Interactions with Industry: DOE EERE Perspective

Gurpreet Singh, Team Leader
Advanced Combustion Engine R&D Subprogram
Vehicle Technologies Program

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Interactions with Industry: DOE EERE Perspective

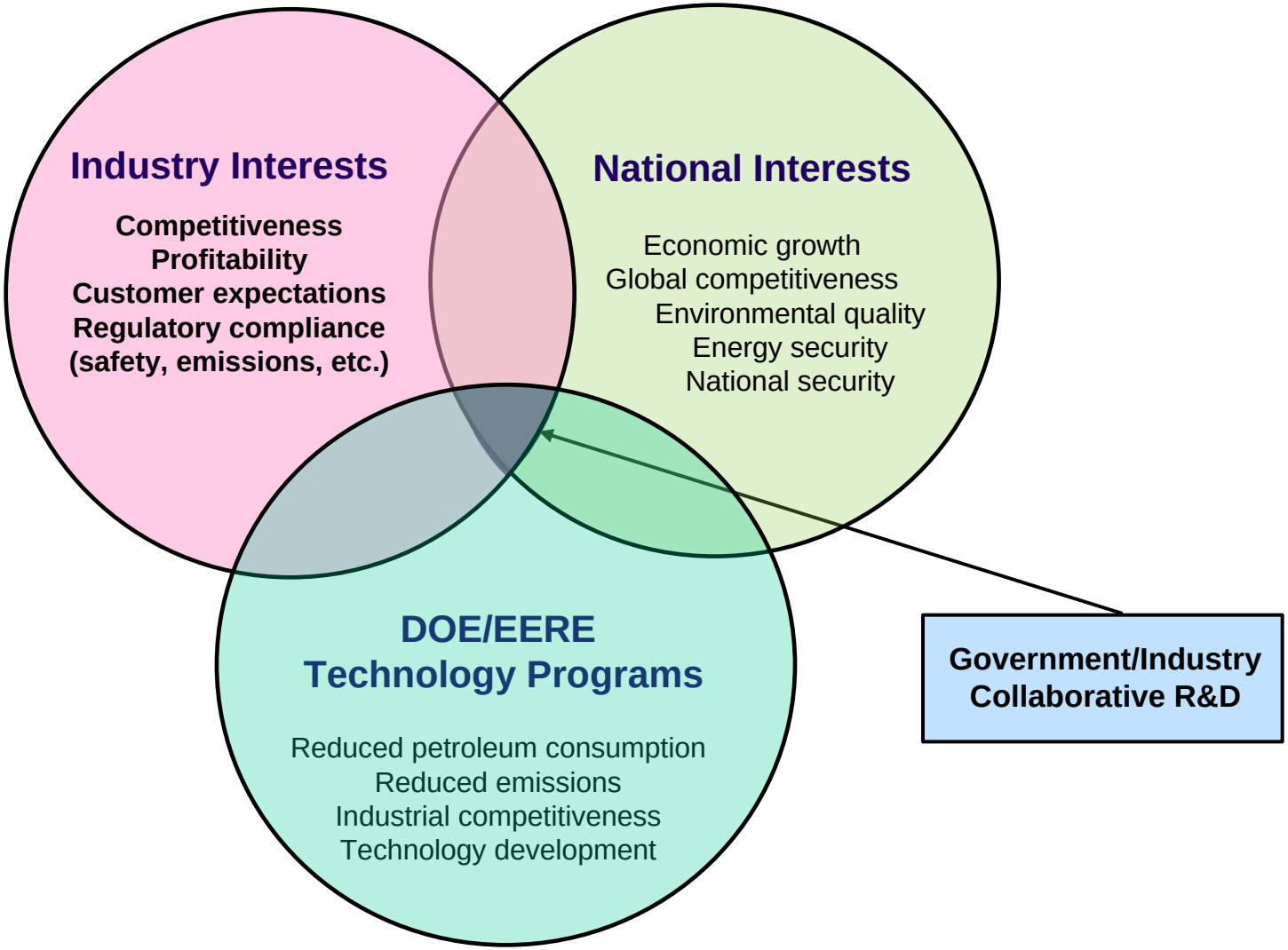
Outline

- Federal Role; U.S. industry vs. public interests
- Industry-EERE R&D Collaborations Target Areas of Common Interest
- Secretary's Major Priorities
- Access to Technology at Laboratories
- Interactions with Industry: EERE Perspective Example – Vehicle Technologies Program
- Summary

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

Industry-EERE R&D Collaborations Target Areas of Common Interest



President's National Objectives for DOE

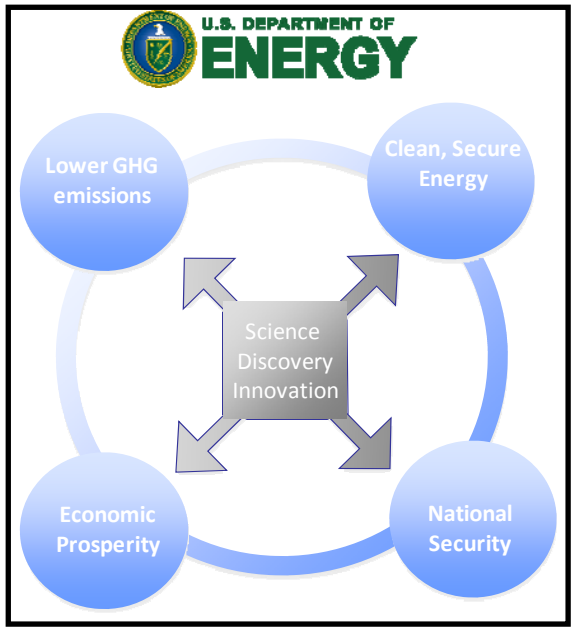
Energy to Secure America's Future

- **Quickly Implement the Economic Recovery Package:** Create Millions of New Green Jobs and Lay the Foundation for the Future.
- **Restore Science Leadership**: Strengthen America's Role as the World Leader in Science and Technology.
- **Reduce GHG emissions**: Drive emissions 20 Percent below 1990 levels by 2020.
- **Enhance energy security:** Save More Oil than the U.S Currently Imports from the Middle East and Venezuela Combined within 10 years.
- **Enhance Nuclear Security**: Strengthen non-proliferation activities, reduce global stockpiles of nuclear weapons, and maintain safety and reliability of the US stockpile.

FIRST PRINCIPLE:

Pursue significant and cost-effective measures with a sense of urgency.

Secretary's Major Priorities*



Strategic Framework: Science and Discovery at the Core

- Excerpts relevant to EERE/Vehicle Technologies

Science and Discovery

Focus on transformational science:
- Connect basic and applied sciences
- Embrace a degree of risk-taking
- Create an effective mechanism to integrate national laboratory, university, and industry activities

Collaborate universally:
- Build research networks and global partners

Clean, Secure Energy

Demo next generation energy technologies:
- Batteries and other storage systems

Drive step-change energy efficiency:
- Novel models for collaboration and IP for commercialization of energy-efficient technologies

Economic Prosperity

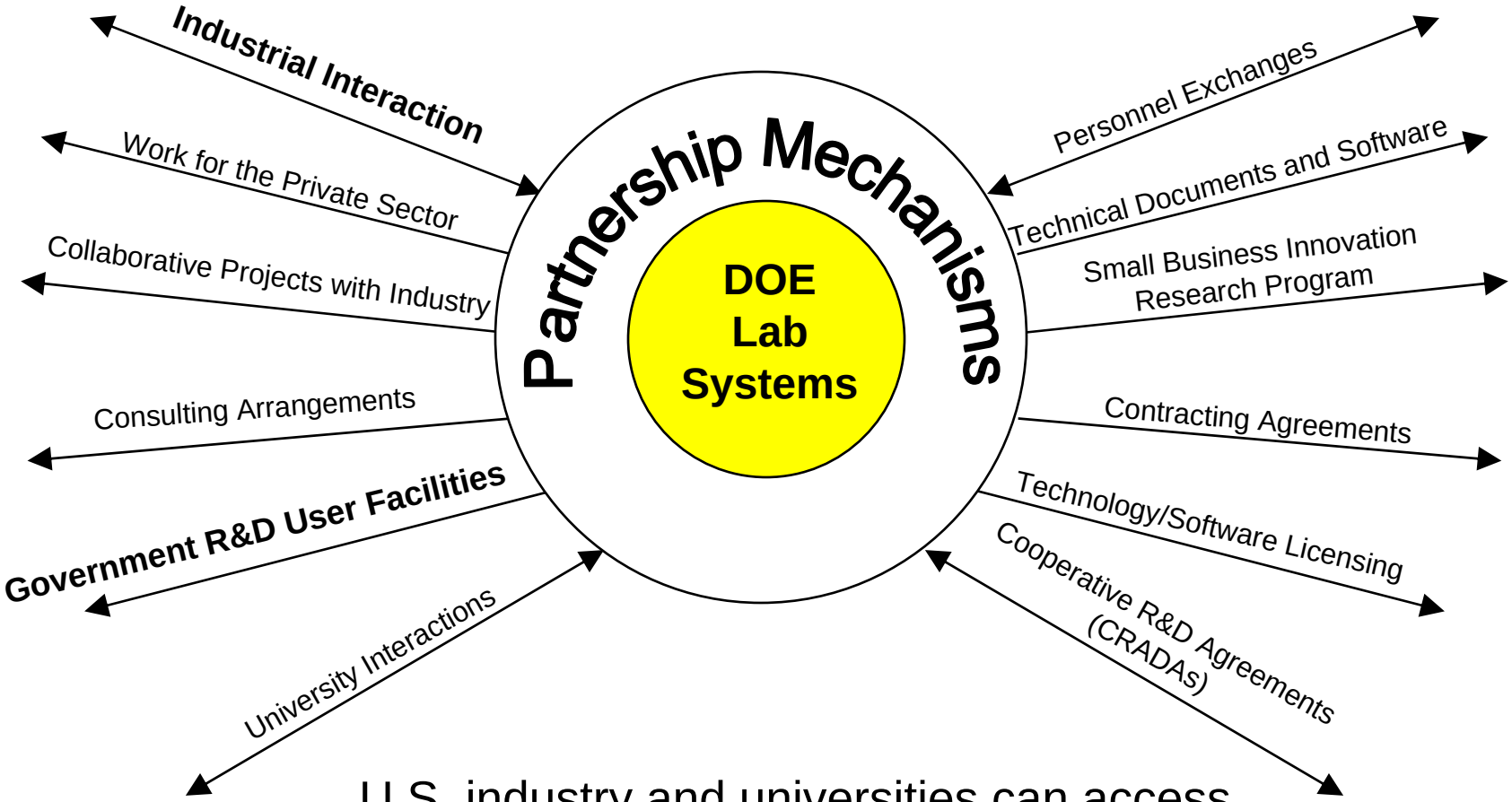
Reduce vehicle energy demand:
- Improve internal combustion engines and develop batteries for vehicle electrification

Build efficient, smart network:
- Smart meters/smart grid (*and vehicle interface*)

Climate Change

Coordinate and share research globally

Access to Technology at DOE Laboratories

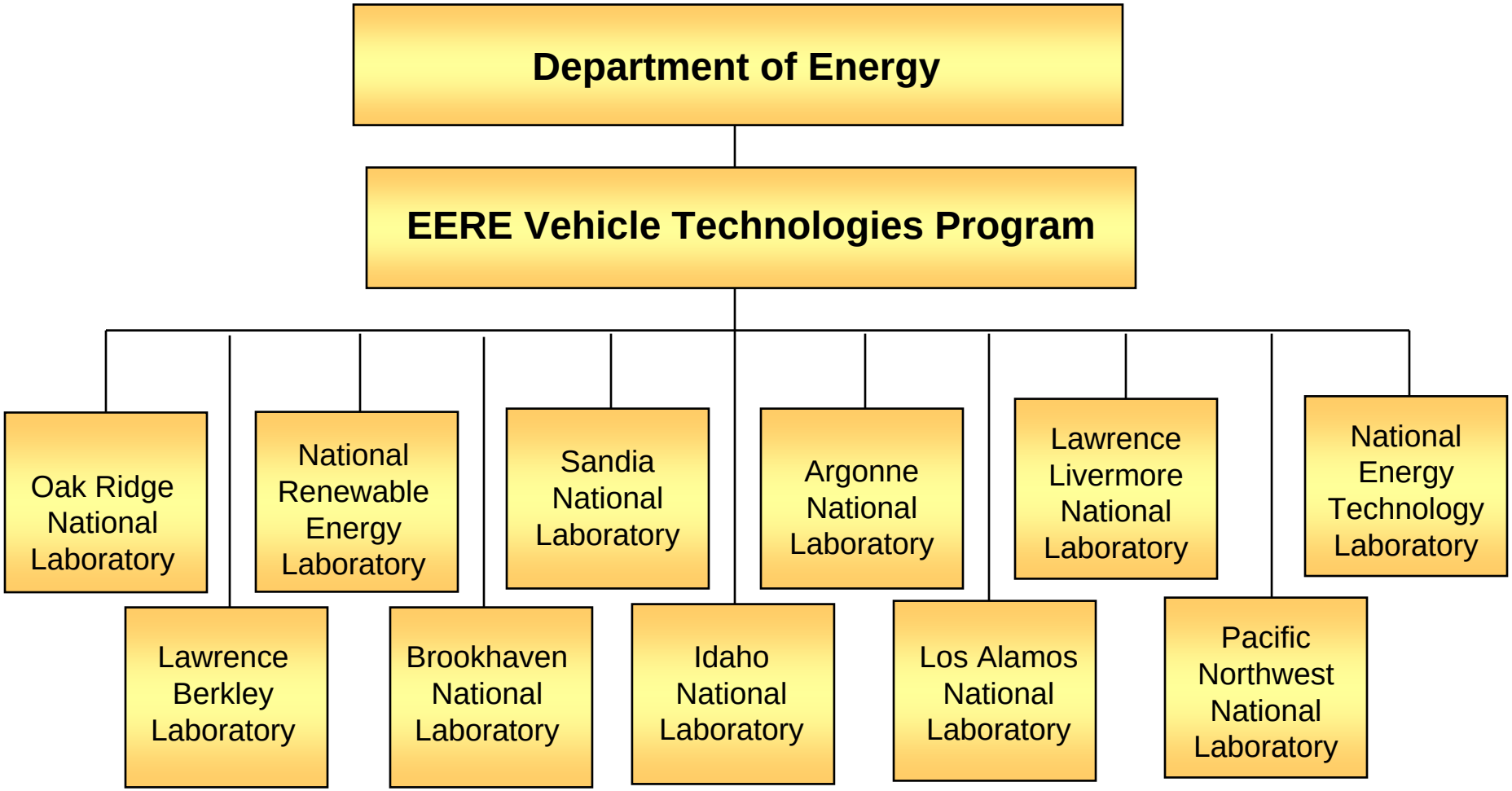


U.S. industry and universities can access technology in the DOE laboratories through many different mechanisms

Industry Interaction/ EERE Perspective

- **Example: Vehicle Technologies Program**

Gateway to Partnering on Vehicle Technologies R&D



What Does DOE Have to Offer?

- **National Laboratory scientific expertise**
  - Unique research facilities
    - Neutron and x-ray residual stress measurement capabilities;
    - High performance computation;
    - Engine Combustion Research Facility;
    - High Temperature Materials Laboratory/User Centers.
- **Catalyze formation of unique teams**
  - Examples: Combustion MOU, Crosscut Lean Exhaust Emissions Reduction Simulation (CLEERS) working group

Partnering Mechanisms

- Cooperative Agreements
- Cost-Shared Contracts/Subcontracts
- Cooperative R&D Agreements (CRADAs)
- R&D Partnerships
  - FreedomCAR Partnership
  - 21st Century Truck Partnership
- ***Government R&D User Facilities***
- Licensing
- Scientist and Engineer Exchanges

Collaborations are Key to Answering Transportation Challenges

The FreedomCAR and Fuel Partnership -- focusing on the high-risk research needed to develop the necessary technologies…to provide a full range of affordable cars and light trucks that are free of foreign oil and harmful emissions.

21st Century Truck Partnership -- pursuing dramatically improved fuel economy with near-zero emissions through advanced combustion engines and heavy hybrid drives that can use renewable fuels.

Deployment Activities

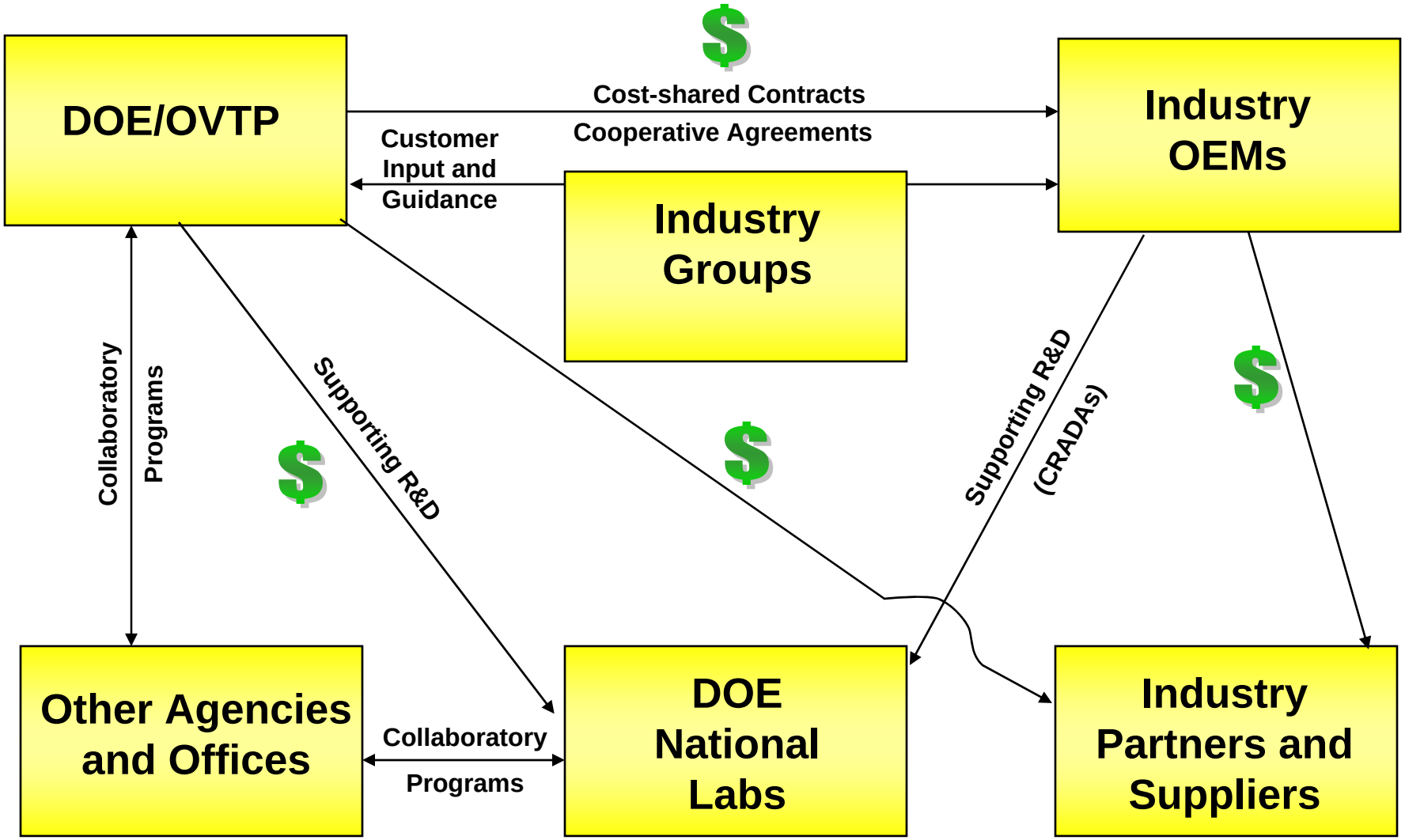
Work with Stakeholders (States, Industry, etc.) to Facilitate Moving Technology to Market:
Clean Cities - supporting local decisions that contribute to the reduction of petroleum consumption

Technology Thrusts

Hybrid Electric Systems	Advanced Materials	Fuels & Lubricants	Engine & Emission Control
❑ Energy Storage ❑ Power Electronics & Electric Motors ❑ Vehicle Systems ❑ Technology Validation	❑ Propulsion Materials ❑ Lightweight Materials ❑ HTML	❑ Adv. Petroleum-Based Fuels ❑ Non-Petroleum Based Fuels ❑ Technology Introduction – Clean Cities	❑ Combustion & Emission Control ❑ Solid State Energy Conversion

Industry/Government R&D Collaborations

Funding Mechanisms



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 2014
- Key customers: the U.S. vehicle and engine industry.
- Strong interactions and collaborations between industry, suppliers, universities, and national labs.

Industry Interaction - Research Approach

Advanced Combustion Engine R&D → Industry

Fundamental Research → Applied Research → Technology Maturation & Deployment

Fundamental R&D

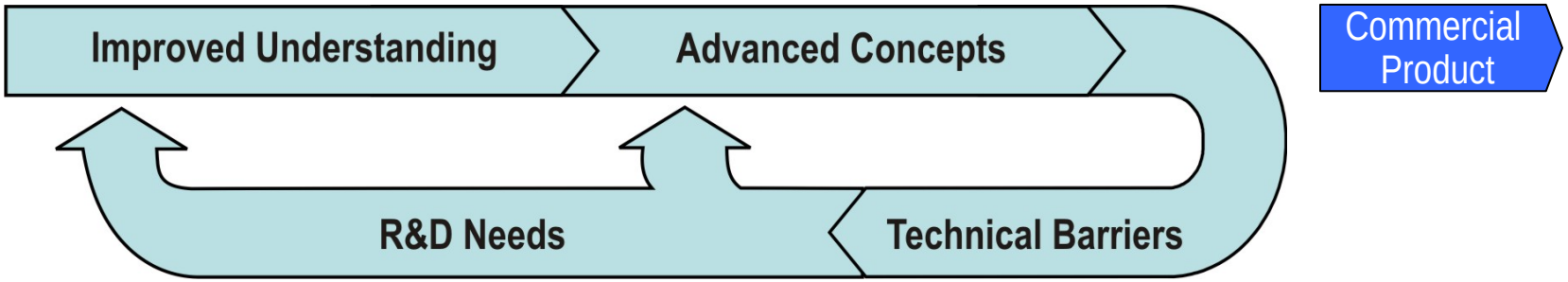
- SNL – Low Temperature Combustion
- PNNL – Catalyst Characterization (NOx and PM Control)
- ANL – X-ray Visualization of fuel sprays
- LLNL – Chemical kinetics models (LTC and emissions)
- LANL – CFD modeling of combustion
- Universities (U. of WI, Texas A&M, U. of MI, MIT, others) – Complementary research

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)



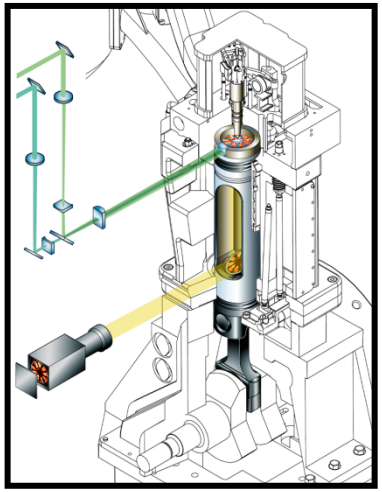
Engine Combustion Research

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

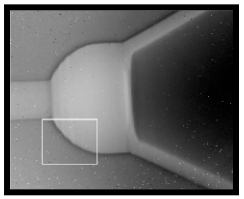
- Combustion work coordinated under a Memorandum of Understanding (MOU)
- Five energy companies joined MOU in 2006
  - Added perspectives for production of potential fuels or fuel blends

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

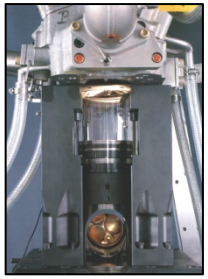


Optical Engine

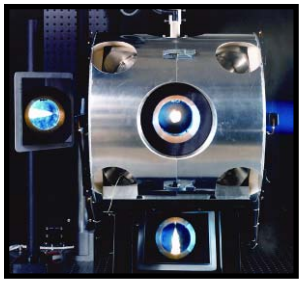


Nozzle Sac X-Ray Image

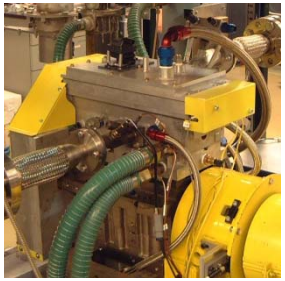
3-Million Cell LES Grid



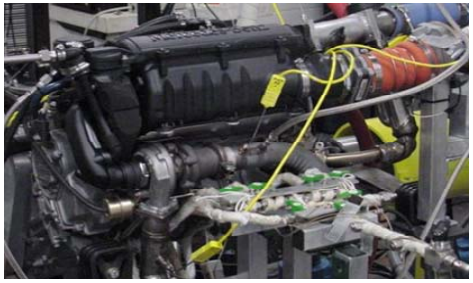
Automotive HCCI



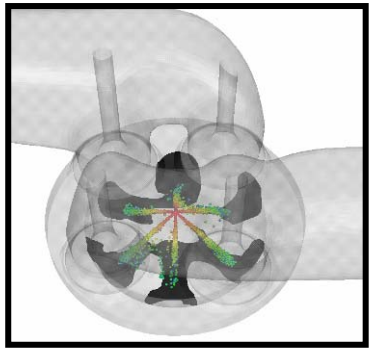
LTC Simulator



H2 Engine



Multi-Cylinder Diesel



Engine Simulation

EERE/VT Program Projects at the APS

- X-ray-based fuel-spray research
  - To improve combustion efficiency and reduction in emissions from transportation internal combustion engines
- There are many emerging areas where x-rays as the major tools to understand the structure-function relationship in energy related materials.
- In situ study of the battery materials
  - New ideas of using inelastic x-ray scattering methods
  - Structure of electrode materials during reduction-oxidation reactions
  - Supported by ANL Laboratory Directed R&D (LDRD), collaboration between the APS and Chemical Science and Engineering (CSE)
- Nanodiffraction of friction wear boundary layer
  - Establish the boundary layer structure to the wear and friction properties
  - Collaboration between the Energy Systems (ES) and APS

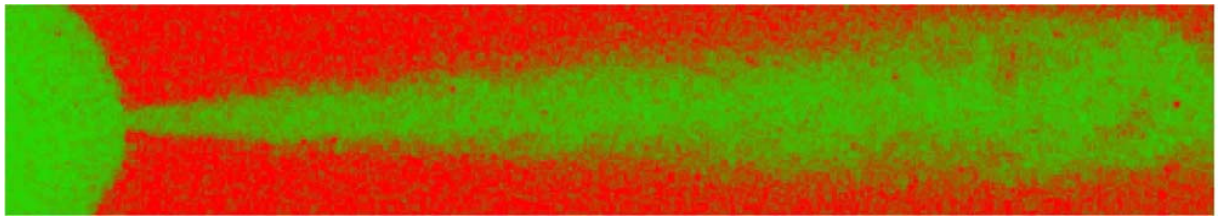
EERE/VTP supported research has achieved many breakthroughs

- Optimized fuel sprays to
  - Improve combustion and reduce emissions
- Fuel sprays have been elusive, even more so now.
  - Higher injection pressure (> 200 MPa)
  - Optimized nozzles, smaller orifice (< 100 µm)
  - Shorter/multiple injection events, more dynamic
- More impetus for understanding fluid dynamics both inside and outside of the injection nozzles
- Validating in-nozzle flow and near-nozzle spray breakup simulation and combustion simulations.

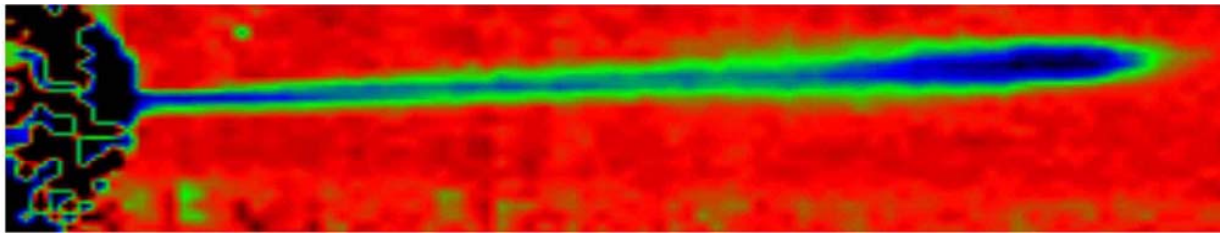
Fast X-radiography Reveals Dense Liquid Fuel Core

- X-ray-absorption-based radiography uses
  - Penetration power of X-rays
  - Quantitative fuel mass distribution
  - μs temporal resolution
- Optical images sensitive to small droplet surrounding the core
- X-radiography sensitive to dense liquid fuel core
- The core has 10% of volume compared to the plume by visible-light images, but contains 99% of fuel mass.

Optical shadowgraph



X-radiography

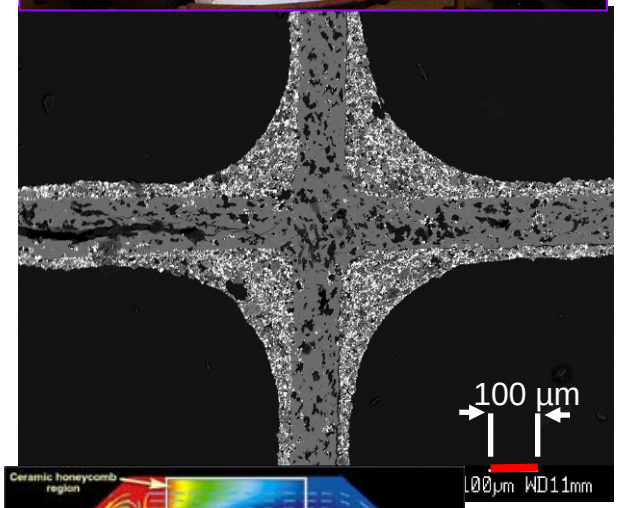


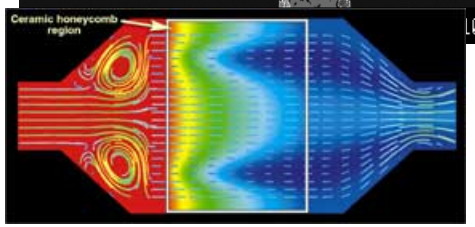
Collaboration with Industry in Emission Control R&D

- CLEERS* started in 2001, encompasses DPF, LNT, SCR.
- Govt.-industry research coordination (www.cleers.org)
- Thousands of NOx catalyst formulations studied
- Emphasis on minimizing "fuel penalty" while achieving emissions levels
- Integration of advanced combustion regimes with emission control
- Creation of "kinetics maps."
- Reduce need for precious metals

*Crosscut Lean Exhaust Emissions Reduction Simulation

12th CLEERS workshop at University of Michigan, Dearborn

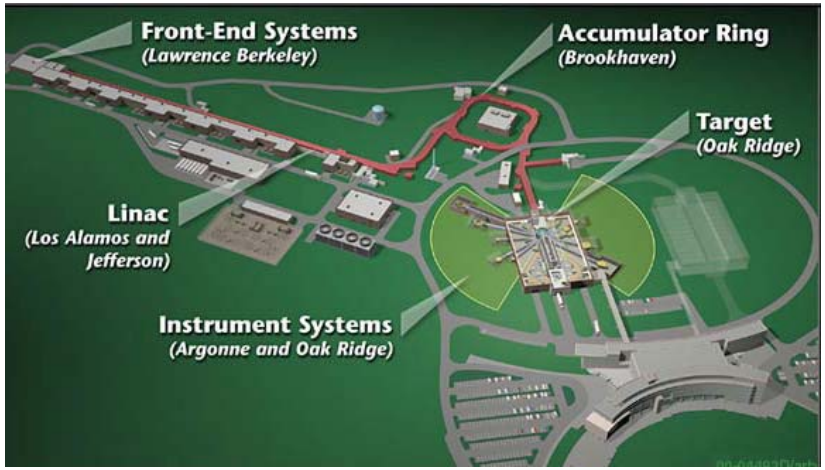




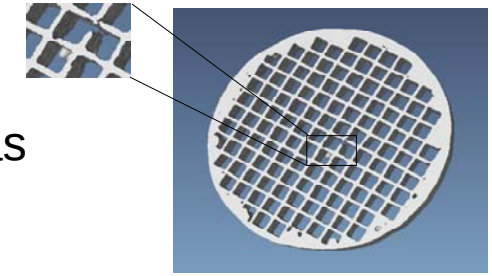
Neutron Imaging To Provide New Insight

New Insight into *once unobservable* physical processes of significance

- **ORNL neutron facilities**
  - **Spallation Neutron Source** – most intense pulsed neutron beam in the world.
  - **High Flux Isotope Reactor** – world class steady neutron source.
- Game-changing technology
  - Ability to penetrate metal.
  - Potential for isotopic tagging.
  - High sensitivity to hydrogen (fuels, oils, deposits).
- Provides new fundamental understanding necessary for more accurate simulation and effective design
  - **Diesel Particulate Filter** – to include spatial/temporal information on soot and ash loading/regeneration as well as substrate integrity.
  - **EGR Cooler** – to address deposit and fouling issues associated with advanced combustion operation.
  - **Fuel Spray** – to include near-nozzle fuel spray behavior and in-nozzle cavitation for high pressure diesel/gasoline injection.
  - **Internal Engine Flows** – to support improvements in heat transfer, lubrication, etc.



Multi-Laboratory effort funded by DOE Office of Science



DPF substrate image reconstruction provides unprecedented substrate detail.

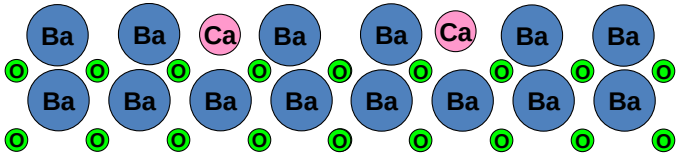
ORNL/Center for Nanophase Materials Sciences

CNMS Contributing to Lean-burn Engine NOx Control Catalysis Research

- One of five Nanoscale Science Research Centers currently funded by the Office of Science.
  - synthesis
  - characterization
  - theory/modeling/simulation
  - design
- CNMS assisted ORNL engine-emissions research team through synthesis and characterization of experimental lean-NOx trap materials.
  - Found Ca substitution for BaO improves NOx conversion
  - Found desulfation achievable at lower temperature (can improve durability)

Center for Nanophase Materials Sciences
A Highly Collaborative and Multidisciplinary
U.S. DOE Nanoscale Science Research Center

OAK RIDGE National Laboratory



Summary

- Industry interactions embodied in transformational science – connecting basic and applied sciences in integrated national laboratory, university, and industry activities – a primary focus of the DOE Secretary.
- Industry is provided access to DOE facilities and technologies through a variety of established mechanisms .
- Industry interactions and collaborations with the DOE National Laboratories are primary elements of the EERE Vehicle Technologies Program approach in addressing transportation R&D needs.

For more information: EERE Website -- www.eere.energy.gov