PHEV Hymotion Prius Model Validation and Control Improvements

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Introduction

Advanced Powertrain Research Facility (APRF)

- State-of-the-art SULEV Facility
- 4-wheel-drive dynamometer

Powertrain System Analysis Toolkit (PSAT)

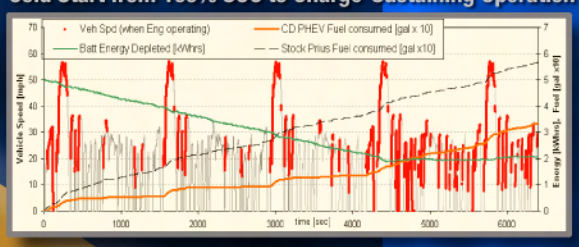
- Selected vehicle simulation tool for DOE's FreedomCAR & Fuels Partnership
- Over 400 worldwide users in more than 80 companies
- "Forward-looking" model
- Matlab/Simulink/StateFlow based

Specific Vehicle Characteristics

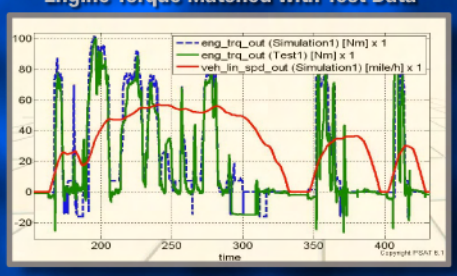
- Test performed on highly instrumented Prius, including engine torque sensor
- Additional 5kWh Li-ion high-capacity battery

From Vehicle Test Data to Model Validation

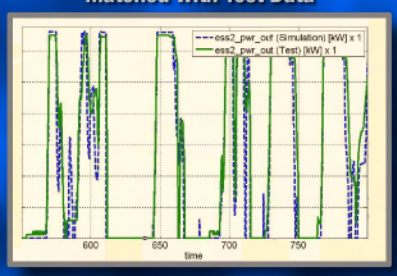
Vehicle Driven on Repeated UDDS Drive Cycles, Cold Start from 100% SOC to Charge-Sustaining Operation



Engine Torque Matched with Test Data



High-Capacity Battery Power Matched with Test Data



Vehicle Test Data on Consecutive UDDS Cycles

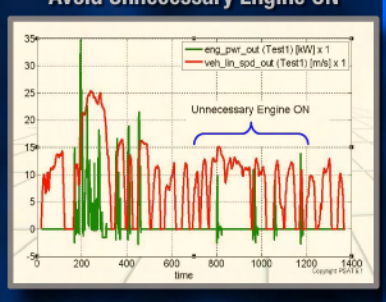
UDDS	#1	#2	#3	#4	#5
Miles Driven (mi)	7.48	7.48	7.48	7.48	7.47
Fuel Used (gal)	0.051	0.037	0.040	0.101	0.113
Electrical Energy Consumed (DC kWh)	0.93	0.96	0.94	0.23	-0.12
Fuel Economy (mpg)	148	200	187	74.3	66.4
Electrical Consumption (DC Wh/mi)	123	128	125	30.6	15.9

Charge Depleting Mode Comparison — UDDS Cycle Hot

	Unit	Test	Simulation
Fuel Economy	miles/gallon	176.7	192.3
Electricity Consumption	Wh/km	86.3	83.8

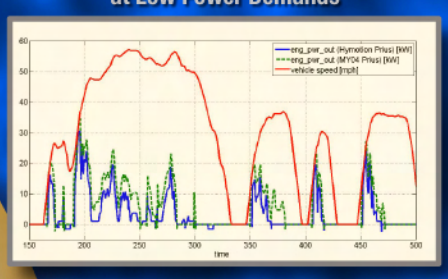
Vehicle Level Control Strategy Improvement

Step #1 — Avoid Unnecessary Engine ON



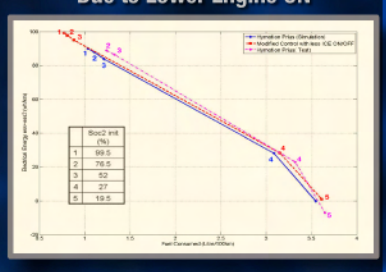
- Several engine ON events occur at low vehicle power demands
- The result is lower engine efficiency

Step #2 — Avoid Using the Engine at Low Power Demands



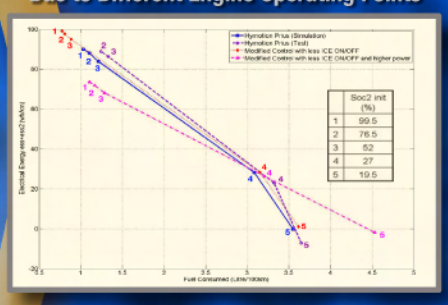
- During charge depletion, the engine is operated at lower power than the Prius HEV
- Control has been altered to operate the engine closer to its best efficiency curve

Energy Consumption Reduction Due to Lower Engine ON



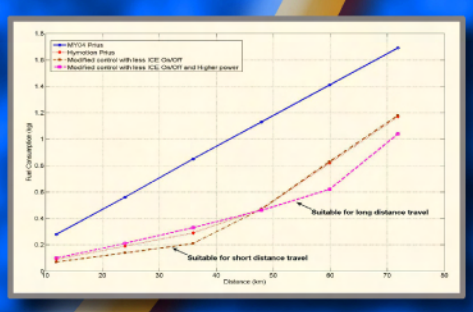
- The updated control demonstrates higher powertrain efficiency
- For the same electrical use, lower fuel consumption achieved

Energy Consumption Change Due to Different Engine Operating Points



- The updated control demonstrates additional fuel economy gains for long distances while the initial engine operating points show more efficiency for short distances

PSAT Conclusions



- PSAT validated the model of the 5kWh Hymotion Prius
- Several changes were proposed to minimize the number of engine ON/OFF events and maximize the engine's efficiency
- Operating the engine at low power during short trips and higher power during longer trips maximizes the efficiency of the entire system

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