Overview of the VTO Advanced Combustion Engine R&D Program

June 8, 2015

Gurpreet Singh, Program Manager

Advanced Combustion Engine R&D

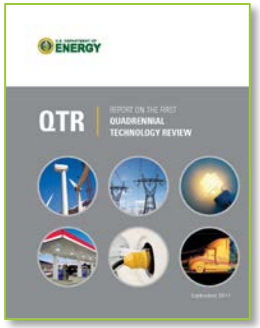
Team Members:

Ken Howden, Roland Gravel, and Leo Breton

Increasing Engine Efficiency

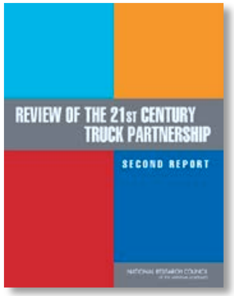
Increasing the efficiency of internal combustion engines (ICEs) is one of the most promising and cost-effective approaches to improving the fuel economy of the U.S. vehicle fleet in the near- to mid-term.

"The performance, low cost, and fuel flexibility of ICEs makes it likely that they will continue to dominate the vehicle fleet for at least the next several decades. ICE improvements can also be applied to both hybrid electric vehicles (HEVs) and vehicles that use alternative hydrocarbon fuels." DOE QTR 2011[1]



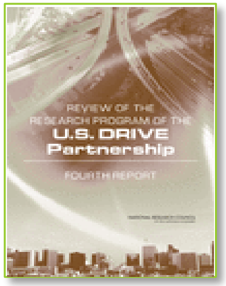
DOE 2011

"The DOE-funded research in advanced engine combustion … addresses important aspects for achieving an integration of advanced combustion processes that should be important enablers for achieving the 55 percent BTE goal as well as providing ongoing improvements." - NRC Report 2012[2]



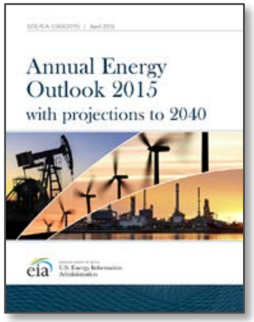
NRC 2012

"…better understanding of the combustion process and emissions production can help to overcome a major barrier to more advanced ICEs, this work is important to the country. …" NRC Report 2013[3]



NRC 2013

EIA *AEO 2015*[3] reference case scenario - even by 2040, ***over 99% of vehicles sold will have ICEs***.



DOE 2015

[1] Quadrennial Technology Review, DOE 2011

[2] *Review of the 21st Century Truck Partnership: 2nd Report,* NRC 2012

[3] *Review of the Research Program of the U.S. DRIVE Partnership: 4th Report,* NRC 2013

[4] *Annual Energy Outlook 2015*, April 2015.

Outline

- State of technology today for ICE
- Overview of the Advanced Combustion Engine R&D Program
- Combustion and Emission Control
  - Engine Combustion Research
    - Low Temperature Combustion
    - Predictive Simulation for ICE Design
  - Emission Control R&D
  - High Efficiency Engine Technologies
- Summary

Passenger Vehicle Fuel Economy Trends

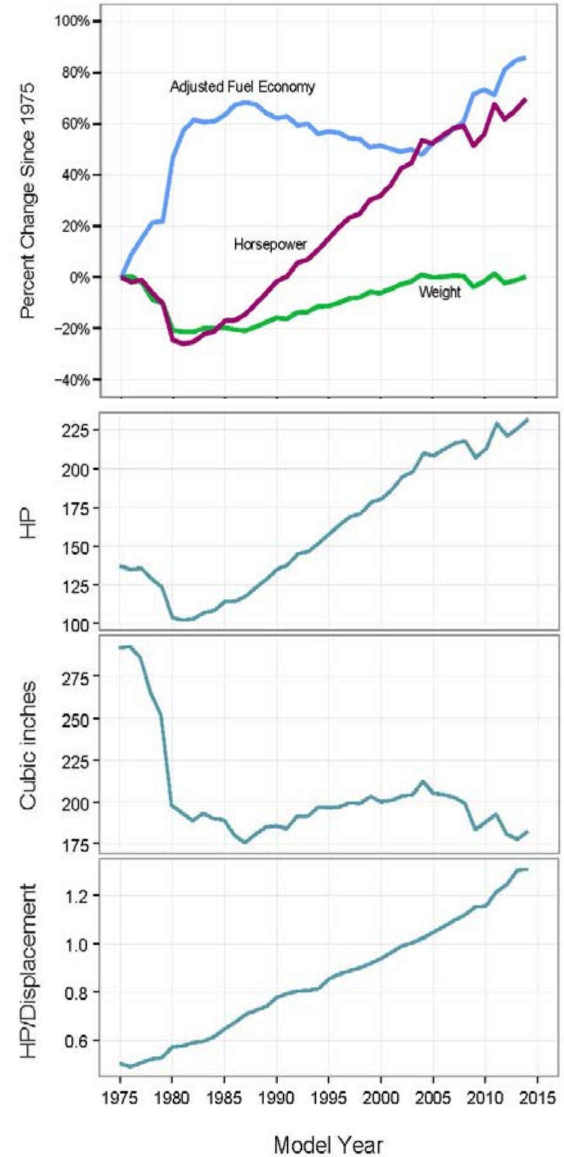
Increase in internal combustion engine performance has been largely responsible for significant fuel economy increases (in spite of increases in vehicle size and weight).

Engine Displacement and Power

Horsepower

Displacement

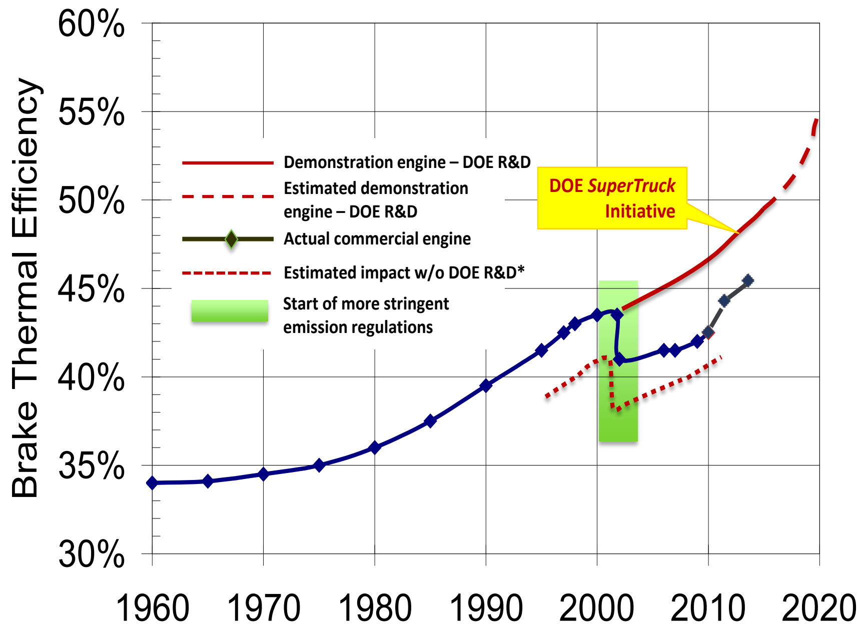
Average Specific Power



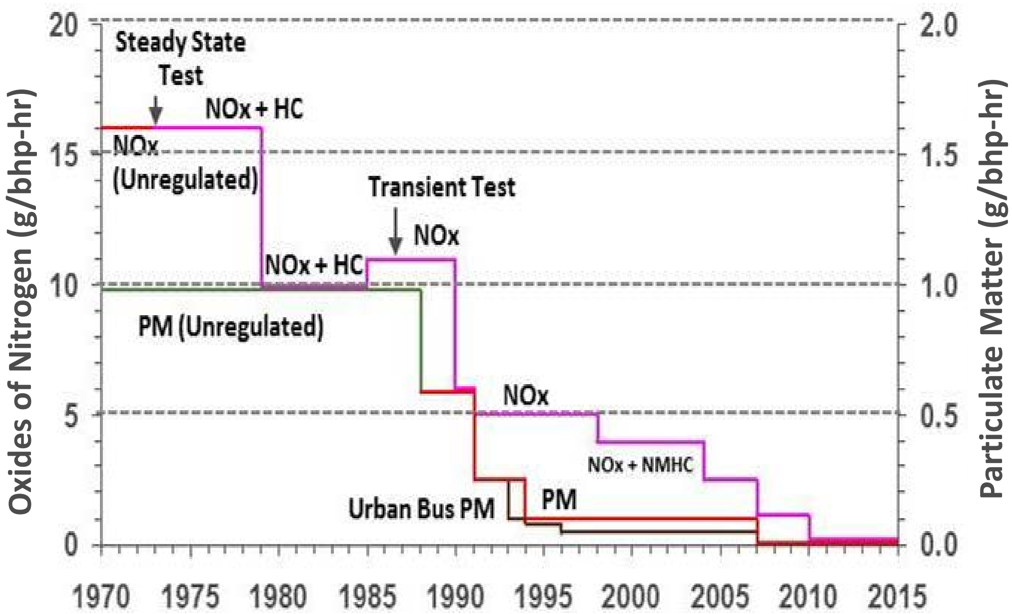
Source: EPA, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014, October 2014.

Progress In Heavy-Duty Diesel Engine Efficiency and Emissions

Historical progress in heavy-duty engine efficiency and the challenge of simultaneous emissions reduction, illustrate positive impact from DOE R&D support.



Historical Trend in Heavy-Duty Diesel Engine Efficiency



Historical Trend in Emissions from New Diesel Engines

- ❑ DOE R&D helped industry improve thermal efficiency of over-the-road heavy-duty diesel engines by over 4.5% .
- ❑ Benefits from heavy-duty vehicles alone (1995 – 2007) represent an over 70:1 return on investment (ROI) of government funds for heavy-duty combustion engine R&D - total savings of over $70B.

[Source: *Retrospective Benefit-Cost Evaluation of U.S. DOE Vehicle Advanced Combustion Engine R&D Investments: Impacts of a Cluster of Energy Technologies,* U.S. DOE, May 2010]

Advanced Combustion Engine R&D

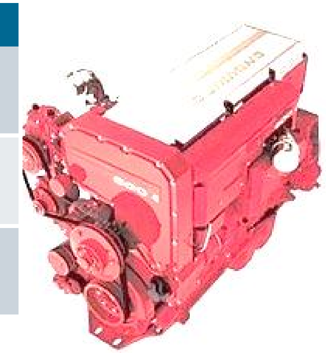
Strategic Goal: Reduce petroleum dependence by removing critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles

Primary Directions

- Improve ICE efficiency through advanced combustion strategies
- Develop efficient aftertreatment technologies
- Reduce losses and recover waste energy

Performance Targets*

	Light-Duty		Heavy-Duty	
	2015	2020	2015	2020
Engine brake thermal efficiency	--	--	50%	55%
Fuel economy improvement	25 – 40%	35 – 50%	20%	30%
NOx & PM emissions	Tier 2, Bin 2	Tier 3/LEV III	EPA Standards	EPA Standards



*compared to 2009 model year baseline

Advanced Combustion Engine R&D Program: *Budget by Subprogram*

Major Activities	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Advanced Combustion Engine R&D	**$49,970K**	**$49,000K**	**$64,500K**
Combustion and Emission Control	45,723	49,000	64,500
Solid State Energy Conversion	4,247	0	0

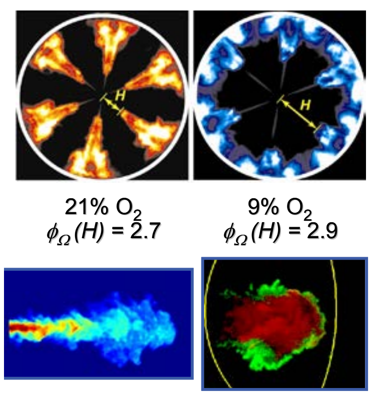
Advanced Combustion Engine R&D

Strategic Goal: Remove critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains in passenger and commercial vehicles

Advanced Combustion Engines Program

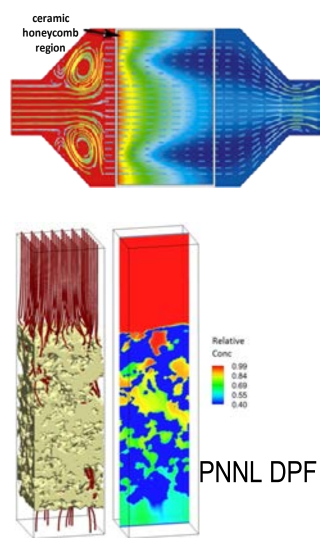
Combustion and Emission Control

- **Combustion R&D**
- **Emission Control R&D**
- **High Efficiency Engine Technologies**

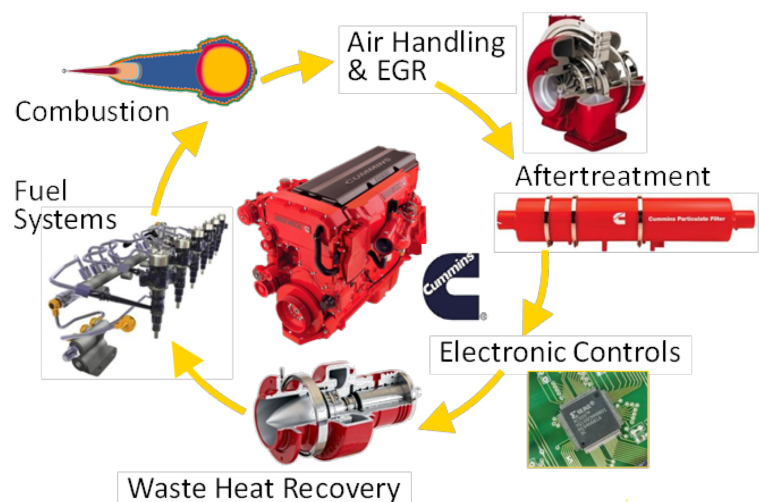


Fuel concentration

Soot (red) and OH (green)



PNNL DPF Model

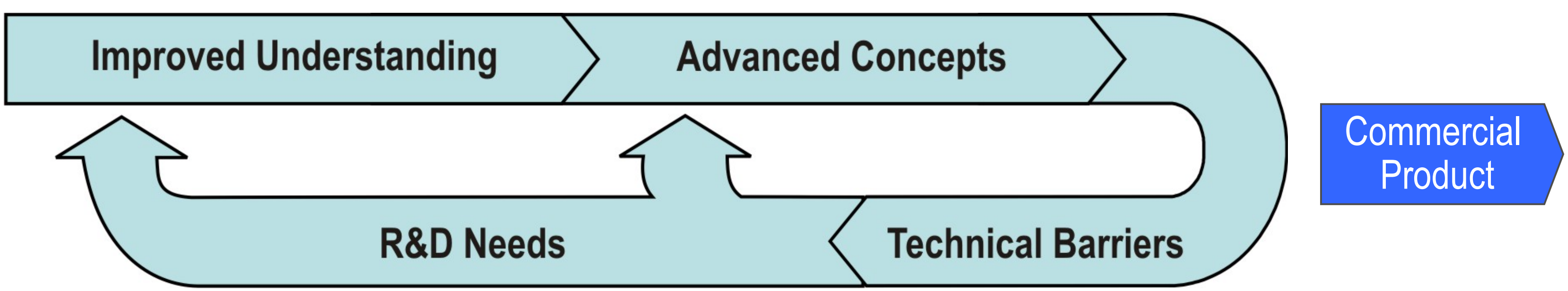


Overall R&D Approach

Fundamental R&D
- SNL – Advanced combustion strategies (LTC, lean-burn gasoline, advanced diesel)
- LLNL – Chemical kinetics models (combustion, fuels and emissions)
- LANL – CFD modeling of combustion
- ANL – X-ray fuel spray characterization and modeling
- PNNL – Catalyst characterization (NOx and PM control)
- 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 – Fuel injector design, LTC engine experiments

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

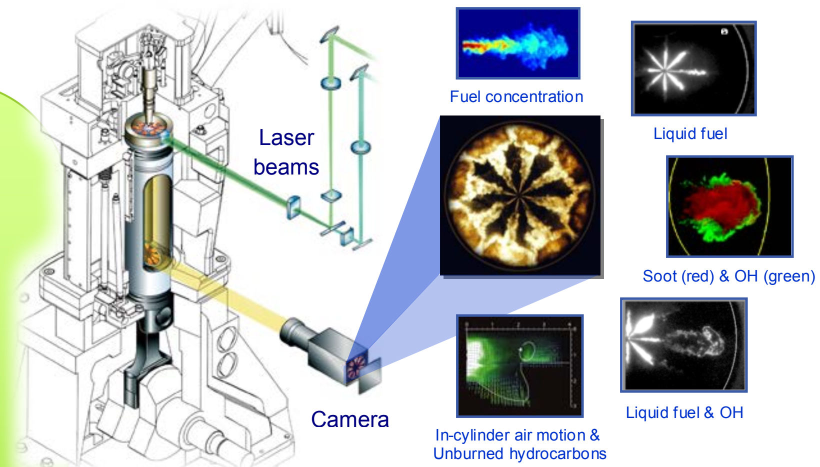


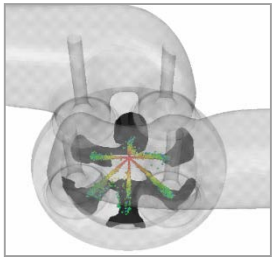
Combustion Research

Combustion and Emission Control

- **Combustion Research**
- Emission Control and Aftertreatment
- High Efficiency Engine Technologies

- ❑ Explore advanced combustion strategies to achieve higher engine efficiencies with near-zero emission of NOx and PM.
- ❑ Develop greater understanding of engine combustion and in-cylinder emissions formation processes.
- ❑ Develop science-based, truly predictive simulation tools for engine design.



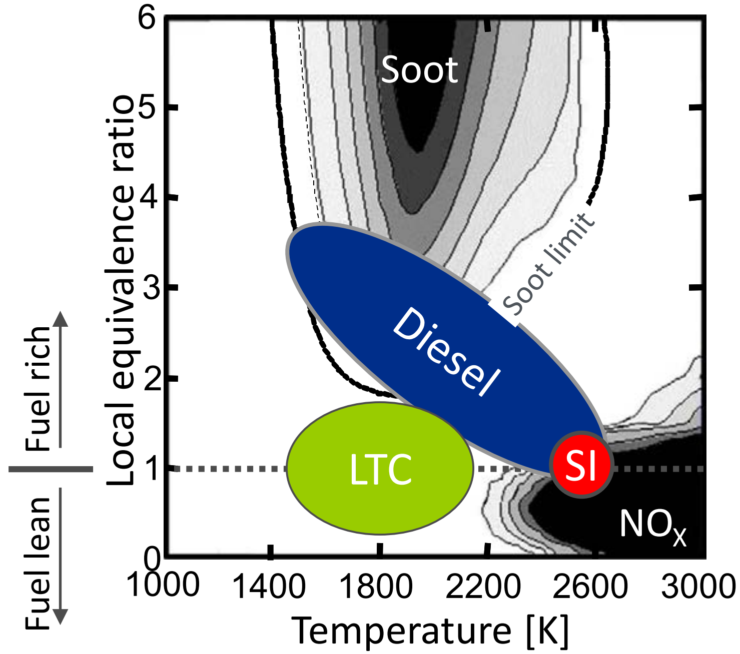


Engine Simulation

Combustion Research - *Directions and Challenges*

Combustion Strategies Enabling Improved Efficiency and Very-Low Emissions

- Low-Temperature Combustion (LTC):
  - Premixed-Charge Compression-Ignition (PCCI), PPCI, PCI, MK, … – “mixed enough”
  - Homogeneous-Charge Compression-Ignition (HCCI) – “heterogeneous enough”
  - Reactivity-Controlled Compression-Ignition (RCCI) – “dual fuel” combustion
- Dilute Gasoline Combustion: Fuel-air mixing, ignition and flame propagation in stratified mixtures, stochastic misfire and knock challenges, fuels, emissions, …
- Clean Diesel Combustion: EGR, high-pressure and multi-pulse injection, lifted-flame combustion, post injections for in-cylinder and aftertreatment emission control, ...



- LTC Challenges:
  - Combustion phasing
  - Load range
  - Heat release rate
  - Transient control
  - HC and CO emissions
  - Fuel characteristics

Diesel and HCCI Combustion

- Conventional Diesel Combustion (movie of hot, glowing soot)
- Homogeneous Charge Compression Ignition (movie of combustion chemiluminescence)

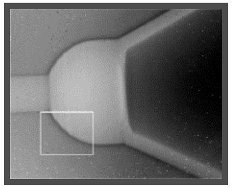
- Fuel injector (center) sprays 8 jets of liquid fuel into combustion chamber
- Compression-heating ignites fuel
- Soot forms in fuel-rich jets, and glows red/orange/yellow
- Some soot escapes combustion ⇒ soot emissions
- High-temperature combustion = high NOx
- High efficiency

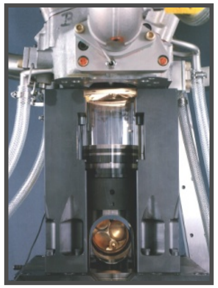
- Fuel is vaporized and premixed with air prior to compression
- Compression-heating ignites fuel
- Mixtures are fuel-lean so no soot forms, but combustion reactions emit light (blue)
- No soot emissions
- Low-temperature combustion = low NOx
- High efficiency

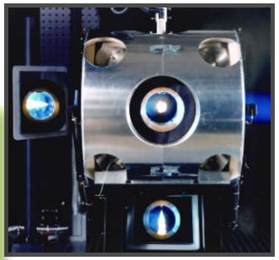
Research Tools Bridge Fundamentals to Application

- Close coupled modeling and experiments
  - Advanced diagnostics including optical, laser, x-ray, and neutron based techniques
  - Multi-dimensional computational models and combustion simulators
  - Fuel kinetics
  - Multi- and single-cylinder engines

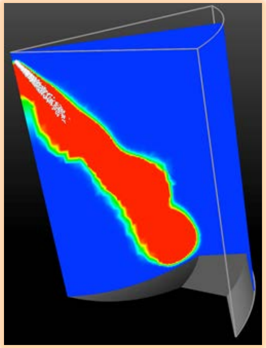

Optical Engine

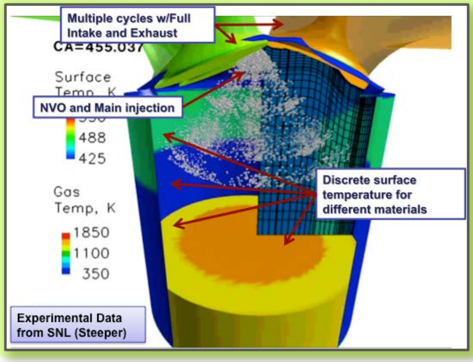

Nozzle Sac X-Ray Image


HCCI & Lean-burn Gasoline

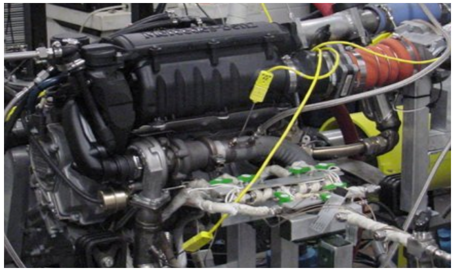

LTC Simulator

Chemical kinetic solver interfaced to CFD code





Engine Simulation



- Close collaboration between industry, national labs and universities
- Cross-cuts light- and heavy-duty engine R&D

Leading to engine modeling tools widely used in industry

Advanced Engine Combustion Memorandum of Understanding (MOU)

- **Goal:** To develop the knowledge base for advanced combustion strategies and carry research results to products.
  - Fundamental combustion research
  - Computational tools for combustion system design and optimization
  - Identify potential pathways for efficiency improvement and emissions compliance
- Close collaboration with industry through the Advanced Engine Combustion MOU led by Sandia National Labs carries research to products.
- Cross cuts light-duty and heavy-duty engine R&D

- University research* integrated with MOU

*Funded under NSF/DOE Partnership on Advanced Combustion Engines

DOE-NSF Engine R&D Grants

$12M over 3 years, equally shared by each agency - *Jointly funded by the DOE Vehicle Technologies Office of the Office of Energy Efficiency and Renewable Energy and the National Science Foundation Division of Chemical, Bioengineering, Environmental, and Transport Systems, Directorate of Engineering*

Combustion Research

- University of California, Berkeley - $1.65M
- Michigan State University - $1.30M
- Michigan Technological University - $0.65M
- University of New Hampshire - $0.60M
- The Pennsylvania State University - $0.60M
- University of Connecticut - $0.80M
- Stanford University - $1.2M
- Clemson University - $1.0M
- Yale University - $0.60M

Emission Control Research

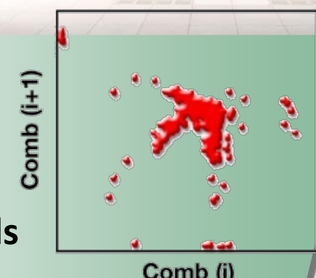
- University of Kentucky - $0.90M
- University of Houston - $1.20M
- Purdue University - $1.50M

High Performance Computing Could Accelerate Engine Design and Optimization

Basic Science

DOE Office of Science

Fundamental expertise in combustion instability mechanisms and leadership in high performance computing including the world's fastest supercomputer



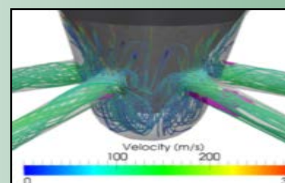
TITAN Use Awards
- ALCC 32.5M hrs
- OLCF 17M hrs

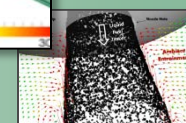
Applied R&D

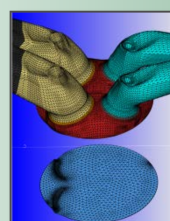
DOE/EERE/VTO

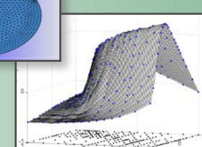
Accelerating high-pressure fuel injector design optimization and providing new insights into combustion instability phenomena

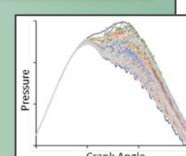
Injector image *(source GM)*











Oak Ridge National Laboratory

Manufacturing/ Commercialization

GM/Ford/GE

Research in close collaboration with automobile and engine manufacturers will directly impact the development of the next generation of high efficiency engines

GM Research & Development

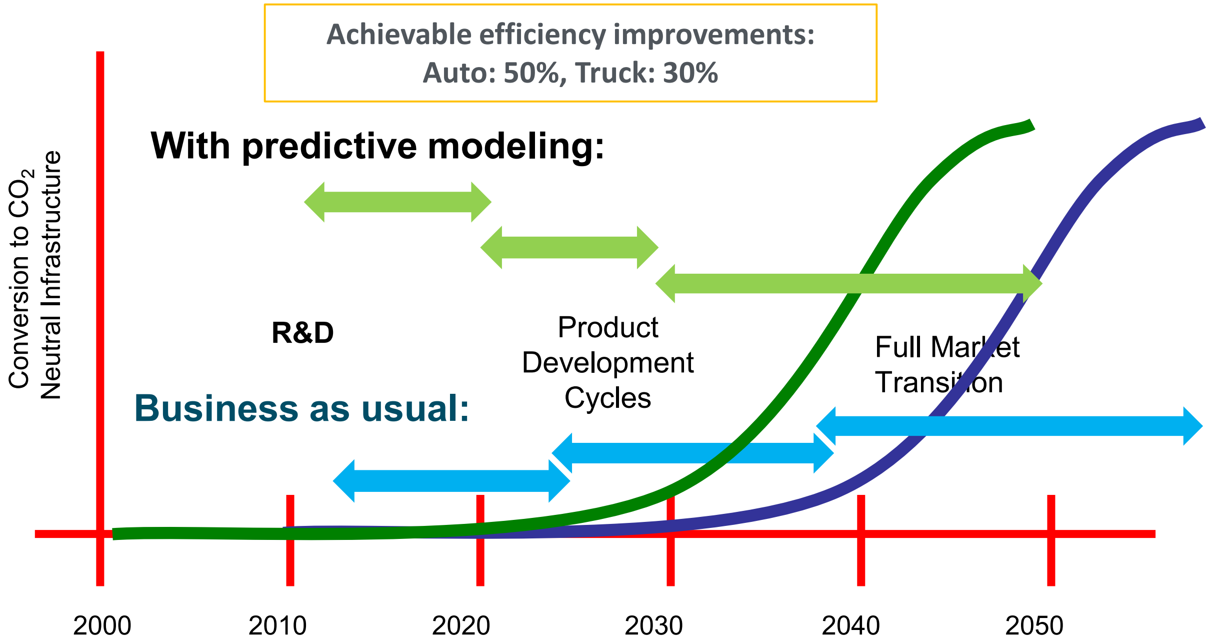
Ford

GE Global Research

Making use of unique world class resources to address real-world challenges

What is the impact if new design simulation tools are developed?

- ❑ Design, testing, and calibration portions of the product development cycle can all be shortened and cheaper
  - Calibration savings alone could reduce the product development cycle time and cost by 25-50% (industry dependent)

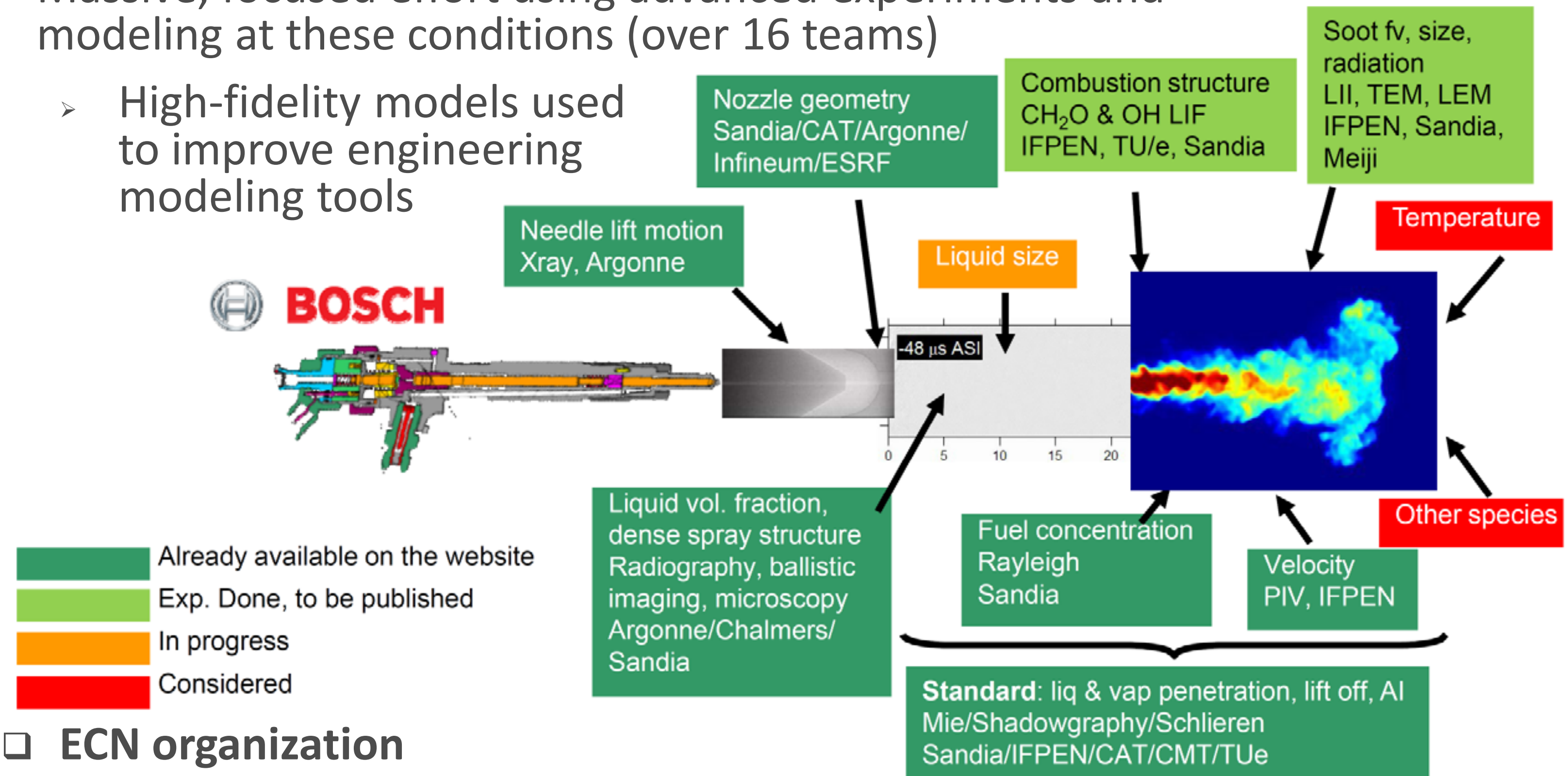


Product Development Must Be Accelerated To Meet Energy Goals

- ❑ Expand design space to broad range of design concepts
- ❑ Reach for the theoretical limits of thermodynamic efficiency
  - Potential for saving 4 M barrel of petroleum per day

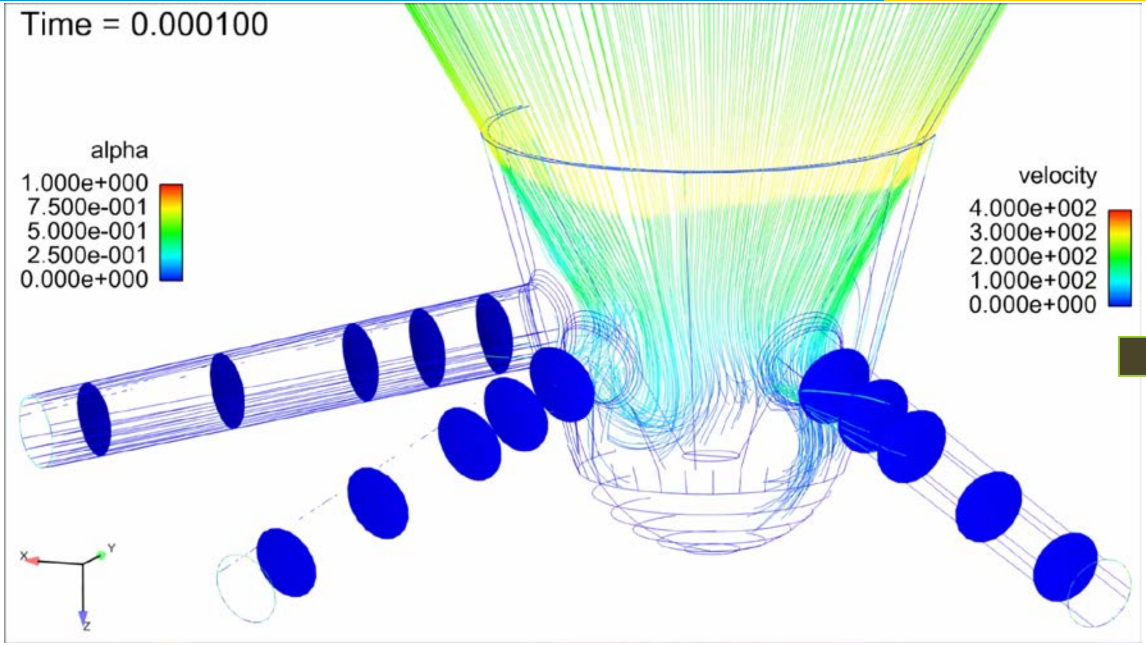
Engine Combustion Network (ECN) – *DOE/VTO-funded web-based collaboration to better CFD tools*

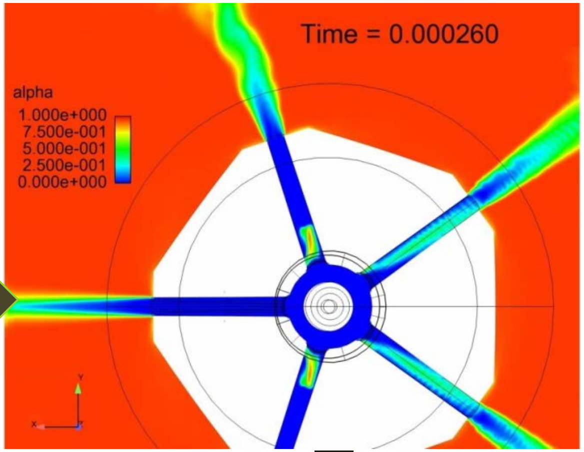
- Spray A diesel experiment:
  - Over 40 different measurements by more than 10 institutions
  - Over 15 years worth of research performed in 3 years
- Massive, focused effort using advanced experiments and modeling at these conditions (over 16 teams)
  - High-fidelity models used to improve engineering modeling tools

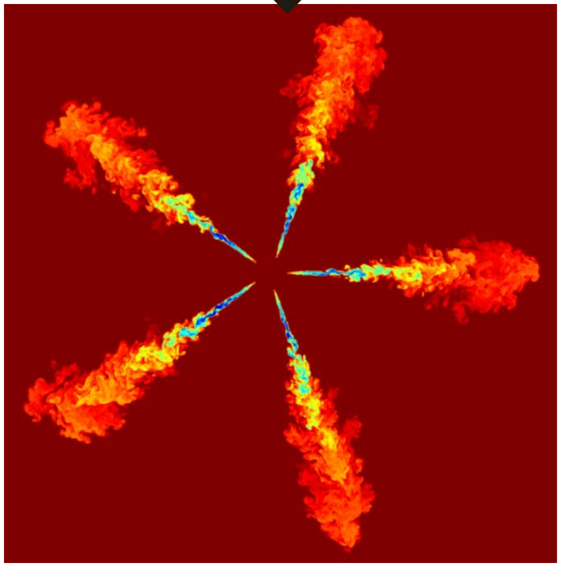


- **ECN organization**
  - Monthly web meetings
  - Workshop organizers gather experimental and modeling data, perform analysis, understand differences, provide expert review
  - Very tight coordination because of target conditions

Multi-hole Nozzle Two-phase Flow Simulations (ANL)



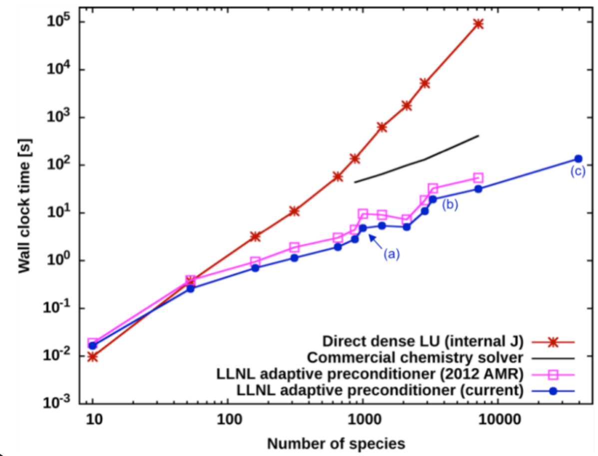


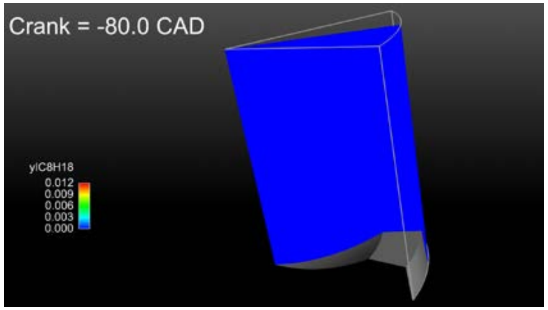


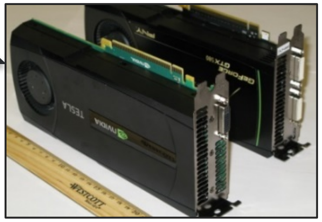
- ❑ **High-fidelity calculations** performed at **Argonne National Laboratory in collaboration with Convergent Science Inc.**
- ❑ Influence of **needle transients on fuel spray development** can now be predicted by a **dynamically coupled nozzle flow and spray** simulation approach
- ❑ Cycle-to-cycle variations partly arising from shot-to-shot variations in the needle lift and wobble profile
- ❑ **Plume-to-plume variations** in multi-hole nozzles can now be captured

Numerical tools and High Performance Computing Enable More Predictive CFD of Advanced Combustion Regimes (LLNL)

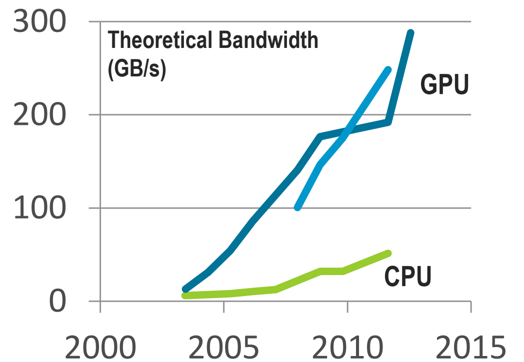
- New chemistry solver combining multi-zone and adaptive preconditioner speeds up detailed kinetic calculations orders of magnitude over traditional methods.
  - The new solver has interfaces to common CFD codes; licensed to Convergent Science Inc. whose ConvergeCFD code is used by many of the automotive and diesel engine MOU partners.
  - The new solver has been ported to the general purpose graphical processing unit (GPU).







- High Performance Computing (HPC) allows examining experimental and modeling uncertainties systematically.
- Incorporating graphics processing unit (GPU) algorithms into CFD codes ensures continued improvement in modeling capability as computing platforms move towards massively parallel architectures.

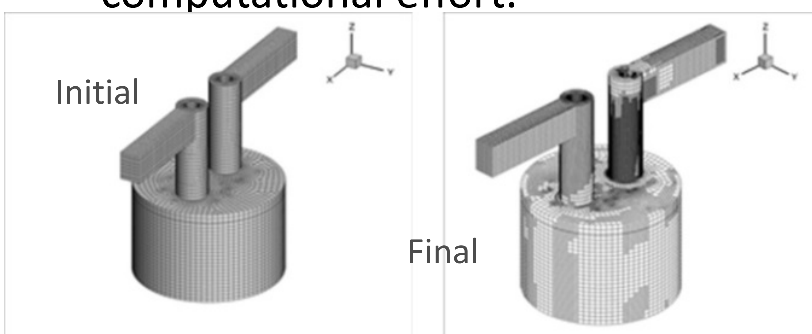


from NVIDIA's *CUDA C Programming Guide v.5.5*

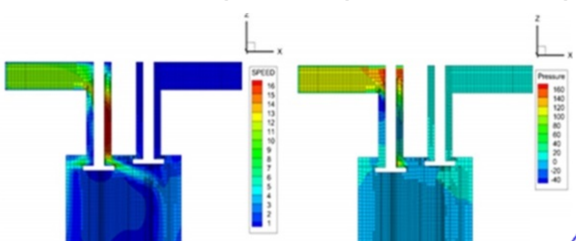
LANL's KIVA-hpFE: *Toward Predictive Engine Modeling*

New hp-adaptive **Finite Element Method (FEM) for turbulent reactive flow modeling** increases **KIVA's accuracy, robustness**, and range of applicability.

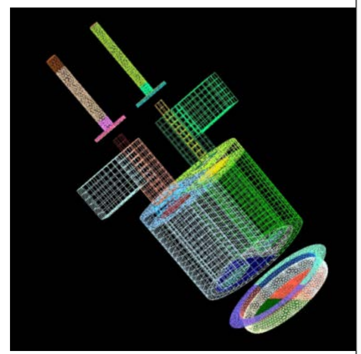
- Grid enrichment (h), polynomial order enrichment (p); ***FEM** error measure drives r*esolution (numerical error is very near zero.
- Excellent spatial accuracy with minimal computational effort.

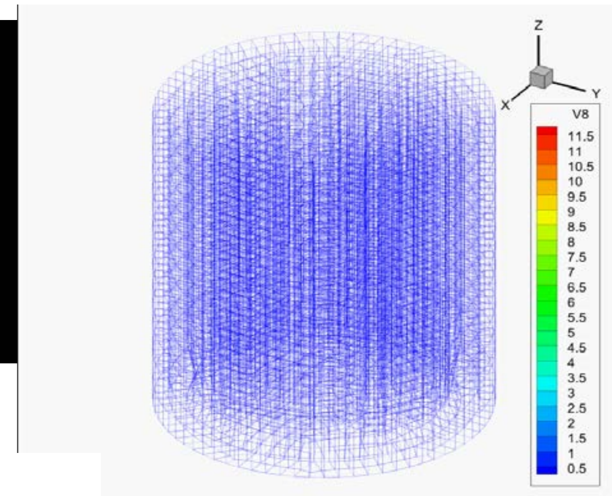


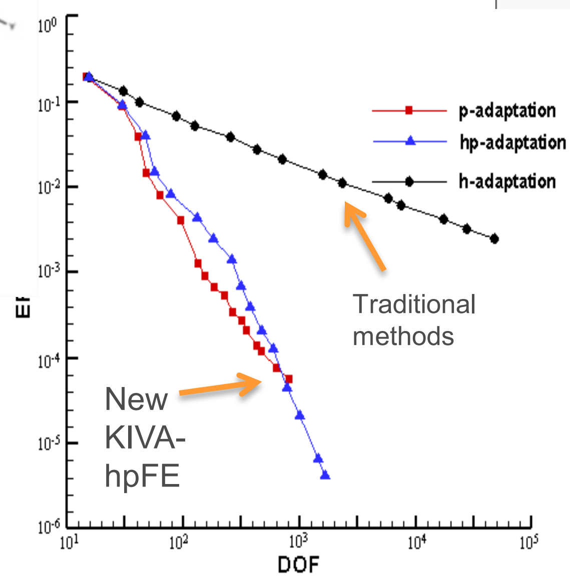
Initial and final grids at given crank angle



- **Superior actuated parts movement**
  - **New local-ALE is robust (no tangle) & accurate**
  - 2^{nd} order spatial convergence having ~zero error







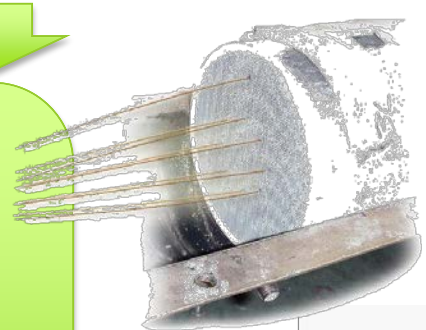
- **KIVA-hpFE** is accurate for all flow regimes with k-ω RANS, LES turbulence and thermal analysis.

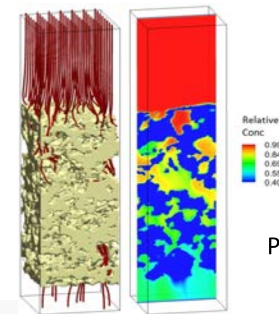
Emission Control R&D

Combustion and Emission Control

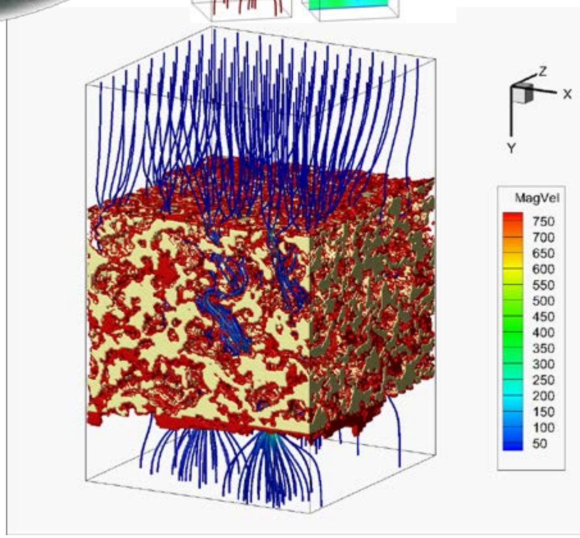
- Combustion Research
- Emission Control and Aftertreatment
- High Efficiency Engine Technologies

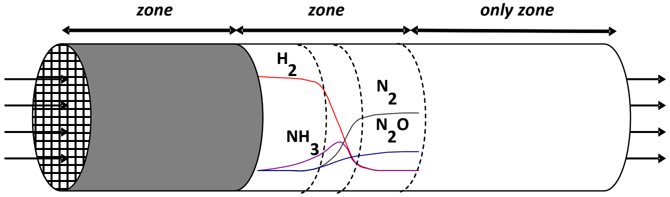
- Develop more efficient approaches for reducing NOx, and oxidizing PM, HC, and CO in low temperature exhaust (150°C).
- Reduce energy penalty and cost of emission control systems.

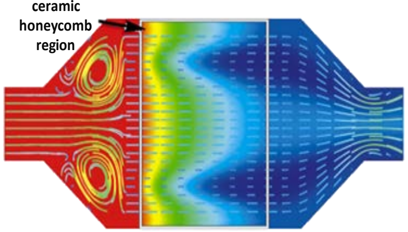




PNNL DPF Model



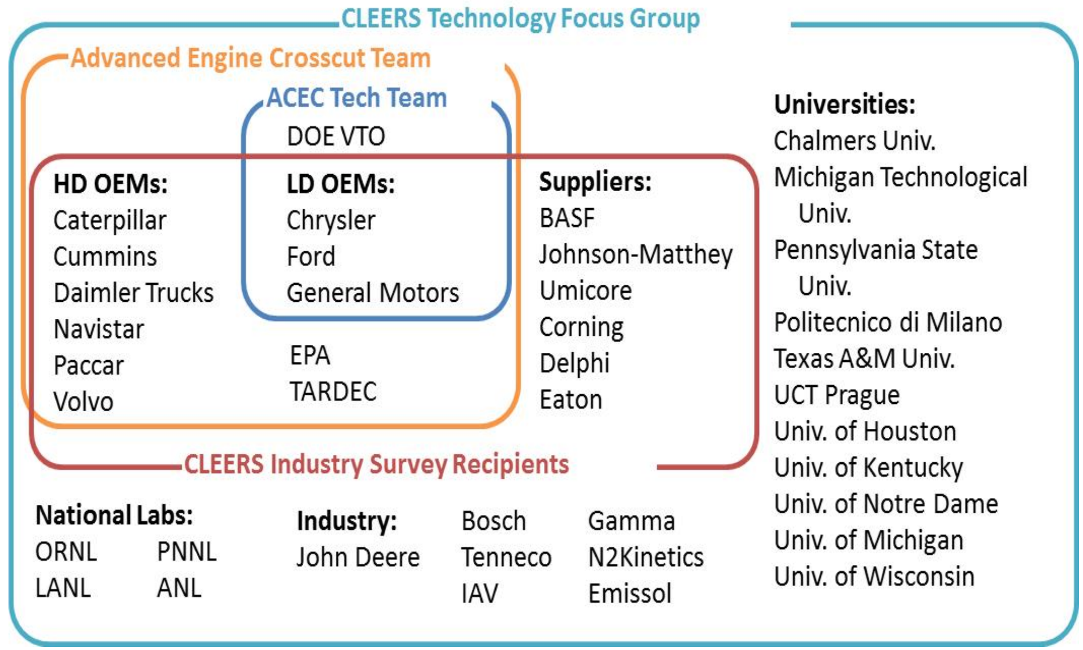




Flow and Temperature Computations during Cold-start of a Catalytic Converter

CLEERS Enables Joint Development and Coordination of Emission Control Data and Models

- **CLEERS** (<u>C</u>ross-cut <u>L</u>ean <u>E</u>ngine <u>E</u>mission <u>R</u>eduction <u>S</u>imulations)
  - An R&D focus group of the DOE VTO Advanced Engine Cross-Cut Team
  - Promotes collaboration and interactions among industry, national labs, and universities to achieve functional models for lean emission control devices and systems

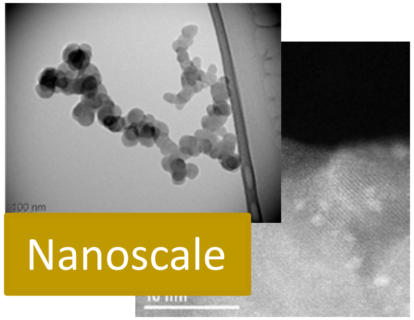


CLEERS Workshop

- Simulations range from fundamental surface-reaction based to component level models
- Key activities include: an annual workshop, monthly teleconferences, and a website (www.cleers.org) with an active database of models and experimental data
- Models are increasingly relied on by industry in product development and optimization

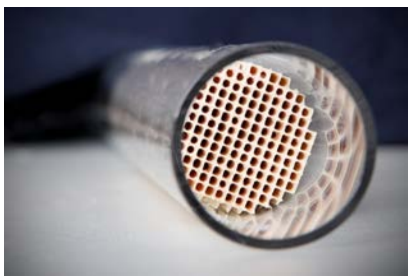
EERE VTO Catalysis Research for Vehicles Spans from Nanoscale to Full Scale

TEM images of PM and PGM dispersed on support



Nanoscale

Monolith supported catalyst core



Engine-catalyst system

Full Scale

Research Areas

Surface Chemistry
Defining surface moieties and intermediates with DRIFTS and other tools

PGM Characterization
Defining Platinum Group Metal (PGM) roles and understanding sintering processes

Poison Effects
Understanding effect of fuel- and oil-borne poisons/fouling agents on aging processes

Reaction Mechanisms
Characterizing reaction processes and measuring kinetics

Characterizing Formulation-Specific Chemistry
Understanding role of components of complex heterogeneous catalyst formulation

Performance and Selectivity
Measuring formulation affect on performance and selectivity (including differentiating regulated vs. unregulated products)

Controlling Unique Advanced Combustion Emissions
Studying combination of advanced catalysts with advanced combustion to achieve overall gains in fuel economy and cost-effective emission compliance

Minimizing Fuel Penalty during Active Regeneration
On-engine studies to minimize fuel use and optimize emission control

Characterizing Combustion-Specific PM and MSATs
Defining morphology, size distribution, and chemical composition of Particulate Matter (PM) and Mobile Source Air Toxics (MSATs)

Particulate Filter-Based Control of PM
Studying oxidation kinetics, thermal issues, and fuel penalty for particulate filters

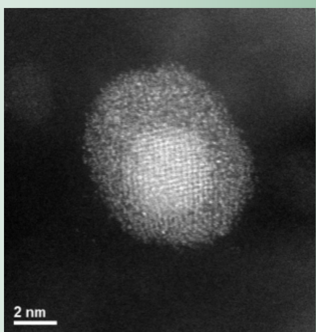
Industry Benefits

- Understanding Catalyst Fundamentals
- Predicting Degradation and Defining Mitigation Strategies
- Developing and Validating Models for Product Design, Controls, and OBD Optimization
- Achieving Cost-Effective Emissions Compliance while Maximizing Fuel Efficiency

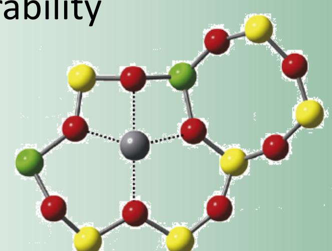
Low Temperature Catalysis Research Addresses New Challenges of Advanced Engines

Basic Science	Applied R&D	Manufacturing/ Commercialization
DOE Office of Science	DOE/EERE/VTO	Industry

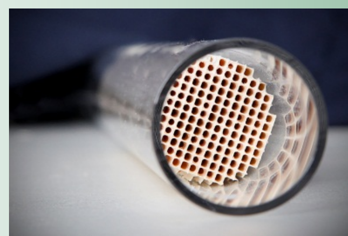
DOE Office of Science



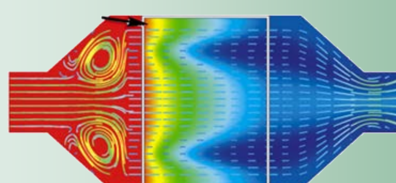
New materials showing excellent low temperature performance and durability



DOE/EERE/VTO



Materials being evaluated under real-world conditions to understand potential with high efficiency combustion strategies



Industry

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

21st CENTURY TRUCK PARTNERSHIP

Supporting automobile and truck manufacturers in the development and execution of a path forward to address this critical enabler for high efficiency engines

Transitioning catalyst material breakthroughs to overcome critical barriers to high efficiency transportation

Low Temperature Emission Control Improvements Enabling Commercialization of Advanced Combustion

Catalyst invented in Basic Energy Sciences (BES) program leading to new discoveries in VTO program that may enable low cost emission control for advanced

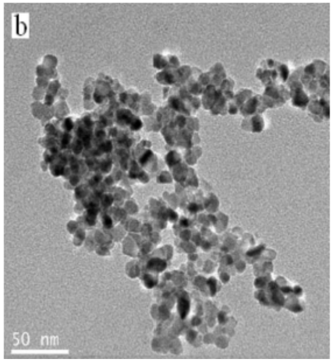
CuO_x-CoO_y-CeO_2 (CCC) catalyst developed in BES program contains no costly Platinum Group Metals


Applied Catalysis A: General 451 (2013) 282–288
Contents lists available at SciVerse ScienceDirect
Applied Catalysis A: General
journal homepage: www.elsevier.com/locate/apcata

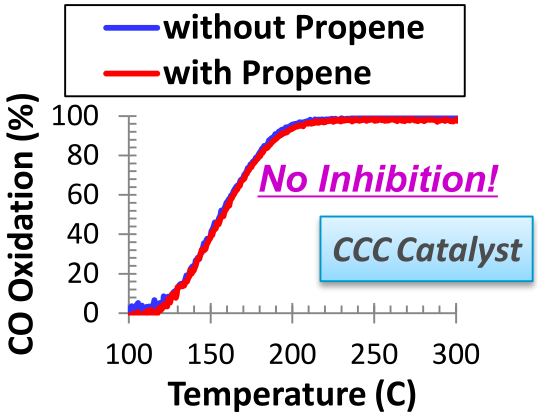
Influence of calcination temperature on the structure and catalytic performance of CuO_x-CoO_y-CeO_2 ternary mixed oxide for CO oxidation

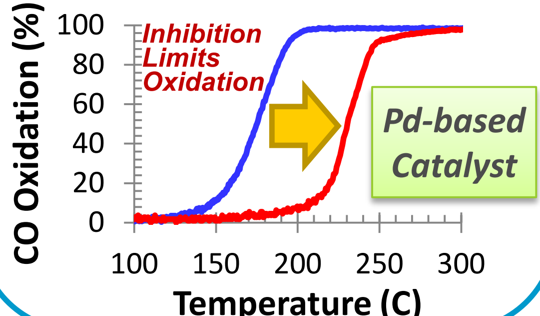
Zhi-Gang Liu[a,*], Song-Hai Chai[b], Andrew Binder[c], Yuan-Yuan Li[a], Lin-Tao Ji[a], Sheng Dai[b,c,**]
[a] School of Chemistry and Chemical Engineering, Hunan University, Changsha 410082, China
[b] Chemical Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[c] Department of Chemistry, University of Tennessee, Knoxville, TN 37996-1600, USA

CuO_x-CoO_y-CeO_2 ("CCC") Catalyst



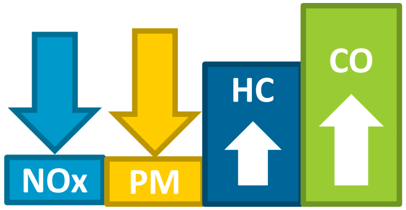
Unlike Pd-based catalysts, VTO studies show CCC's CO oxidation not inhibited by HCs (a unique finding)



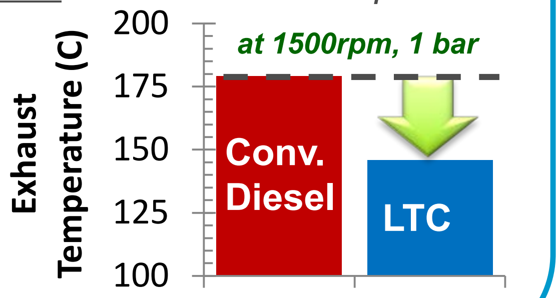


Low-cost catalyst may address LTC's higher CO and HC emissions and lower exhaust temperatures

More fuel-efficient Low Temperature Combustion (LTC) gives higher CO & HCs**



*And lower exhaust temperatures**

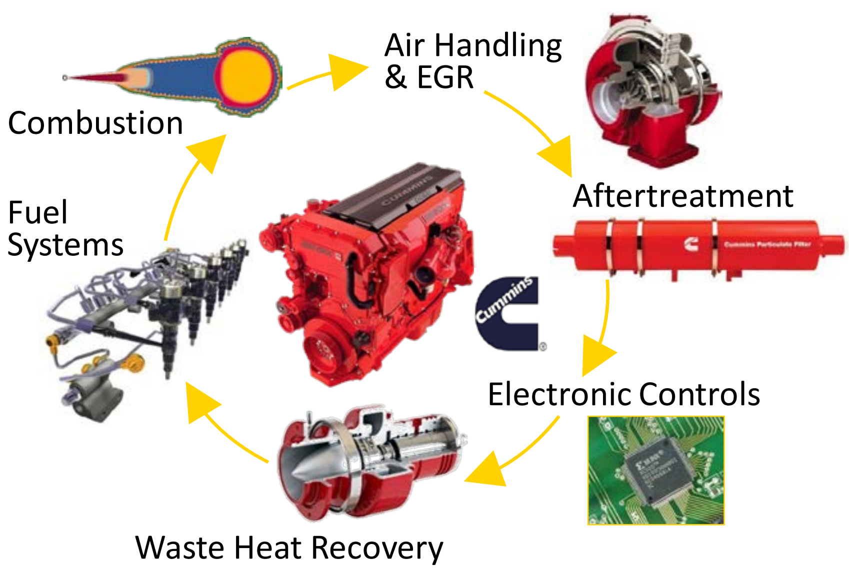


**vs. Conventional Diesel Combustion*

High Efficiency Engine Technologies

Combustion and Emission Control

- Combustion Research
- Emission Control and Aftertreatment
- High Efficiency Engine Technologies



Integration of Component Technologies

- ❑ Develop and demonstrate system level technologies to improve vehicle fuel economy through combination of combustion strategies, emission control, fuel injection, air handling, waste heat recovery, and control systems.

SuperTruck - Develop and Demonstrate System Level Technologies to Improve Long Haul Truck Freight Efficiency by 50%

❑ Heavy-Duty Engine for Class 8 Trucks - *Goals*

- 20% improvement in engine brake thermal efficiency (50% BTE)
- Modeling and analysis for pathway to 55% brake thermal efficiency

Cummins Daimler Trucks North America VOLVO NAVISTAR

❑ Status with respect to 50% engine efficiency goal:

- Cummins and Daimler have demonstrated over 50% engine efficiency.
- Navistar and Volvo have demonstrated over 48% engine efficiency; on track to achieve the 50% goal.

SuperTruck II planned for FY2016

Advanced Technology Powertrain for Light-Duty (ATP-LD) Vehicles

Goal: By 2015, develop and demonstrate system level technologies to achieve 25% and 40% fuel economy improvement for gasoline and diesel vehicles, respectively, over the baseline 2009 gasoline vehicle.

- **Status**
  - Cummins achieved 60% fuel economy improvement with 4 cylinder diesel over comparable gasoline V-8 powered light truck;
  - GM, Chrysler, and Bosch achieved a 25%, fuel economy improvement;
  - Ford on track to achieve 25% fuel economy improvement;
  - Delphi demonstrated 39% increase in fuel economy over FTP; emission standards were exceeded.

GM

CHRYSLER

BOSCH

Ford

DELPHI

Advanced Technology Powertrain for Light-Duty Vehicles – Phase 2 (ATP-2)

Goal: By 2020, develop and demonstrate system level technologies to achieve 35% fuel economy improvement for gasoline vehicles over the baseline 2009 gasoline vehicle.

- **Status:** Initiated two cost-shared cooperative agreements to demonstrate goal while meeting Tier 3 emissions.
  - General Motors will develop a Lean Miller Cycle Gasoline Engine including various other technologies for integration in a Chevrolet Malibu.
  - Delphi will continue developing a Gasoline Direct-injection Compression Ignition (GDCI) engine for integration in a Hyundai Sonata. Partners include Umicore, ORNL and U of Wisconsin.

GM

Vehicle-ready Gen2 GDCI multi-cylinder with thermal management system, sensors, and actuators

DELPHI

Enabling Technologies for Engine and Powertrain System

- MAHLE Powertrain LLC completed testing of turbulent jet injection (TJI) on single-cylinder engine (with boost rig) focused on pre-chamber design optimization and developing TJI operating strategy for the next-generation ultra lean burn engines

BOSCH

- Robert Bosch LLC improved thermal shock robustness and response time of intake air oxygen (IAO2) sensor and validated location for best performance and control of cooled exhaust gas recirculation (cEGR) for advanced engine concepts.

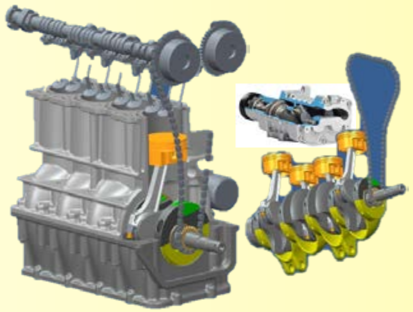
Los Alamos NATIONAL LABORATORY

- LANL demonstrated capability of HC, NOx, and NH_3 sensor during engine dynamometer evaluations at ORNL-NTRC; successfully transformed LANL-patented mixed-potential sensor technology to a commercial manufacturing platform.

Enabling Technologies for Engine and Powertrain System

- Filter Sensing Technologies (FST) Inc. demonstrated a RF sensor that reduced diesel particulate filter regeneration-related fuel consumption by up to a factor of two for MY 2009 Volvo/Mack vocational vehicles, and demonstrated reduced regeneration duration from 15% to 30% on a modern (MY 2013) DD-13 engine relative to the stock control system. (Received R&D 100 Award)

FST RF-DPF™ sensor/control system on Volvo/Mack diesel aftertreatment system.



- Envera LLC is developing a Variable Compression Ratio engine using an Eaton supercharger with a high-speed clutch will demonstrate improved fuel economy while delivering needed torque and power with down-sized engine.

Summary

- Internal combustion engines are forecasted to remain the dominant power source for vehicles in the next several decades, hence increasing their efficiency is one of the most promising and cost-effective approaches to improve the fuel economy of the U.S. vehicle fleet and reduce transportation's energy and climate change impacts.
- EERE Advanced Combustion Engine R&D, in collaboration with industry and academia, using unique DOE national laboratory expertise and facilities, significantly contributes to dramatic increases in engine efficiency and performance leading to improvements in vehicle fuel economy and reduction in emissions.
- There is still significant potential for further improve internal combustion engine efficiency using advanced combustion strategies, engine optimization and efficient emission controls; potential for 50% and over 30% fuel economy improvement for passenger and commercial vehicles, respectively.
- Advanced combustion engine system modeling and predictive simulation offer the potential to further improve engine efficiency, reduce product development time and time-to-market.

Contact Information

Gurpreet Singh

gurpreet.singh@ee.doe.gov

Web site:

http://energy.gov/eere/vehicles/vehicle-technologies-office