Crafting a Common Vision for the Off-Highway Vehicles of the Future

Dr. James J. Eberhardt, Director
Office of Heavy Vehicle Technologies
U.S. Department of Energy

Presented at the
SAE-DOE/OHVT Workshop on Off-Highway Vehicles
Emissions and Systems Efficiency:
Leveraging R&D Resources to Meet Industry Needs
Argonne, IL
April 18-19, 2001

OHVT Mission
To conduct, in collaboration with our heavy vehicle industry partners and their suppliers, a customer-focused national program to research and develop technologies that will enable trucks and other heavy vehicles to be more energy efficient and able to use alternative fuels while simultaneously reducing emissions.
Office of Heavy Vehicle Technologies

- The U.S. Department of Energy - Secretary
- Efficiency and Renewables - Deputy Assistant Secretary, Transportation Technologies

**Office of Heavy Vehicle Technologies**
- Created in the DOE/Office of Transportation Technologies restructuring (March 1996)
- Focuses research and development on critical areas identified with heavy vehicle customers

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To conduct, in collaboration with our heavy vehicle industry partners and their suppliers, a customer-focused national program to research and develop technologies that will enable trucks and other heavy vehicles to be more energy efficient and capable of using alternative fuels while simultaneously reducing emissions.
1 Quad of energy is equivalent to 340,000 tank cars of crude oil stretched from Miami to Seattle (3,300 miles).

<table>
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<tr>
<th></th>
<th>1973</th>
<th>1997</th>
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<tr>
<td>U.S.</td>
<td>74 Quads</td>
<td>91 Quads</td>
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<tr>
<td>World</td>
<td>225 Quads</td>
<td>365 Quads</td>
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# Targets of Opportunity for Heavy Vehicles

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<tr>
<th>Heavy Vehicle Category</th>
<th>1995(^a)</th>
<th>2000(^b)</th>
<th>2010(^b)</th>
<th>2020(^b)</th>
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<tr>
<td>Class 1-2 trucks (GVW&lt;=10,000 lbs)</td>
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<td>7.2</td>
<td>9.1</td>
<td>9.8</td>
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<tr>
<td>Class 3-6 trucks (10,000 &lt; GVW &lt; 26,500 lbs)</td>
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<td>Class 7-8 trucks (GVW &gt; 26,500 lbs)</td>
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<td>4.2</td>
<td>4.5</td>
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<tr>
<td>Buses</td>
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<td>Rail</td>
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<td>0.6</td>
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<td>Domestic marine</td>
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<td>Off-highway</td>
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<td>0.7</td>
<td>0.8</td>
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\(^a\)The 1995 values are from S.C. Davis, *Transportation Energy Data Book, 17th Ed.*, ORNL 6919, Oak Ridge National Laboratory, August 1997

Rationale for a Heavy Vehicle Technologies R&D Program

Since the 1973 Oil Embargo All of the Increase in U.S. Surface Transportation Fuel Consumption has been due to Heavy Vehicles

Transportation Energy Data Book: Edition 20, DOE/ORNL-6959, October 2000
A Healthy National Economy Depends Upon Efficient Heavy Vehicle Freight Transportation

Workshops and Meetings
Soliciting Customer Input

- DOE/OHVT Customer Focus Workshop, May 1996
- SAE Truck and Bus Council Meeting, June 1996
- DOE/OHVT Workshop on Applications of Carbon Products, September 1996
- 1996 SAE International Truck and Bus Meeting and Exposition, October 1996
- DOE Automotive Technology Development Customers’ Coordination Meeting, October/November 1996
- Workshop on Future Fuels Technologies for Heavy Vehicles, November 1996
- Natural Gas Program Planning Workshop, January 1997
- Workshop on Improving Heavy Vehicles Aerodynamics, January 1997
- OHVT Executive Steering Committee Meeting, February 1997
- SAE International Congress and Exposition, February 1997
- Fuels and Engines Workshop: Policy Issues and Technology Directions, April 1997
- OHVT Annual Program Review, May 1997
- Windsor Workshop on Transportation Fuel, June 1997
- 1997 Diesel Engine Emissions Reduction Workshop, July 1997
- DOE Automotive Technology Development Customers’ Coordination Meeting, October 1997
Workshops and Meetings
Soliciting Customer Input (continued)

- Symposium on Air Pollution Health Impacts, November 1997
- National Conference of State Legislators Energy Institute on Alternative Fuel Use in Heavy Vehicles, December 1997
- Workshop on Diesel Fuels and Engine Technology, January 1998
- Workshop on Performance and Emissions of New Diesel Fuels, January 1998
- OHVT Peer Review, February 1998
- Review of Multi-Year Program Plan on Aerodynamic Drag, February 1998
- DOE/EMA Meeting on New Fuel Options for Diesel Engines, March 1998
- DOE-OHVT Workshop on Emissions Control Strategies for ICEs, January 1999
- Workshop on Research Needs for Reducing Friction and Wear, March 1999
- 1999 SAE Government/ Industry Meeting, April 1999
- HTML User Forum, August 1999
- DOE/ORNL Running Resistance and Braking Systems Workshop, August 1999
- Heavy Vehicle Propulsion Materials Workshop, August 1999
- Thermal Management Workshop, October 1999
OHVT Plans Focus on Critical R&D Areas for All Truck Classes

OHVT Technology Roadmap

Office of Heavy Vehicle Technologies (OHVT)
Office of Transportation Technologies

October 1997


Revised OHVT Technology Roadmap

Office of Heavy Vehicle Technologies
Multiyear Program Plan for 1998-2002

August 1998

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Office of Transportation Technologies

OHVT Technology Roadmap Development

**Industry stakeholders provide input to Technology Roadmap**

- Initial draft developed by DOE and the National Laboratories as recommended by industry stakeholders attending the initial OHVT customer-focus workshop.
- **OHVT Executive Steering Committee Meeting**
  held in conjunction with SAE Truck and Bus Show (October 1996).
  
  Draft OHVT Technology Roadmap presented to industry stakeholders for review.

- Additional **targeted workshops** and **one-on-one meetings** with industry stakeholders provided feedback and comments.

- Final version released (October 1997).

- Technology Roadmap updated/revised by OHVT Team (May 1999).

- Revised OHVT Technology Roadmap presented to industry stakeholders at the 1999 SAE International Truck and Bus Meeting and Exposition (November 1999).

- Final revised OHVT Technology Roadmap (February 2000).
OHVT Technology Roadmap

Roadmap Development Approach

- Formulate goals consistent with DOE Strategic Plan required by the Government Performance and Results Act (GPRA).
- Assess the status of the technology.
- Identify technical targets.
- Identify barriers to achieving the technical targets.
- Develop R&D solutions to overcoming the barriers.
- Develop schedules and milestones.
R&D Needs of Three Groups of Trucks are Addressed

**Heavy (Class 7-8) Trucks**

To develop by 2004, the enabling technologies needed to achieve a fuel efficiency of at least 10 miles per gallon (at 65 miles per hour) and meet emissions standards prevailing in 2004, using petroleum-based diesel fuel.

**Medium (Class 3-6) Trucks**

By 2004, to develop and demonstrate commercially viable vehicles that achieve, on an urban driving cycle, at least double the fuel economy of comparable current (1999) vehicles, and as a research goal, reduce criteria pollutant emissions to at least 30 percent below EPA standards prevailing in 2004.

**Light (Class 1-2) Trucks**

To develop by 2004 the enabling technologies for clean diesel engines to be competitive with and at least 35-percent more fuel efficient than equivalent gasoline engines for light trucks, while meeting Federal and state emissions standards prevailing in 2004.
High-efficiency clean diesel-cycle engines utilizing compression ignitable clean fuels/blends derived from diverse feedstocks

**Multiple Alternative Feedstocks**
- Coal
- Biomass
- Natural Gas
- Petroleum

**Clean Diesel Fuels/Blends**
- Synthesis gas route to: Liquid Fuels
- Conventional petroleum refining

**Advanced High-Efficiency Clean Diesel Engine Technologies**
- Common Diesel Fuel Specification
- Uses Existing Infrastructure

**Efficient Low Emission Heavy Vehicles**
- Heavy Truck
- Construction/Farming Vehicles
- Locomotive

**In-cylinder Processes**
- Fuel Quality
- Exhaust Treatment

**Uses Existing Infrastructure**
EPA Emissions Standards

- February 10, 2000 EPA adopted Tier 2 Emissions Standards which became effective April 10, 2000. (Includes reducing sulfur levels in gasoline to 30 ppm.)


- January 18, 2001 EPA issued rule requiring 80 percent of all on-road diesel fuel to have less than 15 ppm sulfur starting in 2006.
EPA Emissions Standards

- Tier 2 Regulations for Light-Duty Vehicles (LDVs):
  - 0.07 g/mi NOx and 0.01 g/mi PM; represents 77 to 95% reduction from Tier 1 levels
  - Includes all LDVs under 10,000 lbs
  - Phased in 2004-2008

- Heavy-Duty Diesel Engine Regulations:
  - 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM; represents about 90% reduction from 2004 regs
  - Phased in 2007-2010

- Heavy-duty regulations include ultra-low sulfur diesel fuel
What Do We Have to Offer?

- National Laboratory scientific expertise
  - Unique research facilities (neutron residual stress measurement capabilities, engine combustion research facility, synchrotron, x-ray sources)

- Catalyze formation of unique teams
  - Example: Industry team on casting of large vehicle components (Alcoa, CMI)
Advanced Laser-Imaging Diagnostics have Changed our Understanding of Diesel Combustion.

Numerous advanced diagnostics have been applied over the past decade.

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<thead>
<tr>
<th>Liquid spray</th>
<th>Mixture &amp; Temp.</th>
<th>Soot: LII and Mie</th>
<th>OH PLIF</th>
<th>NO PLIF</th>
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Old Description

New Conceptual Model

Dec et al., SAE papers 950456, 970873, & 980147
Heavy-Duty Diesel Engine Combustion Research

- **Objective**: To provide the fundamental understanding needed to help manufacturers reduce emissions and improve performance.

- **Approach**: Investigate the processes in the cylinder of an operating diesel engine using advanced optical diagnostics.

- **Modified heavy-duty truck engine** provides good optical access while maintaining the basic combustion characteristics of a production engine.

- Data from multiple advanced laser diagnostics have substantially improved our understanding of diesel combustion and emissions formation.

Sandia/Cummins Optically Accessible Diesel Engine
Recommendation 3

The Office of Heavy Vehicle Technologies (OHVT) should reevaluate its priorities and increase its support for projects focused on overcoming the most critical barriers to success. For example, meeting emissions standards will be critical to OHVT’s program on advanced combustion engines. *Therefore, emissions should be a major focus of this program.*

The Office of Heavy Vehicle Technologies should place a *high priority on integrated emissions-control technology (engine combustion and after-treatment technologies)* to meet future emission requirements.


*Bolding and italicizing provided for emphasis.*
Purpose
To craft a shared vision for Industry-Government R&D collaboration to minimize off-highway vehicle emissions, while maintaining or enhancing system performance.
Within the context of reducing emissions and improving energy efficiency of the off-highway vehicle as a system, what are the high priority R&D opportunities for Industry/Government collaboration?

How can R&D resources be leveraged to meet industry needs?
## OHVT Budget by Activities

### Vehicle Technologies R&D

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### Heavy Vehicle Systems R&D

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### Hybrid Systems R&D

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### Fuels Utilization R&D

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### Materials Technologies

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<td>66.676</td>
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*Potential for R&D related to off-highway heavy vehicles
Industry/Government R&D Partnership for Off-Highway Vehicles of the Future

Summary

- Legislation and policy are in place to encourage and enable industry/government R&D partnerships.

- A variety of mechanisms are available for the U.S. heavy vehicle (including the off-highway) industry to partner with DOE and its national laboratories.

- This workshop can be a first step toward the development of an industry/government (DOE) R&D partnership on off-highway vehicle technologies.