# SuperTruck

**Development and Demonstration of a Fuel-Efficient Class 8 Highway Vehicle**

## Vehicle Systems

DOE Contract: DE-EE0004232

P.I.: Pascal Amar, Volvo Technology of America

**2012 Annual Merit Review**

**Washington, DC**

**May 16, 2013**

Project ID: VSS081

# Project Overview

## Timeline

Start: June 2011

End: June 2016

*37% complete*

## Barriers

- Cost effective & timely evaluation of advanced components and configurations
- Availability of high resolution computational models & simulation methods

## Budget

Total Cost: $37.99M

Cost share: $19.07M

FY12 funding: $4.40M

FY13 funding: $3.78M

## Team

**Lead**: Volvo Technology of America

**Partners:** VOLVO, Grote, PENNSTATE IBSS, FREIGHT WING

# Relevance

- **In support of DOE's mission**

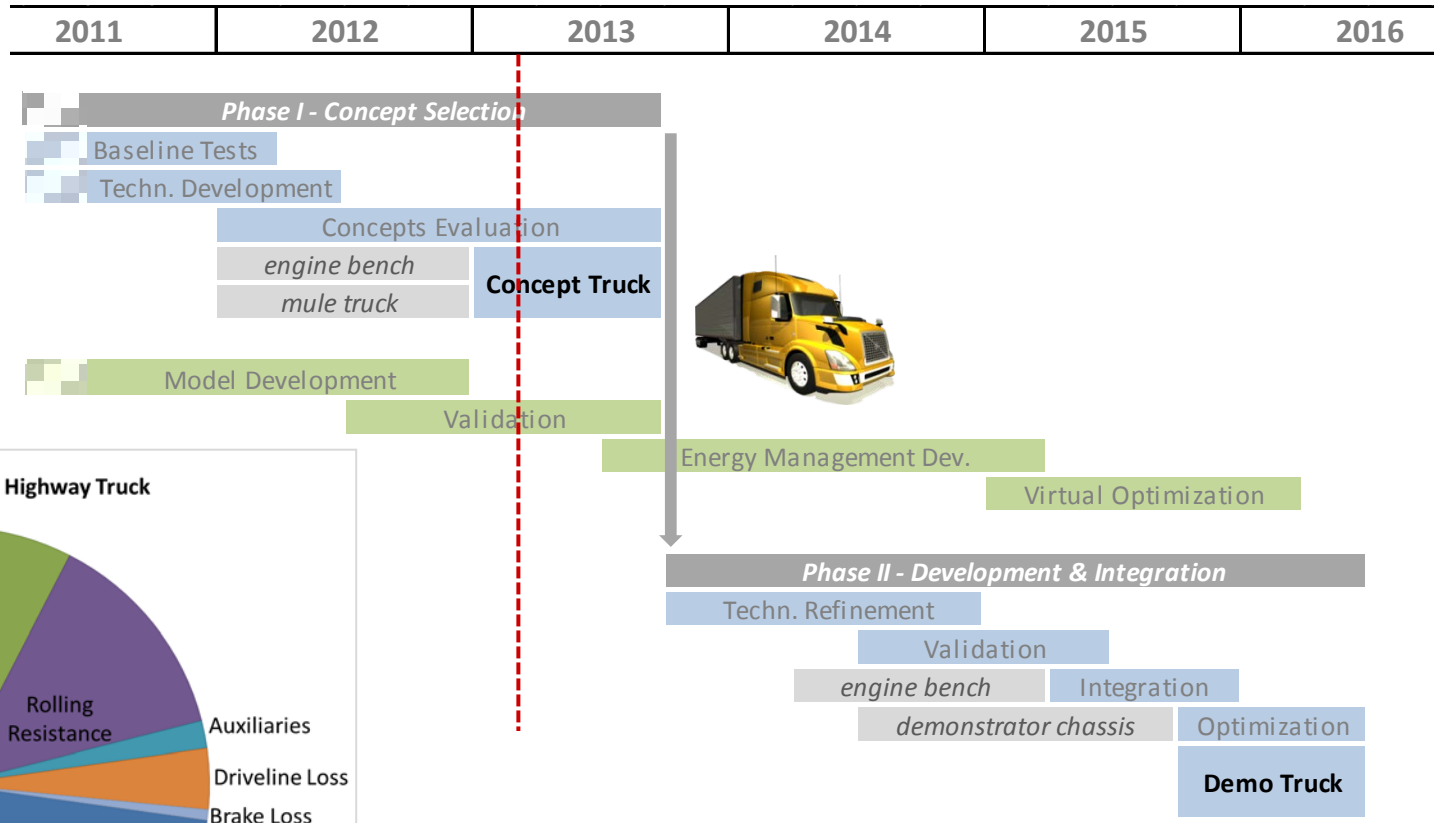
*"[…] more energy efficient and environmentally friendly highway transportation […]"*

- **Project Objectives**

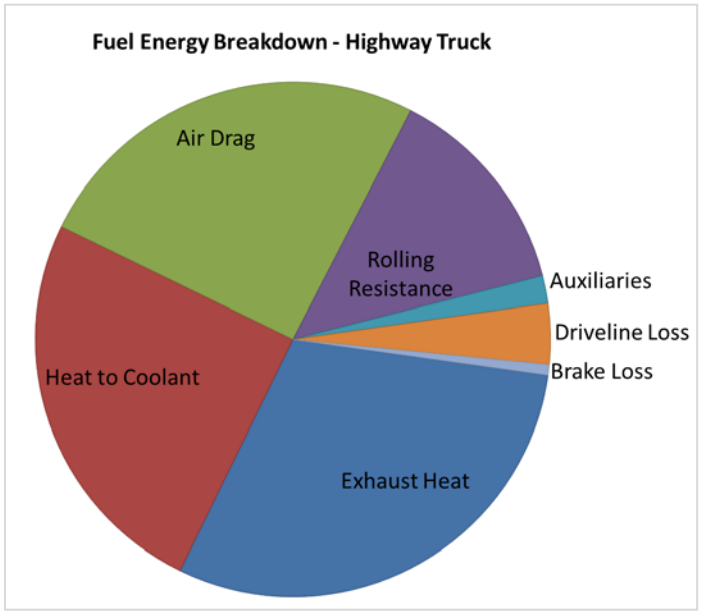
| | |
|---|---|
| Objective 1 | 50% more ton-miles per gallon than a 'best in class' 2009 truck |
| Objective 1a | 50% Brake Thermal Efficiency |
| Objective 2 | 55% Brake Thermal Efficiency Concept |

- **Reporting Period Objectives**
  - Validate and deploy analytical tools
  - Implement new technologies on concept vehicle for evaluation
  - Prepare for final technology selection (Phase I)

# Approach - Concept selection






Identify and evaluate the most promising technologies

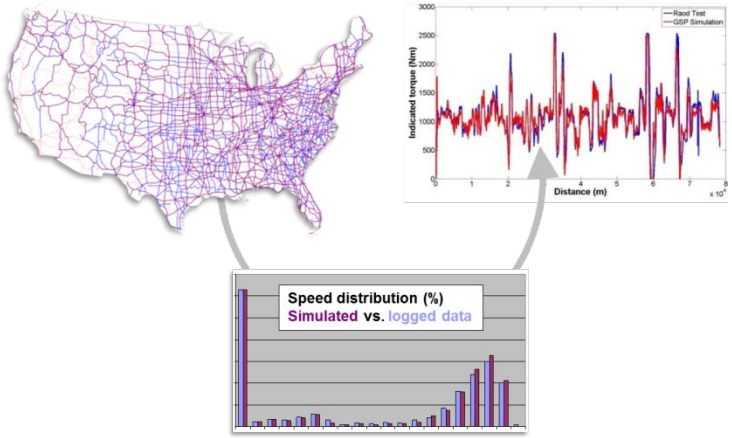
VOLVO FREIGHT WING Grote PENNSTATE

# Approach - System Simulations

- **Complete Vehicle Simulation Platform**
  - Predict the effect of component improvements on the energy efficiency of the complete vehicle
- **Complete Vehicle Aerodynamics**
  - Optimize complete vehicle geometry
  - Balance powertrain & aero requirements

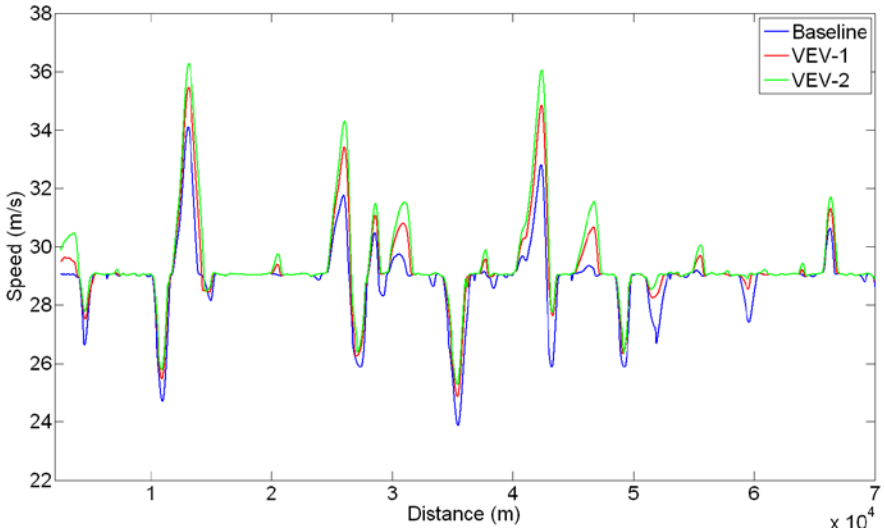
"Optimizing the parts will not optimize the whole."

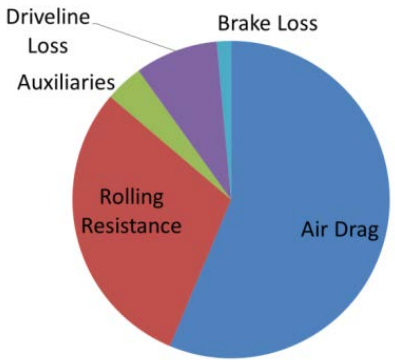
*Systems Engineering Fundamentals*
*Ford Motor Company*

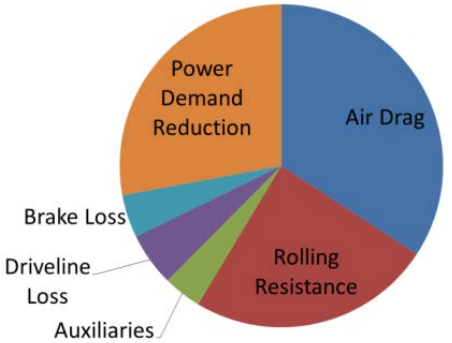



- Quantify powertrain performance requirements
- Predict fuel impact of new technologies
- Evaluate concepts under real-world conditions

# **Accomplishments** - System Simulations

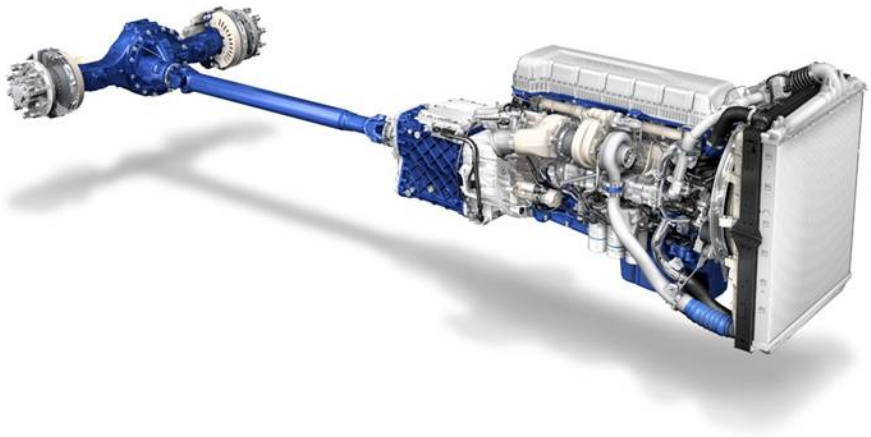


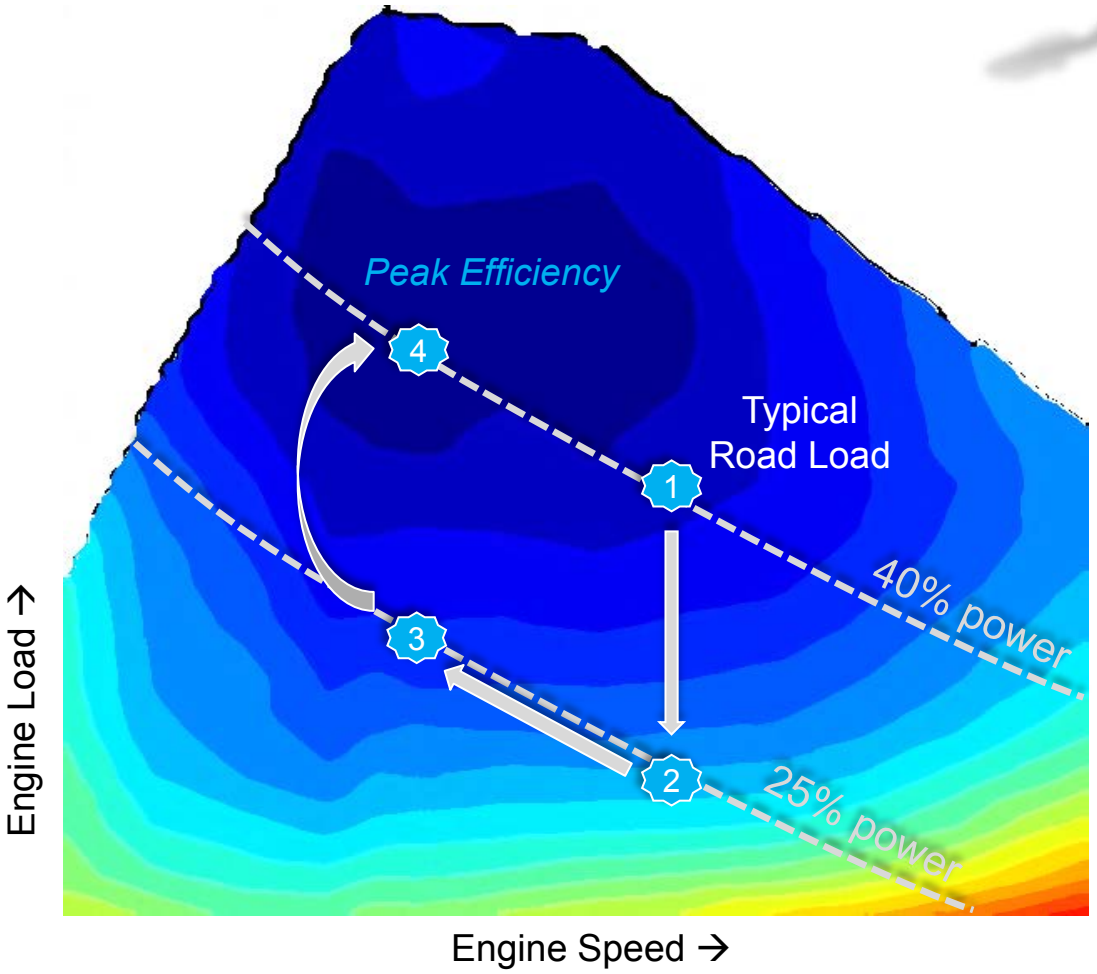




- Average power demand is reduced significantly as a result of reduced friction and drag forces
- Increased benefit of predictive vehicle controls
- Increased potential for complete vehicle energy management solutions, including kinetic energy recovery systems

# **Approach** - Engine "right-sizing"



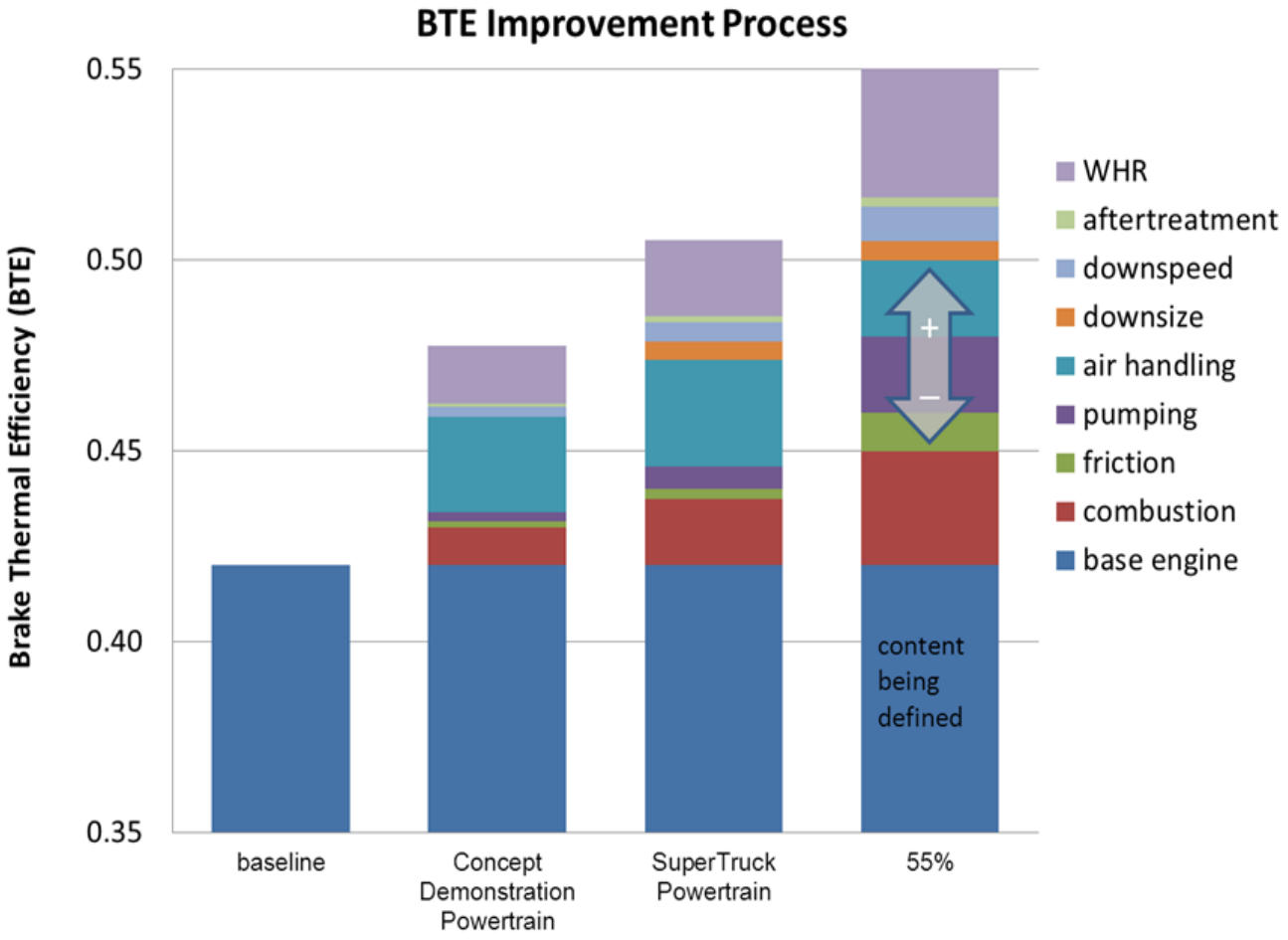



Design powertrain for updated load requirements:

- 1 → 2: Aero improvements
- 2 → 3: Downspeeding
- 3 → 4: Downsizing

→ *Optimized over-the-road engine thermal efficiency*

# **Approach** - Powertrain Improvements




- Evaluate technologies that enable 50% engine thermal efficiency
- Select powertrain system concept for optimal efficiency
- Integrate powertrain system in concept vehicle and evaluate performance on customer duty cycle

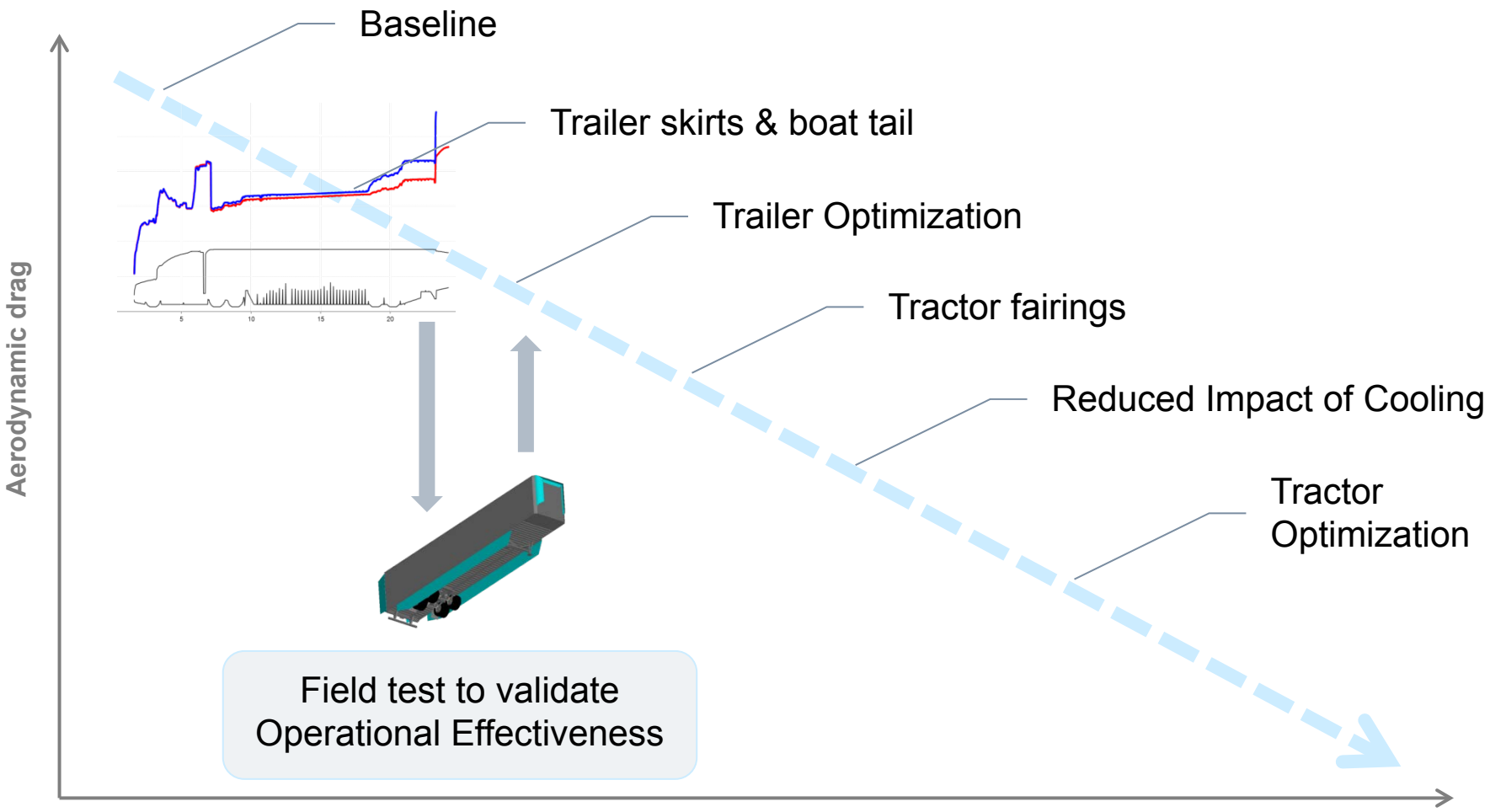
# Accomplishments - Engine Efficiency

- Turbocompound
- Rankine WHR gen.1
- Friction reduction
- Improved cooling circuit
- Improved oil circuit
- New combustion chamber
- High press. fuel injection
- Downspeeding
- Improved aftertreatment

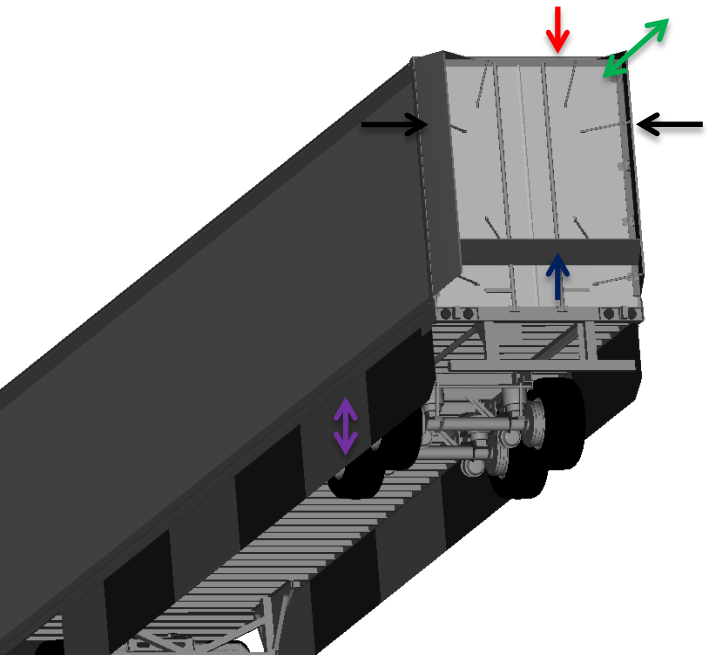



- Demonstrated 48% Brake Thermal Efficiency of integrated powertrain system in test cell 1.5 years ahead of schedule
- Chassis installation on-going for evaluation on-road, expected fuel economy impact 8-10%

# **Approach** - Aero Improvements

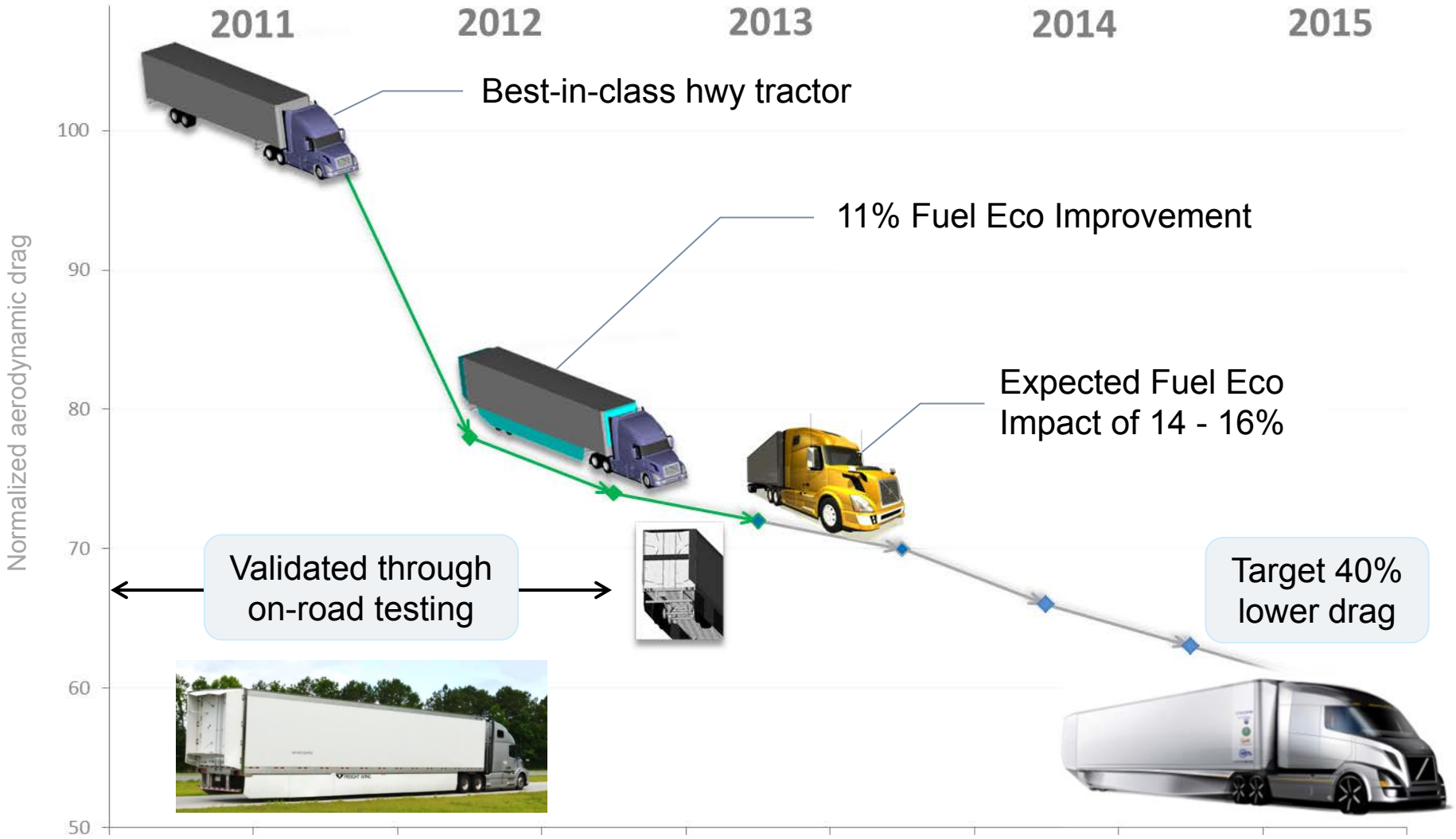


# Accomplishments - Trailer Optimization



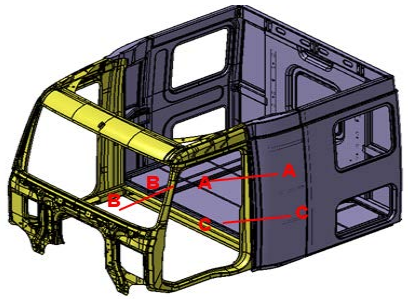
- Optimized key parameters of tail and skirts through CFD simulations
- Produced devices for optimum geometry and installed on test trailer
- Validation road test scheduled for next quarter

# **Accomplishments** - Aero Improvements

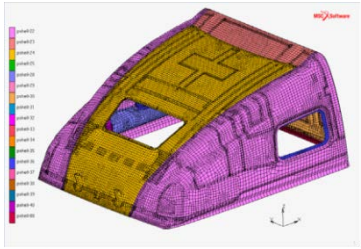


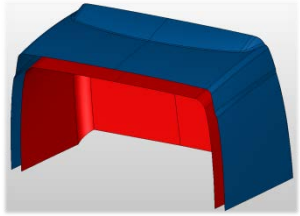
# **Approach** - Weight Reduction

- **Aluminum/Steel cab concept**
  - Minimize impact on assembly methods
  - Maintain structural strength & mechanical properties



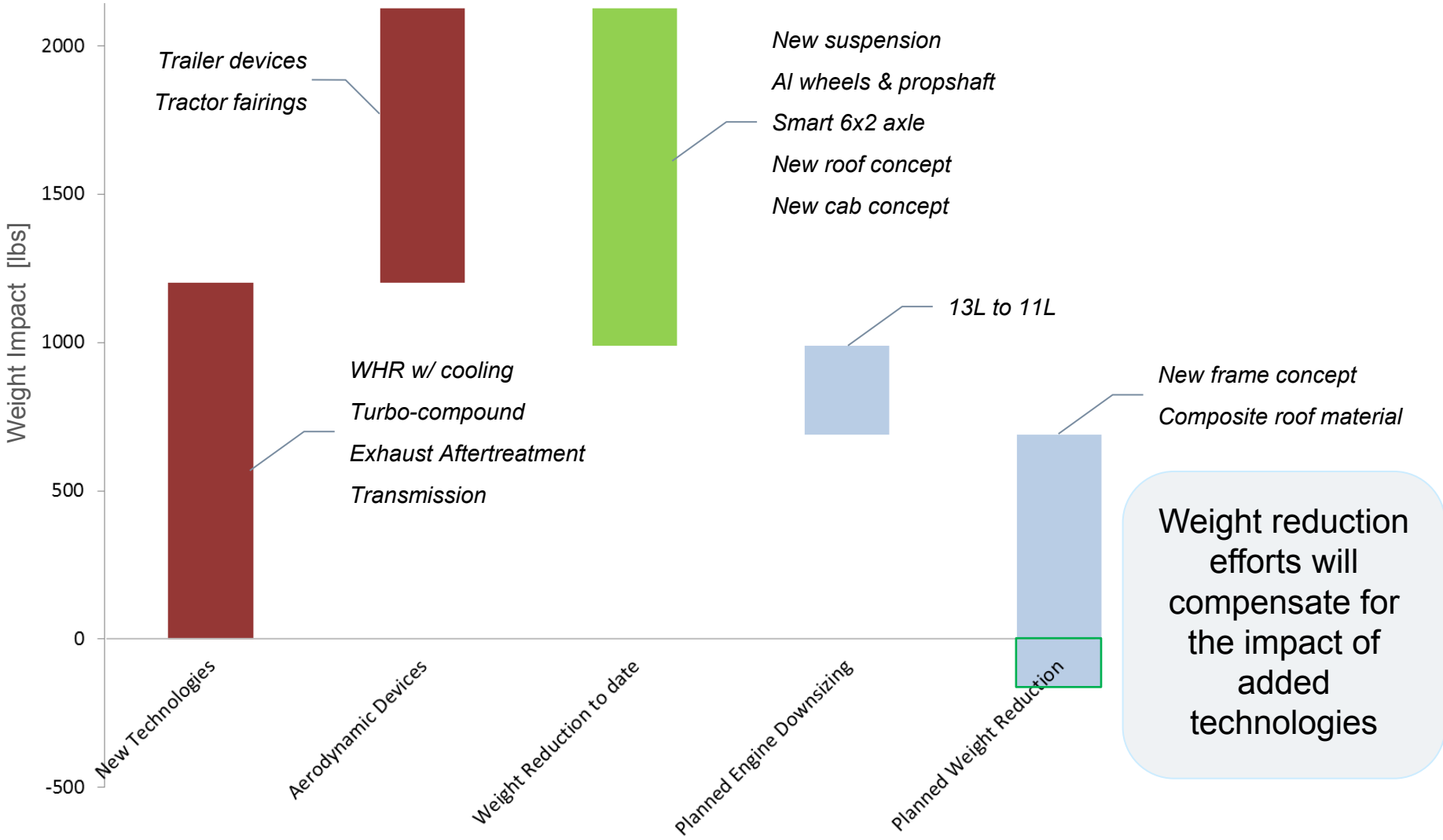

- **New roof concept**
  - Reduce weight & parts though structural simplification
  - Incorporate new materials & bonding methods





- **Coming up… new frame concept**
  - Evaluating several design paths for lightweight frame, goal > 600lb lighter

# Accomplishments - Weight Reduction




Weight reduction efforts will compensate for the impact of added technologies

# **Approach** - Reduced Parasitic Losses

- Improve component efficiency
- Implement intelligent controls
- Maximize benefit of new technologies through complete vehicle integration
- Enabler for idle-free hotel mode

Reduced Duty Cycle

Improved Components

Integrated Energy Mgt

Predictive Controls

*Vehicle Efficiency Increase*

# Accomplishments - Electrical Loads

| Lamp Function | Baseline (Incadescent) Current [A] | Baseline (Incadescent) Wattage at 12.8V | SuperTruck LED System Current [A] | SuperTruck Wattage at 12.8V | Power Saved per Function [W] |
|---|---|---|---|---|---|
| Marker | 3.2 | 41.3 | 0.46 | 5.8 | 35.5 |
| Tail, License | 4.8 | 61.9 | 0.28 | 3.5 | 58.4 |
| Stop | 4.3 | 54.6 | 0.93 | 11.9 | 42.6 |
| Right Turn | 4.3 | 54.5 | 0.52 | 6.7 | 47.8 |
| Left Turn | 4.2 | 54.1 | 0.52 | 6.7 | 47.4 |
| Totals | 21 | 266 | 3 | 35 | 232 |

| Lamp Function | Baseline (Incadescent) Current [A] | Baseline (Incadescent) Wattage at 12.8V | SuperTruck LED System Current [A] | SuperTruck Wattage at 12.8V | Power Saved per Function [W] |
|---|---|---|---|---|---|
| High Beam | 11 | 140.8 | 4 | 51.2 | 89.6 |
| Low Beam | 9 | 115.2 | 3 | 38.4 | 76.8 |
| Front Turn | 4.2 | 53.8 | 1 | 12.8 | 41.0 |
| Front Park | 0.54 | 6.9 | 0.2 | 2.6 | 4.4 |
| Driving | 7.4 | 94.7 | 2.8 | 35.8 | 58.9 |
| Fog | 6 | 76.8 | 2 | 25.6 | 51.2 |
| Totals | 38 | 488 | 13 | 166 | 322 |


- Verified power savings of high-efficiency lighting systems w/ LED lights & LightForm
- Estimated fuel savings > 100Gal/year/truck
- * SAE Paper 2013-01-0753

# **Future Work** (next reporting period)

- Complete retrofit and commissioning of concept vehicle next quarter
- Perform dyno and on-road tests during summer to verify freight efficiency improvements

- Launch field test of trailer aerodynamic devices

→ Freeze concept selection and ramp up development of final demonstrator

  - Next generation components
  - Full vehicle integration incl. Hotel Mode
  - Advanced energy management concepts

# Summary

- **Milestones & Technical Accomplishments**
  - Successfully deployed analytical tools developed previously
  - Validated initial trailer aero improvements on-road (11% FE impact)
  - Completed trailer optimization in CFD (target 14-16% total FE impact)
  - Demonstrated 48% brake thermal efficiency engine test cell
  - Started installing concept powertrain into concept vehicle on-going

- **Next Step**
  - Validate complete vehicle performance

# **Collaborations** & key Suppliers

| Organization | Key Contribution |
|---|---|
| Volvo Technology of America | Project lead & concept simulations |
| Volvo Group Truck Technology | Complete vehicle integration & vehicle testing |
| Volvo Group Powertrain Engineering | Efficient complete powertrain solutions |
| Freight Wing | Optimized aerodynamic geometries & devices for trailer |
| Grote | Advanced lighting systems |
| Penn State University | Advanced combustion modeling, simulation & experiments |
| Hendrickson | Lightweight trailer axle & suspension components |
| ExxonMobil | Advanced fuels & lubricants |
| Alcoa Wheels | Lightweight wheels |
| Michelin | Advanced low-friction tires |
| Meritor | High-efficiency tractor axles |

# Relevant Research

This material is based upon work supported by

- DOE & NETL under Award Number DE-EE0004232
- DOE & NETL under Award Number DE-FC26-07NT43222
- DOE Project ID VSS006, Reduce Truck Aerodynamic Drag w/ LLNL
- DOE Project ID VSS022, CoolCab – Reduce Thermal Load w/ NREL