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PSAT Validation

-

Example of Results

September, 2007

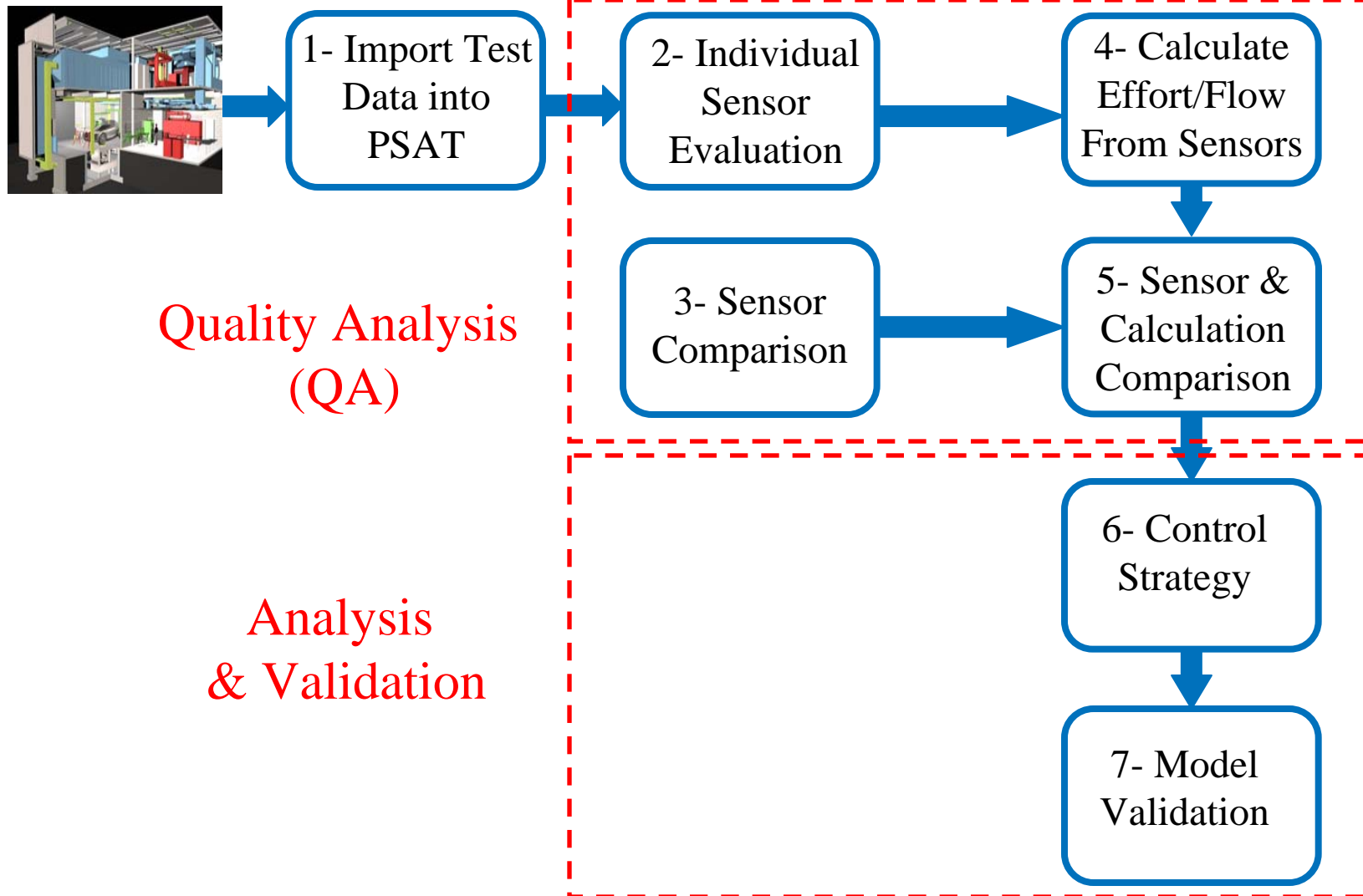
Aymeric Rousseau
Argonne National Laboratory



Outline

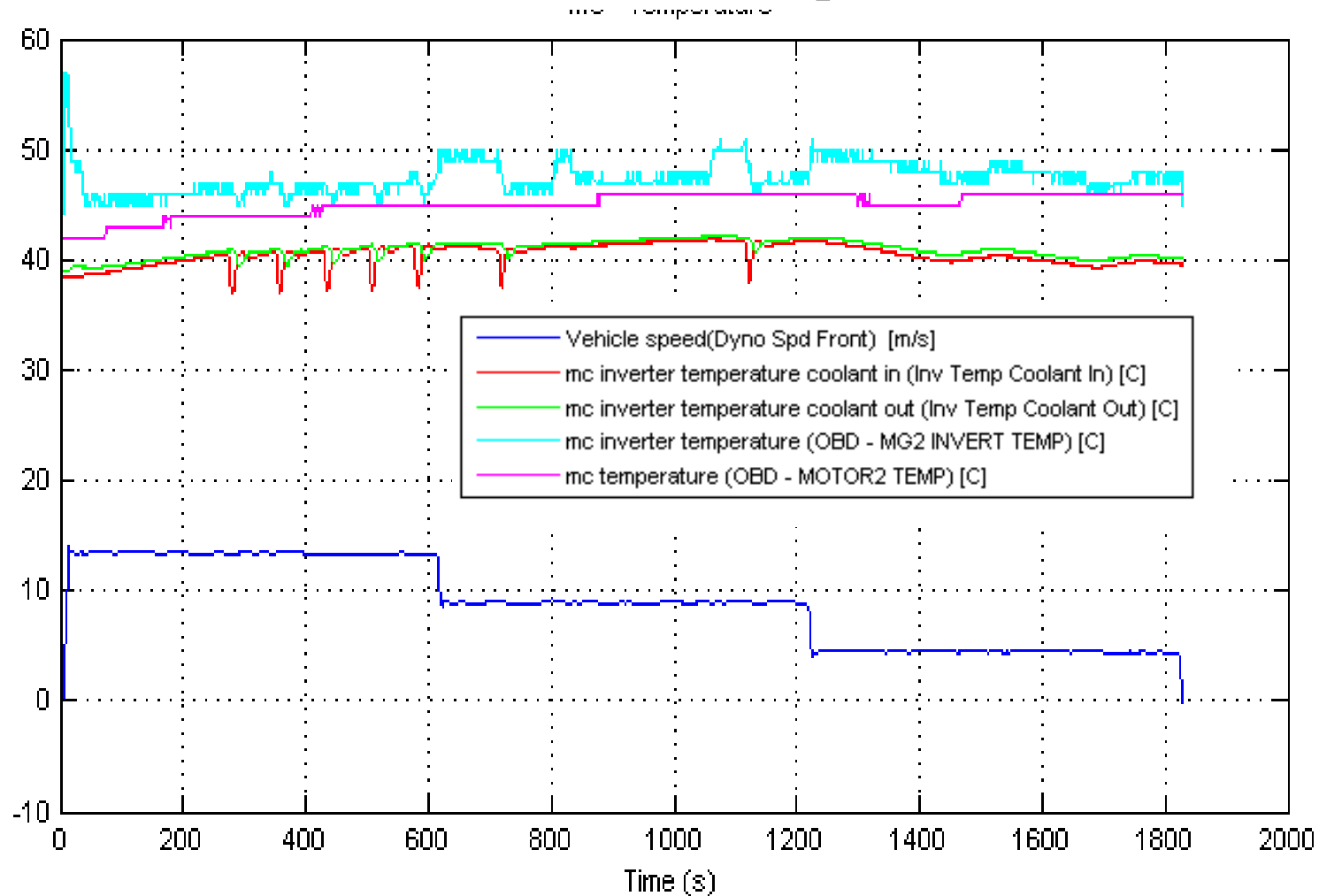
- Validation Process
- Conventional Vehicles
- Mild Hybrids
- Full Hybrids
- Plug-in Hybrids

Generic Methodology: From Test to Validation



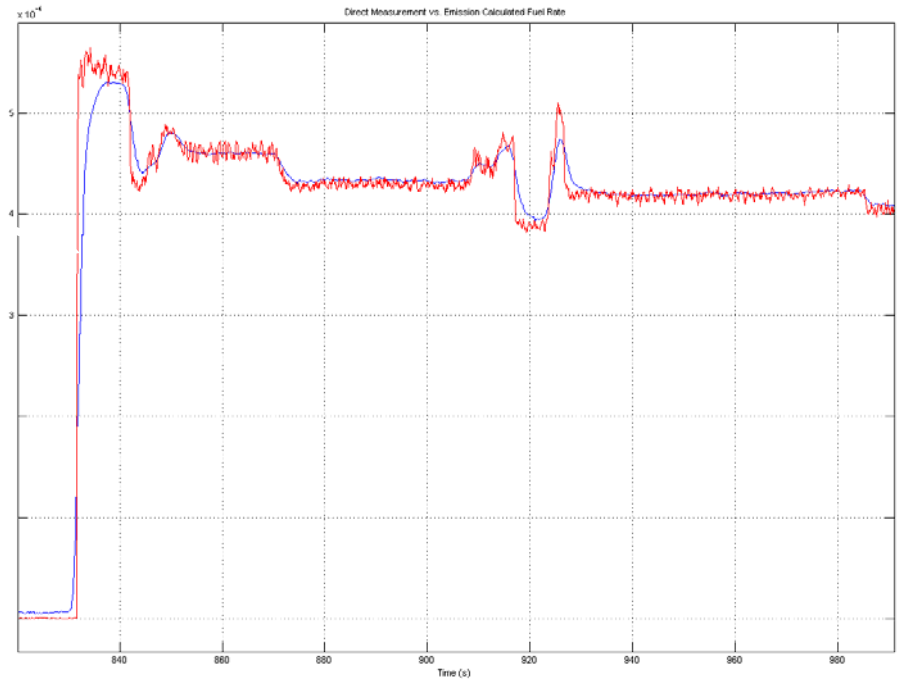
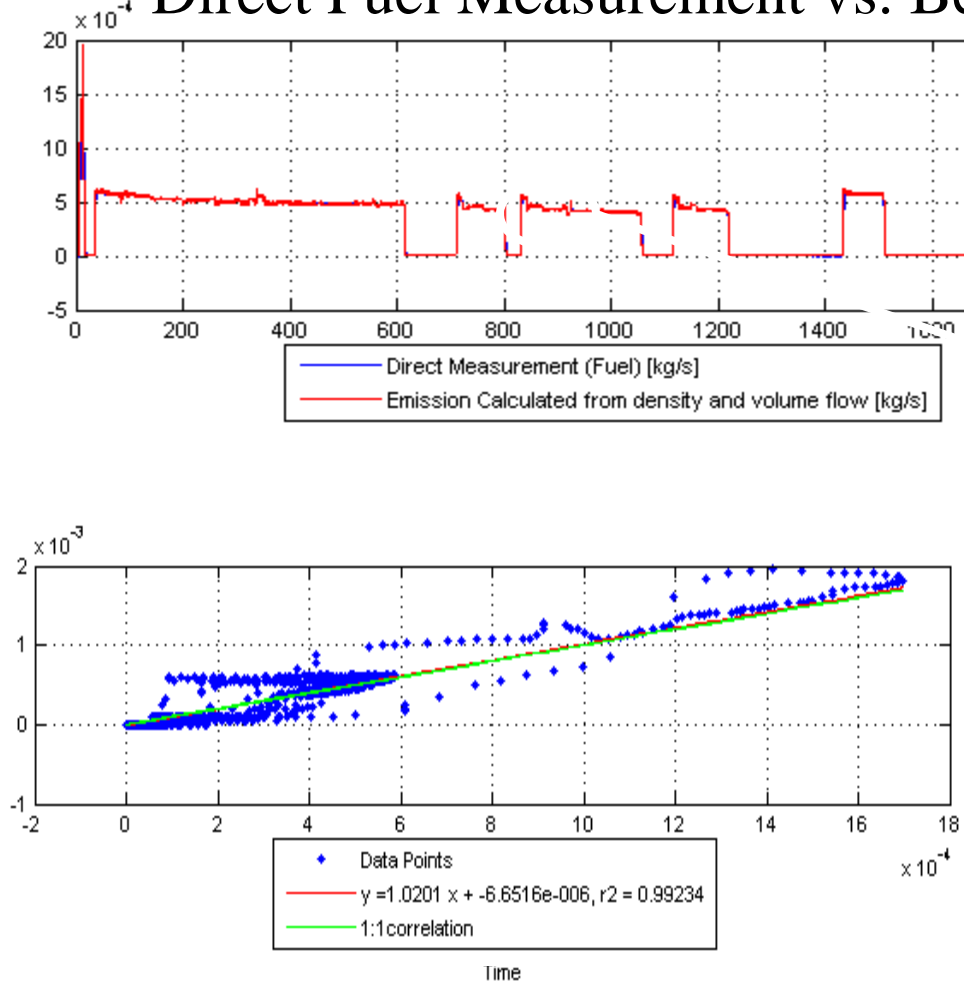
Individual Sensors are Evaluated to Find Major Issues (Range, Sign...)

Electric Motor Temperatures



Redundant Sensors are Compared

Direct Fuel Measurement vs. Bench



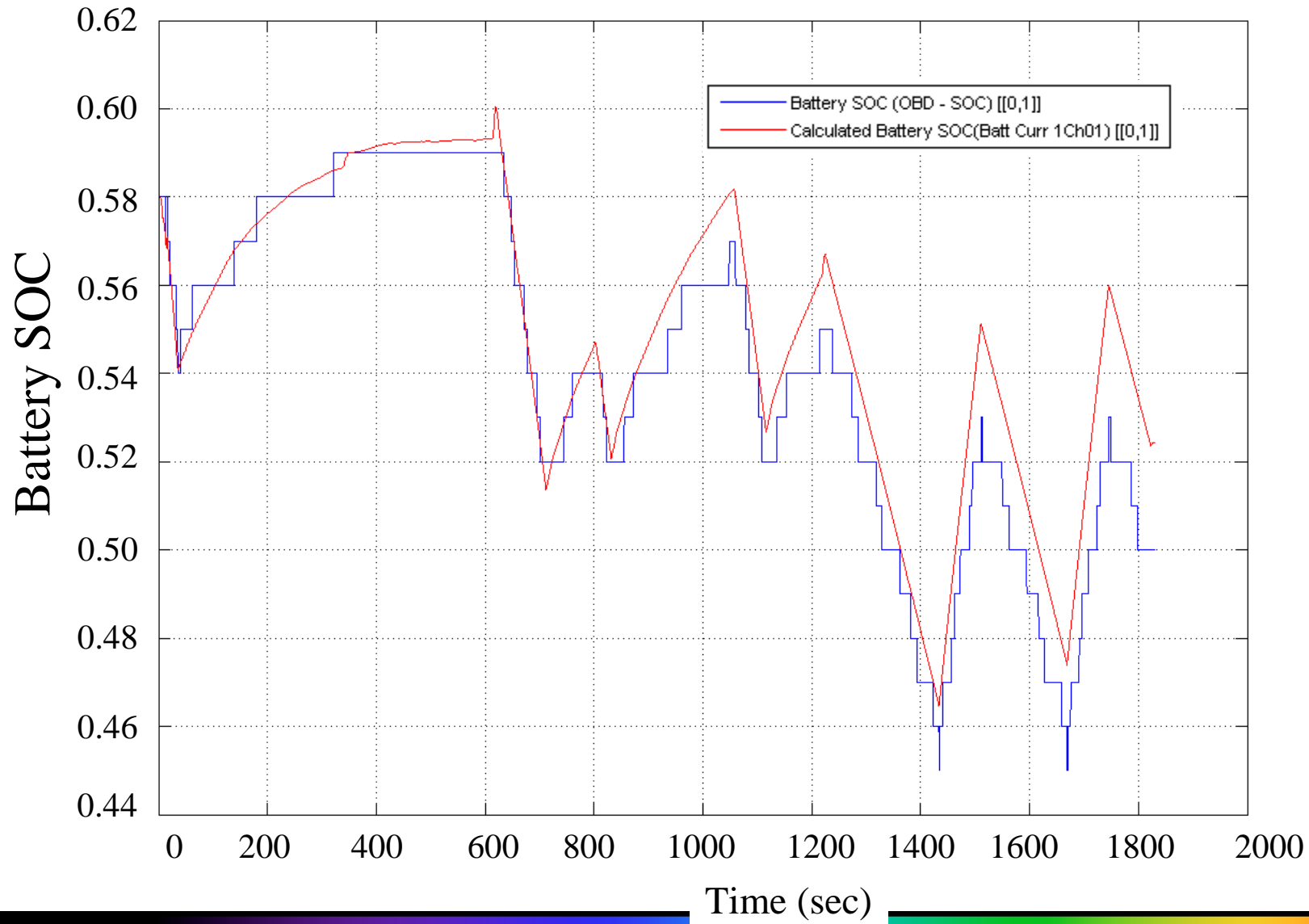
Summary Table Highlights the Main Results of the Comparison

Component / Range	Compared to... / Range	Absolute Difference	Relative Difference	Correlation Coefficient
Sensor(Dyno Spd Front) / [-0.098912,13.9334] [m/s]	OBD (VEHICLE SPD) / [0,128.0917] [m/s]	71.7453 [m/s]	7.9419 [m/s]	0.99971
Sensor (Eng Spd 1Ch15) / [-0.18268,3016.4307] [rpm]	OBD (ENGINE SPD) / [0,2976] [rpm]	20.1937 [rpm]	-0.26785 [rpm]	0.99032
Direct Measurement (Fuel) / [-9e-007,0.0016963] [kg/s]	Emission Calculated from density and volume flow / [3.745e-007,0.0019567] [kg/s]	1.0226e-005 [kg/s]	-0.26594 [kg/s]	0.99234
Boost voltage in(OBD - VL) / [192,238] [volt]	Battery Voltage out(Batt_V_1Ch02) / [198.4637,244.6811] [volt]	7.1356 [volt]	0.032908 [volt]	0.98596
Sensor(Boosted_V_1Ch03) / [206.9815,506.3051] [volt]	OBD(VH) / [204,498] [volt]	3.8596 [volt]	-0.013229 [volt]	0.90283

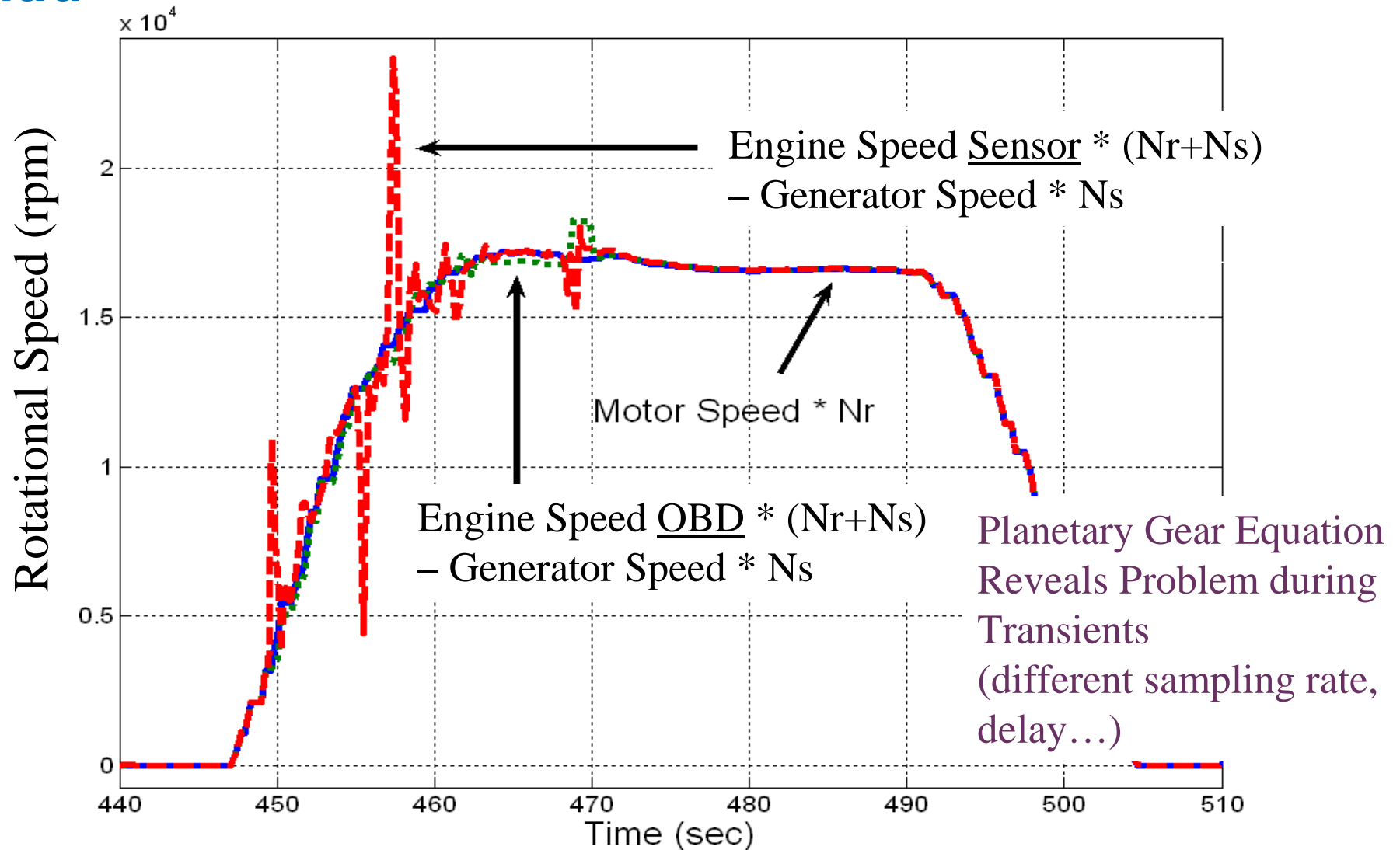
Additional Efforts/Flows are Calculated

The screenshot displays the PSAT v6.0 - Powertrain System Analysis Toolkit interface. The main window is the MATLAB Command Window, which contains a list of test variables. The variables are organized into two columns. The left column lists variables such as `accelec_temp_converter_test`, `accelec_volt_essfan_test`, `accelec_volt_out_test`, `drv_cmd_pedal_accel_pos_test`, `drv_cmd_pedal_brake_pos_test`, `drv_force_pedal_brake_test`, `eng_02_postcat_test`, `eng_02_precat_test`, `eng_air_rate_test`, `eng_cam_advance_test`, `eng_cankshaft_position_angle_test`, `eng_cmd_throttle_test`, `eng_fuel_vol_flow_test`, `eng_ignition_timing_angle_test`, `eng_lambda_test`, `eng_manifold_air_pressure_test`, `eng_pwr_dmd_out_test`, `eng_spd_obd_test`, `eng_spd_out_test`, `eng_stored_coolant_cmd_pump_status_test`, `eng_stored_coolant_temp_out_test`, `eng_stored_coolant_valve_status_test`, `eng_temp_air_in_test`, `eng_temp_coolant_in_test`, `eng_temp_coolant_out_test`, `eng_temp_oil_test`, `env_pressure_ambient_test`, `env_relative_humidity_test`, `env_temp_ambient_test`, `ess_curr_out_test`, `ess_delta_Ah_test`, `ess_soc_test`, `ess_temp_in_test`, `ess_temp_left_test`, `ess_temp_mid_test`, `ess_temp_out_test`, `ess_temp_right_test`, `ess_volt_out_test`, `ex_back_pressure_test`, and `ex_eng_air_relative_humidity_dilute_test`. The right column lists variables such as `ex_eng_comid_gas_rate_test`, `ex_eng_comidppm_dilute_test`, `ex_eng_nmhc_gas_rate_test`, `ex_eng_nox_test`, `ex_eng_noxppm_dilute_test`, `ex_eng_thc_gas_rate_test`, `ex_eng_thcppm_dilute_test`, `ex_temp_post_cat_test`, `ex_temp_pre_cat_test`, `ex_test_cvs_pressure_test`, `ex_test_cvs_vol_flow_corr_test`, `ex_test_cvs_vol_flow_test`, `mc2_inverter_temp_coolant_in_test`, `mc2_inverter_temp_coolant_out_test`, `mc2_inverter_temp_test`, `mc2_temp_test`, `mc2_trq_out_test`, `mc_inverter_temp_coolant_in_test`, `mc_inverter_temp_coolant_out_test`, `mc_inverter_temp_test`, `mc_temp_test`, `mc_trq_in_regen_test`, `mc_trq_out_test`, `pc_accelec_curr_in_dc2dc_test`, `pc_accelec_curr_out_dc2dc_test`, `pc_ess_curr_out_boost_test`, `pc_ess_volt_out_boost_test`, `time_test`, `veh_evapsys_canister_closed_test`, `veh_evapsys_evap_test`, `veh_evapsys_pressvolt_test`, `veh_evapsys_switch_test`, `veh_force_dyno_front_test`, `veh_force_dyno_rear_test`, `veh_lin_spd_out_rear_test`, `veh_lin_spd_out_test`, `veh_temp_inside_test`, `wh_brake_pressure_pedal_front_test`, `wh_brake_pressure_pedal_rear_test`, and `wh_brake_pressure_test`. The interface also shows a menu bar with 'File', 'Simulation', 'Setup', 'PSAT-PRO', 'Units', and 'Help'. The bottom status bar indicates 'Plot File:' and 'Plot'.

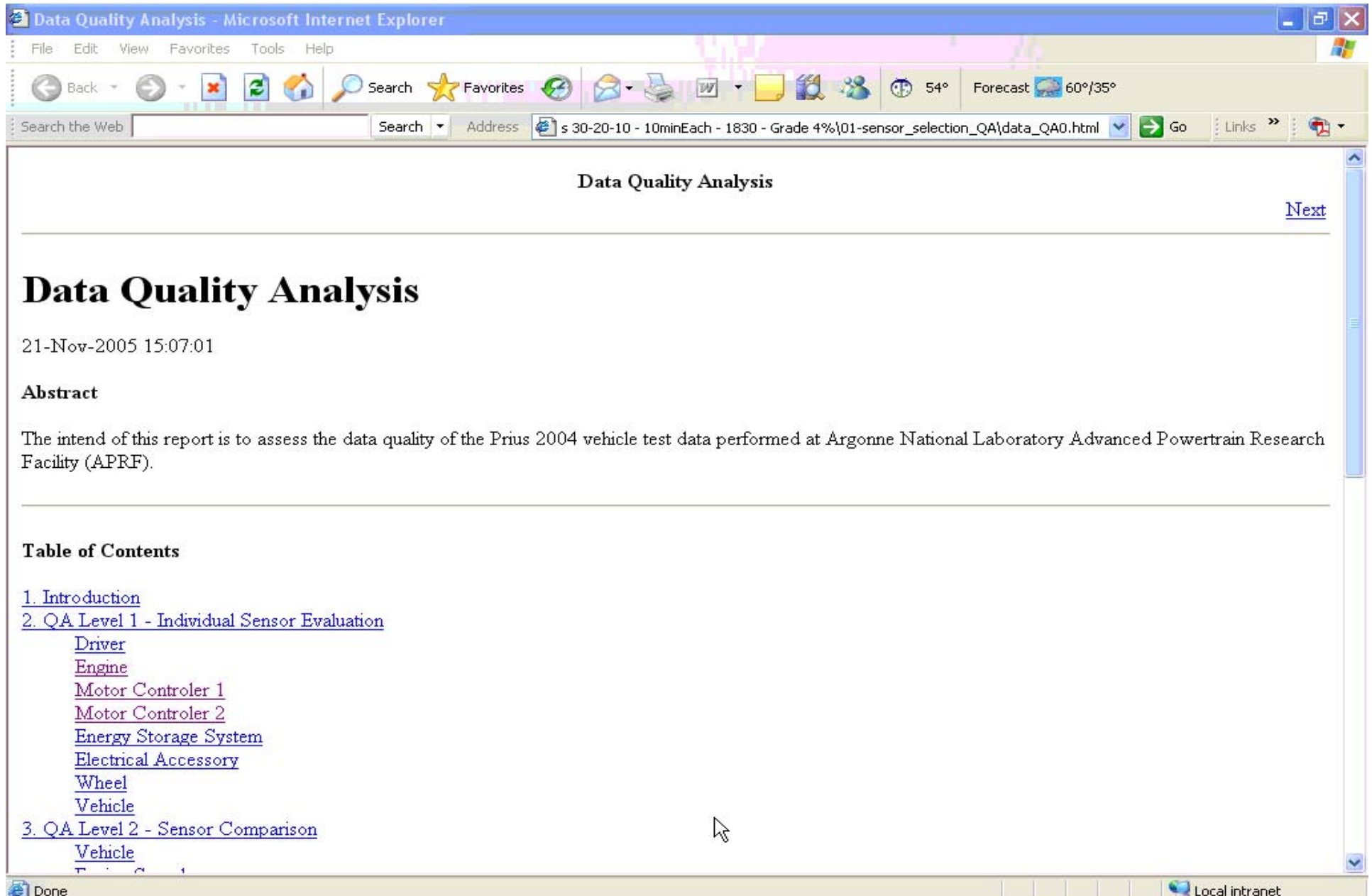
Calculated and Measured Signals are Compared



Using Sensors from Different Sources may Lead to Added Uncertainties



Web Document is Automatically Generated to Accelerate the Process



The screenshot shows a Microsoft Internet Explorer browser window. The title bar reads "Data Quality Analysis - Microsoft Internet Explorer". The address bar contains the URL "s 30-20-10 - 10minEach - 1830 - Grade 4%\01-sensor_selection_QA\data_QA0.html". The main content area displays the following text:

Data Quality Analysis

[Next](#)

Data Quality Analysis

21-Nov-2005 15:07:01

Abstract

The intend of this report is to assess the data quality of the Prius 2004 vehicle test data performed at Argonne National Laboratory Advanced Powertrain Research Facility (APRF).

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 - [Energy Storage System](#)
 - [Electrical Accessory](#)
 - [Wheel](#)
 - [Vehicle](#)
- [3. QA Level 2 - Sensor Comparison](#)
 - [Vehicle](#)

Done Local intranet

Parameters are Selected Based on Detailed QA

- Signals with low correlation coefficients or that appeared suspicious from the visual check are scrutinized.
- Sensors installed by test engineers are preferred to OBD or dynamometer signals.
- Ensure consistency in the mathematical relationships.
- Signals from the OBD were not recognized (issue with units or with meaning).

Outline

- Validation Process
- Conventional Vehicles
- Mild Hybrids
- Full Hybrids
- Plug-in Hybrids

Correlated Conventional Vehicles

Vehicle	Source	UDDS PSAT (mpg)	HWFET PSAT (mpg)	UDDS Adjusted (mpg)	HWFET Adjusted (mpg)	UDDS Delta EPA (%)	HWFET Delta EPA (%)
Civic DX	EPA			29.00	38.00		
	Adjusted Values	34.62	49.35	31.16	38.49	7.4	1.3
Focus ZTW auto	EPA			25.00	31.00		
	Adjusted Values	27.44	39.07	24.70	30.47	-1.2	-1.7
Accord DX	EPA			24.00	34.00		
	Adjusted Values	27.62	44.09	24.86	34.39	3.6	1.1
Taurus	EPA			20.00	27.00		
	Adjusted Values	23.19	39.01	20.87	30.43	4.4	12.7
Equinox	EPA			19.00	25.00		
	Adjusted Values	21.01	32.00	18.91	24.96	-0.5	-0.2
F150	EPA			15.00	19.00		
	Adjusted Values	17.63	25.83	15.87	20.15	5.8	6.0

Vehicle test data was not available except for the Equinox

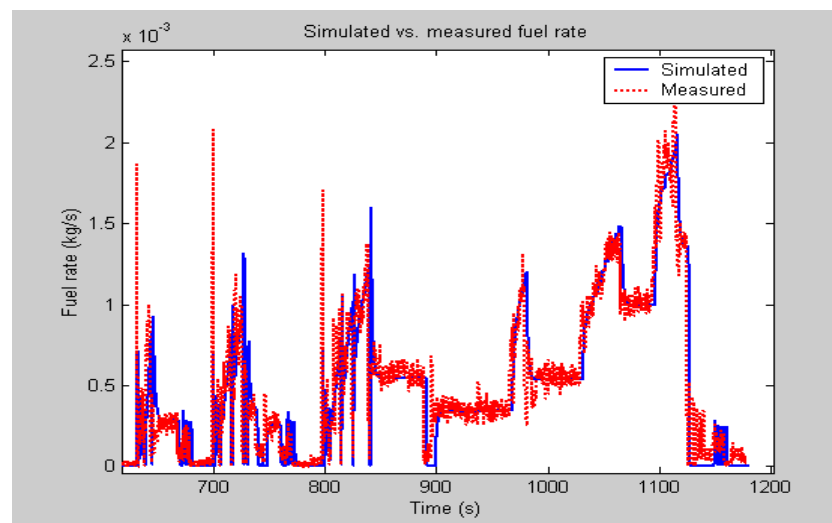
Outline

- Validation Process
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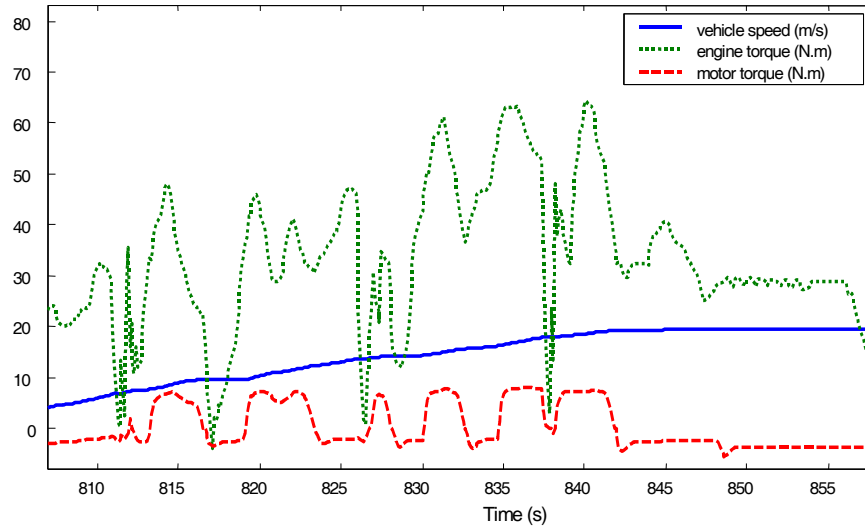
Ford P2000 Validation Results

Cycle	Cons test mpg	Cons simul mpg	Diff in %	SOC init	SOCf test	SOCf simul	Diff in %
Japan 10-15	50.31	51.77	2.91	73	74	75	1.35
NEDC	52.45	52.89	0.85	74	76	77.5	1.97

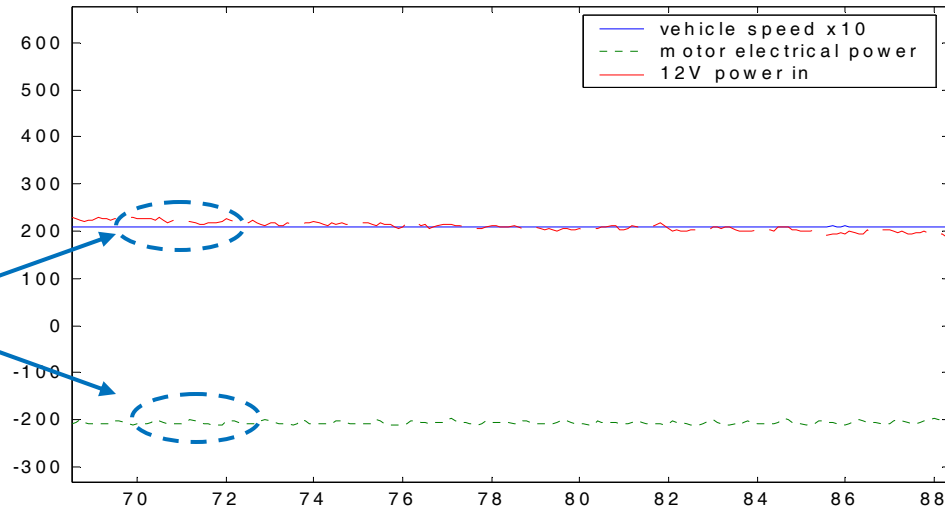
Fuel Rate Comparison on NEDC



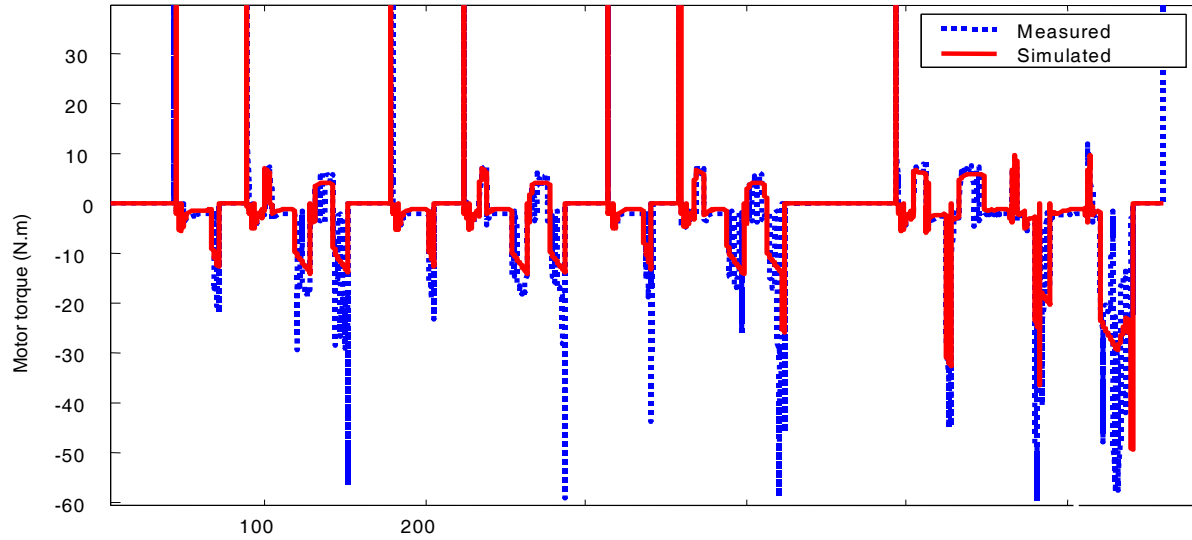
Honda Insight Validation



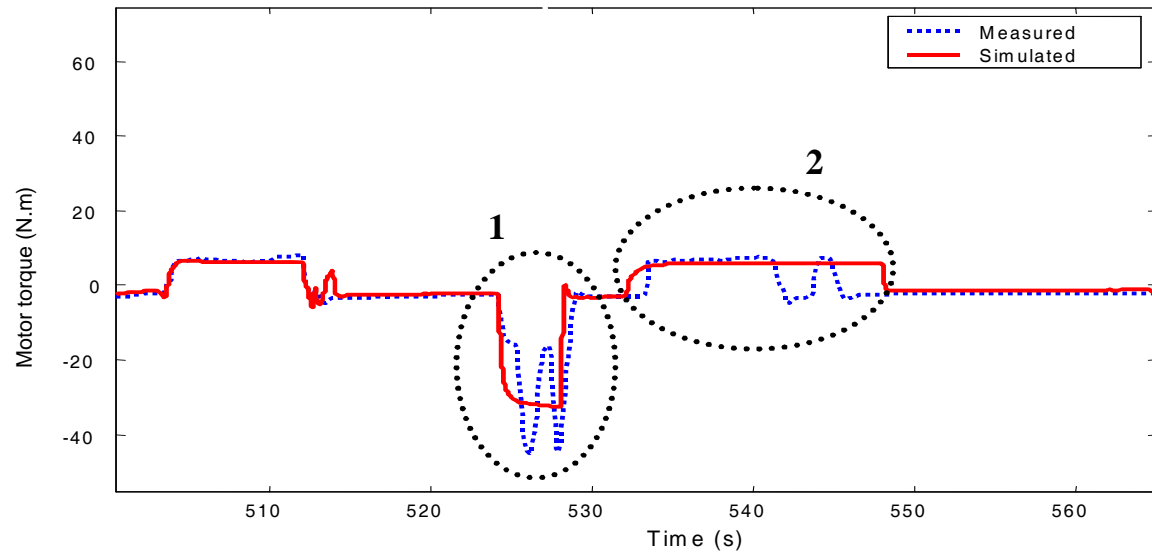
Motor used to compensate 12V load



Honda Insight Validation

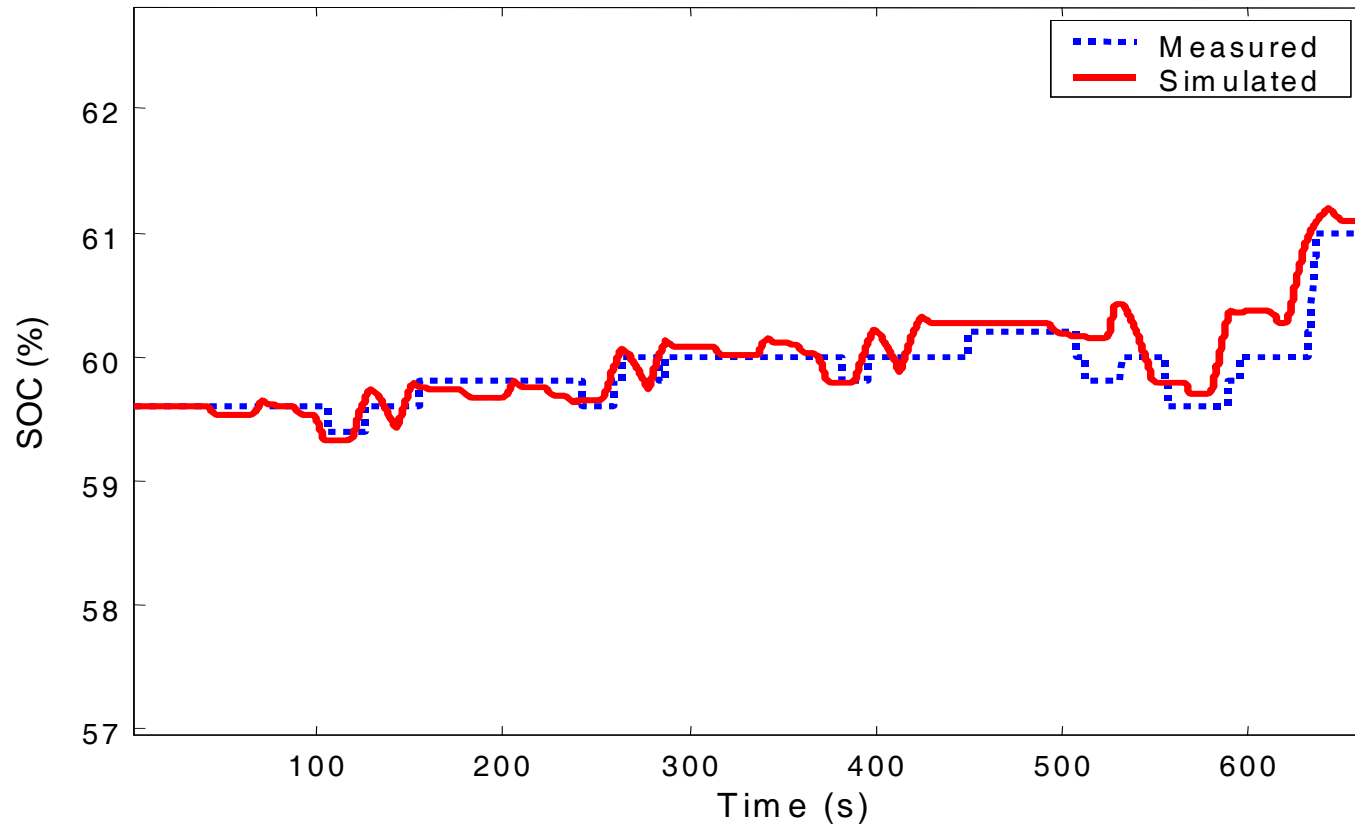


Japan 10-15



Honda Insight Validation

Japan 10-15 SOC Comparison



Honda Insight Validation Results

Cycle	Cons test mpg	Cons simul mpg	Diff in %	SOC init	SOCf test	SOCf simul	Diff in %
Japan 10-15	57.9	58.8	1.5	0.596	0.610	0.611	0.4
NEDC	60.6	60.2	0.6	0.600	0.602	0.583	3.6
HWFET	74.2	75.3	1.4	0.590	0.588	0.589	0.2
UDDS	58.3	57.8	0.8	0.728	0.706	0.720	2.0

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GM Precept Correlation

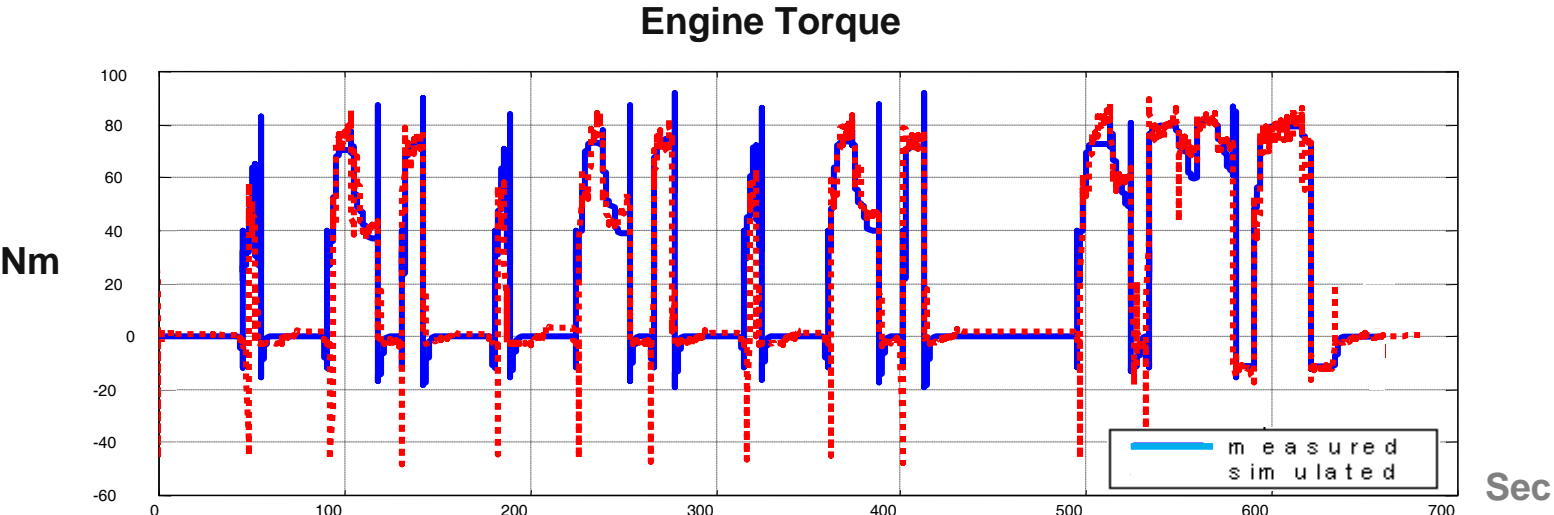
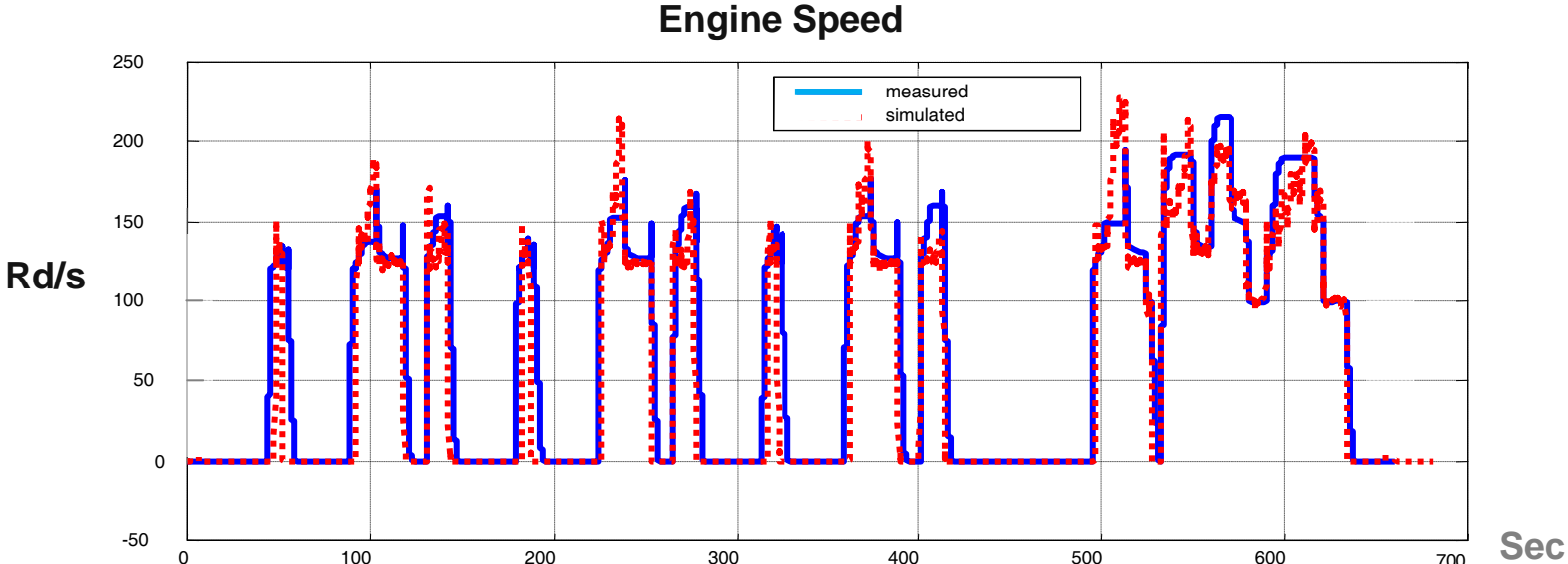


Combined

**Test/Simulated
Consumptions:
79.6 / 76 mpg**

**Small SOC
difference in
Simulation**

Japan Prius Validation

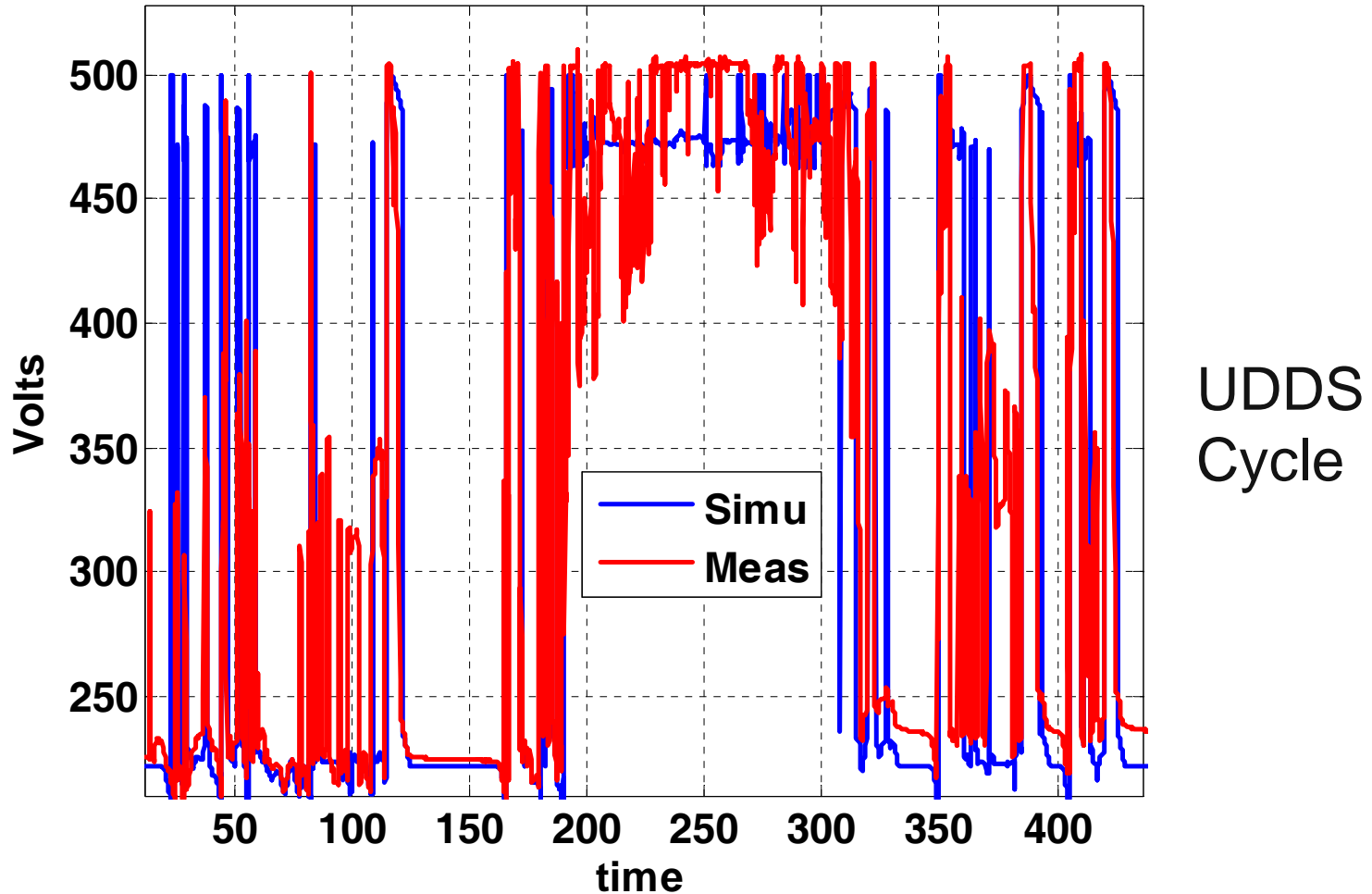


Japan Prius Validation Results

Cycle	Cons test mpg	Cons simul mpg	Diff in %	SOC init	SOCf test	SOCf simul	Diff in %
Japan 10-15	44.9	45.1	0.4	0.600	0.580	0.583	0.5
Japan 10-15	48.8	50.7	3.9	0.610	0.575	0.561	2.3
EUDC	44.0	43.8	0.4	0.610	0.605	0.593	2.0
HWFET	48.2	46.7	3.2	0.550	0.571	0.573	0.3

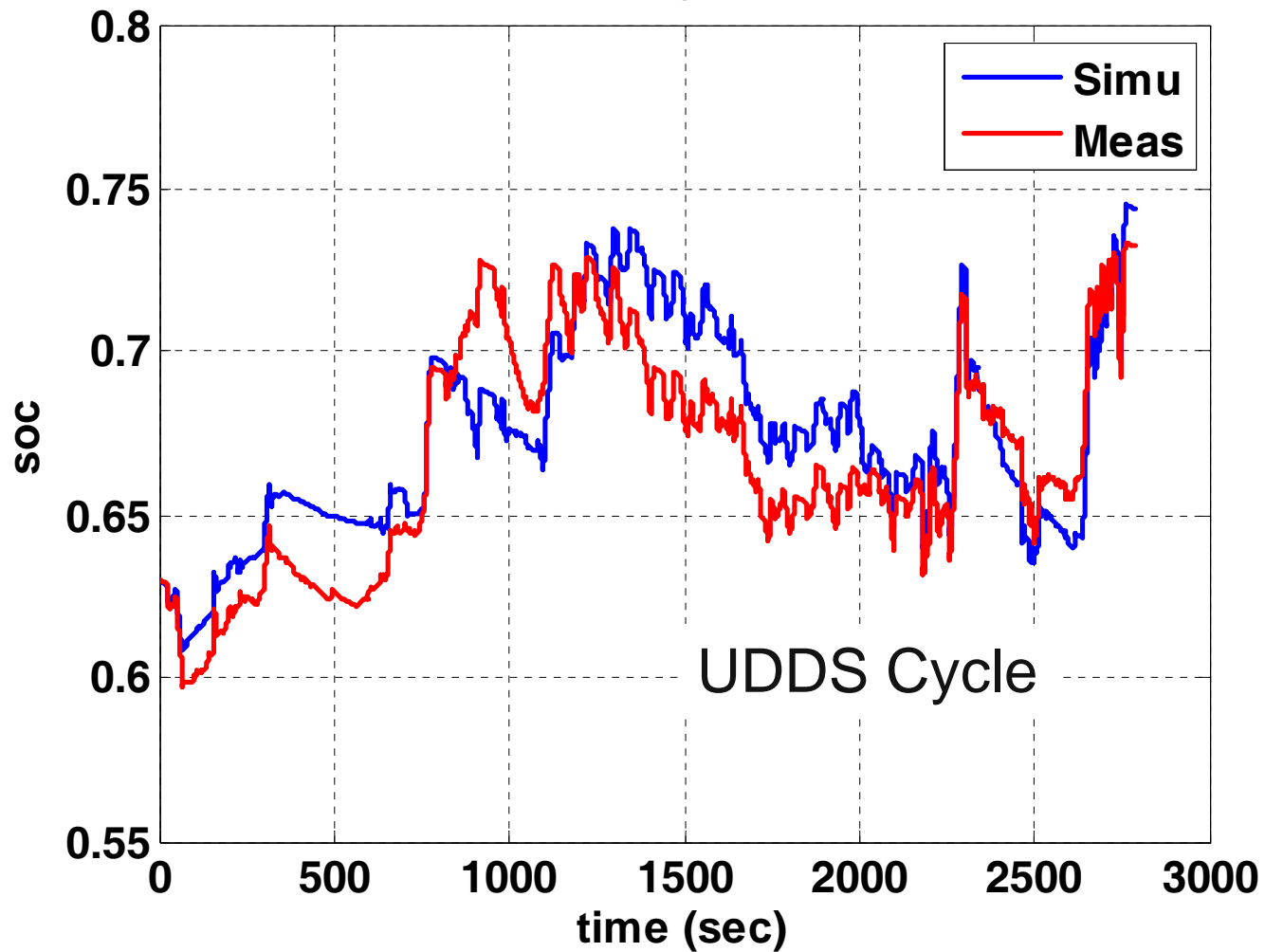
2004 Prius - Boost Converter Output Voltage Follows Test Trends

Boost Converter Output



2004 Prius - Example of SOC Comparison with Final Model

Battery SOC



2004 Prius Fuel Economy Comparison

Drive Cycle	APRF Test ⁽¹⁾	PSAT
UDDS	71	73
HWFET	67	66.2
US06	42	45.3
Japan1015	75	78.1
NEDC	69	68.5

(1) Several averaged test results

Outline

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Plug-in Prius Hymotion – Vehicle Configuration and Specification

Vehicle Mass	1586 kg
High Capacity Battery	5 kWh, Li-ion
A, B, C (SI Unit)	88.6, 0.14, 0.36
Test of date	10/30/2006



Low Capacity Battery

Prius 1.3 kWh NiMH
230 VDC Battery Pack

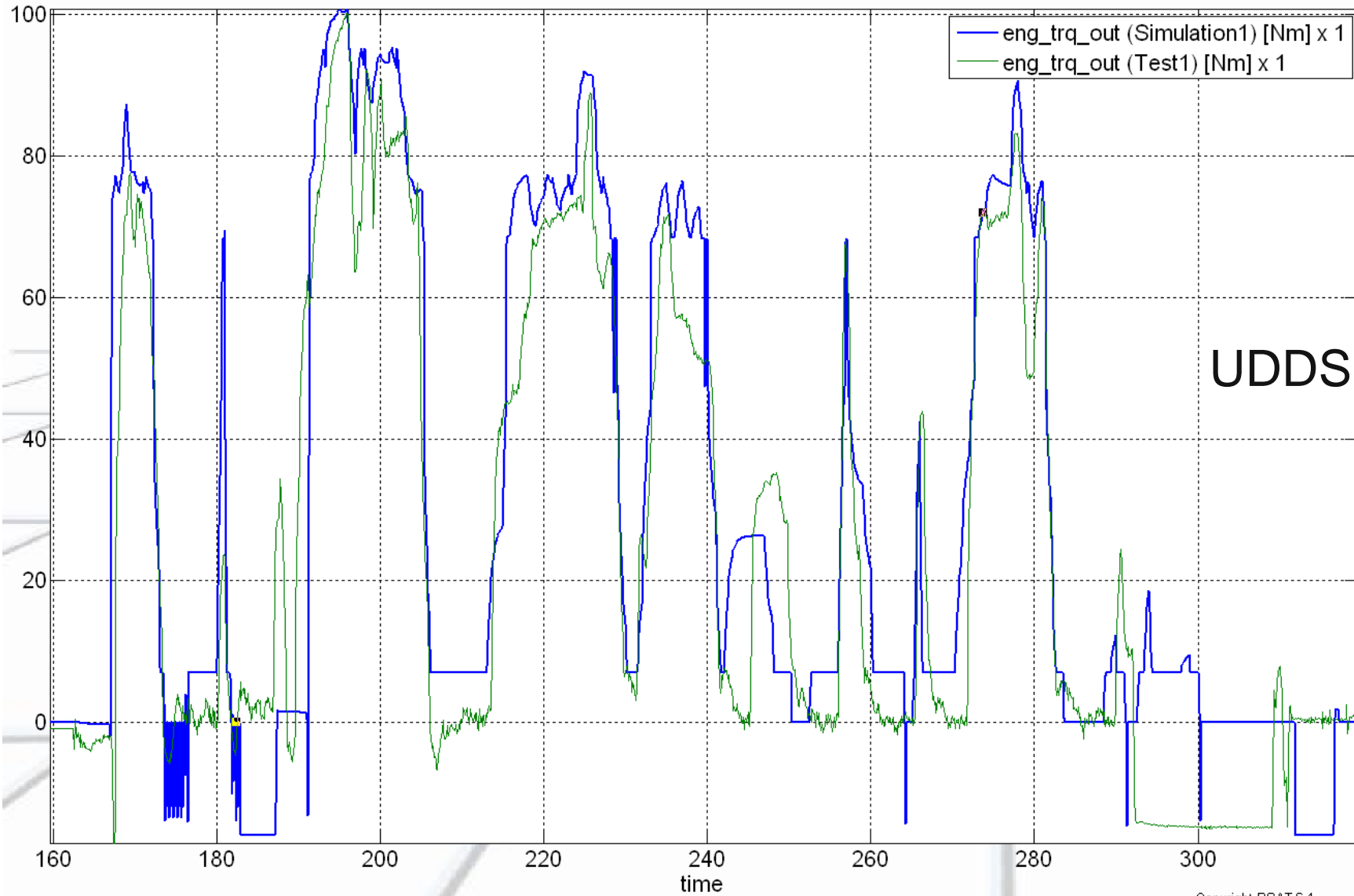
High Capacity Battery

Hymotion 5kWh System

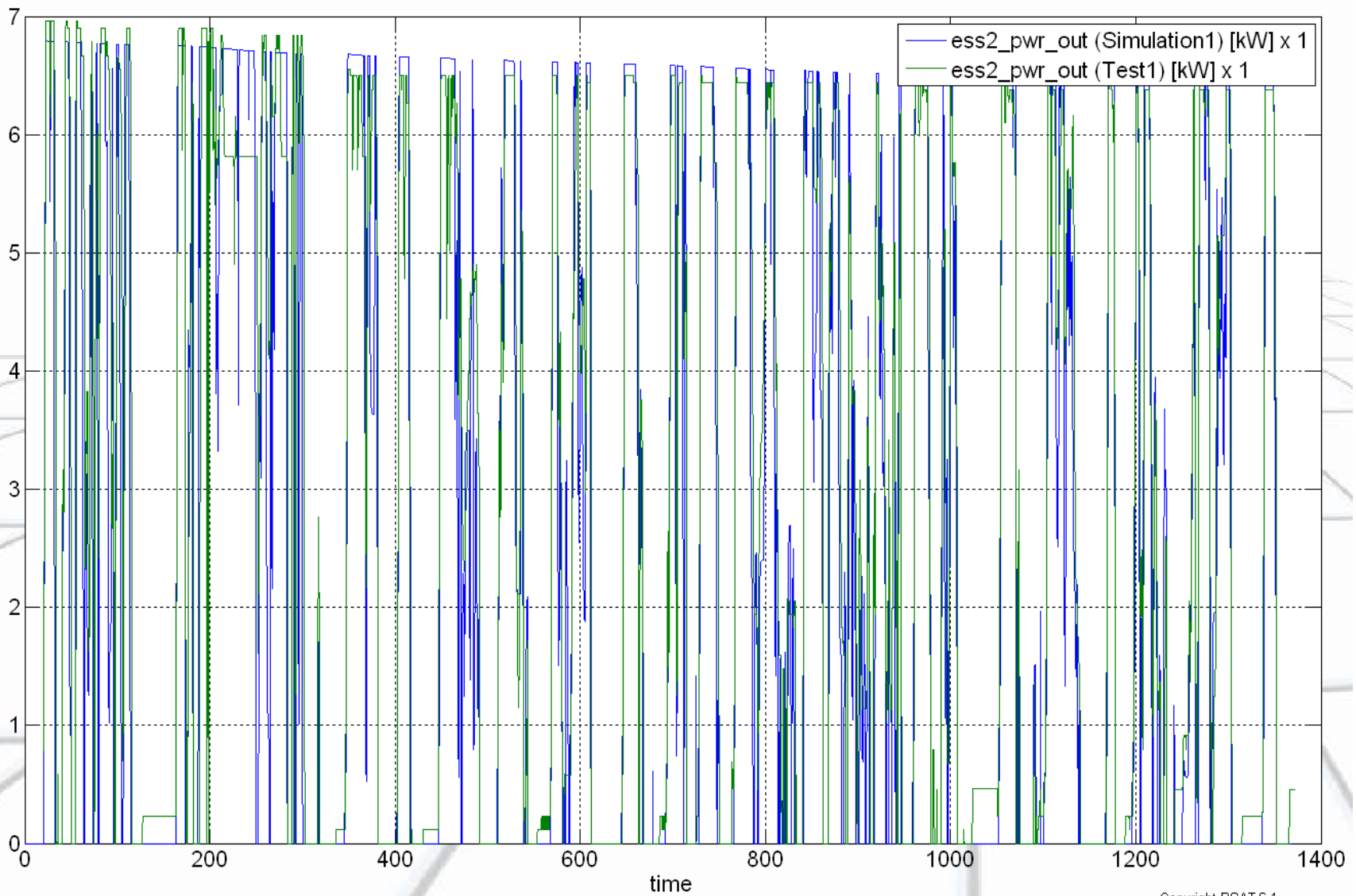
Power
Converter
to 230VDC

115 VDC
Li-Ion

Engine Torque Comparison



High Capacity Battery Power



Charge Depleting Mode Comparison – UDDS

	Unit	Test	Simulation	Absolute Difference	Relative Difference
Fuel Economy	mile/gallon	176.7	192.3	15.2	8.8%
Elec. Consumption	Wh/km	86.3	83.8	2.5	2.8%
SOC Init	%	62	62	0	0
SOC Final	%	62	62.8	0.8	1.3%
System Efficiency	%	56.0	55.2	0.8	1.4%

Test 60610104

Charge Sustaining Mode Comparison – UDDS

	Unit	Test	Simulation	Absolute Difference	Relative Difference
Fuel Economy	mile/gallon	64.5	65.6	1.1	1.7%
SOC Init	%	62	62	0	0
SOC Final	%	62	61.8	0.2	0.3%
System Efficiency	%	41.6	39.1	2.5	6%

Test 60610106