Advanced Technology Vehicle Lab Benchmarking - Level 2 (in-depth)

2012 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

May 15, 2012

Eric Rask, Mike Duoba, Henning Lohse-Busch, Patrick Walsh

Argonne National Laboratory

Project ID # VSS031

Overview

- **Timeline**

  2011 Vehicles
  - Developing test/instrumentation plans
  - Vehicle procurement (OEM delays)
  - Instrumentation
  - Extensive vehicle testing
  - Analysis and reporting

  2012 Vehicles
  - Vehicle provided by collaboration partner (IFP)
  - Vehicle testing to begin in summer

- **Budget**
  - FY 2011 $850k
    - Hyundai Sonata Hybrid
    - VW Jetta TSI with 7-speed DCT
    - Chevrolet Volt EREV
  - FY 2012 $250k
    - Peugeot 3008 HYbrid4

- **DOE strategic goals/barriers addressed**
  - **F:** Constant advances in technology
  - **D:** Lack of standardized test protocols
  - **E:** Computational models, design and simulation methodologies

- **Partners**
  - DOE and other National Laboratories
  - USDrive, OEMs (both LD and HD), and Suppliers
  - IFP Energies Nouvelles for Peugeot testing

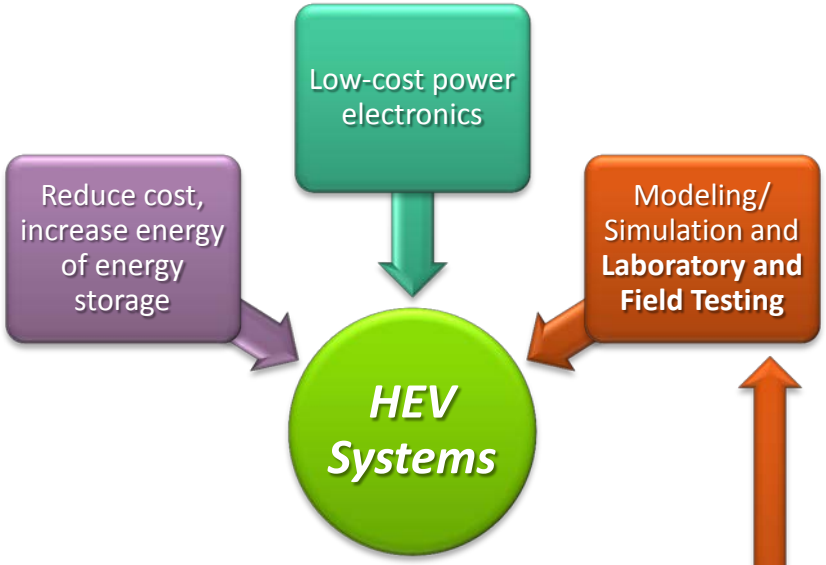
Relevance: Three Components of HEV Systems

In-depth vehicles selected with DOE, Lab, and OEM input to assess emerging vehicle and component technologies:

- **Sonata HEV**: DOE emphasis on HEV content reduction while retaining efficiency
- **Volt PHEV**: objectives for rapid deployment of PHEVs
- **Jetta TSI**: assessing improvements for advanced conventional powertrains

Vehicles typically do not overlap with Level-1 testing

"VTP is advancing the large-scale, cost-competitive production of the next generation of electric-drive vehicles through **three complementary component-and system-level technology pathways**:"

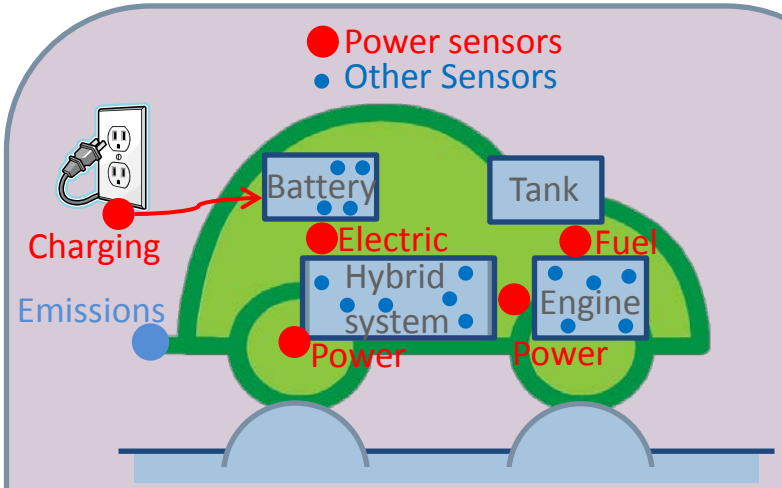


Laboratory and Field Testing Objectives

- Establish the state-of-the-art automotive technology baseline for powertrain systems and components through data generation and analysis
- Provide independent evaluation of technology
- Generate data to support target creation and hardware/model validation

Approach/Strategy: Focus on In-depth Testing and Analysis

Level 2: In-depth Testing



Invasive instrumentation:

- Incremental to level 1 Benchmark Approach
- Engine, shaft torque & speed sensors
- All major power flows (mechanical, electric,…)
- Component specific instrumentation

Purpose:

- Energy analysis, efficiency analysis on vehicle and components
- Component characterization in vehicle system

In-depth Testing Provides:

- Power-flow assessment
- Component performance
- Component duty cycles
- Operating temperatures
  - Nominal and de-rating
- In-situ component assessment

Extensive, publicly available data for advanced vehicles

Approach/Strategy: Test Vehicle Selection

- Vehicles selected to offer a range of prominent technologies for technology assessment and leveraged standards development
  - VW Jetta TSI: Advanced engine and powertrain evaluation
  - Sonata: P2 hybrid architecture versus power-split type systems
  - Volt: Evaluation of first OEM EREV plug-in hybrid

VW Jetta TSI

1.4L boosted Engine with 7-speed DCT offers increased performance and improved fuel economy

Hyundai Sonata Hybrid

Single-motor hybrid systems seeing renewed development as an alternative to power-split

Chevrolet Volt

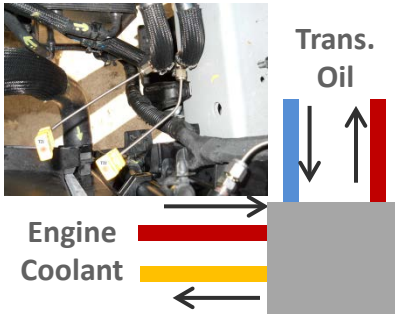
Benchmarking geared toward standards validation and exploration of EREV real-world fuel economy

Approach/Strategy: Extensive Vehicle Instrumentation

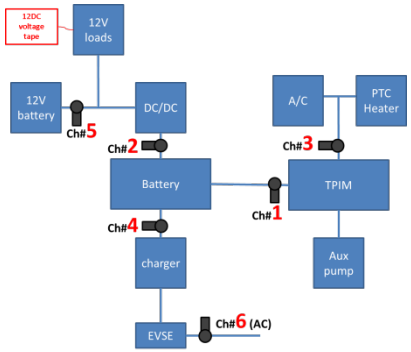
Vehicle specific instrumentation contributes to detailed understanding

(Select examples shown…typically 100+ signals available)

Hyundai Sonata
Engine coolant to trans. oil exchanger



Chevrolet Volt
Extensive electrical instrumentation



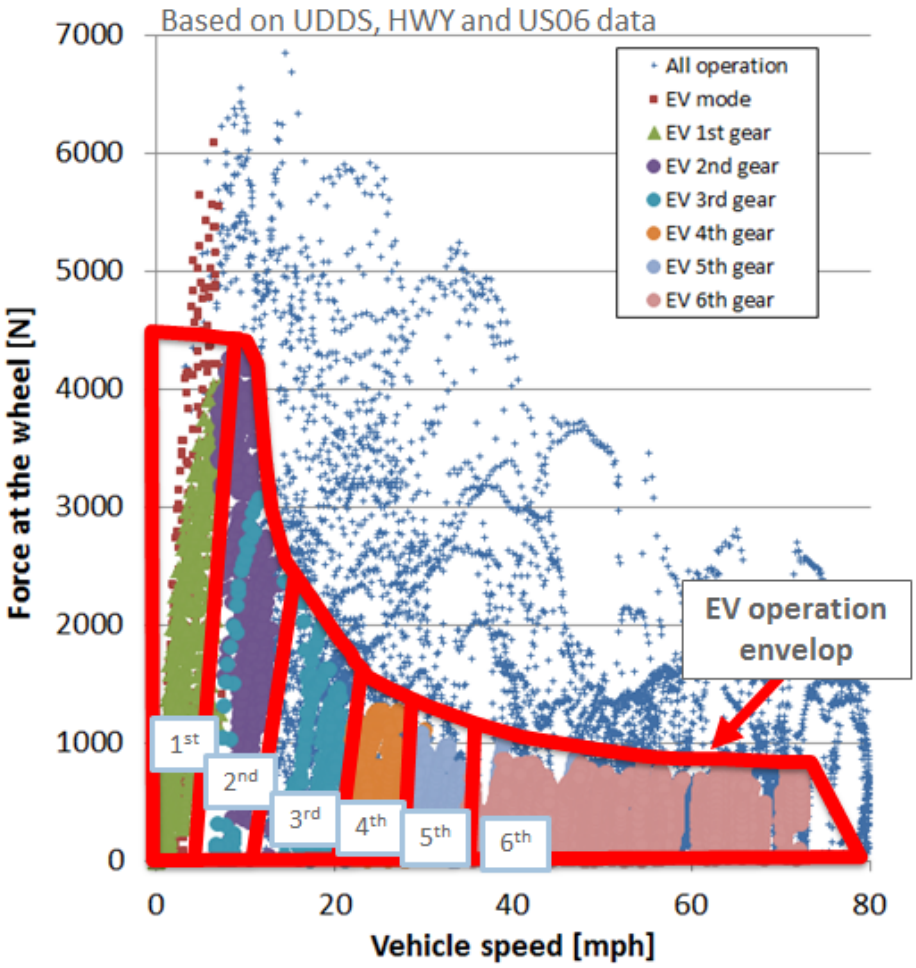
VW Jetta TSI
In-situ coolant and air temperature/pressure

Selected analysis and results are shown in the following slides, but in-depth testing provides:

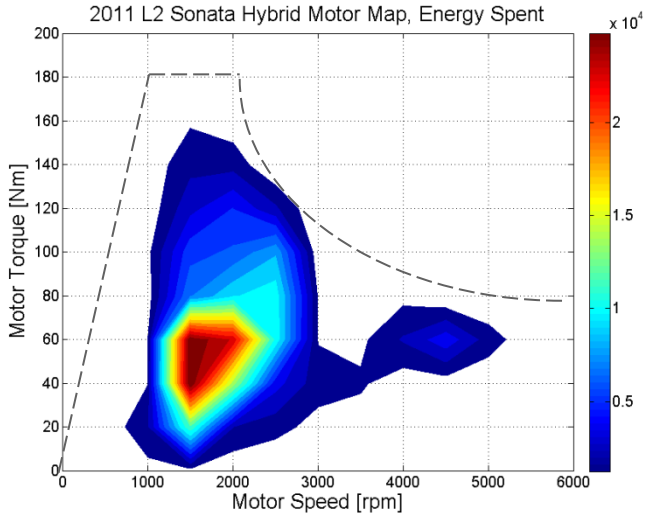
- High-level vehicle operation
- Control strategy assessment during specific operating modes (i.e. “cold” start)
- Evaluation of regenerative braking capability, limitations, and efficiency
- Engine fueling and capability
- Electric machine operation, capability, and efficiency (when possible)
- Assessment of critical thermal nodes (temperature pre/post)
- Evaluation of additional advance components (i.e. electric AC, electric oil pumps)

Accomplishments: Sonata Electric Machine Evaluation

Sonata's P2 hybrid architecture allows for a wide range of engine-off operating points using a fairly small electric machine



Sonata Traction Motor Usage and Capability

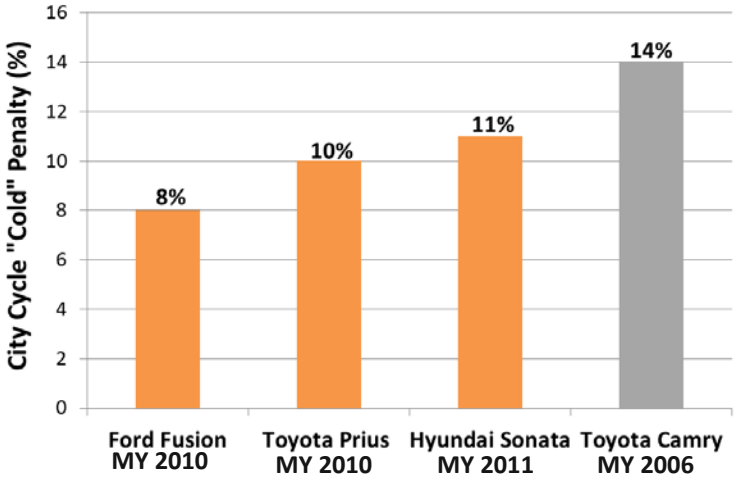


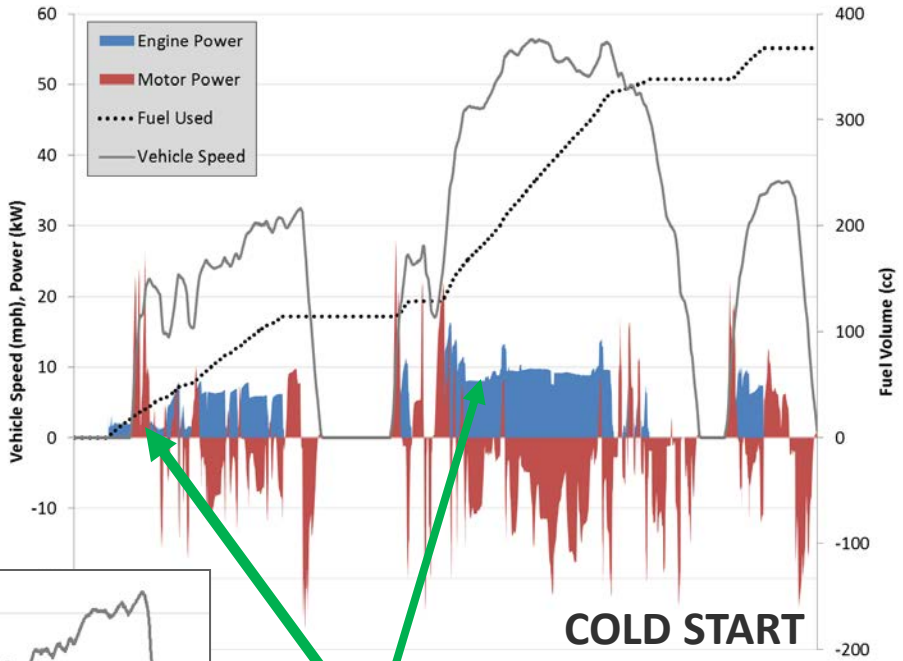
Sonata Traction Motor	
Observed Max Power (kW)	30
Observed Max Torque (Nm)	200
Prius Traction Motor	
Observed Max Power (kW)	55
Observed Max Torque (Nm)	201

Accomplishments: Sonata "Cold" Start Strategy Assessment

Sonata provides an additional data point regarding hybrid cold start penalty reduction

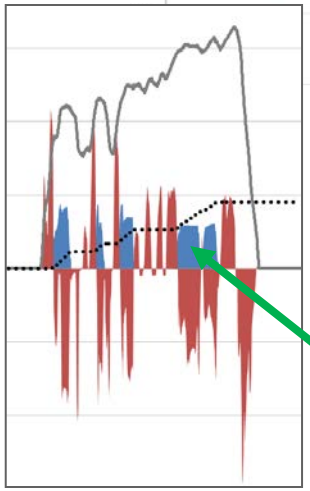
- Sonata uses hybrid architecture to smooth engine load during a cold start
- Operation varies significantly between cold and hot Hill 1 – fairly similar operation during Hill 2
- Observed reduction in cold-start penalty similar to other recent hybrids





COLD START

- Constant fuel rate during cold start for catalyst warm-up
- Would expect some engine off here



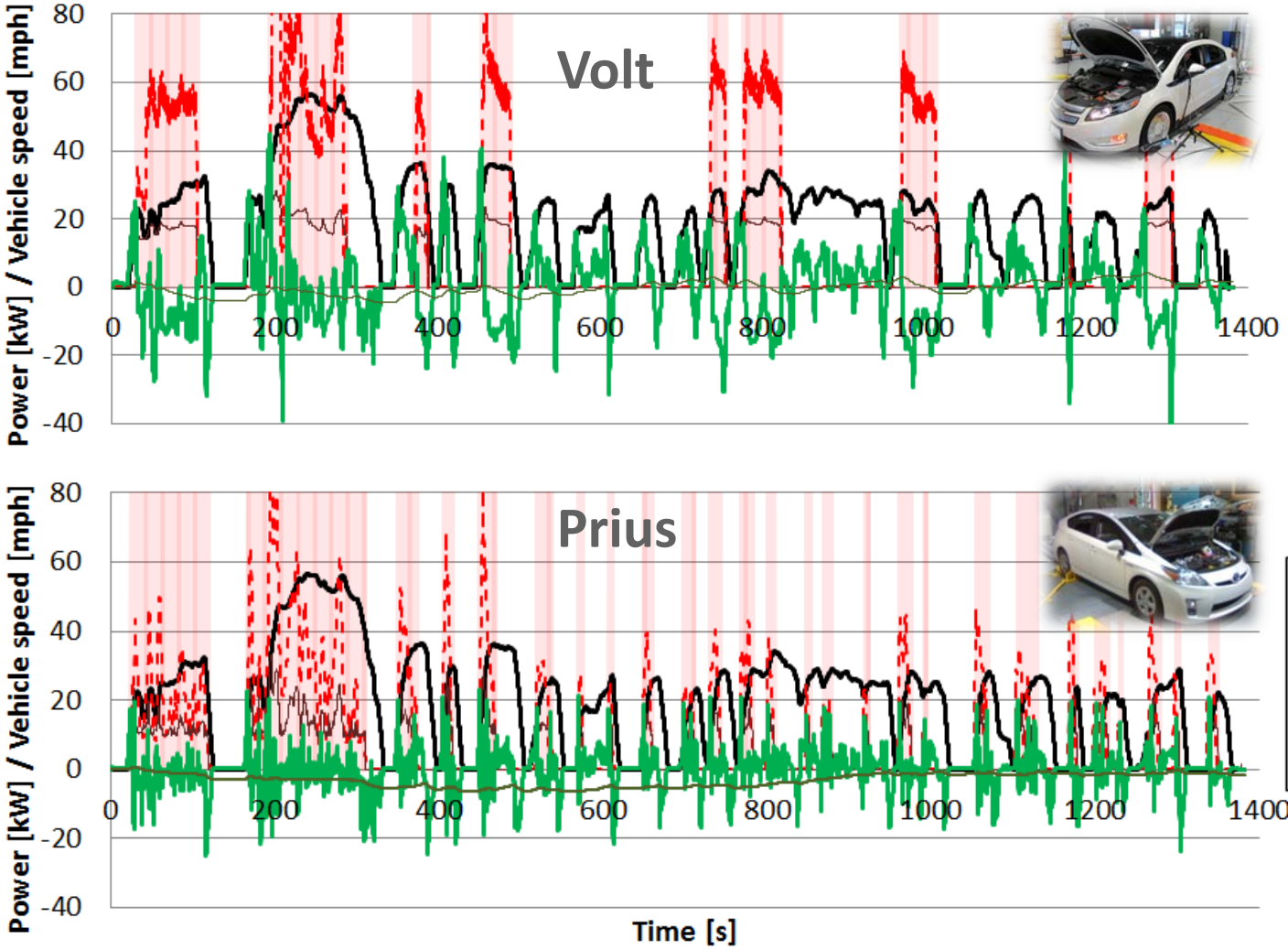
HOT START

- Load-following fuel rate and EV during hot start

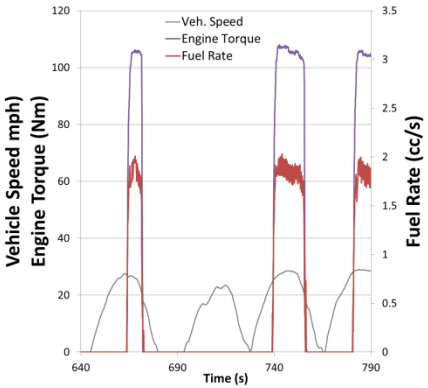
Accomplishments: Evaluation of Volt Charge Sustaining Operation

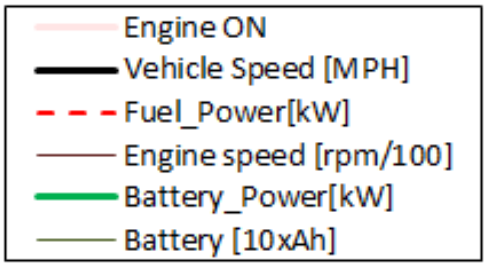
Volt UDDS charge sustaining operation is fairly unique

- Vehicle operates with long periods of EV operation and primarily uses electric launch
- Engine operates at relatively high loads



Engine On During Some Vehicle Decelerations

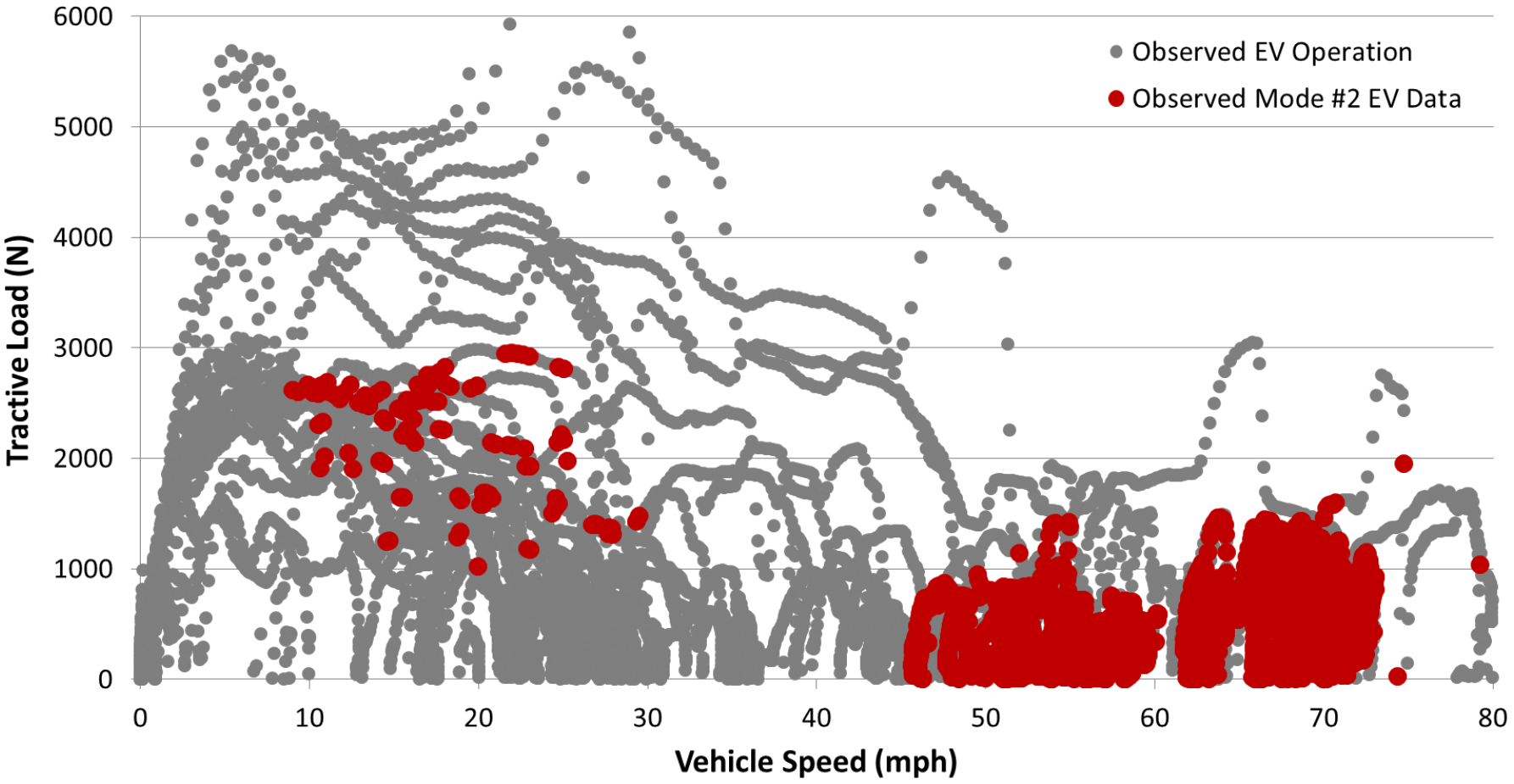




Accomplishments: Volt EV Operating Strategy Overview

Testing provides insight into the unique multi-mode EV capabilities of the Volt

- Second EV (2-motor) mode used primarily for higher speed, lower load EV operation
- Some regenerative braking also observed using this mode

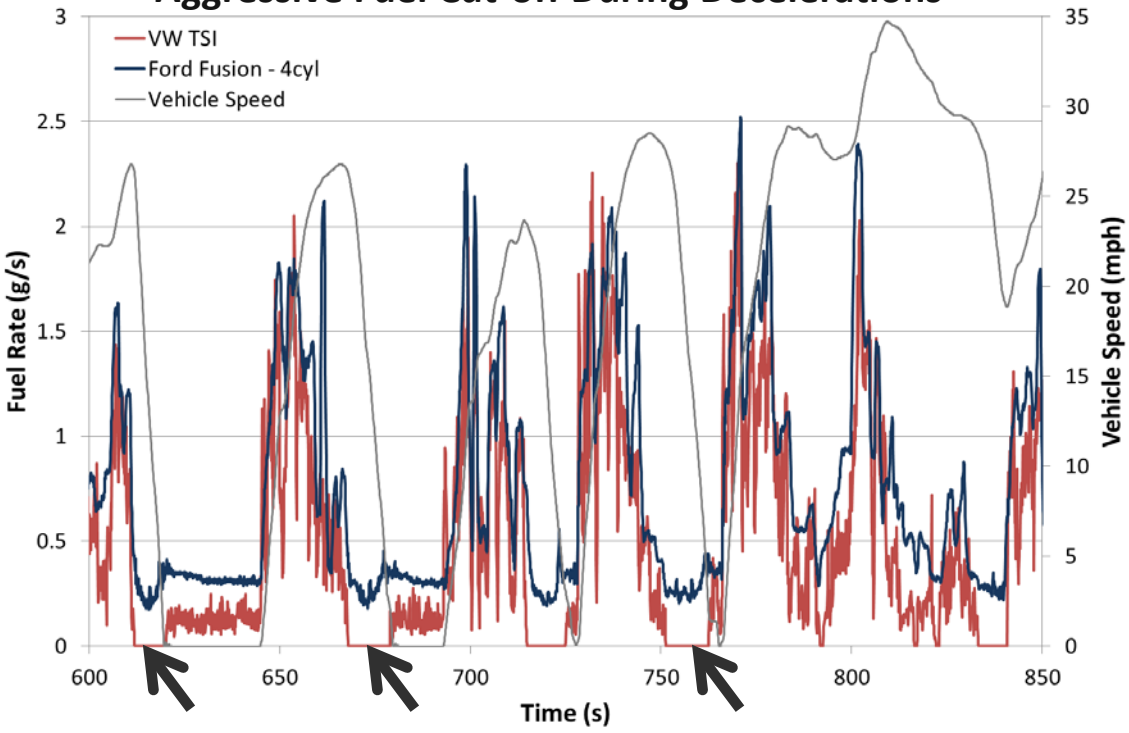


Accomplishments: VW TSI Technology and Operation Assessment

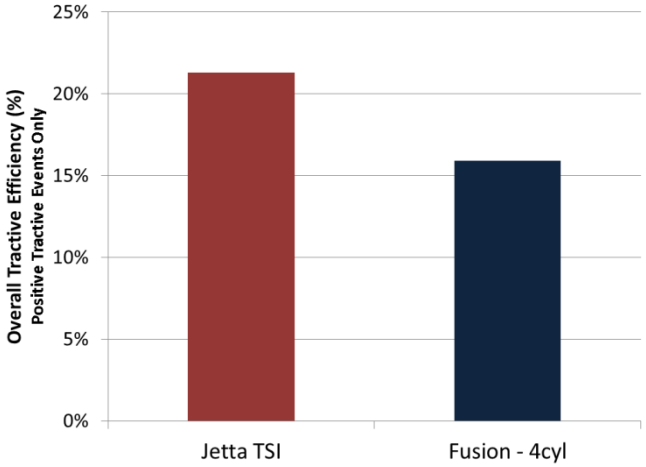
VW TSI provides a benchmark of several advance powertrain technologies and trends

- Reduced engine size + boosting and low loss transmission facilitates improved efficiency
- Aggressive fuel cut-off during decelerations also increases overall efficiency

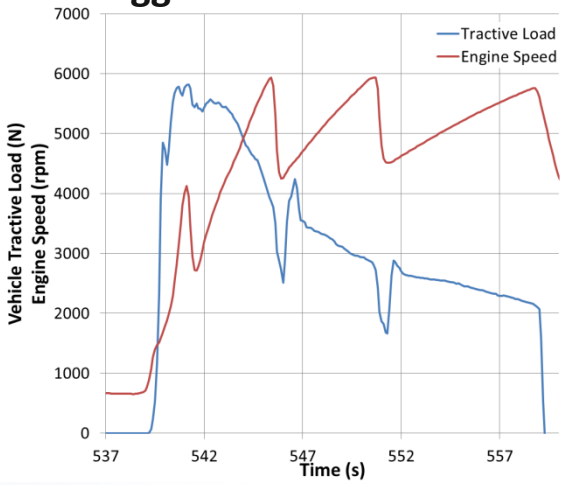
Aggressive Fuel Cut-off During Decelerations



Increased Operating Efficiency



Aggressive Acceleration



Collaboration: Significant Coordination with Other Institutions

AVTA (Advanced Vehicle Testing activities)
Baseline dynamometer testing of vehicles

J1711 HEV & PHEV test procedures
J1634 EV test procedures
J2711 MD/HD test procedures

SAE International®

In-depth Testing

DOE technology evaluation
- DOE requests
- National Lab requests

NREL, ornl, INL Idaho National Laboratory, Argonne National Laboratory

USCAR, tech teams and OEMs
Shared test plans, data and analysis

USDRIVE – Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability

Autonomie®
Support of modeling and simulation with data

AUTONOMIE

Chrysler – CTC

GM – Powertrain, Milford

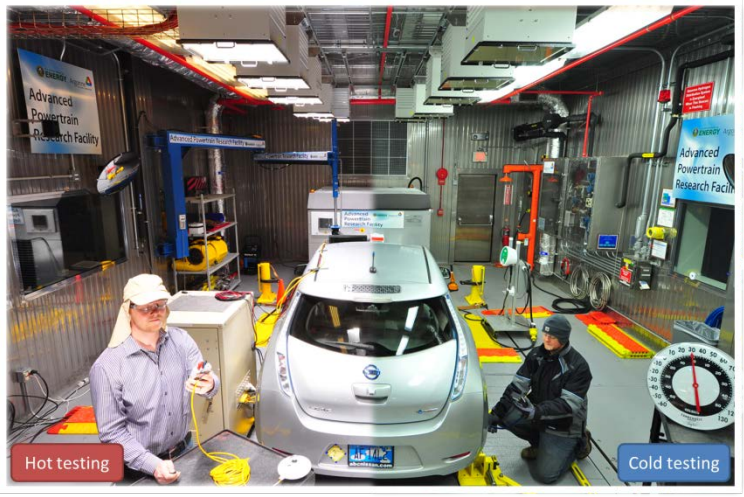
Ford – Powertrain, APTL

Future/On-going Work

Continued in-depth benchmarking of state-of-the-art vehicles for integration into DOE planning, target setting, modeling/simulation, and standards development activities

- Peugeot 3008 HYbrid4 instrumentation and testing to begin Spring/Summer
  - Unique vehicle configuration - diesel hybrid with a stop-start system driving the front wheels and an electric motor driving the rear wheels
  - Allows for many different and unique operating modes and functions

- Continued testing of vehicles under hot/cold ambient conditions leveraging the upgraded APRF



* Vehicle photo from Wikipedia – Peugeot 3008

Summary

In-depth testing of the selected Level-2 vehicles aids the DOE goal of petroleum displacement/reduction through data dissemination and technology assessment

- Hyundai Sonata provides a look at a competing hybrid architecture
- Chevrolet Volt allows for the evaluation of the first widely available EREV
- Jetta TSI illustrates advanced "conventional" developments

- Testing generates data for model development and validation to facilitate increased speed-to-market of advanced technology (1+ GB of test data)
- Supports codes and standards development for unbiased technology assessment

In-depth benchmarking data and analysis are highly leveraged within and outside the DOE (other national labs, OEMs, technical teams, enthusiasts)