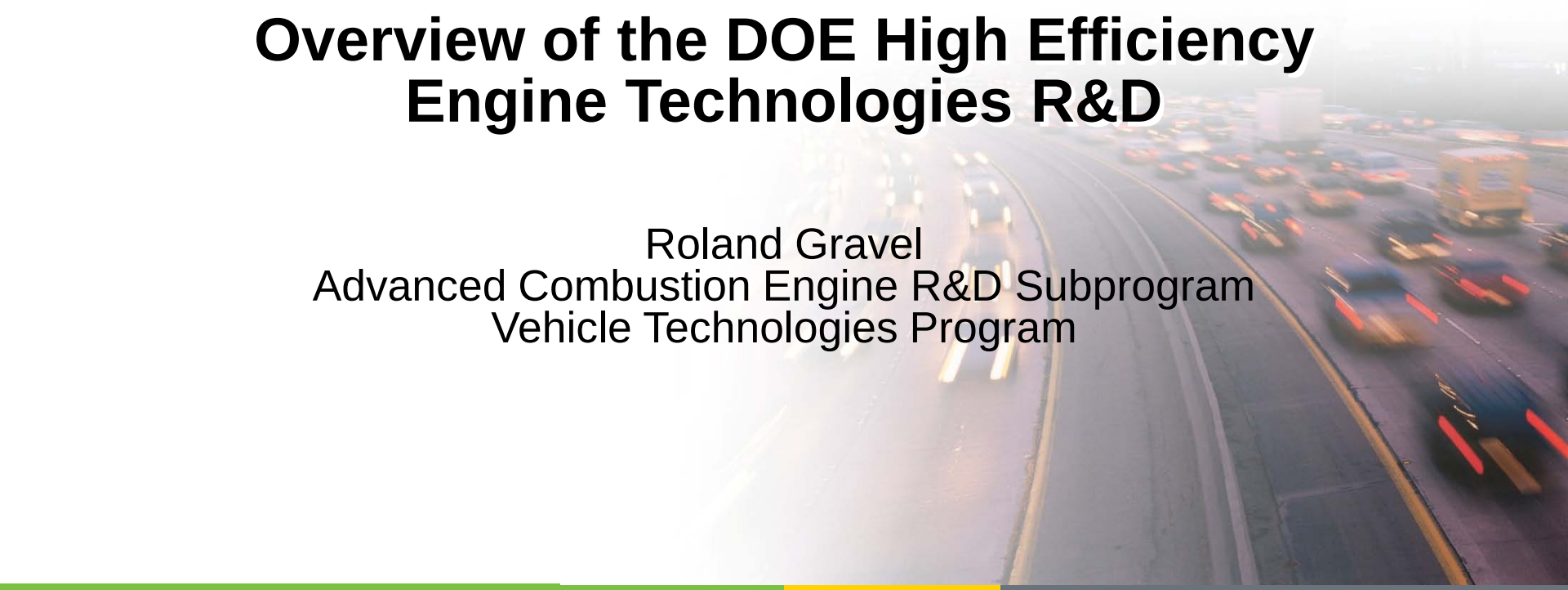
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of the DOE High Efficiency Engine Technologies R&D



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

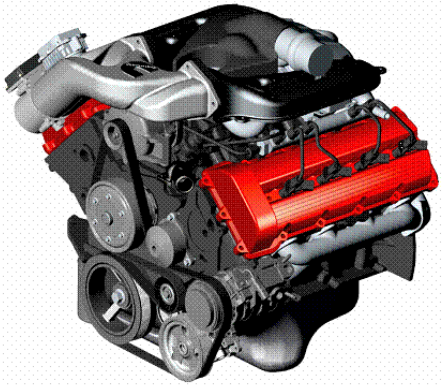
Presented at the
2011 DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review
Washington, DC
May 9-13, 2011

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 knowledge base 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 design tools

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

Research Approach

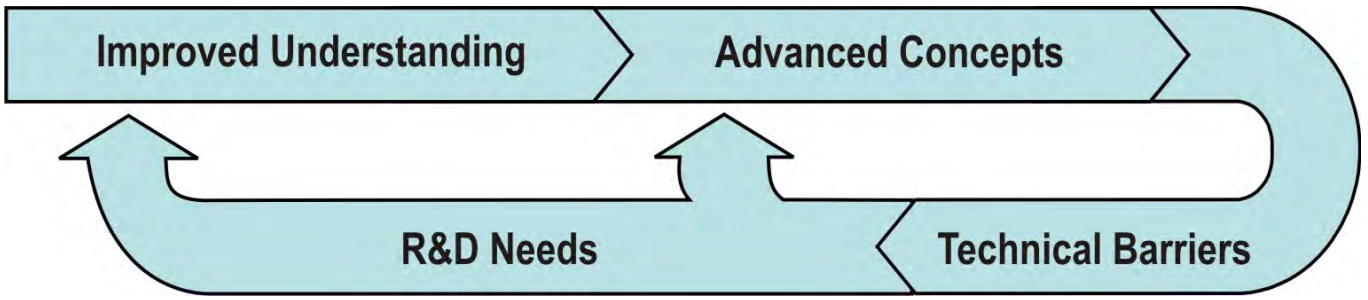
Advanced Combustion Engine R&D → Industry

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 – 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)

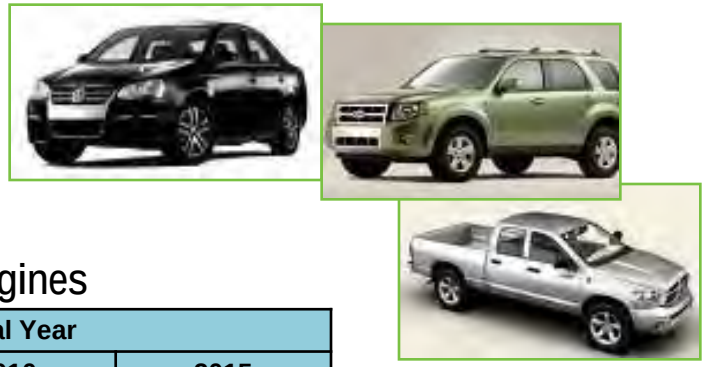


Key Activities

- **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
  - Health Impacts
- **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

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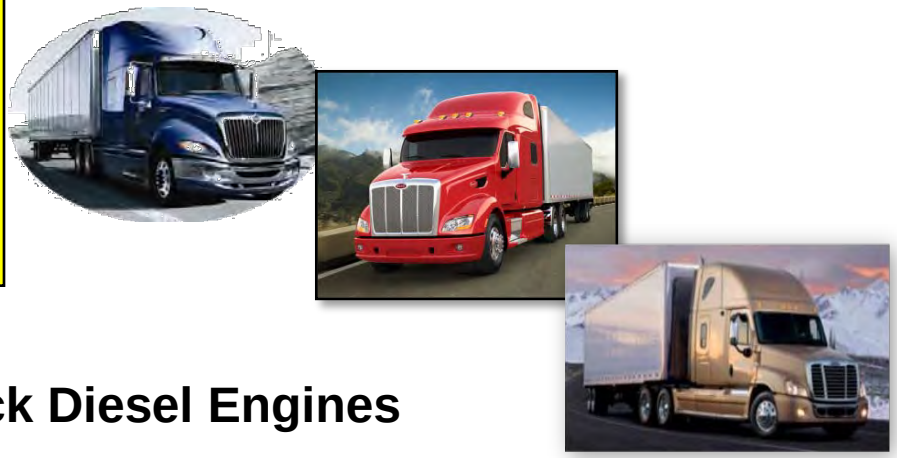
- By 2015, improve heavy truck fuel economy (engine thermal efficiency) by 20 percent with demonstration in commercial vehicle platforms
- By 2018, improve heavy truck fuel economy by 30 percent compared to 2009 baseline



Technical Targets for Heavy Truck Diesel Engines

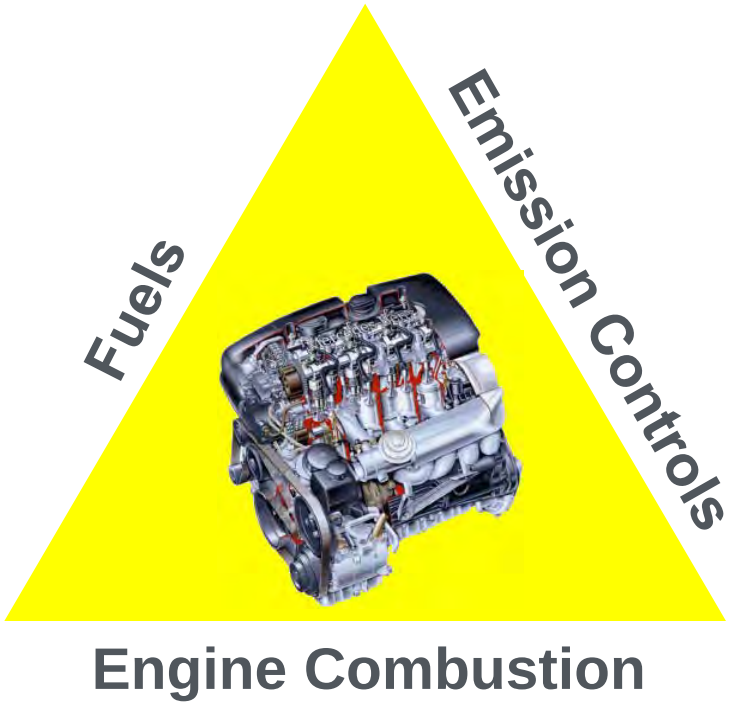
Characteristics	Fiscal Year		
	2010	2015	2018
Fuel Economy Improvement, %	-	20	30
Engine thermal efficiency, %	42	50	55
NO_X emissions, g/bhp-h	<0.20	<0.20	<0.20
PM emissions, g/bhp-h	<0.01	<0.01	<0.01
Stage of development	Commercial	Prototype	Prototype

Challenges

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

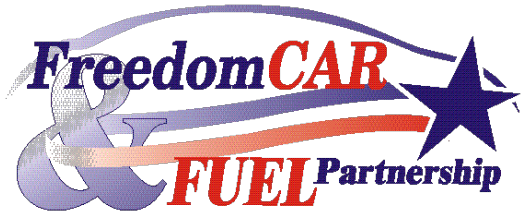
Systems Approach to Dramatically Improve Diesel Engine Efficiency and Reduce Emissions

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



Auto ⟷ **Light Truck** ⟷ ***Heavy Truck***

R&D Coordinated with the FreedomCAR and Fuel Partnership



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

Focus 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

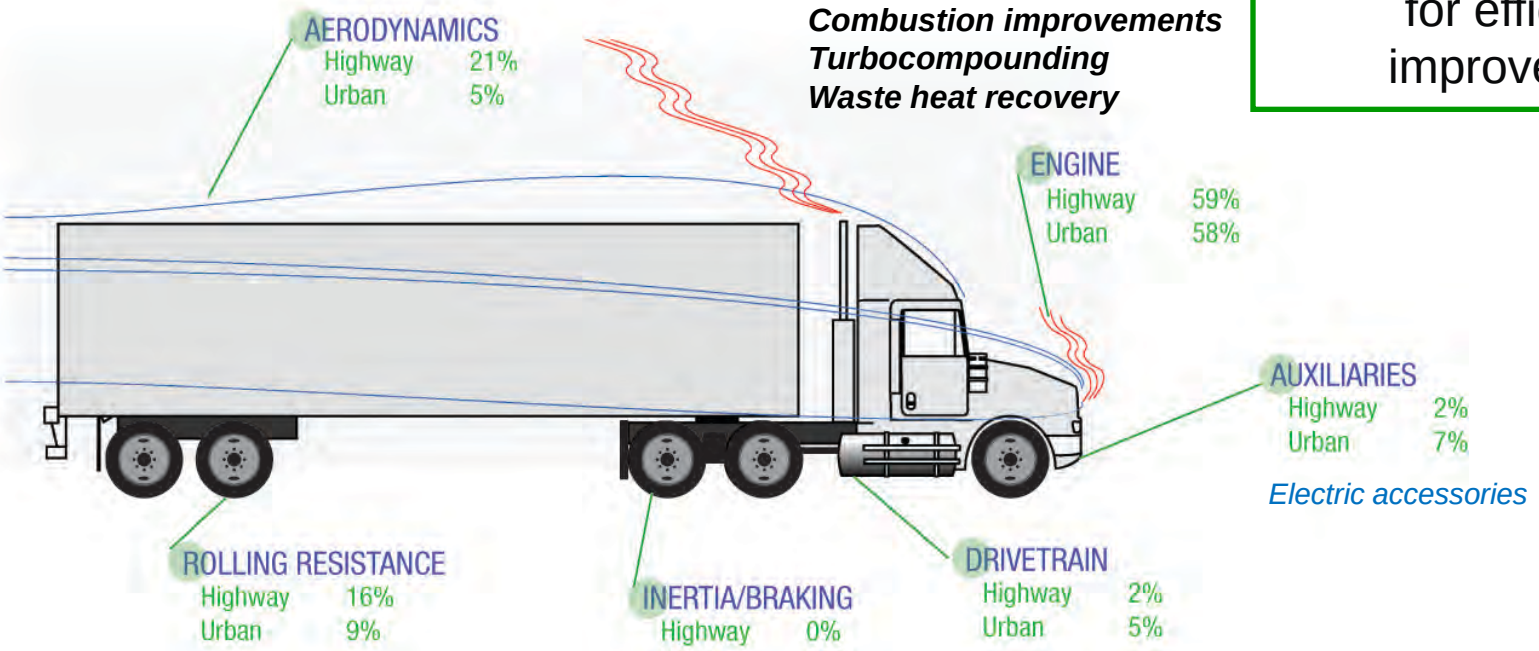
21st CENTURY TRUCK PARTNERSHIP

Allison Transmission GM
BAE SYSTEMS
CATERPILLAR
Cummins
DAIMLERCHRYSLER
DETROIT DIESEL CORPORATION
EATON
FREIGHTLINER LLC
A DaimlerChrysler Company
Honeywell
International
Mack
NOVABUS
OSHKOSH
PACCAR Inc
VOLVO
New Roads.

SuperTruck Initiative

Demonstrate a 50% improvement in freight efficiency by 2015

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



Combustion improvements
Turbocompounding
Waste heat recovery

Energy losses in Class 8 trucks and opportunities for efficiency improvements

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 Advanced Technology Powertrain 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

Advanced Combustion Engine R&D Budget by Activities

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Major Activities	FY 2009 Appropriation	FY 2010 Appropriation	FY 2011 Request	FY 2012 Request
Advanced Combustion Engine R&D	**$40,800K**	**$57,600K**	**$57,600K**	**49,000K**
Combustion and Emission Control *	35,089	47,239	47,239	40,824
Solid State Energy Conversion**	4,568	8,748	8,748	6,804
SBIR/STTR	1,143	1,613	1,613	1,372

**Includes Heavy Truck Engine and Health Impacts.*
***Formerly Waste Heat Recovery*