Volvo SuperTruck

Powertrain Technologies for Efficiency Improvement

DOE Contract DE-EE0004232

2013 Annual Merit Review
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ACE060

Project Overview

Timeline

June 2011 - June 2016

37% complete to date

Barriers

- Cost effective & timely evaluation of advanced components and configurations
- Added weight, packaging, and complexity of technologies
- Reduced aftertreatment efficiency at low temperatures
- Integration of interdependent technologies

Budget

Total Project Funding: 38M USD

Cost Share: 19M USD

- Funding year 2011-12: 4.40M USD
- Funding year 2013-13: 3.78M USD

Project Partners:

Lead: Volvo Technology of America

- Volvo Group Truck Technology
- Penn State University
- Grote
- Freight wing

Relevance to Program Goals

Bring technologies that enable lower customer operational cost and reduced environmental impact to market ahead of normal product development time cycle

Develop more efficient highway transportation technologies to reduce petroleum consumption

Project Objectives

Objective 1:

Develop powertrain technologies to contribute to **50% freight efficiency** improvement in vehicle testing

Objective 1a:

Develop powertrain technologies capable of **50% engine BTE** in vehicle environment

Objective 2:

Investigate engine technologies capable of **55% BTE** through simulation and scoping studies

Reporting Period Project Objectives

Objective 1:

Deliver first powertrain to concept vehicle

Define powertrain requirements for SuperTruck vehicle

Objective 1a:

Demonstrate 47% BTE

Define 50% BTE content

Objective 2:

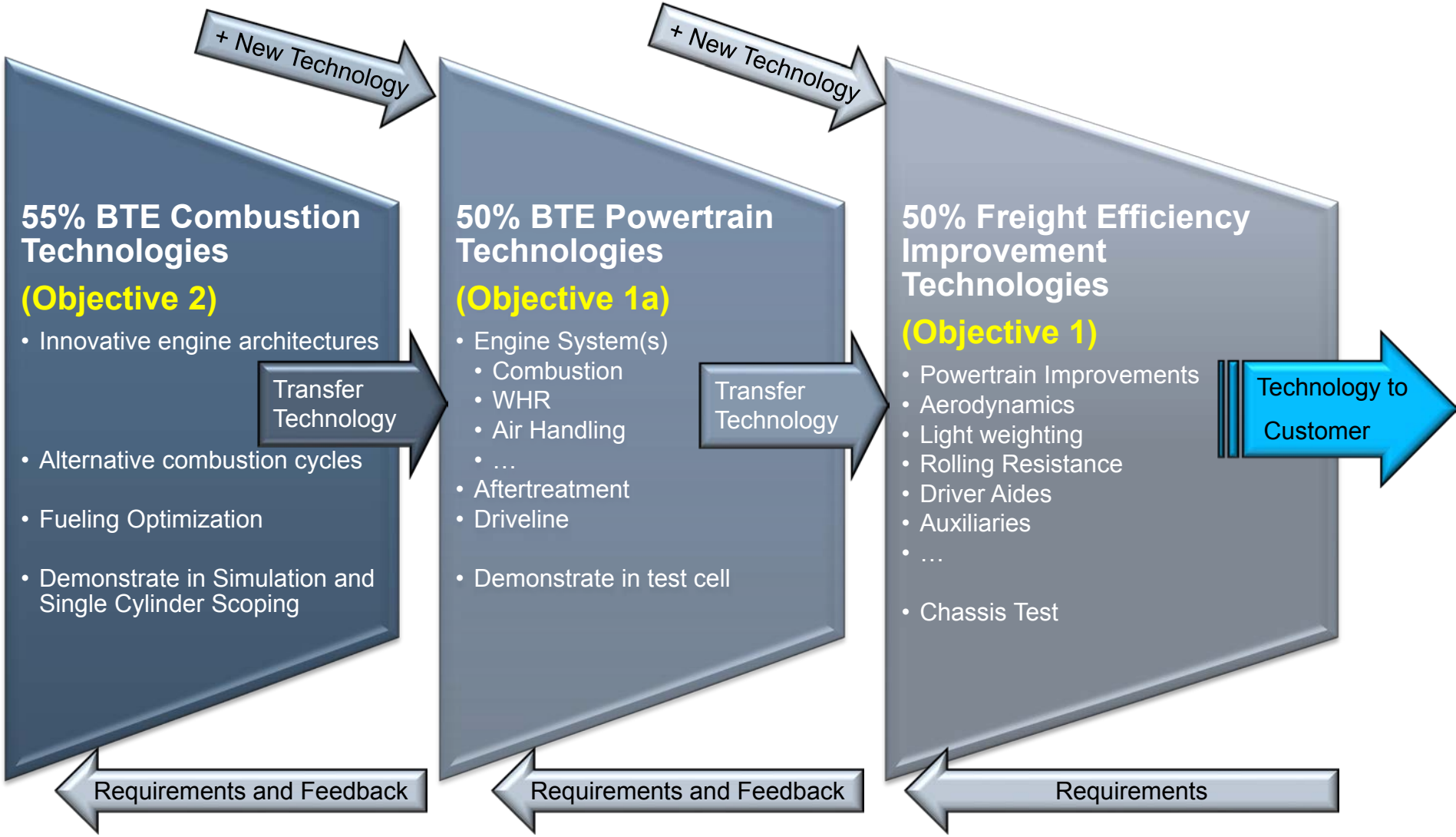
Simulate with high accuracy combustion mechanisms and build plan to 55% BTE

Relevant Research

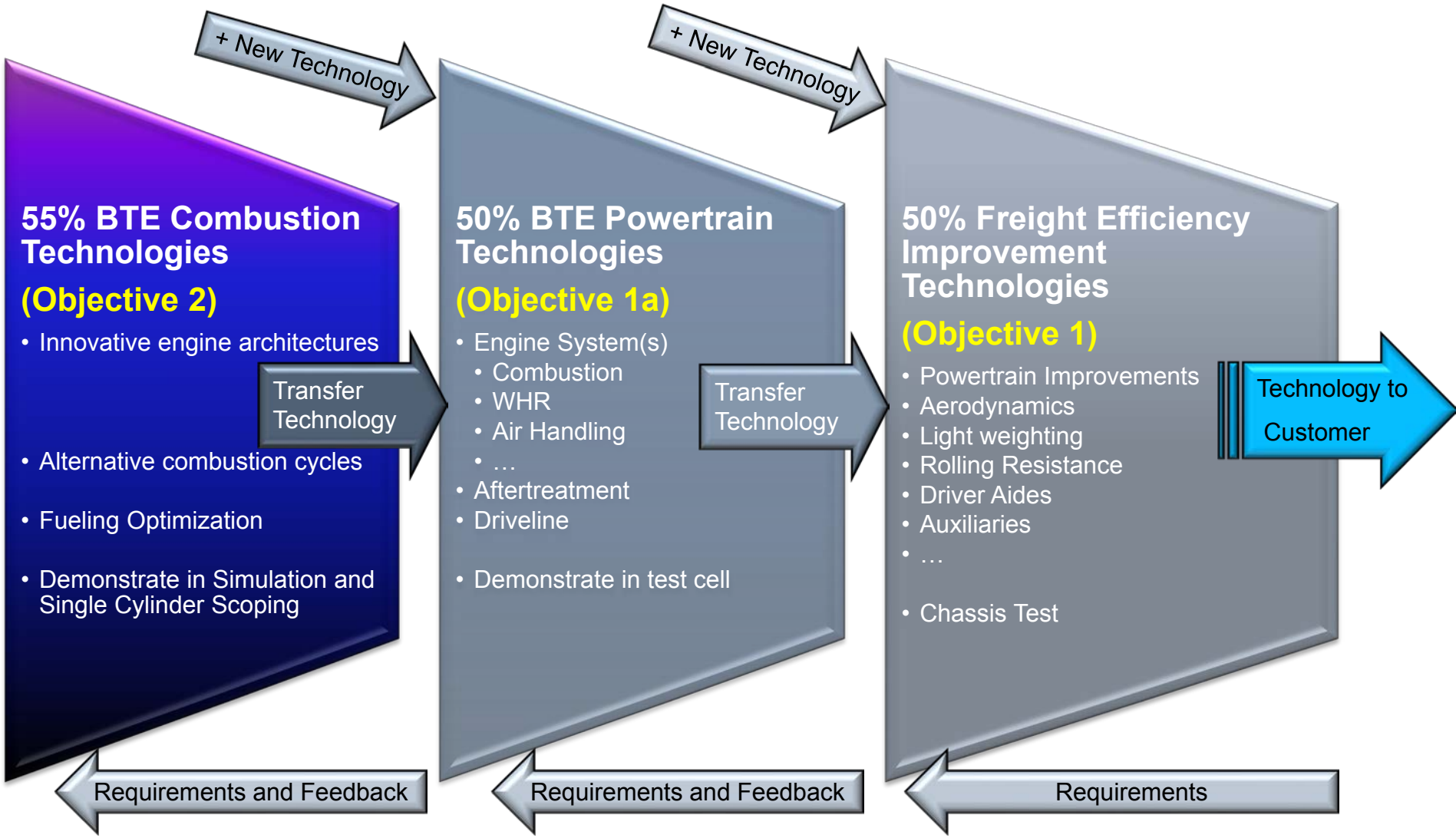
This material is based upon work supported by

- DOE & NETL under Award Number DE-EE0004232
- DOE & NETL under Award Number DE-FC26-07NT43222

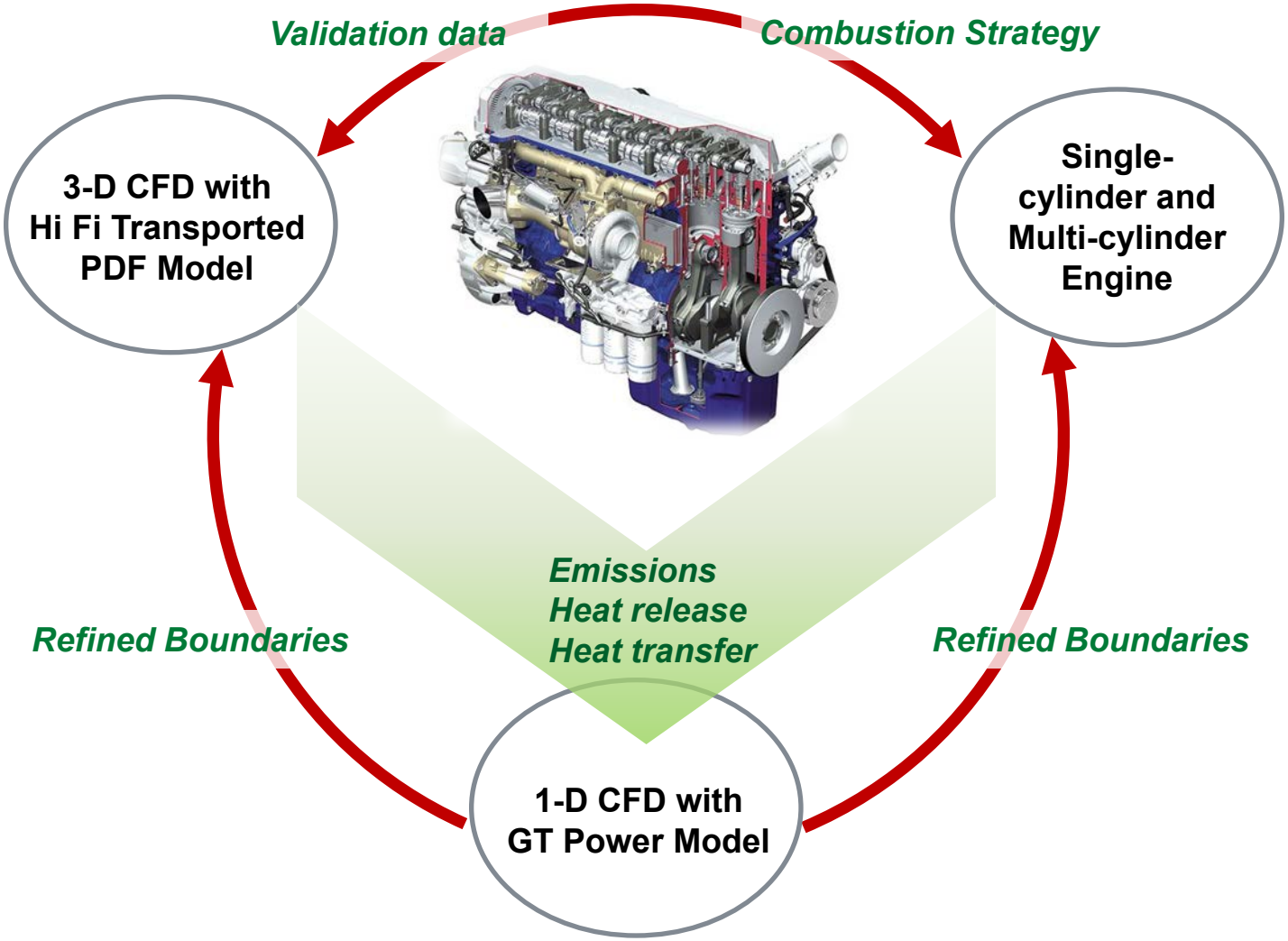
Total Powertrain Workflow Approach



Total Powertrain Workflow Approach



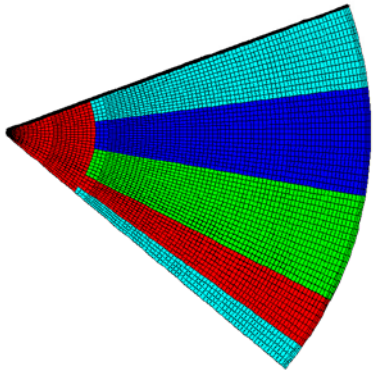
Approach for 55% BTE Engine (Objective 2)

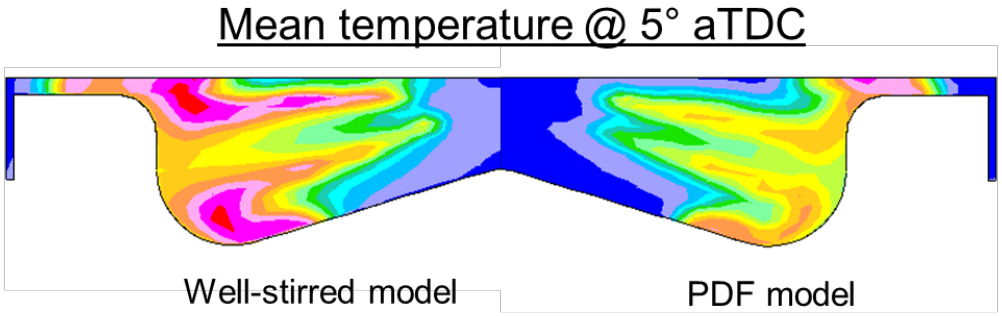


Accomplishments towards 55% BTE (Objective 2)

Validating CFD simulation, Fuel and Chemical Mechanisms

- Transported PDF method complete for baseline conditions.
- Single-component fuels and fuel blends being simulated
- Engine Combustion Network for validation of diesel-relevant conditions (future work)



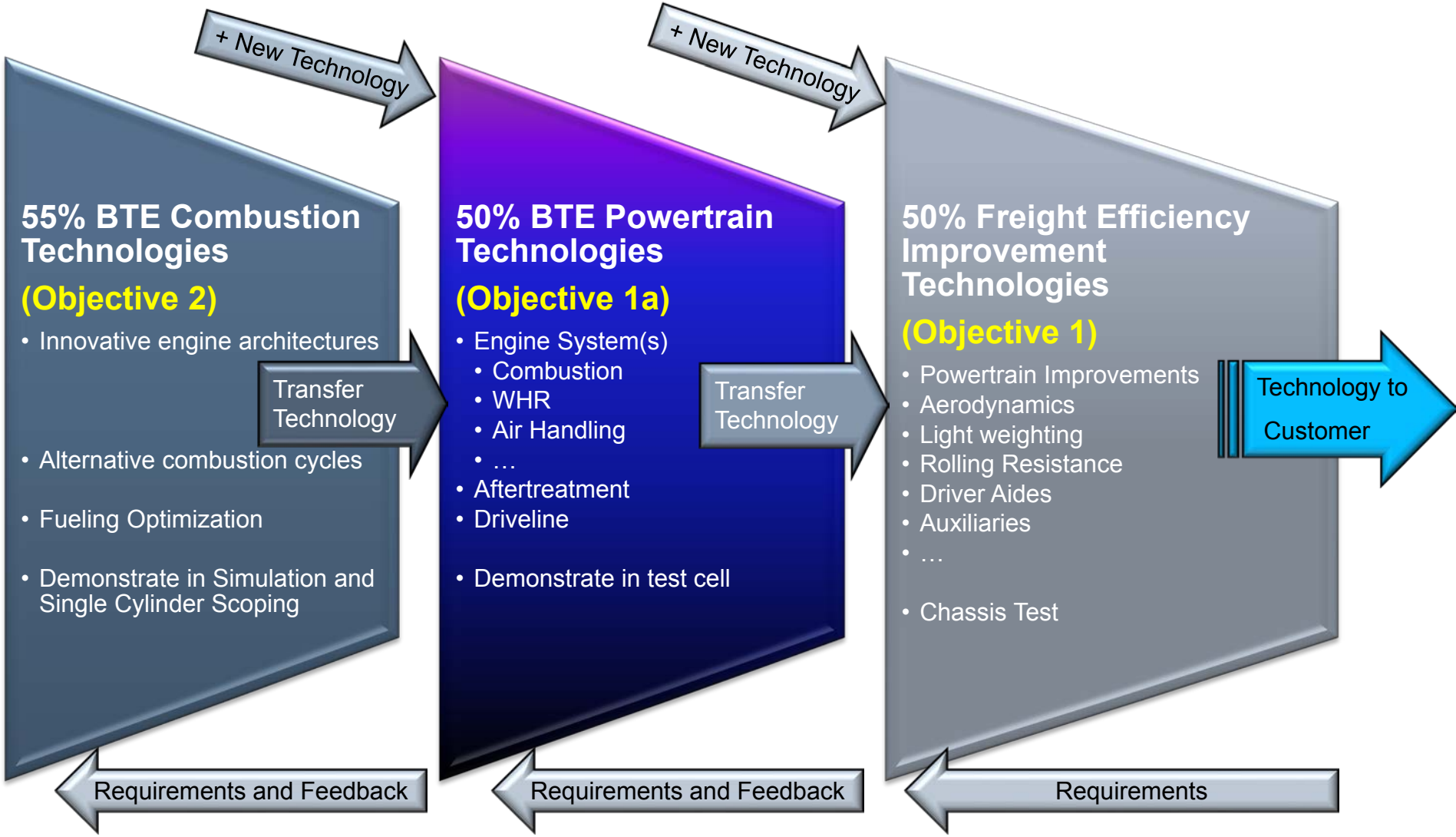


PDF model results match measured data with improved accuracy compared to common modeling techniques

Engine Tests Initiated

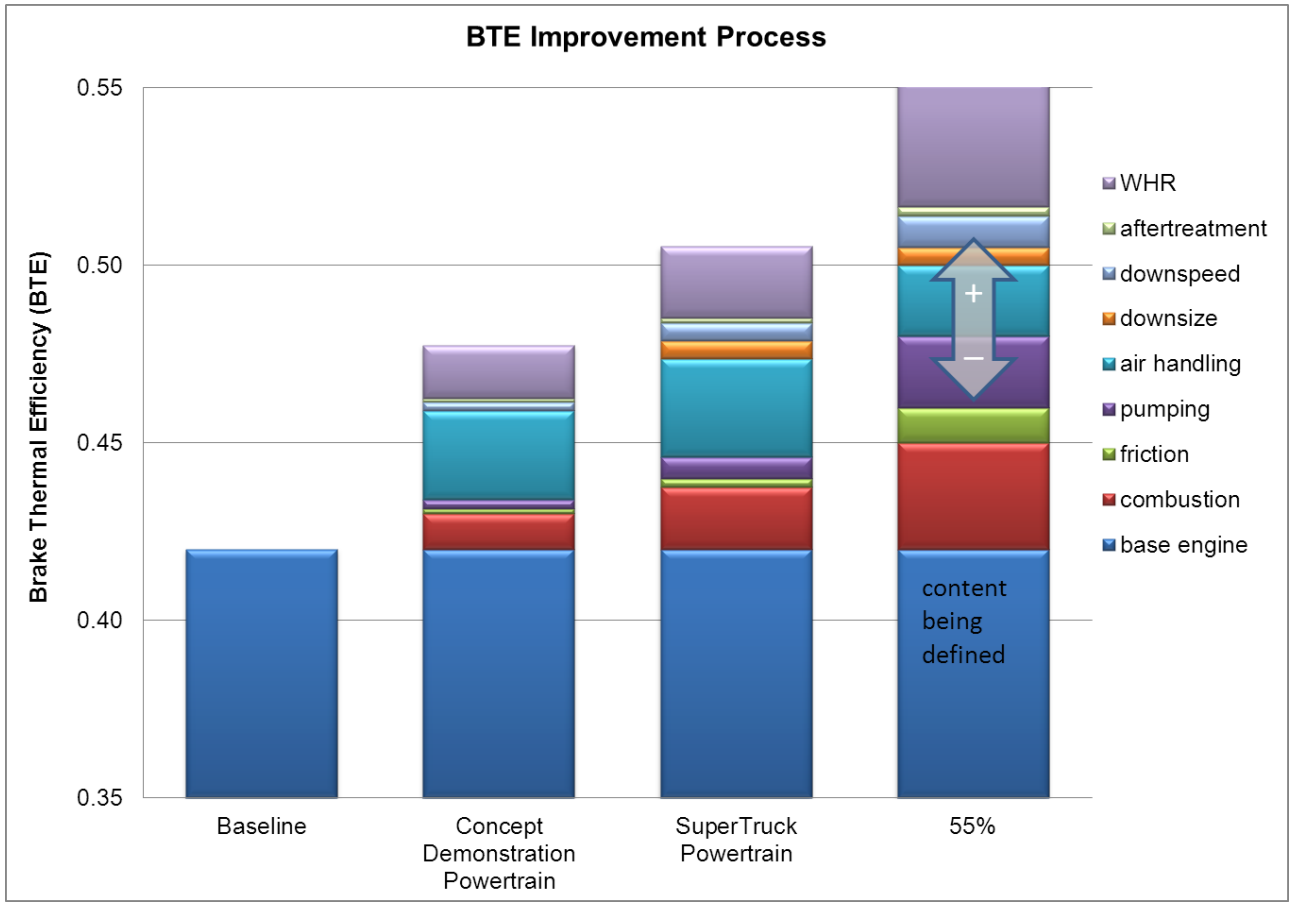
Mixed mode PCCI combustion **51% BTE achieved** with 20% energy substitution by DME and 30% energy substitution by propane

Total Powertrain Workflow Approach



Strategy for 50% BTE
(Objective 1a)

- Develop and verify powertrain components that enable 50% engine BTE.
- Each family of improvements displayed represents many sub-sets of technologies
- Integrate systems into concept vehicles and verify on customer duty cycles



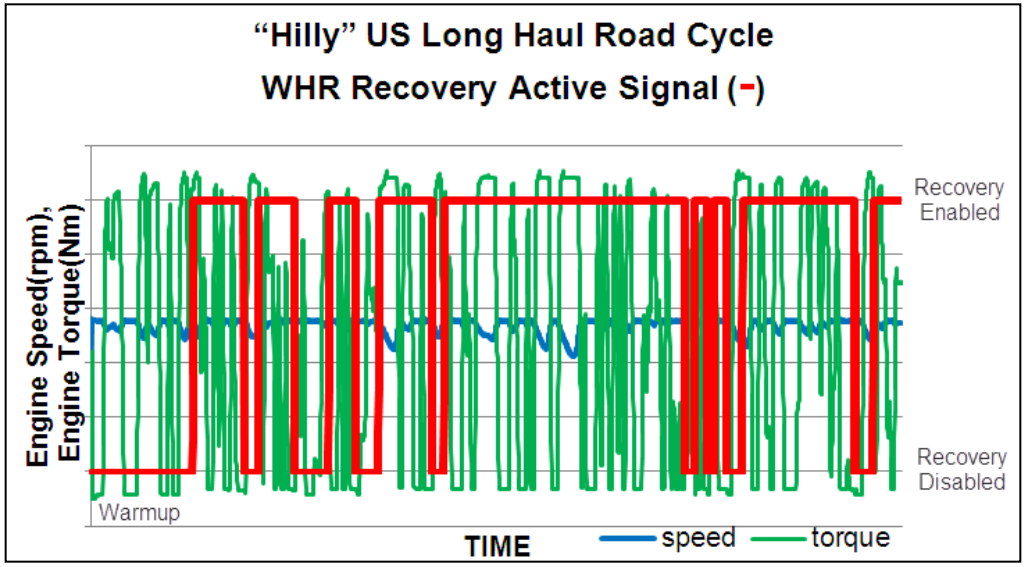
Accomplishments towards 50% BTE (Objective 1a)

Powertrain Delivered to Chassis

- Turbocompound 13liter Engine
- Rankine WHR Generation1
- Reduced Friction PCU
- Improved cooling circuit
- Improved oil circuit
- Improved combustion chamber
- High pressure fuel injection system
- Down-speeded Engine
- Improved aftertreatment system
- Next Generation Axles
- Improved Idle Efficiency
- Dual Clutch Transmission

Accomplishments towards 50% BTE (Objective 1a)

Integrated Powertrain system first generation testing complete



WHR was enabled 77% of the time for the most transient highway drive cycle.

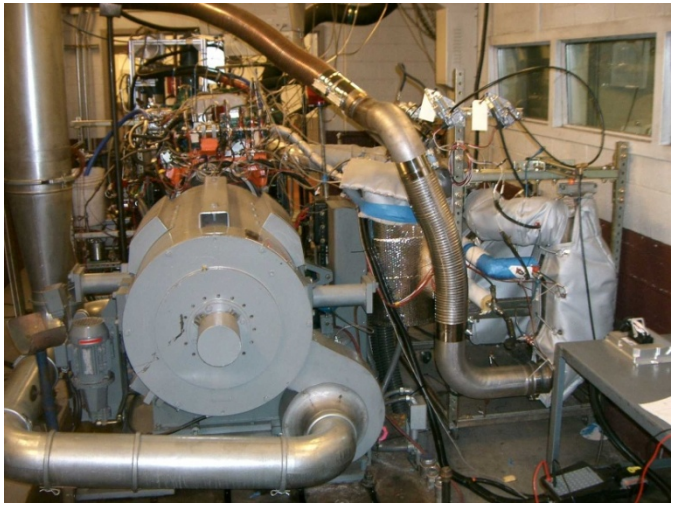
Rankine Waste Heat Recovery
Test results exceeded expectations.

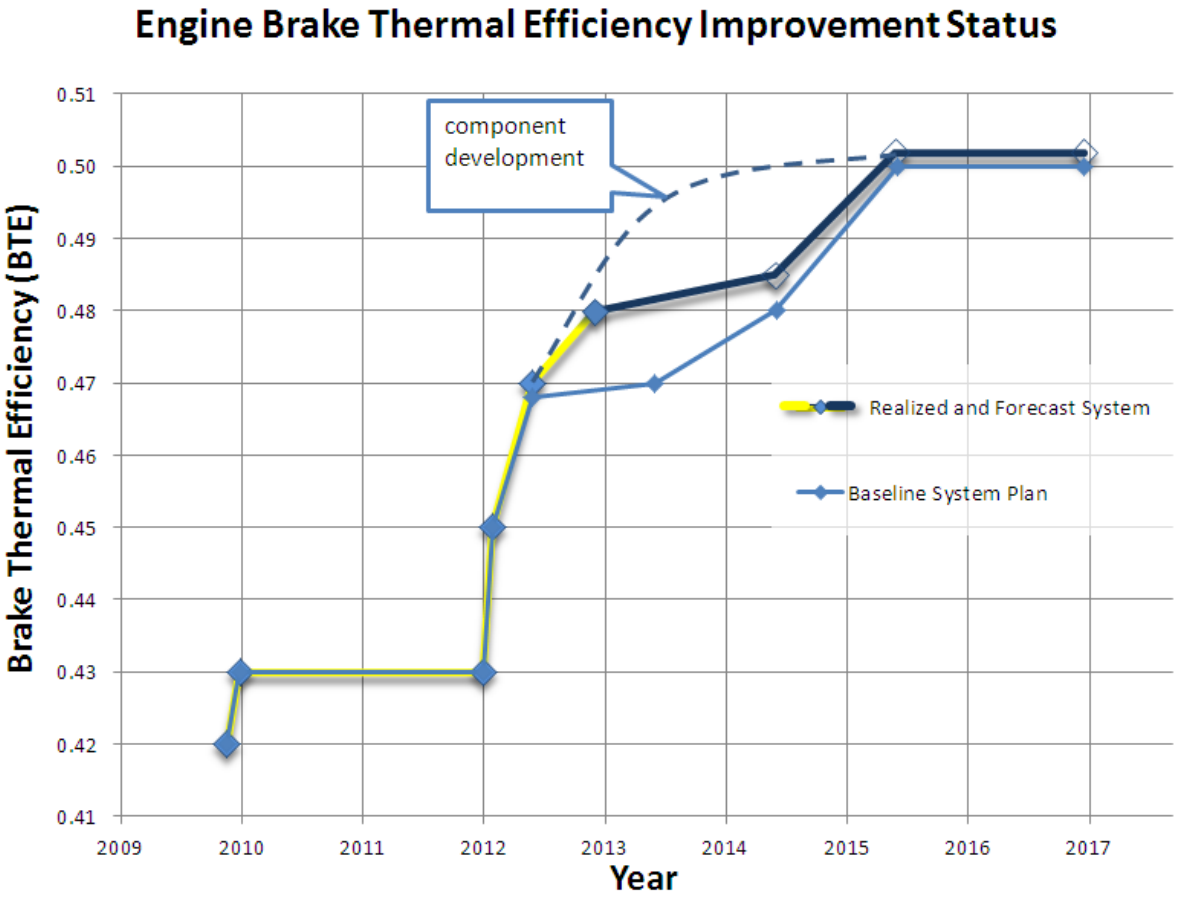
Stable dynamic control of the Rankine WHR system on aggressive highway cycle.

Closed-loop operation of the systems require no interface with the driver.

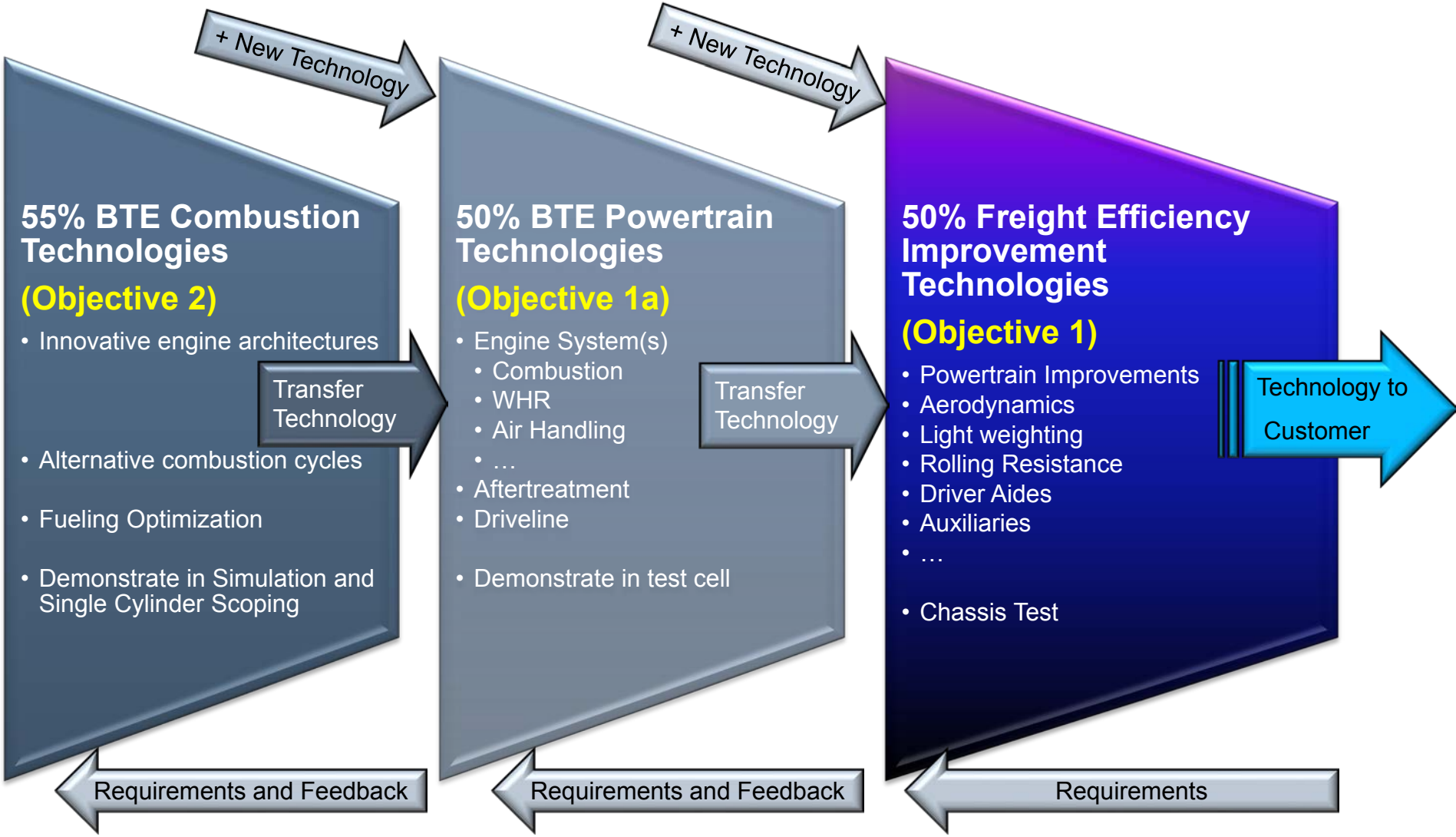
Accomplishments towards 50% BTE (Objective 1a)

- **Demonstrated 48% BTE**, 1.5yrs ahead of schedule
- Equates to 10% fuel economy improvement realized in 2012
- Measured as an integrated powertrain system





Total Powertrain Workflow Approach



Approach - Timeplan

2011	2012	2013	2014	2015	2016

Phase I - Concept Selection

Baseline Tests

Technology Development

Refinements

Concepts Evaluation

engine bench

mule truck

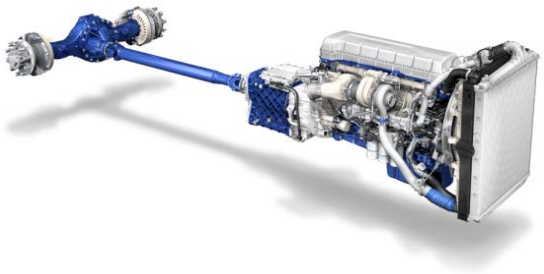
Concept Truck

Model Development

Validation

Energy Management Dev.

Virtual Optimization



Phase II - Development & Integration

Techn. Refinement

Validation

engine bench

Integration

demonstrator chassis

Optimization

Demo Truck

VOLVO FREIGHT WING Grote PENNSTATE

Powertrain Accomplishments towards 50% Freight Efficiency Improvement
(Objective 1)

Concept Truck

- Transferred Powertrain technologies for 2013 concept vehicle validation
- Expect 8-10% Fuel Econ improvement from powertrain alone
- On-road testing initiated for multiple technologies in concept truck

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- Initiated testing of next generation engine for SuperTruck
- Defined powertrain requirements for the highly efficient vehicle
- Digital Mock-up ready

Demo Truck

Collaborators / Partners

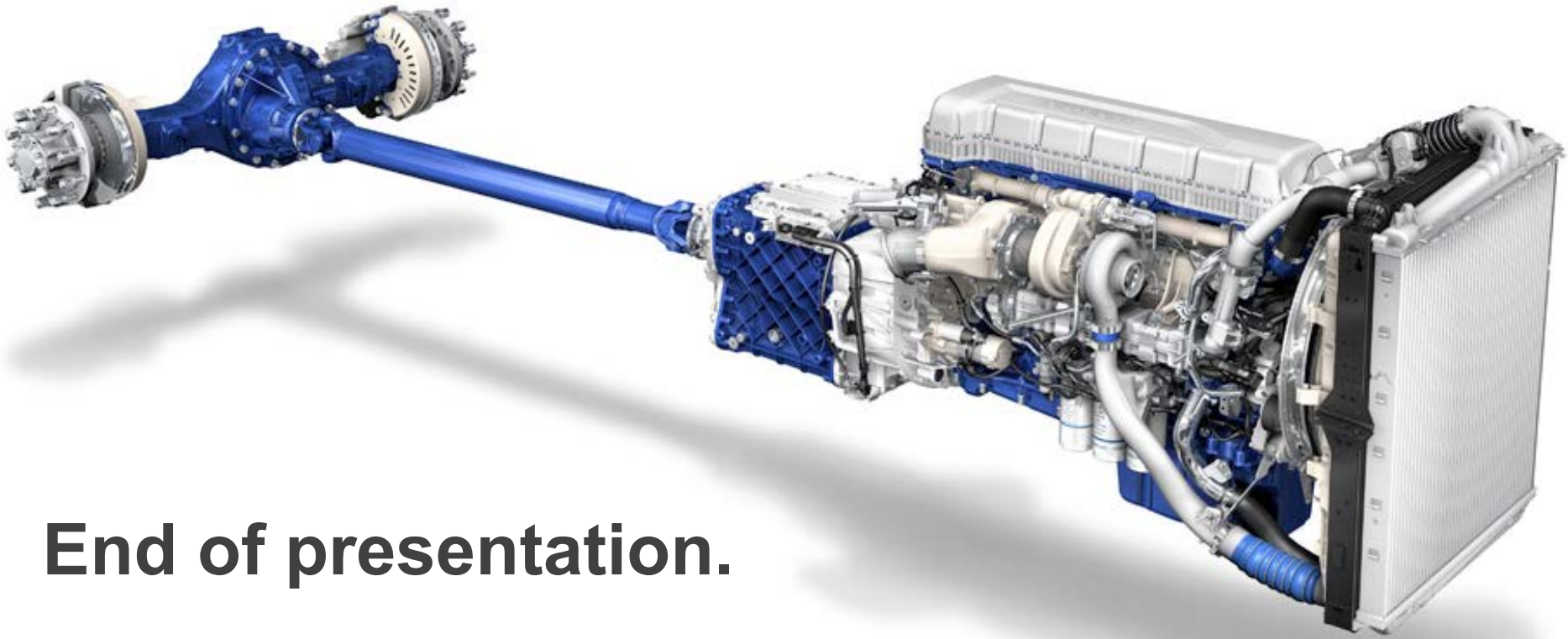
Collaborator / Partner	Focus
The Customer	Log vehicle data used from thousands of highway vehicles on the market is to define drive cycles and requirements
Volvo Technology of America	Contract Management and Collaborator Integration
Volvo Group Trucks Technology	Engine, Transmission, Axles, Light weighting, Chassis Auxiliaries, Integration, Chassis Aerodynamics, …
Freight Wing, Inc.	Trailer Aerodynamics
Grote Industries	Advanced Lighting
Ricardo, Inc.	Rankine WHR Generation 1 Development
University of California Los Angeles	WHR Control Simulation
Drexel University	WHR Topology Simulation
Pennsylvania State University	55% BTE Simulation and Testing
Chalmers University of Technology	55% BTE Testing
Exxon Mobil	Advanced Fuels and Lubrications

Future Plans for Powertrain Development

- 55% BTE (Objective 2)
  - Apply new CFD simulation methods to develop combustion concepts
  - Full engine simulations of proposed regimes and fuels
  - Continued research engine testing to verify concepts
- 50% BTE (Objective 1a)
  - Test integrated system in concept truck through 2013
  - Test final demonstrator engine and components in test cell 2013
  - Test final demonstrator powertrain system in test cell 2014
  - Deliver powertrains system to SuperTruck (Demo Truck) 2015
- 50% Freight Efficiency (Objective 1)
  - Incorporate 50% BTE methods
  - Integrate chassis improvements into powertrain system development

Summary of Volvo Supertruck Project Status

- **Relevance:** Our goal is to reduce fuel consumption and develop technologies of high complexity
- **Approach:** Through rigorous simulation and testing, develop a suite of technologies that are valuable to the customer while insuring program objectives are met
- **Technical Accomplishments:** Completed development of first powertrain, now in verification. Exceeding BTE goals vs. plan. Initiated development of technologies planned final demo truck.
- **Collaborations:** Multiple partners have joined the powertrain and vehicle development team, all working towards an integrated solution for the customer.
- **Future Plans:** Test powertrain system in concept demonstrator through 2013. Develop next generation components for SuperTruck chassis through 2013, to prepare for integrated system testing of successful technologies.



End of presentation.

Thank you for your attention.