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GRPE-HDH Research Project
Status IFA, TU Vienna

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Outline
GRPE-HDH TU Vienna

- Introduction
- Provisional Results of Task 1
  - Review of Interface Model
  - Review of Simulation Model
    - Analysis of the Japanese Simulation Model
    - Suggestions for Modification for a potential global technical regulation
  - Model Verification Process
- Provisional Results of Task 2
- Time Schedule

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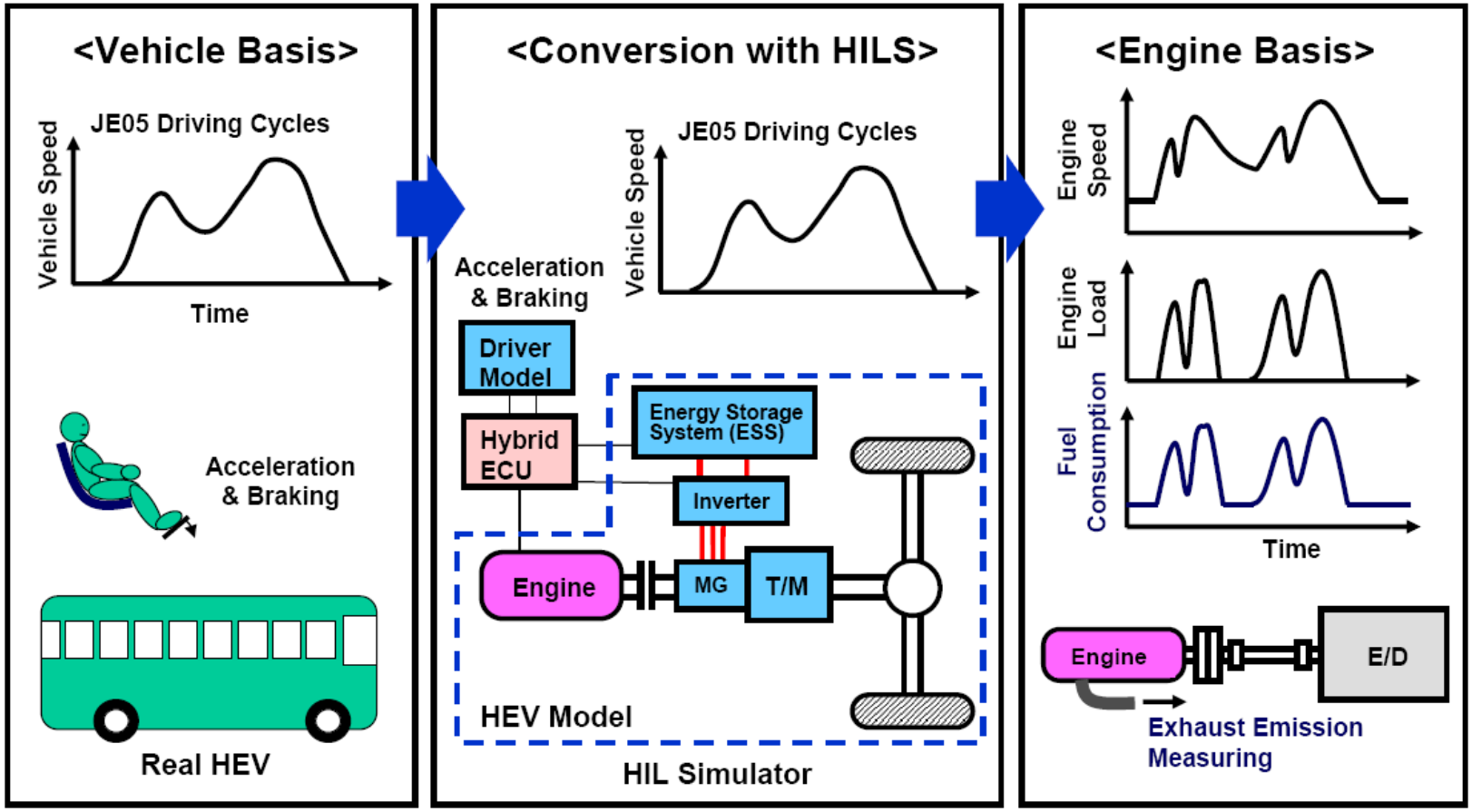
Development of an exhaust emissions and CO_2 measurement test procedure for heavy duty hybrids (HDH)

Introduction

- Japanese HILS method for Heavy Duty Hybrid Vehicle Certification:



Development of an exhaust emissions and CO_2 measurement test procedure for heavy duty hybrids (HDH)

Tasks and research institutes

Task	TU Vienna	TU Graz	Chalmers
#1: Investigation and modification, if applicable, of the HILS model and interface	+++	++	+
#2: Investigation and modification, if applicable, of the HILS component testing	+++		
#3: Extension of HILS to non-electrical hybrids			+++
#4: Inclusion of PTO operation, which normally takes place outside the test cycle		+++	+
#5: Development of WHVC weighting/scaling factors to represent real world vehicle operation		+++	+

+++ main work; ++ single work package; + consulting and dialogue

IFA – PROJECT APPROACH

Task 1: Investigation and modification, if applicable, of the HILS model and interface; this should include a proposal for a verification method without vehicle testing

- Review of the simulation models and submodels used in the Japanese method
  - Modeling method
  - Level of detail, performance, accuracy
  - Simplicity
  - Universality

- Review of interface and software setup
  - Interface is used to connect real Hardware-Hybrid-ECU and simulated engine+powertrain.
  - Interface also provides vehicle-specific signals necessary for proper vehicle operation, which are not considered by the HW-ECU or SW-vehicle model (e.g. outputs of a Gearbox-control unit).

IFA – PROJECT APPROACH

Task 1: Investigation and modification, if applicable, of the HILS model and interface; this should include a proposal for a verification method without vehicle testing

- ☐ Analysis of improvements and relevant gaps for a global regulation
  - Meetings with HDV manufacturers to determine the spectrum of current and future HDH powertrain configurations.
  - Meetings with HDV manufacturers to investigate which additional interface I/Os are needed.
  - Assessment of the possibility to run distributed Hardware Control Units.
  - Determination of the powertrains‘ necessary level of detail.
  - Necessary changes to the Japanese HILS will be outlined.
- ☐ Analysis of the necessary preparation work to run a HIL system
  - Identification of requirements for test bed Hardware and Software, Laboratory infrastructure
  - Workflow for implementing the HIL System
  - Workflow for interface design (Hardware and Software)
  - Development of a common HILS test bed setup concept

IFA – PROJECT APPROACH

Task 2: Investigation and modification, if applicable, of the HILS component testing

- Detailed review of the Japanese test procedure for obtaining HIL input parameters
  - Determination of map characteristics (ICE, Motor/Generator, Battery, Gearbox,…)
  - Evaluation of the required effort.
- Analysis of improvements and relevant gaps concerning component testing
  - Assessment of the potential to minimize measuring effort.
  - Identification of additional necessary measurements following a more detailed level of the simulation model (according to the suggestions made in Task1).
- Improvements for future technological development
  - Assessment of possible future hybrid powertrain components and methods to obtain their characteristics for simulation purpose.

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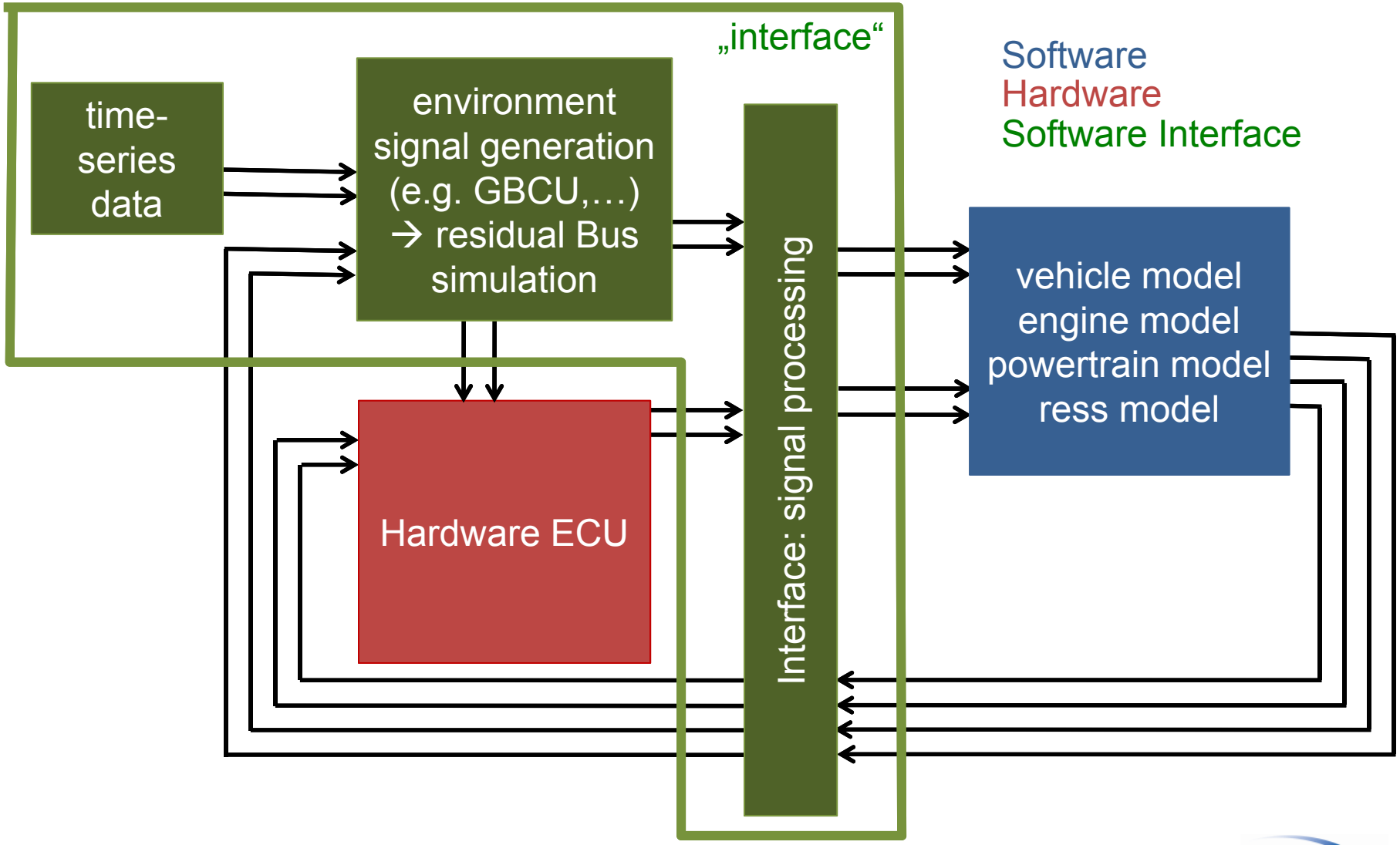
The Japanese Simulink simulation model

HILS Interface connecting the simulation model and the Hardware ECU



What is the „Interface“ Model for?

- Residual Bus Simulation
  - The ECU depends on receiving signals from other Control Units
  - If these Control Units do not exist as hardware, their signals have to be created within the interface model.
- Driver Model
  - A Driver Model is used to create the necessary pedal positions as an input to the ECU and Hybrid Control Unit.
  - The Driver Model can be either a closed-loop-Controller or – more simplified – Time-Dependend Accelerator & Brake Pedal Signals.
- Signal Conversion
  - Model Outputs have to be modified to fit the signal requirements of the Control Unit hardware.
  - Hardware Control Unit‘s Outputs have to be modified to fit the signal requirements of the Simulation Model Inputs.

Who is in charge of developing the interface models?

- **Japanese HILS method:**
  - Manufacturers develop their own Interface models.
  - Each manufacturer has his own ECU Input/Output signal specifications.
  - Each manufacturer uses his own Control Unit environment.
  - Each manufacturer has his own CAN Bus Configuration/Codes.
  - All of the above mentioned are usually non-disclosed.

- In a **worldwide regulation**, we expect that interface models will be developed by the manufacturers due to confidentiality.

- In our Research, we did not have access to an interface model due to confidentiality.
- Interface model Input and Output Signals are described in the Japanese Regulation (Kokujikan No. 281 of March 16, 2007).

How can we deal with a large number of Control Units?

- **Japanese HILS method:** Multi-Control-Units are currently under investigation:
  - In modern vehicles, a network of many different control units exists (e.g. Engine CU, Hybrid CU, AMT CU, IdleStopStart CU, DC/DC CU, etc.). An increase in the number of Control units is expected.
  - The HILS System will become huge, if all of these Control Units are considered.
  - A solution could be, to implement the most important functions of minor important Control units into the Interface Model of the HILS system (which is a kind of simplified software-in-the-Loop).
  - Thus, the verification process (comparing model output to actual measured data) is important to get correct results.
- **Worldwide regulation:**
  - Multiple ECU integration is necessary. Cross-linking between the different Control Units is done by wire connections (like in the vehicle) and/or by the interface model.
  - Alternatively, the most important Control Unit functions could be situated in the interface model (Software-in-the-Loop).
  - no increase in convenience of the HILS method expected.

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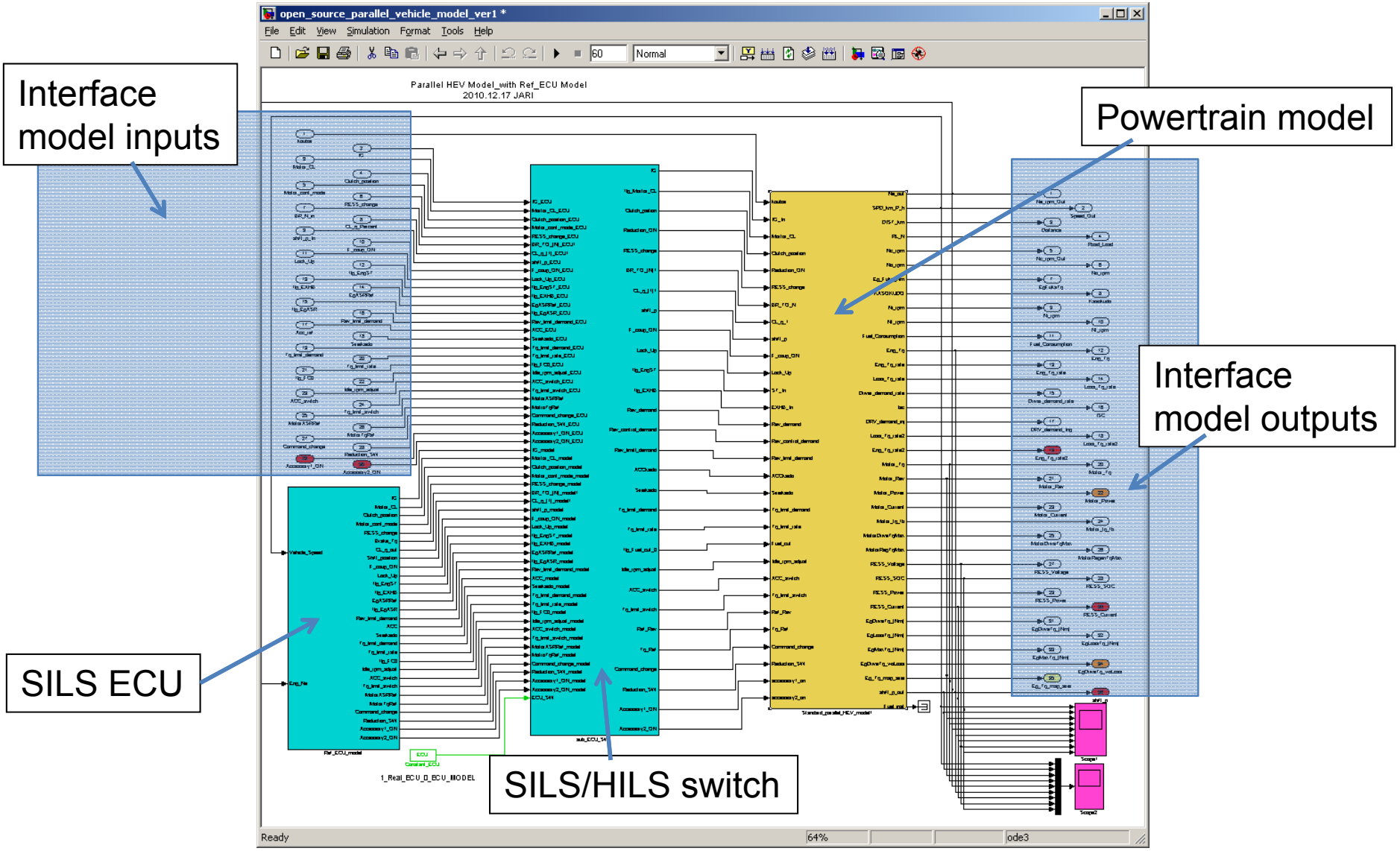
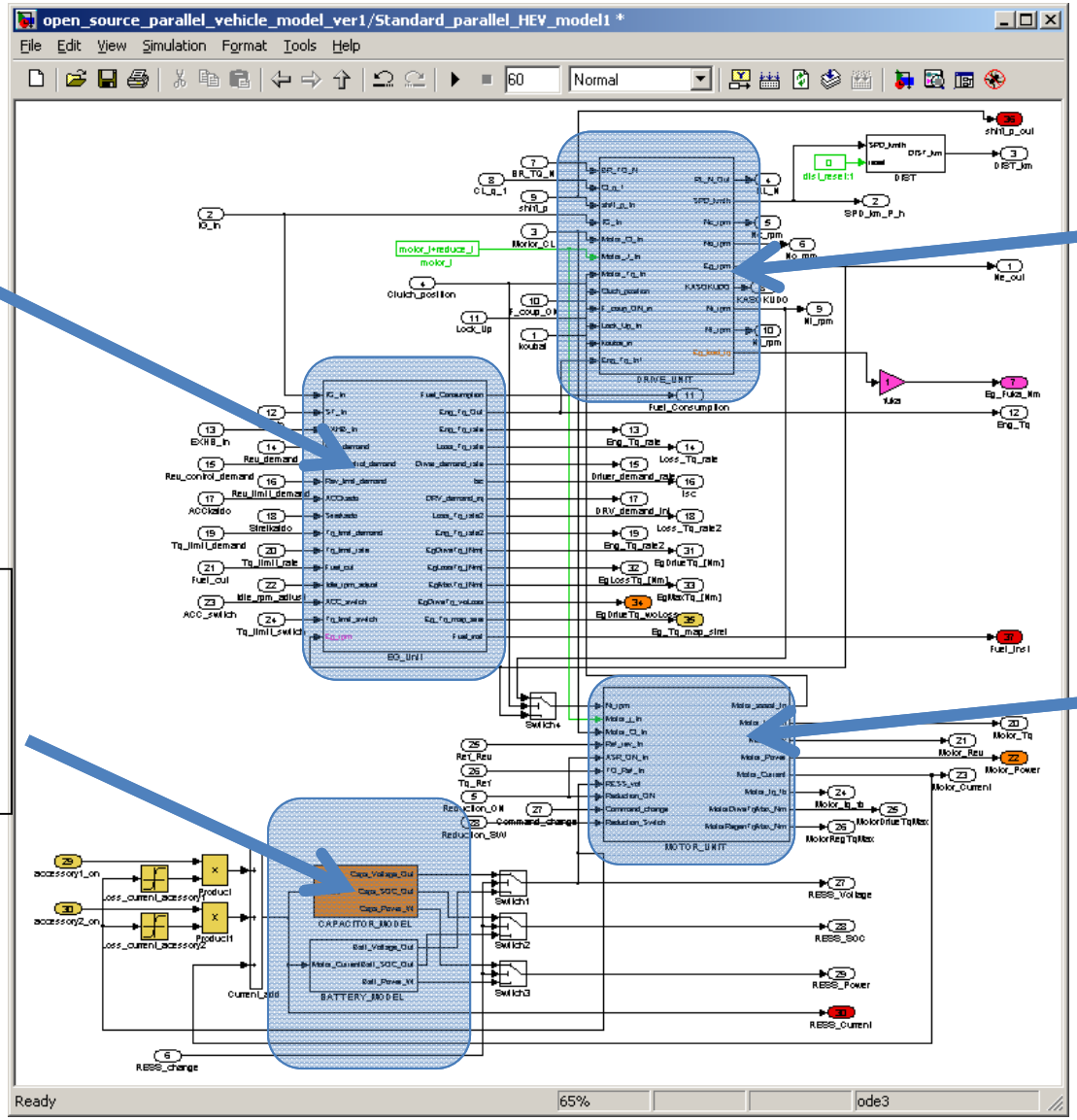
The Japanese Simulink simulation model



Powertrain model (Parallel Hybrid Vehicle)

Internal Combustion Engine (w/o ECU)

Energy storage systems (Battery, Supercapacitor)

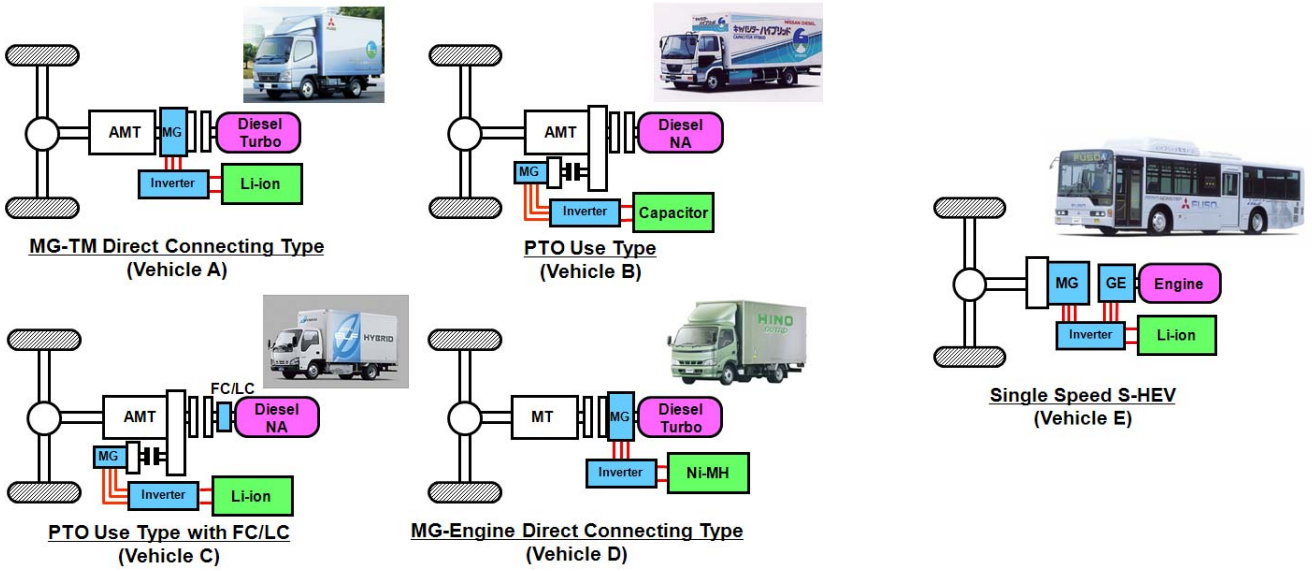


„Drive Unit“ (gearbox, Driving Resistances)

Motor-Generator

Results of the Model Analysis (I)

- Simulink is a well established programming language for this kind of models.
- Modeling in the Japanese method is based on physical models (numerical solving of differential equations) as well as lookup tables.
- Japanese method: There exist models for five different types of powertrains
  Why five? → In the japanese market, there are five different hybrid vehicles.
  Each one of them has ist own powertrain model.



Results of the Model Analysis (II)

- ANY powertrain simulation model is allowed, as long as the verification test (see upcoming slides) is passed.
- If the verification test cannot be passed, obviously the simulation model has to be modified/improved.
- There may occur cases, in which the verification test cannot be passed due to missing input data for the ECU.
  Example: ECU needs an information about a component‘s temperature to calculate realistic behaviour of the hybrid control strategy – In a real vehicle, the temperature signal is provided by a sensor – In HILS, temperature information is not available due to a missing temperature model within the powertrain model.

Suggestions for Simulation Model modification for a potential global technical regulation (I)

- Japanese method: Five different powertrain models exist.
- For a worldwide regulation, we expect that many more powertrain models would have to be developed.

- An official **Component Library** should be built up (the Japanese submodels are well suited as a basis).
- **Components** are physical entities (e.g. Engine, Motor-Generator, Battery, Clutch, Gearbox etc.).
- A combination of different **Components** results in a special **powertrain** topology (e.g. parallel, series hybrid).
- It is necessary to develop temperature models at least in the engine model to (FÖRDERN) development of hybrid control strategies for optimized engine warm-up.

Suggestions for Simulation Model modification for a potential global technical regulation (II)

Who is in charge of developing the simulation models?

- Japanese HILS method: Authorities cooperate with manufacturers.

- Worldwide regulation: there are two possibilities:
- Certification Authority:
  - **Pros:** Transparency
  - **Cons:** High effort, missing in-depth technical background. What happens, if model is not accurate enough?
- Manufacturer:
  - **Pros:** Responsibility is on manufacturer‘s side, detailed models (may be) already available.
  - **Cons:** Transparency, confidentiality of powertrain simulation models
- **Conclusion:** Cooperation between authorities and manufacturers is necessary.

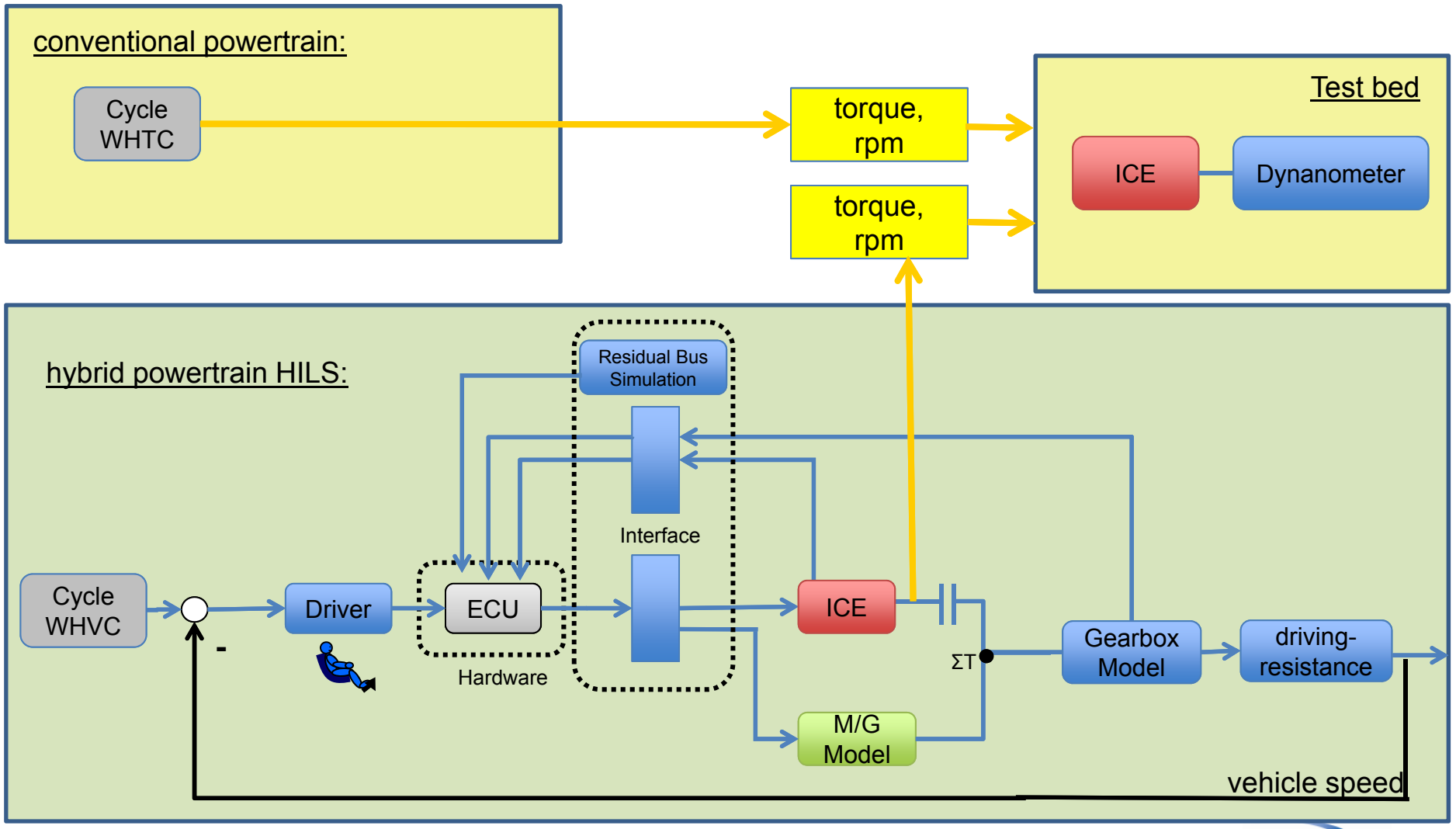
Suggestions for Simulation Model modification for a potential global technical regulation (III)

- Engine work of conventional powertrain (WHTC) and hybrid powertrain (HILS) should be compareable (generic data vs. detailed gearbox+driving resistance model):
- Suggestion:

Japanese method	Possible gtr
Engine Speed+Load is determined by vehicle speed in the driving cycle	Engine Speed+Load is determined by WHTC load at gearbox input

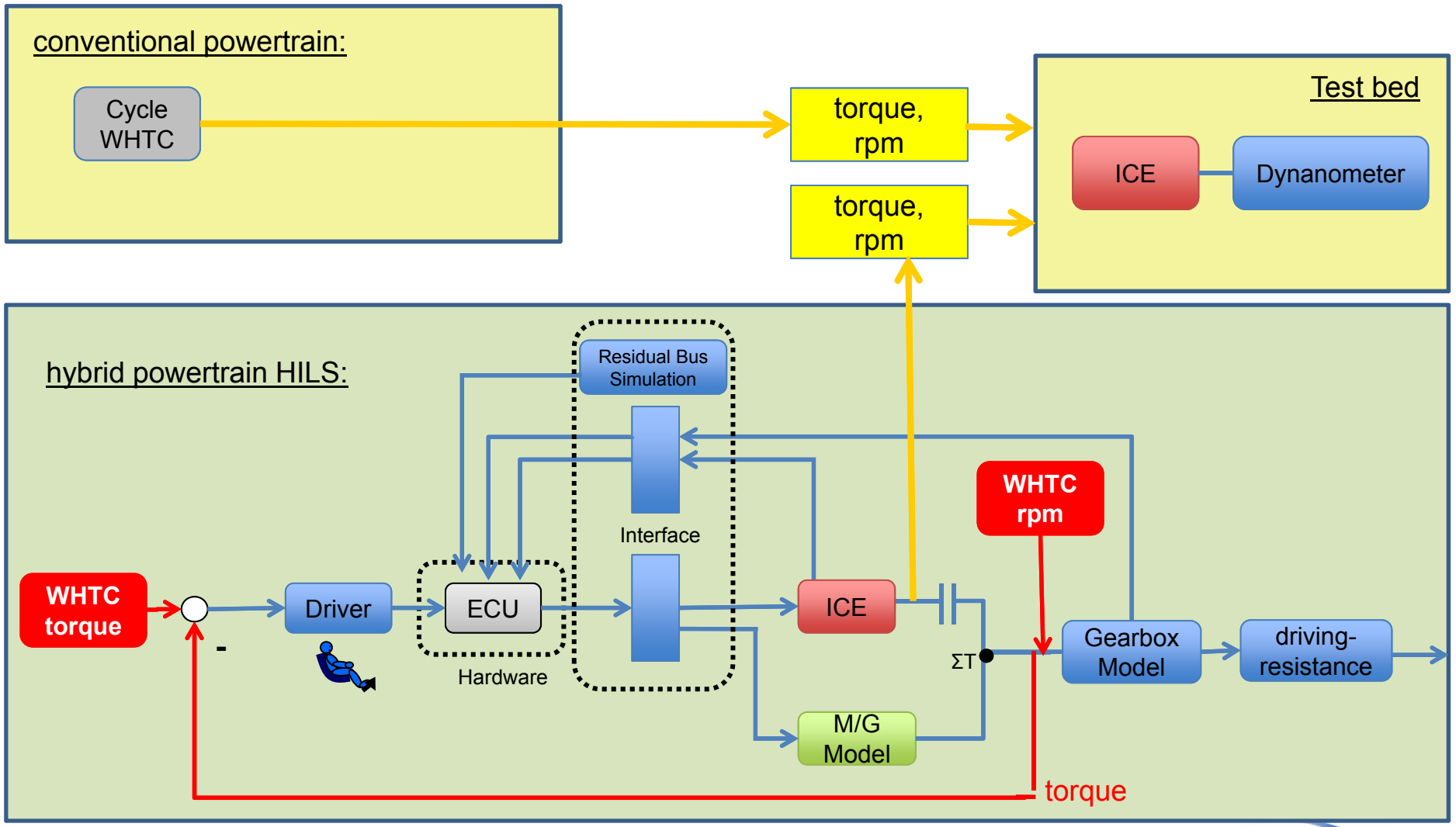
Generic data vs. detailed gearbox+driving resistance model

Compareable results?



Generic data vs. detailed gearbox+driving resistance model

Suggestion: Compareable results



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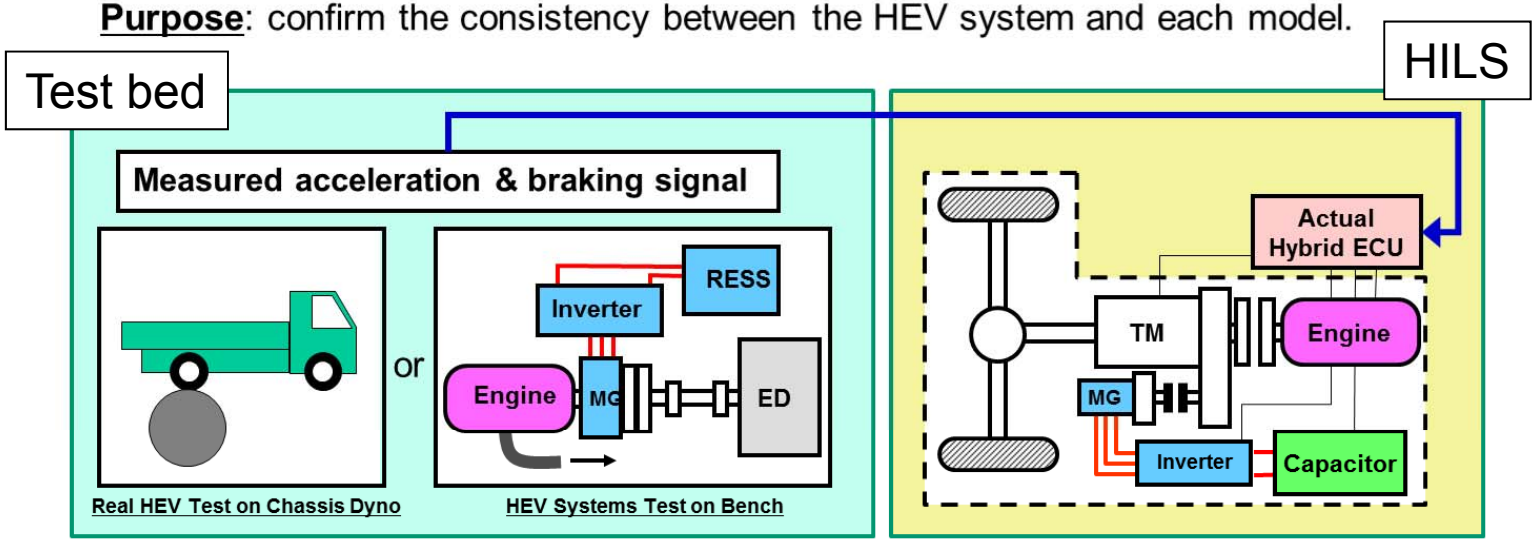
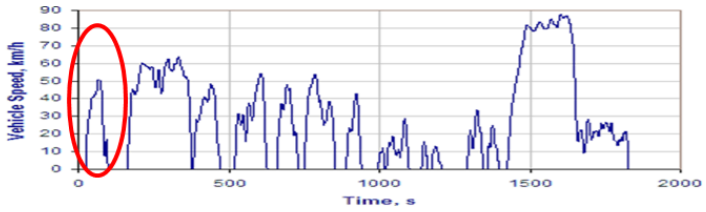
Model Verification Test of the Japanese HILS system (I)

HILS Verification (1st Step)

Purpose: confirm the consistency between the HEV system and each model.



Confirm Consistency: JE05 0-120sec



Comparison of:

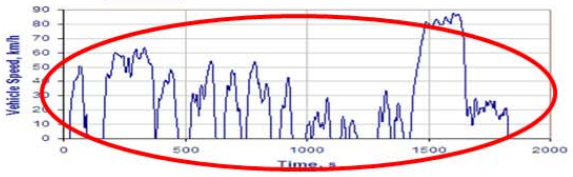
1) vehicle speed or engine rpm
2) torque and power of the electric motor
3) torque and power of the engine
4) power of RESS

Model Verification Test of the Japanese HILS system (II)

HILS Verification (2nd Step)

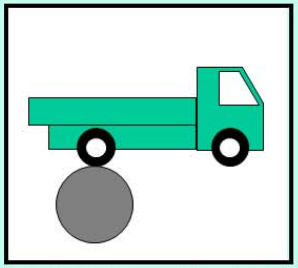
Purpose: confirm the quality of vehicle model.

Confirm Consistency:
JE05

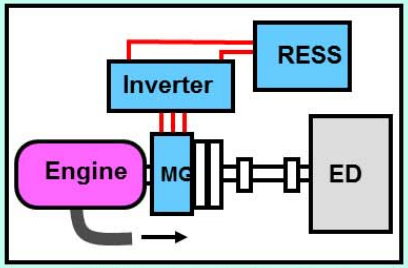


Test bed

Measured acceleration & braking signal



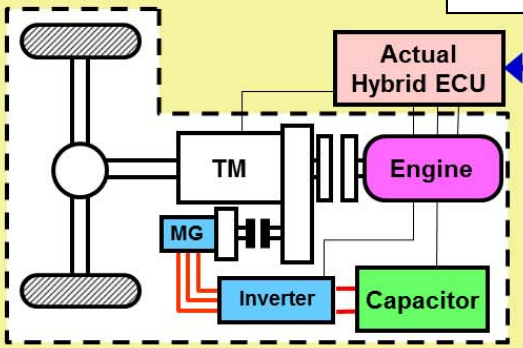
or



Real HEV Test on Chassis Dyno

HEV Systems Test on Bench

HILS



Driver model

Driver model out acceleration & braking signal

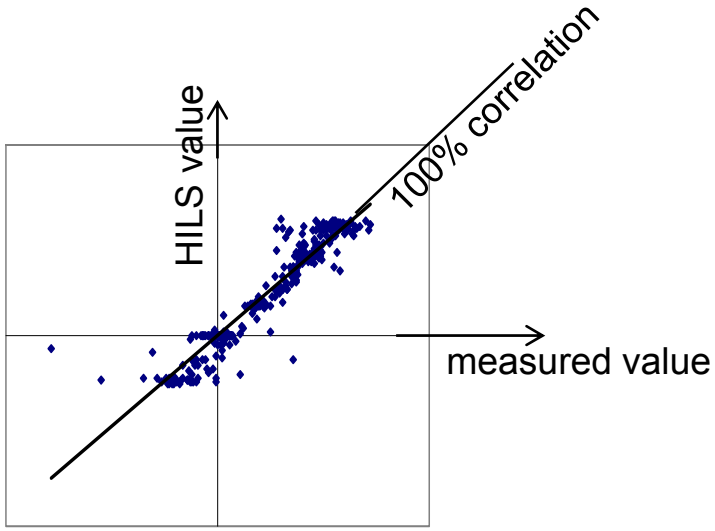
Comparison of:
1) total engine work
2) fuel consumption

Model Verification Test of the Japanese HILS system (III)

- The table below shows an example of maximum allowed tolerances (short-term verification test).
- Correlation coefficients for each variable (e.g. MG Torque or RESS power) are calculated and have to be larger than the specific tolerance value.

	Vehicle speed or Engine rev.	MG		Engine		RESS power
		Torque	Power	Torque	Power	
Tolerance	**0.97 ≤**	**0.88 ≤**	**0.88 ≤**	**0.88 ≤**	**0.88 ≤**	**0.88 ≤**

- Example: Engine Torque



Model Verification Test of the Japanese HILS system
Results (I)

- **Japanese Method:** Model Verification is done by comparing simulation results and measurement data obtained by either powerpack test or chassis dyno tests.

- For a global technical regulation, it is suggested to do the model verification by comparing simulation results to actual measured data from test track driving.
- This is due to problems which may occur in chassis dyno measurements (correct recuperation behaviour, high costs).

Model Verification Test of the Japanese HILS system
Results (I)

- **Japanese Method:** Model Verification method uses well-defined parts of the Japanese test cycle. This contains the risk of „model tuning“: The developed simulation model seems to be accurate in the verfication process, but may not be accurate in a different driving cycle

- For a **global technical regulation**, it is suggested to do the model verification using a random driving cycle.

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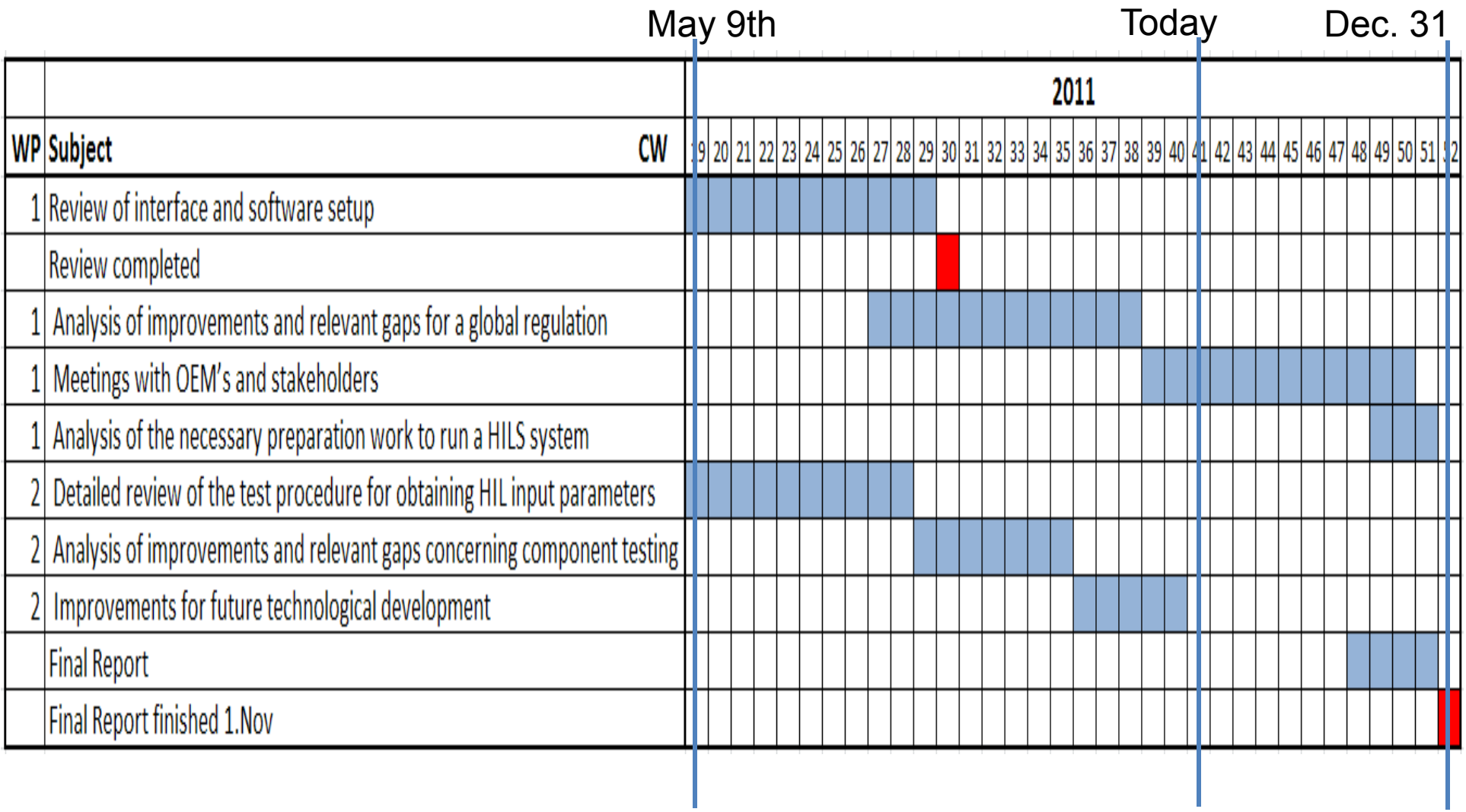
Task 2: Investigation and modification, if applicable, of the HILS component testing - Results

- Component testing strongly depends on requirements of the model
  - modeling depth
  - desired accuracy
- Component testing has to be accurate enough to fulfill the model verification process.

- Japanese method:
  - Common methods are used to obtain component parameters
  - e,g Engine map, Motor/Generator map, Battery: Measurements on test beds
  - according to the engine model, influence of temperature is neglected (engine testing is done in hot condition)
- Global technical regulation:
  - Suggestions for test methods have to be made for additional components like non-electric hybrids.
  - Measurement of engine warm-up behaviour depends on future engine temperature modeling.

Time Schedule IFA - TU Vienna



WP	Subject	CW
1	Review of interface and software setup	
	Review completed	
1	Analysis of improvements and relevant gaps for a global regulation	
1	Meetings with OEM's and stakeholders	
1	Analysis of the necessary preparation work to run a HILS system	
2	Detailed review of the test procedure for obtaining HIL input parameters	
2	Analysis of improvements and relevant gaps concerning component testing	
2	Improvements for future technological development	
	Final Report	
	Final Report finished 1.Nov	

Herzlichen Dank für Ihre Aufmerksamkeit!

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