Argonne NATIONAL LABORATORY

Tutorial on Autonomie,
a Plug-and-Play Software Architecture

AUTONOMIE

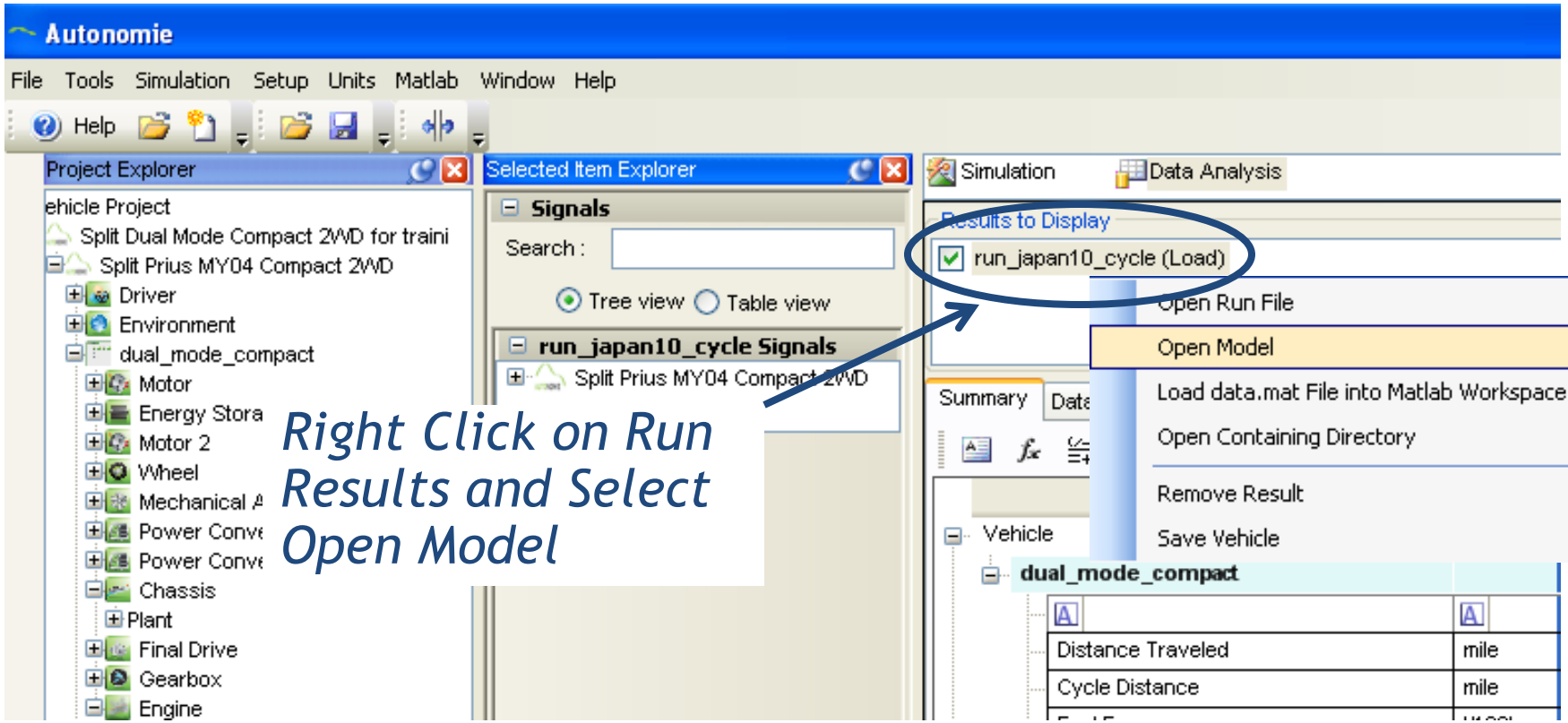
Exercise 4: Understand the Simulink Models and their Organization

IEEE Vehicle Power And Propulsion Conference 2010
Lille, France, August 31st 2010

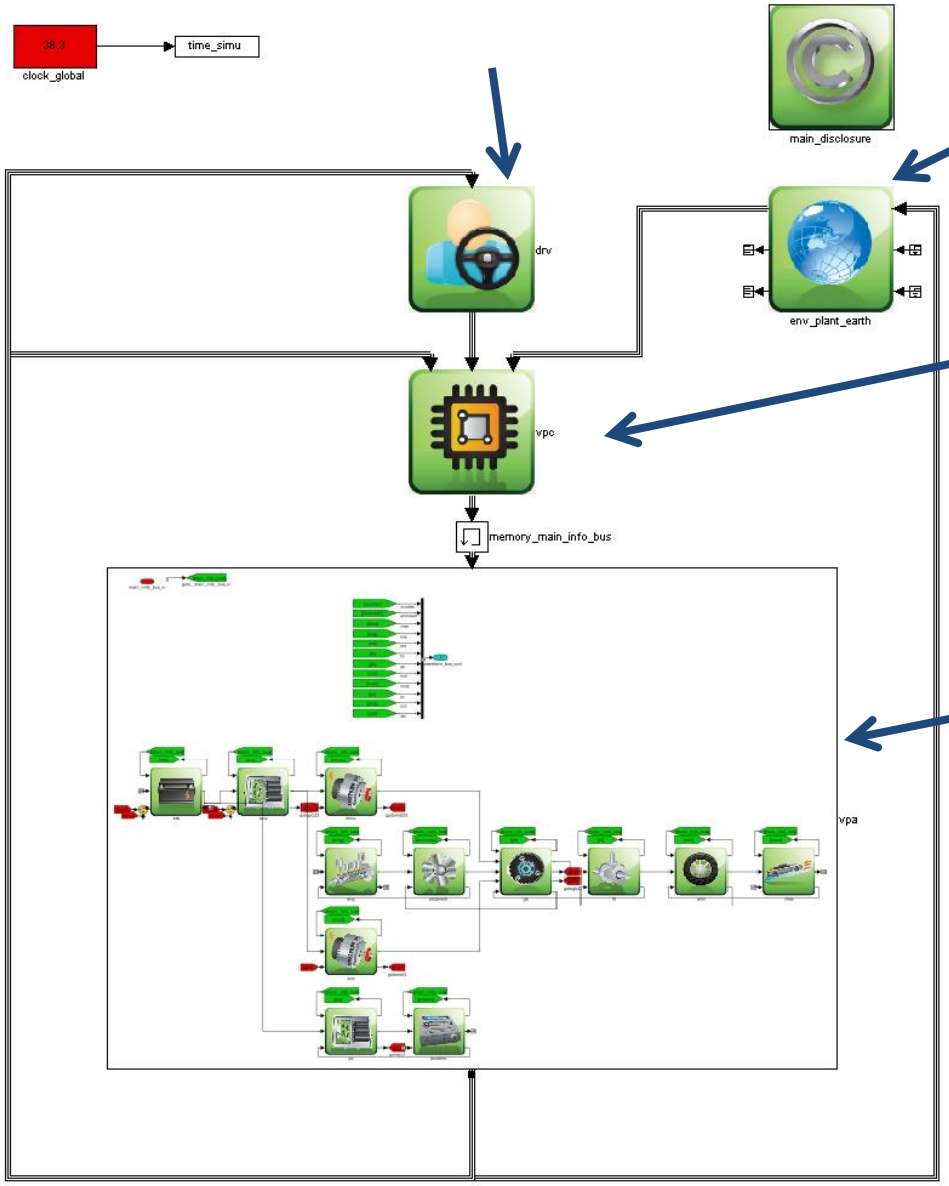
Dominik Karbowski, Sylvain Pagerit,
Aymeric Rousseau,
Argonne National Laboratory

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

From the data Analysis Tab, Open a Simulink Model



The Same Architecture is Used in Simulink



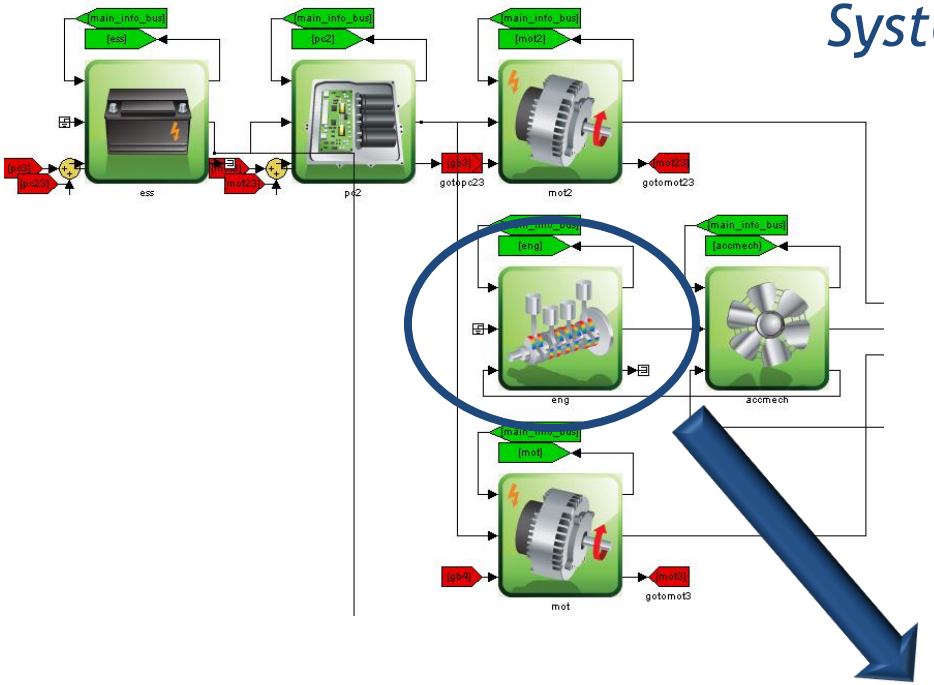
Environment

Vehicle Powertrain Controller (VPC) represents high level control

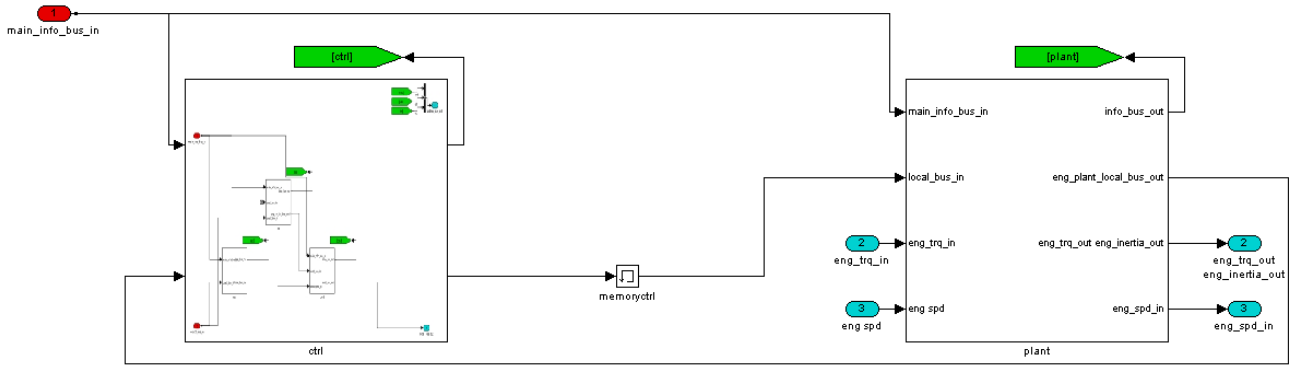
Vehicle Powertrain Architecture (VPA) represents the powertrain systems and their low level controllers

Under the VPA, we Find Systems and Subsystems

Systems



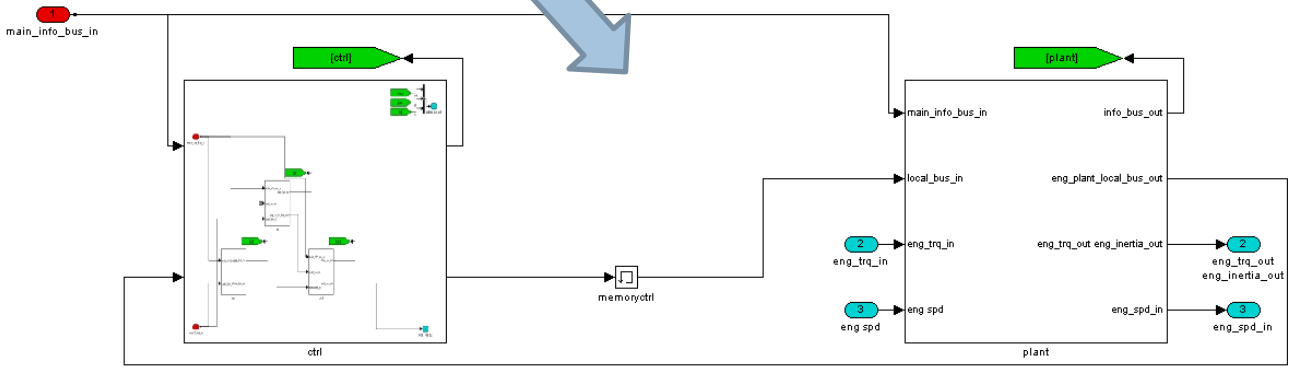
Engine Subsystems



Simulink Structure Follows Structure Defined in Autonomie

Engine System in Autonomie

Engine System in Simulink

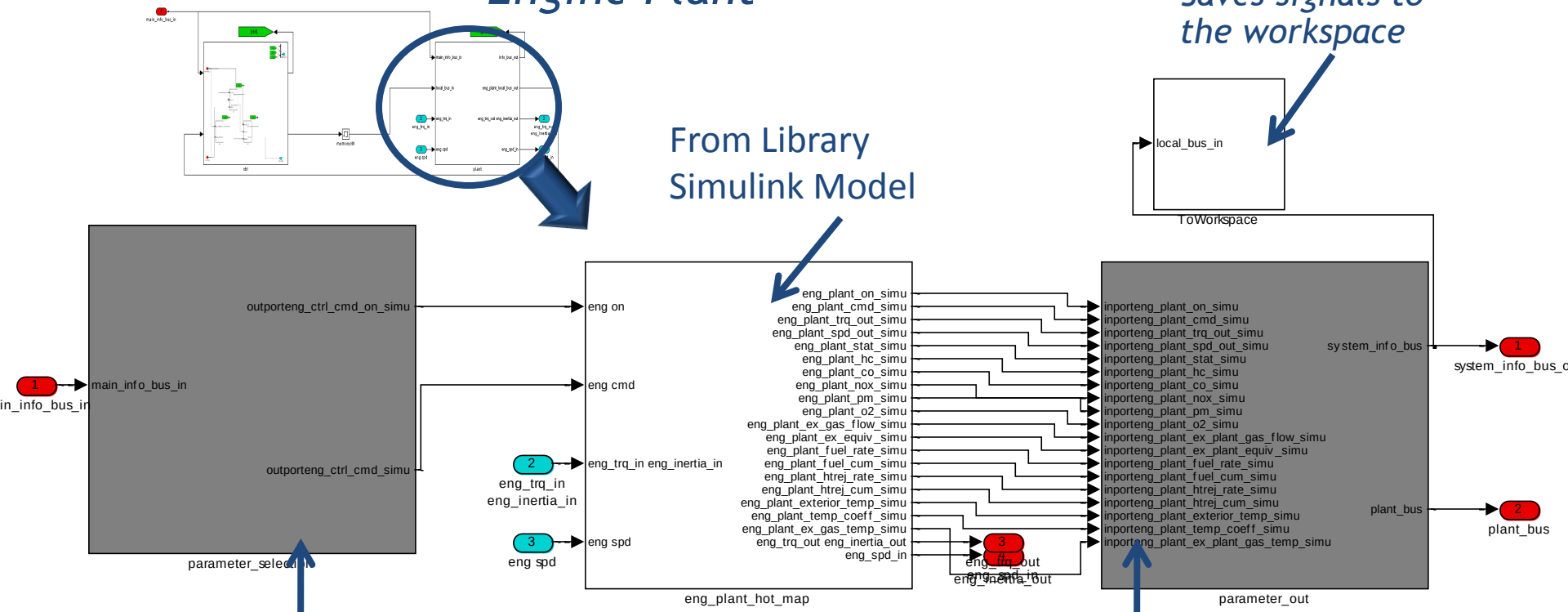


Model Plug&Play Capability Provided by "Wrapper"

Engine Plant

Saves signals to the workspace

From Library Simulink Model



First block **automatically built** to select the required input parameters, change units and data type

Last block **automatically built** to change units (SI) and data type before sending the information to a bus to make them available to other systems

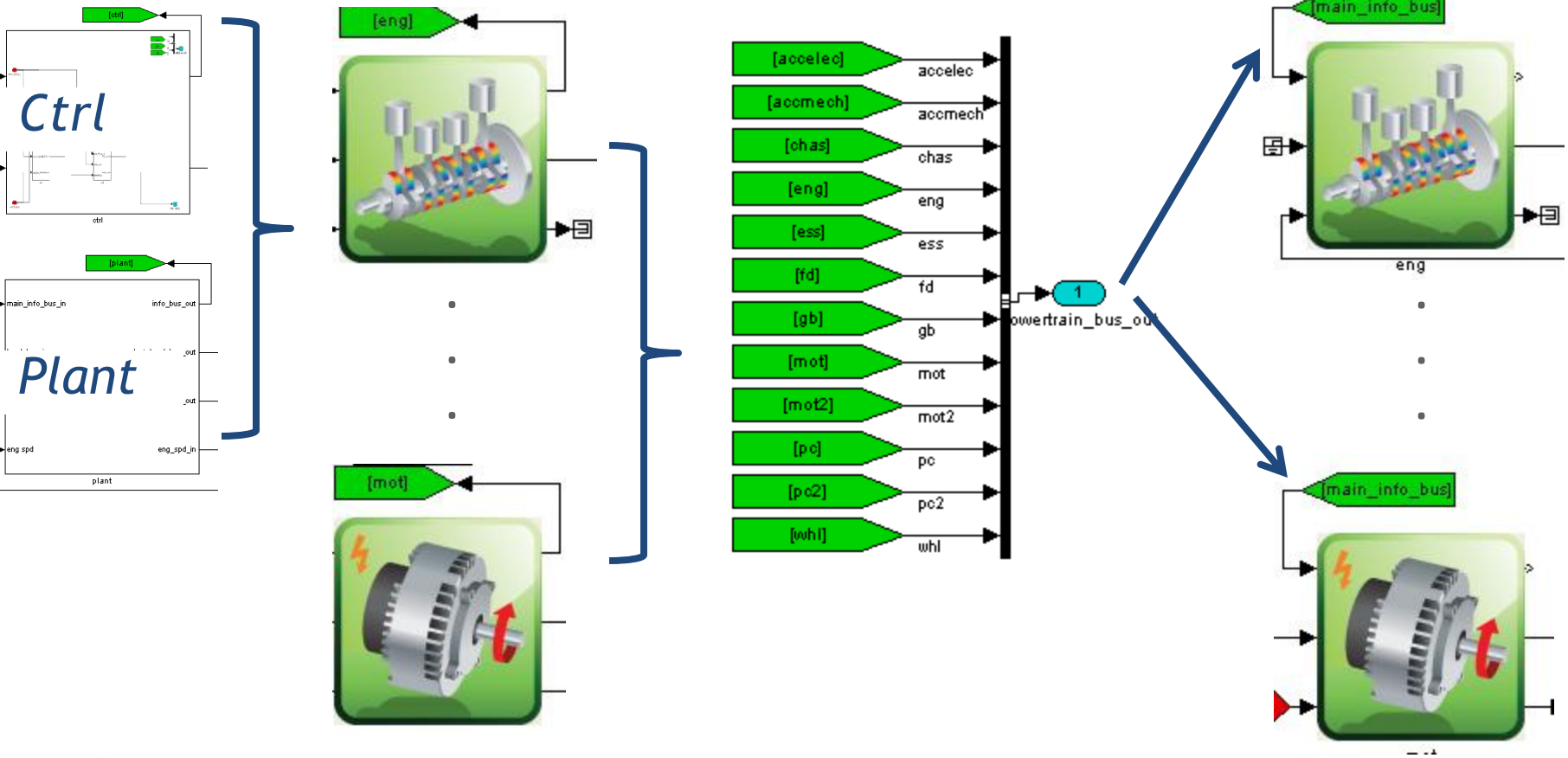
Every System and Subsystem has its Own Bus

Each Lowest System has its Own Bus

Buses are Compiled into Single Bus for Each System

Buses are Compiled into One Main Bus

And made Available to All Systems



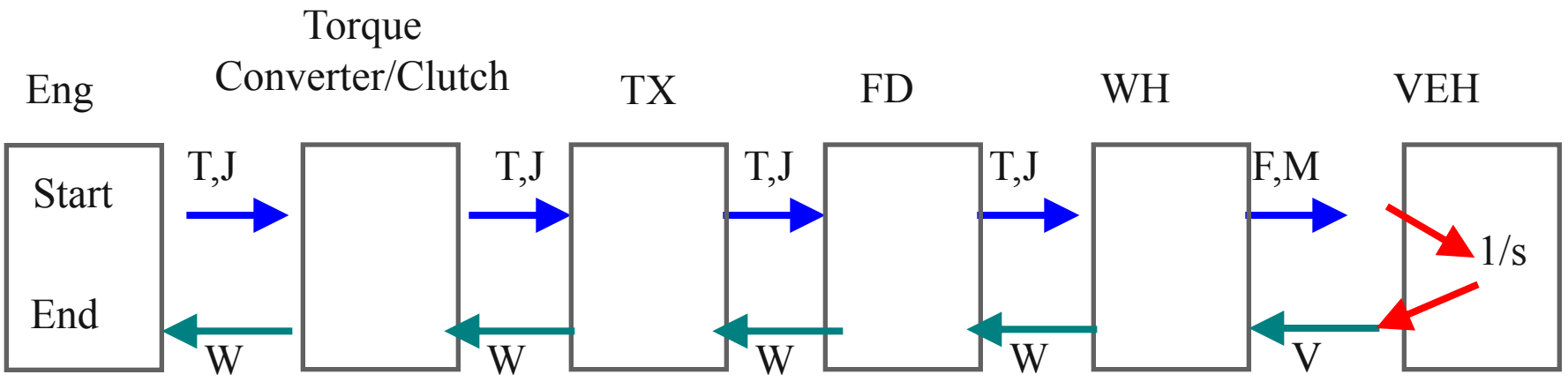
SI Units Recommended for All Models

Value	Units
Torque	Nm
Rotational Speed	rad/s
Force	N
Linear Speed	m/s
Current	Amps
Voltage	Volt
Power	Watt
Energy	Joule
Rotational Acceleration	rad/s2
Linear Acceleration	m/s2
Weight	kg

Naming Nomenclature - Component Models

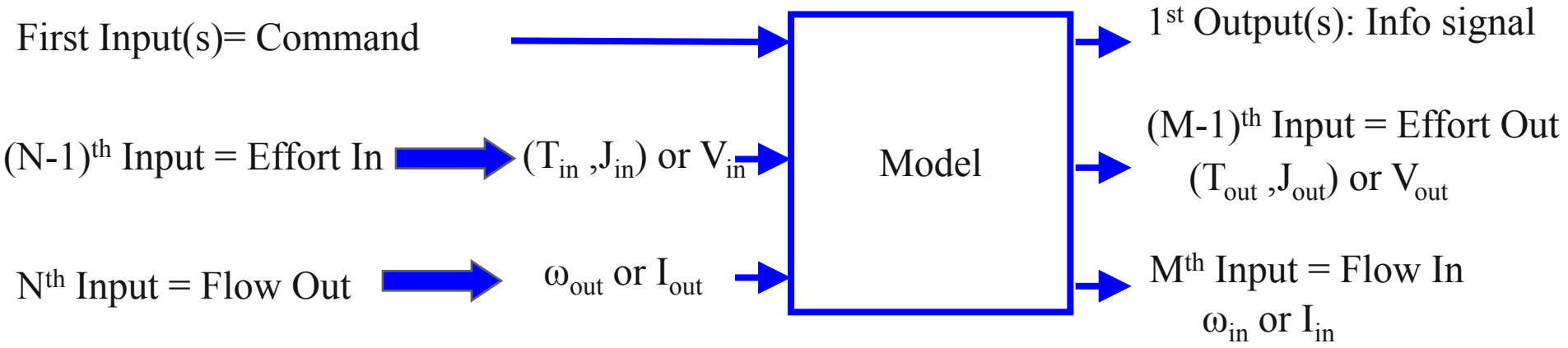
- Based on four parts:
  - Type of component (e.g.: eng = engine)
  - Type of model (e.g.: ctrl = control)
  - Type of data (e.g.: trq = torque)
  - Complement of information (e.g.: max = maximum)
- All the model parameters and variables are composed using these parts

Vehicle Simulation Loop (i.e., conv.)



Carrying the inertia to the vehicle allows to limit the number of integration (1/s) as well as avoid derivative equations

Library Models Follow I/O Standard

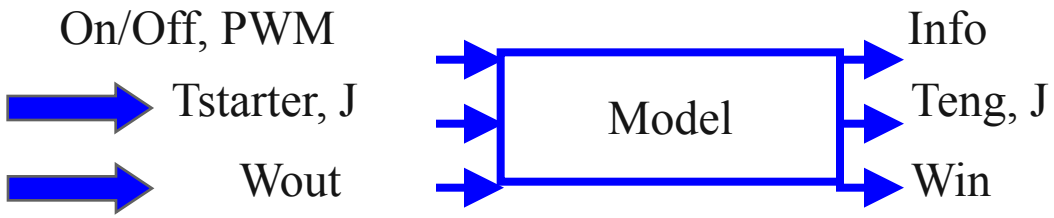


Example: Engine Model (eng_plant_map_hot)

- Inputs/outputs

Second I/O = Effort

Third I/O = Flow



- Constraints

$$T\max = f(W)$$

Engine Model (Cont'd)

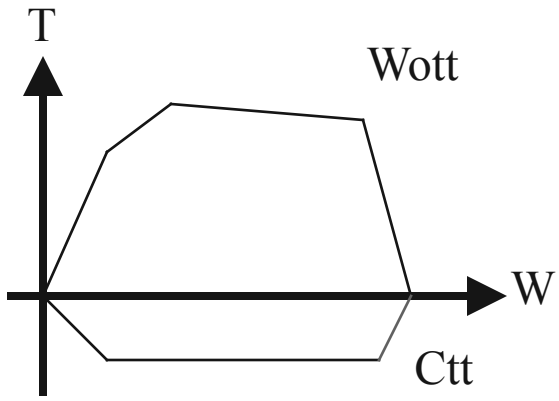
- Hypothesis: From a requested torque from the powertrain controller, the engine model provides the torque (if within the normal operating conditions) and determines the fuel rate and emissions associated with the torque and speed.

- Equations

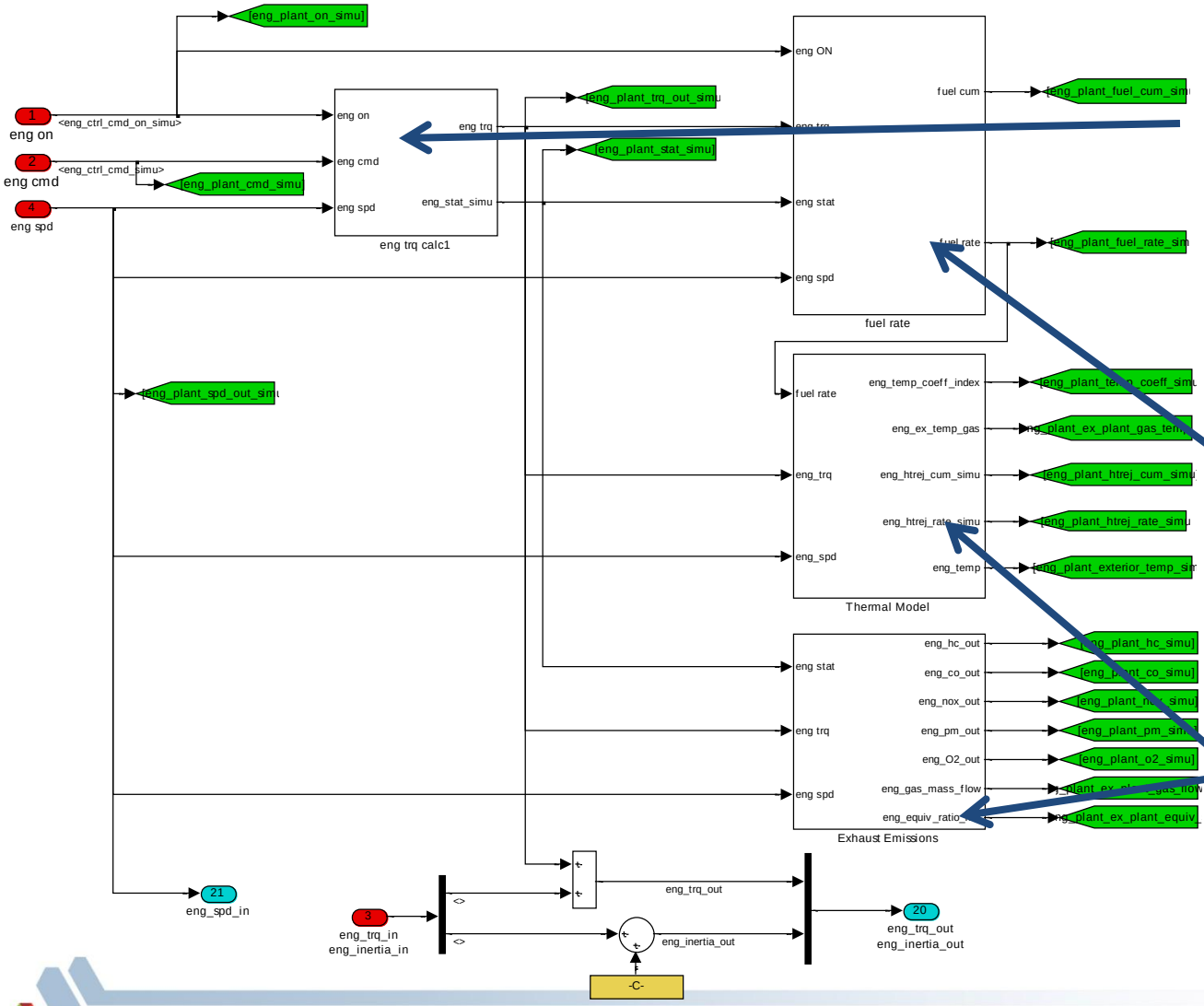
$$Teng = (1 - cmd) * Tctt + cmd * Twott$$

$$Fuelrate(g/s) = f(T, W)$$

$$Emission(g/s) = f(T, W)$$

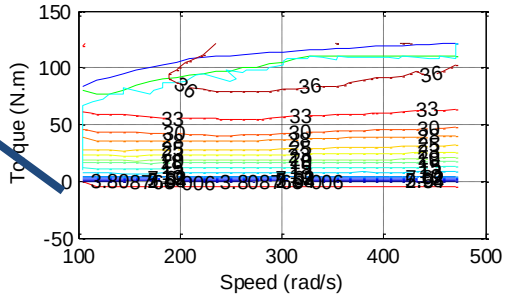


Engine Plant Simulink Diagram



Engine TorqueComputation

Fuel Rate



Emissions

Electric Motor Model (mc_map_Pelec_funTW_volt_in)

- Hypothesis: The motor/controller provides the demanded torque from the powertrain controller. The effect of losses and rotor inertia are taken into account on the electrical side when calculating the current corresponding to the produced torque. The temperature is taken into account by limiting the time allowed above continuous torque.

- Equations

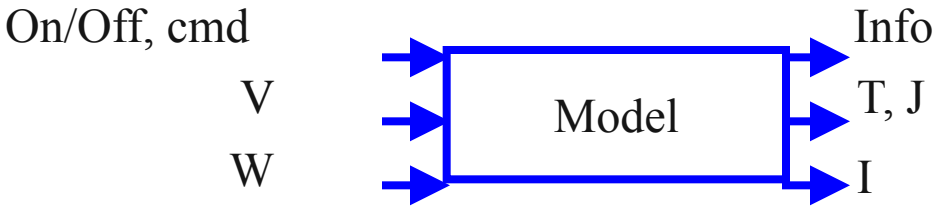
$$Tout = cmd * T\max$$

$$I = \frac{Pmeca - Ploss}{V}$$

$$Ploss = f(W, T)$$

Electric Motor Model (Cont'd)

- Inputs/outputs



- Constraints

$$T\max = \min\left[(1 - Ktemp) * T\max_peak + Ktemp * T\max_cont, T\max_allowed_by_Im ax_at_actual_voltage\right]$$

$$Ktemp = \int \frac{1}{Time_\max_at_overtorque} * \left(1 - \frac{Tactual}{T\max_cont}\right)$$

- Other Models
  - Map based model with power as input for fuel cell applications (mc_map_Pelec_funTW_pwr_in)

Battery Model (ess_generic_map only)

- Hypothesis: Battery pack is modeled as a charge reservoir and an equivalent circuit whose parameters are a function of the remaining charge in the reservoir. The equivalent circuit accounts for the circuit parameters of the battery pack as if it were a perfect open circuit voltage source in series with an internal resistance.

- Equations

$$V = Num_cell * (Voc - R\,\mathrm{int})$$

$$Voc = f(SOC, Temp)$$

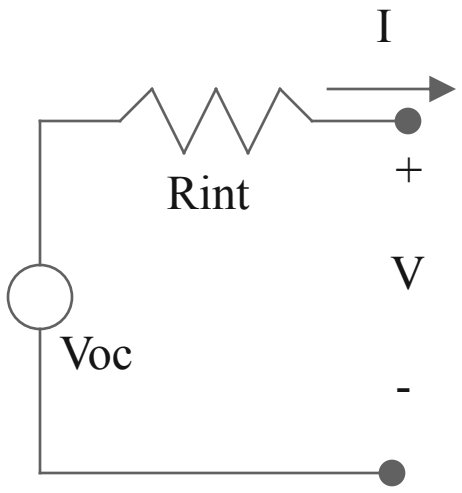
$$R\,\mathrm{int} = f(SOC, Temp)$$

$$Temp = \int \frac{Qess_gen - Qess_case}{Mass * Cp}$$

$$SOCabs = Ah_\max - \int \frac{I * Coulomb_eff}{3600}$$

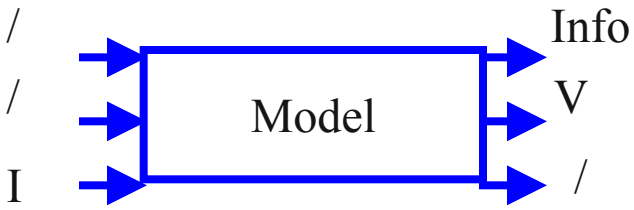
$$Ah_\max = f(Temp)$$

$$SOCusb = \frac{SOCabs - SOC\,\min}{SOC\,\max - SOC\,\min}$$



Battery Model (Cont'd)

- Inputs/outputs



- Constraints

$$P\max_dis = \min\left[\frac{Voc^2}{4*R\text{int}}, \frac{(Voc - V\min)*V\min}{R\text{int}}\right]$$

$$P\max_ch = \frac{(V\max - Voc)*V\max}{R\text{int}}$$

- Other Models
  - Lumped parameter model of ANL Li-ion battery – ess_liion_equation_curve_fit_ANL
  - RC model based on PNGV requirements