



U.S. Department of Energy  
**Energy Efficiency  
and Renewable Energy**

Bringing you a prosperous future where energy  
is clean, abundant, reliable, and affordable

**Vehicle Technologies Program**

# **Overview of the Heavy Truck Engine and Enabling Technologies R&D**

Roland Gravel  
Advanced Combustion Engine R&D Subprogram  
Vehicle Technologies Program

Presented at the  
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Technologies Program Annual Merit Review*  
Arlington, VA  
May 2009

***Vehicle Technologies Program Mission***

*To develop more energy efficient and environmentally friendly highway  
transportation technologies that enable America to use less petroleum.*

*--EERE Strategic Plan, October 2002--*



- ❑ Undertake High-Risk Mid- to Long-Term Research
- ❑ Utilize Unique National Lab Expertise and Facilities
- ❑ Help Create a National Consensus
- ❑ Work Cooperatively with Industry



**Strategic Goal:** Reduce petroleum dependence by removing critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles

## Primary Directions

- › ICE efficiency improvements for cars, light- and heavy-duty trucks through low-temperature combustion and minimization of thermal and parasitic losses
- › Aftertreatment development integrated with combustion strategies for emissions compliance and minimization of efficiency penalty
- › Waste energy recovery with thermoelectrics
- › Coordination with fuels R&D to enable clean, high-efficiency engines using hydrocarbon-based (petroleum and non-petroleum) fuels and hydrogen

## Performance Targets

	2010 (light-duty)	2017 (heavy-duty)
Engine brake thermal efficiency	45%	55%
Powertrain cost	< \$30/kW	
NOx & PM emissions	Tier 2, Bin5	EPA Standards



## Goal

- By 2017, develop the technologies that will increase the thermal efficiency of heavy truck engines to at least **55 percent** while meeting prevailing **EPA emissions standards**.



- ❑ Increasing Efficiency
- ❑ Reducing Emissions
- ❑ Ensuring Durability
- ❑ Maintaining or Reducing Cost



### **Fundamental R&D**

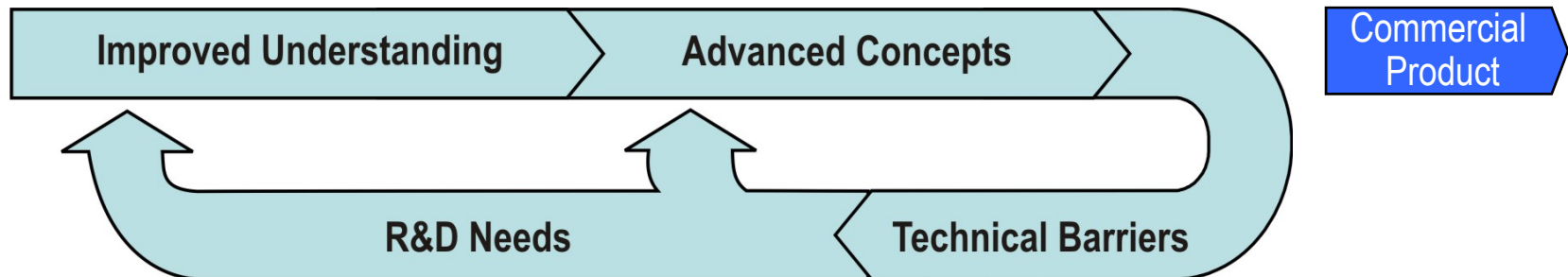
- SNL – Low Temperature Combustion
- PNNL – Catalyst Characterization (NO<sub>x</sub> and PM Control)
- ANL – X-ray Visualization of fuel sprays
- LLNL – Chemical kinetics models (LTC and emissions)
- LANL – CFD modeling of combustion
- Universities (U. of WI, Texas A&M, U. of MI, MIT, others) – Complementary research

### **Fundamental to Applied Bridging R&D**

- ORNL – Experiments and simulation of engines and emission control systems (bench-scale to fully integrated systems)
- ANL – H<sub>2</sub>-fueled ICE; fuel injector design

### **Competitively Awarded Cost-shared Industry R&D**

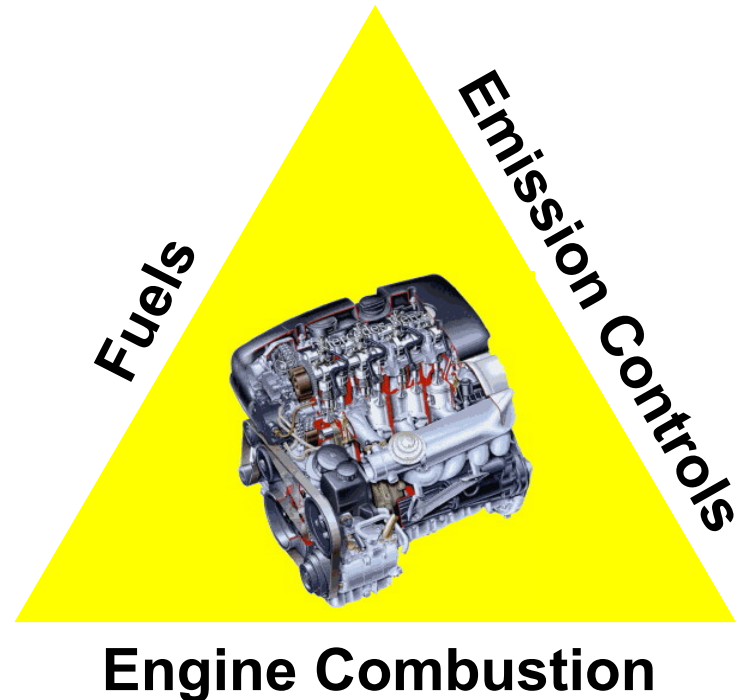
- Auto and engine companies – engine systems
- Suppliers – enabling technologies (sensors, VVA, WHR)





## **Systems Approach** to Dramatically Improve Diesel Engine Efficiency and Reduce Emissions

- ❑ **Partnerships with auto/truck** manufacturing industry, energy companies, suppliers and national laboratories
- ❑ **Improve fundamental understanding**
- ❑ **Use integrated systems approach**
- ❑ **Progress made in all 3 areas**



**Auto** ↔ **Light Truck** ↔ **Heavy Truck**





## Research, Development and Demonstration in Five Key Technology Areas



DOE/EERE  
 FreedomCAR and  
 Vehicle Technologies



DOD/Army  
 TACOM NAC  
 Military Vehicle  
 R&D



DOT / RSPA  
 Intelligent Vehicle and  
 Highway Safety R&D



EPA  
 Vehicle Emissions  
 Regulations

- ❑ **Engine Systems**
- ❑ **Heavy-Duty Hybrid**
- ❑ **Parasitic Losses**
- ❑ **Idle Reduction**
- ❑ **Safety**

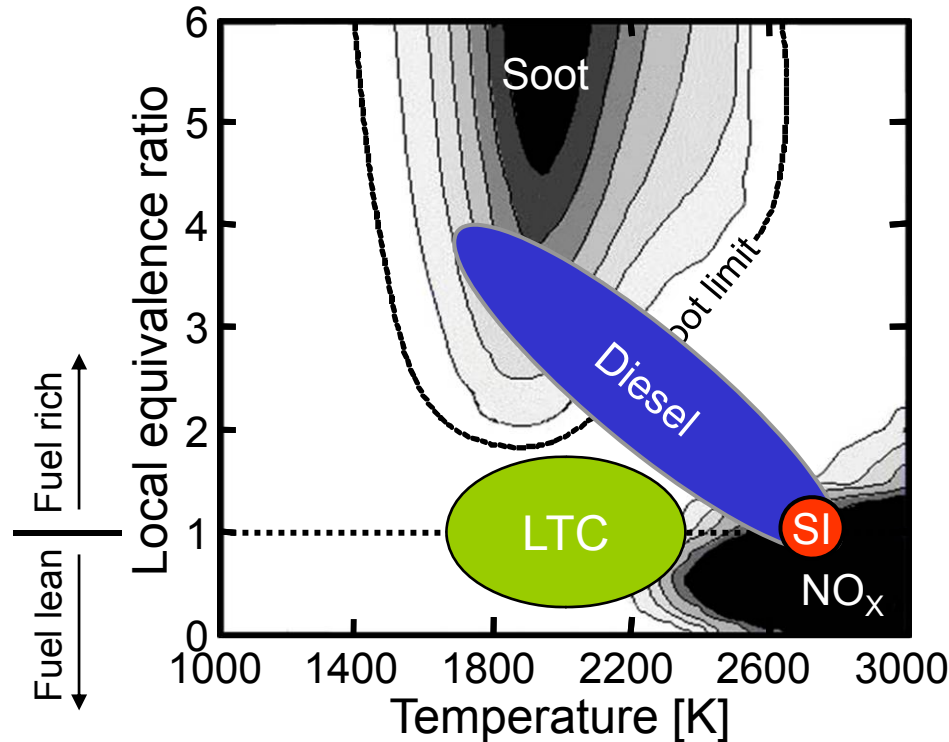






## Focus On Low-Temperature Combustion (LTC) Strategies

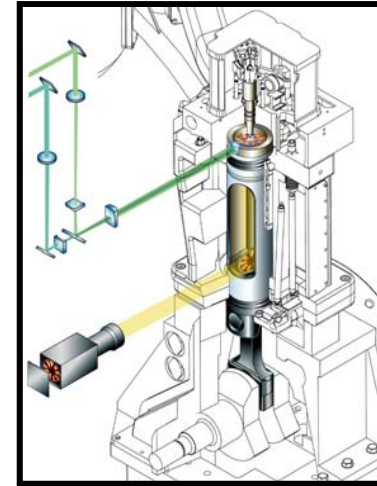
Potential to enable high-efficiency and low-emission operation



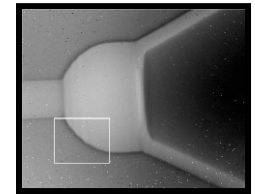
- LTC used generically to represent many processes
  - Homogeneous-Charge Compression-Ignition (HCCI)
  - Premixed-Charge Compression-Ignition” (PCCI), SCCI, HECC, MK, UNIBUS, ...
- Challenges
  - Combustion phasing
  - Load range
  - Heat release rate
  - Transient control
  - HC and CO emissions
  - Fuel



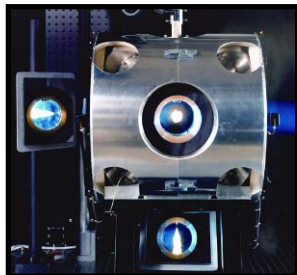
- ❑ **Close collaboration** between industry, national labs and universities
  - Research guided by industry needs
  - DOE/industry prototype engine projects
- ❑ Close coupled **modeling and experiments**
  - Multi-/single-cylinder engines & simulators
  - Advanced diagnostics
    - Optical-, laser-, and x-ray- based techniques
  - Multi-dimensional computational models
- ❑ **Cross-cuts light- and heavy-duty research**



Optical Engine



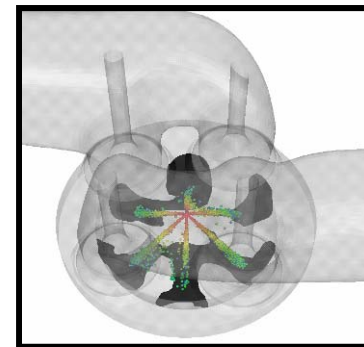
Nozzle Sac  
X-Ray Image



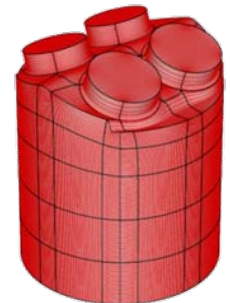
LTC Simulator



Multi-Cylinder Diesel



Engine Simulation



3-Million Cell  
LES Grid



# Advanced Combustion Engine R&D Budget by Activities

Major Activities	FY 2007 Appropriation	FY 2008 Appropriation	FY 2009 Appropriation
<b>Advanced Combustion Engine R&amp;D</b>	<b>\$48,346K</b>	<b>\$44,591K</b>	<b>\$40,800K</b>
Combustion and Emission Control *	26,778	38,815	35,089
<i>Heavy Truck Engine**</i>	<i>14,495</i>	<i>0</i>	<i>0</i>
Solid State Energy Conversion***	4,579	4,527	4,568
<i>Health Impacts**</i>	<i>2,494</i>	<i>0</i>	<i>0</i>
SBIR/STTR		1,248	1,143

## Changes in FY 2008 Request

\*Expanded to include Heavy Truck Engine and Health Impacts.

\*\*Incorporated within expanded Combustion and Emission Control R&D.

\*\*\*Formerly Waste Heat Recovery