Engine test bed's new capabilities based on real time simulation

Karan BANSAL
D2T

Generating excellence

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Simulation
Definition

- Imitate or reproduce the character or conditions of a physical element
- Hardware-in-the-Loop (HiL) simulation : The system to be tested (engine) interacts with the models simulating its environment
  - ✓ Has to be real-time
- Controllers
- Complex calculations

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Engine test-bed context

- Engine calibration process is more and more complex

- With increasing complexities of the complete automobile, it is becoming difficult to isolate the engine development from the vehicle development

- Need to increase the quality of tests performed on engine test-bed.

- The current financial context requires reducing engine calibration time and cost.

- Urgent need to make engine tests as efficient as possible
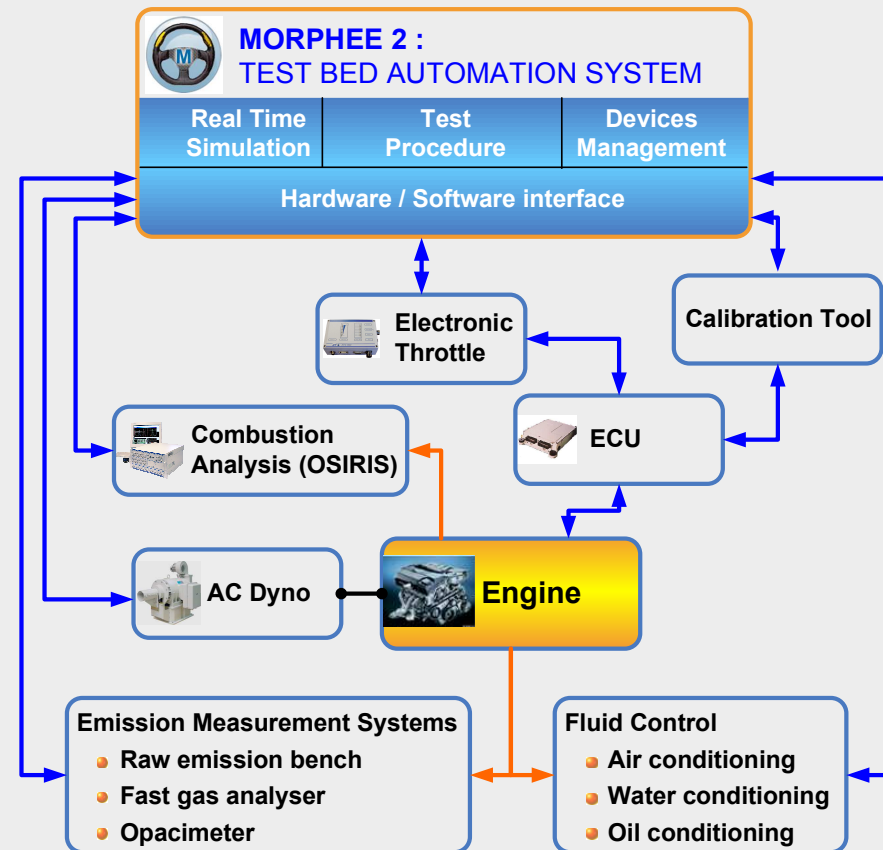
Engine test-bed perspective

- Simulation on engine test bed allows:
  - ✓ To reduce engine development costs by performing some new tasks on engine test-bed with reduced costs compare to roller test-bed

  - ✓ To reduce project time by reducing the need to wait for vehicle prototypes availability

  - ✓ To increase engine testing quality on engine test bed

Engine test-bed perspective
Simulation in automation System

- All data concerning the test, the engine, and the test bed are centralized into the automation system, models can inherit of them automatically

- Models independent of the engine test bed hardware communication

- To have a flexible architecture for future developments using the MORPHEE Component concept

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Engine test-bed perspective
Simulation in Morphee2

- Makes this capability accessible to all engine test bed with a reduced cost
  - ✓ Integration of simulation is only software upgrade, no need new hardware installation on the test bed

- For model definition in Matlab/Simulink only standard Simulink Toolbox are required.
  - ✓ No need to use dedicated Toolbox to make the link compatibility between the model and MORPHEE 2.
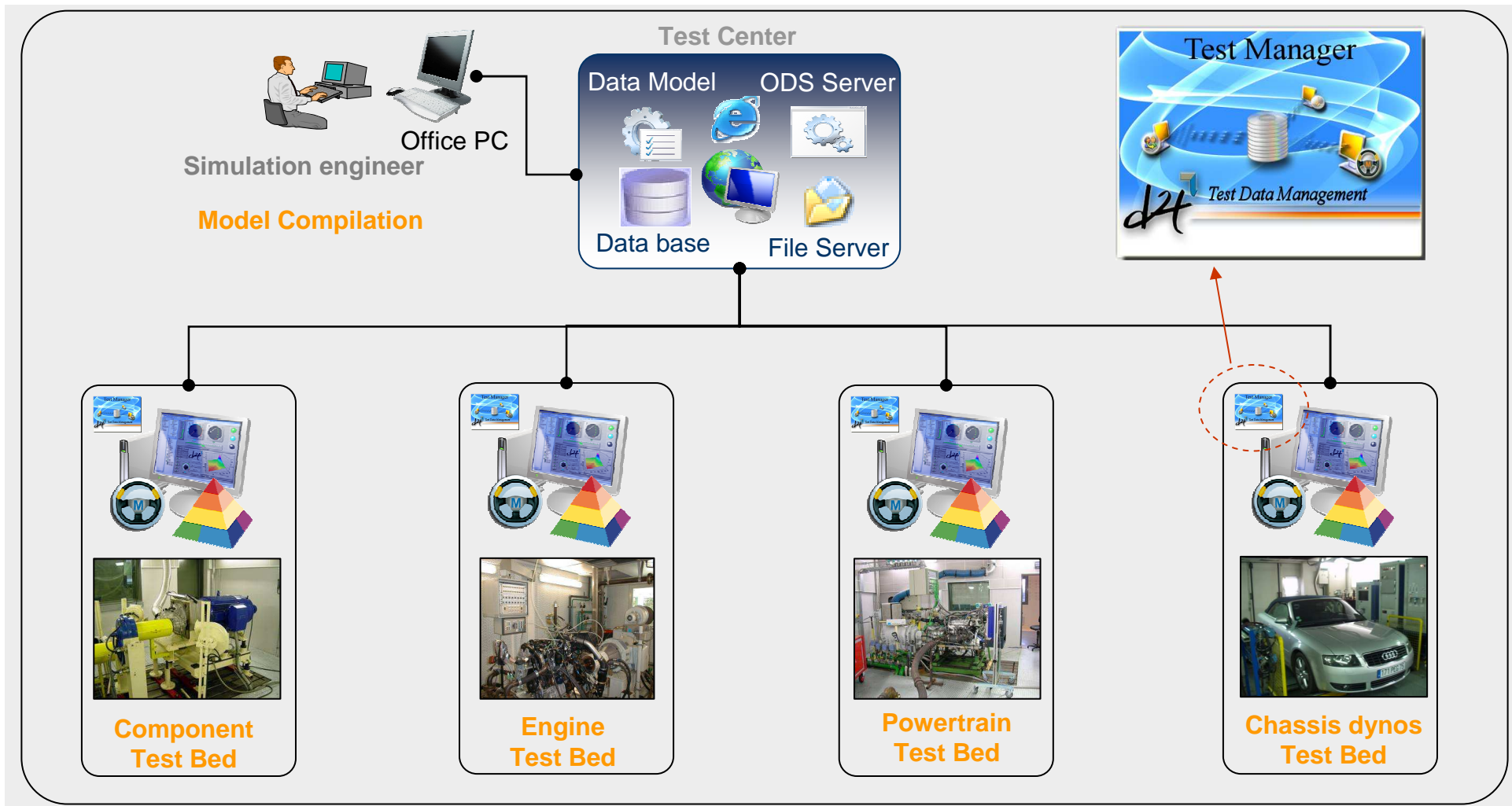 - ✓ Already existing models can be integrated easily

Engine test-bed perspective
Simulation in Morphee2

- Possibility to use several models in the same test and to link them together

- Possibility to adjust models' parameters during the test execution

- Easier to manage w.r.t. data storage and distribution

- *Homogeneous tests : same test procedures can be executed over different types of test-beds*

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Test Manager Client
A unique interface for all test cells

Test Center

Simulation engineer

Office PC

Model Compilation

Data Model   ODS Server

Data base   File Server

Test Manager

Test Data Management

Component Test Bed

Engine Test Bed

Powertrain Test Bed

Chassis dynos Test Bed

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- **Simulation: Engine test-bed perspective**

- **Implementation examples.**
  - ✓ Simudyn2
  - ✓ HyHIL
  - ✓ CAN
  - ✓ Test-bed controller
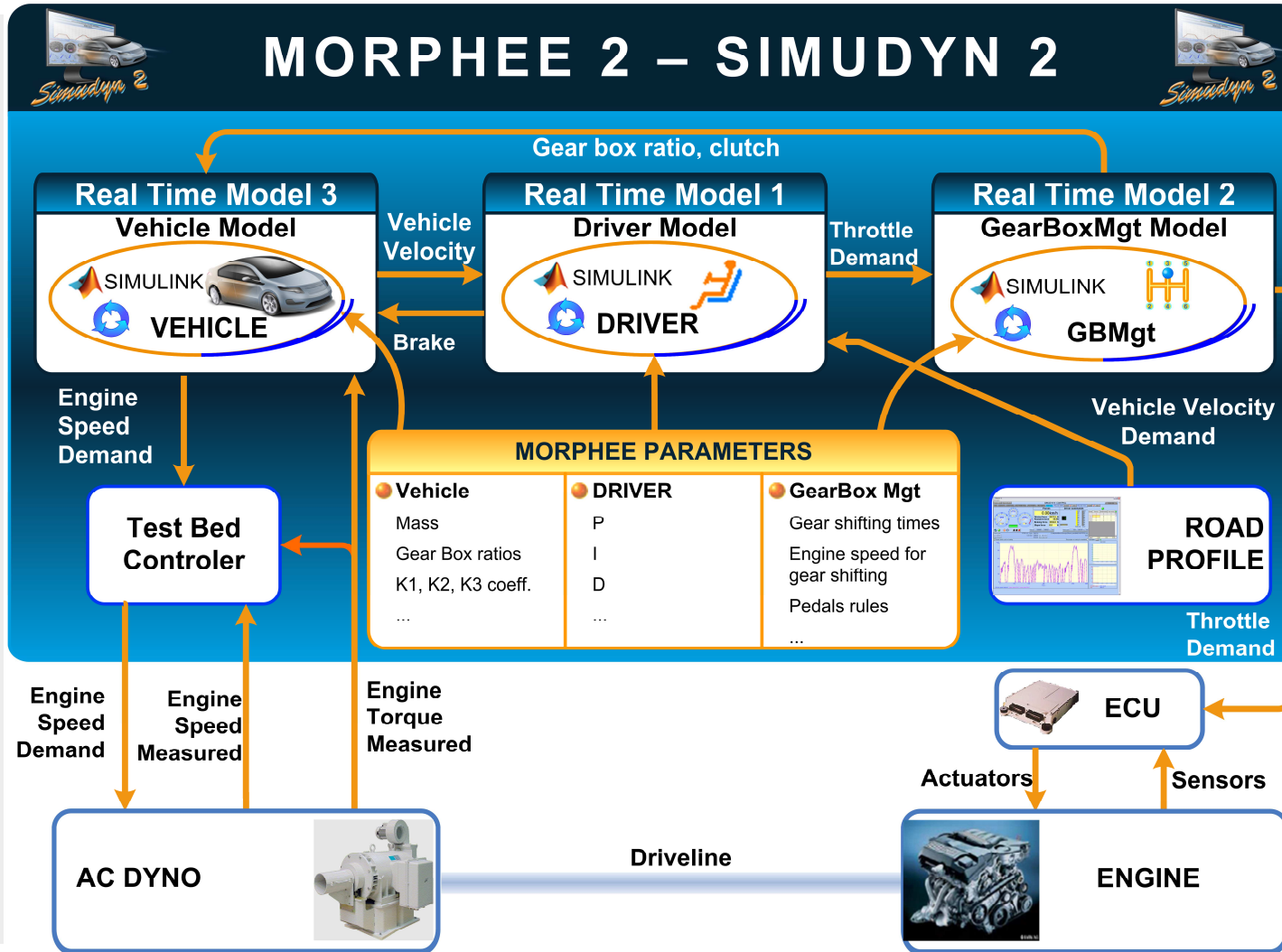
- **Conclusion**

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- D2T product to reproduce the dynamic behavior of the vehicle directly on the engine test-bed.

- Installed on D2T test beds and various customer Test Beds

- Possible to reproduce representatively the certification procedures of roller test-bed directly on the engine test-bed.

- Predict the pollutant emissions over certification cycles.

SIMUDYN 2
Advantages

- Customization of the vehicle models by various physical parameters which are provided.

- Customization of the driver behavior by various management parameters which are provided.

- Reduce expenditure by using a test facility which has a less exploitation cost than a roller test-bed.

- Highly Repeatable tests.

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MORPHEE 2 – SIMUDYN 2

Gear box ratio, clutch

Real Time Model 3		Real Time Model 1		Real Time Model 2
Vehicle Model		**Driver Model**		**GearBoxMgt Model**
SIMULINK VEHICLE	Vehicle Velocity	SIMULINK DRIVER	Throttle Demand	SIMULINK GBMgt

Brake

Engine Speed Demand

Vehicle Velocity Demand

MORPHEE PARAMETERS

Vehicle	DRIVER	GearBox Mgt
Mass	P	Gear shifting times
Gear Box ratios	I	Engine speed for gear shifting
K1, K2, K3 coeff.	D	Pedals rules
...	...	...

Test Bed Controler

ROAD PROFILE

Throttle Demand

Engine Speed Demand **Engine Speed Measured** **Engine Torque Measured**

ECU

Actuators   **Sensors**

AC DYNO   Driveline   **ENGINE**

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ROAD CYCLE

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- Tests done over different engines

	NOx(g/mile)		
	Test 1	Test 2	Test 3
Roller test-bed Real vehicle	0.166	0.16	0.173
Engine test-bed SIMUDYN 2	0.187	0.230	0.182

Gear

Acceleerator pedal

Engine RPM

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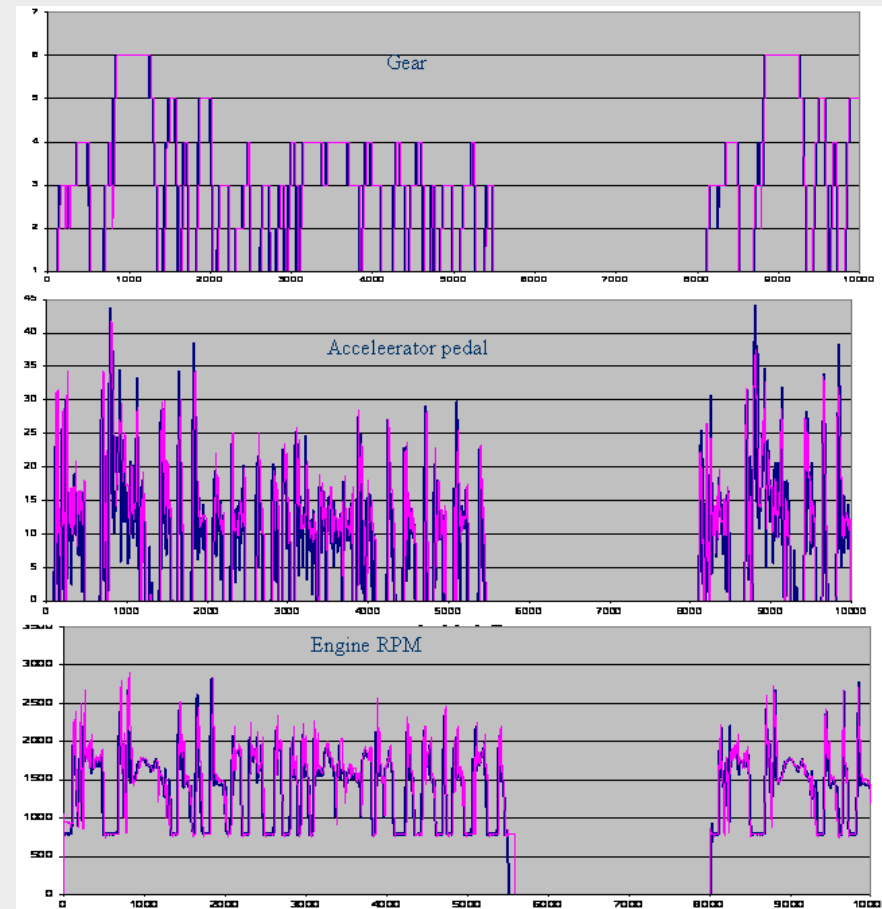
SIMUDYN 2
Results: Repeatability

	CO (g/test)	CO2 (g/test)	HC (g/test)	NOX (g/test)	CS (l/100km)
Test 1	0.91	244.45	0.38	1.207	9.27
Test 2	0.89	244.64	0.38	1.207	9.27
Test 3	0.91	245.18	0.4	1.204	9.3
Test 4	0.91	244.45	0.4	1.209	9.27

	CO (g/test)	CO2 (g/test)	HC (g/test)	NOX (g/test)	CS (l/100km)
Mean	0.905(1)	244.68	0.39	1.20675	9.2775
Standard deviation	0.0075(2)	0.2500	0.0100	0.0014	0.0113
Relative Error	0.83%(3)	0.10%	2.56%	0.11%	0.12%

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Hybrid Research Program
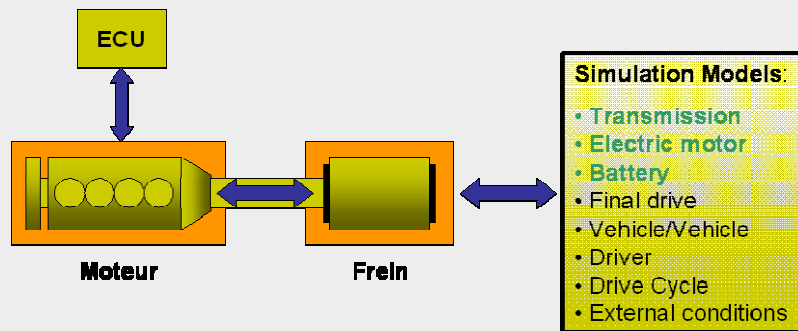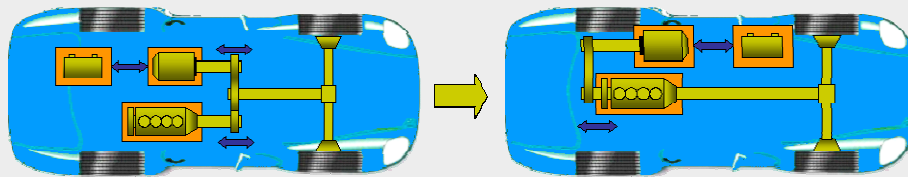## *Introduction*

- To develop a chain of software tool to predict hybrid powertrain performances on an engine test bed
- Why: To anticipate the take into account of the hybrid powertrain in an engine development project
- Partnership:
  - ✓ D2T
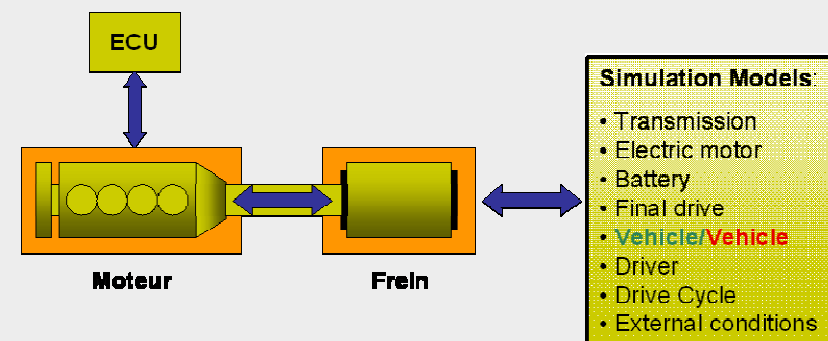 - ✓ IFP
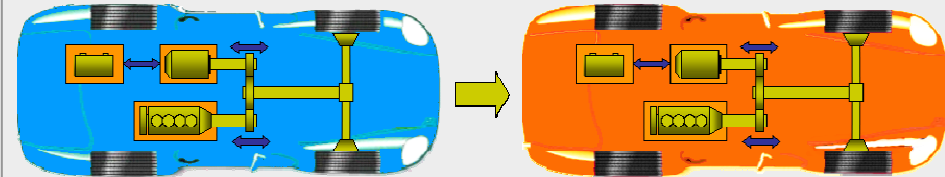 - ✓ LMS-IMAGINE
  - ✓ G2ELAB
  - ✓ RENAULT
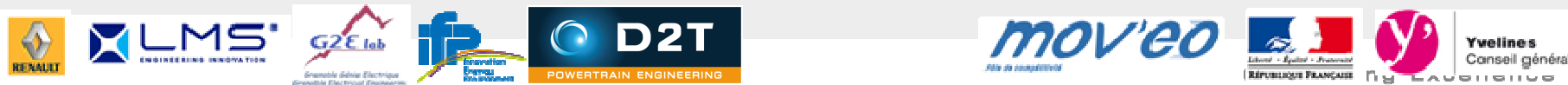
Hybrid Research Program
Introduction

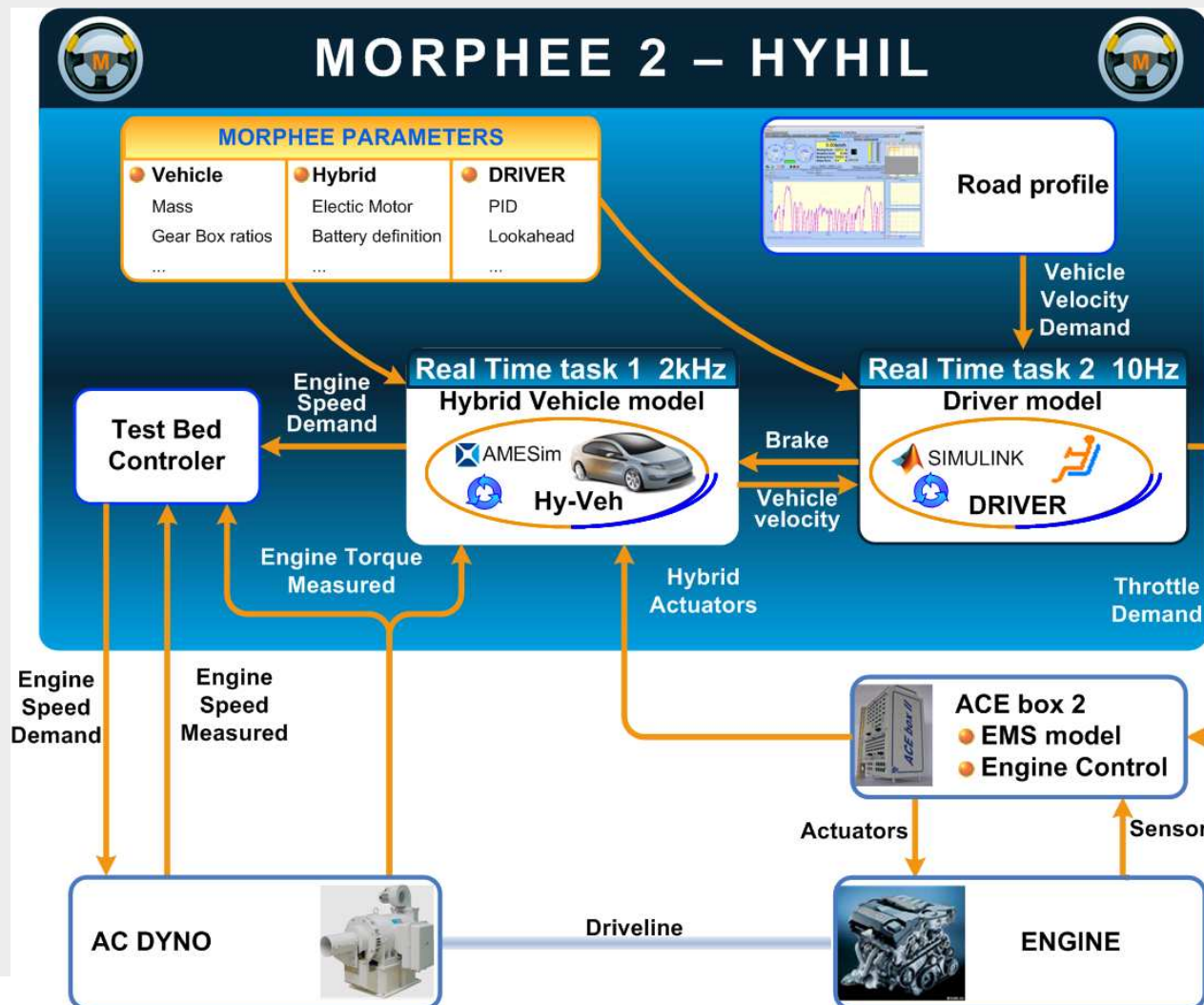- Evaluate several powertrain architecture on a vehicle

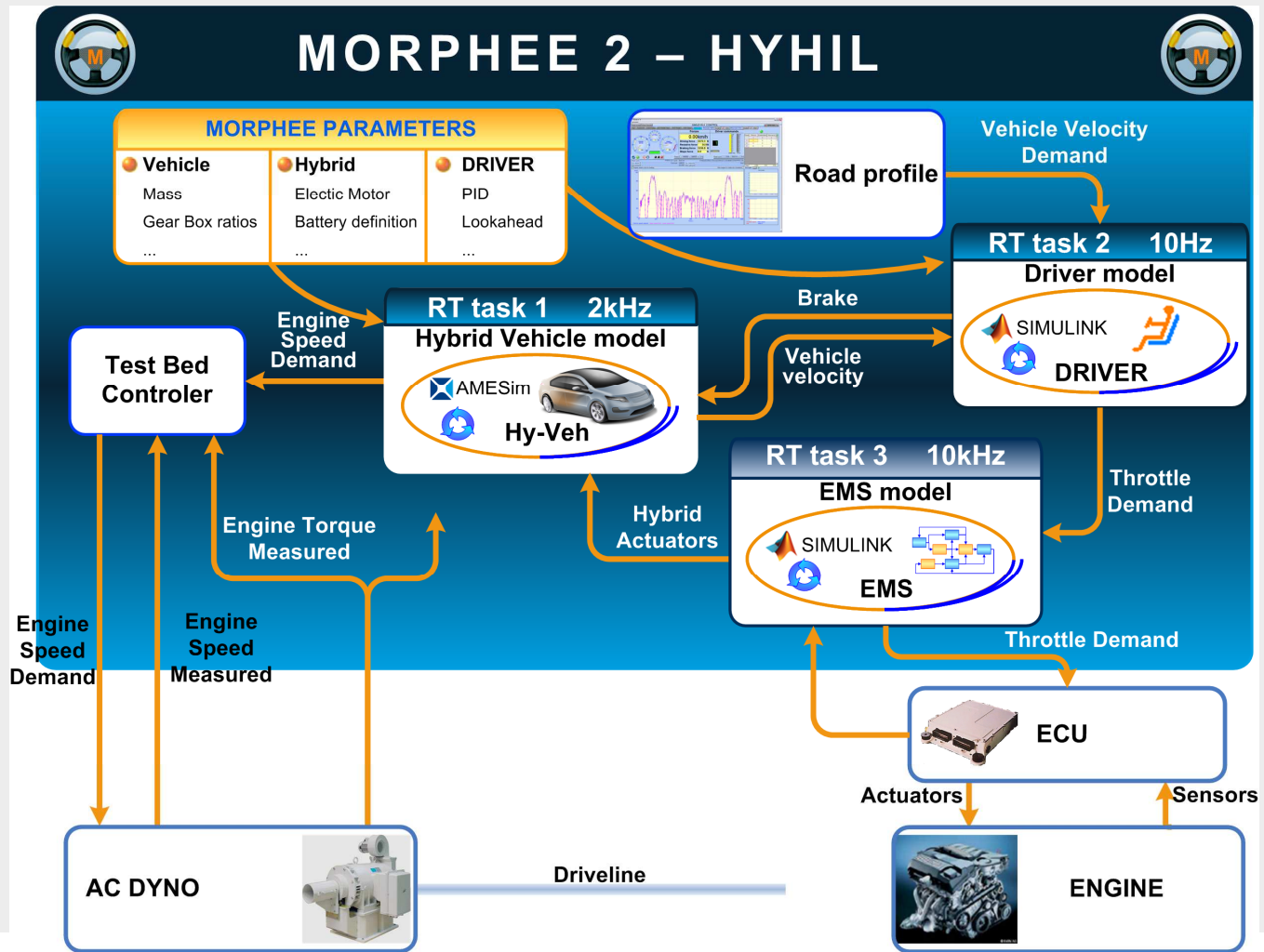- Evaluate a powertrain architecture on several vehicle

Simulation Models:
- Transmission
- Electric motor
- Battery
- Final drive
- Vehicle/Vehicle
- Driver
- Drive Cycle
- External conditions

Simulation Models:
- Transmission
- Electric motor
- Battery
- Final drive
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- Driver
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- External conditions

ECU

Moteur   Frein

ECU

Moteur   Frein

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Hy-HIL
Principle

D2T
POWERTRAIN ENGINEERING

MORPHEE 2 – HYHIL

MORPHEE PARAMETERS

Vehicle	Hybrid	DRIVER
Mass	Electic Motor	PID
Gear Box ratios	Battery definition	Lookahead
...	...	...

Road profile

Vehicle Velocity Demand

RT task 2   10Hz
Driver model
SIMULINK
DRIVER

Test Bed Controler

Engine Speed Demand

RT task 1   2kHz
Hybrid Vehicle model
AMESim
Hy-Veh

Brake

Vehicle velocity

RT task 3   10kHz
EMS model
SIMULINK
EMS

Throttle Demand

Engine Torque Measured

Hybrid Actuators

Engine Speed Demand

Engine Speed Measured

Throttle Demand

ECU

Actuators

Sensors

AC DYNO

Driveline

ENGINE

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Hy-HIL
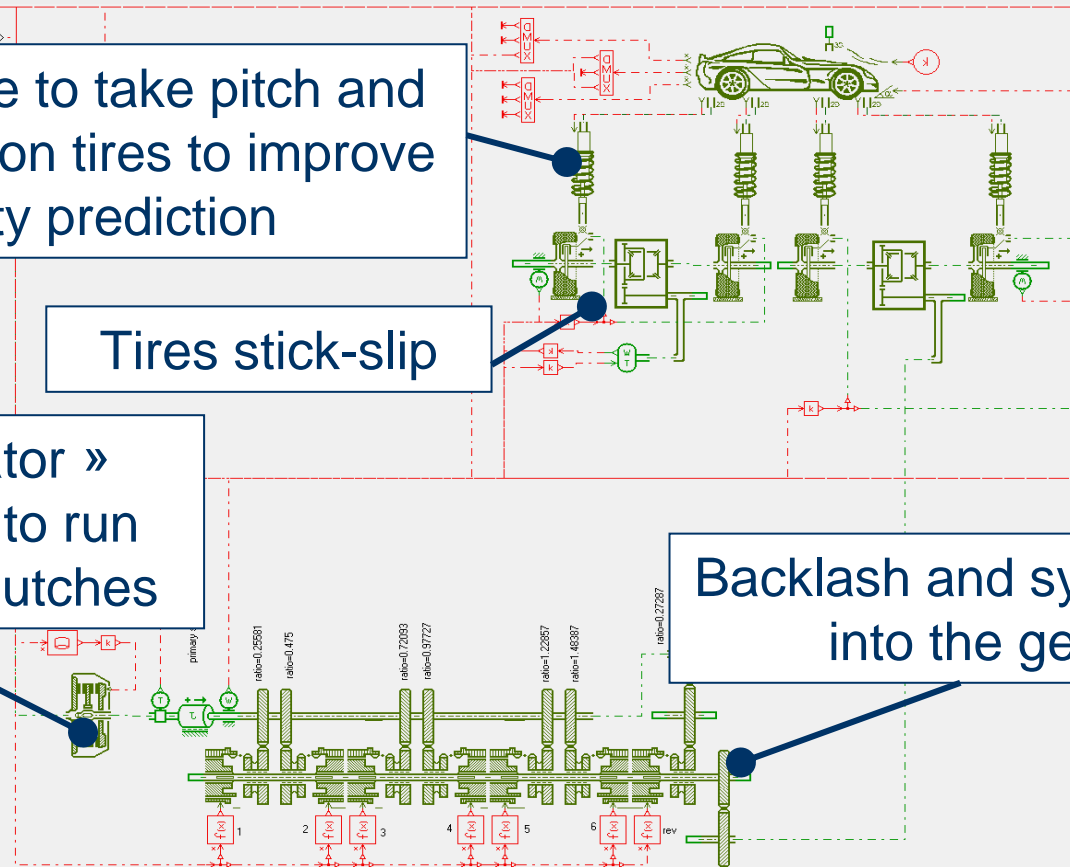## *Passenger car drivability strategies evaluation*

- Using high dynamic vehicle simulation it is possible to evaluate engine drivability strategies on the engine test bed.

Add 2D vehicle to take pitch and changing load on tires to improve drivability prediction
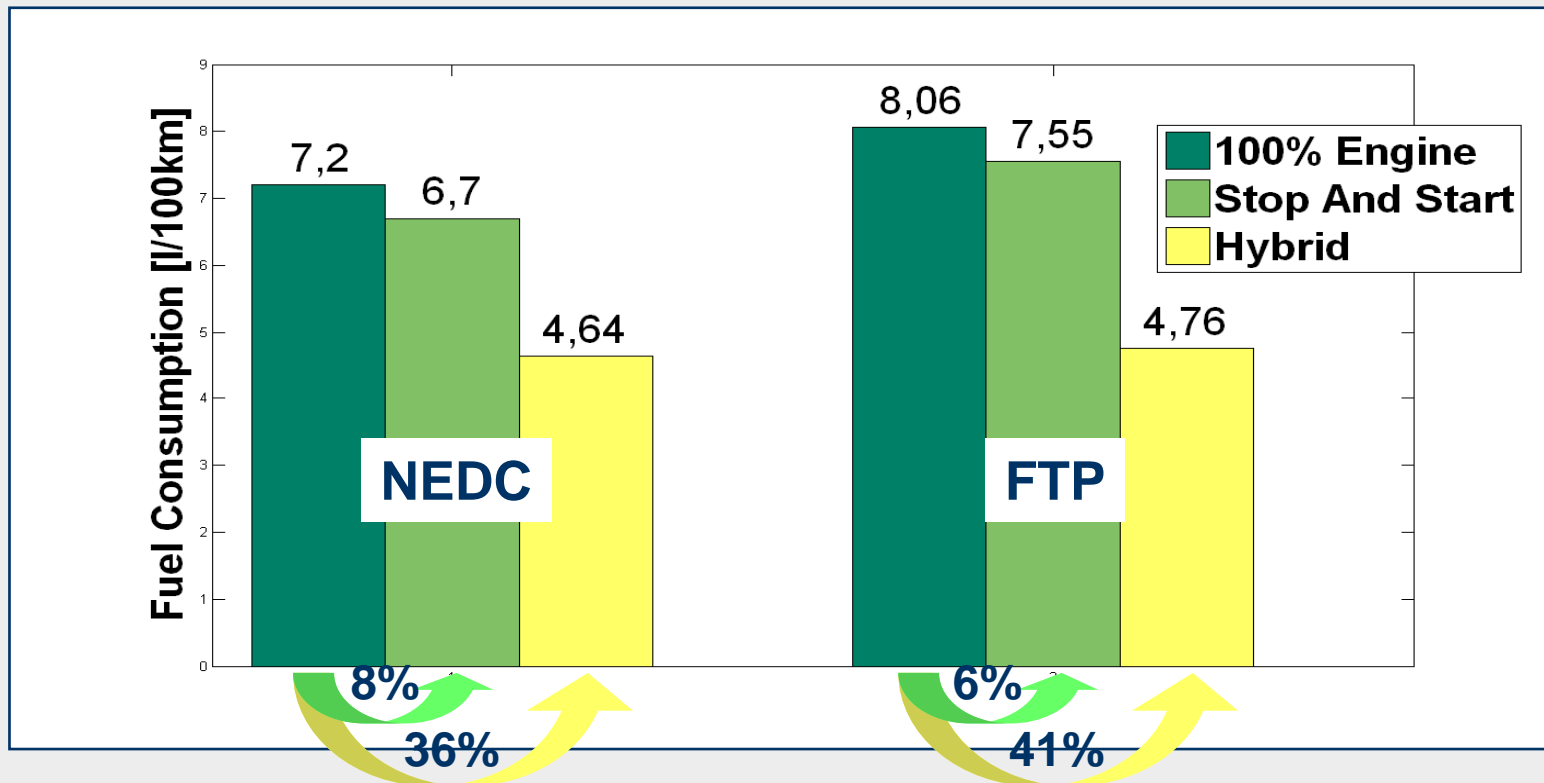
Tires stick-slip

«Reset-integrator» frictions models to run friction parts of clutches

Backlash and synchronizers into the gear box

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Hy-HIL
Results Fuel consumption on different platforms

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POWERTRAIN ENGINEERING

Fuel Consumption [l/100km]

NEDC
- 7,2 — 100% Engine
- 6,7 — Stop And Start
- 4,64 — Hybrid
- 8%
- 36%

FTP
- 8,06 — 100% Engine
- 7,55 — Stop And Start
- 4,76 — Hybrid
- 6%
- 41%

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Hy-HIL
Results Fuel consumption on different platforms

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POWERTRAIN ENGINEERING

NEDC	Engine	Stop And Start		Hybrid	
	1600 kg	1600 kg	Gain	1900 kg	Gain
Simulation	7.01	6.46	7.8%	4.2	40.1%
HIL	7.19	6.63	7.8%	4.42	38.5%
Test bed	7.2	6.7	7.9%	4.64	36.3%

FTP	Engine	Stop And Start		Hybrid	
	1600 kg	1600 kg	Gain	1900 kg	Gain
Simulation	7.78	7.26	6.4%	4.41	43.3%
HIL	7.97	7.45	6.5%	4.52	43.3%
Test bed	8.06	7.55	6.3%	4.76	41%

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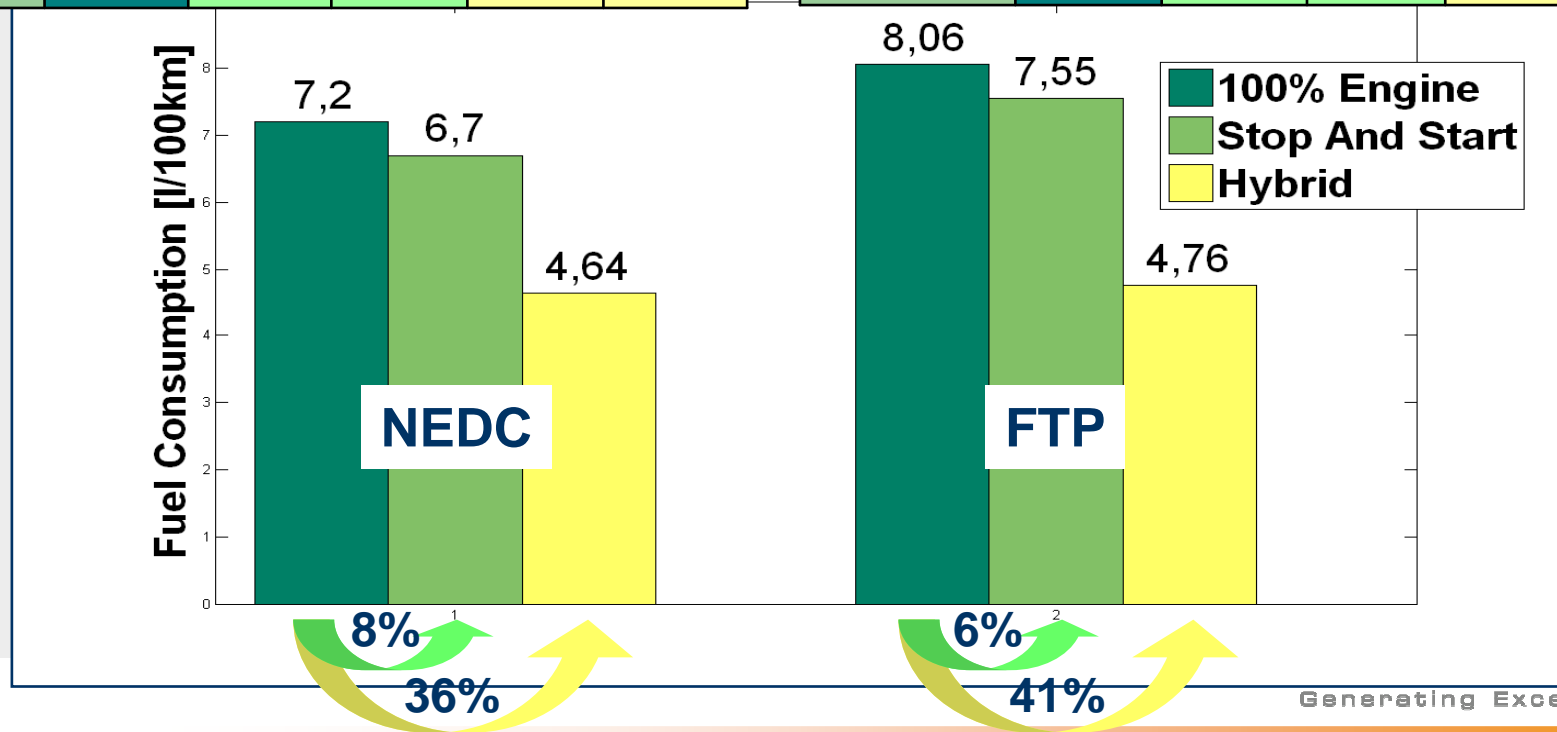
Hybrid Research Program
Conclusion

- Based on future MORPHEE 2 product version allowing real-time models distribution in multiple processors

- Capability to perform parametric studies on the test bed for powertrain architecture definition

- Possibility to evaluate pollutant emissions during cold and hot start emission cycle

- The architecture defined has a high level of flexibility

- Benefits

- Allows to define EMS control stategies directly on the engine test bed:

  - ✓ Take into account engine post treatment control strategies

  - ✓ Possibility to evaluate driveability strategies impacts

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- **Implementation examples.**
  - ✓ Simudyn2
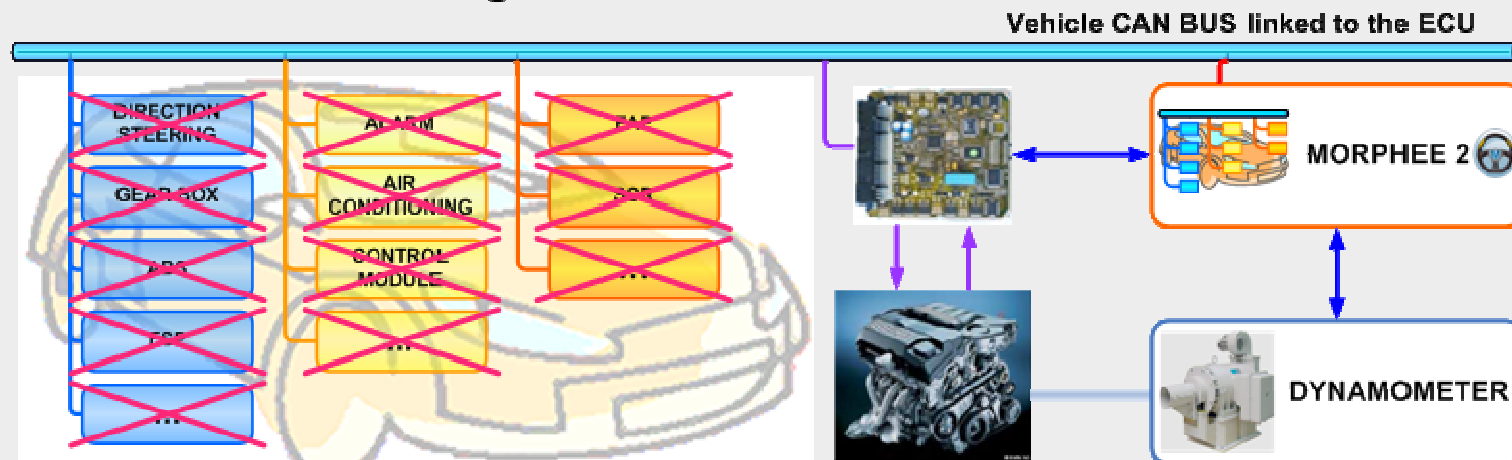 - ✓ HyHIL
  - ✓ CAN
  - ✓ Test-bed controller

- **Conclusion**

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CAN BUS SIMULATION
Context

ECU environment in a vehicle

Vehicle CAN BUS linked to the ECU

- DIRECTION STEERING
- GEAR BOX
- ABS
- ESP
- ...
- ALARM
- AIR CONDITIONING
- CONTROL MODULE
- ...
- FAP
- SCR
- ...
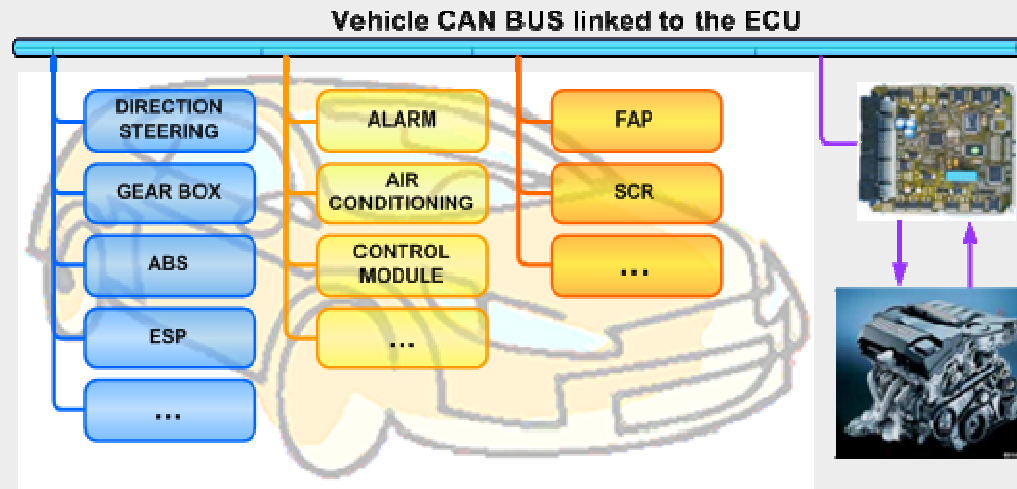
ECU environment in an engine test bed

Vehicle CAN BUS linked to the ECU

MORPHEE 2

DYNAMOMETER

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CAN BUS SIMULATION
Solution: Automatic Interface Generation

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Ready to read and write signal values on the automotive network.

Network automatically defined in MORPHEE environment
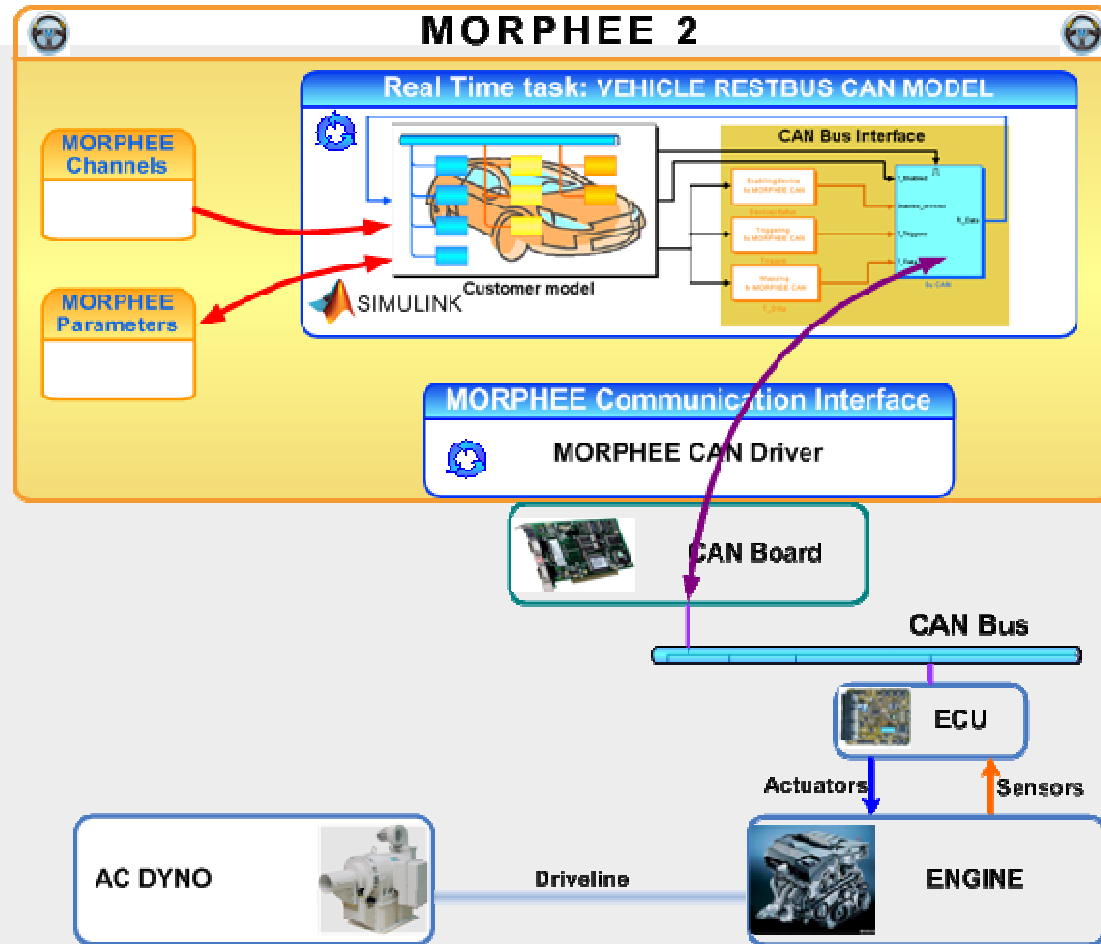
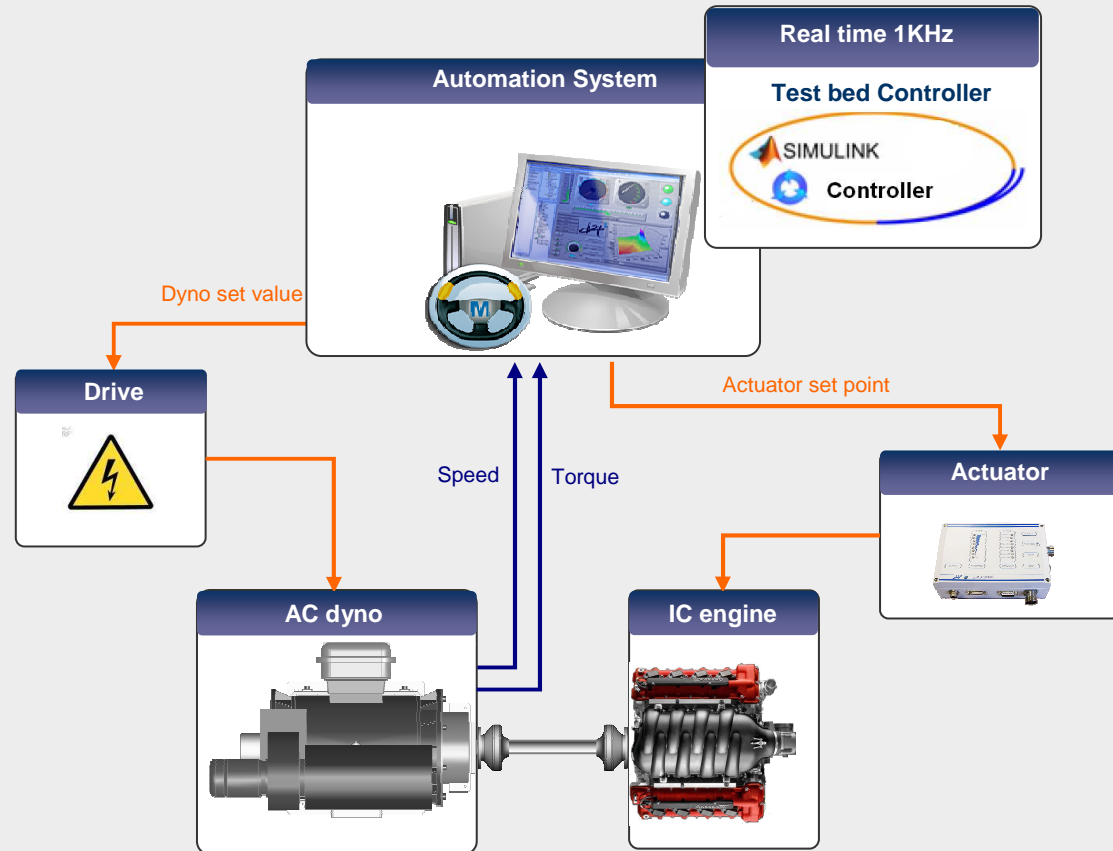## The ECU works in its home electronical conditions

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Test Bed Controllers
Engine Test-Bed
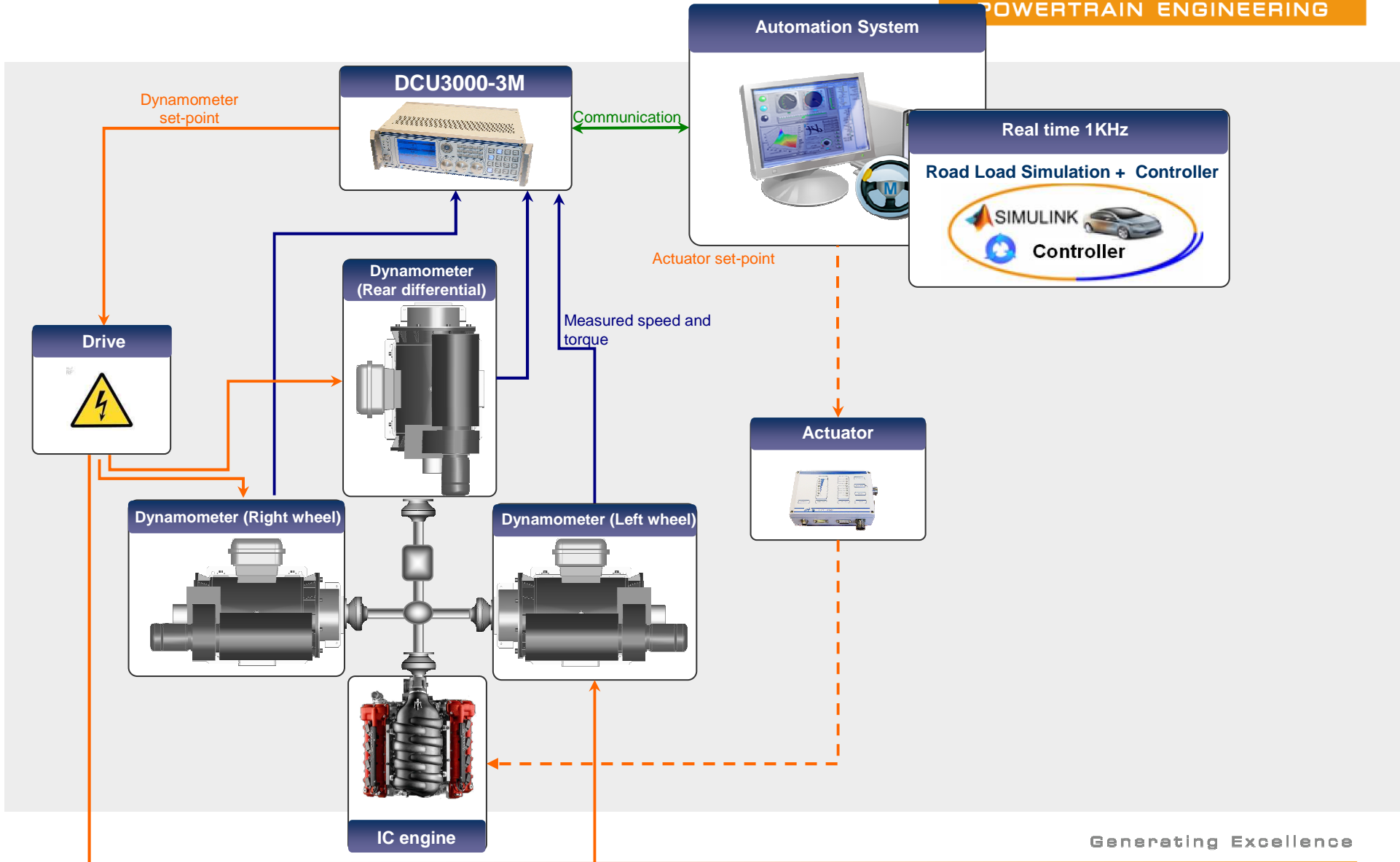
- Possibility to control the test-bed

- Controller model executing at 1kHz in MORPHEE 2

- Controls Dynamometer and Engine

Automation System

Real time 1KHz

Test bed Controller

SIMULINK

Controller

Dyno set value

Actuator set point

Drive

Actuator

Speed   Torque

AC dyno

IC engine

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Test Bed Controllers
Powertrain Test-Bed

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- **Simulation: Engine test-bed perspective**

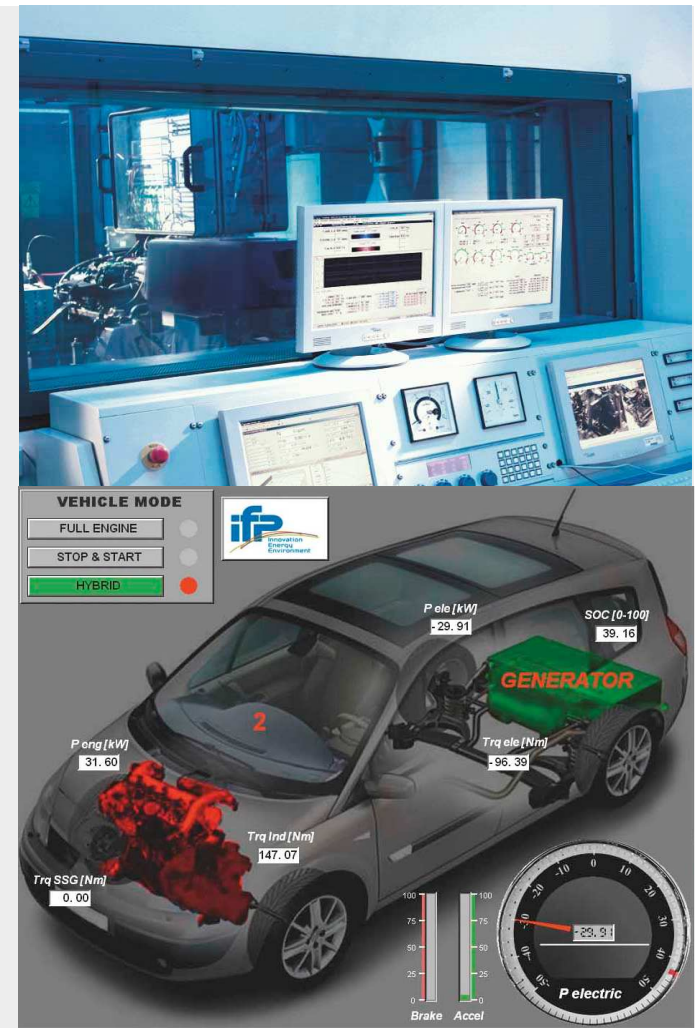- **Implementation examples**

- **Conclusion**

CONCLUSION
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Real Time simulation : an integral part of New generation of Test Bench

- Earlier RT Simulation was limited of few Test Beds
- Now MORPHEE 2 makes it possible to have it on every test beds
- Near future = Multiprocessing

Thanks for your attention
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