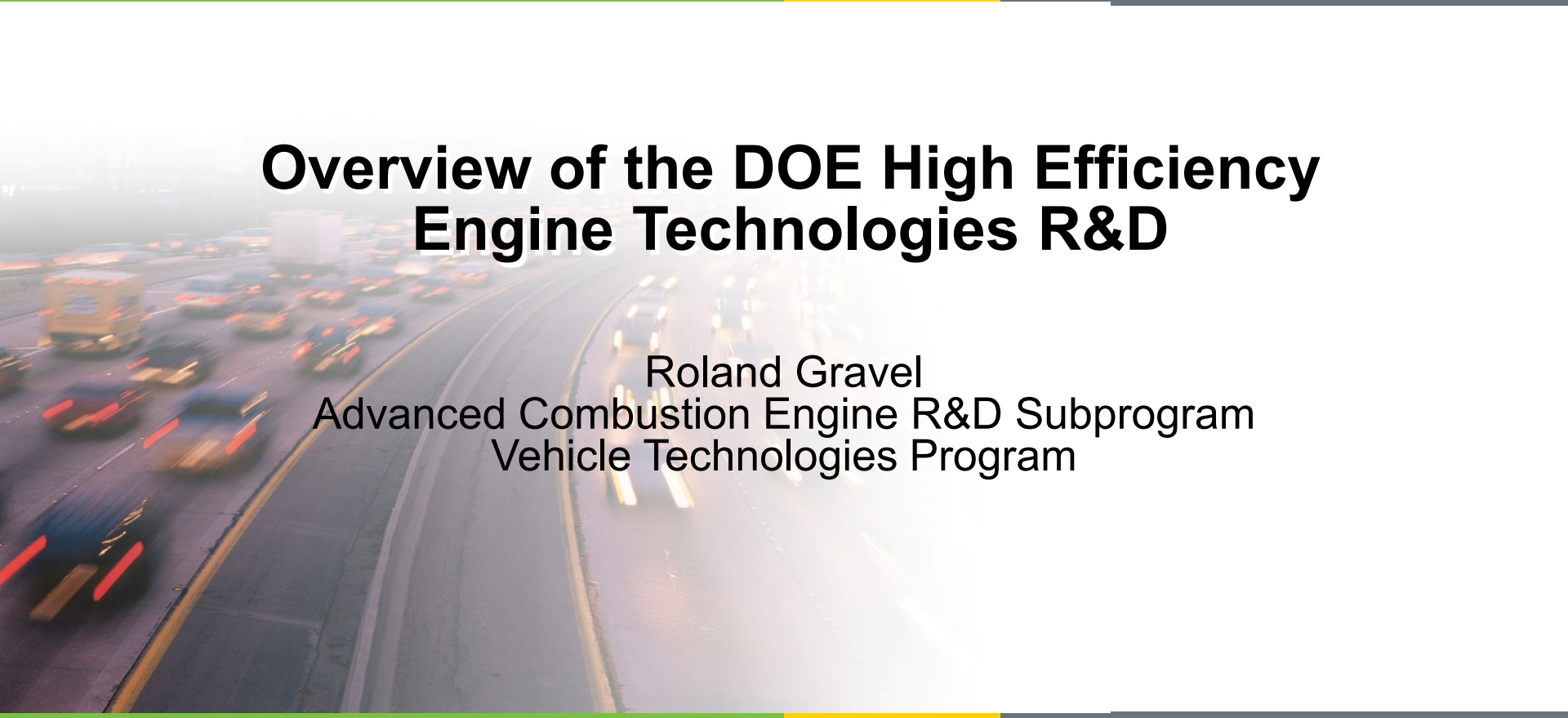
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Overview of the DOE High Efficiency Engine Technologies R&D

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

2012 Annual Merit Review
DOE Vehicle Technologies Program
and Hydrogen and Fuel Cells Program
Washington, DC
May 14-18, 2012

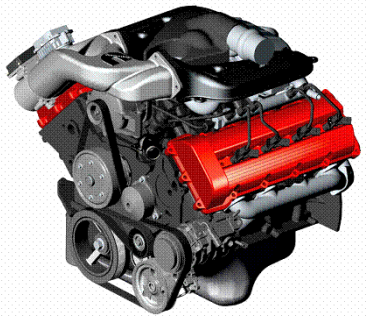
Vehicle Technologies Program Mission
To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.

The Federal Role

- Facilitate development of precompetitive technical know-how through investments in fundamental and applied R&D
- Undertake High-Risk Mid- to Long-Term Research
- Utilize Unique National Lab Expertise and Facilities
- Help Create a National Consensus
- Enable public-private partnerships to integrate R&D into industrially useful technologies

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

- Improve ICE efficiency for cars, light- and heavy-duty trucks through advanced combustion and minimization of thermal and parasitic losses
- Develop aftertreatment technologies integrated with combustion strategies for emissions compliance and minimization of efficiency penalty
- Explore waste energy recovery: with mechanical and advanced thermoelectrics devices
- Coordinate with fuels R&D to enable clean, high-efficiency engines using hydrocarbon-based (petroleum and non-petroleum) fuels and hydrogen

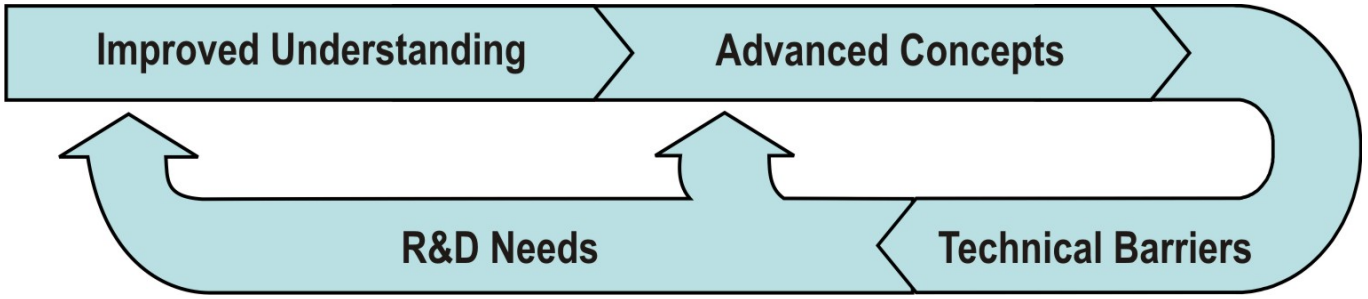
Overall R&D Approach

Fundamental R&D
- SNL – Combustion Research Facility (lean-burn, LTC, advanced DI)
- PNNL – Catalyst Characterization (NOx and PM Control)
- ANL – X-ray fuel spray characterization
- LLNL – Chemical kinetics models (LTC and emissions)
- LANL – CFD modeling of combustion
- Universities – 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

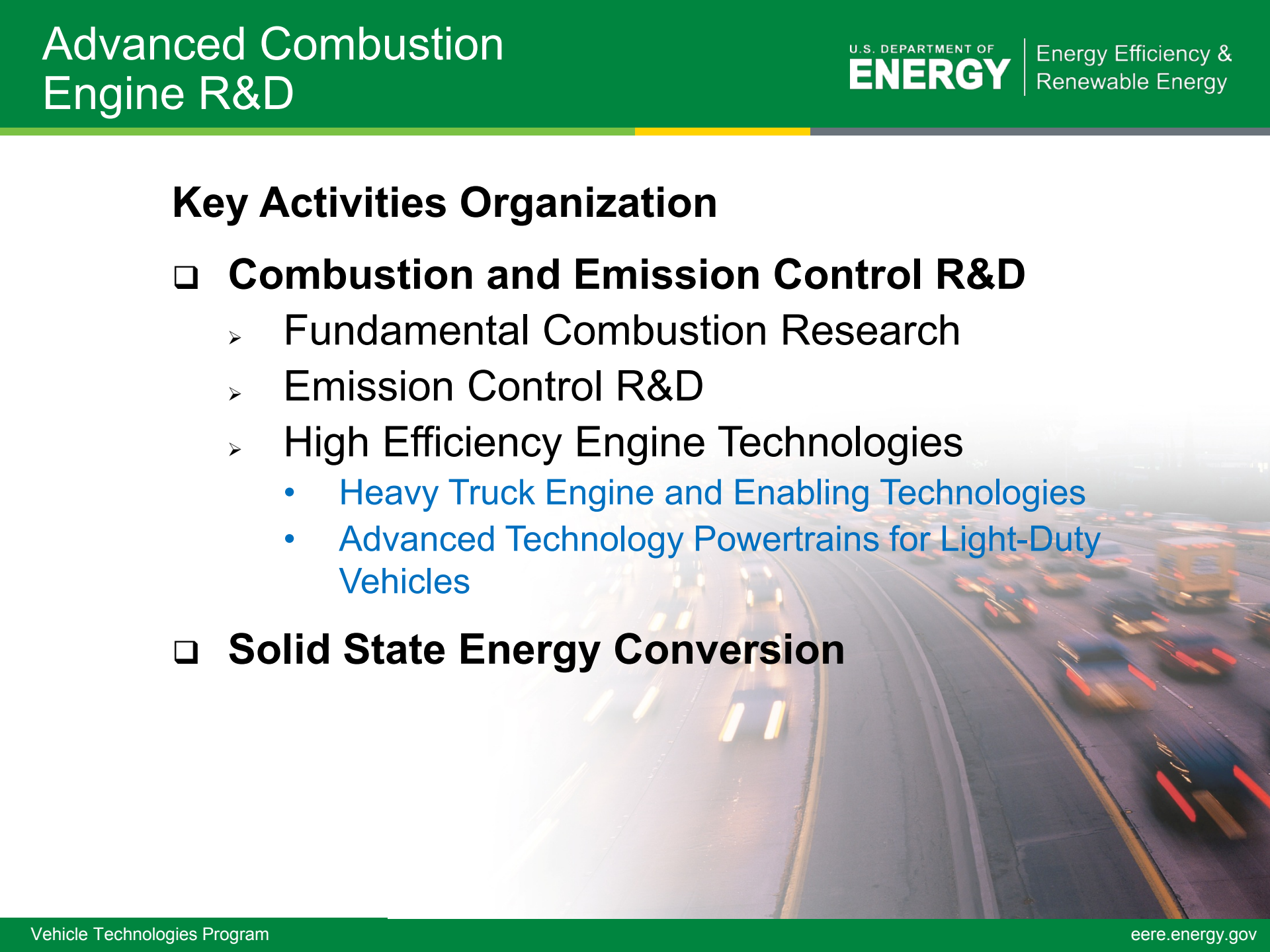
Competitively Awarded Cost-shared Industry R&D
- Automotive and engine companies,– engine systems
- Suppliers – enabling technologies (sensors, VVA, WHR)

Helps inform our R&D



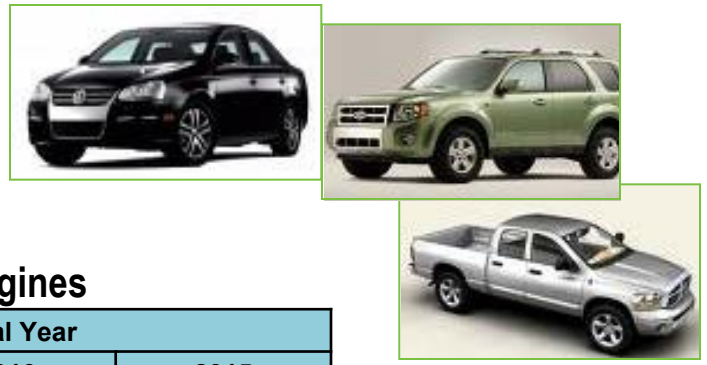
Key Activities Organization

- **Combustion and Emission Control R&D**
  - Fundamental Combustion Research
  - Emission Control R&D
  - High Efficiency Engine Technologies
    - Heavy Truck Engine and Enabling Technologies
    - Advanced Technology Powertrains for Light-Duty Vehicles
- **Solid State Energy Conversion**



Light-Duty Vehicle Goals

- By 2015, improve the fuel economy of light-duty gasoline vehicles by 25% and light-duty diesel vehicles by 40% compared to baseline 2009 gasoline vehicle



Technical Targets for Passenger Vehicle Engines

Characteristics	Fiscal Year		
	2007	2010	2015
Reference peak brake thermal efficiency, %	32	34	*NOTE: After 2010, engine efficiency targets transitioned to vehicle fuel economy improvement targets*
Powertrain cost, $/kW	35	30	
FreedomCAR and Fuel Partnership Goals			
ICE Powertrain			
Peak brake thermal efficiency, %	42	45	
Part-load brake thermal efficiency, % (2 bar BMEP @1500 rpm)	29	31	
Cost, $/kW	35	30	
VTP/C&EC Vehicle Level Goals			
Fuel economy improvement, % (gasoline/diesel)			25/40
Emissions, g/mile	Tier 2, Bin 5	Tier 2, Bin 5	Tier 2, Bin 2
Durability, hrs.	5,000	5,000	5,000
Thermal efficiency penalty due to emission control devices %	<3	<1	<1

DOE Heavy Truck Engine Goals Support the SuperTruck Effort

- By 2015, improve heavy truck fuel economy (engine thermal efficiency) by 20 percent with demonstration in commercial vehicle platforms
- By 2020, improve heavy truck fuel economy by 30 percent compared to 2009 baseline

Technical Targets for Heavy Truck Diesel Engines

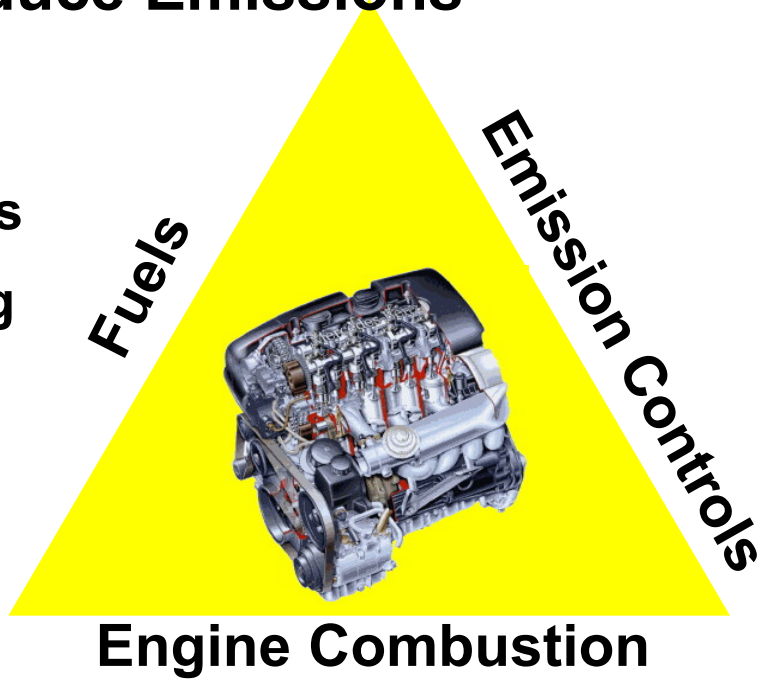
Characteristics	Fiscal Year		
	2010	2015	2020
Fuel Economy Improvement, %	-	20	30
Engine thermal efficiency, %	42	50	55
NO_X emissions, g/bhp-h	<0.20	<0.20	<0.20
PM emissions, g/bhp-h	<0.01	<0.01	<0.01
Stage of development	Commercial	Prototype	Prototype

Challenges

- Increasing Fuel Economy
- Reducing Emissions
- Ensuring Durability
- Maintaining or Reducing Cost

Systems Approach to Dramatically Improve Engine Efficiency and Reduce Emissions

- Partnerships with auto/truck manufacturing industry, suppliers, energy companies, and national labs
- Improve fundamental understanding
- Use Integrated systems approach
- Progress being made in all 3 areas



Auto ⟷ Light Truck ⟷ Heavy Truck

R&D Coordinated with the U.S.DRIVE Partnership

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

Focus R&D in Key Technology Areas

- ❑ **Advanced Combustion Engines**
- ❑ Electric Propulsion Systems
- ❑ Energy Storage
- ❑ Hydrogen-fueled ICEs
- ❑ Materials Technologies

R&D Coordinated with 21st Century Truck Partnership

21st CENTURY TRUCK PARTNERSHIP

Research, Development, and Demonstration in Key Technology Areas

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

INDUSTRY PARTNERS

Allison Transmission
DAIMLER
OSHKOSH
ArvinMeritor
DETROIT DIESEL
PACCAR Inc
BAE SYSTEMS
EATON Powering Business Worldwide
VOLVO
CATERPILLAR
Honeywell
Mack
Cummins
NAVISTAR
NOVABUS

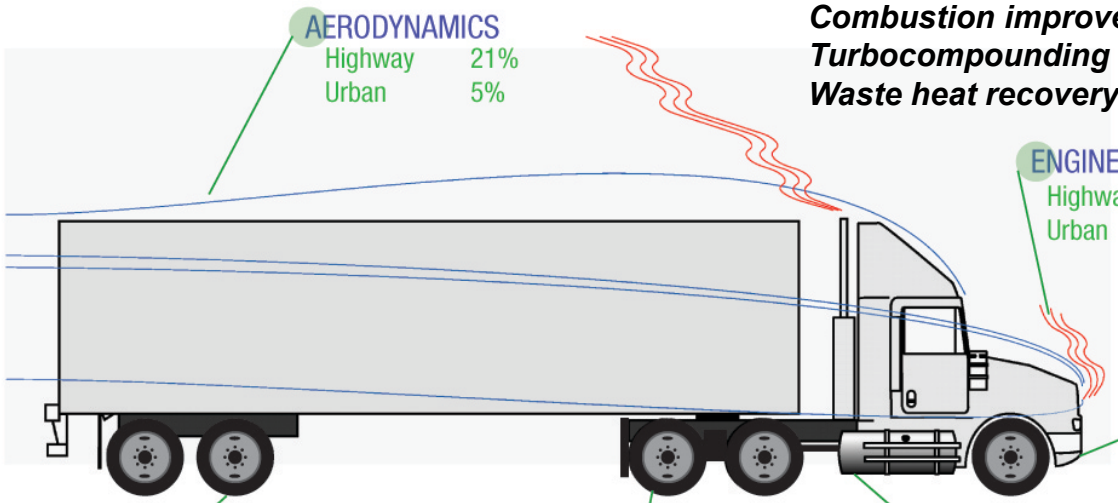
GOVERNMENT PARTNERS

SuperTruck Project

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Demonstrate a 50% improvement in freight efficiency by 2015

Energy losses in Class 8 trucks and opportunities for efficiency improvements



Trailer skirts
Gap reduction
Tractor/trailer integration (major redesign)

Combustion improvements
Turbocompounding
Waste heat recovery

Electric accessories

New generation wide base single tires
Tire rubber compound
Central tire inflation

Hybridization

Reduced drivetrain friction
Automated manual transmissions

Heavy-duty trucks use 20% of the fuel consumed in the United States.
Fuel economy improvements in these trucks directly and quickly reduces petroleum consumption

SuperTruck and ATP-LD Projects

Systems Level Technology Development, Integration, and Demonstration for Efficient Class 8 Trucks (SuperTruck)

Awardees
Cummins, Inc.
Daimler Trucks North America
Navistar, Inc.
Volvo

Advanced Technology Powertrains For Light-Duty Vehicles (ATP-LD)

Awardees
Chrysler Group
Cummins Inc.
Delphi Automotive Systems, LLC
Ford Motor Company
General Motors Corporation
Robert Bosch

Enabling Technologies for Engine and Powertrain System

Awardees
General Motors LLC
MAHLE Powertrain LLC
Filter Sensing Technologies, Inc.
Eaton Corporation

Small Business Innovation Research (SBIR)
FY 2012 Phase I (Release 3)

- Topics Released: Monday, March 5, 2012
- Funding Opportunity Announcement Issued: Monday, April 3, 2012
- Pre-Application Due Date: Tuesday, May 1, 2012
- Feedback Provided on Pre-Applications: Tuesday, June 5, 2012
- Application Due Date: Tuesday, July 3, 2012

Vehicle Technologies Program topics:

(a) Electric drive vehicle batteries
(b) Exhaust Aftertreatment Materials
(c) Innovative engine boosting technologies
(d) Differential compression and expansion technologies
(e) Subsystem component technologies (sensors)
(f) Thermoelectric technologies
(g) Materials for traction drive motor laminations, cores, or structures.
(h) Engine friction reduction

Advanced Combustion Engine R&D Budget by Activities

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Major Activities	FY 2010	FY 2011 Appropriation	FY 2012	FY 2013 Request
Advanced Combustion Engine R&D	**$57,600K**	**$57,600K**	**$58,027K**	**$55,261K**
Combustion and Emission Control	47,239	47,239	49,320	47,505
Solid State Energy Conversion	8,748	8,748	8,707	7,756
SBIR/STTR	1,613	1,613	--	--