Working Paper No. **HDH-14-03e**
(14th HDH meeting, 04 June 2013)

GRPE-HDH Research Project

14th meeting of the GRPE informal group on heavy duty hybrids (HDH)

Report of the Institutes on validation test program 1

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Content

- Validation test program 1
  - Adaptations to time schedule
  - Deliverables and progress
- Drive cycle investigations
- Conclusion

Validation test program 1 overview

Adaptations to time schedule

No.	Task	Note	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	SILS for serial hybrid																
1.1	Set up a serial HDH as SILS																
1.2	Adapt driver model																
1.3	Library for non electric components																
1.4	Meetings with OEM's and stakeholders																
1.5	Library for new power pack components																
1.6	Thermal models																
1.7	Simulation runs and validation																
2	Adaptation of SILS for parallel HDH											!					
2.1	Meetings with OEMs and stakeholders																
2.2	Set up a data bus system in the model																
2.3	Adapt the Software to parallel HDH																
2.4	Simulation runs and validation																
3	Procedure and Manual writing/reporting																
3.1	Report on test procedure, user manual																
3.2	Provide the interface system for real ECUs																
3.3	Adaptations and improvements of methods																
4	Additional time schedule (Borlänge)																
4.1	Decision meeting (support new/old model structure)												08/04				
4.2	Release of signal interface (version 0.1) Feedback requested by 15/05/2013	including new naming convention											15/04				
4.3	Prepare parallel and serial hybrid model	in new model structure															
4.3.1	Release of parallel hybrid (version 0.1) Feedback requested by 22/05/2013	including draft documentation											26/04				
4.3.2	Release of serial hybrid (version 0.2) Feedback requested by 22/05/2013	including draft documentation												03/05			
4.4	Second model release and improvements																

Validation test program 1 overview

Adaptations to time schedule

- Need for new model structure was identified (greater flexibility)
  - Modifications largely feasible in given time frame

    -> Implementation of new model structure for GTR
- Modifications include
  - Set up of comprehensive component model library
  - Establish new signal naming convention
  - Restructure vehicle models

				Apr	May	Jun	Jul	Aug
	4	**Additional time schedule (Borlänge)**						
	4.1	**Decision meeting (support new/old model structure)**		**08/04**				
	4.2	**Release of signal interface (version 0.1) Feedback requested by 15/05/2013**	including new naming convention	**15/04**				
	4.3	**Prepare parallel and serial hybrid model**	in new model structure					
	4.3.1	**Release of parallel hybrid (version 0.1) Feedback requested by 22/05/2013**	including draft documentation	**26/04**				
	4.3.2	**Release of serial hybrid (version 0.2) Feedback requested by 22/05/2013**	including draft documentation		**03/05**			
	4.4	**Second model release and improvements**						

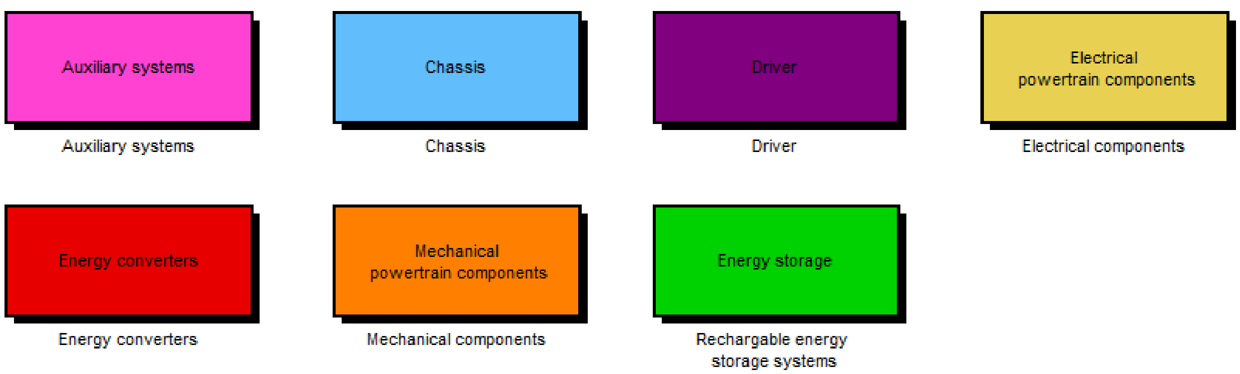
Validation test program 1 overview

New component library and signal naming convention

- New AUTOSAR based signal naming convention established
- Inclusion of relevant powerpack components in library toolbox
- Transfer of previously developed models (thermal, non hydraulic, driver model) into model library

HILS model library toolbox

Basic vehicle components

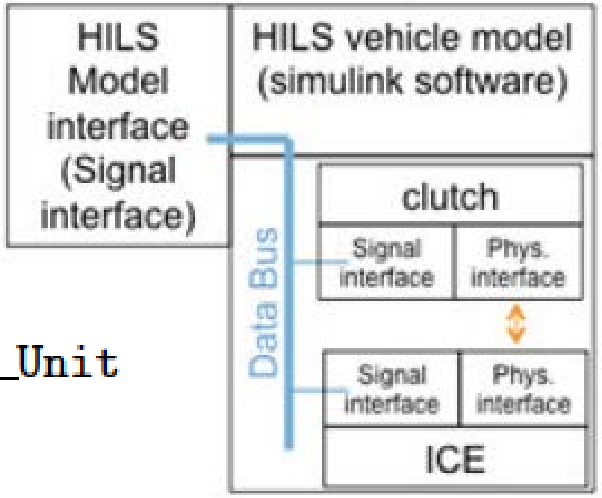


Established by
Chalmers University of Technology,
Vienna University of Technology,
Graz University of Technology, 2013

Validation test program 1 overview

New component library and signal naming convention

- New AUTOSAR based signal naming convention established



- The *physical interface* is related to how different components are connected together physically

  Physical interface: `phys_description_Unit`

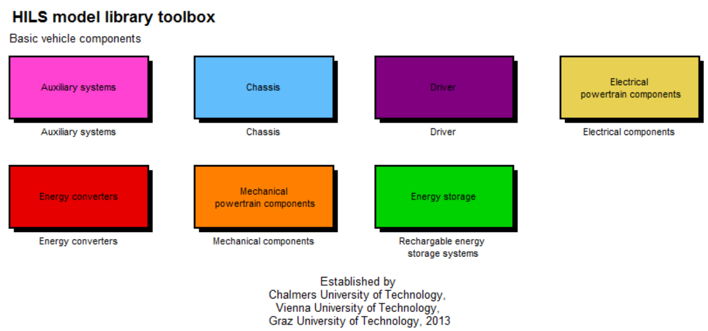
- The *signal interface* is related to control/sensor signals needed to control the components for an ECU

  Signal interface: `Component_description_Unit`

- Example: Eng_tqCrkShftAct_Nm – Engine crank shaft torque

Validation test program 1 overview

New component library and signal naming convention

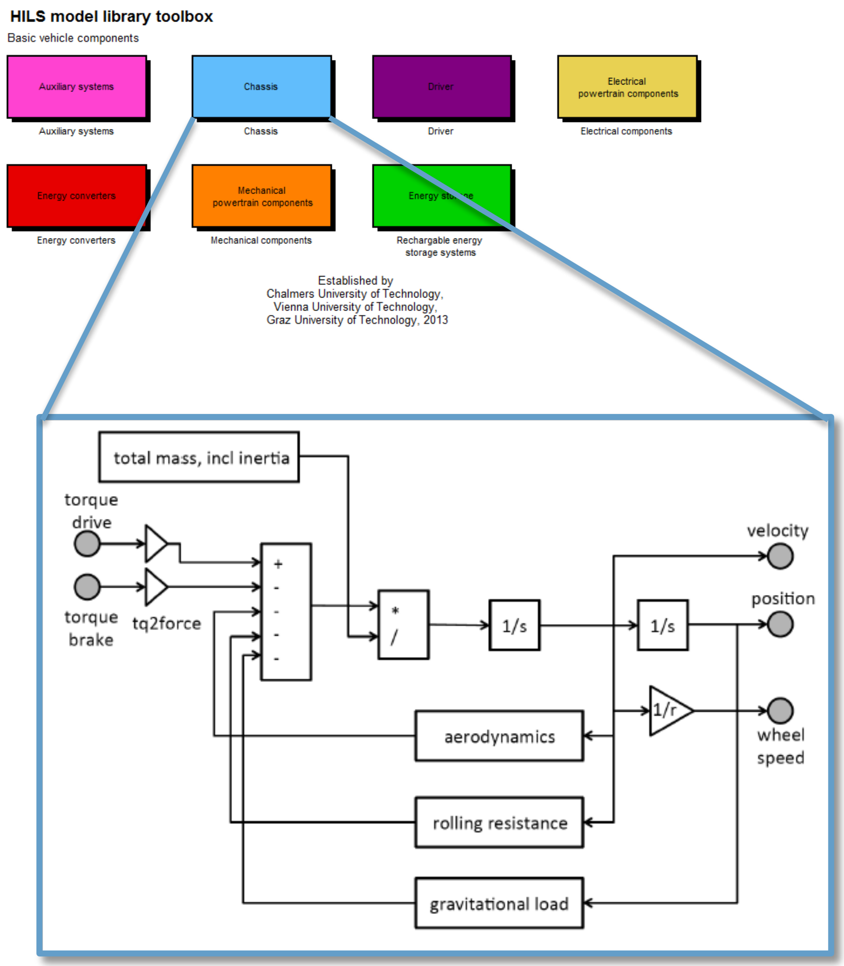


Structure of the HILS model library toolbox

HILS_GTR — The main folder
|--> Documentation — The documentation is located here
|--> DrivingCycles — Data of the different driving cycles
|--> Library — The Simulink blocks of the HILS model library are here
|--> Parameter files — Template parameter files for all models (copy if used)
|--> Misc... — All additional files for the HILS model library are stored here
|--> Vehicles...................................... — Vehicle models are stored here
|--> Parallel — Models for parallel hybrid vehicles
|--> PostTransmission — Simulink models of different post transmission parallel hybrids
|--> Parameter data — Data of the different component models for parallel hybrids
|--> PreTransmission — Data of the different energy converters
|--> Series — Models for series hybrid vehicles
|--> Parameter data — Data of the different component models for series hybrids

Validation test program 1 overview

New component library and signal naming convention



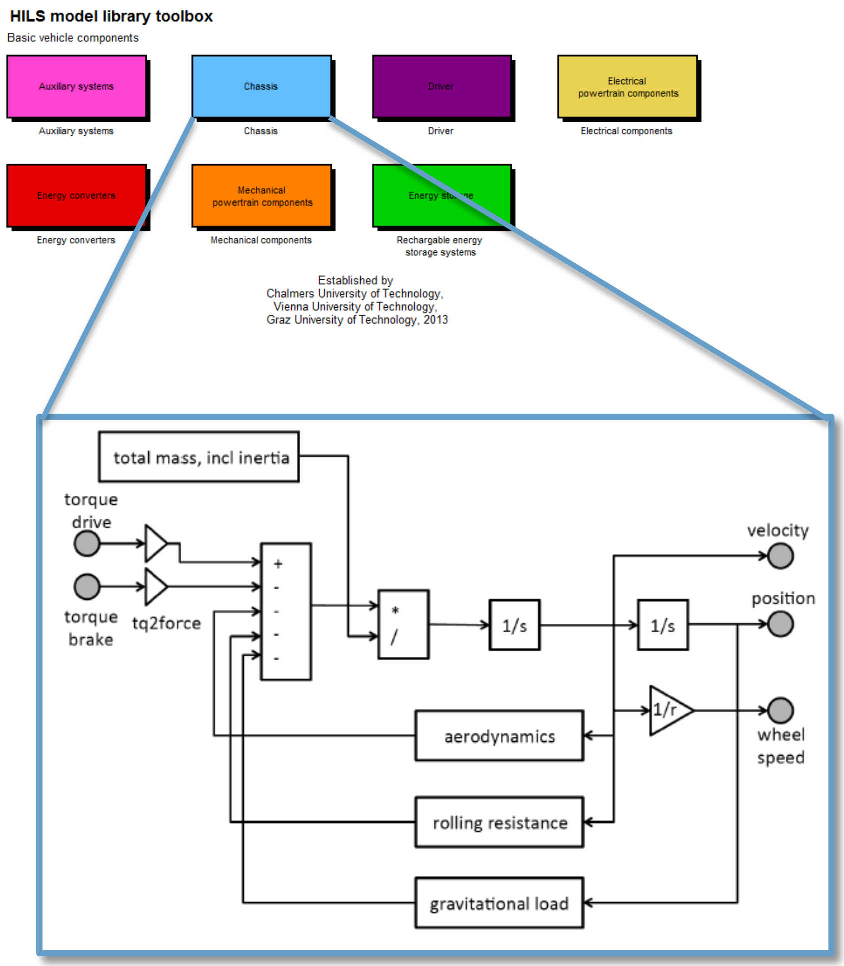

```
dat.comment = 'Chassis model data - kukojikan data';
dat.filename = 'para_chassis_japan.m';
dat.version = '1.1';
dat.lastModified = '18.04.2013';
dat.modifiedBy = 'Jonas Fredriksson';


%-----------------------------------------------------------------------
% Vehicle parameters
%-----------------------------------------------------------------------
dat.vehicle.mass.comment = 'vehicle mass';
dat.vehicle.mass.unit = 'kg';
dat.vehicle.mass.value = 6000;

%-----------------------------------------------------------------------
% Final gear parameters
%-----------------------------------------------------------------------
dat.fg.comment = 'final gear parameters';
dat.fg.ratio.comment = 'final gear ratio';
dat.fg.ratio.unit = '-';
dat.fg.ratio.value = 4.9;
dat.fg.efficiency.comment = 'final gear efficiency';
dat.fg.efficiency.unit = '-';
dat.fg.efficiency.value = 0.99;
dat.fg.inertia.comment = 'final gear inertia';
dat.fg.inertia.unit = '-';
dat.fg.inertia.value = 0;
…
```

Validation test program 1 overview

New component library and signal naming convention



A.2 Chassis

A.2.1 Parameters and constants

Parameter name	Unit	Description	Name in Simulink model
$m_{vehicle}$	kg	Vehicle mass	dat.vehicle.mass.value
r_{fg}	-	Final gear ratio	dat.fg.ratio.value
η_{fg}	-	Final gear efficiency	dat.fg.efficiency.value
	kgm^2	Final gear inertia	dat.fg.inertia.value
A_{front}	m^2	Vehicle front area	dat.aero.af.value
C_d	-	Drag coefficient	dat.aero.cd.value
r_{wheel}	m	Wheel radius	dat.wheel.radius.value
	kgm^2	Wheel inertia	dat.wheel.inertia.value
f	-	Rolling resistance coefficient	dat.wheel.rollingres.value

A.2.2 Signal interfaces

When using this component model, the following control signals must be sent to the component model in a signal bus:

Node	Name	Description	Unit
cmd	Chassis_tqBrakeReq_Nm	Requested brake torque	Nm

The following measurement signals are available from the component model:

Node	Name	Description	Unit
sensor	Chassis_vVehAct_mps	Actual vehicle velocity	m/s
sensor	Chassis_nWheelAct_radps	Actual wheel speed	rad/s
sensor	Chassis_massVehAct_kg	Vehicle mass	kg
sensor	Chassis_slopRoad_rad	Road slope	rad

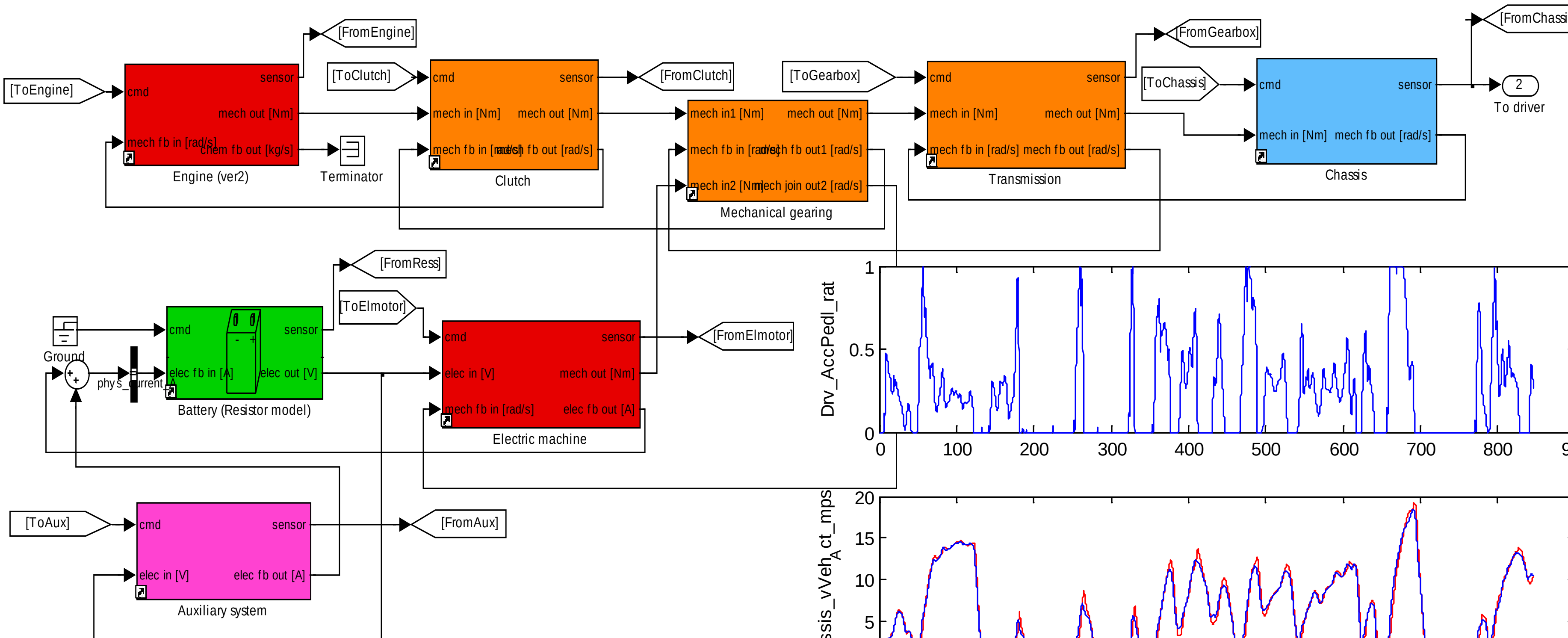
A.2.3 Physical interfaces

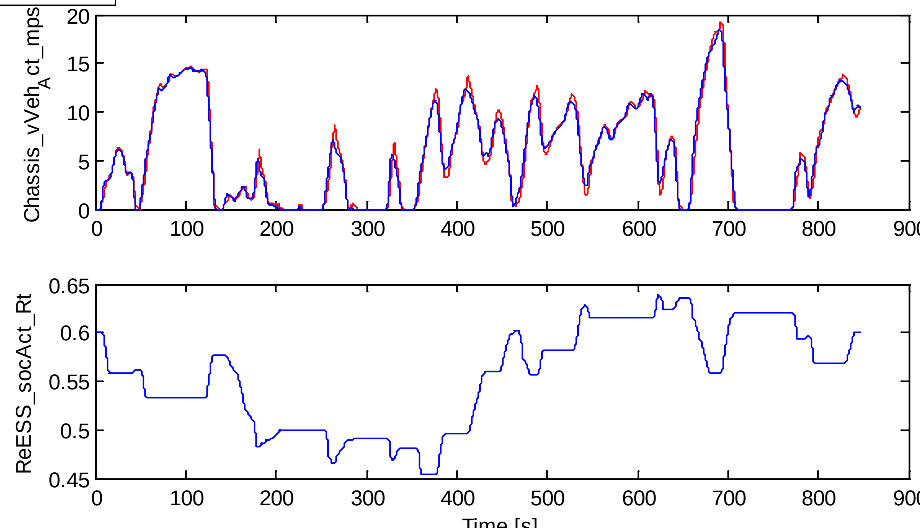
Electrical interface:

Node	Name	Description	Unit
mech in [Nm]	phys_torque_Nm phys_inertia_kgm2	torque inertia	Nm kgm^2
mech fb out [rad/s]	phys_speed_radps	rotational speed	rad/s

Validation test program 1 overview

New component library and signal naming convention

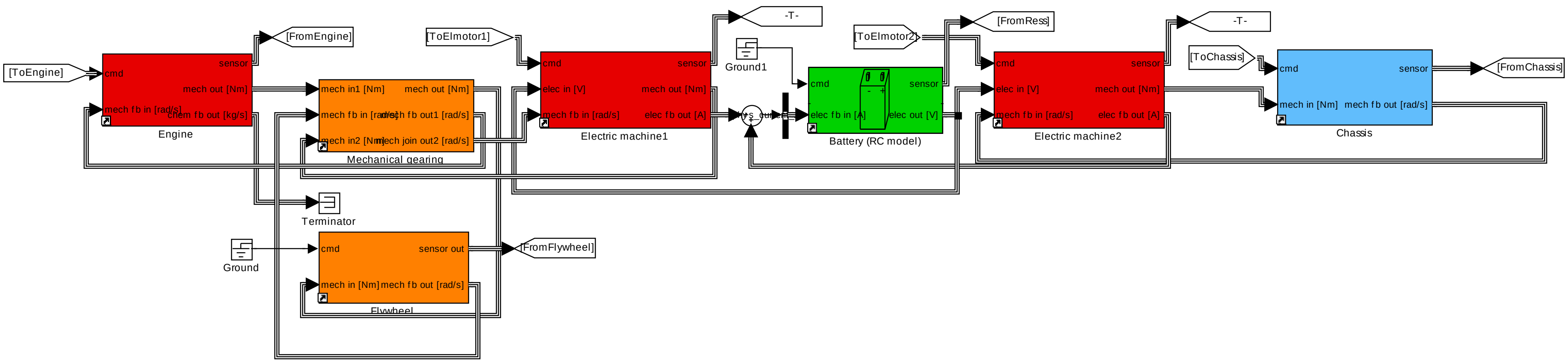




Pre transmission parallel hybrid

Validation test program 1 overview

New component library and signal naming convention



Series hybrid

Validation test program 1 overview

New structured vehicle models

- New parallel+serial hybrid model circulated (component library based)
- Implementation of simple control strategy „software ECU“
  - First model test runs performed

- New structure enabled implementation of flexible signal data bus
  - Minimum number of signals specified to run models
  - Flexible for adding more signals on data bus

- Models will be further developed based on feedback of stakeholders

Validation test program 1 overview

Task 1.4) Meetings with OEM's and stakeholders

- Meeting with DAF - Eindhoven
  - Hybrid component performance not temperature-dependent at 20°C
    - No need for additional component tests to cover cold start
  - ECU test modes foreseen for HILS test or "dummy" signals at interface model to prevent failure modes? → representative software?

- Extended contact with
  - Volvo for preparation of chassis dyno tests at JRC (test cycles,..)
  - Daimler for road gradient calculation procedure and test cycle output frequency investigation

Validation test program 1 overview

Task 1.4) Meetings with OEM's and stakeholders

- Feedback to new model structure, interface signals and models
  - Generally positive feedback on new models from OEMs
  - Useful comments on general and specific needs, on improvements, modeling guidelines → good conversation basis

- Open issues
  - Actuation of different brake systems in driver model (different needs for different OEMs → find a flexible solution)
  - Time or distance based slope pattern

Drive cycle investigations

Calculation of road slopes

- WHVC with road gradients will be the basic vehicle cycle
  - 2 different methods of calculating the slopes
    - „mini cycle“ calculation tool was circulated at HDH HP
    - 30 sec. mov. avg. slope calculation was investigated

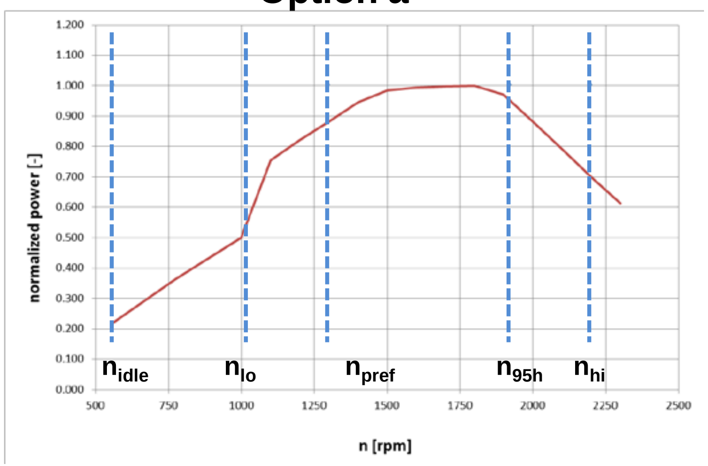
- Mini cycle method with constant slope for each mini cycle was presented at 13th HDH meeting
  - Tool was used for first measurements at JRC
  - 1st version of further developed slope calculation including a balanced altitude could also be investigated on the rollers
- (Modified) 30 sec. mov. avg. slopes method was also tested

Drive cycle investigations

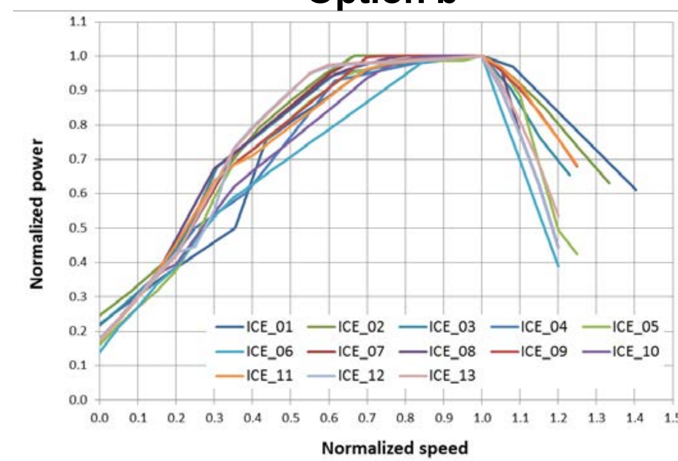
Differences between slope calculation methods

- Reference power pattern (pos. WHTC equivalent) for cycle work definition
  - Option a) WHDHC power pattern (30sec.mov.avg)
    - WHTC denormalization methods are used
    - Depending on characteristic engine speeds acc. to shape of full load curve
  - Option b) average normalized WHTC power pattern (minicycle slope)
    - mean value of specific normalized WHTCs is used
    - Depending on rated power of hybrid power-pack

Option a



Option b



Drive cycle investigations

Differences between slope calculation methods

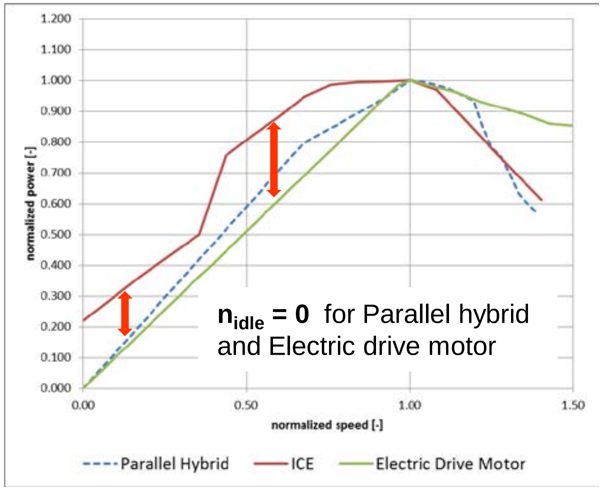
- WHTC denormalization method leads to lower characteristic speeds for hybrid powertrains
  - operated at lower speeds
  - lower available maximum power at these speeds > operated at lower power
  - lower positive cycle work

Example data for three system full load curves
(**same rated power**, transmission and final drive ratios)

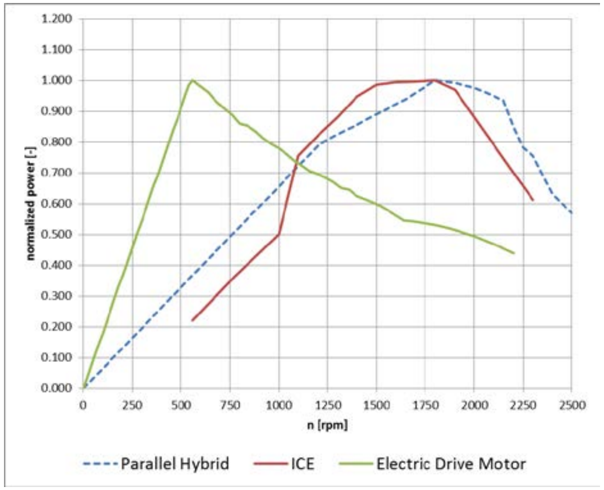
rated system power: 200kW

	prefered speed [rpm]
ICE	1300
Electric drive motor	338
Parallel hybrid	1026

lower characteristic speeds
acc. to WHTC denormalization method



less power at lower normalized speeds



BUT: more power at
lower absolute speeds!

Drive cycle investigations

Differences between slope calculation methods

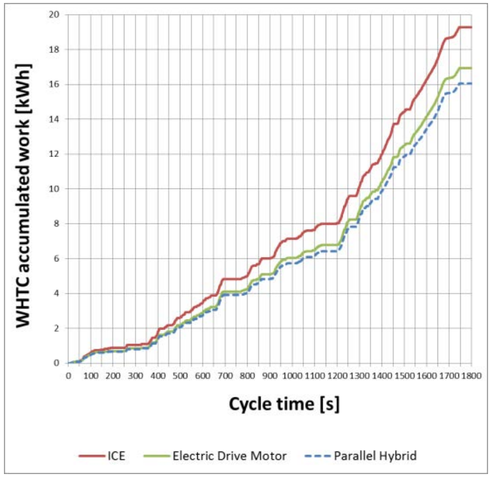
- WHTC denormalization method leads to lower characteristic speeds for hybrid powertrains
  - operated at lower speeds
  - lower available maximum power at these speeds → operated at lower power
  - lower positive cycle work

Example data for three system full load curves
(**<u>same rated power</u>**, transmission and final drive ratios)

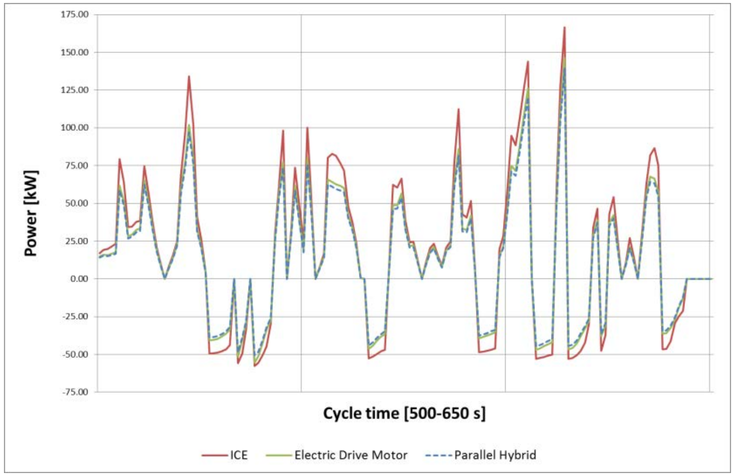
rated system power: 200kW

	pos. cycle work [kWh]
ICE	19.28
Electric drive motor	16.92
Parallel hybrid	16.04

lower pos. cycle work
acc. to WHTC denormalization method



lower positive cycle work



operated at lower power in WHTC

Drive cycle investigations

Differences between slope calculation methods

- Both options (a and b) not directly comparable due to big deviations in resulting reference power pattern

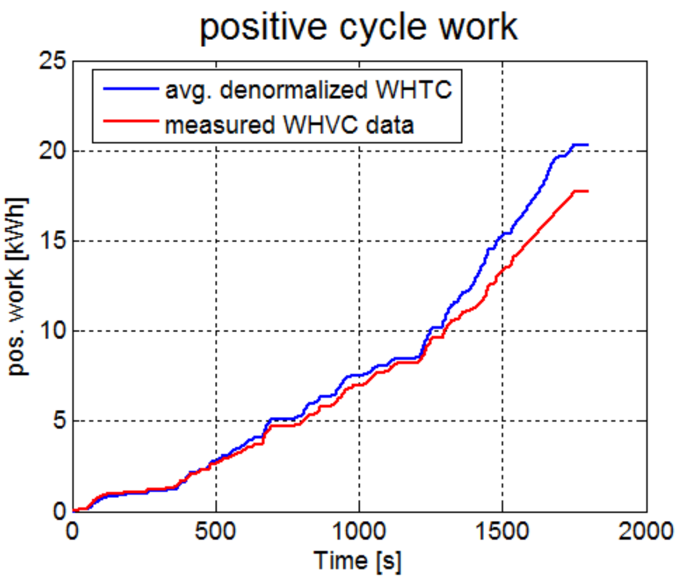
- WHTC denormalization method leads to operation points at lower loads and speeds for hybrid powertrains
  → WHDHC calculation tool maybe not suitable any longer
- Alternative solution: use average normalized WHTC for pos. cycle work calculation
  → also remaining open issues

- Further investigations needed

Drive cycle investigations

Balanced altitude approach (draft)

- Example:
  - Red: actual vehicle at WHVC
  - Blue: Reference cycle work for equal powered ICE at WHTC

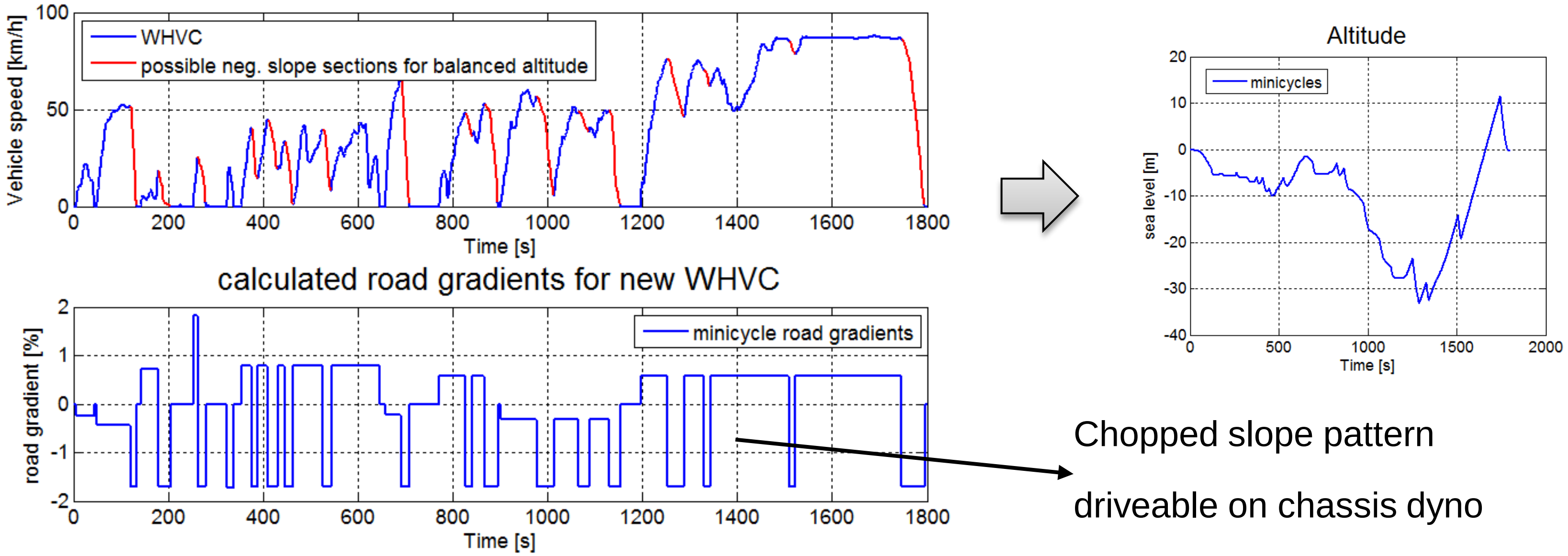


- Positive road gradient is needed to increase WHVC cycle work
- Vehicle would end at higher sea level
- Recuperation during deceleration at positive road gradient → less energy available → burden of hybrid systems

Drive cycle investigations

Balanced altitude approach (draft)

- Specify time of considered deceleration (e.g. at least 10 sec.)
- Gained altitude resulting from pos. slopes will be reduced during deceleration phases (no effect on pos. cycle work)
- Further development will be done at next OEM test runs



Chopped slope pattern

driveable on chassis dyno

Conclusion

Validation test program 1

- Extensive changes on models and model structure were made
  - Nevertheless project time schedule can be maintained
  - Positive feedback and good cooperation with OEMs
- Next model release (including stakeholder remarks) planned
- Comprehensive model and work program documentation will start
- Drive cycle modifications need further investigations

THANK YOU FOR YOUR ATTENTION!

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