Validation Process of a HEV System Analysis Model: PSAT

Aymeric Rousseau
Phil Sharer and Maxime Pasquier
Argonne National Laboratory

SAE Congress 2001, Detroit, Michigan, March 8, 2001

Outline

- PSAT Introduction
- Vehicle Testing
- Component Validation
- Control Strategy Understanding
- Drivetrain Validation
- Conclusion

ANL PSAT

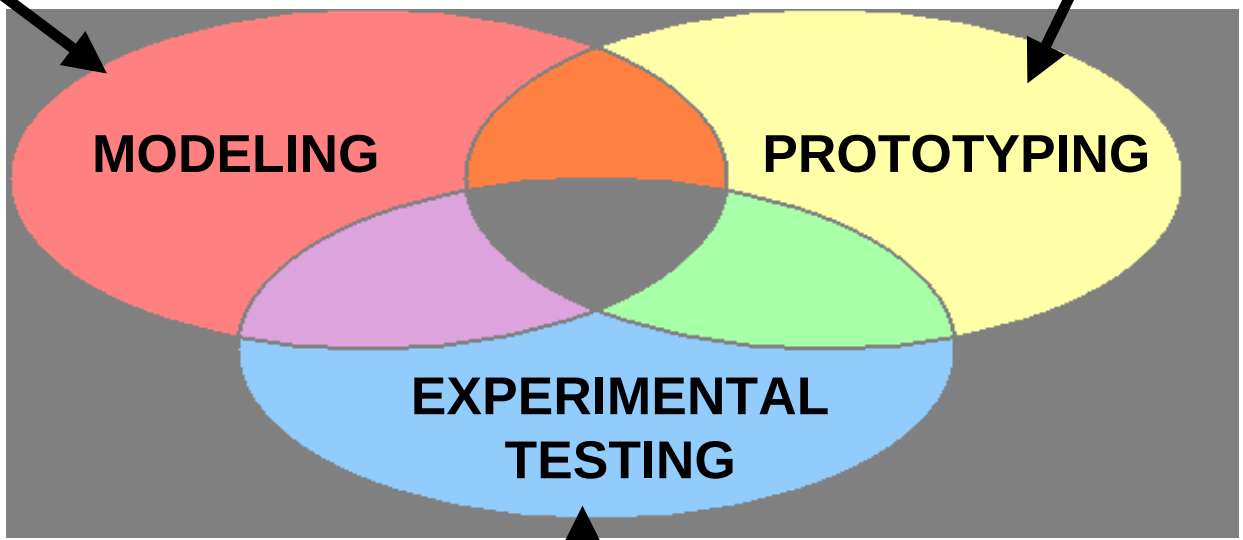
Argonne Systems Analysis Program

ANL PSAT

- **Modeling, testing, and hardware control used to investigate various technologies of advanced vehicles (diesel emissions, CVTs,…)**

1. Modeling software: PSAT
2. Development/integration of new models/data into PSAT
3. Control strategy development

1. Control software: PSAT-PRO
2. Rapid Prototyping (RP)
3. Hardware In the Loop (HIL)



1. Instrumentation
2. Emissions equipment
3. Data processing

What Is the PNGV System Analysis Toolkit?

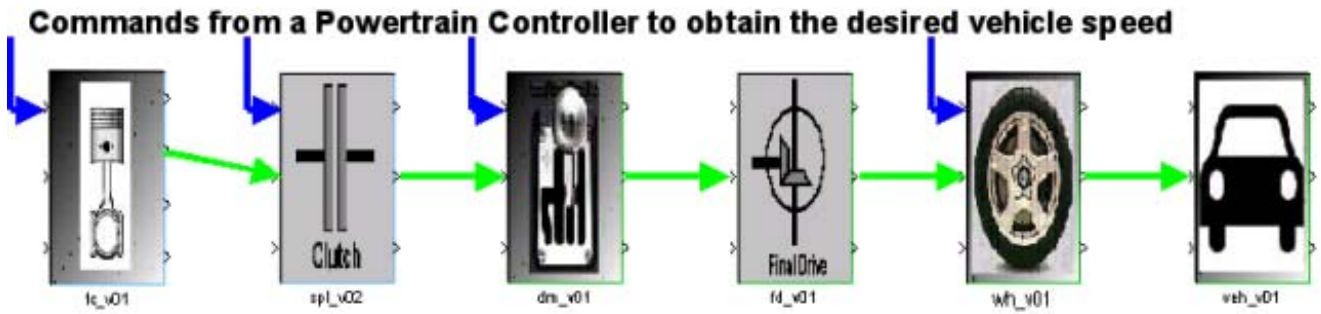
ANL PSAT

- Developed by Argonne under the direction and with the contribution of Ford, General Motors, and DaimlerChrysler for the Partnership for a New Generation of Vehicle (PNGV)
- Funded by USCAR and now by the U.S. Department of Energy
- A powerful forward-looking modeling tool that allows the user to realistically simulate
  - Fuel consumption and exhaust emissions (e.g., Federal Test Procedure, highway, all other cycles)
  - Performance (e.g., 0-30 mph, 0-60 mph, 40-60 mph, distance in 5 sec, maximum launch grade, maximum continuous speed, 55 mph at 6% grade)

Forward-Looking Modeling

ANL PSAT

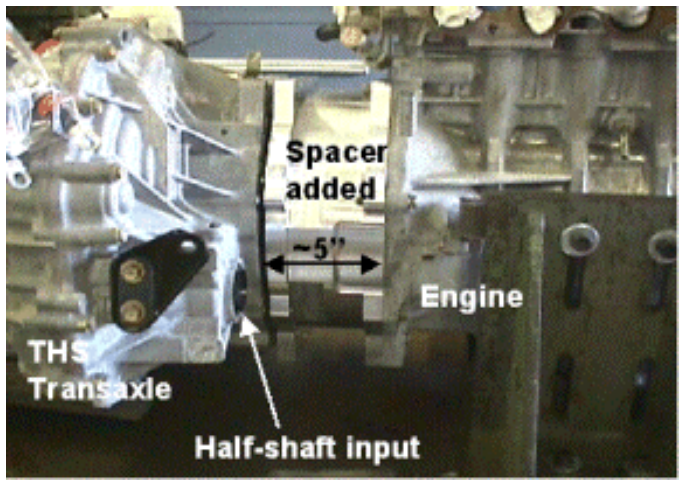
- Forward-looking models (PSAT) represent how systems respond in reality
- In a vehicle, the driver input creates the vehicle response

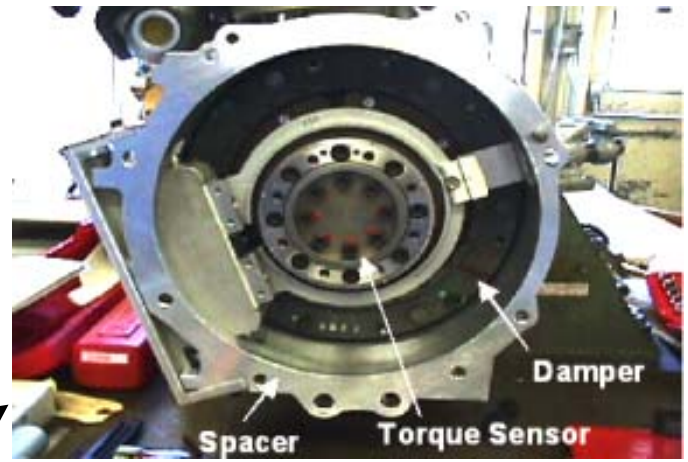


- Forward-looking modeling is consistent with industry practice for vehicle design
- Accurate representation of a dynamic system (e.g., engine starting, shifting, clutch engagement/disengagement...)
- Possibility to implement advanced component models (e.g., 1-D engine model to characterize emissions…)
- Develop control strategies that can be later tested on a bench or in a vehicle
- Small time step

Extensive Data Collection with Torque Sensors

ANL PSAT





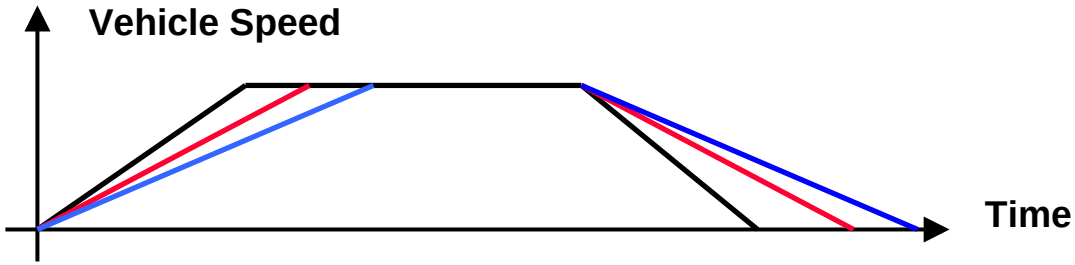
Prius engine torque sensor

Insight axle torque sensor

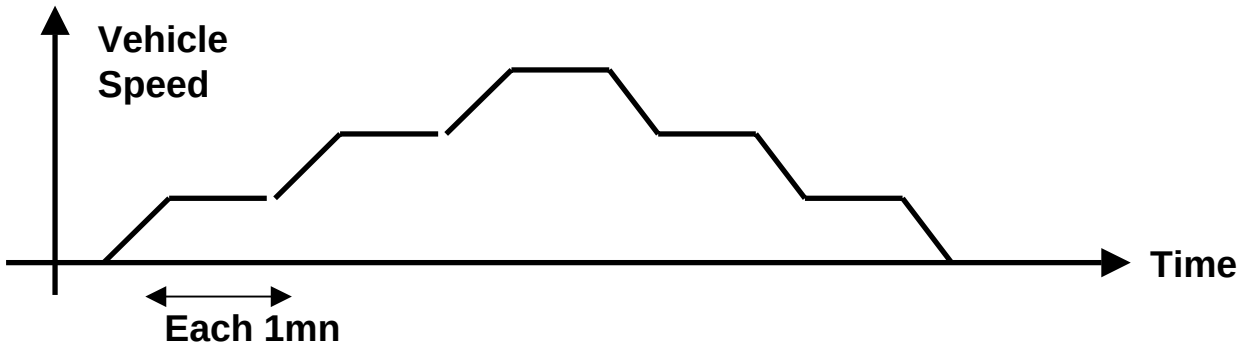
Different Type of Tests Are Needed

ANL PSAT

- Steady-state speeds



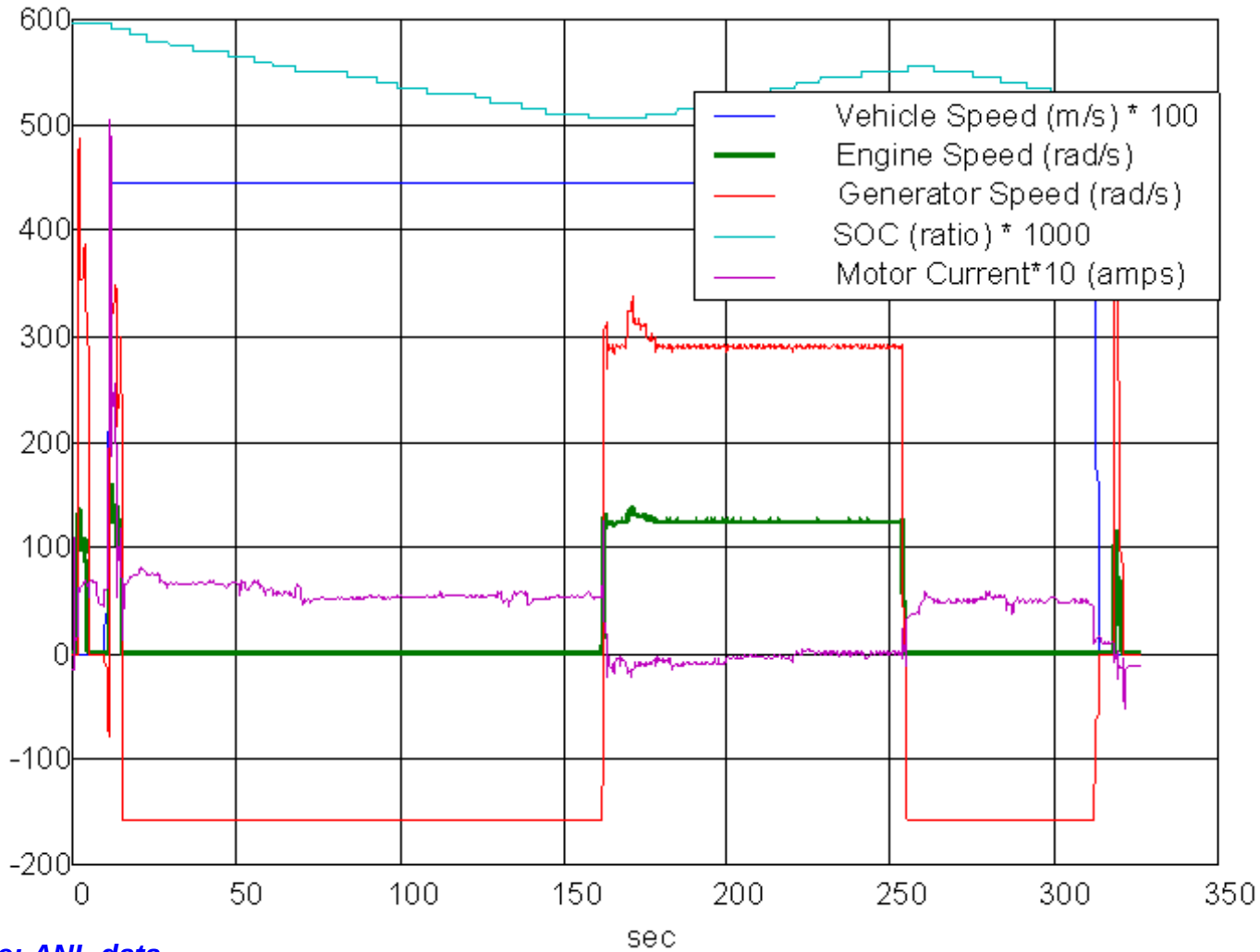
- Succession of accelerations and decelerations at different speeds



- Standard cycles (EUDC, Japan…)

Control Strategy Understanding

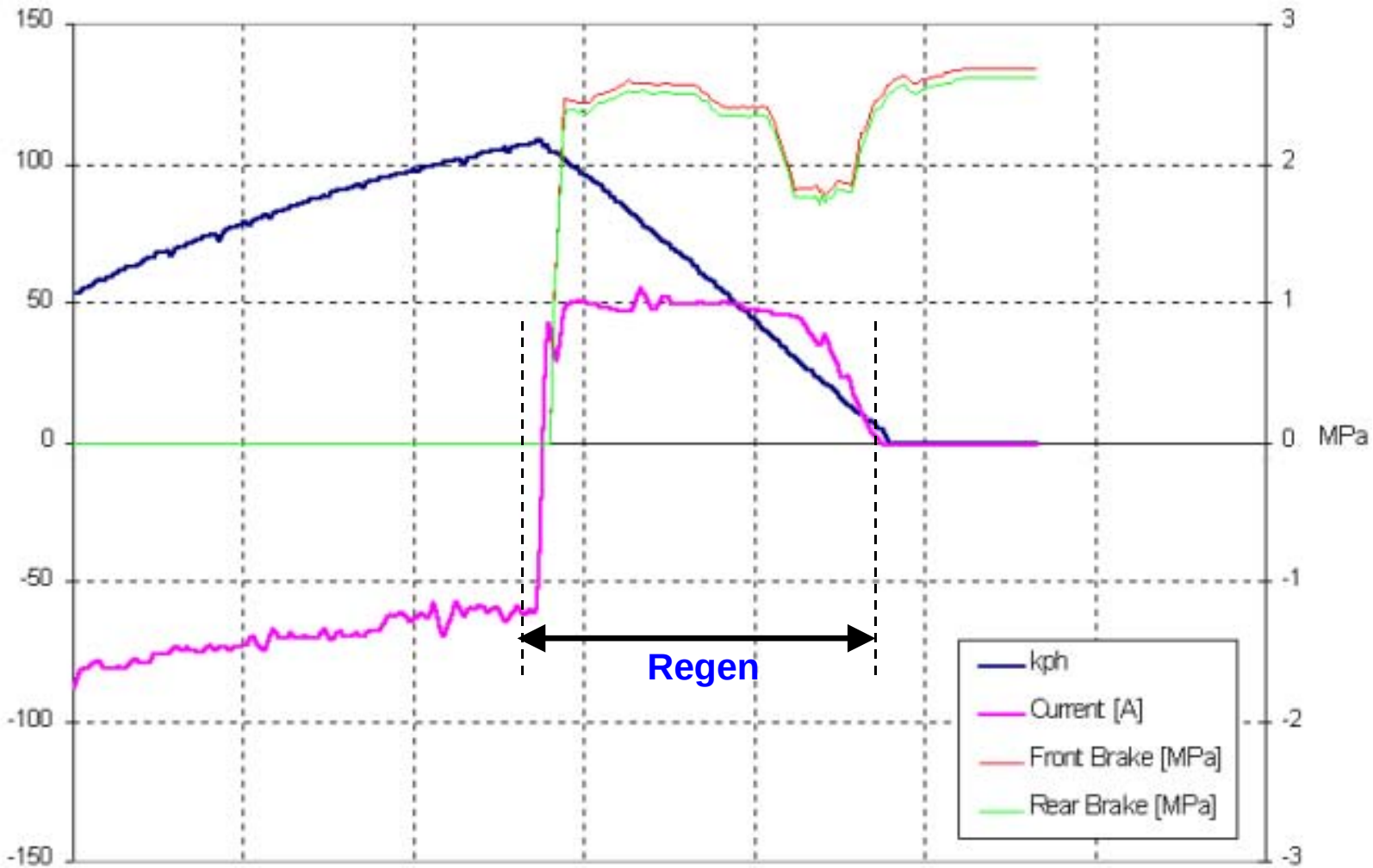
ANL PSAT



Source: ANL data

Acceleration/Deceleration Test

ANL PSAT



Source: ANL data

What Is The Uncertainty Of Each Model?

ANL PSAT

Physical Vehicle

Simulated Component

Measured Current

Simulated SOC

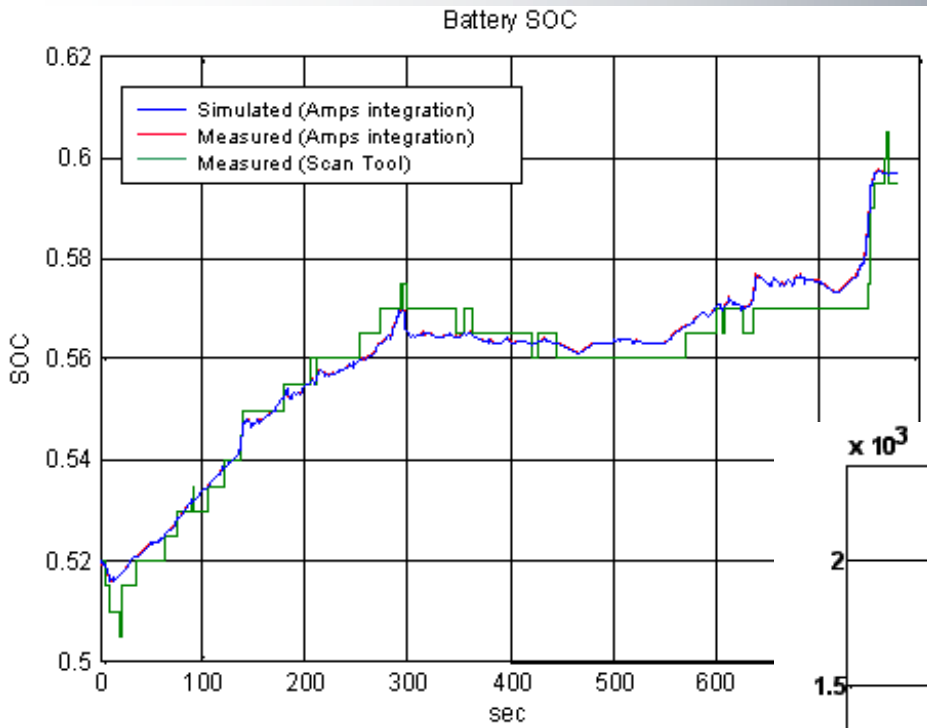
Measured Voltage = Simulated Voltage ✓

Measured SOC = Simulated SOC ✓

Valid Battery Model ✓

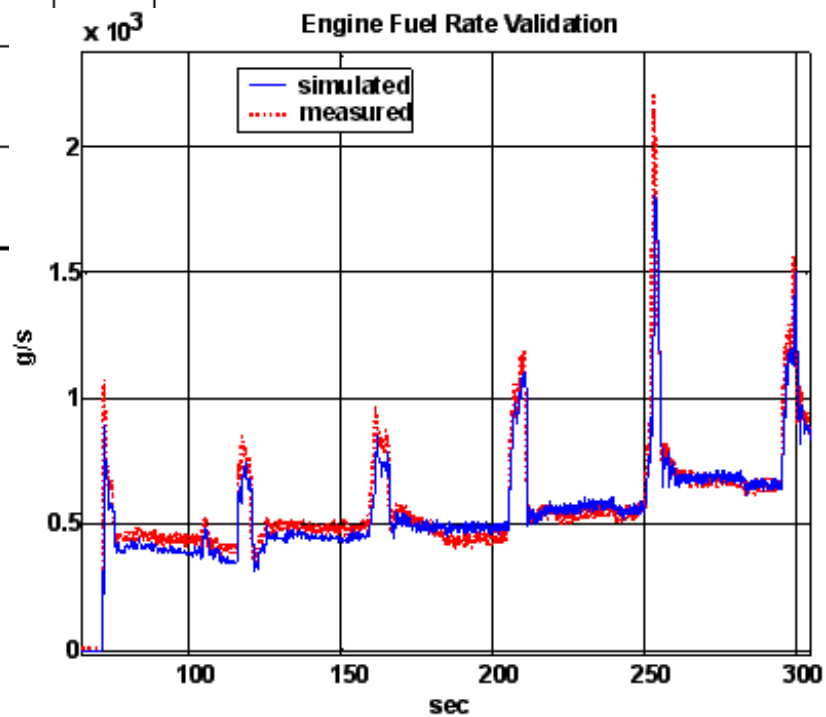
Battery and Engine Validations

ANL PSAT



Battery Validation

Engine Validation



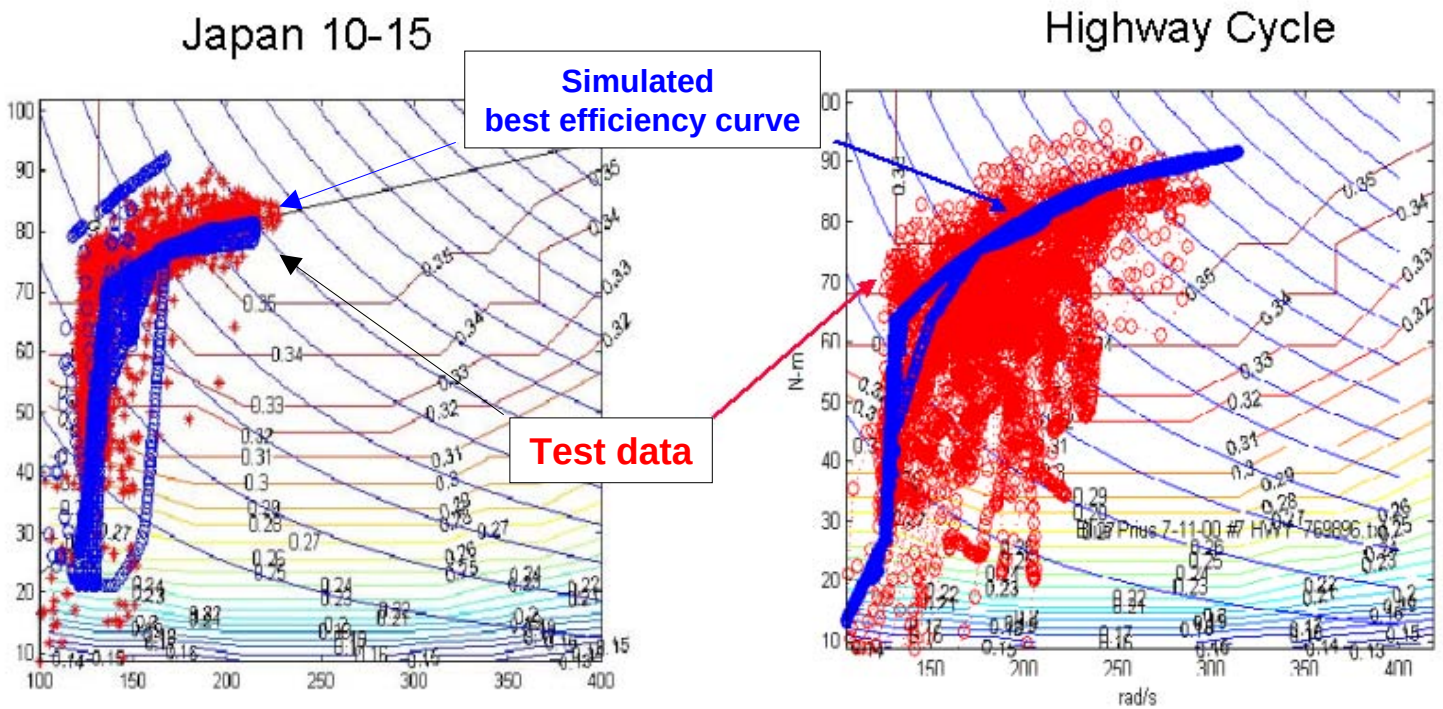
Source: ANL data

Argonne National Laboratory

Control Strategies May Differ From One Cycle to Another

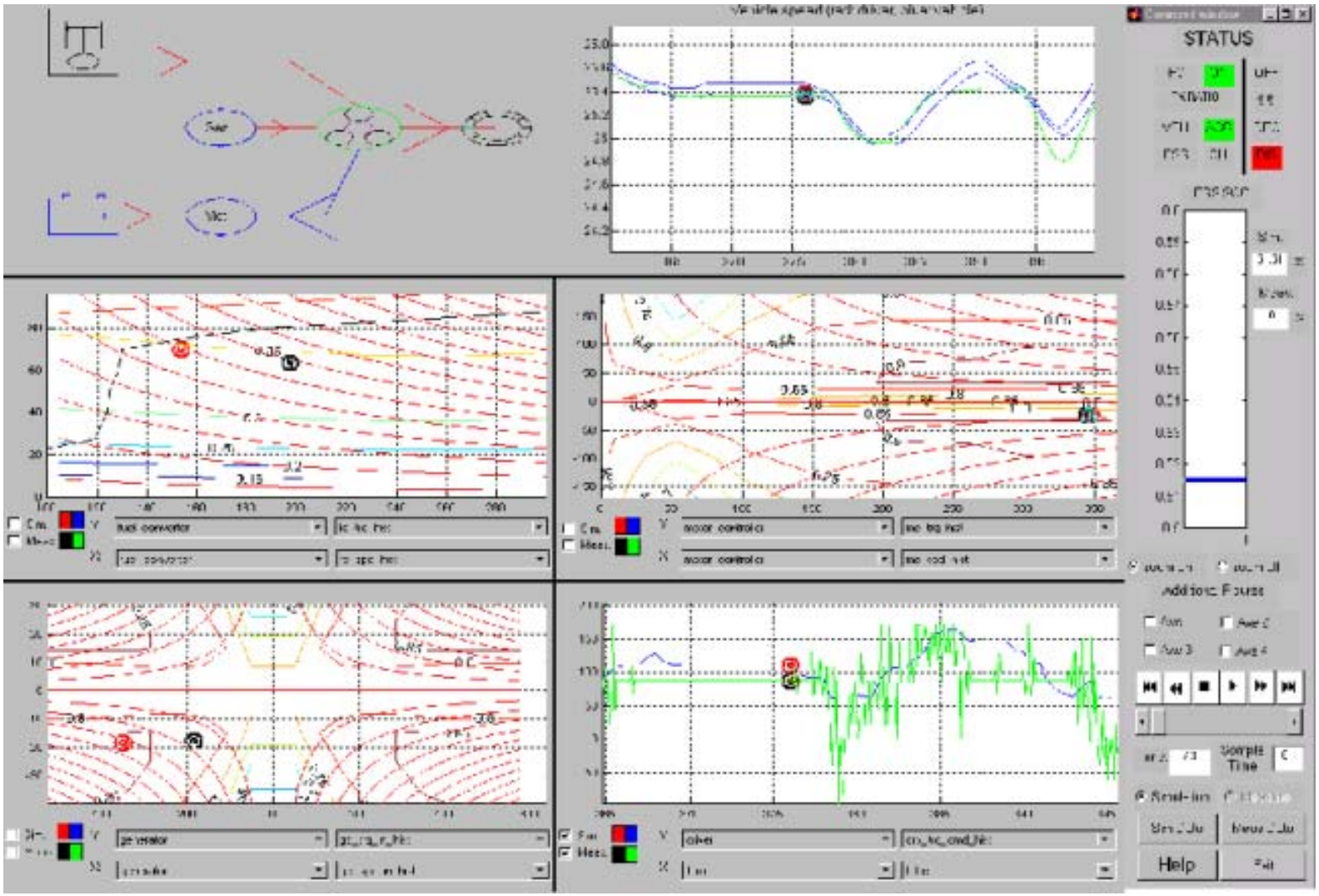
ANL PSAT

Engine Torque vs. Engine Speed



Source: ANL data

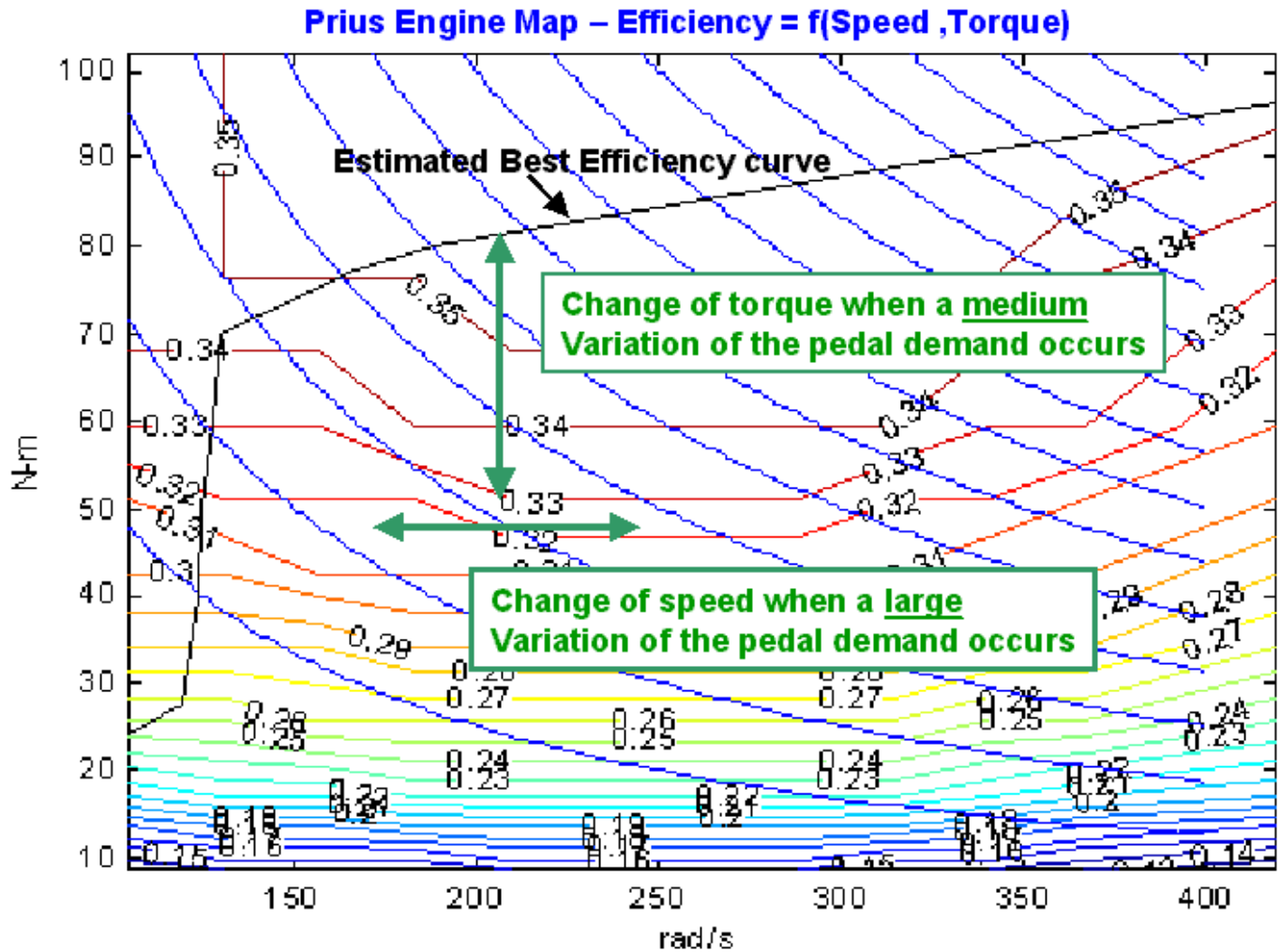
Specific Tools Are Necessary To Understand HEV Control Strategies



ANL PSAT

Argonne National Laboratory

The Japanese Prius Doesn't Always Follow The Best Efficiency Curve



ANL PSAT

Argonne National Laboratory

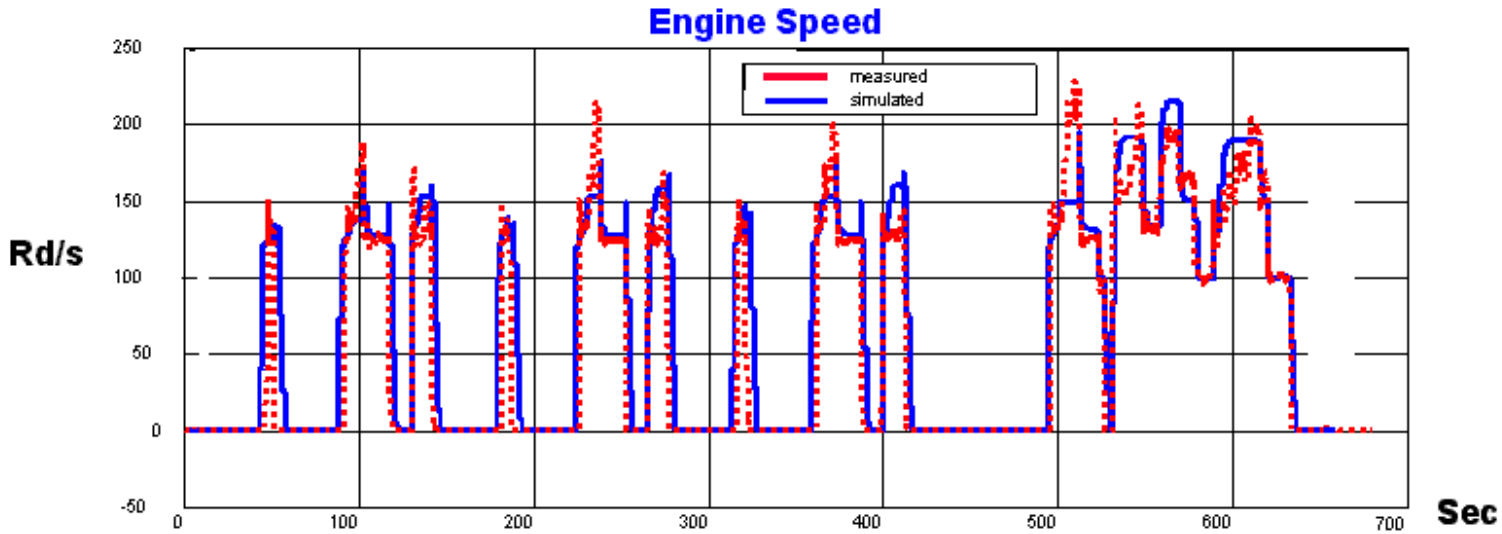
PSAT Prius Validation Is Within 5%

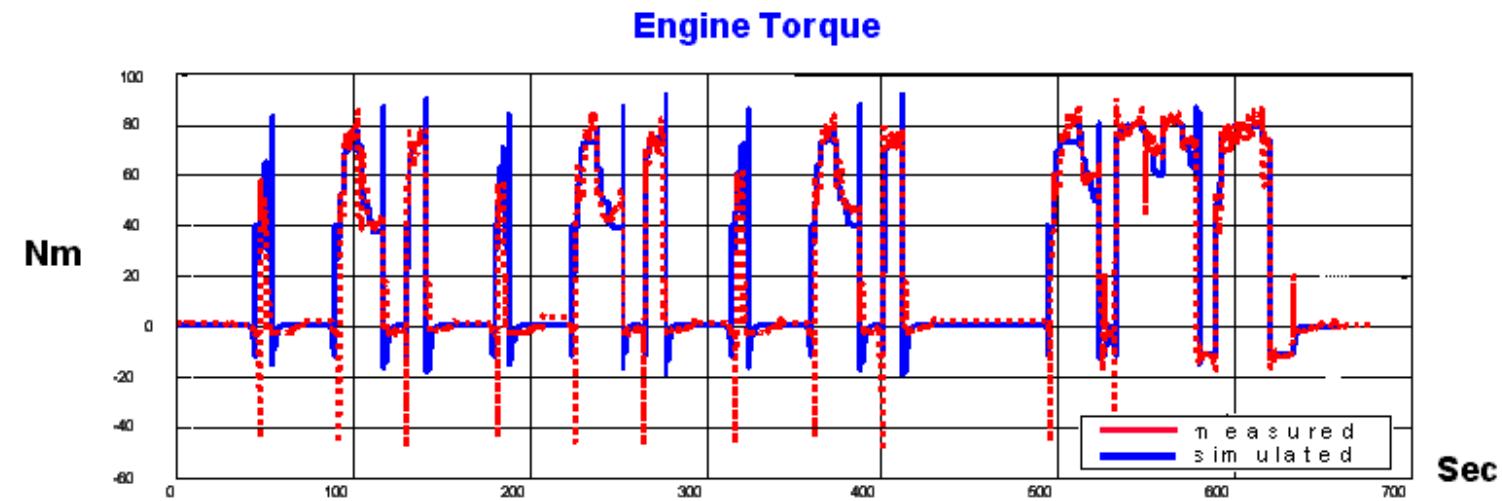
ANL PSAT

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
FHDS	48.2	46.7	3.2	0.550	0.571	0.573	0.3
UDDS	42.3	39.9	5.9	0.550	0.530	0.570	8.7

Component Behavior Is Validated

ANL PSAT





Conclusions

- HEVs require A new approach for validation
- A validation methodology has been developed for HEV validation
  - Specific tests have been defined
  - Specific tools have been developed
- The Japan Toyota Prius has been validated within 5% on different cycles with different SOC using PSAT
- The generic methodology and tools developed can be applied to any HEV validation process

ANL PSAT