



## **Advanced Collaborative Emissions Study (ACES) NETL Agreement 13919**

*Cooperative multi-party effort to characterize emissions and possible health effects of new advanced heavy duty engine and control systems and fuels in the market 2007 – 2010.*

*Conducted by Health Effects Institute (HEI) and Coordinating Research Council (CRC)*

### **PROJECT SPONSORS**

DOE OVT and NETL  
Engine Manufacturers Association (EMA)  
US Environmental Protection Agency (EPA)  
California Air Resources Board (ARB)  
American Petroleum Institute (API)  
Aftertreatment Manufacturers  
Coordinating Research Council (CRC)

**February 2008**

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## **Evaluating Emissions of Advanced Technology Diesels**

- The combination of advanced-technology, compression-ignition engines, aftertreatment systems, reformulated fuels and reformulated oils developed to meet the 2007/2010 emission standards will result in substantially reduced emissions.
- Substantial public health benefits are expected from these reductions.
- With any new technology it is prudent to conduct research to ensure that there are no adverse impacts to public health and welfare.

# Project Overview

## Phases:

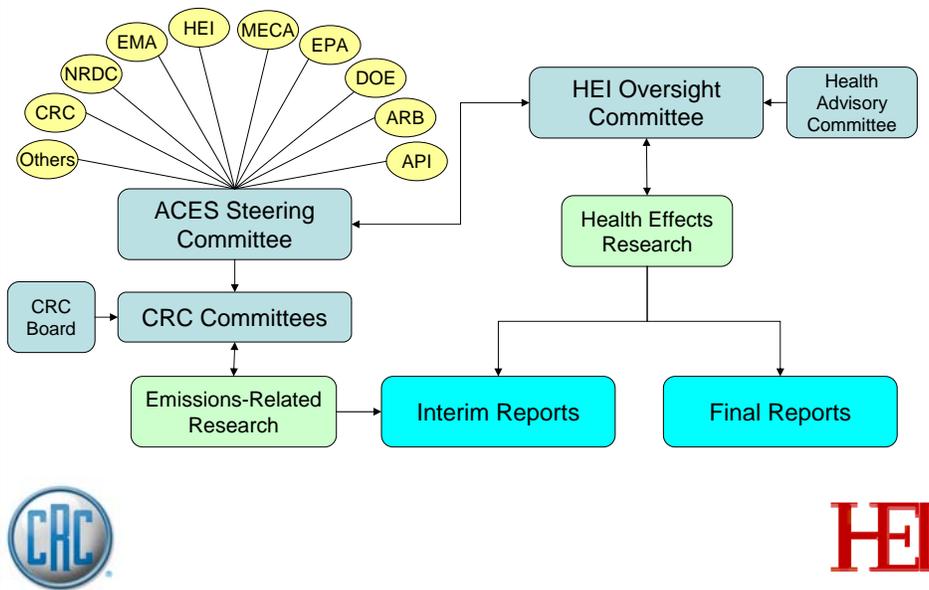
1. 2007 Engine Emissions Characterization (Southwest Research Institute (SWRI))
  - CRC Technical Leader
2. 2010 Engine Emissions Characterization
  - CRC Technical Leader
3. 2007/2010 Engine Health Effects Testing (Lovelace Respiratory Research Institute (LRR))
  - Short Term biological screening and Long-Term Health Effects Test on 2007 Engines
  - HEI Technical Leader
  - CRC Technical Monitor

## Overall Project Timeline

	2007	2008	2009	2010	2011	2012
Phase 1: Testing	█	█				
Phase 1: Analysis & Reporting		█	█	█		
Phase 2: Testing				█	█	
Phase 2: Analysis & Reporting				█	█	
Phase 3: Facilities Development	█	█	█			
Phase 3: Animal Biological Screening and Health Testing			█	█	█	█
Phase 3: Analysis & Reporting					█	█



# Project Organization



# Phase 1 Schedule

revised January 15<sup>th</sup>, 2008 by SwRI



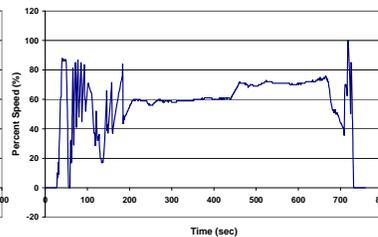
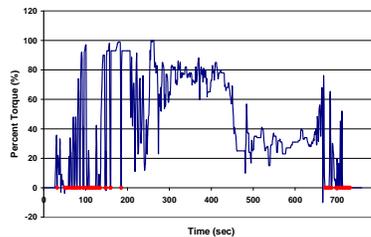
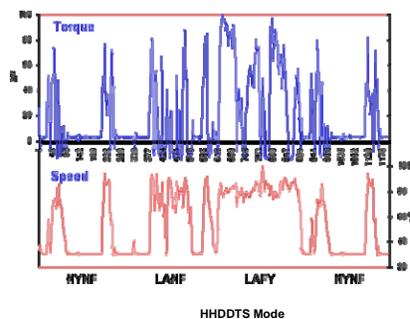
	Apr	May	Jun	Jul to Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Develop and Submit Program Plan	█																		
Deliver Four Engines At SwRI		█	█																
Test Cell Set-up and Program Plan Review		█	█																
Test Engines A, B, C, and D				█	█	█	█	█	█										
Analyze Data and Report Results																			
Select the Fifth Engine																			
Manufacturer Preparation of Fifth Engine																			
Test the Fifth Engine																			
Complete All Results and Analysis																			
Submit Draft Final Report																			
Review of Draft Report by ACES Committee																			
Submit Revised Draft																			
Review of Revised Draft by ACES Committee																			
Submit Final Report																			



## Phase 1 Approach: Test Cycles

- Foundation: HD-FTP
- CRC Project ACES-1
  - Conversion of CARB Chassis Cycles using E-55/59 data
  - Creep, Transient, 2 Cruise Cycles
- CRC Project ACES-1a
  - 16-hour test schedule based on HD-FTP & ACES-1/CARB Engine Cycles

FTP



# Phase 1 Testing

## Engines A, B, C, D

Cycle	Regulated Pollutants	Unregulated
Hot-Start FTP	3	a
Mode 1	3	a
Mode 3	3	a
Mode 5	3	a
Cold-Start FTP	1	a
Hot-Start FTP	6 <sup>a</sup>	6 <sup>b</sup>
Composite CARB HHDE Cycle Mode 1, 2, and 5 (idle, creep, transient)	2	2
Composite CARB HHDE Cycle Mode 3 and 4 (cruise and high-speed cruise)	2	2
16-Hour Transient Cycle	3	3
Tunnel Blanks <sup>c</sup>	4	4

<sup>a</sup> Only real time particle size, number, total mass, solid mass, and semi-continuous OC will be performed for these modes of engine operation  
<sup>b</sup> Three hot-start FTP runs with blow-by and three without blow-by  
<sup>c</sup> One tunnel blank after cleaning CVS tunnel but before running the engine. A second tunnel blank after finishing the six hot-start FTP runs, which is also before starting the CARB composite modes. A third tunnel blank after finishing the CARB composite modes but before the 16-hour transient cycle. A fourth tunnel blank after finishing the 16-hour transient cycle.

### 5<sup>th</sup> (Duplicate) Engine Tests

- Three hot-start FTP runs with blow-by, normal altitude
- Three hot-start FTP runs without blow-by, normal altitude
- Three hot-start FTP runs with blow-by, high altitude simulation
- Three hot-start FTP runs without blow-by, high altitude simulation



## 2007 Class 8 Engine and Control Systems at SwRI

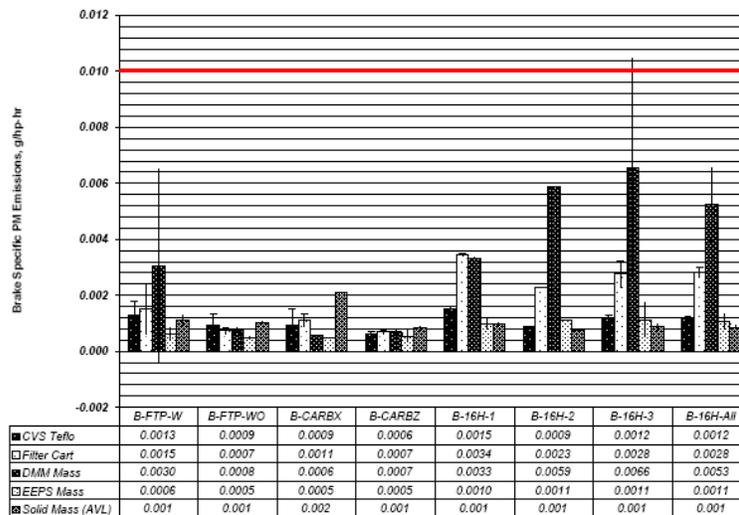


# Phase 1 Status

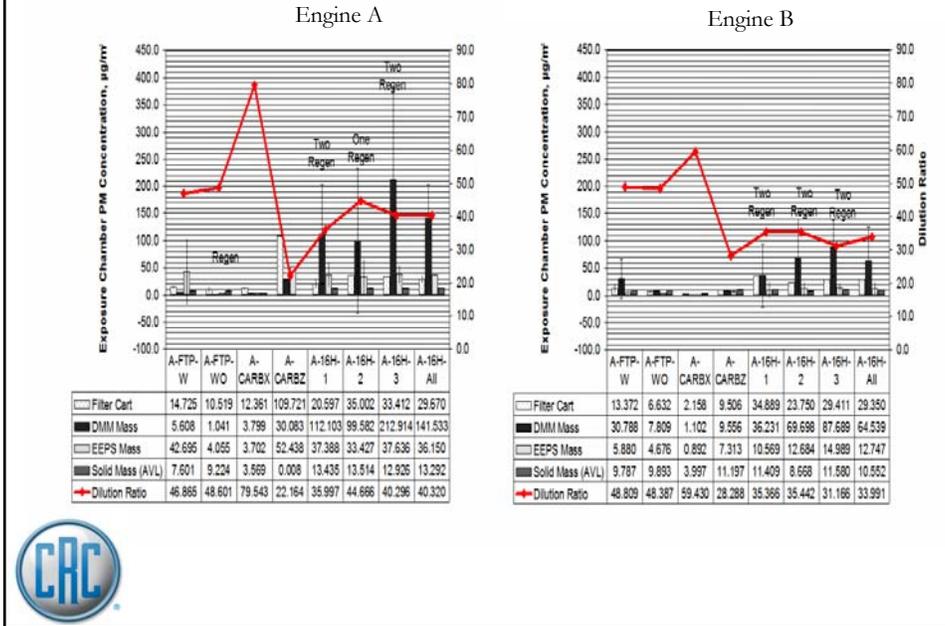
- ACES contract testing of Engines A, B, C, D complete
- Additional testing (funded by ACES co-sponsors)
  - Engine A: re-testing for w/o blow-by; related to regeneration event
  - Engine C: 16-hour testing completion with new test engine
  - Dioxin / Furans testing on Engines A, C, D:
    - EPA funding Engines D, C, & fuel / oil analysis
    - Engine A testing desired (HEI); funding not established
    - EMA committed to fund background dilution air tests, if EPA does not



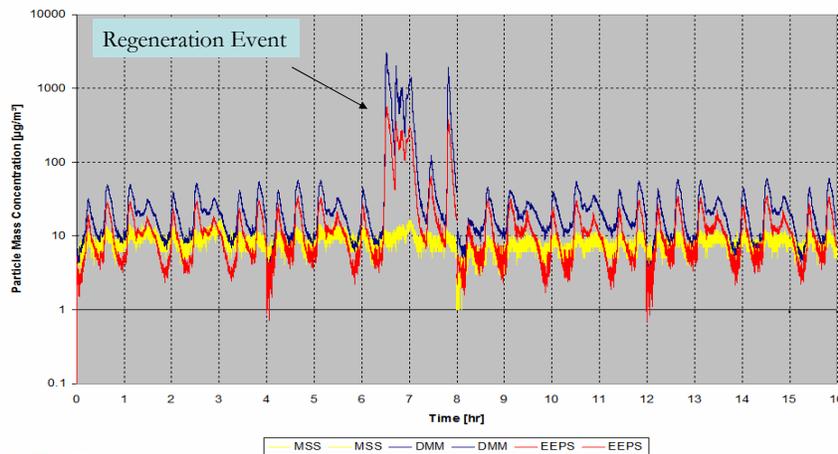
## Phase 1 Data: Engine B PM Mass Emissions



## Engine A and B PM Mass Concentration in Exposure Chamber



## PM Mass Concentration Profile in Exposure Chamber for 16-hour cycle



## CRC ACES Panel

Reynaldo Agama	Caterpillar	M. Matti Maricq	Ford Motor Company
James Ball	Ford Motor Company	Mani Natarajan	Marathon Petroleum Company LLC
Nicholas Barsic	John Deere	Ralph Nine	US Department of Energy / National Energy Technology Laboratory
Steve Berry	Volvo	Robert Okamoto	California Air Resources Board
Steven Cadle	General Motors R&D Center	Charles Schleyer	ExxonMobil
Timothy French	Engine Manufacturers Association	Shirish Shimpi	Cummins
Thomas Hesterberg	International	Joseph Somers	US Environmental Protection Agency
Donald Keski-Hynnala	Detroit Diesel	Chris Tennant	CRC
Chris Laroo	US Environmental Protection Agency	Steve Trevitz	Volvo
Douglas Lawson	National Renewable Energy Laboratory	Urban Wass	Volvo
Hector Maldonado	California Air Resources Board	Jane Warren	Health Effects Institute



## ACES Health Effects Studies



## Diesel Health Effects Issues

### Historically

- Lung cancer –primary driver of diesel debate
- Contribution to PM exposures and effects
- Asthma and allergies –emerging issues

### New (2007-2010) Diesel

- Most diesel health assessments based on 1980s and earlier technology. “As cleaner engines replace older engines.. the general conclusions will need to be reevaluated” (EPA 2002)
- Most pollutants will decrease, but new species may be formed. Although effects expected to be reduced, new technologies should be evaluated before widespread introduction

HEI

## Main Hypotheses

- *Regulated and unregulated exhaust emissions from 2007/2010 compression ignition engine equipped vehicles will be greatly reduced compared to older vehicles.*
- *Exhaust emissions from these vehicles will not cause an increase in tumor formation or substantial toxicity to any organ or other serious health effects in rats and mice at the dilution ratios used compared to animals exposed to filtered air, although some biologic effects may occur.*

HEI

## ACES Health Effects Studies

- Phase 3A: Develop combined emissions and animal exposure facility, verify emissions and exposure accuracy
- Phase 3B: Biological screening assay in mice and rats
  - Core health effects study
  - Cancer and noncancer endpoints; short and long term
- **Progress Phases 3A and 3B:**
  - Facility development underway at Lovelace Respiratory Research Institute (LRRRI) – Joe Mauderly Principal Investigator
  - Potential additional investigators identified for specialized short-term biological screening endpoints in Phase 3B
- Phase 3C (*still under development*): Additional Studies that add value but cannot be accommodated within the chronic bioassay
  - Compare new engine with aged engine exposures (e.g. genotoxicity)
  - Studies with special procedures or animal models
  - Noncancer effects



## Long- and Short-Term Biological Screening and Health Testing (Phase 3B)

- Core ACES Health Testing at LRRRI:
  - Rats exposed for 24 or 30 months; interim sacrifices at 1, 3, 12, 24 months
  - Mice exposed for 3 months, with an interim sacrifice at 1 month.
- To be done by Lovelace:
  - Rats only: chronic toxicity, including carcinogenicity (Health Endpoints similar to Standard NTP endpoints); pulmonary function testing
  - Rats and mice: pulmonary inflammation, oxidative damage, cell proliferation in respiratory tract tissue



## Long- and Short-Term Biological Screening and Health Testing (Phase 3B)

- Additional endpoints in animals allocated to intermediate sacrifices and unassigned animals; to be done by other competitively selected teams:
  - Genotoxicity measurements:
    - micronucleus formation (indicator of genetic damage—double-strand DNA breaks, interference with chromosome segregation),
    - DNA damage (Comet assay),
    - gene expression related to cell cycle control,
    - DNA damage repair pathways, and
    - cell damage
  - Vascular inflammation measurements:
    - systemic inflammation, thrombosis, and vascular inflammation (more specifically: acute-phase reactants, thrombotic markers in blood, vascular expression of adhesion molecules and oxidative stress in vascular tissues)



## Phase 3: Current Schedule

- Development of engine/exposure facility to be completed late spring 2008
- Engines to be delivered late spring 2008
- Exposure generation trials, system validation Summer 2008
- Start of rat and mouse exposures (staggered) Fall 2008
- Interim sacrifices; potential report of shorter term exposures
- Final sacrifice of rats Spring 2011
- Final Report submitted to HEI Review Committee Summer 2011
- Projected publication Fall 2012



## HEI ACES Oversight Committee

Mark Utell, Chair	University of Rochester	David Kittleson	University of Minnesota
Richard Albertini	University of Vermont	Eugene McConnell	Consultant, Former NTP Director
Melvyn Branch	Colorado University	Gunter Oberdorster	University of Rochester
Helmut Greim	Technical University of Munich	Charles Plopper	UC Davis
Ken Demerjian	SUNY Albany	Howard Rockette	University of Pittsburgh
Tom Kensler	Johns Hopkins University		

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