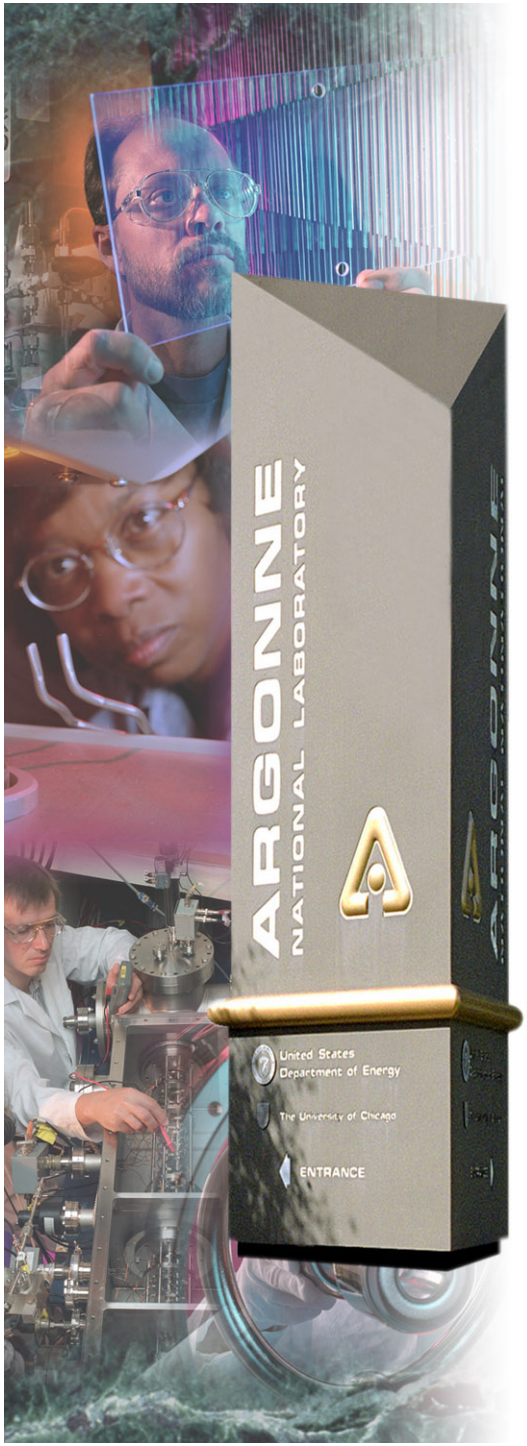

Honda Insight Validation Using PSAT

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Office of Science Laboratory
Operated by The University of Chicago

Office of Science
U.S. Department of Energy

Outline

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Vehicle Testing at APTF

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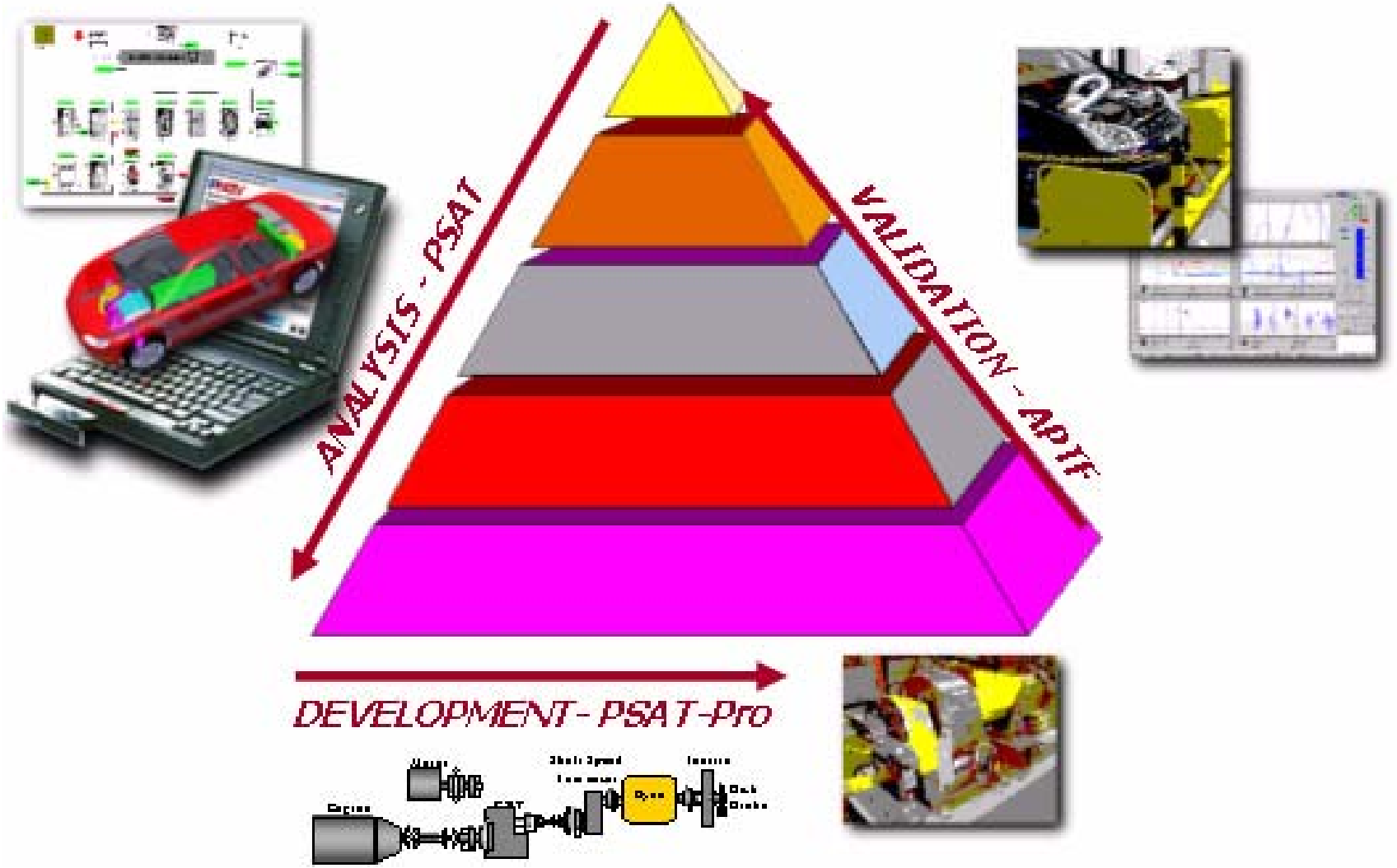
Integrated Development Process



Background

The PNGV Systems Analysis Toolkit was initiated in 1995 by USCAR (contract to TASC and SwRI).

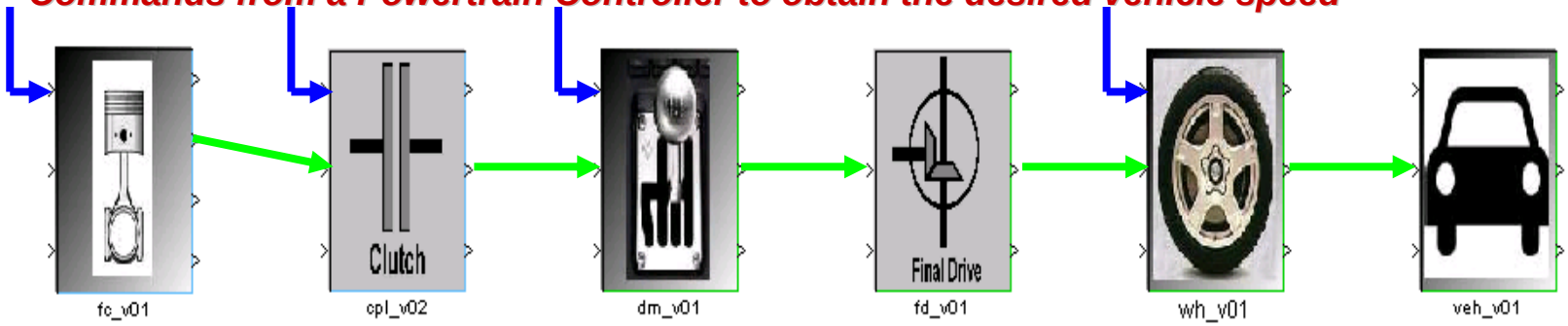
ANL redesigned PSAT in 1999 to meet the needs of DOE's integrated analysis, hardware-in-the-loop and validation activities.

- **Proprietary version available to PNGV partners**
- **Non-proprietary version to other selected users**
- **Approximately 100 active users ... 25 companies plus universities**

PSAT Looks Forward

Forward modeling (driver-to-wheels) more realistically predicts system dynamics, transient component behavior and vehicle response.

Commands from a Powertrain Controller to obtain the desired vehicle speed



- Consistent with industry design practice
- More accurately represents component dynamics (e.g. fuel cell starting and warm-up, shifting, clutch engagement …)
- Allows for advanced (e.g. physiological) fuel cell models
- Allows for the development of control strategies that can be utilized in hardware-in-the-loop or vehicle testing
- Small time steps enhance accuracy

Honda Insight Testing at APTF

Vehicle:

- ✓ 2-passenger sedan
- ✓ 2,125-lb Curb weight (Aluminum body)
- ✓ Drag Coefficient: 0.25

Internal Combustion Engine:

1.0 L, 3-cylinder (67 hp @ 5700 RPM)

Traction Motor:

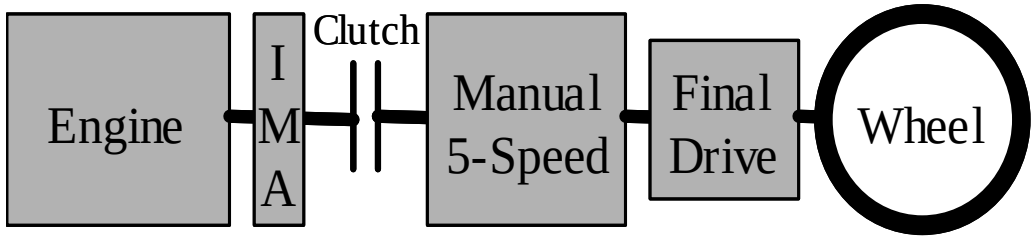
10 KW Brushless Permanent Magnet DC

Traction Battery:

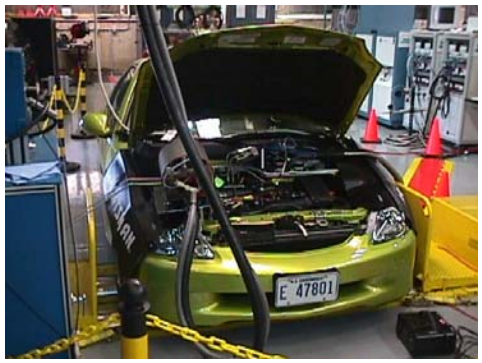
- ✓ Nickel Metal-Hydride
- ✓ Spiral-wound cells144v (120 cells @ 1.2v)
- ✓ Rated Capacity = 6.5 Ah (0.9 kWh)

EPA Mileage Estimates: 61 City / 70 Highway

INSIGHT POWERTRAIN



Honda Insight Testing at APTF

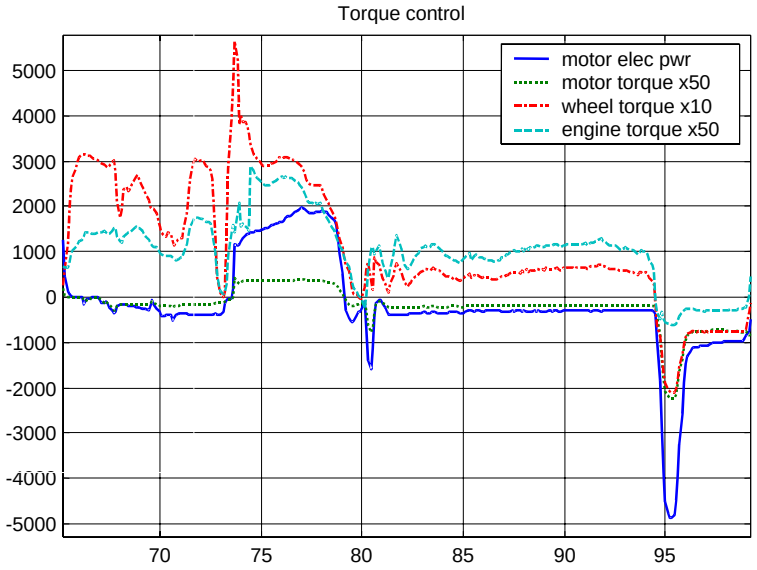


Insight on chassis dynamometer

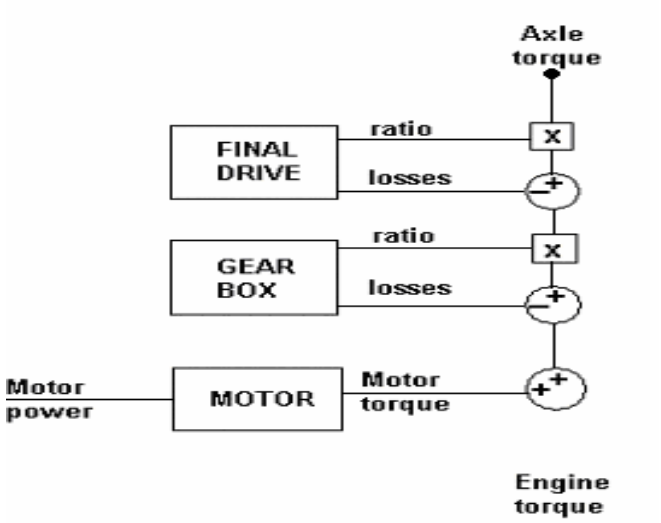
Data collection: vehicle speed, engine speed, battery voltage, state of charge, half-shaft torque…

Problem: No engine torque measured

Post processing: engine torque calculation



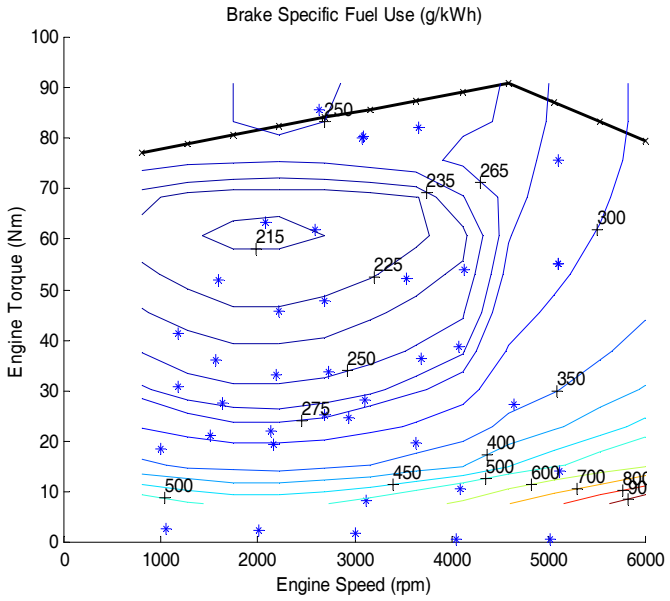
Post-processed results



Honda Insight Testing at APTF

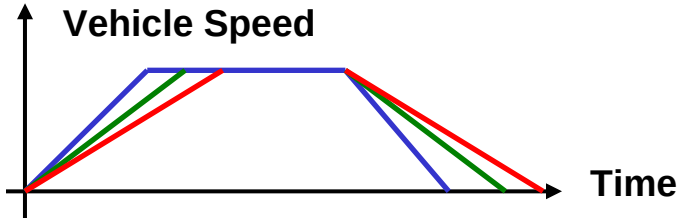
DIFFERENT TESTS ARE NEEDED:

✓ **Engine mapping**



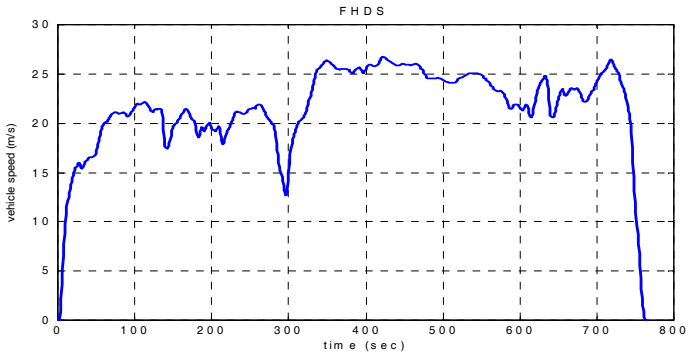
✓ **Road load test**

✓**Specific tests**



Ramps + steady-states

✓**Standard cycles**

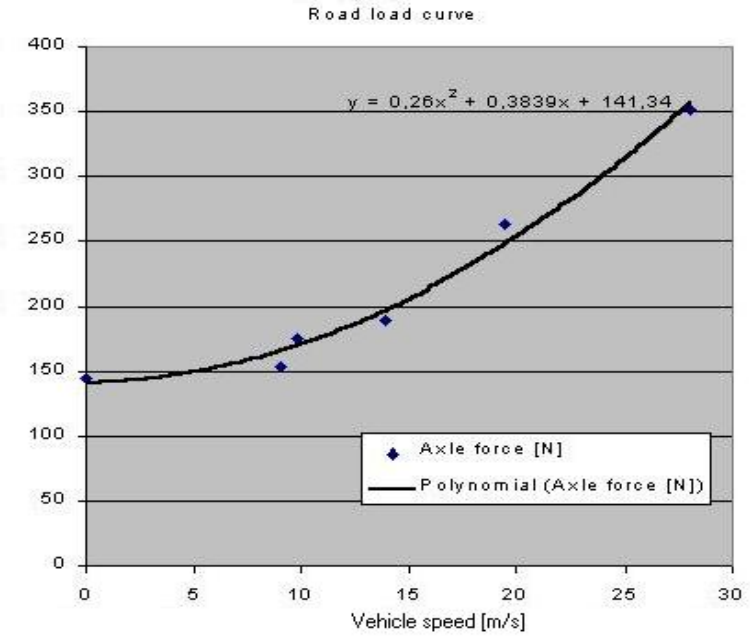


FHDS (Federal Highway Driving Cycle)

Road Load and Initialization Files

ROAD LOAD MATCH

- ✓ Points extracted from tests
- ✓ Second-degree polynomial trend line
- ✓ $F = A + B.V + C.V^2$



INITIALIZATION FILES

- ✓ Files from PSAT proprietary version
- ✓ Hot engine map developed
- ✓ Files from tests

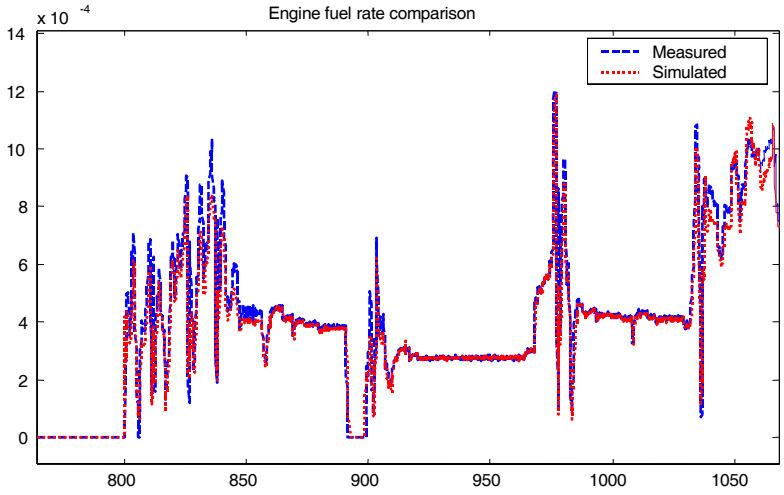
FEED PSAT COMPONENT MODELS

Single Component Validation

✓ **Measured fuel rate = simulated fuel rate**

Estimated engine torque

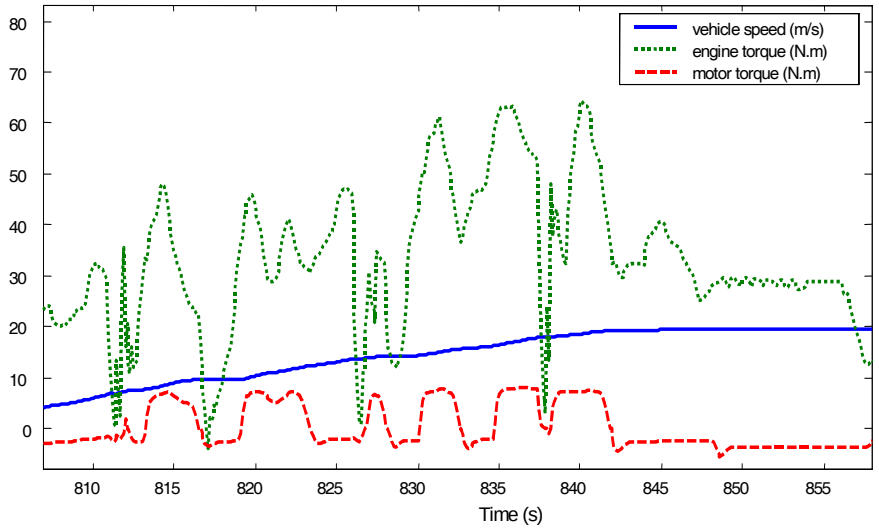
Measured engine speed



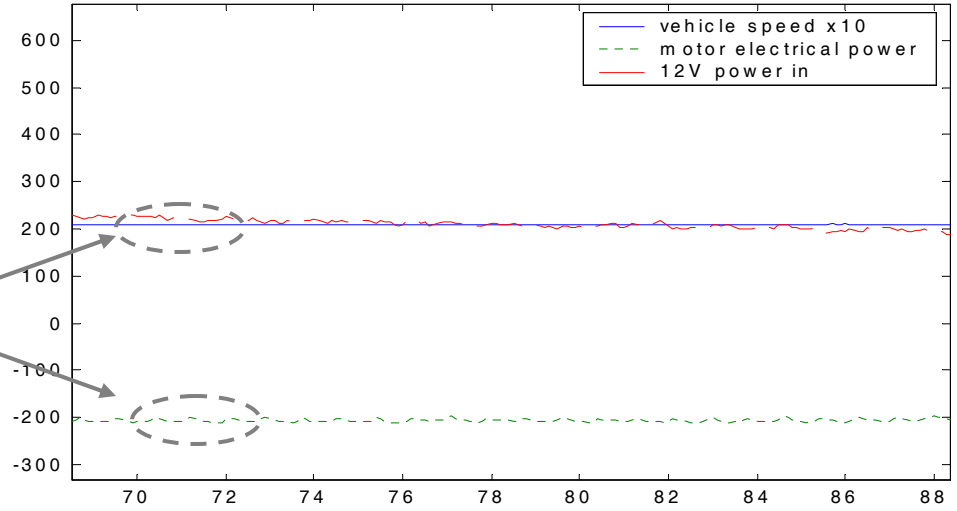
Control Strategy

Operating Mode		Start	Acceleration	Cruising	Deceleration	Stop
Engine		Engine Start	Vehicle Propulsion		Fuel Cut	No idle
Motor			Assist	Regen / Off	Regenerative braking	Off
Dependence of battery State Of Charge	Full	IMA starts engine	Assist with partial load and wide open throttle	No battery charging		Engine and motor off
				Generate for 12V system	Battery charging	
	Low		Wide open throttle assist	Battery charging		
	Zero	Starter starts engine	No assist			Battery charging
IMA contribution		Best fuel control	Reduce engine load and transients	Reduce unnecessary generation and load	Recover and store energy without fuel consumed	No fuel consumed

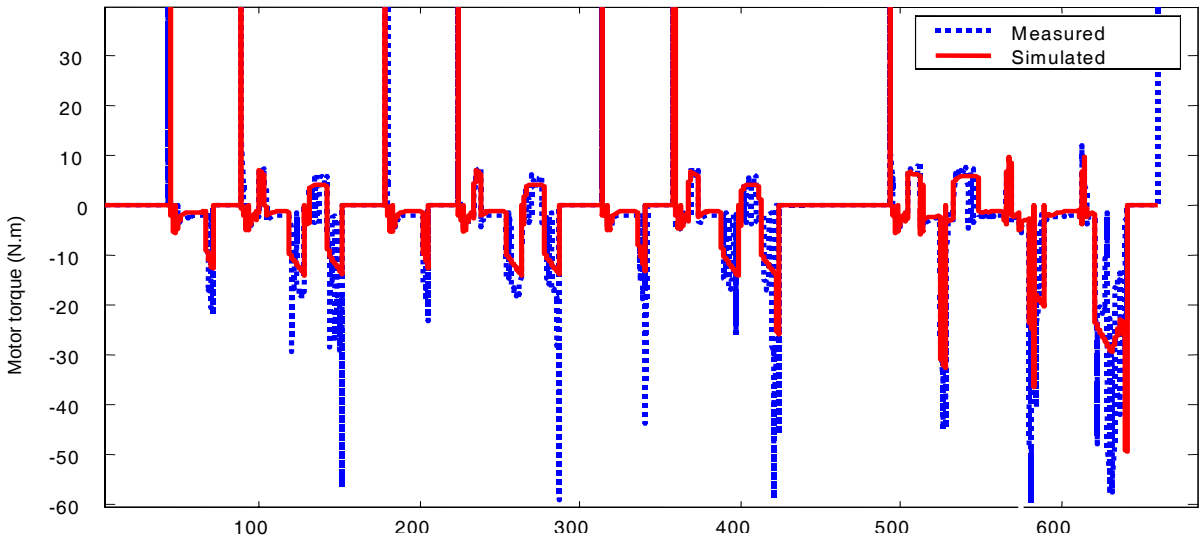
Control Strategy



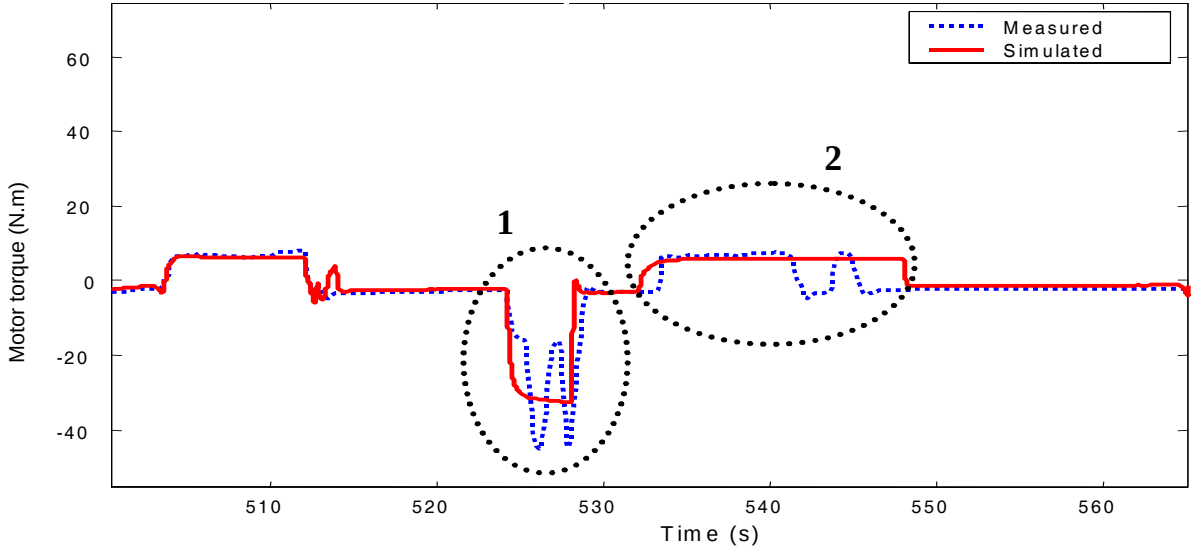
Motor used to compensate 12V load



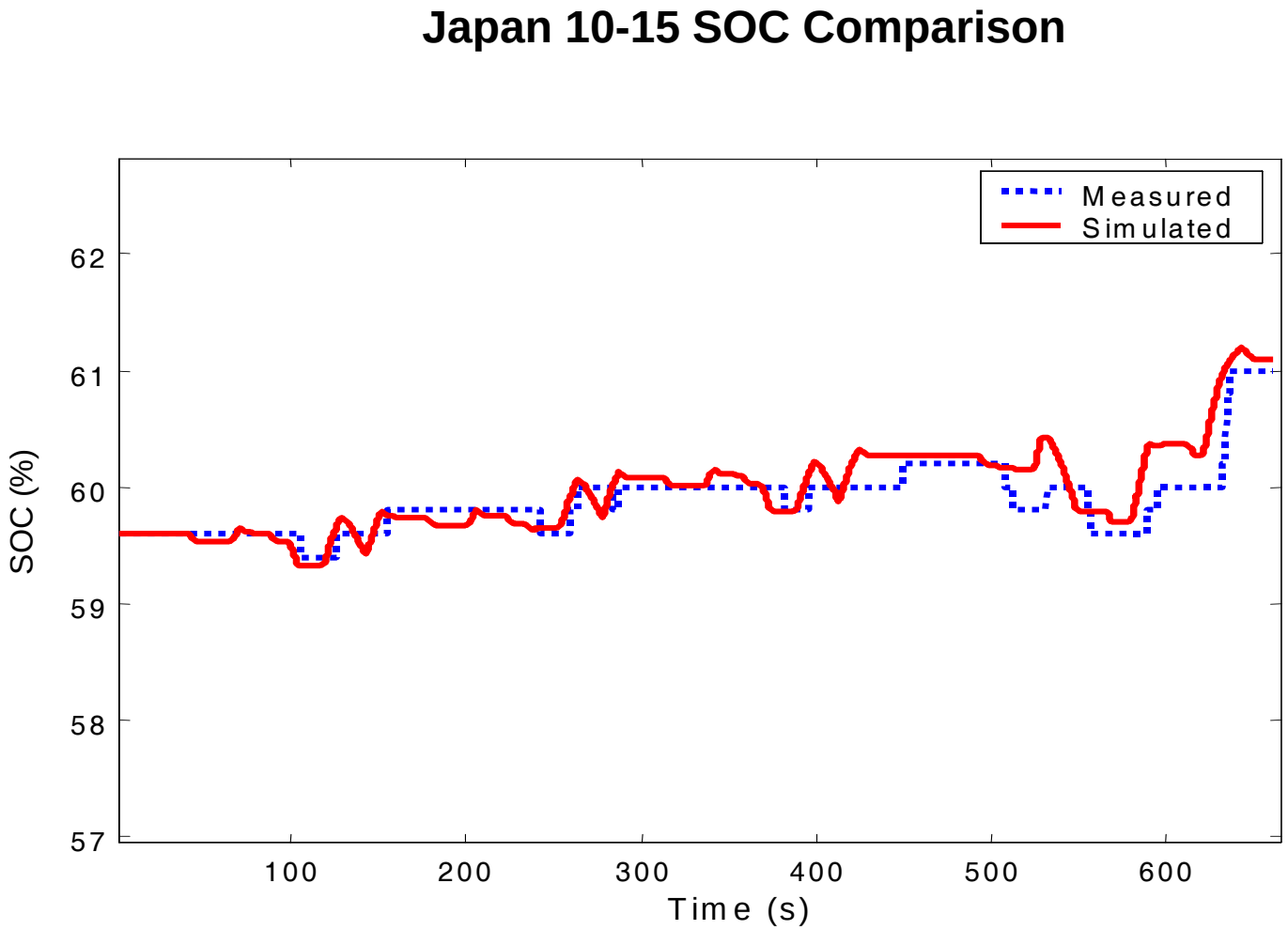
Cycle Validation



Japan 10-15



Cycle Validation



Validation Summary

Drive Cycle	Measured Fuel Economy (mpg)	Simulated Fuel Economy (mpg)	%Difference	Initial SOC	Measured Final SOC	Simulated Final SOC	%Difference	ANL Test
Japan 10-15	57.95	58.8	1.5%	59.6	61	61.1	0.16%	0#12 04-12-01 1015 JAA 1165805.txt
NEDC	60.65	60.25	0.66%	60	60.2	58.3	3.26%	0#5 04-12-01 ECE JAA 1165580.txt
FHDS (US Highway)	74.25	75.3	1.4%	59	58.8	58.9	0.17%	0#9 04-12-01 HWY JAA 1165750.txt
FUDS (US City)	58.3	57.85	0.8%	72.8	70.6	72	2%	0#2 04-11-01 UDDS JAA 1164340.txt

Perspectives

PSAT is a powerful modeling tool for both, fuel consumption and performances.

Following the Japan Prius, PSAT Honda Insight model has also been validated within 5%:

- **Final fuel economy and SOC match**
- **Transient behavior has been accurately reproduced**

In a near future, ANL plans to extend PSAT capabilities to better serve its users.