DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE — U.S. DEPARTMENT OF ENERGY — DEER 2010 DETROIT

High Efficient Clean Combustion for SuperTruck

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Principal Investigator

September 29, 2010

Work Supported by DoE

DoE Technology Development Manager: Roland Gravel

Changing the Climate on Climate Change

Outline

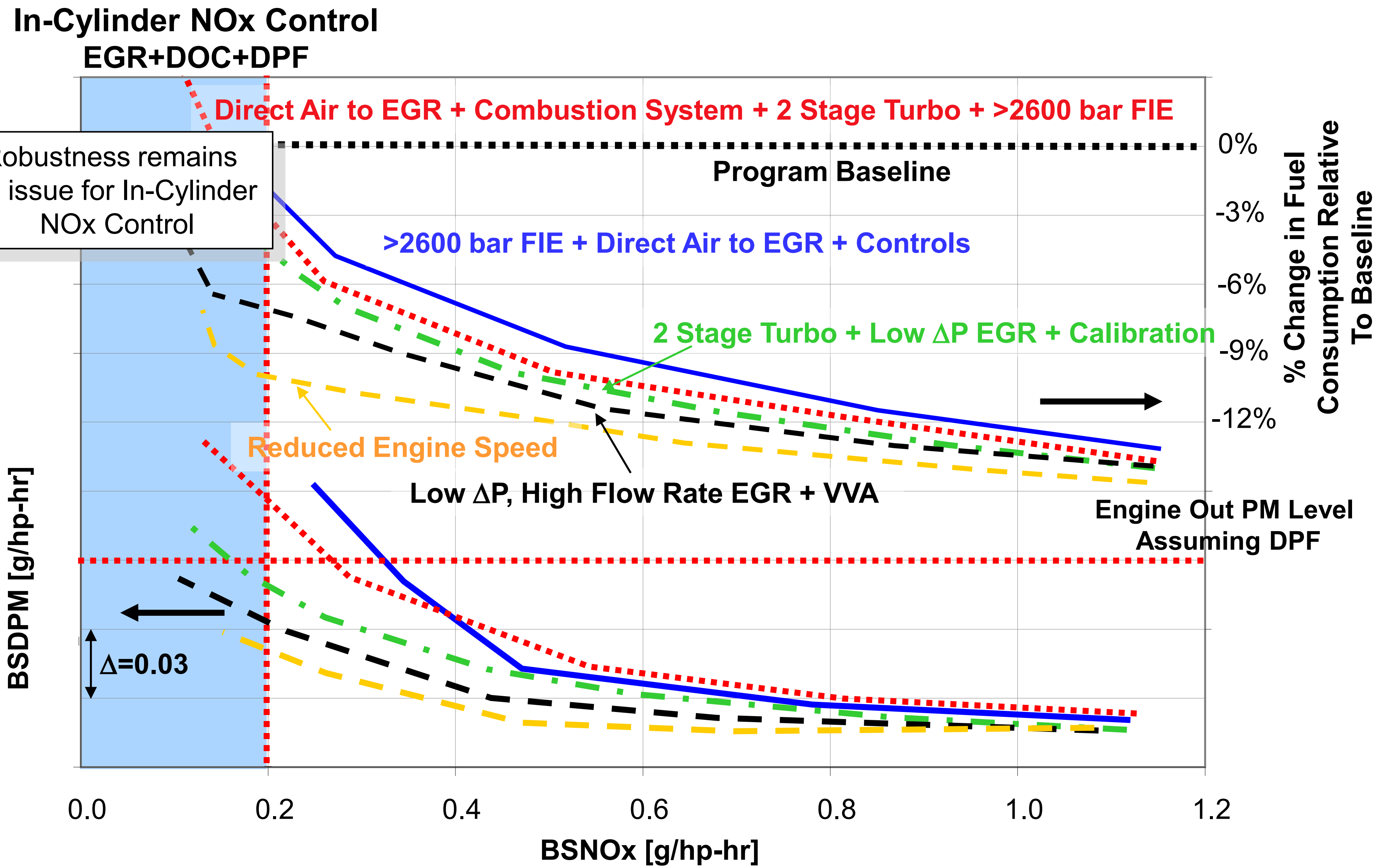
- Achievements of HECC and WHR Programs
- SuperTruck Program
  - Objectives
  - Team Members
  - Technologies
  - Schedule
- Summary / Q&A

HECC Program Objectives

(October 2005 – March 2010)

1. Improve brake thermal efficiency by 10% while meeting US EPA 2010 emissions
   - Baseline - engine meeting 2007 US EPA regulations
2. Design and develop enabling components and subsystems (air handling, fuel injection, base engine, controls, aftertreatment, etc.)
3. Specify fuel properties conducive to improvements in emissions and fuel efficiency
4. Vehicle integration for fuel economy optimization

HECC: Achieving In-Cylinder NOx Control with Improved Efficiency



Reference: Stanton, 2009 DEER Conference

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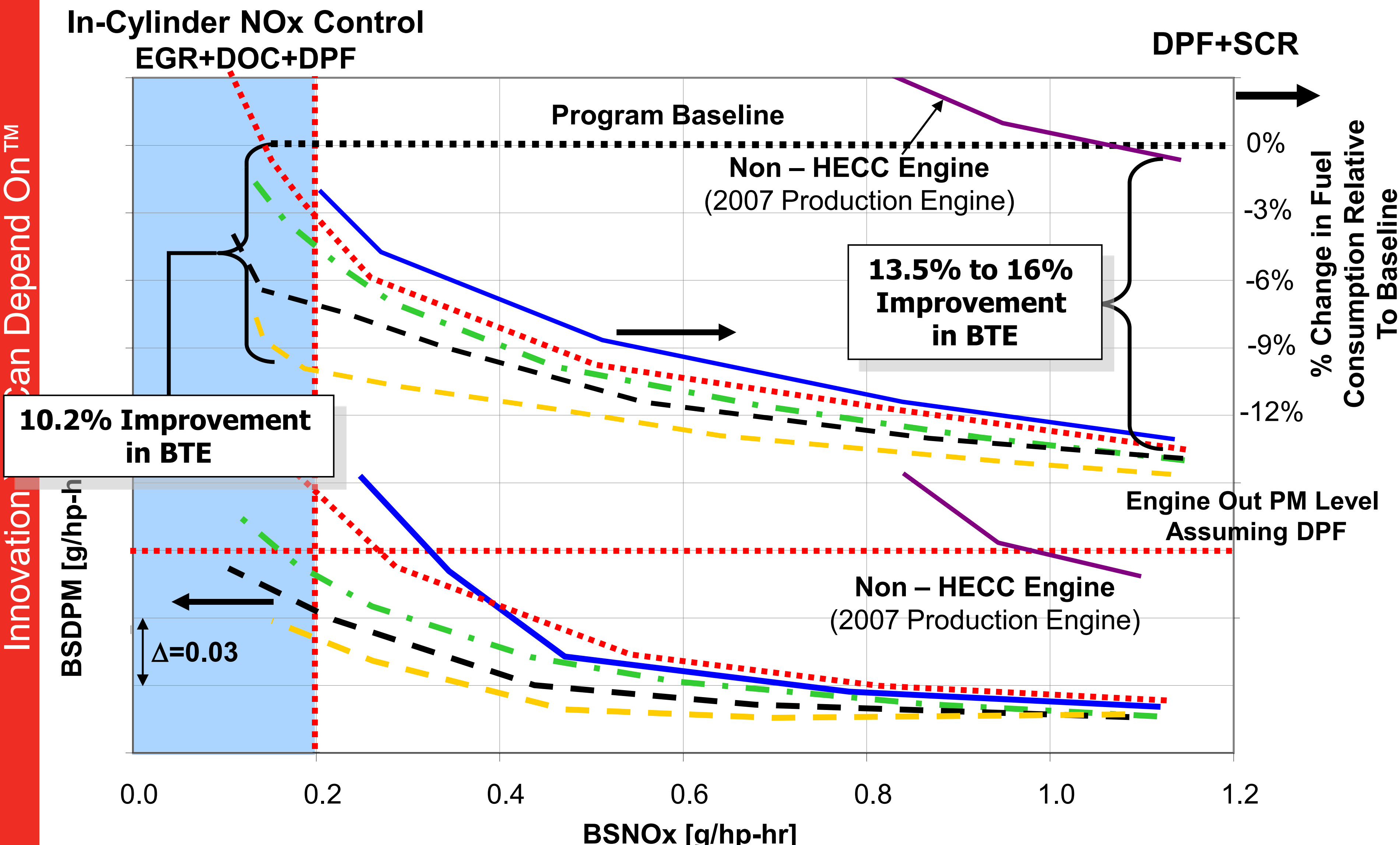

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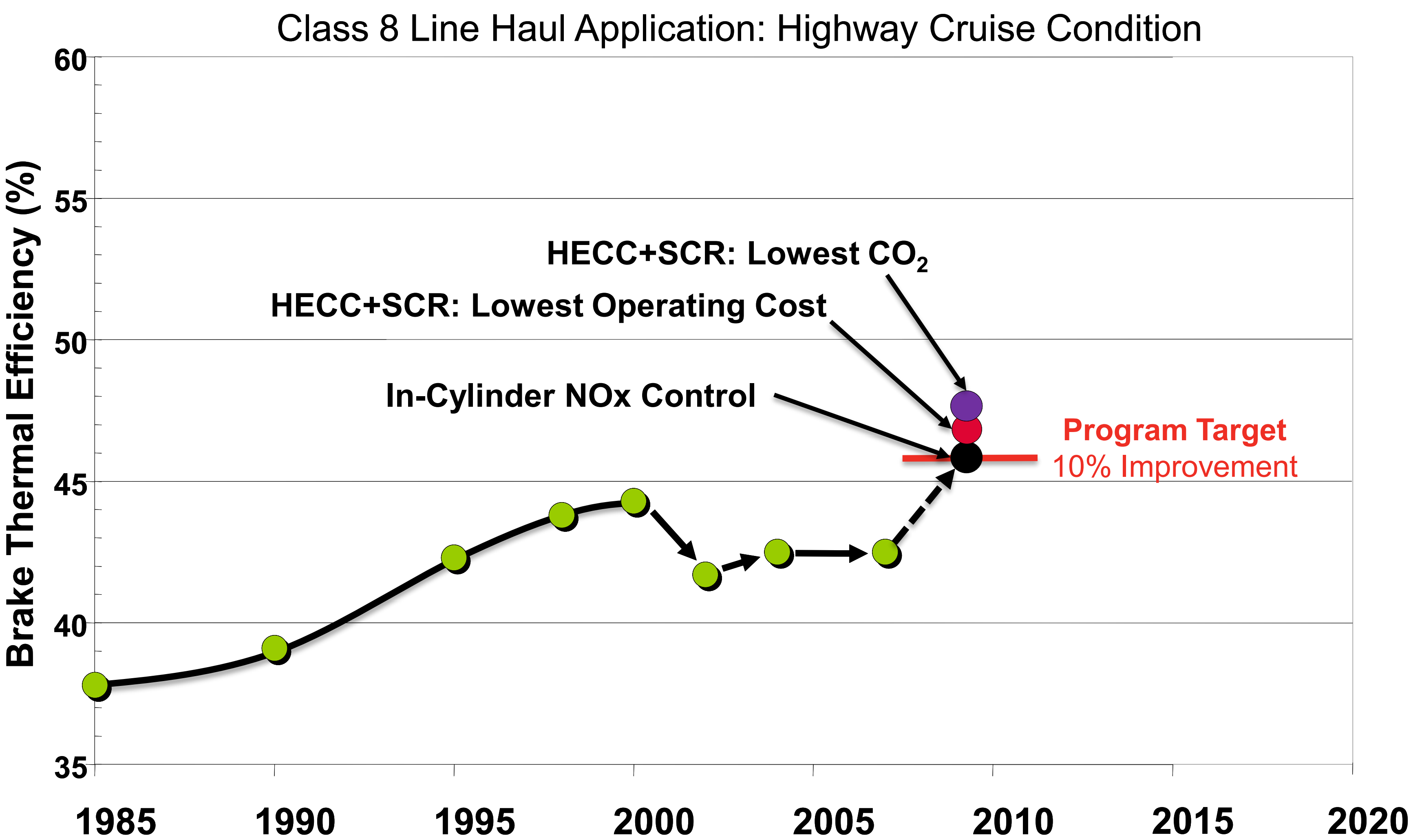
HECC Engine Efficiency Improvements



Waste Heat Recovery Program Objectives

(October 2005 – March 2010)

1. Improve brake thermal efficiency by 10%
   - Baseline – engine meeting 2007 US EPA regulations
2. Reduce the need for increased vehicle heat rejection capacity for Class 8 line haul applications
   - Helps maintain aerodynamic design of the tractor

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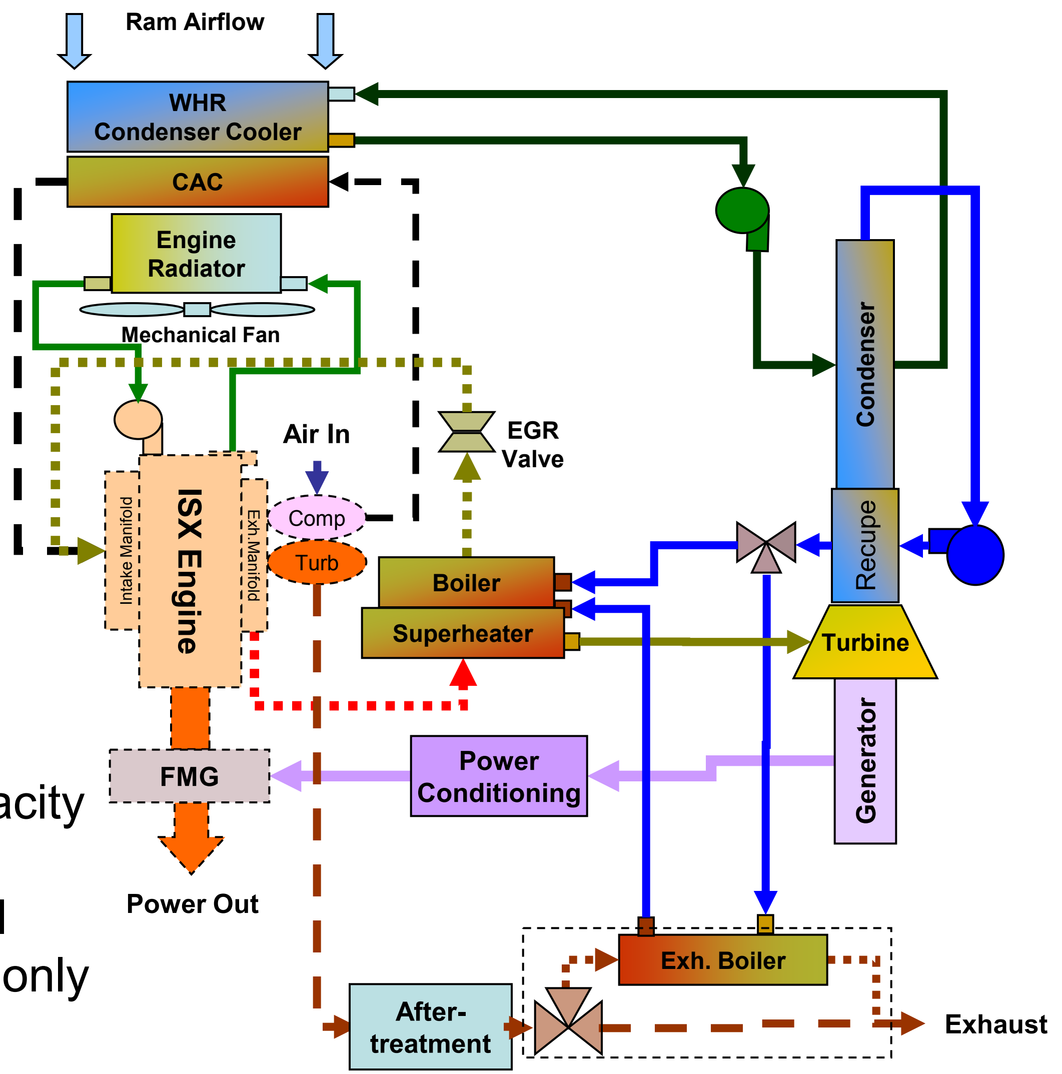
Generation 1 WHR: Electrical ORC

6% from EGR energy

+ 2% from Exhaust

+ 2% from Electric Acc.

10% Improvement

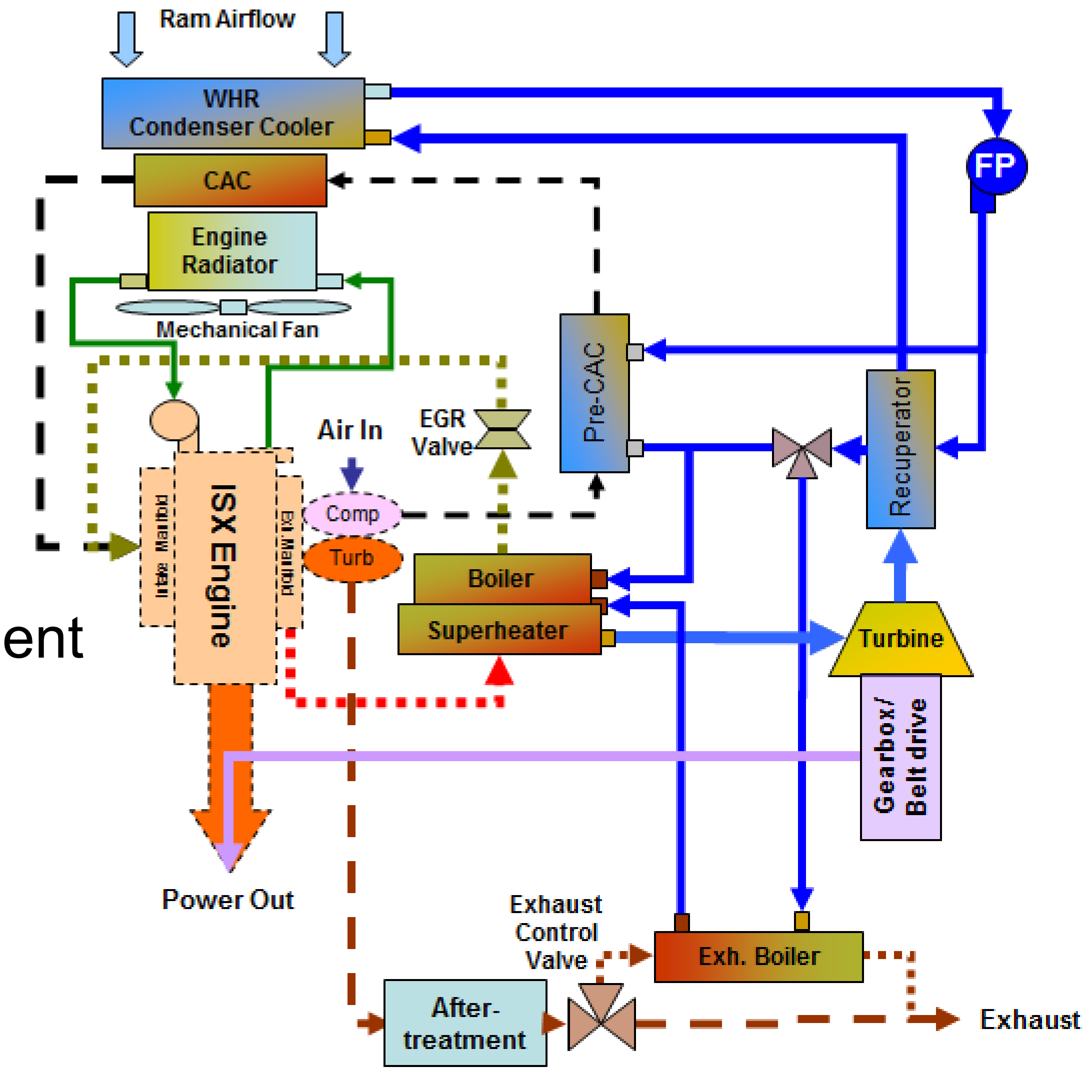


- **No NOx Aftertreatment**: 8% fuel efficiency improvement from WHR only with 2007 vehicle cooling capacity
- **SCR NOx Aftertreatment**: 6% fuel efficiency improvement from WHR only with 2007 vehicle cooling capacity

Reference: Nelson, 2009 DEER Conference

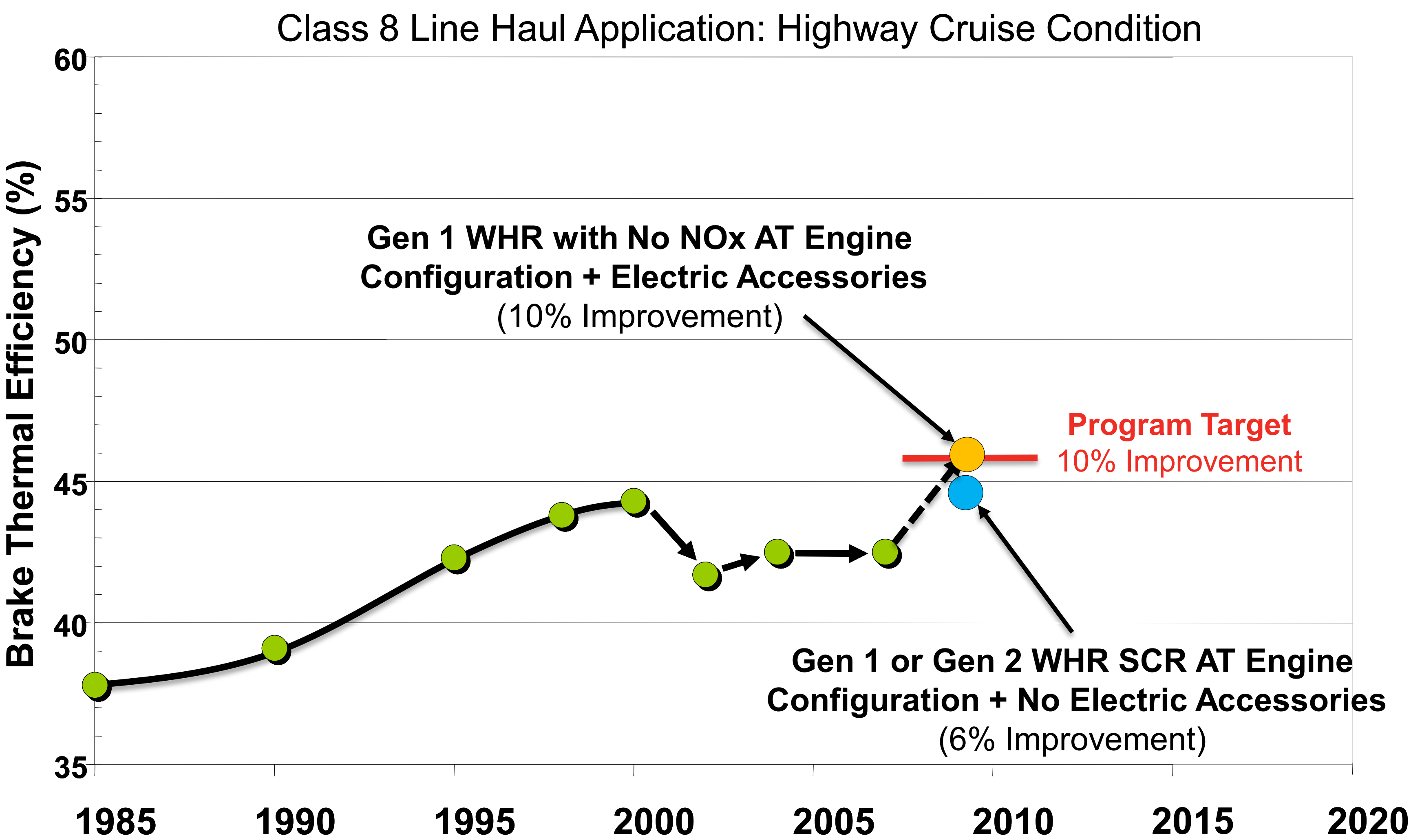
Generation 2 WHR: Mechanical ORC

- Sources of energy
  - EGR
  - Charge Air
  - Exhaust heat
- Mechanical coupling of WHR power to engine
- Fuel Economy improvement of ~6% for SCR engine architecture

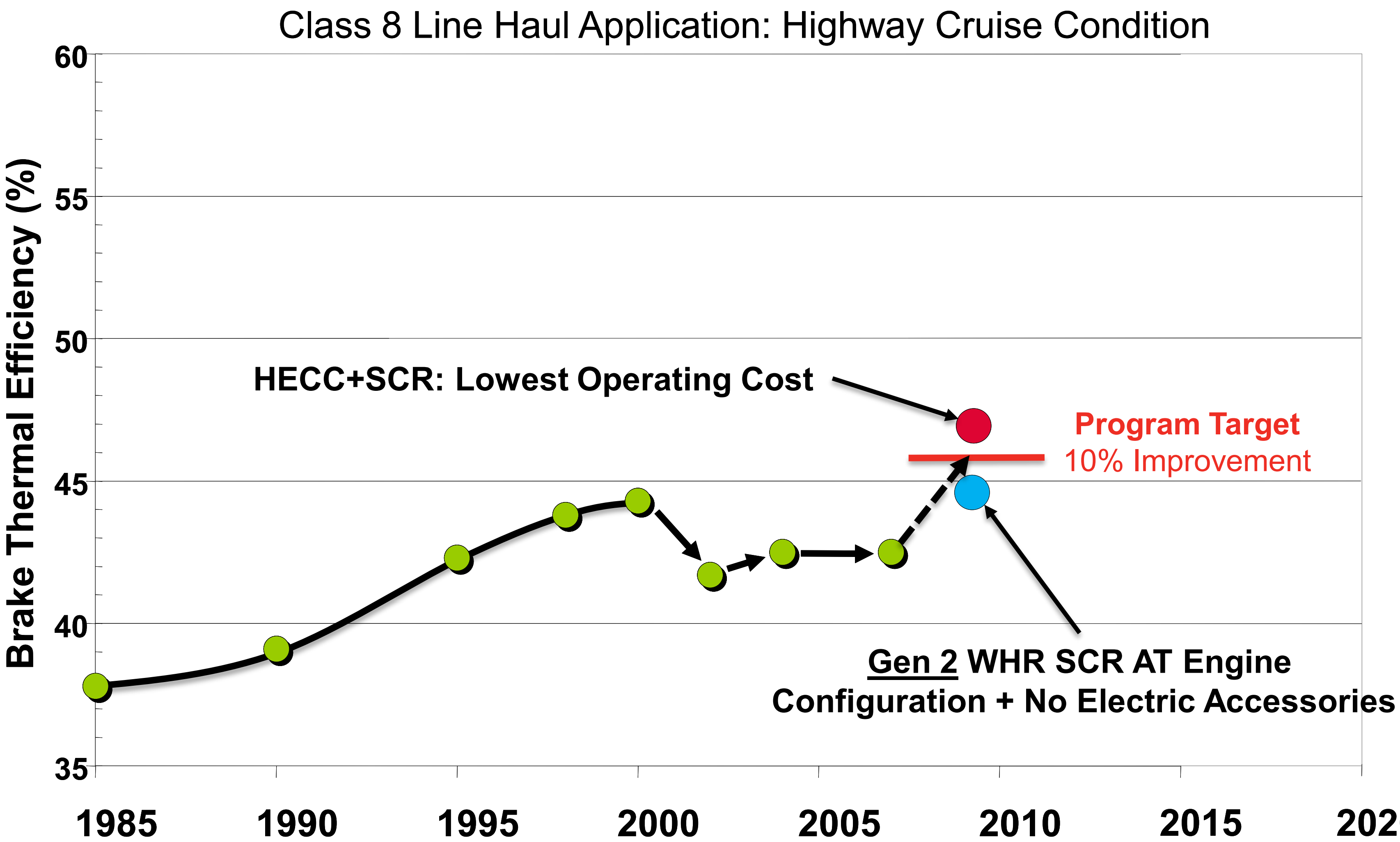


Reference: Nelson, 2009 DEER Conference

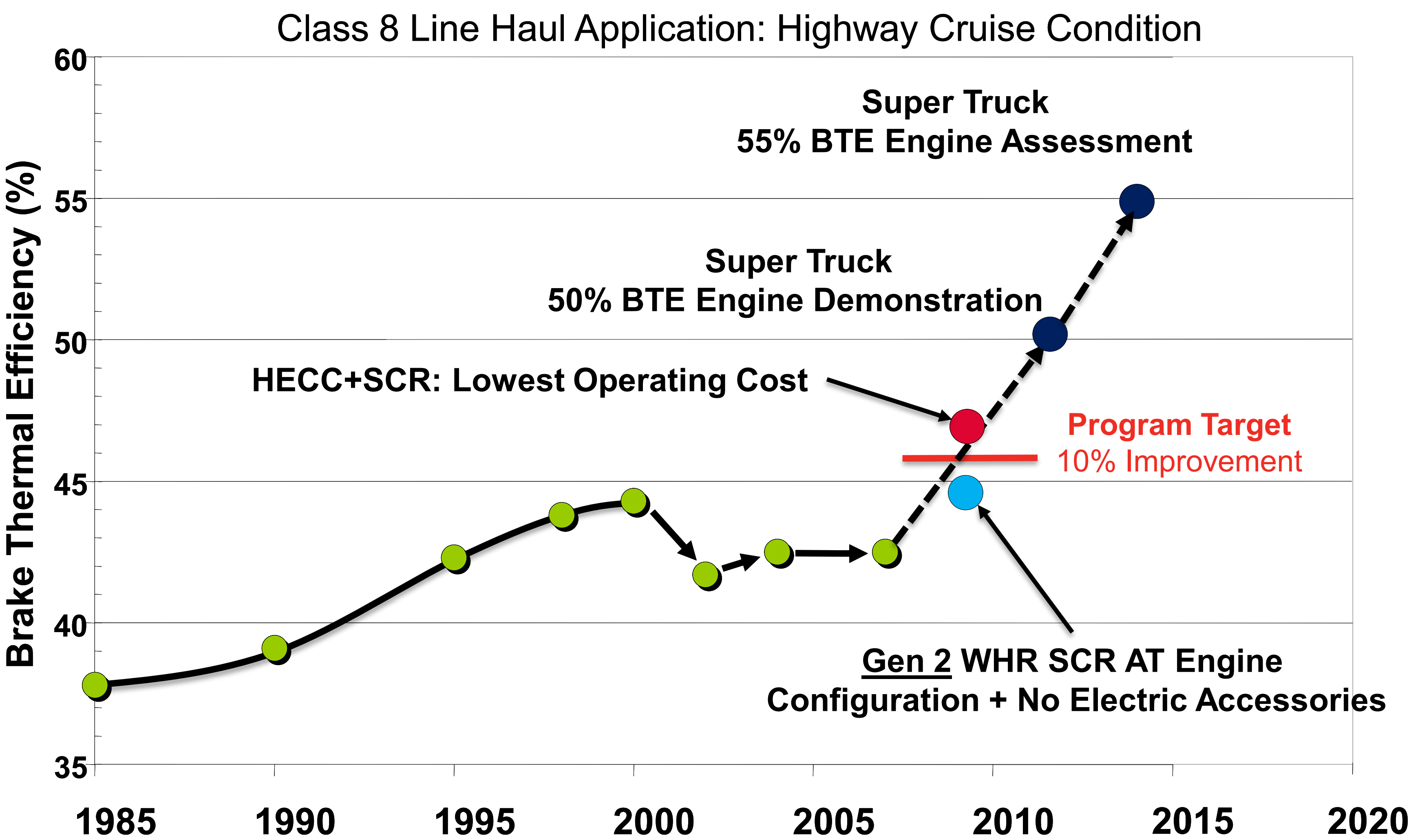
WHR Engine Efficiency Improvements



Engine Efficiency Improvements



Engine Efficiency Improvements



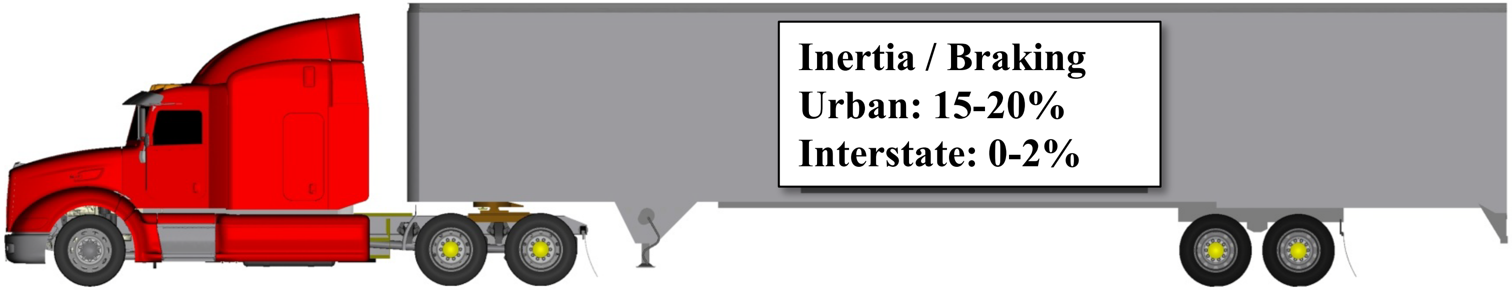
SuperTruck Program Objectives

- 50% increase in vehicle freight efficiency (ton – miles per gallon)
- 20% improvement through engine efficiency development – 50% BTE under highway cruise conditions
- Pathways to 55% BTE in engine lab.

Comprehensive Approach to Fuel Consumption and CO_2 Reduction

Engine Losses
Urban: 58-60%
Interstate: 58-59%

Aerodynamic Losses
Urban: 4-10%
Interstate: 15-22%



Inertia / Braking
Urban: 15-20%
Interstate: 0-2%

Auxiliary Loads
Urban: 7-8%
Interstate: 1-4%

Drivetrain
Urban: 5-6%
Interstate: 2-4%

Rolling Resistance
Urban: 8-12%
Interstate: 13-16%

SuperTruck Program Participants

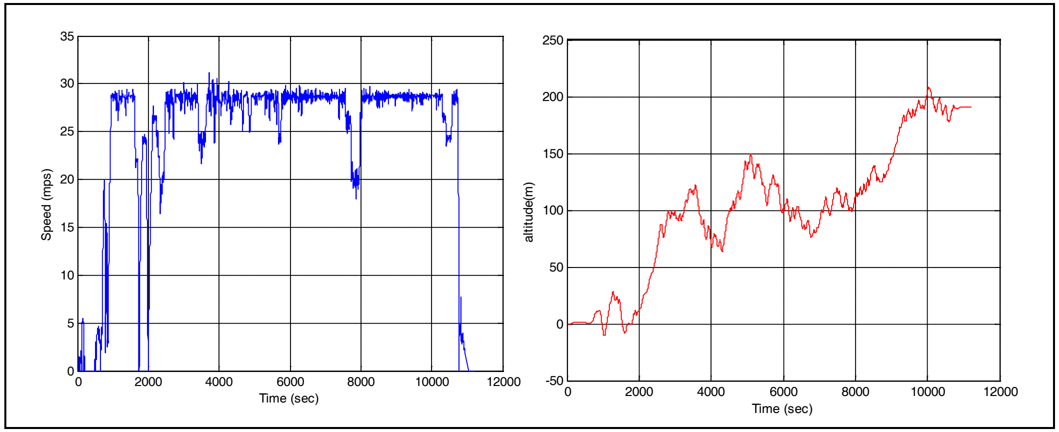
Program Lead

Cummins Inc.
- Cummins Fuel Systems
- Cummins Turbo Technologies
- Cummins Emissions Solutions
- Cummins Electronics
- Cummins Filtration
- Modine
- VanDyne SuperTurbo Inc.
- Oak Ridge National Lab.
- Purdue University

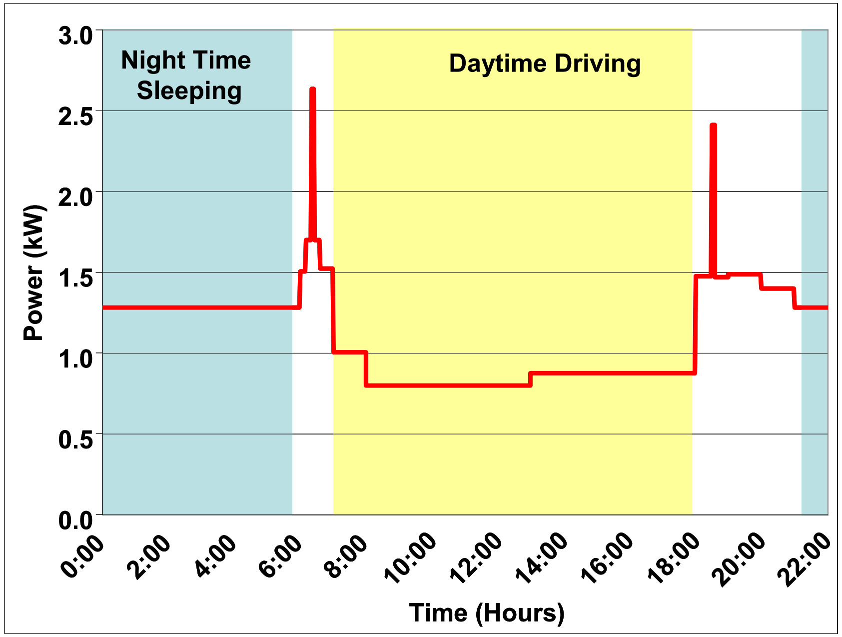
Peterbilt Motors Company
- Eaton
- Delphi
- Modine
- Utility Trailer Manufacturing
- Bridgestone
- Dana
- U.S. Xpress

Vehicle Demonstrations of Freight Efficiency

- **Vehicle Demonstration #1 – Drive Cycle**
  - 75% at highway cruise
  - Gentle rolling hills
  - 11 hours of driving



- **Vehicle Demonstration #2**
  - 24 hour duty cycle
  - Extended Idle
  - No-idle compliant technology
  - Power demand < 3kW
  - Active power management



Vehicle Freight Efficiency Path to Target

	Drive Cycle Vehicle Demonstration	24 Hour Duty Cycle Vehicle Demonstration
Technology	**Freight Efficiency Improvement (%)**	**Freight Efficiency Improvement (%)**
Vehicle Aerodynamics	Harmonized Tractor-Trailer	Harmonized Tractor-Trailer
Engine	WHR, Low Temperature Combustion, Base Engine, AT, etc..	WHR, Low Temperature Combustion, Base Engine, AT, etc.
Transmission/ Road Load Management	Advanced Transmission, GPS, Adaptive Cruise, Driver Feedback	Advanced Transmission, GPS, Adaptive Cruise, Driver Feedback
Rolling Resistance	Robustness to wear, low resistance	Robustness to wear, low resistance
Axles	Smart axle technology	Smart axle technology
Idle Management	N/A	Solid Oxide Fuel Cell APU
Total	**50%**	**> 50%**

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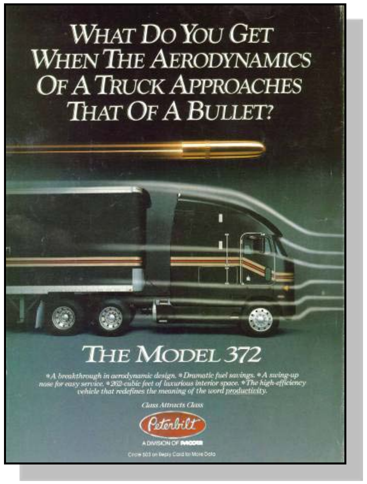
Harmonized Tractor – Trailer Aerodynamics



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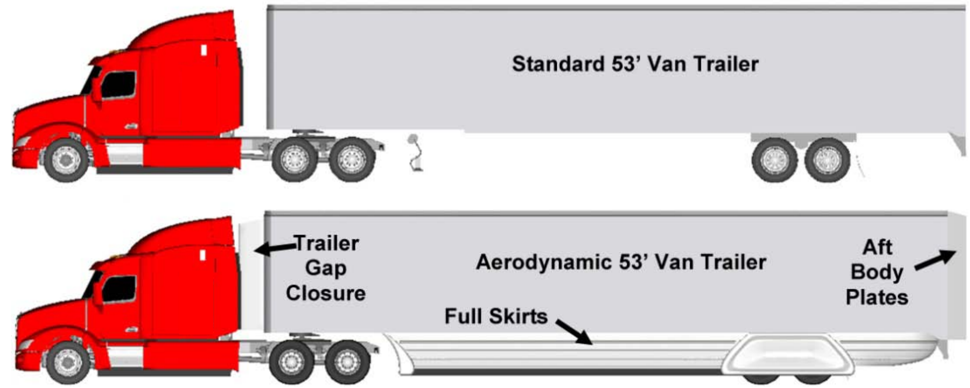

1958

Cd = ~0.85

1999

Cd = ~0.55

Model 386

Model 587

Aerodynamic Improvement Evolution

SuperTruck Effort

- **Will meet 50% freight efficiency improvement with technology that adheres to current transportation rules, regulations and existing transportation infrastructure**
- **Explore technologies that leverage changes in existing rules and regulations**

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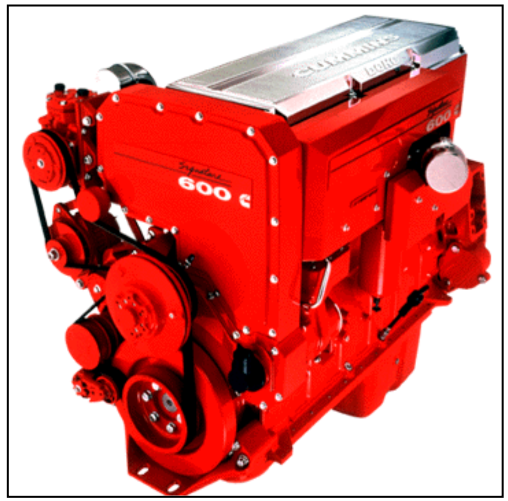
ISX Technology Roadmap for Efficiency Improvement

Base Engine
-PCP
- Friction/Parasitics

Fuel System

Advanced LTC

Variable Valve Actuation



Controls

EGR Loop

Electrically Driven Components

Turbo Technology

Aftertreatment

Waste Heat Recovery

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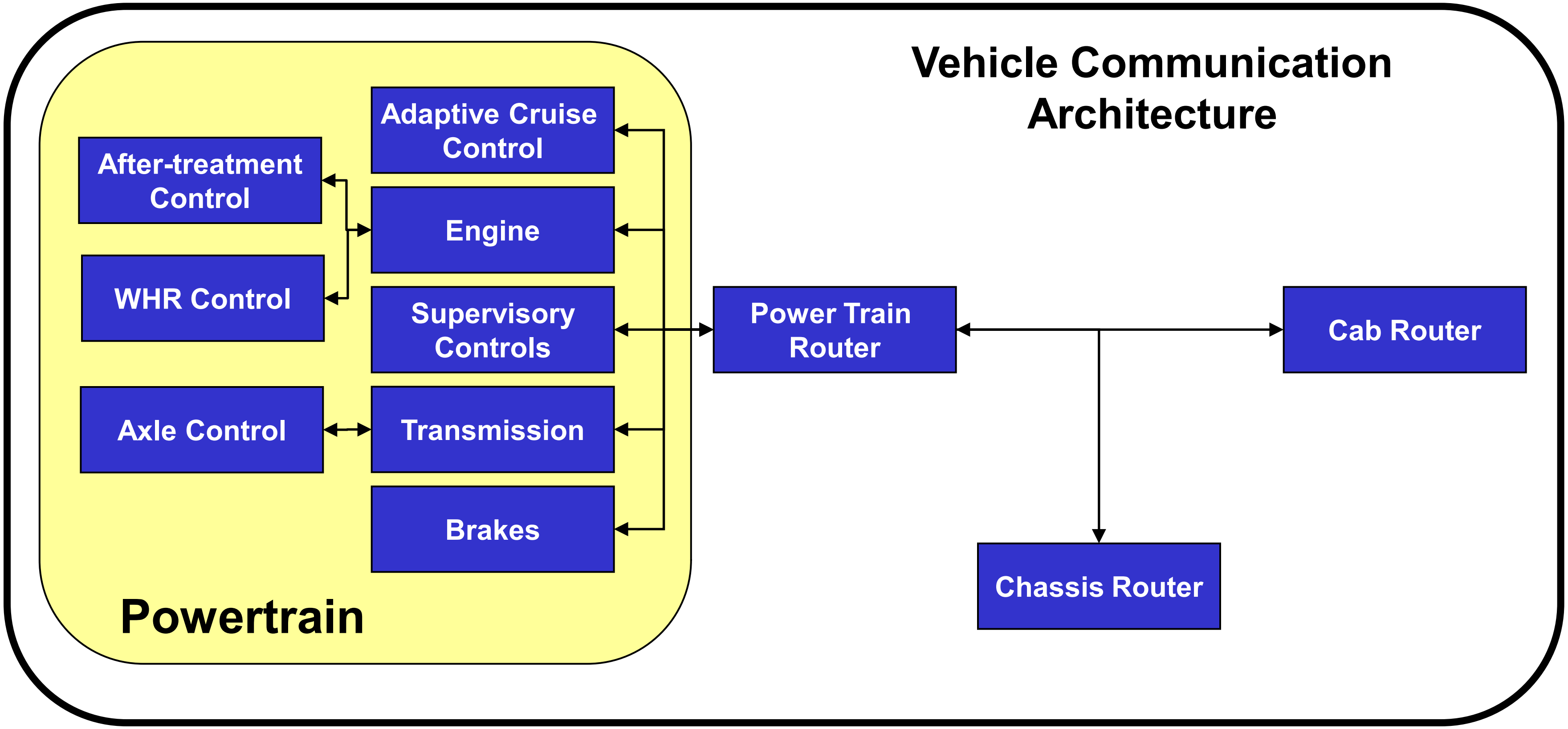
Vehicle and Powertrain Electronics Communication Architecture



- Establish requirements for future vehicle communication architecture
- New level of vehicle and powertrain optimization for fuel efficiency
- Provide additional customer value

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Acknowledgements

- HECC work supported by the Department of Energy under Award Number DE-PS26-04NT42099-01
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- DoE Technology Development Manager: Roland Gravel

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