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# Engine ECU HIL simulation using Matlab-Simulink

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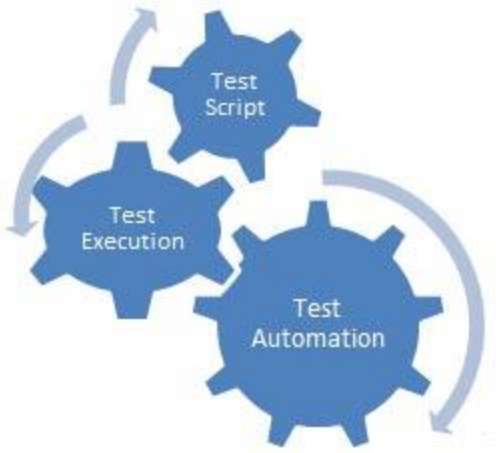
# Agenda

- Why Hardware-in loop (HIL) simulation
- Hardware-in loop introduction and workflow
- Typical HIL setup
- Software components of HIL system
- Matlab-Simulink Model and Results

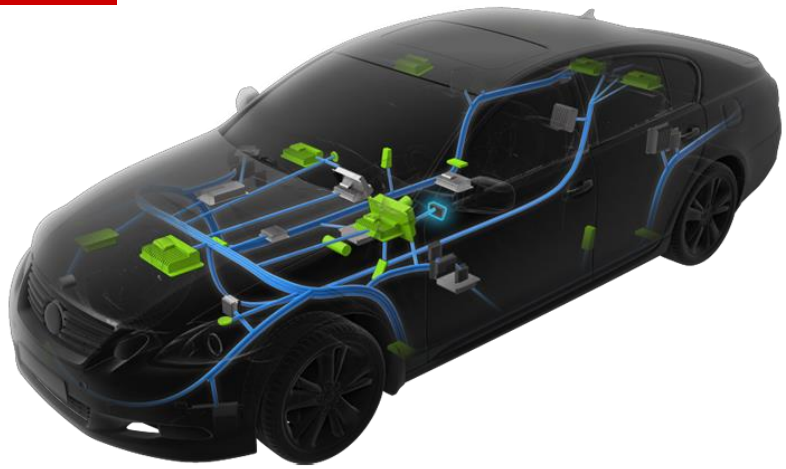


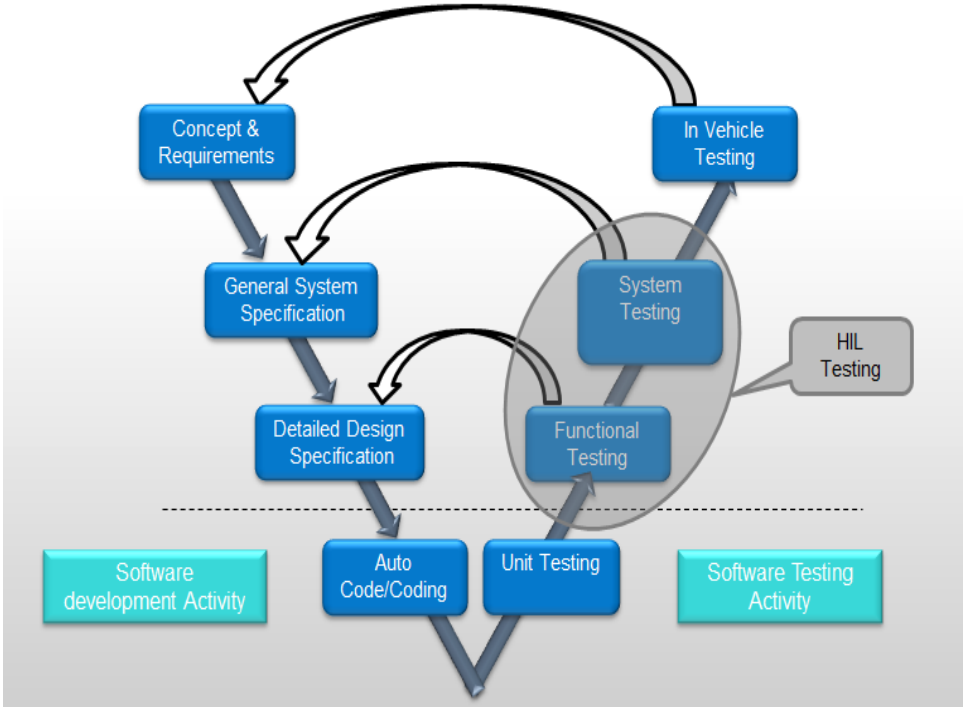
# Introduction

- Emission norms, safety and customer convenience have been the driving factors of increasing electronic controller hardware and software complexity in the recent years.

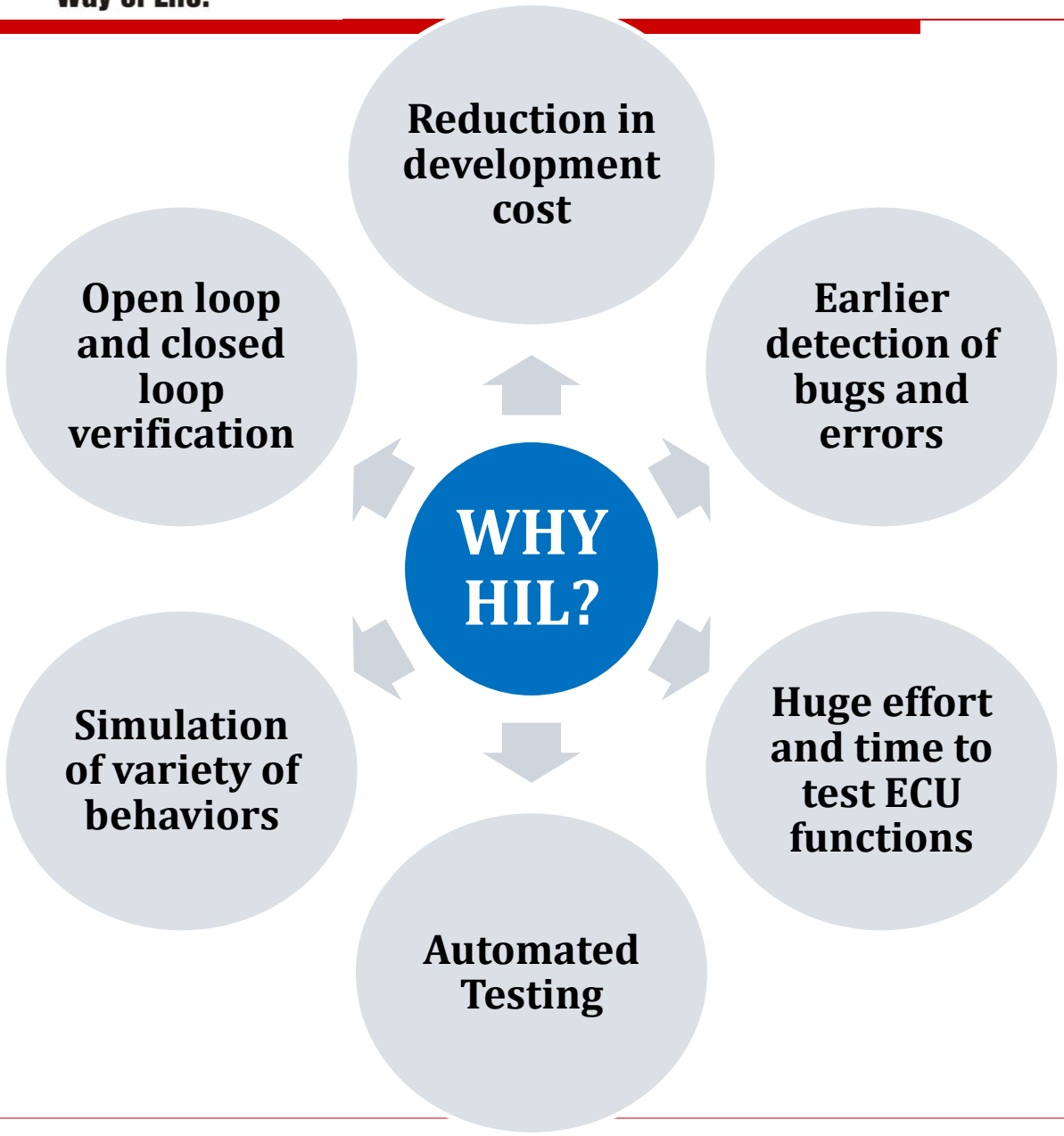
- The increased complexity and sophisticated specifications demand rigorous and reliable testing to ensure error free product to the customer.

- The need for testing and validation of the controller software before proto vehicle is immense





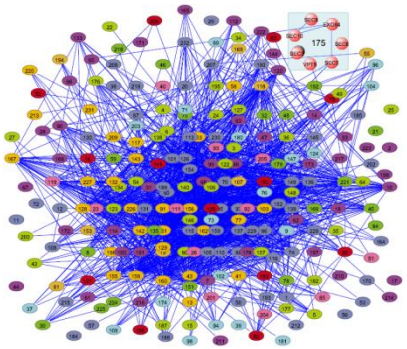
# Why HIL?



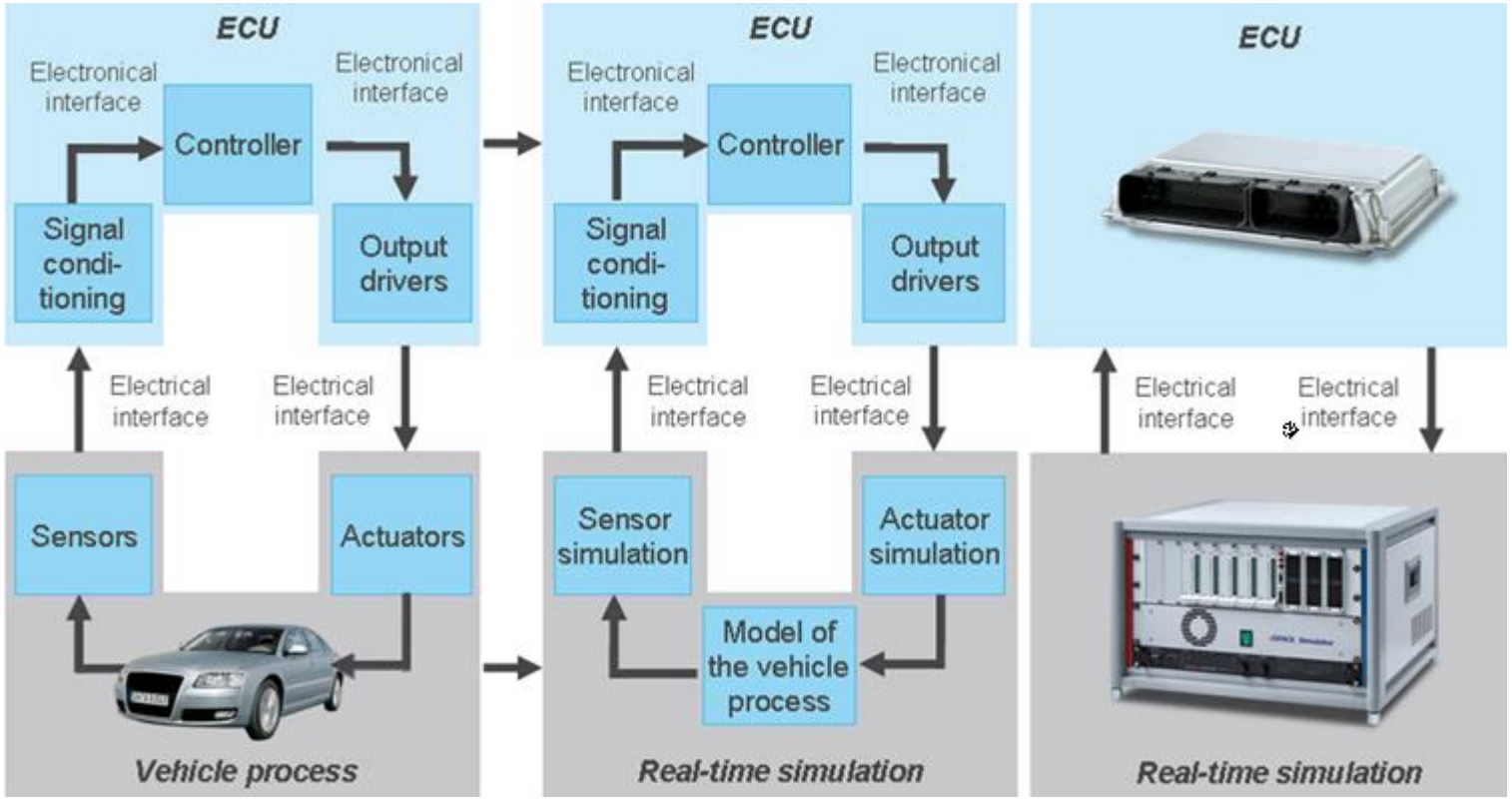

## Challenges

Standardization


Complex modeling required



# Hardware in Loop Simulation




Proto vehicle setup

Simulated vehicle setup

Simulated vehicle setup (HIL)

**Signal Flows in real system and HIL system**

Image Source: dSPACE Gmbh

# HIL setup

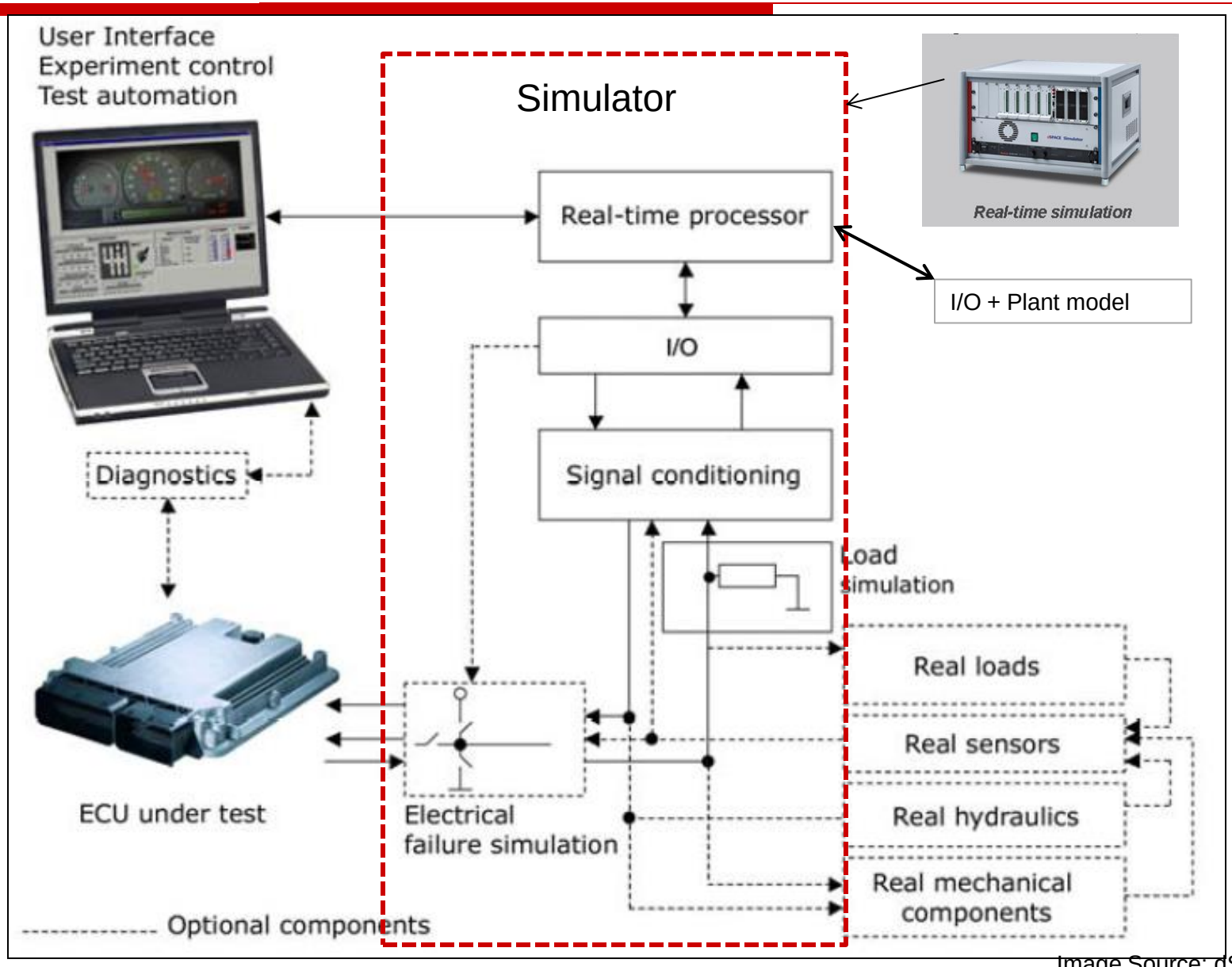
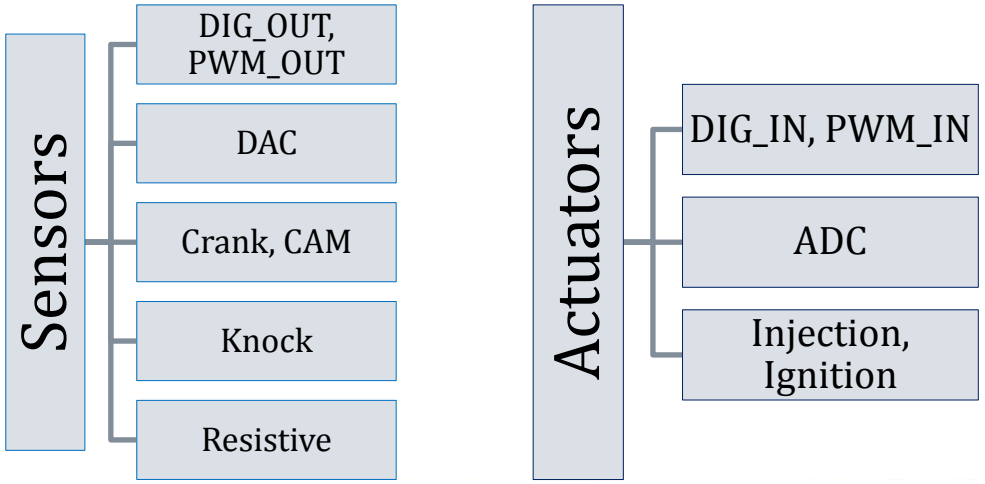



Image Source: dSPACE Gmbh

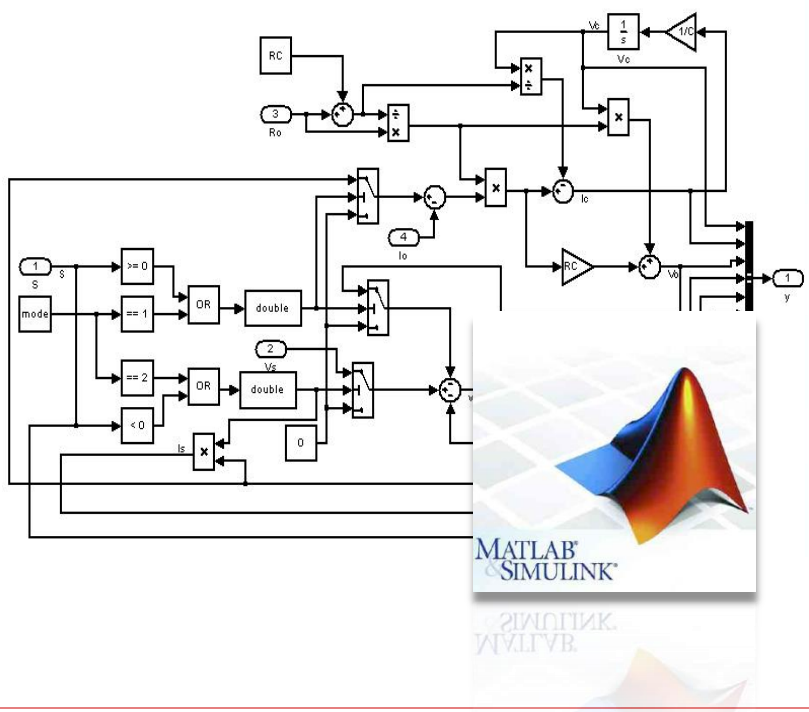
# Software components of HIL system

- Real time system – For simulation of sensors and observation of actuator signals (**IO-Open loop test configuration**)
- Dynamic Plant model (**Closed Loop test configuration**)



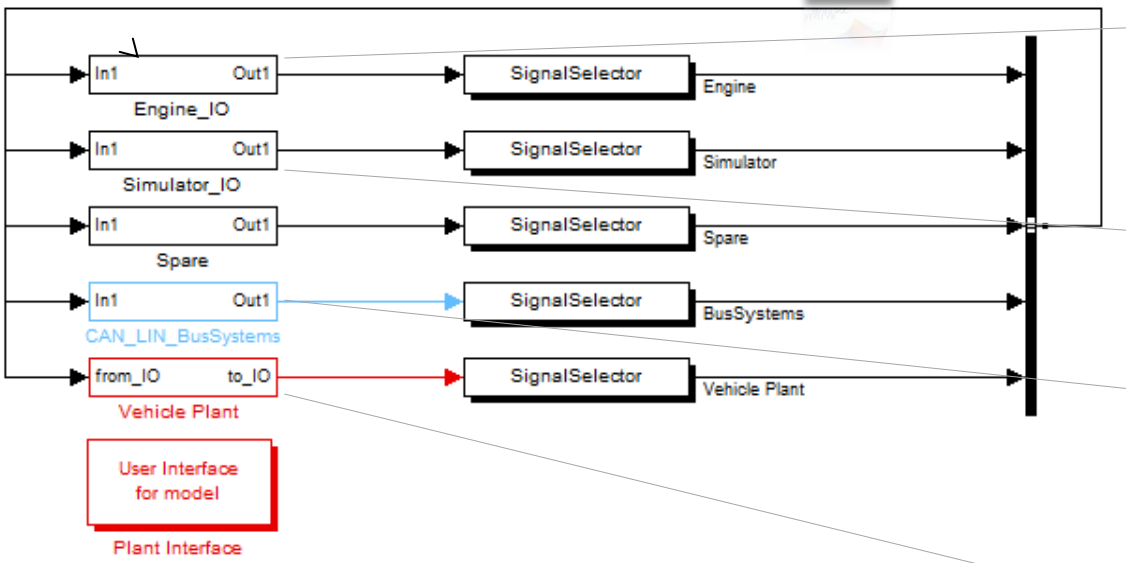

**Matlab/Simulink** to describe :

- The definition and configuration of the I/O
- The dynamic behavior of the plant



# Simulink Model Architecture

## ECU point of view architecture

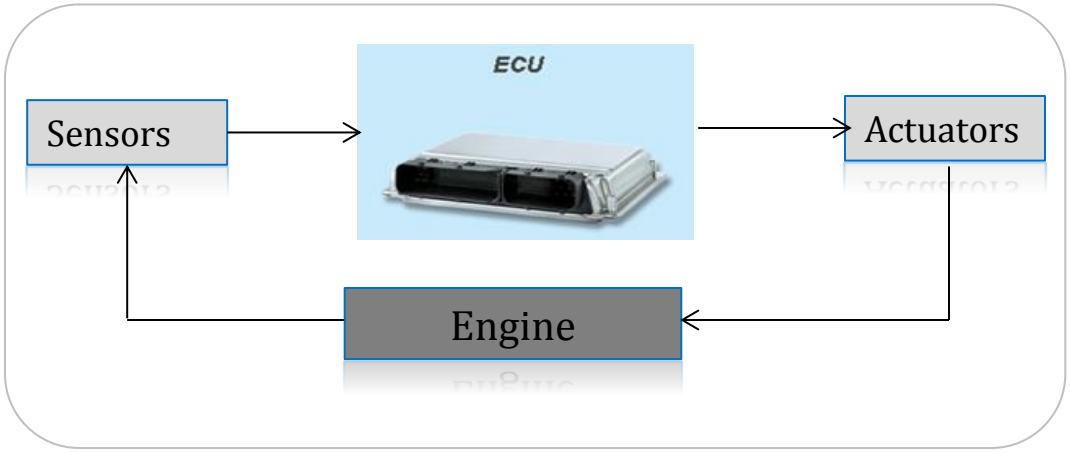



Engine IO: Sensor and actuator Interface

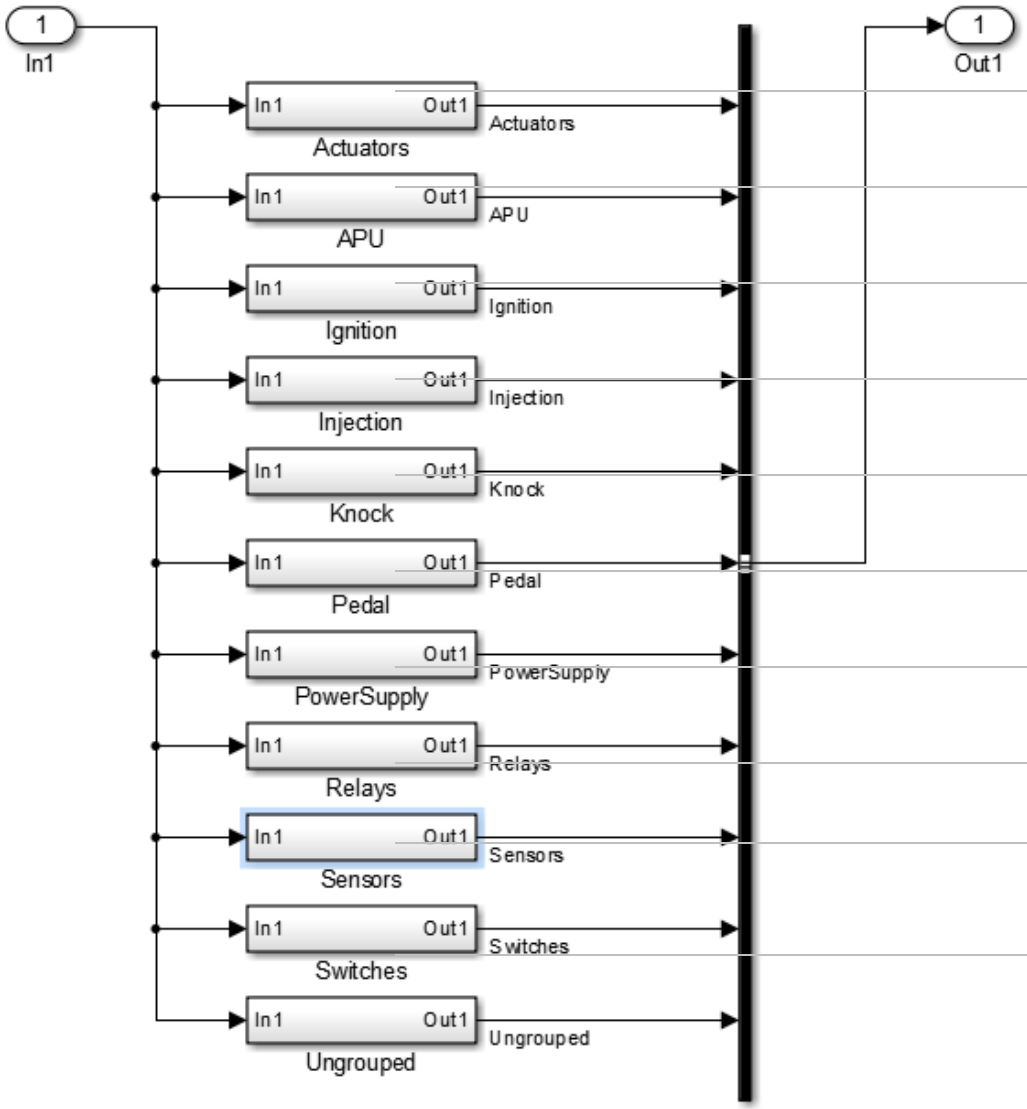
Simulator IO: Simulator and Relay control

Bus Systems: CAN and LIN bus interface

Vehicle Plant: Detailed engine and basic vehicle plant model

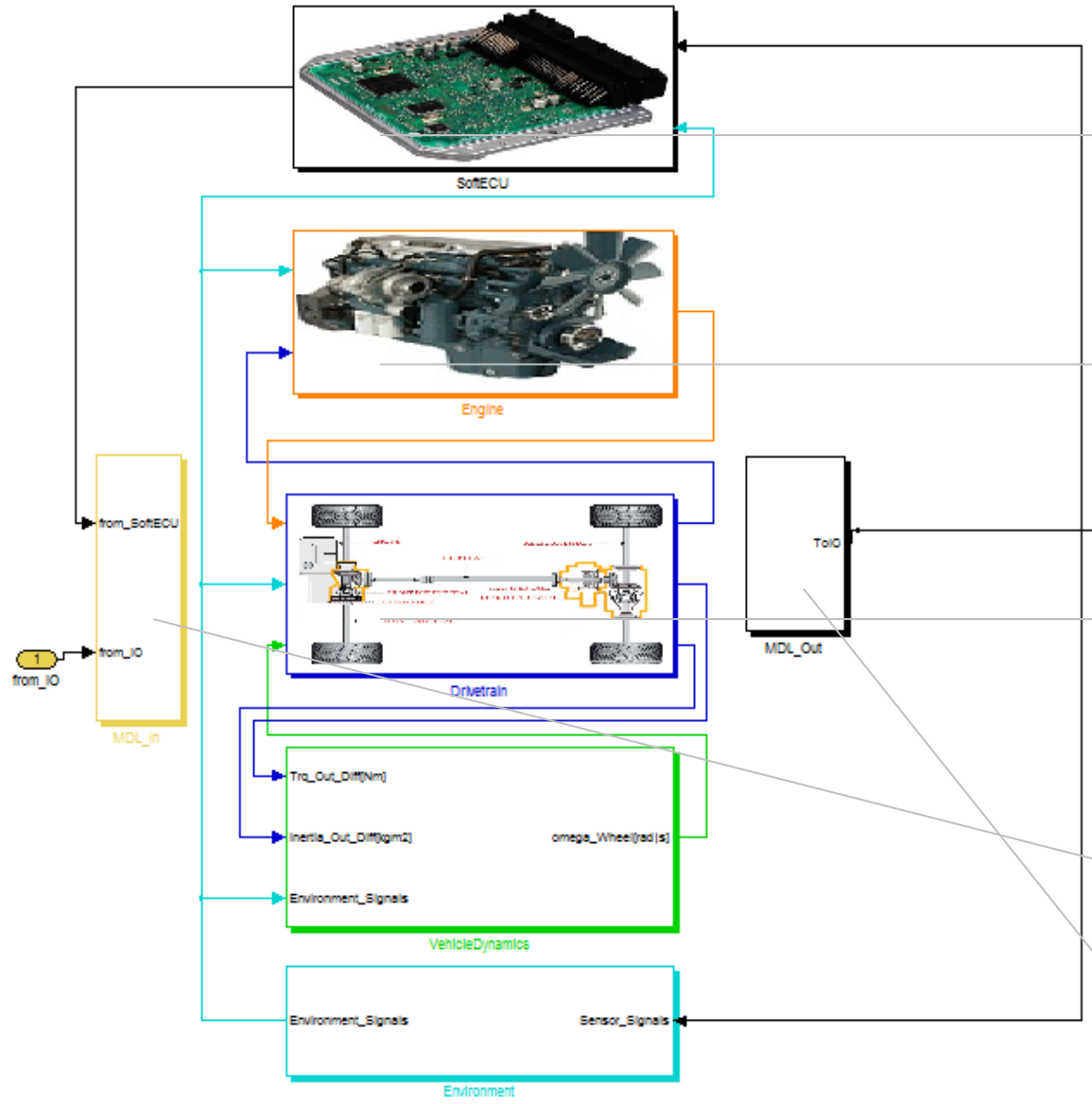


# Engine-IO Model Architecture




- Actuator Interface
- Crank and CAM sensor Interface
- Ignition angle capture
- Injection angle, timing capture
- Knock sensor simulation
- Accelerator pedal simulation
- Power supply (Battery Simulation)
- ECU controlled relay switching
- Analog sensor simulation
- Digital switch simulation

# Dynamic Vehicle Plant model




**Virtual ECU:** Basic Functionality of ECU to validate the plant model in SIL mode

**Engine Model:** Consists of Airpath, Fuel system and Mean torque model

**Drivetrain Model:** Consists of crankshaft, differential and starter model

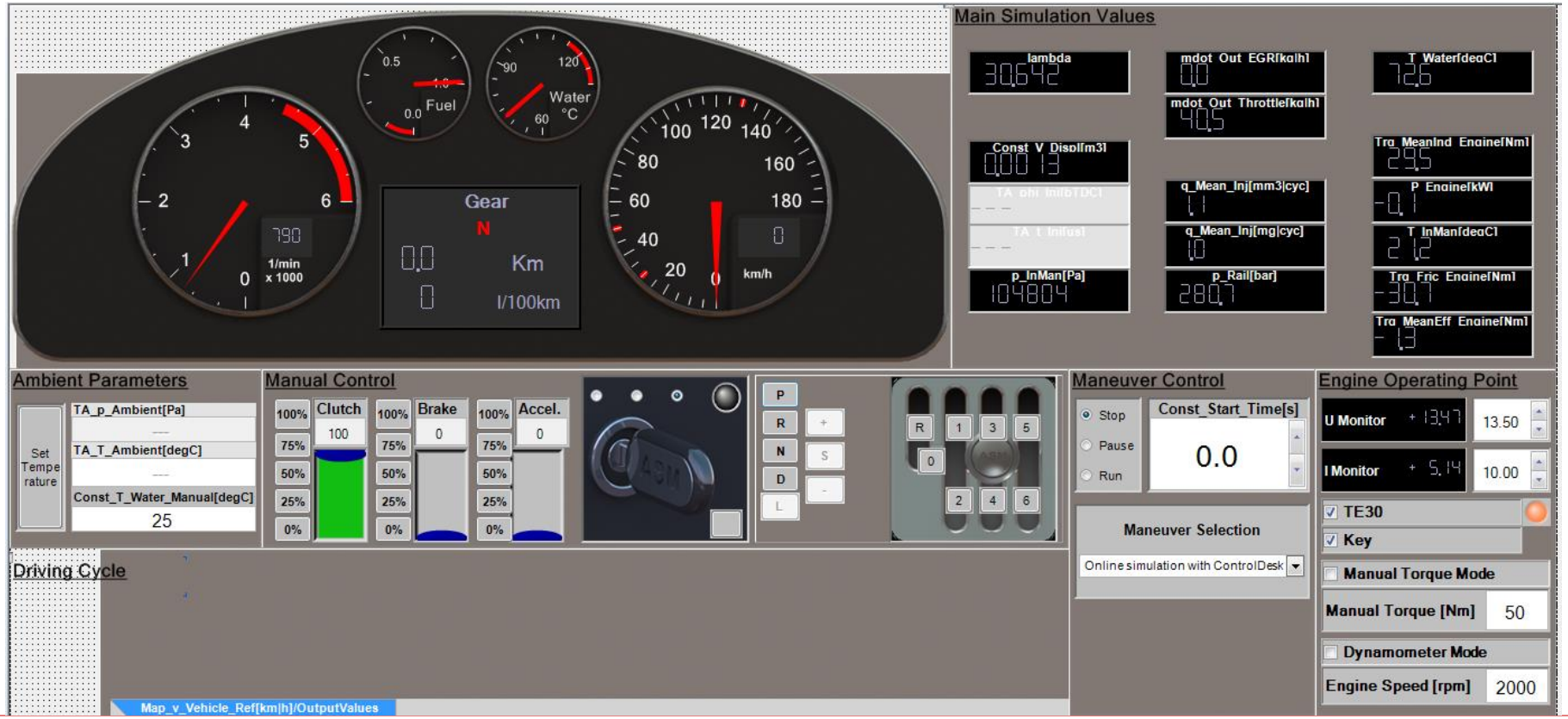
To select between virtual ECU and Actual ECU signals (HIL mode)

To output signals to Engine IO and BusSystems

# Tester-Simulator Interface

**Tester Interface for Manual Closed Loop Testing**

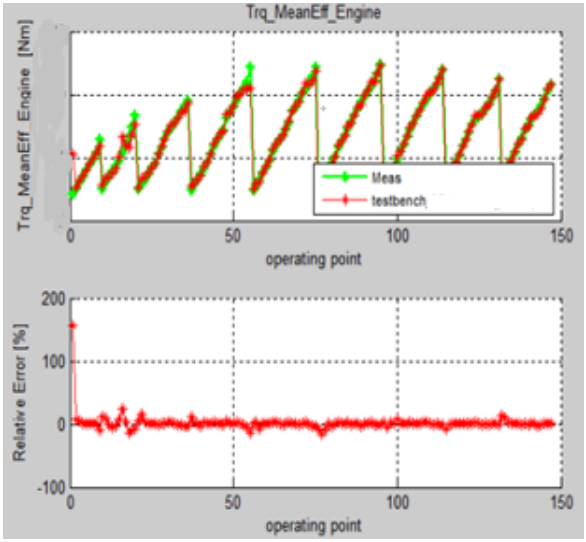
**Major Outputs:** Engine RPM, Vehicle speed, Indicated torque, Friction torque, Fuel injected, rail pressure, Intake manifold pressure



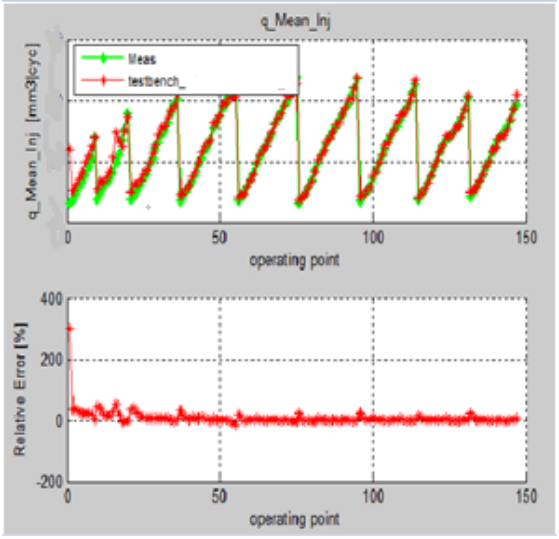
# Plant Model Results

## Simulation results compared with actual engine dyno data

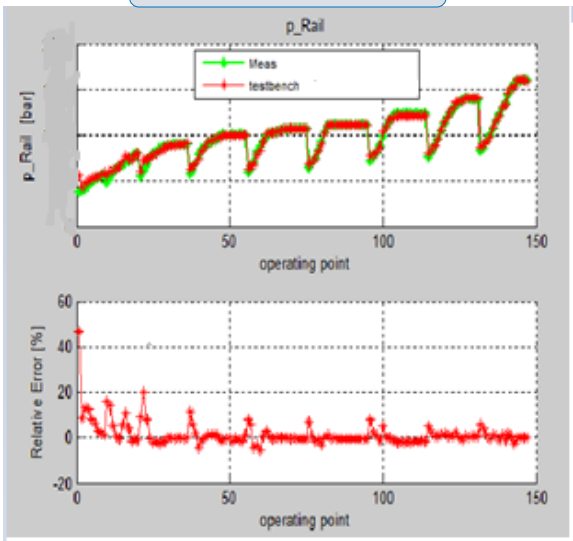
### Mean Effective torque



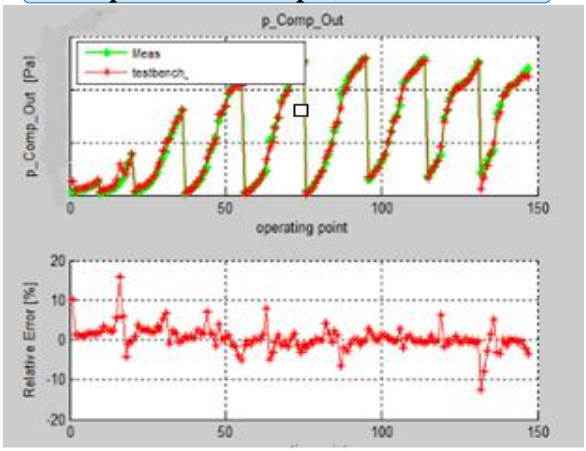

### Fuel Injection



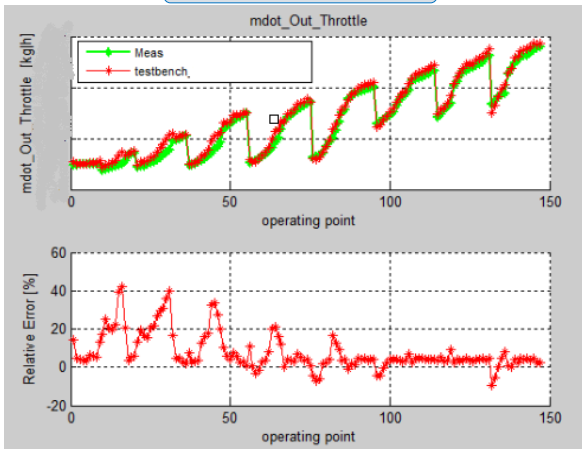

### Rail Pressure




### Compressor Output Pressure




### Air mass flow



# Summary

## Advantages of Hardware in loop

- ✓ Possible to simulate both Open loop and Closed loop tests
- ✓ Possible to simulate certain test cases that are not possible to simulate on proto vehicle
- ✓ Automated and regressive testing

## Advantages of Matlab/Simulink in Hardware in loop

- ✓ Input output libraries of major simulator providers are available in Matlab/Simulink
- ✓ Customizable models from different suppliers can be integrated with ease
- ✓ Reusability and standardization for different simulators and systems

# Thank You

## Q&A