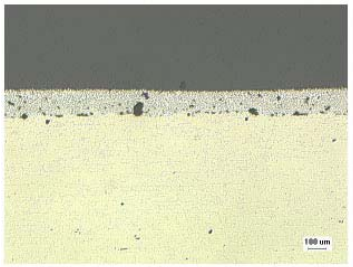
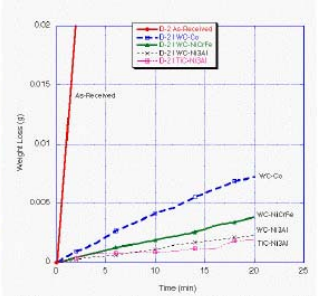


WC/$Ni_3Al$ coating on D2 tool steel




Wear resistance significantly improved

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18518 / PM 10636 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-36 |

# High Toughness Materials

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop low-cost high-toughness materials to significantly improve the durability of diesel engine fuel systems.

## Current FY Focus

Complete support effort for TiC-Ni3Al cermetcomponents for diesel fuel injection systems done in conjunction with both CoorsTek (parts producer) and Cummins Engines (engine manufacturer)

**Duration** 10/1/2001 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $95K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Developed refined processing parameters to produce TiC-Ni3Al composites from cost-effective NiAl precursors having mechanical properties sufficient for engine use. (September 2004).
- Prepared large batch of TiC-Ni3Al (~15 kg) for injection molding of armatures for large engine test. (March 2005)

## Significant Future Milestones

Complete the support effort for the TiC-Ni3Al cermetcomponents for diesel fuel injection systems that is done in conjunction with both CoorsTekand Cummins Engines. (September 2005)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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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DOE056 FINAL

Metering plungers for fuel injectors. Cermet plungers in center and two zirconia ones for comparison.

Test armatures for use in fuel injection systems. Cermets produced by injection molding and sintering.

# IEA Annex on Materials for Transportation Applications

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Promote commercialization of new materials technologies by developing standard testing and characterization methods in conjunction with national and international standards communities.

## Current FY Focus

Completed preliminary investigation of characterization techniques for assessment of contact damage and quantitative adherence measurements for ceramic coatings for wear and thermal management.

**Duration** 10/1/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $190K / $K FY06 = $127K / $K FY07 = $0K / $K

## Accomplishments

Demonstrated capability of laser shock method to initiate debondingand spallation in both metallic and ceramic coatings

## Significant Future Milestones

Develop model to predict tensile stress magnitude generated in thin coatings due to the laser shock process-June 2006


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**Partners** ORNL

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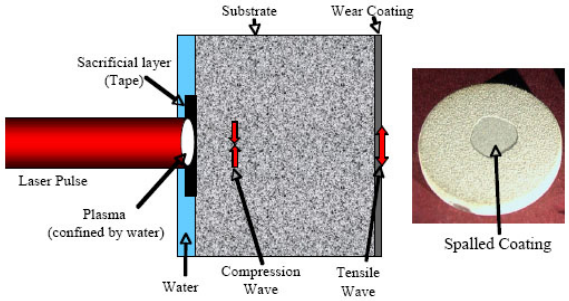


Laser Shock Method Provides for Quantitative Assessment of Coating Adherence

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|---|---|---|---|---|---|
| 18523 / PM 9098 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-38 |

# Integrated Surface Modification

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop surface texture features and patterns that will control friction and increase durability. Develop cost-effective fabrication techniques. Develop thin films to enhance/protect the textures. Develop lubricant chemistry to further increase the robustness of the surface technology.
Work with industrial partners to validate the technology. Develop a design guideline (tool chest) for various materials and application conditions

## Current FY Focus

Develop ISM processing, modeling, and validation.

**Duration** 10/1/2004 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Demonstrated size and shape effect on friction under high speed low load conditions
- Developed a low-cost lithographic-electrochemical etching technique to fabricate surface textures on metal surfaces suitable for high speed low load applications
- Developing a new texturing design based on size and built-in wedge for high load medium speed conditions

## Significant Future Milestones

Working with industrial partners to develop thin films and lubricant chemistry to demonstrate the friction reduction potential of thecombined effects ( 9-30-06)


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**Partners** NIST

**Congressional Information**


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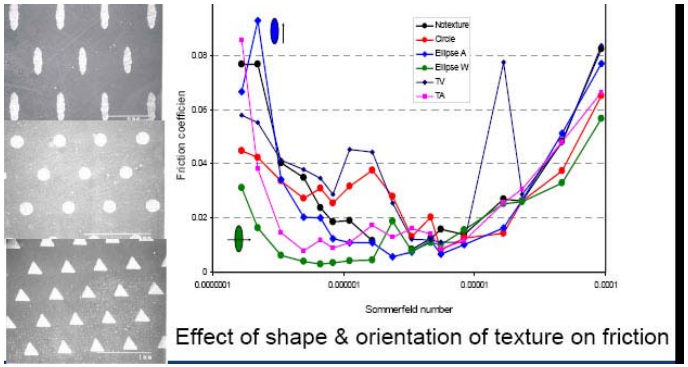


Effect of shape & orientation of texture on friction

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| 18522 / PM 9407 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-39 |

# Life Prediction for Diesel Engine Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Ceramic and advanced TiAl alloys can improve thermal management and reduce rotating mass of an engine, increasing engine efficiency by as much as 5%. This task is to perform characterization and design methodology development (life prediction) for advanced Si3N4 ceramics and TiAl alloys in order to manufacture consistent and reliable complex-shaped components for diesel engine applications.

## Current FY Focus

1) Evaluation of mechanical properties and microstructure characterization of NT551 Si3N4valves and valve stems after 500h bench rig test. 2)Mechanical database for co-processed SN235P Si3N4valve material. 3) Valve field test preparations.

**Duration** 10/1/2001 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $95K / $K FY06 = $71K / $K FY07 = $95K / $K

## Accomplishments

-Completed evaluation of mechanical properties and microstructure characterization of NT551 Si3N4 valves and valve stems after 500h bench rig test

-Completed mechanical properties validation for SN235P Si3N4 co-processed with exhaust vales in as-machined and after 1000h oil immersion test

## Significant Future Milestones

-Complete mechanical properties and microstructure characterization of SN235P valves after engine field test. Sept. 2006

-Complete stress rupture database for TiAl alloy at elevated temperatures.
Sept. 2006

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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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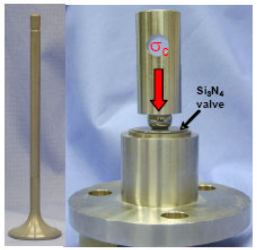


Figure 1. Photo of NT551 valve after 500h test and valve mechanical testing fixture.

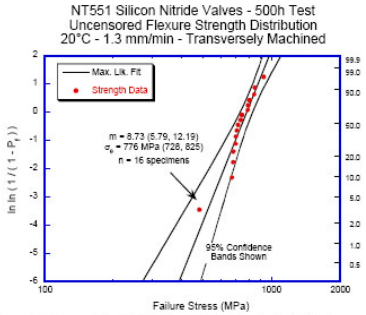


Figure 2. Strength distribution of 500h-tested Norton NT551 $Si_3N_4$ valve transversely machined and tested at 20°C

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18865 / PM 9110 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-40 |

# Lightweight Valve Train Materials (Titanium)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Ceramic and advanced TiAl alloys can improve thermal management and reduce rotating mass of an engine, increasing engine efficiency by as much as 5%. This project has two tasks: (1) Design, procure and validate heavy duty TiAl and Si3N4 valves. (2) Develop life prediction tool to assist in component design with brittle materials.

## Current FY Focus

Validation of valve performance on a Caterpillar G3406 engine platform at the National Transportation Research Center

**Duration** 10/1/2001 through 4/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $150K / $150K FY06 = $124K / $K FY07 = $175K / $K

## Accomplishments

(1) Designed and procured 12 TiAl and 45 Si3N4 heavy duty valves for G3406 engine platform –June 2005.
(2) Completed preliminary life prediction model using FEA-based NASA cares code –Jan 2005.

## Significant Future Milestones

(1) Complete G3406 engine test and evaluate performance of advanced valves (12-05)
(2) Evaluate wear performance and retained strength of engine-tested valves; correlate to probabilistic life prediction model (6-07


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**Partners** Caterpillar

**Congressional Information** Illinois 18th
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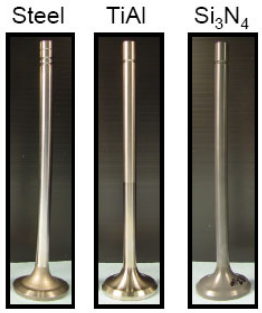


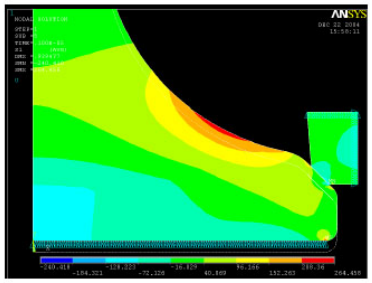


FEA-based life prediction tool development

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| 18518 / PM 9128 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-41 |

# Low Cost Manufacturing of Precision Diesel Engine Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Through experiments and modeling, advance cost-effective machining technology for diesel engine materials.

## Current FY Focus

- Participate in the Third Wave Systems (TWS) consortium to develop software for high-speed Ti machining.
- Develop new ceramic-based cutting tool materials.
- Investigate grinding characteristics of advanced cermets.

**Duration** 10/1/2001 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $150K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Prepared and characterized new ceramic composites for possible use in machining titanium alloys. (6/2005)
- Conducted instrumented grinding experiments and microscopy studies on cermets for diesel engine structural components. (9/2005)

## Significant Future Milestones

This project is ending in FY 2005. A new effort is planned for FY 2006. It will develop new synergistic process-enhanced grinding technology to enhance cost-effectiveness and improve material removal rates on hard materials.


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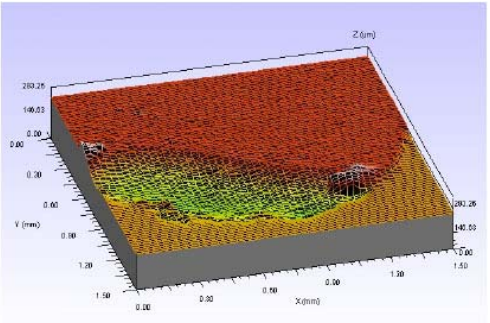

Wear of a $TiB_2$ coated tool used to cut Ti alloys (3D laser topographic map)

# Materials for Exhaust Aftertreatment

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Materials research and development that will be applied in advanced diesel engine aftertreatment systems to comply with future emission regulations with minimum fuel penalty.

## Current FY Focus

1. Evaluate new materials for particulate matter filtration efficiency & back pressure. 2. Assess impact of phosphorus on oxidation, NOx adsorber (LNT) and urea-SCR catalysts.

**Duration** 1/1/2005 through 12/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $250K FY06 = $245K / $245K FY07 = $0K / $K

## Accomplishments

- Various catalyzed and uncatalyzed DPF materials were obtained from suppliers and screened for filtration efficiency and back pressure. A promising material was identified.
- The cause of LNT deactivation by phosphorus poisoning was identified. For LNTs, the NOx storage capacity function is affected first and more severely than NO oxidation and NOx reduction.(June 2005)

## Significant Future Milestones

1. Study durability of selected filter materials (Dec. 2006)
2. Assess impact of combination of phosphorus, sulfur and thermal deactivation on OXICAT, LNT and SCR catalysts.(Dec. 2006)


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**Partners** Caterpillar

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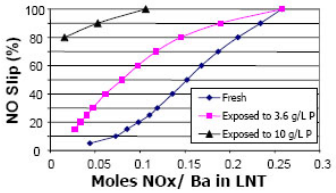
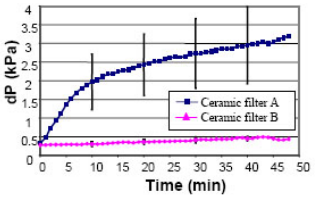



1. The effect of phosphorus exposure on LNT NOx storage for three different P exposures




2. Backpressure change during the soot-loading process of two uncatalyzed high filtration efficient DPF materials.

# Materials for HECC/HCCI Engine Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

One development need for HECC/HCCI engines that still remains is better, but affordable materials that can withstand higher temperatures without losing appreciable strength, hot hardness, and wear resistance. This collaborative effort between PNNL and Caterpillar proposes to address the last two bullets facing HECC/HCCI advancement by developing friction stir processing (FSP) of ferrous alloys and applying it to traditional engine materials, such as cast iron and alloy steels, as a means to increase the high temperature properties and durability that will enable HECC/HCCI combustion for future engines.

## Current FY Focus

PNNL and Caterpillar are planning to apply friction stir reaction processing (FSRP), an off-shoot technology of friction stir welding, that PNNL has been developing over the last few years. This effort will focus on further developing the process for cast iron and steels, which can be used to enhance surface properties by creating localized dispersion-strengthened regions within a part, such as a cylinder heads, pistons, cylinder liners, etc. This approach is thought to be more economical than selecting expensive high-temperature monolithic materials, and provides the flexibility to tailor surface properties to performance requirements. The goal of this collaborative effort with CAT is to optimize the FSRP techniques and apply the process to specific alloy systems of interest to CAT for future engine construction.

**Duration** 10/1/2006 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $200K / $K

## Accomplishments

## Significant Future Milestones

Develop process parameters, including selection of tool material and designs to successfully process selected ferrous based materials.9/2007

Process coupon-scale FSP samples in micro-alloyed steels and hypereutectic cast aluminum alloys of interest for mechanical and thermal property characterization including strength, fatigue life, and thermal conductivity and heat capacity. 12/2007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**Partners** PNNL, Caterpillar

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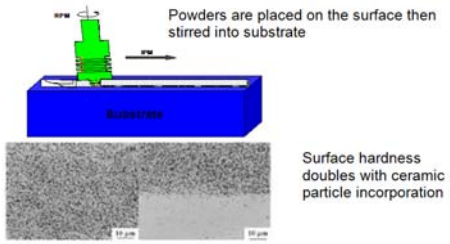


**Friction Stir Processing to Incorporate Ceramic Particles into Metal Surface for Increased Hardness and Reduced Thermal Conductivity**

# Mechanical Behavior of Ceramic Materials

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Enable the development of more wear-resistant and mechanically robust ceramic components through the systematic evaluation of contact damage in ceramics.

## Current FY Focus

- Evaluate rate and grain size effects on contact damage in candidate ceramics for diesel engine components.
- Develop criterion to rank/compare damage resistance.

**Duration** 10/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $275K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Established dynamic indentation and instrumented scratch testing facilities.
- Co-developed and copyrighted μ-FEAsoftware that facilitates microstructural stress analysis.

## Significant Future Milestones

Develop a generic FEM that predicts the onsets of quasi-plasticity and fracture/cracking in any target material as a function of indentation load, indenter material, friction, and confinement. (9-05)


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**Partners** ORNL

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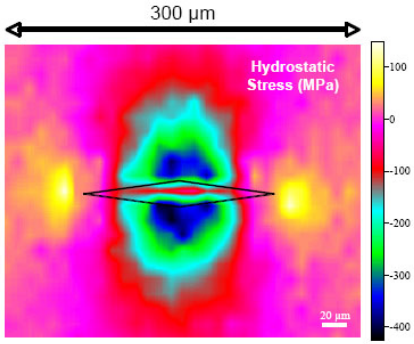


Residual stress field about region of contact damage (2kg Knoop indent) in an $Al_2O_3$ ceramic. Measured using optical fluorescence.

# Mechanical Reliability of Piezo-Stack Actuators

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

The use of piezoelectric stack actuators for diesel fuel injectors can potentially reduce injector response time, provide greater precision and control of the fuel injection event, and improve engine energy efficiency. This project will evaluate current piezoceramic materials, piezoelectric stack actuator designs, identifying material limitations, and present methods to improve system performance and increase the likelihood of their use.

## Current FY Focus

Apply established structural ceramic probabilistic design and reliability methods to piezo-stack actuators. Generate the required mechanical property data for the design and reliability analysis.

**Duration** 10/1/2005 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $200K / $K FY07 = $305K / $K

## Accomplishments

Created preliminary FEA models to predict stress states in piezo-stack actuators. Established miniature mechanical test setup to measure strength of thin piezoceramics. Designed and procured hardware that will enable mechanical testing of piezoceramics as a function of electric field, and cyclic fatigue testing of piezostacks with concurrent confined load.

## Significant Future Milestones

Establish piezoactuator reliability test facility. (09/07)
Assess reliability of a piezoactuator design and identify performance-limiting flaws. (09/08)


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**Partners** ORNL

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**Examples of piezo-stack actuators. Left is a top view, middle is a side view, and right is a stack removed from the protective covering.**

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| 18518 / 13329 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-46 |

# Microstructural Changes in NOx Trap Materials

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Our objectives is to understand the changes in the microstructure of Nox trap materials that occur during various modes of operation (lean, rich, and lean-rich cycles). This information forms the basis for selection and design of new NOx trap materials that can resist the deterioration under normal operation.

## Current FY Focus

Our focus has been to understand microstructural changes in NOx trap materials under accelerated aging conditions.

**Duration** 10/1/2003 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $95K / $K FY06 = $78K / $K FY07 = $0K / $K

## Accomplishments

- We updated the ex-situ reactor to include lean-rich cycling capability and used it to examine selected areas repeatedly for microstructural changes under accelerated aging protocol at 240s/60s and 60s/5s lean-rich cycles at 700ºC using simulated diesel exhaust without SO2 (6/30). We expect to complete accelerated aging protocol using simulated exhaust with SO2 by 9/30.The results suggest significant sintering at early stages of aging.
- We have completed a study of microstructural changes in model lean NOxtrap catalysts in air, lean, and rich using sulfur free simulated diesel exhaust using the ex-situ reactor at 500ºC. The results suggest minimal aging at this temperature.

## Significant Future Milestones

Correlate microstructural changes with NOx trap efficiency and establish microstructural changes as indicators for high-throughput screening of new catalyst materials. (9/30/06)


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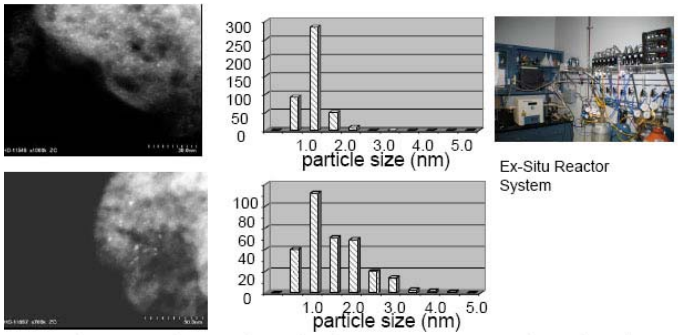


Accelerated aging protocol resulting in Pt- particle size change using ex-situ reactor system

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| 18519 / PM 9138 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-47 |

# Nanocrystalline Materials by Machining

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop high performance MMCs to reduce mass of engine rotating components, potentially improving engine efficiency by 5%. Develop ultra-fine-grained alloys from machining chip particulate via advanced powder processing.

## Current FY Focus

- TEM studies of nanostructure development in machining.
- Low-temperature consolidation routes for Al 6061-T6.

**Duration** 10/1/2004 through 4/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $110K / $K FY06 = $100K / $K FY07 = $50K / $K

## Accomplishments

- Several nanocrystalline alloys (e.g. Al alloys, titanium, steels and copper alloys) created by machining
- Initial low-temperature extrusion and pressing methods for consolidation of these alloys into monolithic/composite materials showing promise

## Significant Future Milestones

Creation of fully dense and bonded bulk alloy prototypes (7-06).
Quantify enhancement of mechanical properties of nano-structured bulk Al alloy samples and extension of processing approach to Ti. (9-07)


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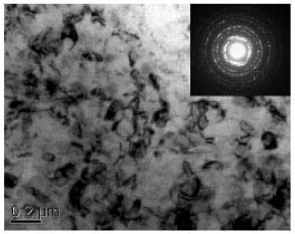

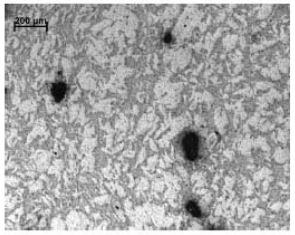

**Left:** Bright-field TEM showing sub-100 nm grains in Al 6061-T6 chip. **Right:** Optical micrograph showing 1:1 composite of 6061-T6 chip particulate and pure Al produced by powder extrusion at room temperature (~99% dense).

# Non Destructive Evaluation of Diesel Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop NDE methods to detect defect/damage in diesel components made from advanced materials

## Current FY Focus

Develop fast and reliable laser-scatter NDE systems for characterization of ceramic and intermetallicvalves being validated in engine duration tests

**Duration** 10/1/2001 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $175K / $K FY06 = $143K / $K FY07 = $190K / $K

## Accomplishments

Six times (6X) increase in scan speed for a laser-scatter system that allows for fast NDE inspection of large number of valves to meet tight engine test schedule (03/05)
Established detection sensitivity for fracture initiation flaws in cylindrical Si3N4specimens machined at various conditions (05/05)

## Significant Future Milestones

Complete NDE evaluation of accumulated damage in prototype valves from engine duration tests (06/06)
Complete analysis and correlation of NDE data with microstructure and mechanical property for 1000-hour engine-tested TiAl intermetallic and Si3N4 ceramic valves (9/07)


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**Partners** ANL

**Congressional Information** Illinois 13th
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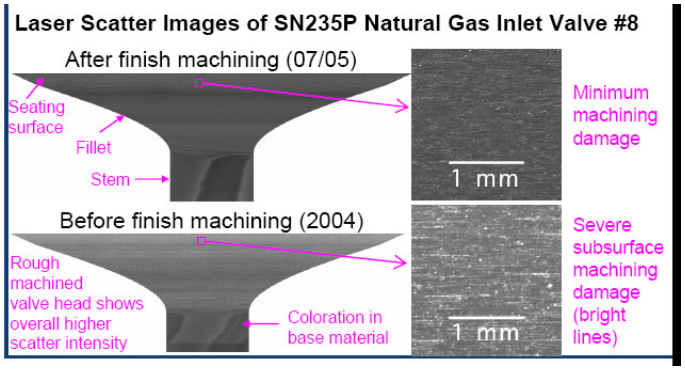

# NOx Sensor Development (CRADA with Ford)

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop NOx sensors suitable for OBD (remediation and/or monitoring) of diesel engine exhausts.

## Current FY Focus

1. Stability of electrode materials.
2. Cross-sensitivity.

**Duration** 10/1/2001 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $175K / $175K FY06 = $150K / $K FY07 = $100K / $K

## Accomplishments

1. Developed electochemicaltotal NOx sensor (January 04)
2. Developed electrochemical NO selective sensor (September 04)
3. Eliminated electrode stability issues in steam (July 2005).

## Significant Future Milestones

Characterize cross-sensitivity and performance of new electrode compositions in real (dyno) exhausts (12-05).
Demonstrate sensor sensitivity from 5 to 100 ppm NH3 (9/07)


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**Partners** ORNL

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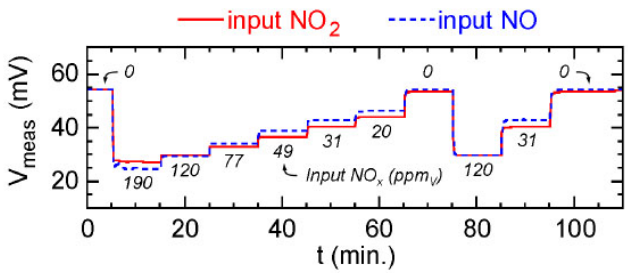


"Total $NO_x$" (similar response to NO and $NO_2$) sensing behavior of ORNL sense element at 600 °C.

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| 18519 / PM 9118 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-50 |

# Processing and Characterization of Structural and Functional Materials for Heavy Vehicle Applications

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

- Establish CCVD facility for SOFC materials processing
- Study and optimize deposition parameters, nucleation and microstructural evolution of the electrolyte
- Fabricate cathode, anode and electrolyte for SOFC
- Integrate anode, cathode and electrolyte development into single SOFCs and study their performance

## Current FY Focus

Study the electrophoretic deposition of YSZ electrolyte and the effect of the processing parameters on the porosity of the NiO/YSZ anode

**Duration** 10/1/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $50K / $K FY06 = $43K / $K FY07 = $0K / $K

## Accomplishments

- CCVD facility for SOFC was established (2001-2002)
- Electrolyte deposition technique with CCVD was optimized (2002-2004)
- Parametric study of electrophoretic deposition of YSZ provided basis for low-cost fabrication of thin dense coatings on SOFC electrode (3/05).
- Manufacturing method based on materials factorial design has been optimized for the development of SOFC anode with desired level of porosities (8/05)

## Significant Future Milestones

Continue to develop fundamental understanding of ceramic materials and processing techniques for potential energy sourcesin heavy vehicle applications


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**Partners** North Carolina A&T

**Congressional Information** North Carolina 12th
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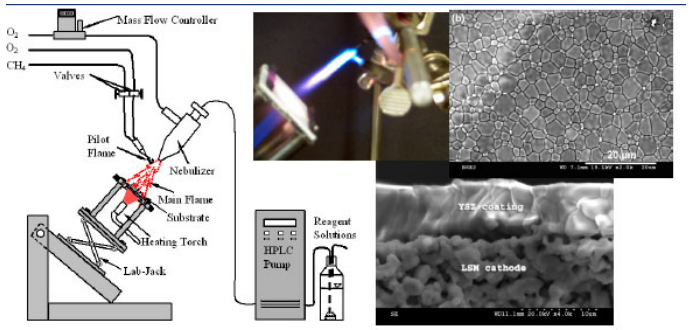


CCVD deposition setup and SEM images of YSZ coating on porous LSM cathode

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| 18865 / PM 9140 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Exploratory R and D | DOE | 12/21/2006 | A-51 |

# Testing Standards

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop new test method standards to facilitate the incorporation of new materials in diesel engines.

## Current FY Focus

Refine and standardize test methods for round shaped parts.

**Duration** 10/1/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $K FY06 = $60K / $K FY07 = $0K / $K

## Accomplishments

13 ASTM, 3 ISO, and 1 MIL STD, and 1 US Customs standards have been created.
5 generic test standards have been used in a new silicon nitride ball bearing material specification: ASTM F 2094.
Methods for the fractographic detection of machining damage have been refined and standardized in ASTM C 1322.

## Significant Future Milestones

An ASTM draft standard for flexural strength of round rods will be written and balloted in the Spring of 2006

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**Partners** NIST

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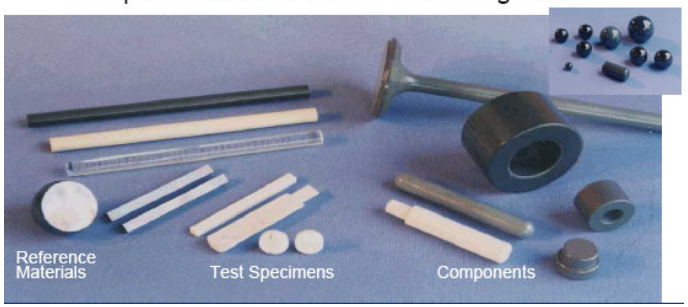
DOE055 FINAL

Refined test methods, reference materials, and standards support innovation and expedite the incorporation of new materials into engines.




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18523 / PM 8925 | Materials Technologies -- Heavy Vehicle Propulsion Materials | Applied Research | DOE | 12/21/2006 | A-52 |

# Thermoelectrics Modeling

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

The project will develop high efficiency thermoelectric materials for heat recovery through characterization, computational modeling, and experimental validation of advanced thermoelectric devices. Thermoelectric devices have the potential to generate usable energy from engine waste heat, which could result in a significant increase in vehicle efficiency.

## Current FY Focus

Develop preliminary FEA model for TE module.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $75K / $K

## Accomplishments

Developed working ANSYS FEA model of an arbitrary TE module.

## Significant Future Milestones

Generate thermomechanical property database on a candidate p- and n-type oxides that will be used to model and predict probabilistic reliability of a TE device. (09/07)

Perform probability design sensitivity analysis on a TE device and rank those material properties or dimensions whose control would have the largest effect on reliability. (09/08)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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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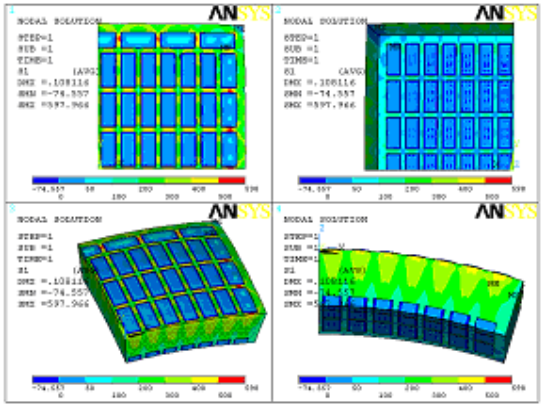

**Multiple views of first principal stress distribution in the thermoelectric device due to the applied thermal loading.**

# Titanium Engine Components

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

1.Using FEA, predict operating temperatures and stresses of a Cummins ISB diesel engine with a Ti cylinder head and block (with cast iron liners) rated at 305 hp and compare to the production grey cast iron. 2.Determine the technical feasibility of using Ti for engine cylinder heads and blocks from temperature, stress and fatigue predictions. 3.Predict operating temperatures and stresses of the engine with a titanium cylinder block and cylinder head, (with inserts in the flame face of each cylinder). Determine feasibility of simultaneously increasing the rating of the engine from 305 hp to 450 hp. 4.Investigate Al and Mg as cylinder block and head materials and compare to cast iron.

## Current FY Focus

Complete modeling work and explore potential of manufacturing and testing prototype engines.

**Duration** 10/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $235K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

1.FEA modeling demonstrated that Ti is a feasible substitute forgrey cast iron in the head and block castings allowing a diesel engine to be up-rated by 50% in hp and still achieve a 10% overall weight savings. –4/5/05
2. FEA modeling has shown that it is feasible to replace cast iron in a diesel engine head and block with Al and achieve an overall engine weight saving of 20%. –10/5/04
3.FEA modeling had shown that it is feasible to replace cast iron in a diesel engine head and block with Mg and achieve an overall weight saving of 33%. -8/10/04

## Significant Future Milestones

1. Final report on the FEA modeling work. 9/30/05


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**Partners** University of Tennessee

**Congressional Information** Tennessee 2nd
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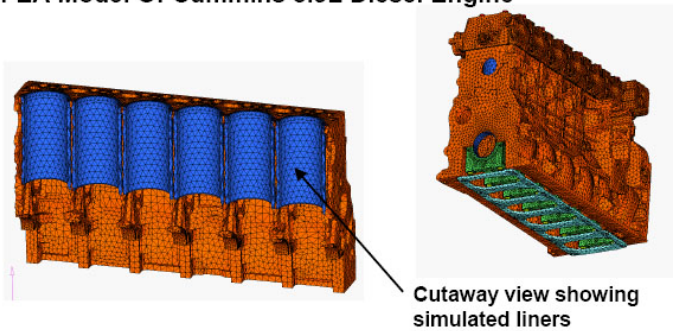
**FEA Model Of Cummins 5.9L Diesel Engine**



# Titanium Machining Consortium

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

To improve the material removal rate in machining of Ti-6Al-4V

## Current FY Focus

Delivery and validation of drilling modeling capability for titanium workpieces

**Duration** 4/1/2004 through 3/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $75K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Addition of the following modeling enhancements/capabilities:
- Drilling simulation capability
- Face milling simulation capability
- Boring simulation capability

## Significant Future Milestones

- Modeling of metal matrix composite tool materials (3-06)
- Modeling of titanium brake rotor machining (3-06)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**Partners** U.S. Air Force

**Congressional Information** Minnesota 3rd
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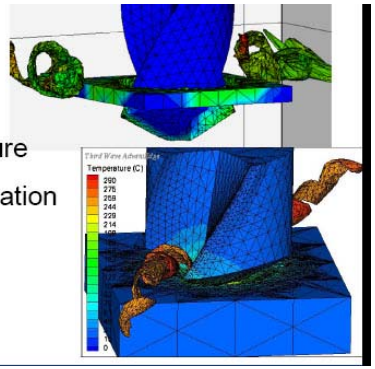
DOE065 FINAL

- Prediction of Forces
- Prediction of Temperature
- Prediction of Chip Formation
- Modeling of Drilling Entry/Steady State/Exit



# Titanium Turbocharger Development

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop, procure and test TiAl turbine assembly on heavy duty engine to demonstrate improved transient response vs. traditional Ni-based turbine wheel.

## Current FY Focus

Develop technology to join TiAl turbine wheel to steel shaft.

**Duration** 3/1/2003 through 12/31/2005

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

(1) Demonstrated joining of TiAl turbine wheel to Ti-6Al-4V shaft –April 2005
(2) Demonstrated joining of TiAl specimens to steel shaft material –June 2005
(3) Evaluated physical and mechanical properties of candidate TiAl alloys –July 2005

## Significant Future Milestones

(1)Demonstrate joining of TiAl turbine wheel to steel shaft. (9-05)
(2)Perform engine test on TiAl turbine assembly to compare response and performance to Ni-based turbine assembly. (12-05)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**Partners** Caterpillar

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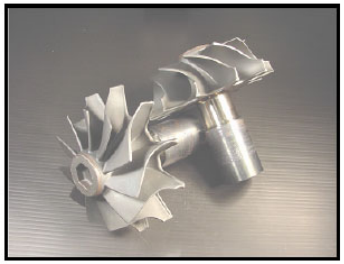

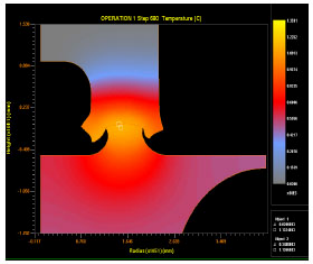

**Left:** TiAl turbine wheel welded to Ti-6Al-4V shaft with joint tensile strength higher than TiAl.
**Right:** FEA of the joining process is used to understand the sensitivity of the joint strength to friction welding control parameters

# Walker Process for Stress Relief

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

Develop and demonstrate a new process for accelerated residual stress relief and heat treat processing, resulting in 50% or more savings in energy and efficiency in processing, while enabling reductions in weight and improvements in cycle life.

## Current FY Focus

Validate process and demonstrate capabilities.

**Duration** 3/1/2004 through 11/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Process has been validated for stress relief in 7075-T6 aluminum and in 4340 steel, December 2004.
Process has been validated for weld stress relief in steel truck wheels, resulting in 100% improvement in fatigue life of the parts, March 2005.

## Significant Future Milestones

Develop technology for use in casting production and in aging of aluminum alloys for process acceleration and energy use reduction.


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**Partners** Acceledyne

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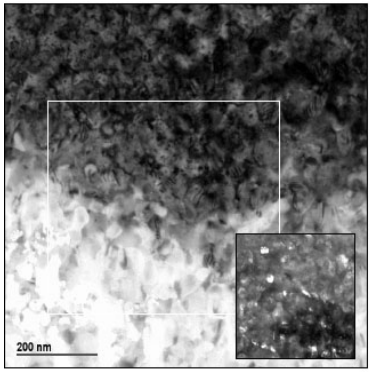


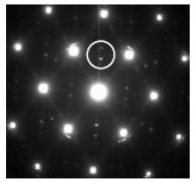

Bright-field TEM image of Al alloy shows oriented second phase, seen in inset dark-field image taken using precipitate spots shown in above diffraction pattern. Area of inset corresponds to white box. TEM is allowing correlation of microstructure to processing and stress-relief effects.

# Laser Surface Texturing of Materials

**21CTP Technical Goal** Engine Systems: Achieve thermal efficiency of 55% by 2012 in prototype systems.

## Objectives

-Increase fuel efficiency by reducing engine friction.
-Develop laser surface texturing (LST) to reduce hydrodynamic friction, and, apply low-friction coatings to laser textured surfaces to reduce boundary-layer friction.
-Understand role of dimple shape, size, and density on friction

## Current FY Focus

-Friction, scuffing, and oil film rheology studies
-Piston ring & liner, and piston pin studies

**Duration** 10/1/2002 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $125K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Accomplishment 1: Lab demonstration that LST reduces friction in face seals (20-30%) – 2003.
Accomplishment 2: Lab demonstration that LST modifies Stribek behavior under mixed and boundary conditions – 2004.
Accomplishment 3: Lab demonstration that LST reduces friction on piston pins – 2005.

## Significant Future Milestones

Milestone 1 Measure friction reduction on LST treated ring & liner components – 2006.


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**Partners** ANL, Technion University

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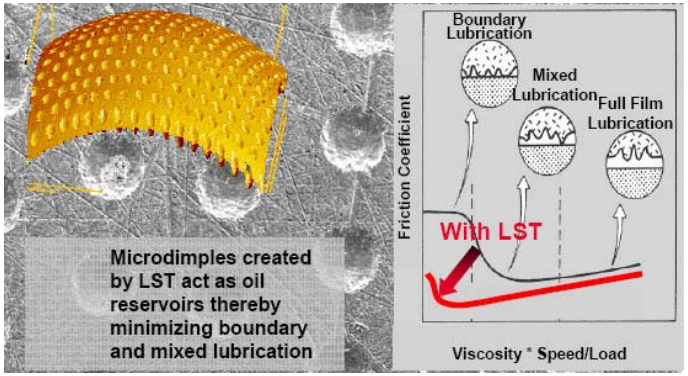


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|---|---|---|---|---|---|
| 18541 / WR 9015 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 12/21/2006 | A-58 |

# LLNL APBF: Kinetic Modeling of Combustion of Practical Hydrocarbon Fuels

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Develop of chemistry models to represent components in 21st Century fuels such as oil-sand derived fuels and bio-derived fuels. Continue development of surrogate fuel mixtures for diesel and HCCI engine development (large paraffin, cycloparaffin, olefin and biodiesel compounds). Modeling comparisons of single component and a surrogate fuels with HCCI experiments at Sandia.

## Current FY Focus

Development of chemistry models for components to represent large alkanes, bio-diesel and cyclohexane. Compare results from enhanced fuel surrogate models to HCCI engine experiments.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $420K / $K FY06 = $420K / $K FY07 = $420K / $K

## Accomplishments

Completed collaborative work on the validation of a chemical kinetic mechanism for MCH in a rapid compression machine. Completed a collaborative work on developing and validating a chemical kinetic mechanism for DIB, a model olefin for a gasoline surrogate fuel. Made modeling comparisons with Sandia HCCI experiments on MCH and DIB using new chemical kinetic mechanisms

## Significant Future Milestones

Chemical kinetic model or larger molecular weight fuel.
Effects of fuel molecular structure on sooting tendency on fuels.
Chemical kinetic model for a biodiesel surrogate with a larger molecular weight.
New mechanism for cylcohexane, a surrogate component of cyclo-alkanes.
Improved mechanism for methyl-cyclohexane.
Further modeling of enhances surrogate fuels with comparison to engine experiments.


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**Partners** LLNL

**Congressional Information** California 10th
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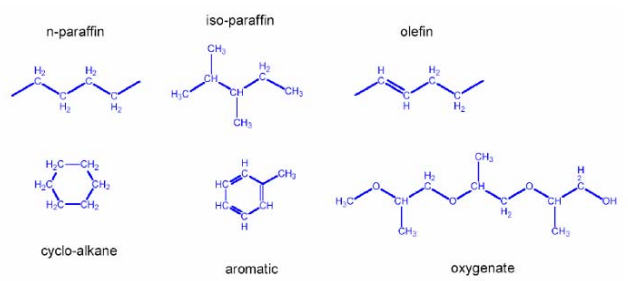


**Classes of Compounds in Gasoline and Diesel Fuel**

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18546 / 13419 | Fuels Technologies-Advanced Petroleum Based Fuels | Applied Research | DOE | 10/30/2006 | A-59 |

# NREL APBF: Biodiesel Effects on NOx Emissions: Engine vs. Chassis Test Cycles

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Reveal why some tests show NOx going down and some show it going up for B20. Provide unbiased technical data to regulatory agencies on biodiesel emission factors.

## Current FY Focus

Testing of 8 heavy-duty vehicles and review of recently published data

**Duration** 10/1/2005 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $300K / $K FY07 = $200K / $K

## Accomplishments

Completed testing of 8 heavy-duty vehicles on conventional diesel fuel and B20. Results show on average no change in emissions of NOx, however NOx emissions may increase or decrease depending upon driving cycle and vehicle/engine design. A review of recently published data also shows highly variable NOx emissions, but on average no change for B20. A comparison of engine and chassis test results suggests NOx increase occurs at higher load conditions or higher loading duty cycles for engines that show an increase in NOx- preliminary result.

## Significant Future Milestones

Work to understand differences in chassis cycles by examining real-time NOx and horsepower at wheels and other approaches. Examine engine dynamometer test data to define impact of speed, load, and other parameters on relative NOx emissions from biodiesel blends. Planned testing additional vehicles to improve emission factor estimates.


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**Partners** Environmental Protection Agency

**Congressional Information** Colorado 7th
Bob Beauprez


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DOE352 FINAL

2005 MY International Green Diesel School Bus

# NREL APBF: Diesel Particulate Filter (DPF) Performance with Biodiesel Blends

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

(Phase I)
Testing of a 2002 engine retrofitted with a DPF on USLD and biodiesel blends (B5 and B20) to understand how biodiesel impacts DPF performance. Heavy-duty transient test (federal test procedure) to measure impact on regulated pollutant emissions. Balance point temperature and regeneration rate testing to understand how biodiesel blends impact temperature of soot oxidation on DPF. Soot characterization to understand fundamental differences in biodiesel soot
(Phase II)
Move to a 2007 compliant engine and transient testing with controlled exhaust temperatures.

## Current FY Focus

Impact of biodiesel on 2002 engine retrofitted with DPF

**Duration** 10/1/2005 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $200K / $K FY07 = $200K / $K

## Accomplishments

Demonstrated that B20 provides additional reduction in PM emissions in comparison to ULSD even with a DPF. The additional PM reduction ranges from 25 to 65% and can vary with the base ULSD.
BPT and Regeneration Rate Testing shows measurable differences with increasing biodiesel blends. BPT decreased by 45oC with B20 and 112oC with B100 and significant differences in regeneration rate with blend levels as low as 5%
Soot Characterization – TGA confirms higher reactivity, higher oxygen and higher ratio of disordered carbon for biodiesel soot

## Significant Future Milestones

During 2007 additional testing will be conducted on the 2002 engine/DPF setup, and testing will be conducted on a 2007 model year engine. The objective will be to confirm the benefits of biodiesel blends and quantify the impact of increased soot reactivity on improving fuel economy and reducing DPF backpressure.


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**Partners** Cummins, National Biodiesel Board

**Congressional Information** Colorado 7th
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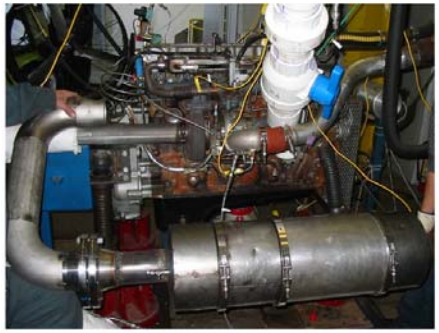

2002 Cummins ISB w/ Particle Filter

# NREL APBF: Fuels for Advanced Combustion Engines (FACE)

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

To establish common matrices of research fuels for investigation of fuel effects on advanced combustion regimes for both gasoline-like and diesel-like fuels and combustion processes to aid determination how fuel properties affect advanced combustion regimes (efficiency, emissions, range of operations). Investigate the most critical fuel properties, and determine if they are the same for the various forms of advanced combustion. Characterize fuels appropriately for new types of combustion. Determine the fuel properties suitable for advanced combustion aftertreatment.

## Current FY Focus

Design sets of research fuels in the diesel and gasoline ranges.

**Duration** 10/1/2006 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $500K / $125K FY07 = $400K / $100K

## Accomplishments

Formations of strawman teams and initial designs of matrices of research fuels

## Significant Future Milestones

Blend sets of research fuels and distribute to labs for combustion studies


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**Partners** ORNL, NREL, CRC, Cummins, BP, ExxonMobil, others

**Congressional Information** Tennessee 3rd
Zach Wamp


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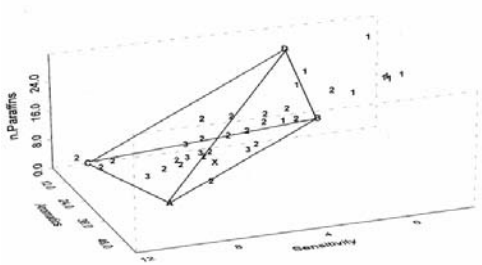


R&D Fuels Parameter Space Illustration

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18546 / 13416, 16668, 16347 | Fuels Technologies-Advanced Petroleum Based Fuels | Exploratory R and D | DOE | 10/30/2006 | A-62 |

# ORNL APBF: Diesel Range Fuel Effects in a Single Cylinder HCCI Engine

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Provide straight-forward comparisons of combustion and performance of diesel fuels differing in properties and chemistry in an single-cylinder HCCI engine. Determine if the effect of fuel cetane number on performance and emissions. Determine if the cetane number metric is sufficient to allow for comparison between reference fuels, commercial petroleum fuels, and alternative fuels. Investigate how fuel compositions affect the composition of exhaust hydrocarbons.

## Current FY Focus

Effects of new fuel chemistries derived from oil sand and oil shale crude and biodiesel.
Large, funded, WFO program with engine company/oil company partnership.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $170K / $K FY06 = $365K / $264K FY07 = $365K / $264K

## Accomplishments

Completed fuel effects studies of SRF fuels, commercial fuels, and biodiesel fuels. Established relationships between CN, combustion phasing, LTHR, engine speed, and high MW oxygenated species. Published results in SAE, ACS, and IJER.

## Significant Future Milestones

Continue research of fuel properties and chemistries with emphasis on real fuels. Complete fuel effects study with NCUT Canada on cycloparaffin chemistry effects.
Complete stages of WFO diesel range fuel study


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**Partners** ORNL, NCUT, PNNL

**Congressional Information** Tennessee 3rd
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**Technical Development Manager/Project Manager** Kevin Stork, U.S. Department of Energy
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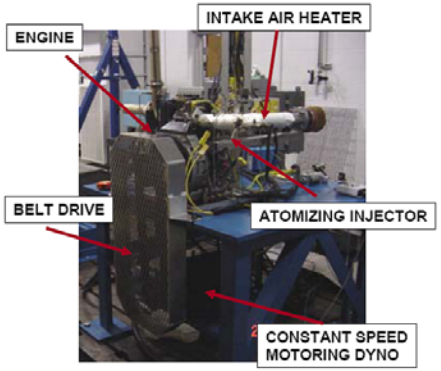


HCCI Engine

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
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| 18546 / 13415, 16668, 16347 | Fuels Technologies-Advanced Petroleum Based Fuels | Exploratory R and D | DOE | 10/30/2006 | A-63 |

# ORNL APBF: Fuel Property Effects on Diesel High Efficiency Clean Combustion

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

To research the effects that fuel formulations can have on new combustion regimes and exploit those properties for improved emissions and efficiency. Work at ORNL involves multiple test stands: Two multi-cylinder common-rail engines with full pass control, a single-cylinder diesel research engine; and a two-cylinder VCR (variable compression ratio) gasoline engine. The effort in this summary is for the mulitcylinder engine studies.

## Current FY Focus

Examine the effects of biodiesel blend levels and formulations on engine efficiency and emissions performance in advanced combustion regimes.

**Duration** 0 year

**Gov't Funding/Industry Cost Share**

FY05 = $600K / $K FY06 = $600K / $K FY07 = $600K / $K

## Accomplishments

Partially-premixed charge compression ignition (PCCI) has been demonstrated to be tolerant of a wide variety of diesel-range fuels, including soy-biodiesel and oil-sands derived fuels. Increases in hydrocarbon and formaldehyde emissions that are typical of PCCI can be reduced through the use of low-aromatic and 5% biodiesel blends for some diesel fuels. Fuels that exhibit relatively high levels of PM production in normal combustion generally exhibit higher levels of unburned hydrocarbon and formaldehyde emissions in PCCI regimes.

## Significant Future Milestones

Further understanding of the potential impacts of advanced- and non-petroleum based fuels on the performance of engines in HECC combustion modes. Transition research to a GM 1.7 liter engine in support of ongoing collaboration with Sandia National Lab, the University of Wisconsin, and General Motors.


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Robert Wagner, Oak Ridge National Laboratory
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**Partners** ORNL, NCUT

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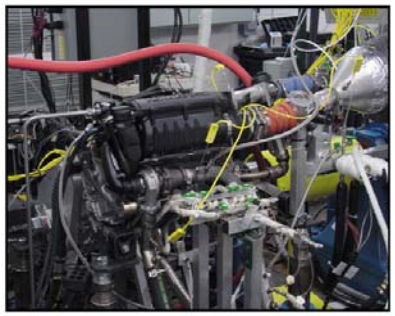


Mercedes 1.7L Diesel Engine

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18546 / 13415 | Fuels Technologies-Advanced Petroleum Based Fuels | Exploratory R and D | DOE | 10/30/2006 | A-64 |

# ORNL APBF: Fuels and Lube Constituent Effects on Emissions Control Aging

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Develop rapid aging and poisoning protocols with characterization and analysis techniques to study mechanisms of aging and poisoning while adding to understanding of processes and changes.

## Current FY Focus

Continue LNT high temperature aging, continue accelerated ash loading of DPF, start aging and poisoning of combined SCR-DPF systems.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $K FY06 = $401K / $88K FY07 = $366K / $40K

## Accomplishments

Completed DOC phosphorous study and correlated results to field aged catalysts.
Developed protocol for thermal aging LNT's and rapid ash loading of DPF.

## Significant Future Milestones

Determine kinetic parameters for LNT thermal aging.
Correlate rapid ash loading to field return DPF.
Develop research hardware for poisoning and aging protocol with SCR-DPF systems.


**Principal Investigator** Todd Toops, Oak Ridge National Laboratory
(865) 946-1207, toopstj@ornl.gov

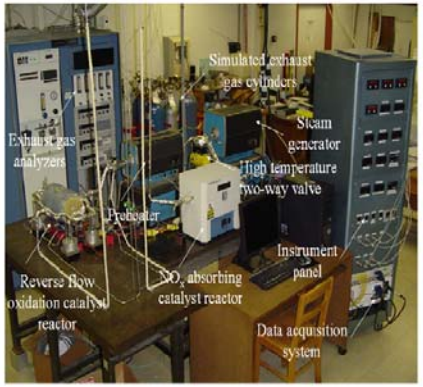
Bruce Bunting, Oak Ridge National Laboratory
(865) 946-1512, buntingbg@ornl.gov

**Partners** ORNL, University of Tennessee

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Kevin Stork, U.S. Department of Energy
(202) 586-8306, kevin.stork@ee.doe.gov


DOE344 FINAL




U. Tenn's Bench Reactor System

# ORNL APBF: Gasoline-Range Fuel Effects on HCCI

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Study the effects of fuel chemistry and properties on advanced combustion regimes with gasoline range fuels. Gain further understanding of fuel behavior under operating conditions of HCCI engines. Study combustion behavior of fuels derived from new sources such as ethanol, vegetable derived fuels, heavy crude oil, and other non traditional sources. Provide experimental and modeling data which can be used to anticipate and optimize engines and controls for new fuels. Provide experimental and modeling data which can be used to help shape fuel decisions in the future.

## Current FY Focus

Improved understanding of fuel mechanisms and chemistry effects by combined kinetic modeling and experimental research.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $210K / $K FY06 = $226K / $14K FY07 = $310K / $145K

## Accomplishments

Established oil company research relationships.
Published results as SAE papers.
Provided input and consulting to AVL and CRC.
Established new research platform.

## Significant Future Milestones

Gasoline surrogate study combined with kinetic modeling.
More ethanol research.
Funded WFO program with major oil company.

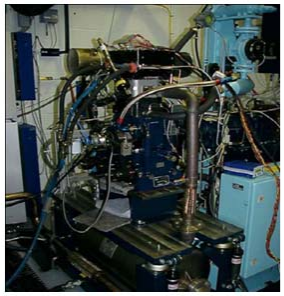

**Principal Investigator** Bruce Bunting, Oak Ridge National Laboratory
(865) 946-1512, buntingbg@ornl.gov


**Partners** ORNL, AVL Powertrain, Battelle, MIT, ExxonMobil

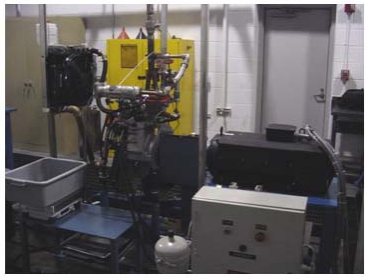
**Congressional Information** Tennessee 3rd
Zach Wamp


**Technical Development Manager/Project Manager** Kevin Stork, U.S. Department of Energy
(202) 586-8306, kevin.stork@ee.doe.gov


DOE348 FINAL



AVL Engine
500 CC, 11.34 CR
Hydraulic VVT



ORNL Engine
1000 CC
VCR, 8.5 to 20 CR

# SNL APBF: High Efficiency Clean Combustion (HECC) with Conventional and Unconventional Diesel Fuels

**21CTP Technical Goal** Engine Systems: Develop new diesel fuel specifications to achieve efficiency/emission goals at 5% petroleum displacement

## Objectives

Reduce petroleum consumption and displace petroleum imports, while complying with emissions regulations, by inventing/developing combustion strategies that overcome technical barriers to achieving robust HECC engine operation. Accomplished by synthesizing experimental observations into the science base of fuel effects on HECC that is required to support industry development of HECC engines operating on conventional, bio-derived, and emerging fuels.

## Current FY Focus

Measure the extent to which fuel composition affects soot emissions under high-efficiency, low-NOx, mixing-controlled operating conditions.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $500K / $K FY06 = $746K / $K FY07 = $750K / $K

## Accomplishments

- Determined extent to which mixing-controlled HECC is possible with #2 diesel, paraffinic diesel, and biodiesel using N2 dilution: NOx reduction with dilution is nearly independent of fuel; smoke emissions are strongly fuel-dependent; incomplete combustion (PM, HC, CO) is a large challenge; overlimit function introduced to quantify distance from targets.
- Showed that fuel-dependent differences in soot nanostructure could contribute to differences in smoke emissions: soot with less-ordered nanostructure oxidizes up to 5x faster; different fuels can produce soot with different nanostructure; differences in smoke are consistent with differences in nanostructure.
- Created computer model of engine gas compositions and flow rates to enhance simulation of thermal and chemical effects of exhaust gas recirculation (EGR) in experiments.

## Significant Future Milestones

Study fuel effects on wall impingement and soot emissions under early direct-injection, low-temperature combustion (LTC) operating conditions. Identify origins of increased biodiesel NOx emissions. Quantify hydrocarbon molecular-structure effects on soot emissions using carbon-14 labeling and tracing. Implement engine/hardware upgrades for higher peak cylinder pressure operation and improved EGR simulation.

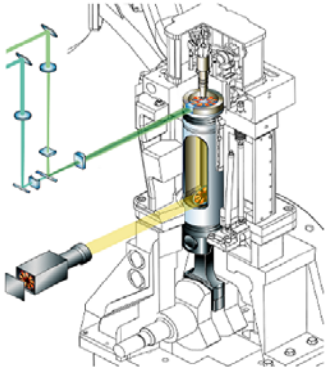

**Principal Investigator** Chuck Mueller, Sandia National Laboratories
(925) 294-2223, cjmuell@sandia.gov

**Partners** SNL

**Congressional Information** California 10th
Ellen Tauscher

**Technical Development Manager/Project Manager** Kevin Stork, U.S. Department of Energy
(202) 586-8306, kevin.stork@ee.doe.gov


DOE347 FINAL



In-Cylinder Optical Diagnostics

# Advanced Hybrid Propulsion and Energy Management System for Mine Haul Trucks

**21CTP Technical Goal** Hybrids: Develop drive unit with 15 year life and cost of $50/kW peak power.

## Objectives

Design, build, and validate a diesel-electric mining OHV with a hybrid energy storage system to recover braking energy and use this energy for useful work, thus reducing fuel consumption

## Current FY Focus

-- Full-scale experimental prototype development and testing
-- On-board system validation
-- Energy storage component teardown and analysis

**Duration** 6/1/2002 through 12/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $317K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – NaNiCl2 (ZEBRA) batteries identified, 2003
Accomplishment 2 – Modeling and system design complete, 2004
Accomplishment 3 – Full scale prototype assembled, 2005
Accomplishment 4 – Truck integration design complete, 2005

## Significant Future Milestones

Milestone 1 – Completion of full-scale experimental prototype testing and control software validation – May 2006
Milestone 2 – On-truck validation of hybrid propulsion system – August 2006
Milestone 3 – Battery analysis / Project completion – December 2006


**Principal Investigator** Tim Richter, General Electric
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Henry Young, General Electric
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**Partners** General Electric

**Congressional Information** New York 21st
Michael McNulty

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov


DOE096 FINAL

# Advanced Heavy Hybrid Propulsion System Program: Caterpillar Inc.

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Hybrids: Develop technology to achieve 60% fuel economy improvement while meeting emission standards

## Objectives

- (Phase I -completed Nov 2006). Design and develop advanced thermoelectric (TE) component and systems to capture waste heat in truck exhaust to generate electricity for hybrid-electric heavy vehicles. Focus on Si/SiGe and B4C/B9C Quantum Well or thin-film advanced TE materials and structures.
- Goal is a 20% efficient advanced TE waste heat recovery system, while not sacrificing 2007 EPA emissions standards.
- Potential fuel savings for a heavy hybrid of 8% for driveline power only, 13% for system also powering auxiliary systems instead of using an alternator.
- AHHPS overall objectives. Develop advanced heavy hybrid propulsion systems for increased fuel efficiency and decreased emissions, which can save approximately 20 million barrels/year of oil in 2010 and 250 million barrels/year of oil in 2020.

## Current FY Focus

Complete Phase I objectives.

**Duration** 2 years

**Gov't Funding/Industry Cost Share**

FY05 = $751K / $751K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Developed state-of-the-art TE waste heat recovery systems relevant to heavy hybrid vehicle propulsion architectures.
- Advanced TE materials, such as coating and batch application processes to help produce effective low-cost, TE manufacturing processes, components, and systems.
- Seebeck coefficients of annealed coatings were measured and the data obtained had little substrate effects. CAT thermoelectric measurement setup was verified by a leading company in the area.
- Project successfully completed in 2006

## Significant Future Milestones

N/A

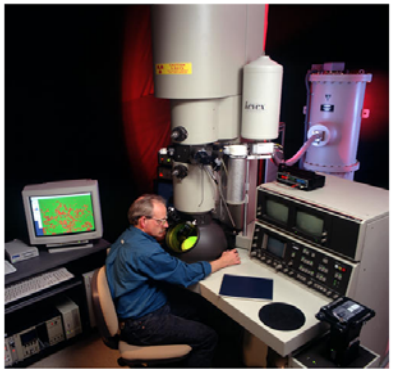

**Principal Investigator** Terry Penney, National Renewable Energy Laboratory
(303) 275-4434, terry_penney@nrel.gov


**Partners** NREL, Caterpillar

**Congressional Information** Illinois 18th
Ray LaHood

**Technical Development Manager/Project Manager** Susan Rogers, U.S. Department of Energy
(202) 586-8997, susan.rogers@ee.doe.gov

DOE383 FINAL-2



NREL's scanning transmission electron microscope used to analyze and develop advanced thermoelectric systems.

# Advanced Heavy Hybrid Propulsion System Program: Eaton/International Truck

**21CTP Technical Goal** Hybrids: Develop technology to achieve 60% fuel economy improvement while meeting emission standards

## Objectives

- Develop a Class 6 hybrid delivery truck with Advanced Parallel Hybrid Powertrain in International 4200 chassis: Down-sized 3.0L I4 Diesel Engine; DC-DC converter for electric accessories (water pump, AC, steering); 55 kW Permanent Magnet Drive Motor incorporated in UltraShift Drive unit; 340 VDC Ni-MH Battery
- AHHPS overall objectives. Develop advanced heavy hybrid propulsion systems for increased fuel efficiency and decreased emissions, which can save approximately 20 million barrels/year of oil in 2010 and 250 million barrels/year of oil in 2020.

## Current FY Focus

Complete Phase I objectives and finalize project

**Duration** 3 years

**Gov't Funding/Industry Cost Share**

FY05 = $958K / $958K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Demonstrated advanced heavy hybrid technologies with fuel economy improvement of 44% over conventional vehicle.
- New engine, motor/inverter, battery pack, DC-DC converter, EV only mode packaged in a Class 6 vehicle
- Heavy-duty chassis testing completed at NREL's Renewable Fuels and Lubricants Research Laboratory (ReFUEL).
- Project successfully completed in 2006

## Significant Future Milestones

N/A


**Principal Investigator** Robert Rehn, National Renewable Energy Laboratory
(303) 275-4418, robert_rehn@nrel.gov


**Partners** NREL, Eaton, International, Ricardo, Hitachi

**Congressional Information** Michigan 6th
Fred Upton


**Technical Development Manager/Project Manager** Susan Rogers, U.S. Department of Energy
(202) 586-8997, susan.rogers@ee.doe.gov


DOE384 FINAL-2

Class 6 hybrid delivery truck tested and developed

# Advanced Heavy Hybrid Propulsion System Program: GM-Allison

**21CTP Technical Goal** Hybrids: Develop technology to achieve 60% fuel economy improvement while meeting emission standards

## Objectives

- (Phase I – completed December 2006). Research, develop, and validate advanced, next-generation hybrid technologies to greatly improve the current Class 8 heavy-hybrid application. Focus on motor and inverter module.
- Motor/generator redesign goals: introduce advanced materials to significantly reduce cost, reduce mass by 30%, reduce motor losses and improve reliability.
- Improve overall vehicle fuel economy by 3-10% real world over current production EP 40/50 system.
- Dual power inverter module redesign goals: reduce cost, improve power density: reduce mass by 60% and decrease volume by 40% while maintaining reliability and power
- AHHPS overall objectives: Develop advanced heavy hybrid propulsion systems for increased fuel efficiency and decreased emissions, which can save approximately 20 million barrels/year of oil in 2010 and 250 million barrels/year of oil in 2020.

## Current FY Focus

Complete Phase I work and finalize project.

**Duration** 3 years

**Gov't Funding/Industry Cost Share**

FY05 = $244K / $244K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Motor redesign completed: 20% reduction in continuous power losses; significant cost savings estimated at 40%
- Dual power inverter module redesigned: volume reduced by 65%; mass reduced by 32 kg (44%); power density improved by 170%
- Both components designed to maintain or exceed previous durability and operational specifications.
- Project successfully completed in 2006

## Significant Future Milestones

N/A

**Principal Investigator** Kevin Walcowicz, National Renewable Energy Laboratory
(303) 275-4492, kevin_walcowicz@nrel.gov

**Partners** NREL, Allison

**Congressional Information** Indiana 7th
Julia Carson

**Technical Development Manager/Project Manager** Susan Rogers, U.S. Department of Energy
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DOE382 FINAL-2

Component redesign for electric bus

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 19034 / 13325 | Heavy Vehicle Systems -- Heavy Hybrids | Applied Research | DOE | 1/23/2007 | A-71 |

# Advanced Heavy Hybrid Propulsion System Program: Oshkosh

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Hybrids: Develop technology to achieve 60% fuel economy improvement while meeting emission standards

## Objectives

- (Phase I – completed June 2006). Research, develop, and validate advanced hybrid powertrain technologies, power electronics, energy storage technologies, and powertrain control systems for Class 7-8 truck applications to improve fuel economy by up to 2 times and maintain vocational performance.
- (Phase II – to be completed Nov. 2007). Phase II focuses on advancement in 7 key technology areas to achieve 2x fuel economy goal.
- AHHPS overall objectives. Develop advanced heavy hybrid propulsion systems for increased fuel efficiency and decreased emissions, which can save approximately 20 million barrels/year of oil in 2010 and 250 million barrels/year of oil in 2020.

## Current FY Focus

Complete Phase I, and implement Phase II scope of work

**Duration** 3 years

**Gov't Funding/Industry Cost Share**

FY05 = $1262K / $1262K FY06 = $2619K / $2619K FY07 = $K / $K

## Accomplishments

- Hybrid electric refuse truck designed and built
- Demonstrated advanced heavy hybrid technologies
- Heavy-duty chassis testing completed at NREL's Renewable Fuels and Lubricants Research Laboratory (ReFUEL).
- Successful industry partnership leading to future work with AHHPS Phase II
- Phase I test truck used to prove-out new technology
- Demonstrated test truck in Waste Management fleet

## Significant Future Milestones

- Advances in 7 key technology areas to achieve up to 2x fuel economy goal
- Build second demonstration truck using all 7 technologies
- Update the commercialization plan
- NREL's Power Electronics lab to test ultracapacitor module to validate NREL's thermal/fluids model
- ReFUEL currently testing Oshkosh validation vehicle


**Principal Investigator** Robert Rehn, National Renewable Energy Laboratory
(303) 275-4418, robert_rehn@nrel.gov


**Partners** NREL, Oshkosh, Rockwell Automation, Rockwell Scientific, Ohio State University, ElectraStor, JME

**Congressional Information** Wisconsin 6th
Thomas Petri


**Technical Development Manager/Project Manager** Susan Rogers, U.S. Department of Energy
(202) 586-8997, susan.rogers@ee.doe.gov


DOE385 FINAL-2

Completed advanced hybrid electric refuse truck

# Pony Pack APU/Truck Fleet Demo

**21CTP Technical Goal** Idle Reduction: Develop 5 kW diesel fuel ICE APU at $200/kW.

## Objectives

- This project will identify ways to reduce time and cost of installation at the time manufacturing or installation after manufacturing.
- Project will evaluate and validate fuel reduction, energy savings, equipment life, preventative and operational maintenance and emissions reduction.
- Pony Pack will partner with one or two truck fleets to share the cost of purchasing, installing, and monitoring the performance of Pony Pack APUs on a portion of the trucks in the fleet

## Current FY Focus

**Duration** 2 years

**Gov't Funding/Industry Cost Share** *Total Funding Level = $100K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- New project, fleets identified, grant has not been awarded to sub-grantee.

## Significant Future Milestones

**Principal Investigator** Richard Grier, Pony Pack
(505) 243-1381, rex@ponypack.com

**Partners**

**Congressional Information** New Mexico 1st
Heather Wilson

**Technical Development Manager/Project Manager** Ernie Oakes, U.S. Department of Energy
(303) 275-4817, ernie.oakes@ee.doe.gov

DOE012 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Clean Cities -- Idle Reduction Deployment | Applied Research | DOE | 3/1/2005 | A-73 |

# National Idling Reduction Plan

**21CTP Technical Goal** Idle Reduction: Develop codes and standards for on-board and off-board electrification technologies

## Objectives

- Develop coordinated approach among DOE, DOT, and EPA to tackle the issues associated with the idling of all modes of heavy vehicles
- Bring stakeholders together to determine actual needs and identify major issues, actions, and actors
- Create an action plan acceptable to Federal agencies that offers national solutions and courses of actions to reduce idling of heavy vehicles
- Use 21CTP to implement plan and measure benefits

## Current FY Focus

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- National Idling Reduction Conference held last May to lay groundwork for a national plan to reduce idling of all modes of heavy vehicles
- National Idling Reduction Network News, an outcome of Conference, now e-mailed monthly to 1200 people, and available on FreedomCAR and Vehicle Technologies web site
- Drafts of sections on technology solutions, financial incentives, regulatory approaches, and outreach and education under review by working groups
- Final approval by Federal agencies expected by end of September 2005
- Roll-out scheduled at the SAE Commercial Vehicle Engineering Congress in November 2005

## Significant Future Milestones

**Principal Investigator** Linda Gaines, Argonne National Laboratory
(630) 252-4919, lgaines@anl.gov

Terry Levinson, ANL
(202) 488-2413, tlevinson@anl.gov

**Partners**

**Congressional Information** Illinois 13th
Judy Biggert

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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Diane Turchetta/Paul Bubbosh, DOT/EPA

DOE011 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Idle Reduction | Applied Research | DOE | 3/15/2005 | A-74 |

# Diesel Fueled SOFC for Class 7/Class 8 On-Highway Truck Auxiliary Power

**21CTP Technical Goal** Idle Reduction: Develop fuel cell APU at 5-30 kW on diesel fuel at delivered cost of $400/kW by 2012

## Objectives

- In-vehicle evaluation of SOFC APU
- Define, Analyze and Design the Balance of Plant
  - Controls and Power Electronics
  - Diesel Reformer System
- SOFC Stacks
- Sub-system test and development
- Laboratory testing of complete system

## Current FY Focus

**Duration** 9/30/2004 through 8/31/2007

**Gov't Funding/Industry Cost Share** *Total Funding Level = $4790K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Technical Profile
- Analysis of Truck Electrical and Thermal load profile
- Micro reactor testing underway to support reformer catalyst evaluations
- Alternative internal water management concepts being evaluated
- Suitable truck vibration signatures identified to aid in SOFC isolation and design and test

## Significant Future Milestones


**Principal Investigator** Daniel A Norrick, Cummins Power Generation
(763) 574-5301, daniel.a.norrick@cummins.com


**Partners**

**Congressional Information** Indiana 9th
Baron Hill

**Technical Development Manager/Project Manager** John Garbak, U.S. Department of Energy
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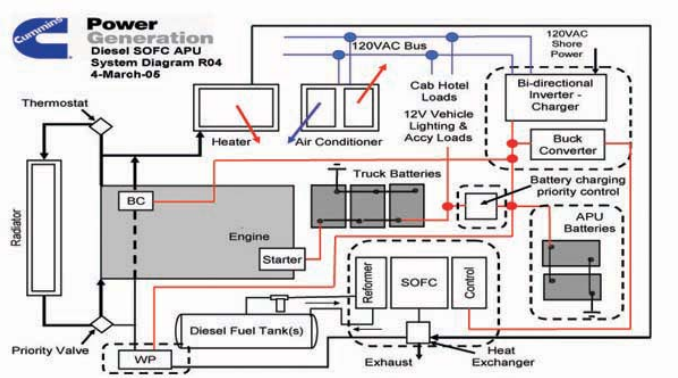
DOE015 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Idle Reduction | Technology Development | DOE | 3/1/2005 | A-75 |

# Solid Oxide Fuel Cell (SOFC) Development for Auxiliary Power in Heavy Duty Vehicle Applications

**21CTP Technical Goal** Idle Reduction: Develop fuel cell APU at 5-30 kW on diesel fuel at delivered cost of $400/kW by 2012

## Objectives

- To demonstrate an SOFC APU capable of operating on low sulfur diesel fuel, in a laboratory environment, for the Commercial Trucking Industry.
- Develop APU system requirements and concepts with major truck OEMs input
- Design, test and develop the needed subsystems for the selected concept
- Build and demonstrate the selected diesel fueled APU system to the DOE

## Current FY Focus

**Duration** 9/30/2004 through 8/31/2008

**Gov't Funding/Industry Cost Share** *Total Funding Level = $4700K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completing Milestone #1: Requirements Review
- Collaboration with PACCAR and Volvo Truck NA underway to define and document the application requirements for the APU for on-board power and climate control.
- Quantifying the power, load profile, operating conditions, durability requirements, cost targets, operator interfaces, safety parameters, volume, mass and mounting requirements for various truck models

## Significant Future Milestones


**Principal Investigator** George Simopoulos, Delphi Technical Center Kokomo
(765) 451-3755, george.n.simopoulos@delphi.com


**Partners**

**Congressional Information** Michigan 9th
Joe Knollenberg


**Technical Development Manager/Project Manager** John Garbak, U.S. Department of Energy
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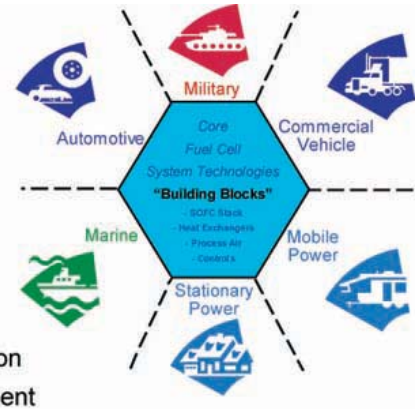
DOE016 FINAL

SOFC Power Systems Product Development Strategy:




Each application adjusted for:
- Fuel Type
- User Interface
- Electrical Configuration
- Application Environment

# Greater Sacramento Clean Air Coalition Truck Stop Electrification

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- This project seeks to advance marine-style, shorepower systems that provide grid electricity to stationary, long-haul trucks for the operation of on-board HVAC units, block heaters, and in-cab convenience appliances. The availability of electric power while overnighting, allows the diesel engine of a shorepower-capable truck to be shut down; thus saving energy and eliminating the associated noise and air pollution.

## Current FY Focus

**Duration** 2 years

**Gov't Funding/Industry Cost Share** *Total Funding Level = $80K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- New Project, no accomplishments yet. Sub-grant has not yet been awarded from CEC to SMUD.

## Significant Future Milestones

**Principal Investigator** Bill Warf, Sacramento Municipal Utilities District
(916) 732-6976, bwarf@smud.org

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Roxanne Dempsey, U.S. Department of Energy
(206) 553-2155, roxanne.dempsey@ee.doe.gov

DOE013 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Clean Cities -- Idle Reduction Deployment | Applied Research | DOE | 3/1/2005 | A-77 |

# New York State Research & Development Authority Truck Stop Electrification

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- This project installs 50 shorepower pedestals in Waterloo, NY. It also will quantify the extent and growth potential of shorepower-capable HD vehicles and provide web-based outreach and technology transfer.

## Current FY Focus

**Duration** 0 year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $100K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Construction is awaiting the spring thaw.

## Significant Future Milestones

**Principal Investigator** NYSERDA

ATRI/Shurepower/Waterloo Travel Center

**Partners**

**Congressional Information** New York 21st
Michael McNulty

**Technical Development Manager/Project Manager** Mike Scarpino, U.S. Department of Energy
(617) 565-9716, michael.scarpino@ee.doe.gov

DOE014 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Clean Cities -- Idle Reduction Deployment | Applied Research | DOE | 3/1/2005 | A-78 |

# Caterpillar MorElectric Technology Idle Reduction Demonstration

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- Benchmark and conduct in-use fleet evaluation of available and near term idle reduction technologies
- Demonstrate potential idle reduction benefits of MorElectric technology for truck heating, ventilating, and cooling
  - HVAC Unit
  - Generator
  - Auxiliary Power Unit (APU)
  - Shore Power

## Current FY Focus

**Duration** 10/1/2003 through 9/30/2007

**Gov't Funding/Industry Cost Share** *Total Funding Level = $205K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completed build and delivered 5 MorElectric system equipped International trucks to Cox Transfer
- Implemented improved electric heat controllability during idle reduction mode
- Fuel economy, performance, reliability and ease of use to be evaluated starting Jan 05

## Significant Future Milestones

**Principal Investigator** Dave Husted, Caterpillar Inc.
(309) 578-2752, dphusted@cat.com

**Partners**

**Congressional Information** Illinois 18th
Ray LaHood

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov

DOE009 FINAL

| Cox Truck # | Mileage | Main Engine Hours |
|---|---|---|
| 450 | 14,836 | 306 |
| 451 | 8,587 | 180 |
| 452 | 2,009 | 50 |
| 453 | 78 | 4 |
| 454 | 107 | 4 |
| Total | 25,617 | 544 |

# Espar Idle Reduction Technology Demonstration

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- Benchmark and conduct in-use fleet evaluation of available and near term idle reduction technologies
- Conduct in-use fleet evaluations (Wal-Mart) of idle reduction technologies
  - Espar Airtronic bunk heater (diesel fueled)
  - Espar Hydronic 5 engine preheater (diesel fueled)
  - Bergstrom Nite System (electric A/C unit)

## Current FY Focus

**Duration** 10/1/2003 through 9/30/2007

**Gov't Funding/Industry Cost Share** *Total Funding Level = $72K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Systems Installed
  - 20 Trucks with heating and A/C systems
  - 5 Trucks with generator sets and Espar Airtronic bunk heaters
  - 5 control trucks
- New project start: data currently being collected and analyzed

## Significant Future Milestones

**Principal Investigator** John Dennehy, Espar
(905) 670-0960, jdennehy@espar.com

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov

DOE010 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Idle Reduction | Applied Research | DOE | 3/15/2005 | A-80 |

# Schneider National Cab Heating & Cooling

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- Benchmark and conduct in-use fleet evaluation of available and near term idle reduction technologies
- Determine performance of Webasto cab coolers, Webasto Airtop 2000 cab heaters, and Bergstrom Nite cooling systems

## Current FY Focus

**Duration** 6/1/2003 through 10/31/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $137K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Determined Webasto cab cooler not suitable for retrofit
  - Installation technically difficult
  - At high temperatures, performance degrades 85°F - 10 hrs, 90°F - 7 hrs, >90°F proportional drop
- Webasto Airtop heaters demonstrated significant improvement, 0.3 to 0.4 mpg.
  - Idle 17% vs. 37% for control in coldest months
  - Driver satisfaction is high

## Significant Future Milestones


**Principal Investigator** Dennis Damman, Schneider
dammand@schneider.com


**Partners**

**Congressional Information** Wisconsin 8th
Steve Kagen M.D.

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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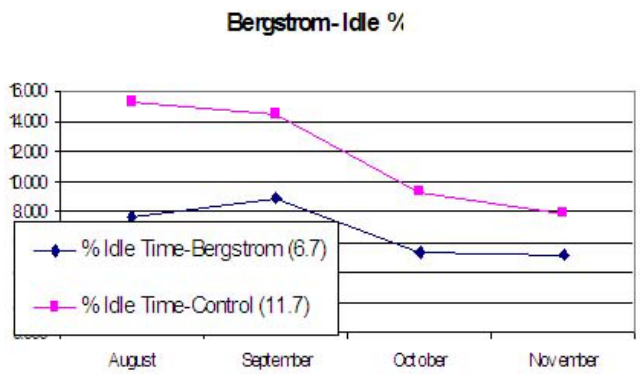
DOE008 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Idle Reduction | Applied Research | DOE | 3/15/2005 | A-81 |

# Health Impacts of Engine Emissions

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** | Other 21CTP Research Areas

## Objectives

This project will improve our current understanding of the role of lubricating oil on particulate matter (PM) emissions from gasoline, diesel, and CNG-powered vehicles by characterizing emissions under a variety of engine operating conditions at room temperature and cold operating conditions

## Current FY Focus

Wrote white paper describing influence of lube oil on mobile source emissions; completed project plan; issued RFP; evaluated proposals; selected winning contractor

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $570K / $K FY06 = $500K / $K FY07 = $500K / $K

## Accomplishments

Completed project planning with California Air Resources Board and South Coast Air Quality Management District – March 2006
Issued RFP, evaluated proposals, and selected winning bid – October 2006

## Significant Future Milestones

Begin Vehicle Testing on Chassis Dynamometer – March 2007
Complete Chemical Analysis of Exhaust Samples – January 2008
Draft Final Report – April 2008; Final Report – June 2008

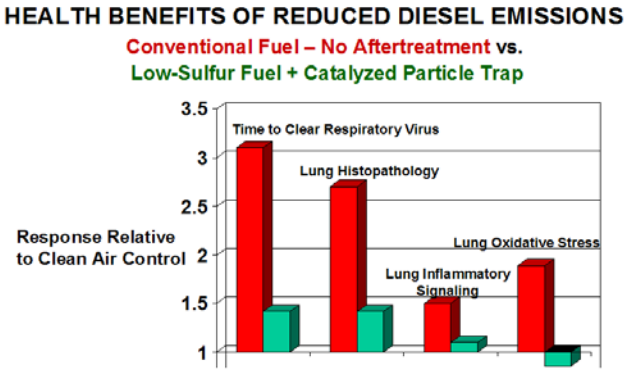
**Principal Investigator** Joe Mauderly, Lovelace Respiratory Research Institute
(505) 348-9432, jmauderl@lrri.org

**Partners** API, Cummins, Chevron, DCX, EPRI, Exxon, Ford, GM, Int'l, others

**Congressional Information** New Mexico 1st
Heather Wilson

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
(202) 586-9837, james.eberhardt@ee.doe.gov

DOE356 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18546 / | Health Impacts | Applied Research | DOE | 10/30/2006 | A-82 |

# ORNL APBF: Watt Road Environmental Laboratory

**21CTP Technical Goal** | Other 21CTP Research Areas

## Objectives

- Improve understanding of "real-world" mobile source evolution as a function of meteorology, geography, and traffic at unique site near Knoxville, TN with high volume of heavy-duty truck traffic (>20,000 trucks per day on Interstates 40 and 75)
- Understand potential impact of developing fuel, combustion, and aftertreatment technologies on air quality and, thereby, human health

## Current FY Focus

Mobile Source Air Toxics from advanced combustion modes

**Duration** 9/30/2004 through

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $K FY06 = $250K / $K FY07 = $350K / $K

## Accomplishments

- Developed and deployed (3) remote sensing techniques for mobile source emission characterization: UV spectroscopic technique for NO measurement; LIDAR technique for PM measurement; and acoustic technique for engine operation characterization.
- Determined that idling trucks at (3) major truck stops contribute more emissions than trucks traveling on interstate in air quality studies at Watt Road-I-40/75 interchange (with EPA and DOT)

## Significant Future Milestones

Characterize the mobile source air toxics from advanced combustion modes on a diesel engine platform

**Principal Investigator** Jim Parks, Oak Ridge National Laboratory
(865) 946-1283, parksjeii@ornl.gov
John Storey, Oak Ridge National Laboratory

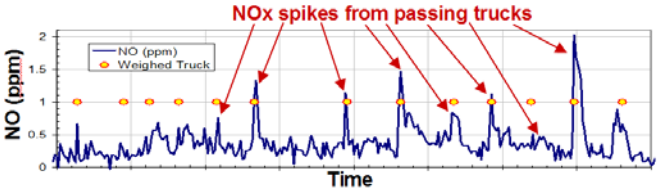
**Partners** ORNL, DOT FHWA

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
(202) 586-9837, james.eberhardt@ee.doe.gov

DOE230 FINAL

**Remote Sensing of Heavy-Duty Truck Emissions at I-40/75 Weigh Station**




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18546 / 13415 | Health Impacts | Applied Research | DOE | 10/30/2006 | A-83 |

# Characterization of Long-Haul Heavy Vehicle Duty Cycles

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** | Other 21CTP Research Areas

## Objectives

Collection, Analysis, and Archiving of Heavy Truck Driving Characteristics and Duty Cycles to:
- Support the Evaluation of Benefits of Energy Efficiency Technologies (DOE)
- Support ANLs Development and Evaluation of the PSAT Class-8 Truck Module
- Support the Vehicle Dynamics Needs of Dana and Michelin
- Possibly Provide DOT With Additional Data on Long-Haul Naturalistic Driving (discussions with FMCSA & VTTI)

## Current FY Focus

**Duration** 1/1/2005 through 5/30/2006

**Gov't Funding/Industry Cost Share** *Total Funding Level = $900K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Identification of Relevant Heavy Truck Performance Measures (Draft Completed)
- Development of a Pilot Testing Plan (Draft Completed)
- Procure/Develop Necessary Sensors and Develop an Integrated Sensor Architecture (Initiated)

## Significant Future Milestones


**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
(865) 946-1300, kneehe@ornl.gov


**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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DOE001 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Heavy Hybrids | Applied Research | DOE | 3/15/2005 | A-84 |

# 21st Century Locomotive (System) Technology

21CTP Technical Goal | Other 21CTP Research Areas

## Objectives

-- Locomotive system developments for 15-20% fuel usage reduction through energy management and fuel optimization: capturing and storing regenerative braking energy, fuel optimization control (route, terrain, and train characteristics)

## Current FY Focus

-- Develop and test advanced energy storage system modules
-- Demonstrate advanced hybrid locomotive energy management system
-- Develop and demonstrate locomotive consist manager
-- Develop and demonstrate trip optimizer

**Duration** 1/1/2003 through 12/31/2007

**Gov't Funding/Industry Cost Share**

FY05 = $575K / $K  FY06 = $335K / $K  FY07 = $K / $K

## Accomplishments

1: Accomplishment –Selected high-energy-density, temperature-insensitive Na-NiCl2energy storage technology
2: Project Deliverable –Demonstration of hybrid locomotive on test track with advanced EMS controls, February 2005
3: Project Deliverable –Track demonstration of locomotive consist fuel optimizer using one degree of freedom controls, February 2004
4: Accomplishment –developed interactive fuel optimizer demo simulator and demonstrated trip optimizer to railroads

## Significant Future Milestones

Project Deliverable –Hybrid locomotive test track demonstration incorporating the integrated fuel optimization controls –December 2007


**Principal Investigator** Lembit Salasoo, General Electric
(518) 387-5024, salasoo@crd.ge.com
Robert King, General Electric
(518) 387-5747, kingrd@crd.ge.com

**Partners** General Electric

**Congressional Information** New York 21st
Michael McNulty

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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DOE338 FINAL

Railroad modality: 2.5% national fuel usage
Project's 20% fuel reduction gives **0.5% impact on national fuel usage**

***Project deliverable*** *Advanced hybrid energy management demonstration on GE's "on-board" proof-of-principle hybrid locomotive demonstrator*

***Project deliverable***
Consist manager demonstration on Class 1 RR 2x1740mi mission

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18497 / 15455 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 4/1/2006 | A-85 |

# Aerodynamic Drag (Includes Spray from Rolling Tires)

**21CTP Technical Goal** Parasitic Losses: Reduce aerodynamic drag by 20%

## Objectives

-- Insure safety of drag savings devices in presence of splash & spray
-- Experimentally characterize initial droplet distribution to aid numerical computations at LLNL
-- Utilize physical understanding gained from study as a means to mitigate spray from heavy trucks

## Current FY Focus

Assemble tire spray simulator and perform preliminary experiments

**Duration** 9/28/2002 through 10/1/2008

**Gov't Funding/Industry Cost Share**

FY05 = $110K / $K FY06 = $412K / $K FY07 = $232K / $K

## Accomplishments

Accomplishment 1 – Devised new technique for studying spray in the laboratory
Accomplishment 2 – First laser sheet pictures of water break-up in tire-tread

## Significant Future Milestones

Milestone 1 – Negotiate commercial interaction with Michelin Americas interested in making spray studies – April 2006
Milestone 2 – Apply spray study results in conjunction with LLNL to produce safe, effective underbody drag reducing devices


**Principal Investigator** Fred Browand, University of Southern California
(213) 740-5359, browand@spock.usc.edu
Lawrence Livermore National Laboratory


**Partners** LLNL, Michelin, USC

**Congressional Information**


**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov


DOE080 FINAL

# DOE Consortium on Heavy Vehicle Aerodynamic Drag

**21CTP Technical Goal** Parasitic Losses: Reduce aerodynamic drag by 20%

## Objectives

- Through experiments & computations, develop understanding of heavy vehicle aerodynamics for design of drag reduction concepts, splash & spray, & brake cooling
- Establish a database of experimental, computational, & conceptual design information
- Demonstrate potential of new drag-reduction devices
- Goals to develop concepts & devices that achieve 25% drag reduction & improve safety

## Current FY Focus

**Duration** 5 years

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Drag reduction concepts developed/tested
  - 25% reduction, billions of gallons!
- Computations with experimental validation
  - insight & guidelines
- Collaborations with industry – getting devices on road
- Open documentation/database -international recognition

## Significant Future Milestones


**Principal Investigator** Rose McCallen, Pacific Northwest National Laboratory
(925) 423-0958, mccallen1@llnl.gov


**Partners**

**Congressional Information** Washington 4th
Doc Hastings


**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE007 FINAL

**Reduce truck aero drag through joint experiments & computations leading to intelligent design**

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Aerodynamics | Exploratory R and D | DOE | 3/15/2005 | A-87 |

# Heavy Vehicle Drag and Safety: Spray from Rolling Tires

**21CTP Technical Goal** Parasitic Losses: Reduce aerodynamic drag by 20%

## Objectives

-- Insure safety of drag savings devices in presence of splash & spray
-- Experimentally characterize initial droplet distribution to aid numerical computations at LLNL
-- Utilize physical understanding gained from study as a means to mitigate spray from heavy trucks

## Current FY Focus

Assemble tire spray simulator and perform preliminary experiments

**Duration** 1/1/2005 through 3/31/2007

**Gov't Funding/Industry Cost Share**

FY05 = $110K / $K FY06 = $75K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Devised new technique for studying spray in the laboratory
Accomplishment 2 – First laser sheet pictures of water break-up in tire-tread

## Significant Future Milestones

Milestone 1 – Negotiate commercial interaction with Michelin Americas interested in making spray studies – April 2006
Milestone 2 – Apply spray study results in conjunction with LLNL to produce safe, effective underbody drag reducing devices


**Principal Investigator** Fred Browand, University of Southern California
(213) 740-5359, browand@spock.usc.edu


**Partners** Michelin

**Congressional Information**


**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
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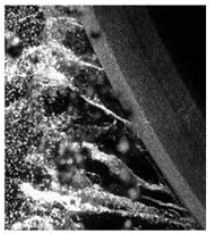
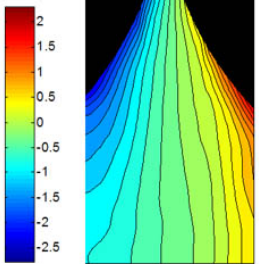
DOE328 FINAL



Droplet formation is the result of the break-up of thin sheets of water (laser image, 5 ns exposure)

Water motion tracked with digital particle image velocimetry




*Lateral water velocity, m/s*

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18493 / 15608 | Heavy Vehicle Systems -- Aerodynamics | Exploratory R and D | DOE | 4/19/2006 | A-88 |

# Heavy Vehicle Drag Estimation Using Commercial CFD Tools

**21CTP Technical Goal** Parasitic Losses: Reduce aerodynamic drag by 20%

## Objectives

Enable use of commercial CFD to achieve improvements in tractor-trailer fuel economy through significant reductions in parasitic losses resulting from aerodynamic drag

## Current FY Focus

-- Demonstrate applicability of lessons learned to realistic tractor trailer geometries
-- Demonstrate applicability for predicting changes in aerodynamic drag

**Duration** 5/1/2001 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $310K / $K FY06 = $212K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Signed CRADA with PACCAR Technical Center – September 2002
Accomplishment 2 –Demonstrated applicability to simplified truck geometry at zero yaw – September 2003
Accomplishment 3 –Demonstrated applicability to simplified truck geometry at yaw angles – March 2005
Accomplishment 4 – Signed CRADA with Caterpillar, Inc, -- July 2005
Accomplishment 5 – Initial Application to prediction of changes in drag resulting from changes in radiator size– March 2006

## Significant Future Milestones

Milestone 1 –Demonstrate applicability to realistic tractor trailer geometries– September 2006
Milestone 2 – Demonstrate applicability to prediction of changes in drag resulting from significant geometric changes – September 2006
Milestone 3 – Demonstrate applicability to prediction of changes in drag resulting from subtle geometric changes – September 2007


**Principal Investigator** W. David Pointer, Argonne National Laboratory
(630) 252-1052, dpointer@anl.gov


**Partners**

**Congressional Information** Illinois 13th
Judy Biggert

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov

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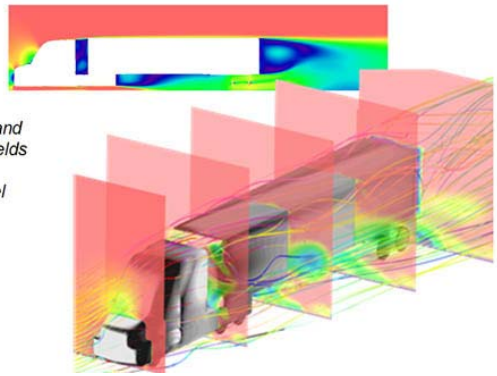
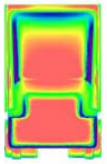


*Predicted velocity and surface pressure fields for the Generic Conventional Model*



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18493 / 16625 | Heavy Vehicle Systems -- Aerodynamics | Exploratory R and D | DOE | 4/18/2006 | A-89 |

# TMA - Test, Evaluation, and demonstration of practical devices and systems to reduce aerodynamic drag of tractor-Semitrailer combination-unit trucks

**21CTP Technical Goal** Parasitic Losses: Reduce aerodynamic drag by 20%

## Objectives

Determine aerodynamic drag/fuel economy effects of additions or changes to Class 8 tractor/semitrailer configurations through combination of analysis, wind tunnel testing, and on-road vehicle testing

## Current FY Focus

Conduct preliminary testing and analysis on a wide range of candidate devices and systems to determine effectiveness of such devices and downselect devices for further research

**Duration** 9/30/2004 through 9/29/2006

**Gov't Funding/Industry Cost Share**

FY05 = $642K / $K FY06 = $600K / $K FY07 = $142K / $K

## Accomplishments

-- Completed wind tunnel and CFD modeling of Class 8 truck and mirror system to establish mirror effect on aerodynamic drag: mirrors contribute approximately 4.5% to total aero drag (based on experimental results) (Freightliner)
-- Completed evaluation of modifications to trailer sides, trailer wake, and tractor-trailer gap through two rounds of one-eighth scale model wind tunnel testing: aerodynamic drag reductions of up to 23% were demonstrated in wind tunnel testing (International)
-- Developed preliminary CFD design for cab side extenders for gap enclosure, and estimated potential for 2-4% reduction in drag force. Conducted workshop with aerodynamics experts to identify devices with best potential for significant drag reduction. Added aerodynamic aids to van trailer for further on-road testing (Mack)
-- Performed CFD analysis of the effect of vehicle underside design and airflow management on truck aerodynamics. Estimated that vehicle underside design is associated with ~35% of total vehicle drag, and that modifications to underside design and trailer gap could reduce overall drag by ~5-6% (Volvo)

## Significant Future Milestones

Fabricate and test several promising aerodynamic devices in real-world on-road testing and through wind tunnel testing

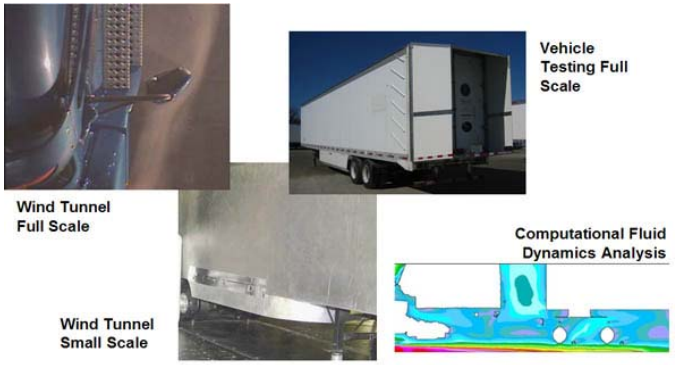

**Principal Investigator** Robert Clarke, Truck Manufacturers Association
(202) 638-7825, robertmclarke@truckmfgs.org


**Partners** TMA

**Congressional Information** DC At Large
Eleanor Holmes Norton


**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov


DOE083 FINAL



# Demonstration of Air-Power-Assist Engine Technology For Clean Combustion and Direct Energy Recovery In Heavy Duty Application

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Demonstrate a minimum of 15% fuel economy improvement over the state-of-the-art 2007 emissions capable baseline engine, with emissions meeting the 2010 EPA regulation through the development of air-power-assist (APA)/air hybrid engine technology. Attainment of the fuel economy and emissions target will be verified in engine transient testing in a laboratory environment.

## Current FY Focus

APA engine functional specifications and component design were completed in this year.

**Duration** 8/29/2005 through 4/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $234K / $234K FY06 = $259K / $259K FY07 = $350K / $350K

## Accomplishments

APA engine functional specifications were completed.
Vehicle simulation with APA technology showed 4-18% efficiency improvement over a wide range of driving cycles.
Low temperature exhaust gas recirculation (EGR) circuit offered additional 3-4% efficiency improvement in vehicle simulation tests.

## Significant Future Milestones

Integrate the hydraulic valve actuator (HVA) system with Volvo MD11 engine for baseline testing.
Upgrade the HVA system and install air handling system.
Develop hybrid engine control strategy.
Perform testing of low-temperature EGR circuits for improved engine efficiency.


**Principal Investigator** Chun Tai, Mack Trucks Inc
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**Partners** Mack Trucks Inc., Sturman Industries, University of California Los Angeles

**Congressional Information** Maryland 6th
Roscoe Bartlett


**Technical Development Manager/Project Manager** Roland Gravel, U.S. Department of Energy
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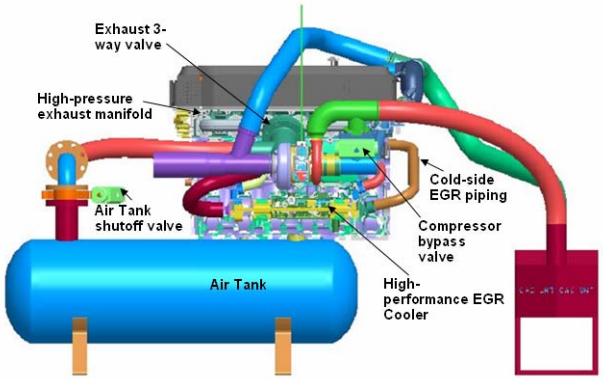
Sam Taylor, National Energy Technology Laboratory
(304) 285-4681, samuel.taylor@netl.doe.gov


DOE316 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 19042 / 14534 | Advanced Combustion | Applied Research | DOE | 1/9/2007 | A-91 |

# Very High Fuel Economy, Heavy Duty, Constant Speed, Truck Engine Optimised via Unique Energy Recovery Turbines and Facilitated by High Efficiency Continuously Variable Drivetrain

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Increase engine efficiency by 10% while meeting US2010 emissions standards.
Achieve efficiency increase by implementing energy recovery devices in the form of turbo compound and narrow the engine operating speed range. Couple the engine to a CVT to enable the engine to operate in a narrow or constant speed (1000-1300 RPM).
Test the engine CVT combination over road cycles in a test cell to demonstrate system efficiency increase.

## Current FY Focus

Detailed engine simulations were done considering the Volvo MD13 (485hp/2600Nm) engine to determine the benefit of reducing the engine speed and impact on efficiency. Based on the engine simulations, prototype turbocharger and turbo compound hardware will be designed and manufactured. The prototype hardware will be installed onto a 13L Volvo engine for testing to compare simulation results with actual.

**Duration** 9/1/2005 through 1/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $250K FY06 = $11K / $11K FY07 = $650K / $650K

## Accomplishments

Through simulation, demonstrated an engine efficiency increase of 8.2% when operating over a road cycle and 10.5% during steady state operation over the ESC/OICA at US2010 NOx levels (0.2 g/bhp-hr).
Met the milestone that the added investment for the CVT and energy recovery devices will be returned in less than 1.5 years assuming fuel prices of $2.50 per gallon.
Net fuel efficiency when coupled to a CVT was estimated to be 5%.

## Significant Future Milestones

Design a compressor and two turbines (turbocharger and compound), tailored for the highly weighted operating points.
Design of complete turbocharger and turbo compound units.
Test these compressor and turbines in special rigs in order to verify the theoretical performance.
Build prototype high efficiency turbo and turbo compound units for testing.
Begin baseline engine development that will include high efficiency turbo and turbo compound units.
Demonstrate the engine and CVT system in a test cell environment to determine system efficiency.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**Partners** Mack Trucks Inc

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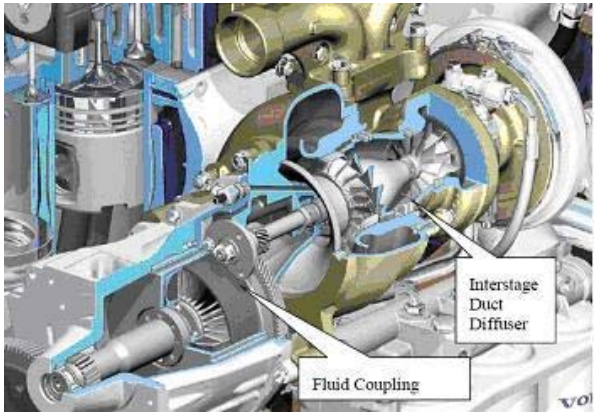

# Systems Analysis for Heavy Vehicles

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Provide scientific evaluations, using analytical techniques, of technologies to increase fuel efficiency and reduce emissions of heavy vehicles

## Current FY Focus

Idling reduction

**Duration** 0 year

**Gov't Funding/Industry Cost Share**

FY05 = $240K / $K FY06 = $220K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1: Organized/chaired National Idling Conference
Accomplishment 2: Co-chaired Technology Working Group
Accomplishment 3: Wrote paper to be published in Transportation Research Review
Accomplishment 4: Presented posters at DEER and AWMA
Accomplishment 5: Presented information on idling nationwide (>12 locations)
Accomplishment 6: Extended analysis to workday idling and upstream emissions

## Significant Future Milestones

Milestone 1: Analysis of technology costs (September 2006)
Milestone 2: Survey of workday idling (2006)
Milestone 3: Analysis of total fuel cycle impacts (2007)


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**Partners**

**Congressional Information** Illinois 13th
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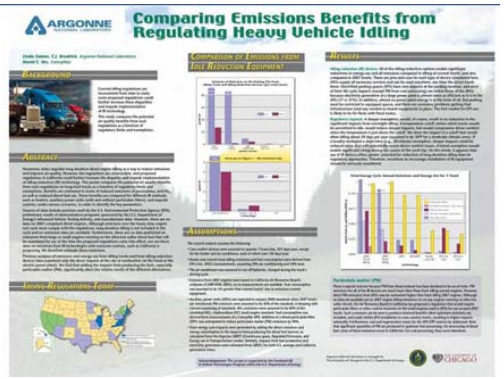
DOE335 FINAL

Poster shows results of the full fuel cycle analysis




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18497 / 15564 | Heavy Vehicle Systems -- Idle Reduction | Applied Research | DOE | 4/1/2006 | A-93 |

# Advanced Brake Systems and Undercarriage Aerodynamic Flow

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

To assess the potential of alternate disc brake system designs and technology concepts to improve energy efficiency, performance, and vehicle safety and stability. System and
material optimization will lead to increased energy efficiency, reduced environmental impact, and improved life cycle costs.

## Current FY Focus

-- Develop system-based computational tools for the evaluation of the impact of new brake materials and designs on brake cooling, underhood temperature, and overall vehicle thermal management. Incorporate model into a module for a PSAT-like simulation tool.
-- Experimentally determine thermo-mechanical, wear, and durability properties of several new material options for brake rotors, pads and calipers, and use this data set to validate
and calibrate the computational model.

**Duration** 1/1/2004 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $K FY06 = $90K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Developed generalized thermal / stress model of a disc brake system. The thermal model allows for interchangeable material parameters and designs to predict the effect on heat transfer and stresses caused by material and design changes.
Accomplishment 2 – Evaluated several candidate advanced material friction pairs, and used the new material properties in the simulations to predict heat generation and heat transfer

## Significant Future Milestones

Milestone 1 – Validate model by on-vehicle testing using baseline current disk brake systems (OEM support)
Milestone 2 – With OEM and Brake Tier 1 supplier , use numerical model to investigate new lightweight advance brake materials and design changes, and validate with on-vehicle testing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**Partners**

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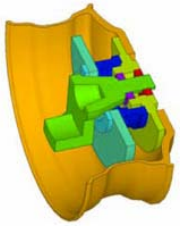
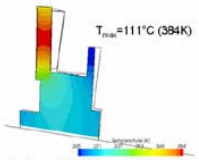
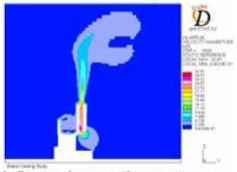


Generalized solid model




Brake transient thermal profile



Air flow and convection at rotor

**Predictive modeling of stress, heat transfer, and airflow in response to new brake materials and designs**

# Advanced Electric Systems and Aerodynamics for Efficiency Improvements in Heavy Duty Trucks

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Analyze, design, build, and test a cooling system that provides at least 10% greater heat rejection with no increase in parasitic fan load.
-- Quantify the effect of aerodynamic drag due to the frontal shape mandated by the area required for the cooling system.
-- Realize fuel savings with advanced power management and mild hybrid operation, utilizing motor generator and energy storage devices.

## Current FY Focus

-- Complete integration of electric components into test vehicle
-- Conduct thermal and fuel economy chassis dyno testing
-- Conduct on-road fuel economy testing

**Duration** 10/1/2004 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $412K / $412K FY07 = $320K / $320K

## Accomplishments

-- Integrated Motor Generator (IMG) algorithms and dyno testing complete, fully characterized for engine assist operation over 0 to 2400 rpm range.
-- Engine stop/start mode with IMG operational, allowing engine idle stop.
-- Electric Thermostat Valve installation and initial testing in MET complete.
-- 2 prototype 20 kW Electric cooling fan motors designed and fabricated, motors on-site at Caterpillar, motor drive communication testing complete.
-- Underhood thermal analysis complete
-- High fidelity vehicle simulation model and drive cycle analysis complete.
-- Engine Cooling Module with electric fan, high temp charger air cooler, and auxiliary oil cooler complete.
-- NiMH energy storage system installed in MET.

## Significant Future Milestones

Milestone 1 – Complete component integration on vehicle – March 2007
Milestone 2 – Complete cooling and fuel economy performance testing – July 2007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**Partners** Caterpillar

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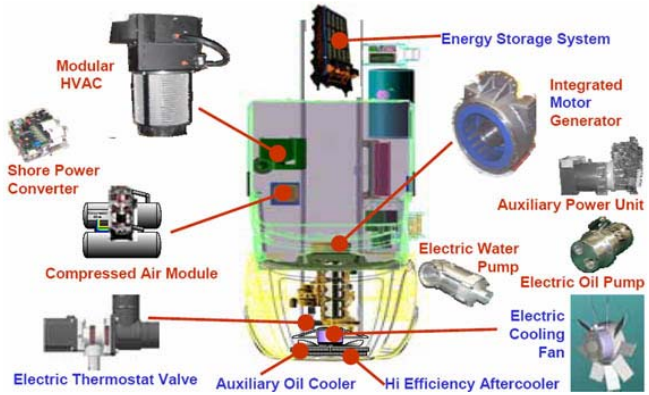

# Autothermal Diesel Reformer

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Develop a kW-auxiliary power unit (APU) based on an autothermal reforming process to convert diesel fuel into hydrogen-rich gas on-board a heavy-duty vehicle. Main issues are avoiding preignition and coke formation and achievement of catalyst stability.

## Current FY Focus

**Duration** 0 year

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

-- Built a single-injector (ITEC's fuel injector) test facility
-- Conducted air/fuel mixing tests with a parallel flow mixing geometry
-- Conducted cool-flame tests

## Significant Future Milestones

-- Complete mixing tests with varied O2/C and O2/C/H2O ratios
-- Complete cool-flame tests at different air/steam/fuel mixing conditions
-- Conduct tests to optimize the ANL catalytic ATR process


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**Congressional Information** Illinois 13th
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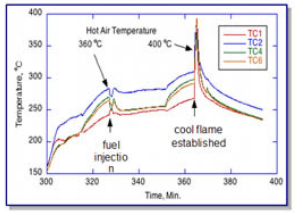
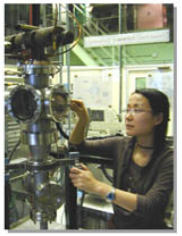
DOE115 FINAL

Fuel mixing quality can be determined by measuring the temperature profile downstream the fuel injector.
Cool flame can be characterized by rapid temperature rise.



Argonne has built a Fuel/Steam/Air Mixing Facility where engineers can vary fuel type, fuel-air-steam ratios, flow rates, temperature, and mixing methods. The facility will be used for evaluation and optimization of the catalytic diesel fuel ATR process.

# Boundary Layer Lubrication Mechanisms - A Systems Approach

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Develop better understanding of friction mechanisms under boundary lubrication regime.
-- Determine the mechanisms and methods to prevent catastrophic failure in lubricated surfaces in terms of material behavior and properties
-- Establish and validate performance and failure prediction methodology for lubricated systems
-- Integrate surface and lubrication technologies to minimize friction and wear

## Current FY Focus

-- Validate and extend scuffing model to other material, lubrication systems
-- Continue to develop and refine boundary film characterization by x-ray analysis and its relation to friction and wear properties

**Duration** 10/1/2002 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $600K / $K FY06 = $300K / $K FY07 = $400K / $K

## Accomplishments

Accomplishment 1 –Developed a model for scuffing mechanism based on adiabatic shear instability. Accomplishment 2 –Applied x-ray-based techniques to characterize tribofilms; developed an x-ray accessible tribotester. Accomplishment 3 –Active participant as subcontractor on Eaton project to achieve a minimum of 2.5% fuel efficiency by reductingfriction in drivetrains.Accomplishment 4 –Extensive industrial interaction for effective technology transfer.

## Significant Future Milestones

Milestone 1 –Refine scuffing model to incorporate other material behavior.Milestone 2 –Measure mechanical behavior to tribochemicalfilms.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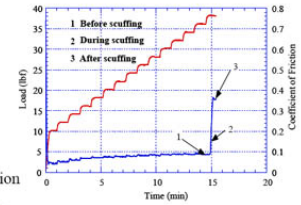
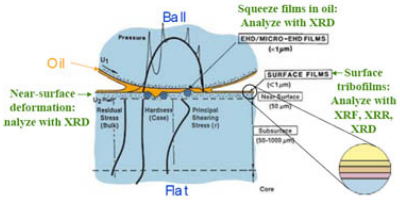
ANL model predicts that the critical shear strain to initiate scuffing is given by:

$$\gamma = \frac{n\rho C_v}{0.9\frac{\partial \tau}{\partial T}}$$




Using the APS to analyze boundary lubrication



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18496 / 8979/15473 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 4/19/2006 | A-97 |

# Caterpillar-Parasitic Energy Loss Reduction and Enabling Technologies for Class 7/8 Trucks

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Reduce Parasitic Losses for Fuel Savings
-- Reduce Radiator Heat Load
-- Provide Anti-Idling Solutions

## Current FY Focus

**Duration** 9/1/2001 through 5/31/2004

**Gov't Funding/Industry Cost Share**

FY05 = $550K / $K FY06 = $K / $K FY07 = $490K / $K

## Accomplishments

-- Prototype electric accessory components developed, integrated and tested
-- Prototype integrated starter generator and power distribution architecture developed, integrated and tested
-- Auxiliary power unit and shore power converter developed, integrated and tested
-- Supervisory control algorithms developed and implemented
-- Completed fuel economy and thermal performance testing – fuel economy improvement of 1-2 % demonstrated for over the road operation; yearly fuel savings of 5-7 % potential demonstrated from reduced main engine idling

## Significant Future Milestones

Project platform has been continued with Advanced Electric Systems project – NT 42189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**Partners** Caterpillar

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DOE094 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18494 / 11509, 17812 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Applied Research | DOE | 4/19/2006 | A-98 |

# Cooling Fan and System System Performance and Efficiency Improvements

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Develop cooling system fans and fan systems that will allow off-highway machines to meet Tier 3 emissions regulations and reduce spectator sound levels with improved fuel efficiency, and within the functional constraints of machine size.

## Current FY Focus

-- Complete design of large high performance axial fan
-- Complete performance and sound tests of 'aerodynamic' fan shroud
-- Complete lab development of radiator air filtration system

**Duration** 6/1/2002 through 7/31/2005

**Gov't Funding/Industry Cost Share**

FY05 = $138K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 –Demonstrated 5% flow (goal of 10%) improvement and 10% efficiency improvement (met goal) of large axial fan
Accomplishment 2 –Demonstrated ability to meet performance goals of 'aerodynamic' fan shroud over a narrow operating range. Noise level of fan reduced by up to 2dB
Accomplishment 3 –Fan CFD modeling guide completed to provide 5% accuracy
Accomplishment 4 –Small fan performance demo terminated when unable to meet performance goal
Accomplishment 5 –Fan drive development terminated when unable to meet performance goal
Accomplishment 6 –Demonstrated 'air knife' concept to provide fine debris filtration for high performance radiators

## Significant Future Milestones


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**Partners**

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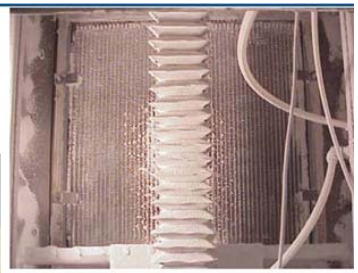
DOE337 FINAL-R1

A moving, high velocity 'air knife' used to clean fine inorganic debris from the face of a radiator



'Aeroshroud' concept can change the point of fan stall, and dramatically change fan performance over a narrow range.

# Cummins CRADA: Diesel Engine Underhood Thermal Analysis

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Develop an integrated thermal analysis capability to help OEM's design more energy efficient vehicles with acceptable underhood temperatures: determination of accurate temperature distributions in an engine allows redesign of the underhood configuration and help achieve fuel efficiencies through cooling system optimization and radiator size reduction
-- Address issues related to emission control technologies needed to meet the new diesel engine emission requirements

## Current FY Focus

-- Built a thermo-fluid systems model to characterize a Cummins engine with cooled EGR
-- Develop new models for cooling system package
-- Conduct thermal performance tests to generate data for model validation

**Duration** 2/1/2006 through 1/31/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $270K / $300K FY07 = $330K / $300K

## Accomplishments

-- A predictive capability developed to study thermal conditions and identify hot-spots inside divided engine compartment of an off-road machine: a prototypical test-rig was built at Caterpillar and experiments were conducted with controlled ventilation air inlet locations and flow rates; assessments of 1-D and 3-D simulation methods were performed to study effects of ventilation on heat rejection and component temperatures
-- Joint effort led to a validated integrated analysis capability that needs only the flow rates and inlet temperatures as boundary conditions

## Significant Future Milestones

-- Extend ANL's integrated analysis approach to simulate diesel engine thermal performance with after-treatment devices in heavy-duty trucks
-- Through cooling system optimization, OEMs can achieve up to 20% increase in heat rejection without increasing radiator size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**Congressional Information** Illinois 13th
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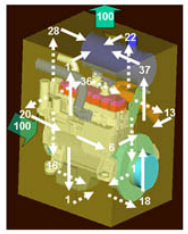
DOE334 FINAL

An extension of collaborations with Caterpillar on underhood thermal analysis of an off-road machine with divided engine and cooling system compartments



Since high underhood temperatures reduce component durability and life, maintaining acceptable underhood temperatures in the engine compartment with limited ventilation is an important element of design cycle

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|---|---|---|---|---|---|
| 18494 / 9938/16625 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 4/19/2006 | A-100 |

# EATON - Efficiency Improvement Through Reduction of Friction and Wear in Powertrain Systems

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- To conduct research and development to reduce friction and parasitic energy loss in truck transmissions and axles.
-- Create an integrated component design and analysis procedure to minimize friction and oil churning losses without compromise in performance and durability.

## Current FY Focus

-- Develop boundary film characterization capability.
-- Assess potential benefits due to friction reduction in gears.

**Duration** 10/1/2004 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $500K / $K FY06 = $418K / $K FY07 = $400K / $K

## Accomplishments

Accomplishment 1 –Modified bench tests for friction measurements. Conducted friction prediction utilizing a range of surface characteristics, lubricants, and surface topographies demonstrating significant potential for parasitic energy loss reduction.
Accomplishment 2 –Calibrated rough surface contact model using test data and data from literature. Published/presented six technical papers.
Accomplishment 4 –Established in-situ boundary film analysis capability and validated its operation.

## Significant Future Milestones

Milestone 1 –Complete development of individual models and start to integrate them into a surface design capability –Oct. 06
Milestone 2 –Select the best lubricant for friction reduction in axles and transmissions using both coupon and selected component tests –Oct 06.


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**Partners** Eaton, ANL, Northwestern University, Caterpillar

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Sander Levin


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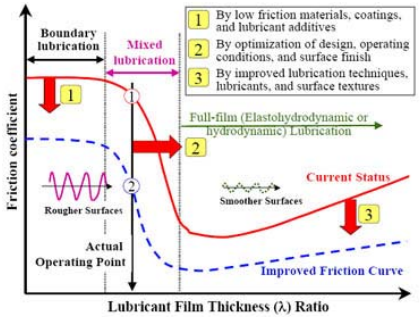
DOE106 FINAL-R1




*Stibeck curves showing project strategy & goals.*

*Typical truck diriveline gears*

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18496 / 11511/12039/17814 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 1/23/2007 | A-101 |

# Efficient Cooling in Engines with Nucleate Boiling

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Reduce cooling system size by development of more efficient heat transfer method.
- Determine two-phase flow engine coolant heat transfer rates and pressure drops.
- Develop design models/correlations.
- Determine limits of two-phase flow application.

## Current FY Focus

- Design, fabricate, instrument, and verify vertical test section..
- Experimentally measure boiling heat transfer, pressure drop, and critical heat flux of vertical flow.
- Establish working relation with industry.

**Duration** 10/1/1999 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $K FY06 = $275K / $K FY07 = $200K / $K

## Accomplishments

- Determined water boiling differences between small and large tubes.
- Determined ethylene glycol/water boiling rates and characteristics in small tubes.
- Developed engineering/design models/correlations.
- Determined practical limits of engine coolant boiling.

## Significant Future Milestones

- Determine vertical channel boiling heat transfer rates; compare to horizontal channel; model/correlate results.
- Investigate alternative engine coolants.
- Investigate higher temperature coolant boiling.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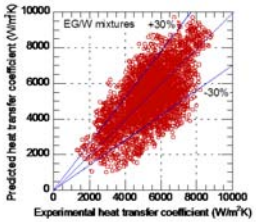
DOE331 FINAL-R1

*Horizontal test section for boiling ethylene glycol/water mixtures*




*Comparison of experimental and predicted boiling heat transfer coefficients*

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|---|---|---|---|---|---|
| 18494 / 16624 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 1/23/2007 | A-102 |

# Erosion of Advanced Radiator Materials

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Demonstrate the viability of nanofluids for HV radiator systems
- Develop apparatus to study erosive effects of high thermal conductive nanofluids on radiator systems.
- Determine effect of nanofluids as a lubricant in engine systems.
- Develop predictive models for nanofluid erosion and wear in engine components/systems.
- Establish the applicability of nanofluids as a coolant for HV radiator systems as well as for tribological applications in engine systems.

## Current FY Focus

- Collect erosion data for Cu nanoparticles in triethylene glycol at velocities of 1 to 10 m/s and impact angles of 30-90° impacting Al 3003
- Study effect of using both Cu and Al2O3 nanoparticle in a fluid on friction and wear of steel

**Duration** 10/1/2004 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $365K / $K FY06 = $175K / $K FY07 = $50K / $K

## Accomplishments

- Apparatus to study erosion built and calibrated.
- Baseline erosion data on aluminum using ethylene glycol/water established
- Baseline erosion data on aluminum using Cu nanofluid established
- Tests to study tribological behavior of nanofluids initiated

## Significant Future Milestones

- Complete investigation of effect of CuO nanoparticles in ethlylene glycol as a function of velocity, impact angle, and particle loading
- Establish wear behavior using nanofluids
- Develop predictive models for erosion and wear using nanofluids – September 2008
- Establish working relationship to major radiator company.


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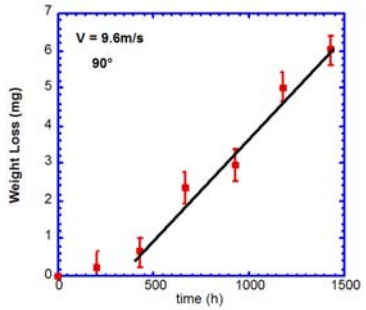
DOE090 FINAL




Weight loss for Al 3003 using 0.01 vol.% Cu nanoparticle in triethylene glycol. Erosion is insignificant.

# Heat Transfer in Nanofluids

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Determine feasibility of nanofluid applications in heavy vehicle engine cooling to reduce cooling system size.
- Quantify single-phase heat transfer enhancement and pressure drop.
- Determine two-phase heat transfer, pressure drop, and critical heat flux.

## Current FY Focus

- Design, fabricate, and verify experimental test facility.
- Measure single-phase heat transfer coefficient and pressure drop in model nanofluids.

**Duration** 10/1/2005 through 9/30/2010

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $K FY06 = $150K / $K FY07 = $150K / $K

## Accomplishments

- Designed, fabricated, and instrumented an experimental test facility.
- Quantify experimental test section heat loss.
- Developed data acquisition and reduction techniques and programs.
- Performed single-phase heat transfer tests of ethylene glycol.

## Significant Future Milestones

- Experimentally investigate single-phase heat transfer and pressure drop of nanofluids.
- Perform boiling heat transfer and pressure drop tests of nanofluids.
- Investigate boiling critical heat fluxes of nanofluids.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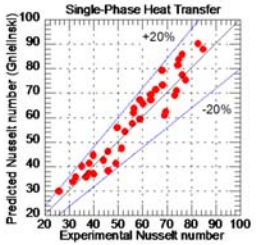
DOE092 FINAL-R1

*Overview of nanofluid heat transfer experimental test facility*




*Comparison of experimental and predicted single-phase Nusselt numbers*

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18494 / 9937/16624 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 1/23/2007 | A-104 |

# Nanofluids for Thermal Control Applications

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Develop nanotech-based heat transfer fluids with ultra-high thermal conductivity.
- Investigate thermal conductivity and heat transfer enhancement of nanofluids.
- Determine the mechanisms of enhanced thermal conductivities of nanofluids.
- Develop and transfer nanofluid technology to the industry

## Current FY Focus

- Produce and characterize nanofluids
- Develop models for the enhanced thermal conductivity of nanofluids
- Conduct flow experiments with base fluids and nanofluids

**Duration** 9/1/1999 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $300K / $K FY06 = $275K / $K FY07 = $175K / $K

## Accomplishments

- Produced and characterized nanofluids containing various nanoparticles.
- Measured and demonstrated significant thermal conductivity enhancement of nanofluids.
- Conducted laminar flow experiments and developed a model for the effective viscosity of nanofluids by including in the Einstein viscosity equation the effect of slip velocity.

## Significant Future Milestones

- Develop and refine mathematical models for enhanced thermal conductivity of nanofluids.
- Conduct nanofluid heat transfer experiments in laminar and turbulent flows.
- Develop ways for scale-up production of well characterized nanofluids.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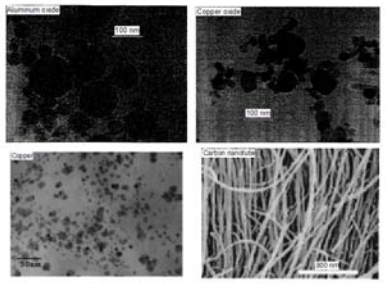
DOE332 FINAL-R1



*Typical nanoparticles used for making nanofluids*

# Parasitic Energy Loss Mechanisms - Impact on Vehicle System Efficiency

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-Increase fuel efficiency by reducing engine friction.
-Develop mechanistic models of parasitic engine losses (and integrate with vehicle system analysis codes – e.g. PSAT)
-Validate models and codes with experiments
-Identify/assess advanced tribological concepts/systems to reduce engine friction (e.g. lubricants, additives, engineered surfaces)

## Current FY Focus

-Model development, application of codes to predict fuel economy savings, and laboratory tests of advanced tribological concepts
-Laboratory tests of low friction additives and coatings
-Design of instrumented single-cylinder diesel engine

**Duration** 10/1/2002 through 9/30/2009

**Gov't Funding/Industry Cost Share**

FY05 = $180K / $K FY06 = $175K / $K FY07 = $275K / $35K

## Accomplishments

Accomplishment 1: Mechanistic model predictions of 3-4% fuel savings with low friction surfaces and low-viscosity lubricants
Accomplishment 3: Lab demonstrations of reduced friction surface treatments (up to 80 % reduction)

## Significant Future Milestones

Milestone 1: Instrumented single cylinder test rig – Mar 07
Milestone 2: Lab ring-on-liner tests of low-friction additives – Dec 07
Milestone3: Single cylinder tests of Low-friction coatings – June 08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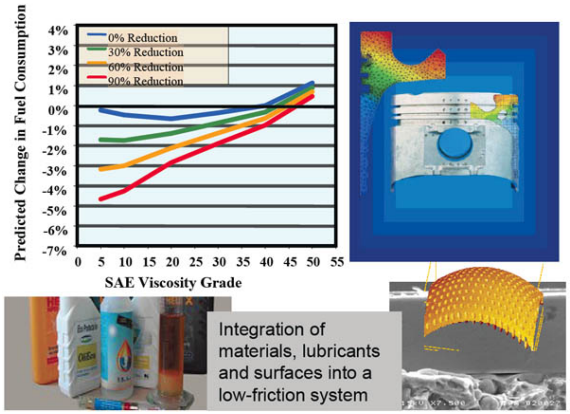

# Regenerative Shocks/Tires for Recovery of Parasitic Energy Losses

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Determine feasibility of regenerative shock absorber to recover 10% of energy presently lost in rolling resistance
-- Experimentally demonstrate regeneration in shock absorber and test on small vehicle
-- Determine feasibility of regenerative tire concepts to recover 20% of energy presently lost in rolling resistance

## Current FY Focus

Investigate concepts for regenerative tire

**Duration** 10/1/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $70K / $K FY06 = $25K / $K FY07 = $K / $K

## Accomplishments

-- Designed, fabricated, and instrumented a regenerative shock absorber
-- Tested shock absorber on small vehicle
-- Developed model to predict performance and energy recovery of regenerative shocks
-- Developed road data for accelerations to be used in predictive model

## Significant Future Milestones

Find and work with industrial partner(s) to integrate findings of regenerative shocks and tires into commercial produc


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DOE097 FINAL

Experimental regenerative shock absorber

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18495 / 11760/15441 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 4/1/2006 | A-107 |

# Residual Stresses and Adhesion in Coating Systems

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Develop techniques to measure depth-dependent residual stresses and strains in thin films and coatings using high-intensity X-rays from the Advanced Photon Source
- Develop indentation techniques to measure surface adhesion
- Correlate residual stresses with surface adhesion

## Current FY Focus

- Measurement of residual stresses and strains in MoN and MoCuN superhard nanocrystalline thin films
- Develop indentation techniques to measure surface adhesion

**Duration** 2/20/2006 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $125K / $K FY07 = $100K / $K

## Accomplishments

- Developed two techniques to measure depth-dependent residual stresses and strains in MoN on silicon
- Invention report filed
- Applied Physics Letters paper published
- Indentation technique to measure surface adhesion is promising

## Significant Future Milestones

- Extend stress and strain measurements to various tribological coatings on transportation materials
- Correlate surface adhesion and residual stresses
- Correlate depth-dependent strains and stresses to film processing conditions
- Develop predictive processing approach to coating durability


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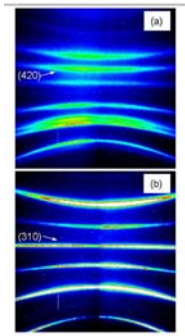
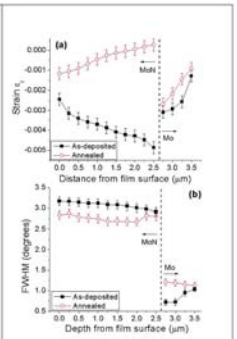
DOE358 FINAL




Two-dimensional x-ray diffraction patterns of the MoN layer (a) and the Mo layer (b).




Depth-resolved residual strain (a) and FWHM (b) for as-deposited and annealed MoN/Mo bilayer films.

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18496 / 14753 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 1/2/2007 | A-108 |

# Super Hard Coating Systems

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

Explore Super Hard Coating Systems for heavy vehicle system components to reduce friction and wear in engine and drive-train components. The reduction of friction in these components could result in improved vehicle performance and energy efficiency.

## Current FY Focus

**Duration** 11/10/2005 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $50K / $K FY07 = $75K / $K

## Accomplishments

1. Demonstrated extreme resistance to wear and scuffing in bench-top test machines and n piston pins of a fired engine
2. Verified 70% reduction in friction under boundary lubricated sliding conditions
3. Patented superhard coating systems and currently transferring technology to industry.

## Significant Future Milestones

1. Demonstrate superior performance with ring/liner assembly and powertrain components of engines, increase industrial collaboration
2. Elucidate wear and lubrication mechanisms
3. Accelerate technology transfer activities.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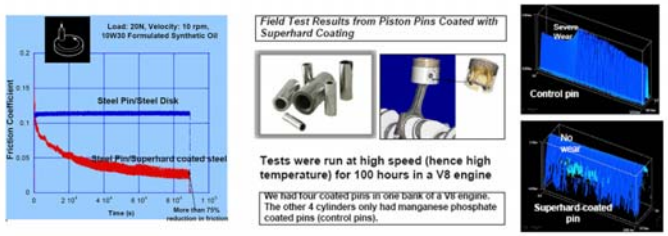


These figures compare the friction (left) and wear (right) performance of superhard coated surfaces with that of uncoated or control surfaces. Wear measurements are from a fired engine.

# Superhard Coatings For Advanced Vehicle Systems Applications

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Design, develop, and optimize superhard and low-friction coatings to increase durability and to reduce parasitic energy losses in engines.
- Control and optimize coating chemistry, adhesion, thickness, uniformity.
- Demonstrate large-scale production of such coatings in a commercial-scale deposition system.
- Implement demonstrated technology in engine systems in collaboration with industrial partners,
- Confirm energy saving benefits and durability.

## Current FY Focus

**Duration** 10/1/2005 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $125K / $K FY07 = $50K / $K

## Accomplishments

Accomplishment 1 – Patented methods of making superhard coatings
Accomplishment 2 – Demonstrated extreme resistance to wear and scuffing under severe boundary lubricated sliding conditions.
Accomplishment 3 – Applied coatings on numerous parts for tests in actual engines.

## Significant Future Milestones

Milestone 1 – Demonstrate superior performance in fired engines
Milestone 2 – Increase industrial collaboration and testing.
Milestone 3 – Transfer technology to industry


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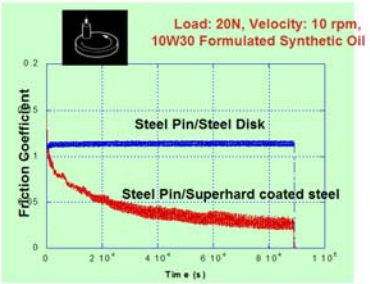
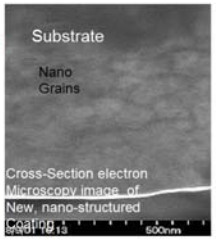
DOE103 FINAL-2

Superhard (more than 60GPa) coating with nano-composite grain morphology, also providing super low friction and extreme resistance to wear and scuffing under boundary lubricated sliding regimes.




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18496 / 13648, 13721 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Applied Research | DOE | 1/23/2007 | A-110 |

# Truck Essential Power Systems Efficiency Improvements for Medium-Duty Trucks

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

-- Improve fuel efficiency of a medium duty truck via truck electrification. Demonstrate idle reduction capability.
-- Implement power source diversity to benefit both body builders and end-users.

## Current FY Focus

-- Fabricate and bench test components
-- Complete baseline testing and initiate vehicle integration

**Duration** 10/1/2004 through 12/31/2007

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $794K / $K FY07 = $558K / $K

## Accomplishments

-- Energy storage chemistry and size specified
-- Electrical architecture designed
-- EHPS fabricated and assembled
-- Downsize by 40% and assemble ISG electronics
-- Interface PCB's assembled and tested
-- High fidelity model and ISG algorithms developed

## Significant Future Milestones

Milestone 1 – Complete vehicle baseline testing, July 2006
Milestone 2 – Complete component bench testing, August 2006
Milestone 3 – Complete vehicle integration, March 2007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**Partners** Caterpillar

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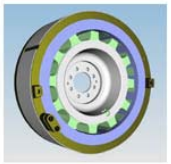
DOE124 FINAL

Bench testing of the electro-hydraulic power steering (EHPS) unit.

Integrated starter generator (ISG) elements. Water-cooled power converter and machine design rendering.



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|---|---|---|---|---|---|
| 18499 / 13875 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Applied Research | DOE | 4/1/2006 | A-111 |

# Underhood Thermal Control: Coupled-Simulation with 3-D CFD Code and 1-D Network Model

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- To develop, evaluate, and validate the integrated 1-D and 3-D simulation methods to study the effects of ventilation on heat rejection and component temperatures.
- To cool systems, maintain engine efficiency, and minimize environmental impacts by building completed network model for overall thermal control of systems – engine loop, coolant loop, air loop, and oil loop.

Safety Benefits: Underhood design flexibility to support better crash energy management

## Current FY Focus

**Duration** 1 year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $600K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Studied five different inlet configurations were studied for various ventilation flow rates and calculated the corresponding flow field and temperature distributions.
- Used the results to determine the pressure drop through the test-rig, the flow splits around the engine, the heat transfer coefficients on the engine and other heat-generating component surfaces, convected heat with the ventilation air, and the air and surface temperatures on various thermocouple locations.

## Significant Future Milestones


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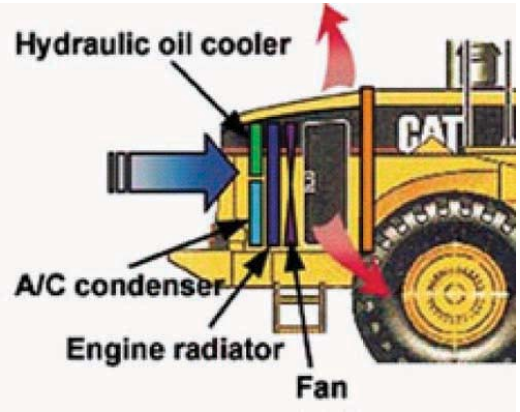

# Advanced Tribological Coatings

**21CTP Technical Goal** Parasitic Losses: Reduce essential power loads by 50%

## Objectives

- Advanced Engineered Surfaces to reduce parasitic losses and component durability/reliability have applications in vehicle safety

Safety Benefits: Reliability and durability of sensors and mechanical actuators/MEMs, Validation and testing of safety systems/components under accelerated conditions

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- DOE OFCVT projects include: coatings (near frictionless carbon - NFC, and superhard nanocomposites – SHNC), orifice coatings/deposit formation, laser glazing, laser texturing, erosion, joining, and modeling.

## Significant Future Milestones


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**Partners**

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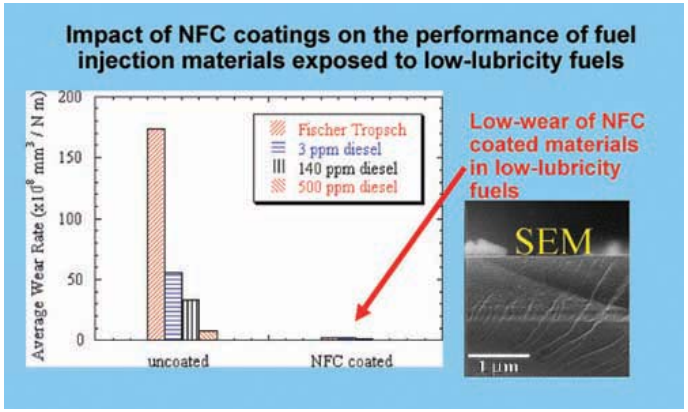


| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Materials Technologies -- Heavy Vehicle Propulsion Materials | Exploratory R and D | DOE | 3/15/2005 | A-113 |

# System Optimization of an UltraLight Electric Transit Bus

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

-- Perform the integration and optimization of a hybrid or battery/electric propulsion system and various vehicle subsystems into a lightweight bus body.
-- Reduce the cost of advanced technology transit buses

## Current FY Focus

Propulsion system modeling and design

**Duration** 9/1/2004 through 12/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $170K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Propulsion System Modeling and Simulation•9/2004
Traction Motor Controller and Regenerative Braking: 10/2004
Diesel Engine/Generator and Power Unit Controller: 3/2005
Vehicle Controller: 4/2005
Energy Storage System: 3/2006
Driver's Station and Controls: 12/2005
Windows, Glass and Emergency Exits: 2/2006

## Significant Future Milestones

Completion of drivable prototype: December 2006


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**Partners** Autokinetics

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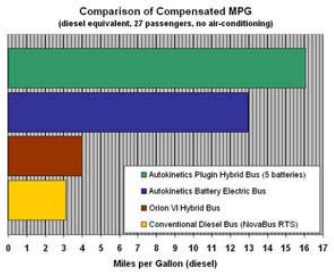


The full system optimization of Autokinetics' UltraLight Electric Transit Bus will result in a 3X improvement in fuel economy.

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18497 / 16626 | Heavy Vehicle Systems -- Parasitic Loss Reduction | Exploratory R and D | DOE | 4/1/2006 | A-114 |

# Advanced Composite Cab Structures

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop an economical, durable, polymer composite Class 8 cab component with ≥ 30% weight reduction
- Commercialize and produce cab components for a mid or high-volume Class 8 tractor

## Current FY Focus

Product launch analysis

**Duration** 6/30/2001 through 9/30/2004

**Gov't Funding/Industry Cost Share**

FY05 = $15K / $15K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Satisfied all technical requirements with improved structural performance
- Demonstrated cost reduction
- Demonstrated ability to resin transfer mold large, ~1.5 mm thick parts with oriented fiber architecture in ~ 20 min cycle time, using inexpensive composite tool
- Developed innovative, cost-saving kitting and metal hardware integration schemes

## Significant Future Milestones

Launch decision


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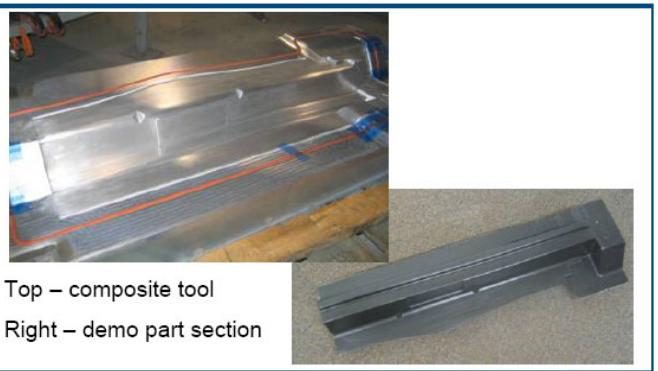

Top – composite tool

Right – demo part section

# Advanced Composite Structural Chassis Components

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop composite tie rods, trailing arms, and axles for auxiliary lift axle assemblies
- Reduce component mass by 50%, lift axle assembly mass by 100 lb. or more

## Current FY Focus

Tie rod validation for front steer axle

**Duration** 6/30/2001 through 12/31/2004

**Gov't Funding/Industry Cost Share**

FY05 = $20K / $20K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Tie rods commercialized ~ 9 mo after project started
- ~ 7,000 auxiliary axle tie rods (total), typically saving 11 lb., sold to multiple customers
- Composite trailing arm design morphed into cast aluminum and was commercialized, saving 56 lb/vehicle; over 5,000 suspensions shipped to date
- Auxiliary axle prototype fabricated and tested with excellent structural performance

## Significant Future Milestones

None.


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**Partners** Delphi, National Composites Center

**Congressional Information** Michigan 9th
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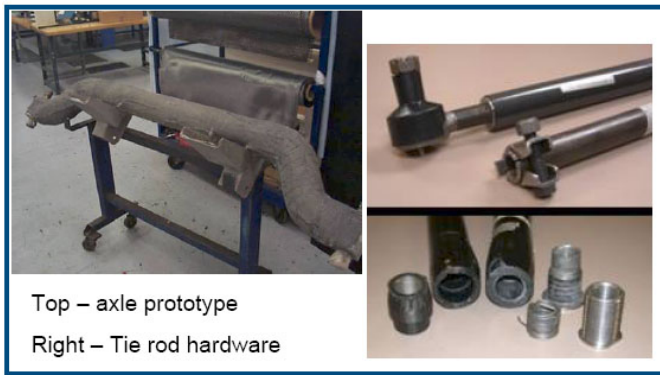

Top – axle prototype

Right – Tie rod hardware

# Advanced Composite Support Structures

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop economical, durable, polymer composite support members for Class 7/8 trucks with 50% component mass reduction
- Commercialize and produce composite support members for two or more OEM customers

## Current FY Focus

Design validation

**Duration** 3/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $600K / $600K FY06 = $125K / $K FY07 = $0K / $K

## Accomplishments

- Performed value engineering
- Developed and analyzed multiple component designs
- Performed frame system analysis to determine composite component impact on system performance
- Performed preliminary progressive failure analysis for various material architectures, quality specifications, and load spectra
- Fabricated carbon-fiber reinforced composite prototype

## Significant Future Milestones

Design validation tool fabricated – June 2006


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**Partners** National Composites Center

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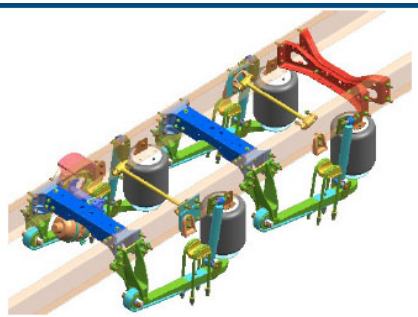
DOE043 FINAL



Class 8 truck frame & suspension hardware rendering

# Advanced Materials for Friction Brakes

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Identify, test, and analyze the friction and wear characteristics of advanced materials and surface treatments that enable weight
reduction in truck brake components while equaling or bettering their performance.

## Current FY Focus

- Evaluation of titanium alloy brake materials, surface coatings, and manufacturing technologies.
- Evaluation of ceramic composite brake materials for heavy vehicles.

**Duration** 3/31/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $175K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Used ORNL-designed, high-speed friction tester to evaluate new materials and to measure the effectiveness of their conversion of braking friction into heat. December 2004
Down-selected from a variety of candidate materials to ultimately focus on advanced Ti-based composites and thermally-sprayed Ti-alloy discs. March 2005.

## Significant Future Milestones

Complete evaluation of full-scale, thermal-sprayed Ti truck brake discs in a commercial test facility at a major truck braking system supplier, June 2006.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**Partners** ORNL

**Congressional Information** Tennessee 3rd
Zach Wamp


**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE037 FINAL

Advanced, light-weight materials for brakes were investigated:
(CW from upper left: coated Ti, ceramic composite, Ti 6-4 alloy)

# Advanced Superplastic Forming Development for Heavy Vehicle Structures

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop superplastic forming (SPF) manufacturing technology to meet heavy vehicle design and service requirements

## Current FY Focus

Provide OEM with mechanical properties for use in design analysis, identify low cost tooling methods and identify challenges for high strength SPF alloy use

**Duration** 3/1/2005 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $175K / $158K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Design data provided to OEMs for SPF 5083 parts; Room temperature and SPF tensile values from trays formed completed at PNNL – May 2005
- Completed fabrication of advanced test grips and forming die built – June 2005
- Scoping study for advanced low cost 6XXX SPF materials completed – Sept. 2005.

## Significant Future Milestones

Complete report of mechanical properties for formed 5083 aluminum sheet for OEM use in design – Dec. 2005
Demonstrate high strength SPF forming process technology and form test components for evaluation - Sept. 2006


**Principal Investigator** Curt A. Lavender, Pacific Northwest National Laboratory
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Don Trettin, PACCAR Technical Center
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**Partners** PNNL, PACCAR

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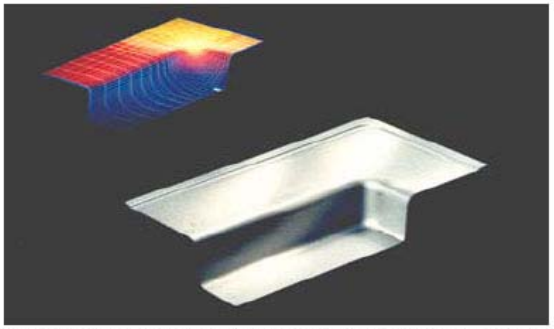

Sample SPF part used to characterize tensile properties from 0.047 inch 5083 aluminum sheet.

# Application of Carbon Fiber for Large Structural Components

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop cost-effective, high strength, class A carbon fiber reinforced composites for large structural applications. Develop property database for unique hybrid carbon fiber/glass reinforced composite materials

## Current FY Focus

Complete design and material property and processing database, and initiate tooling development for prototype component

**Duration** 1/1/2002 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $150K FY06 = $192K / $K FY07 = $0K / $K

## Accomplishments

- Developed carbon fiber/glass fiber composite materials with significantly increased impact properties and class A finish –
May 2004.
- Completed molding process development for thinwall, large area hybrid composite structural panels – February 2005
- Completed component and tooling design for prototype heavy truck component – July 2005.

## Significant Future Milestones

Complete tooling fabrication and molding of large-scale prototype test components for Freightliner test and evaluation – July 2006


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Gary Jones, Freightliner LLC
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**Partners** PNNL, Freightliner

**Congressional Information** Washington 4th
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DOE040 FINAL

Significant weight savings can be achieved by replacing glass fiber hoods, fairings, and cab components with thinwall hybrid carbon fiber/glass composites

# Application of Superplastically Formed (SPF) Aluminum for Truck Body Panels

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Investigate applications of superplastic aluminum for low to moderate volume (up to 30000/year) body panels to provide a light weight and low tooling cost alternative to steel and SMC.

## Current FY Focus

To demonstrate the feasibility of SPF technology for a large exterior body panel as phase 1 of the project.

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $125K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Appropriate exterior truck body part has been selected.
- Preliminary design concepts have been completed.
- Forming simulations have been completed to verify the manufacturability
- A preliminary Finite Element Analysis of part design is completed.

## Significant Future Milestones

- Complete SPF Tooling built – Sept. 2005.
- Prototype production and appearance evaluation – Oct. 05
- Complete structural evaluation of the prototype parts under real vehicle environment.- Feb. 06

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**Partners** International

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Rahm Emmanuel

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DOE048 FINAL

# Attachment Techniques for Heavy Truck Composite Chassis Members

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop robust and economical joining techniques for lightweight polymer composite structural chassis components

## Current FY Focus

- developing durable hybrid composite/steel joining concepts
- fatigue testing of composite and composite/steel joints
- progressive damage modeling at a bolted joint interface

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $425K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

- Conducted FEA modeling, utilizing progressive failure analysis in Genoa, to evaluate damage at bolt holes in 3d glass reinforced thick composites – June 2005
- Tested composite/steel joints to evaluate design modifications to improve static and fatigue performance as well as validate modeling results– July 2005

## Significant Future Milestones

Optimize a composite/steel joint with design modifications including metal reinforcement of the composite at bolt holes – September 2006


**Principal Investigator** Lynn Klett, Oak Ridge National Laboratory
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**Partners** ORNL, PNNL

**Congressional Information** Tennessee 3rd
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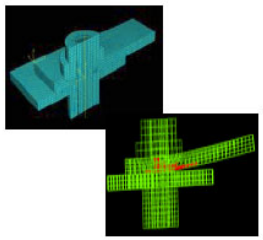
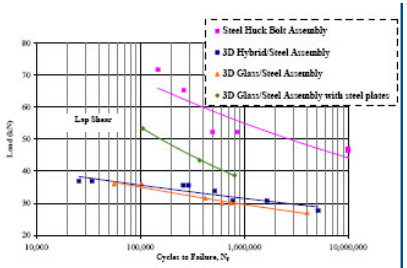
DOE052 FINAL



FEA Model of Bolted Composite/Steel Joint Illustrating Areas with Damage




Cyclic Fatigue Results for Baseline Steel/Steel Joint and 3D Composite/Steel Joints

# Basic Studies of Ultrasonic Welding for Advanced Transportation Systems

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop a fundamental understanding of Ultrasonic Welding process.
- Explore opportunities for joining similar and dissimilar materials.
- Explore ultrasonic processing of materials in other novel and unique situations, such as low temperature consolidation of powder materials

## Current FY Focus

- Investigate acoustic energy distribution during welding
- Explore low-temperature powder metal consolidation

**Duration** 10/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Accomplishment 1 – Developed basic process conditions for joining Al alloys – September, 2004
Accomplishment 2 – Established correlation between joint quality and acoustic energy distribution – June, 2005
Accomplishment 3 – Demonstrated the feasibility of low temperature ultrasonic metal consolidation – August 2005

## Significant Future Milestones

Milestone 1 – Process development for dissimilar materials (Mg to Al, Al to AHSS, metal composite) – Sept 2006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**Partners** ORNL

**Congressional Information** Tennessee 3rd
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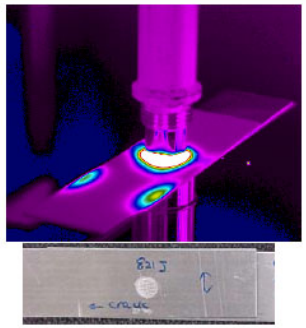
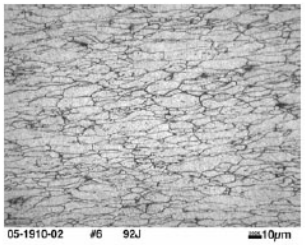
DOE044 FINAL



IR observation of abnormal acoustic energy distribution resulting cracking




Low-temperature ultrasonic consolidation of Al powders

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18541 / WR 9880 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 12/21/2006 | A-123 |

# Carbon Fiber SMC Hood

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop competent structural and Class A CF-SMC
- Demonstrate satisfactory CF-SMC processing
- Prove durability of CF-SMC hood system
- Commercialize 30 % lighter CF-SMC truck hood system

## Current FY Focus

Process quality; launch decision; tool procurement

**Duration** 9/30/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $296K / $300K FY06 = $0K / $K FY07 = $K / $K

## Accomplishments

- Developed competent structural CF-SMC compound and installed compounding line
- Demonstrated excellent moldability in large area, thin parts with complex geometry
- Satisfied all technical criteria for product launch decision
- Identified key commercial barriers to product launch and commenced developing a path to resolution

## Significant Future Milestones

Engineer standard carbon fiber surface for VE resins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**Partners** Volvo, Meridian Automotive Systems

**Congressional Information** North Carolina 6th
Howard Coble

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DOE036 FINAL

Above – CF-SMC compounding line

Top right – demo molded part

Right – SMC hood

# Counter Gravity and Pressure Assisted Lost Foam Magnesium Casting

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

To evaluate the Hitchiner process and pressure assisted lost foam casting of magnesium alloys

## Current FY Focus

Develop melting and casting capabilities at TTU for lost foam casting of magnesium alloys
Carry out experimental evaluations of the coatings and foam materials for magnesium lost foam casting

**Duration** 9/1/2004 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $225K / $K FY06 = $0K / $K FY07 = $0K / $K

## Accomplishments

Accomplishments 1 – The casting systems have been setup at TTU and ORNL
Accomplishment 2 – Initial Experiments have been carried on lost foam magnesium casting and microstructure characterization

## Significant Future Milestones

Milestone 1 – Complete the analysis of mold filling and molten metal interaction. August 2006.
Milestone 2 – Start the simulation of the Hitchiner lost foam process. March 2006.


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Ralph Dinwiddie, Oak Ridge National Laboratory
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**Partners** ORNL

**Congressional Information** Tennessee 3rd
Zach Wamp

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DOE047 FINAL

The Hitchiner System Donated from MCT Has Been Setup at the TN Tech University for Testing Count Gravity Lost Foam Magnesium Casting

Researchers from ORNL and Foseco Are Examining an Engineered Flask for Pressure Assisted Lost Foam Magnesium Casting

# Development of Magnesium Powertrain Components

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop magnesium composite casting technology and associated low-cost tooling for manufacturing of ultralightweight low-cost heavy-vehicle powertrain components

## Current FY Focus

Evaluation of a modified lost-foam casting process that combines casting and compositing into one process step

**Duration** 8/1/2004 through 9/30/2008

**Gov't Funding/Industry Cost Share**

FY05 = $125K / $125K FY06 = $125K / $K FY07 = $K / $K

## Accomplishments

- Down selection of magnesium powertrain component for project application focus: transmission case w/ potential for 50% weight reduction over Al case – Oct. 2004
- Experimental trials for in-situ compositing during casting completed – Aug. 2005

## Significant Future Milestones

Demonstrate the ability to in-situ cast and mix a Mg composite casting – June 2006

**Principal Investigator** Darrell Herling, Pacific Northwest National Laboratory
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Guy Rini, Mack Trucks, Powertrain Division
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**Partners**

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**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE054 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18538 / WR 13431 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 12/21/2006 | A-126 |

# Development of Technologies for the Application of Magnesium Metal Matrix Composites for Heavy Vehicles

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Cast AZ91 into a variety of ceramic preforms to attain promising mechanical and metallurgical results. The team has worked with squeeze casting and pressureless infiltration before designing process-controlled squeeze casting equipment.

## Current FY Focus

Casting press design & installation. Casting MMC's under highly controlled atmosphere.

**Duration** 9/1/2004 through 7/31/2007

**Gov't Funding/Industry Cost Share**

FY05 = $200K / $140K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Cast samples exhibiting elastic moduli three times that of AZ91D (from 6.5 to ~20 Mpsi).
Accomplishment 2 – Acquired extensive knowledge in casting magnesium composites.
Accomplishment 3 - Developed in-house casting capability with the focus of extensive process control.

## Significant Future Milestones

Milestone 1 – Refine selection of preform-to-matrix system.
Milestone 2 – Optimize casting parameters and develop components for heavy duty specialty trucks.


**Principal Investigator** Adam Loukus, Ph.D., GS Engineering, Inc
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**Partners**

**Congressional Information** Michigan 1st
Bart Stupak


**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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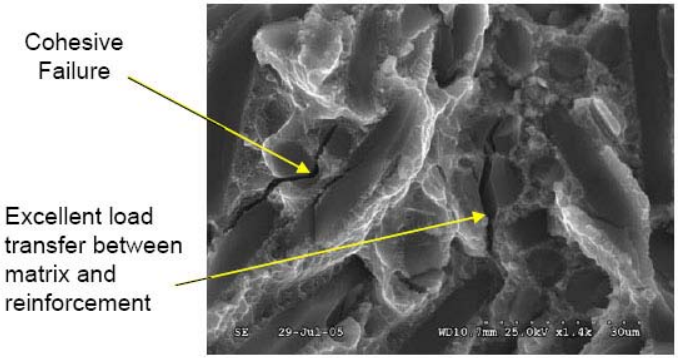
DOE046 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18539 / WR 10637 | Materials Technologies -- High Strength Weight Reduction | Technology Development | DOE | 7/1/2005 | A-127 |

# Effects of Ice Clearing Treatments on Corrosion of Heavy Vehicle Materials and Components

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Evaluate corrosion associated with new ice-clearing chemicals, in particular MgCl2
- Understand corrosion interactions of these chemicals with lightweight, heavy vehicle materials and structures
- Develop a "rust-jacking" model for heavy vehicle brakes

## Current FY Focus

Continuation of field testing, accelerated laboratory corrosion testing, & modeling development

**Duration** 5/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $135K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Conducted in-service winter field evaluations in collaboration with Montana Department of Transportation – December 2003 - May 2005
- Characterized the effects of MgCl2 anti-icing/deicing solutions and other ice-clearing chemical products on heavy vehicle materials (Phase 1) – April 2005
- Modeled brake "rust jacking" and determined that 0.10 mm oxide creates force larger than pad strength – July 2005

## Significant Future Milestones

- Complete analysis of corrosion field evaluations – October 2005
- Complete assessment of Boeing's anti-icing technologies for heavy vehicles and trailers for the elimination of ice and ice-clearing chemical accumulation – April 2006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Dane F. Wilson, Oak Ridge National Laboratory
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DOE050 FINAL

Illustration of "Rust Jacking" Where Brake Lining is Pushed away from Brake Table

Coupon Rack Consisting of Representative Heavy Vehicle Alloys Placed on MDT Trucks

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18541 / WR 10650, WR 11126 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 9/1/2005 | A-128 |

# Equal Channel Angular Extrusion of Soft Ferromagnetic Materials

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Research the theory, synthesis, and properties of soft and hard ferromagnetic alloys having the potential for improving the efficiency of energy conversion devices.

## Current FY Focus

Soft ferromagnetic alloys based on compacted Fe-Al-Si nanocrystalline powders. Explore the limits of soft magnetism in nanocrystalline alloys prepared by mechanical alloying.

**Duration** 10/1/2001 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $150K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

1. In nanocrystalline powders prepared by mechanical alloying, the coercivity is a non-linear function of the grain size and the residual stress within the particles.
2. Demonstrated that the Williamson-Hall method, frequently used to deduce the residual strain and grain size of deformed solids, is inappropriate for analyzing powders of elastically anisotropic materials. Proposed new method.
3. Explained the magnetic anisotropy of nanocrystalline powders in terms of 3 contributions: a) long-range magneto-elastic anisotropy; b) random short-range magneto-elastic anisotropy; and c) random short-range magneto-crystalline anisotropy. The main contribution to the coercivity of nanocrystalline alloys arises from the fluctuating long-range residual stress which is proportional to the square root of the dislocation density.

## Significant Future Milestones

Study the theory, synthesis and properties of strong magnets. Focus on "spring" magnets consisting of nanosize crystals of a soft ferromagnetic phase surrounded by nanosize particles of a hard magnetic phase.


**Principal Investigator** R. B. Schwarz, Los Alamos National Laboratory
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**Partners**

**Congressional Information** New Mexico 3rd
Tom Udall

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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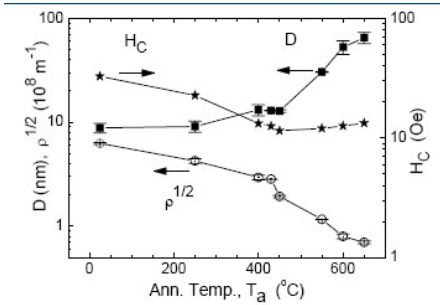
DOE067 FINAL




Optimal soft magnetism is achieved after a 1-hr anneal at 450°C, which decreases the residual dislocation density (thus decreases the microstress) but is too low to promote grain growth.

Coercivity, $H_C$, crystallite size, $D$, and square root of dislocation density, $\rho^{1/2}$, as a function of annealing temperature, $T_a$, for mechanically alloyed nanocrystalline $Fe_{52}Al_2Si_6$ (wt.%) powder. Shen, Schwarz, and Thompson, Phys. Rev. B (in press, 2005)

# Equal Channel Angular Extrusion Processing of Alloys for Improved Mechanical Properties

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Apply ECAE processing to enable the use of advanced, lightweight materials by improving material properties (e.g. enhanced formability, strength, formability, fatigue, higher strength-to-weight ratio, and higher stiffness) leading to reduced vehicle weight and increased fuel-efficiency.

## Current FY Focus

ECAE processing and property evaluation of magnesium alloys and aluminum alloys composites.

**Duration** 10/1/2000 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completed high strain rate superplastic testing of ECAEprocessed ZK60A – 03/2005
- ECAE-processed 5 additional ZK60A billets based on superplastic testing results – 05/2005
- ECAE-processed 6 billets of aluminum alloy MMCs at low temperature (<150oC) – 06/2005

## Significant Future Milestones

- High strain rate superplastic testing of ECAE-processed ZK60A
- Mechanical testing of ECAE-processed aluminum alloy MMCs


**Principal Investigator** Thomas M. Lillo, Idaho National Laboratory
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**Partners**

**Congressional Information** Idaho 2nd
Michael Simpson

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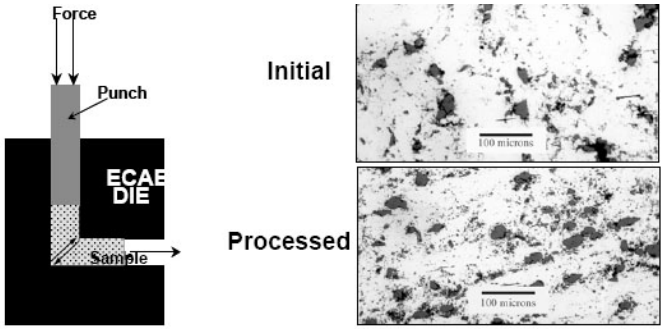
DOE073 FINAL




The high shear strains in ECAE processing are used to refine microstructure of lightweight alloys for better properties.

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18541 / WR 9215 | Materials Technologies -- High Strength Weight Reduction | Exploratory R and D | DOE | 7/1/2005 | A-130 |

# Friction Stir Joined Aluminum Sheet Materials for Heavy Vehicle Cab Structures

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop and deploy friction stir joining (FSJ) as a weight and cost-saving manufacturing technology for heavy vehicle cab structures

## Current FY Focus

- Develop tool designs and FSJ process parameters that lead to stronger, more formable, and lower cost welded blanks
- To develop appropriate techniques to join similar and dissimilar aluminum alloys of specific interest to project partners

**Duration** 12/1/2003 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $290K / $K FY06 = $200K / $K FY07 = $K / $K

## Accomplishments

- Developed process parameters and joining conditions to fabricate blanks in several similar and dissimilar aluminum alloys. Fabricated welded blanks that were subjected to stamping trials - Mar 04
- Constructed three full Class 8 truck cabs using friction stir welded TWBs for the door inners, door opening panels, backwall, and floor - Jun 04
- Cabs passed full size crash and durability testing (no weld related structural failures were observed) - Sept 04

## Significant Future Milestones

- Weld process development to lower blank costs – increased weld speeds, etc. - Oct 05
- Tool development and design to increase robustness in stamping of dissimilar aluminum alloy combinations – Feb 06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**Partners**

**Congressional Information** Washington 4th
Doc Hastings

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE051 FINAL

Successfully stamped door inner panel

Freightliner is investigating the possibility of using Tailor Welded Blank (TWB) technologies on aluminum cab structures

# Friction Stir Joining and Processing of Advanced Materials - PNNL

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop Friction Stir Joining and Processing
(FSJ / FSP) to enable more widespread use of lightweight, advanced materials in heavy vehicle manufacturing

## Current FY Focus

Three primary areas investigated:
- Use FSP to create engineered surfaces on lightweight materials that display enhanced surface properties
- Use FSJ to join sheet materials for superplastic forming applications
- Develop Fundamental Process Models using a new approach: Smooth Particle Hydrodynamics (SPH)

**Duration** 9/1/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $135K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Developed methods to incorporate ceramic powder into the surface of aluminum and cast iron brake rotor material to produce engineered surfaces for improved wear resistance: June 05
- Developed FSJ weld metal with superplastic properties: Dec 04
- Developed unique computational code based on SPH to predict material flow, mixing and defect formation in FSJ/P: April 05

## Significant Future Milestones

- Initiate wear testing of engineered surfaces created using FSP: Dec 05
- Develop weld process parameters that enhance superplasticity in joined assemblies to allow for part consolidation in light-weight SPF cab structures: July 06


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**Partners**

**Congressional Information** Washington 4th
Doc Hastings

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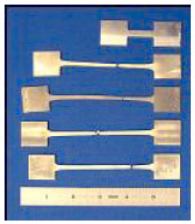
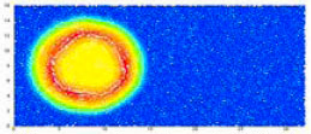
DOE041 FINAL

Friction Stir Processing can create wear resistant surfaces



FSP can enhance superplasticity in aluminum and magnesium sheet



New modeling approaches allow insight into fundamental properties

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / WR 9040 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 9/1/2005 | A-132 |

# Friction Stir Welding and Processing of Advanced Materials - ORNL

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop an improved understanding of the fundamental aspects of Friction Stir Technologies
- Evaluate Friction Stir Welding for construction of lightweight vehicle substructures

## Current FY Focus

Process modeling, surface modification, tool materials

**Duration** 9/30/2001 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $300K / $90K FY06 = $100K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – CRADA established with Ford – March 2005
Accomplishment 2 – Demonstrated tensile property improvement to magnesium casting surfaces – May 2005
Accomplishment 3 – Conditions established for friction stir welding of 5454 aluminum for tanker bodies – August 2005

## Significant Future Milestones

Milestone 1 – Influence of process parameters on defect formation in 5454 aluminum will be established – June 2006
Milestone 2 – Initial evaluation of dissimilar aluminum combinations will be completed – September 2006


**Principal Investigator** Zhili Feng, Oak Ridge National Laboratory
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Michael Santella, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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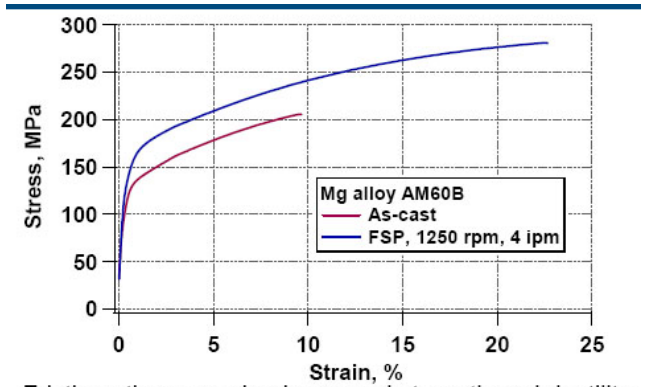
DOE038 FINAL




Friction stir processing increased strength and ductility

# High Conductivity Carbon Foam for Thermal Control in Heavy Vehicles

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Solve Participant specific design issues and overcome existing constraints in the development and commercialization of heat exchanger packages for class 7-8 heavy vehicles.

## Current FY Focus

Optimization and testing and of second design iteration prototype

**Duration** 1/1/2000 through 12/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $125K / $125K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Completed a thermo-mechanical database that identifies the baseline strength, durability, thermal shock resistance, thermal conductivity and thermal fatigue of various graphite foams that are candidates for light weight, compact heat exchangers. 12/2003

Accomplishment 2 – Assisted in the modeling of graphite foam and key foam properties for optimization of second iteration prototype 6/2005

## Significant Future Milestones

Produce successful prototype to meet participant specifications 08/2006

Complete evaluation of heat exchanger performance in heavy-duty application.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Ron Dupree, Caterpillar Inc.
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

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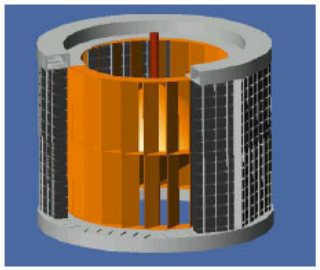

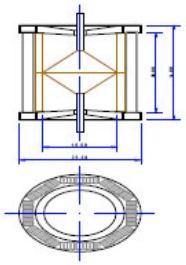

Annular Design Proposed for 2nd Prototype Test

# Hybrid Composite Materials for Weight Critical Structures

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Develop and demonstrate (1) the application of hybrid composites and composite metal hybrid structures to heavy duty vehicles and (2) the ability of these material to be integrated into moderate-volume production

## Current FY Focus

Fabrication of prototype doors and design validation through component testing.

**Duration** 2/1/2001 through 12/31/2005

**Gov't Funding/Industry Cost Share**

FY05 = $250K / $150K FY06 = $192K / $K FY07 = $K / $K

## Accomplishments

Design completed that demonstrated higher performance, lower cost, and a 40% mass savings – December 2003
Completed fabrication of the sub-components required to build 3 prototype doors – November 2004
Assembled doors for performance trials – January 2005
Performed initial performance trials on prototype doors – February 2005

## Significant Future Milestones

Cab tests to be completed – December 2005


**Principal Investigator** Curt A. Lavender, Pacific Northwest National Laboratory
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Don Trettin, PACCAR Technical Center
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**Partners**

**Congressional Information** Washington 4th
Doc Hastings

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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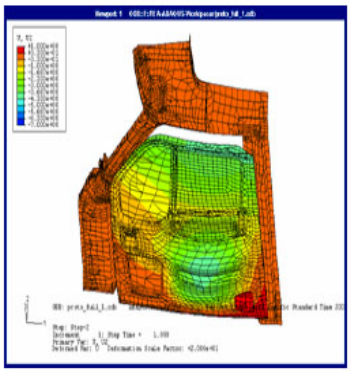

Finite element analysis of door and aperture

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18537 / WR 9030 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 7/31/2005 | A-135 |

# Improved Friction Tests for Engine Materials

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Enable the use of light-weight diesel engine materials by developing a standard method to evaluate frictional characteristics of alternative cylinder and liner materials.

## Current FY Focus

Completion, validation, and final approval of a new ASTM standard.

**Duration** 3/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $50K / $K FY06 = $50K / $K FY07 = $K / $K

## Accomplishments

- Final approval of a new ASTM standard (G-181-04) for testing ring and liner materials in the presence of engineconditioned lubricants (1/2005).
- Development and submission of a companion ASTM standard for the wear testing of ring and liner materials (7/2005)

## Significant Future Milestones

None. This project ends in FY 2005.


**Principal Investigator** Peter Blau, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp


**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE071 FINAL

*The new standard uses part of a diesel engine piston to hold the ring specimen.*

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18541 / WR 9027 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 7/1/2005 | A-136 |

# Integrated Approach for Development of Energy-Efficient Steel Components for Heavy Vehicle and Transportation Applications

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Develop tools to simulate the formation and influence of nonhomogeneous microstructures in steel processing
- Demonstrate the techniques developed for a defined component.
- Develop methods and tools to produce energy-efficient steel components

## Current FY Focus

Formation and influence of non-homogeneous microstructures during and after heat treatment processes

**Duration** 9/1/2003 through 9/30/2007

**Gov't Funding/Industry Cost Share**

FY05 = $505K / $250K FY06 = $50K / $K FY07 = $K / $K

## Accomplishments

Completed investigation of machining process - March 2005
Completed Microstructure-Level Simulator of Austenitization of Eutectoid and Hypo-eutectoid Steel - May 2005
Completed Microstructure-Level Model for Accurate Stress State and Damage in Individual Constituents - June 2005

## Significant Future Milestones

Initial Integration of Microstructure-Level Manufacturing Model – July 2006
Approach Validation of 5 Production Components – June 2007


**Principal Investigator** Leo Chuzhoy, Caterpillar Inc.
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Gerard Ludtka, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Illinois 18th
Ray LaHood

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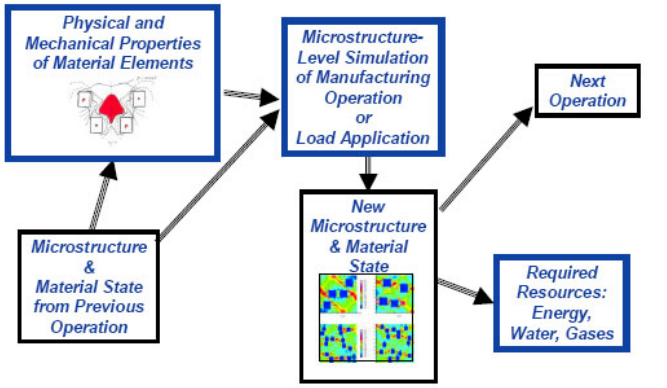
DOE049 FINAL

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|---|---|---|---|---|---|
| 18539 / WR 10648 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 7/1/2005 | A-137 |

# Inventory of Heavy-Duty Truck Lightweighting Candidates

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Identify components and systems of heavy-duty trucks that have the greatest total fleet weight savings potential.
- Inventory Class 8 tractor-trailer systems / components
- Provide a model for estimating the relative weight-mile and fuel consumption contribution of lightweighting candidate components

## Current FY Focus

Complete inventory, report and model.

**Duration** 3/1/2004 through 9/30/2005

**Gov't Funding/Industry Cost Share**

FY05 = $1K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

1. Quantitatively demonstrated that Van, Platform, Dump and Tank trucks account for 90% of vehicle numbers and miles.
2. Determined representative weights of components contributing significant weight to vehicles
3. Constructed computer model for calculation of combined weight and mileage carried, and fuel consumed due to carrying candidate lightweighting components.

## Significant Future Milestones

Present and make model available to industry


**Principal Investigator** Edwin H. Kraft, EHKTechnologies
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**Partners**

**Congressional Information** Washington 3rd
Brian Baird


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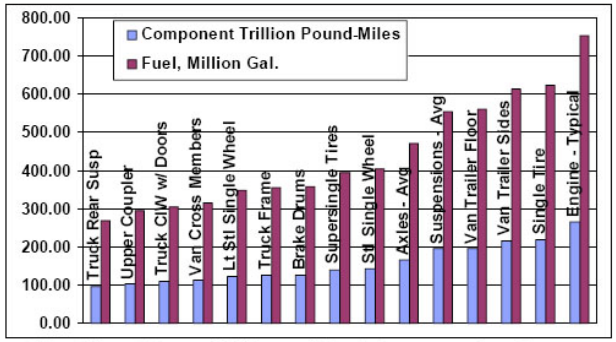


Most Significant Pound-Mile and Fuel Consumption Components

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / WR 9034 | Materials Technologies -- High Strength Weight Reduction | Technology Development | DOE | 7/1/2005 | A-138 |

# Joining of Advanced Materials by Plastic Deformation

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Produce pore-free, strong joints in advanced materials, including ceramics, cermets, intermetallics using grain rotation that occurs during grain-boundary sliding (GBS)
- Understand and characterize the underlying principles of deformation joining

## Current FY Focus

- Produce improved oxygen sensors having internal reference sealed by plastic joining, applied for patent
- Grain rotation measurements during plastic joining

**Duration** 10/1/1999 through 9/30/2006

**Gov't Funding/Industry Cost Share**

FY05 = $75K / $K FY06 = $68K / $K FY07 = $75K / $K

## Accomplishments

- Patented plastic joining process-August 2005
- R&D 100 Award for Oxygen Sensor with Internal Reference, July 2005
- Published 23 papers in reviewed journals
- Measured for the first time grain rotation during GBS in a ceramic as it was deformed.
- Two patent applications filed, negotiations for license in progress.

## Significant Future Milestones

- Complete licensing agreement.
- Apply joining technique to engine and brake applications to increase efficiencies and reliability.
- In-situ grain rotation experiments using Advanced Photon Source.


**Principal Investigator** Jules Routbort, Argonne National Laboratory
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Dileep Singh, Argonne National Laboratory
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**Partners**

**Congressional Information** Illinois 13th
Judy Biggert

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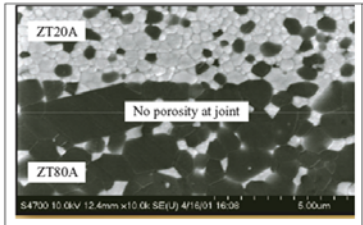
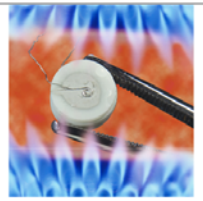



*Strong, pore-free joint between two pieces of Y-TZP containing 20% and 80% alumina*



*Oxygen sensor with internal reference sealed gas tight using patented plastic joining technique*

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18518 / 9010 | Materials Technologies -- High Strength Weight Reduction | Exploratory R and D | DOE | 1/2/2007 | A-139 |

# Lightweight Stainless Steel Bus: Manufacturing, Cost, and Crashworthiness

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

Investigate and demonstrate the mass saving potential of ultra-high-strength stainless steel as applied to the structure and chassis of a full-size urban transit bus.

## Current FY Focus

Detail design of suspension.
Final assembly of body structure and suspension.

**Duration** 7/1/2001 through 12/31/2005

**Gov't Funding/Industry Cost Share**

FY05 = $100K / $217K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Completed assembly of primary structure – 2/2004
Completed cost analysis of body structure with IBIS – 5/2005
Completed side impact analysis with ORNL – 6/2005

## Significant Future Milestones

Completion of body/chassis prototype – December 2005


**Principal Investigator** Bruce Emmons, Autokinetics Inc.
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**Partners**

**Congressional Information** Michigan 9th
Joe Knollenberg

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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DOE042 FINAL

Autokinetics' Lightweight Stainless Steel Bus Structure is a Key Enabler to Achieving 3X Fuel Economy

# Rapid, Low-Cost Tooling Development

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

- Determine whether current tooling technology inhibits lightweight materials development and commercialization
- Develop a roadmap for tooling technology R&D
- Recommend DOE course of action

## Current FY Focus

Engage tool manufacturers in roadmapping

**Duration** 7/1/2003 through 3/31/2006

**Gov't Funding/Industry Cost Share**

FY05 = $120K / $K FY06 = $50K / $K FY07 = $K / $K

## Accomplishments

- Conducted industry workshops to obtain expert opinions about tooling impact on energy efficiency
- Estimated energy savings potential attributable to "better, faster, cheaper" tooling
- Conducted socioeconomics analysis
- Engaged selected toolmakers and Center for Automotive Research in roadmapping

## Significant Future Milestones

Issue final funding recommendations to DOE


**Principal Investigator** Cliff Eberle, Oak Ridge National Laboratory
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Curt Lavender, Pacific Northwest National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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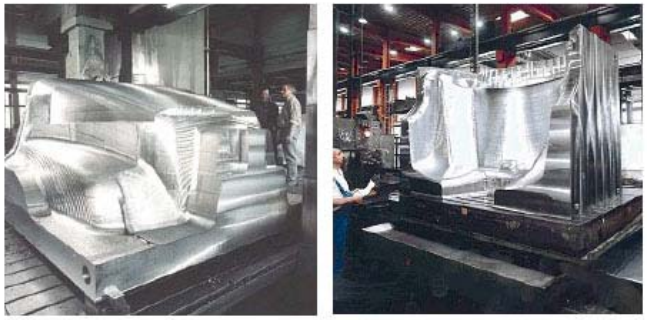

Matched metal molds for truck hood

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| 18541 / WR 9883, WR 10389 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 7/1/2005 | A-141 |

# Thermomechanical Processing of Ti and Ti-6Al-4V sheet and Plate

**21CTP Technical Goal** Parasitic Losses: Reduce Tare Weight by 15-20%

## Objectives

To provide weight reduction in heavy-duty vehicles such as Class 8 trucks through utilization of titanium leaf spring elements developed from new low cost titanium powders, and processing technologies.

## Current FY Focus

Production, Chemical Analysis, and Mechanical Testing of Low Cost Ti, Grade 2 and Ti-6Al-4V, Grade 5 Parts.

**Duration** 10/1/2003 through 6/30/2008

**Gov't Funding/Industry Cost Share** *Total Funding Level = $50K*

FY05 = $K / $200K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

Accomplishment 1 – Early 2005
Production of Powder Consolidated, Low Cost Ti, Grade 2 and Ti-6Al-4V, Grade 5 Plates and Sheets Via Vacuum Hot Pressing and Roll Compaction
Accomplishment 2 – Early 2005
Mechanical and chemical analysis of ITP consolidated Ti and Ti6Al-4V reveal that Ti Grade 2 properties can be achieved as well as standard values for Ti-6Al-4V. An average YS of 530 MPa, an average UTS of 600 MPa, and an average elongation of 13.84% was observed for the Ti consolidate samples as compared with standard values of 345 MPa, 450 MPa, and 14%, respectively.

## Significant Future Milestones

Work is presently underway to make plates as large as 10.5 inches in diameter and 0.75 inches thick.


**Principal Investigator** Craig Blue, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp


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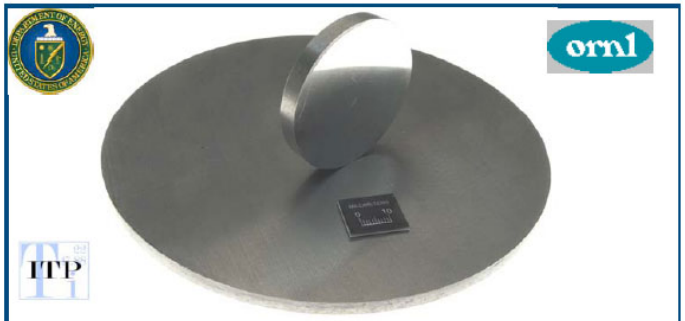


7"-Dia. Consolidated Ti Grade 2 Plate Using Low Cost Powder

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / WR 8638 | Materials Technologies -- High Strength Weight Reduction | Applied Research | DOE | 7/31/2005 | A-142 |

# Advanced Brake Systems for Heavy Vehicles

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- To assess the potential of alternate disc brake designs, friction materials, and technology concepts to improve the performance of heavy vehicle brake systems.
- Use Computational Fluid Dynamics, coupled heat flow models, and FEA to characterize the thermal and stress environments found in heavy vehicle brake systems, and to help drive new material and brake system design.

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Developed a disc-brake rotor model for thermal performance studies and evolution of rotor design concepts and waste-heat recovery methods.
- Selected candidate friction materials.
- Initiated friction and wear evaluation of candidate materials at Tribo Materials and Rockwell Scientific.
- Demonstrated friction stir reaction processing (FSRP) as a manufacturing method for friction materials that have a selectively graded, wear-resistant structure.

## Significant Future Milestones


**Principal Investigator** Darrell Herling, Pacific Northwest National Laboratory
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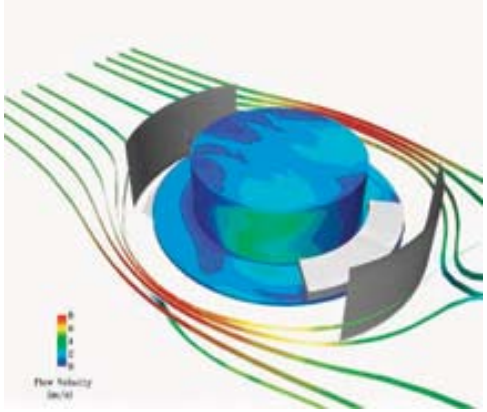
**Partners**

**Congressional Information** Washington 4th
Doc Hastings

**Technical Development Manager/Project Manager** Lee Slezak, U.S. Department of Energy
(202) 586-2335, lee.slezak@ee.doe.gov

DOE005 FINAL



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Materials Technologies -- High Strength Weight Reduction | Exploratory R and D | DOE | 3/15/2005 | A-143 |

# Research on Next Generation Truck Brake Materials

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- To identify, test, and evaluate promising candidates for the next generation of heavy vehicle brakes and to understand how their structure and performance are related

Safety Benefit: Save weight (fuel economy) while improving both frictional performance and durability.

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Designed and built a subscale brake testing apparatus instrumented to record applied force, friction force, surface temperature, and vibration.
- Selected and tested a variety of materials with the potential to serve as lightweight brake components.
- Investigated the effects of wet and dry braking conditions on frictional behavior.
- Used infrared imaging to study frictional heating of both cast iron and ceramic brake materials.

## Significant Future Milestones


**Principal Investigator** Peter Blau, Oak Ridge National Laboratory
(865) 574-5377, blaupj@ornl.gov


**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** James Eberhardt, U.S. Department of Energy
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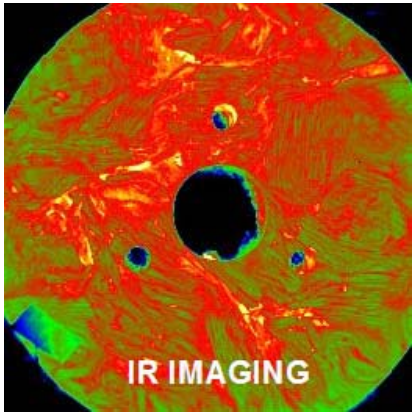
DOE002 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Materials Technologies -- High Strength Weight Reduction | Technology Development | DOE | 3/15/2005 | A-144 |

# 21st Century Truck Partnership
# Project Quad Sheets
# January 2007

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## U.S. Department of Transportation Projects

**Idle Reduction: Other idle reduction activities.**

*Program Area: Vehicle Safety*

B-1. U.S. DOT Funding Opportunities for Idle-Reduction Projects

**Safety: Develop and implement advanced technologies for high performance crash avoidance.**

*Program Area: Vehicle Safety*

B-2. Brake Lining Coding & Marking
B-3. Deployment of Safety Technologies
B-4. Driver Experience with the Enhanced Object Detection System (EODS) for Transit Buses
B-5. Drowsy Driver Field Operational Test
B-6. Enhanced Rear Signaling for Commercial Vehicles
B-7. Evaluation of the Large Truck Crash Causation Study (LTCCS) Data
B-8. Finite Element Truck Crash Modeling (with FHWA/NTRCI)
B-9. Freightliner Field Operational Test (Electronically Controlled Braking System-ECBS)
B-10. Inspection Station Demonstration of Remote Sensing of Truck Brake Condition
B-11. Integrated Braking Systems Analysis-Experimental Efforts
B-12. Integrated Braking Systems Analysis-Laboratory Efforts
B-13. Integrated Braking Systems Analysis-Modeling Efforts
B-14. Integrated Vehicle-Based Safety Systems (IVBSS)
B-15. On-Board Monitoring to Improve Commercial Motor Vehicle Safety
B-16. Optimizing Performance and Use of Indirect Visibility Systems
B-17. Roadside Testing Laboratory
B-18. Straight Truck Stopping Distance and Brake Lining Wear
B-19. Testing and Analysis of Braking Characteristics of Heavy Trucks
B-20. Tire Pressure Maintenance and Management
B-21. Tractor-Trailer Rollover Characterization
B-22. Transit Forward and Side Collision Warning Integration
B-23. Volvo Advanced Safety Systems Field Operational Test
B-24. Wireless Roadside Truck and Bus Safety Inspections

**Safety: Other safety activities.**

*Program Area: Vehicle Safety*

B-25. Advanced Photonics Technology for Transportation Safety & Security
B-26. Assessment of Heavy Vehicle Impacts on Emergency Evacuation Operations
B-27. Commercial Vehicle Driver Risk Factors: Final Study Design
B-28. Evaluation of the SafeStat Algorithm for Ranking the Safety of Motor Carriers
B-29. Operational Requirements for Hydrogen Fuel Systems
B-30. Safety Technologies for Commercial Vehicles Website

# U.S. DOT Funding Opportunities for Idle-Reduction Projects

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- Improve air quality
- Reduce energy consumption and greenhouse gas emissions
- Improve health and safety of drivers
- Fulfill National Energy Policy requirement

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $20000K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Development of a multi-agency (DOT, EPA and DOE) coordination effort to reduce idling emissions
- National Idle-Reduction Planning Conference (May 2004)
- Idle-reduction workshops (I-95 Corridor and Clean Cities events)
- Development of a National Idle-Reduction Plan (in progress)
- Introduction of innovative finance strategies for idle-reduction projects
- Expanded effort into a multi-modal initiative

## Significant Future Milestones

**Principal Investigator** State DOTs

FHWA Divisions

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Mike Savonis, DOT FHWA
(202) 366-2080

Diane Turchetta, DOT FHWA
(202) 493-0158

DOT030 FINAL

IdleAire system – Petro Travel Center – Knoxville, TN

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-1 |

# Brake Lining Coding & Marking

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Developed recommendations for a coding system for replacement linings suitable for fleets to use in selecting aftermarket products that match or exceed original equipment performance.
- Supplements current FMVSS for brakes (which apply to original equipment only) with criteria for replacement linings (>70% of the vehicles on the roads).

## Current FY Focus

None: project completed.

**Duration** year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $300K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Worked with ATA, TMC, SAE Linings Committee, PRI, HDBMC and fleet owners to define needs for aftermarket linings.
- Surveyed existing tests, practices, and standards to select appropriate and useful marking criteria for large and small fleet operators.
- Developed a marking code and an educational plan to implement the recommended code in the heavy truck brake industry.
- Prepared final report – published November 2005.

## Significant Future Milestones

None-project completed.

**Principal Investigator** Peter Blau, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Jim Britell, DOT NHTSA
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Joe Petrolino, NTRC, Inc.

DOT029 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 1/22/2007 | B-2 |

# Deployment of Safety Technologies

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Increase deployment and use of CMV onboard safety systems.
- Disseminating Information
- Developing ROI data
- Voluntary Performance Requirements for Collision Avoidance Systems:
  - Provide "performance benchmark"
  - Encourage additional vendors to enter marketplace
  - Provide a basis for qualifying technologies for incentive programs
  - Working towards TMC Recommended Practices
- Forward Collision Warning w/ACC
- Vehicle Stability
- Lane Departure Warning

## Current FY Focus

**Duration** 8/31/2005 through 12/31/2006

**Gov't Funding/Industry Cost Share** *Total Funding Level = $250K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Deployment plans for onboard safety technologies
- Additional ROI analysis
- DRAFT performance specifications

## Significant Future Milestones

**Principal Investigator**

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Amy Houser, DOT FMCSA
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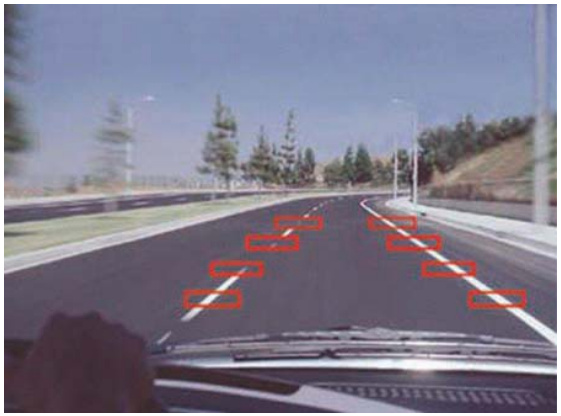
DOT010 FINAL



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-3 |

# Driver Experience with the Enhanced Object Detection System (EODS) for Transit Buses

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Determine usability of the EODS under normal driving conditions
- Determine how the EODS affects the driving environment and driver workload
- Determine if driver behaviors are affected by use of the EODS
- Determine if drivers value the EODS and believe that it is effective for improving safety
- Determine drivers' and mechanics' perceptions of system quality and improvement needs

## Current FY Focus

**Duration** 1/1/2003 through 12/31/2003

**Gov't Funding/Industry Cost Share** *Total Funding Level = $311K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- The 100 day FOT and final report were completed. Reports indicated that it is critical to minimize false alarms, training is necessary, and workload differed among drivers and vehicle speed.
- Significant feedback was received as to how to improve the system. Those comments have been incorporated into a newer, commercially available system that is now being installed on bus fleets around the country.
- An additional large scale FOT recently started to test the system on a larger number of buses throughout the country.

## Significant Future Milestones

**Principal Investigator** Battelle

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Brian Cronin, DOT FTA
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DOT013 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / FHWA-ITS 6 | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-4 |

# Drowsy Driver Field Operational Test

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- To improve agency understanding regarding the safety benefit and usability of a second generation drowsy driver detection and warning system for commercial vehicle operation.
- Data to evaluate the DDWS will be collected in a field operational test involving 102 commercial truck drivers from both long-haul and overnight operations. Additional information will be gathered through questionnaires and focus groups. The Volpe team has established five evaluation goals for the project, which will assess:
  - Safety benefits of the device
  - Driver acceptance
  - Performance and capability of the device
  - Deployment prospects
  - Fleet management acceptance.

## Current FY Focus

- Technical evaluation-statistical analyses.

**Duration** 5 years

**Gov't Funding/Industry Cost Share** *Total Funding Level = $3799K*

FY05 = $960K / $K FY06 = $120K / $K FY07 = $K / $K

## Accomplishments

- Develop detection technology by conducting laboratory and field-based studies in order to understand the usefulness of this technology and the feasibility of real-time monitoring of drivers.
- A full-day project meeting at the Transportation Institute in October 2003 included a demonstration of the DDWS, a review of driving data that will be collected during the test, and data-sharing issues. Volpe team members presented their progress in preparing for the evaluation, in particular their work in estimating safety benefits and in developing the experimental design, or research protocol.
- Completed data collection, reduction, and preliminary analysis (VTTI)

## Significant Future Milestones

- Final draft evaluation report (May 30, 2007)
- Final presentation (May 30, 2007)

**Principal Investigator** Bruce Wilson, Volpe
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Rich Hanowski, Virginia Tech
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**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Paul Rau, DOT NHTSA
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DOT004 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / NHTSA-ITS 1 | Vehicle Safety | Applied Research | DOT | 1/22/2007 | B-5 |

# Enhanced Rear Signaling for Commercial Vehicles

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Conduct data analyses to gain a better understanding of why a significant percentage of rear end collisions occur with the striking vehicle's driver taking no evasive actions or countermeasures at all, or taking them too late to avoid the accident.
- Develop countermeasures to reduce these accidents based on causal factors analysis.
- Test these countermeasures in the real world.

## Current FY Focus

**Duration** 9/3/2003 through 3/31/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $500K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completed causal factors analysis
- Completed concept of operations that outlines two countermeasure systems for testing
- Development of countermeasure specs
- Follow-on test and evaluation plan

## Significant Future Milestones

**Principal Investigator** Richard Knox, General Dynamics
(734) 480-5197

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Chris Flanigan, DOT FMCSA
(202) 385-2384, chris.flanigan@fmcsa.dot.gov

DOT012 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-6 |

# Evaluation of the Large Truck Crash Causation Study (LTCCS) Data

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Identify the important driver, carrier, vehicle, roadway and environmental factors that contribute to commercial motor vehicle collisions. ORNL – Contributed to Design of the Study and Development of Analytical Approach

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- NHTSA conducted detailed investigations of a national sample of about 1,000 large truck crashes for FMCSA over nearly three years, 2001 - 2003. ORNL contributed to the study design, methodology and is now participating in the analysis of the LTCCS data.
- A series of papers is being prepared for FMCSA on the study design, methodology and preliminary findings on factors that contribute to large-truck collisions.

## Significant Future Milestones

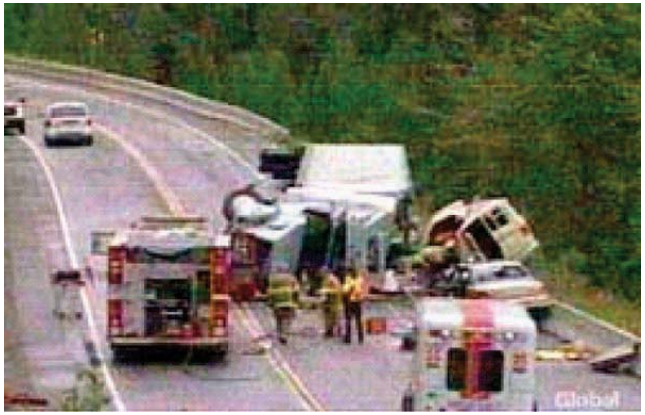
**Principal Investigator** Ken Campbell, Oak Ridge National Laboratory
(865) 946-1323, campbellkl@ornl.gov

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Ralph Craft, DOT FMCSA
(202) 366-0324, ralph.craft@fmcsa.dot.gov

DOT026 FINAL



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-7 |

# Finite Element Truck Crash Modeling (with FHWA/NTRCI)

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Model and assess different scenarios of truck vehicle run-off-road collisions with roadway infrastructure elements, vehicle structural modes of failure, and subsequent vehicle stability.
- Identify areas of the existing NCAC Single Unit Truck (SUT) model that could be improved to make it more immediately useful as-downloaded from the NCAC Finite Element Model archive.

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $130K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Crash test simulation analyses were performed using the NCAC F800 Single Unit Truck to simulate crash tests performed by the Texas Transportation Institute in the 1990s.
- Comparisons of analysis results and experiments were used to develop a series of recommendations for 13 enhancements of the model. Modifications now being made.
- Analyses and recommendations documented in a draft report.

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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Srdjan Simunovic, ORNL
(865) 241-3863

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT016 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-8 |

# Freightliner Field Operational Test (Electronically Controlled Braking System-ECBS)

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- FOT will evaluate current versions of electronically controlled braking systems (ECBS), which are enabling technologies that can help provide shorter stopping distances, improved dynamic brake force distribution, and improved combination vehicle brake balance. Other advanced safety systems being evaluated are adaptive cruise control, forward collision warning, roll stability and control, air disc brakes and trailer roll stability.
- Partners with DOT include Freightliner, Great Dane, Battelle Memorial Institute, Wal-Mart Corporation, Meritor Wabco, Bendix, and Hendrickson

## Current FY Focus

None: project completed.

**Duration** 5/1/2003 through 1/31/2007

**Gov't Funding/Industry Cost Share** *Total Funding Level = $6627K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Evaluation of the status of current versions of electronically controlled braking systems and improved vehicle performance
- Completed FOT test plan
- Completed FOT data collection
- Completed FOT data analysis and final report (to be published second quarter of FY 2007)
- Completed FOT independent evaluation and final report (to be published second quarter of FY 2007)

## Significant Future Milestones

None: project completed.

**Principal Investigator** Scott Smith, Freightliner
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**Partners**

**Congressional Information** Oregon 3rd
Earl Blumenauer

**Technical Development Manager/Project Manager** Matt Lehmer, DOT NHTSA
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DOT003 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / FMCA-ITS 1 | Vehicle Safety | Applied Research | DOT | 1/22/2007 | B-9 |

# Inspection Station Demonstration of Remote Sensing of Truck Brake Condition

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Demonstrate a safety-focused remote diagnostics proof of concept for Class 8 trucks
- Vehicle Demonstration Site (Campbell Station Weigh Station near Knoxville, Tennessee)

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $130K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Field Test Conducted in early-FY-2005
- Deliverables: Draft Report describing the ECBS system, the communications system and its implementation, and results of the proof-of-concept demonstration and validation. Video footage of the test and evaluation.

## Significant Future Milestones

**Principal Investigator** Tom Urbanik, University of Tennessee
(865) 974-7709, turbanik@utk.edu

Skip Yeakel, Volvo
(336) 393-2825, skip.yeakel@volvo.com

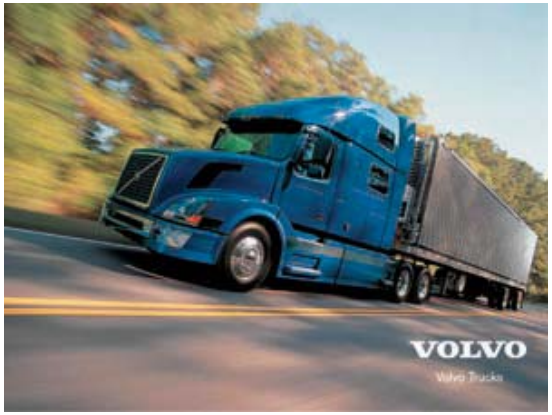
**Partners**

**Congressional Information** Tennessee 2nd
John Duncan

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT022 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-10 |

# Integrated Braking Systems Analysis-Experimental Efforts

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Proof of concept of a unique device that can simultaneously detect vehicle braking forces developed by each brake and do so in the time it takes to conduct a single stop from 20 mph. It can also weigh each end of every axle on the vehicle being tested.

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2004

**Gov't Funding/Industry Cost Share** *Total Funding Level = $120K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Prototype Developed
- Testing Conducted With Positive Results
- Final Report Completed

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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Tom Urbanik, University of Tennessee
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT020 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-11 |

# Integrated Braking Systems Analysis-Laboratory Efforts

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- To support braking models through the development of 'friction maps' that portray relationships between pressure, sliding speed, temperature and the frictional response for various lining materials.

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2004

**Gov't Funding/Industry Cost Share** *Total Funding Level = $100K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Modified ORNL Sub-Scale Brake Materials Tester (SSBT) to take differently-size lining samples (study effects of contact pressure).
- Procured, machined, and tested three commercial brake lining materials with different TMC RP 628 (FMVSS 121 - dyno) torque levels. Supplied initial friction data to brake modelers.
- Correlated relative SSBT friction coefficient levels with relative torque levels for the same lining materials.

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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Peter Blau, ORNL
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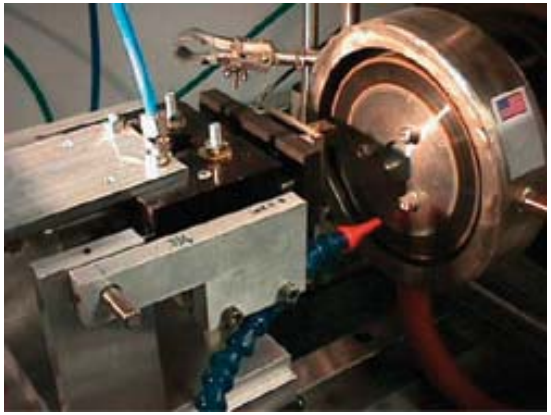
**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT019 FINAL



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|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-12 |

# Integrated Braking Systems Analysis-Modeling Efforts

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Develop and demonstrate full-vehicle dynamic model to study the incompatible combinations of systems between the tractor and trailer, such as disk versus drum brakes; EBS versus ABS versus wholly pneumatic (conventional); and fresh versus burnished versus worn.

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2004

**Gov't Funding/Industry Cost Share** *Total Funding Level = $100K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Basic model developed and demonstrated. Parametric studies of different brake combinations were completed

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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Denny Stephens, Battelle
(614) 424-4469, stephens@battelle.org

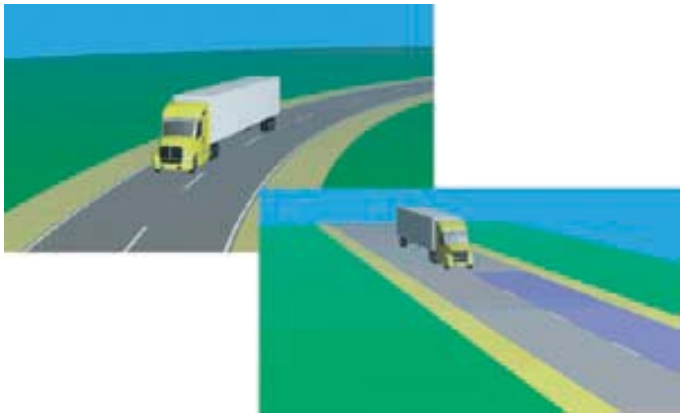
**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT018 FINAL



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-13 |

# Integrated Vehicle-Based Safety Systems (IVBSS)

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- To reduce crashes via accelerated introduction and commercialization of integrated vehicle-based safety systems for light vehicles, heavy trucks and buses. (crash problems addressed are: rear-end, road departure, and lane change/merge)
- Completion of a Field Operational Test (FOT) that will determine the safety benefit, user acceptance, cost, and system performance of an integrated safety system.

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Public Meeting held to explain IVBSS initiative and obtain feedback from the public, September 21, 2004 in Detroit, MI
- As part of the Preparatory Analysis phase of the project, a Market Research Project was initiated in late December 2004 for trucks and buses (completion April 3)

## Significant Future Milestones

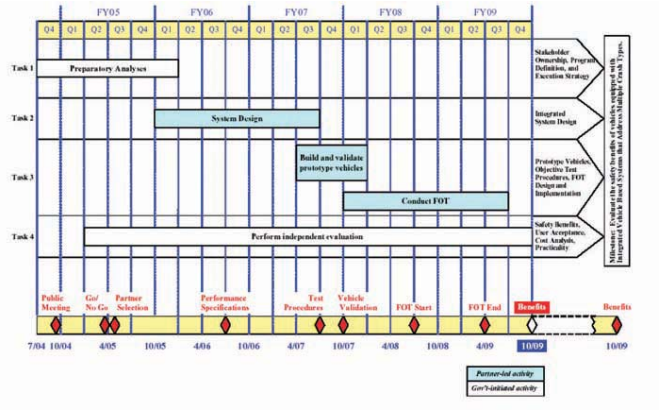
**Principal Investigator** Jack Ference, DOT NHTSA
(202) 366-0168, jack.ference@nhtsa.dot.gov

**Partners**

**Congressional Information** DC At Large
Eleanor Holmes Norton

**Technical Development Manager/Project Manager** Tim Johnson, DOT FMCSA
(202) 366-2362, tim.johnson@fmcsa.dot.gov

DOT006 FINAL




**Program Timeline (from IVBSS Program Plan)**

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-14 |

# On-Board Monitoring to Improve Commercial Motor Vehicle Safety

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Determine whether onboard monitoring and feedback can improve commercial motor vehicle driver performance and safety
- Requirements Generation –defining which driver performance aspects should be measured
- Human Factors Studies – determining best means of communicating information to the driver
- On-board Monitoring Suite – design and development of suite
- Field Operating Test and Evaluation Plan – development of the research methodology for the follow-on study

## Current FY Focus

**Duration** 9/30/2004 through 10/31/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $354K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Established a Cooperative Agreement with California Department of Transportation (CalTrans) and California Partners for Advanced Transit and Highways (PATH)
- Kick off meeting scheduled for second quarter FY 2005`

## Significant Future Milestones

**Principal Investigator** Randy Wooley, California DOT
(949) 756-4930, Randy.Woolley@dot.ca.gov

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Jerry Robin, DOT FMCSA
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DOT011 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-15 |

# Optimizing Performance and Use of Indirect Visibility Systems

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Addresses lane change and merge crashes involving heavy-duty trucks by assessing visibility from today's tractors, documenting current mirror design and aiming, and measuring quality and quantity of fields of view.
- Partners with DOT include Virginia Tech and Weststat.
- Determine performance requirements for indirect viewing surfaces and cameras.
- Develop 360-degree all-weather visibility system for heavy trucks

## Current FY Focus

- Analysis of dynamic testing from drivers performing standard heavy vehicle maneuvers.

**Duration** 5 years

**Gov't Funding/Industry Cost Share** *Total Funding Level = $469K*

FY05 = $K / $K FY06 = $426K / $K FY07 = $0K / $K

## Accomplishments

- Develop a database regarding mirror design and aiming, and measurements in quality and quantity of a driver's field of view.
- Completed Track I, static characterization of field of view versus West Coast mirrors with a heavy truck.
- Completed Track II, data collection of dynamic tests for comparing candidate indirect viewing technologies.

## Significant Future Milestones

- Complete final report and oral final presentation by September 30, 2007

**Principal Investigator** Walt Wierwille, Virginia Tech
(540) 231-1543, waltw@vt.edu
Neil Lerner, Weststat

**Partners** Virginia Tech, Weststat

**Congressional Information** Virginia 9th
Rick Boucher

**Technical Development Manager/Project Manager** Paul Rau, DOT NHTSA
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DOT005 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 1/22/2007 | B-16 |

# Roadside Testing Laboratory

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Provide a test capability where new and emerging commercial vehicle safety technologies, inspection procedures, and other countermeasures can be evaluated in a real-world roadside setting.
- May include testing at a dedicated site, corridor testing, and regional tests.
- Could also include laboratory, bench-top, simulator, test-loop, and test-track testing.
- Provides support for accelerated deployment of safety and inspection technologies.

## Current FY Focus

**Duration** 6/1/2004 through

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Initial Testing at Campbell Station Weigh Station in Knoxville, Tennessee

## Significant Future Milestones

**Principal Investigator** Pat Hu, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Jeff Loftus, DOT FMCSA
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DOT015 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-17 |

# Straight Truck Stopping Distance and Brake Lining Wear

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Provide objective test data to further refine the database available to NHTSA of single-unit truck stopping distances. (Vehicle testing, bench-top brake materials – wear testing, age/field testing, and analysis)
- DOT partners include the National Transportation Research Center, Oak Ridge National Laboratory, and TRC, Inc..

## Current FY Focus

**Duration** 2 years

**Gov't Funding/Industry Cost Share** *Total Funding Level = $492K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Through track tests, bench top work and actual commercial operations examine the stopping distance of various brakes, and brake lining wear in commercial service.

## Significant Future Milestones

**Principal Investigator** National Transportation Research Center

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Chris Flanigan, DOT FMCSA
(202) 385-2384, chris.flanigan@fmcsa.dot.gov

DOT002 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-18 |

# Testing and Analysis of Braking Characteristics of Heavy Trucks

21st CENTURY TRUCK PARTNERSHIP

21CTP

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Provide objective test data to further refine the database on stopping distances for single-unit trucks utilizing OE brakes (Test Track Data),
- Provide objective test data for stopping distance performance utilizing aftermarket brake linings for the same vehicles as item 1 (Test Track Data),
- Study braking material behavior via small-scale brake testing and Chase tests, for the same braking materials addressed in items 1 and 2 (Bench Top Testing),
- Provide real-world driving environment data for the same vehicles and brake materials addressed in items 1, 2 and 3 (Field Tests), and
- Attempt to correlate the results of the bench top, test track, and field tests.

## Current FY Focus

None: project completed.

**Duration** 1/1/2005 through 12/31/2006

**Gov't Funding/Industry Cost Share** *Total Funding Level = $490K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completed objectives described.
- Project summarized in final report to be published second quarter of FY 2007

## Significant Future Milestones

None: project completed.

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
(865) 946-1300, kneehe@ornl.gov

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Matt Lehmer, DOT NHTSA
(202) 366-4705, matthew.lehmer@dot.gov

DOT024 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 1/22/2007 | B-19 |

# Tire Pressure Maintenance and Management

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Test and evaluate various on-board sensors and systems in a comparative "round robin" setting.
- 10 systems selected for testing (6 direct monitoring – valve stem, wheel, tire mounted; 6 pressure management – 2 equalizing, 2 central inflation).

## Current FY Focus

**Duration** 12/31/2004 through 5/1/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $487K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- December 2003: Task Order awarded.
- 1st quarter 2004: Market survey of tire pressure monitoring and pressure maintenance systems.
- 2nd quarter 2004: Recommendation of systems for testing.
- 3rd quarter 2004: Development of test plans, plans for obtaining test vehicles, begin to acquire systems.
- 4th quarter 2004: Continued to acquire systems; instrumented test wheels; fabricated special inflation/deflation manifold.
- 1st quarter 2005: Data acquisition system upgraded (used in prior Task Orders); pretests run; full test cycle begun.

## Significant Future Milestones

**Principal Investigator**

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Deborah Freund, P.E., DOT FMCSA
(202) 366-5541, deborah.freund@fmcsa.dot.gov

DOT009 FINAL

Michelin eTire System

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-20 |

# Tractor-Trailer Rollover Characterization

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Conduct test track experiments to evaluate rollover propensity of a tractor-trailer during and after FMVSS-121-type tests.
  - Quantify Vehicle Dynamics
  - Gather Baseline Data
  - Gather Truck-Trailer-Tire Family Data (Standard Duals vs. Next Generation Singles)
  - Contribute to Rollover Models
  - Contribute to Roll Predictive Indicators
  - Baseline for Improving Torsional Stiffness

## Current FY Focus

**Duration** 3/1/2004 through 9/30/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $165K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Tilt Table measurements were made at University of Michigan's Transportation Research Institute
- Vehicle dynamic measurements were made at Transportation Research Center Inc., using standard dual tires and next generation single tires

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT023 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-21 |

# Transit Forward and Side Collision Warning Integration

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Integrate the forward and side collision warning systems into a unified whole with one transit operator interface
- Specify and build a usable driver vehicle interface (DVI) prototype
- Conducted limited operational testing and evaluation of enhanced commercial systems in transit use
- Develop and test a collision warning system leading toward commercialization

## Current FY Focus

**Duration** 6/1/2003 through 6/30/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $1475K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Field and limited operational testing underway on buses being used in revenue service in Pittsburgh, PA and San Mateo, CA
- A driver-vehicle interface (DVI) was developed and extensively tested for the transit bus environment
- Development of material for operators and an outreach program was completed
- An interface control document was created; final performance specifications are nearing completion
- System is currently undergoing an internal evaluation as well as additional human factors evaluations

## Significant Future Milestones

**Principal Investigator** Caltrans

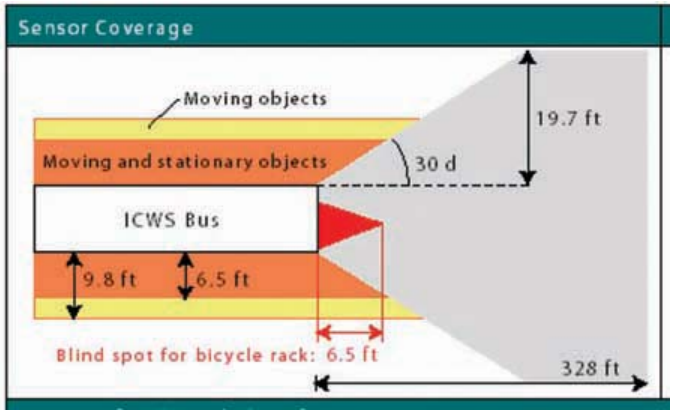
PennDOT

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Brian Cronin, DOT FTA
(202) 366-8841, brian.cronin@fta.dot.gov

DOT014 FINAL




| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / FTA-ITS 4 | Vehicle Safety | Applied Research | DOT | 3/15/2005 | B-22 |

# Volvo Advanced Safety Systems Field Operational Test

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Evaluate the durability, reliability, operational costs, and driver acceptance and safety effect of the following integrated Advanced Safety Systems: forward collision warning, adaptive cruise control, disc brakes, and an electronically controlled brake system on heavy duty tractors.
- DOT partners include Aberdeen Test Center- U.S. Army, Par- Rome Research Corporation, Volvo Trucks North America, Inc., U.S. Express, Leasing, Inc., and Battelle.

## Current FY Focus

None: project completed.

**Duration** 8/1/2000 through 8/31/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $5656K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Evaluated forward collision warning, adaptive cruise control, disc brakes, and an electrically controlled brake system on heavy-duty tractors for commercial use.
- Completed FOT data analysis and independent evaluation summarizing advanced safety system durability, reliability, operational and maintenance costs, user acceptance, performance, benefit-cost analysis, and safety benefits analysis.
- Final reports completed (to be published second quarter of FY 2007).

## Significant Future Milestones

None: project completed

**Principal Investigator** Nicholas Rini, Volvo
(336) 393-2771, nicholas.rini@consultant.volvo.com

Nancy McMillan, Battelle
(614) 424-7942, mcmillann@battelle.org

**Partners** Aberdeen Test Center- U.S. Army, Par- Rome Research Corporation, Volvo Trucks North America, Inc., U.S. Express, Leasing, Inc., and Battelle

**Congressional Information** North Carolina 6th
Howard Coble

**Technical Development Manager/Project Manager** Matt Lehmer, DOT NHTSA
(202) 366-4705, matthew.lehmer@dot.gov

DOT001 FINAL-R3

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / NHTSA-ITS 3 | Vehicle Safety | Applied Research | DOT | 1/22/2007 | B-23 |

# Wireless Roadside Truck and Bus Safety Inspections

**21CTP Technical Goal** Safety: Develop and implement advanced technologies for high performance crash avoidance.

## Objectives

- Develop and analyze various concepts of operation that would link on-board safety data and the associated sensors and monitoring technologies needed to produce the data together with a means of wirelessly communicating such information to inspections sites in order to improve the quality and/or quantity of commercial vehicle inspections completed annually in the U.S.
- Development of new operational concepts (April 2005)
- Concept Feasibility Evaluation (May 2005)
- System Development and Deployment Plan (August 2005)

## Current FY Focus

**Duration** 9/30/2004 through 8/31/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $400K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Project Initiated (September 2004)
- Completed Requirements Analysis

## Significant Future Milestones

**Principal Investigator** Robert Kreeb, Booz-Allen & Hamilton

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Tim Johnson, DOT FMCSA
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DOT007 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Technology Development | DOT | 3/15/2005 | B-24 |

# Advanced Photonics Technology for Transportation Safety & Security

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- Improved Road Striping with Long-Persistence Phosphors (LPPs): characterize candidate materials.
- UV-Activated Visibility Enhancement: characterize UV LED arrays and begin investigation of associated optics for long-distance projection

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2005

**Gov't Funding/Industry Cost Share** *Total Funding Level = $170K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Evaluation of emission and excitation characteristics of several candidate LLPs, including study of LLPs in binder materials.
- Preliminary testing of UV LED arrays

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
(865) 946-1300, kneehe@ornl.gov

Mike Cates

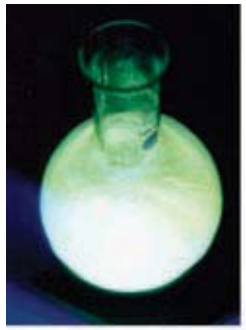
**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

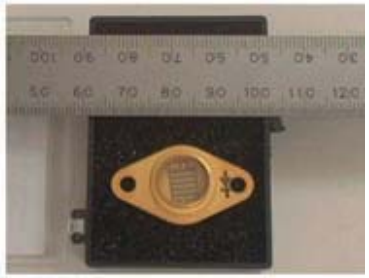
**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.

Mike Trentacoste, DOT FHWA

DOT021 FINAL



Self-luminous LPP



UV LED array

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-25 |

# Assessment of Heavy Vehicle Impacts on Emergency Evacuation Operations

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- Assess the emergency evacuation modeling capability of FHWA's TrEPS-P (Traffic Estimation and Prediction System)
- Use TrEPS-P to formulate solutions specific to heavy vehicles in emergency evacuation planning.

## Current FY Focus

**Duration** 3/1/2003 through 9/30/2004

**Gov't Funding/Industry Cost Share** *Total Funding Level = $100K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Completed Emergency Evacuation Model Assessment
  - TrEPS-P can be used for emergency evacuation planning process
  - Trucks are modeled by TrEPS-P using Passenger-Car-Equivalence factor specified by HCM
  - Posted Bridge Load Limit can be modeled by TrEPS-P's "Congestion Pricing" or HOV Lane capabilities
- Evaluated Existing Databases Capable of Being Used by TrEPS-P
  - Identified means of generating truck O-Ds, and means for accounting for "households without vehicles," and daytime population

## Significant Future Milestones

**Principal Investigator** Bill Knee, Oak Ridge National Laboratory
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Shih-Miao Chin

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Joe Petrolino, NTRC, Inc.
Mike Trentacoste, DOT FHWA

DOT017 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-26 |

# Commercial Vehicle Driver Risk Factors: Final Study Design

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- Design an exposure-based, case-control study of the relationship of driver personal traits, fitness, medical conditions and medications to the risk of collision involvement.

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- A draft final report describing the sample design was submitted in October 2004. A pilot phase is next, followed by the full study.
- This exposure-based study will compliment the LTCCS that is based only on crash investigations. No comprehensive assessment of CMV driver risk factors has been conducted to date.

## Significant Future Milestones

**Principal Investigator** Ken Campbell, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Albert Alvarez, DOT FMCSA
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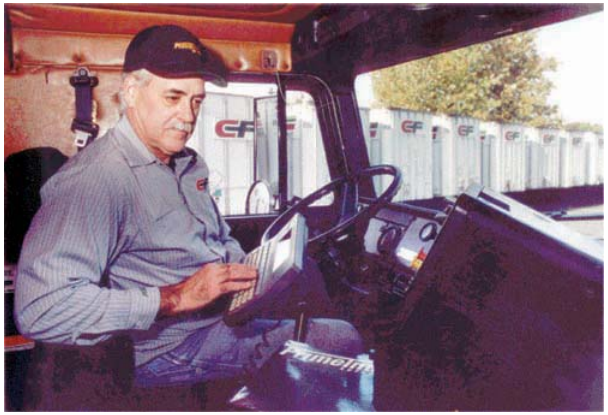
DOT027 FINAL



| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-27 |

# Evaluation of the SafeStat Algorithm for Ranking the Safety of Motor Carriers

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- Evaluate the reliability and accuracy of the FMCSA motor carrier safety measurement system (SafeStat)
- There is an opportunity to substantially improve the identification of unsafe motor carriers and improve the effectiveness of State and Federal enforcement activities

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- The current SafeStat algorithm does not adequately address the inherent variability in the source data. The use of statistical methods could greatly improve the identification of unsafe carriers. Final report delivered October 2004, not yet released.

## Significant Future Milestones

**Principal Investigator** Ken Campbell, Oak Ridge National Laboratory
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**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Dale Sienicki, DOT FMCSA
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DOT025 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-28 |

# Operational Requirements for Hydrogen Fuel Systems

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- Develop guidelines for fleets to use when assessing proper design of hydrogen fuel systems, as well as guidelines for safe operation and inspection of commercial vehicle hydrogen fuel systems.
- Assess the impact that hydrogen technology may have on FMCSA regulations and inspection procedures when used as an alternative fueled in commercial vehicle fleets.

## Current FY Focus

**Duration** year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $150K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Project not yet underway.

## Significant Future Milestones

**Principal Investigator**

**Partners**

**Congressional Information**

**Technical Development Manager/Project Manager** Tim Johnson, DOT FMCSA
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DOT008 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-29 |

# Safety Technologies for Commercial Vehicles Website

**21CTP Technical Goal** Safety: Other safety activities.

## Objectives

- To inform agencies and end-users about the types and benefits of ITS/CVO Safety Technologies.
- Increases stakeholder awareness of safety technology by providing a "One-Stop" information format
- A useful tool providing general safety technology information to the user and providing links to product manufacturers

## Current FY Focus

**Duration** 1/1/2003 through

**Gov't Funding/Industry Cost Share** *Total Funding Level = $300K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Draft site developed; 25 partnerships finalized; 71 potential partners identified

## Significant Future Milestones

**Principal Investigator** Gary Capps, Oak Ridge National Laboratory
(865) 946-1285, cappsgj@ornl.gov

**Partners**

**Congressional Information** Tennessee 3rd
Zach Wamp

**Technical Development Manager/Project Manager** Doug McKelvey, DOT FMCSA
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DOT028 FINAL

| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Vehicle Safety | Exploratory R and D | DOT | 3/15/2005 | B-30 |

# 21st Century Truck Partnership
# Project Quad Sheets
# January 2007

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## U.S. Environmental Protection Agency
## Projects

**Engine Systems: Improve fuel efficiency by 20% by 2010.**

*Program Area: Advanced Combustion*

C-1. Aftertreatment Testing as Support to EPA Diesel Rulemaking

**Idle Reduction: Other idle reduction activities.**

*Program Area: Heavy Vehicle Systems – Idle Reduction*

C-2. EPA SmartWay Ground Freight Transportation Initiative

*Program Area: Idle Reduction Deployment*

C-3. EPA's Idle Reduction Deployment Program

# Aftertreatment Testing as Support to EPA Diesel Rulemaking

**21CTP Technical Goal** Engine Systems: Improve fuel efficiency by 20% by 2010.

## Objectives

Demonstrate, in support of the 2007 Highway HD Standards, a 90% emissions reduction in NOx and PM in a laboratory environment. Demonstrate, in support of the biennial technology reviews, desulfurization and long term durability of catalyst equipment.

## Current FY Focus

- Thermal management of NOx aftertreatment devices to meet the HD standards.
- Continue to benchmark NOx adsorber performance improvements

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Demonstrated 90% 2010 emission standard.
- Demonstrated desulfurization of NOx adsorber catalysts.
- Demonstrated impacts of alternative test cycles on standard stringency.

## Significant Future Milestones

- Demonstrate passive and active thermal management paths for HD applications.
- Complete benchmarking of latest NOx adsorber formulations.


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| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Advanced Combustion | Applied Research | EPA | 10/5/2006 | C-1 |

# EPA SmartWay Ground Freight Transportation Initiative

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

The SmartWaySM Transport Partnership is a voluntary collaboration between U.S. EPA and the freight industry designed to increase energy efficiency while significantly reducing greenhouse gases and air pollution. SmartWay Transport Partners lead the way towards a cleaner, more efficient transportation future by adopting fuel-saving strategies that increase profits and reduce emissions -- a "win-win" opportunity for all.

## Current FY Focus

Enrollment of small to medium-size fleets to help them benefit from SmartWay solutions. Explore ways of distinguishing low-emission high-efficiency SmartWay trucks that represent the highest level of environmental performance in freight truck technology.

**Duration** year

**Gov't Funding/Industry Cost Share**

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- 470 Partners (after 2 years). Companies include: trucking, shippers, logistics, associations, truck stops.
- Fuel Saved: 228 Million Gallons/year; CO2 Reduced: 2.5 Million tons/year; NOx Reduced: 12,000 tons/year; PM Reduced: 556 tons/year

## Significant Future Milestones

- Expanding efforts to include other important “players” in the trucking industry.
- Building more sustainable innovative mechanisms (beyond grants) to assist the trucking industry.

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| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Heavy Vehicle Systems -- Idle Reduction | Applied Research | EPA | 11/27/2006 | C-2 |

# EPA's Idle Reduction Deployment Program

**21CTP Technical Goal** Idle Reduction: Other idle reduction activities.

## Objectives

- Deploy and Demonstrate idle reduction technologies (mobile and stationary) on heavy-duty diesel trucks
- Reduce emissions of nitrogen oxides, fine particulate matter and other air toxics, and carbon dioxide.
- Reduce petroleum consumption
- Improve quality of life for truck drivers (health, idling laws)

## Current FY Focus

**Duration** 1 year

**Gov't Funding/Industry Cost Share** *Total Funding Level = $5000K*

FY05 = $K / $K FY06 = $K / $K FY07 = $K / $K

## Accomplishments

- Deployment of 1,000 electrified parking spaces along major interstates (I-5, I-95, etc)
- Leveraging of $8 million in state and industry funds
- Indoor cab exposure study (in process)
- Idling emissions testing
- State anti-idle law model (in process)
- Deployment of auxiliary engines on 6 "switch" yard locomotives
- Expanding SmartWay recognition to railroads, ports, border, and airports

## Significant Future Milestones

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| PROJECT ID/AGREEMENT ID | PROGRAM STRUCTURE/SUBPROGRAM ELEMENT | R AND D PHASE | AGENCY | DATE | PAGE |
|---|---|---|---|---|---|
| N/A / N/A | Idle Reduction Deployment | Applied Research | EPA | 3/15/2005 | C-3 |

21st CENTURY TRUCK PARTNERSHIP

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