HD Powertrain Optimization

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Overview

Timeline	Barriers*
• Project start date: 10/01/2016 • Project end date: 09/30/2018 • Percent complete: 20%	• Cost • Constant advances in technology • Lack of standardized test protocols **from 2011-2015 VTP MYPP*
Budget (DOE share)	**Partners**
• FY17 funding: $776,964 • FY18 funding: $800,000	• Oak Ridge National Laboratory (Project Lead) • Cummins, Inc. • Eaton Corporation

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Any proposed future work is subject to change based on funding levels

Relevance

- Supports 21st Century Truck Partnership :
  - Accelerate technology development through collaborative, pre-regulatory, and **pre-competitive R&D component and system-level projects**
  - Research one of six key technical focus areas :Drivetrain Systems technologies (**Advanced transmission-engine controls**, hybrid systems, reduced parasitic losses, and **engine down-speed integration**)

- Addresses the following VSST Barriers*:
  - **Cost**: Powertrain integration optimization requires expensive and rare powertrain testing facilities. ORNL's VSI lab is such a facility, ideally suited to demonstrate benefits of integrated powertrain in a controlled lab environment.
  - **Constant advances in technology**: This project researches system level approach to fuel efficiency improvement.
  - **Lack of standardized test protocols:** This project supports SAE J2711 standard for HD powertrain test procedures.
  - **Computational models, design, and simulation methodologies:** This project refines state of the art HD powertrain technology models with experimental dynamometer data to provide accuracy suitable for powertrain optimization activities.

*Reference: Vehicle Technologies Multi-Year Program Plan 2011-2015:
http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

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Objectives

- **Reduce petroleum consumption for heavy duty trucks through powertrain optimization**
  - Utilize modeling, simulation, and advanced hardware-in-the-loop (HIL) experimental methodologies to develop HD powertrain and vehicle systems.
  - Optimize HD powertrain efficiency as a system by coordinating engine and transmission operations

- **Establish process for system approach to powertrain optimization in horizontally integrated industry**

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Approach

- **Establish baseline and state-of-the-art (SOA) HD powertrain efficiencies**
- **Develop a simulation environment for powertrain optimization**
- **Develop optimal supervisory control strategies designed to coordinate the engine and transmission controllers.**
- **Validate control algorithms offline**
- **Develop a prototype supervisory controller capable of implementing the previously designed control algorithms and apply them to a powertrain installed in ORNL's Vehicle System Integration (VSI) lab**
- **Integrate ORNL supervisory control onto the SOA powertrain in Hardware-In-the-Loop VSI lab.**
- **Compare SOA powertrain results with new controller powertrain.**

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FY2017 Milestones

Month /Year	Milestone or Go/No-Go Decision	Description	Status
Dec 2016	Milestone	Establish powertrain efficiency baseline for representative Class 8 vehicle	**COMPLETE**
Mar 2017	Milestone	Complete detailed powertrain and vehicle reference model for development of ORNL supervisory control strategies	**COMPLETE**
June 2017	Milestone	Complete baseline ORNL supervisory controller (hardware and software)	**ON SCHEDULE**
Sept 2017	Milestone	Procure and install advanced state-of-the-art powertrain in the ORNL VSI Lab	**ON SCHEDULE**

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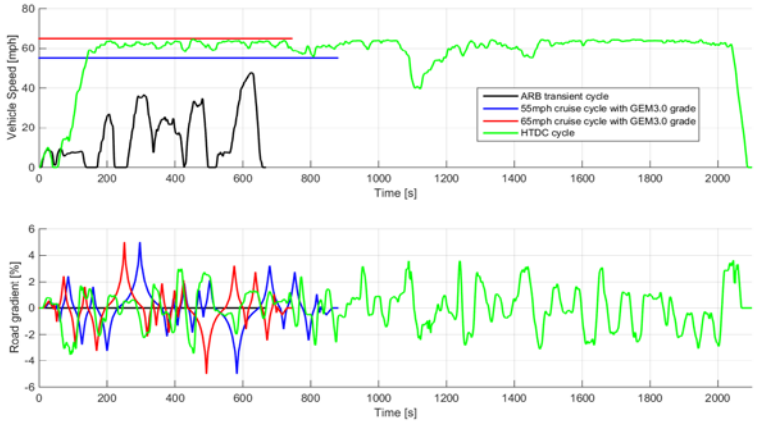
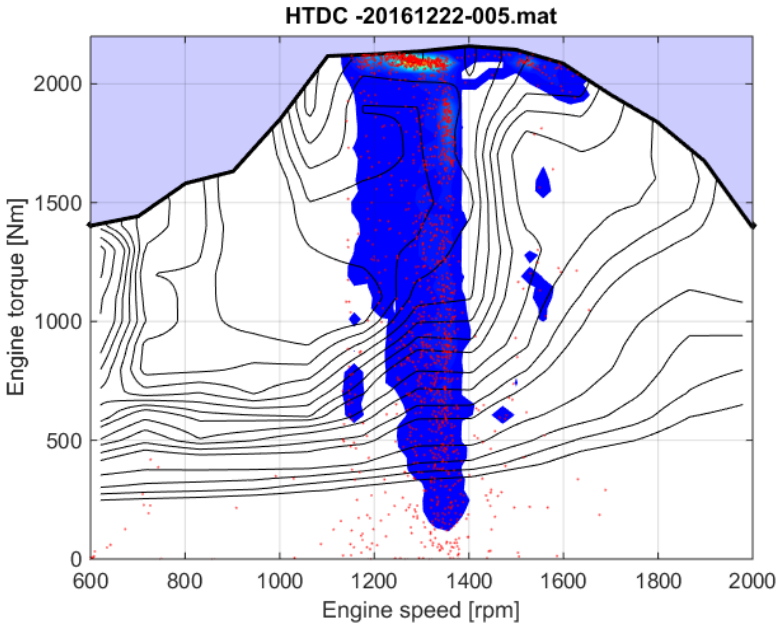
Accomplishment (1): Baseline Powertrain Benchmarking

- Selected "Un-integrated" baseline powertrain:
  - Cummins 15l 450hp MY12 ISX15 engine
  - Eaton UltraShift Plus 10-speed Automated Manual Transmission (AMT) (16E310C-LAS).
  - No co-optimization between engine controller and transmission controller.
  - Representative of class 8 truck long haul application powertrains
- Commissioned powertrain in VSI lab test cell
- Developed Hardware-In-the-Loop environment for real world operation of powertrain .

Accomplishment (2): Baseline Powertrain Benchmarking

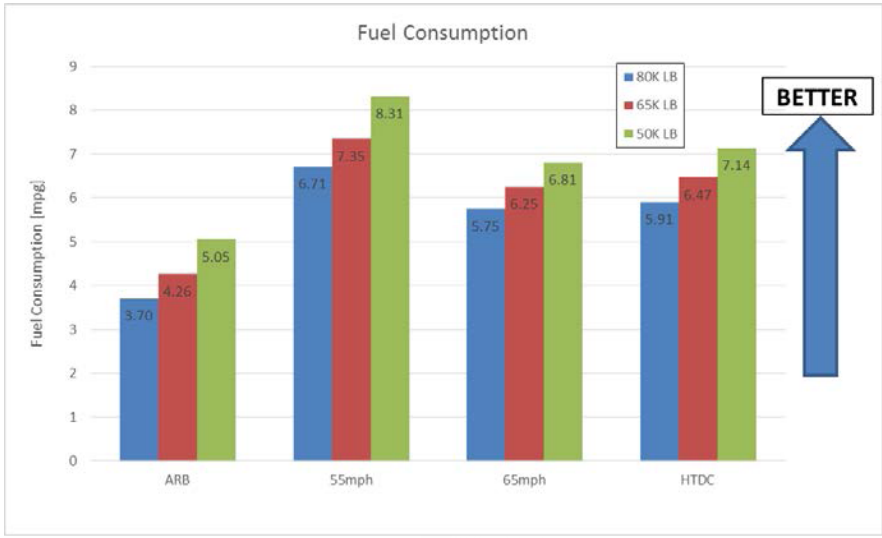
- Benchmarking matrix:
  - 4 drive cycles
    - CARB transient cycle
    - EPA GHG2 55mph cycle
    - EPA GHG2 65mph cycle
    - ORNL's real world cycle (HTDC)
  - 3 Test weight
    - 50,000lbs
    - 65,000lbs
    - 80,000lbs
- Virtual test vehicle: Kenworth T700
  - Axle ratio: 3.36:1;
  - Rolling resistance: 0.00584
  - Aero drag: 6.86

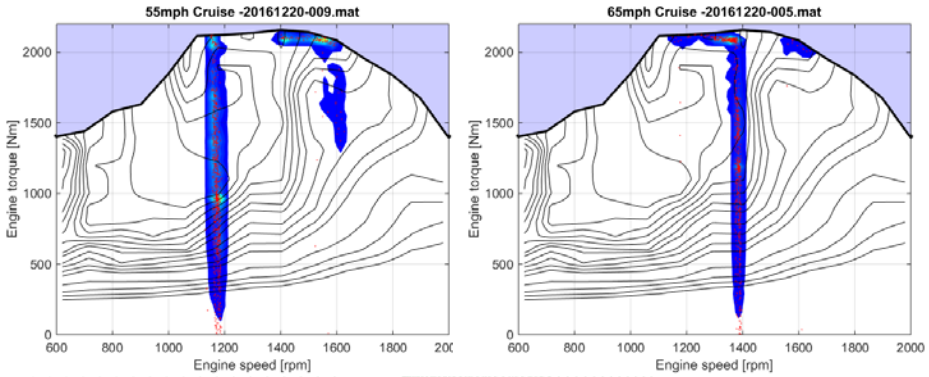




Accomplishment (3): Baseline Powertrain Benchmarking

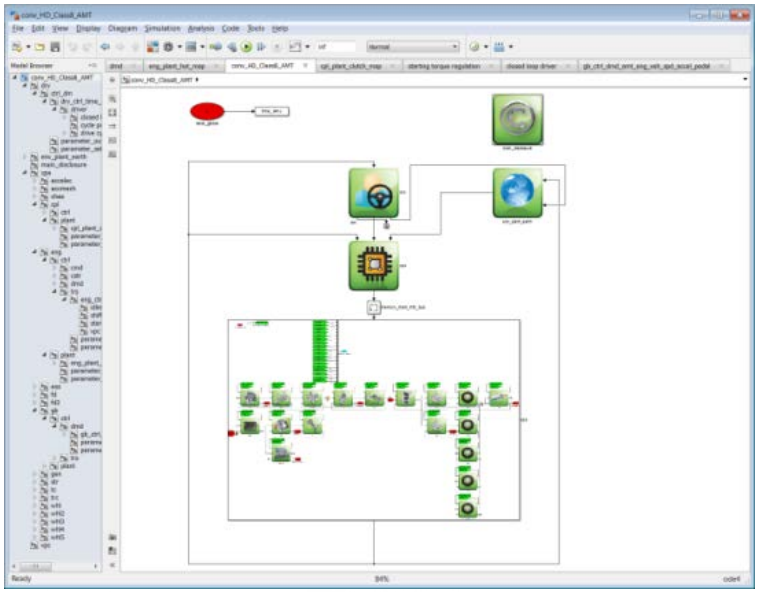
- 55mph cruise cycle gets the best fuel economy because of:
  - Lower vehicle speed and lower drag losses
  - Engine operation closer to peak efficiency and lower speed.
- 65mph cruise cycle and HTDC cycle get comparable higher fuel consumption due to:
  - Higher vehicle speed and losses
  - Engine operation farther from peak efficiency and higher speed.
- Opportunity for down-speeding

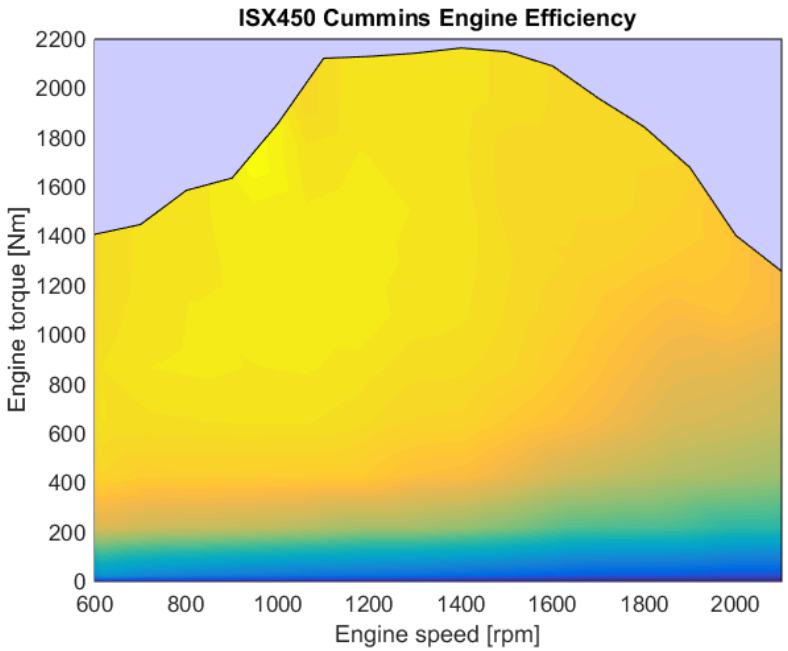


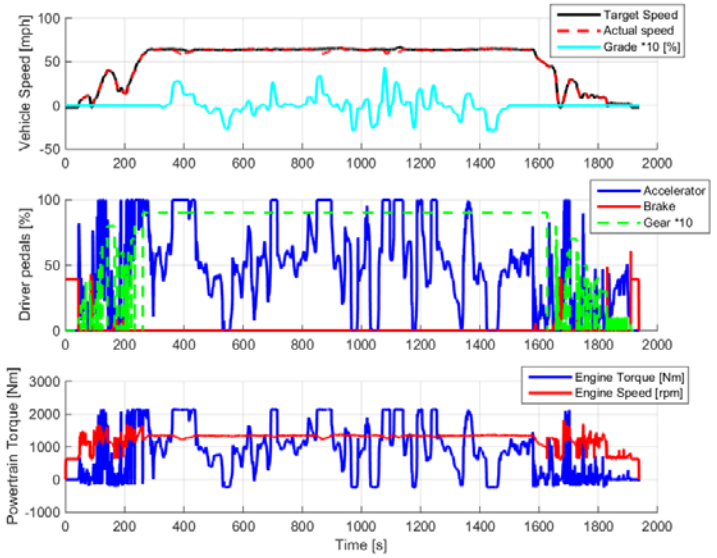


Accomplishment (4): Modelling Environment Setup

- **Generated heavy duty truck model with Autonomie**
- **Parametrized vehicle model for same Kenworth T700 vehicle used in HIL benchmarking**

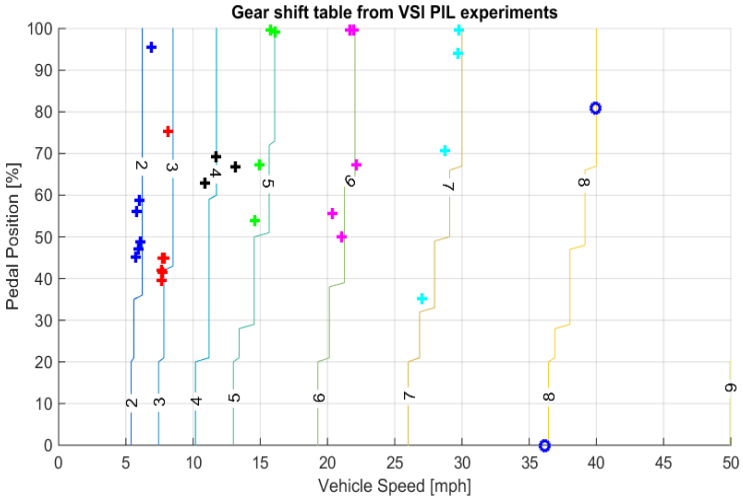


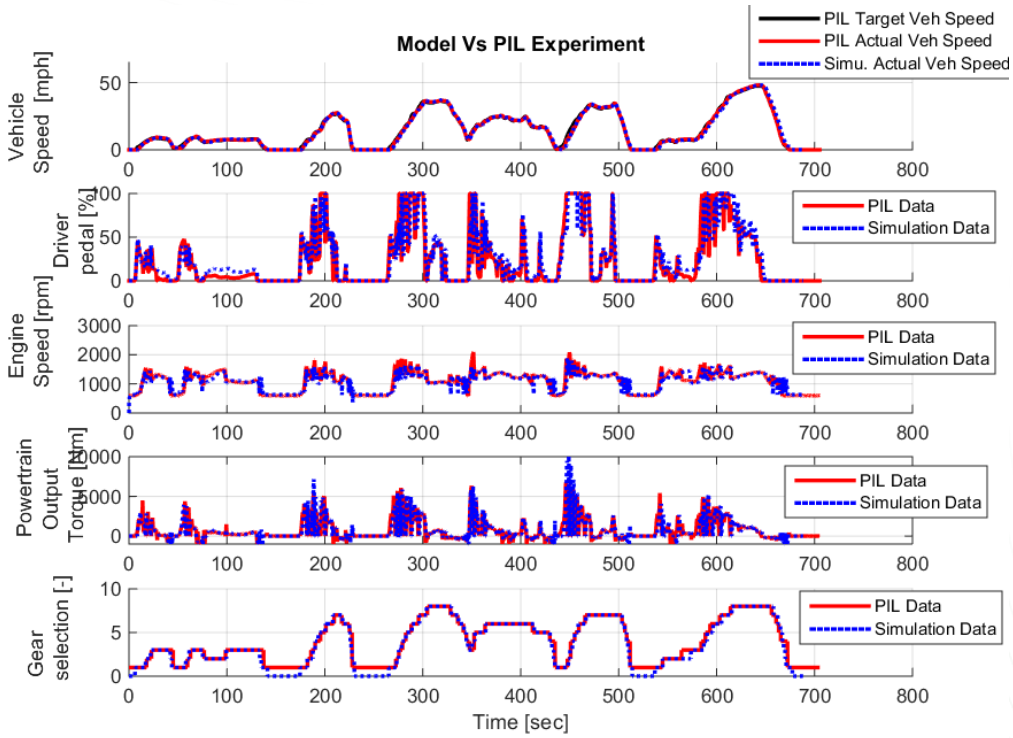


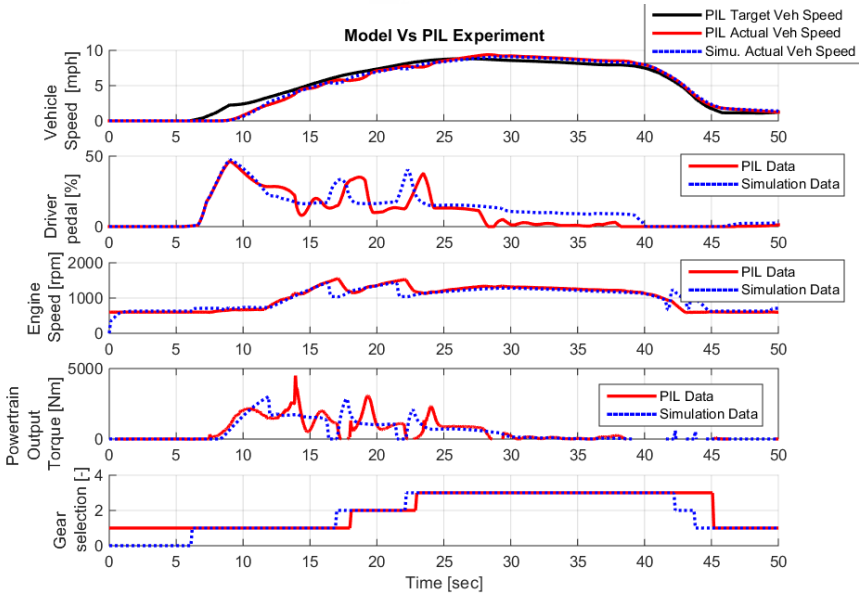


Accomplishment (5): Modelling Environment Setup

- **Parameterized transmission model and shift strategies with experimental data logged during the benchmark phase.**







Collaboration and Coordination

- **Cummins, Inc.**
  - Supply of X15 engine, after-treatment and controller
  - Technical support to:
    - Commission engine in test cell
    - Optimize/calibrate engine controls for specific transmission

- **Eaton Corporation**
  - Supply of SmartAdvantage transmission
  - Technical support to:
    - Commission transmission in test cell
    - Optimize/calibrate transmission controls for specific engine

Remaining Challenges and Barriers

- **Some optimization will require calibration (or maybe even code) changes inside the production controllers. This can only be performed by original equipment manufacturers (OEMs).**
  - Because of the working relationship with Eaton and Cummins and their expressed interest in this project, such support is expected to be available such that it won't affect the project.

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Proposed Future Work

- **Complete baseline ORNL supervisory controller (hardware and software) (Q3 FY17)**
- **Procure, commission and characterize State Of the Art integrated powertrain (Cummins-Eaton SmartAdvantage) (Q4 FY17)**
- **Complete benchmark of State Of the Art powertrain (Q1 FY18)**
- **Integrate and verify ORNL supervisory control into the SOA powertrain (Q2 FY18)**
- **Complete testing with SOA and ORNL supervisory controller (Q3 FY18)**
- **Complete Final Report (Q4 FY18)**

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Summary

- **Relevance:**
  - Reduce petroleum consumption for heavy duty trucks through powertrain optimization
- **Approach:**
  - Optimize HD powertrains as a system to improve component integration and efficiency, and overcome industry horizontal integration
- **Collaborations:**
  - ORNL, Cummins, Eaton
- **Technical Accomplishments:**
  - MY12 Class8 Truck Powertrain benchmark completed
  - Simulation environment and model validation completed
  - Procured SAO integrated powertrain
- **Future Work:**
  - Develop supervisory powertrain controls
  - Benchmark SOA integrated powertrain
  - Demonstrate supervisory powertrain controls on SAO powertrain in VSI lab
  - Publish system level optimization process for potential commercialization

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