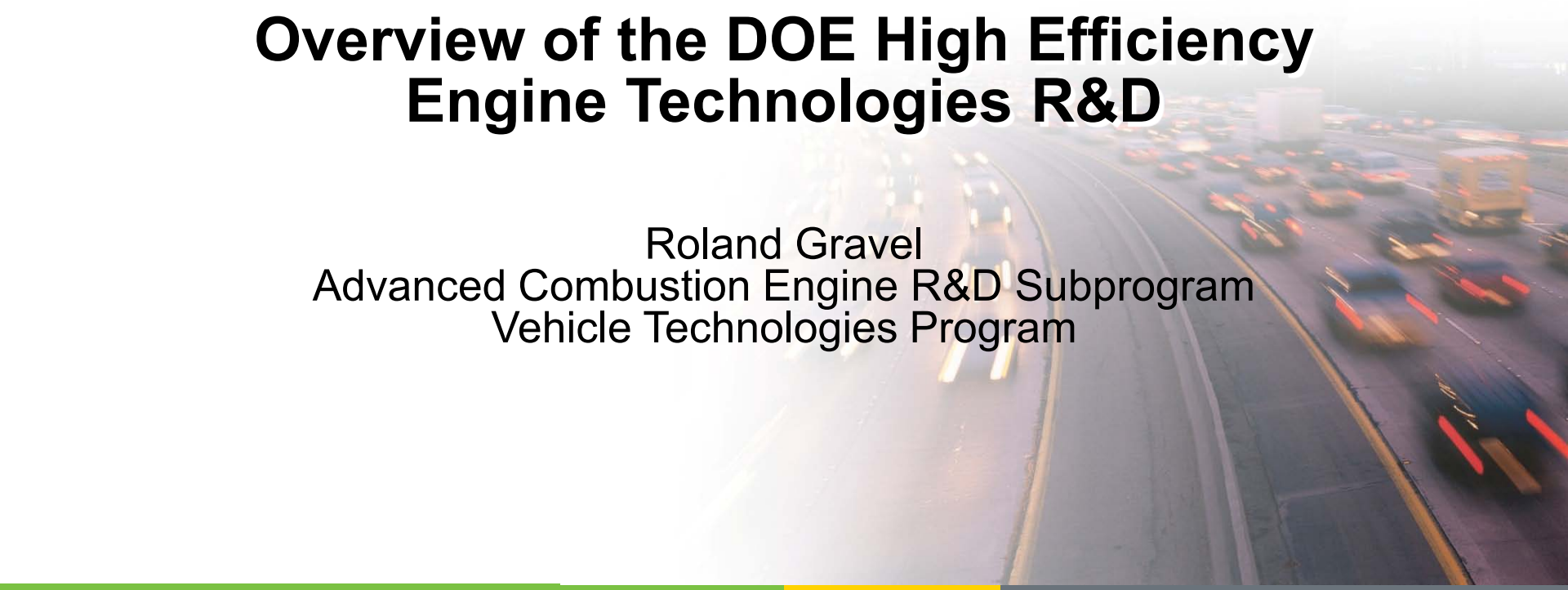
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of the DOE High Efficiency Engine Technologies R&D



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

Presented at the
2010 DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review
Washington, DC
June 7-11, 2010

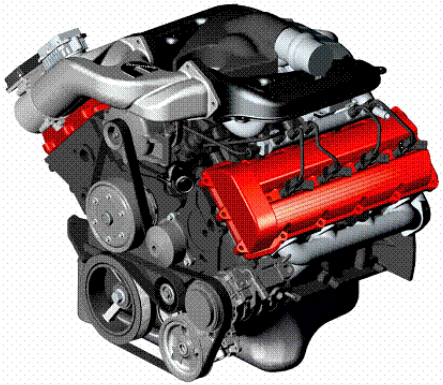
Vehicle Technologies Program Mission

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

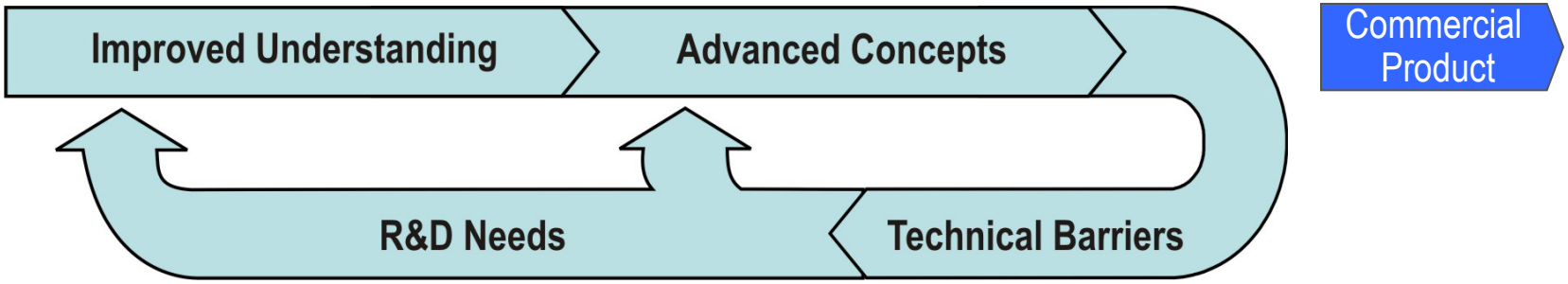
Advanced Combustion Engine R&D → Industry

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**

Heavy Truck Engine Technologies R&D

Goals

- By 2015, improve heavy truck engine efficiency to 50 percent with demonstration in commercial vehicle platforms. This represents about a 20 percent improvement over current engine efficiency.
- By 2018, further increase the thermal efficiency of a heavy truck engine to 55 percent which represents about a 30 percent improvement over current engines.

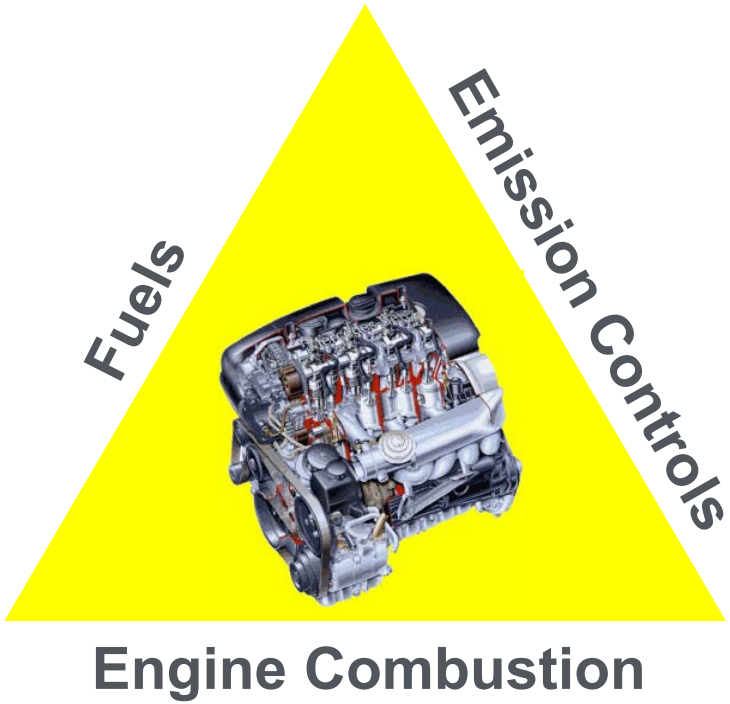
	Light-Duty		Heavy-Duty	
	2010	2015	2015	2018
Engine brake thermal efficiency	45%		50%	55%
Powertrain cost	< $30/kW			
NOx & PM emissions	Tier 2, Bin5	Tier 2, Bin2	EPA Standards	EPA Standards
Fuel economy improvement		25 – 40%	20%	30%

Challenges

- Increase Efficiency
- 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 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

Funding Opportunity Announcement Recently Awarded

Systems Level Technology Development, Integration, and Demonstration for Efficient Class 8 Trucks (SuperTruck) and Advanced Technology Powertrains For Light-Duty Vehicles (ATP-LD)

- Objectives are to develop and demonstrate advanced engine and vehicle technology as follows:
  - Heavy-Duty Class 8 Trucks
    - 20% improvement in engine brake thermal efficiency (50% BTE)
    - 50% improvement in freight efficiency (ton-miles/gallon)
    - Modeling and analysis for pathway to 55% Brake Thermal Efficiency
  - Light-Duty Vehicles
    - 25% fuel economy improvement over for gasoline engines baseline*
    - 40% fuel economy improvement over for diesel engines baseline*
- Funding:
  - $100M in ARRA Funding
  - $87M in annual appropriations over six fiscal years

*Baseline is state-of-the-art port-fuel injected gasoline engine

SuperTruck Initiative

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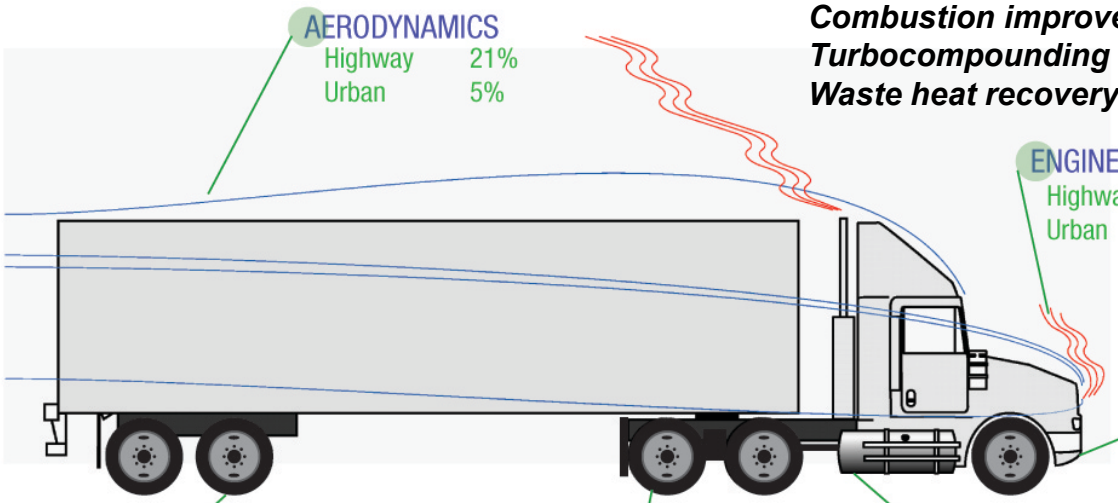
Demonstrate a 50% improvement in freight efficiency by 2015

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

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

Awardees	Additional Team Members
Cummins, Inc.	Peterbilt, Eaton, Delphi, Bridgestone, Modine, U.S. Xpress, Purdue University, University of Wisconsin, and Oak Ridge National Laboratory
Daimler Trucks North America	Detroit Diesel, Oak Ridge National Laboratory, Massachusetts Institute of Technology, and University of Oregon
Navistar, Inc.	Arvin Meritor, ATDynamics, Bosch, FEV, Federal Mogul, Michelin, Modine Swift, Sheppard, Safeway, University of Illinois, Southwest Research Institute, Wabash National, University of Wisconsin, Argonne National Laboratory, and Lawrence Livermore National Laboratory

Future Awards

Funding Opportunity Announcement (FOA) - Multiple topic areas for near and mid-term projects in technology areas that support the vehicle technologies mission and goals.

Area of Interest 4 - Advanced Thermoelectrics and Enabling Technologies for Energy Efficient Powertrains (supplier base focused)

Advanced Combustion Engine R&D Budget by Activities

Major Activities	FY 2008 Appropriation	FY 2009 Appropriation	FY 2010 Appropriation	FY 2011 Request
Advanced Combustion Engine R&D	**$44,591K**	**$40,800K**	**$57,600K**	**$57,600K**
Combustion and Emission Control *	38,815	35,089	47,239	47,239
Solid State Energy Conversion**	4,527	4,568	8,748	8,748
SBIR/STTR	1,248	1,143	1,613	1,613

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