Volvo SuperTruck

Powertrain Technologies for Efficiency Improvement

DOE Contract DE-EE0004232

2014 Annual Merit Review
Washington, DC
June 20, 2014

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ACE060

Project Overview

Timeline

June 2011 - June 2016

55% 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

DOE Cost Share: 19M USD

- Funding received to date $9.1M
- Total project cost to date $18.3M

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:

Test 48% BTE powertrain in concept vehicle

Objective 1a:

Develop 50% BTE technologies

Objective 2:

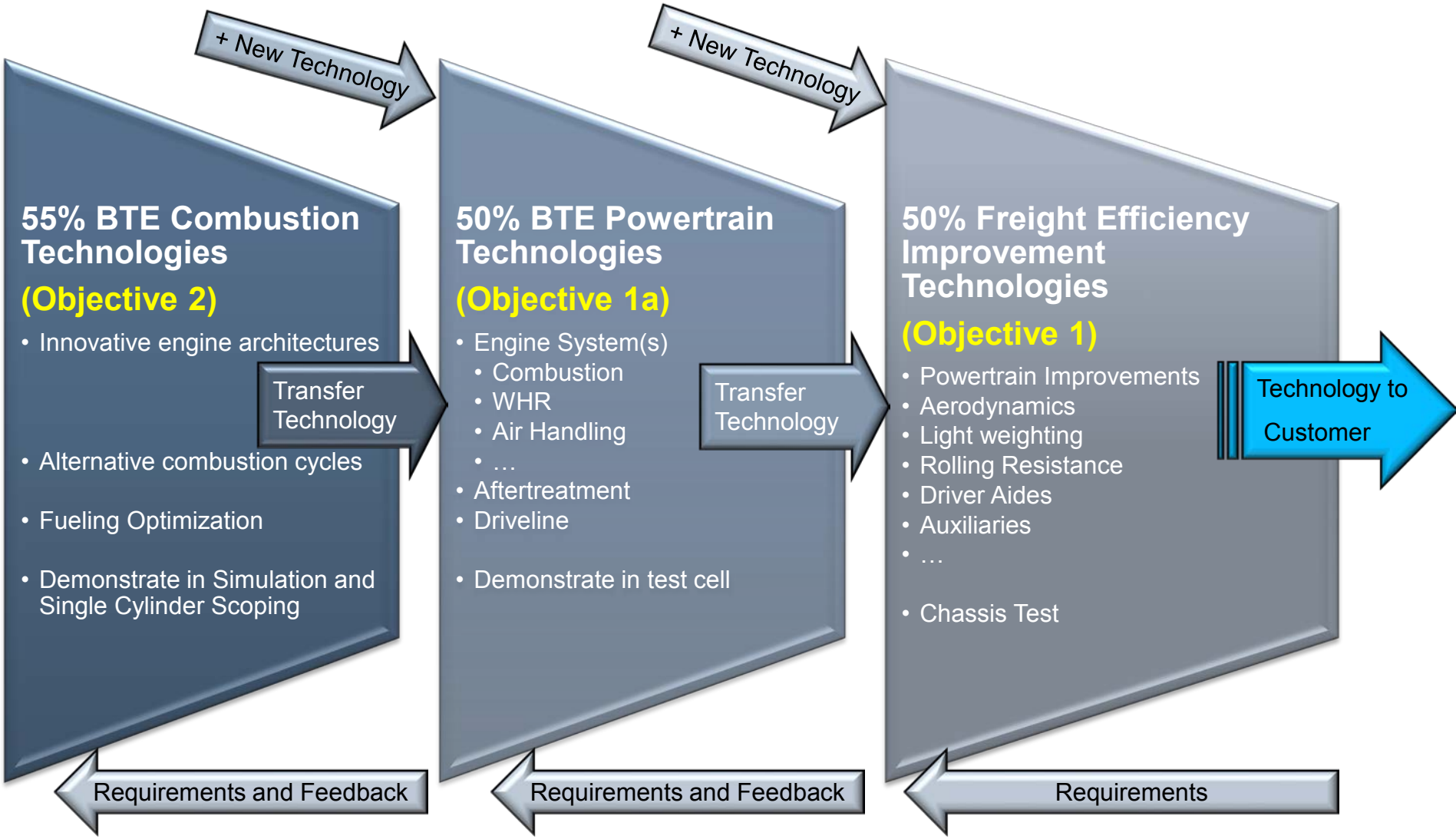
Simulate technologies to achieve 55% BTE

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



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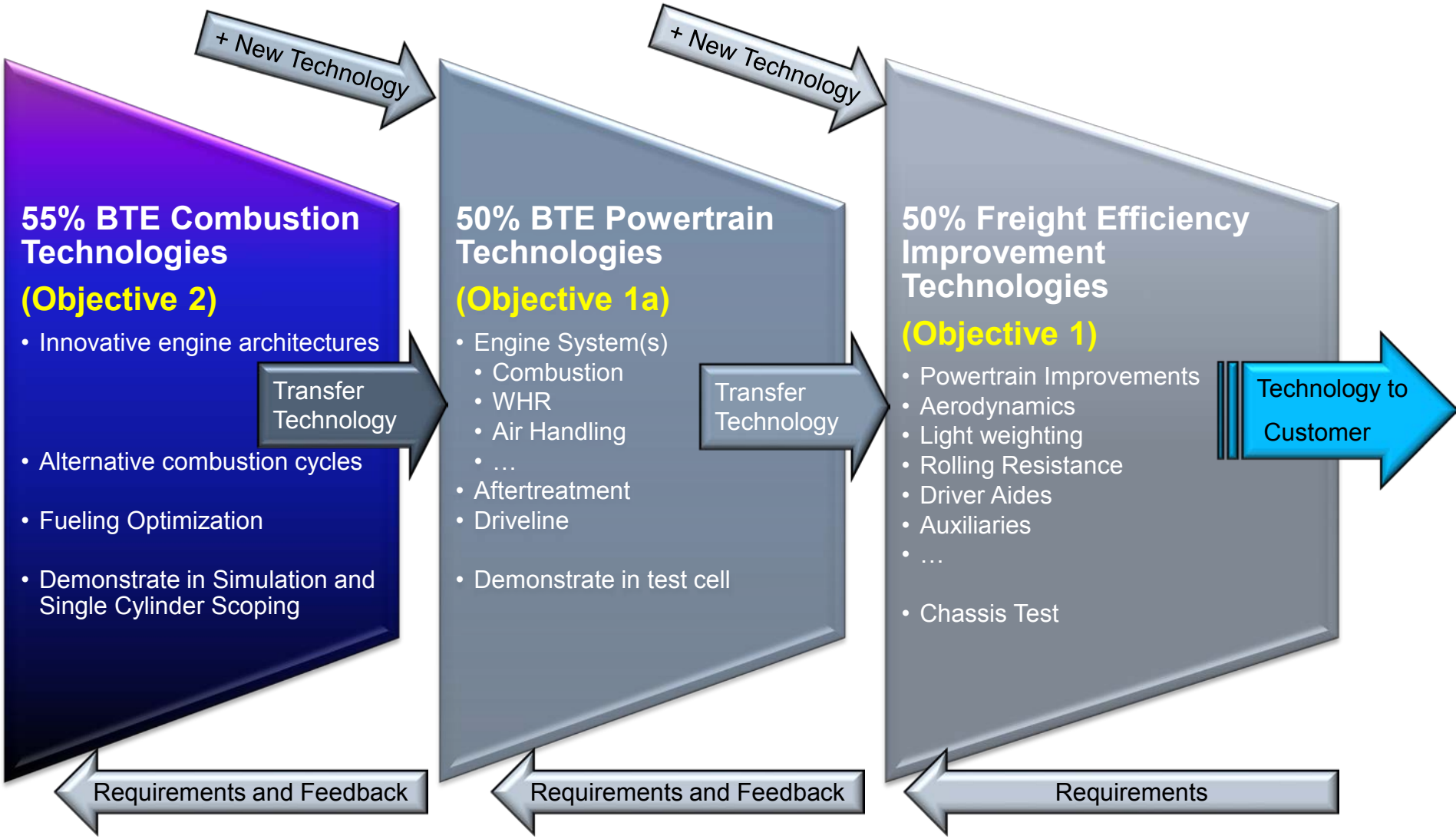
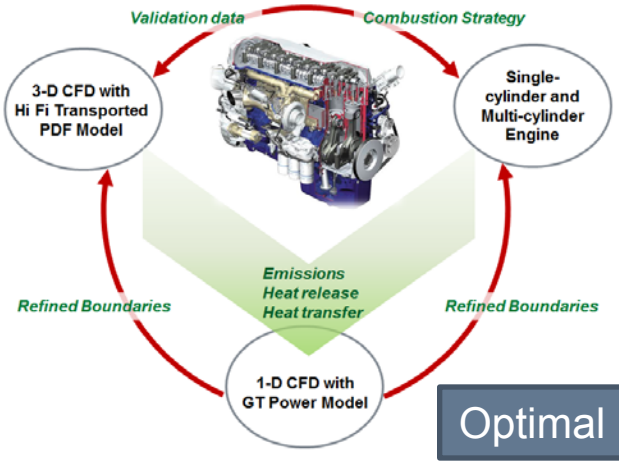


Approach for 55% BTE Engine (Objective 2)

Optimize gross ITE

Probability Density Function (PDF) is a more accurate method to model combustion behavior during turbulent mixing



Optimal BTE

2011	2012	2013	2014	2015	2016

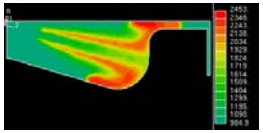
Phase I - Tools & Method Development

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

Currently in Phase II. A 55% BTE engine is conceptualized.

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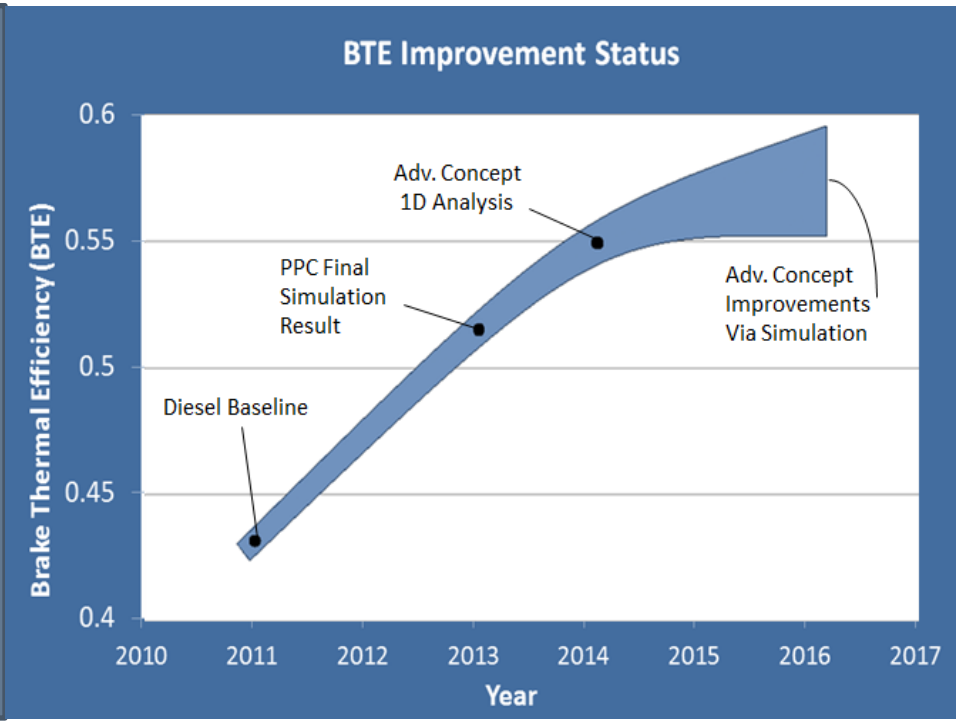
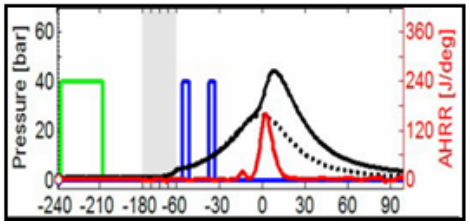
Progress on 55% BTE Engine (Objective 2)

- For PPC mode, the PDF model matches measured data with improved accuracy compared to common techniques. PDF and 1D multi-cylinder simulations are complete.

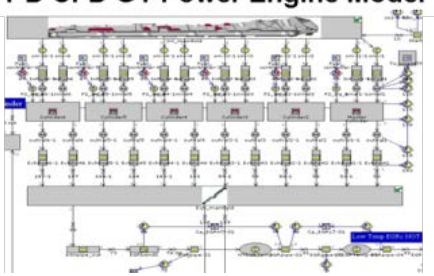
- 'Advanced Concept' developments are now in progress.
- Work on improving the computational method for 'Advanced Concept' thru:
  - Fuel mechanism research
  - Computational speed reduction
  - Heat transfer developments
  - Spray model developments



Refined In-cylinder Combustion



1-D CFD GT-Power Engine Model



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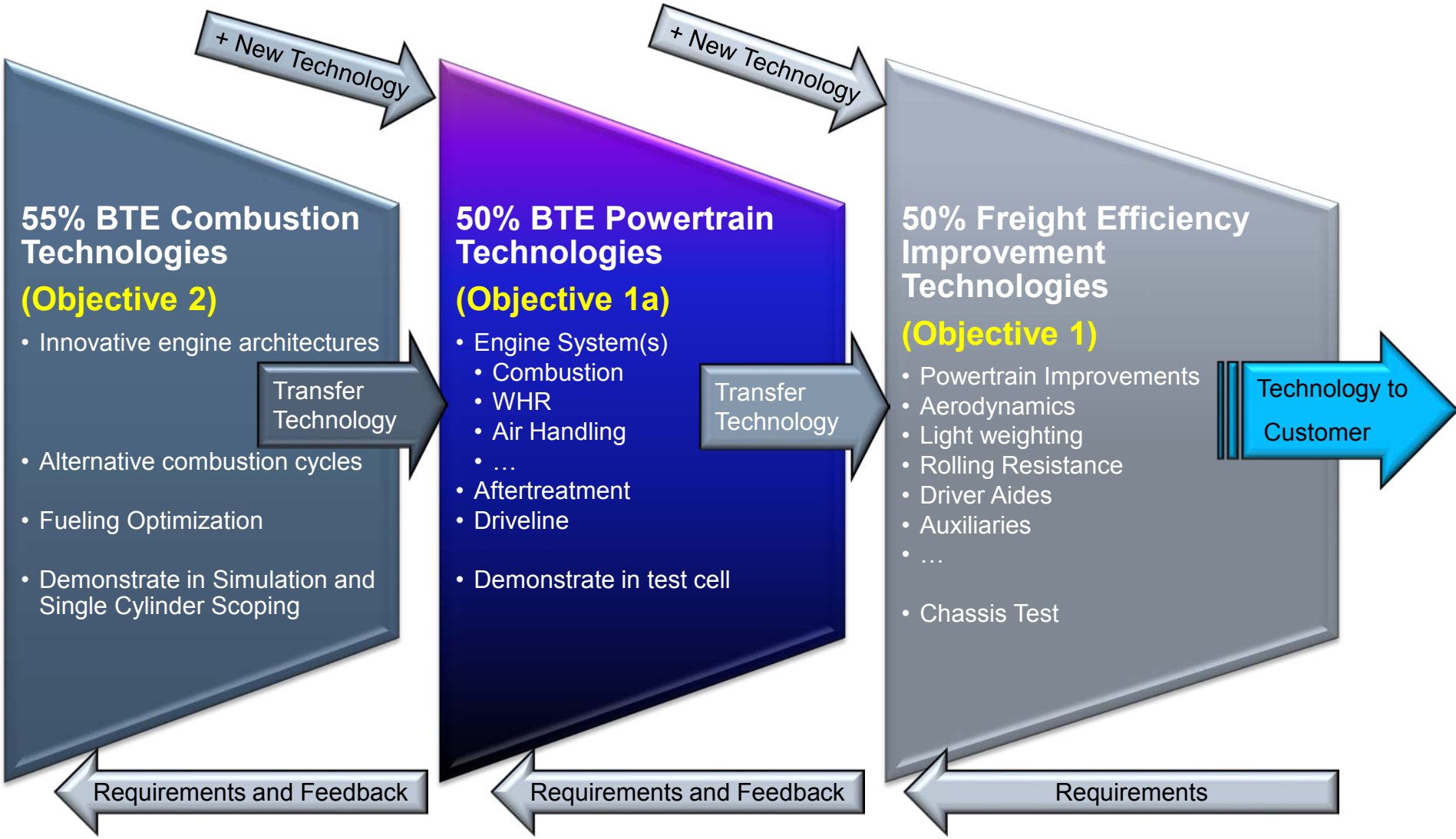
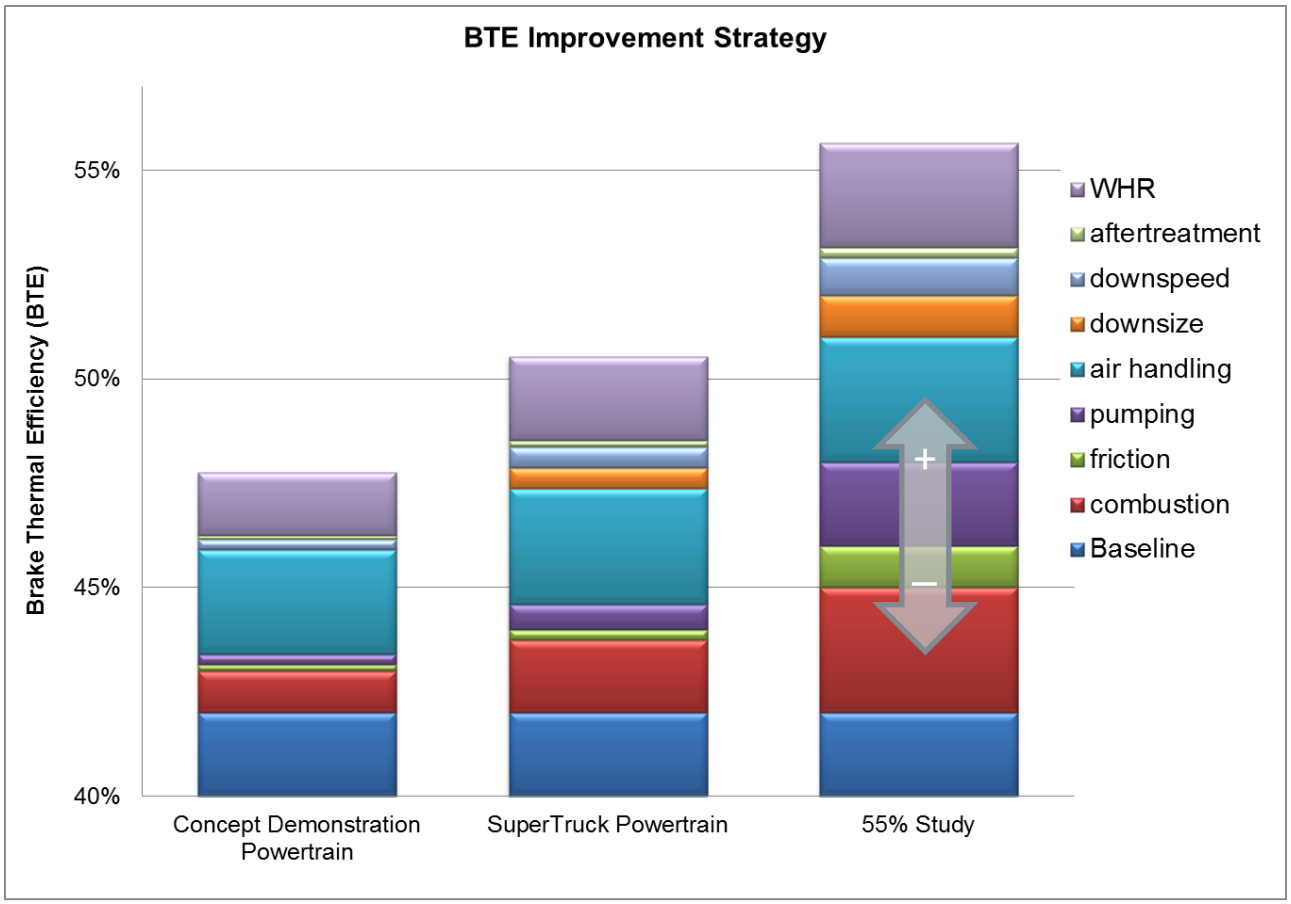


Strategy for Brake Thermal Efficiency
(Objective 1a)

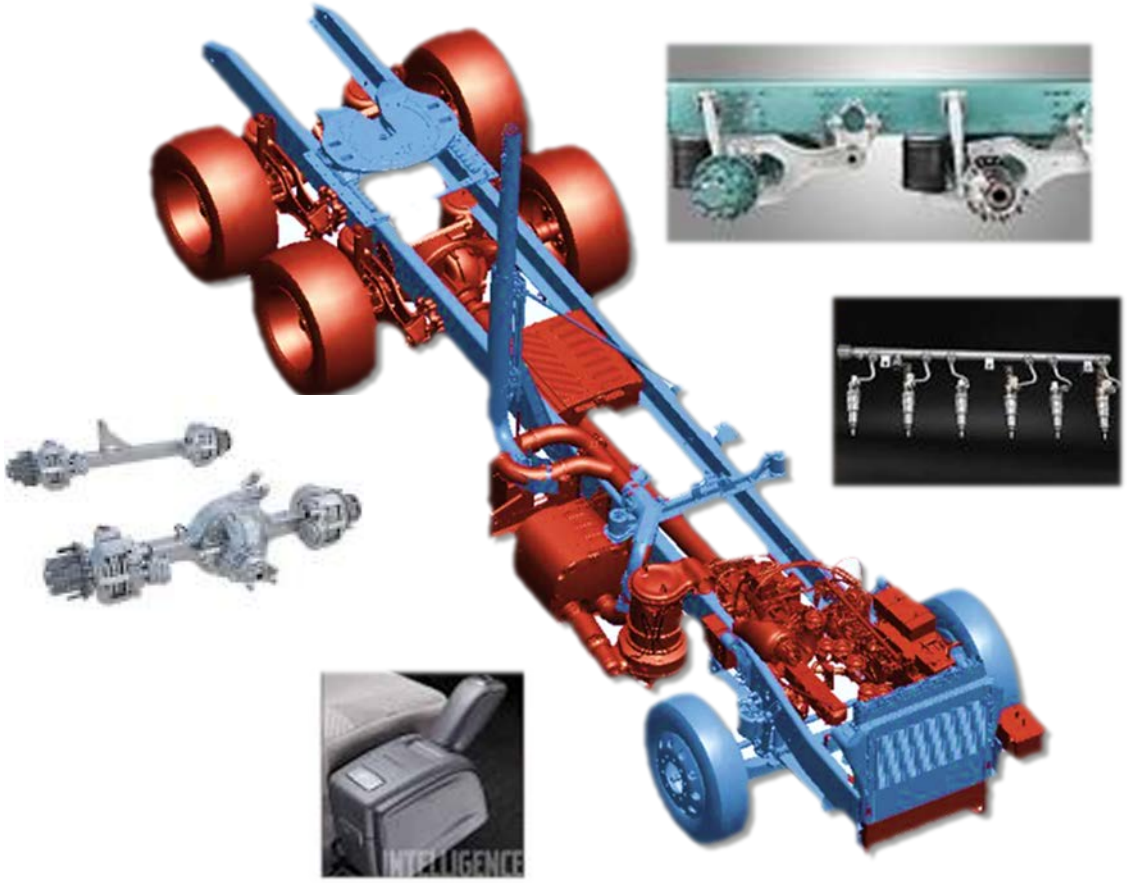
- Develop and verify powertrain components that enable 50% engine BTE.
- Each family displayed represents many sub-sets of technologies
- Integrate systems into concept vehicles and verify on customer duty cycles



Accomplishments towards 50% BTE (Objective 1a)

Testing Completed for Intermediate (48% BTE) Powertrain in 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



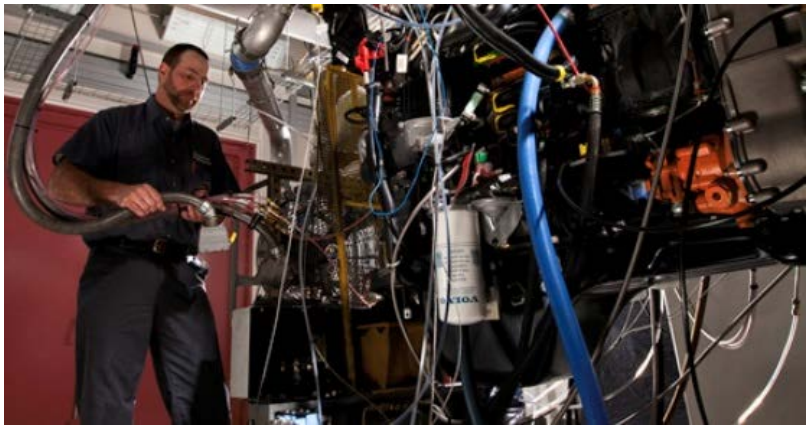
Suspension, Injection System, Axles and Downspeeding Technology are or will be in production soon

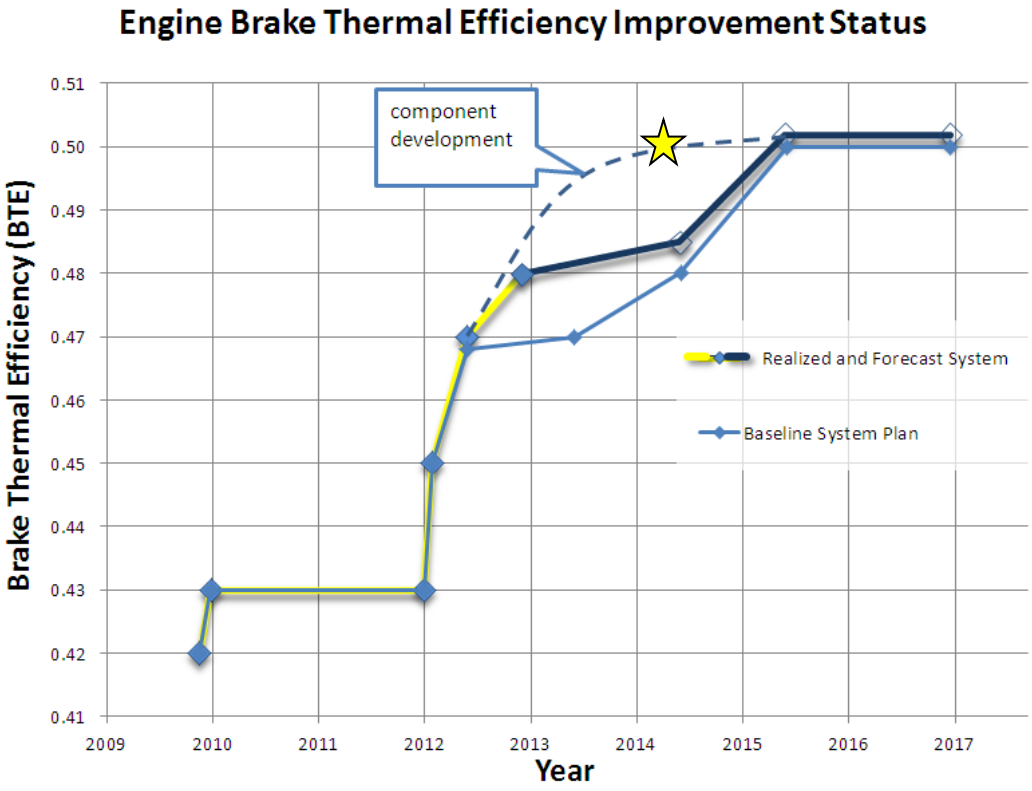
Accomplishments towards 50% BTE (Objective 1a)

★ The 50% BTE powertrain is under development, with three engines running and 6 component stands maturing technologies in parallel.

Downsized 13 → 11 Liter Engine

- 11liter capable of same power as 13liter
- Powertrain weight reduction >400lbs





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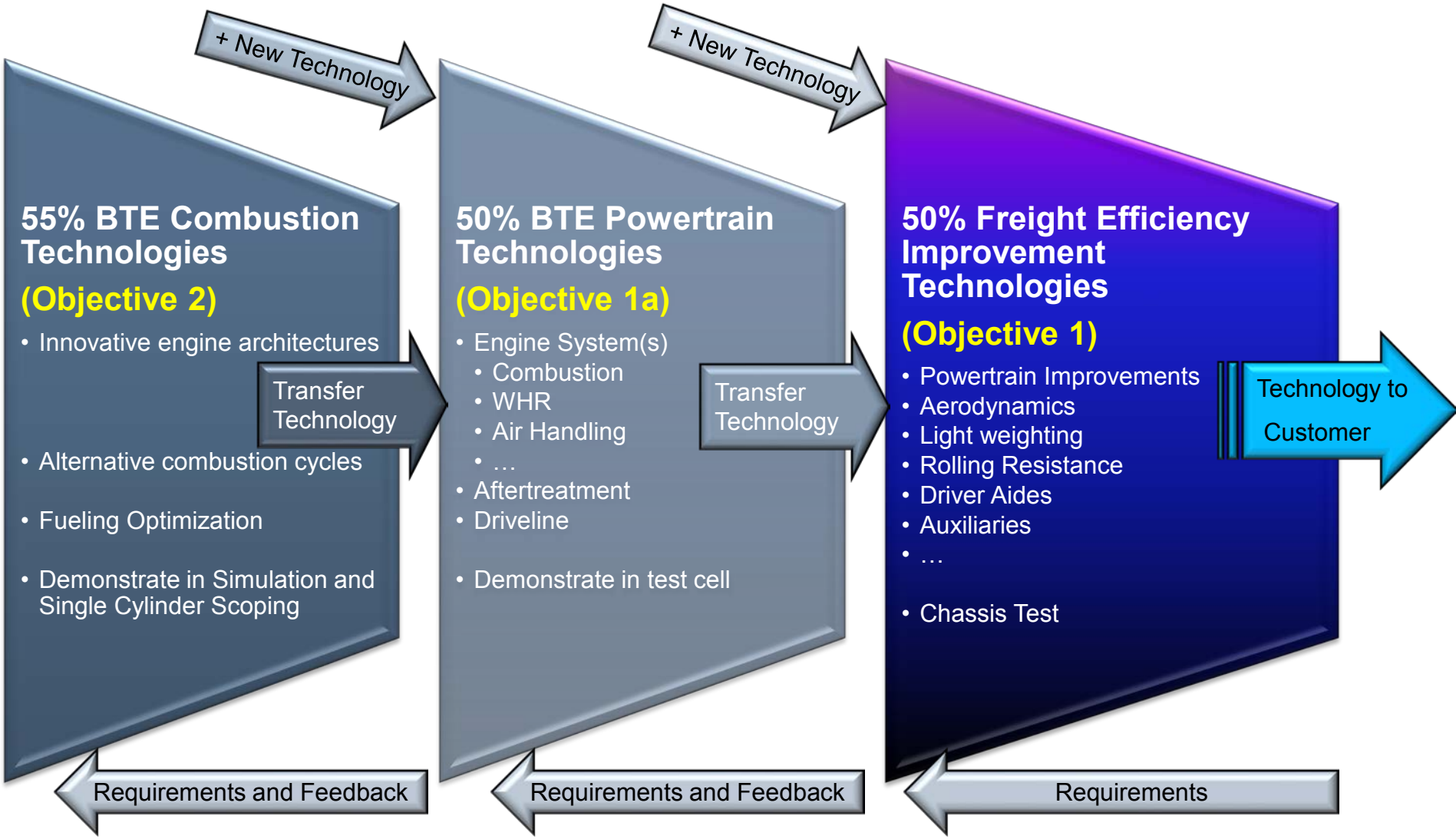

Approach to Freight Efficiency Improvement

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

Two phases of development

- ✓ Phase 1 complete
- ○ Phase 2 engine started 6 months ahead of schedule

Phase II - Development & Integration

Techn. Refinement

Validation

engine bench

Integration

demonstrator chassis

Optimization

Demo Truck

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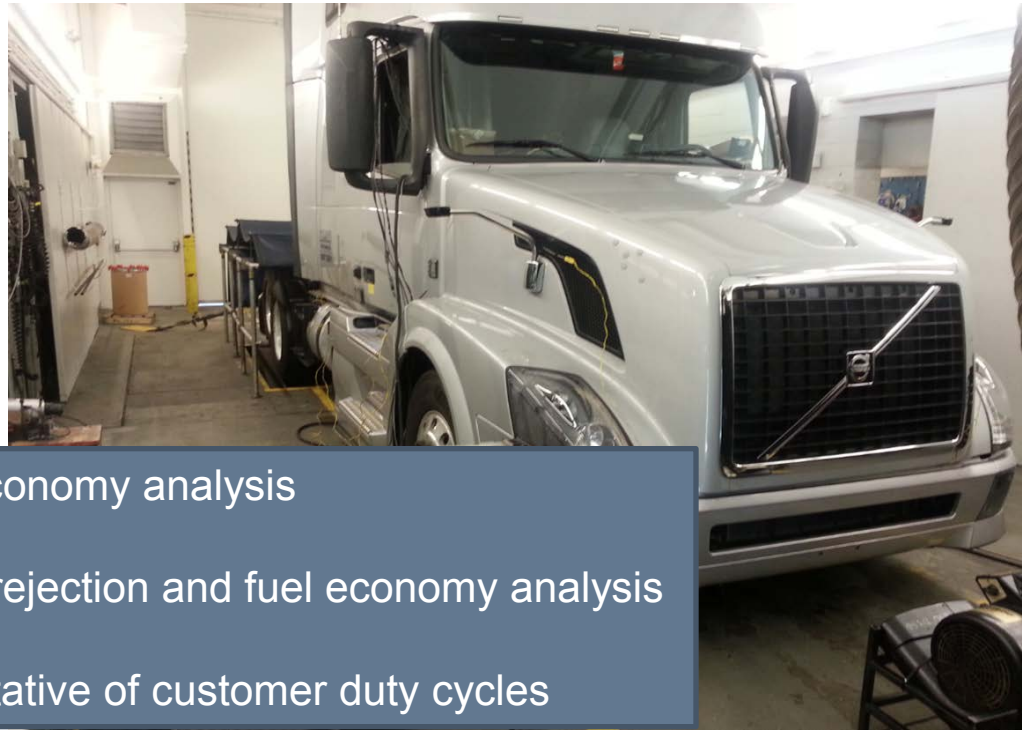
Powertrain Accomplishments towards 50% Freight Efficiency Improvement (Objective 1)

Completed testing of first generation powertrain system in concept truck



- Tested on road for performance and fuel economy analysis
- Tested in a chassis dynamometer for heat rejection and fuel economy analysis
- Successfully completed missions representative of customer duty cycles

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

Concept Truck

- Vehicle Test Complete
- 43% Freight Efficiency improvement measured
  - 18% Contribution from Powertrain
  - 48% BTE engine and advanced powertrain tested in vehicle

Final Demonstration Truck

- Initiated testing of engine for Demo Truck 6 months early
- Preparing to deliver mock-up engine to chassis team for fitment studies

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.

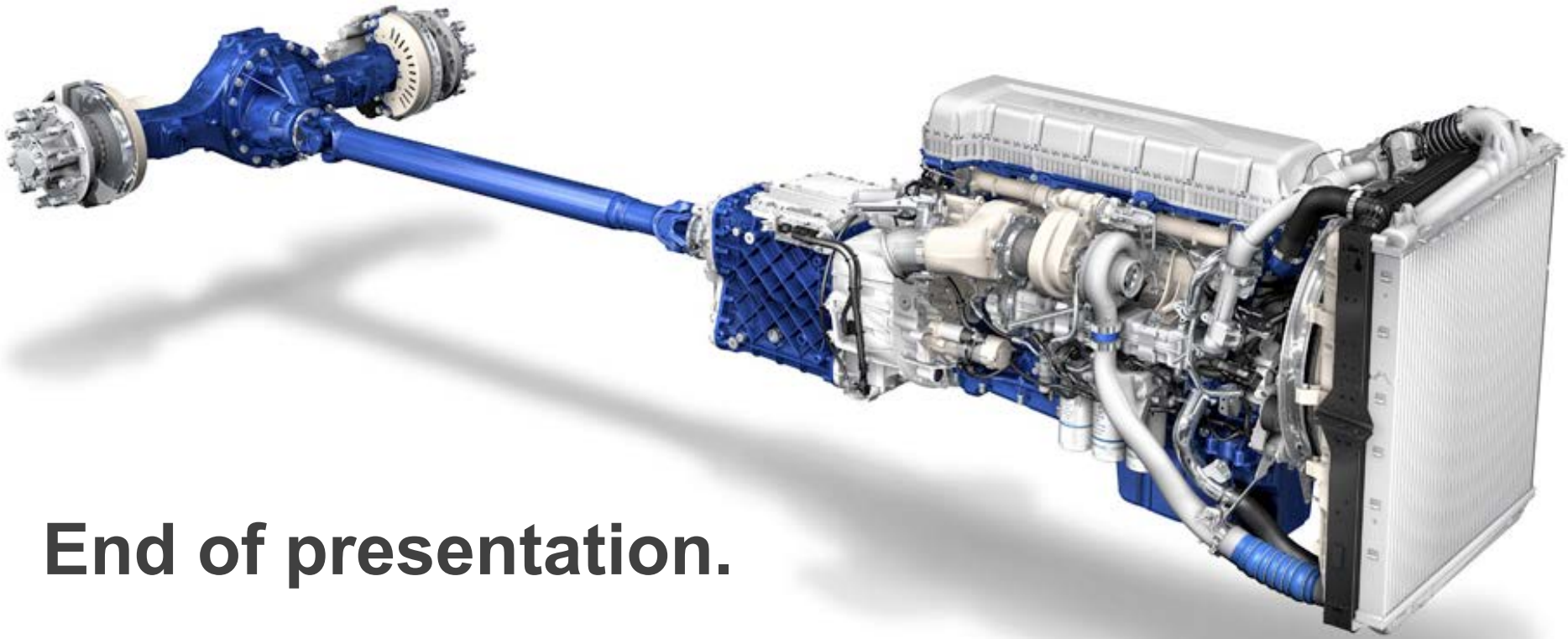
Collaborator / Partner	Focus
The Customer	Log vehicle data used from thousands of highway vehicles on the market is to define drive cycles and requirements
Volvo Technology of America	Contract Management and Collaborator Integration
Volvo Group Trucks Technology	Engine, Transmission, Axles, Light weighting, Chassis Auxiliaries, Integration, Chassis Aerodynamics, …
Freight Wing, Inc.	Trailer Aerodynamics
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 work on applying verified fuel chemistries to the PDF model
  - Optimize the ‘advanced concept’ engine and its sub-models using the integrated computational method with a goal to exceed 55% BTE.
- 50% BTE (Objective 1a)
  - Continue testing and integration of final demonstrator powertrain system in an engine test cell 2014
  - Deliver functional 50% BTE powertrain system to Demo Truck 2015
- 50% Freight Efficiency (Objective 1)
  - Deliver reduced weight powertrain
  - Incorporate 50% BTE methods into 50%+ Freight Efficient chassis
  - Integrate chassis improvements into powertrain system development

Summary of Volvo Supertruck Project Status

- **Timeline:** Project is 55% complete to date
- **Budget:** On track vs. plan
- **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 **54.5% BTE** capable engine. Volvo also tested the **48% BTE** powertrain in vehicle with success. The 50% BTE powertrain is under development, with three engines running and 6 component stands maturing technologies in parallel. The first concept vehicle achieved a **45% Freight Efficiency** Improvement.
- **Collaborations:** 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.
- **Future Plans:** Technologies selected as viable and ready will be tested as part of integrated concept powertrain system in 2014 in an engine test cell environment. In 2015 the 50% BTE capable powertrain will be demonstrated in vehicle. Simulation 55% components will progress through upcoming funding year.



End of presentation.

Thank you for your attention.