MATLAB EXPO 2019

전동식 파워트레인 설계 및 검증 방안

류성연

Agenda

- Challenges with HEV design
- Modeling HEV
- Developing HEV Controls
- HEV Design Optimization

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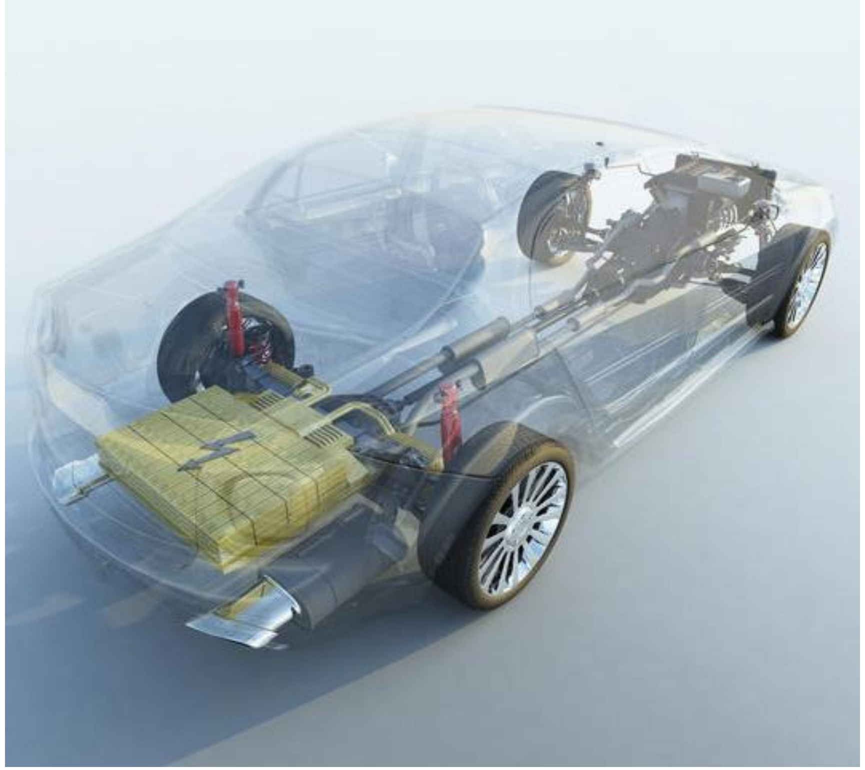
Challenges with HEV Design

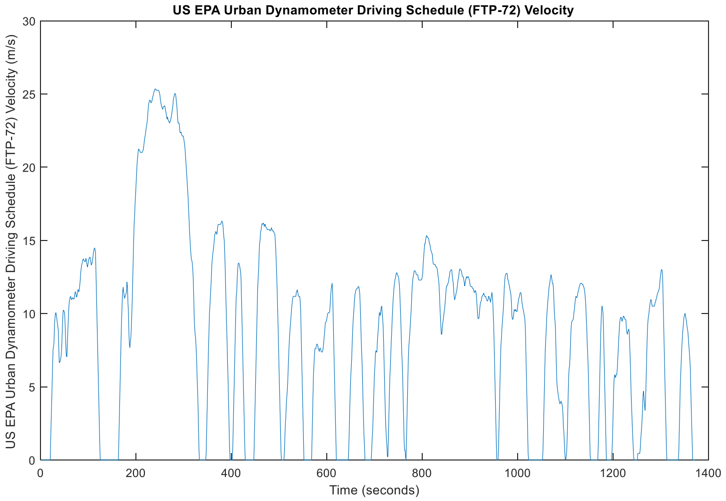
- Architecture / topology selection
- Selection and sizing of components
- Complexities in modeling plant and controllers

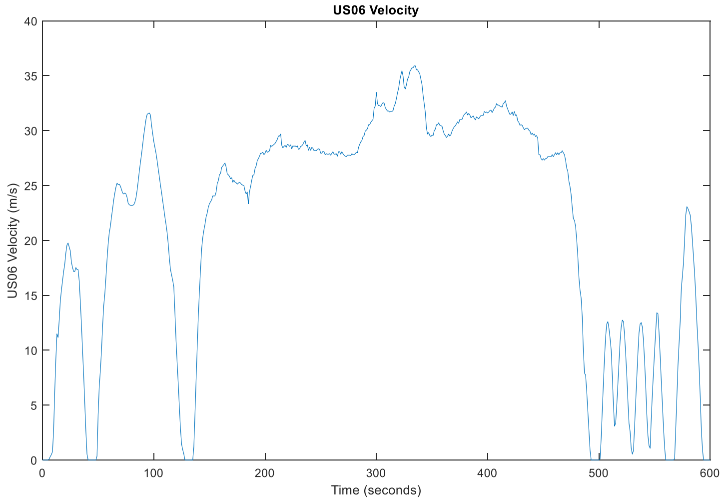


- How to optimize performance over wide range of conditions?
- Control algorithms real-time implementable

Challenges with HEV / EV Design – Example

- How to optimize performance over wide range of conditions?
  - Reduce energy consumption
  - Driveability requirements
    - Acceleration time
    - Gradeability
    - …





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- Challenges with HEV design
- Modeling HEV
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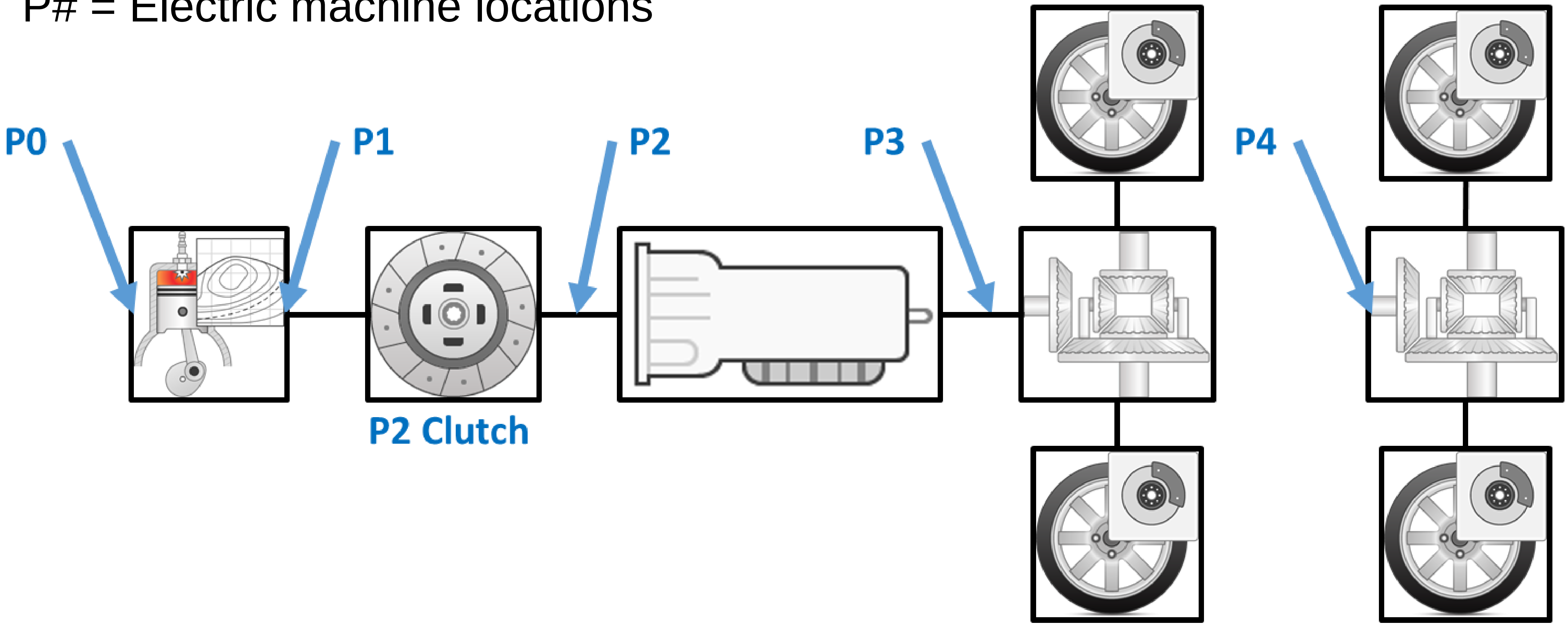
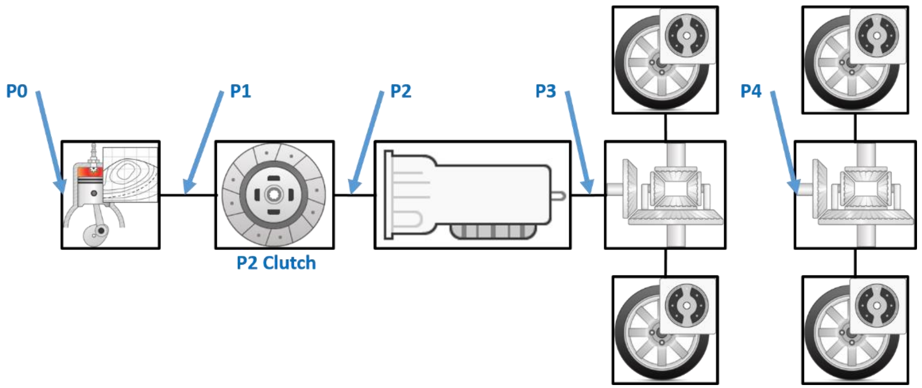
- HEV Design Optimization

Nomenclature for HEV Topology

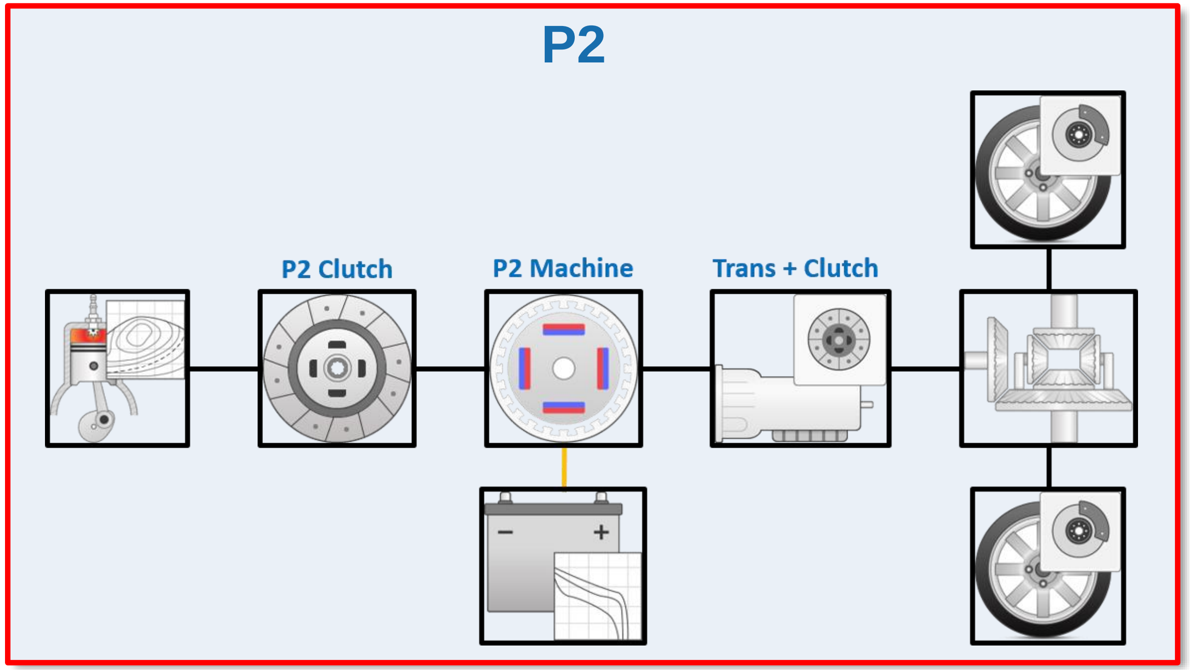
- P# = Electric machine locations

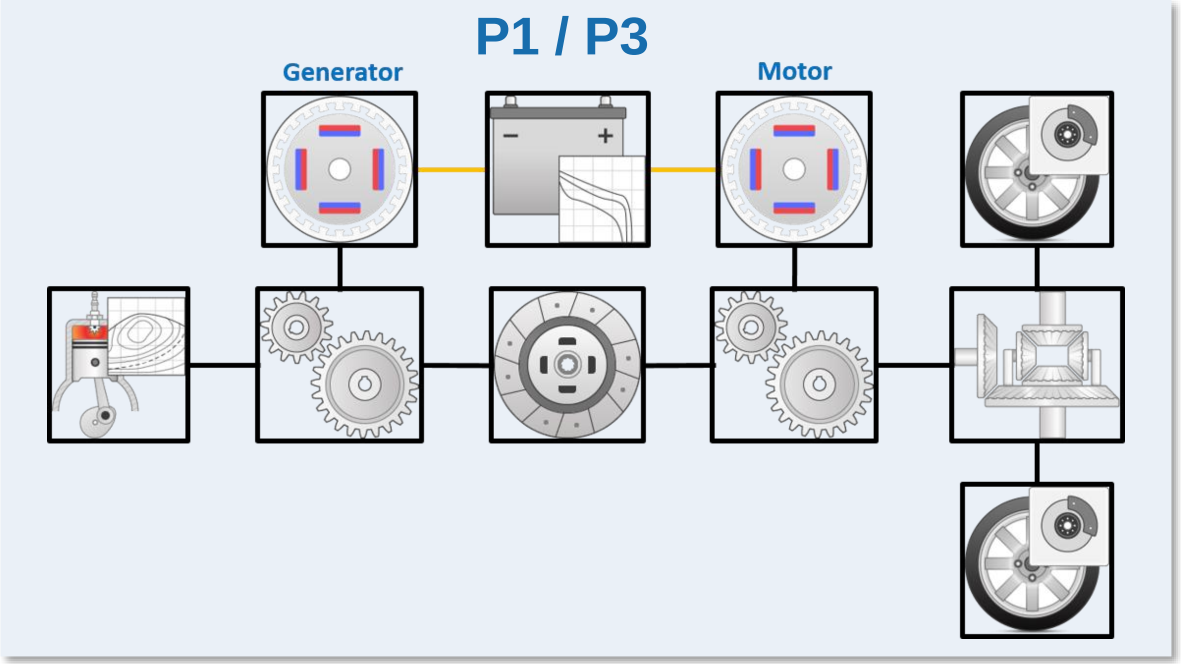


Hybrid Electric Vehicle Architecture



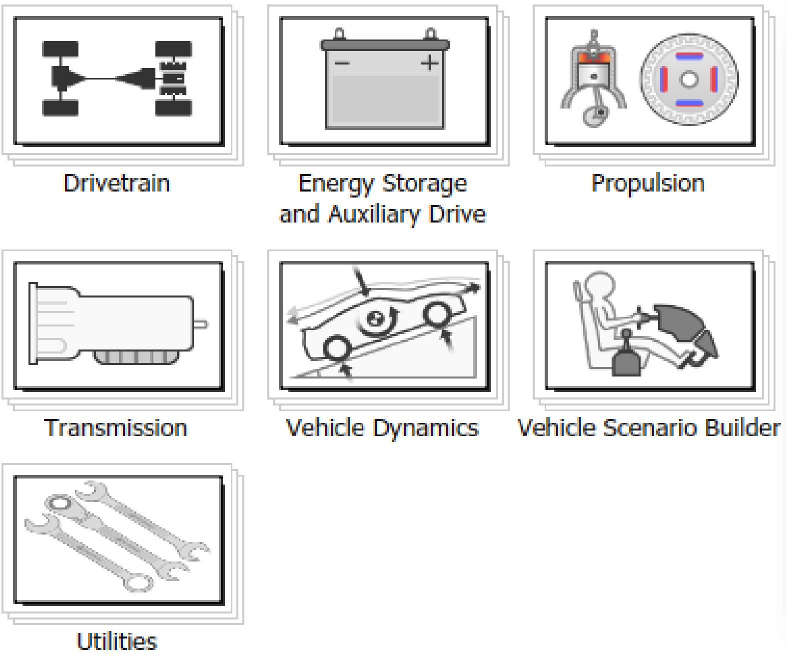
- HEV examples
  - **P2 parallel HEV**
  - P1/P3 multimode HEV



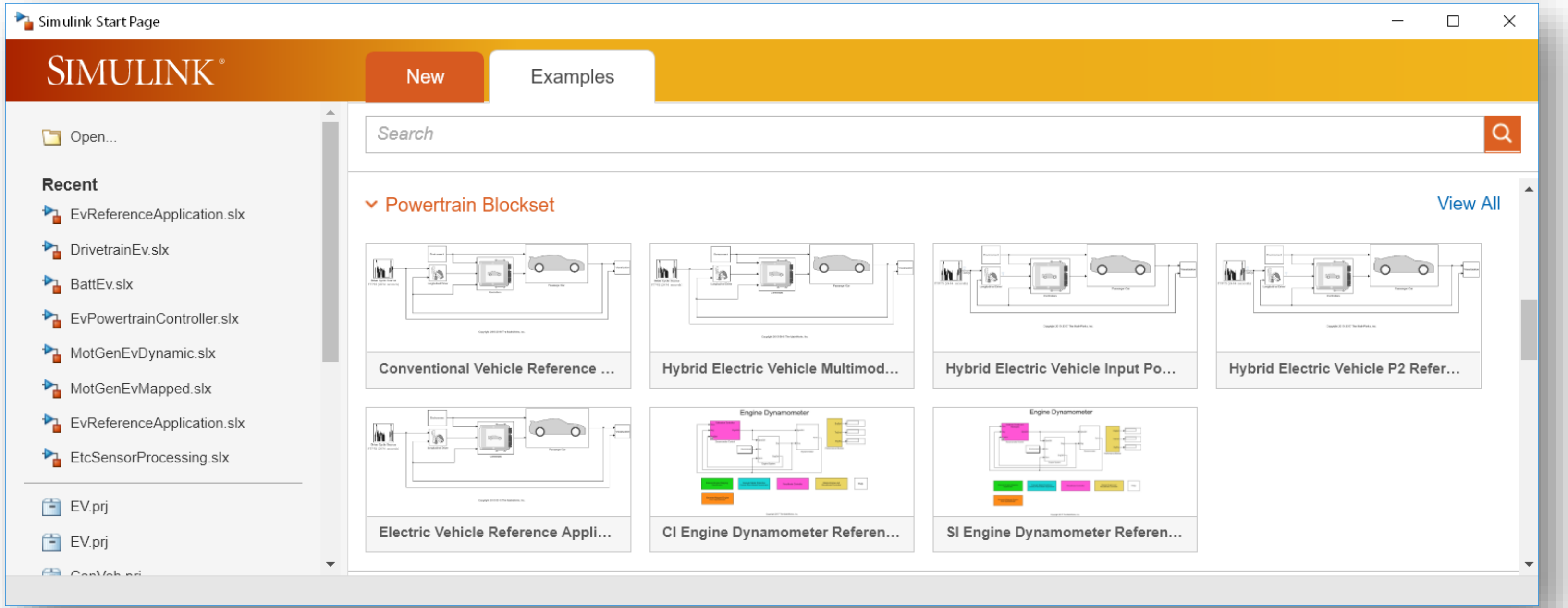


Powertrain Blockset Features

Library of blocks



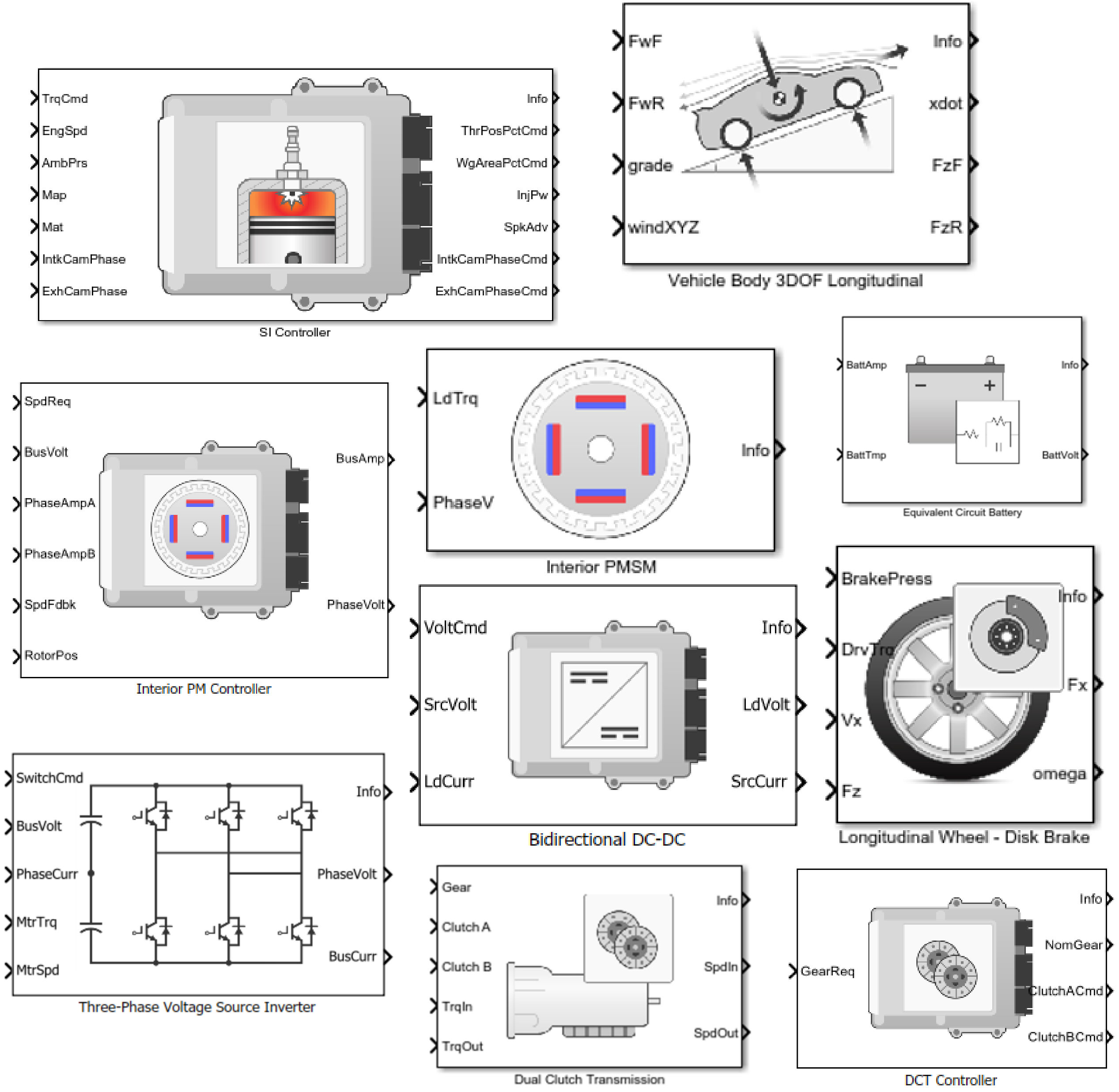
Pre-built reference applications



- Conventional (Spark Ignition / Compression Ignition) vehicle
- Electric vehicle (EV)
- Multi-mode / Power Split / P2 hybrid electric vehicle (HEV)
- Virtual engine dynamometer system

Library: Ready to Use

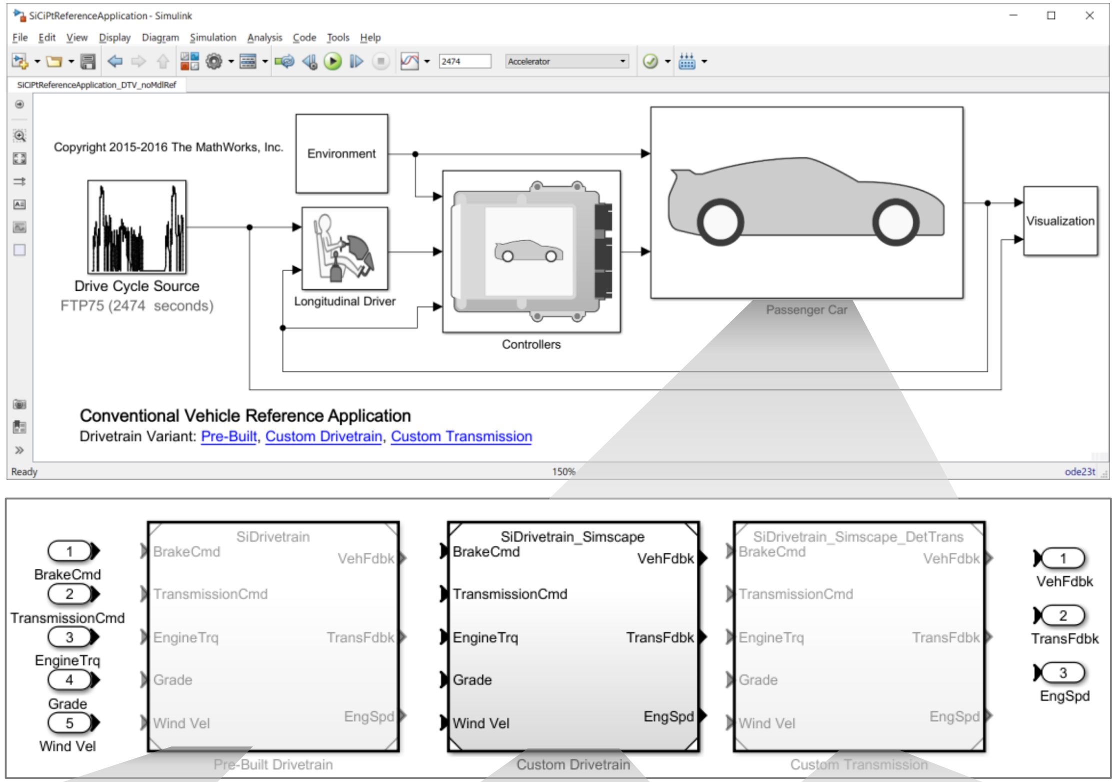
- Including basic components and subsystem controllers
  - Electric parts (ex. battery, alternator)
  - Mechanical parts (ex. clutch, wheel, differential gear)
  - Vehicle dynamics model (1~3 DOF)
  - Prebuilt controllers (ex. HCM/ECM/TCM)
  - Inverter, converter
- Open and reconfigurable
- Realistic starting point for your own controller development

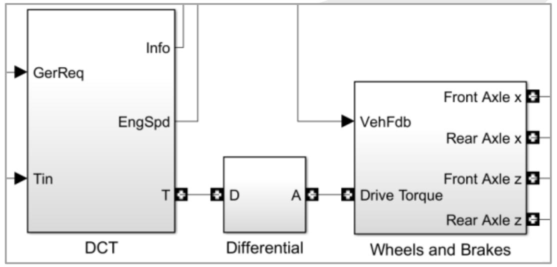


Custom Drivetrain or Transmission

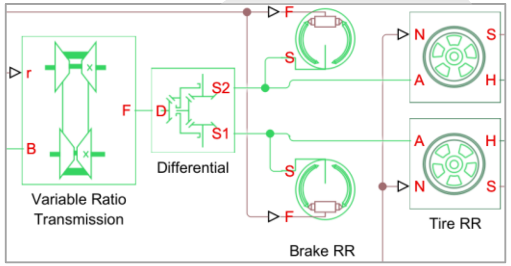
- Replace portions of reference application with custom models assembled from Simscape libraries

- Use Variant Subsystems to shift back and forth based on current simulation task

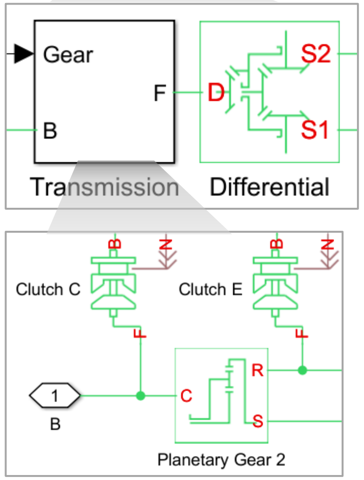




Pre-Built Drivetrain

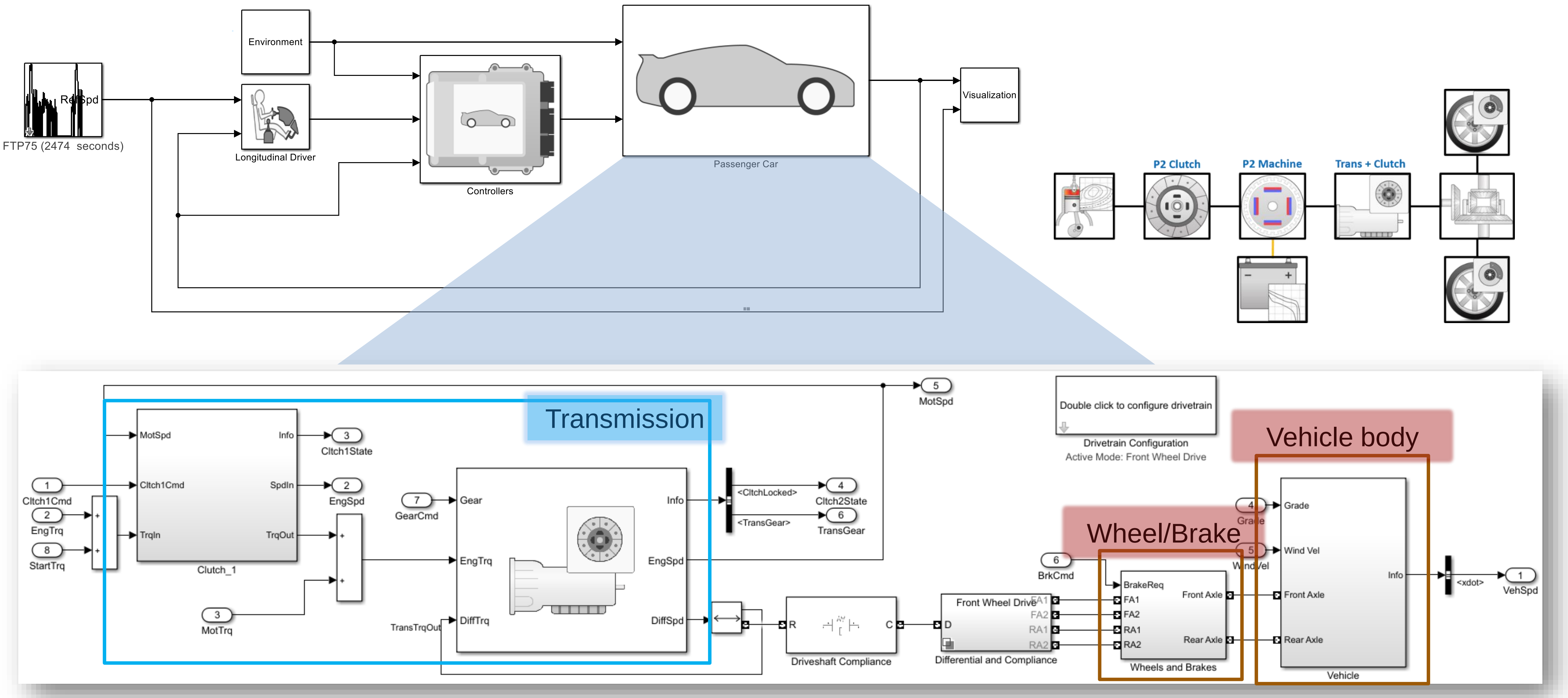


Custom Drivetrain

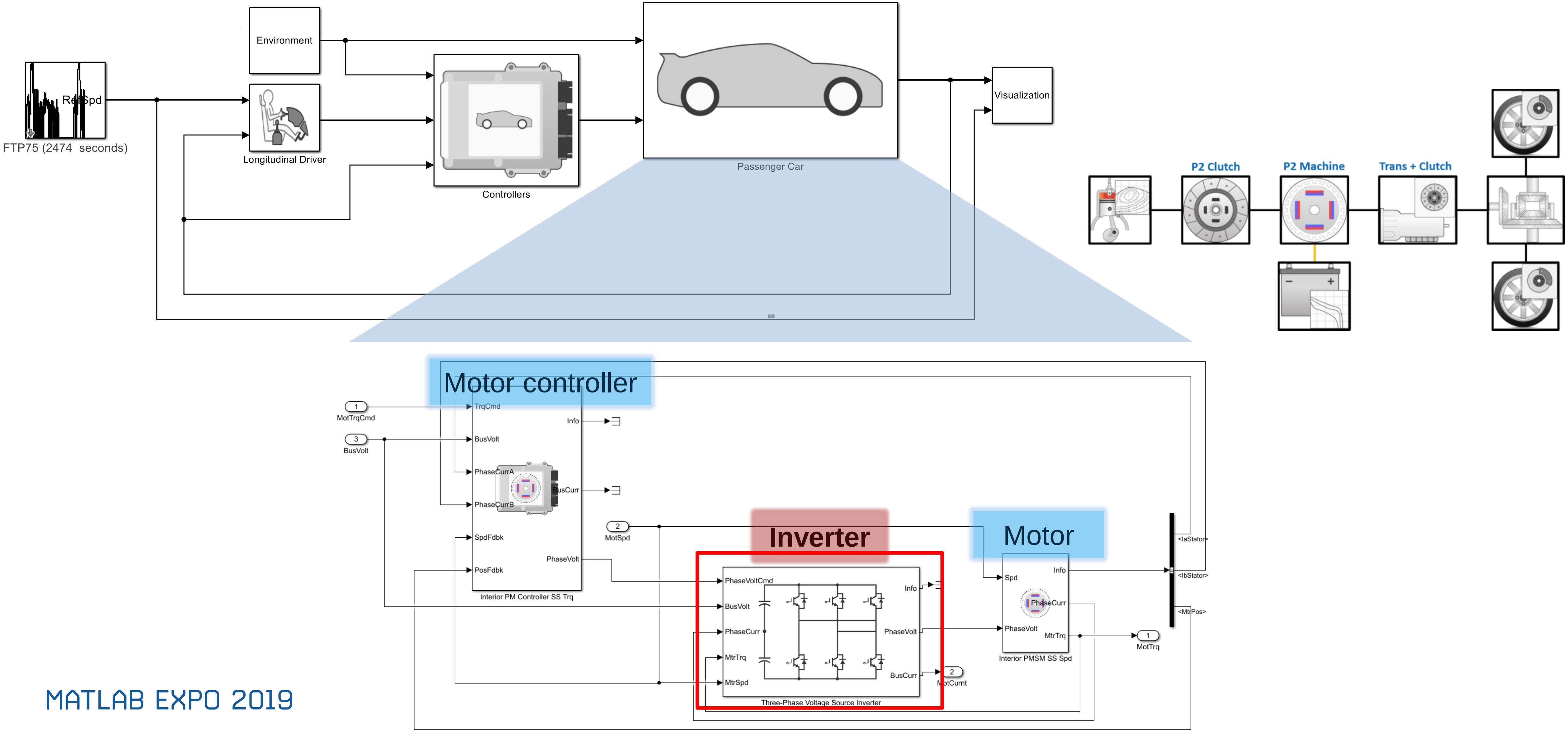


Custom Transmission

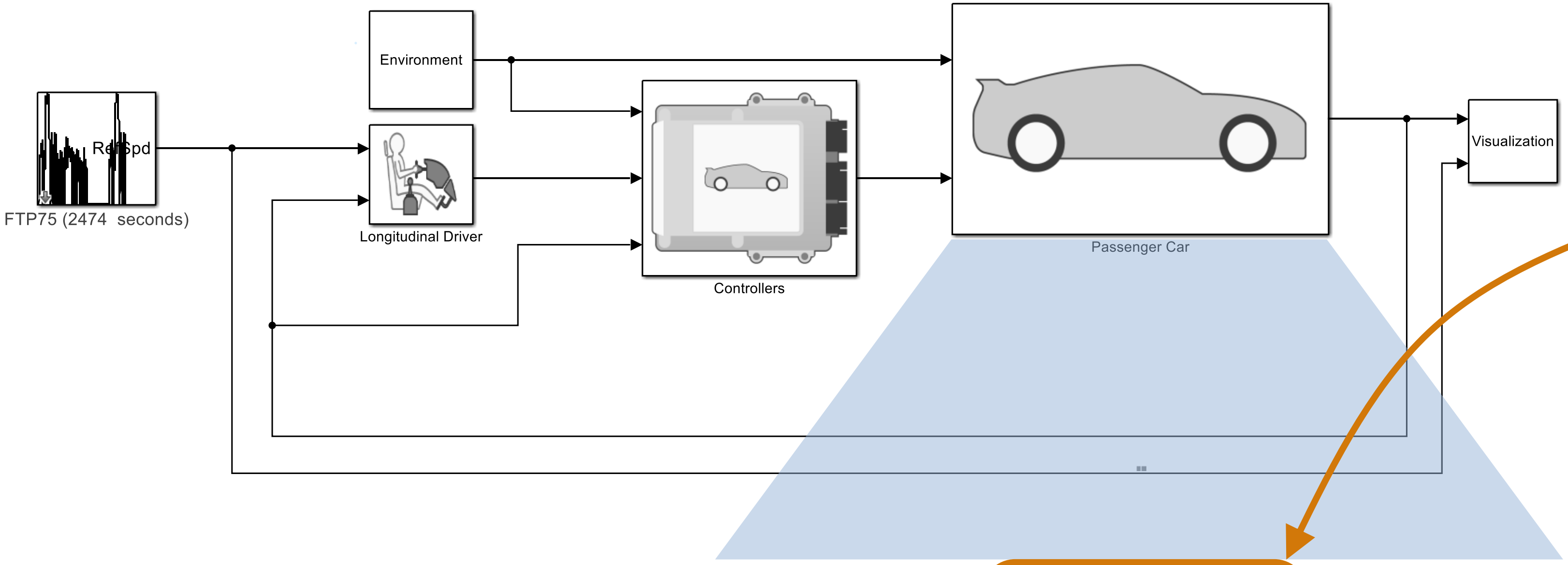
Reference Example – Vehicle Models

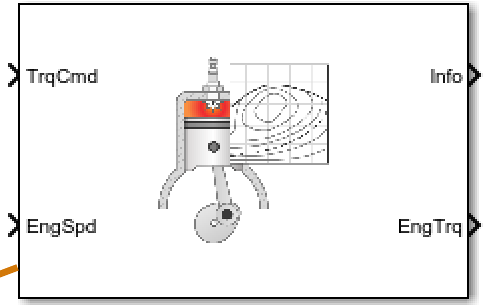


Reference Example – Motor Models

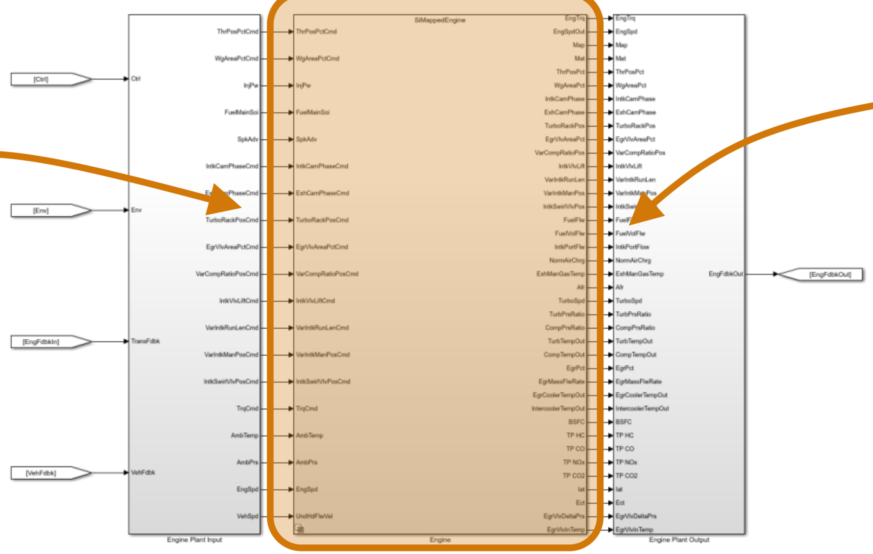


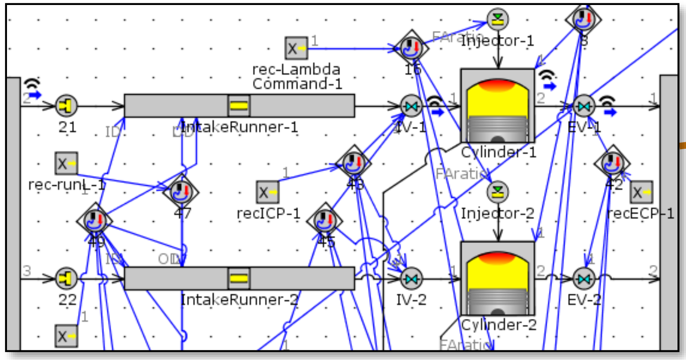
Reference Example – Engine Models



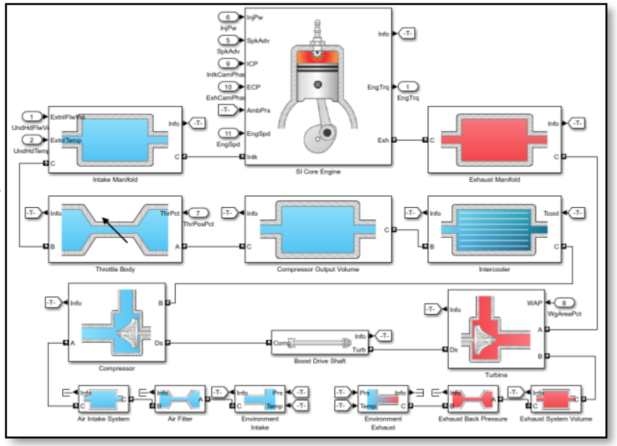


Use Powertrain Blockset *mapped* engine blocks with your own data



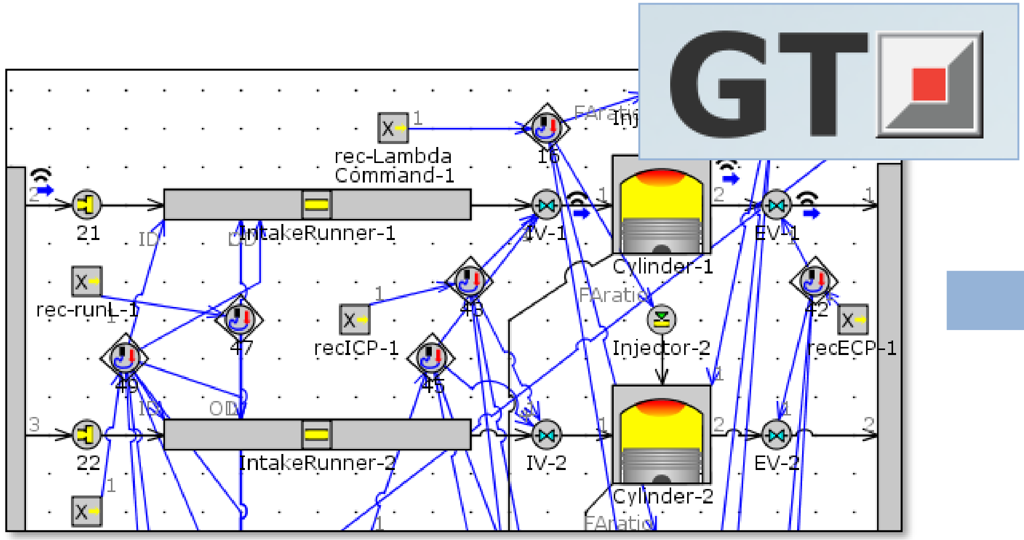


Connect in your own CAE model (e.g., GT-POWER)



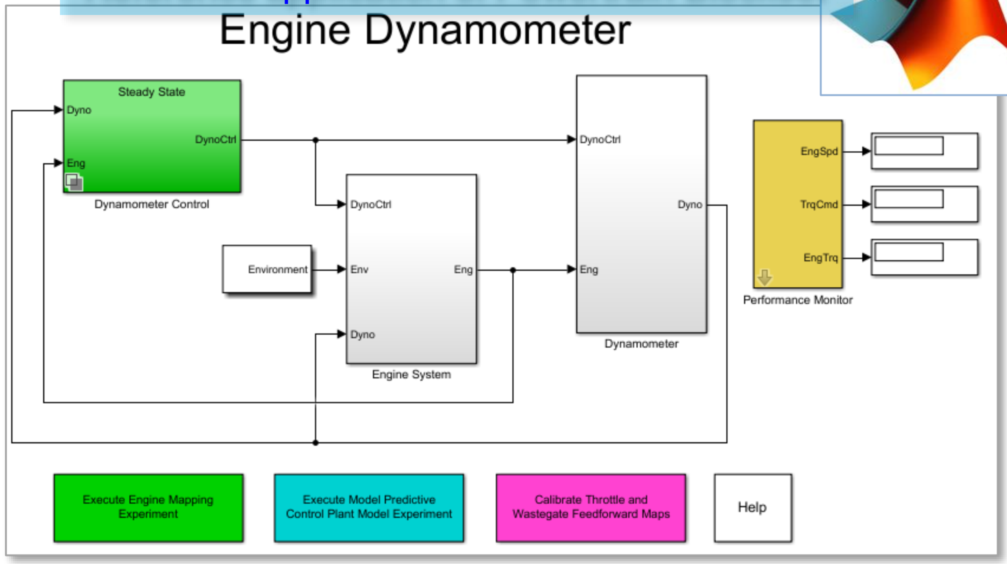
Create *dynamic* engine models using Powertrain Blockset library components

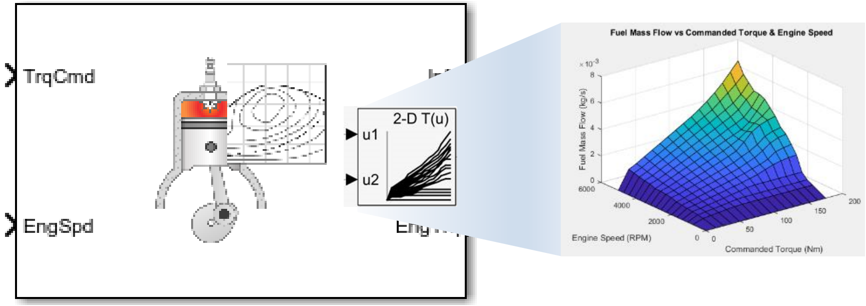
Controls-Oriented Model Creation



Detailed, design-oriented model

Reference application of Powertrain Blockset

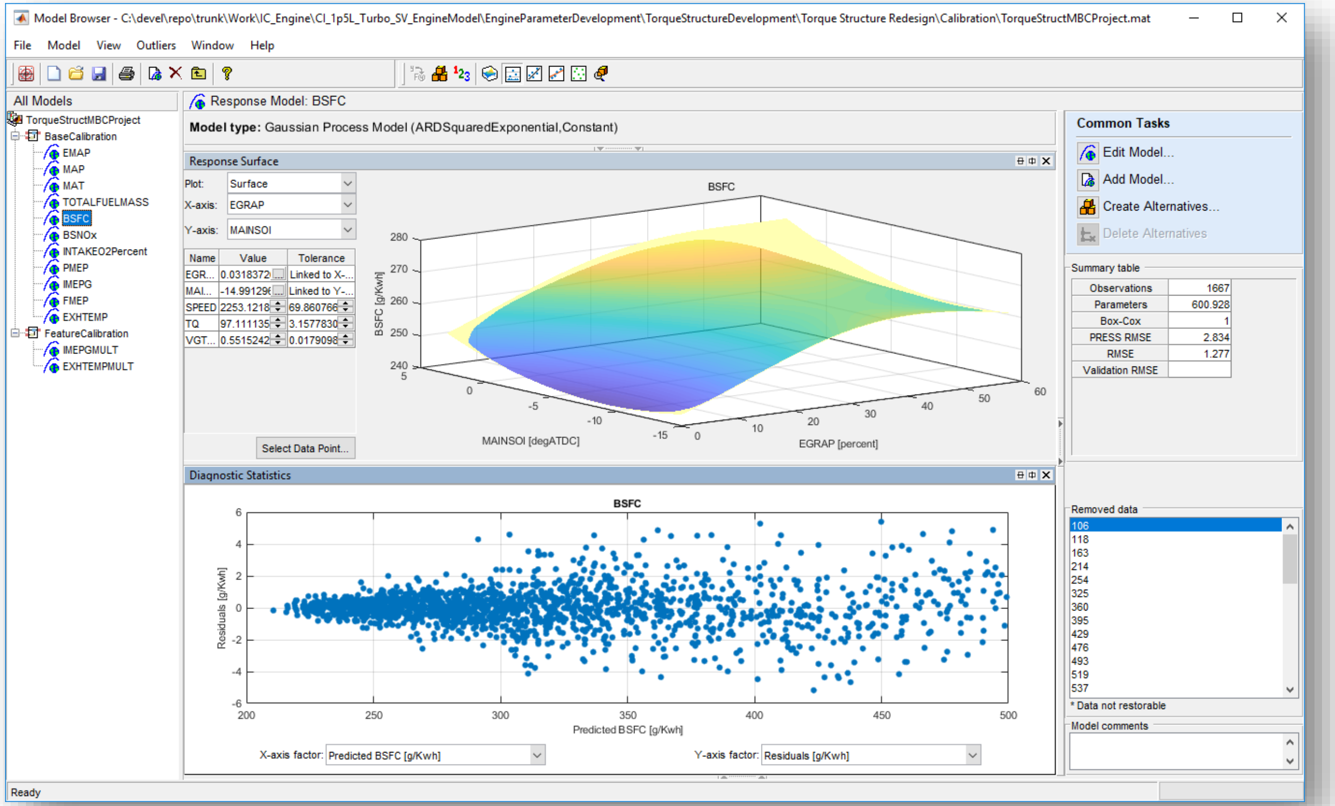




Fast, but accurate controls-oriented model

Calibration Support: Model-Based Calibration Toolbox

- User provides spreadsheet data
  - Torque
  - Fuel
  - BSFC
  - Etc.

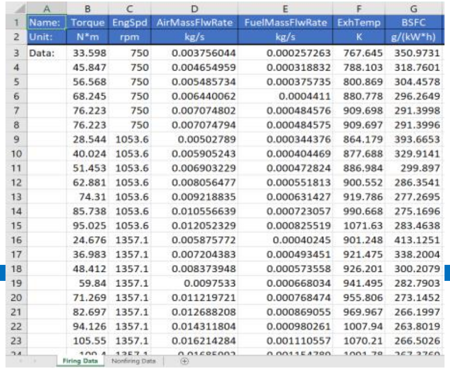


- MBC builds model automatically
  - Engines
  - Turbochargers

- MBC/CAGE writes calibrations to model
- User can open MBC to inspect and modify results

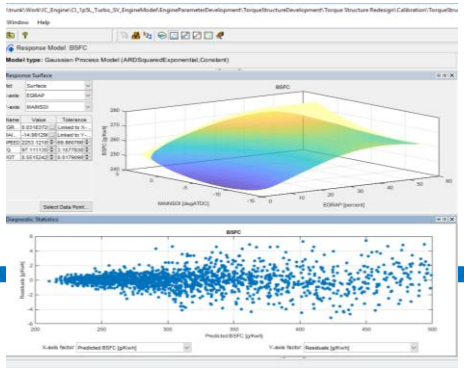
Building Blocks using Model Calibration Toolbox

- Integration with existing data collection tool and measurement data
- Measurement data is essential to achieving high model quality

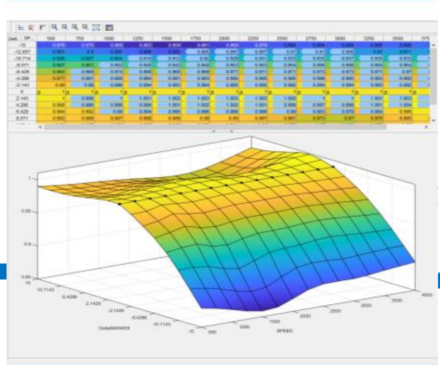


	A	B	C	D	E	F	G
1	Name:	Torque	EngSpd	AirMassFlwRate	FuelMassFlwRate	ExhTemp	BSFC
2	Unit:	N*m	rpm	kg/s	kg/s	K	g/(kW*h)
3	Data:	33.598	750	0.003756044	0.000257263	767.645	350.9731
4		45.847	750	0.004654959	0.000318832	788.103	318.7601
5		56.568	750	0.005485734	0.000375735	800.869	304.4578
6		68.245	750	0.006440062	0.0004411	880.778	296.2649
7		76.223	750	0.007074802	0.000484576	909.698	291.3998
8		76.223	750	0.007074794	0.000484575	909.697	291.3996
9		28.544	1053.6	0.00502789	0.000344376	864.179	393.6653
10		40.024	1053.6	0.005905243	0.000404469	877.688	329.9141
11		51.453	1053.6	0.006903229	0.000472824	886.984	299.897
12		62.881	1053.6	0.008056477	0.000551813	900.552	286.3541
13		74.31	1053.6	0.009218835	0.000631427	919.786	277.2695
14		85.738	1053.6	0.010556639	0.000723057	990.668	275.1696
15		95.025	1053.6	0.012052329	0.000825519	1071.63	283.4638
16		24.676	1357.1	0.005875772	0.00040245	901.248	413.1251
17		36.983	1357.1	0.007204383	0.000493451	921.475	338.2004
18		48.412	1357.1	0.008373948	0.000573558	926.201	300.2079
19		59.84	1357.1	0.0097533	0.000668034	941.495	282.7903
20		71.269	1357.1	0.011219721	0.000768474	955.806	273.1452
21		82.697	1357.1	0.012688208	0.000869055	969.967	266.1997
22		94.126	1357.1	0.014311804	0.000980261	1007.94	263.8019
23		105.55	1357.1	0.016214284	0.001110557	1070.21	266.5026

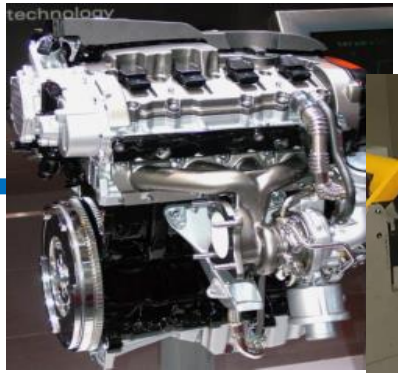
Measure



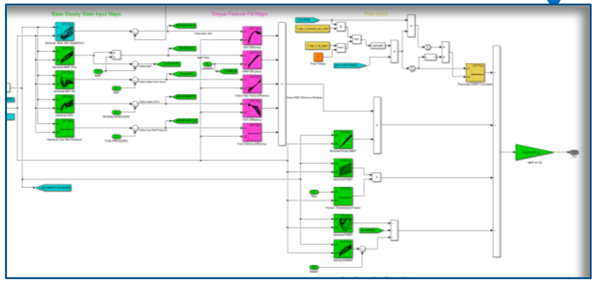
Model Response



Optimize Control

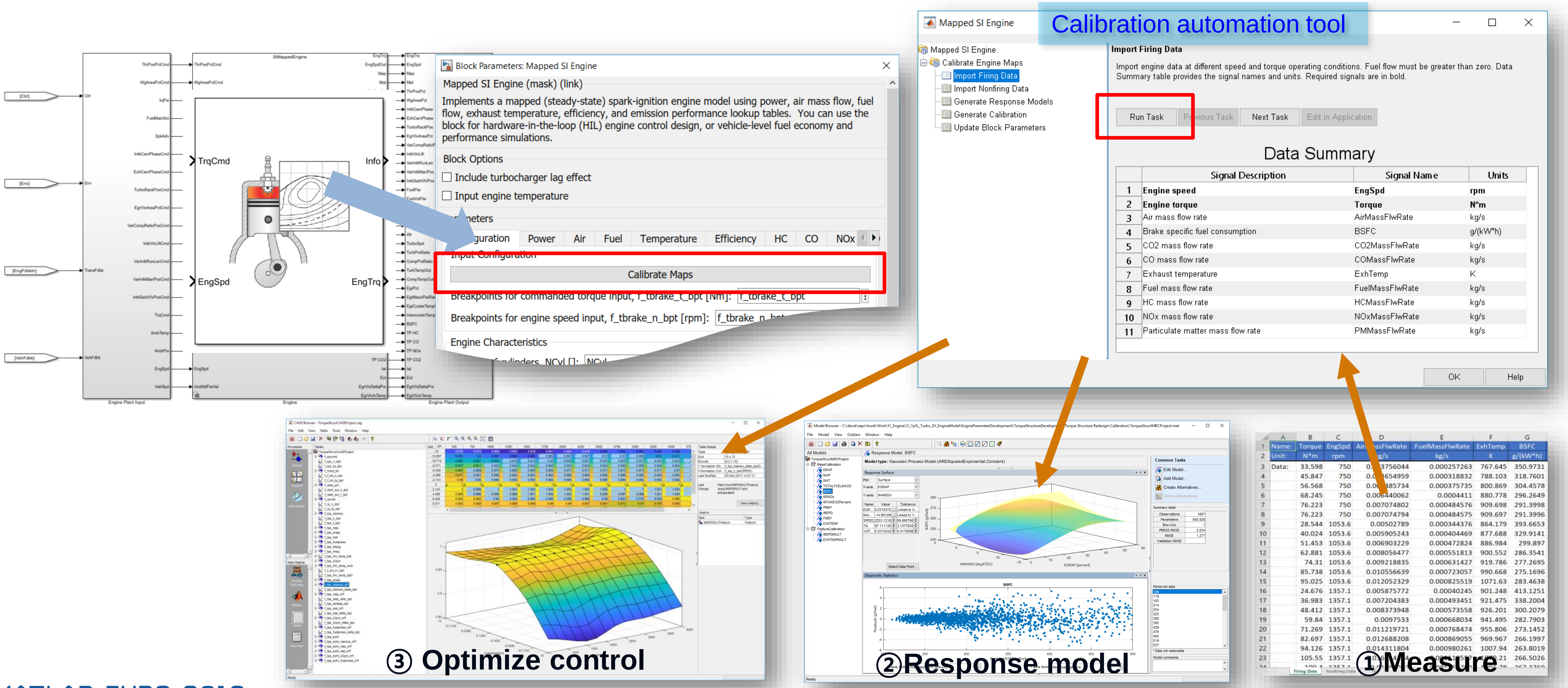


Set Up Hardware



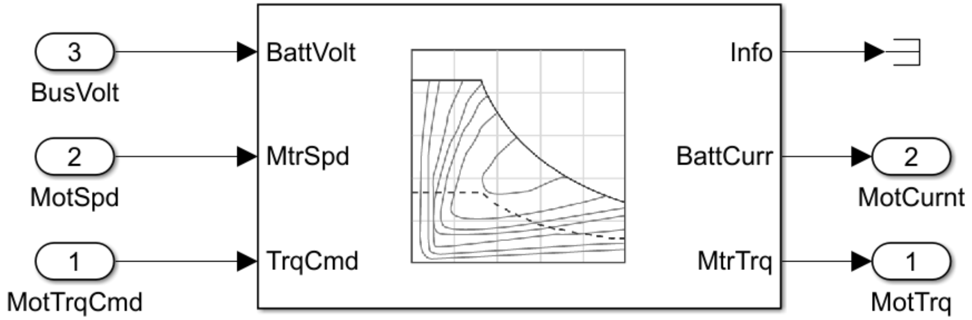
Embed

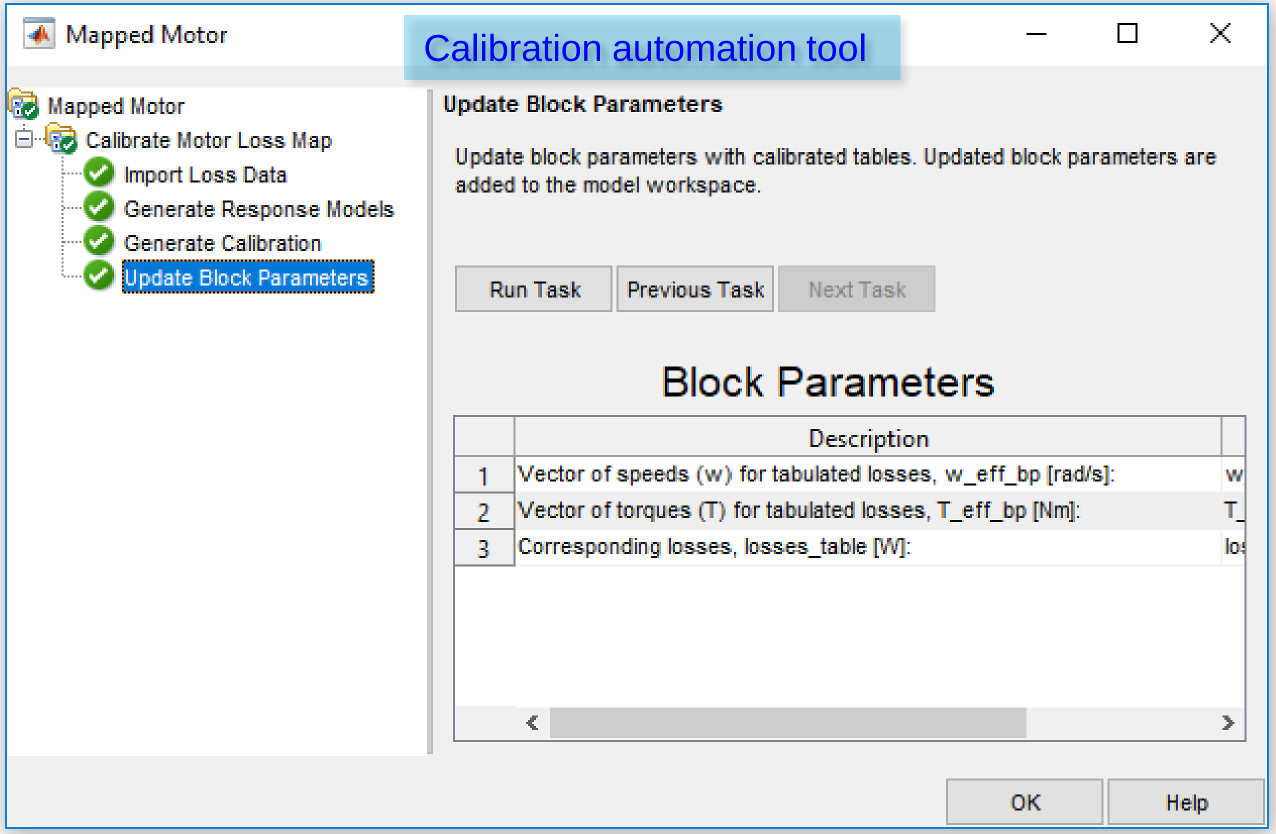
Virtual Calibration From Powertrain Blockset



Virtual Calibration From Powertrain Blockset

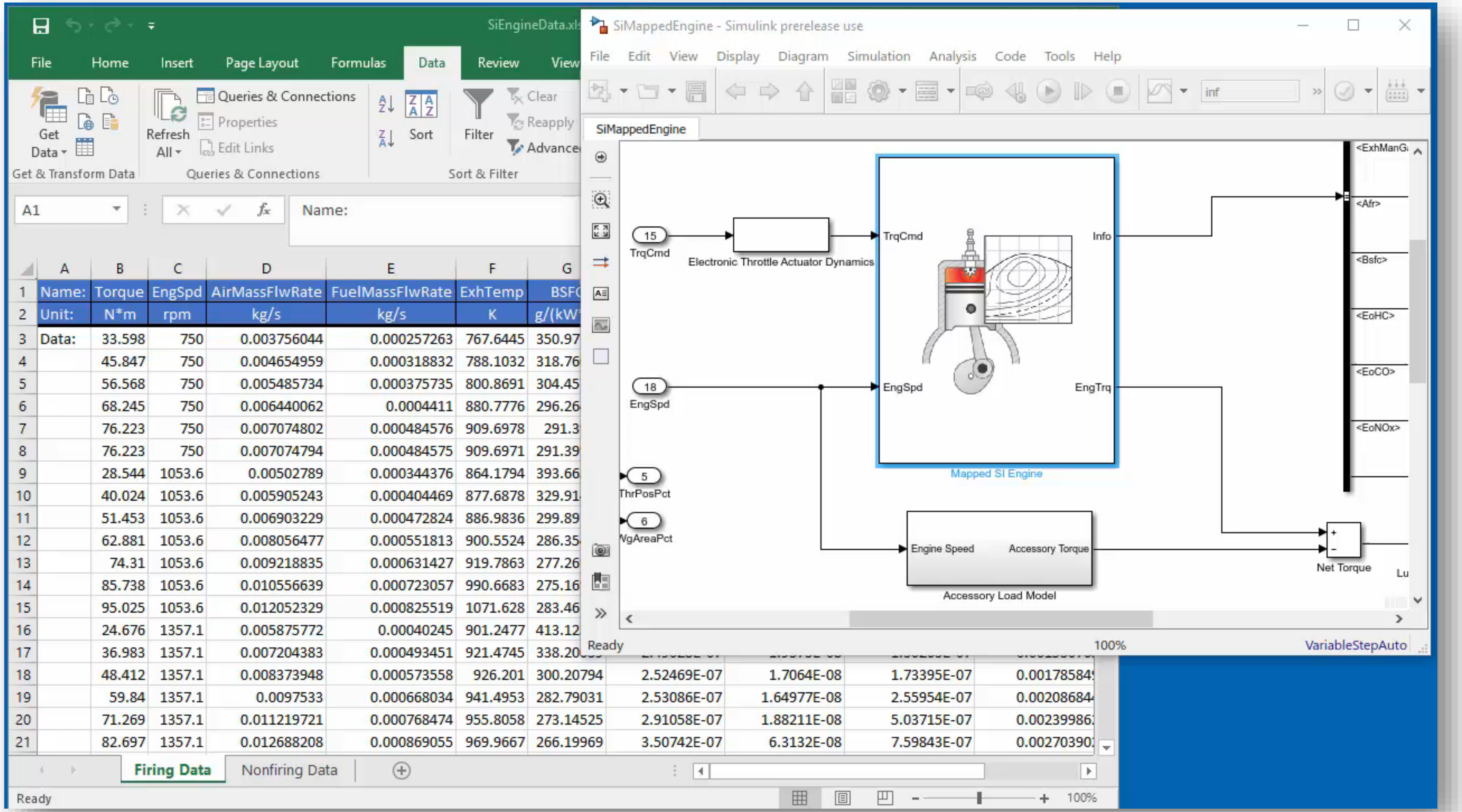
- Automate Mapped Motor parameterization using Model-Calibration Toolbox





Demo: Calibration Automation

- Methods team creates MBC templates for each step in calibration workflow
- Deploy experience via automation, e.g., Powertrain Blockset Mapped Engine



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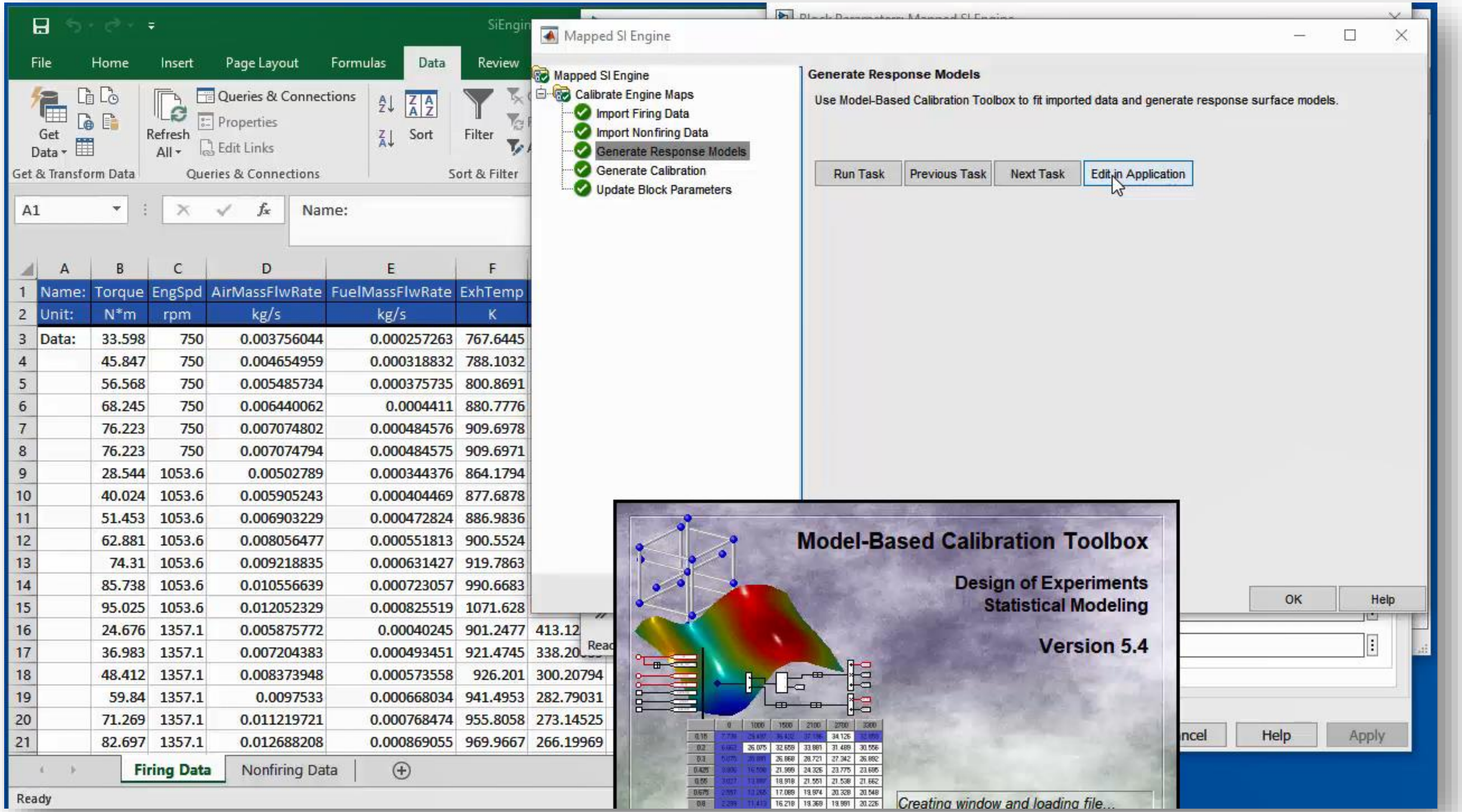
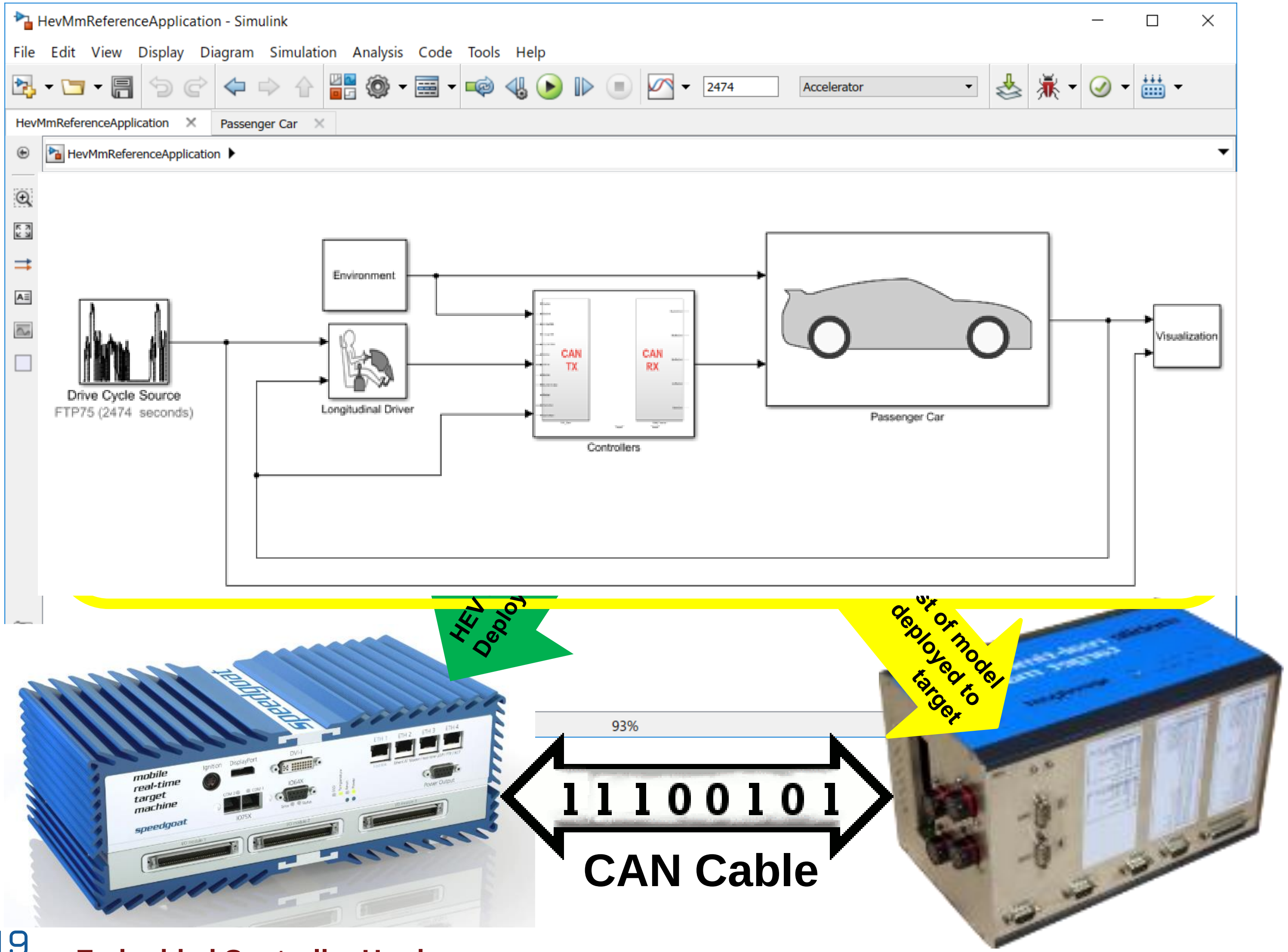


HIL Testing with Powertrain Blockset HEV Model



Rapid Control Prototyping with Simulink Real-Time

Hardware In-the-Loop with Simulink Real-Time

Embedded Controller Hardware

Target Computer Hardware

Agenda

- Challenges with HEV design
- Modeling HEV
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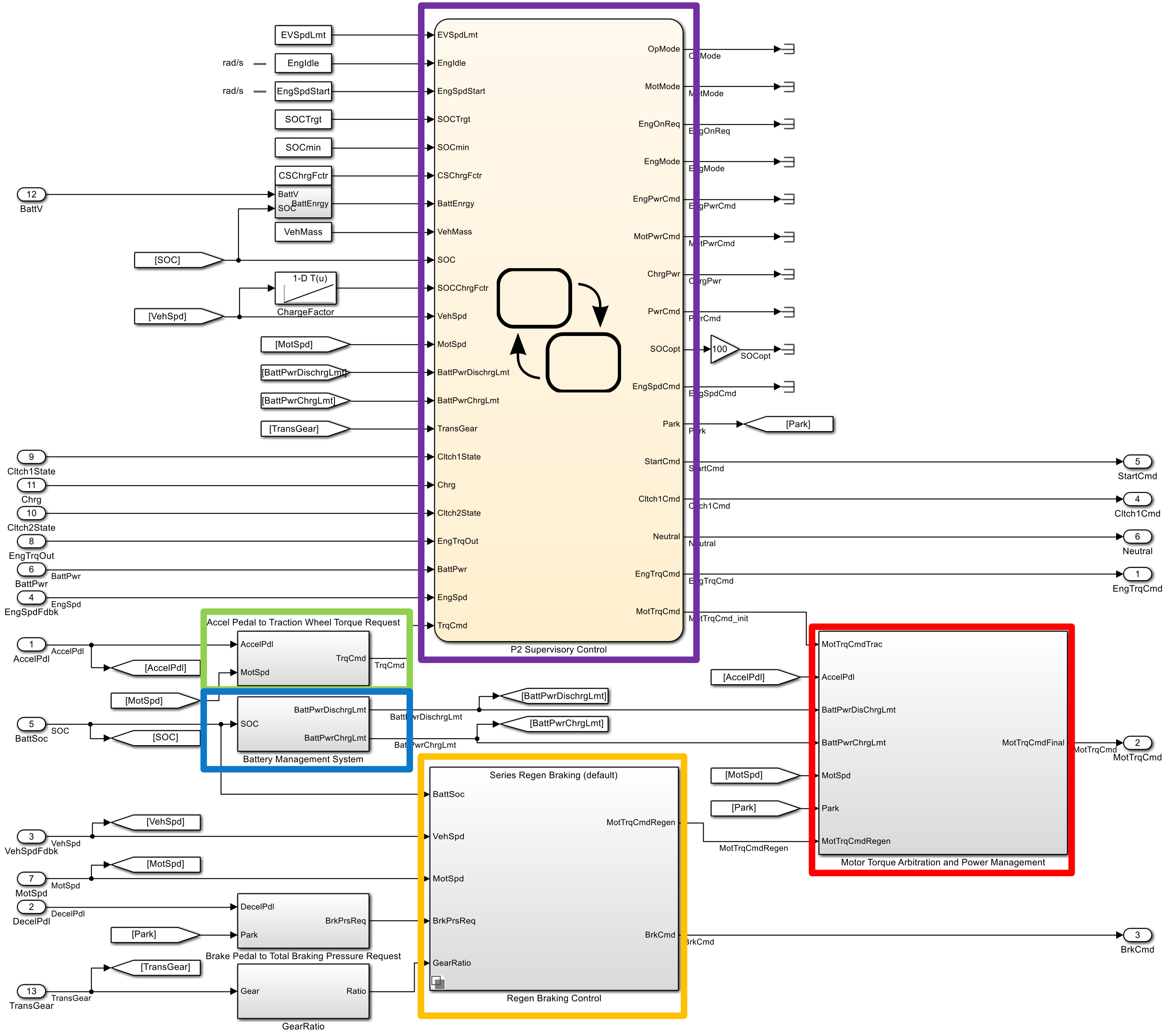
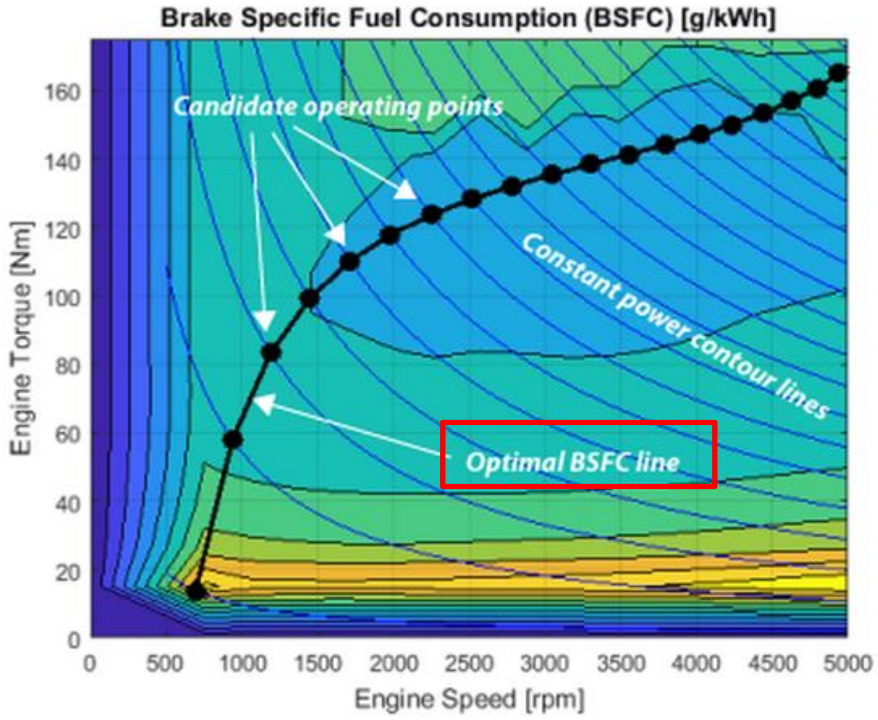
HEV Supervisory Control

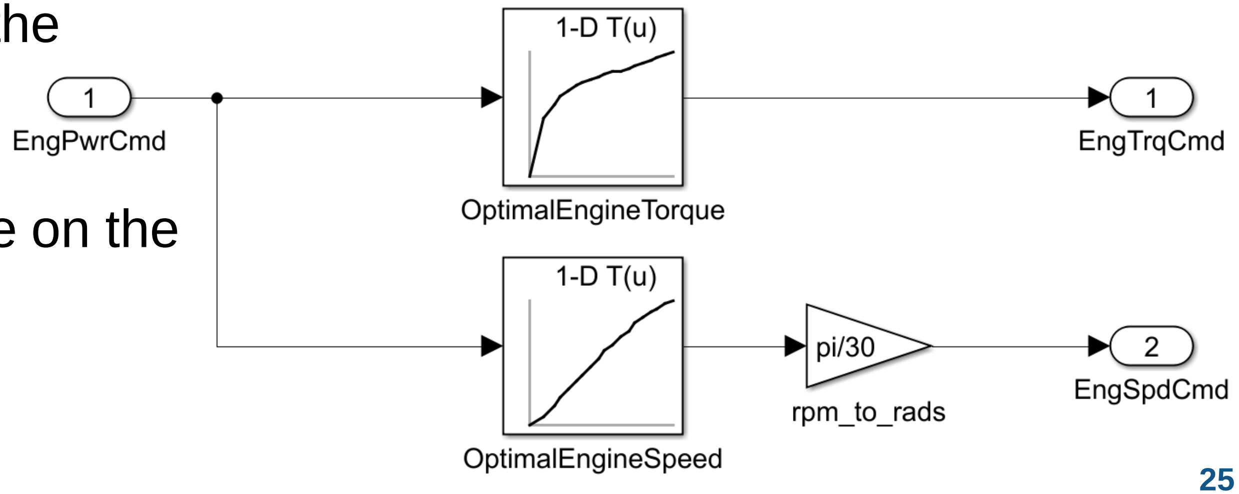
- Major Functions
  - Accel Pedal → Torque
  - Regenerative Brake Blending
  - Battery Management System
  - Power Management
  - Supervisory Control (Stateflow)
- Only supervisory control system changes for different HEV architectures
  - Other functions are reusable



Engine Control in HEV Mode

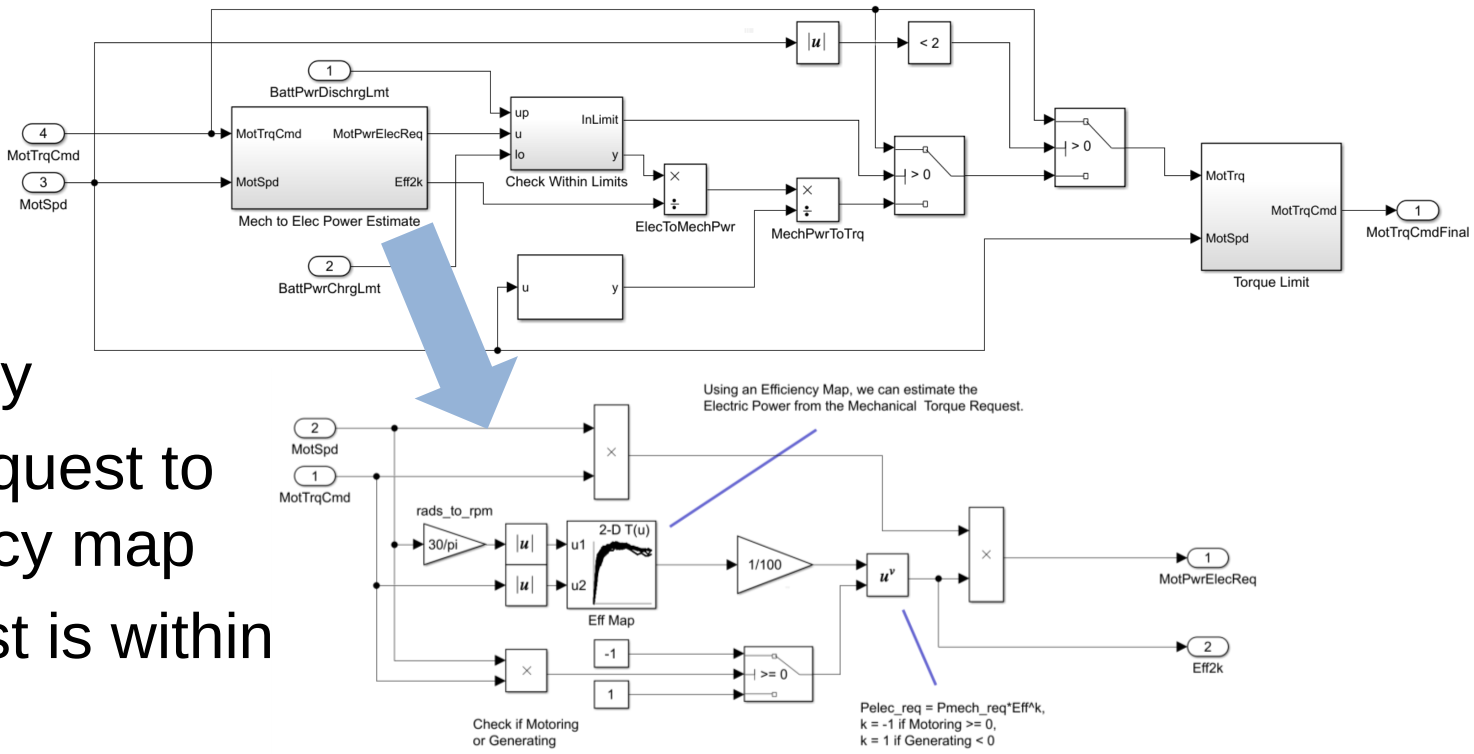
- Optimization algorithm used to find minimum BSFC line
- Results placed in lookup tables
- For an engine power command
  - Stationary mode can operate directly on the optimal BSFC line
  - Parallel HEV mode will attempt to operate on the optimal BSFC line

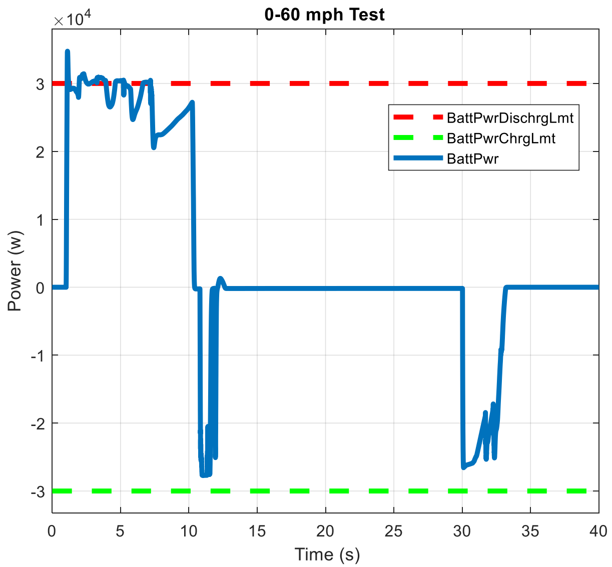




Power Management

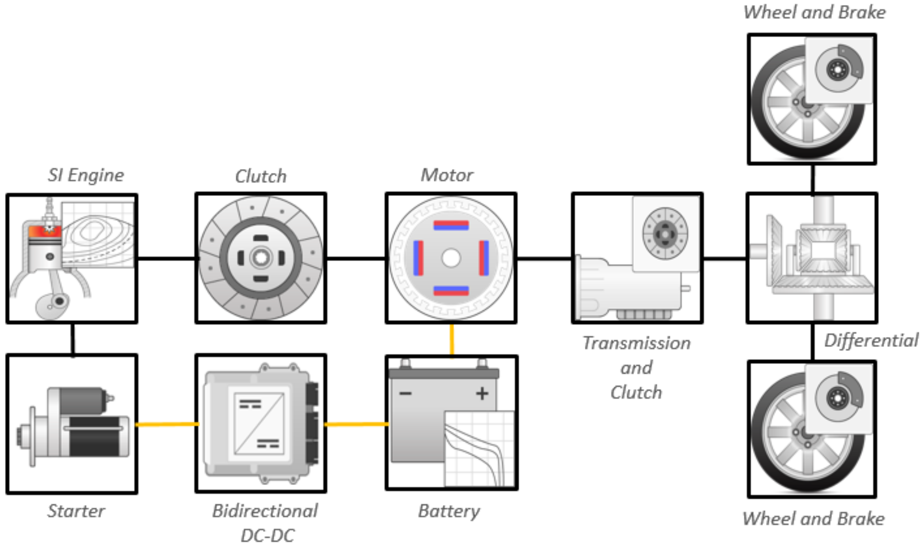
- Bound battery power within dynamic power limits of battery
- Convert mechanical power request to electrical power using efficiency map
- Check if electric power request is within limits
  - OK → allow original mechanical power request
  - Not OK → use limit for electrical power, and convert to an allowable mechanical power request

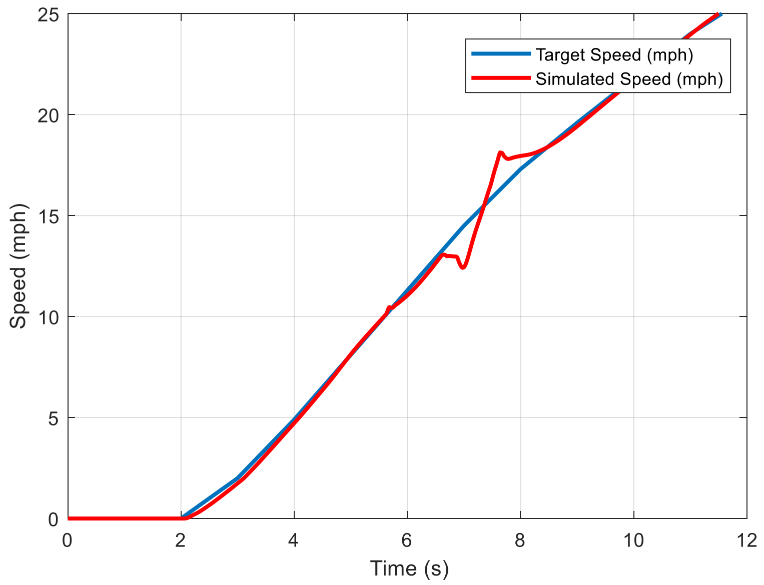




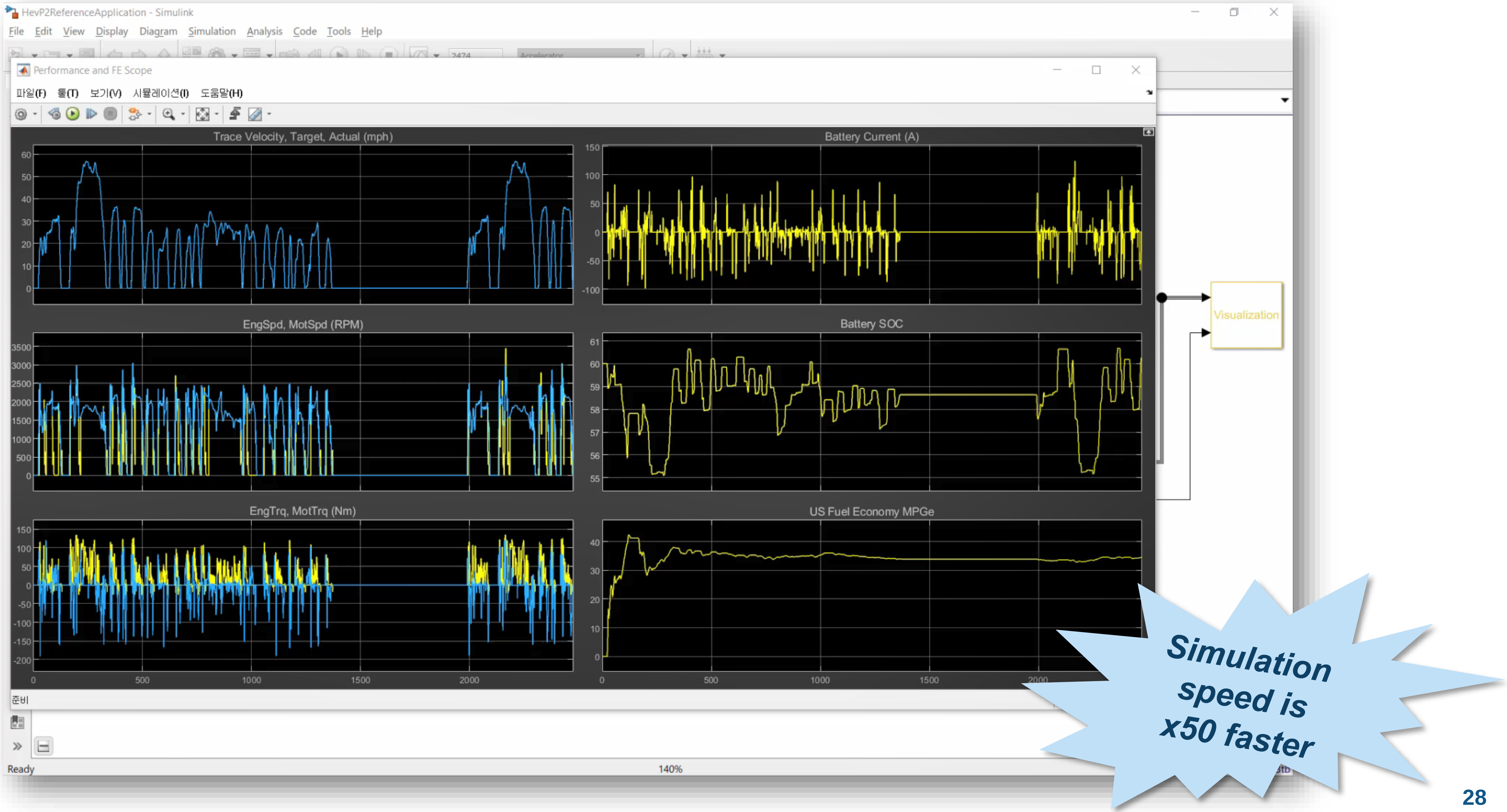
Starting the ICE in a P2 HEV: EV → Parallel

- "Bump" start
  - Can cause driveline disturbance
- "Shuffle" clutches
  - Process takes ~400-500 ms, causes vehicle speed to decrease
- Use low voltage Starter (or P0 machine)
  - Implemented in P2 Reference Application
  - 12V starter cranks ICE → ICE speed match mode → close P2 clutch





FTP75 Simulation



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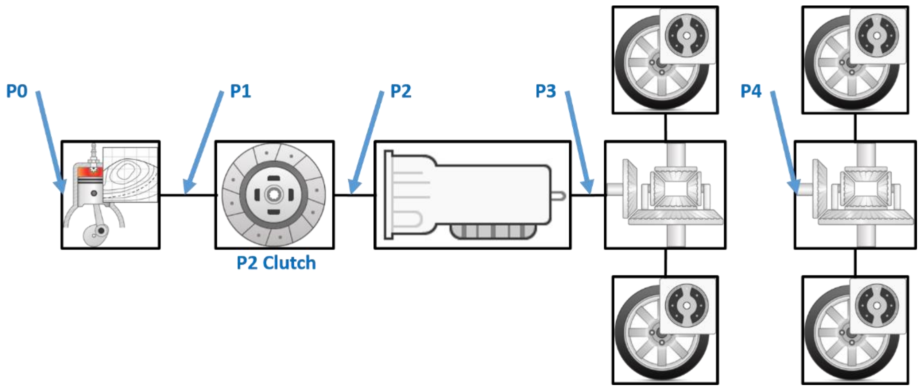
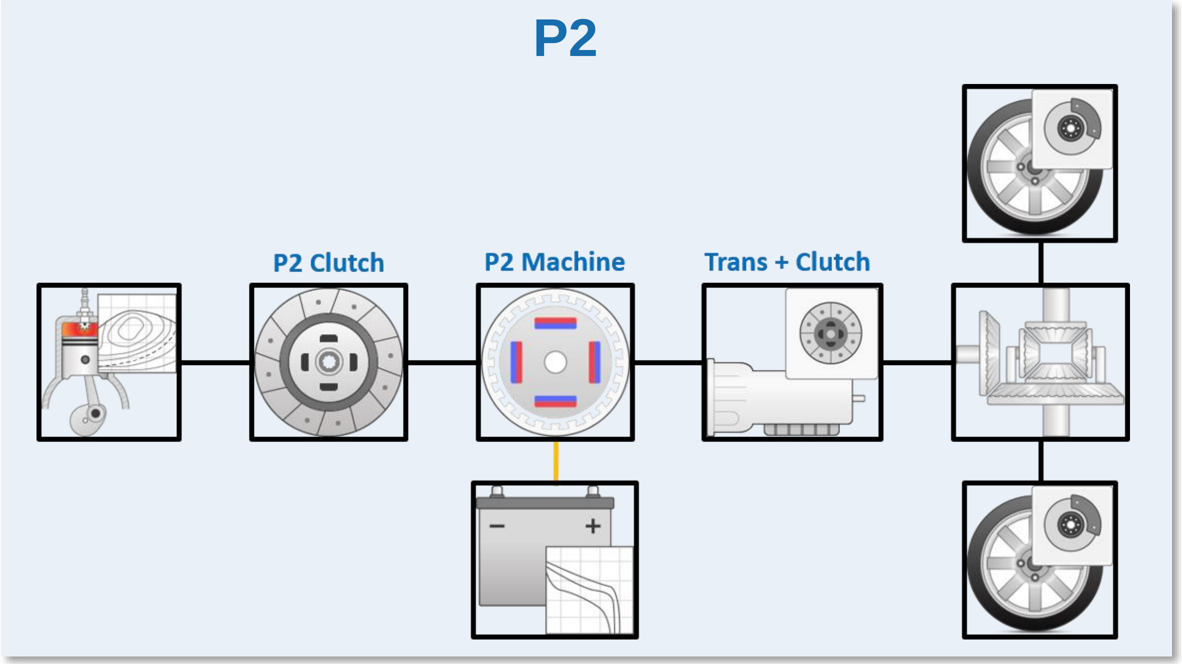
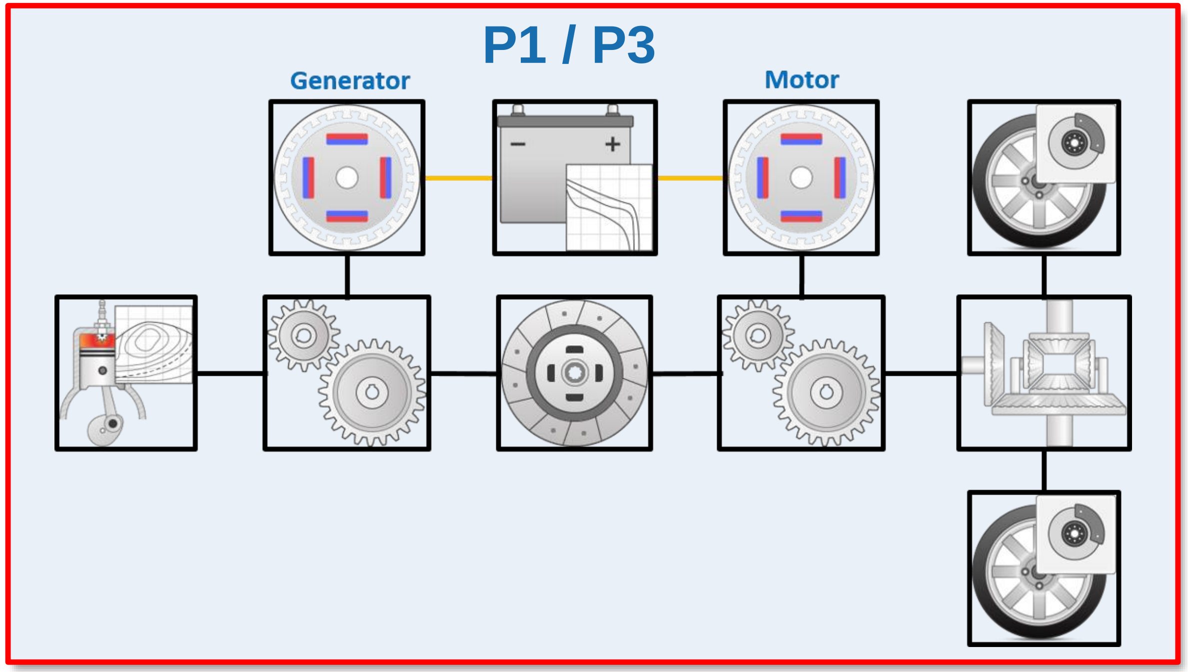
Hybrid Electric Vehicle Architecture

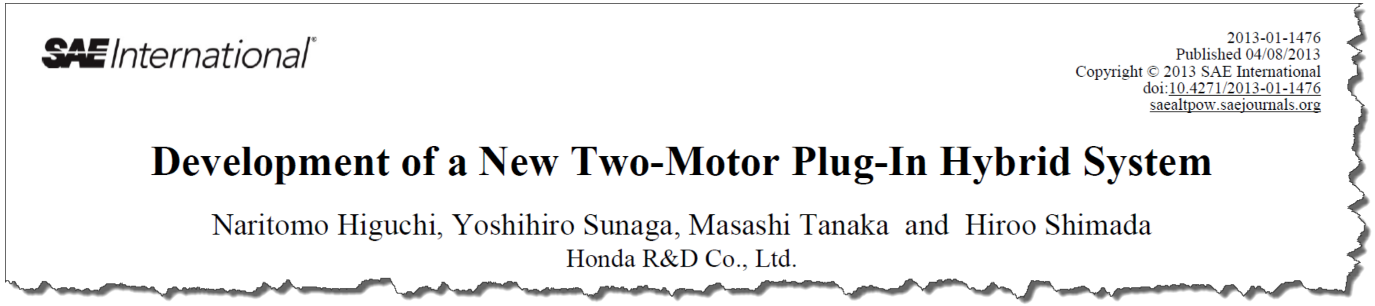


- HEV examples
  - P2 parallel HEV
  - **P1/P3 multi-mode HEV**





Multi-Mode HEV Review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2013-01-1476
Published 04/08/2013
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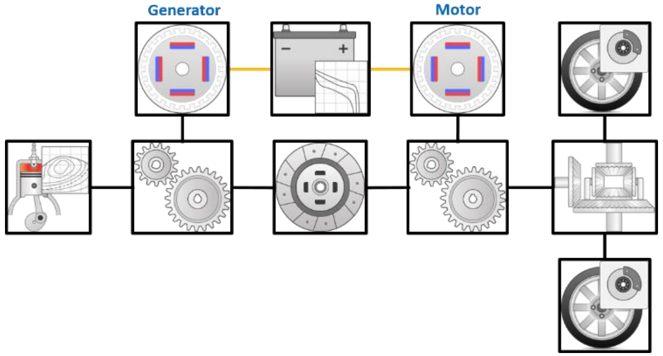
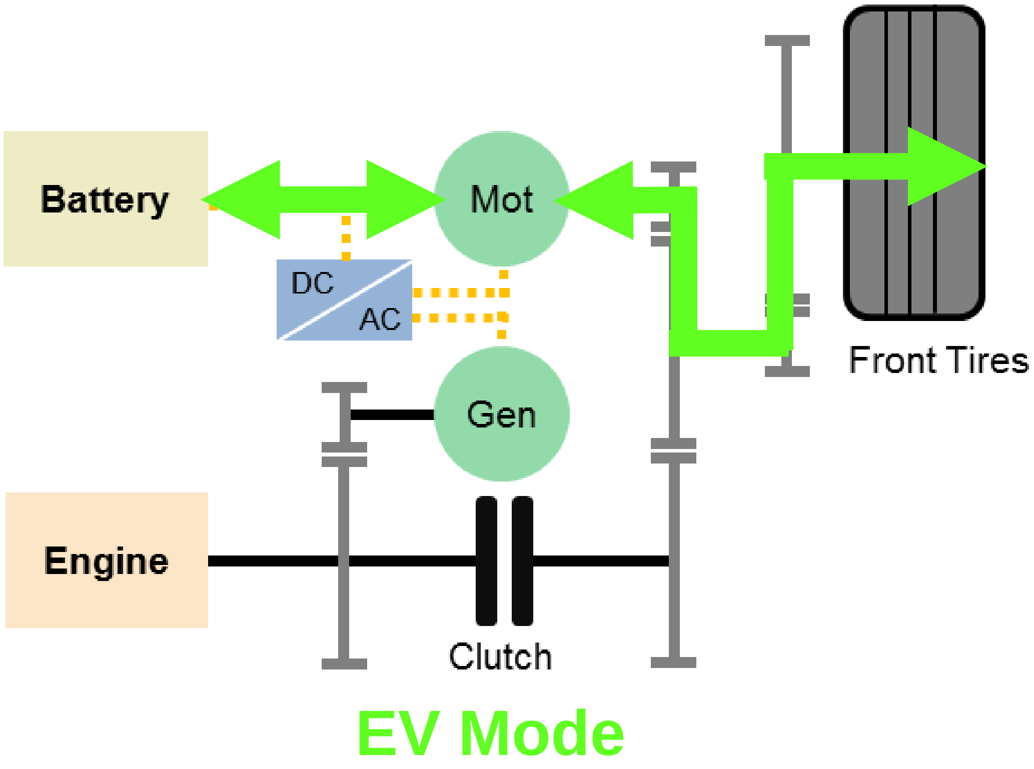
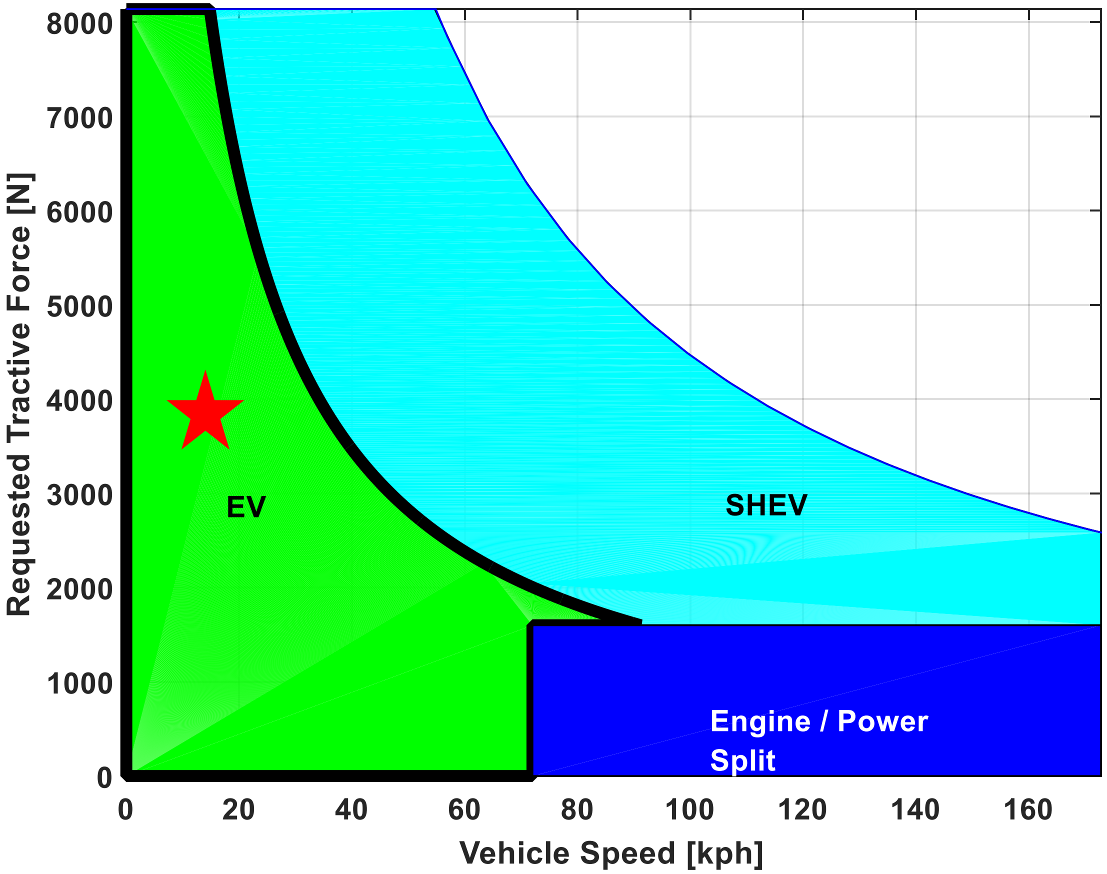
Development of a New Two-Motor Plug-In Hybrid System

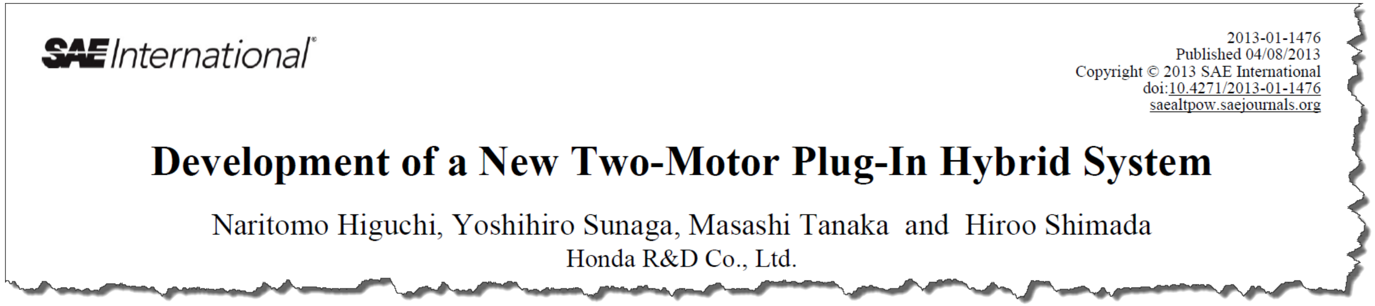
Naritomo Higuchi, Yoshihiro Sunaga, Masashi Tanaka and Hiroo Shimada
Honda R&D Co., Ltd.







Multi-Mode HEV Review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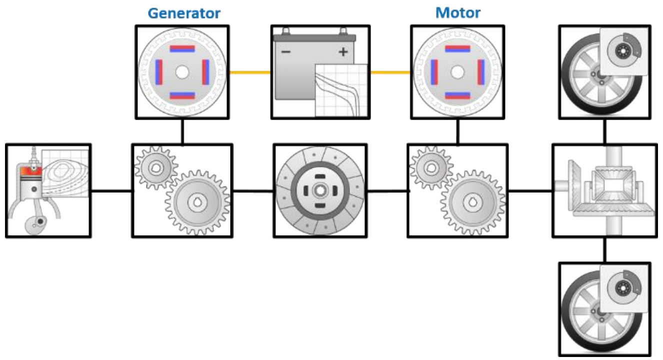
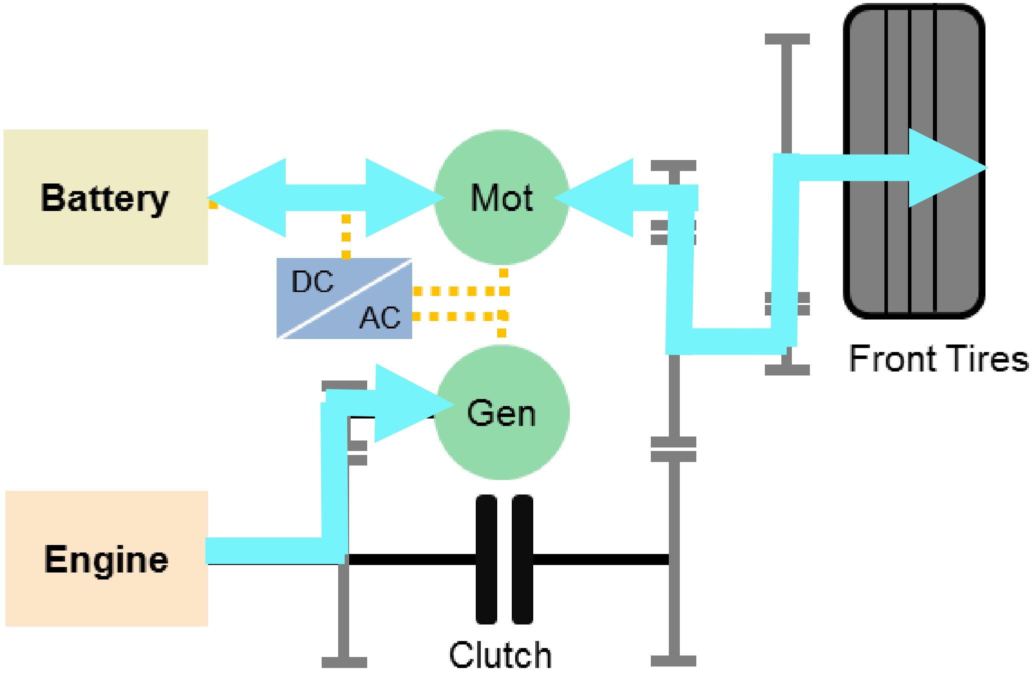
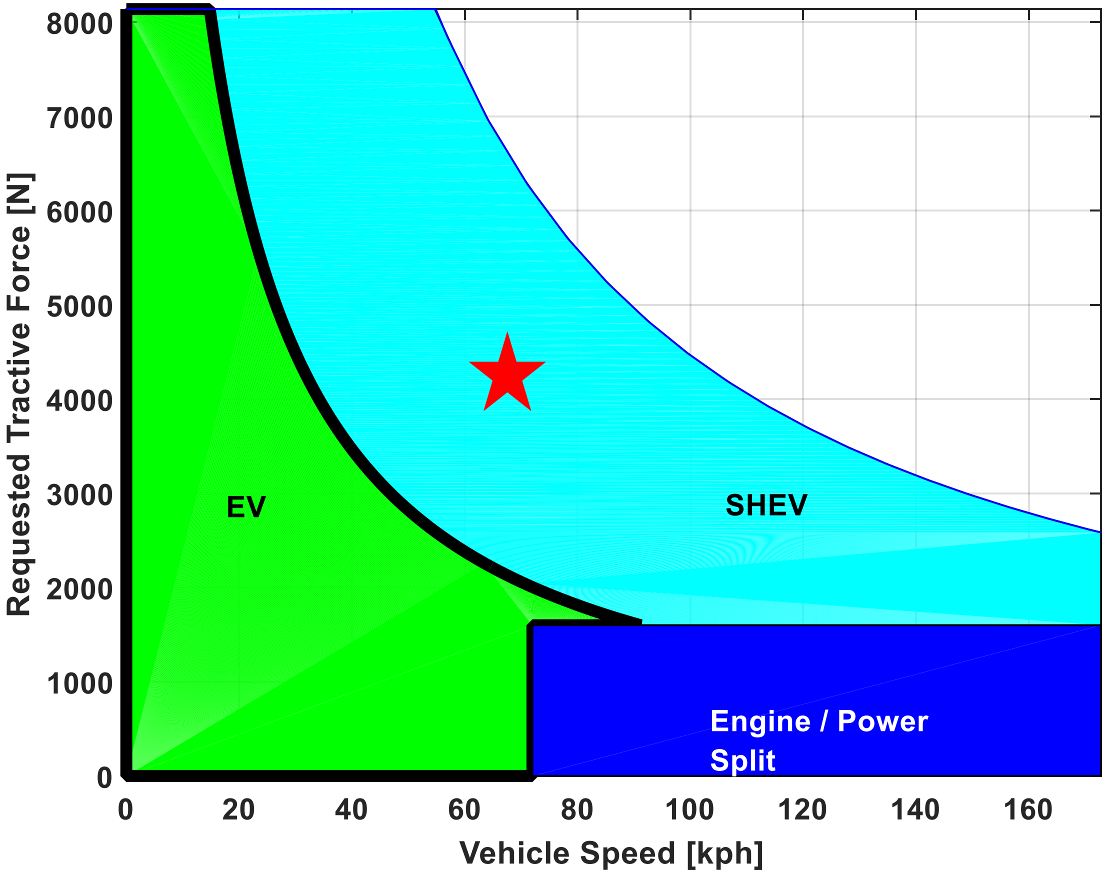
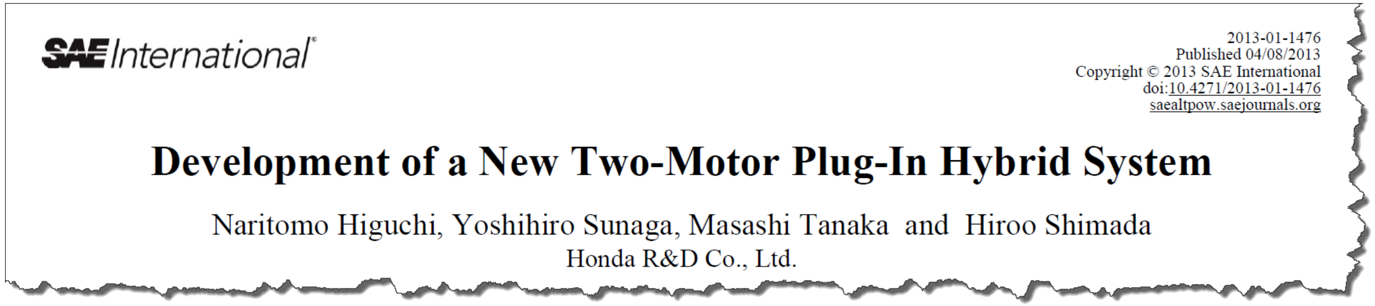




SHEV Mode



Multi-Mode HEV Review



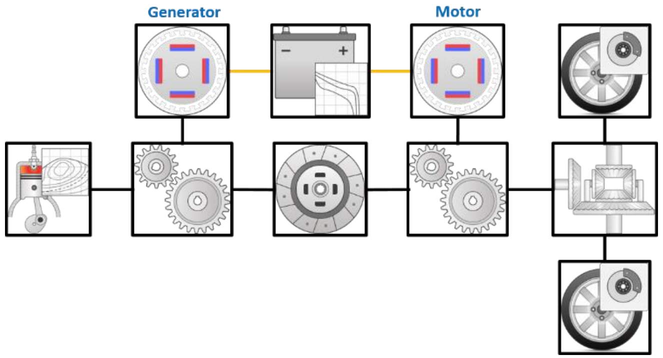
SAE International

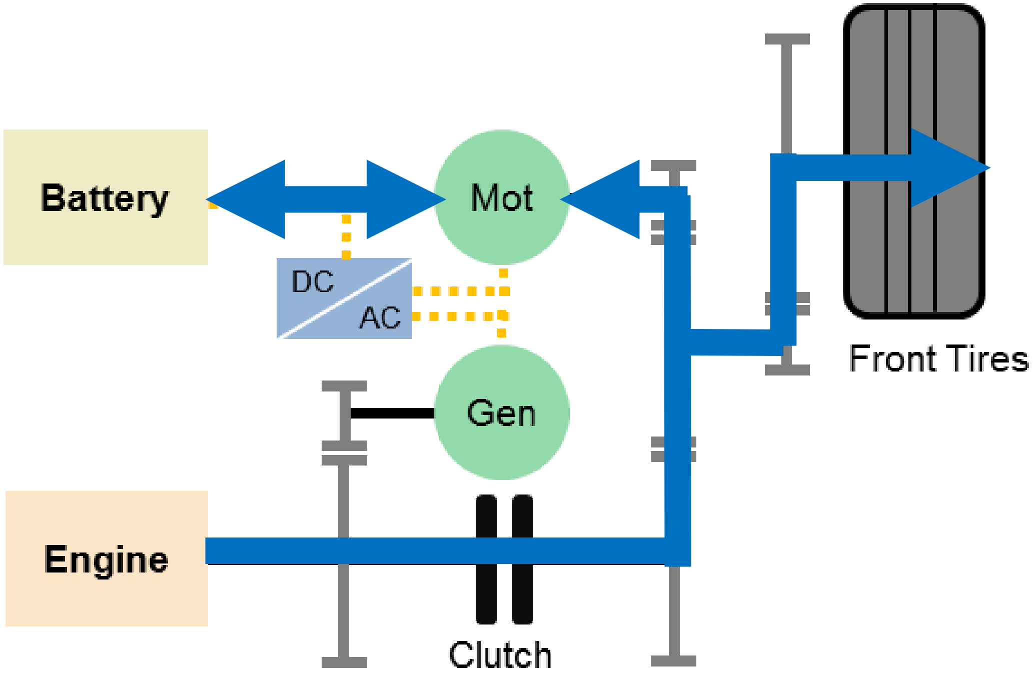
2013-01-1476
Published 04/08/2013

doi:10.4271/2013-01-1476
saealtpow.saejournals.org

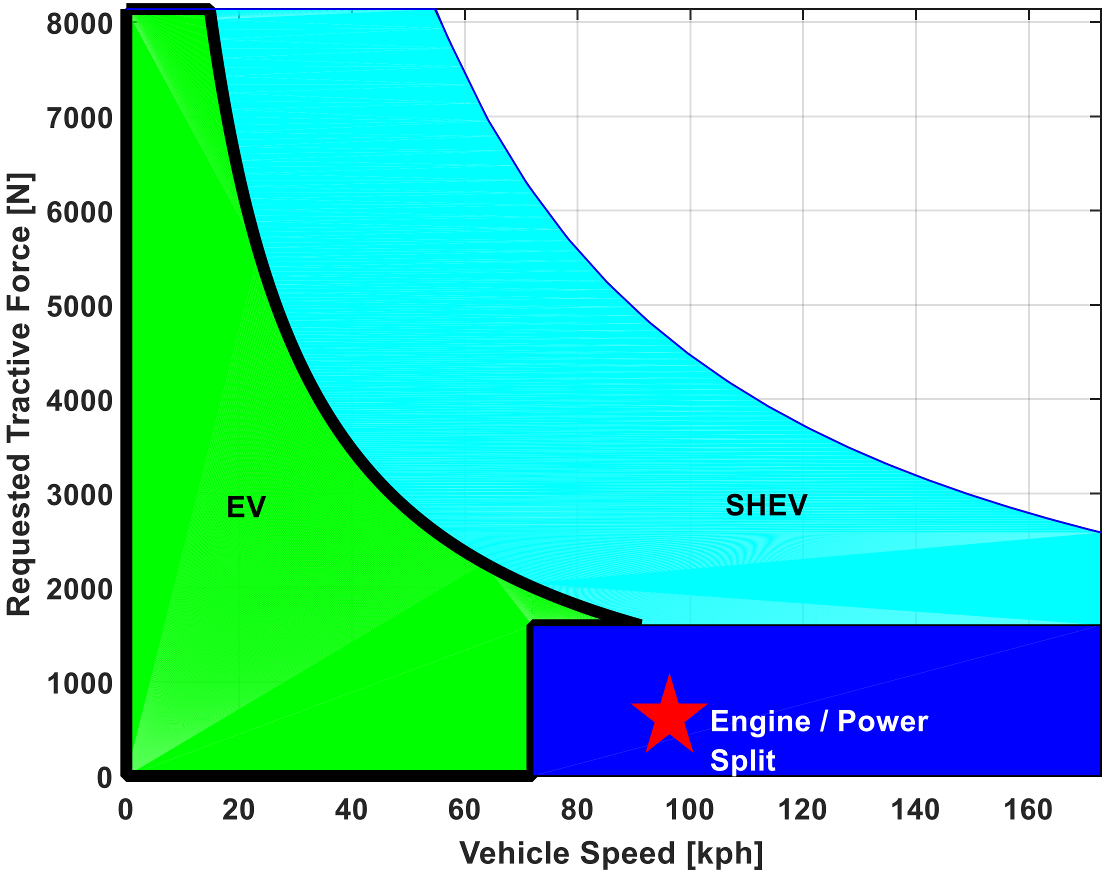
Development of a New Two-Motor Plug-In Hybrid System

Naritomo Higuchi, Yoshihiro Sunaga, Masashi Tanaka and Hiroo Shimada
Honda R&D Co., Ltd.



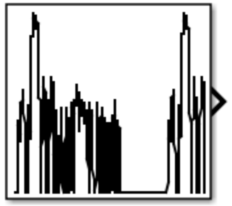


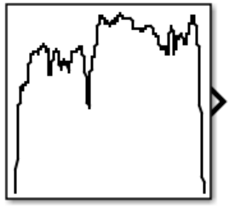
Engine Mode

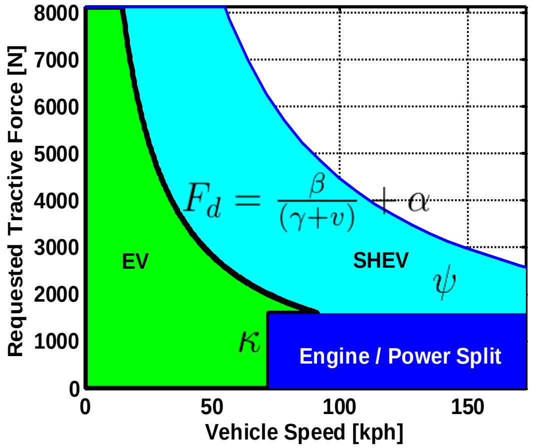


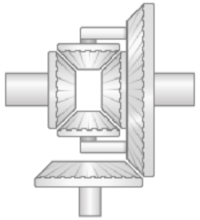
Design Optimization Problem Statement

- Maximize MPGe
  - FTP75 and HWFET
  - Weighted MPGe = 0.55(FTP75) + 0.45(HWFET)
- Optimize Parameters:
  - 5 control parameters
    - EV, SHEV, Engine mode boundaries
  - 1 hardware parameter
    - Final differential ratio
- Use PC
  - Simulink Design Optimization (SDO)
  - Parallel Computing Toolbox (PCT)


Drive Cycle Source1
FTP75 (2474 seconds)


Drive Cycle Source
HWFET (765 seconds)

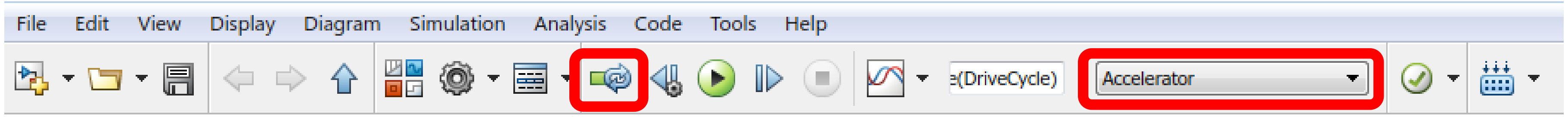



Differential Ratio

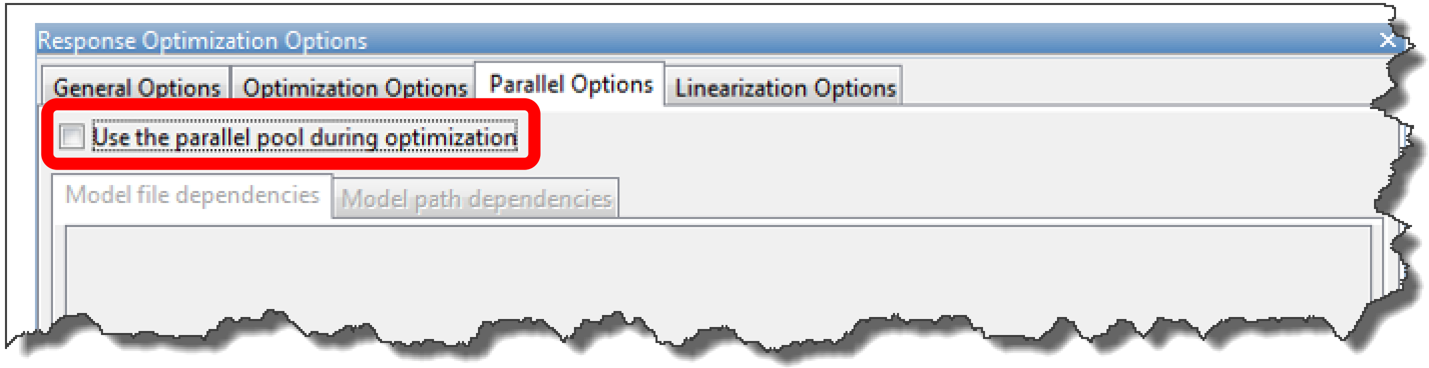

Lenovo ThinkPad T450s
Dual Core i7 2.60GHz
12 GB RAM

Simulink Design Optimization

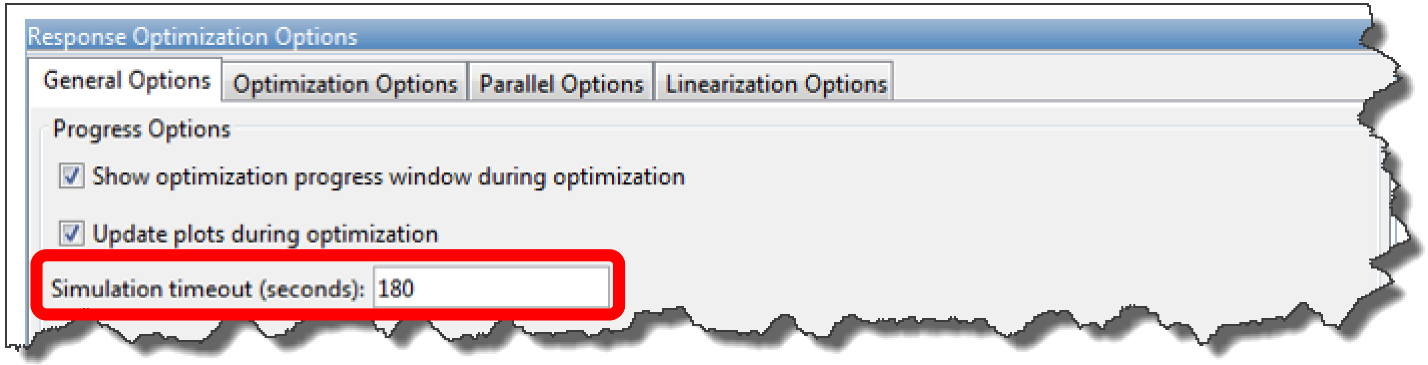
- Speed Up Best practices
  - Accelerator mode
  - Fast Restart



  - Use Parallel Computing Toolbox

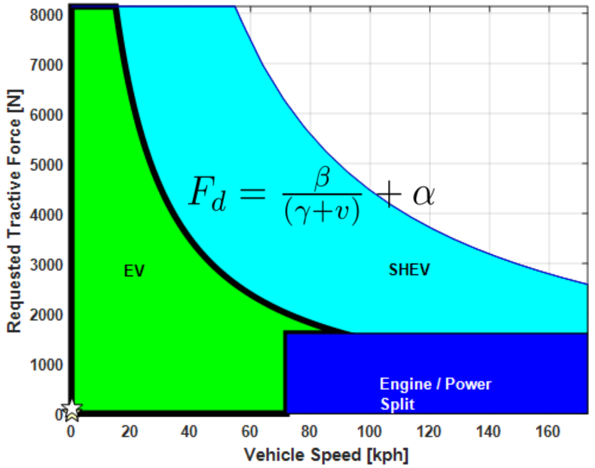


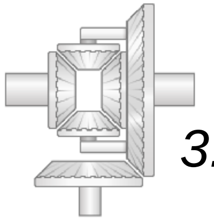
  - Specify Simulation timeout



Optimization Results

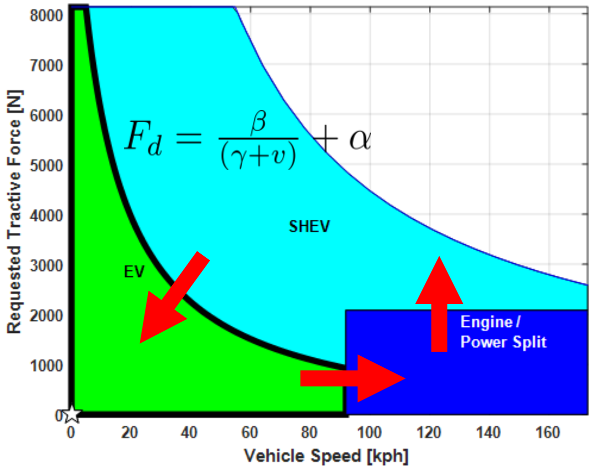
Simulink Design Optimization → Response Optimization

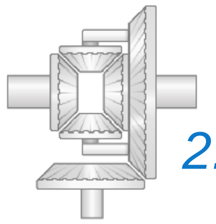




3.42:1

+ 2% MPGe



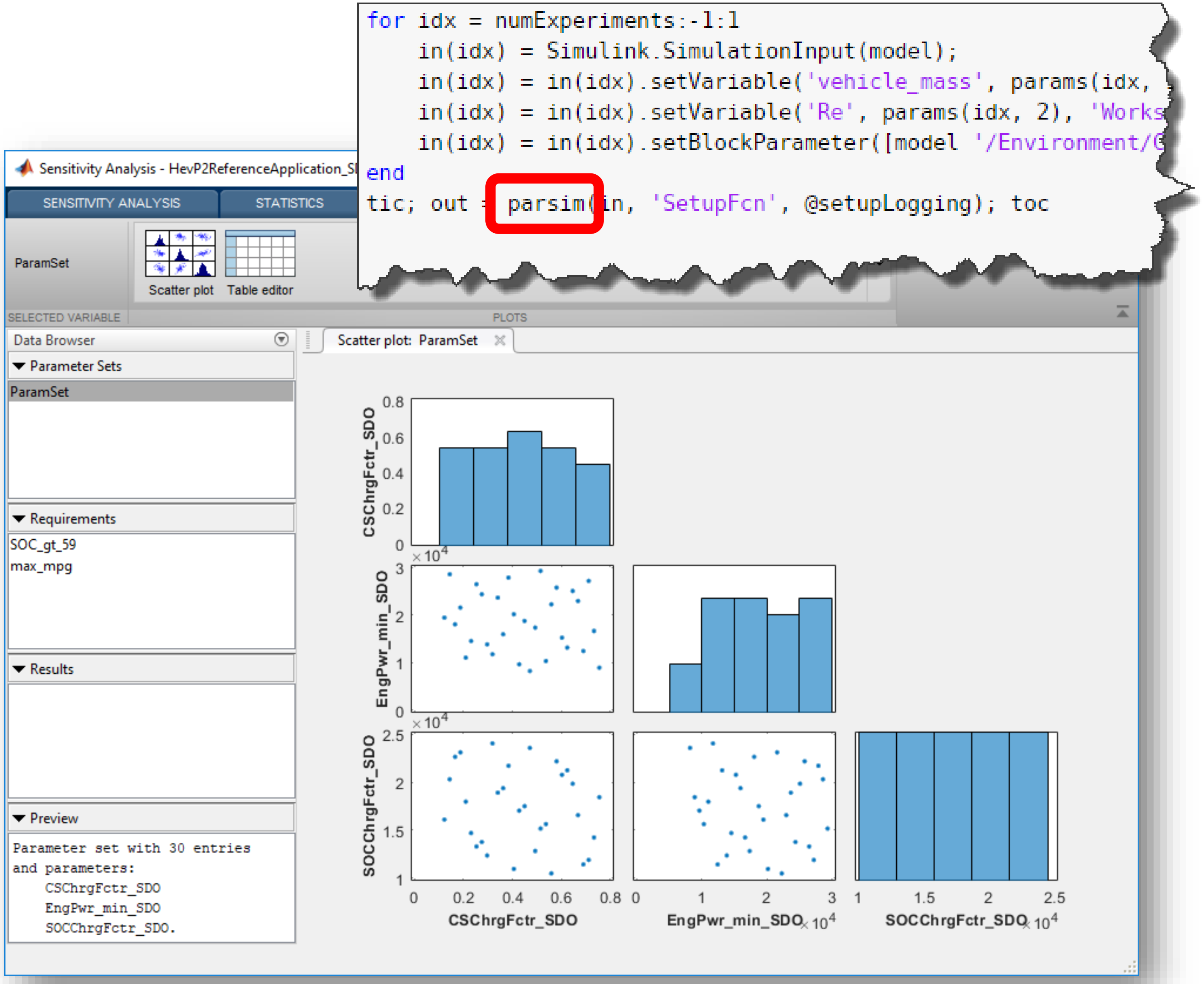


2.92:1

Sensitivity Analysis

- Determine sensitivity of fuel economy and ability to charge sustain to changes in design parameters

- Simulink Design Optimization UI
  - Create sample sets
  - Define constraints
  - Run Monte Carlo simulations
  - Speed up using parallel computing



Powertrain Control – Charge Sustaining / PHEV Power-Split

SAE International

2011-01-2451
Published 06/01/2012
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doi:10.4271/2011-01-2451
saealtpow.saejournals.org

Optimization of Electrified Powertrains for City Cars

Andreas Balazs
Aachen Univ.

Edoardo Morra
Politecnico di Torino

Stefan Pischinger
FEV GmbH

- SOC Optimal calculation

$$SOC^*_{opt} = \frac{E_{batt}SOC_{opt} - \boxed{\eta_{rech}} \cdot M_{veh}v_{veh}{}^2}{E_{batt}}$$

η_{rech} → CSChrgFctr
– i.e. charge sustaining factor

- Engine Power Calculation

$$P_{ICE,dem} = P_{dem,trac} + \boxed{k_2}(SOC^*_{opt} - SOC_{act})$$

k2 → SOCChrgFctr
– Low speed cutoff for EM to not run as generator

– Minimum Eng On Power

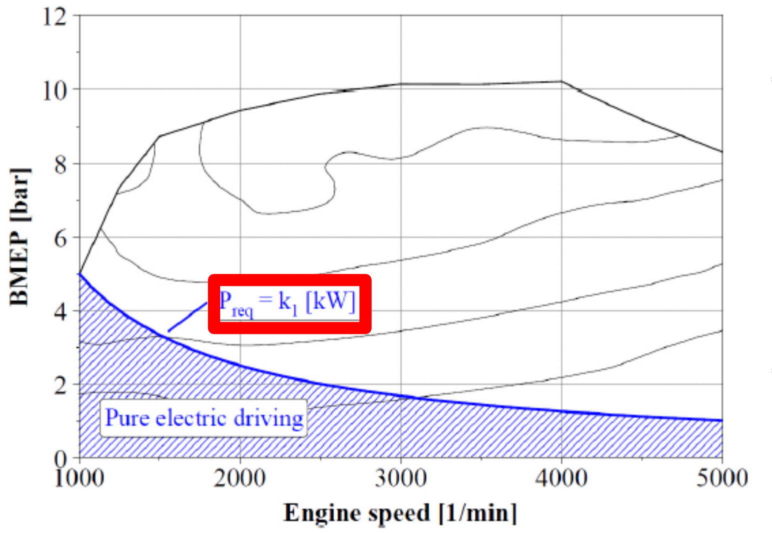


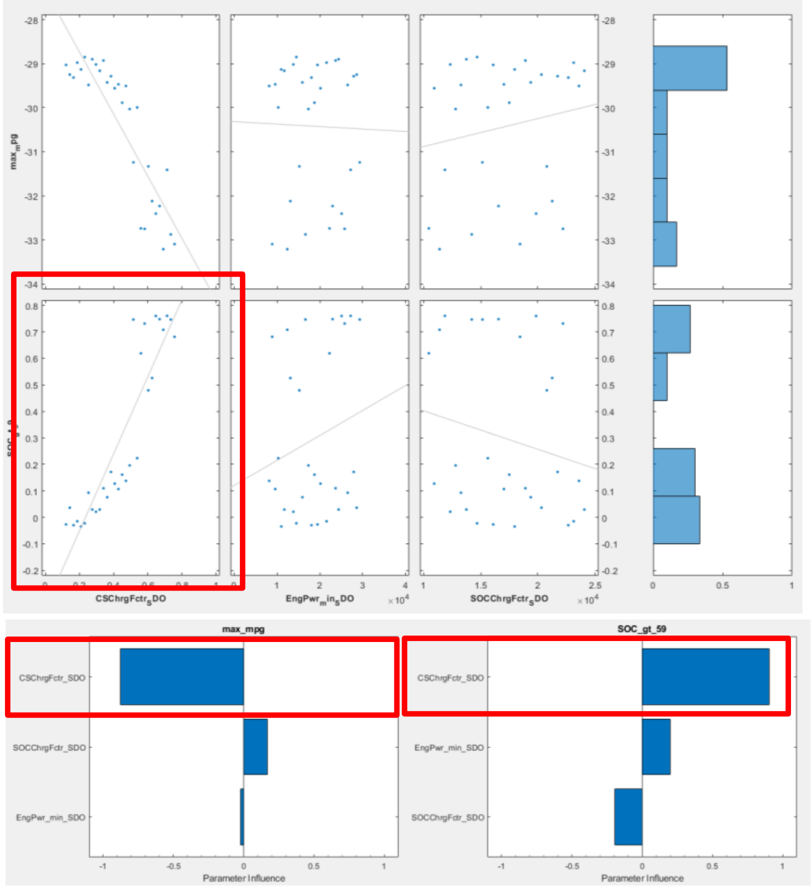
Figure 5. Hybrid operating strategy: parameter k_1

Sensitivity Analysis – Results

- HWFET

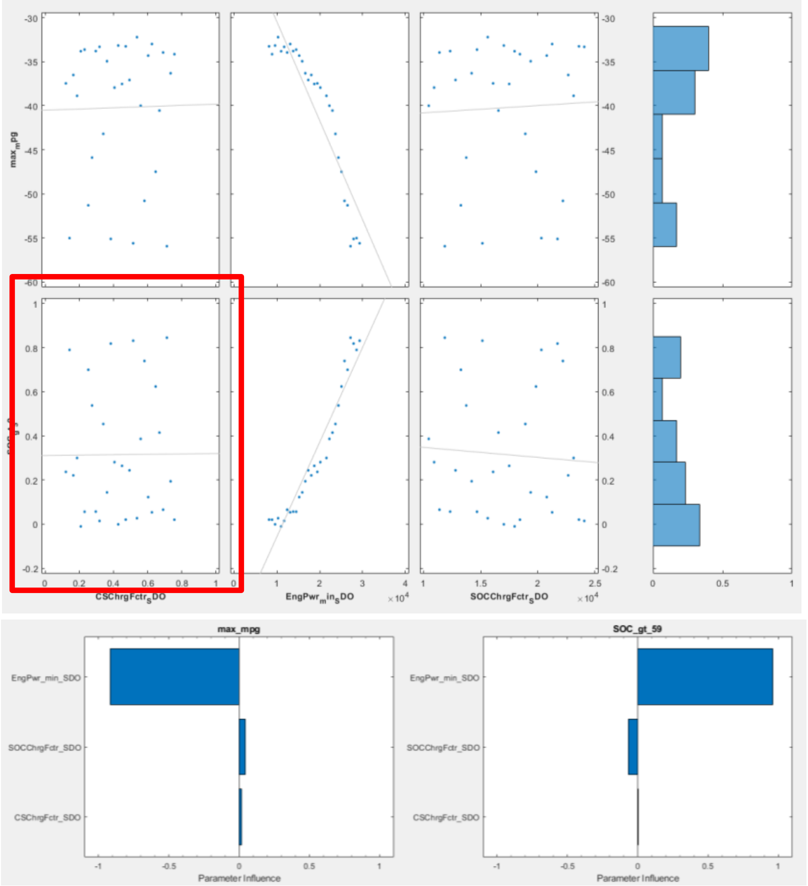
  – CS Factor highest correlation for charge sustaining
  – Min Engine Power highest correlation for max mpg

- US06



  – CS Factor highest correlation for charge sustaining and max mpg

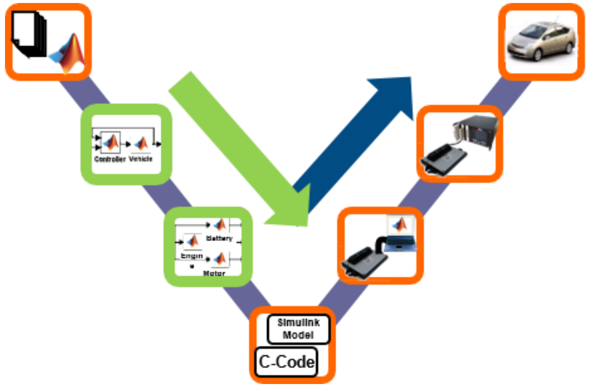
- FTP72



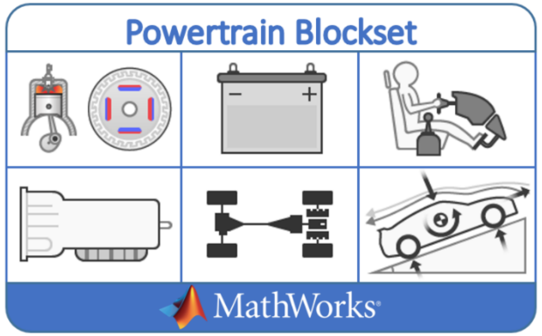
  – Min Engine Power highest correlation for maximizing mpg and charge sustaining

Key Points

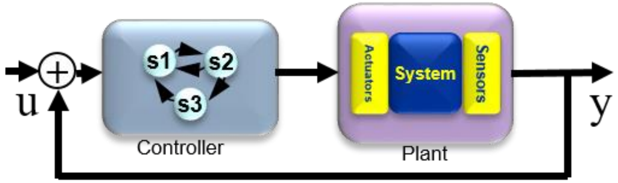
- Efficient plant modeling enables Model-Based Design (MBD)



- Powertrain Blockset provides HEV modeling framework, components, and controls



- Design / optimize plant and controls together as a system



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