SuperTruck

Powertrain Technologies for Efficiency Improvement

2015 Annual Merit Review
Washington, DC
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Presenter: John Gibble
Advanced Engineering Chief Project Manager
Volvo Group Trucks Technology

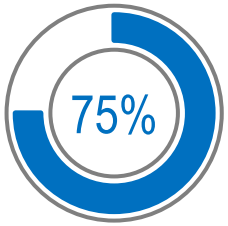
Principal Investigator: Pascal Amar
Volvo Technology of America

ACE060

Project Overview

Timeline

June 2011 - June 2016



complete to date

Barriers

- Cost effective & timely evaluation of complex technologies and systems
- Added weight and packaging of technologies
- Integration of interdependent technologies
- Development of robust solutions with broad application and customer acceptance

Budget

Total Project Cost: $38M

DOE Funding: $19M

Funding received to date $12.3M

Total project cost to date $25.9M

Project Partners:

VOLVO

Grote

RIDGE CORPORATION

PENNSTATE 1855

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:

Test 48% BTE powertrain in concept vehicle

Objective 1a:

Develop 50% BTE technologies

Objective 2:

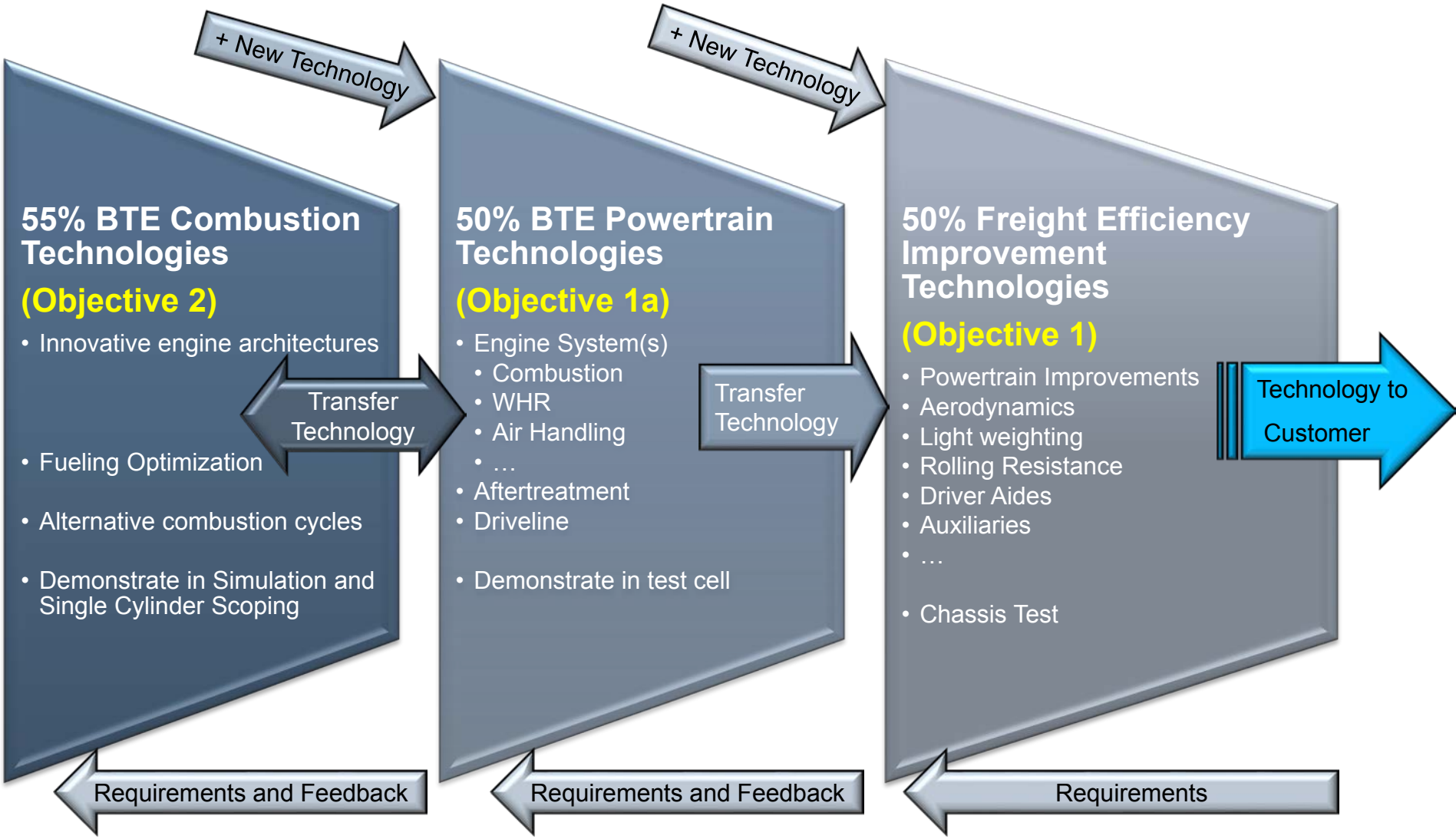
Simulate technologies to achieve 55% BTE

Relevant Research

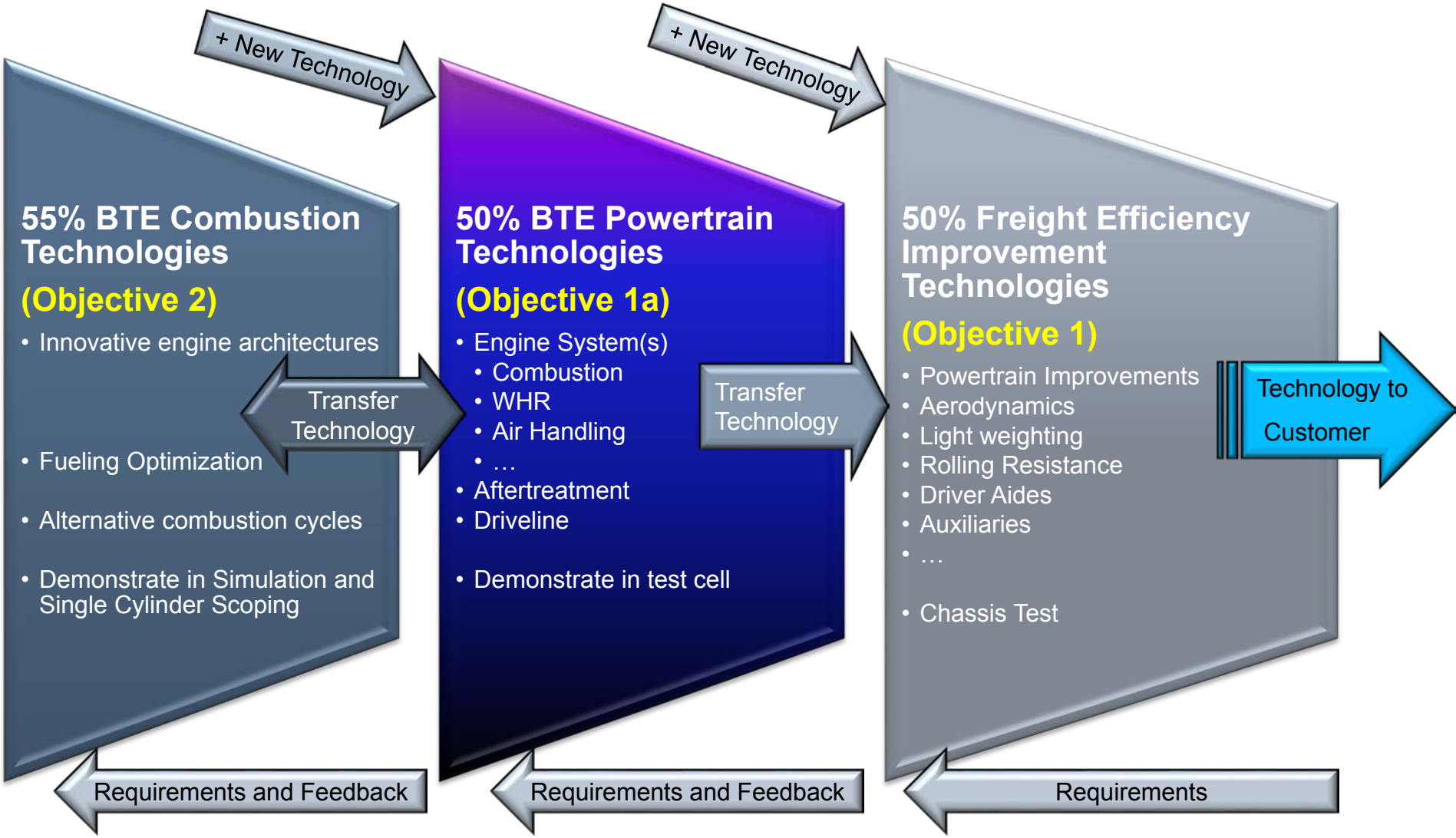
Projects supporting the objective to develop more efficient highway transportation technologies to reduce petroleum consumption, operating cost, fuel consumption, environmental impact, and time to market for high risk high complexity items are as follows:

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

Total Powertrain Workflow Approach

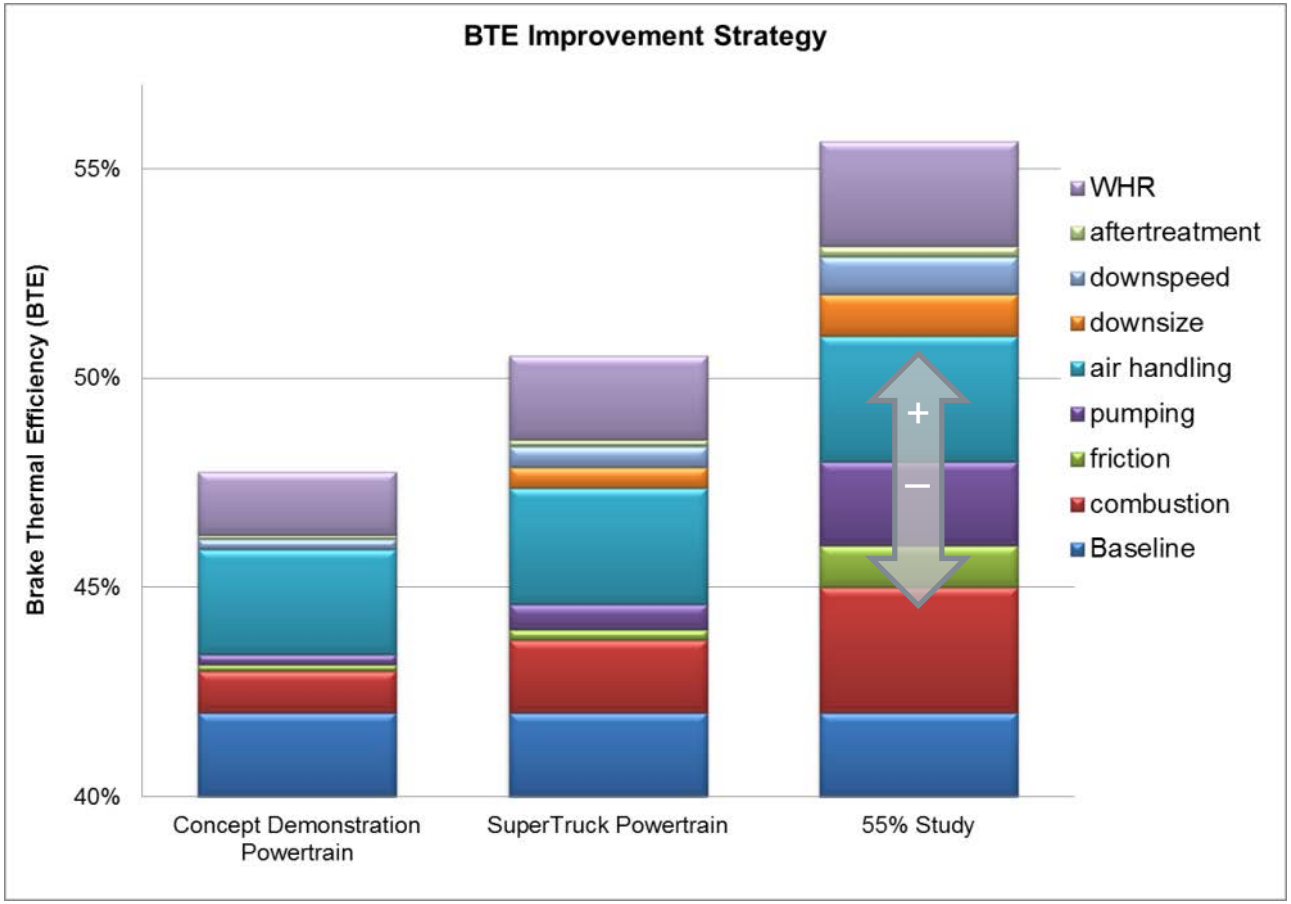


Total Powertrain Workflow Approach



Strategy for Brake Thermal Efficiency
(Objective 1a and 2)

- Develop and verify powertrain components that enable 50% engine BTE.
- Each family displayed represents many sub-sets of technologies
- Integrate systems into concept vehicles and verify on customer duty cycles
- Provide pathway to 55% BTE engine



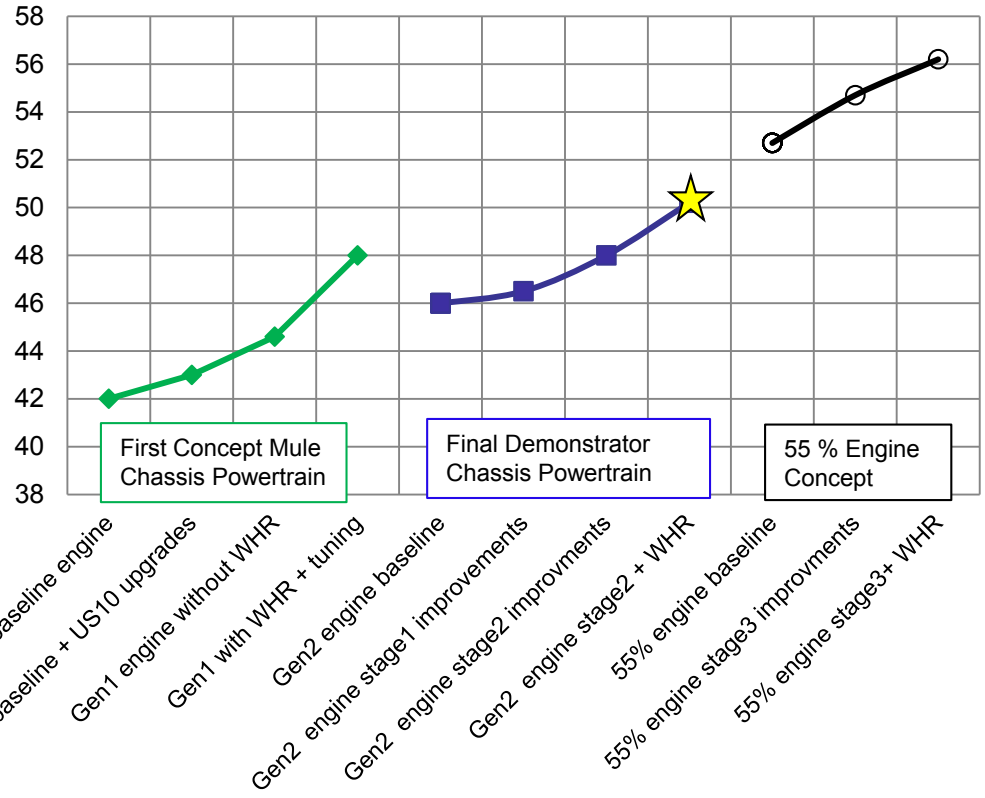
Accomplishments towards 50% BTE (Objective 1a)

★ The 50% BTE engine component development is complete.

System integration & test is ongoing.

Engine program has run the equivalent of 1,600,000 miles (to the moon and back >3 times)

Volvo SuperTruck BTE Progression



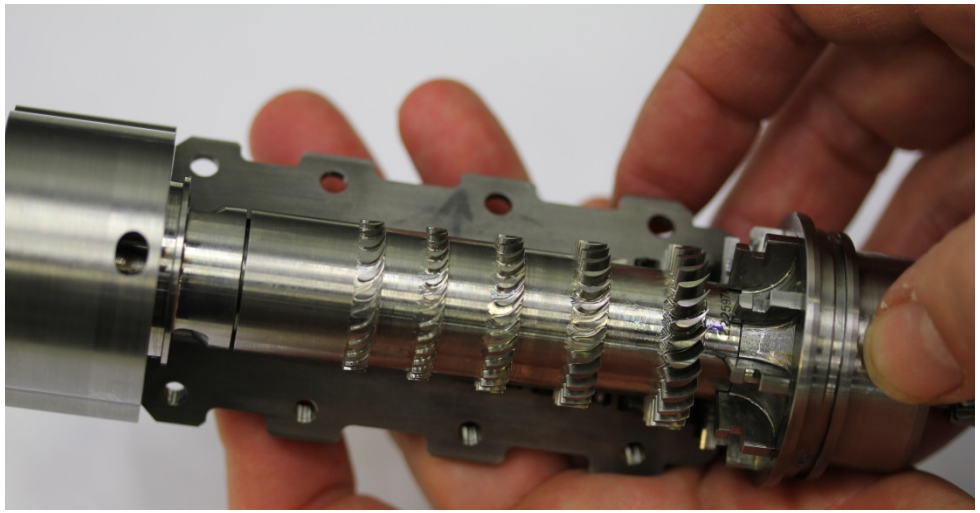
New engine is as good without WHR as previous engine with WHR, measuring 48% BTE.

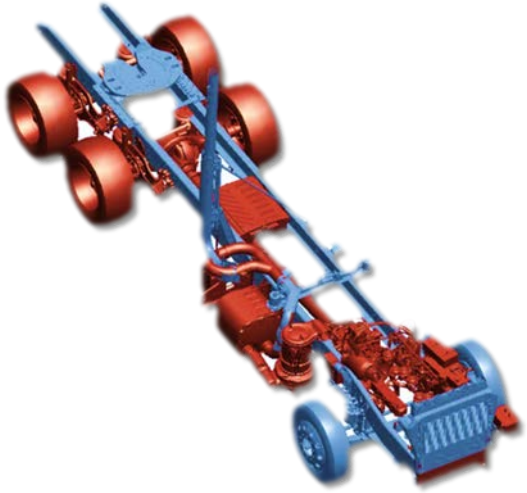
Accomplishments towards 50% BTE (Objective 1a)

Improvements in advanced concepts:

Testing initiated with Volvo-designed WHR expansion machine, a 5 stage axial turbine.

An elegant solution with significant reductions in weight and size compared to alternatives



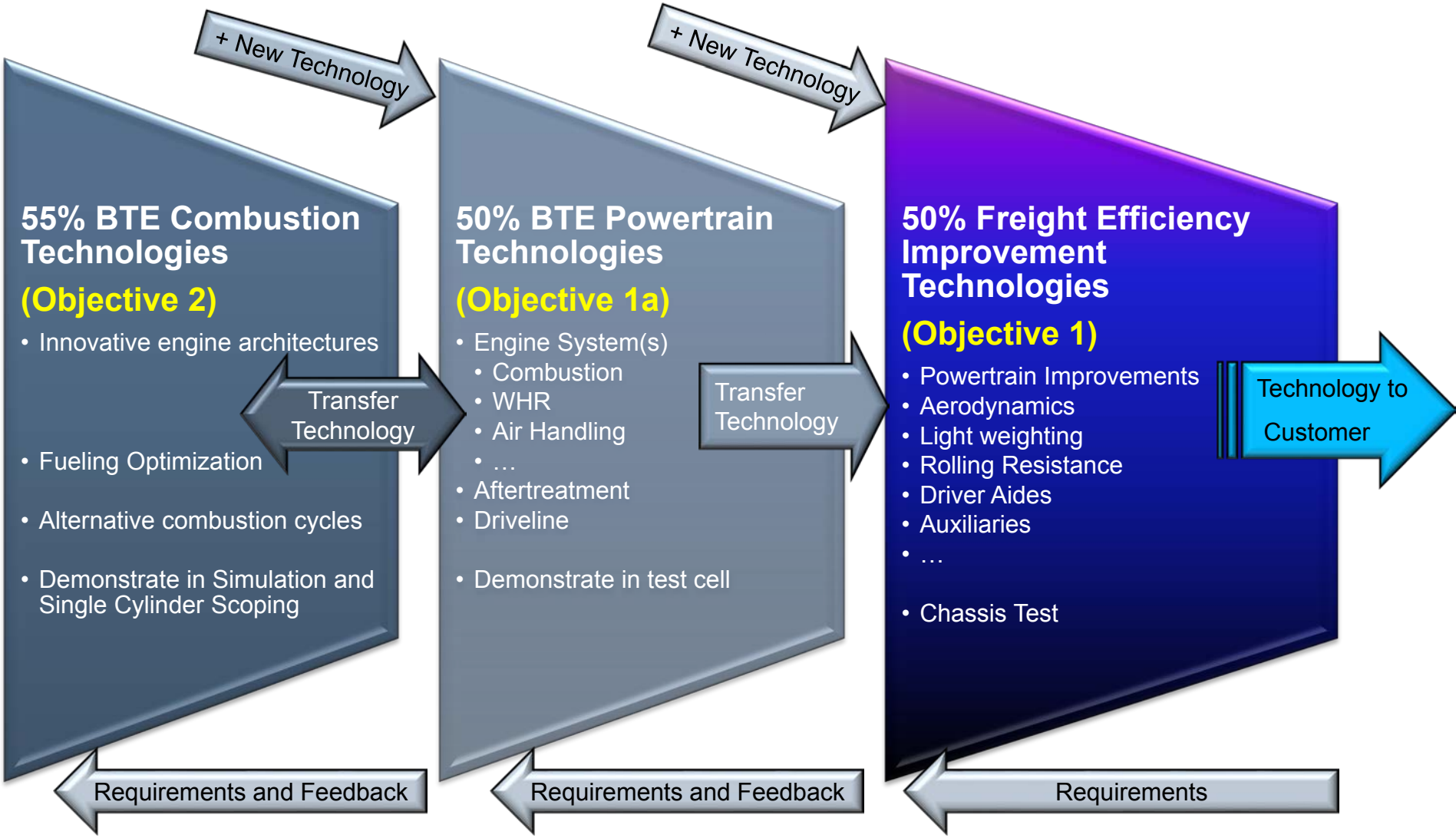


Technology to Customer

Realized project benefit to customers:

The SuperTruck first demonstrator propshaft, combustion system, axles, down-speeding technology (and more) will be in production soon, some are already available for purchase.

Total Powertrain Workflow Approach



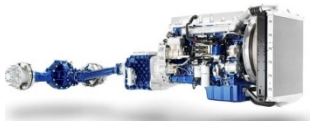
Approach to Freight Efficiency Improvement

2011	2012	2013	2014	2015	2016

Phase I - Concept Selection

Baseline Tests

Techn. Development



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

Two phases of development

- ✓ Phase 1 complete, test concepts early in concept truck to assist final design
- ○ Phase 2 ongoing, deliver 50%BTE engine to demo truck

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

First Concept / Mule Chassis

Test Complete.

Technology Commercialized from First Concept Chassis:

Aforementioned Powertrain Components plus:

- ✓ Improved Roof
- ✓ Improved Bumper
- ✓ Flared Chassis Faring
- ✓ LED Headlamps
- ✓ LED Interior Lighting
- ✓ New Tail Fairing

Technology to Customer

Production Truck

FUEL ECONOMY IMPROVEMENTS DELIVERED TO CUSTOMER!

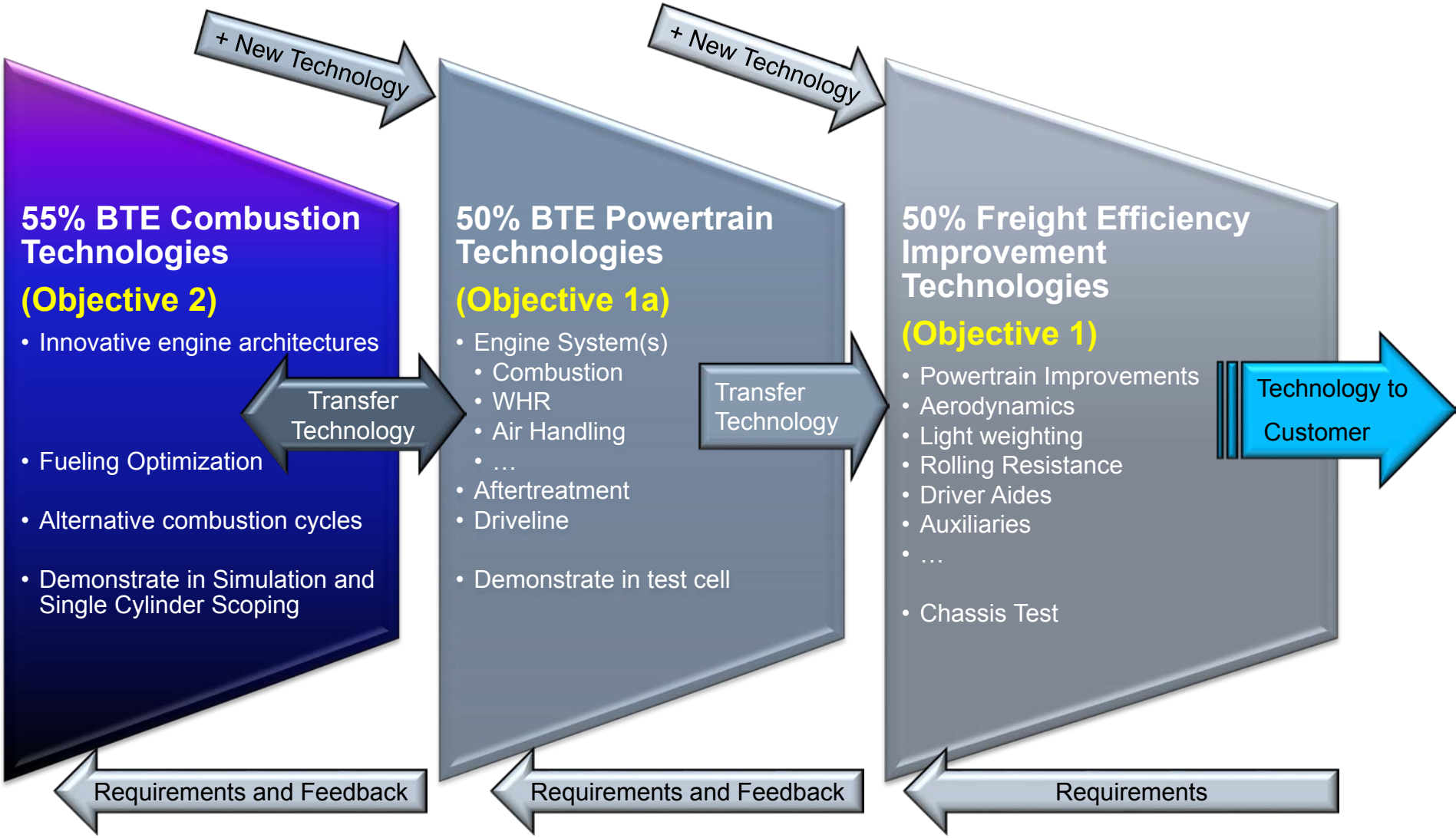
Powertrain Accomplishments towards 50% Freight Efficiency Improvement (Objective 1)

Powertrain delivered to final demonstrator chassis, vehicle is in build phase

Test cell results indicate road cycle fuel economy exceeds initial expectations

Engine designed for lighter loads resulting from an aerodynamic and low rolling resistance vehicle

Total Powertrain Workflow Approach



Approach for 55% BTE Engine (Objective 2)

2011	2012	2013	2014	2015	2016

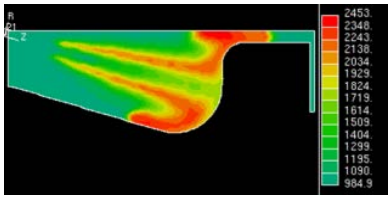
Phase I - Tools & Method Development

Penn State - CFD Development

PDF Diesel Development

PDF PPC Validation

GT Power modelling & Eff. Calculations



"Concept 55" Chosen

Phase II - Concept Development

Concept 55 CFD Simulations

Concept 55 model validation

Concept 55 GT Power

Fuel Mechanism Research

Concept 55 prototype

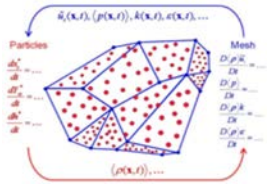
Tool development/Cal. Eff.

Goal:

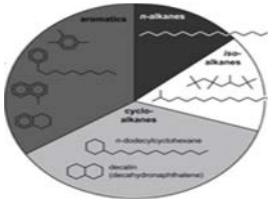
Define a powertrain system capable of 55% engine BTE using an integrated computational method.

Verify assumptions for robustness.

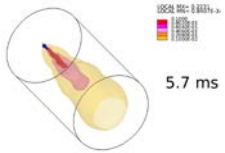
Approach for 55% BTE Engine (Objective 2)



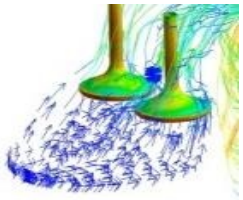
PDF Model



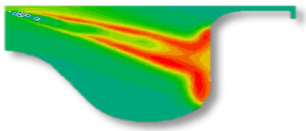
Chemical Mechanism Model



Fuel Spray Model

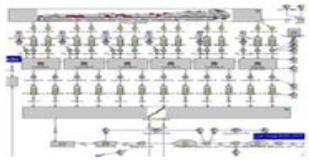


Gas Exchange Simulations



3D Combustion Simulations

Goal: simulate a powertrain system capable of 55% engine BTE using an integrated computational method. Verify assumptions for robustness.



GT Power Engine Model / Fundamental Engine Design

Tests to support simulation

e.g. :

Characterization of Fuel Injection

Combustion Analysis

Engine Tests

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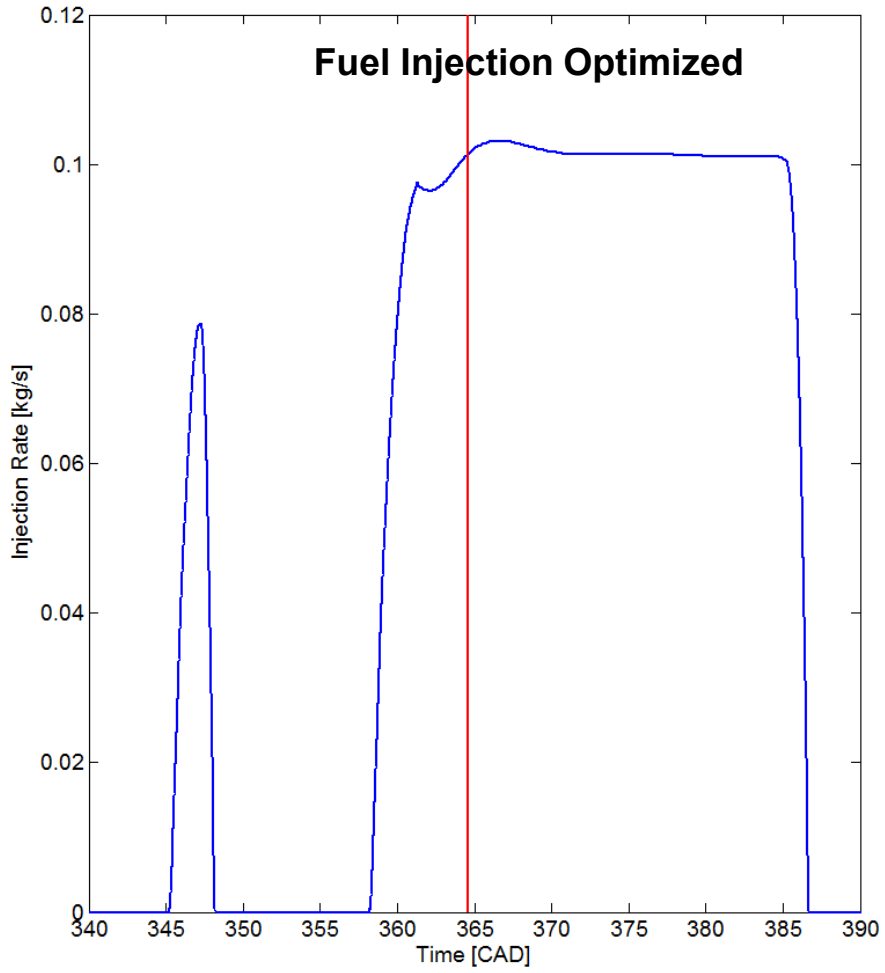
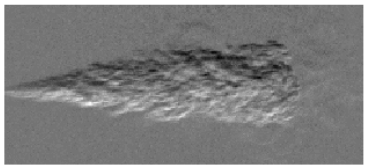
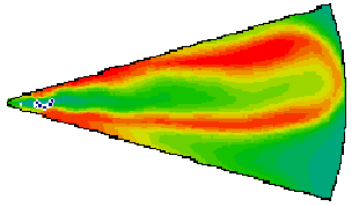
Accomplishments toward 55% BTE Engine
(Objective 2)

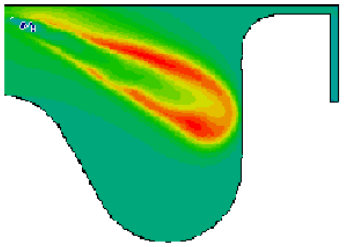




Fuel / air mixing tests performed



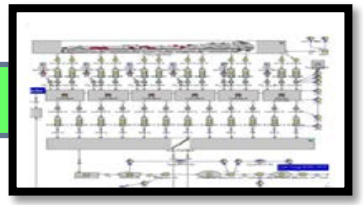
3-D Combustion Simulation Progressing



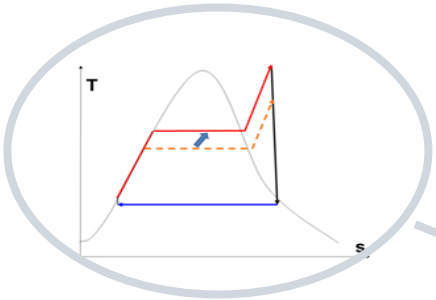
Piston Bowl Geometry Optimization Ongoing

Inter-dependent simulation tools have improved the combustion system design. Tests have been initiated to validate the simulations.

Accomplishments towards 55% BTE Engine
(Objective 2)

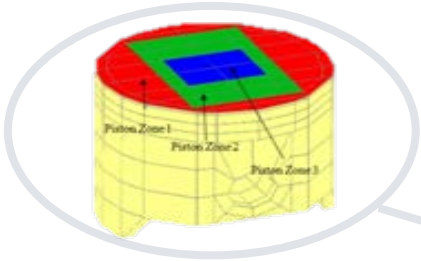


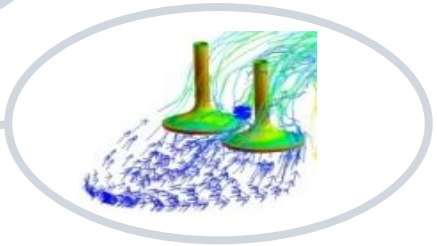
✓ 56.2% BTE engine simulated



Parasitic Reduction

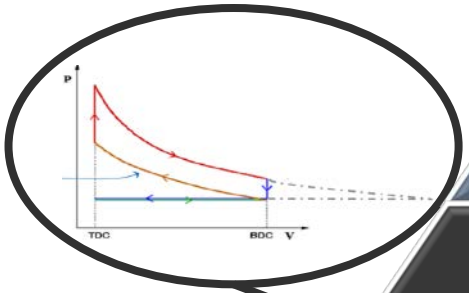
Waste Heat Recovery

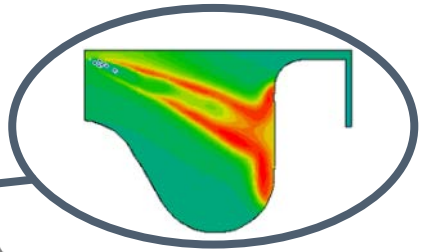




Improved Gas Exchange

Heat Loss Reductions





Combustion Improvements

Over-Expansion

48% BTE engine baseline

Collaborators / Partners

Suppliers and development partners have developed methods to integrate all new technologies in simulation and test phase, striving to deliver an optimized powertrain and chassis for maximum return on investment. Academic partners are assisting in simulations.

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, …
FreightWing/Ridge Corp.	Trailer Aerodynamic Devices
Grote Industries	Advanced Lighting
Ricardo, Inc.	Rankine WHR Generation 1 Development
University of Michigan	55% BTE Simulation and Testing
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)
  - Continue to refine tools and validate models with test data
  - Progress in engine design
- 50% BTE (Objective 1a)
  - Prepare technology transfers from SuperTruck to customer
  - Refine WHR system for optimal road cycle operation
- 50% Freight Efficiency (Objective 1)
  - Support Vehicle test of 50% BTE powertrain
  - Use data from vehicle test to guide future product development

Summary of Volvo Supertruck Project Status

- **Timeline:** Project is 75% complete to date
- **Budget:** On track
- **Relevance:** Develop more efficient highway transportation technologies to reduce petroleum consumption, reducing operating cost, fuel consumption, environmental impact, and time to market for high risk high complexity items
- **Approach:** Through simulation and testing, develop technologies that meet or exceed 55% BTE scoping, 50% BTE powertrain system in chassis, and 50% Freight Efficiency improvement.
- **Technical Accomplishments:** In 2013/14 Volvo verified combustion simulation for PPC and simulated a **56.2% BTE** capable engine. The 50% BTE powertrain is under development, with **48% BTE realized without WHR** (previously 48% with WHR). The first concept vehicle achieved a 45% Freight Efficiency Improvement.
- **Collaborations:** Suppliers and partners have developed methods to integrate all new technologies in simulation and test phase, striving to deliver an optimized powertrain and chassis for maximum return on investment. Academic partners are assisting in simulations with great success and collaboration.
- **Future Plans:** In 2015-2016 the 50% BTE capable powertrain will be demonstrated in vehicle. Simulation 55% components will progress through upcoming funding year. Technologies considered viable will be prepared for transfer to customer.

End of presentation.

Thank you for your attention.