Geneva, 17.01.2012

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GRPE-HDH Research Project Status, TU Vienna

Institut für Fahrzeugantriebe & Automobiltechnik

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

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Outline

GRPE-HDH TU Vienna

- Introduction
- 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
- Results of Task 2
- Summary and Suggestions
- Outlook

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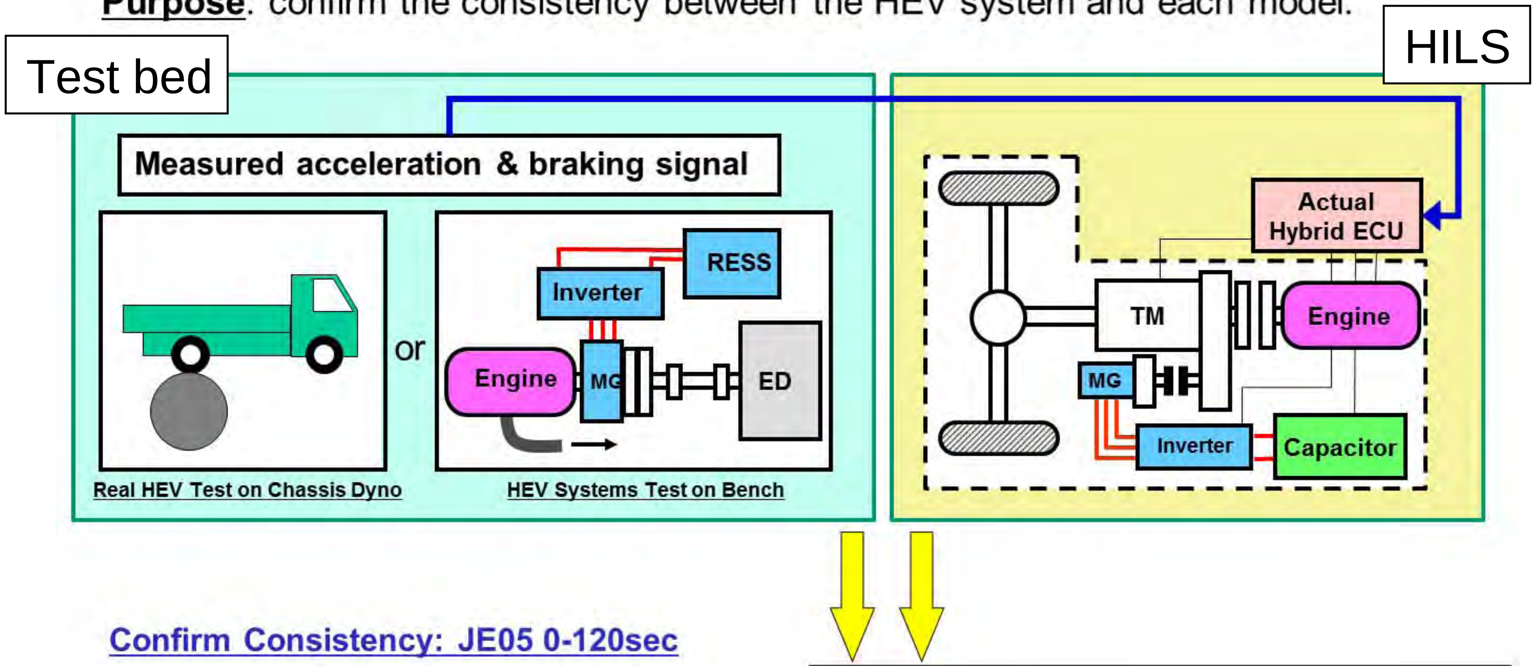
Model Verification Test of the Japanese HILS-System (I)

1st Step of Verification

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

Source: Combination of Japanese presentation

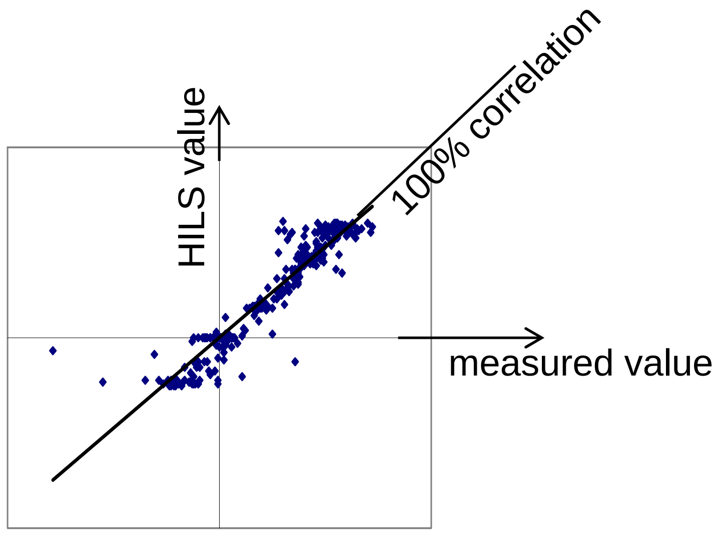
Model Verification Test of the Japanese HILS-System (II)

1st Step of Verification

- 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



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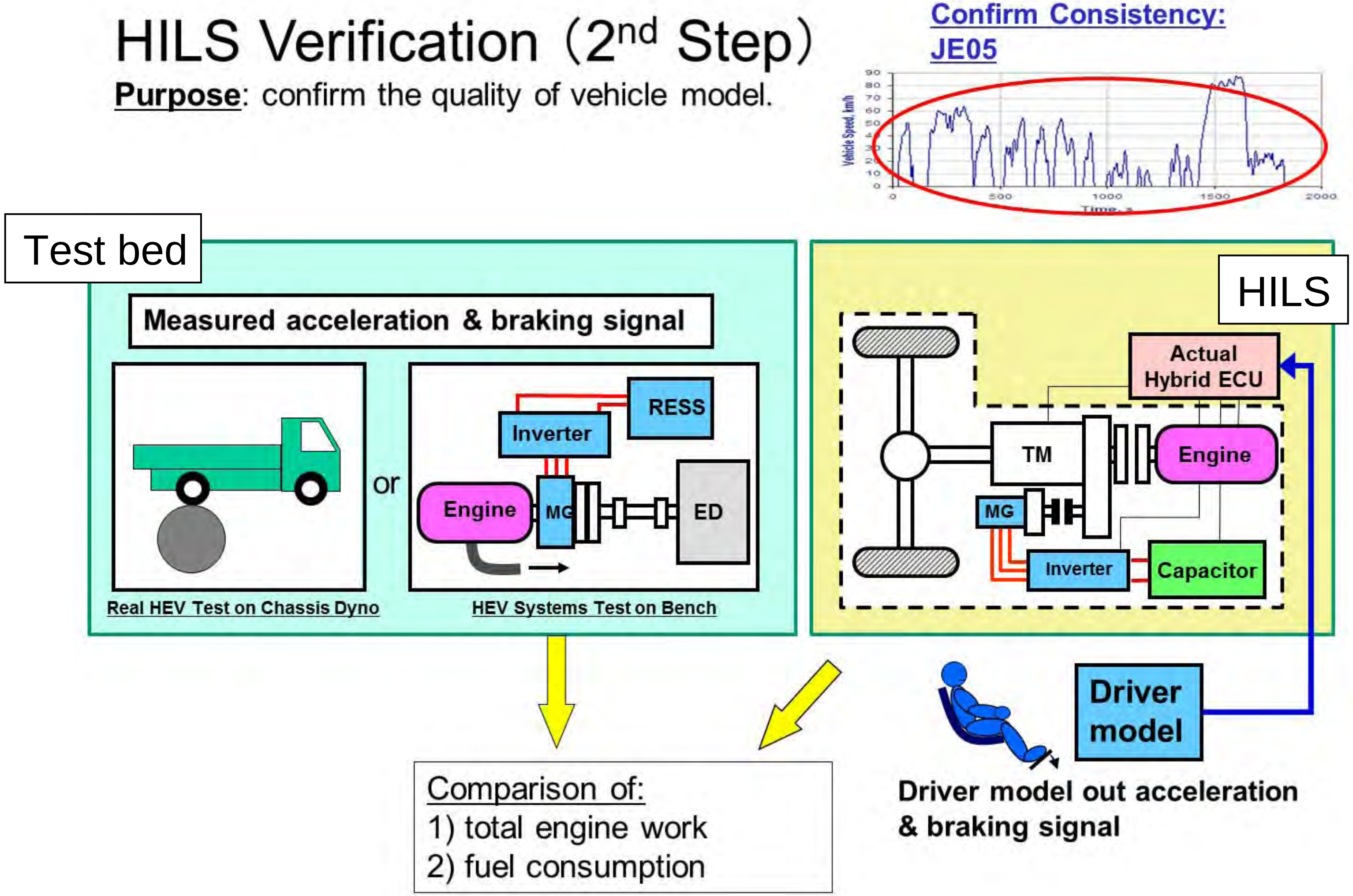
Model Verification Test of the Japanese HILS-System (II)

2nd Step of Verification



Source: Combination of Japanese presentation

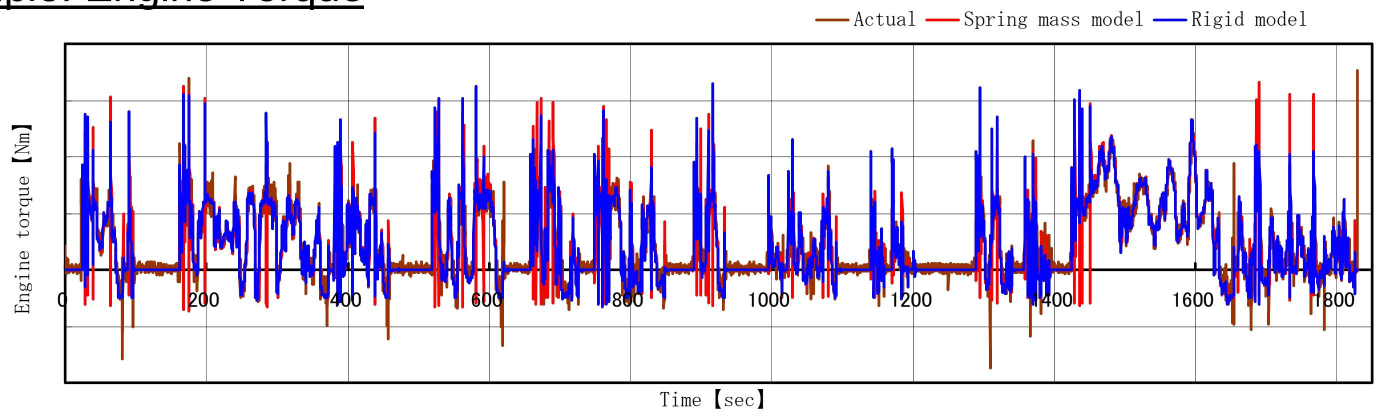
Model Verification Test of the Japanese HILS-System (IV)

2nd Step of Verification

– The table below shows an example of maximum allowed tolerances (long-term verification test).

Verification item	Vehicle speed or Engine rev.	Engine		Fuel Economy
		Torque	Positive work	
	Determination coefficient	Determination coefficient	W_{eng_HILS} / $W_{eng\_vehicle}$	FE_{HILS} / $FE_{vehicle}$
Tolerance	0.97≤	0.88≤	0.97≤	≤1.03
Spring mass model	0.982	0.921	0.993	1.018
Rigid model	0.994	0.895	1.003	0.999

Example: Engine Torque



Model Verification Test of the Japanese HILS-System

- **<u>Japanese Method</u>:**

Model Verification is done by comparing simulation results with measured real data obtained by either powerpack test or chassis dyno tests.

- Two steps of model verification (long and short-time verification test)
- Model depth of simulated powertrain components depends on regulations tolerances
- If the verification test cannot be passed, obviously the simulation model depth has to be modified/improved
- This model verification test is done once for a certain powertrain
- If compound changes, new verification is necessary

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Model Verification Test of the Japanese HILS-System

☐ **Assessment:**

In principle Japanese process is a promising concept in order to verify simulated results to real data. In order to a global regulation following suggestions have to be recognised:

–Model Verification method uses well-defined parts of the Japanese test cycle. The developed simulation model seems to be accurate in the verification process, but may not be accurate in a different driving cycle

–If model verification cannot be passed, compound models have to be improved as often as needed in order to pass verification test → high effort

–In cases of very complex compounds high effort of setting up measurement data for simulation model is needed. Especially of engine data maps

–Promising concept will be an extended version of s HILS-system (see upcoming slides)

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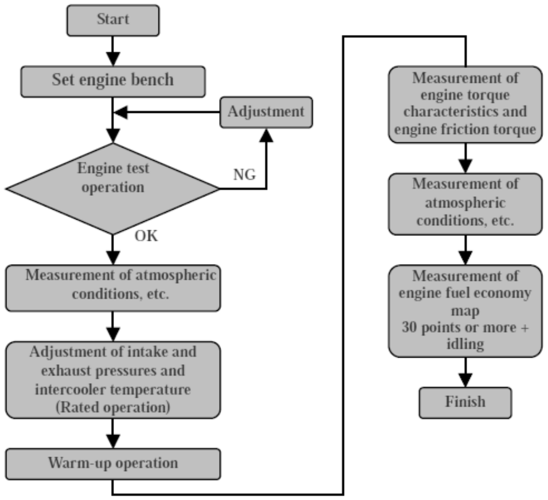
- ☐ **Results of Task 2**
- ☐ Summary and Suggestions
- ☐ Outlook

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

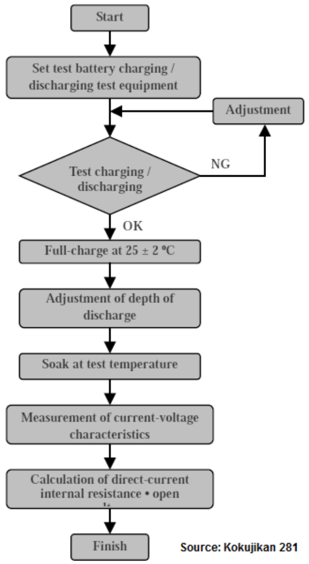
- **Japanese Method:**
  - Measured compound specific data (e.g. data maps) are needed for each simulated compound/unit of the powertrain model (Engine map, Motor/Generator map, Battery
  - Therefore special test procedures/methods are used to obtain component parameters (Measurements on test beds)

Test Procedure for Engine Torque Characteristics Fuel Economy Map for HILS System



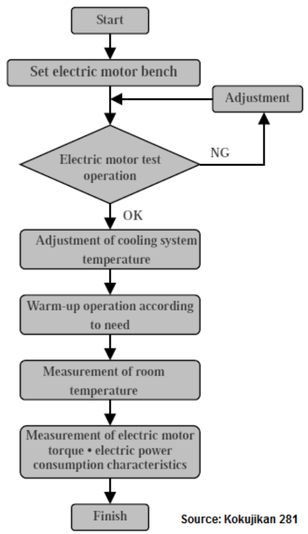
Source: Kokujikan 281

Test Procedure for Electric Motor Torque



Source: Kokujikan 281

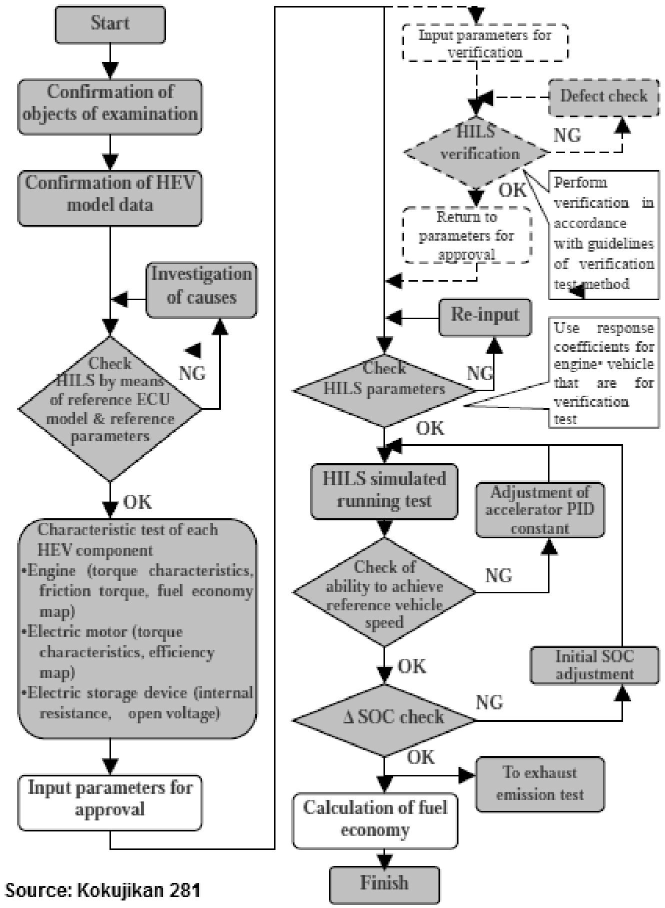
Test Procedure Battery



Source: Kokujikan 281

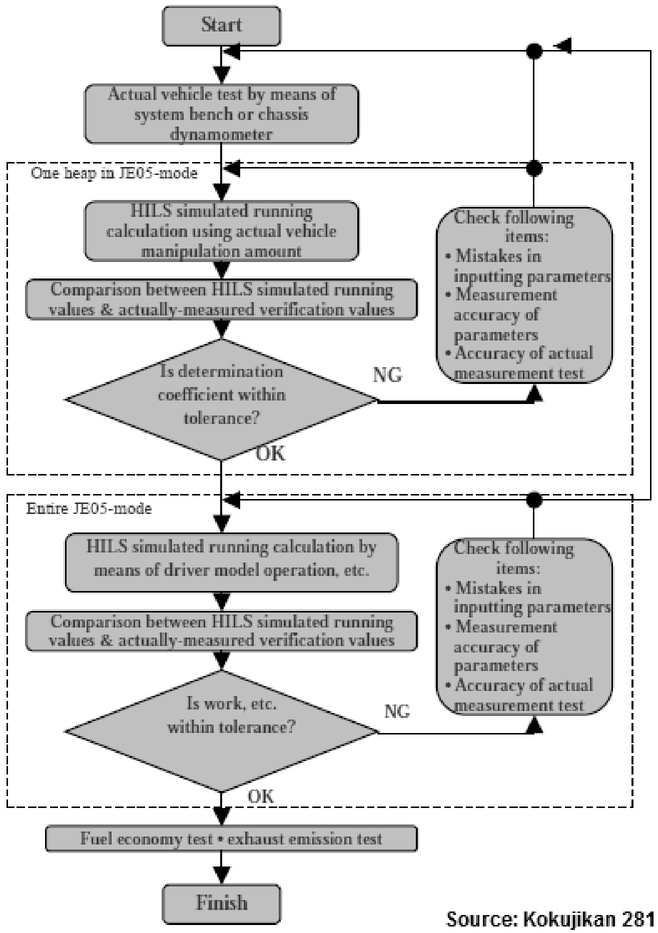
Task 2: Investigation and modification, if applicable, of the HILS component testing

Test Procedure for Fuel Consumption Rate of Heavy-Duty Hybrid Electric Vehicles



Source: Kokujikan 281

Verification Test Procedure for HILS System for Heavy-Duty Hybrid Electric Vehicles



Source: Kokujikan 281

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

- **Assessment:**
  - Common methods are used to obtain component parameters.
  - according to the engine model, influence of temperature is neglected (engine testing is done in hot condition), therefore temperature influence should be recognised in future.
  - Proposals of test methods have to be made in order to include additional components like non-electric hybrids.
  - Component testing strongly depends on requirements of the model. Therefore the modelling depth is dependent of the desired accuracy
  - Component testing has to be accurate enough to fulfil the model verification process → high effort for very complex parts (e.g. thermodynamics of the combustion engine)
  - Solution for passing the verification test and keeping the effort on a low level is needed → Promising concept will be an extended version of s HILS-system

Proposal of an “extended - HILS-System”

In cases of high effort in providing data maps of complex compounds for software model, an extended HILS-System is a promising concept.

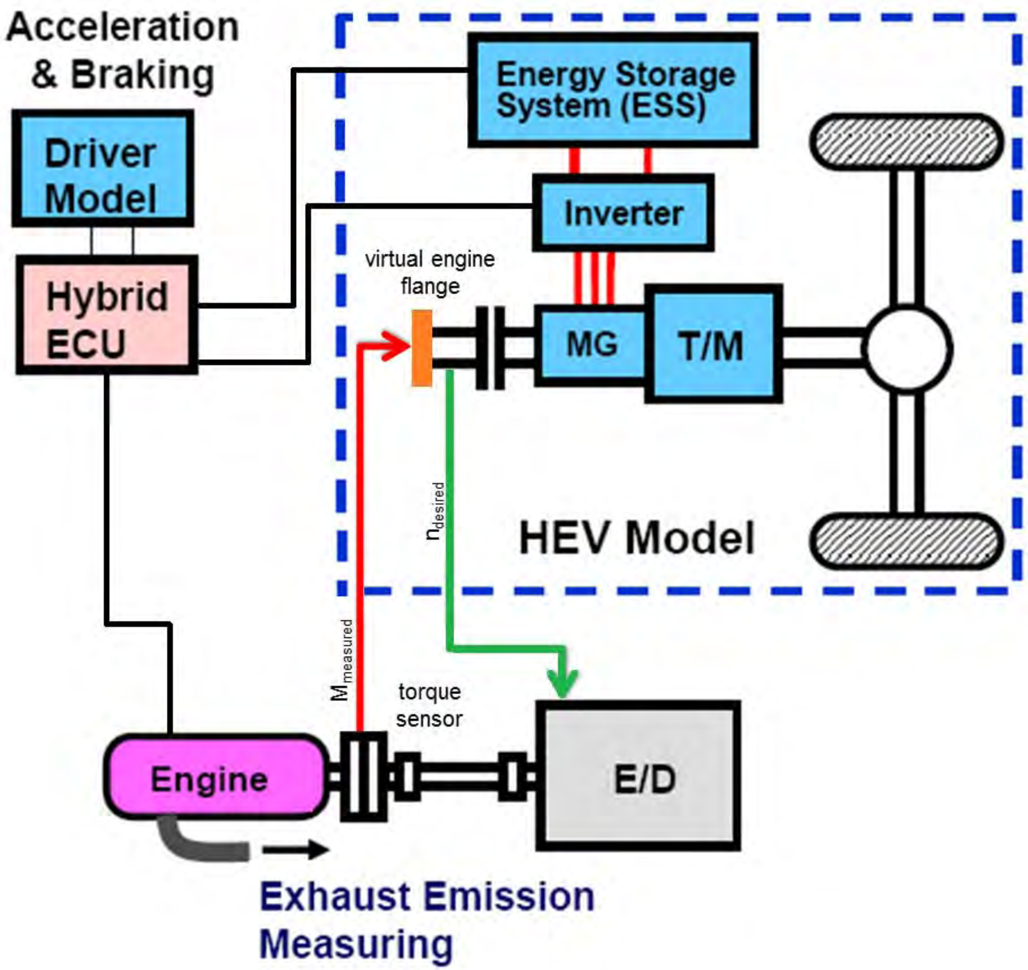
–A compound with high testing effort in order to reflect its specific properties by a software model, won’t be simulated. Real hardware is used

Example: Combustion Engine

- Engine test bed must be available
- Data of specific signals can directly be used by ECU
  → no need of simulation and complex compound testing effort
- Model required signals and data are shifted to the simulation model via the interface
- Simultaneously measurements of real consumption and exhaust emission rates are given
- No falsified hybrid strategy because of real ECU data input

Proposal of an “extended - HILS-System”

A so called “Engine in the Loop” System is actually used at IFA



Summary and Suggestions

- **Japanese Method:**
  - Authorities cooperate with manufacturers
  - Well-established software and hardware are used
  - A long term and a short term verification of the model is used for verification
  - Common methods to obtain component parameters and to verify simulation results are used
  - Model depth depends on regulations tolerances
  - If model passes verification test, model can be used for certification

Summary and Suggestions

☐ Suggestions for global regulation:

- Cooperation between authorities and manufacturers is necessary.
- Japanese HILS certification method is a possible concept and provides a good basis in order to do certification of heavy duty hybrids
- For a global regulation additional work has to be done
  - Interface and powertrain model have to modified in case of additional necessary signals
  - If simulation results are not accurate enough, model depth has to be enhanced
  - Additional components like non-electric hybrids have to be modelled for future certification process. Promising concept is the usage of a component library.
  - In cases of using multiple ECUs, measurement hardware and the software model have to be able to handle ECUs signals
  - In cases of high effort for setting up an HILS-Model, variations or modifications have to be done (e.g. extended HILS-Method)

Summary and Suggestions

- **Manufacturers opinion:**

  - Japanese HILS method is a possible concept but has to be modified in order to a global regulation because of:
    - Additional required signals within simulation models
    - Additional required components like non-electric hybrids have to be modelled for future certification process. Promising concept is the usage of a component library.
    - If simulation results are not accurate enough, model depth has to be enhanced maybe with to high effort

  - In cases of high effort alternatives like IFA's suggestion of an "extended HILS-Method" would be a promising concept
  - For global regulation close cooperation between authorities and manufacturers is necessary

Outlook

- ☐ **Possible next steps:**

1. Build up a real heavy duty hybrid vehicle which can be modelled with Japanese open source model
   - Replacement dummy data from open source model with real data.
   - Recognition of real hybrid ECU by usage of software modelled ECU
   - Recognition of real component data/map
   - Passing a full verification process
   - Validation and verification of simulation results on engine test bed

2. Sensitivity analysis
   - Influence of individual models on the overall quality result
   - Necessity of model depth for each compound
   - Break even point of minimal effort and maximum model quality

3. Investigations on possible alternatives
   - Extended HILS-Testing-Method
   - Powerpack Testing

Additional Investigation

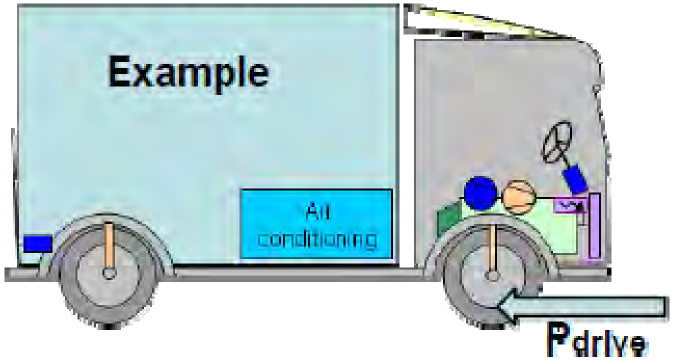
Institute for Internal Combustion Engines and Thermodynamics

TU Graz

Options to handle vehicle specific differences in HILS

Analysis of compatibility of generic vehicle data with WHTC

Simulation of power demand:



$P_{engine} = P_{drive} + P_{transm} + P_{aux} + P_{PTO}$

$P_{drive} = P_{roll} + P_{air} + P_{gradient} + P_{acc.}$

$P_{transm} = P_{loss\ gear\ boxes} + P_{loss\ axis}$

$P_{aux} = P_{cooling\ fan} + P_{compressor} + P_{alternator} + \ldots$ (all auxiliaries not engaged in engine test)

P_{PTO} = Power take off (e.g. compressor for cooling system)

Engine load from HILS test shall be fair compared to engine load in WHTC.
2 options to solve this demand:

a) HILS simulator + WHVC shall give P_{drive} comparable to WHTC (=suggested)
P_{transm} P_{PTO} and P_{aux} can be different for HDH compared to conventional HDV.
Disadvantage: difficult to include vehicle specific auxiliary and PTO data in simulator (main open topic in the actual European HDV-CO_2 test procedure study)

b) HILS simulator + WHVC shall give P_{engine} comparable to WHTC.
Disadvantage: Intelligent transmission and auxiliary designs at HDH will not be awarded.
Maybe OK for pollutant tests, not ok for CO2?

Stefan Hausberger | Vienna, 12.10.2011 | HILS HDH

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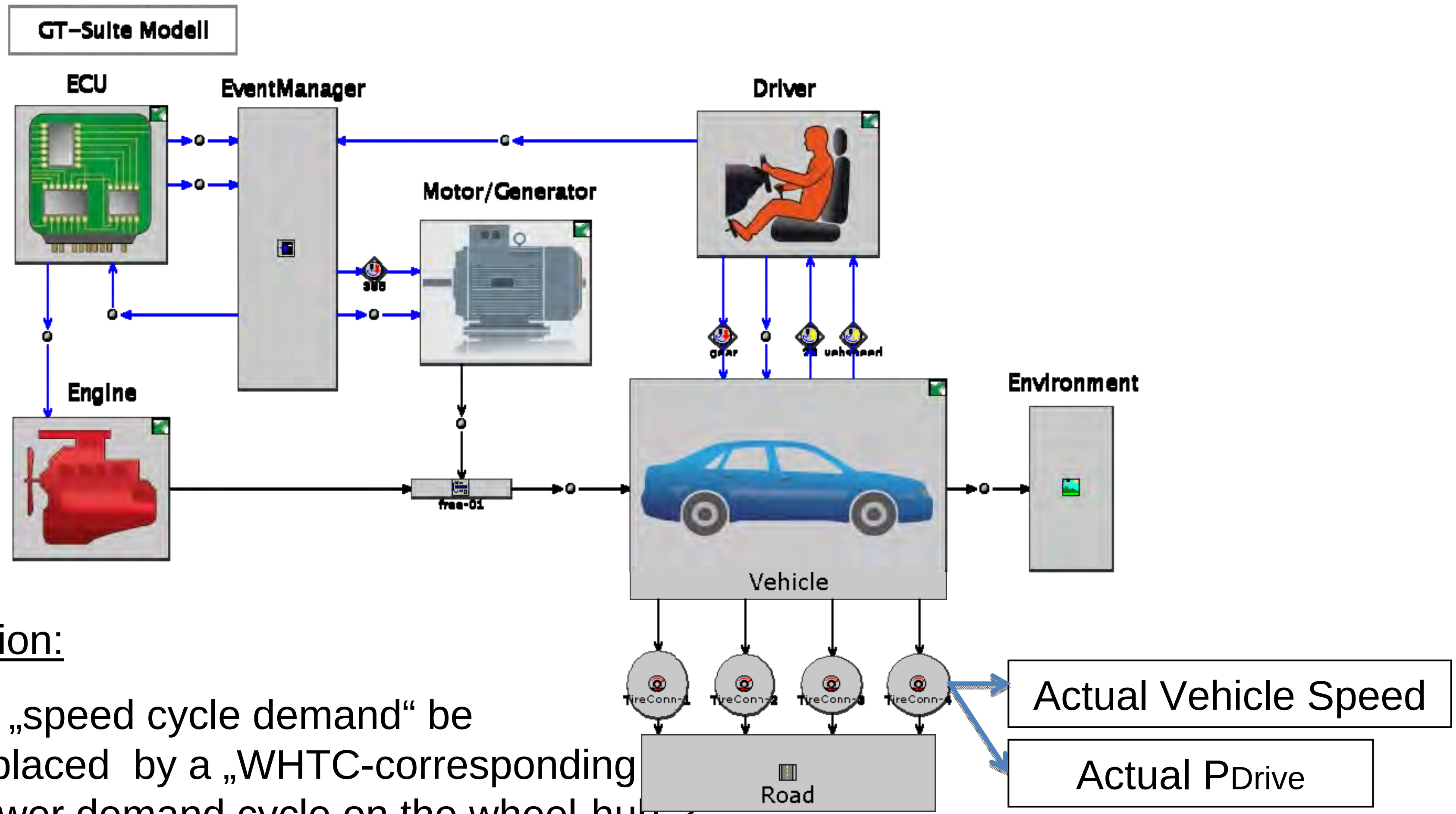
Additional Investigation

- ☐ **Feasibility Analysis:**

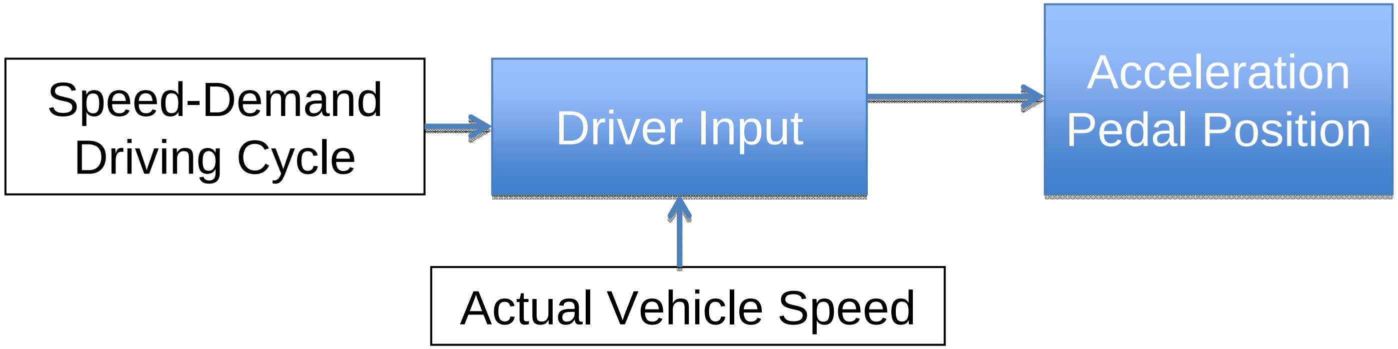


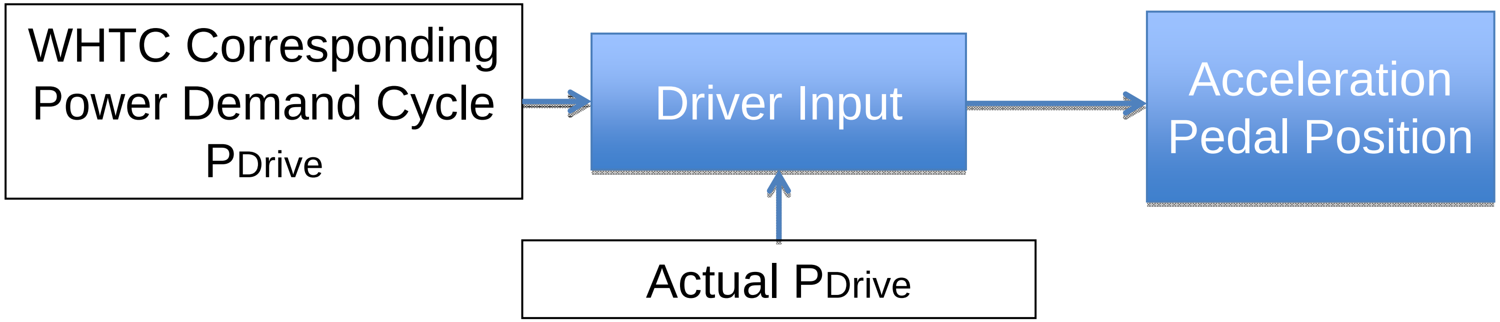
<u>Question:</u>

Can a „speed cycle demand“ be raplaced by a „WHTC-corresponding power demand cycle on the wheel-hub“?

Additional Investigation

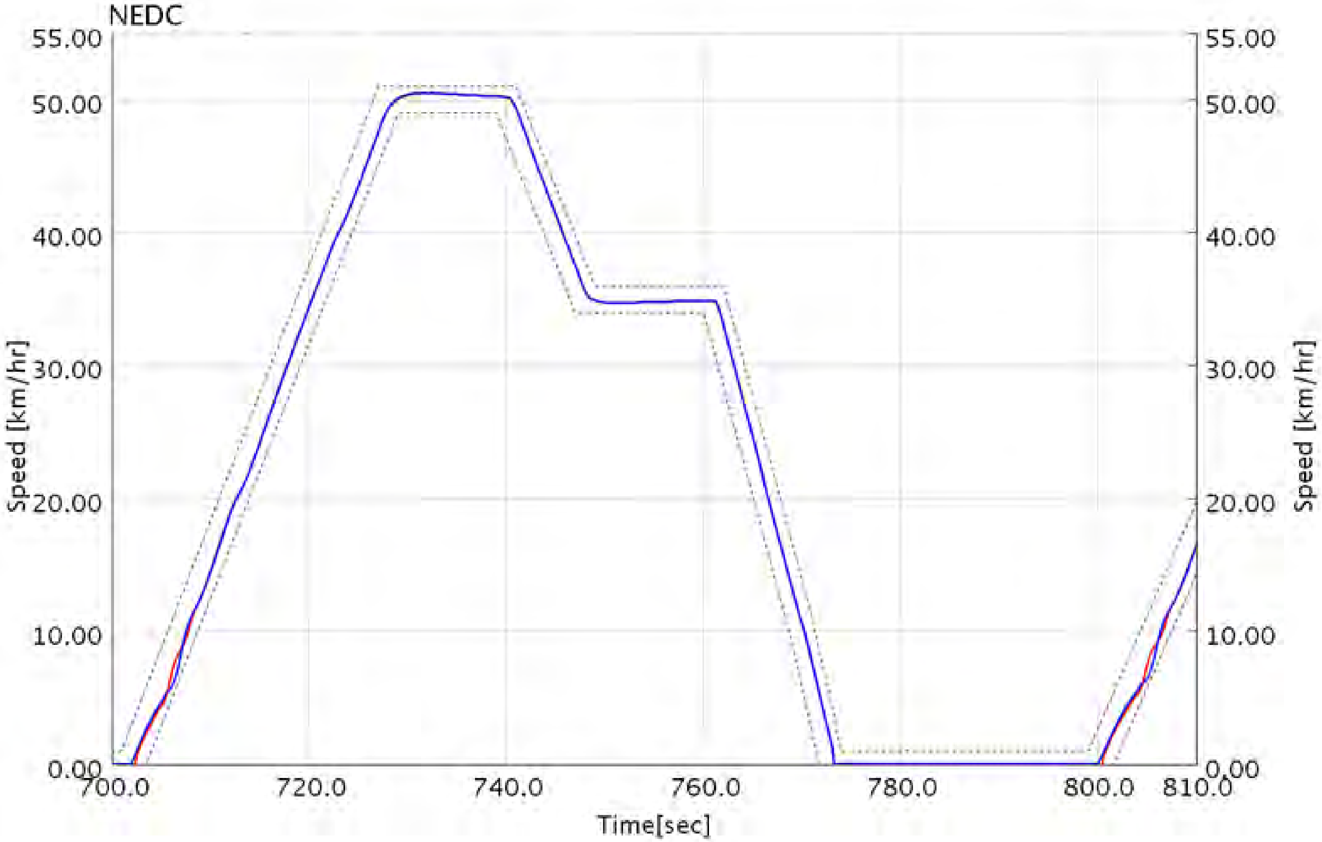
- ☐ **Feasibility Analysis:**





Additional Investigation

- **Feasibility Analysis:**



Result: vehicle stays within speed tolerance band

Conclusion: replacement of driver input demand is feasible.

Thank you for your attention!

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