

# Integrating Data, Performing Quality Assurance, and Validating the Vehicle Model for the 2004 Prius Using PSAT

A. Rousseau, J. Kwon, P. Sharer,  
S. Pagerit, M. Duoba  
Argonne National Laboratory

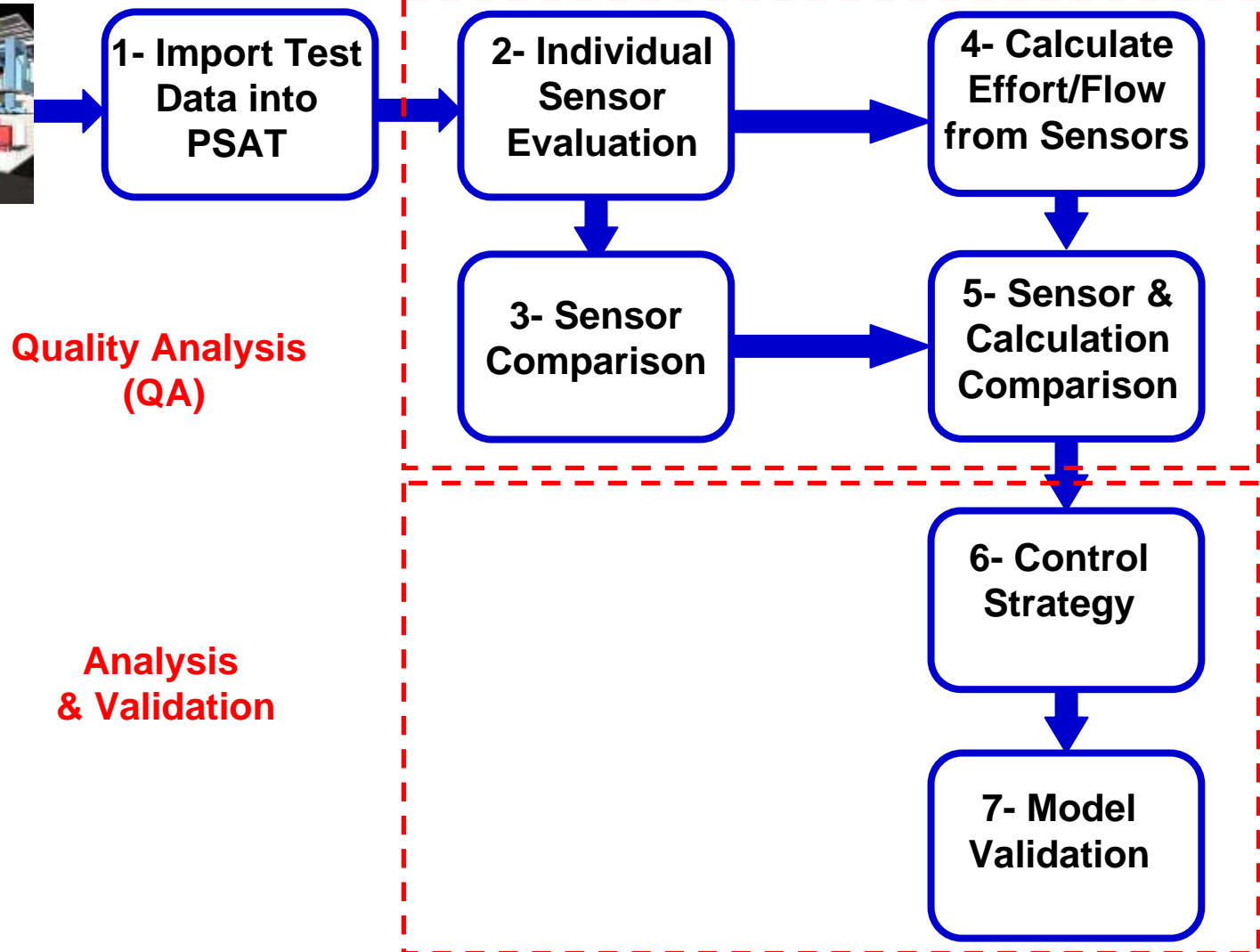
*Work sponsored by  
Lee Slezak, OFCVT/EERE/DOE*



# Accelerating Data Processing & Analysis

- Argonne performs extensive vehicle instrumentation (>100 sensors) and numerous tests (>100) for advanced vehicles => Huge amount of data
- Current test data analysis performed manually with EXCEL => Process long and painful
- Advance in computer tools allow the development of an automated process, from test data QA to analysis and validation
- 2004 Toyota Prius tested at Argonne National Laboratory will be used as an example

# Generic Methodology: From Test to Validation



# Test data are renamed, rescaled, and imported into the same environment as simulation

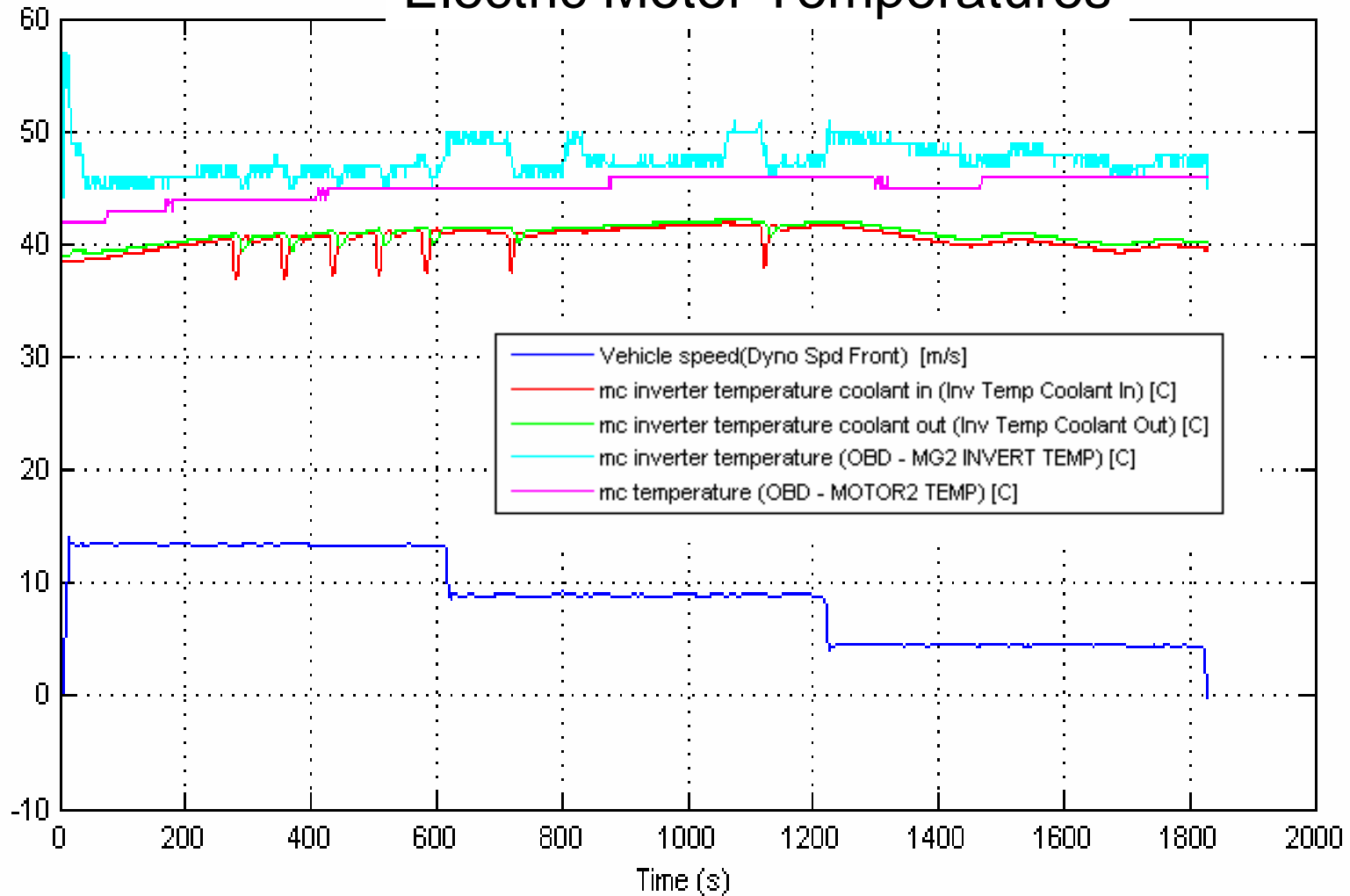
The screenshot shows the PSAT v6.0 - Powertrain System Analysis Toolkit interface. The main window has a menu bar with 'File', 'Simulation', 'Setup', 'PSAT-PRO', 'Units', and 'Help'. Below the menu bar is a toolbar with 'Simulation', 'Import Data' (selected), 'Data Analysis', and 'Matlab'. The interface is divided into several sections:

- Project Path:** Includes dropdown menus for 'Powertrain:', 'Transmission:', 'Drivetrain:', and 'Cycle: No Cycle'. A 'Project Date:' field is also present.
- Data File:** A table with columns for 'Variable List', 'Variable Name', 'Unit', and 'Length'. Below the table are buttons for 'Load All Data' and 'Load Variable List'.
- Data Table:** A table with columns: 'Data File', 'Variable Name', 'Unit', 'Unit Conversion', 'PSAT Component', 'PSAT Variable Name', and 'PSAT Unit'. Below the table are buttons for 'Remove all', 'Remove Selected Variables', and 'Remove Conversion for Selected Variables'.
- Template File:** Includes a 'Template File:' field and an 'Apply Template' button.
- Calculation File:** Includes a 'Calculation File:' field and an 'Apply Calculation' button.
- Plot File:** Includes a 'Plot File:' field and a 'Plot' button.

Buttons for 'Load Converted Variables to Matlab' and 'Save Test Variables' are also visible.

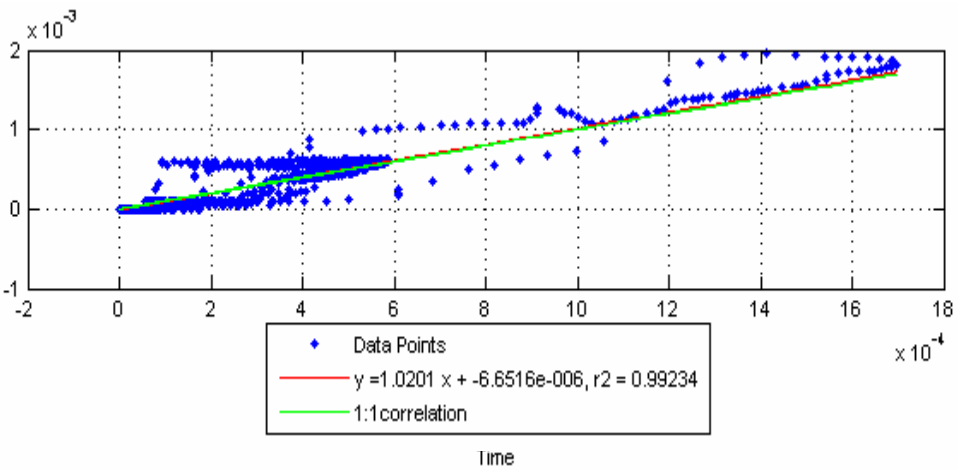
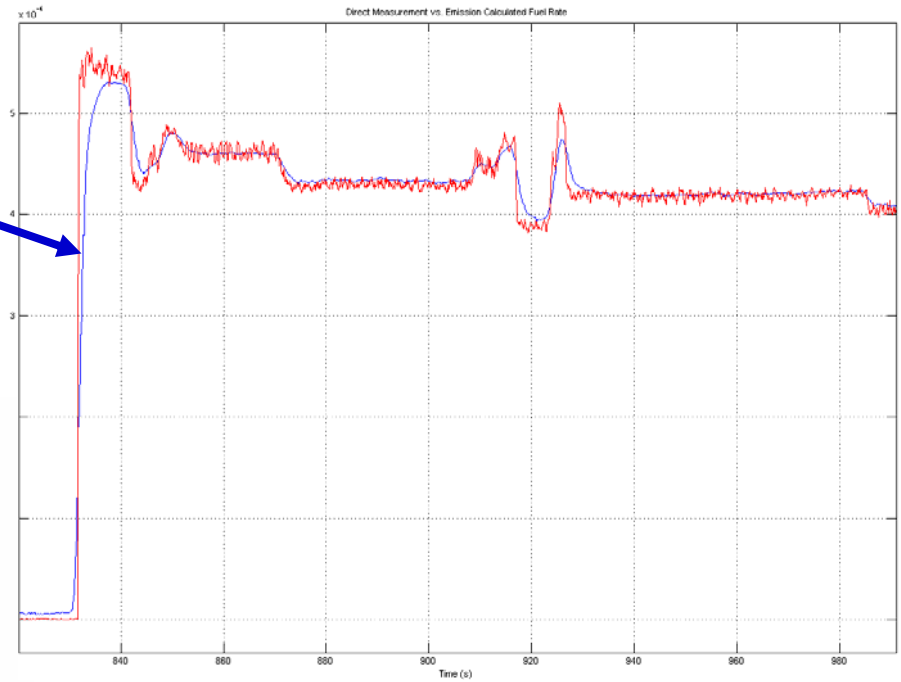
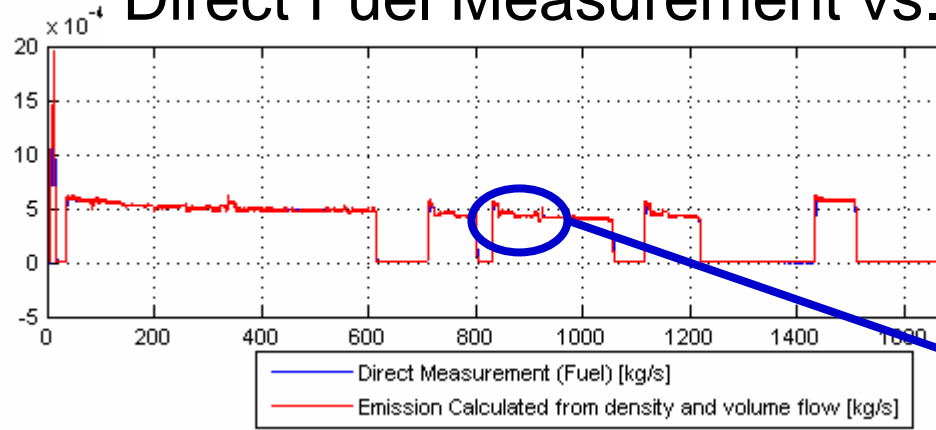
# Individual Sensor are Evaluated to Find Major Issues (Range, Sign...)

## Electric Motor Temperatures



# Redundant Sensors Are Compared

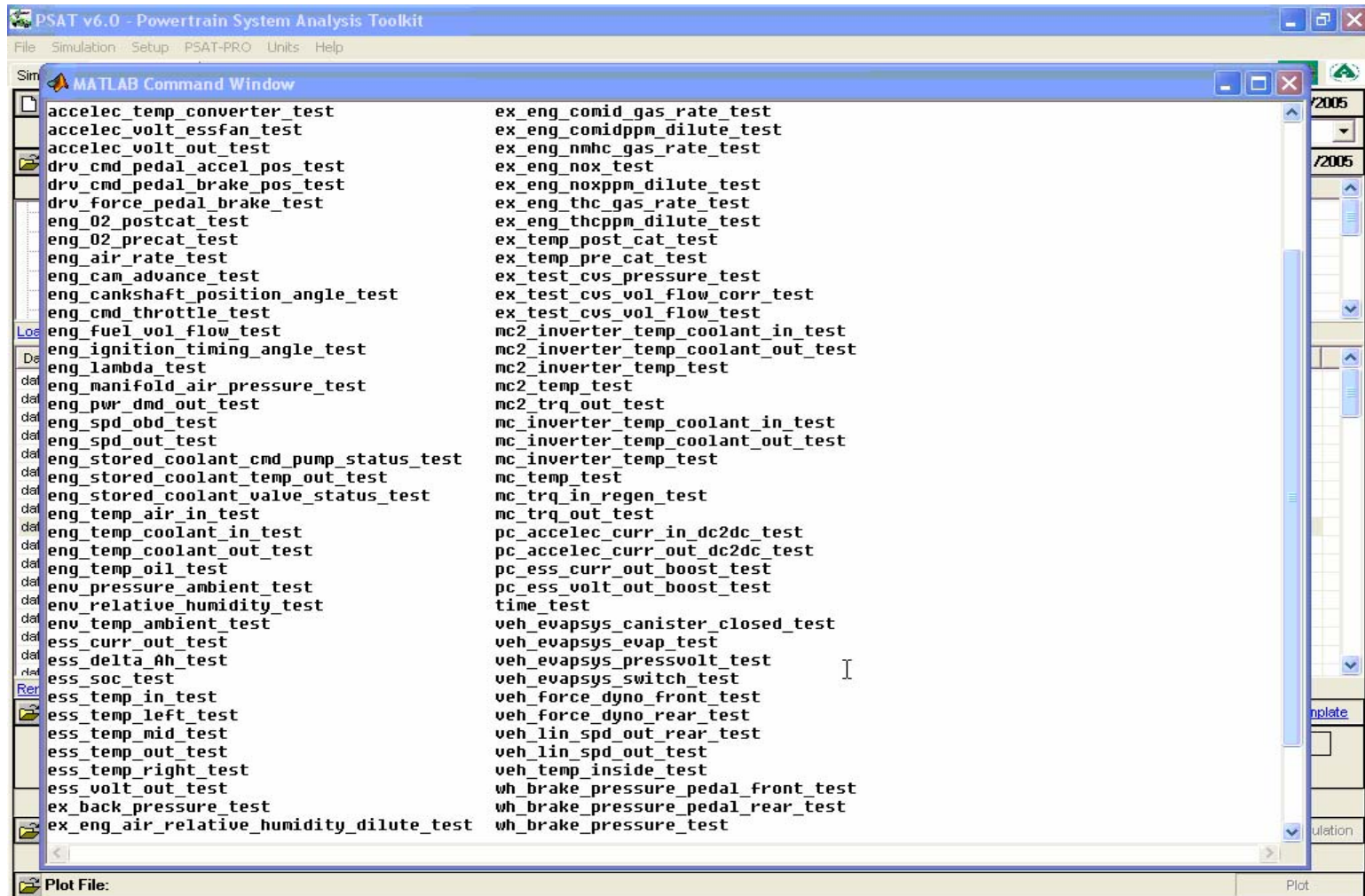
## Direct Fuel Measurement vs. Bench



# 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 shows the PSAT v6.0 - Powertrain System Analysis Toolkit interface. The main window is titled "MATLAB Command Window" and displays a list of test cases organized into two columns. The left column lists tests such as "accelec\_temp\_converter\_test", "drv\_cmd\_pedal\_accel\_pos\_test", "eng\_02\_postcat\_test", "eng\_fuel\_vol\_flow\_test", "eng\_lambda\_test", "ess\_soc\_test", and "ex\_eng\_air\_relative\_humidity\_dilute\_test". The right column lists tests such as "ex\_eng\_comid\_gas\_rate\_test", "ex\_eng\_nmhc\_gas\_rate\_test", "ex\_eng\_nox\_test", "mc2\_inverter\_temp\_coolant\_in\_test", "mc2\_inverter\_temp\_coolant\_out\_test", "mc2\_inverter\_temp\_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 includes a menu bar (File, Simulation, Setup, PSAT-PRO, Units, Help), a toolbar, and a status bar at the bottom with "Plot File:" and "Plot" labels.

```
PSAT v6.0 - Powertrain System Analysis Toolkit
File Simulation Setup PSAT-PRO Units Help

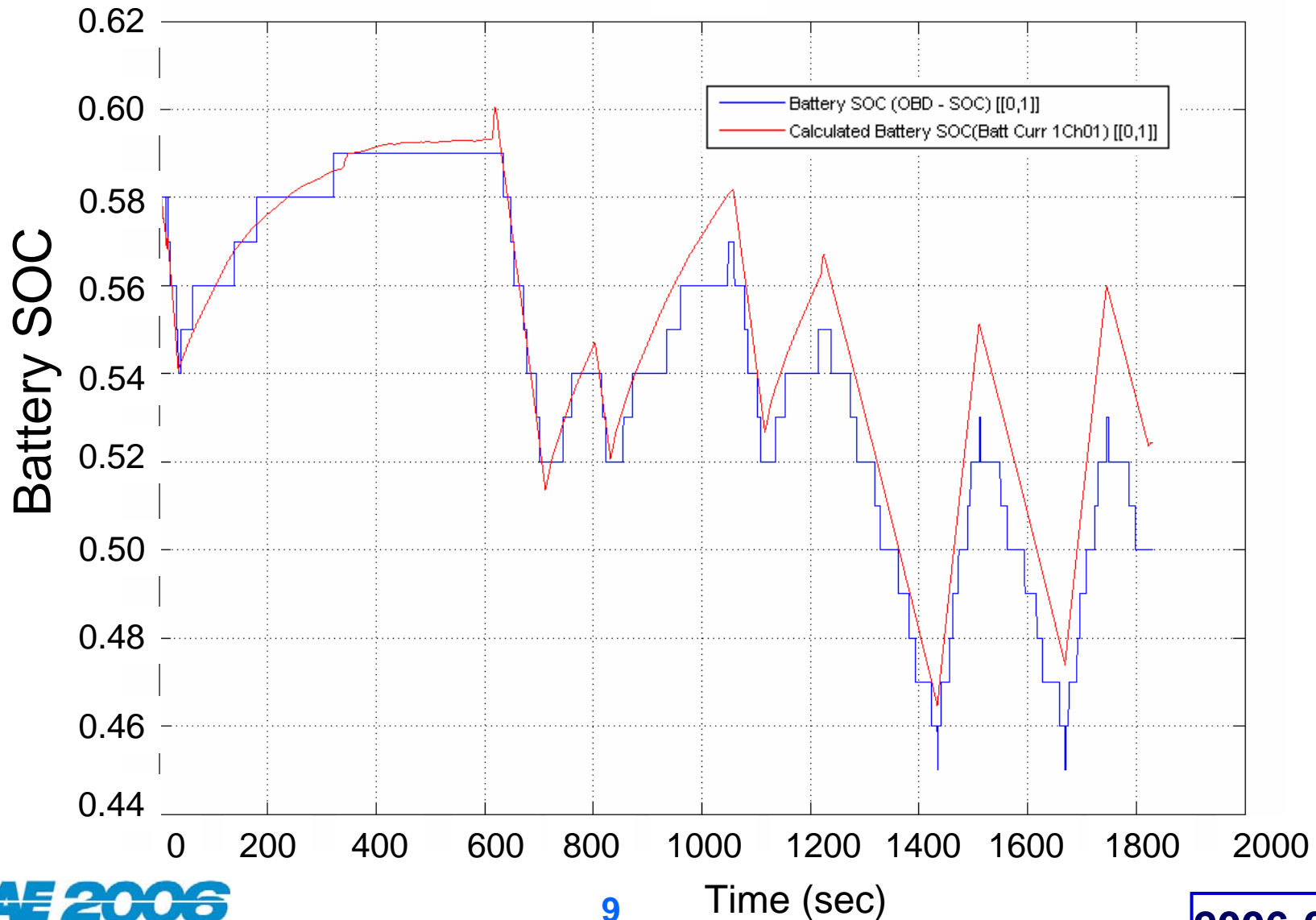
MATLAB Command Window

accelec_temp_converter_test      ex_eng_comid_gas_rate_test
accelec_volt_essfan_test        ex_eng_comidppm_dilute_test
accelec_volt_out_test          ex_eng_nmhc_gas_rate_test
drv_cmd_pedal_accel_pos_test    ex_eng_nox_test
drv_cmd_pedal_brake_pos_test    ex_eng_noxppm_dilute_test
drv_force_pedal_brake_test      ex_eng_thc_gas_rate_test
eng_02_postcat_test            ex_eng_thcpcm_dilute_test
eng_02_precat_test             ex_temp_post_cat_test
eng_air_rate_test              ex_temp_pre_cat_test
eng_cam_advance_test           ex_test_cvs_pressure_test
eng_cankshaft_position_angle_test ex_test_cvs_vol_flow_corr_test
eng_cmd_throttle_test          ex_test_cvs_vol_flow_test
eng_fuel_vol_flow_test         mc2_inverter_temp_coolant_in_test
eng_ignition_timing_angle_test mc2_inverter_temp_coolant_out_test
eng_lambda_test               mc2_inverter_temp_test
eng_manifold_air_pressure_test mc2_temp_test
eng_pwr_dmd_out_test          mc2_trq_out_test
eng_spd_obd_test              mc_inverter_temp_coolant_in_test
eng_spd_out_test              mc_inverter_temp_coolant_out_test
eng_stored_coolant_cmd_pump_status_test mc_inverter_temp_test
eng_stored_coolant_temp_out_test mc_temp_test
eng_stored_coolant_valve_status_test mc_trq_in_regen_test
eng_temp_air_in_test          mc_trq_out_test
eng_temp_coolant_in_test      pc_accelec_curr_in_dc2dc_test
eng_temp_coolant_out_test     pc_accelec_curr_out_dc2dc_test
eng_temp_oil_test            pc_ess_curr_out_boost_test
env_pressure_ambient_test     pc_ess_volt_out_boost_test
env_relative_humidity_test    time_test
env_temp_ambient_test        veh_evapsys_canister_closed_test
ess_curr_out_test            veh_evapsys_evap_test
ess_delta_Ah_test           veh_evapsys_pressvolt_test
ess_soc_test                 veh_evapsys_switch_test
ess temp in test             veh_force_dyno_front_test
ess temp left test          veh_force_dyno_rear_test
ess temp mid test           veh_lin_spd_out_rear_test
ess temp out test           veh_lin_spd_out_test
ess temp right test         veh_temp_inside_test
ess_volt_out_test           wh_brake_pressure_pedal_front_test
ex_back_pressure_test        wh_brake_pressure_pedal_rear_test
ex_eng_air_relative_humidity_dilute_test wh_brake_pressure_test

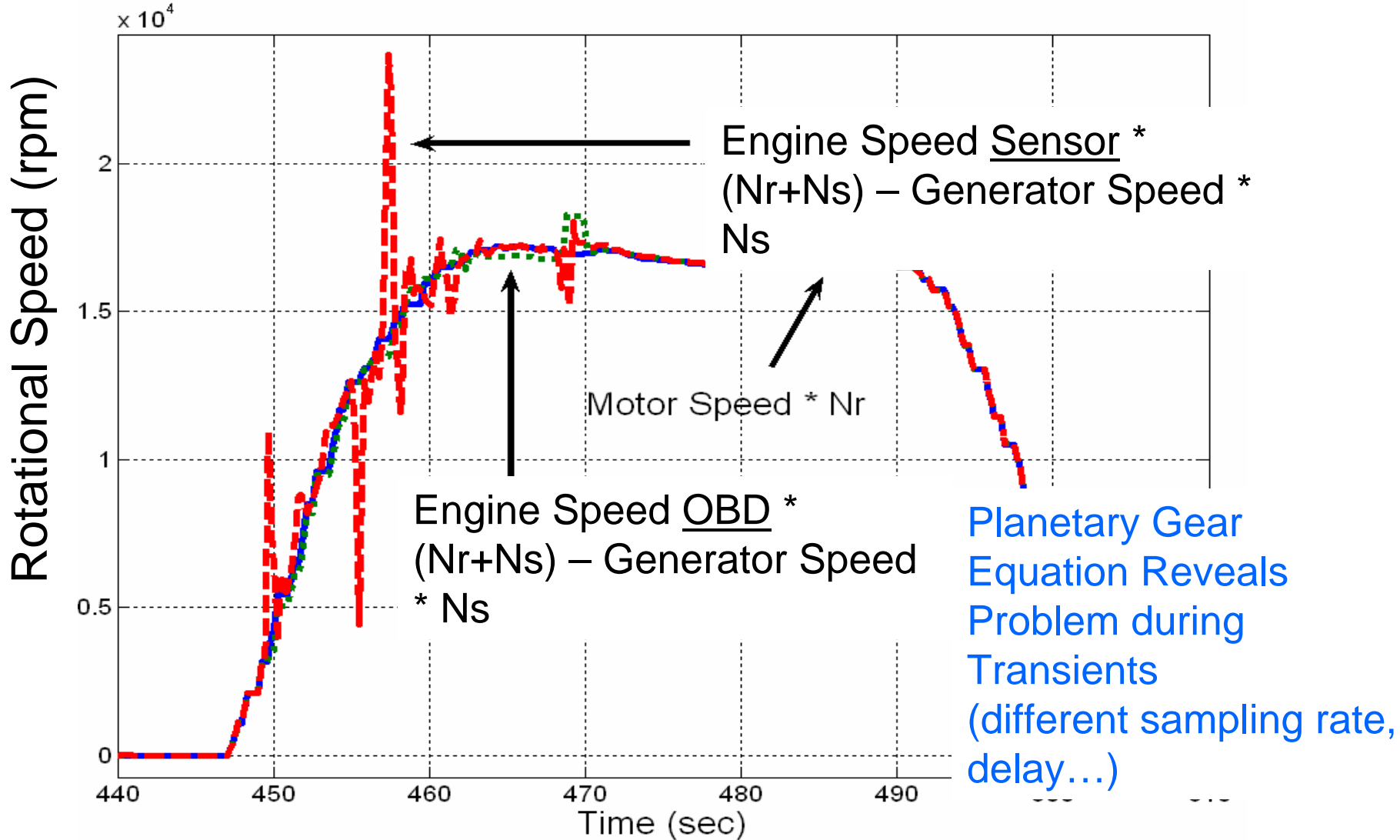
Plot File: Plot
```



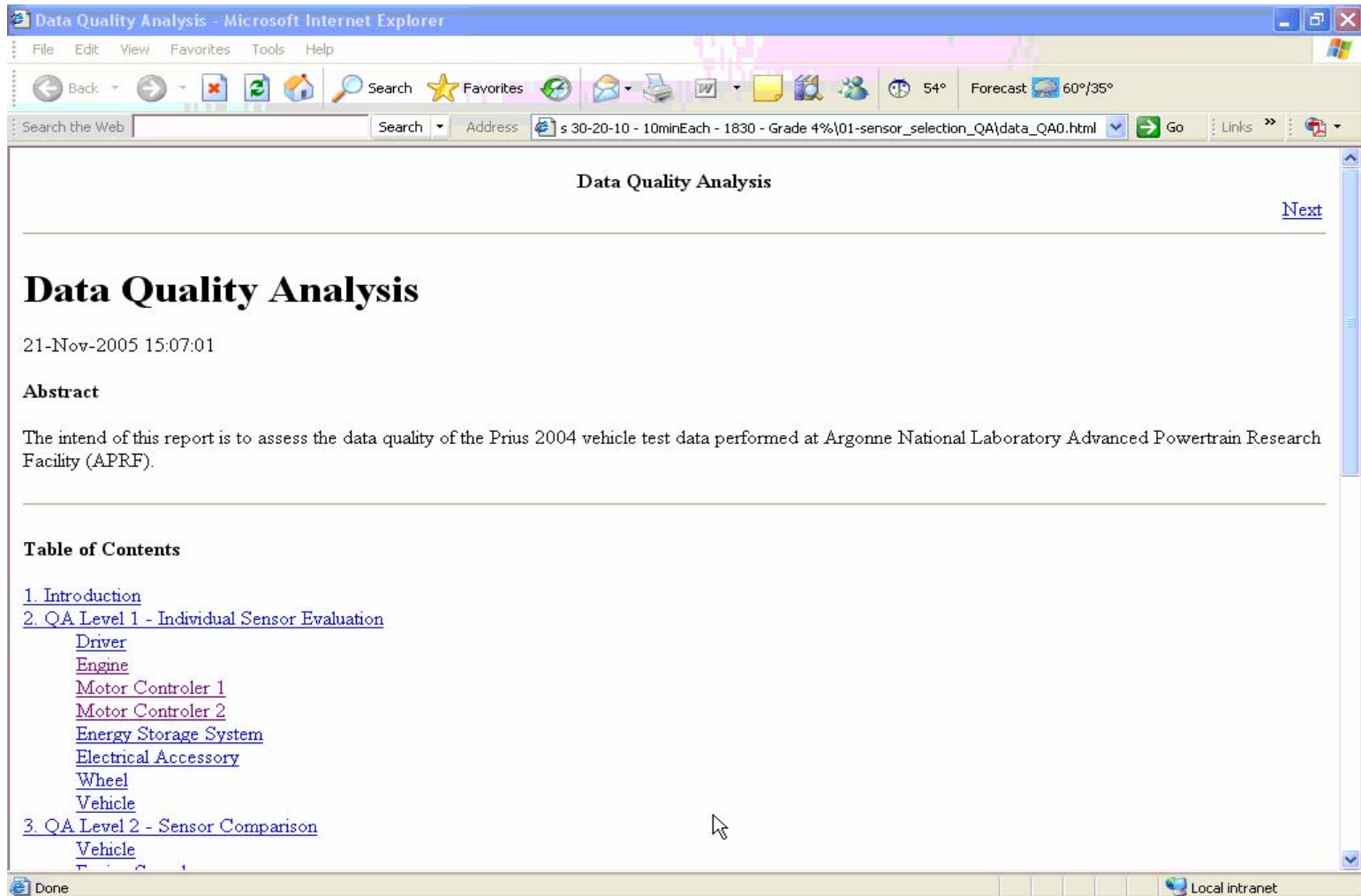
# Calculated and Measured Signals Are Compared



# Using Sensors from Different Sources may Lead to Added Uncertainties



# Web Document 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).

---

**Table of Contents**

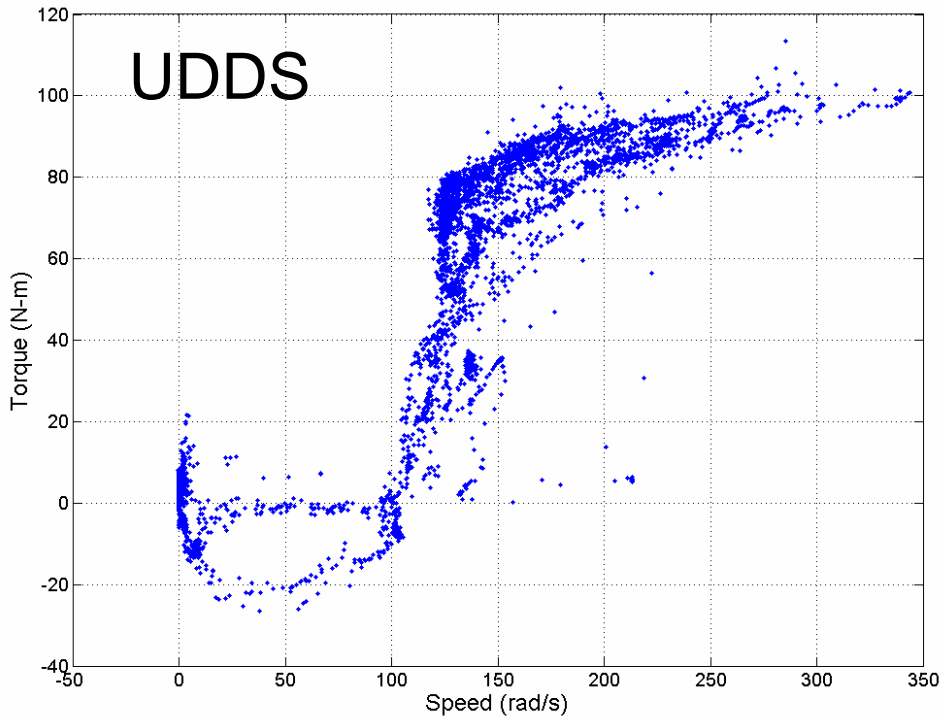
- [1. Introduction](#)
- [2. QA Level 1 - Individual Sensor Evaluation](#)
  - [Driver](#)
  - [Engine](#)
  - [Motor Controler 1](#)
  - [Motor Controler 2](#)
  - [Energy Storage System](#)
  - [Electrical Accessory](#)
  - [Wheel](#)
  - [Vehicle](#)
- [3. QA Level 2 - Sensor Comparison](#)
  - [Vehicle](#)

The browser status bar at the bottom shows "Done" and "Local intranet".

## Parameters Selected According to Detailed QA

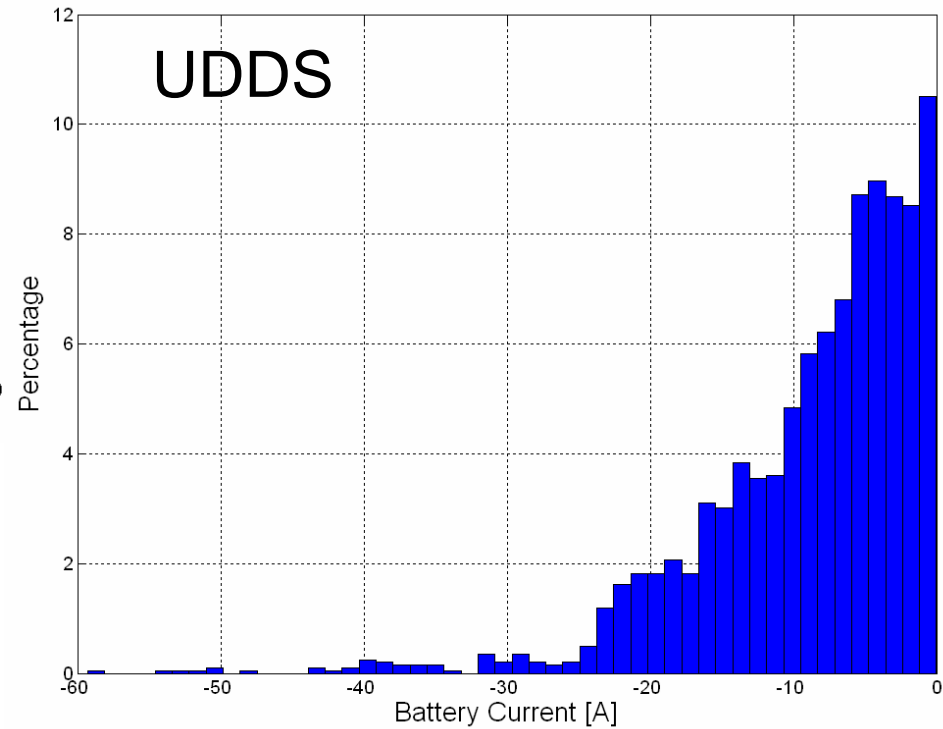
- Signals with low correlation coefficients or that appeared suspicious from the visual check are scrutinized.
- Sensors installed by test engineers are preferred to OBD or dynamometer signals.
- Ensure consistency in the mathematical relationships.
- Signals from the OBD were not recognized (issue with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

# Control Strategy Understanding

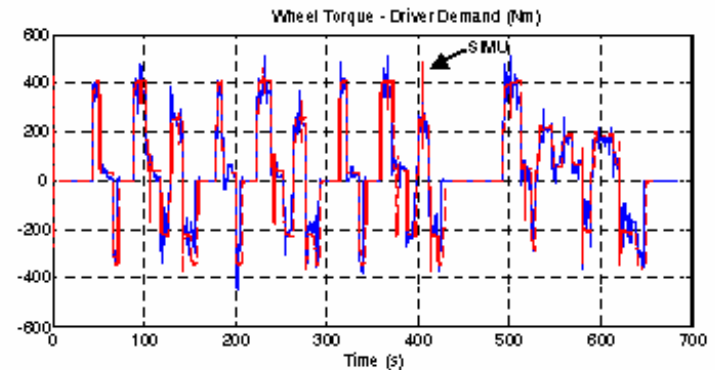
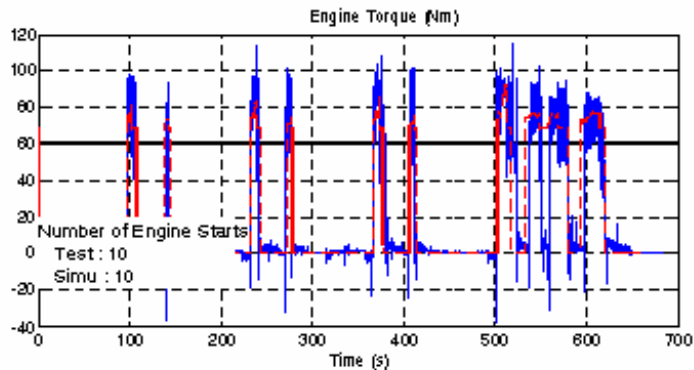
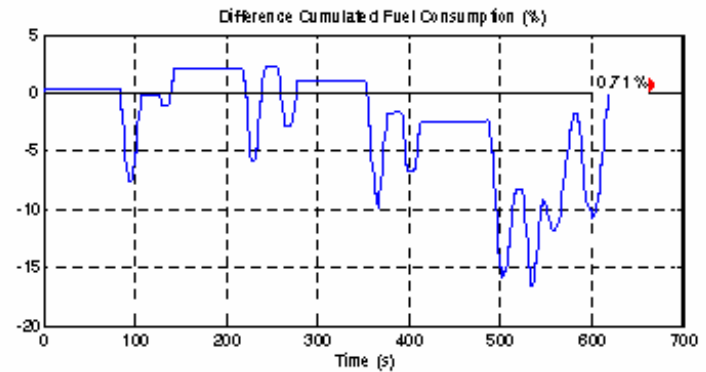
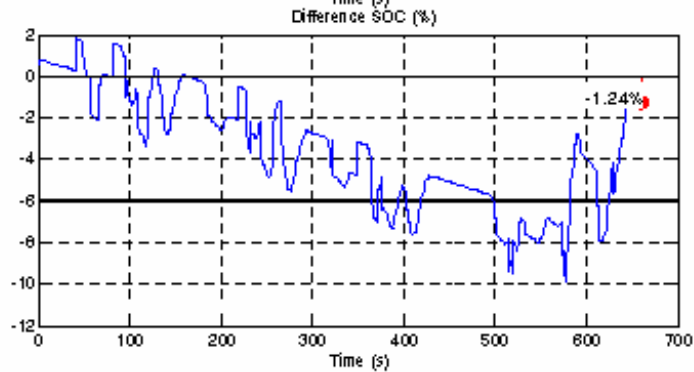
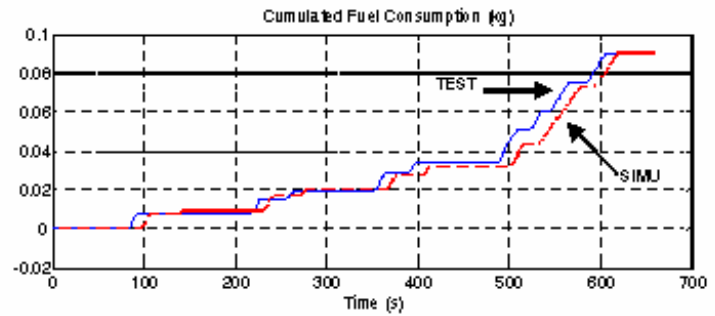
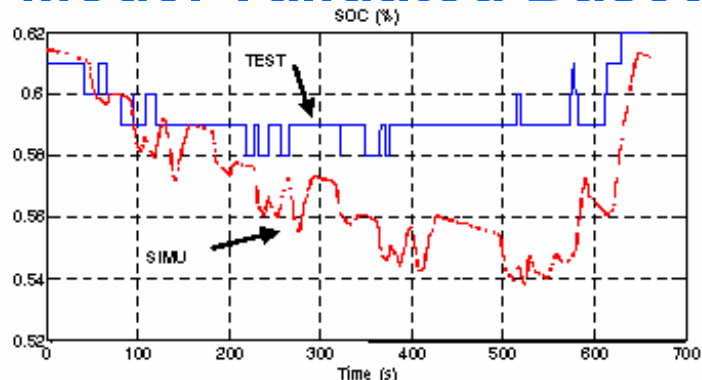


Engine operating conditions

Battery Current Histogram during Regenerative Braking



# PSAT Model Validated Based on Test Data



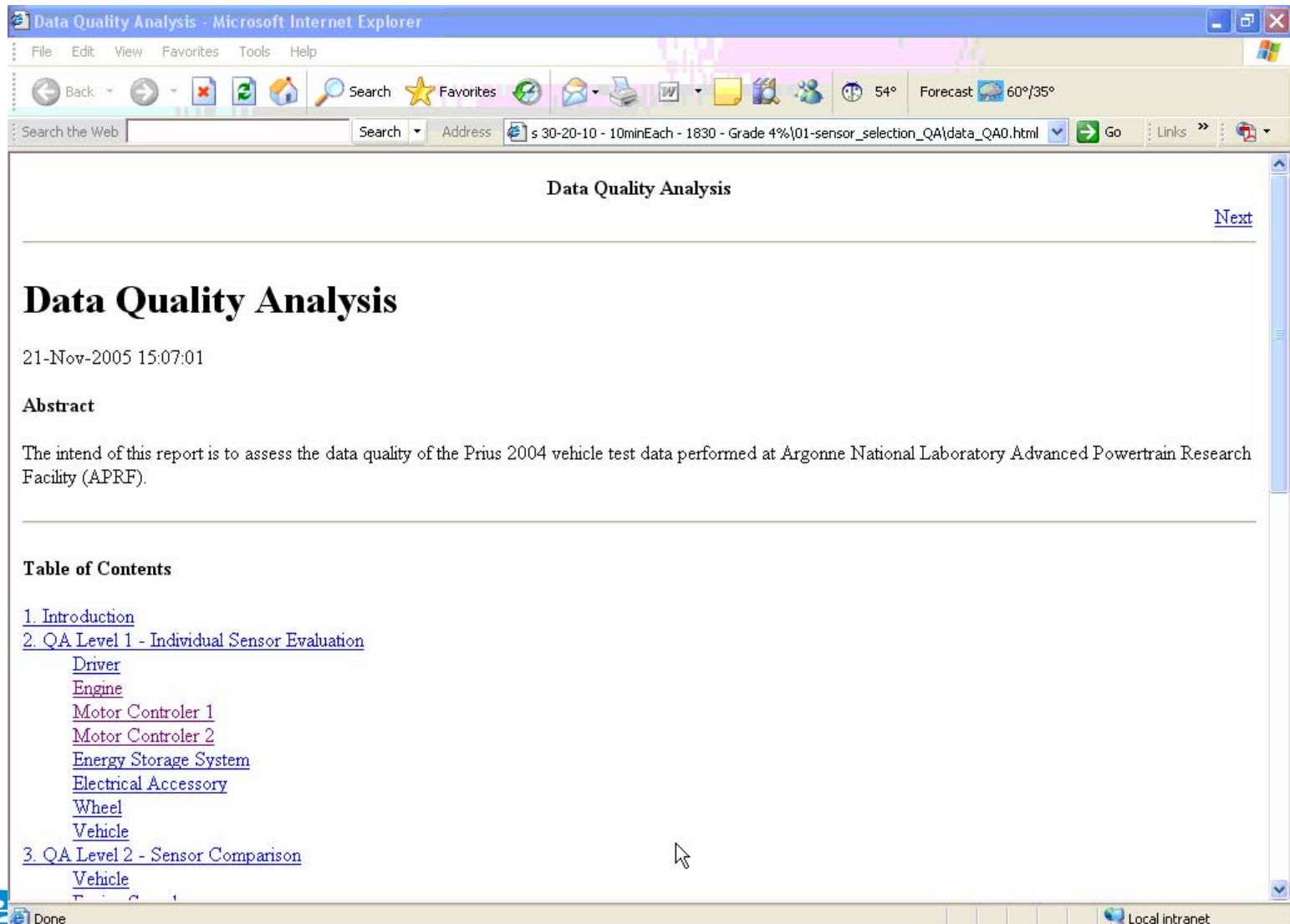
# Conclusion

- A generic process allowing automated data quality analysis and facilitating vehicle model validation has been presented.
- In addition to significantly accelerating the process, the methodology allows an in-depth analysis of test sensor uncertainties and vehicle control strategy.
- Reports are generated in minutes as opposed to days, accelerating both the analysis and the validation process.
- Prius 2004 Model has been validated within 5% fuel economy and battery SOC for several driving cycles
- Additional work needs to be done to characterize the acceptable test and validation errors as well as cumulative signal uncertainties.





# HTML Report (click to see video)



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 of the browser 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).

---

**Table of Contents**

- [1. Introduction](#)
- [2. QA Level 1 - Individual Sensor Evaluation](#)
  - [Driver](#)
  - [Engine](#)
  - [Motor Controller 1](#)
  - [Motor Controller 2](#)
  - [Energy Storage System](#)
  - [Electrical Accessory](#)
  - [Wheel](#)
  - [Vehicle](#)
- [3. QA Level 2 - Sensor Comparison](#)
  - [Vehicle](#)

The browser's status bar at the bottom shows "Done" and "Local intranet".

# Test Calculation (click to see video)

