Overview of the DOE Advanced Combustion Engine R&D

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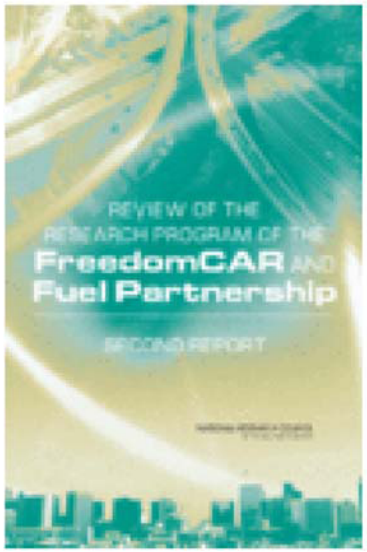
Vehicle Technologies Program Mission

To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.
--EERE Strategic Plan, October 2002--

The Federal Role

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



The National Research Council fully supports advanced combustion engines research:

"***Internal combustion engines (ICEs) will be the mainstay of the nation's automotive fleet for a very long time***, even if the goals of the fuel cell program and the hydrogen infrastructure program are met, enabling fuel cell vehicles to be introduced in large numbers by 2020."

"This kind of ***research has provided understanding*** that allows ICE engines ***to meet emission constraints and efficiency goals simultaneously***. …would have an immediate, significant effect on petroleum use. … new findings are quickly translated into large-scale development activities and, if these are successful, ***will be rapidly deployed by industry***. …"

Source: *Review of the Research Program of the FreedomCAR and Fuel Partnership: Second Report,* Committee on Review of the FreedomCAR and Fuel Research Program, Phase 2, National Research Council, 2008.

Advanced Combustion Engine R&D

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

Research Approach

Advanced Combustion Engine R&D → Industry

Fundamental Research → Applied Research → Technology Maturation & Deployment

Fundamental R&D

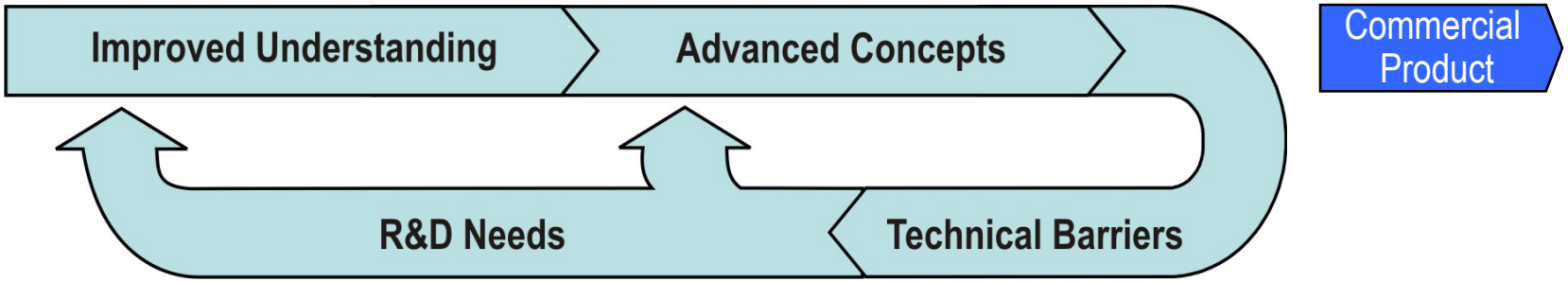
- SNL – Low Temperature Combustion
- PNNL – Catalyst Characterization (NOx and PM Control)
- ANL – X-ray Visualization of fuel sprays
- LLNL – Chemical kinetics models (LTC and emissions)
- LANL – CFD modeling of combustion
- Universities (U. of WI, Texas A&M, U. of MI, MIT, others) – Complementary research

Fundamental to Applied Bridging R&D

- ORNL – Experiments and simulation of engines and emission control systems (bench-scale to fully integrated systems)
- ANL – H_2-fueled ICE; fuel injector design

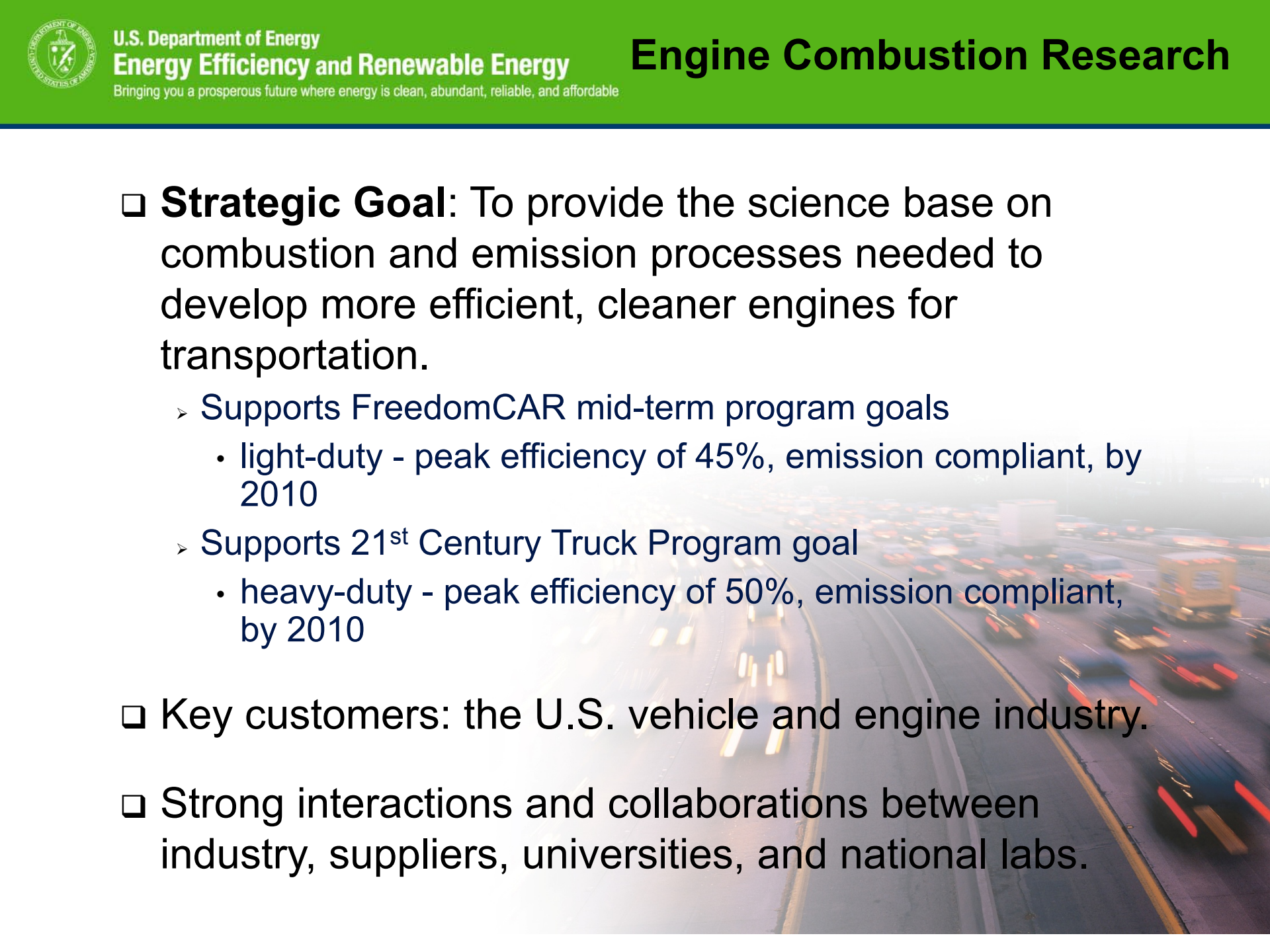
Competitively Awarded Cost-shared Industry R&D

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



Engine Combustion Research

- **Strategic Goal**: To provide the science base on combustion and emission processes needed to develop more efficient, cleaner engines for transportation.
  - Supports FreedomCAR mid-term program goals
    - light-duty - peak efficiency of 45%, emission compliant, by 2010
  - Supports 21st Century Truck Program goal
    - heavy-duty - peak efficiency of 50%, emission compliant, by 2010
- Key customers: the U.S. vehicle and engine industry.
- Strong interactions and collaborations between industry, suppliers, universities, and national labs.



Engine Combustion Research

Goal: To develop the knowledge base for low-temperature combustion (LTC) strategies and carry research results to products.

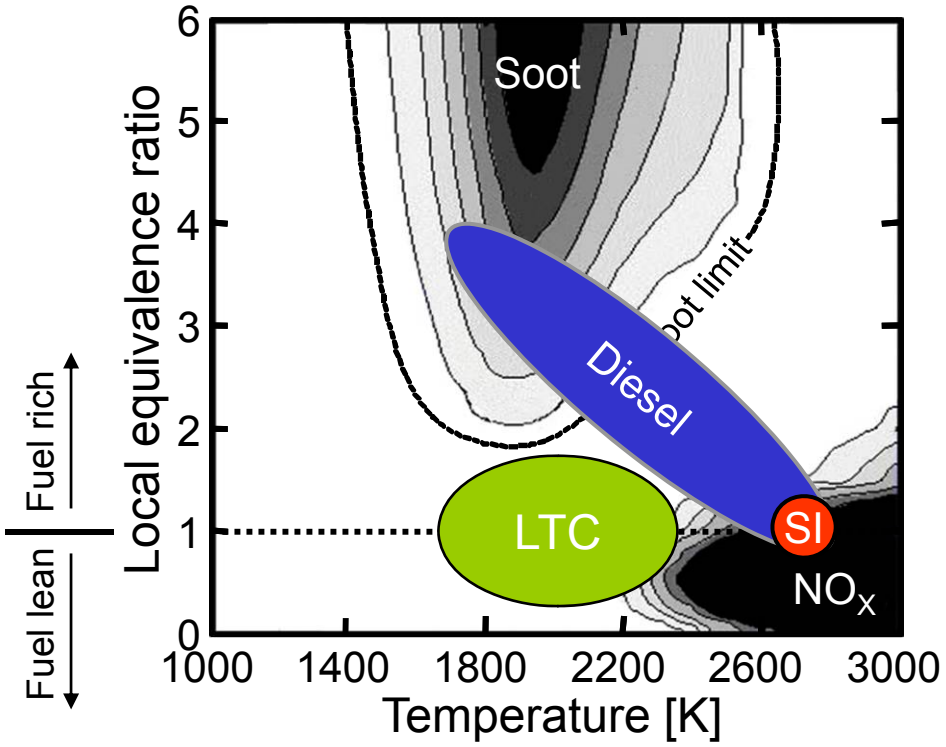
- Combustion work coordinated under a Memorandum of Understanding (MOU)
- Five energy companies joined MOU in 2006
  - Added perspectives for production of potential fuels or fuel blends

Ford, GM, Cummins, Mack Driven, ExxonMobil, Chrysler, GE, Lawrence Livermore National Laboratory, Shell Global Solutions, Oak Ridge National Laboratory, ConocoPhillips, Caterpillar, Sandia National Laboratories, International, Detroit Diesel, John Deere, Argonne National Laboratory, Chevron, bp, Los Alamos National Laboratory

Engine Combustion Research

Focus On Low-Temperature Combustion (LTC) Strategies

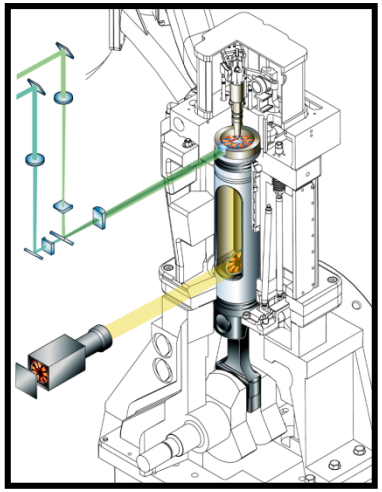
Potential to enable high-efficiency and low-emission operation



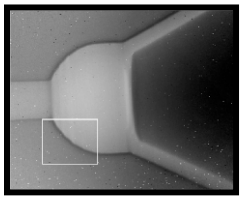
- LTC used generically to represent many processes
  - Homogeneous-Charge Compression-Ignition (HCCI)
  - Premixed-Charge Compression-Ignition (PCCI), SCCI, HECC, MK, UNIBUS, …
- Challenges
  - Combustion phasing
  - Load range
  - Heat release rate
  - Transient control
  - HC and CO emissions
  - Fuel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

Research Approach

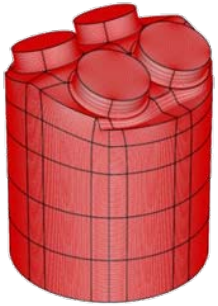
- Close collaboration between industry, national labs and universities
  - Research guided by industry needs
  - DOE/industry prototype engine projects
- Close coupled modeling and experiments
  - Multi-/single-cylinder engines & simulators
  - Advanced diagnostics
    - Optical-, laser-, and x-ray-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



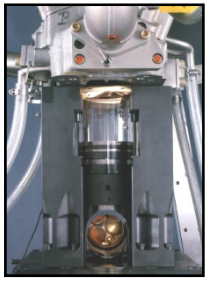
Optical Engine



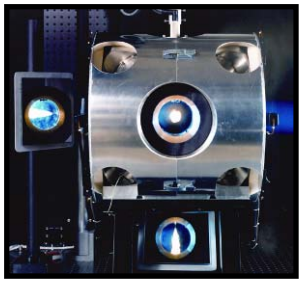
Nozzle Sac X-Ray Image



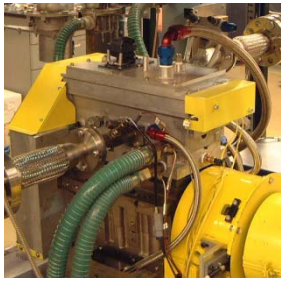
3-Million Cell LES Grid



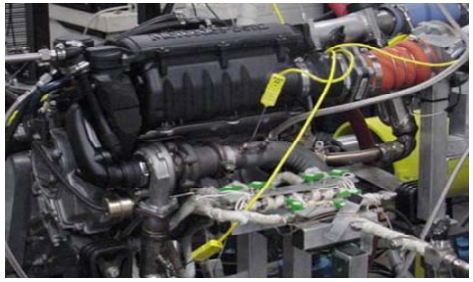
Automotive HCCI



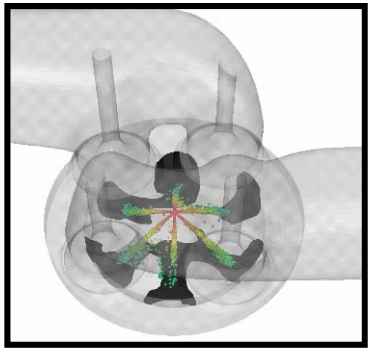
LTC Simulator



H2 Engine



Multi-Cylinder Diesel



Engine Simulation

Advanced Combustion Engine R&D Budget by Activities

Major Activities	FY 2007 Appropriation	FY 2008 Appropriation	FY 2009 Appropriation
Advanced Combustion Engine R&D	**$48,346K**	**$44,591K**	**$40,800K**
Combustion and Emission Control *	26,778	38,815	35,089
*Heavy Truck Engine***	*14,495*	*0*	*0*
Solid State Energy Conversion***	4,579	4,527	4,568
*Health Impacts***	*2,494*	*0*	*0*
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